Rate/Reach, Impulse Noise, and RFI Egress Results for EFM Copper Objectives

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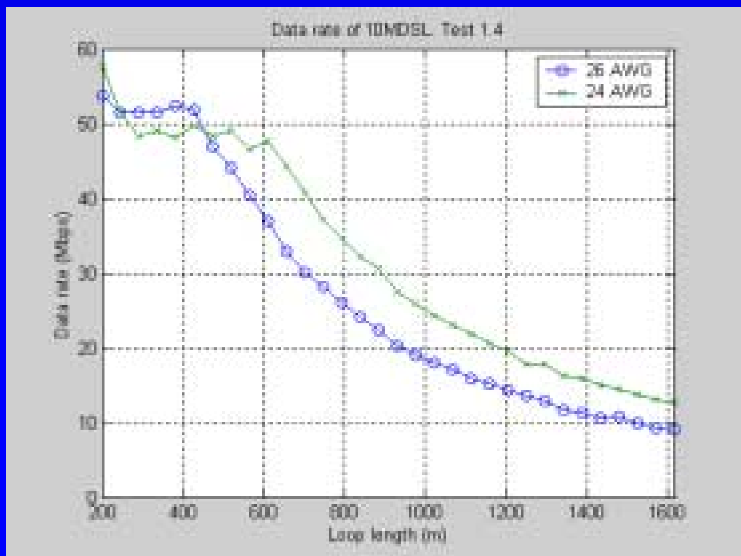
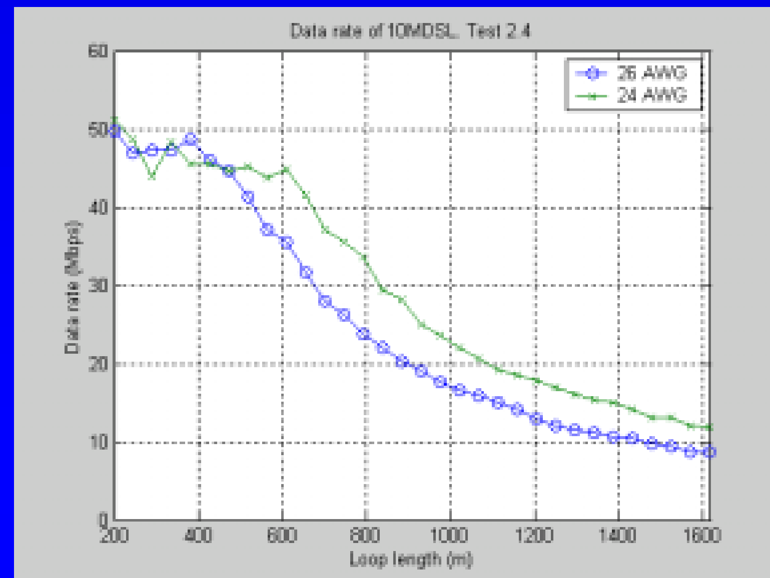
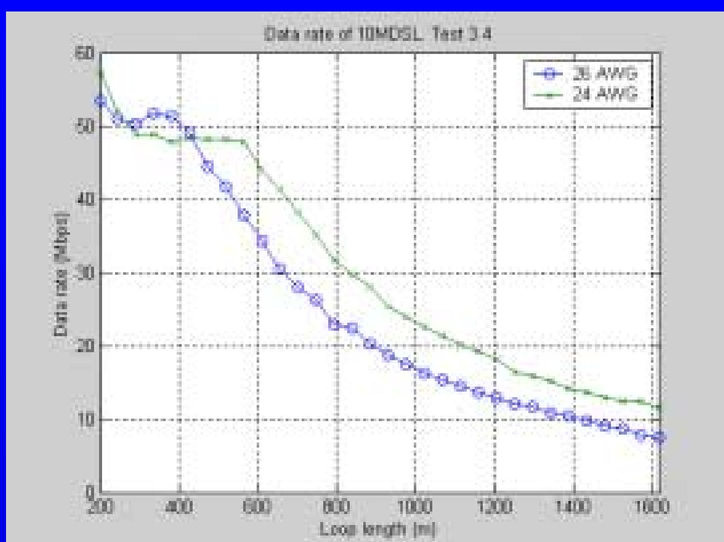
EFM Evaluation for first rate/reach Cu Objective (see O'Mahony et. al.)

