



End to End Links

A new Ethernet channel definition

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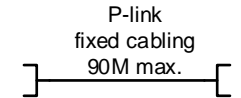
As Ethernet expands so does the methods of measuring the cabling system performance. Industrial customers tend to install cables and then terminate in-place. The quality of the field termination is dependent on many factors including wire end preparation. The cables and connectors used in the channel may meet or exceed the component specifications, but if improperly terminated the link or channel may not. The cabling industry channel definitions and tests do not include the plugs (or connections) at the two ends of the channel. This means that, if the ends of the cables are improperly prepared the channel will pass but the performance may be less than satisfactory. The international standards committees for industrial have been working to define a new definition called End to End Links (E2E Links). These links not only include the connections between the two ends but also include the end connections. This paper will discuss these new links and how they will help your customers and field service personnel diagnose cable problems and verify cabling in the field.

Elements of a Ethernet of an Connection

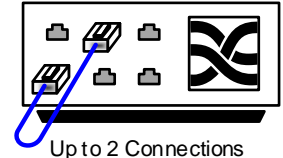
- Cords
 - Normally limited to 10 Meters maximum
 - Typically uses higher loss cables (flexible cables)
- Permanent Link
 - Typically ends with jacks, accounting for up to 2 connections with plugs
 - Up to 90 meters in length
- Cross Connect or Interconnect
 - Accounts for up to 2 connections
 - Uses two of the three cord definitions, Patch cord and Equipment cord
- Channel
 - Typically constructed of Equipment Cord + Cross Connect + Patch Cord + P-Link and Work area cord.
 - 100 Meters



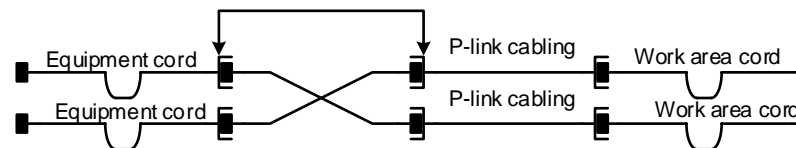
Cord 1 or 2 Plugs



Up to 2 Jacks



Up to 2 Connections

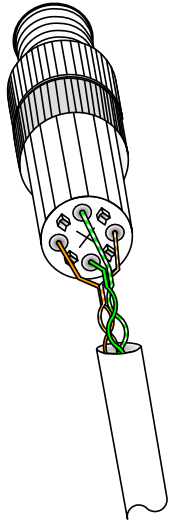


Industrial Channel

- Typically Constructed of Long Cords >10 meters
 - Generic standards limit these cords to 10 Meters total
 - Industrial Control connections frequently exceed the 10 Meter total with one cord
 - Industrial Control connections frequently are point to point without X-connects
- Industrial cords are constructed in place. Generally are field terminated
- Field constructed cords are common practice but has two risks
 - Long cords are out side the specifications and limits
 - Performance of field terminations may have hidden problems.

Hidden Problems

- Channel definitions do not include the two plugs at the end of the channel.
- Channels constructed from multiple segments of field terminated plugs are not tested during a Channel test.
 - Problems in the individual conductor routing can cause poor performance and is not tested during channel testing.
 - Breaking a channel apart and testing each segment (element) can be costly in time.
- End 2 End Links solve this problem by adding the two Plugs at the ends of the channel to the models and pass/fail limit lines.



Limit Lines

- The differences between the pass/fail limit lines for a channel and E2E Link are slightly different.
- The key is the test hardware is now required to report problems found in the two end plugs.
- End to End Links define limit lines for the standard parameters

