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Vectoring Techniques for Multi-line EFM Systems

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Contributors

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Supporters

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Also Presented for 10 MDSL in support of T1E1.4/2002-196 at Westminster, CO

Motivation: Vectoring and EFM

- **Needs: 10Mbps preferably at CSA range**
  - **10 MDSL in T1E1**
- **Single line capabilities: ~1.5Mbps at CSA range**
  - **Some form of pair bonding is necessary**
- **Do we need physical layer bonding?**
  - **Does it improve performance?**
  - **How complex is it?**
  - **Do we need a completely new PHY?**
- **Vectoring can improve performance and can be implemented with incremental changes to existing PHYs**

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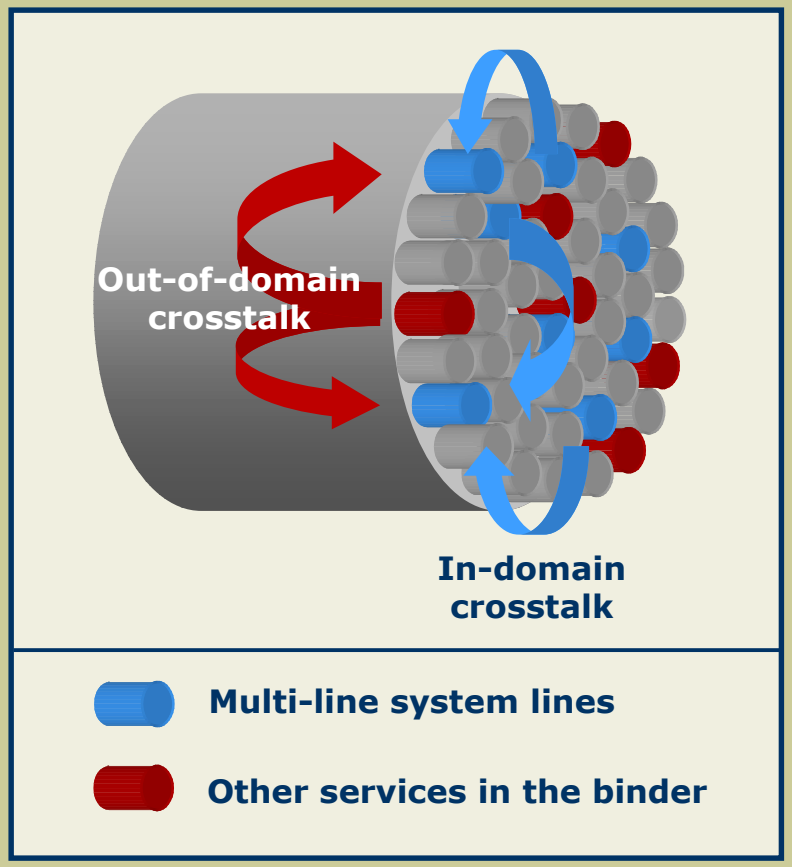
The Interference Environment

Q: What is the right multipair PHY?

A: Start with the interference conditions



- **FEXT/NEXT crosstalk**
- **In-domain crosstalk**
- **Out-of-domain crosstalk**

