ADSL for the EFM Long Reach Objective

A Baseline Proposal

802.3ah Task Force

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A combined presentation from Daun Langston and Doug Artman

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Presentation Overview

- Introduction
- ADSL Annex J
- Performance Studies and Results
- Baseline Proposal Summary
- Baseline Reference Models
- Additional Simulation Results
- Impact of Self-NEXT

Introduction – How did we get here?

Daun Langston

What features of Ethernet should be applied to the Wide Area Network?

- Ethernet is hard to define
  - Always works, simple to configure
  - Copper Phys interoperate at a lowest common rate
  - Ethernet always works
- Consumers think of Ethernet as a copper cable with a RJ-45 running at 10 or 100 Mbit
- Interoperability is a valuable objective
  - But can interoperability be accomplished while maintaining Spectral Compliance?
  - Will the data rate be fast enough to be called Ethernet?
  - Can this be accomplished with existing standards?

What is being proposed now

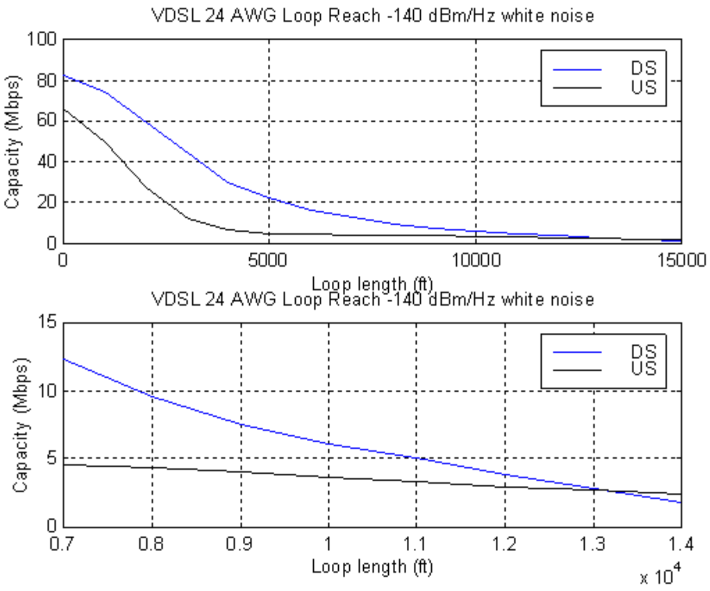
- VDSL is a passband technology and has wide support for meeting the short reach objective
- SHDSL is one proposal being put forth for a long reach objective
  - SHDSL is a baseband technology and is thus not interoperable with VDSL
  - Is SHDSL the most effective modulation strategy for a long reach objective?
- ADSL is another proposal being put forth for a long reach objective
  - ADSL is a passband system with provisions for using spectrum down close to baseband
  - Can ADSL meet the performance requirements?

VDSL and ADSL are related

- Multiple carrier ADSL is the largest installed base of broadband residential connectivity
  - ADSL is here today
  - ADSL is proven (many millions of dollars in R&D)
  - ADSL is cheap
- Can we use ASDL instead of shdsl for the long reach objective?
  - ADSL downstream band has enough bandwidth
  - ADSL upstream bandwidth is limited
  - More ADSL bandwidth is required to offer a solution

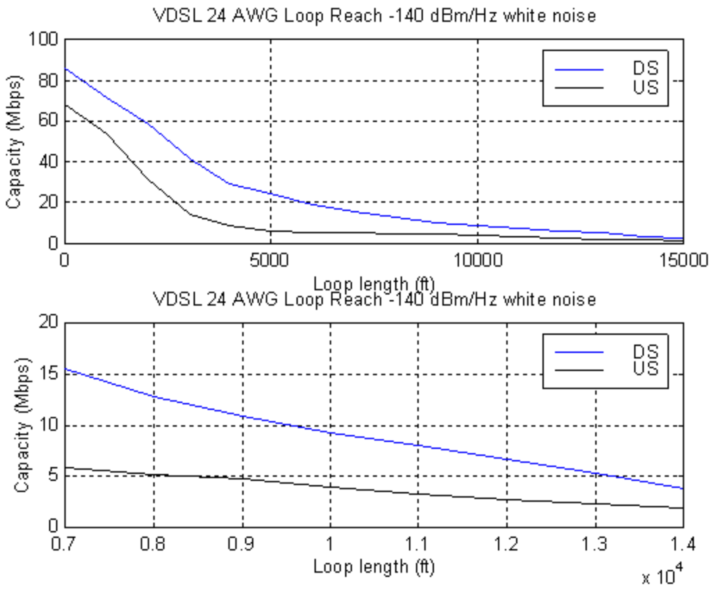
How much upstream bandwidth can be made available?

- We modified the ADSL upstream band and moved the upstream bandsplit from 138 kHz to 414 kHz to see how much bandwidth is available.
  - The second plot is just an expansion of the first from 7 kft to 14 kft
  - This modification can support 2.5 Mbps sym up to about 13 kft with 24 AWG
  - Solution is not Spectrally Compliant



Is there a Spectrally Compliant Solution?

- The shdsl PSD is known to be Spectrally Compliant
  - What happens if the exact shdsl PSD is used for upstream?
  - Moved bandsplit to bin 128 and echo cancelled spectrum overlapped bins 32 - 128
  - This example is Spectrally Compliant
  - Meets CSA range objective



Must we invent a new technology?

- Using echo cancellation for bins 32-128 and the shdsl psd for upstream is a new technology
- Can we use an existing standard ADSL technology to expand the upstream bandwidth
  - Which is a spectrally compliant solution
  - Does not use echo cancellation
    - Echo cancellation has drawbacks – introduces large NEXT
  - Has sufficient or better rate /reach compared to shdsl
  - Maintains interoperability with VDSL at some common rate
- Can we bond this technology to get to 10 Mbit rates within the CSA reach range?

ADSL Annex J

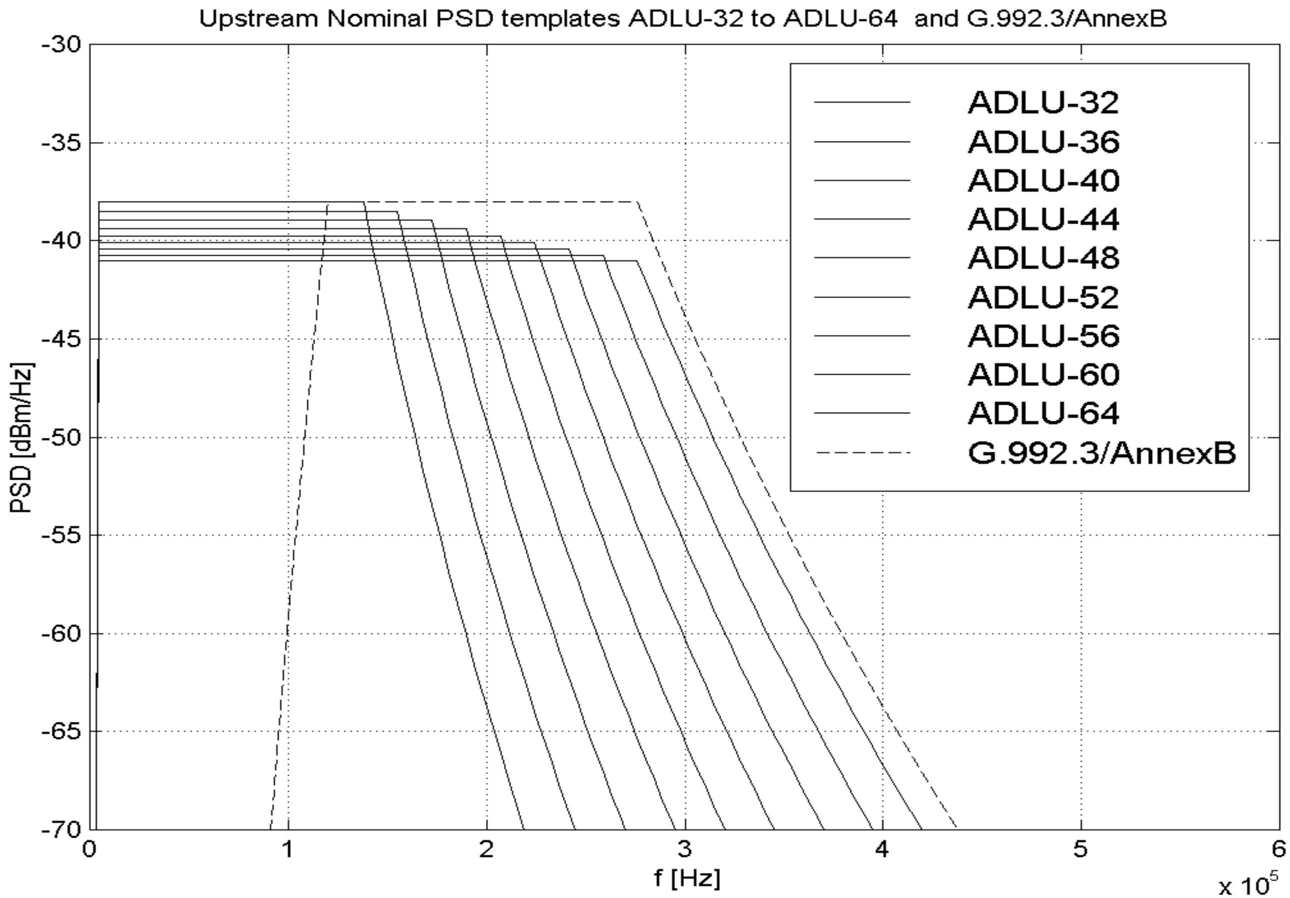
ADSL and the Long Reach Objective

- Long reach objective for EFM
  - PHY for single-pair non-loaded voice grade copper, all distances >= 2700 m, 24 AWG, rates >= 2 Mbps full duplex
- Existing ADSL standards support the long reach objective, meet the spectral compatibility requirements and leverage an enormous amount of existing technology and R&D investment

