10BASE-T1S Scrambler Analysis

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Outline

- Compare different schemes including the complementary Golay sequence preamble and payload scrambler as proposed by Tazebay, Cordaro, et al. *(referred as Tazebay's proposal in following slides)*
- Propose a new scheme which scrambles both the payload as well as part of the standard preamble
- Simulation and laboratory measurement results
- Conclusion

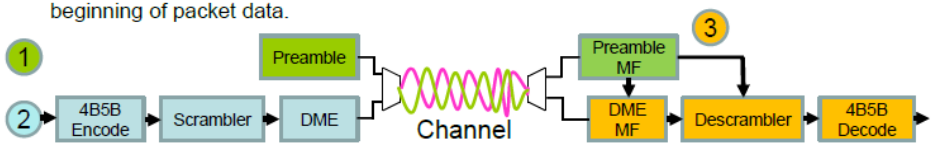
Introduction

- Tazebay, Cordaro, et al., proposed payload scrambling and complementary Golay sequence preamble replacement (cordaro_8023cg_short_reach_new_preamble_proposal_1220.pdf, cordaro_8023cg_01_0118_v2.pdf, tazebay_3cg_01b_0118.pdf)
  - Scramble payload – reduce the peak emissions for some payload
  - New preamble – better synchronization performance, further improvement in the PSD

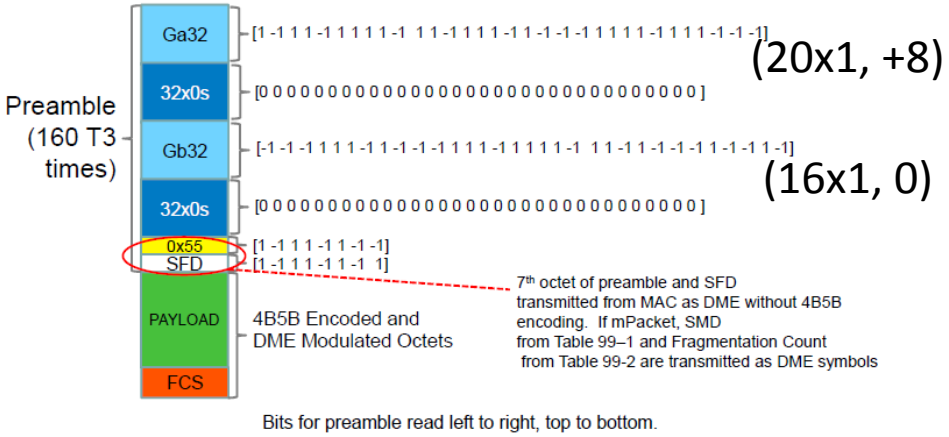
How to scramble 10BASE-T1S Frames

- 10BASE-T1S does not transmit IDLEs on the line when no data present.
  → No continuously running scrambler.
- How to synchronize the scrambler?

1. Transmit preamble unscrambled in order to synchronize.
   →Emissions performance of raw preamble is important.
2. Scramble the 4B5B-encoded payload at the transmitter with $x^{15}+x^4+1$ scrambler with same initial state loaded at beginning of every frame.
   scr_initial_state = ([0 0 1 1 1 1 1 1 0 0 1 1 0 1 0 1])
3. At receiver, detect preamble and then start descrambler with same fixed initial state at beginning of packet data.



Proposed Preamble and Payload Format



Introduction

802.3cg D1.1 147.3.3 Preamble and payload format

Preamble and payload format proposed by Cordaro, Tazebay, et al.

Some observations on Cordaro and Tazebay's proposed changes:

- The scrambler does effectively reduce the worse payload peak emissions
- However, the proposed complementary Golay preamble results in:
  - Preamble is not encoded and not DC balanced – AC coupling drift, PoDL issue
  - Breaks DME encoding and its self-clocking property – the most important feature for a multi-drop system for fast data and clock recovery (a few bits); but still doubles the channel bandwidth (no advantages over DME but inherits the disadvantages)
  - Much longer synchronization (lock) time for the receiver; requires an individual preamble generator and detector increasing design complexity;
  - Introduces a 3 level signaling scheme instead of a 2 level binary of DME requiring an ADC for preamble detection; a dramatic increase in the receiver complexity;
  - PLCA may require significant modification, e.g. BEACON needs to be synchronized the same way as preamble (add preamble for sync), significantly reducing network efficiency

Possible Alternate Solution

- After analysis of different payload patterns, we propose to scramble the 6 preamble octets following the JJJK and the payload of the frame:

Scramble Preamble (six octets) and Payload

- This has the advantage of:
  - Maintains DME and clocking recovery
  - Does not introduce three-level encoding and unbalanced DC
  - Does not change 10BASE-T1S frame format
  - PLCA scheme remains the same

Can the same level of PSD peak emission reduction be obtained??

Analysis

Standard Preamble, Unscrambled Payload

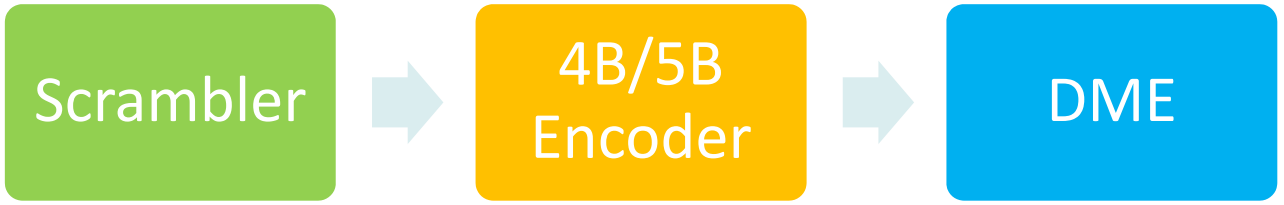
Standard Preamble, Scrambled Payload

Both Standard Preamble (six octets) and Payload Scrambled (new proposal)

Cordaro & Tazebay's Complementary Golay Sequence Preamble, Scrambled Payload

Scrambler Positioning

Mode 1: Scrambler inserted before 4B/5B Encoder



Mode 2: Scrambler inserted after 4B/5B Encoder

- Simulations show that better performance is achieved by inserting the Scrambler after the 4B/5B Encoder (Mode 2) than when inserting the Scrambler before the 4B/5B Encoder (Mode 1).
- The following plots only show the cases for Mode 2

Simulation Conditions

Scrambler: $x^{15} + x^4 + 1$

Scrambler initial (Tazebay): [0 0 1 1 1 1 1 0 0 1 1 0 1 0 1]
(new set) [0 0 1 0 1 0 0 1 1 0 0 0 0 0 1]

Payload: 5 different payloads captured by Wireshark

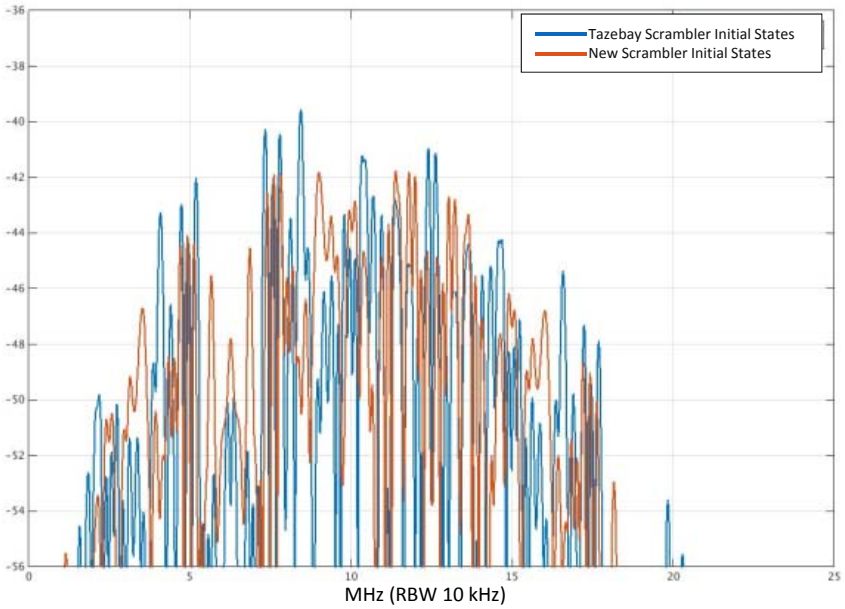
5 different Payload lengths: 60, 160, 170, 342, and 1560 bytes

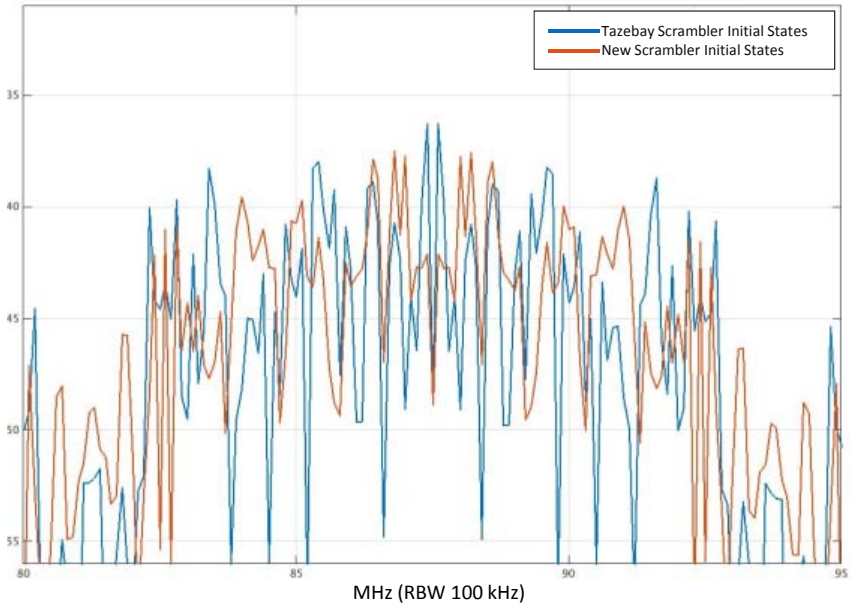
Spectrum RBW: 10 kHz, 100 kHz

Determine Scrambler Initial State

Scrambler initial state (Tazebay): [0 0 1 1 1 1 1 0 0 1 1 0 1 0 1]