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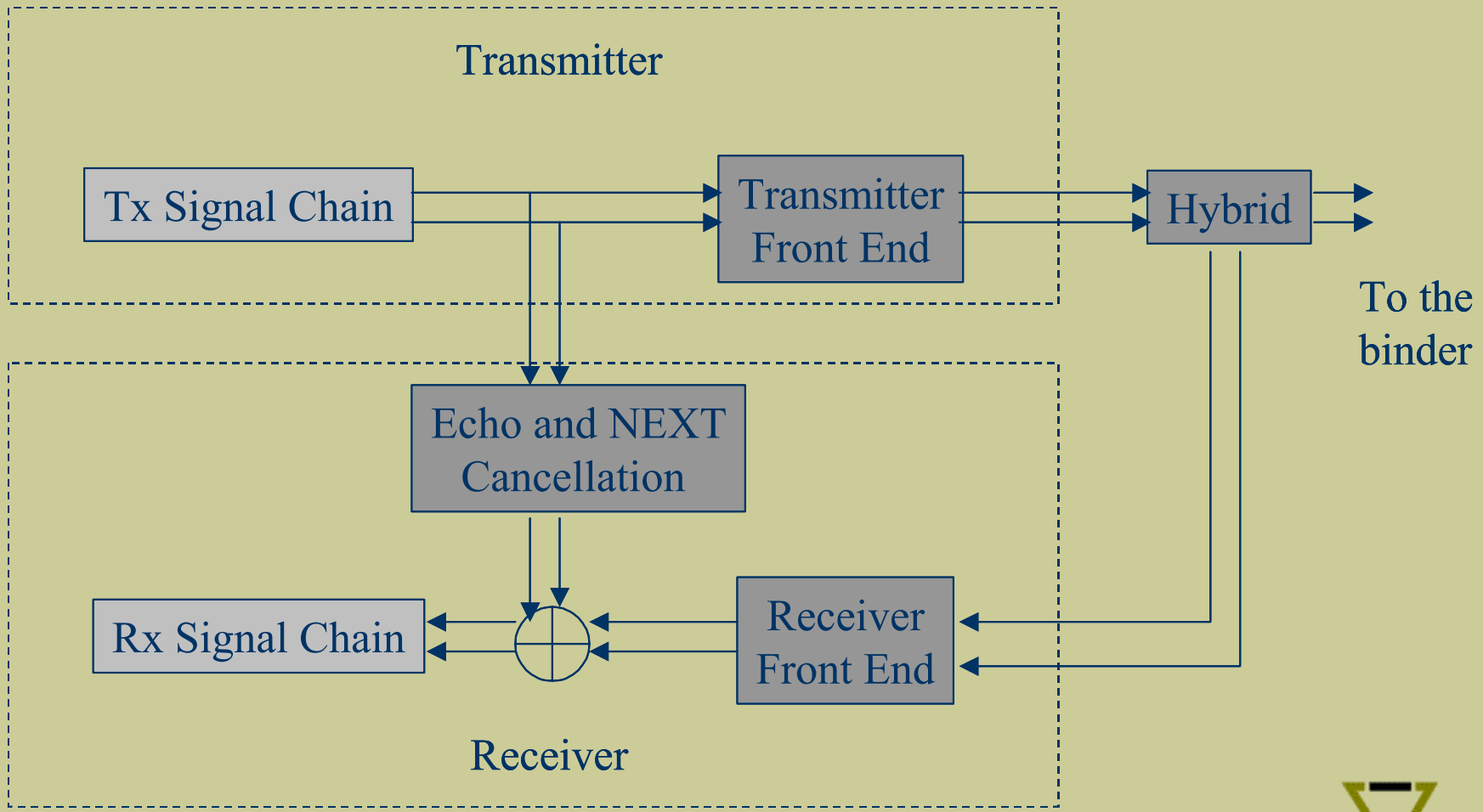
Mitigation of In Domain Interference