The Solution – ADSL Annex J

- Sometimes referred to as ADL – All-Digital Loop
- Annex J provides for 64-tone (276 kHz) upstream and also allows upstream to exist down to 3 kHz (tone 1)
  - Optionally can modify Annex J PSD masks like ADSL Annex A masks to allow underlying POTS
- Annex J specifies a family of 9 upstream PSD masks
  - Constant power of 13.4 dBm
  - Widest bandwidth (276 kHz) PSD can be used for loops out to ~2700m and preserves spectral compatibility
  - Increasingly narrower bandwidth PSDs are used at longer loops and provides graceful degradation of symmetric rates
  - Spectral flexibility of ADSL easily allows varying PSD bandwidths
  - Appropriate PSD easily chosen during training based on loop length

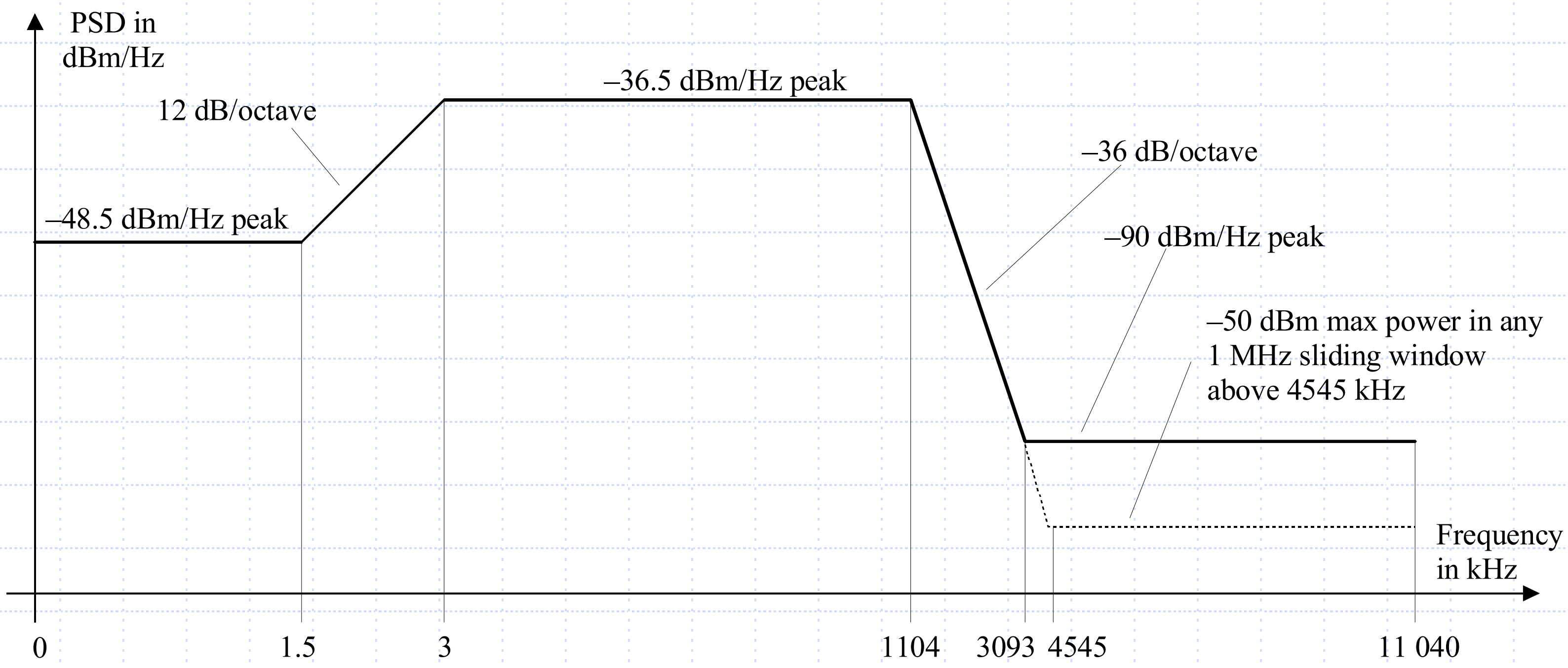
Annex J Upstream PSD Masks



Annex J Upstream PSD Masks (cont'd)

Upstream Mask Number	Designator	Template Nominal PSD (dBm/Hz)	Maximum Aggregate Transmit Power (dBm)	Inband Peak PSD (dBm/Hz)	Frequency f1 (kHz)	Frequency f2 (kHz)
1	ADLU-32	-38.0	13.4	-34.5	138.00	307
2	ADLU-36	-38.5	13.4	-35.0	155.25	343
3	ADLU-40	-39.0	13.4	-35.5	172.50	379
4	ADLU-44	-39.4	13.4	-35.9	189.75	415
5	ADLU-48	-39.8	13.4	-36.3	207.00	450
6	ADLU-52	-40.1	13.4	-36.6	224.25	485
7	ADLU-56	-40.4	13.4	-36.9	241.50	520
8	ADLU-60	-40.7	13.4	-37.2	258.75	554
9	ADLU-64	-41.0	13.4	-37.5	276.00	589

Annex J Downstream PSD Mask



Benefits of ADSL

- Leverages enormous amount of existing technology and current developments in ADSL
  - ADSL is here today
  - ADSL is the widest deployed and most proven DSL technology
  - Cost and density of ADSL solutions already optimized
  - Cost savings in service provisioning via multimode capability
- ADSL is a flexible passband system which can be provisioned for business or residential
  - Upstream PSD masks optionally allow underlying POTS
  - Double upstream bandwidth option provides more symmetric version of ADSL
- Easily allows bonding for higher data rates
- Uses narrow bandwidth for upstream -> increased deployment guideline for spectral compatibility

Performance Studies and Results

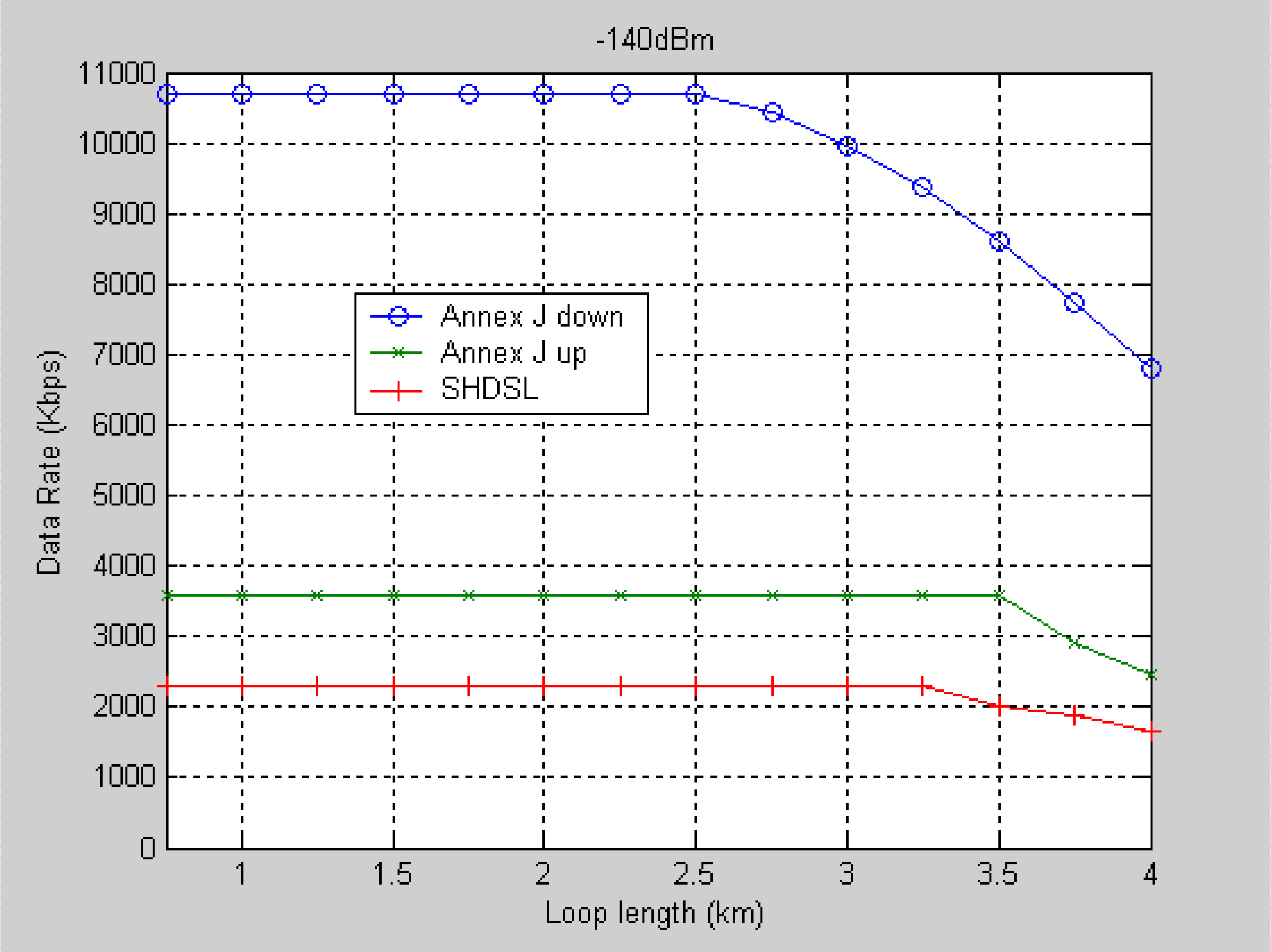
Crosstalk Scenarios

- Measure the impact of realistic crosstalk environments on performance of proposed solution
- All scenarios include -140 dBm/Hz line noise
- Simulated scenarios
  - No disturbers
  - Self-disturbers
  - Mixed disturbers (12 self-disturbers + 12 ADSL/Symmetric disturbers)