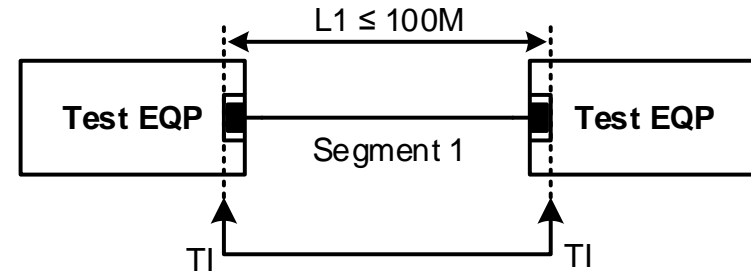
PARAMETERS			
Insertion Loss	Measured	PSNEXT	Derived
Return Loss	Measured	PSACRF	Derived
NEXT	Measured	TCL	Measured
FEXT	Measured	ELTCTL	Measured
ACR-F	Measured	CA	Lab only
Delay	Measured	DCR	Measured
Delay Skew	Measured/Derived	DCR Unbalance	Measured

IEEE APPLICATIONS AND BW NEEDS

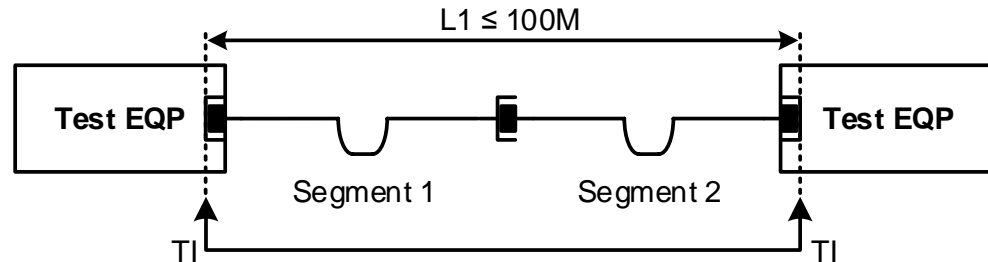
- Applications supported by cabling are categorized by their BW
 - US uses Category ratings Cat5, Cat5E, Cat6, Cat6_A.....
 - ISO/IEC uses Classes, Class D, Class E, Class E_A.....
 - E2E Links supports Cat5E/Class D and Cat 6/Class E channels
 - Limit lines are described in a set of equations as a function of frequency
 - Category 5E and Class D channels support up to 1G 4-pair
- ODVA Applications
 - Currently Chapter 8 supports 10/100 Mb/s Industrial
 - Served by a Category 5E or Class D channel.
 - ODVA recommends transmission performance CAT 6 or Class E or above for 1G industrial applications.
 - These class of channels provide better balance and tighter NEXT and RL