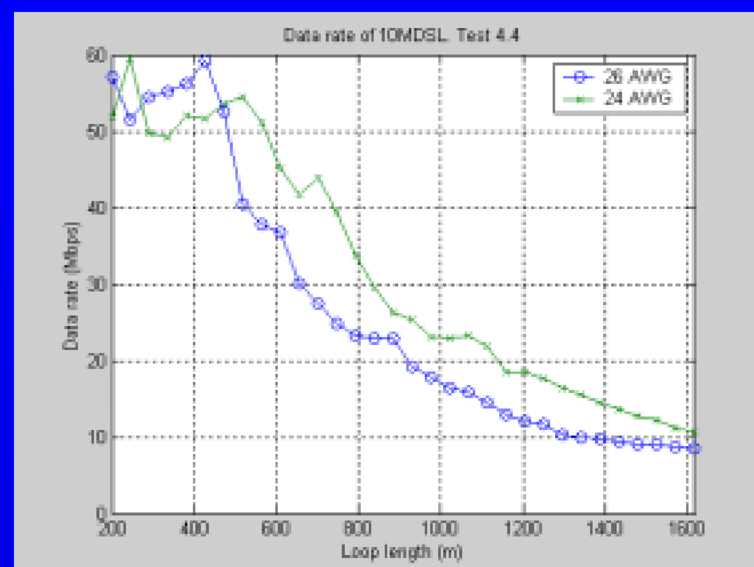
- Rate/Reach Test:
  - 10 Mbps symmetric from Table 12.9 of T1.424 Part 1
- Impulse Noise Tolerance:
  - Tolerate 250 μs burst with <= 10 ms interleaver delay, and
  - Tolerate 500 μs burst with <= 20 ms interleaver delay
- Egress Control:
  - PHY shall have capability to reduce PSD level HAM bands below –80 dBm/Hz

