100BASE-Cu

Simulation Details

Proposed Copper EFM PHY

ELASTIC
NETWORKS

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100BASE-Cu PHY Review

- ✓ **100BaseCu [1]…[3] is a half-duplex, burst mode, frequency agile, symmetry agile, spectrally compatible [4]…[8] access technology that builds on successfully deployed technology**
- ✓ **This symmetry agile Time Division Duplexing technology does NOT require central synchonization, or common timing between carriers**
- ✓ **100BASE-Cu offers flexible provisionable services, either symmetric, or asymmetric, with flexible symmetry ratio**

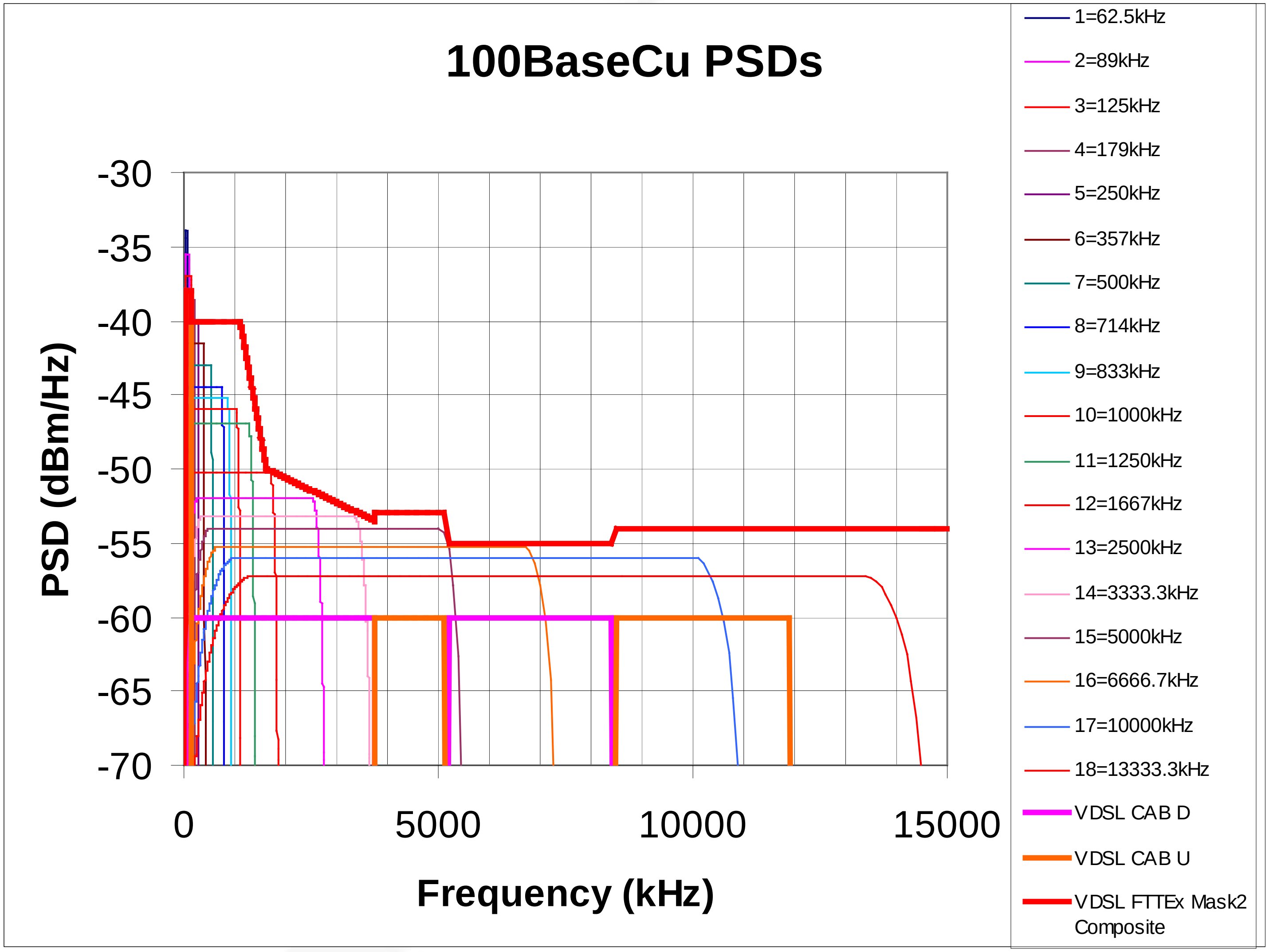
Simulation Refinement

- ✓ **Calculation accuracy increased**
- ✓ **Bandplan refinement, based on prototype development**
  - Center Frequency now equals (Symbol Rate + Excess Bandwidth)/2 + Linesharing Offset (20kHz for POTS)
  - Effectively puts first null at linesharing offset rather than corner of passband

Modified Bandplan PSDs

- ✓**Total Power reduced (1 to 2 dB) on 5 mid rate symbol rates to comply with composite mask in draft Trial Use T1E1.4 Standard**

- ✓**PSD of lowest symbol rates within T1.417 Spectrum Management Class PSDs**



Simulation Parameters

- ✓ **6dB Margin, 5.2dB Coding Gain**
- ✓ **Insertion Gain calculated using linear fit model in T1.417 [9]**
- ✓ **SNR calculated using DFE based QAM equation from T1.417 A.2.5 [9],**

SNR Calculation

DFE-based QAM/CAP signals

Margin for DFE-base CAP/QAM technologies is computed using an Optimal DFE calculation for QAM:

$$Margin = \frac{1}{fbaud}\int_0^{fbaud} 10 * \log 10(1 + f\_SNR(f))df - SNR\_req \ \ \mathrm{dB}$$

where f_SNR is the folded received signal-to-noise ratio, defined as:

$$f\_SNR(f) = \sum_{n=0}^{3} \frac{S(f + fbaud \times n)\,|\,H(f + fbaud \times n)\,|^2}{N(f + fbaud \times n)}$$

NEXT & FEXT Model

- ✓ **Simplified T1E1 NEXT Model**

$$NEXT_n = x_n \times f^{3/2}$$

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

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

- ✓ **FEXT Model**

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

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

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

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

Origin of T1E1 NEXT/FEXT Models

- ✓ **In “Statistical Behavior of Multipair Crosstalk,” [10], S.H. Lin states:**
  - “ In this paper we present experimental data from more than 600 cables, comprising ***91,875 measurements***, to show that the gamma distribution (with log variate) is a more satisfactory approximation to modeling the multipair crosstalk behavior.”
  - ◆ These measurements of NEXT and FEXT were made at 772kHz and 3.15MHz
- ✓ **In “Cable Crosstalk Parameters and Models,” [11], Craig Valenti measured NEXT and FEXT from 0.3-40MHz, and validated model at frequency ranges of interest to EFM Cu PHY**