E2E Link Examples

1 Segment, 2 Connection

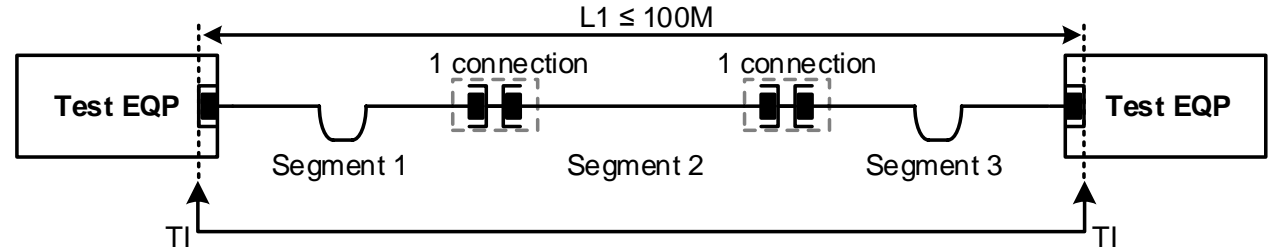


2 Segment, 3 Connection

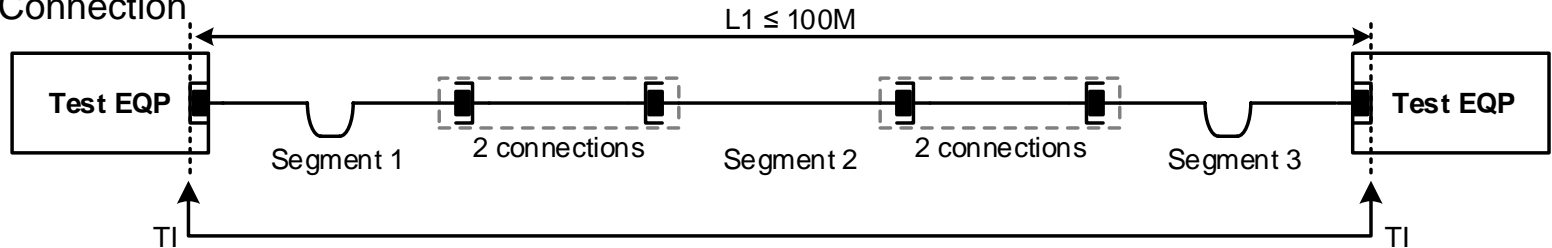


End 2 End Link Examples

3 Segment, 4 Connection

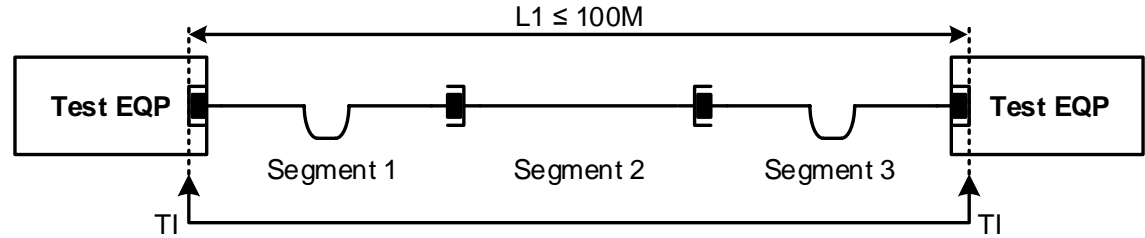


3 Segment, 6 Connection

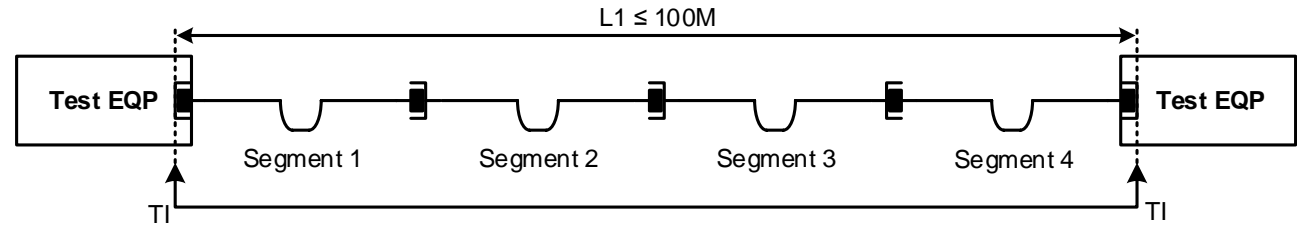


End 2 End Link Examples

3 Segment, 4 Connection

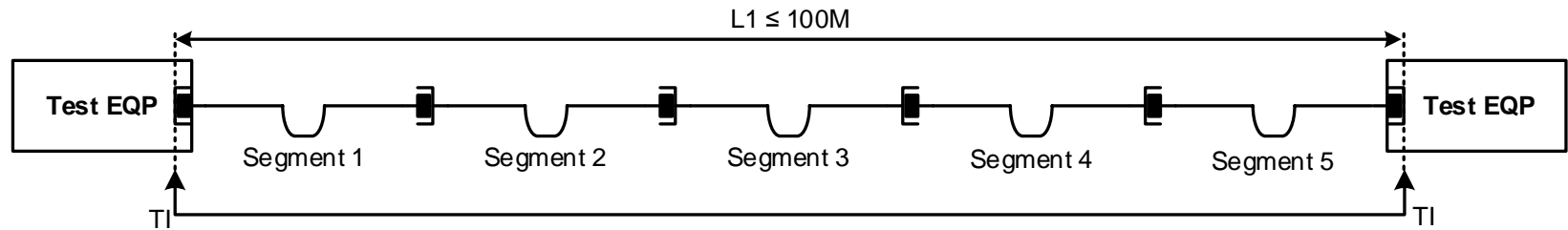


4 Segment, 5 Connection



End to End Link Examples

5 Segment, 6 Connection



E2E Link Modeling

- Channel mathematical models were modified to include the two end plugs
- Produced a set of equations that describe the Pass/Fail Limits for the defined applications (BW) and configurations.
- The following graphs and equations are for Class D, 6 connections
- Insertion Loss - Class D E2E Link 6 Connections