10 MDSL performance with Test 1.4 – 4.4 (T1.424 Part 1) – Passed All Tests





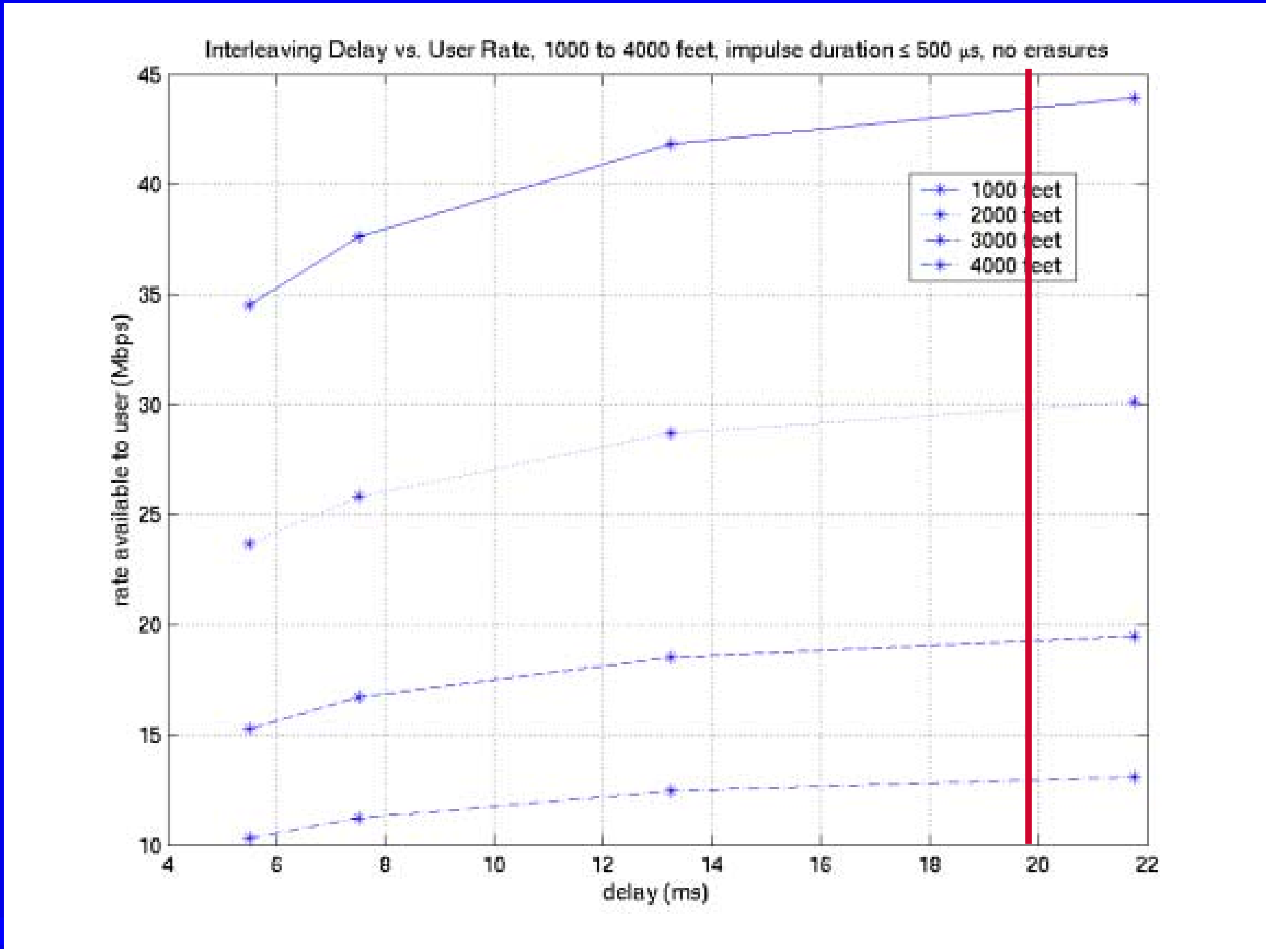




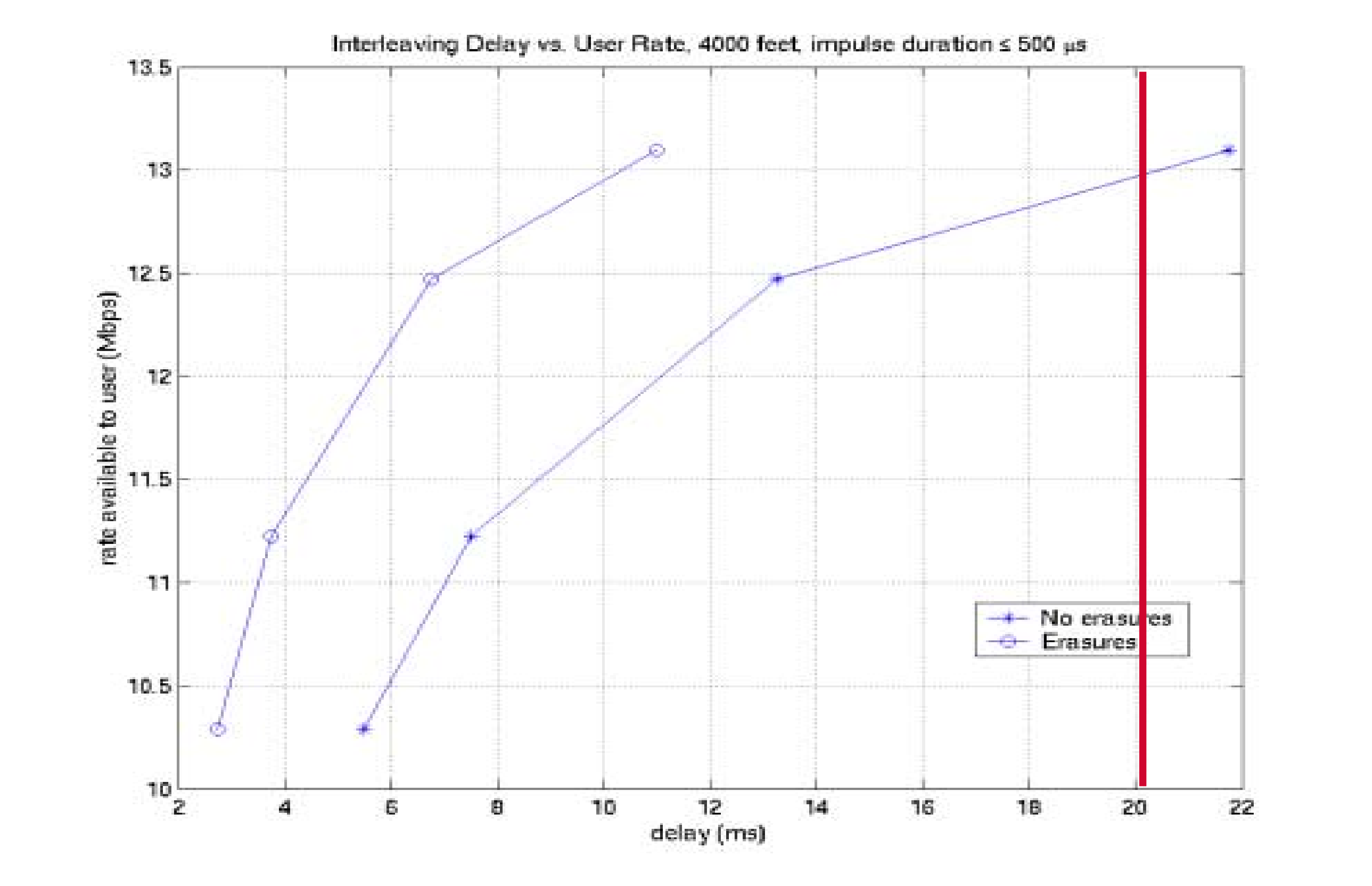
Impulse Noise?