NEXT Power Sum Loss 99th Percentile Case

Figure B.1 – NEXT power sum losses for 25 pairs of PIC cable binder group

NEXT Model vs. Measurements

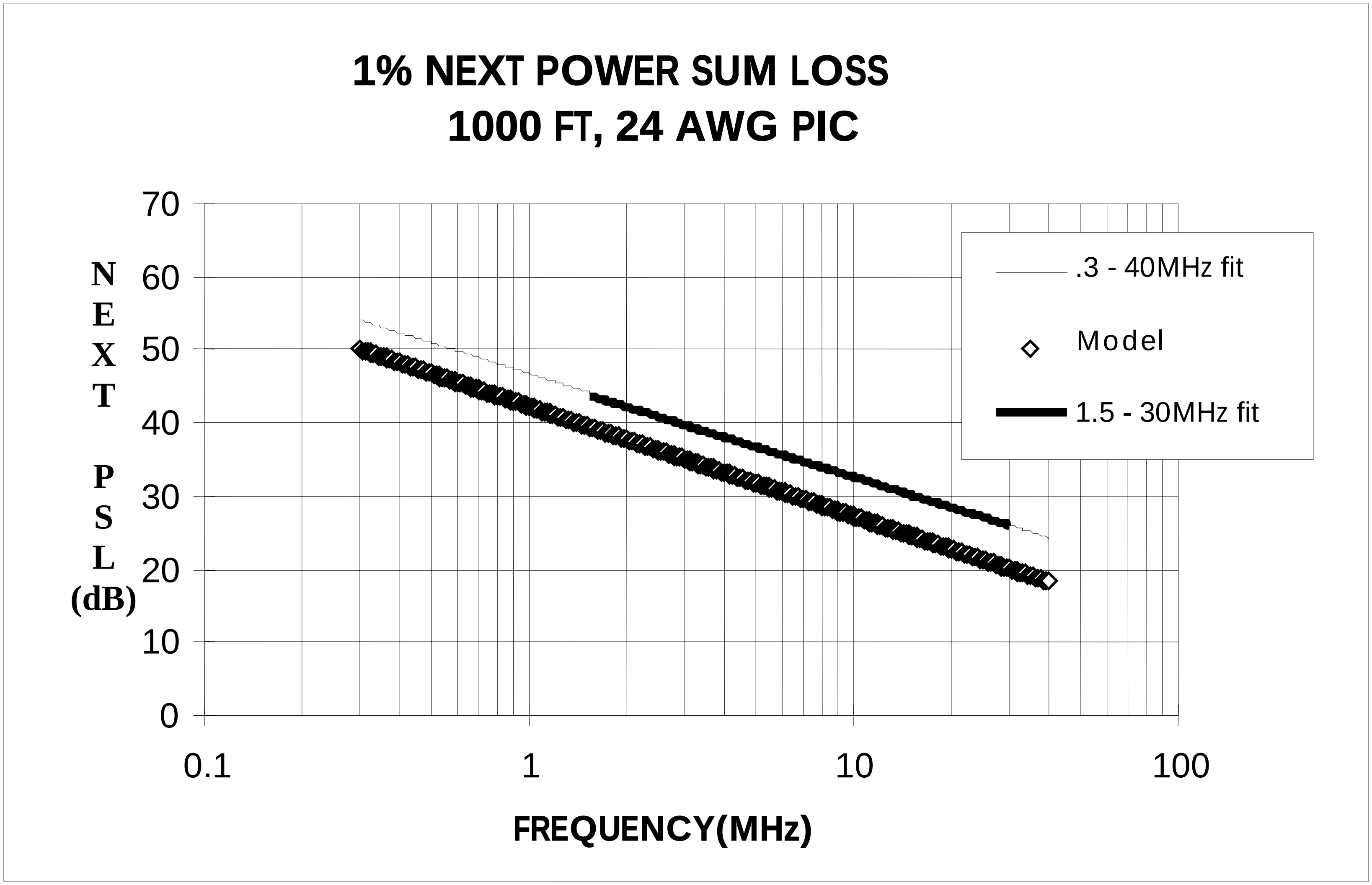


Figure B.1 – Comparison of Simplified Model NEXT with Measured NEXT

FEXT Power Sum Loss 99th Percentile Case

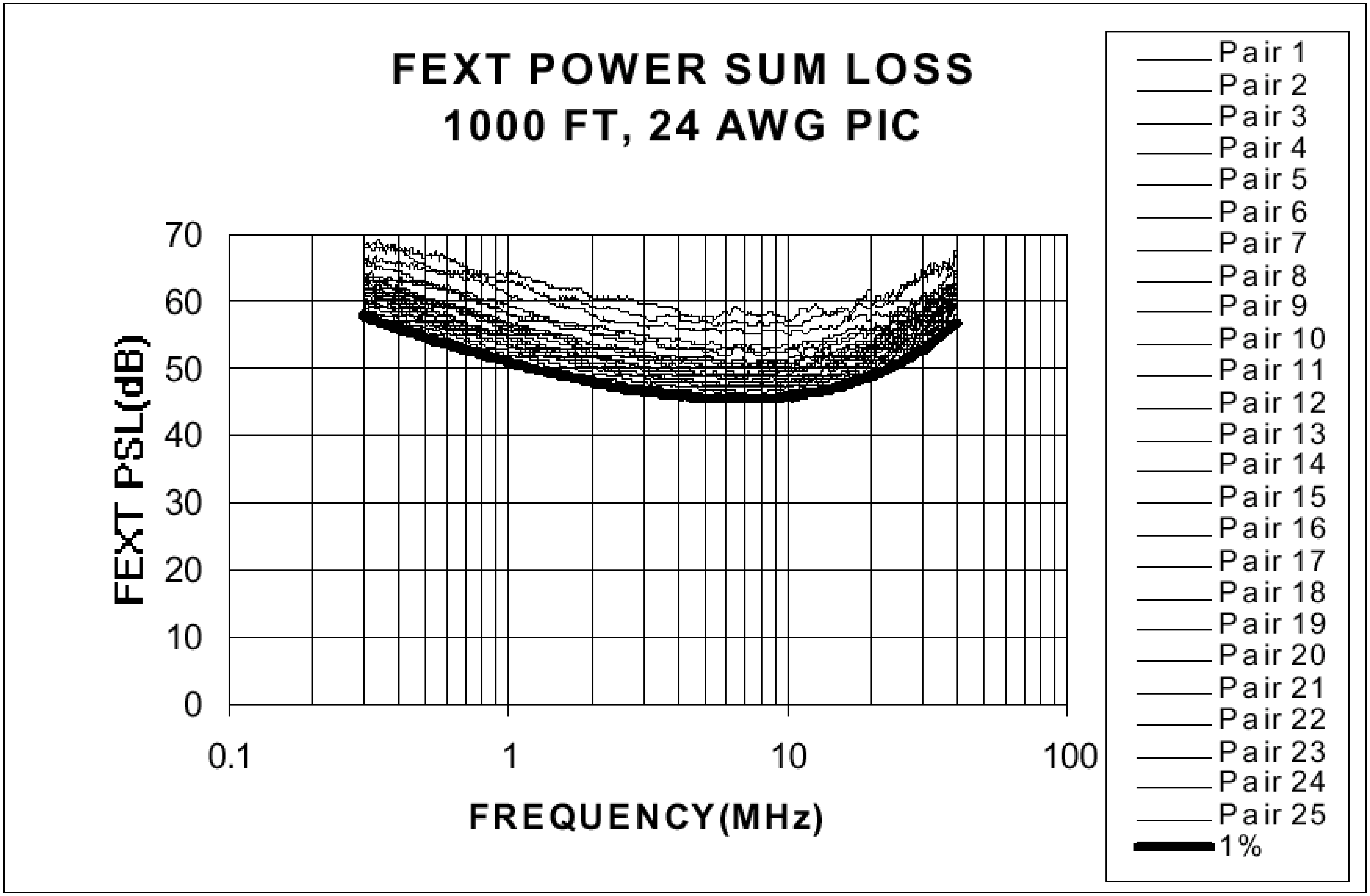


Figure 5: FEXT Power Sum Losses for 25 pairs of PIC cable binder group

FEXT Model vs. Measurements