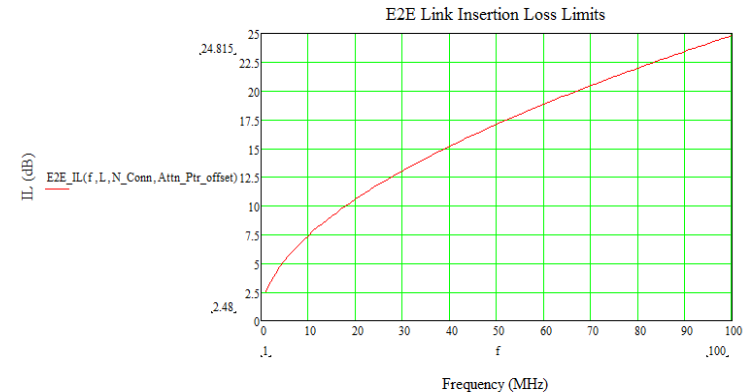
Class D E2E link insertion loss dB [n = number of connections 6]

$$\left(\frac{L}{100}\right) \cdot \left(1,9108 \cdot \sqrt{f} + 0,0222 \cdot f + \frac{0,2}{\sqrt{f}}\right) + (n \cdot 0,04 \cdot \sqrt{f})$$

NOTE 1 To align with ISO/IEC 11801-1 permanent link requirements, the maximum length for 1- and 2-segment E2E links is 90 m

NOTE 2 Calculated values less than 4 dB revert to 4 dB

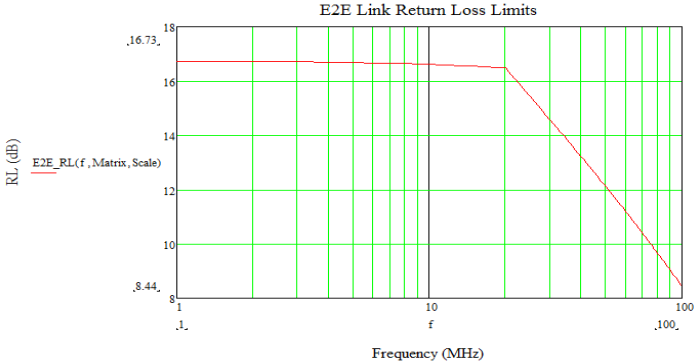
For connections numbers > 2 (L/100) is replaced with 1.05



E2E Link Limits

- Return Loss - Class D E2E Link 6 Connections

Class D E2E link return loss 6 Connections	
	dB
$1 \leq f \leq 20$	$17 - \left(0,27 + \left(1,29 \cdot \left(\frac{f-1}{99} \right) \right) \right)$
$20 < f \leq 100$	$30 - 10 \cdot \log(f) - \left(0,27 + \left(1,29 \cdot \left(\frac{f-1}{99} \right) \right) \right)$



