10G Extended frequency primary Parameters for Channel Link Segment performance.

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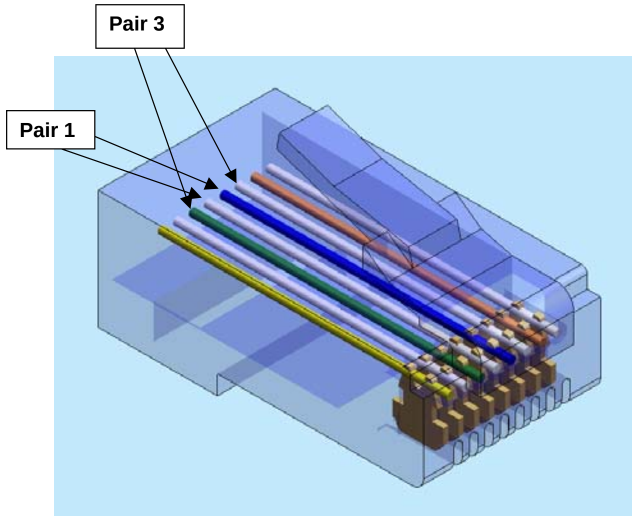


Figure 1, Modular Plug

As is well known, connector response above 250 MHz for NEXT for the 36-45 pair combination follows an increased slope with respect to frequency than at lower frequencies. This phenomenon is caused by the vector summation of the crosstalk components within the plug and jack that become increasingly out of phase as the frequency increases. The Plug vector crosstalk magnitude for the Pair 1 to Pair 3 configuration shown is –37 dB. The Jack must necessarily incorporate a crosstalk vector of –37 dB with opposite phase polarity. (The resultand must be less than –54 dB at 100 MHz). There is an inherent delay between the plug crosstalk vector and the Jack crosstalk vector which causes increasing phase disparity as the frequency increases. Thus, the vectors do not cancel as well at higher frequencies. This response is confirmed by modeling and by test results of connectors. Figure 3 shows results for limit plugs for NEXT for a Cat6 compliant connector and extended limit lines with slope of 60 dB (!) per decade above 250 MHz.

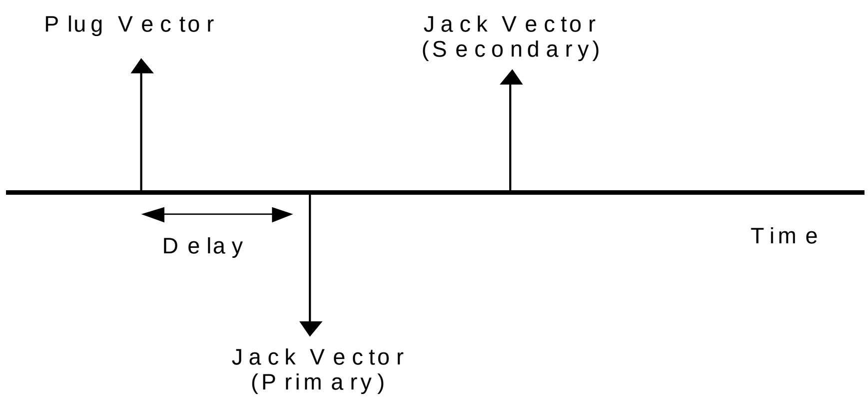
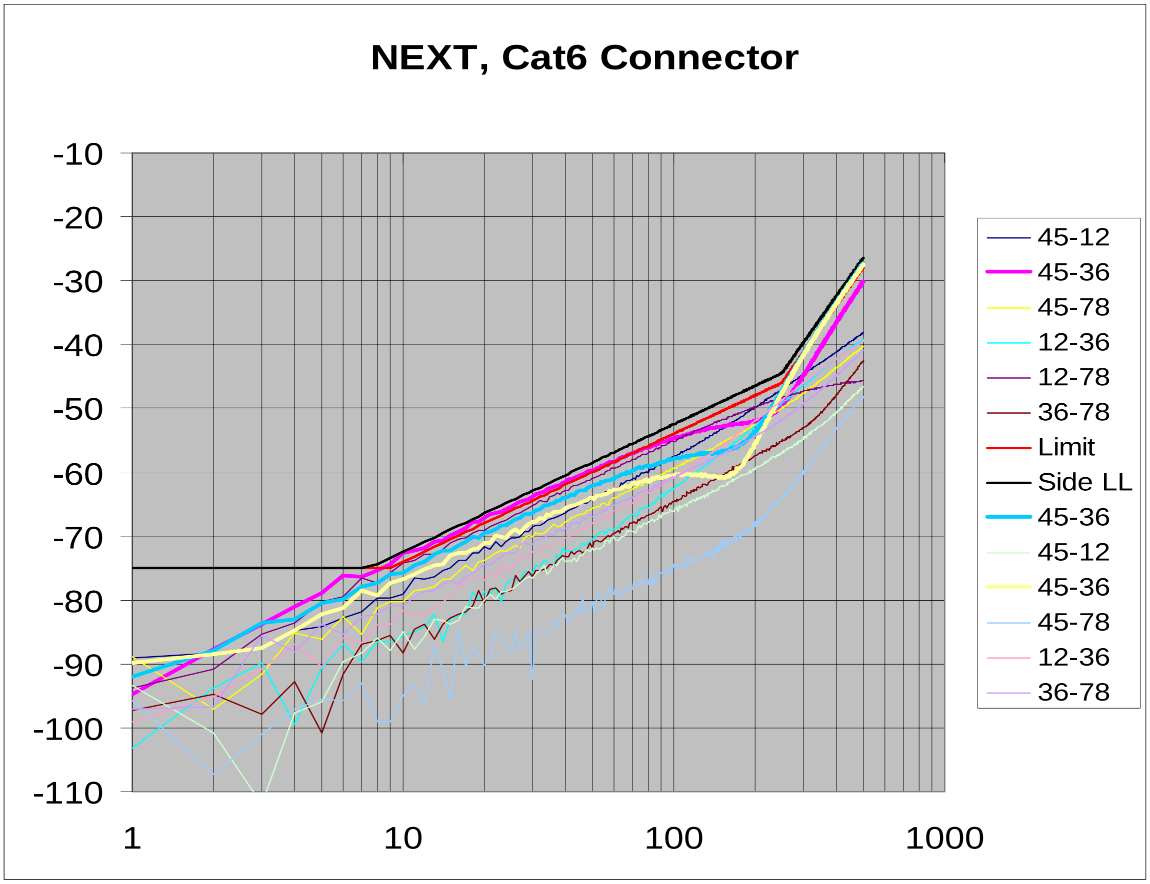