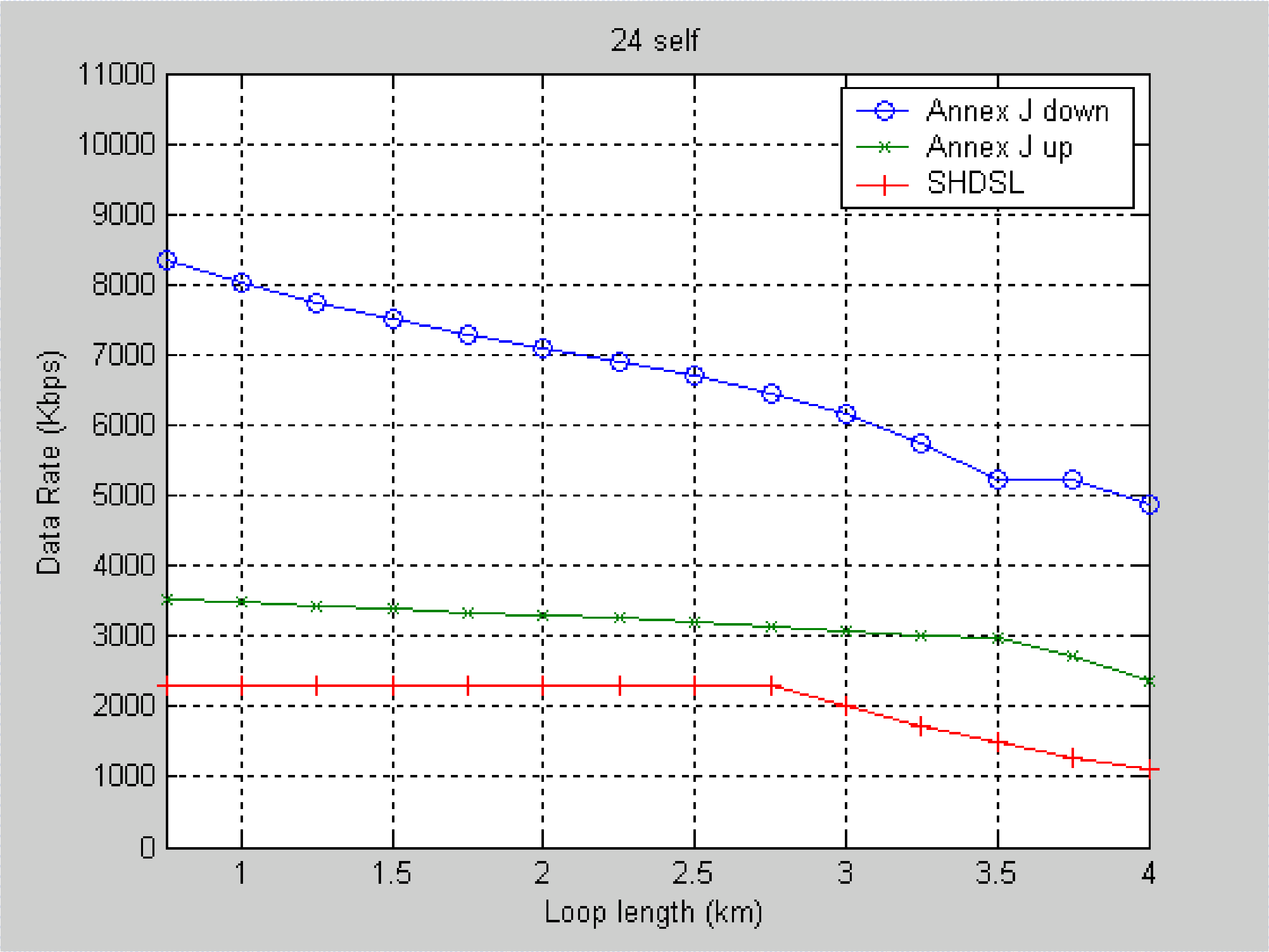
Simulation Parameters

- Coding gain = 5.1 dB
- Noise margin = 6.0 dB
- Bit allocations of 1 to 14 bits per tone
- Always include white noise at –140 dBm/Hz on the line
- Assumes 24 AWG loops
- Uses Annex J Upstream PSD masks
- Downstream always starts at tone 65
  - Although allowed by downstream PSD, we assumed no overlapped spectrum (self-NEXT issues)