MIMO Echo/NEXT cancellers

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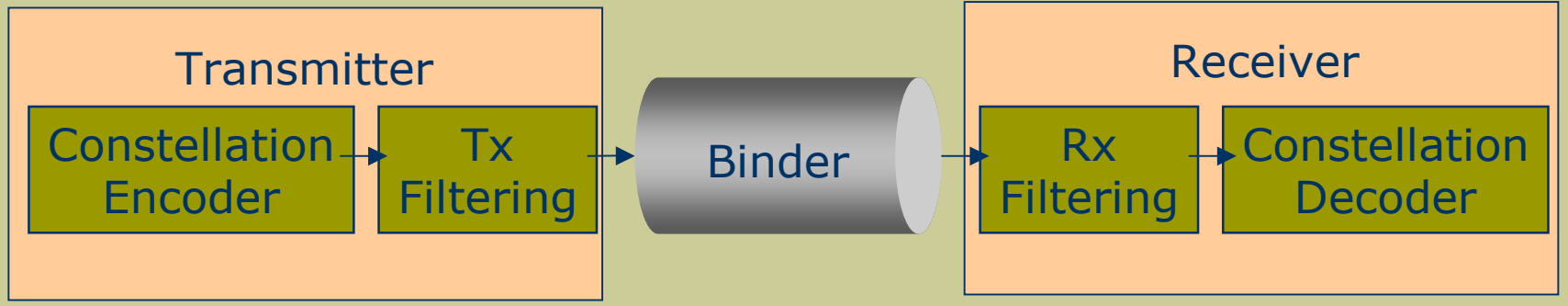
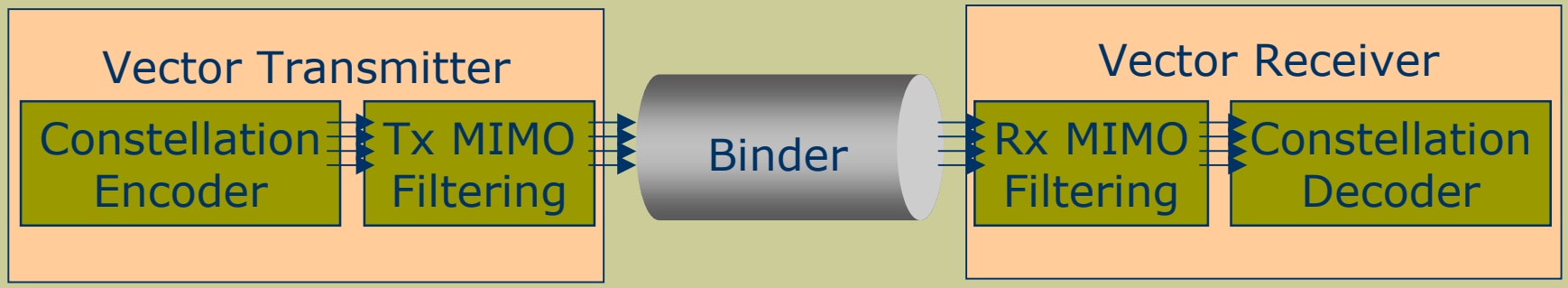
Mitigation of Out of Domain Interference

SISO Transceiver



MIMO Transceiver



Implications:

- **DMT: Vector FFT and MIMO equalizers**
- **Single carrier: MIMO precoder**

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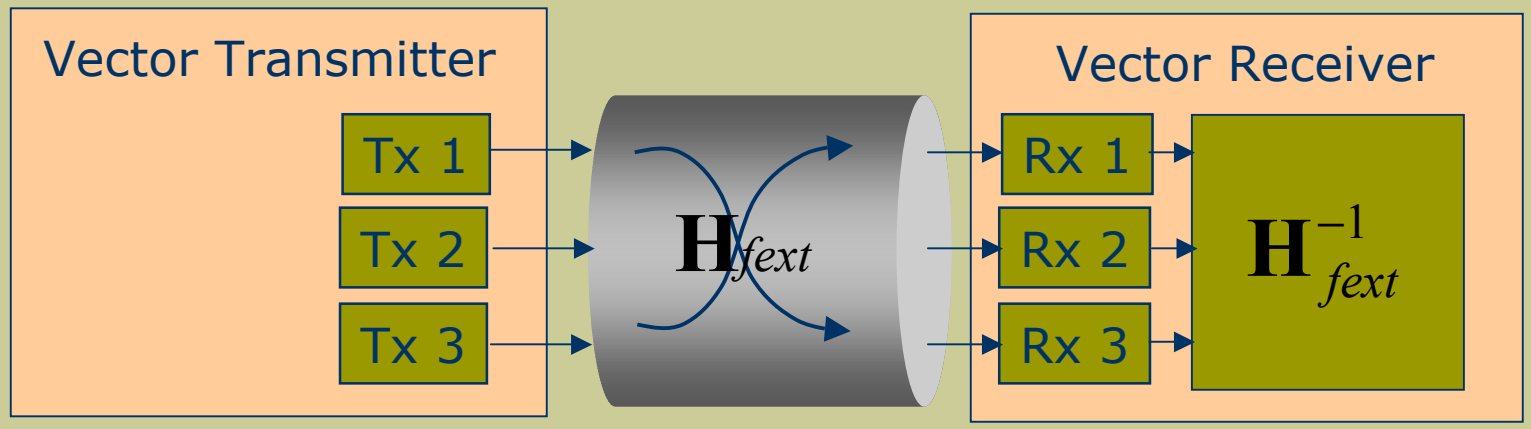
Benefits of Vectoring: FEXT Mitigation