New initial states were searched by PSD flatness in the 6 preamble octets 55 55 55 55 55 SFD

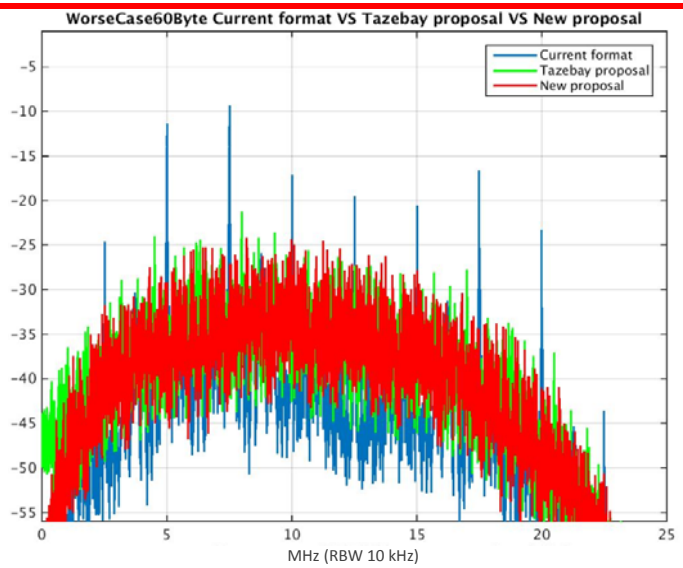


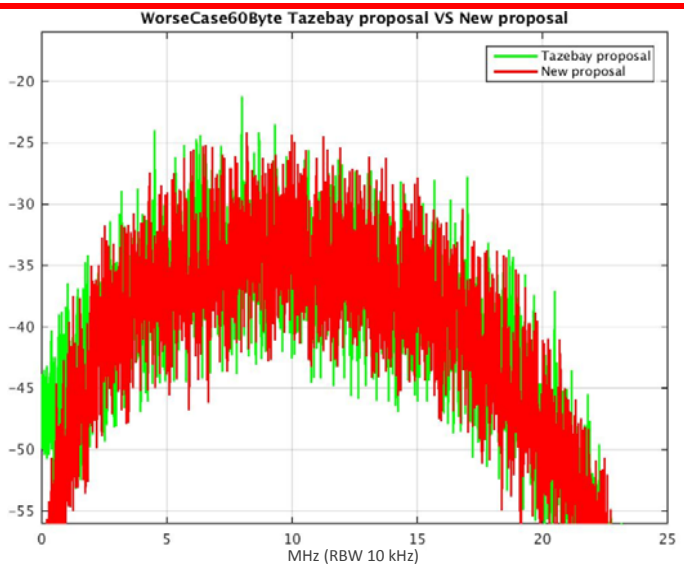


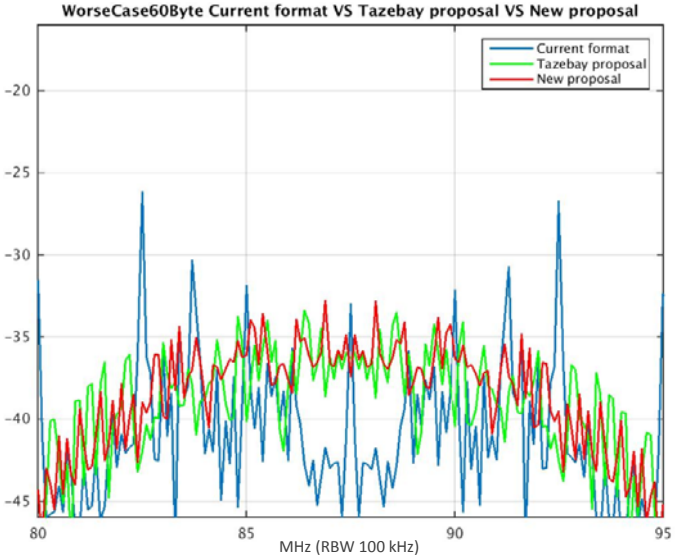
New Scrambler initial state (this work): [0 0 1 0 1 0 0 1 1 0 0 0 0 0 1]
Gives 2.2 dB and 1.2 dB better results for 10 kHz and 100 kHz RBW, respectively

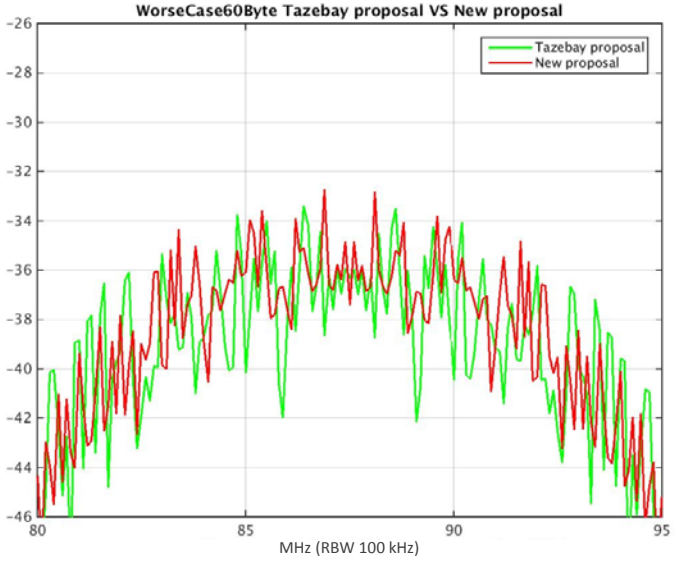
60 Byte – Worse Case

(3 dB better at low band, 0.6 dB worse at high band)
(Tezebay's vs this new proposal, same for next slides)









60 Byte – Worse Case

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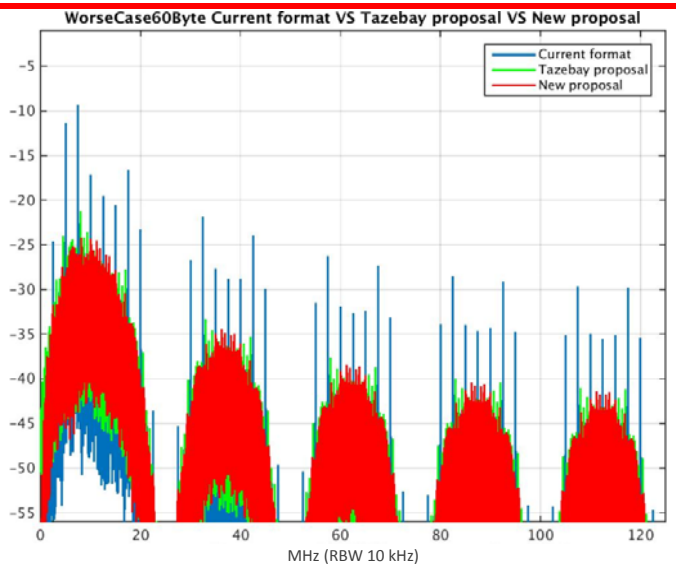
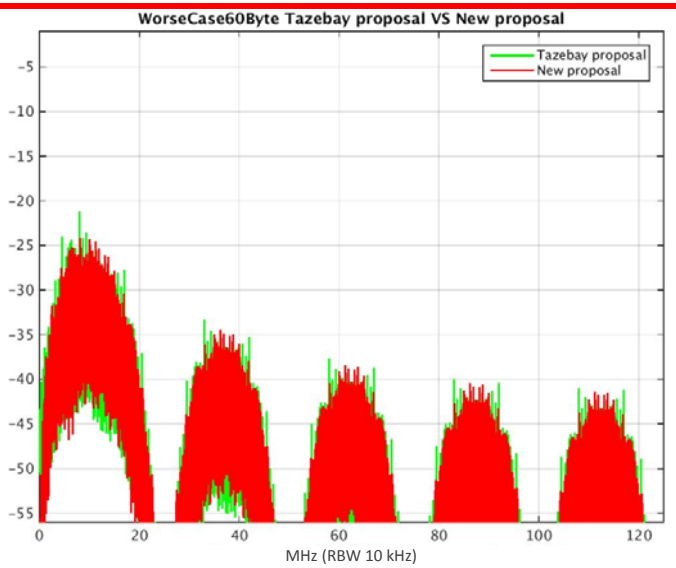
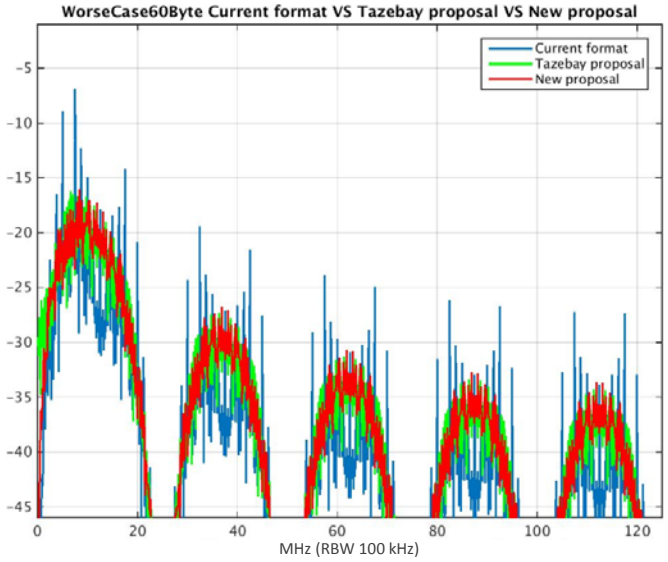
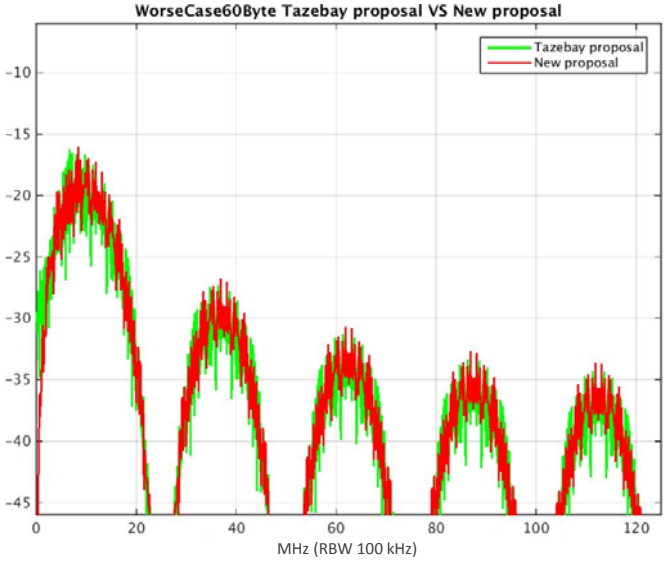