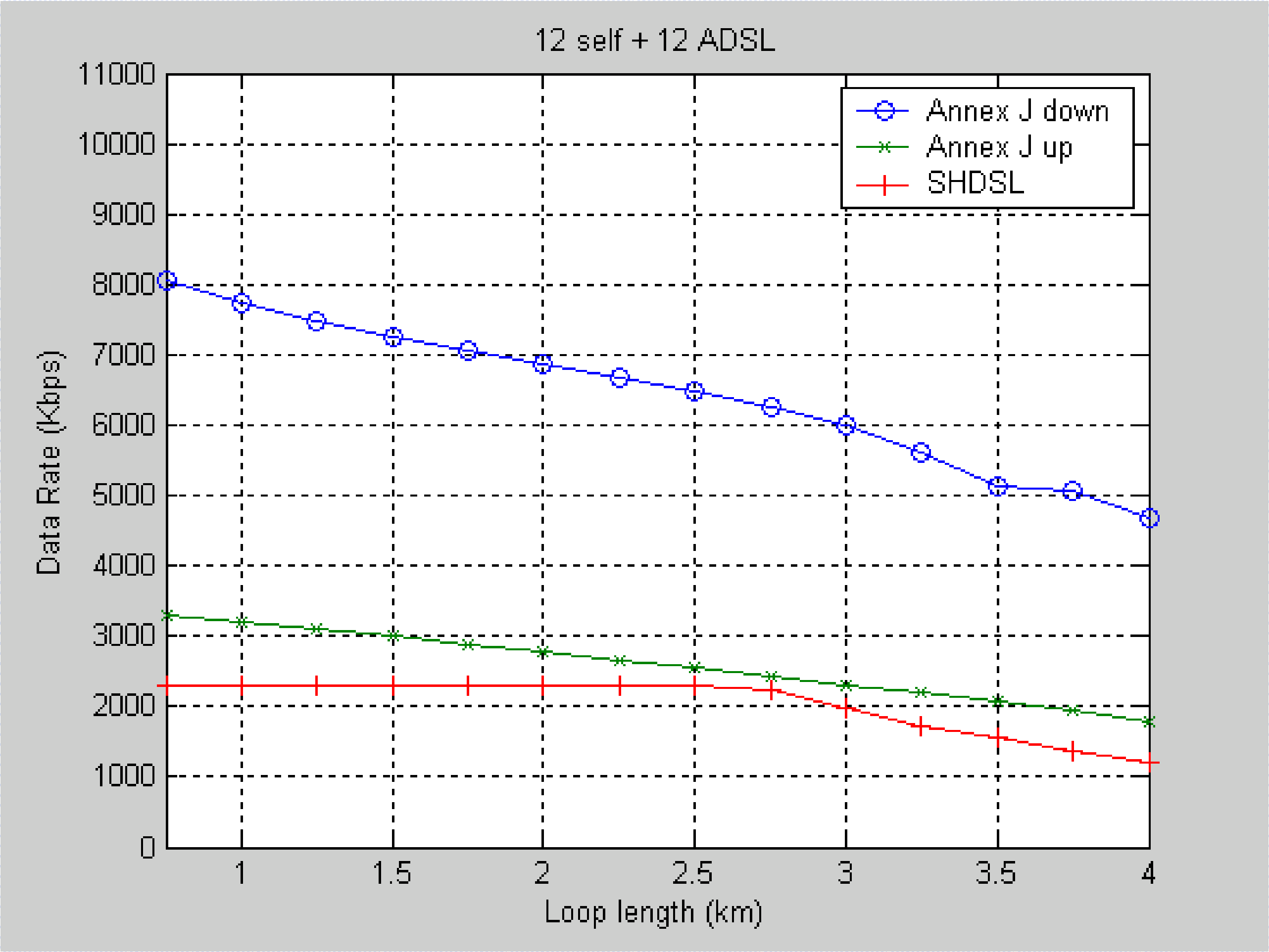
No Disturbers



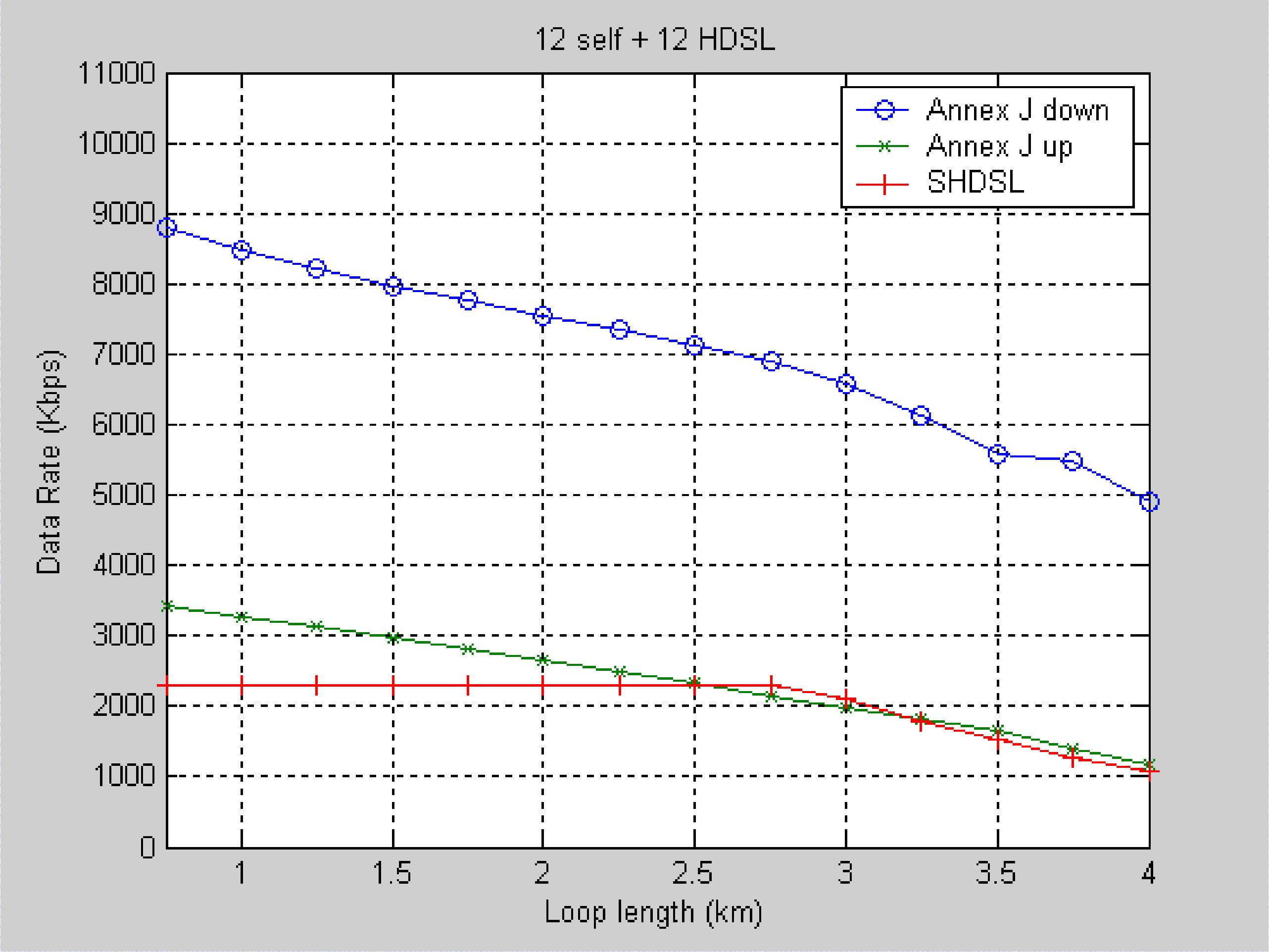
24 Self-Disturbers



12 Self- and 12 ADSL Disturbers



12 Self- and 12 HDSL Disturbers



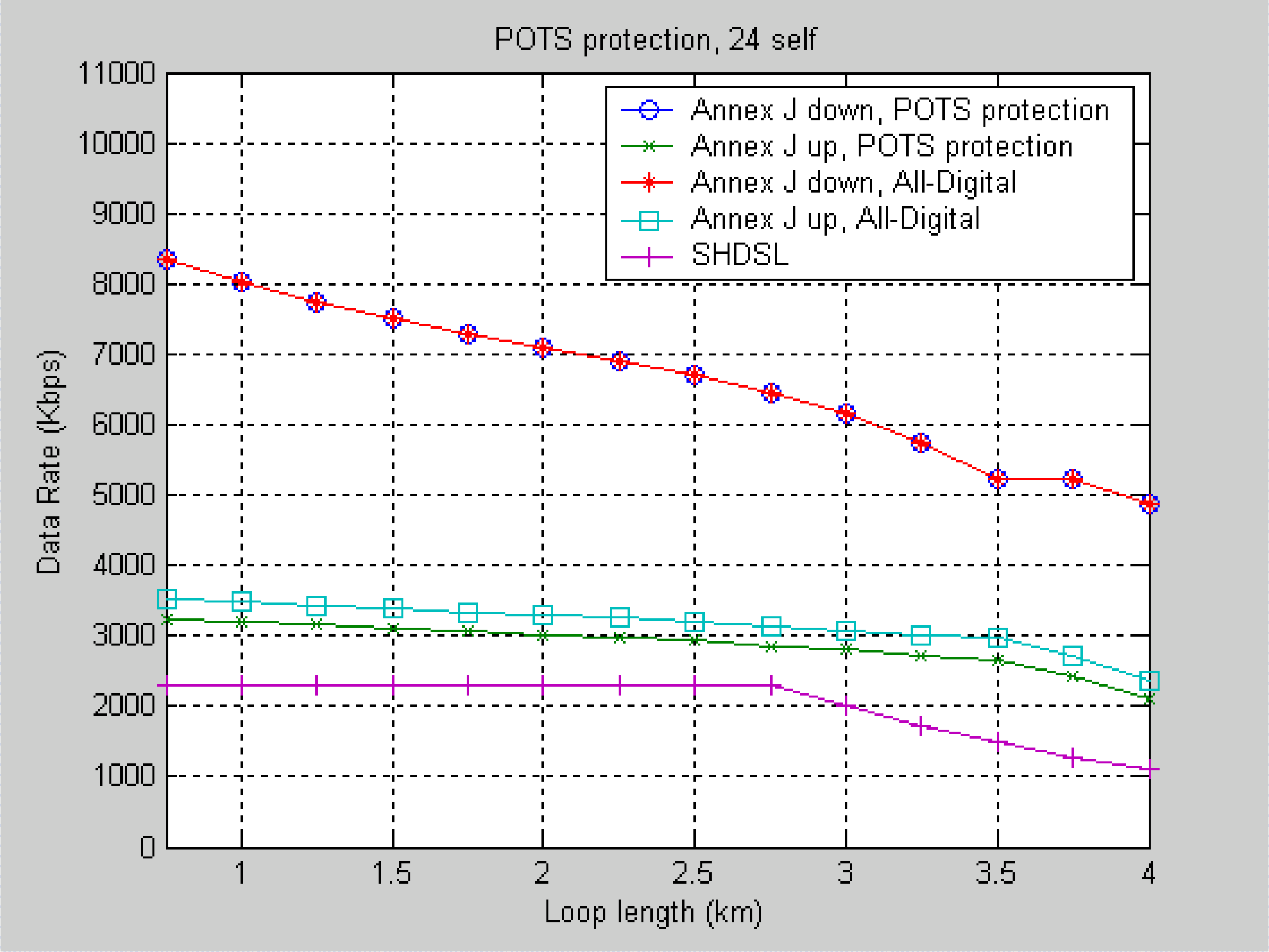
Selected Upstream PSD & Spectral Compatibility

- PSD selected to optimize performance and meet spectral compatibility (T1.417)
  - L < 3700 meters — Mask 9
  - 3700 <= L < 3900 meters — Mask 6
  - 3900 <= L < 4100 meters — Mask 4
  - 4100 <= L < 4300 meters — Mask 3
  - 4300 <= L < 4500 meters — Mask 2
  - L >= 4500 meters — Mask 1
- Spectral compliance for all of the ADSL PSDs generated in this contribution was verified
  - Verified using Method B
  - Verified against ADSL, SHDSL basis systems

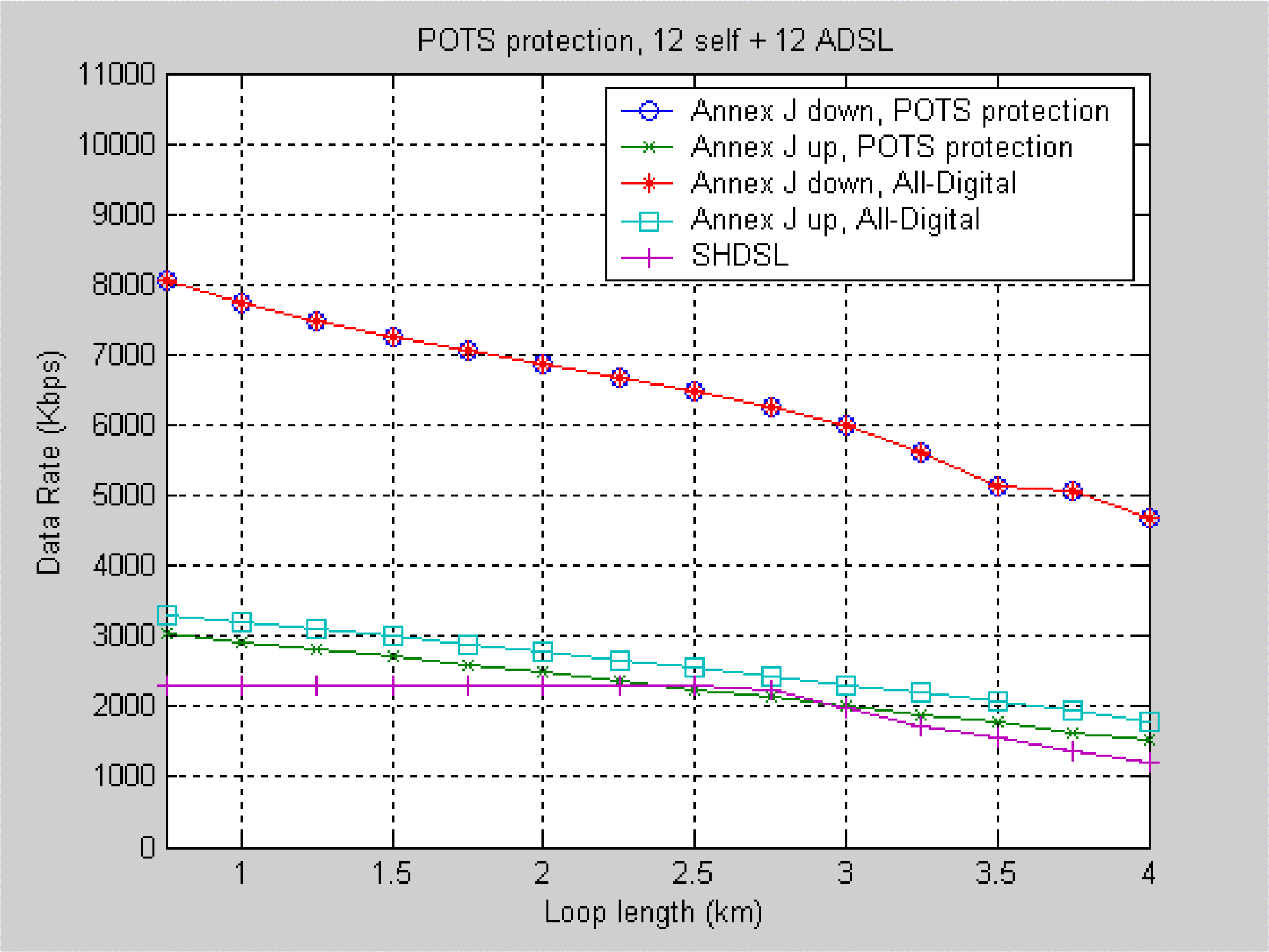
ADSL-based EFM over POTS

- Annex J upstream PSD masks are easily modified to allow underlying POTS
  - LPF side of mask is unchanged
  - HPF side is modified to be exactly like Annex A mask
  - Result is simple hybrid of Annex J and Annex A masks
  - Same work to be done in ITU as part of ADSL+ project
- Performance hit for allowing underlying POTS is minimal
  - Still easily meets long reach objective
- Benefits
  - Suitable for residential market – much broader market potential
  - Allows operators to use ½ the number of copper pairs in providing Ethernet-based access and POTS telephony
- Recommend creating optional versions of Annex J upstream PSD masks to allow underlying POTS

