10GBASE-T Link Segment Specifications and ANEXT Consideration

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Overview

Purpose of presentation:

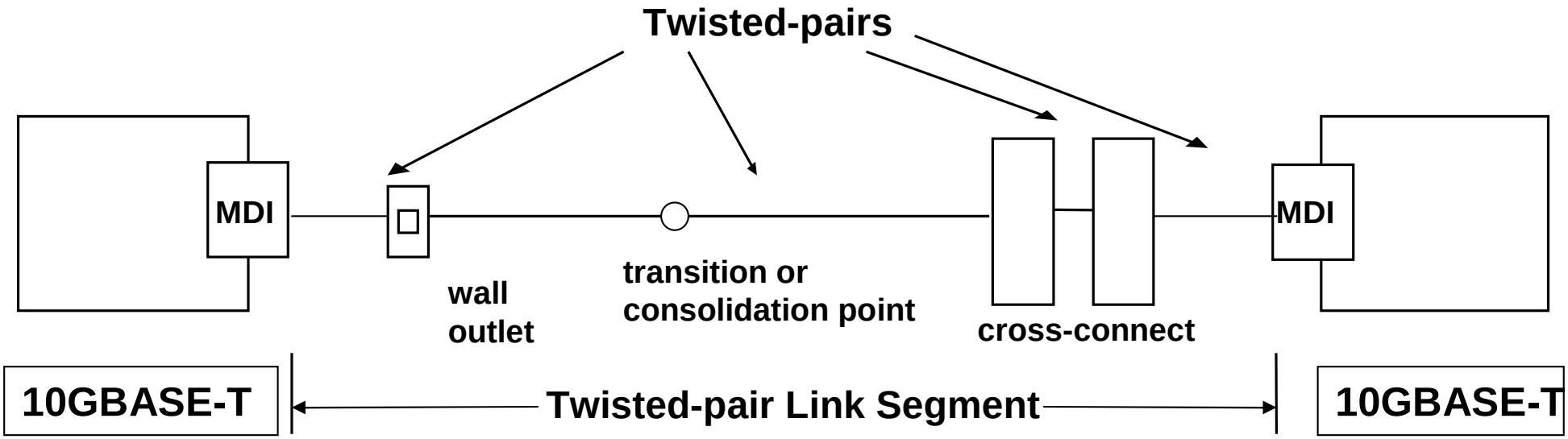
- **Outline: 10GBASE-T link segment specifications**
- **Considerations for 10GBASE-T over installed cabling**
  - **Deployment:**
    - **Installation procedures**
    - **Field test limits**
  - **Alien Crosstalk Field testing**
    - **† feasibility and alternatives**

10GBASE-T Link Segment

Cabling system characteristics

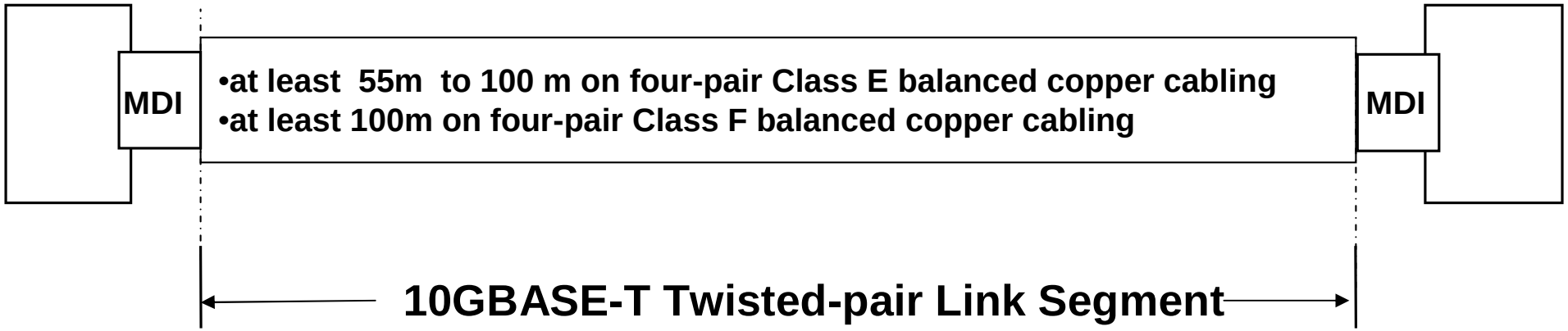
- 4-connector structured 4-pair, twisted-pair copper cabling
- ISO/IEC 11801:2002, with any appropriate augmentation
- at least 55m to 100 m on four-pair Class E balanced copper cabling
- at least 100m on four-pair Class F balanced copper cabling

Type 10GBASE-T – Link Segment



Link transmission parameters

- **Link segment transmission parameters based on cabling system characteristics**



Link Transmission Parameters

Transmission parameters:

- **Insertion loss**
- **Differential characteristic impedance**
- **Return loss**

Delay parameters:

- **Maximum link delay**
- **Link delay skew**

Link Transmission Parameters

Coupling parameters:

- Near-End Crosstalk (NEXT)
  - Differential Near-End Crosstalk
- Far-End Crosstalk (FEXT)
  - Equal Level Far-End Crosstalk (ELFEXT) loss
- Multiple Disturber
  - Equal Level Far-End Crosstalk (MDELFEXT) loss
    - †PSELFEXT

Link Transmission Parameters

Coupling parameter:(between link segments)

- Alien crosstalk

Clause 40: 1000BASE-T: Annex 40A (informative)

Additional cabling design guidelines

40A.1 Alien crosstalk

- Bundled or hybrid cable configurations
  - –PSNEXT specified- between link segments

    35 – 15*log(*f*/100) (dB)

    At all frequencies from 1 MHz to 100 MHz.

