Rate v. Reach of Duplexing Options

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Long Reach Objective

- **Current EFM Copper Objectives:**
  - PHY for single Pair Non-loaded Voice Grade Copper, Distance >= 2500 Feet With >= 10mbps Aggregate Bit Rate
  - PHY for Single Pair Non-loaded Voice Grade Copper, Distance >= 4600m, 0.4mm >= 256kbps
  - PHY for Single Pair Non-loaded Voice Grade Copper, Distance >= 3700m, 0.5mm >= 4mbps
  - Can support optional specification for combined operation on multiple copper pairs
  - The point-to-point copper PHY is Compliant with spectrum management restrictions imposed by operation in public access networks, including: Recommendations from NRIC-V (USA), ANSI T1.417-2001 (for frequencies up to 1.1MHz), Frequency plans approved by ITU-T SG15/Q4,T1E1.4 and ETSI/TM6
- ***This Analysis shows how dynamic TDD can achieve 1Mbps for self-disturber case at 4600m, 0.4mm***

Duplexing Options

- **This contribution analyzes the long loop performance of 3 duplexing options:**
  - Dyanmic Time Division Duplexing (TDD) – no synchronization between loops
  - Frequency Division Duplexing (FDD) – T1.413 non-overlapped ADSL
  - Echo Cancelled (EC) – T1.413 overlapped ADSL

NEXT & FEXT Models

- **Updated T1E1 NEXT Model (T1.417 Issue 2)**

$$NEXT = x_n \times f^{3/2} \cdot \left(1 - \left|H(f,L)\right|^4\right)$$

$$x_n = 8.818 \times 10^{-14} \times (n/49)^{0.6}$$

n is the number of disturbers, and f is frequency in Hz,

$|H(f,L)|$ is the magnitude of the insertion gain transfer function for a loop of length , L. This update reflects reduced NEXT on short loops (<2kft)