Figure 2, Plug and Jack Vector Diagram



Near end crosstalk of Cat6 compliant connector with 60 dB slope above 250 MHz

While this phenomenon is primarily associated with the 36-45 (1-3) pair combination due to the intimate crosstalk coupling geometry inherent in the modular plug, it is also seen to some extent on other pair combinations, such as 12-36, and 36-78 pin pair combinations. The crosstalk couplings will tend to have a greater slope above about 150 MHz than below that value. The Cat5e connectors exhibit similar characteristics, but typically without the pole in the response. This response is typical of Cat6 connectors, as is shown by results for 11 different connectors currently marketed.

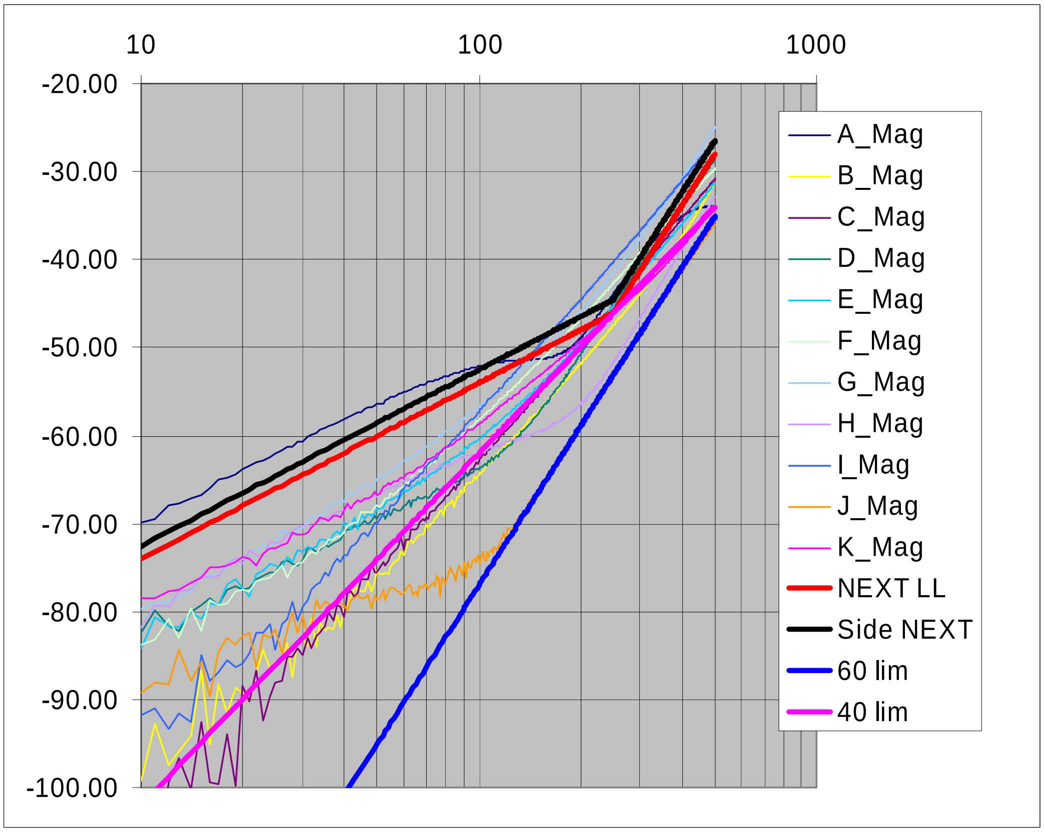


Figure 4, Response of 11 connectors with average test plug

The figure above shows the response of 11 Cat6 connectors for the 36-45 pair combination when tested with a single "average" plug. The response of each connector was compared to a slope line above 100 MHz. The minimum slope was found to be 40 dB per decade, the average, 49.91, and the Maximum 60 dB per decade. The min and max slopes are shown on the chart with their respective data sets. These connectors were selected from currently available product which represent what is thought to be current design techniques.

Mathematical models of the connector response can be constructed based upon known principles. Using reasonable estimates for the primary variables, the response can be adjusted between 60 dB per decade slope estimate above 250 MHz and a 40 dB slope above that frequency by decreasing the primary delay. Unfortunately, the primary delay is inherent to a connector design, and there are some fundamental limitations because of mechanical considerations. Connector designers are continually attempting to improve the performance of their products, but the cost is very high to replace hard tooling for stampings, forming tools, plastic molds and automated assembly equipment. In addition, the modeling is imperfect, so there can be considerable disparity from design to implementation. The only variable changed between the following two graphs is the delay between the plug and connector crosstalk vectors.