Insertion Loss proposal

- **The insertion loss link transmission parameter for a twisted-pair-link segment is bounded by the Class F requirement for 100 meters and the Class E requirements for 55 meters**

- **The proposal satisfies the minimum requirements for the Class F (100 m) and Class E (55 m) objectives**

- **The proposal satisfies the 4-connector structured 4-pair, twisted-pair copper cabling (Class E Channel IL)**

- **The proposal provides a basis for satisfying objectives without applying a ratio**

10GBASE-T Link segment Insertion Loss:

$$1.05 \times (1.82 \sqrt{f} + 0.0169 \times f + 0.25/\sqrt{f}) + 4 \times 0.02 \times \sqrt{f}$$

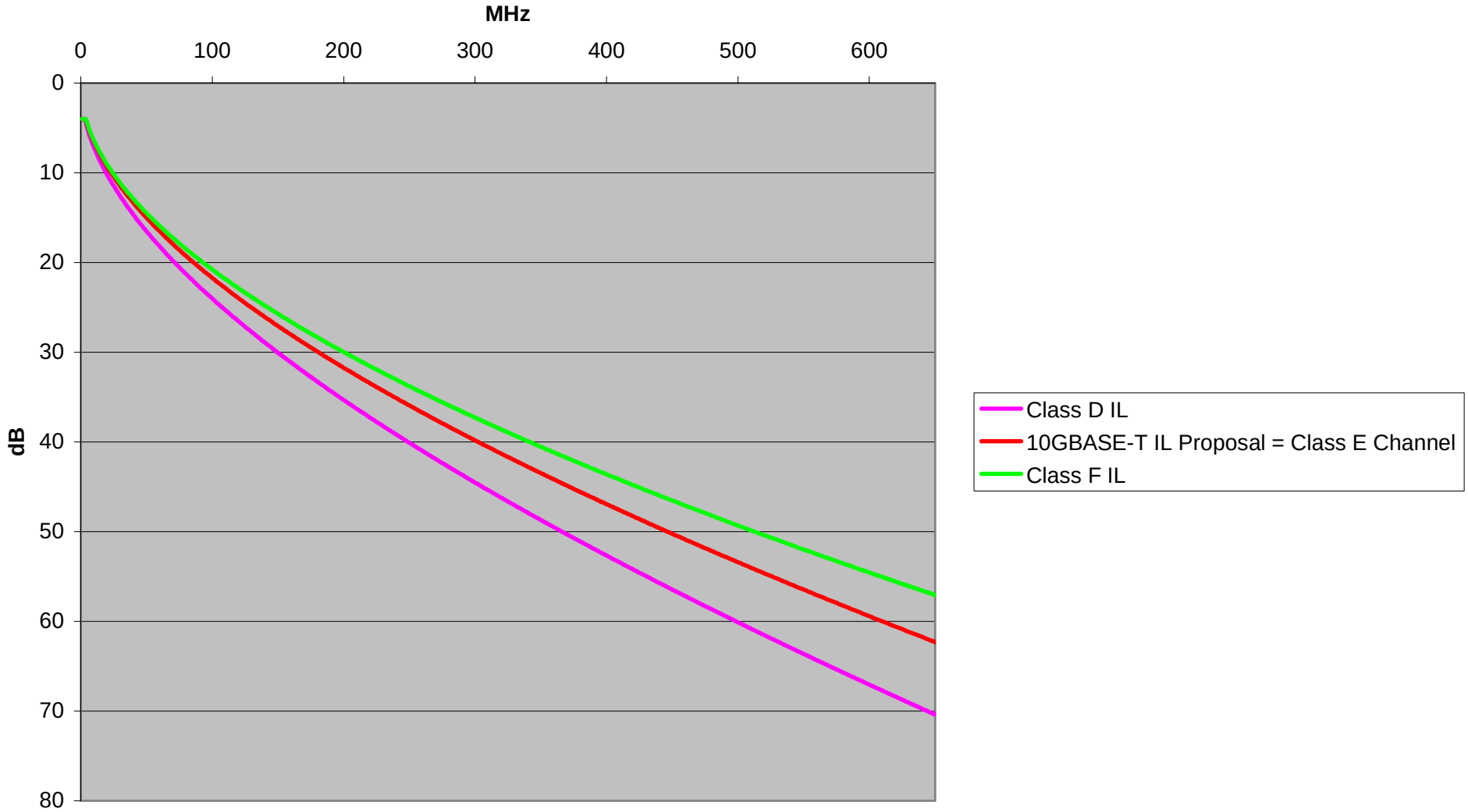
Insertion Loss proposal

Frequency	10GBT IL Proposal	Class E Channel IL
MHz	dB	dB
1	4.0	4.0
16	8.3	8.3
100	21.7	21.7
250	35.9	35.9
600	59.4	
625	60.9	

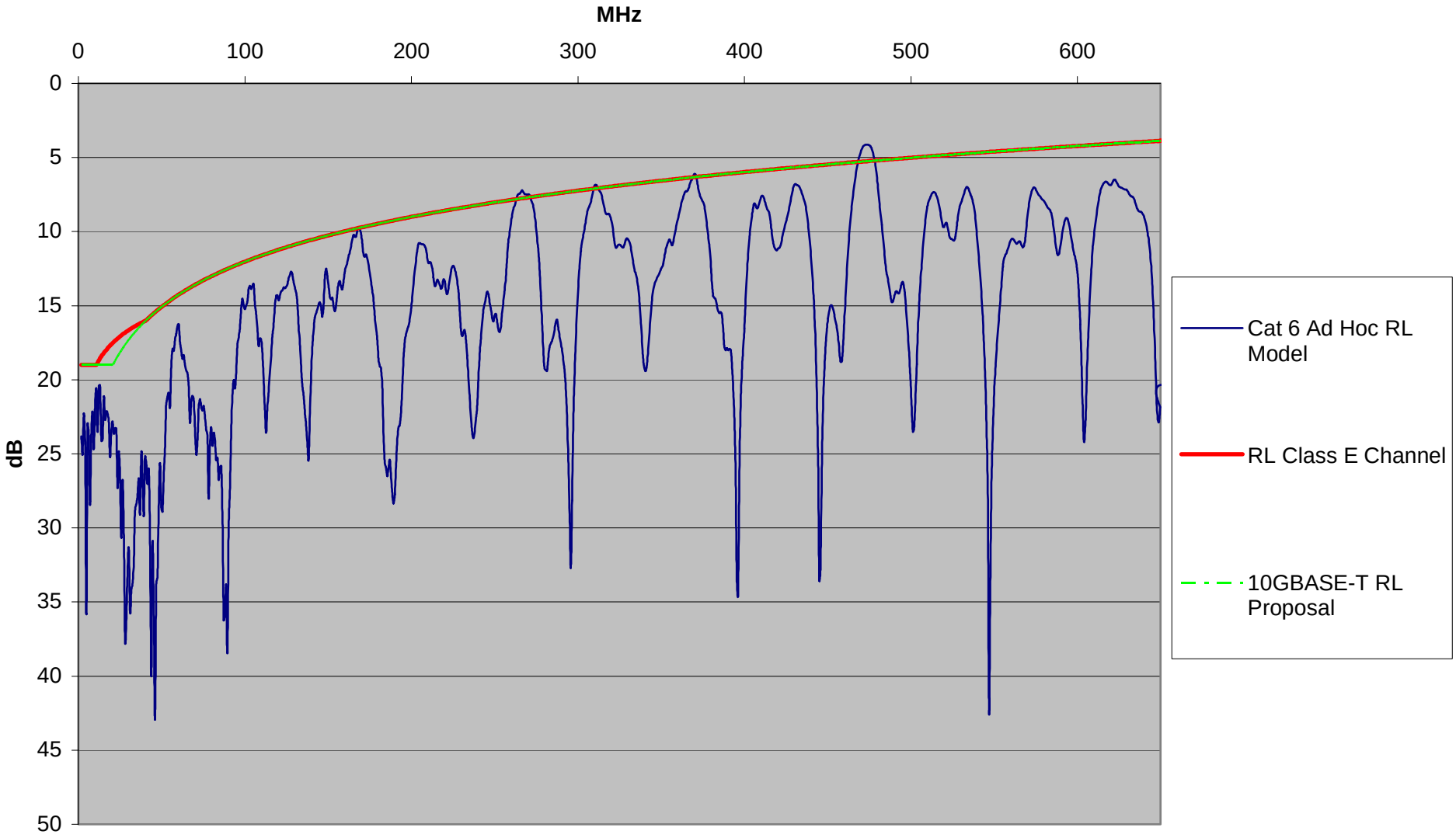
10GBASE-T Link segment Insertion Loss 100 m:

