An Executive Summary of the MLSE Proposal

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Introduction

- Defining MLSE for COM reference receivers was highlighted as one of the priorities in phase 1 (lusted_3dj_elec_01_231207.pdf)
- MLSE seems necessary for KR/CR receivers
- MLSE may be necessary for C2M/C2C, depending on the loss target (TBD)
- 1st priority is to agree if MLSE is needed to be a part of the reference receiver
- 2nd priority is to find the best practical approach to achieve this
- Some options are:
  A. Include MLSE COM calculations based on the existing proposal
  B. Use MLSE coding gain as a rough estimate (costs accuracy)
  C. Further simplify and relax COM margin by a constant amount (costs more accuracy)
  D. Find a better replacement for MLSE (currently no clear path)
  E. Ignore MLSE for channel compliance (channels need to become better)

History

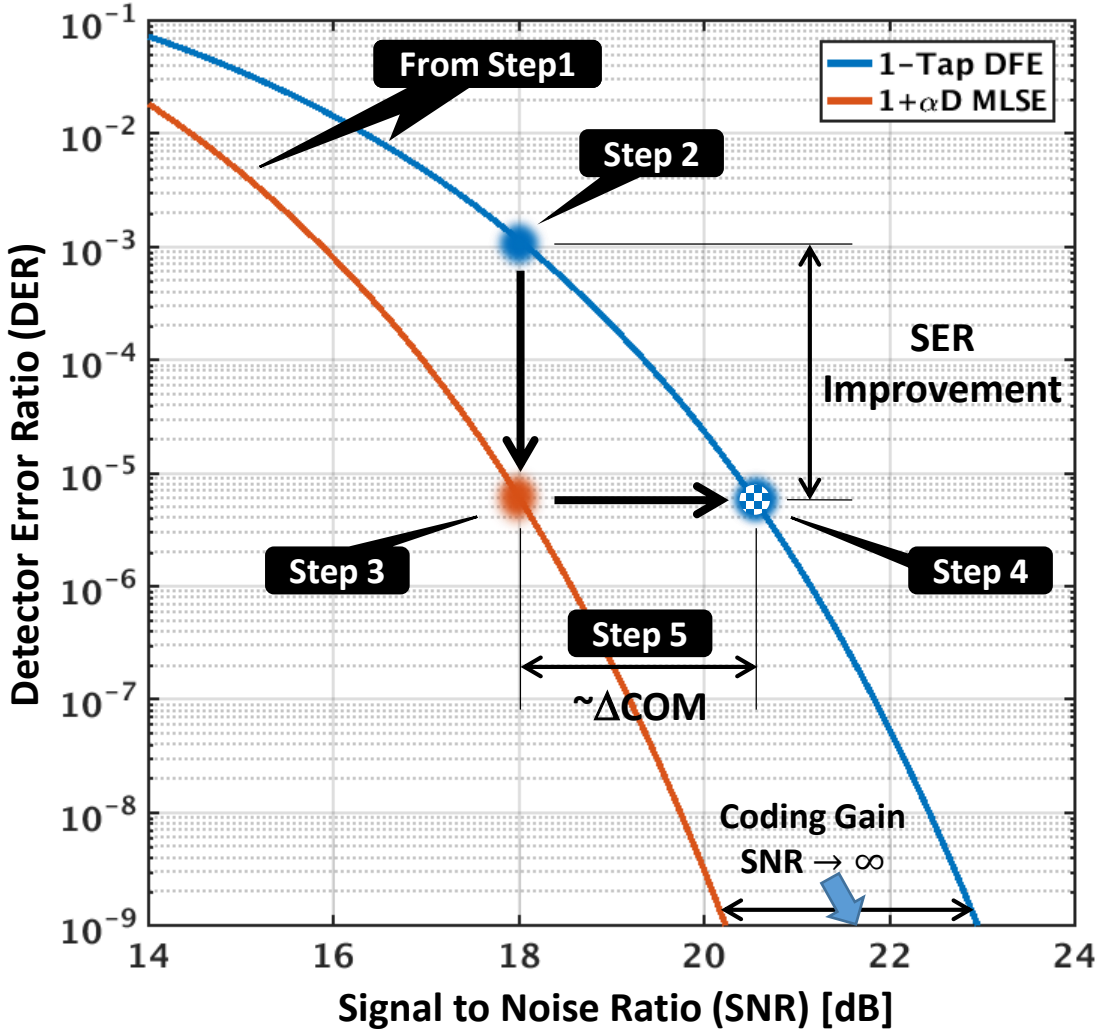
Date	Content	Reference Contribution
November 2022	Original Proposal	shakiba_3df_01a_2211.pdf
January 2023	Further Details	shakiba_3dj_01_230116.pdf
February 2023	Recap	shakiba_3dj_elec_01_230223.pdf
February 2023	First COM Matlab Code	mellitz_3dj_elec_01a_230223.pdf
April 2023	First Update (U1.a, U1.b, U1.c)	shakiba_3dj_elec_01_230420.pdf
April 2023	MLSE Error Propagation	shakiba_3dj_elec_02_230420.pdf
January 2024	Recap and Test Data	shakiba_3dj_elec_01a_240104.pdf