- France Telecom Impulses (11,000 measured) – for 650 μs impulse
- All Corrected at 10 Mbps with < 5 ms latency
  - See T1E1.4/2002-127 report from FT for results
  - Needs DMT and DSM to achieve the low latency

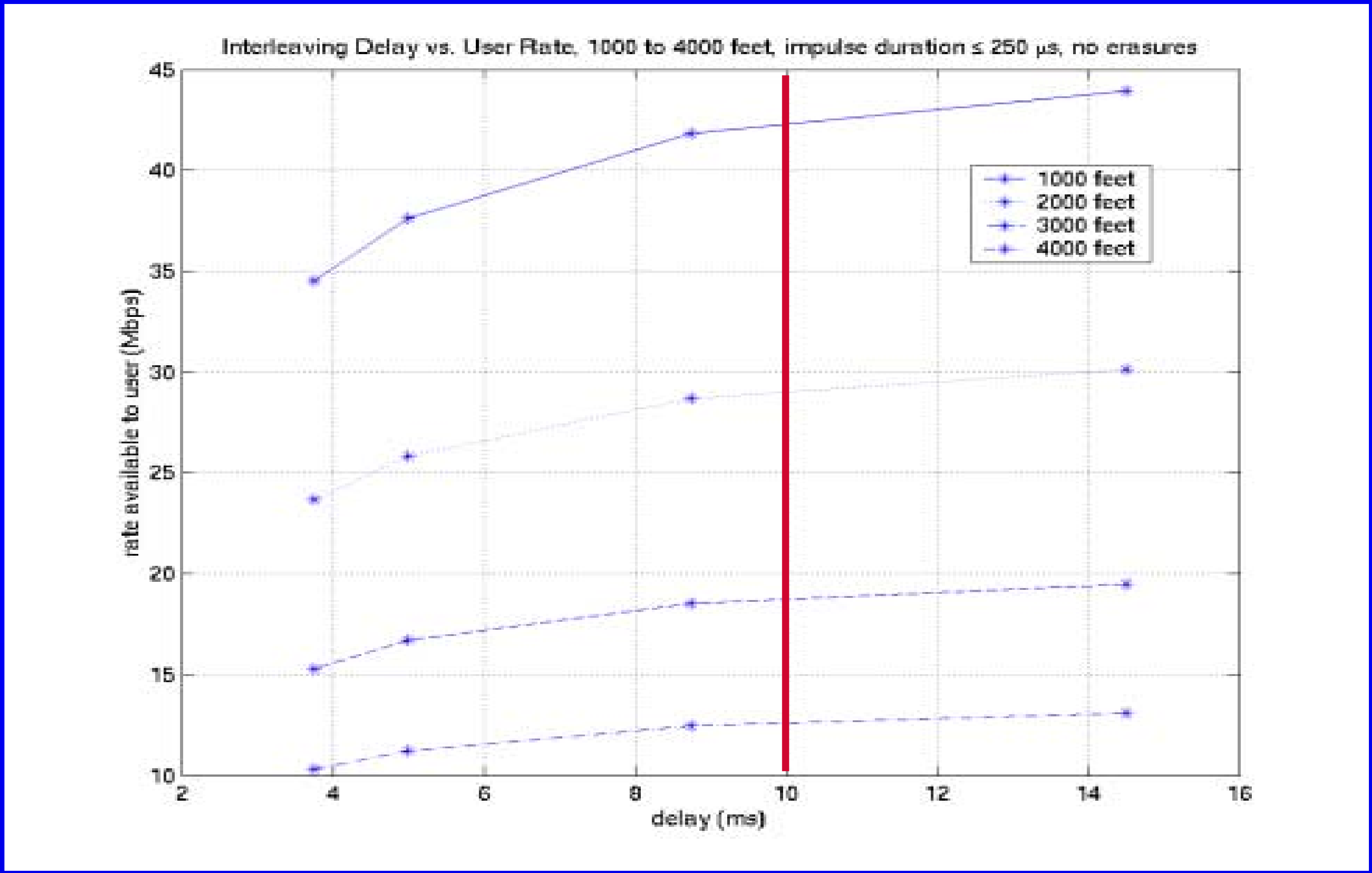
Rate/Interleaving Delay Tradeoff (500 μs minimum Impulse burst)