Receiver can invert MIMO loop plant channel



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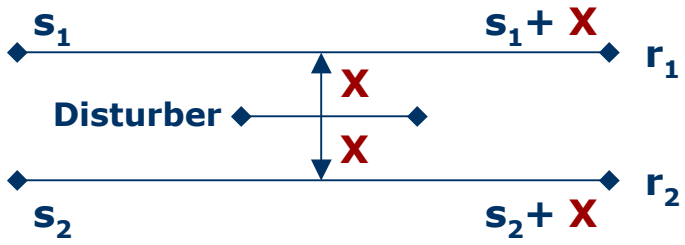
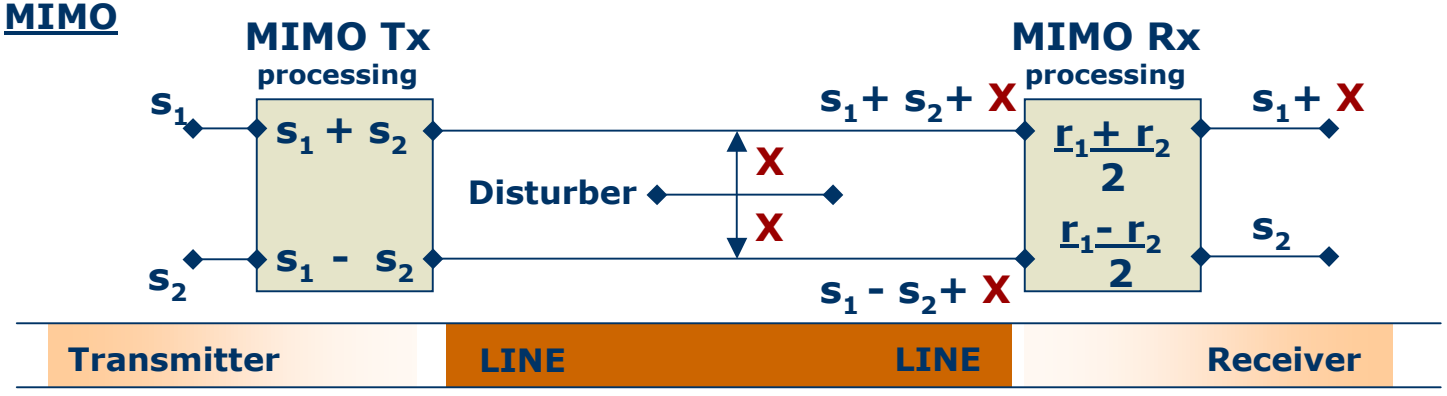
Benefits of Vectoring: Out-of-Domain Crosstalk Mitigation

Multiple SISO



Every SISO line must contend with crosstalk (X)

MIMO



Crosstalk contrained to one channel
Other channel freed of crosstalk

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Performance Results

Simulations

- **MIMO capacity:** $C = \frac{1}{2}\int \log_2 \det(I + R^{-1/2} H S_{xx} H' R^{-1/2}) df$
- **Telcordia channels**
- **Upstream results (Annex J and SHDSL mask)**
- **1e-7 BER, 6 dB margin, 5.1 dB of coding gain**

Lab results

- **DMT Implementation**
- **Annex J and SHDSL mask**
- **Real loops and disturbers**
- **9,000ft 26AWG binder**