- Considering an MLSE implementation penalty was suggested in shakiba_3df_01a_2211.pdf as a later step (amount TBD)
- This presentation suggests making this explicit and as the last step of the proposal

Proposal Recap

- The proposal specified following steps:

1) Use COM analysis to find DFE tap, α
2) From COM data calculate SNR_{DFE}
3) Use analysis to calculate DER_{MLSE} at SNR_{DFE}
4) Use analysis to calculate $SNR_{DFE,\ equivalent}$ for the same DFE that yields the same DER_{MLSE}
5) Increase from SNR_{DFE} to $SNR_{DFE,\ equivalent}$ gives a good estimate of COM advantage of MLSE (ΔCOM)
★ 6) Consider an MLSE implementation penalty (TBD) to be subtracted from ΔCOM



Summary of ΔCOM Equations

- The original equation (currently coded in COM Matlab function) includes error propagation and should be disregarded and updated moving forward
- The following updated equations are all based on DER and exclude error propagation

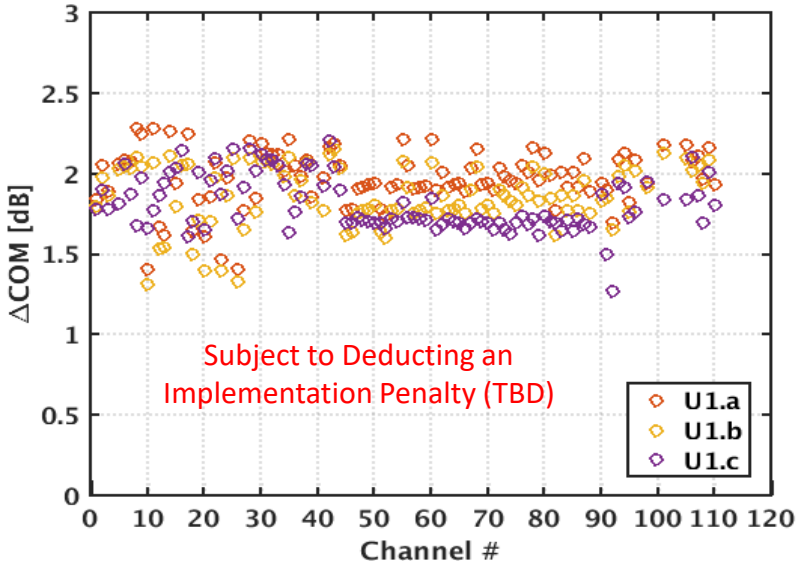
	Intermediate Equation	MLSE ΔCOM Equation	Comment
U1.a	$DER_{MLSE} \approx 2\sum_{j=1}^{\infty}\left(\frac{3}{4}\right)^{j}\left(1 - CDF_{noise}\left(A_s\sqrt{1+(j-1)(1-\alpha)^2+\alpha^2}\right)\right)$	$\Delta COM \approx 20\log_{10}\left(\frac{1}{A_s}CDF_{noise}^{-1}\left(1-\frac{2}{3}DER_{MLSE}\right)\right) - \textit{Implementation Penalty}$	Excludes Error Propagation
U1.b	$DER_{MLSE} \approx 2\sum_{j=1}^{\infty}\left(\frac{3}{4}\right)^{j}\left(1 - CDF_{noise,jEE}\left(A_s(1+(j-1)(1-\alpha)^2+\alpha^2)\right)\right)$ $PDF_{noise,jEE}(x) = PDF_{noise}(x) * \text{conv}_{i=2}^{j} PDF_{noise}(x/(1-\alpha)) * PDF_{noise}(x/\alpha)$		U1.a + Improved MLSE Noise Calculation
U1.c	$DER_{MLSE} \approx 2\sum_{j=1}^{\infty}\left(\frac{3}{4}\right)^{j}\left(1 - CDF_{noise,jEE}\left(A_s\frac{\left(\text{trace}(\rho_{noise,jEE})\right)^{\frac{3}{2}}}{\sqrt{\sum_{vertical}\sum_{horizental}(\rho_{noise,jEE})}}\right)\right)$ $PDF_{noise,jEE}(x) = PDF_{noise}(x) * \text{conv}_{i=2}^{j} PDF_{noise}(x/(1-\alpha)) * PDF_{noise}(x/\alpha)$ For calculating the correlation matrix ($\rho_{noise,jEE}$) from the colored noise PSD, see shakiba_3dj_elec_01a_240104.pdf		U1.b + Noise Coloring Effect

- For analysis details and derivation of these equations refer to the previous contributions