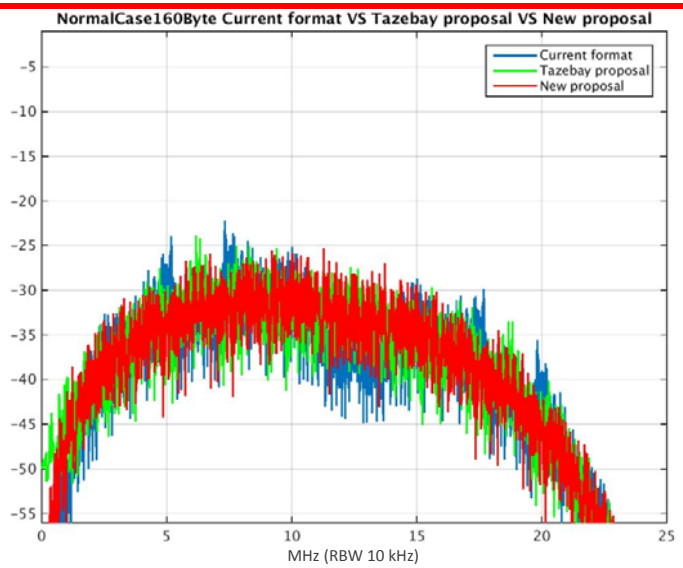


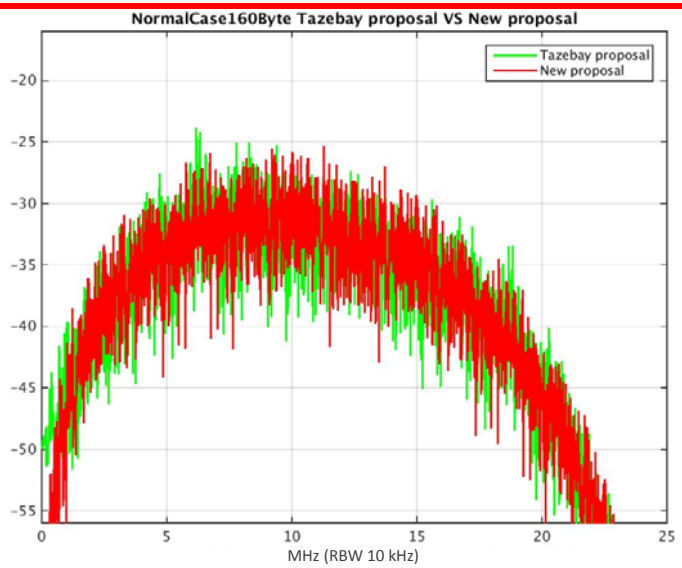


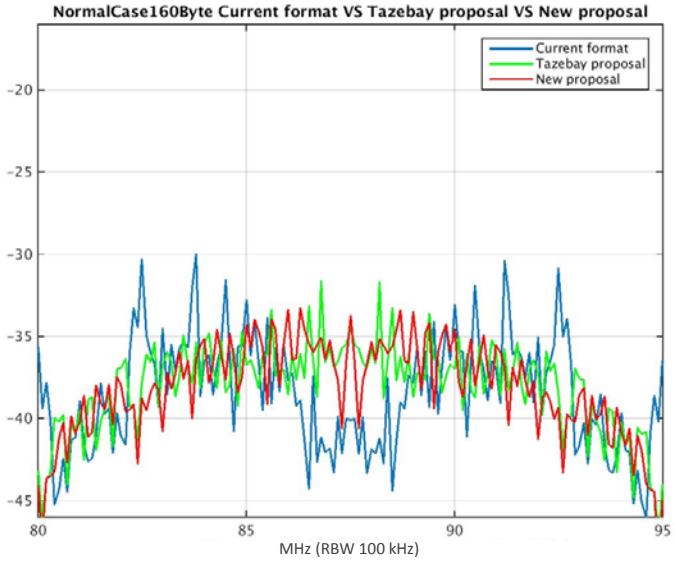


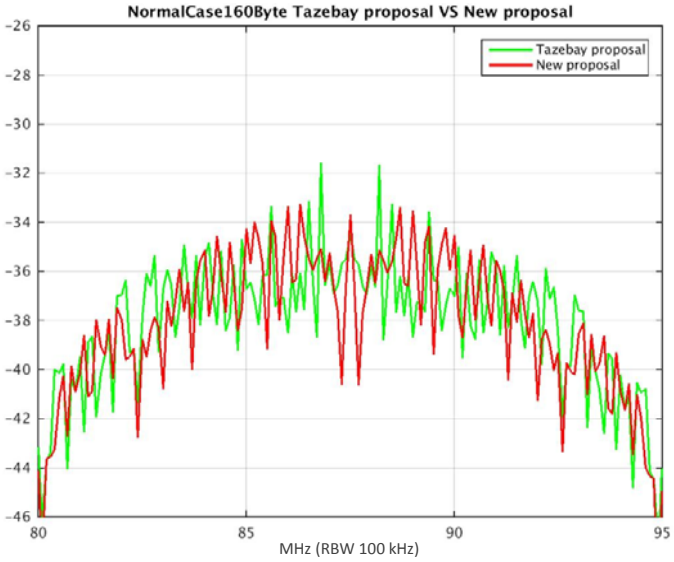
160 Byte – Normal Case

(1.5 dB better at low band, 1.7 dB better at high band)









160 Byte – Normal Case

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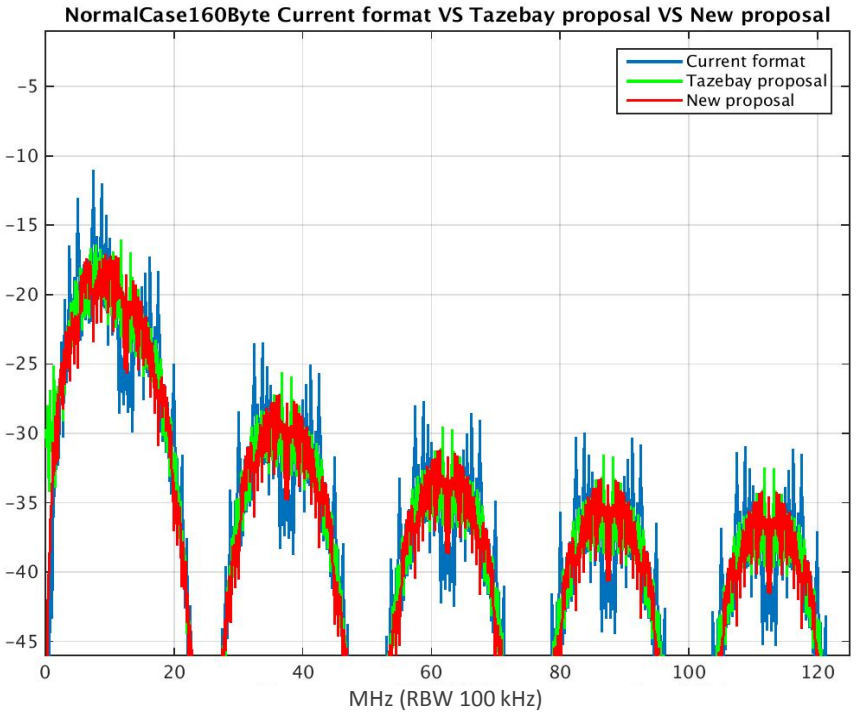
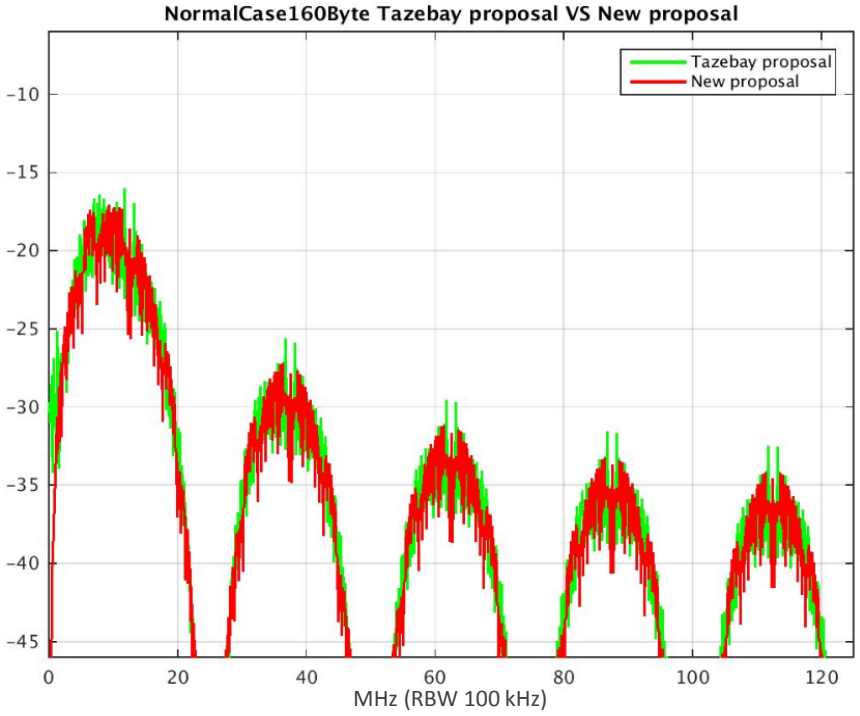
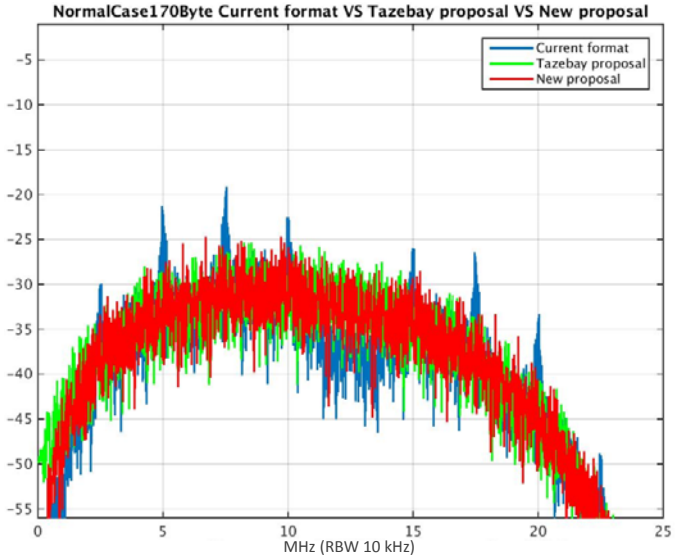
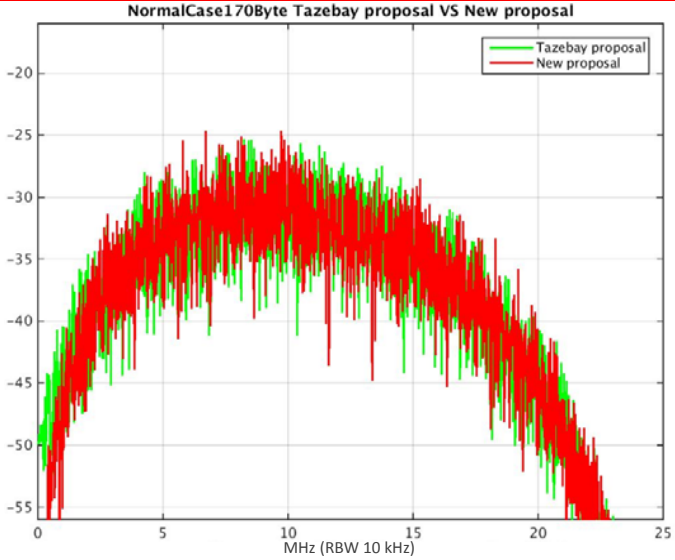