$$1.05 \times (1.82 \sqrt{f} + 0.0169 \times f + 0.25/\sqrt{f}) + 4 \times 0.02 \times \sqrt{f}$$

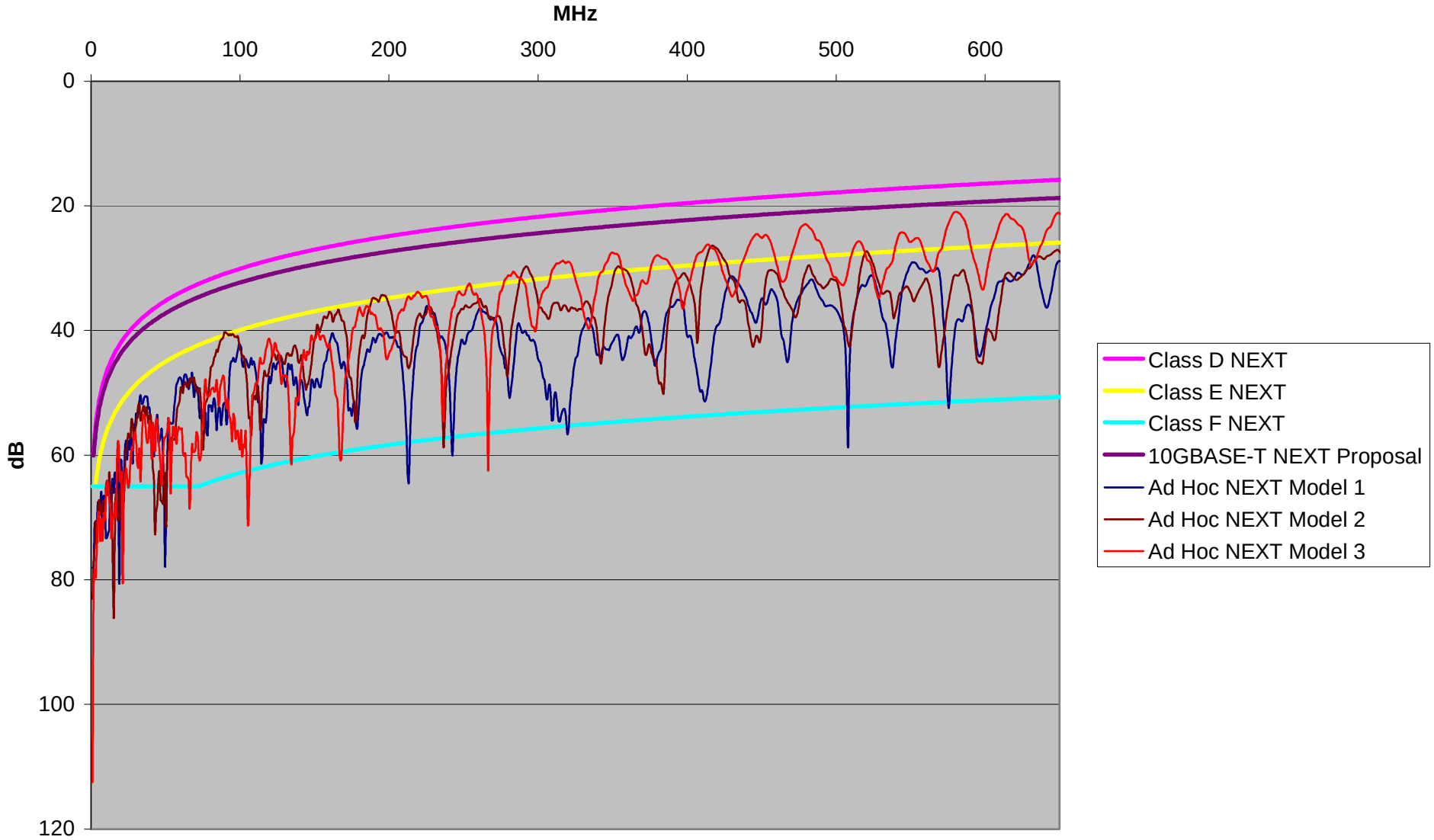
Channel Insertion Loss - Class D-E-F and 10GBASE-T Proposal