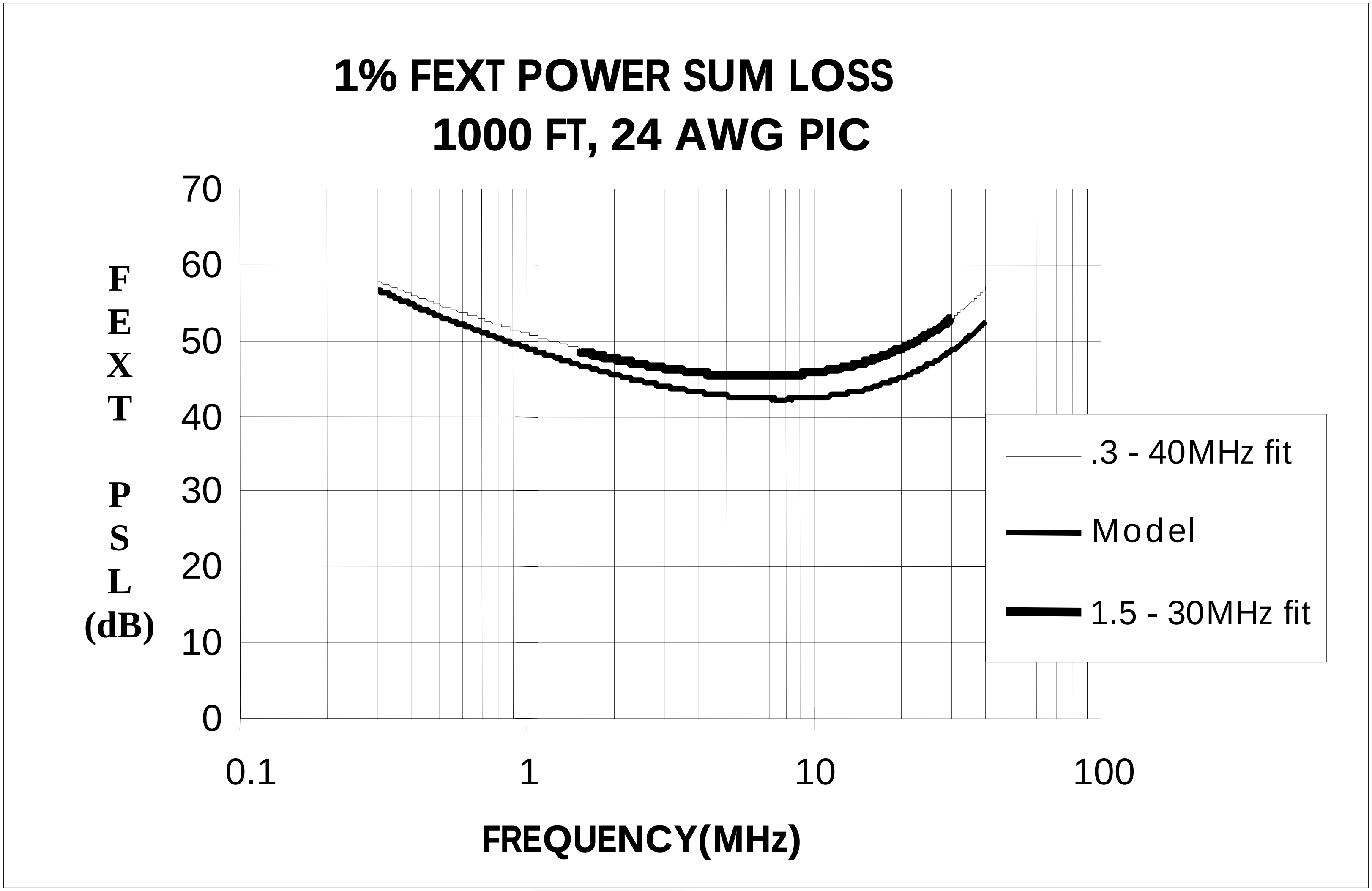
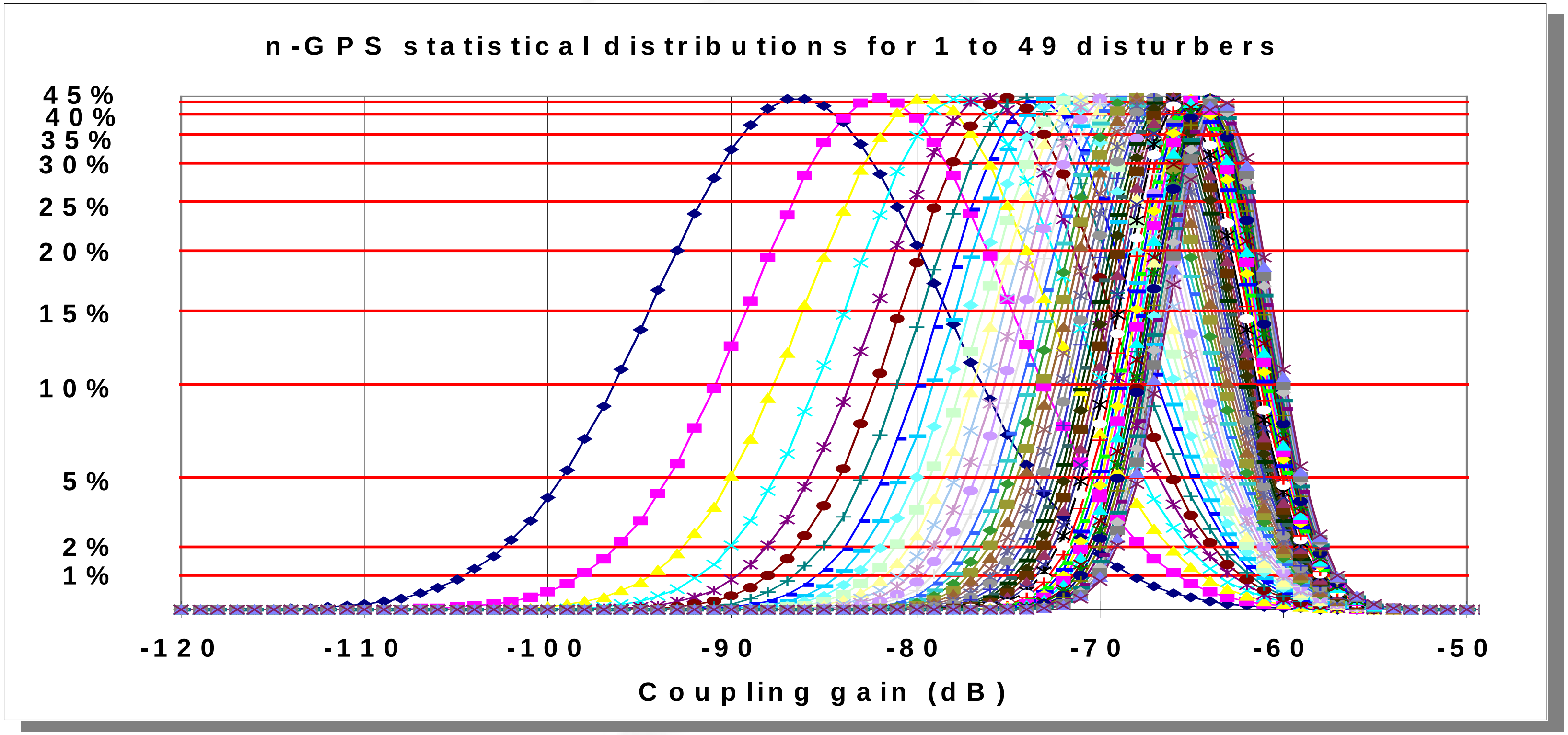


Figure B.1 – Comparison of Model FEXT with Measured FEXT

Rank Ordering of Disturbers

- ✓ These 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 burst mode 100BASE-Cu, 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, TDD 100BASE-Cu 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 worst case 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