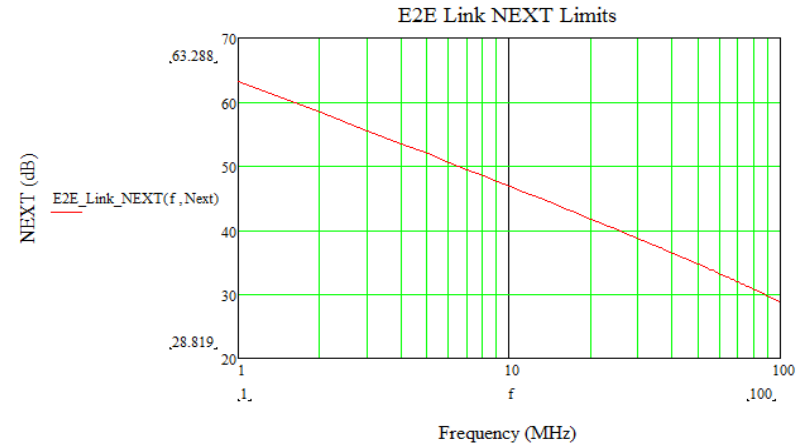
E2E Link Limits

- NEXT - Class D, E2E Link 6 Connections

Class D E2E link NEXT 6 Connections
dB

$$\left(-20 \cdot \log \left(10^{\frac{65,3 - 15 \cdot \log(f)}{-20}} + 2 \cdot 10^{\frac{83 - 20 \cdot \log(f)}{-20}} \right) \right) - \left(1,26 \cdot \left(\frac{f - 1}{99} \right) \right)$$

NOTE Calculated values greater than 65 dB revert to 65 dB.

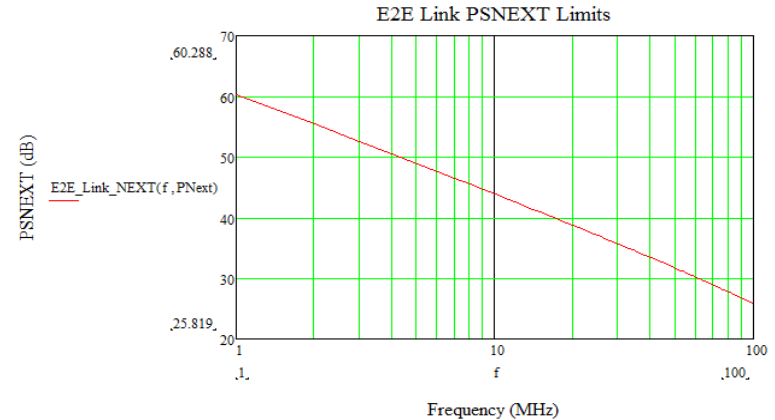


PSNEXT - Class D, E2E Link 6 Connections

Class D E2E link PSNEXT 6 Connections
dB

$$\left(-20 \cdot \log \left(10^{\frac{62.3 - 15 \cdot \log(f)}{-20}} + 2 \cdot 10^{\frac{80 - 20 \cdot \log(f)}{-20}} \right) \right) - \left(1.26 \cdot \left(\frac{f - 1}{99} \right) \right)$$

In cases where measured insertion loss is less than 4 dB, the pass/fail limits for PSNEXT should not apply.



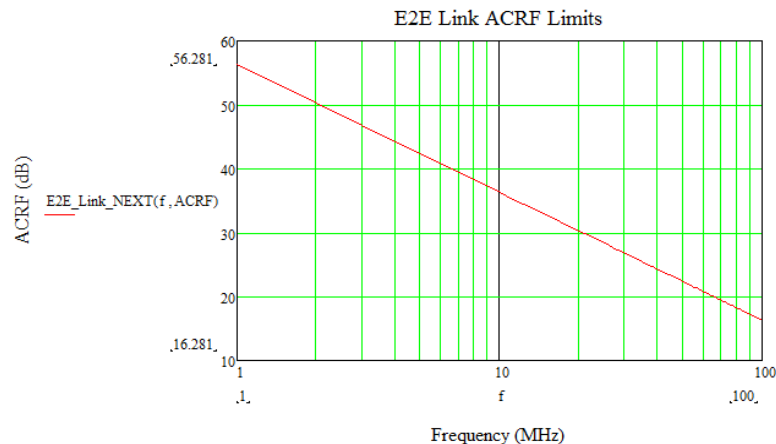
E2E Link Limits

- ACR-F - Class D, E2E Link 6 Connections

Class D E2E Link ACR-F 6 Connections
dB

$$\left(-20 \cdot \log \left(10^{\frac{63,8 - 20 \cdot \log(f)}{-20}} + 4 \cdot 10^{\frac{75,1 - 20 \cdot \log(f)}{-20}} \right) \right) - 1,12$$

ACR-F at frequencies that correspond to measured FEXT values of greater than 70,0 dB are for information only.