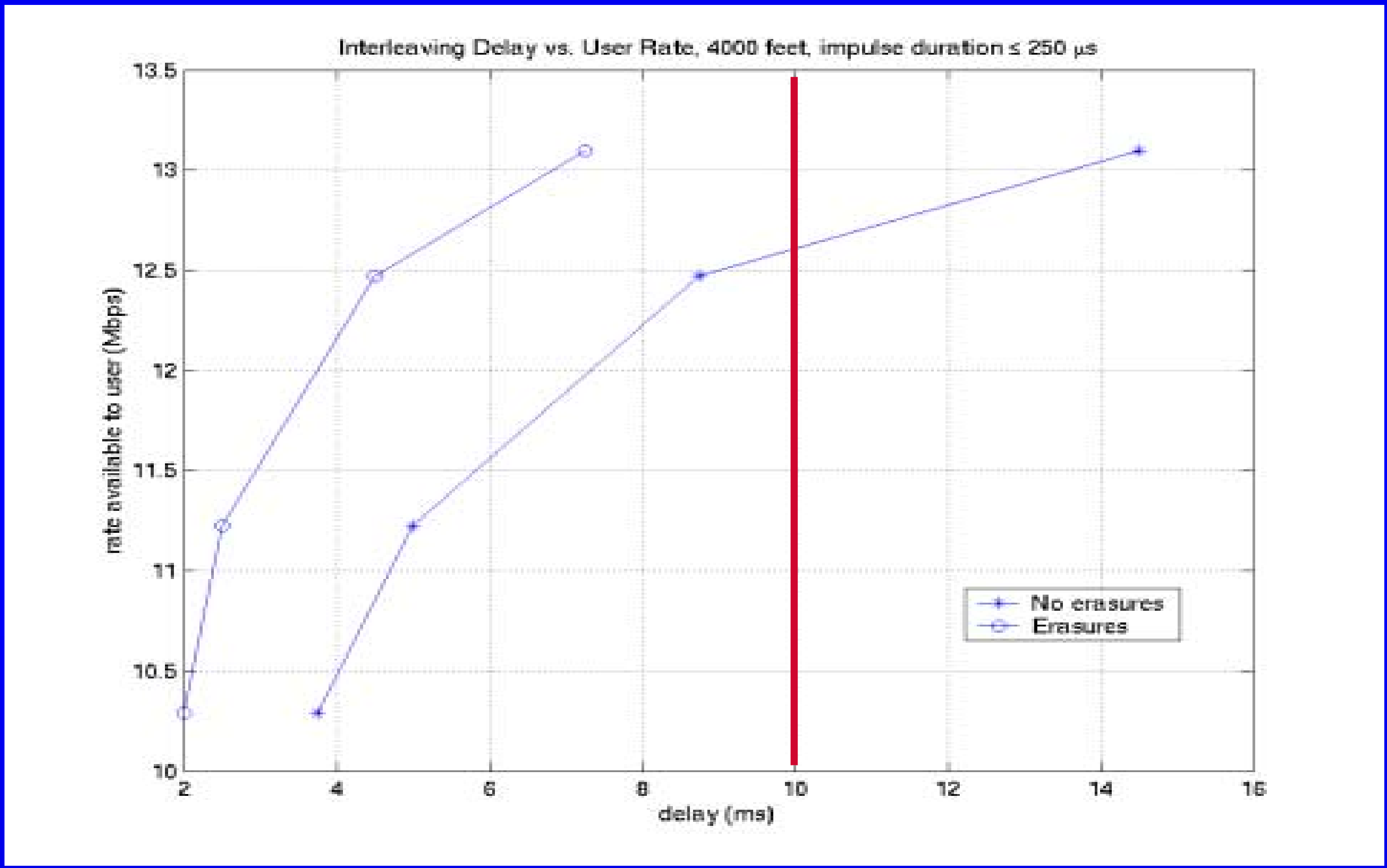
Rate/Interleaving Delay Tradeoff (500 μs minimum Impulse burst) – With and Without Erasures



Rate/Interleaving Delay Tradeoff (250 μs minimum Impulse burst)