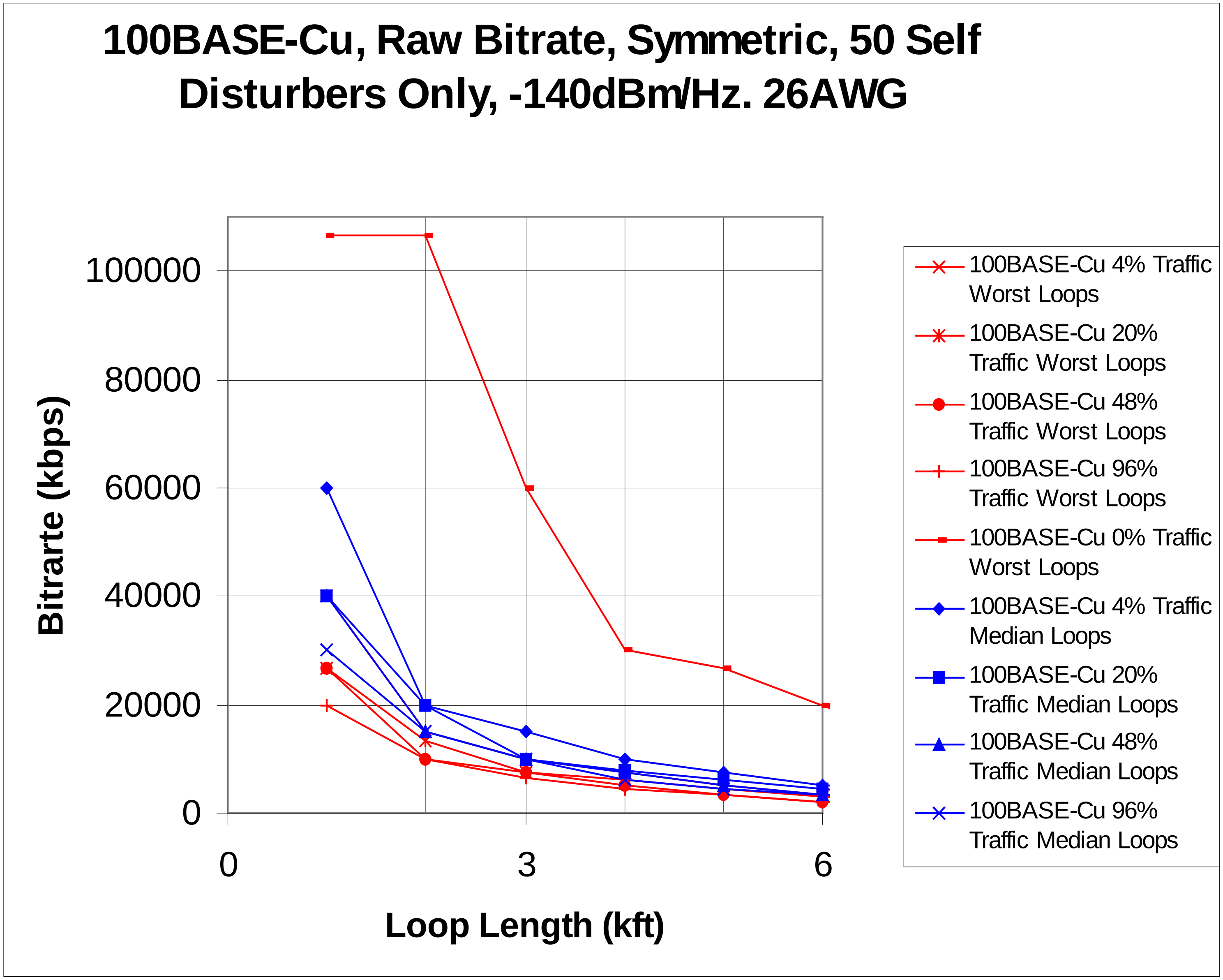
Probability of Simultaneous Worst Case Loops

- ✓ **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 Disturber, Symmetric Service, Short

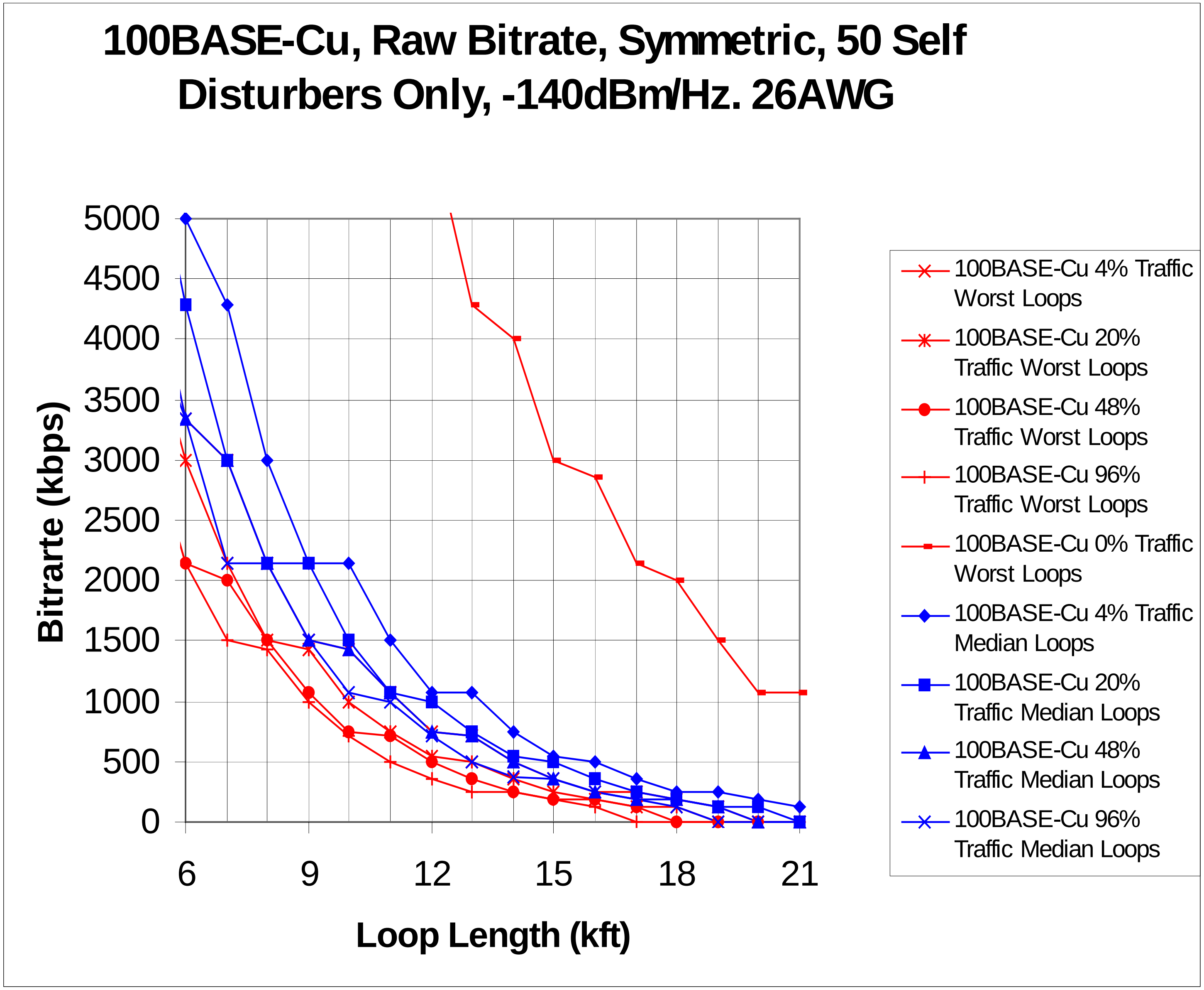
- ✓**Compare with G.shdsl**
- ✓**100BASE-Cu Still offers Linesharing with POTS**