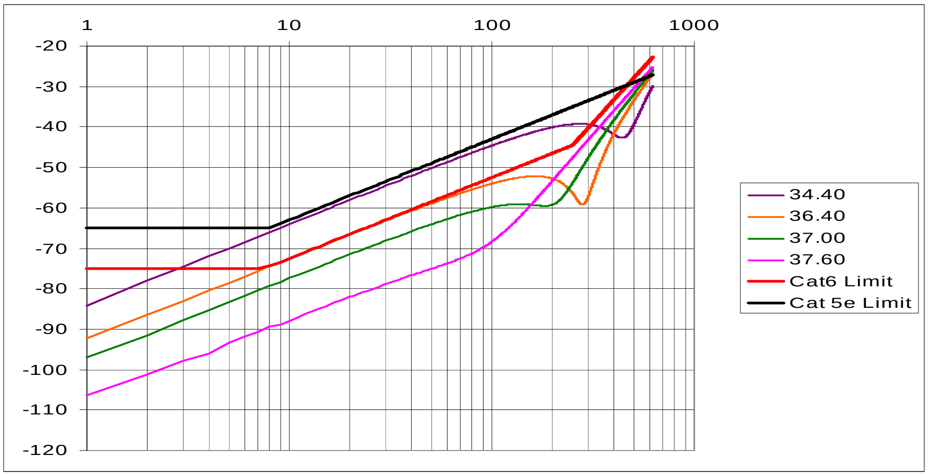


Figure 5, Cat 6 Connector vector model minimally compliant with a 55 dB/decade slope above 250 MHz

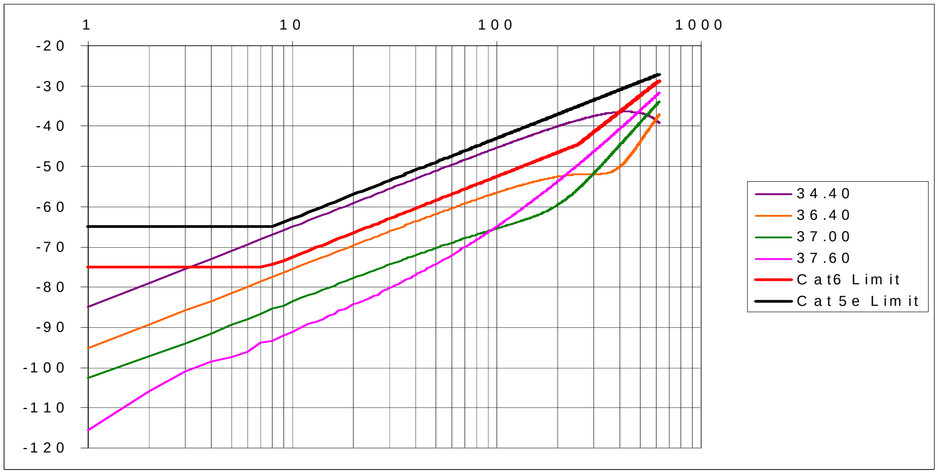


Figure 6, Cat 6 Connector vector model with 40 dB/decade slope above 250 MHz

It is therefore proposed that the connector contribution for pair to pair NEXT for the pair combination pins 4,5 and 3,6 be approximated by the equations:

$$NEXT_{conn} \geq -54 + 20\log(f/100) \text{ dB} \qquad 21$$

where 1 MHz <= f <= 250 MHz

And

$$NEXT_{conn} \geq -46.04 + 60\log(f/250) \text{ dB} \qquad 23$$

where 250 MHz < f <= 625 MHz

Channel measurements and Channel Limits

A channel NEXT model provided by Henri Koeman to the TIA modeling task group is used for predicting the Channel NEXT response from component parameters. This model uses the more complex (and accurate) method of summation of component NEXT to generate Channel NEXT that is used for component patch cord limit calculations in TIA 568-B.2. The calculation takes into account the NEXT and insertion loss of cable and connector components appropriately scaled for length. It is an envelope model, not incorporating phase response.

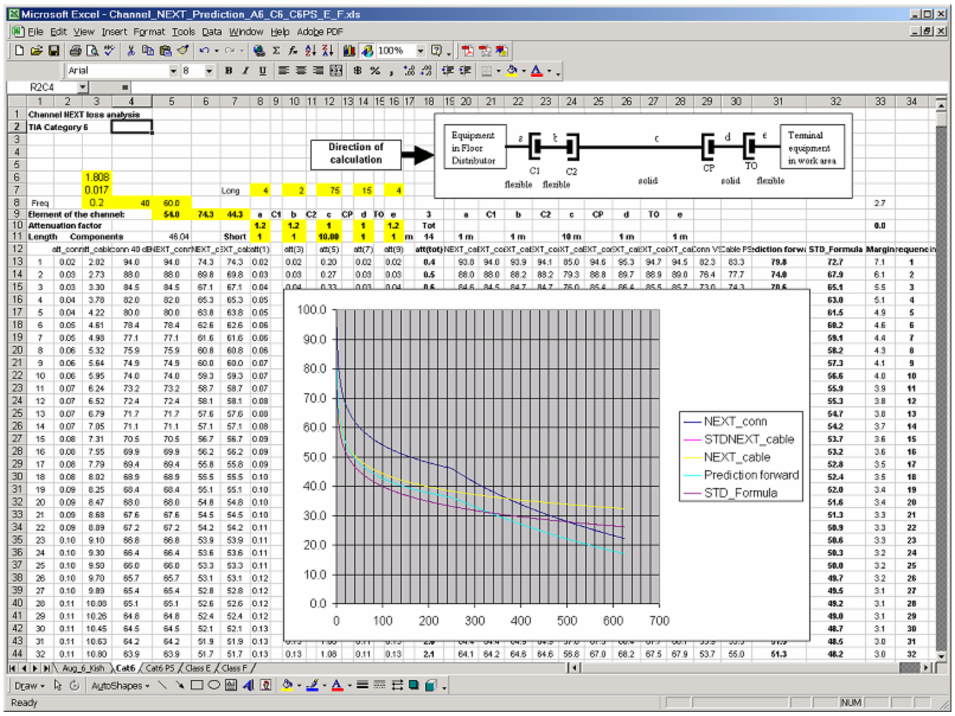
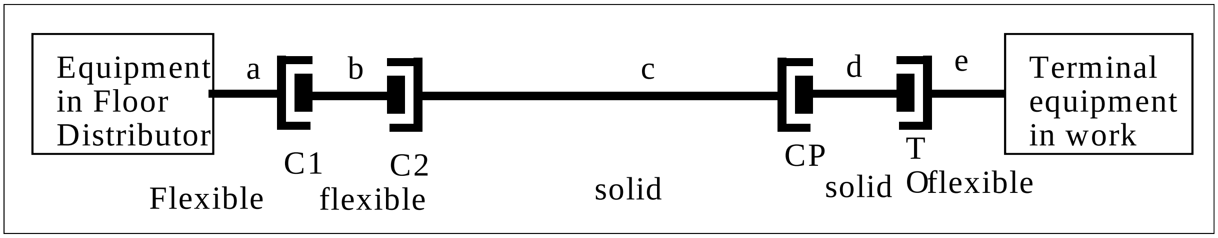