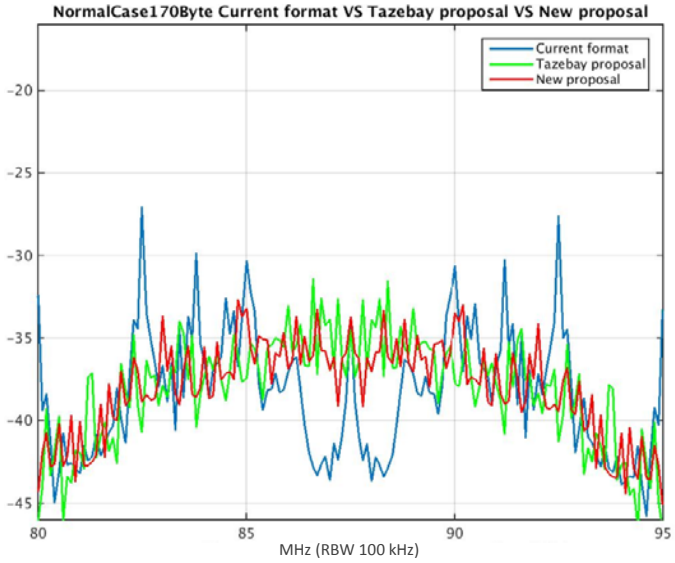


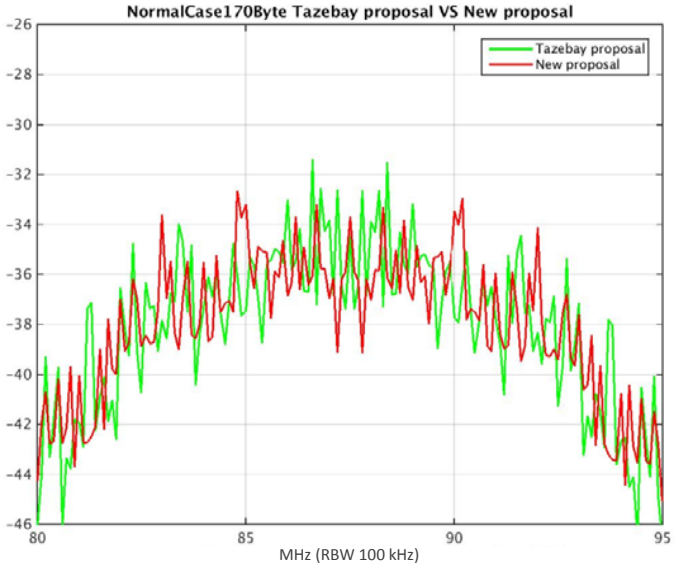
170 Byte – Normal Case

(0.7 dB worse at low band, 1.2 dB better at high band)



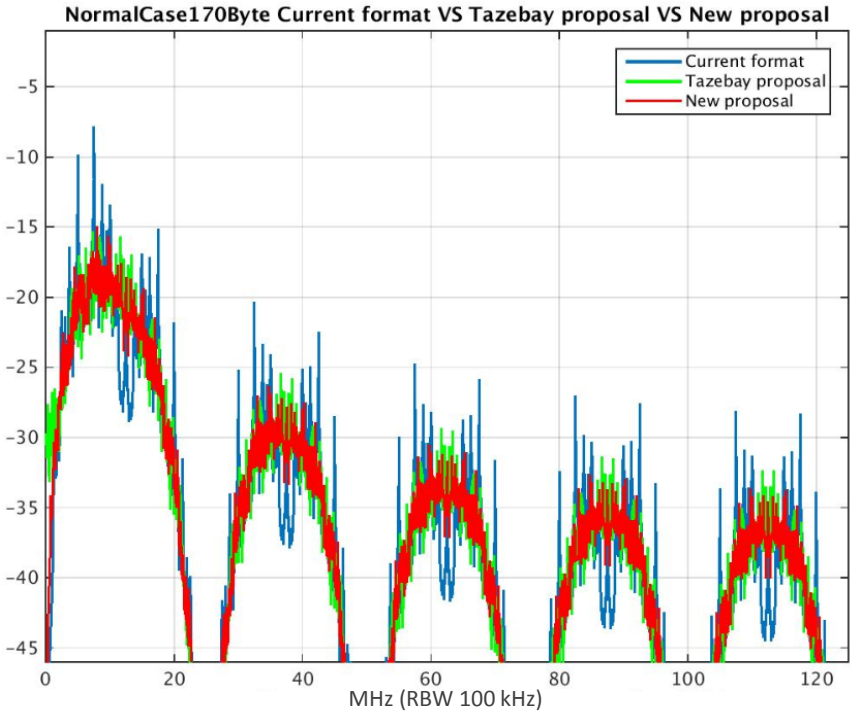


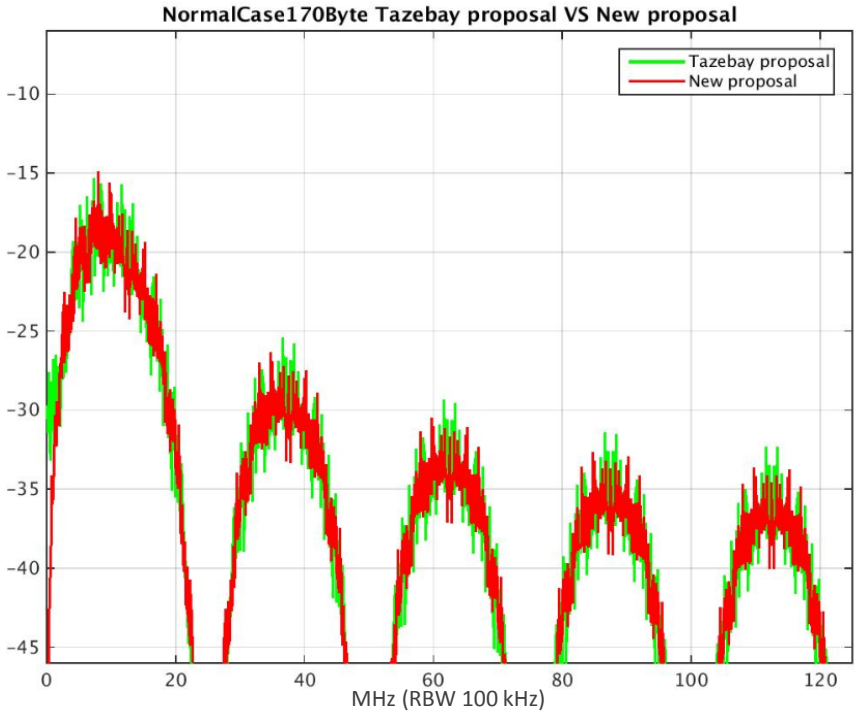




170 Byte – Normal Case

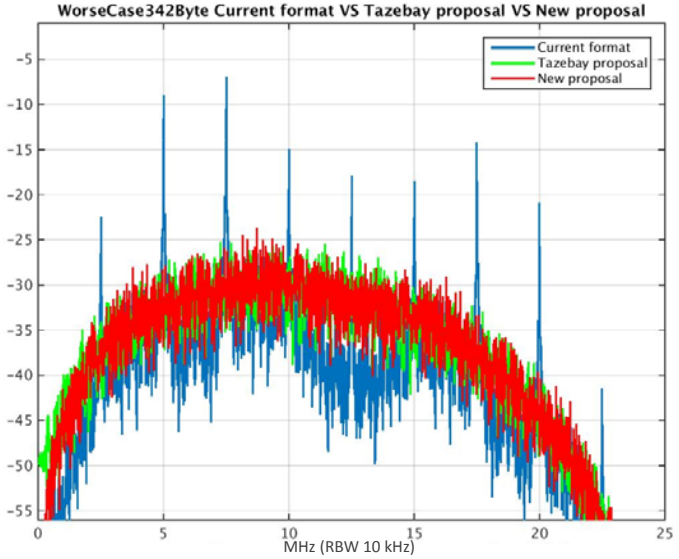
(0.7 dB worse at low band, 1.2 dB better at high band)