Self Disturber, Symmetric Service, Long

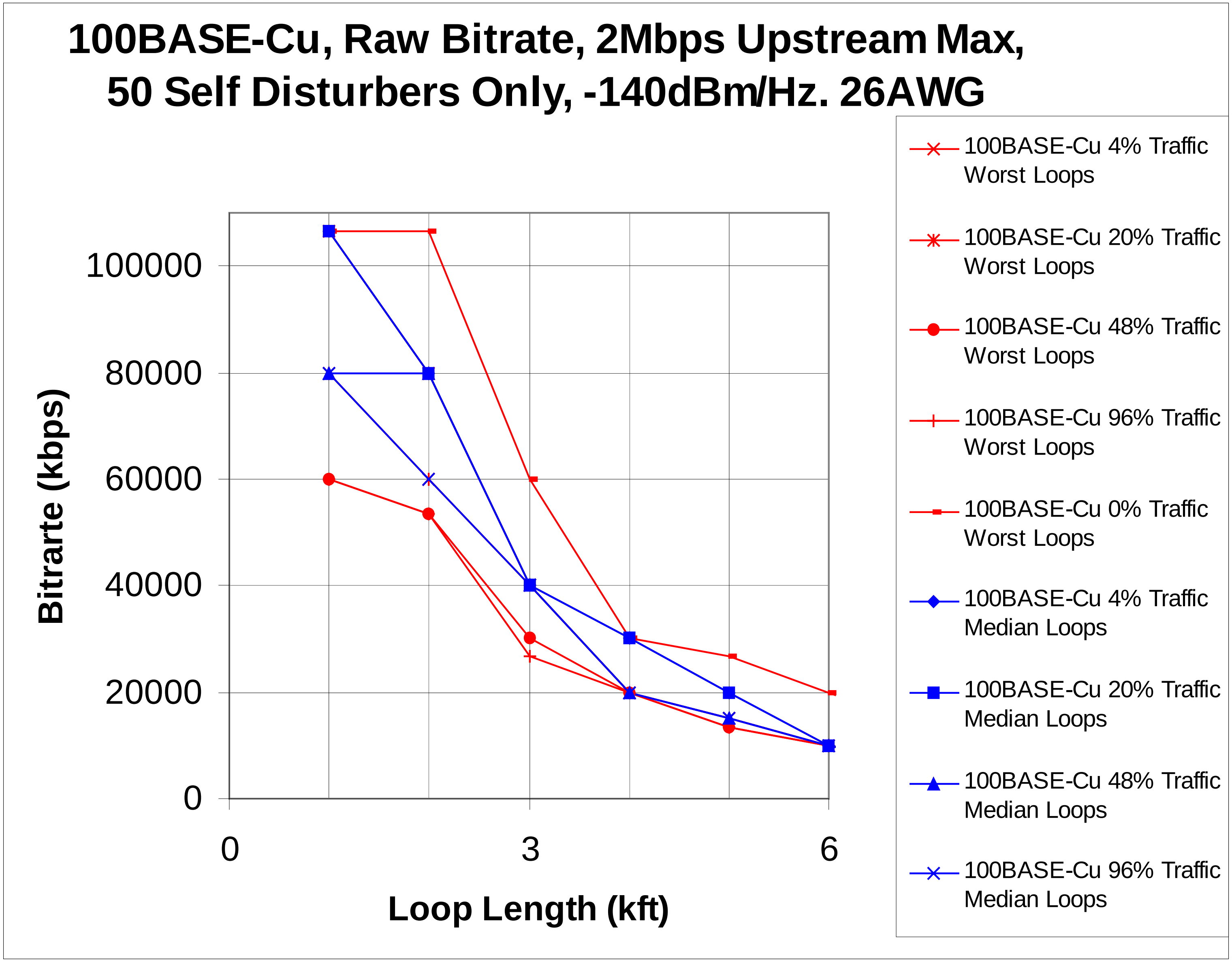
✓**Compare with G.shdsl**

✓**100BASE-Cu Still Offers Linesharing with POTS**



Self Disturber, Asymmetric Service (2M Up), Short

- ✓**Compare with ADSL**
- ✓**Twice the Upstream Bandwidth of ADSL**



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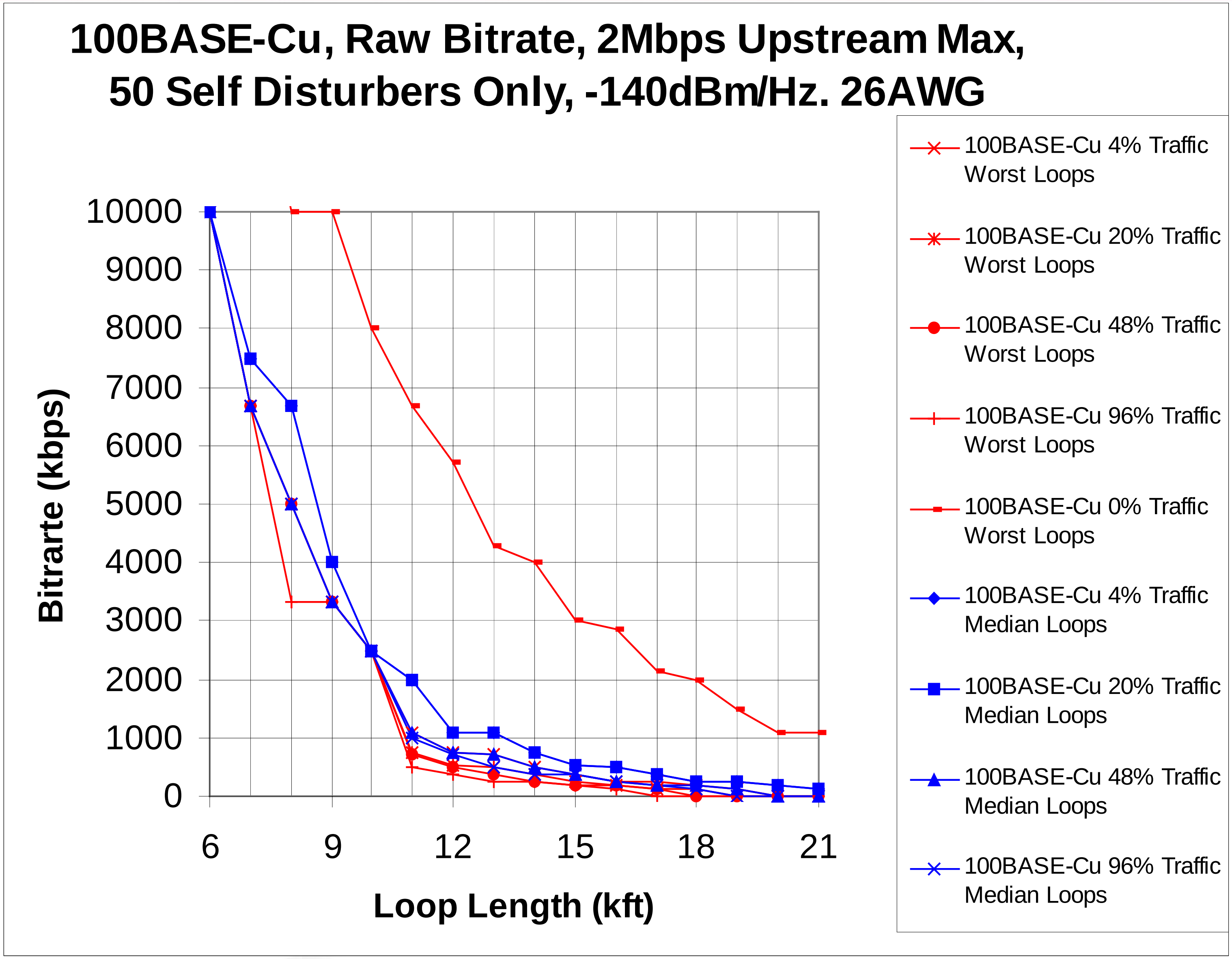
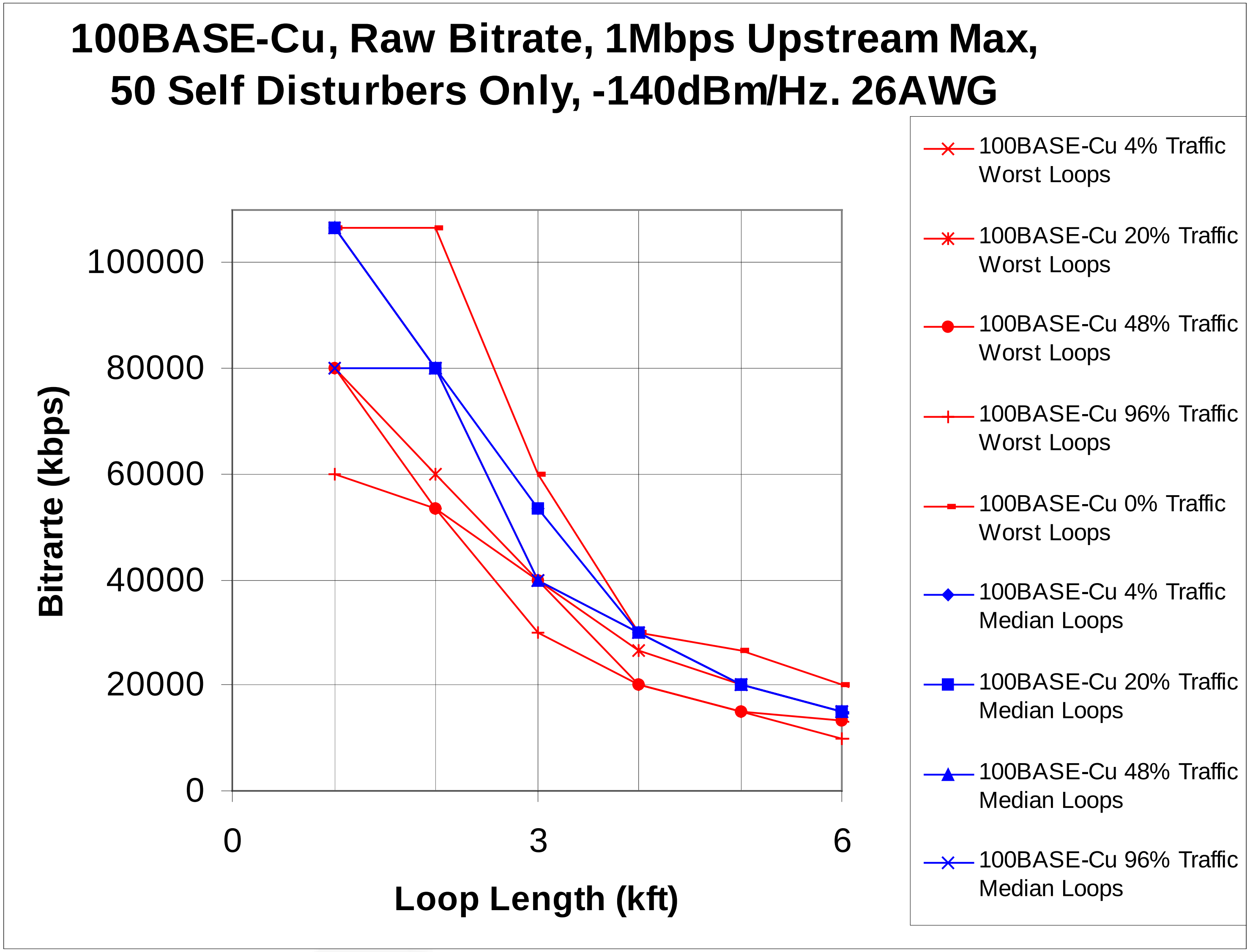