ADSL over POTS - 24 Self-Disturbers



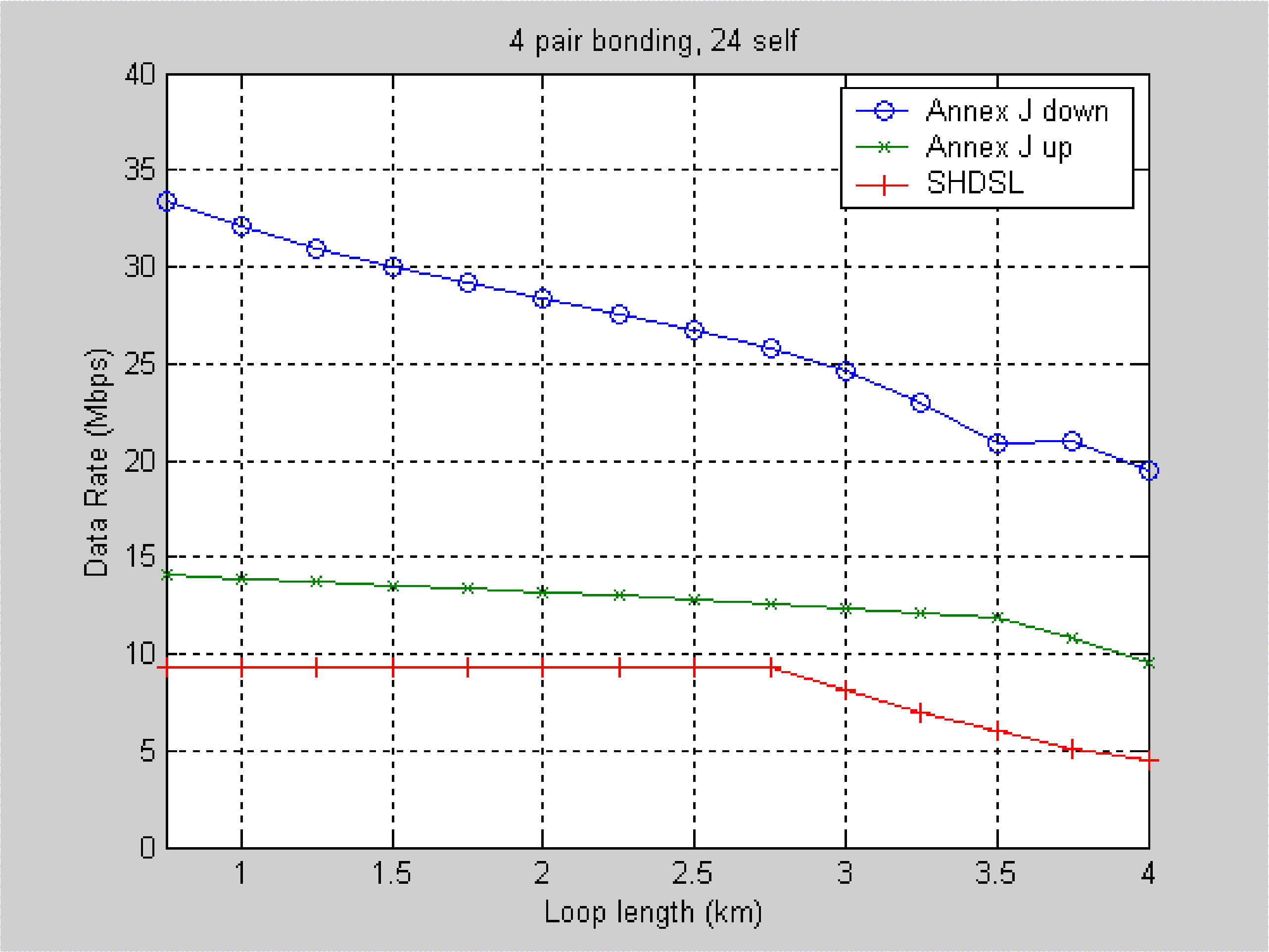
ADSL over POTS - 12 ADSL and 12 Self-Disturbers



Loop Aggregation – Reaching 10 Mbps symmetric

- Loop aggregation part of 802.3ah baseline
  - Fosmark_1_0302.pdf
- ADSL Annex J provides >= 2.5 Mbps symmetric on most loops <= 2700m
- Utilizing loop aggregation of 4 pairs yields >= 10 Mbps on these loops
- 4 pairs is an attractive number
  - CO chipset densities are a multiple of 4
  - Matches the max number of pairs operators have indicated they're willing to allocate to a single service

Loop Aggregation – 24 Self Disturbers



Baseline Proposal Summary

ADSL Performance Benefits

- Provides higher rates at longer reaches than SHDSL or any other standardized DSL technology on most loops
- Higher downstream rates available for certain applications
  - Similar to VDSL for short reach – Excess downstream rates are available
- Spectrally friendlier to the large amount of ADSL already in the binder
  - Does not introduce large amounts of NEXT into the binder

ADSL Performance Benefits (cont'd)

- Extended reach of 2 Mbps symmetric service
  - Provides coverage of CSA range (3600m, 24AWG) under many scenarios
  - This is the range of loops ideally covered
    - 3600m covers 95% of DLC-fed loops
    - 3600m covers 85% of business and residential loops
    - (from Frazier_1_0901.pdf)
- Loop aggregation of 4 pairs able to provide 10 Mbps symmetric service
  - All CO chipsets developed with densities that are a multiple of 4
  - Operators have expressed they don't want to allocate more than 4 pairs

EFM Copper High Level Summary

- Two copper ports to address the two copper objectives
  - VDSL baseline as in Rezvani_1_0302.pdf addresses the short reach objective of 10 Mbps full duplex on a single pair >= 750 meters
  - ADSL baseline as in Artman_1_0702.pdf addresses the long reach objective of 2 Mbps full duplex on a single pair >= 2700 meters
- Both PHYs utilize G.994.1 handshake protocol to identify which PHY(s) exist in the equipment
- Both PHY baselines support optional multi-pair (bonding) mode
  - Both solutions can provide 10 Mbps symmetric services

ADSL and the 5 PAR Requirements

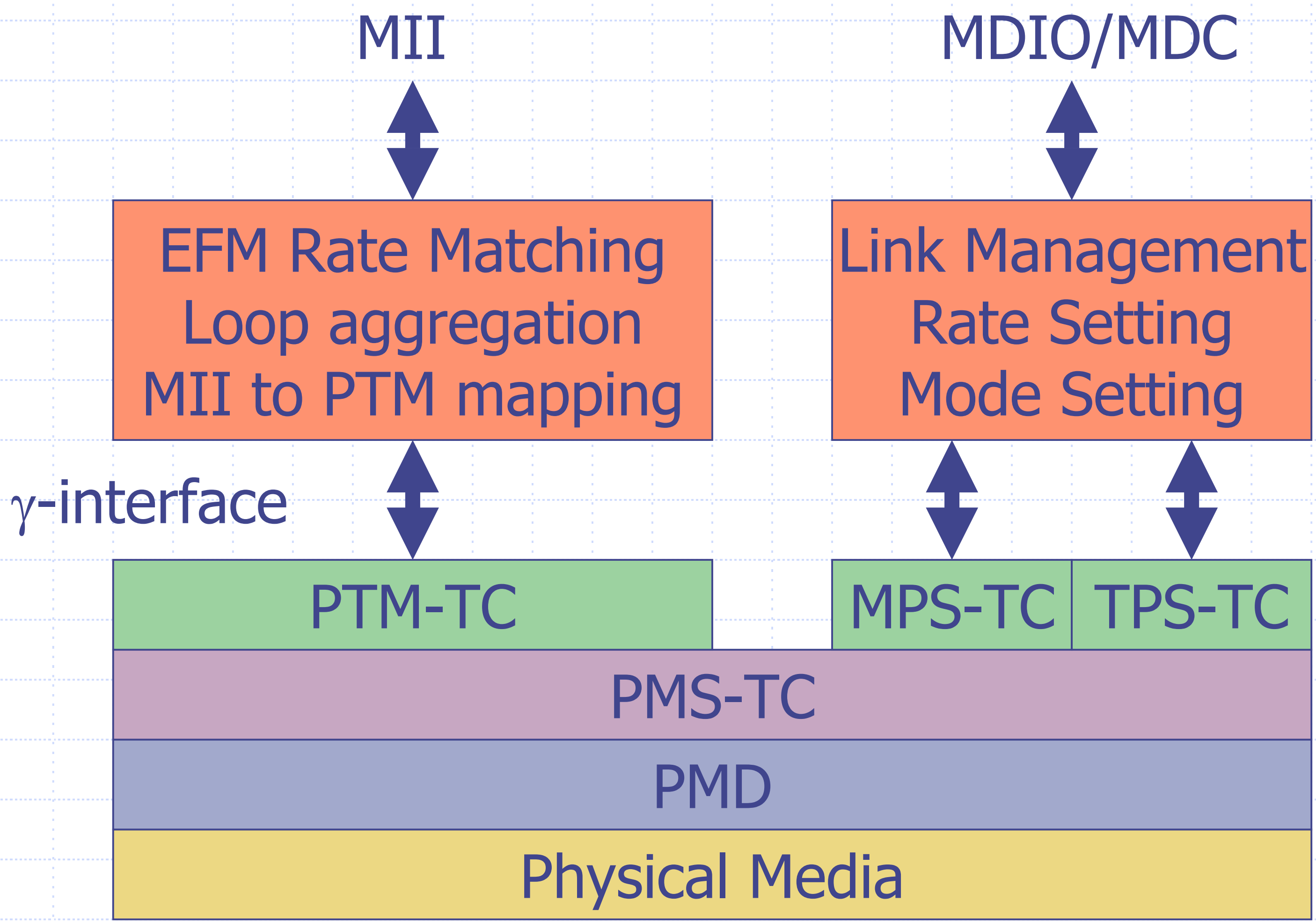
- Broad Market Potential
  - Addresses longest symmetric reach
  - Many, many ADSL chipset and equipment vendors today
  - ADSL costs balanced and proven between CO and CPE
- Compatibility
  - γ-interface and PTM-TC allow integration of ITU xDSL PHYs with higher layer 802.3 protocols
  - G.hs available to select appropriate 802.3ah port
- Distinct Identity
  - Addresses different problem/market than proposed VDSL PHY for EFM