- **FEXT Model**

$$FEXT_n = \left|H_{channel}(f)\right|^2 \times klf^2$$

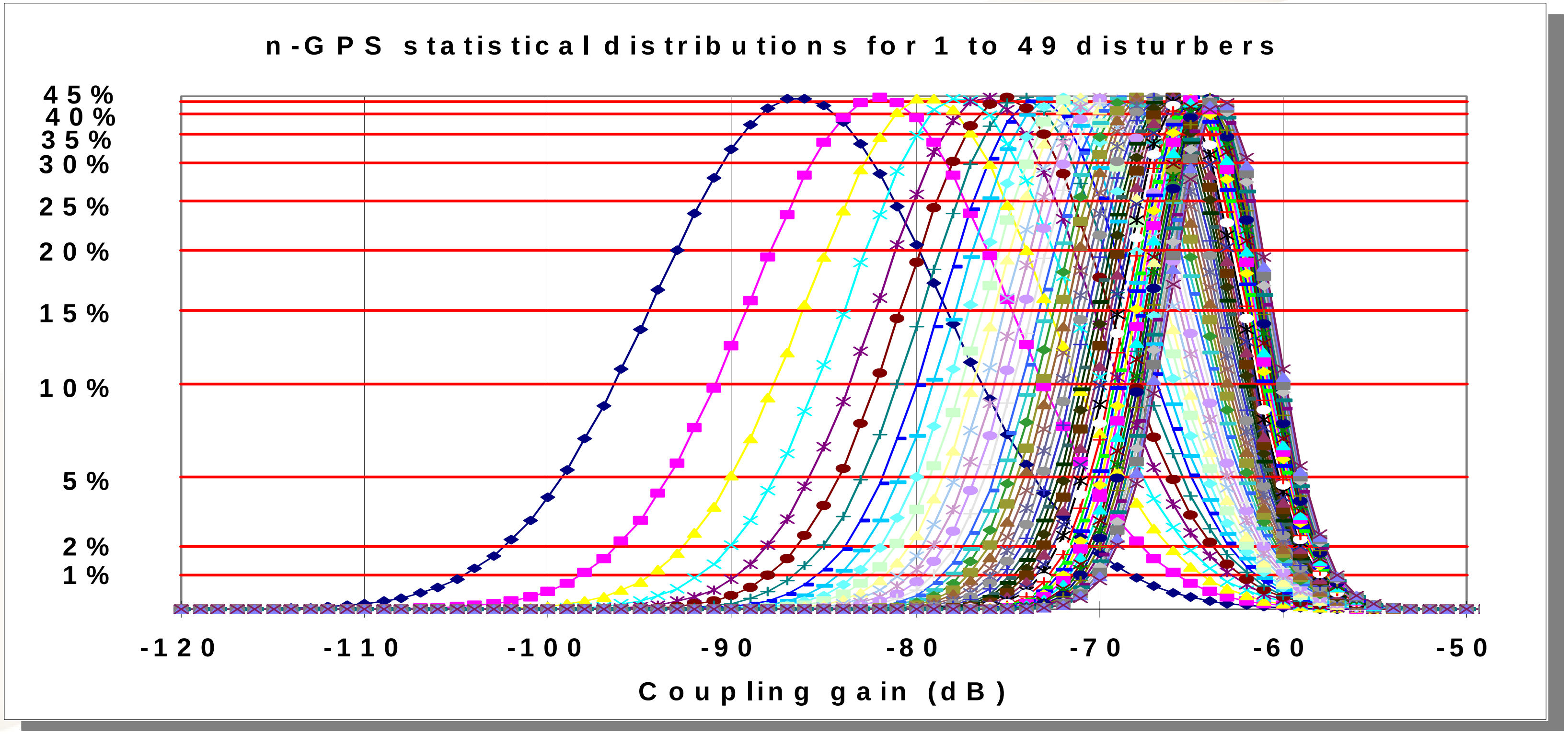
$$k = 8 * 10^{-20} * (n/49)^{0.6}$$

n = number of disturbers, l = the loop length in feet, and f = frequency in Hz.

$|H_{channel}(f)|^2$ is the channel insertion gain

Rank Ordering of Disturbers

- T1E1 models rank order disturbers so that the 1st disturber has the most impact, 2nd disturber a little less, and so on
- These are 99th Percentile, worst case models, based on statistics plotted below:



Binder Fill or Traffic Pattern?

- For continuously transmitting DSLs, performance level is plotted as a function of binder fill
- For dynamic burst mode systems, which only transmits high bandwidth signal when user data is sent, binder always assumed full, and traffic level is the parameter for performance

Mapping Traffic Pattern to Number of Disturbers

- **Convert percentage utilization to number transmitting at any given instant:**

  4% : 2 out of 50

  20% : 10 out of 50

  48%: 24 out of 50

  96%:48 out of 50

- **For symmetric traffic, dynamic TDD system is transmitting downstream 50% of the time, and upstream 50% of the time**
- **So for:**

  4%, symmetric, 1 NEXT, 1 FEXT

  20%, symmetric, 5 NEXT, 5 FEXT

  48% symmetric, 12 NEXT, 12 FEXT

  96% symmetric, 24 NEXT, 24 FEXT

Stacking Worst Cases

- Plugging these disturber numbers into NEXT and FEXT equations means not only is it the 99th percentile worst case cable, but the worst case NEXT and worst case FEXT loops happen to be transmitting in the same direction concurrently
- Coupling Factor for each loop can be derived from power sum equations
- Using this same 99th percentile power sum equation, but picking best, or median loops from ranked list, instead of worst reduces coupling factor as follows:

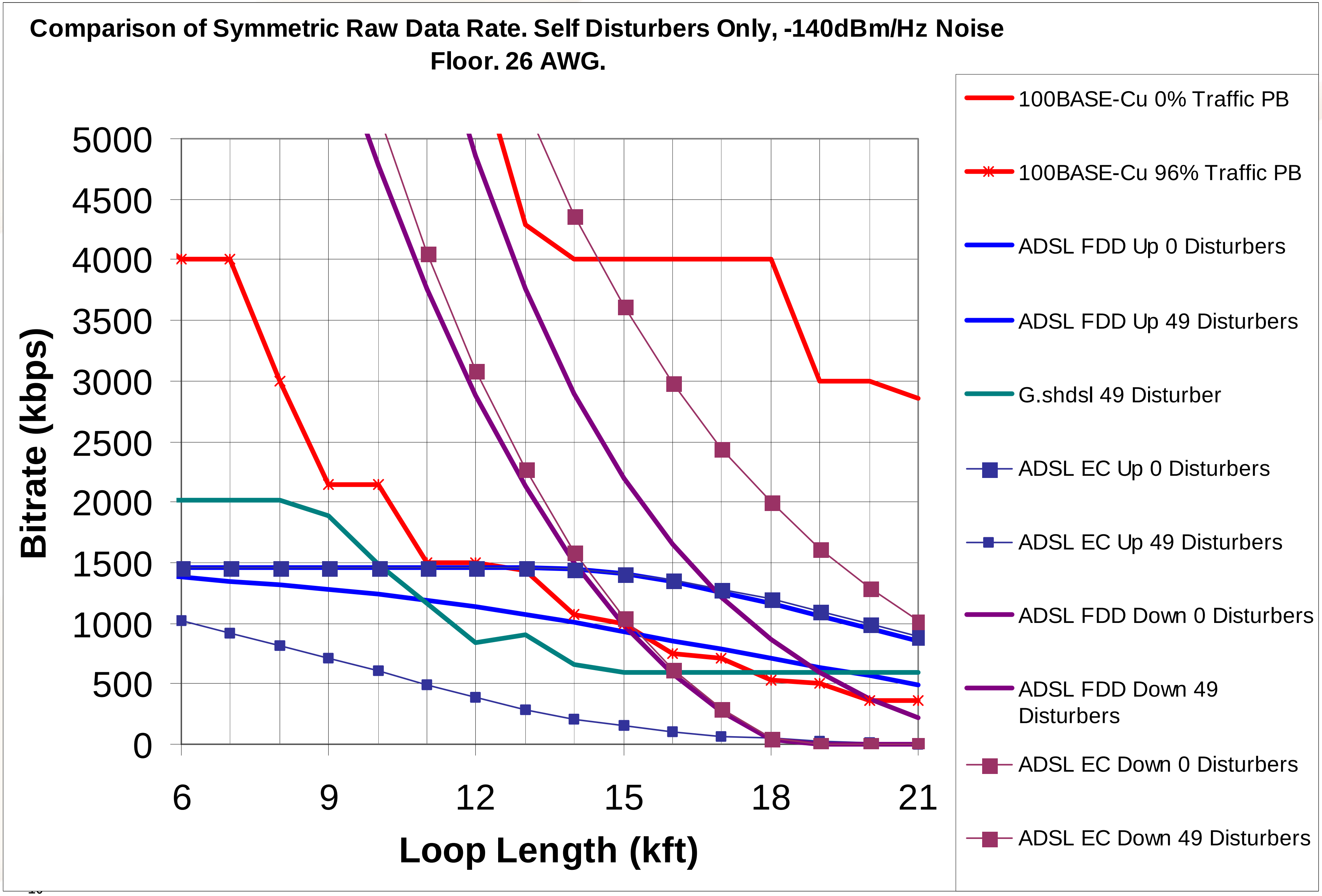
Median	Best
6.5dB less	7.7dB less

Probability of Simultaneous Worst Case Loops

- Given ranked list of 49 loops from 99th percentile model, and assuming each loop is equally likely to transmit, then the probablity that N worst case loops will simultaneously transmit is $C_{49,N}$

- Probabilities: 2 Disturbers 1 in 1176, 5 Disturbers 1 in 2e6, 12 Disturbers, 1 in 9e10, 24 Disturbers, 1 in 6e13