100BASE-Cu, Raw Bitrate, 2Mbps Upstream Max, 50 Self Disturbers Only, -140dBm/Hz. 26AWG

Self Disturber, Asymmetric Service (1M Up), Short

- ✓**Compare with ADSL**
- ✓**Same Upstream Bandwidth as ADSL**



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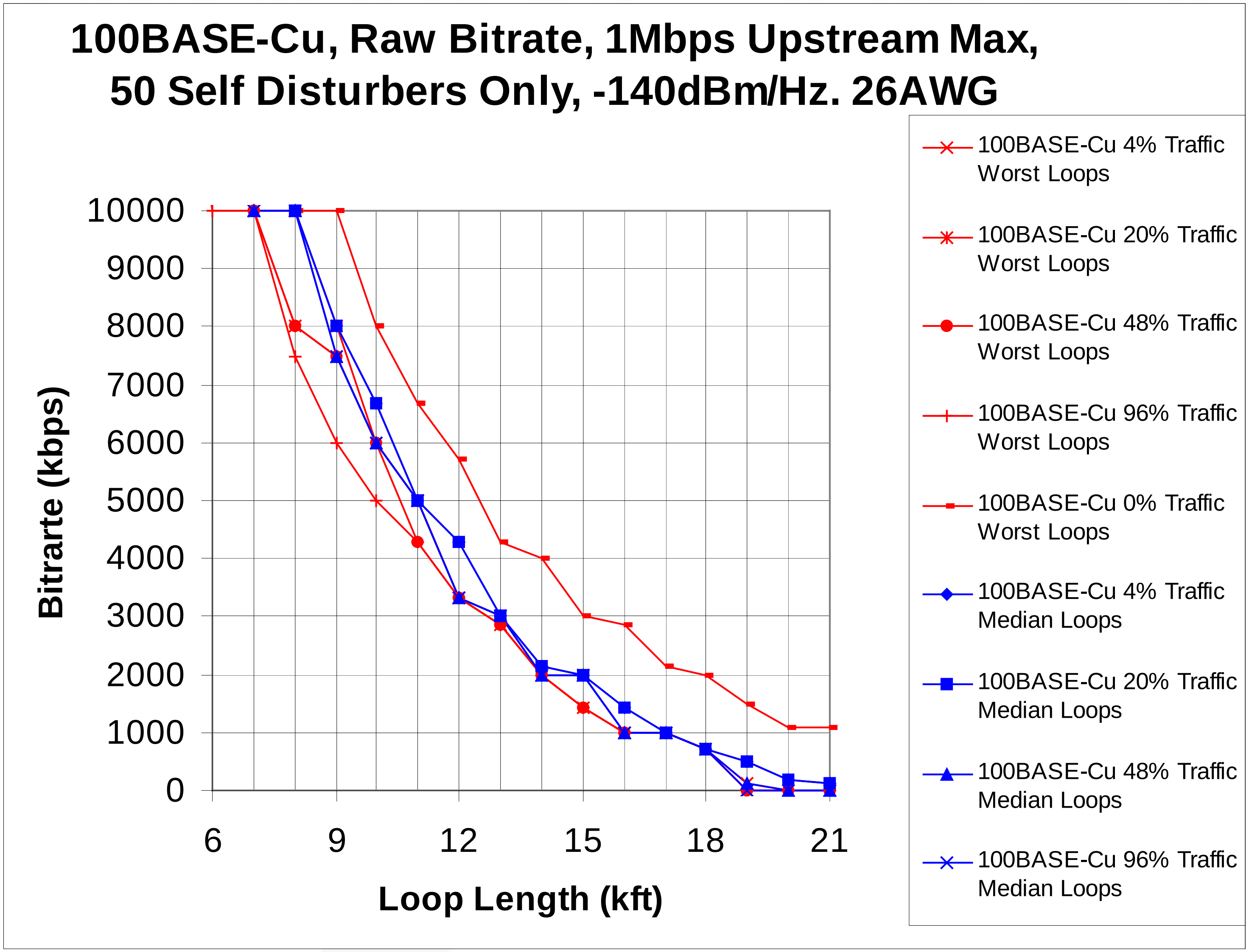
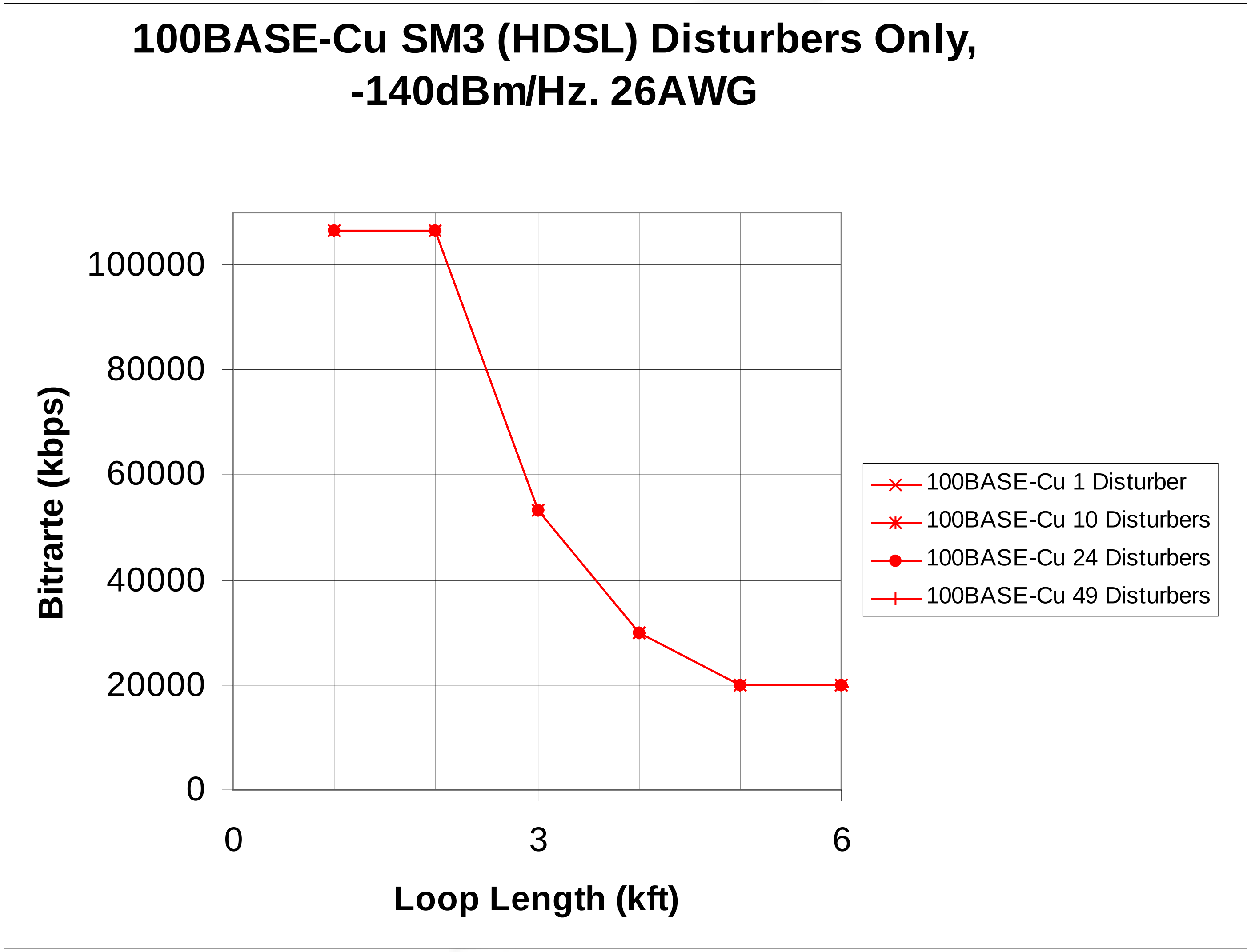
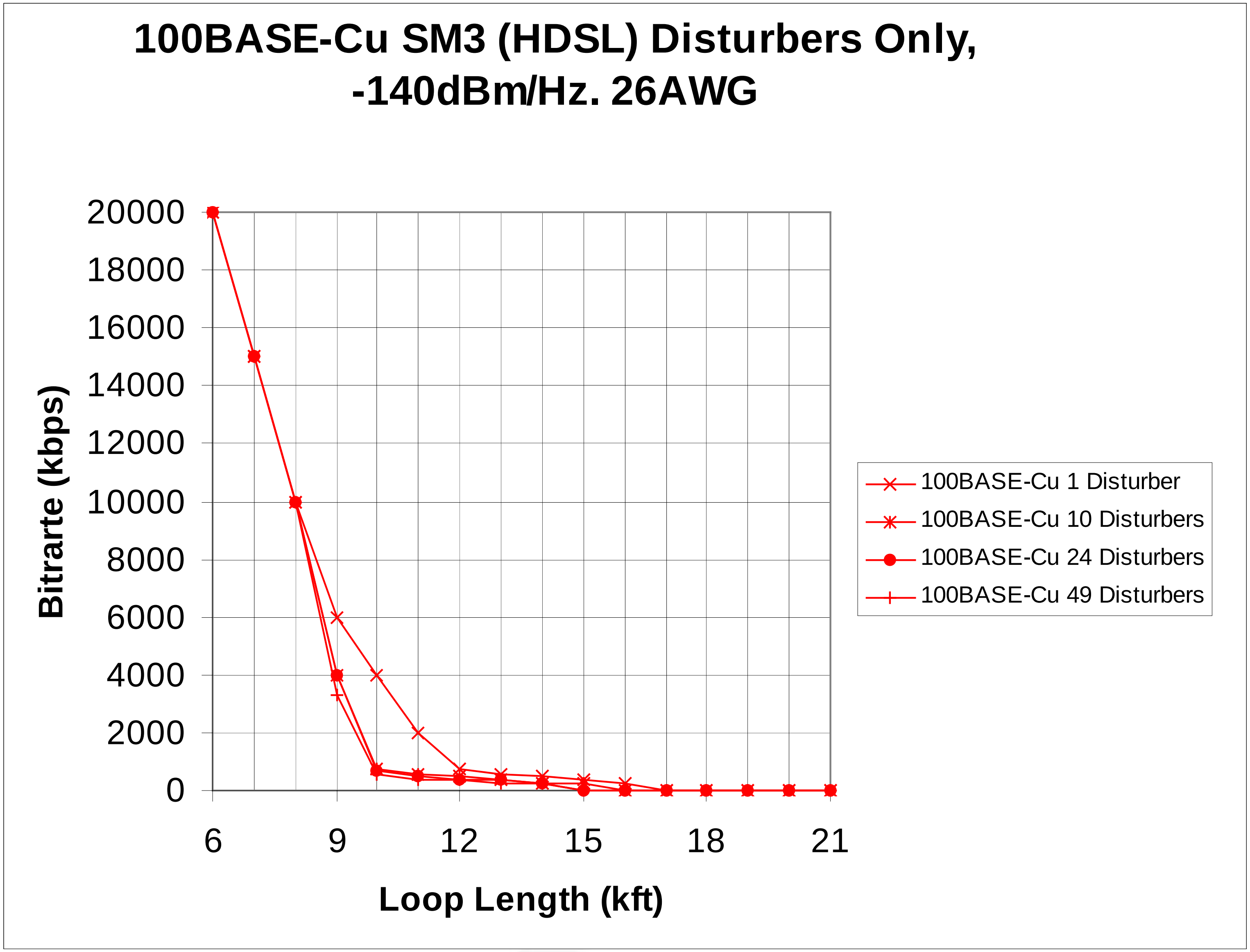


100BASE-Cu, Raw Bitrate, 1Mbps Upstream Max, 50 Self Disturbers Only, -140dBm/Hz. 26AWG