ADSL and the 5 PAR Requirements (cont'd)

- Technical Feasibility
  - No xDSL more proven and widely deployed than ADSL
- Economic Feasibility
  - ADSL cost structure proven and well-known
  - Annex J adds negligible system cost/complexity
  - ADSL costs are extremely competitive due to large volume of the market

Baseline Reference Models

ADSL Protocol Reference Model



PTM-TC Description

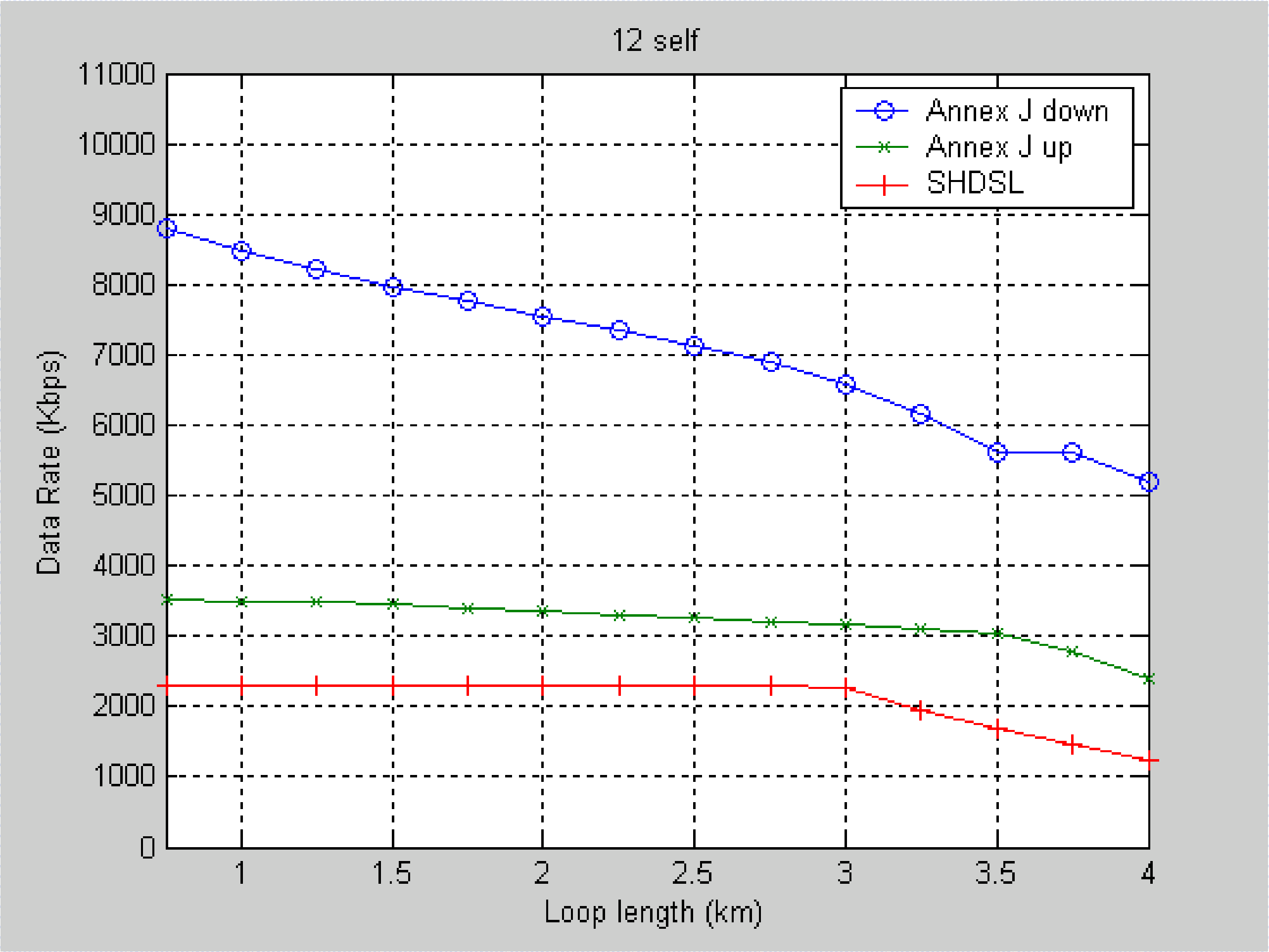
- Specified in G.992.3, exactly equivalent to that of VDSL
  - Allows common higher layers to be used over both PHYs
- PTM-TC utilizes HDLC encapsulation
  - Octet stuffing mode
  - 0x7E octets inserted between packets
  - Utilizes CRC-16

ITU Reference Documents

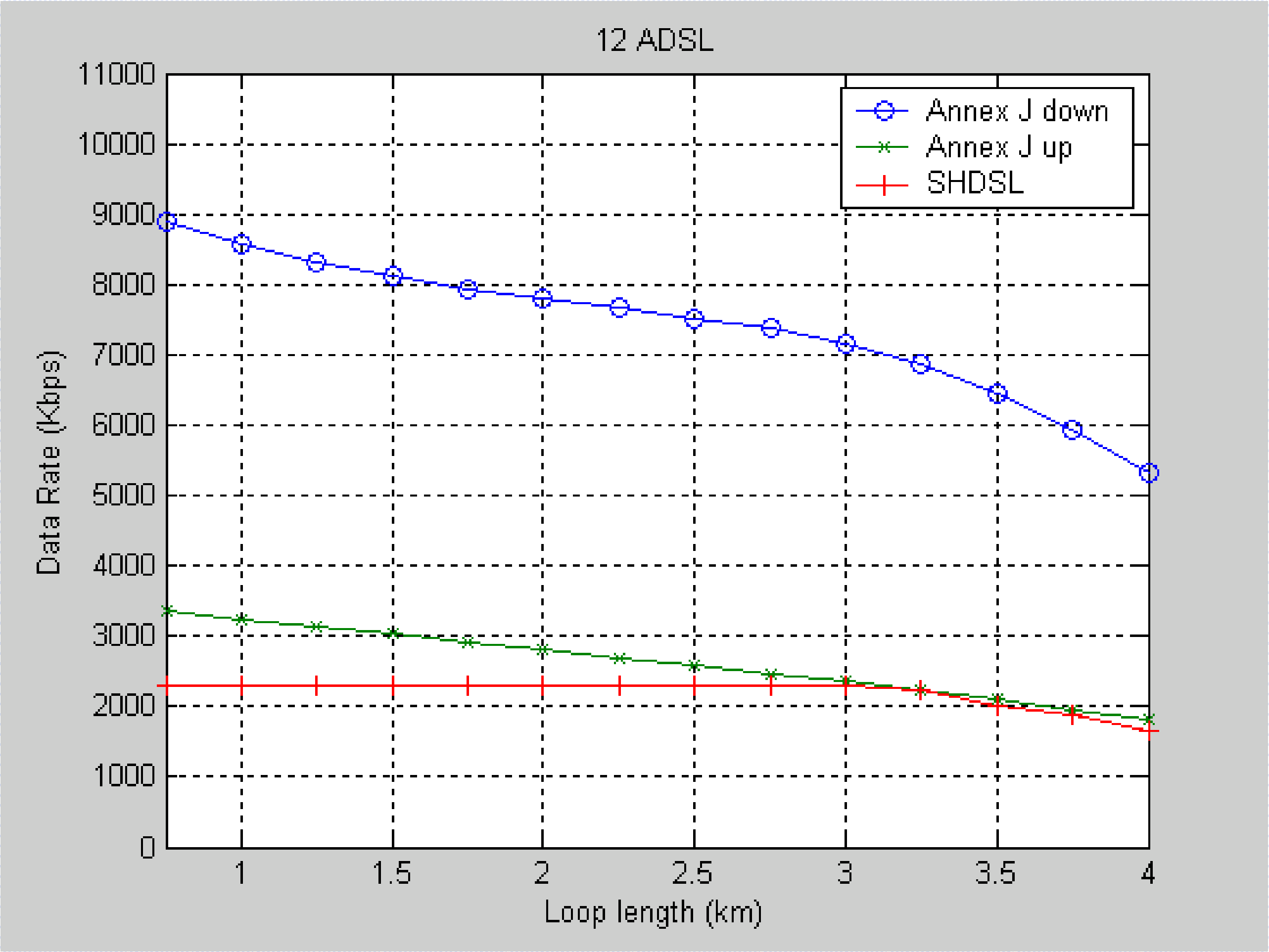
- G.992.3 – "Asymmetric Digital Subscriber Line (ADSL) Transceivers - 2"
- G.994.1 – "Handshaking Procedures for DSL Transceivers"
- G.995.1 – "Overview of DSL Recommendations"
- G.996.1 – "Test Procedures for DSL Transceivers"
- G.997.1 – "Physical Layer Management for DSL Transceivers"