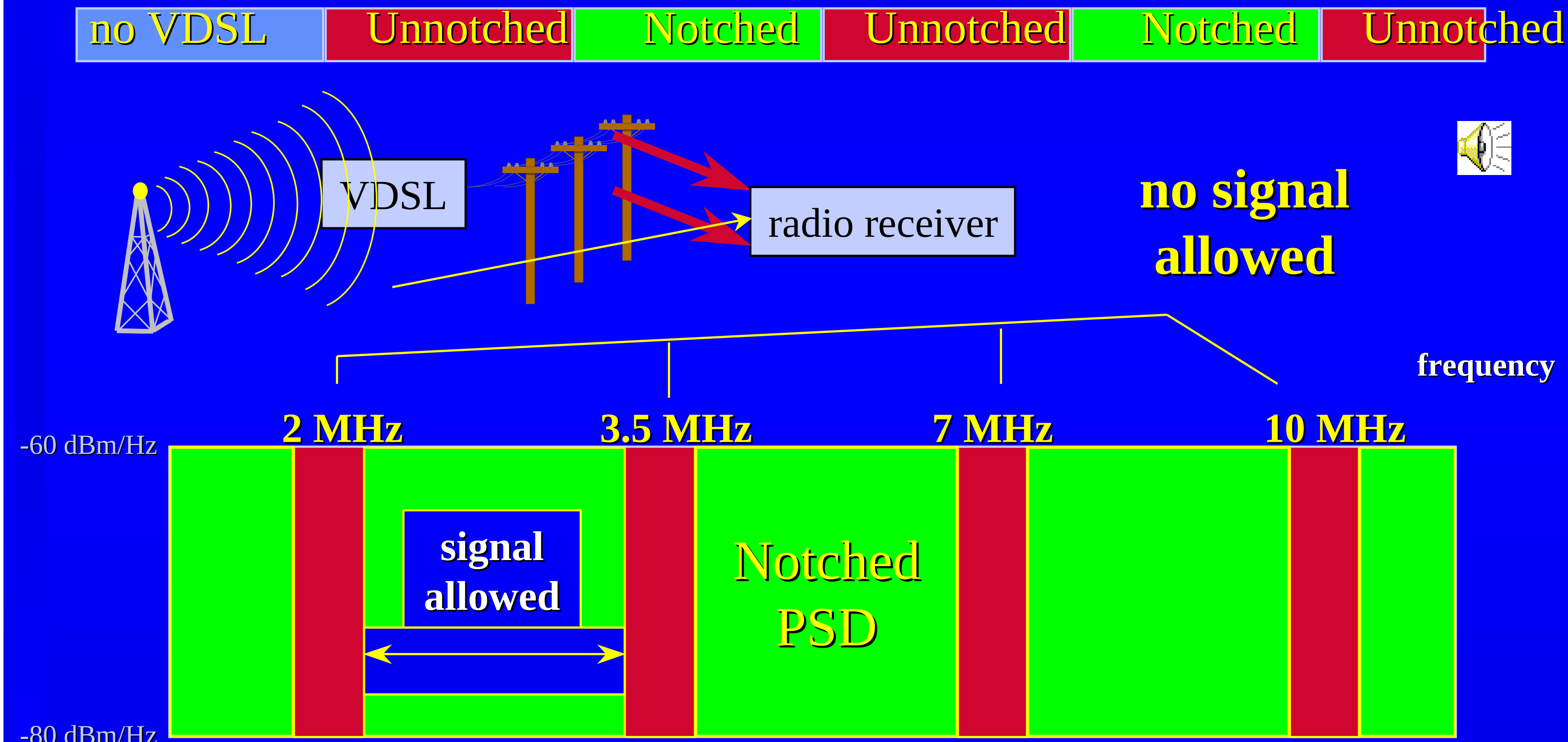


Rate/Interleaving Delay Tradeoff (250 μs minimum Impulse burst) – With and Without Erasures



Radio Egress

- like crosstalk, except into radio receivers ("hogs" their band)



T1.424 Amateur Radio Bands

Start Frequency	Stop Frequency
1.81 MHz	2.00 MHz
3.50 MHz	4.00 MHz
7.00 MHz	7.30 MHz
10.10 MHz	10.15 MHz
14.00 MHz	14.35 MHz
18.07 MHz	18.17 MHz
21.00 MHz	21.45 MHz
24.89 MHz	24.99 MHz
28.00 MHz	29.70 MHz