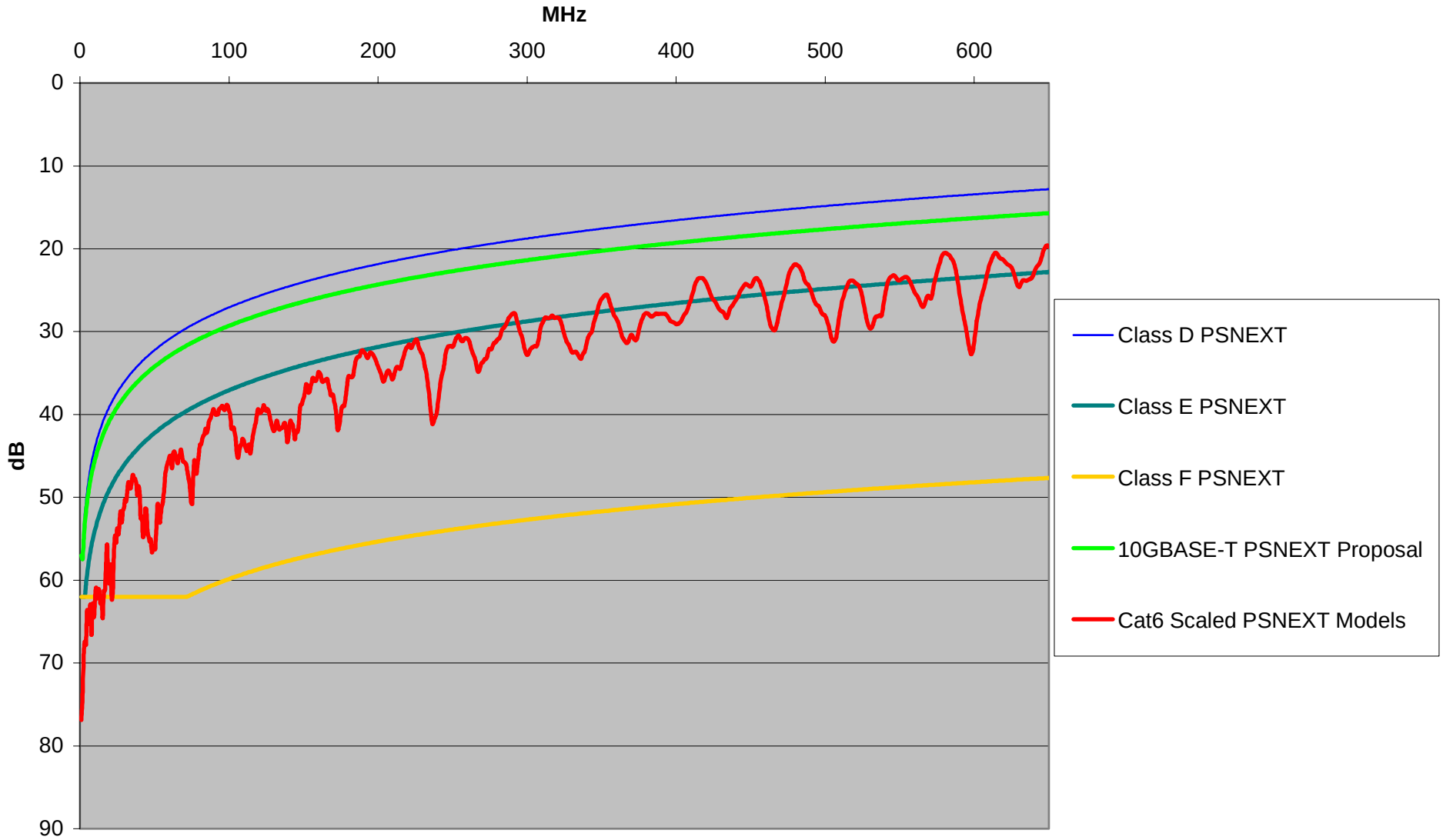
10GBASE-T RL Specification Proposal



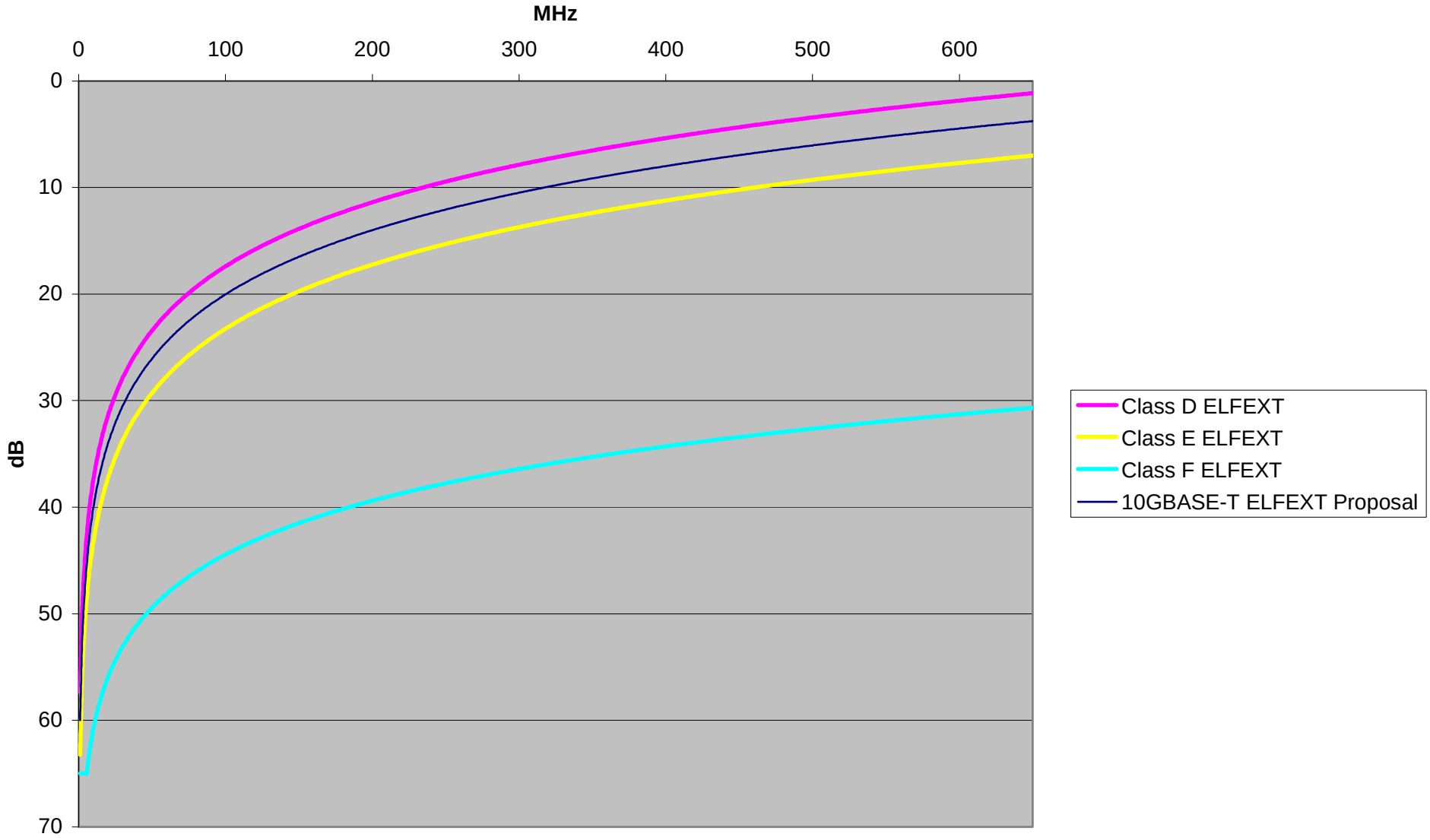
Pair-to-Pair NEXT Class D-E-F and 10GBASE-T NEXT Proposal