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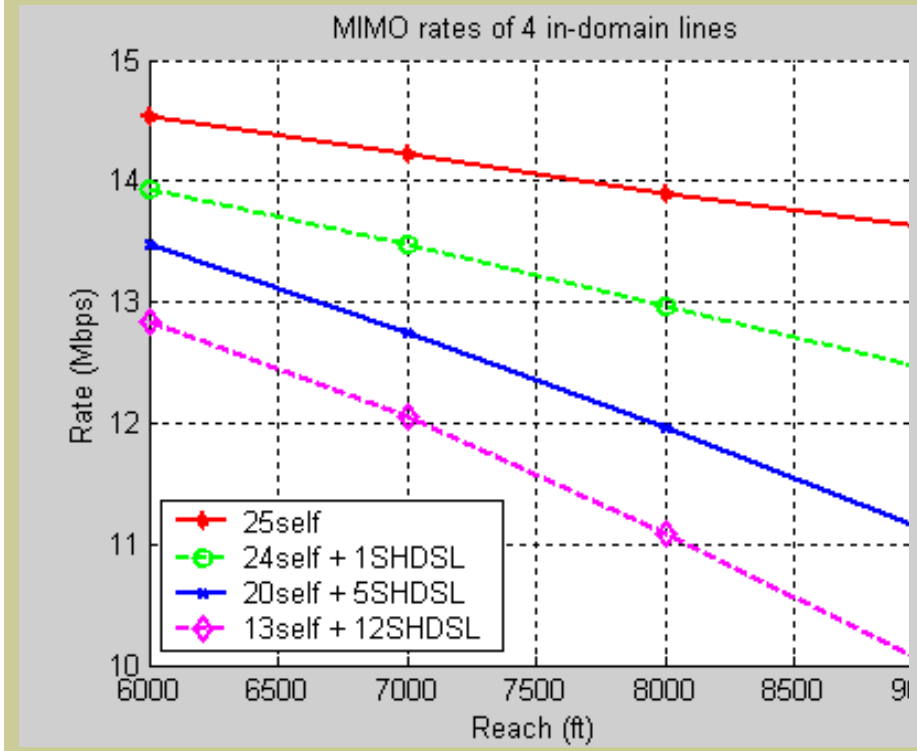
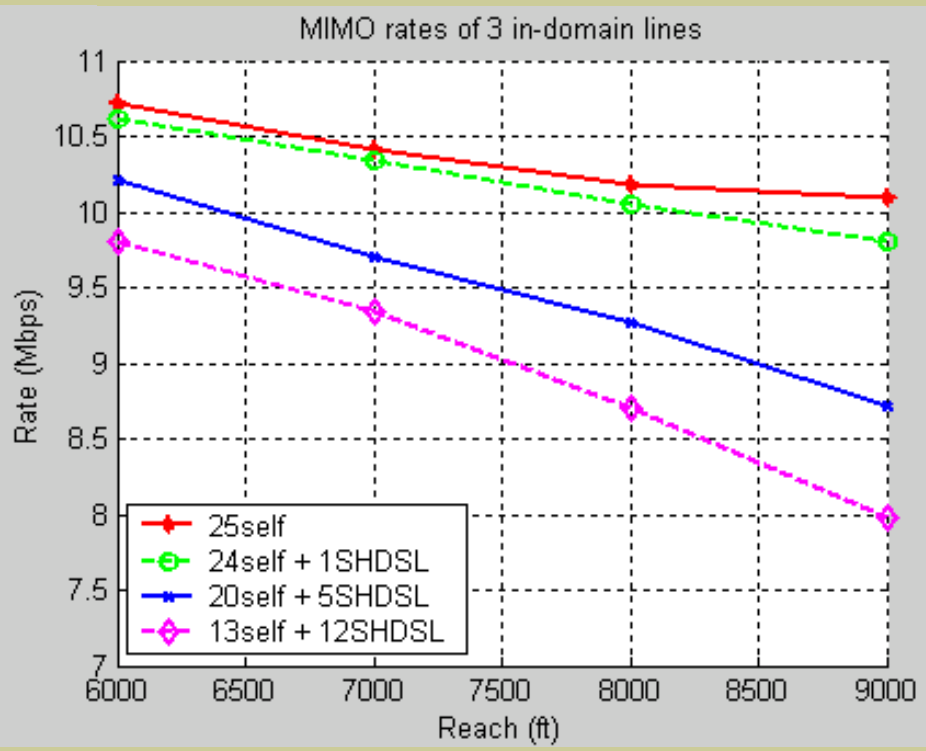
Performance Results for Annex J Mask