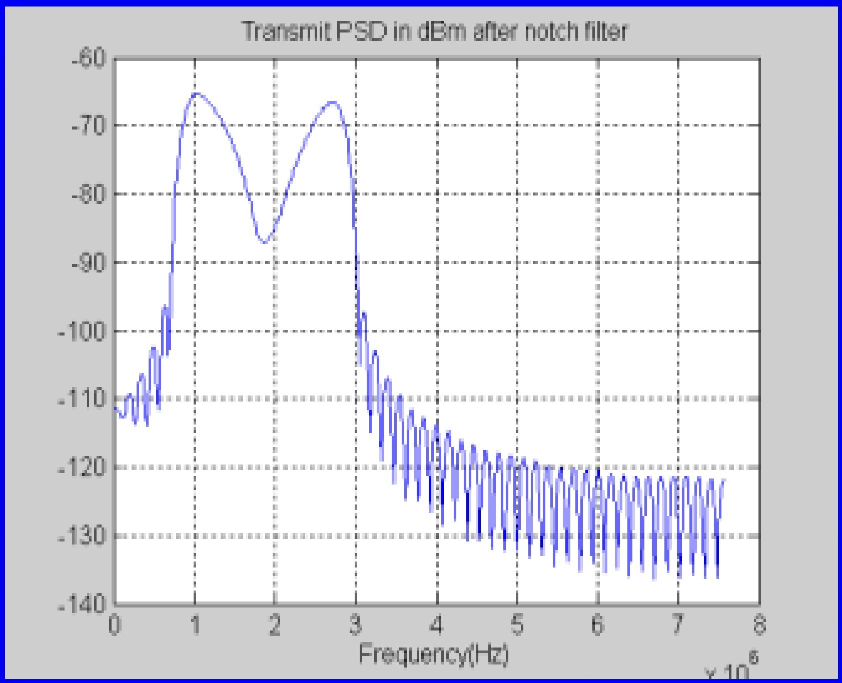
SCM -DMT

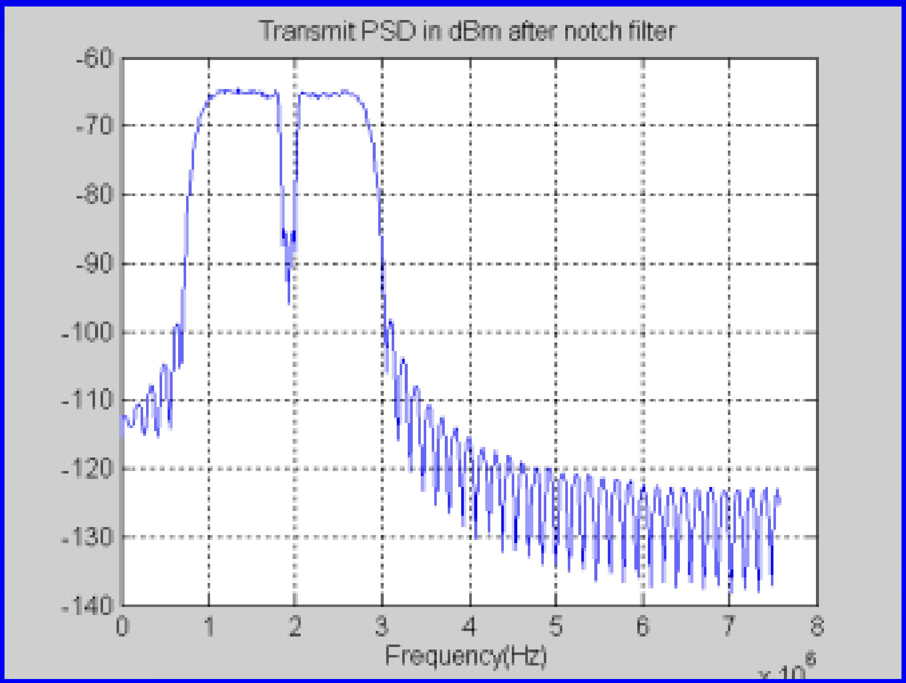
- DFE-receiver notching does NOT eliminate the performance loss caused by transmitter egress-notch filters in SCM
  - Statements to the contrary have no basis in transmission theory
- Turning off tones in forbidden bands in DMT does avoid the performance loss that is unique to SCM

Example Situation

- 1 km loop
- DMT uses same bandwidth as QAM
  - So DMT bandwidth advantage turned off
    - Bandwidth used between 1 and 3 MHz with tones between 1.8-2.0 silenced
  - Symbol rate of QAM is 2 MHz between 1 and 3 MHz
    - Notch filters, FIR and IIR used
    - Adaptive MMSE-DFE with infinite-precision used in receiver