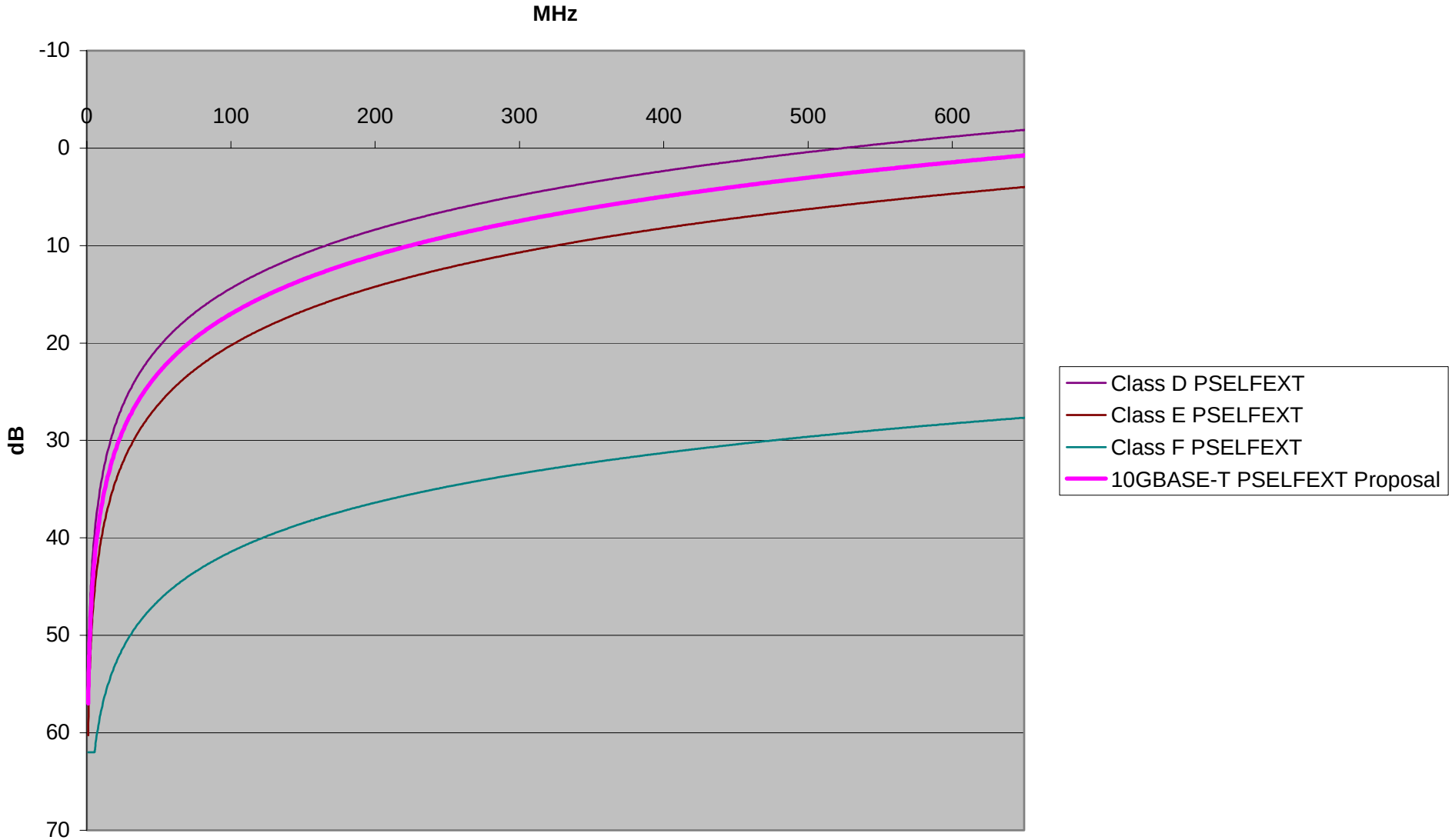
PSNEXT Class D-E-F and 10GBASE-T PSNEXT Proposal



Pair-to-Pair ELFEXT Class D-E-F and 10GBASE-T Proposal



PSELFEXT - Class D-E-F and 10GBASE-T Proposal



Link Segment Proposal : Extended Frequency Specifications

- **Pair-to-pair NEXT:**
  - **-20*LOG((10^((65.3-(15*LOG(f)))/-20))+((10^((83-(20*LOG(f)))/-20))))**
- **Power sum NEXT:**
  - **-20*LOG((10^((62.3-(15*LOG(f)))/-20))+((10^((80-(20*LOG(f)))/-20))))**
- **Pair-to-pair ELFEXT:**
  - **-20*LOG((10^((63.8-(20*LOG(f)))/-20))+(2*(10^((75.1-(20*LOG(f)))/-20))))**
- **Power sum ELFEXT:**
  - **-20*LOG((10^((60.8-(20*LOG(f)))/-20))+(2*(10^((72.1-(20*LOG(f)))/-20))))**
- **Return Loss:**
  - **(1MHz ≤ f < 20MHz) 19 dB,**
  - **(1MHz ≤ f < 625MHz) 32-10*LOG(f)**

Motion

Move that the Task Group accept the link Segment specifications of Insertion Loss, Return Loss, NEXT, PSNEXT,ELFEXT and PSELFEXT as the technical baseline link segment specifications for those parameters.

Moved By:

Seconded By:

Yes: No: Abstain:

Importance of Alien Crosstalk

- **Alien crosstalk (AXT) is a critical parameter for determining channel capacity**
  - **Need to create alien crosstalk specification for complete channel (connectors and cables)**
  - **Test methodology and test channel TBD by ISO/IEC and TR42**
    - **Define suitable test channel as per expected worst-case installation practices**

10GBASE-T Channel Capacity

- Shannon capacity is a useful figure of merit for 10GBASE-T channels

$$Pair\_Capacity = \int_{f_{MIN}}^{f_{MAX}} \log_2\left(1 + SNR(f)\right) df$$

  - **SNR(*f*) is absolute magnitude, NOT dB !!**

- For 10GBASE-T available channel capacity can be approximated by a ratio of insertion loss (IL) to alien crosstalk (AXTIR).
  - Other impairments (echo, NEXT, FEXT, etc) are cancelable
  - use AXTIR(*f*) for SNR(*f*)
- 18 Gb/s minimum target capacity for 10GBASE-T on four-pair cable

Alien crosstalk to insertion loss ratio (AXTIR)