Figure Channel NEXT model

If we look at the channel model for short and long cable selection, the model reveals that for the shortest cable, the prediction is the worst case for high frequencies, and that for long cable, the prediction is the worst case for low frequencies. we will evaluate the response for two channel configurations, one with the shortest cables (1,1,10,1,1 meters) and for the longest cables (4,2,75,15,4 meters) The topology is as follows:

Short channel topology

	a	C1	b	C2	c	CP	d	TO	e
IL factor	**1.0**		**1.2**		**1**		**1.2**		**1.2**
Length, m	**1**		**1**		**10**		**1**		**1**

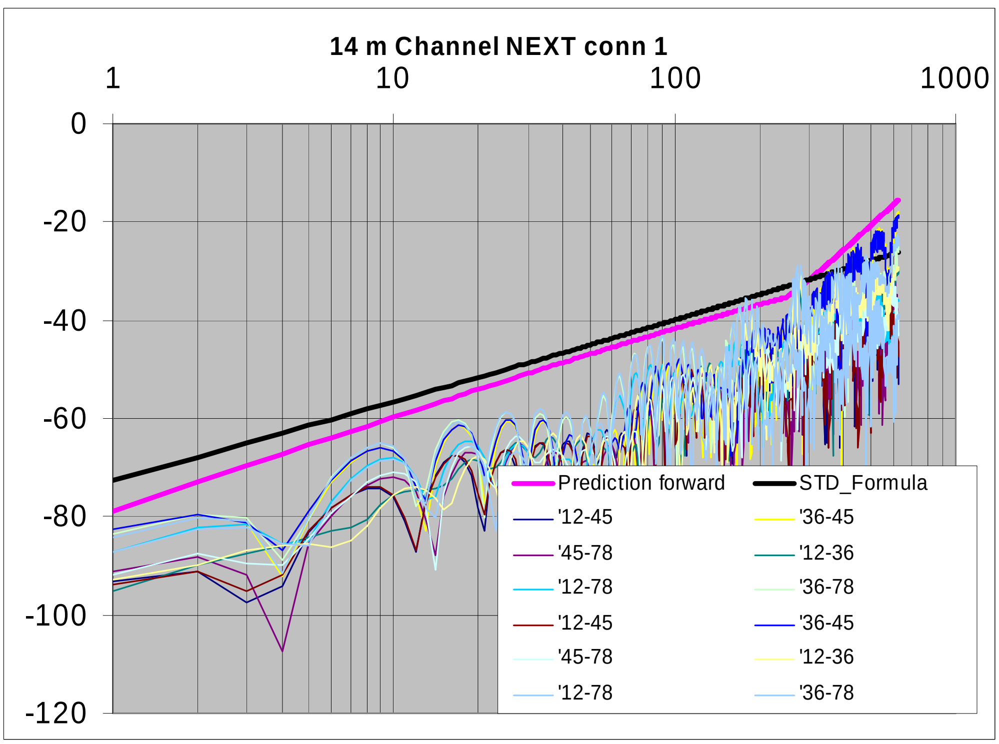


Long channel topology

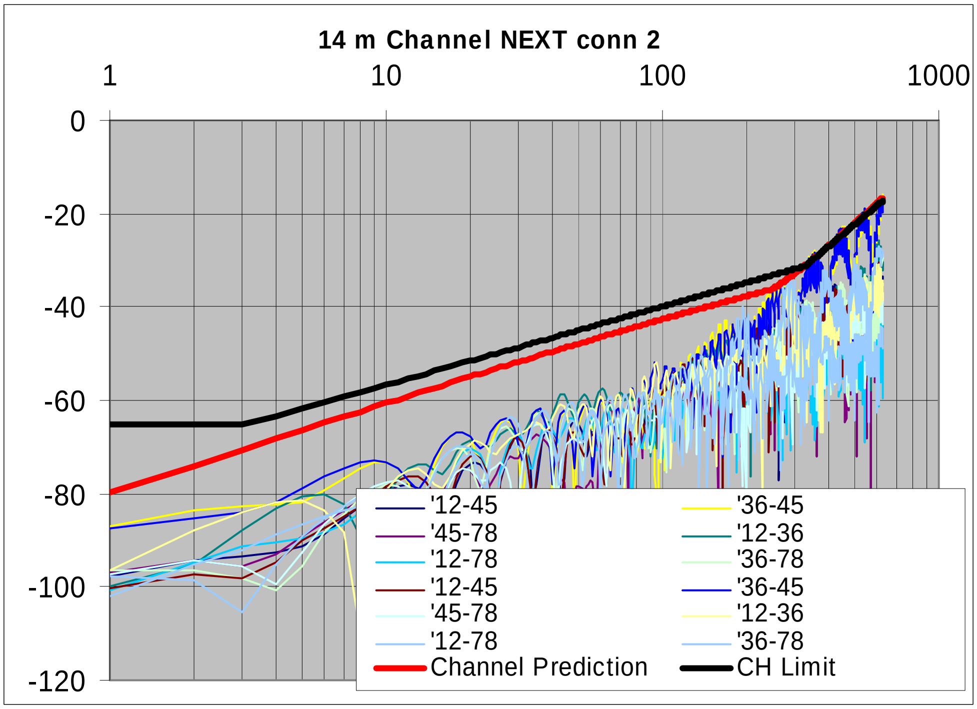
	a	C1	b	C2	c	CP	d	TO	e
IL factor	1.2		1.2		1		1.0		1.2
Length, m	4		2		75		15		4