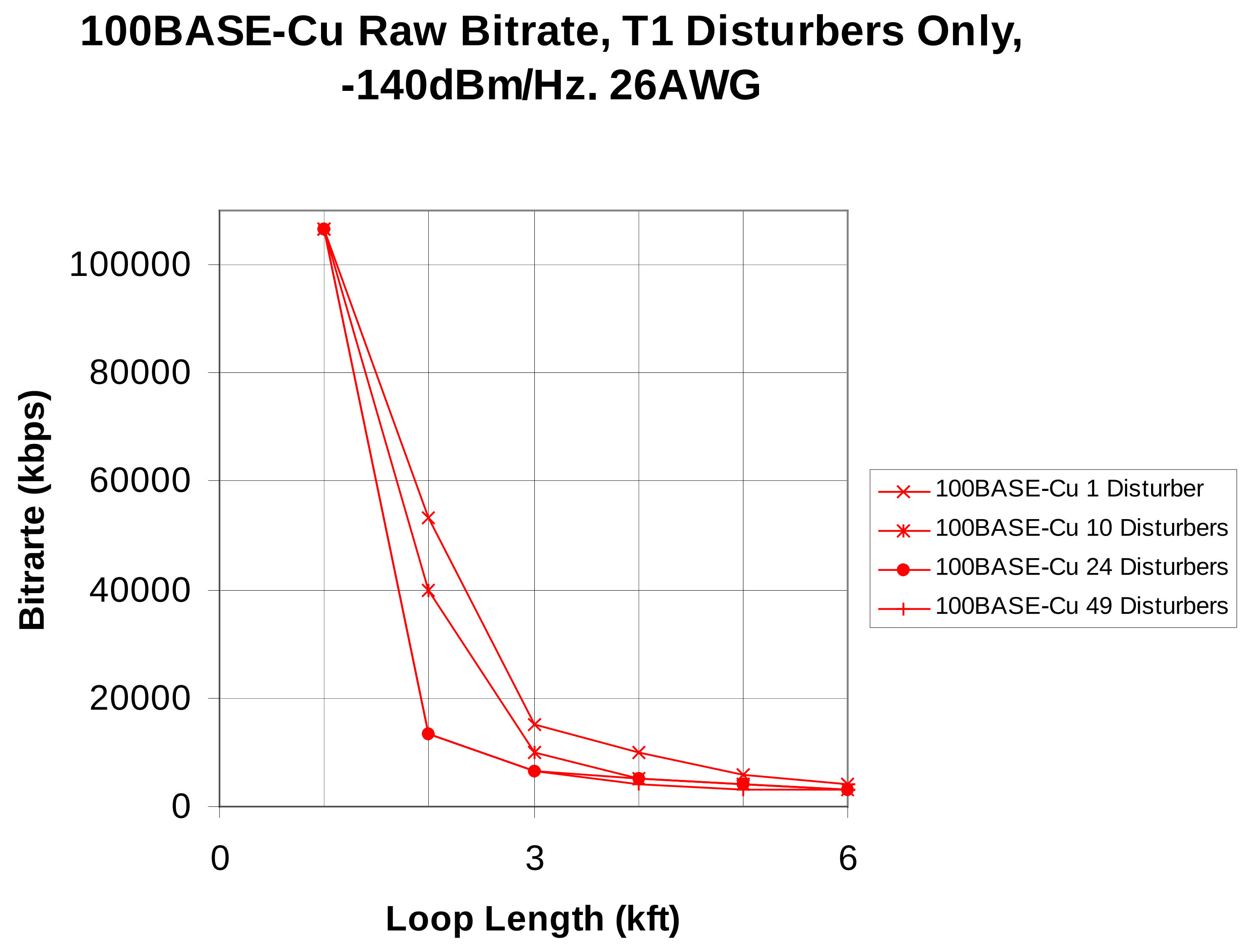
HDSL (SM3) Disturber, Short



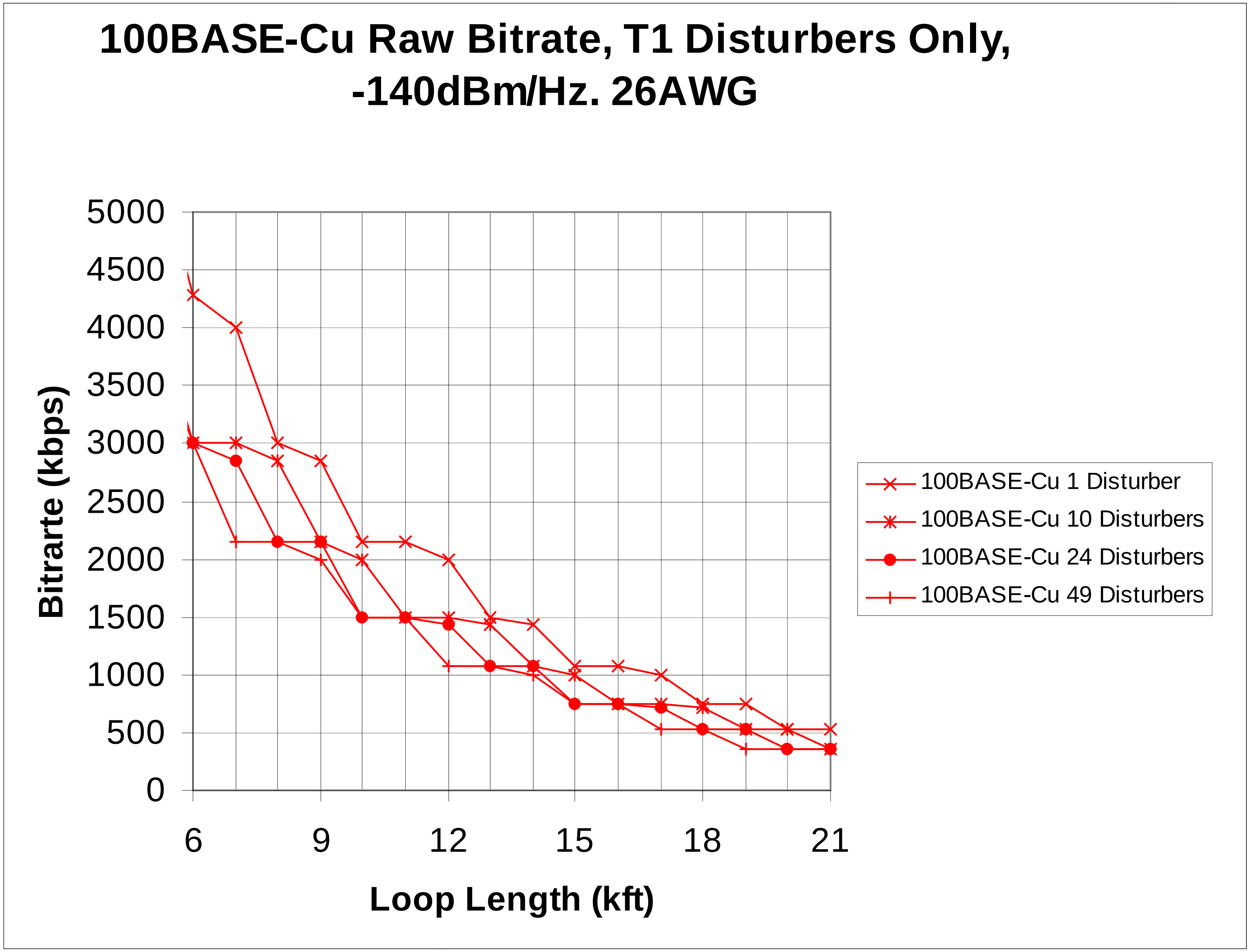
HDSL (SM3) Disturber, Long



T1 Disturber, Short



T1 Disturber, Long



Benefit Summary

- ✓ **Robust: Leverages current loop-tolerant implementations**
- ✓ **Much larger addressable market due to greater rate vs. reach [2]**
- ✓ **One technology that covers both in-building and outside plant**
- ✓ **Spectrum Manager Function gives visibility of binder conditions [1]**
- ✓ **Fully compliant with T1.417 [4]..[8]**
- ✓ **Flexible Service Offerings, Symmetric with Full BW in either direction, or provisionable upstream limit to increase downstream reach**

References

[1] “Fast Robust EFM,” Elastic Networks, IEEE 802.3 EFM Study Group, Plenary, March 2001

[2] “Carrier Grade Ethernet ,” Elastic Networks, IEEE 802.3 EFM Study Group, Interim Meeting, May 2001

[3] “100BASE-Cu Details,” Elastic Networks, IEEE 802.3 EFM Study Group, Plenary Meeting, July 2001

[4] Bellcore, Elastic Networks, “Analytical Study of the Spectral Compatibility of ADSL, HDSL, ISDN, T-Carrier and POTS with EtherLoop,” ANSI T1E1.4/98-334, December 1998.

[5] AU-931, *Spectral Compatibility Analysis of the Elastic Networks EtherLoop Transceiver*, Telcordia Technologies Technical Analysis Report, April 1999.

[6] Telcordia (formerly Bellcore), Elastic Networks, “Spectral Compatibility and EtherLoop’s Spectrum Manager,” ANSI T1E1.4/99-191R1

[7] Elastic Networks, “Method B Analysis of EtherLoop Spectral Compatibility,” ANSI T1E1.4/2000-228

[8] Elastic Networks, “Membership of EtherLoop PSDs in Spectrum Management Classes,” ANSI T1E1.4/2000-304

[9]”Spectrum Management for Loop Transmission Systems,” T1.417-2001

[10] S.H. Lin ,“Statistical Behavior of Multipair Crosstalk,” BSTJ,59, No. 6, (July-Aug 1980), pp.955-974

[11] Telcordia, “Cable Crosstalk Parameters and Models,” ANSI T1E1.4/97-302