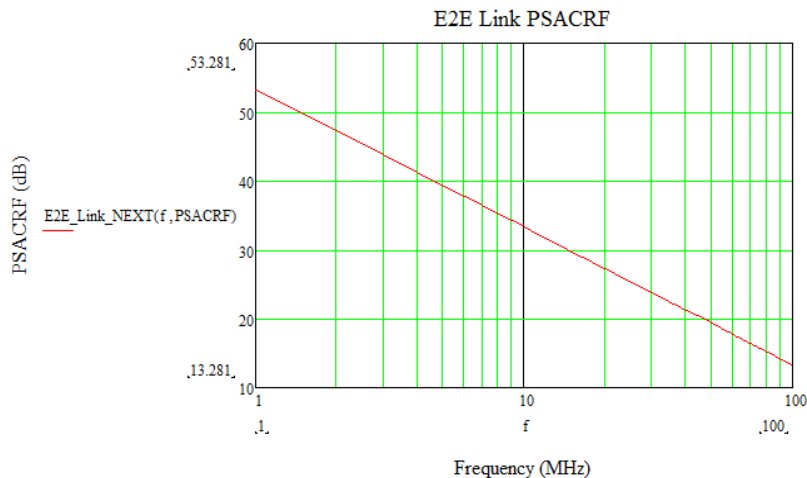


E2E Link Limits

- PSACR-F - Class D, E2E Link 6 Connections

Class D E2E link PSACR-F
dB

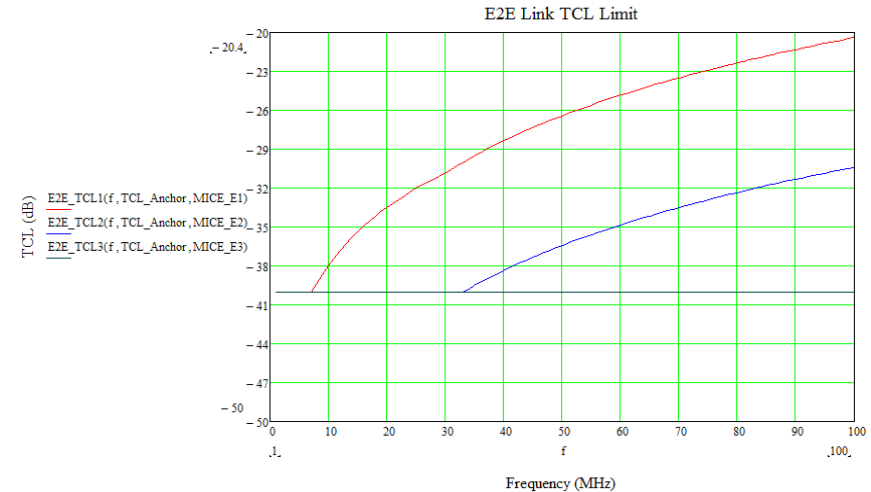
$$\left(-20 \cdot \log \left(10^{\frac{60,8 - 20 \cdot \log(f)}{-20}} + 4 \cdot 10^{\frac{72,1 - 20 \cdot \log(f)}{-20}} \right) \right) - 1,12$$



E2E Link Limits

- TCL- E2E Link 6 Connections for un-screened (UTP)
 - Class D and Class E
 - E1, E2 and E3

Class	Frequency MHz	E2E link TCL dB ^a		
		E1	E2	E3
Class D & E	$1 \leq f \leq 30$	$53-15\log(f)$	$63-15\log(f)$	$73-15\log(f)$
	$30 \leq f \leq 100$	$60,4-20\log(f)$	$70,4-20\log(f)$	$80,4-20\log(f)$
^a TCL at frequencies that correspond to calculated values of greater than 40 dB revert to 40 dB.				