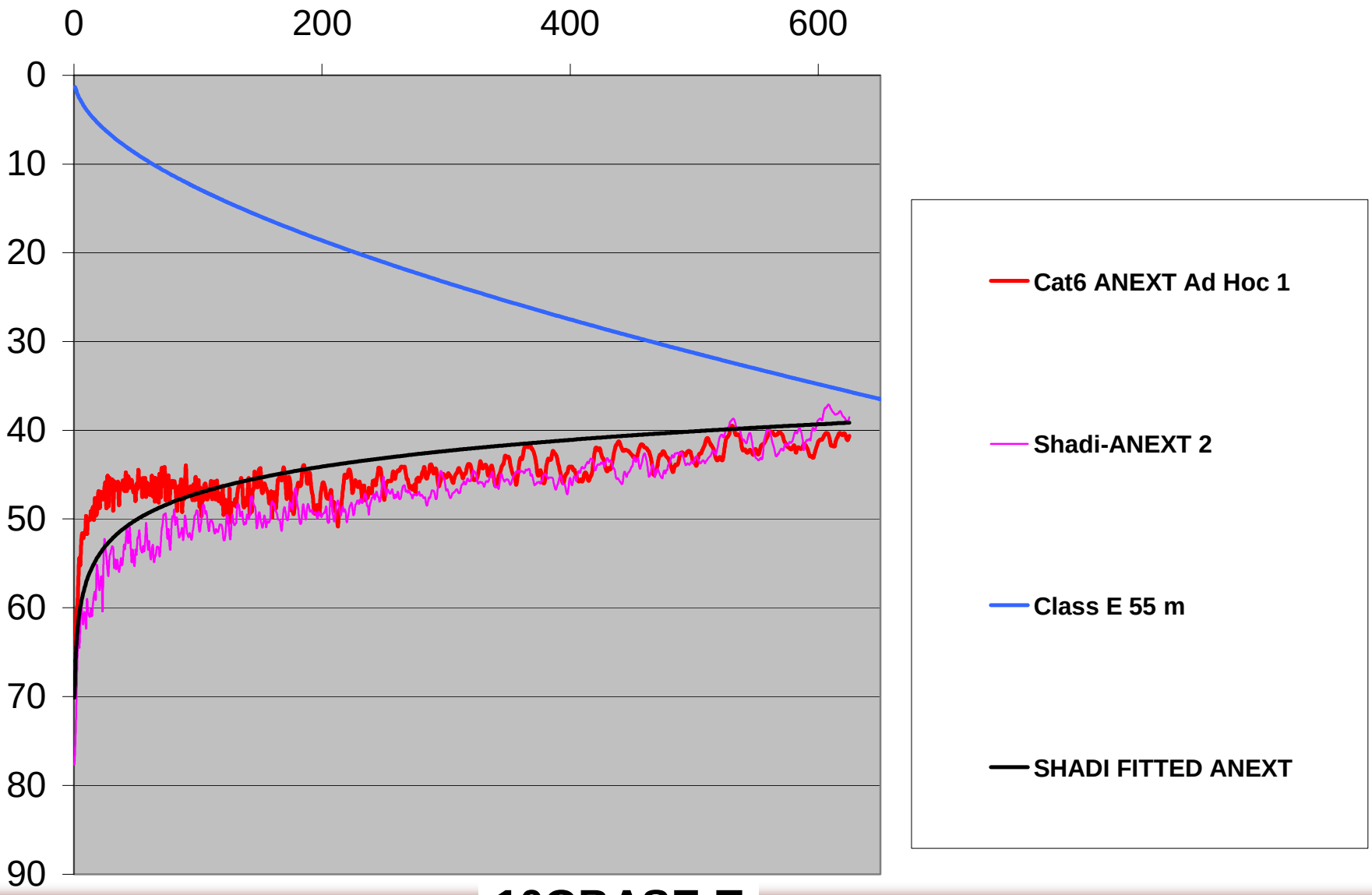
- **Alien crosstalk to insertion loss ratio (AXTIR) useful for field validation limits and application usage limits (e.g., coexistence of 10GBASE-T link segments in close proximity).**

- **AXTIR ratio is useful as a reference metric for guidance on cabling design**

AXTIR = Cat6 ANEXT – Class E 55 m

AXTIR = -(-47.1+10*LOG(f/100)) – ((.6 x (1.82 √f +0.0169 x f + 0.25/√f))+ 4 x 0.02 x √f)

Example AXTIR Graph



10GBASE-T Deployment

- **Procedures for three cases:**
  - **Case 1: Installed base channel lengths and topologies less than or equal to minimum objective for specified cable class**
  - **Case 2: Installed base channel lengths and topologies greater than minimum objective for specified cable class**
  - **Case 3: New cabling components specially designed to support 10GBASE-T**

10GBASE-T Deployment

- Additional deployment considerations
  - Single port installation vs. multiple port installation
  - Non-intrusive vs. intrusive (requires plant shutdown)
- Field measurement of alien crosstalk (AXT) required for 10GBaseT deployment Case 2

10GBASE-T Deployment Case 1

- **Installed base: channel length less than or equal to minimum objective for specified cable class (e.g., < 55m for Class E)**
- **Known absolute upper bound limit on AXT for installed base channels**
  - **Upper bound based on worst-case laboratory and/or field measurements**
- **Does NOT require AXT field qualification test**
  - **Assume AXT is at upper bound levels; no need to measure (AXT) in field**
  - **Only need to verify channel maximum insertion loss (length)**
  - **No new field qualification test equipment required**
    - **Can be qualified with existing test equipment**

10GBASE-T Deployment Case 2

- **Installed base: channel length greater than minimum objective for specified cable class (e.g., > 55m for Class E)**
- **Variable upper bound on AXT limit from specified AXT to IL Ratio (AXTIR) defined up to selected frequency**
  - **Allowable AXT limit increases as channel IL decreases**
  - **AXTIR defined to provide minimum Shannon capacity of 18 Gbps over required bandwidth**
- **Proposed AXTIR limit:**
  - **AXTIR = Cat6 ANEXT Model – Class E 55 m**
- **Requires AXT and IL field qualification test**
  - **Test equipment must have AXT measurement capability**

10GBASE-T Deployment Case 3

- New cabling components specially designed to support 10GBaseT
  - Channel performance depends solely on proper installation practice
- AXT and IL limits for new cabling components derived by application of specified AXTIR for 100 meter channel
  - Guarantees minimum Shannon capacity of 18 Gbps
  - Requires field qualification test for installation validation
  - Extended bandwidth basic testing required
  - AXT measurement capability may not be required