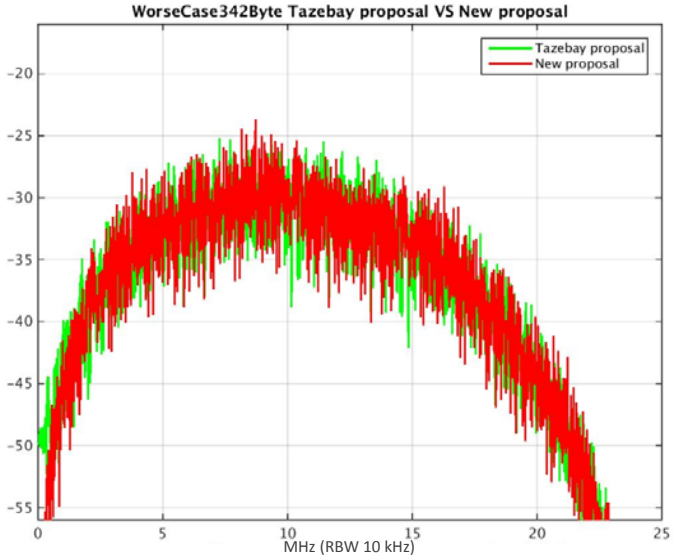


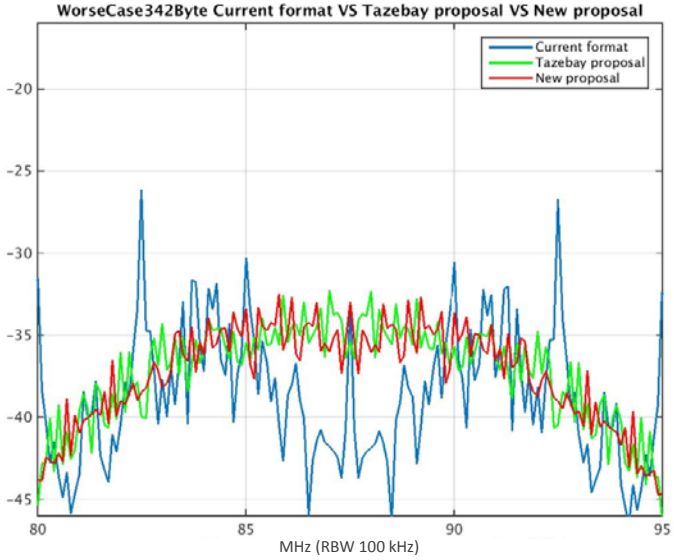


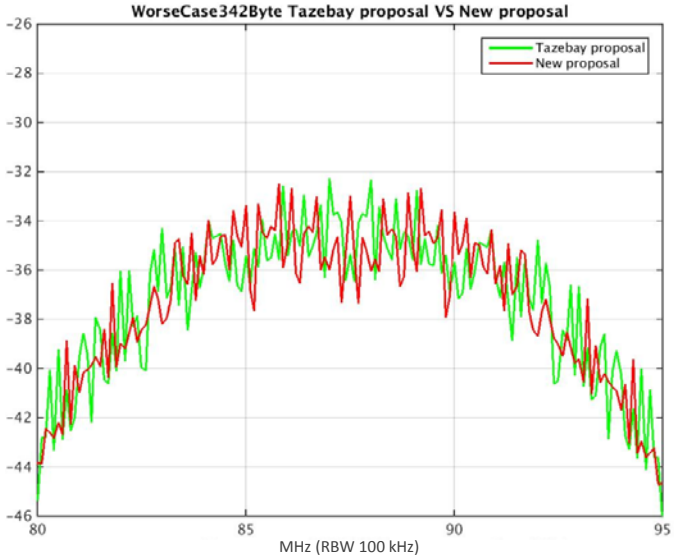
342 Byte – Worst Case

(1.5 dB worse at low band, 0.2 dB better at high band)









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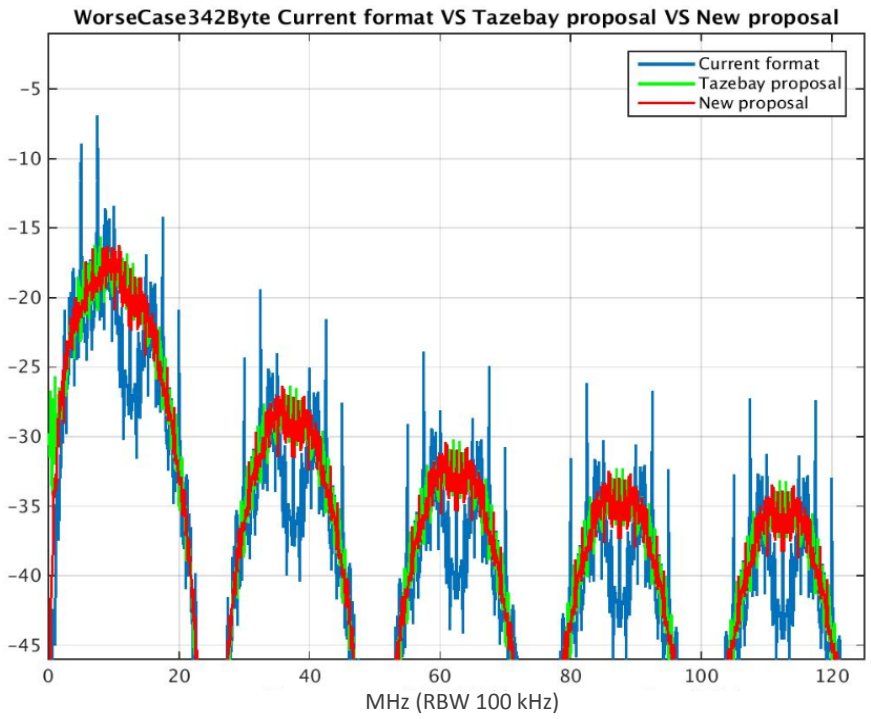
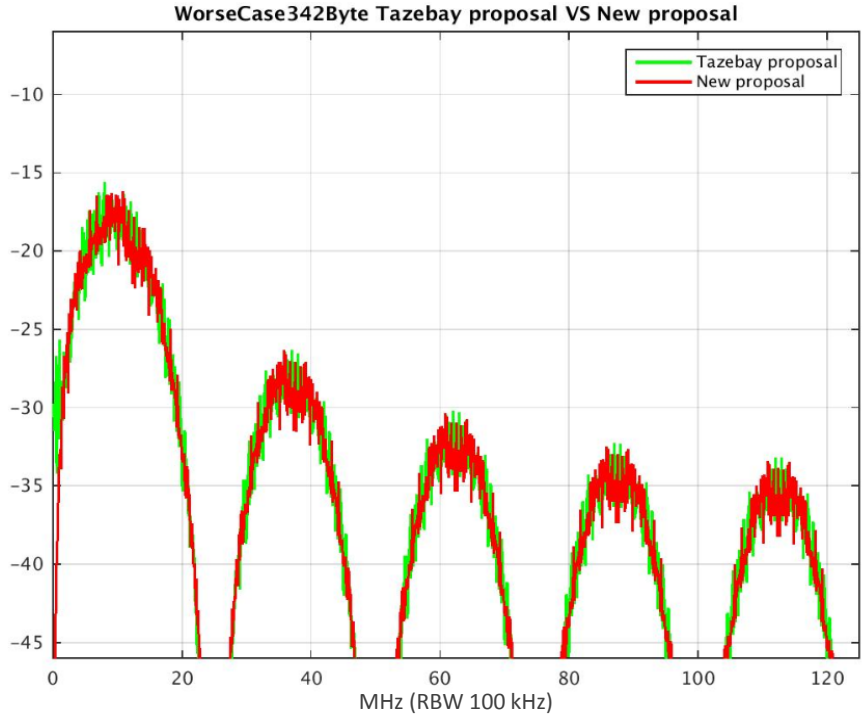
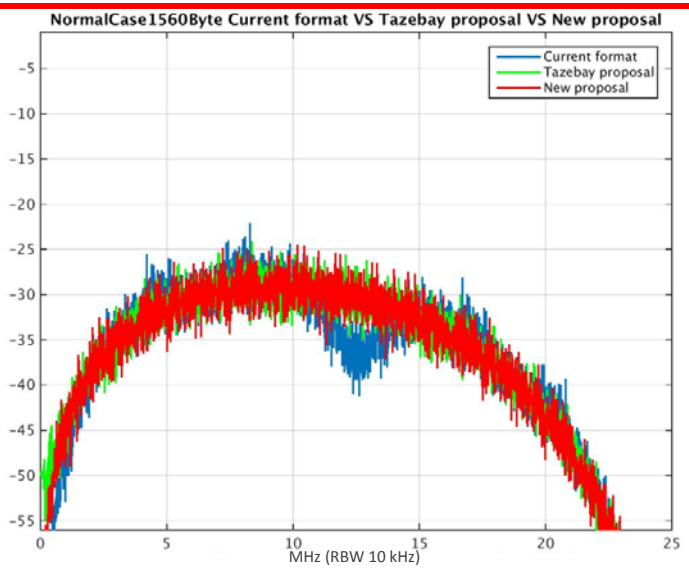
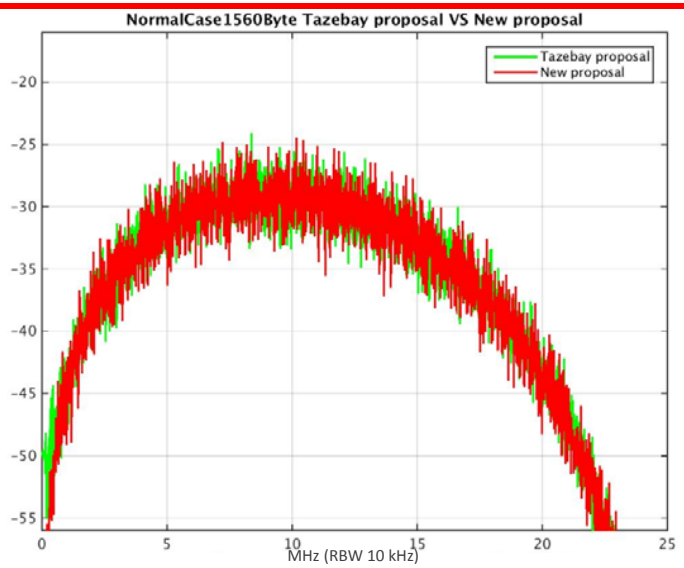