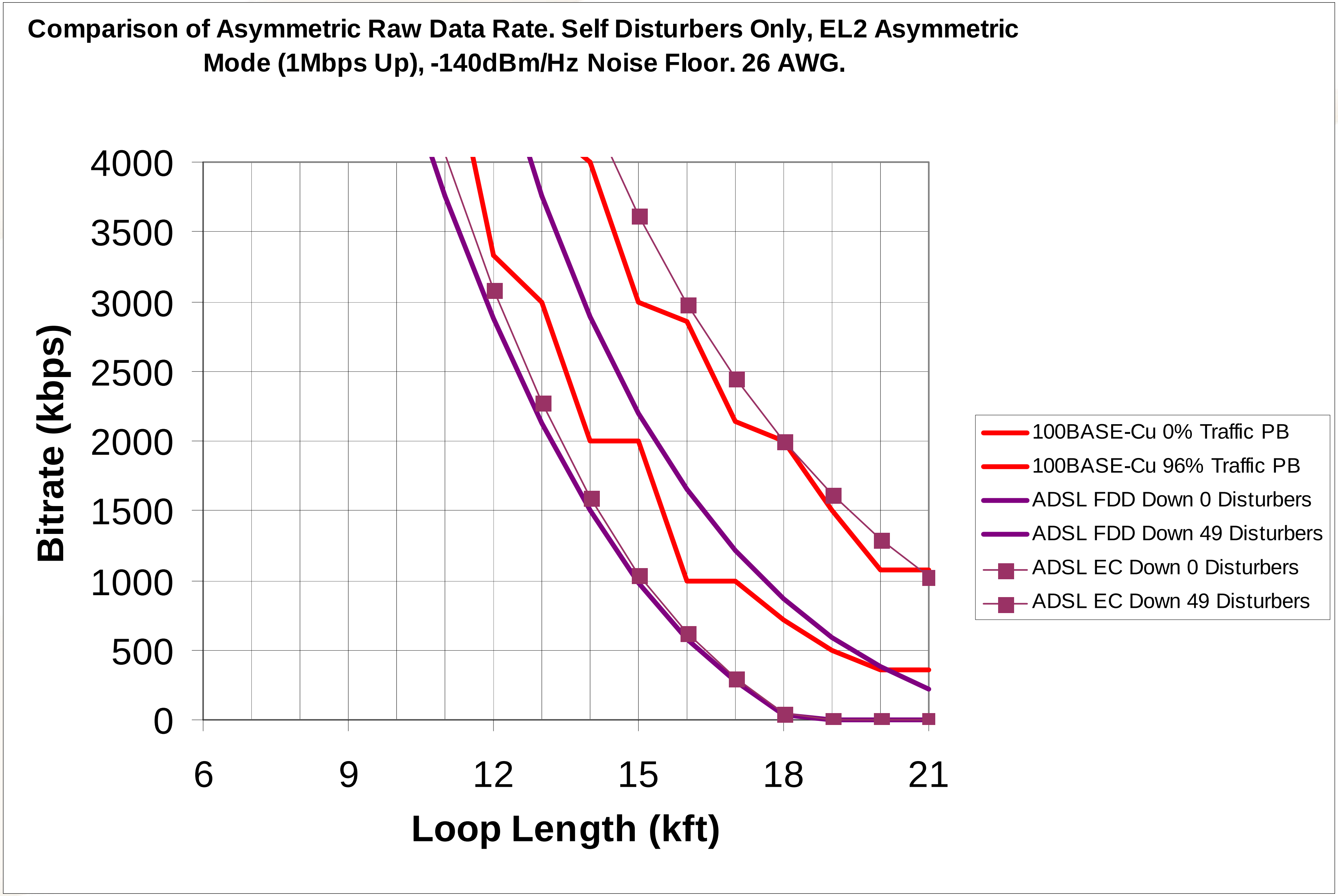
Self Disturbers, Symmetric Service



Self Disturbers, Symmetric Service Results

- For symmetric service, the lower bitrate (up/down) Governs for ADSL (after 14kft, downstream is less than upstream for FDD)
- Dynamic TDD gives 4x the symmetric rate of EC for full binders 6kft and longer
- Dynamic TDD gives from slightly better - up to 3x, the symmetric rate of FDD for full binders 6kft and longer
- Dynamic TDD gives much higher rate when single service in binder, or traffic is bursty.
- Dynamic TDD offers full binder service to greater than 21kft vs. 18kft for FDD or EC
- G.shdsl is not considered as it can not lineshare with POTS

Self Disturbers, Asymmetric Service



Self Disturbers, Asymmetric Service Results

- Dynamic TDD gives greater asymmetric bandwidth service than EC or FDD for full binders, 6kft and longer
- Dynamic TDD gives equivalent downstream rate to single service EC, if single service dynamic TDD or traffic is bursty
- Dynamic TDD gives better downstream rate than single service FDD, if single service dynamic TDD or traffic is bursty
- Dynamic TDD gives 2x the bandwidth at 15kft, which is loop length of the longest reach objective
- Dynamic TDD offers full binder service to greater than 21kft, vs. 18kft

Conclusion

- **Dynamic TDD gives superior long loop, full binder rates compared to FDD and EC**
- **Dynamic TDD gives the best performance for the long reach objective (15kft, 26 AWG)**
- **A Bitrate of 1Mbps (Self-disturbers) at >= 4600m, 0.4mm Copper Can be achieved (Rate within the scope of current 802.3 standards).**