- **4 and 3 lines in full binder of self and SHDSL interferers**





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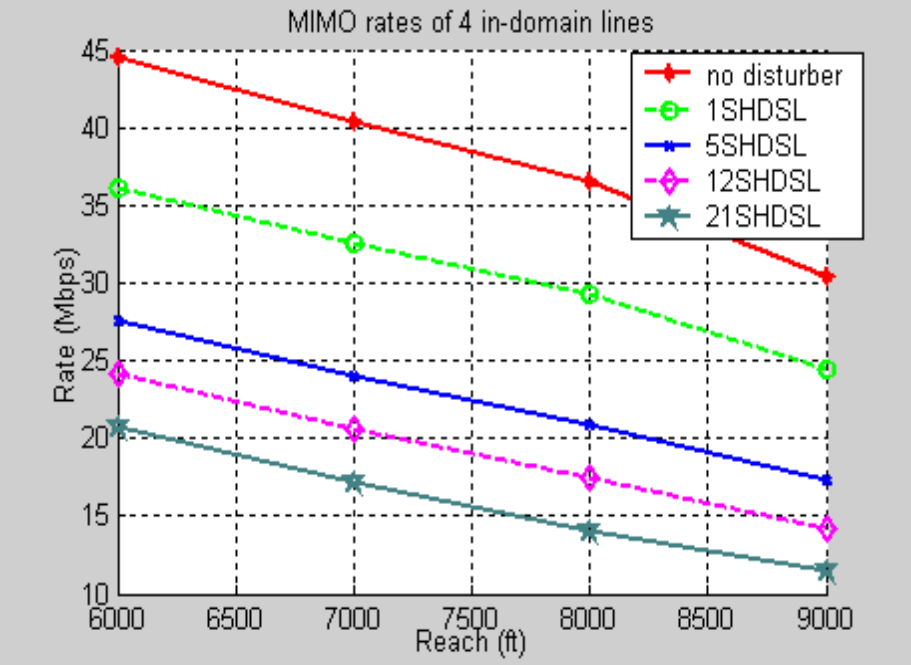
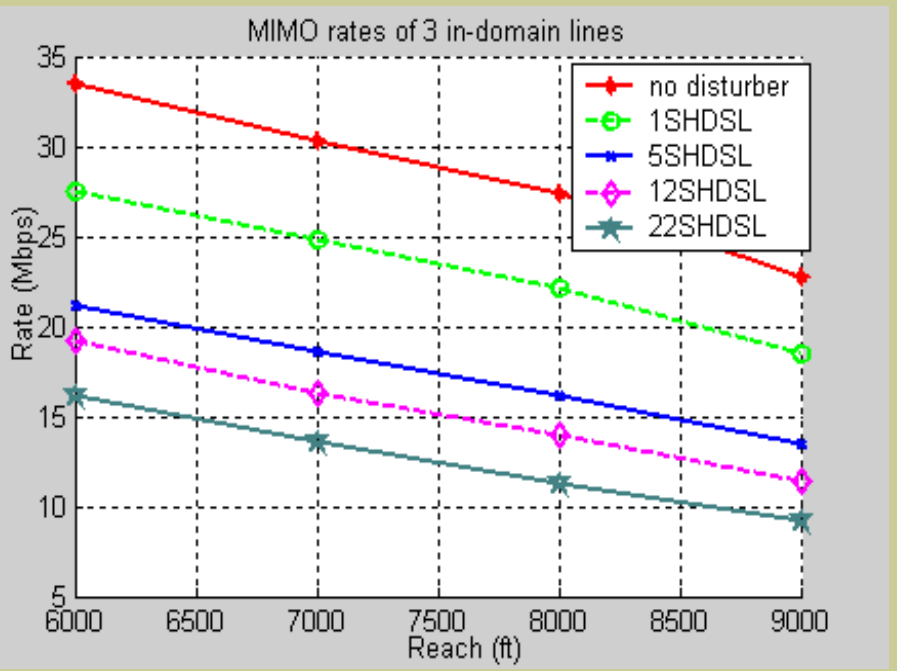
Performance Results for SHDSL Mask