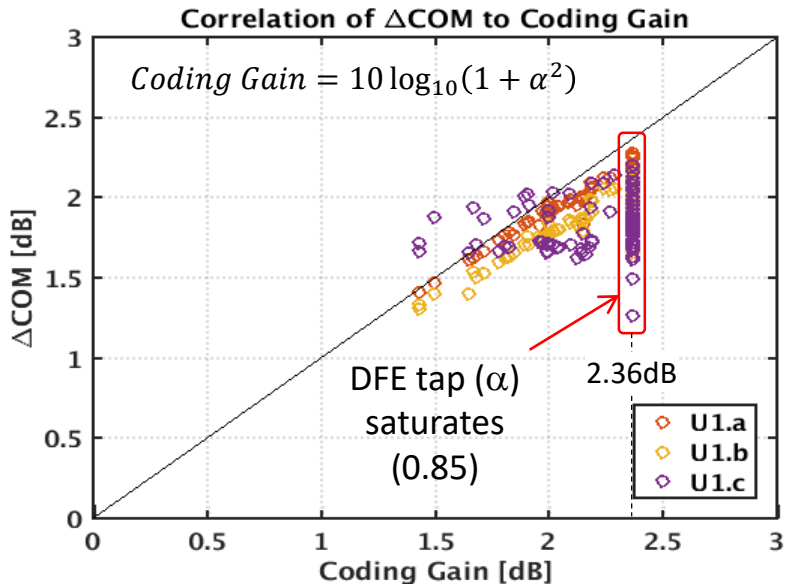
Note: There is a typo in this equation in all previous contributions. Please correct to this equation.

Test Results (See Backup Slide for Test Channels)

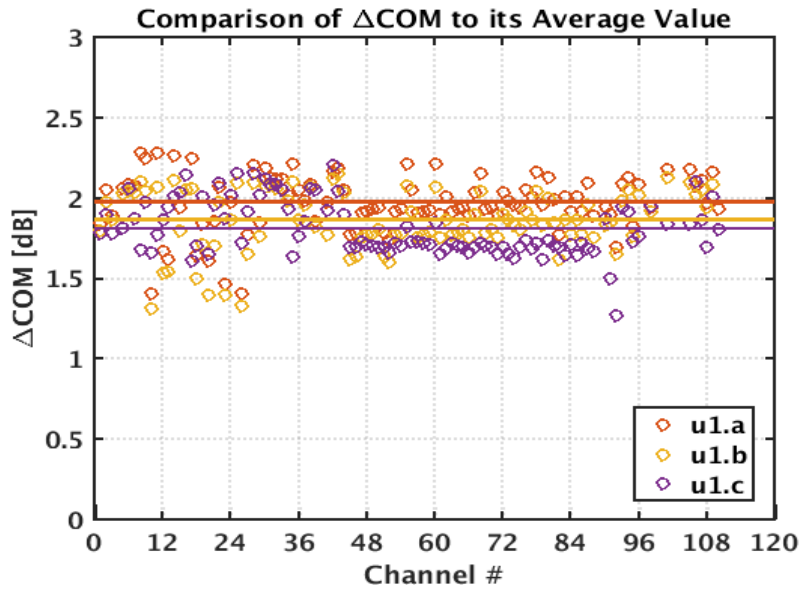
Option A



Option B



Option C



- Implementation penalty is not included
- As updated equations kick in, ΔCOM reduces and becomes more channel dependent
- Coding gain is not a representative of MLSE COM advantage when DFE tap saturates
- For the test channels:
  - The difference between ΔCOM and coding gain could be as much as +0.4dB / -1.1dB
  - The difference between ΔCOM and its fix average value could be as much as +0.4dB / -0.6dB
- At 200+G every dB (or even a fraction of a dB) counts and **must be meaningful** to close the link

Backup Slide – Test Channels

Channel #	Channel Source
1	https://www.ieee802.org/3/dj/public/tools/CR/lim_3dj_03_230629.zip
2	https://www.ieee802.org/3/dj/public/tools/CR/lim_3dj_04_230629.zip
3 – 7	https://www.ieee802.org/3/dj/public/tools/CR/kocsis_3dj_02_2305.zip
8 – 34	https://www.ieee802.org/3/dj/public/tools/KR/mellitz_3dj_02_elec_230504.zip
35 – 40	https://www.ieee802.org/3/dj/public/tools/CR/shanbhag_3dj_01_2305.zip
40 – 44	https://www.ieee802.org/3/dj/public/tools/KR/shanbhag_3dj_02_2305.zip
45 – 80	https://www.ieee802.org/3/dj/public/tools/KR/weaver_3dj_02_2305.zip
80 – 88	https://www.ieee802.org/3/dj/public/tools/KR/weaver_3dj_elec_01_230622.zip
89	https://www.ieee802.org/3/dj/public/tools/CR/lim_3dj_07_2309.zip
90 – 96	https://www.ieee802.org/3/dj/public/tools/KR/akinwale_3dj_01_2310.zip
97 – 100	https://www.ieee802.org/3/dj/public/tools/CR/akinwale_3dj_02_2311.zip
101 – 112	https://www.ieee802.org/3/dj/public/tools/CR/weaver_3dj_02_2311.zip