Channel NEXT

The measurements for the short channel show that the channel NEXT above the break frequency behave according to the model using connector response as stated above.



10m Channel NEXT with prediction using WC RL connector



14m Channel NEXT with prediction using improved RL connector

Proposed limit for Channel Near-End Crosstalk:

The limit proposal for Link segment NEXT is based upon the short channel prediction at high frequencies combined with the standard Cat6 channel requirement at all frequencies below the break point. The long channel prediction is shown as well compared to the proposed limit.

For all frequencies from 1 MHz to 330 MHz, link segment (channel) pair-to-pair NEXT loss shall meet the values determined using equation (20).

$$NEXT_{channel} \le 20\log(10^{\frac{NEXT_{cable}}{20}} + 2\cdot 10^{\frac{NEXT_{conn}}{20}})\ dB \qquad 20$$

Where

$$NEXT_{conn} \le -54 + 20\log(f/100)\ dB \qquad 21$$

For all frequencies from 330 MHz to 625 MHz, category 6 channel pair-to-pair NEXT loss shall meet the values determined using equation (23).

$$NEXT_{channel} \le -31 + 50\log(f/330)\ dB \qquad 22$$

Where

$$NEXT_{conn} \le -46.04 + 60\log(f/250) \qquad 23$$

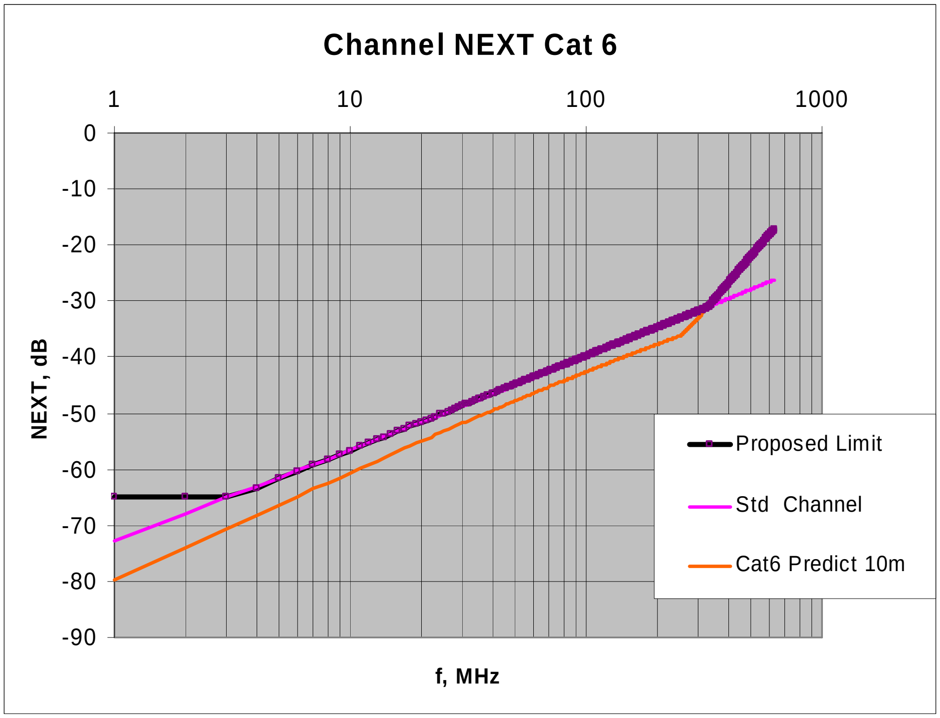


Figure 4, Channel NEXT proposed limit compared to 14 meter prediction

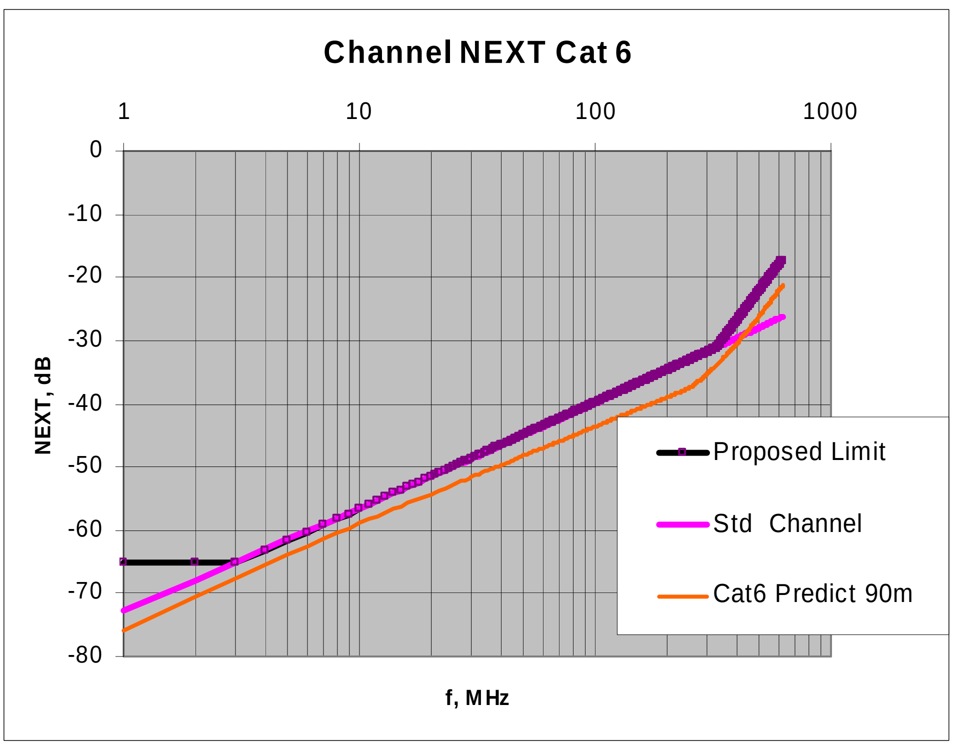
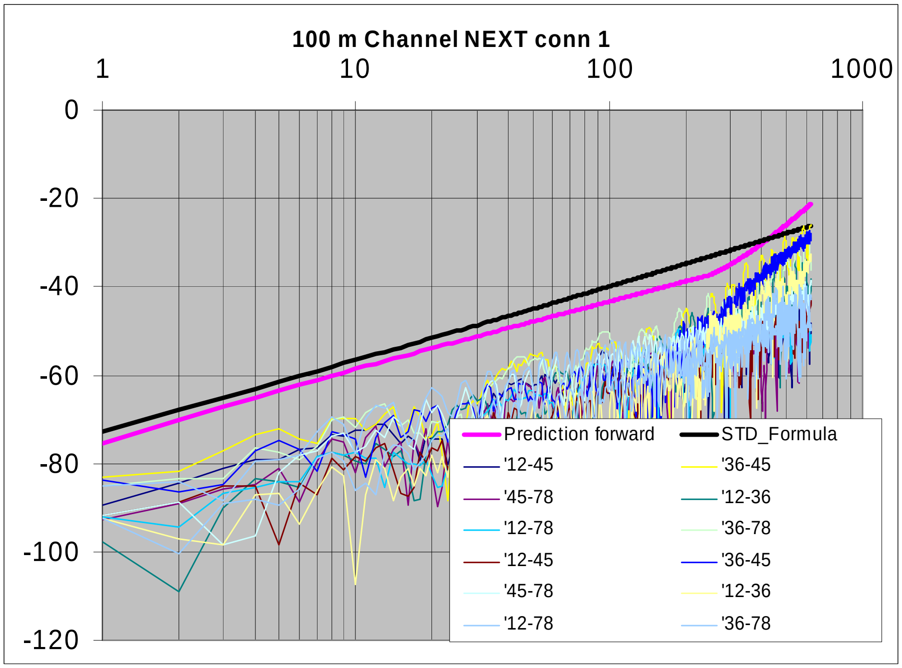
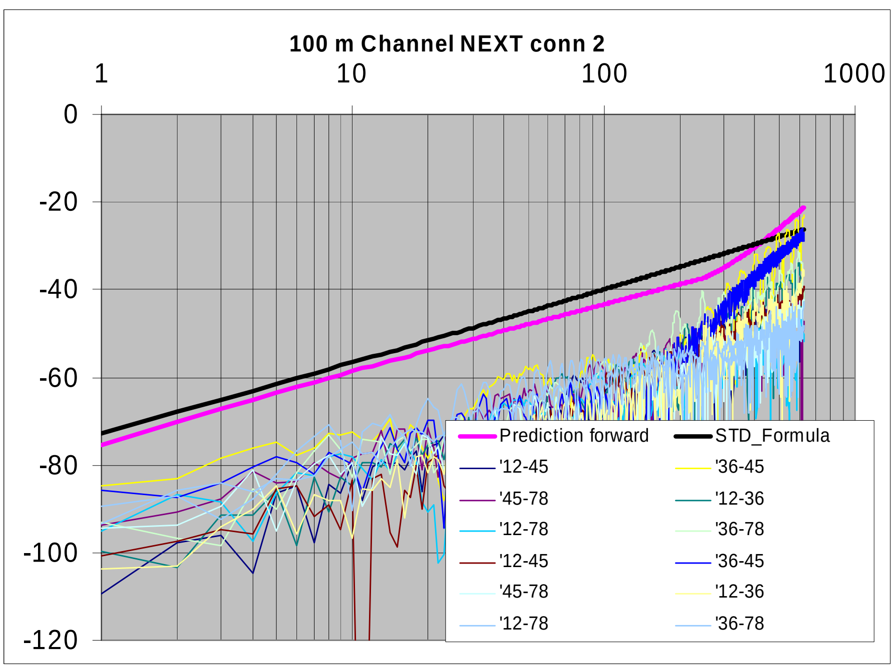