- **Results for 4 and 3 line systems, 0 - full binder of SHDSL interferers**





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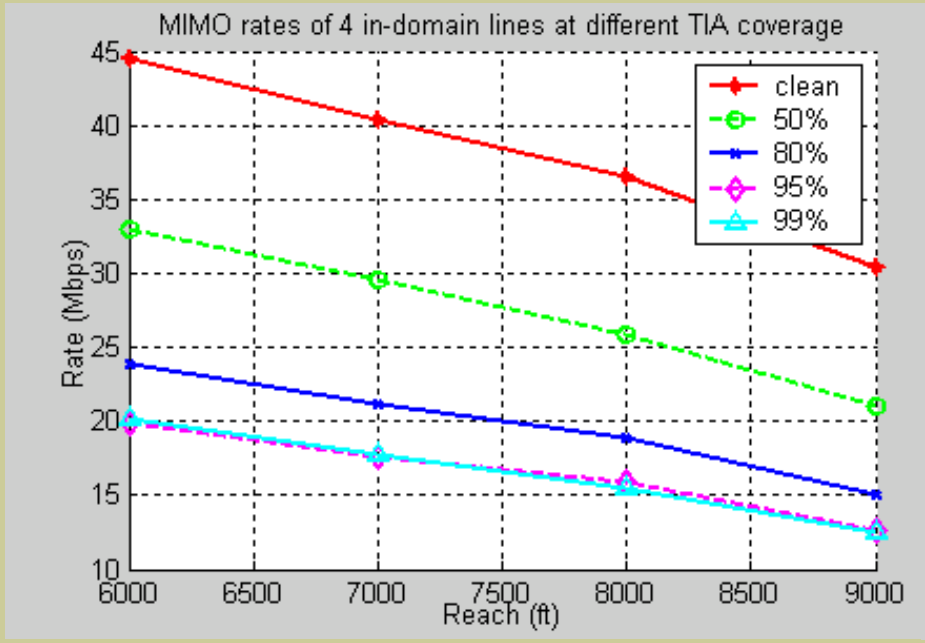
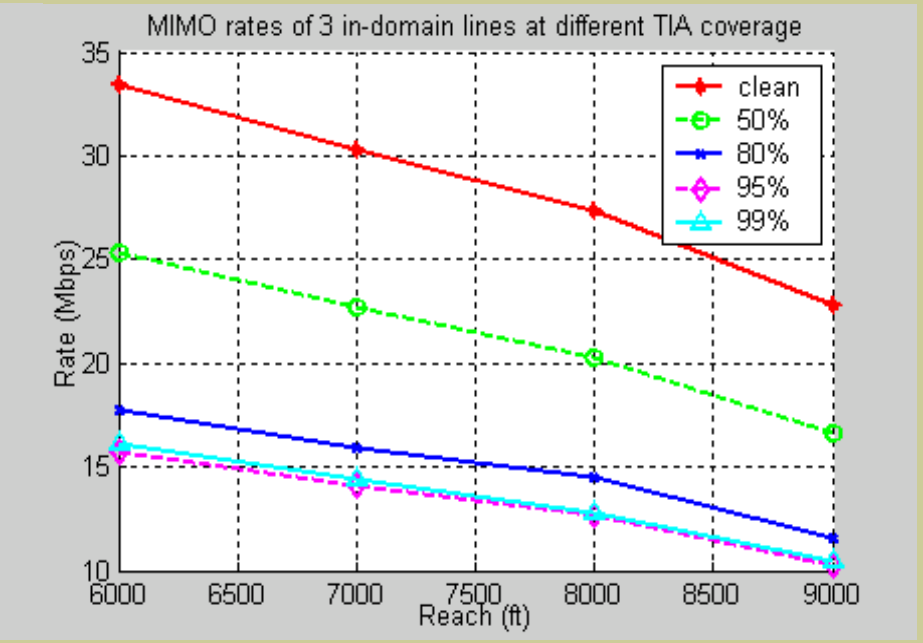
Performance Results Under TIA-876 Disturber Scenarios