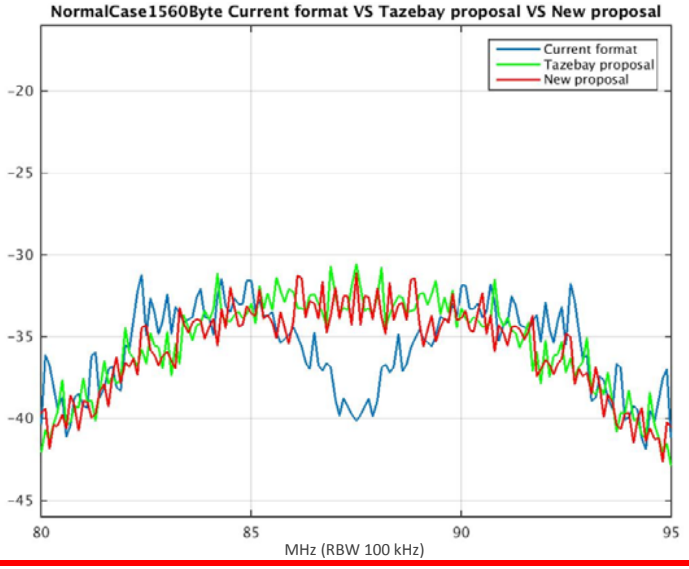


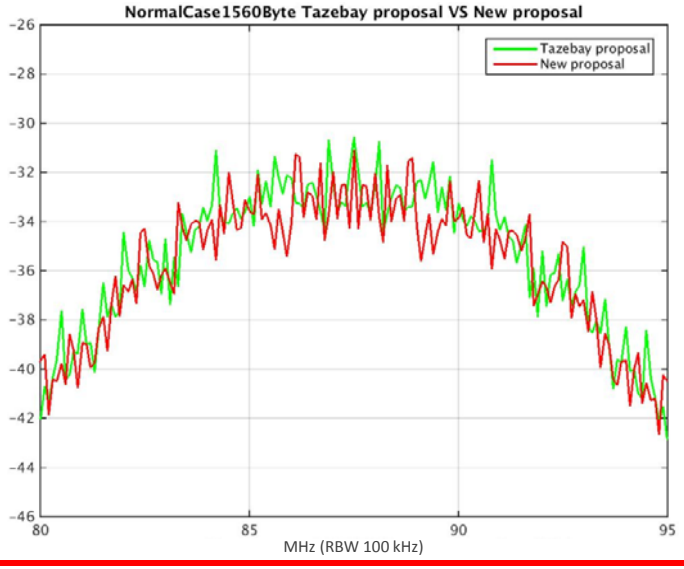
1560 Byte – Normal Case

(0.4dB better at low band, 0.5 dB better at high band)