Notch Filters for QAM

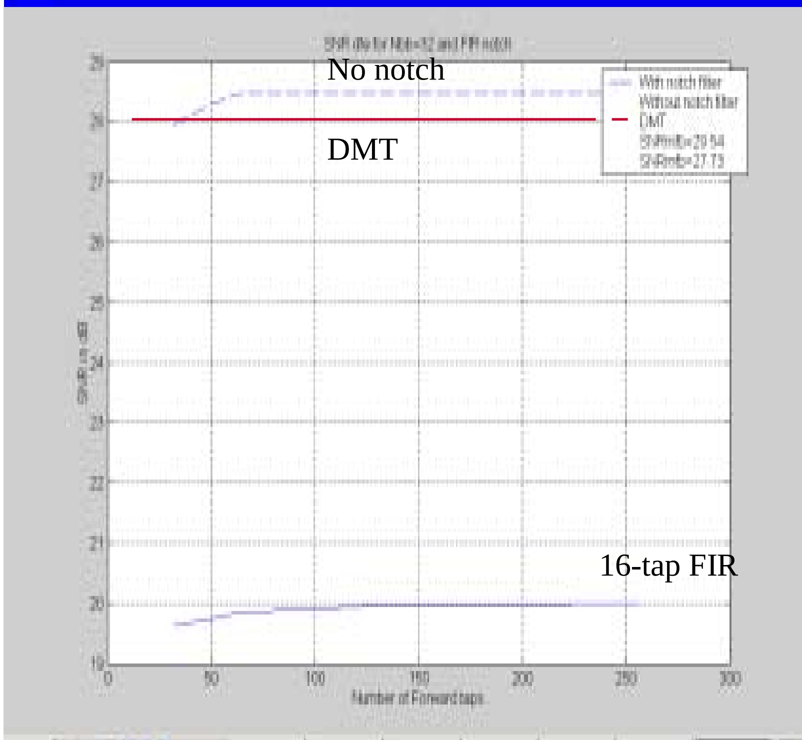


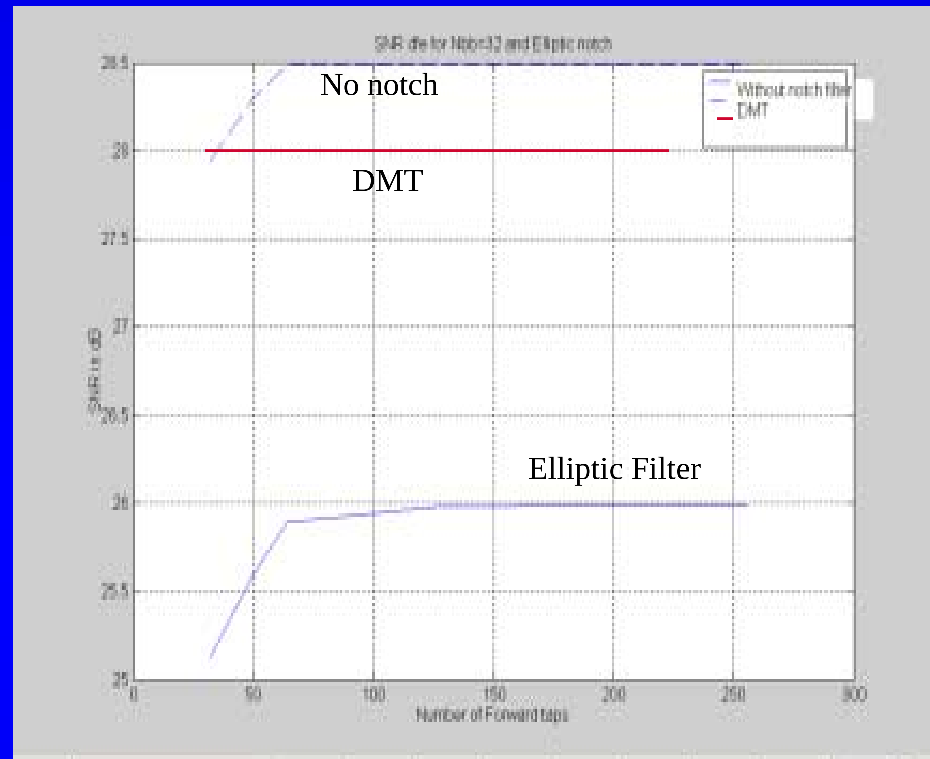


16-tap FIR Filter
(used in field because Receiver is easier)

6^{th}- order Elliptical Filter
(leads to numerical problems & Complex receiver)

SNRs for various





- 32 feedback taps
- Optimized Infinite-precision DFE
- PAR loss of QAM not included here

PAR Issue for RF

- QAM notch filters increase PAR by 5 dB, so loss reflected in actual designs
  - Observed in lab measurements
- No change in DMT modems
  - .8 dB loss for turning off 200 kHz of bandwidth
  - Analog driver at 11.5 dBm – 150 mW
- Total Loss of QAM
  - 5+8=13 dB for practical FIR with components sold
  - 5+2.5 = 7.5 dB for IIR (which is not used for complexity reasons)
  - 2.5 dB theoretical limit with transmitter with >1 Watt for analog driver alone (11.5 dBm transmit power)
- Clearly complexity adds to ability to reduce RF emissions loss in QAM

Radio Conclusions

- Radio egress should not be ignored
  - Could lead to loss of EFM/VDSL opportunity because amateur radios are harmed if notching is not used
  - Emergency/safety bands
- DMT solves problem easily with almost no performance loss
- SCM cannot solve the problem so well, even with infinite complexity
  - For “low complexity” SCM – loss is 14 dB

Motions

Add the following criteria for Copper Objectives:

- Pass all 10 M symmetric rate tests from Table 12.9 of T1.424 Part 1
- Impulse Noise Immunity:
  - Tolerate 250 μs burst with <= 10 ms interleaver delay, and
  - Tolerate 500 μs burst with <= 20 ms interleaver delay
- PHY shall have capability to reduce PSD level HAM bands below –80 dBm/Hz
- All Criteria must be MEASURED performance to account for implementation-related degradation/complexity