- **Results for 4 and 3 line systems, 0, 50%, 80%, 95%, 99% coverage**





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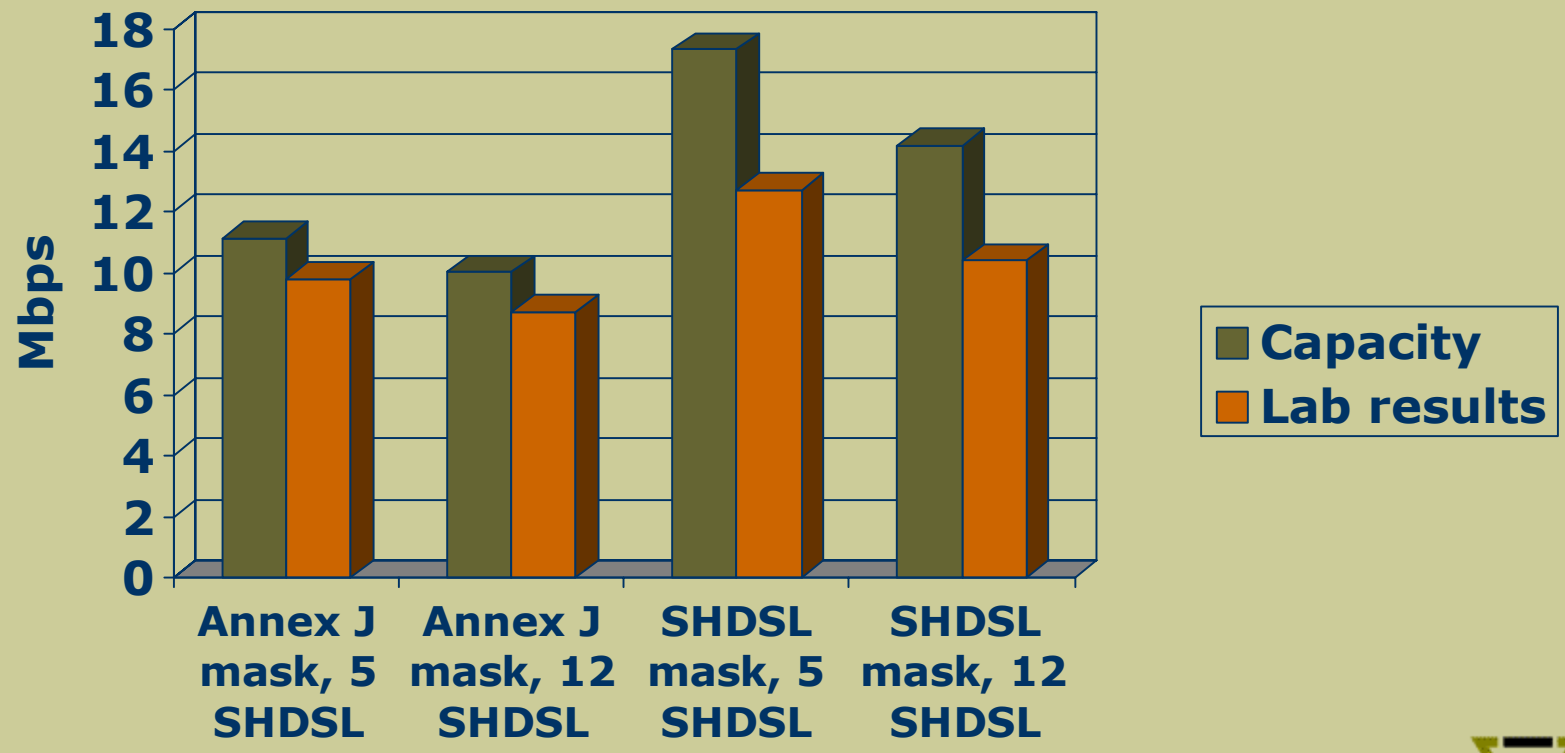
Laboratory Results

- 9Kft, 26AWG, SDSL disturbers @1Mbps



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Conclusions

- **Vectoring performance exceeds EFM / 10MDSL nominal and "desired" reach objectives**
- **Can be implemented through MIMO extensions of existing PHYs**
- **Can enable EFM deployment at 10Mbps over CSA range on 3 to 4 pairs.**

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