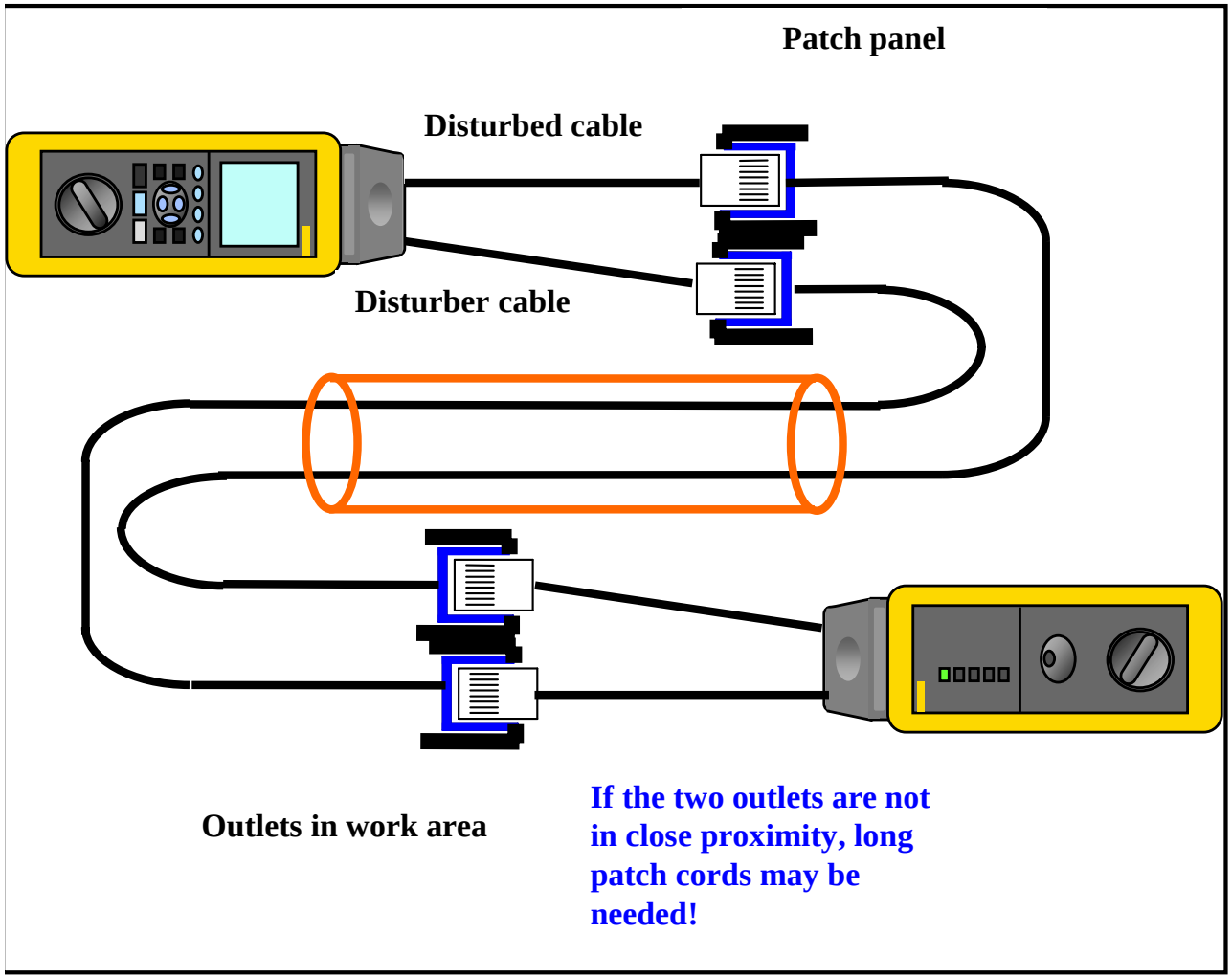
Alien Crosstalk – Field Tester Functionality

- **AXT field measurement functions**
  - **Measure power sum AXT coupling between channels**
  - **Store and process data from multiple channels**
    - **Calculate AXT limits from measured IL and AXTIR spec**
- **AXT measurement capability incrementally added to existing test equipment**
  - **Hardware add-on modules and/or firmware upgrades**
  - **Minimize cost to installers and test manufacturers**
  - **Leverage investment in current equipment**
  - **Reduce learning curve**
- **Additional requirement for non-intrusive deployment (i.e., not requiring network shut down)**
  - **Measure ambient AXT power in channels (listen mode)**

AXT Field Testing - available tools

- **Split cable adaptor for single cable channel**
  - **Use external hardware adaptor to split 4-pair channel into 1-pair + 3-pair on two different channels**
    - **Adaptor pairs must be reconfigurable for different cable types**
    - **Use existing test tools without internal hardware modification**
  - **Performs ANEXT/AFEXT measurement with existing test tool NEXT/FEXT measurement engine**
    - **Uses dominant pair property to obtain power sum estimate**
  - **Requires firmware modification to base platform**
  - **Difficult to perform non-intrusive deployment**

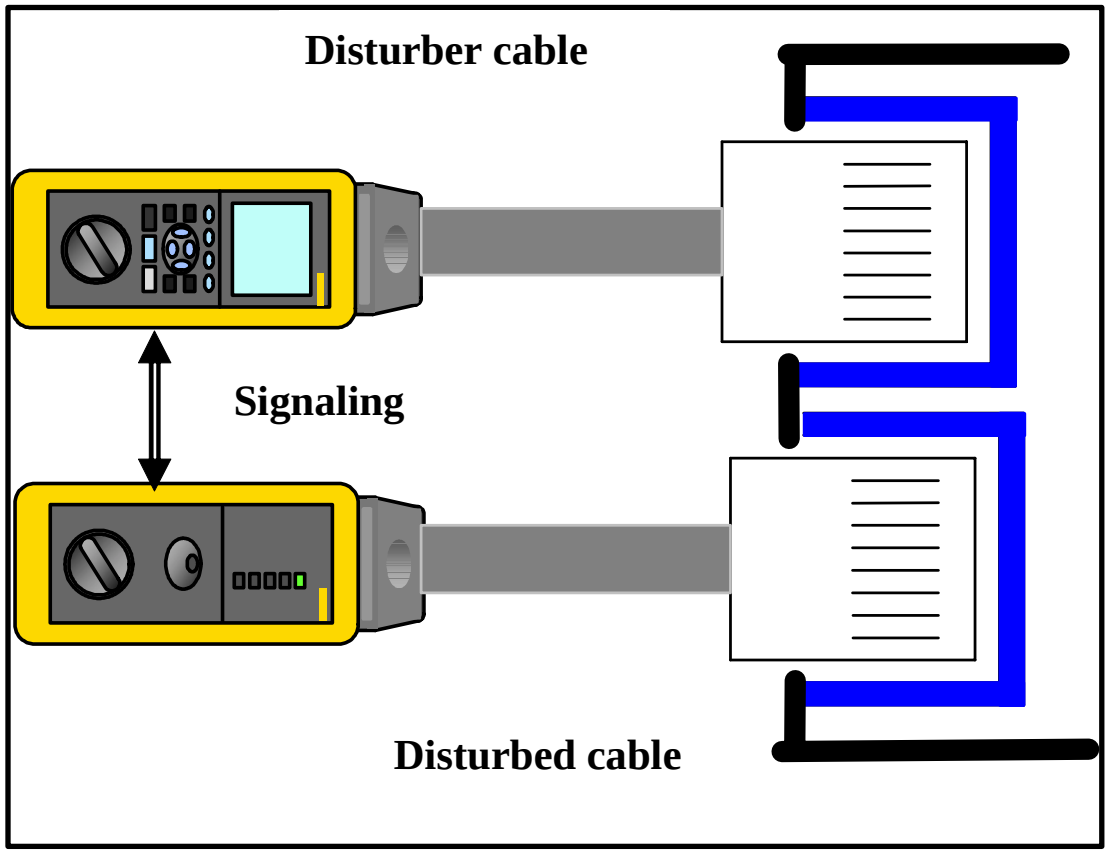
Alien NEXT field testing - Technical Feasibility