Figure 5, Channel NEXT proposed limit compared to 100 meter prediction

100 meter channel NEXT response



100 m Channel NEXT, conn 1



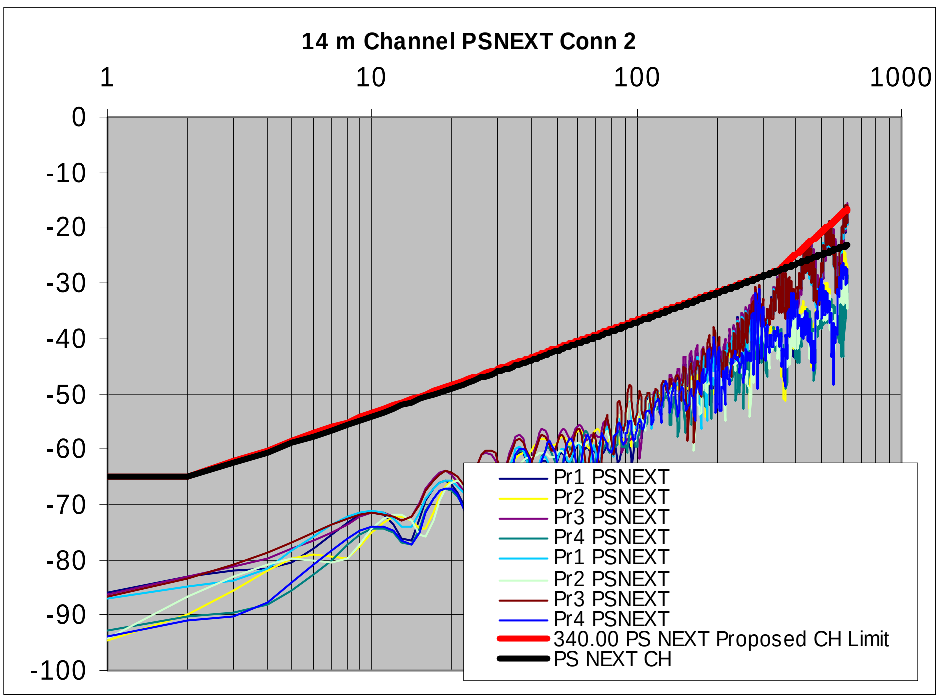
100 m channel NEXT, conn 2

Channel Power Sum NEXT

The channel PSNEXT can be predicted accurately by modeling the connecotr NEXT at –50 dB at 100 MHz (per component PSNEXT assumptions in TIA 568-B.2-1) and approximating the PSNEXT slope above 250 MHz at 50 dB per decade. This results from the worst case PSNEXT being the sum of pairs 2-3, 1-3, and 3-4 crosstalks the 2-3 and 3-4 crosstalks following a 40 dB per decade slope above 250 MHz.

Proposed limit for Power Sum Channel Near-End Crosstalk:

The limit proposal for Link segment PSNEXT is based upon the short channel prediction at high frequencies combined with the standard Cat6 channel requirement at all frequencies below the break point.



14 m Channel PSNEXT

For all frequencies from 1 MHz to 340 MHz, link segment (channel) pair-to-pair NEXT loss shall meet the values determined using equation (24).

$$NEXT_{channel} \leq 20\log(10^{\frac{PSNEXT_{cable}}{20}} + 2 \cdot 10^{\frac{PSNEXT_{conn}}{20}})\ dB \qquad 24$$

Where

$$NEXT_{conn} \leq -50 + 20\log(f/100)\,dB \qquad 25$$

For all frequencies from 330 MHz to 625 MHz, category 6 channel pair-to-pair NEXT loss shall meet the values determined using equation (23).

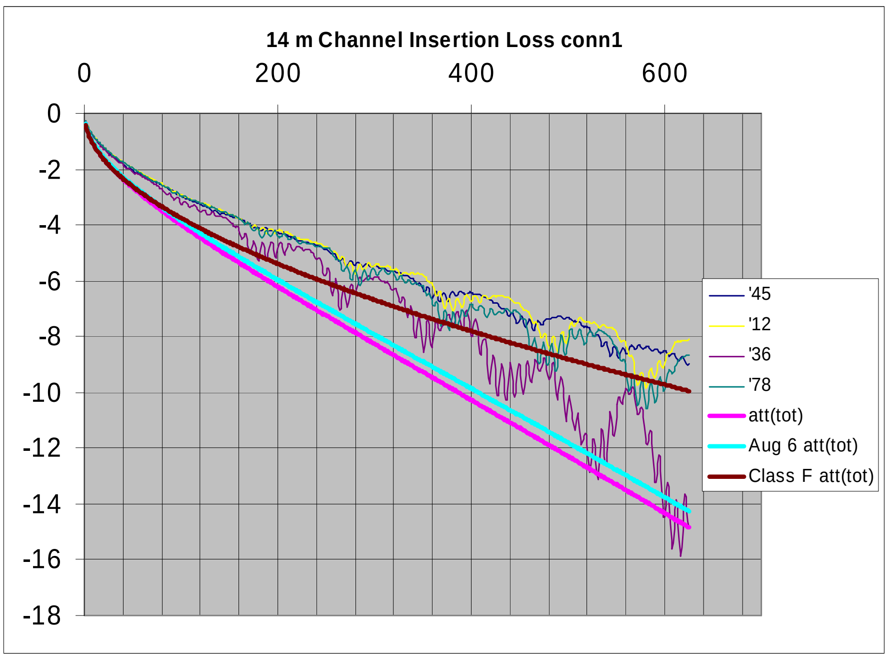
$$NEXT_{channel} \leq -28 + 42\log(f/330)\ dB \quad 26$$