Additional Simulation Results

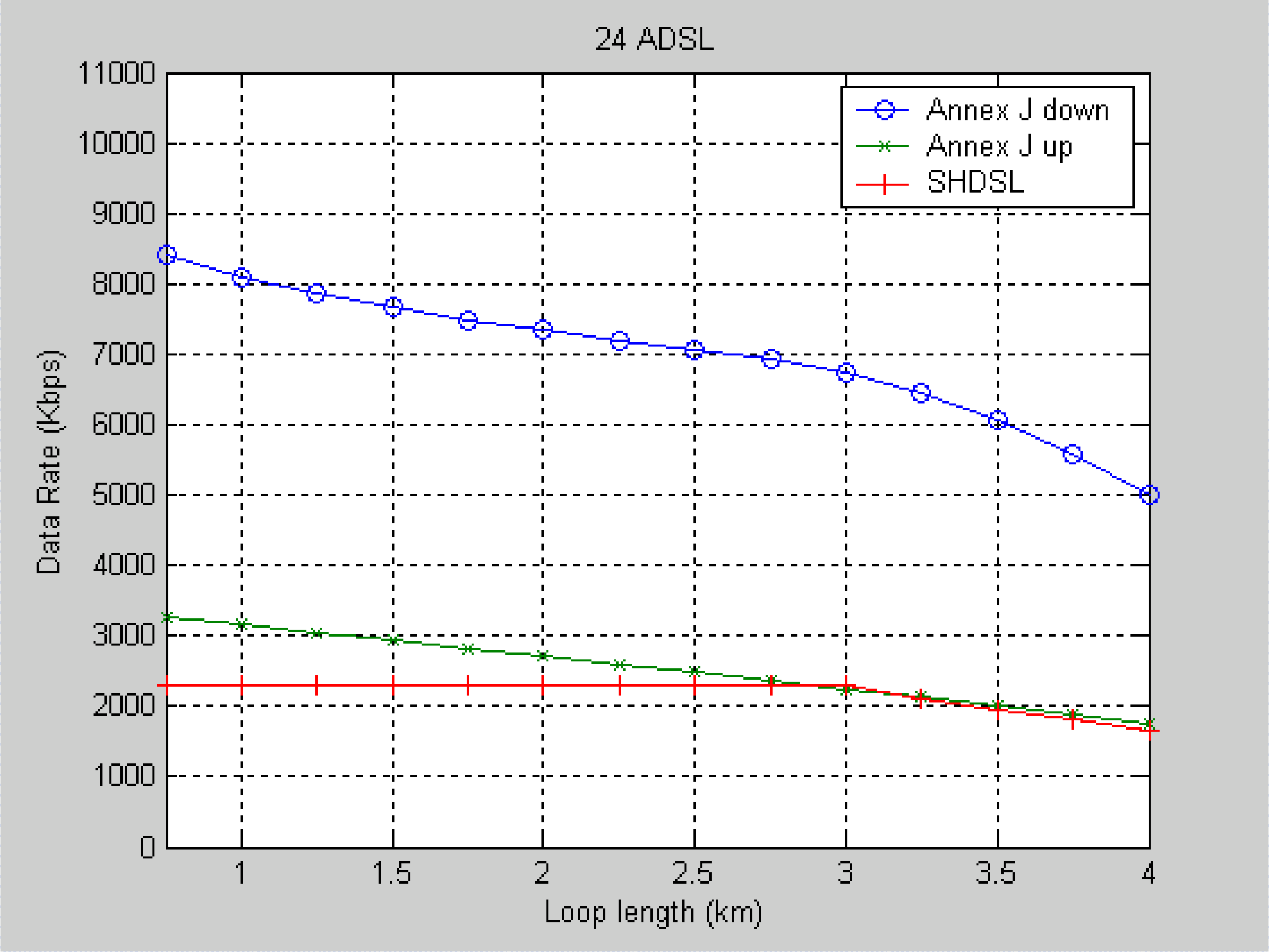
12 Self Disturbers



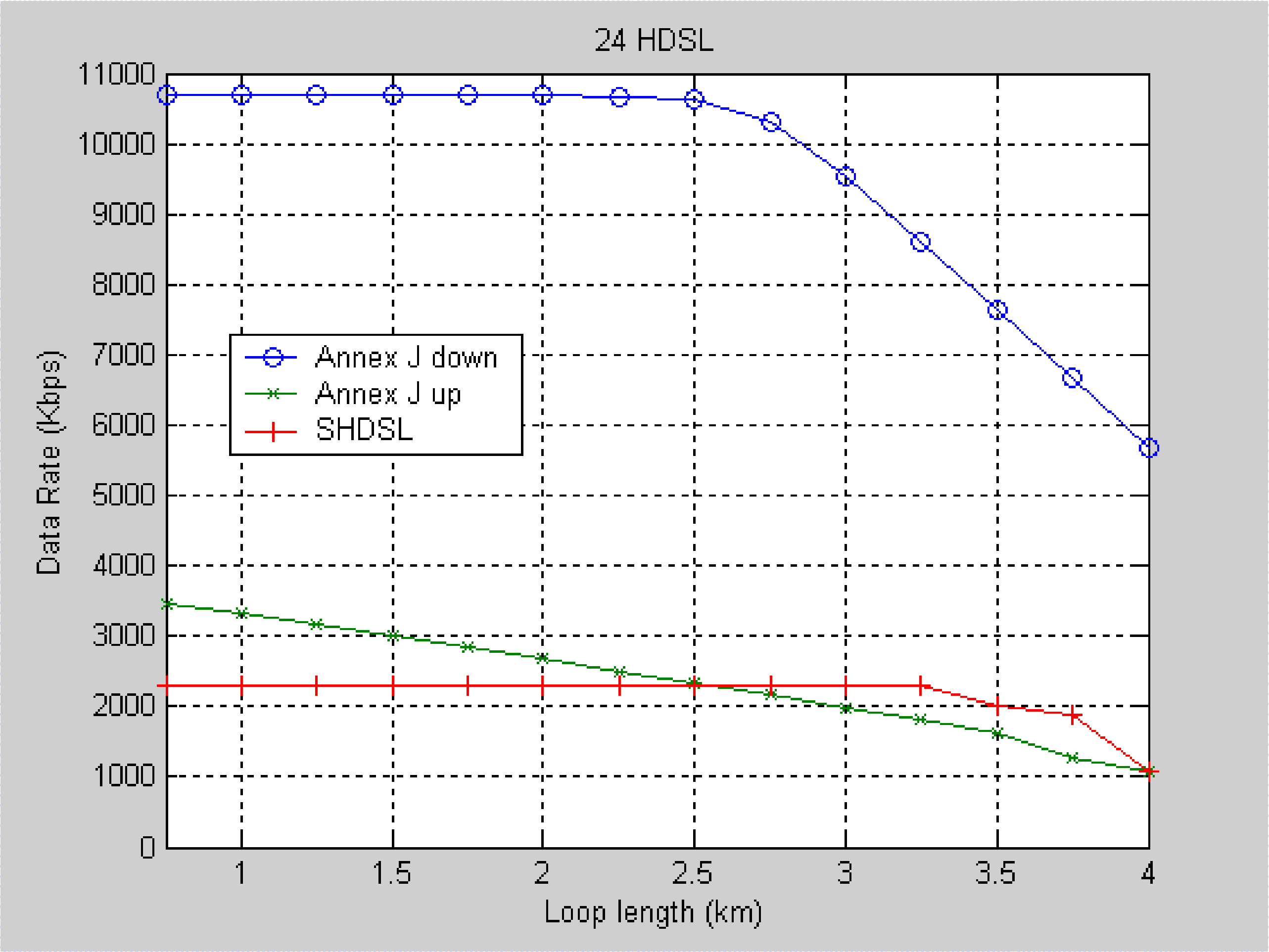
12 ADSL Disturbers



24 ADSL Disturbers



24 Symmetric (HDSL) Disturbers

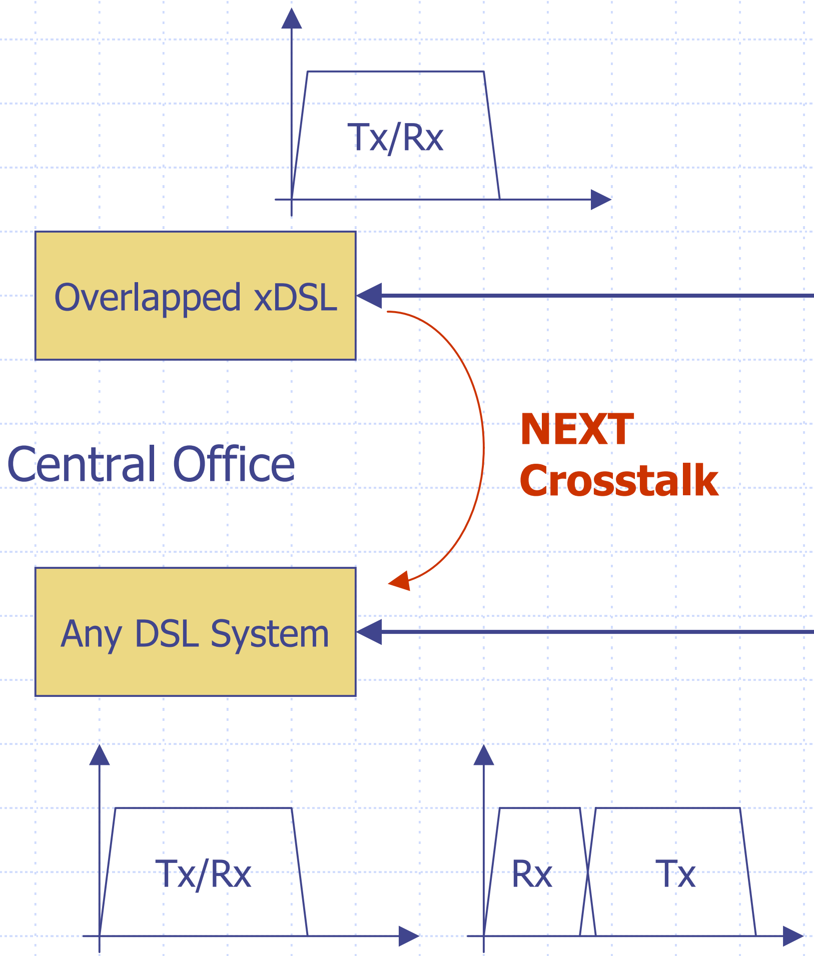


Impact of Self-NEXT

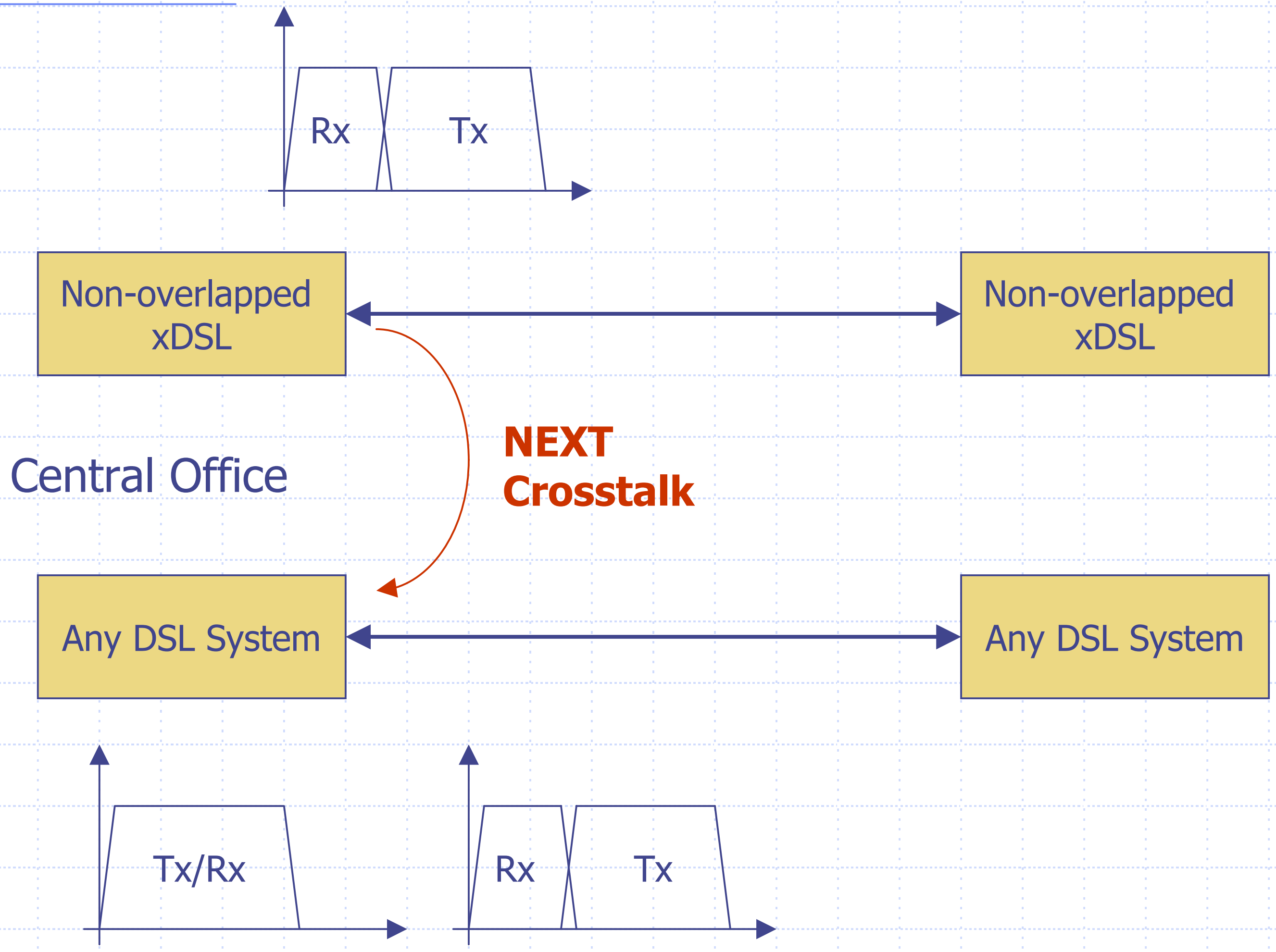
Overlapped vs. Non-overlapped

- ADSL outperforms SHDSL, except where there is large amount of symmetric crosstalk
  - SHDSL has small advantage in this case
- Increasing the number of high rate (ie high bandwidth) overlapped broadband systems in the network further pollutes the network