- Separation of connections at the remote-end may require long patch cords

Alien NEXT field testing – Technical Feasibility

- **Connect the main and remote unit to two different cables at the same end. Measure NEXT**

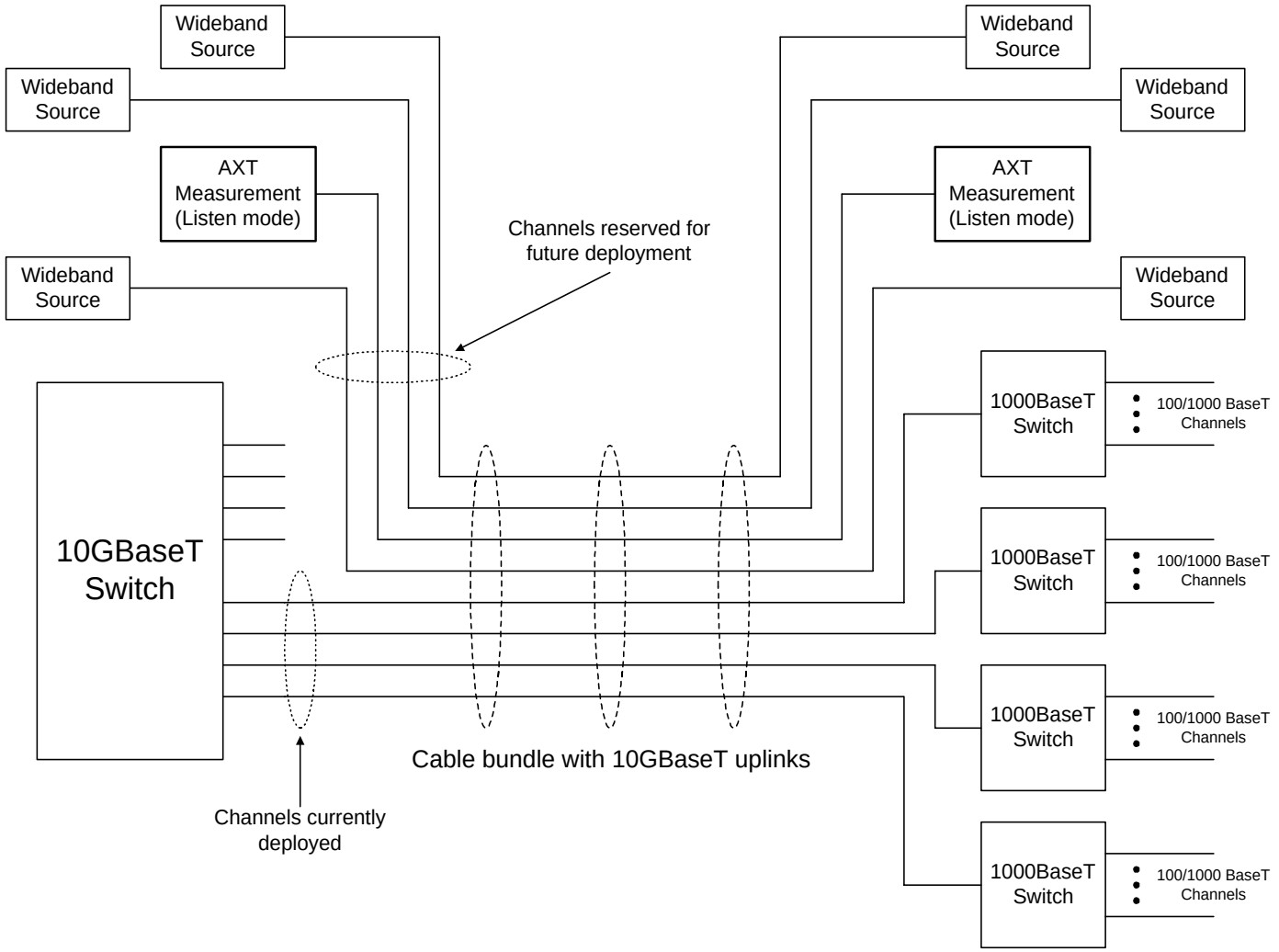


- **Requires connection for synchronization between units not generally available**
- **Limited to NEXT measurement**

AXT Field Testing – Noise power

- Noise power measurement
  - Derive AXT from direct measurement of background noise
    - New channels flooded with wideband signal emulating 10GBaseT
  - More difficult to incorporate into existing test equipment
    - May require hardware and firmware modifications
    - Hardware for AXT listen mode and wideband signal sources
  - Allows non-intrusive deployment (no network shutdown)

Noise Power Measurement



Noise Source Requirements/Examples

- **General requirements**
  - **Four uncorrelated sources per channel (one per pair)**
  - **Battery powered**
  - **Controllable from master test platform**
- **Analog Gaussian white noise generator**
  - **High signal PAR (closer to multi-level PAM)**
  - **High power consumption (implementation dependent)**
  - **Approximates PAM PSD; PSD level and lowpass bandwidth determined by line code selection**
- **2-level PAM from digital LFSR PN generator**
  - **Low signal PAR (lower PAR than multi-level PAM)**
  - **Lower power consumption (for four uncorrelated sources)**
  - **Directly produces PAM PSD**

AXT Field Testing - Measurement Reductions

- **AXT characterization for N channels requires 32N(N-1) pair-to-pair measurements for ANEXT *and possibly* AFEXT**
- **Useful properties for simplifying process**
  - **Reciprocity**
    - **Coupling (victim→ disturber) = coupling (disturber → victim)**
  - **Dominant disturber/victim pairs**
    - **Cable twist pitch and connector pins identify dominant disturber pairs**
    - **Estimate total power sum coupling from dominant pairs**
  - **Relationship between ANEXT and AFEXT**
    - **Eliminate need to measure AFEXT**
    - **ANEXT dominates AXT as channel length increases**
    - **Requires complex measurement algorithm to measure "asymmetric" configurations**
  - **Extrapolation of field test measurements ≥ 250 MHz**
    - **Enables the use of existing level 3 field test equipment for 10GBASE-T**