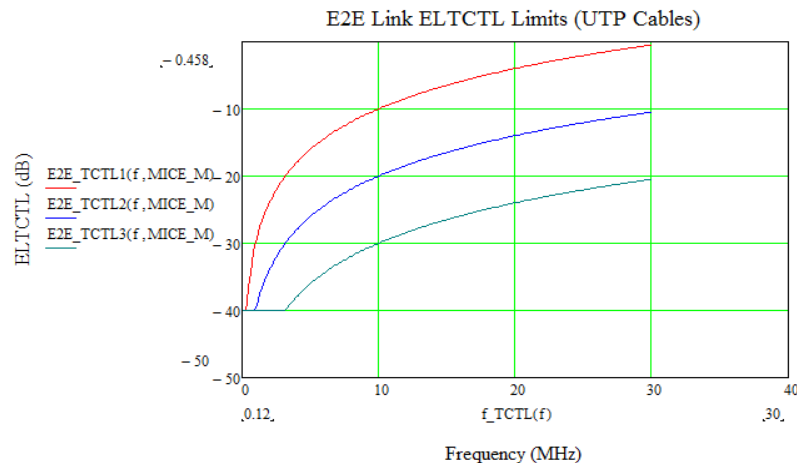


E2E Link Limits

- ELTCTL - E2E Link 6 Connections for un-screened (UTP)
 - Class D and Class E
 - E1, E2 and E3

Class	Frequency MHz	E2E link ELTCTL dB ^a		
		E1	E2	E3
Class D & E	$1 \leq f \leq 30$	$30-20\log(f)$	$40-20\log(f)$	$50-20\log(f)$

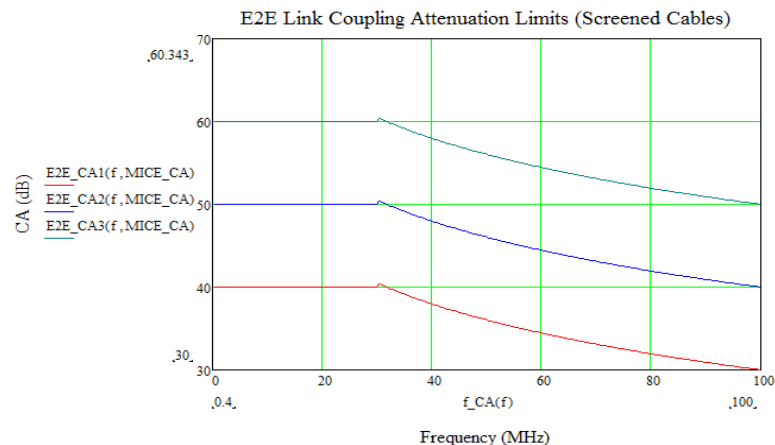
^a ELTCTL at frequencies that correspond to calculated values of greater than 40 dB revert to 40 dB.



E2E Link Limits

- Coupling Attenuation - E2E Link 6 Connections for un-screened (UTP)
 - Class D and Class E
 - E1, E2 and E3

Class	Frequency MHz	E2E link CA MICE E1, E2 and E3 dB		
		E1	E2	E3
Class D & E	$1 \leq f \leq 30$	40	50	60
	$1 \leq f \leq 100$	$80-20\log(f)$	$90-20\log(f)$	$90-20\log(f)$



Testing of End two End Links

- The new channels defined by ISO/IEC, supported by ANSI/TIA will greatly benefit the end customer, field installer and service personnel.
- For short cords (<10 meters) current testers can be used
- For P-Links current testers can be used
- For long cords and full channels (Links) a capable field tester is needed.
- The field test manufactures have released testers that have the capability of performing E2E link testing to the limits.
- All constructed in-place channels should be tested to this new definition.

Conclusion

- The new channel (End to End Link) definitions will, in most cases be effective.
- Depending on the accuracy and precision of the test equipment some bad links may not be discovered.
- Links designed to meet Class D and E, tested to MICE E3 using RJ45 will fail under these test limits. RJ 45 do not have sufficient balance to meet this spec.
- The degraded performance has gone uncovered and only found by replacement. These new limit and link definitions now provide a means to find these problems through testing.



**THANK YOU
Questions?**

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