  - Adds significant amounts of NEXT crosstalk to all services
  - This is the reason why North American operators prohibited overlapped ADSL
- The NEXT crosstalk introduced by these systems is manageable if low rate (ie low bandwidth)/long reach
- Best way to expand broadband data services into network is with a non-overlapped system which does not dump NEXT into the network

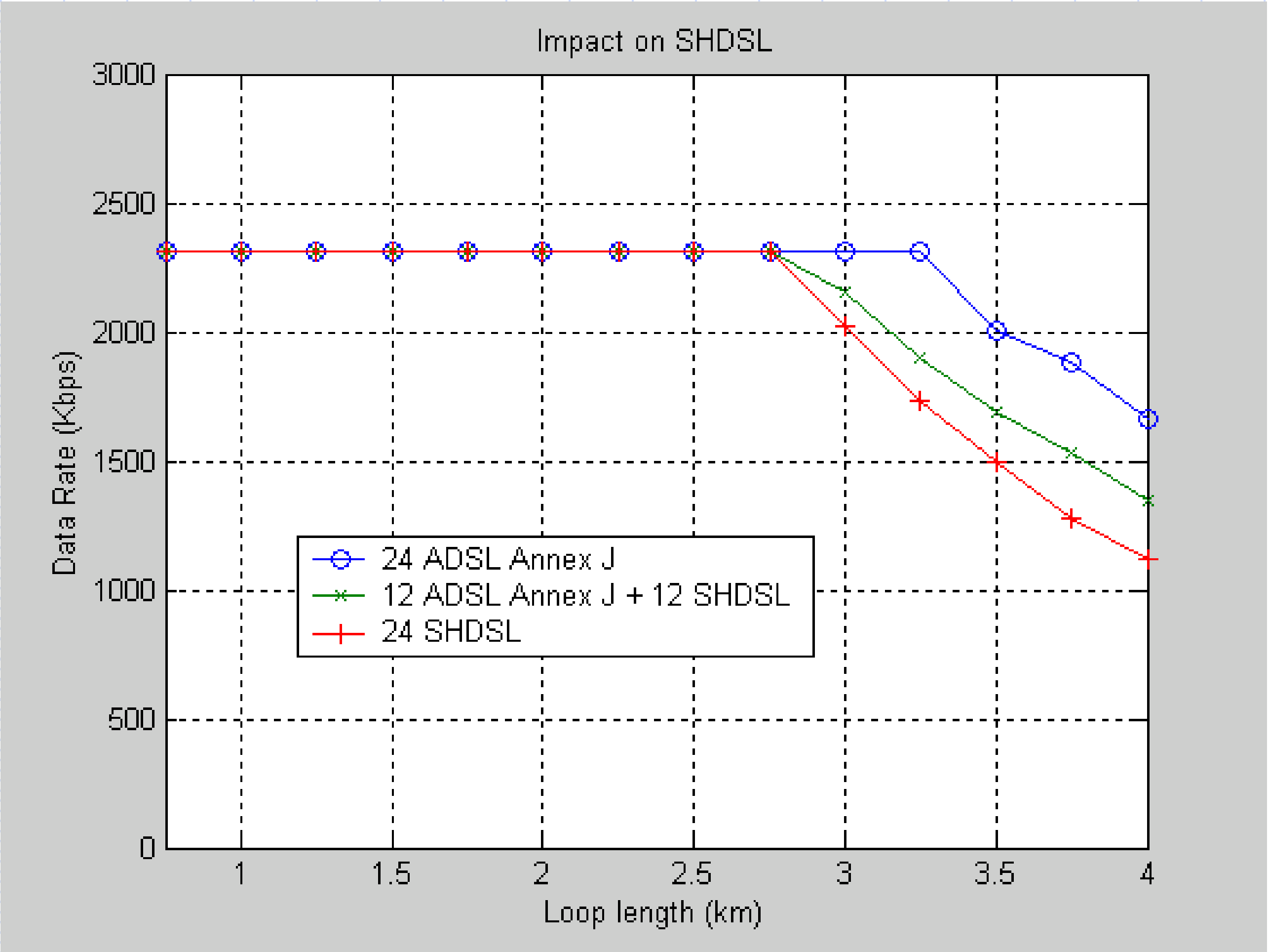
NEXT Crosstalk Issue - Overlapped Transmitters



NEXT Crosstalk Issue - Non-Overlapped Transmitters



Impact on SHDSL



Impact on ADSL POTS