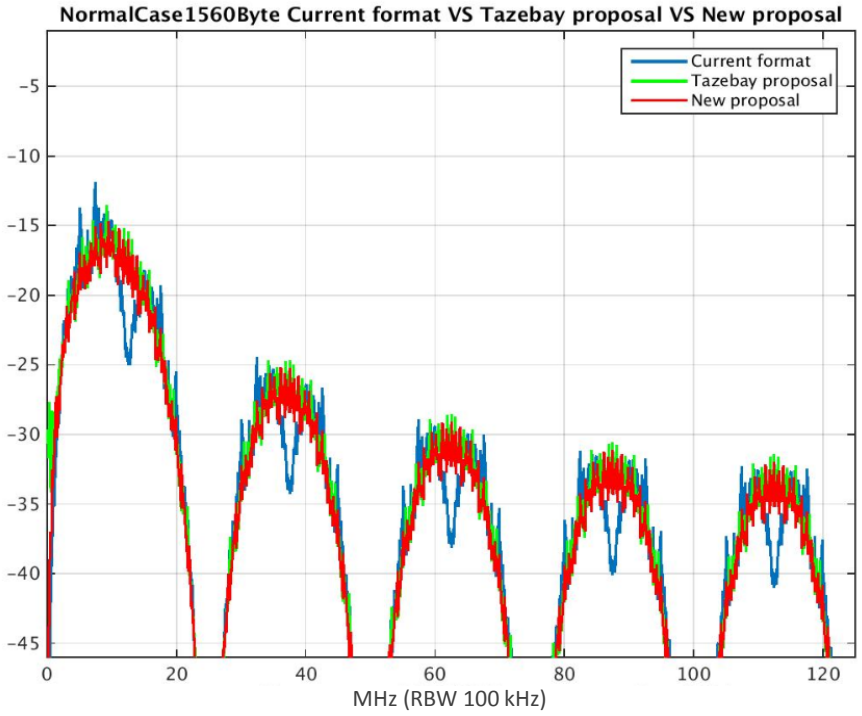


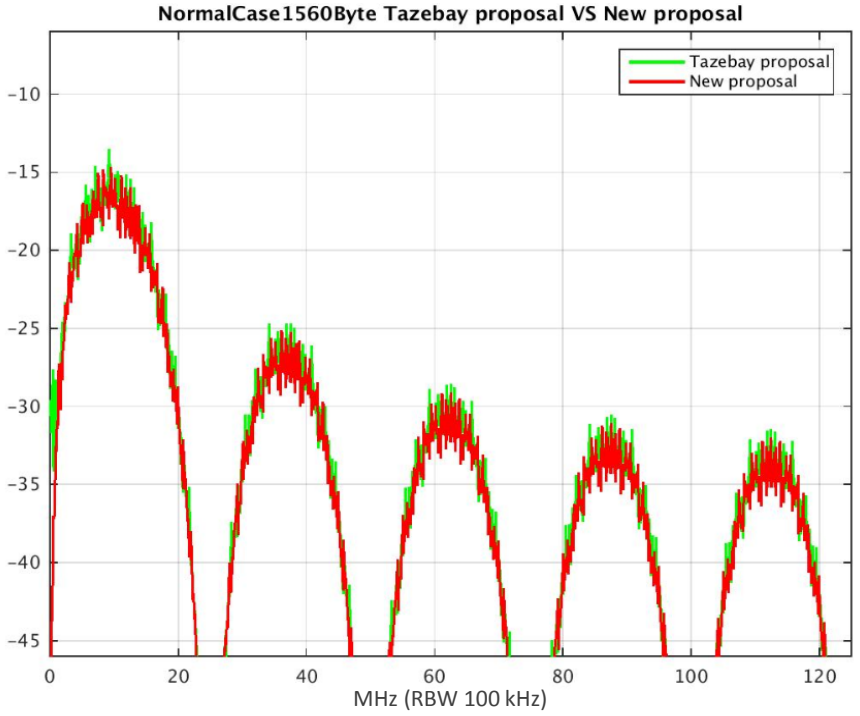




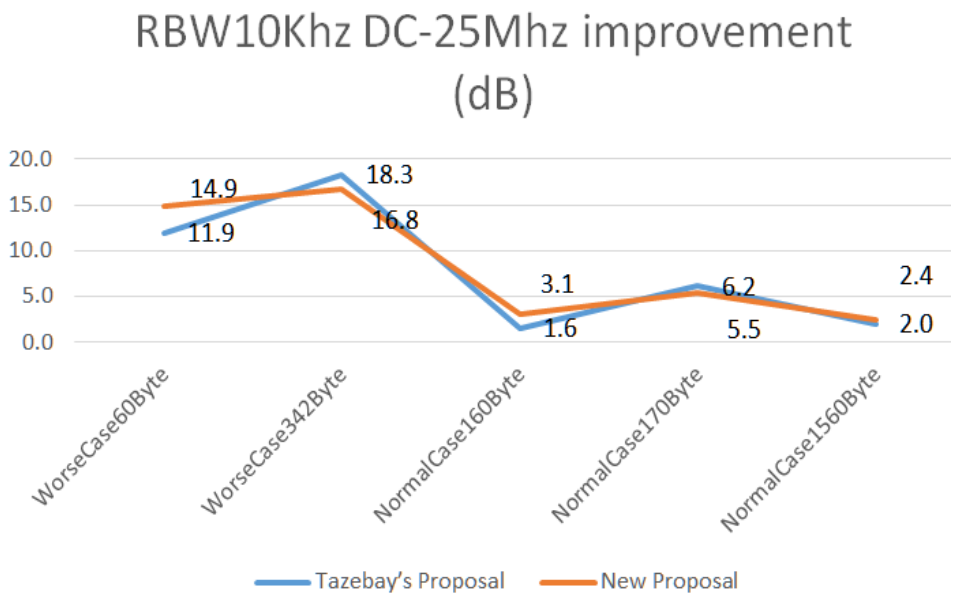
1560 Byte – Normal Case

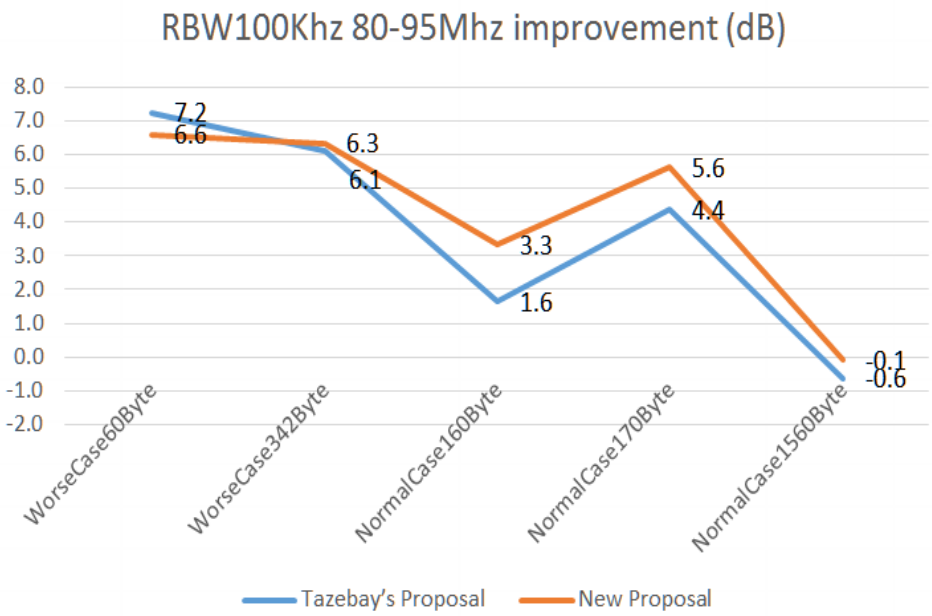
(0.4dB better at low band, 0.5 dB better at high band)





Improvement Summary



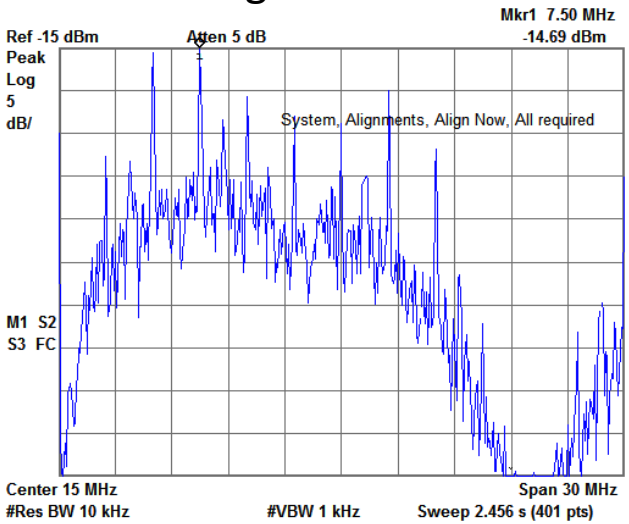


Lab Measurements

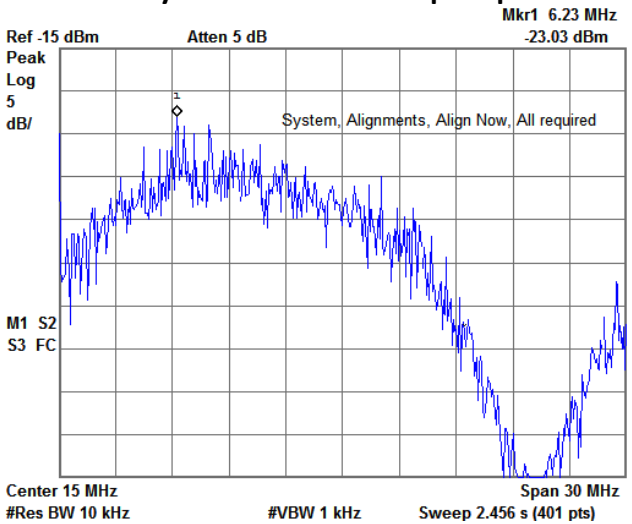
- The lab data is measured using:
  - Tektronix AWG4162 arbitrary waveform generator
  - Agilent E4404B spectrum analyzer

60 Byte – Worst Case Lab Results
(0-30 MHz Span)

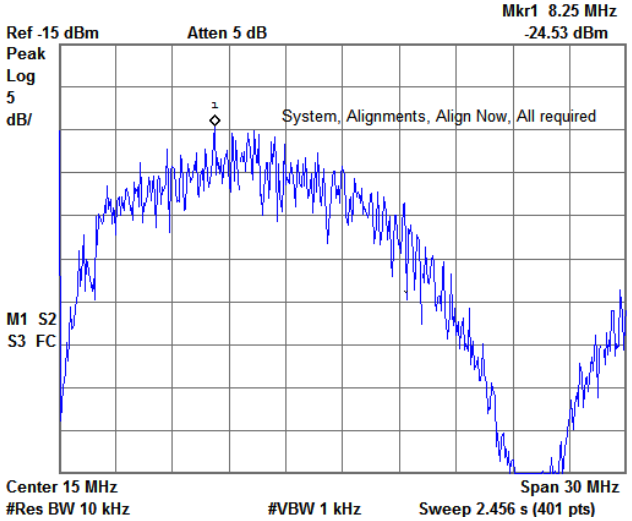
Original data



Tazebay & Cordaro's proposal



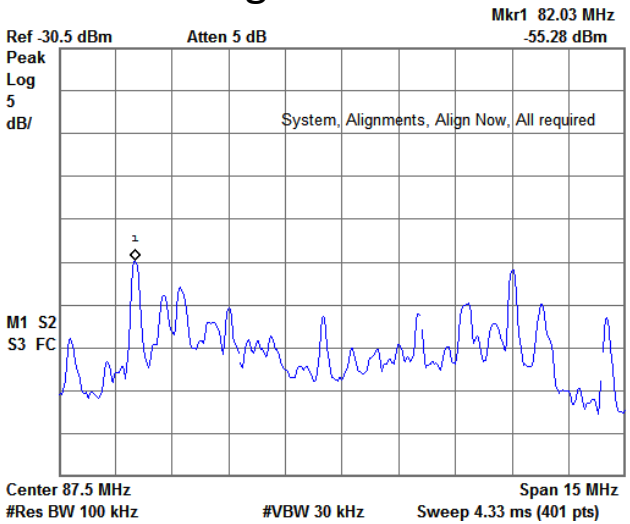
- 15 dB peak on original data
- 8.3 dB reduction with Tazebay & Cordaro's proposal
- 9.8 dB with this proposal
- 1.5 dB vs 3 dB from analysis



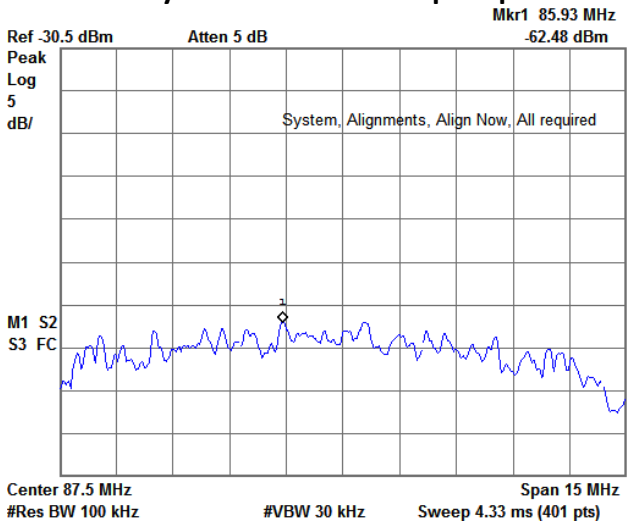
This proposal

60 Byte – Worst Case Lab Results
(80-95 MHz Span)

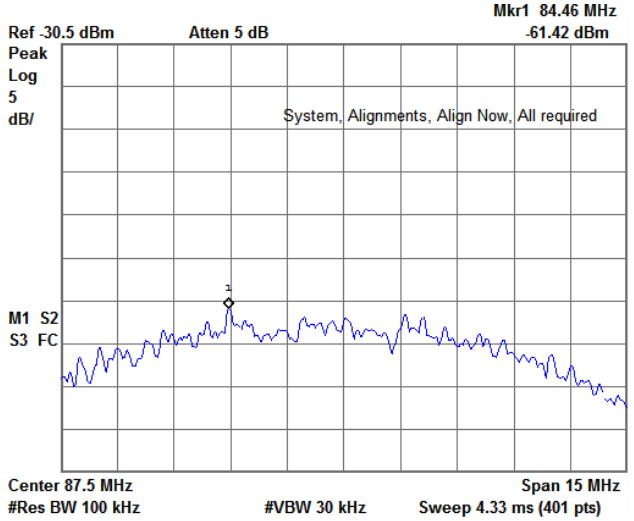
Original data



Tazebay & Cordaro's proposal



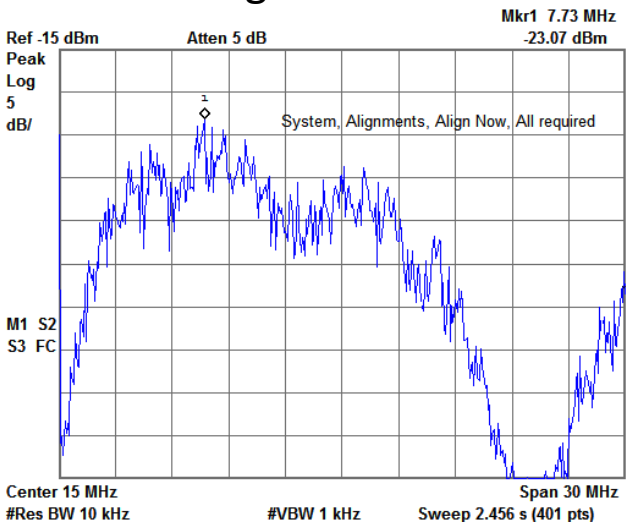
- 7.2 dB reduction with Tazebay & Cordaro's proposal
- 6.1 dB with this proposal
- 1.1 dB vs 0.6 dB from analysis



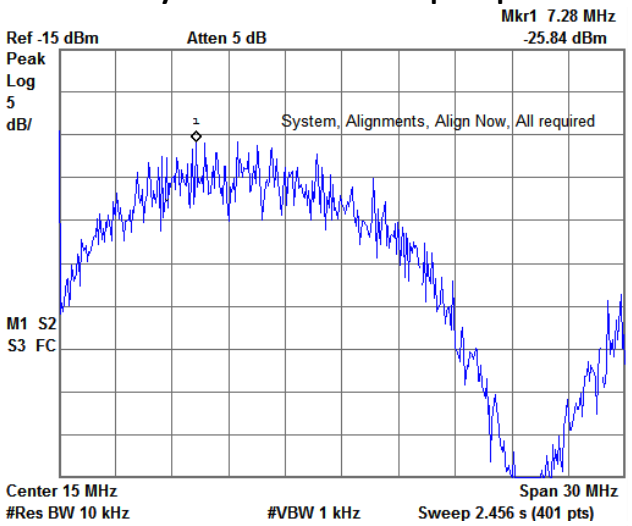
This proposal

1560 Byte – Normal case Lab Results
(0-30 MHz Span)

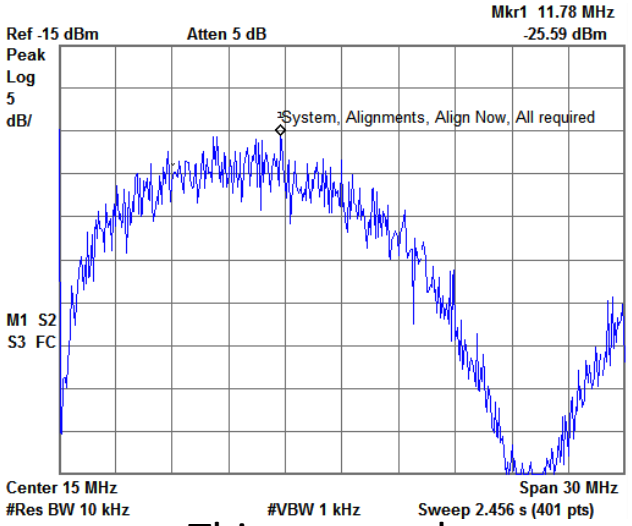
Original data



Tazebay & Cordaro's proposal



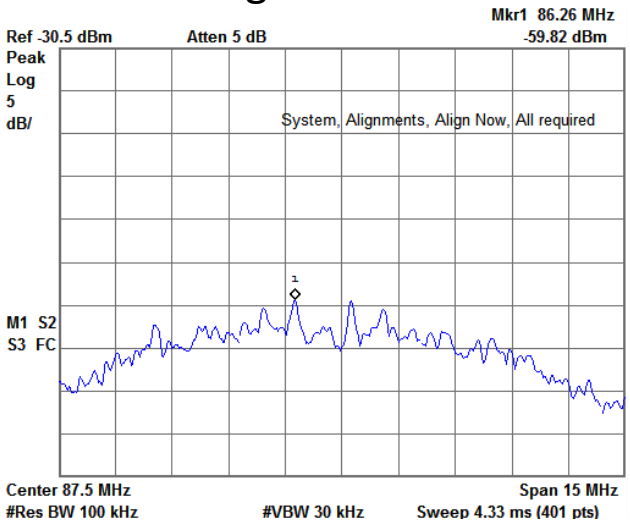
- 2.8 dB reduction with Tazebay & Cordaro's proposal
- 2.5 dB with this proposal
- 0.3 dB worse vs 0.5 dB better from analysis



This proposal

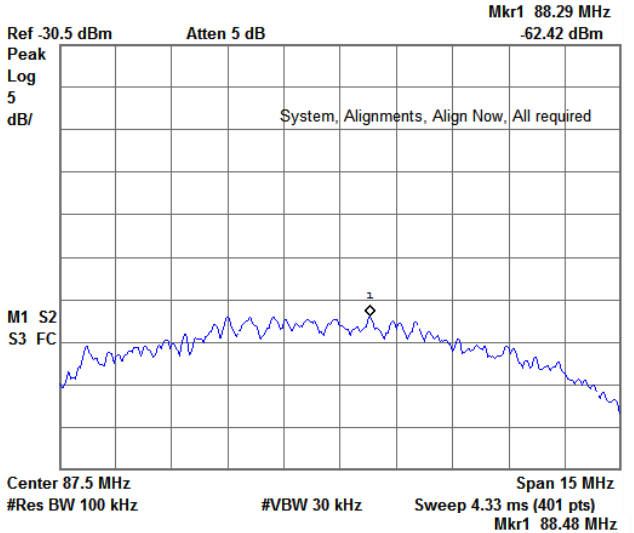
1560 Byte – Normal case Lab Results
(80-95 MHz Span)

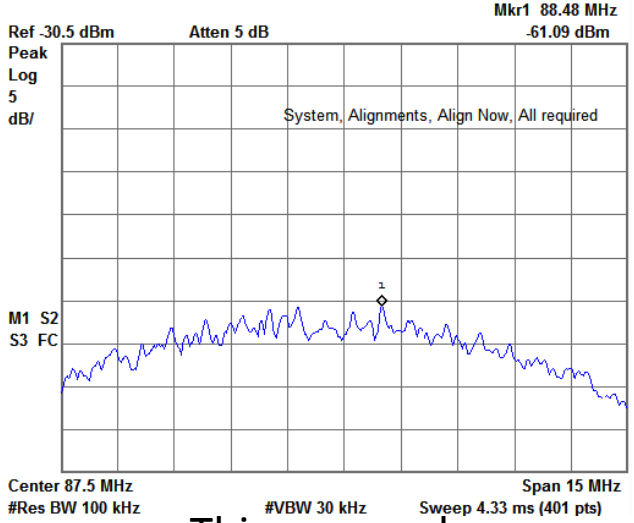
Original data



- 2.6 dB reduction with Tazebay & Cordaro's proposal
- 2.1 dB with this proposal
- 0.5 dB worse vs 0.5 dB better from analysis

Tazebay & Cordaro's proposal





This proposal

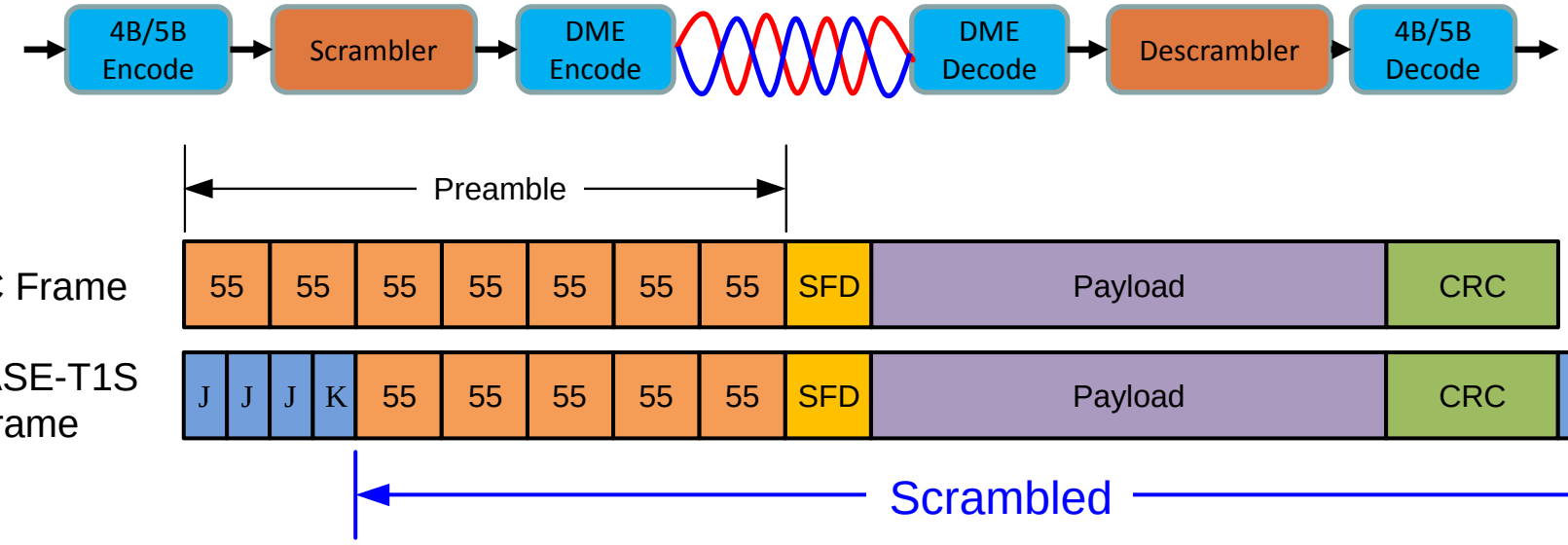
Results Summary

Simulation and lab measurements demonstrate that

- the proposed scrambling of the preamble and payload will achieve the same level of PSD peak emission reduction the preamble and scrambler proposed by Cordaro, Tazebay, et al.,
- keeps the PLCA untouched and maintaining the DME encoding self-clocking property permitting a lower cost system implementation.

10BASE-T1S Scrambler Proposal

- Scrambler is inserted after the 4B/5B encoder and before the DME
- Scrambler:
  - Polynomial: $X^{15} + X^4 + 1$
  - Initial value: [0 0 1 0 1 0 0 1 1 0 0 0 0 0 1]
- Scramble all data after "JJJK", including "ESD" and "ESDOK/ESDERR"
- Descrambler is initialized after receiving "K"



Conclusion

- A new scrambler for scrambling the preamble and payload is proposed for 10BASE-T1S
- The proposed preamble and payload scrambling scheme provides the following advantages:
  - As effective at reducing peak PSD peak emissions as the method proposed by Cordao, Tazebay, et al.,
  - Maintains the DME self-clocking property for fast CDR (a few bits),
  - Retains two-level binary signaling,
  - Keeps the original frame preamble and format, and
  - No change in PLCA scheme needed and therefore no reduction in the efficiency of the network.