Where

$$NEXT_{conn} \leq -42.04 + 50\log(f/250) \quad 27$$

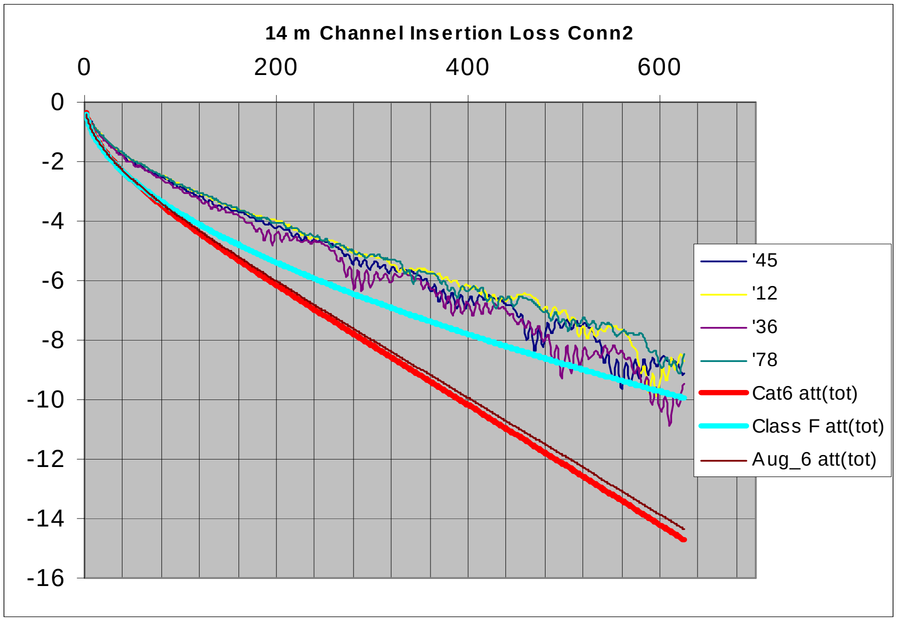
Other parameters, Return Loss, ELFEXT, Insertion Loss

There does not appear to be the need for alteration of the existing limits extrapolated to 625 MHz for these other paramaters.



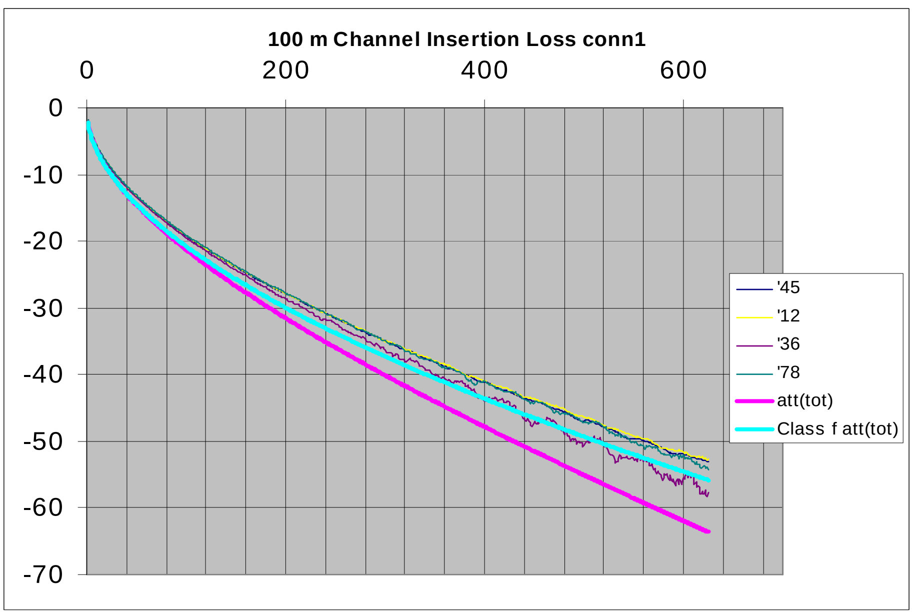
Channel Insertion loss prediction for 14m short channel with Worst case RL connectors

The channel insertion loss was based upon current Cat6 cable factors Note that the insertion loss crosses the predicted value at a little over 600 MHz. The channel insertion loss is not correctly scaled with Class F insertion loss.

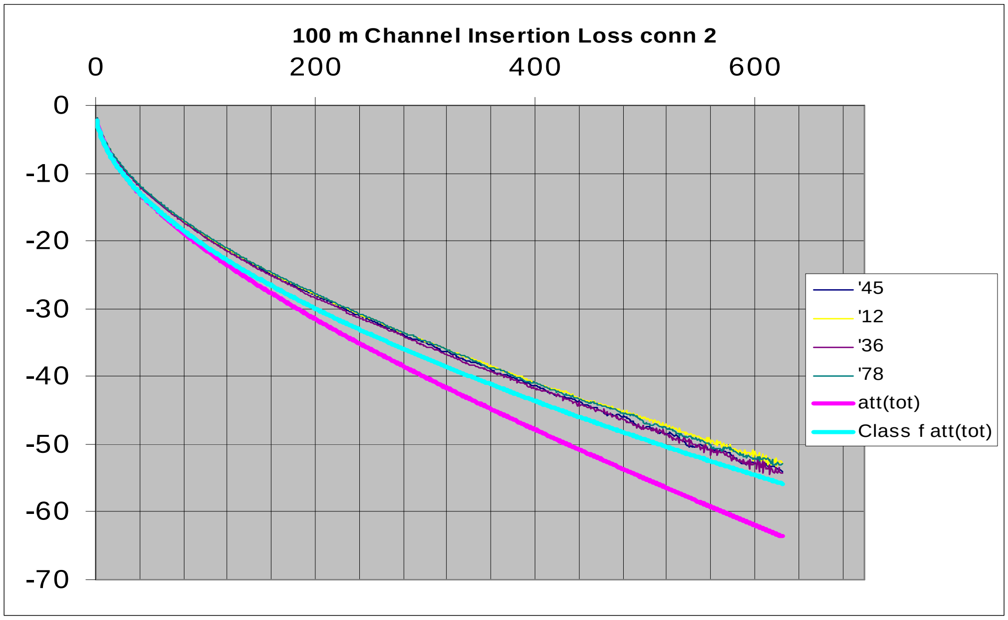


Channel Insertion loss prediction for 14m short channel with 30 dB RL connectors

The results for connector 2 which has improved (30 dB vs 24 dB) return loss shows improved insertion loss. It still, however is not correctly predicted by the Class F limit. The above two figures illustrate the channel insertion loss deviation (ILD) that is due to re-reflection of the signal between connectors. The result is channel insertion loss that is greater than what is predicted simply by adding cable and connector insertion loss. Improving connector return loss requirements improves channel insertion loss.



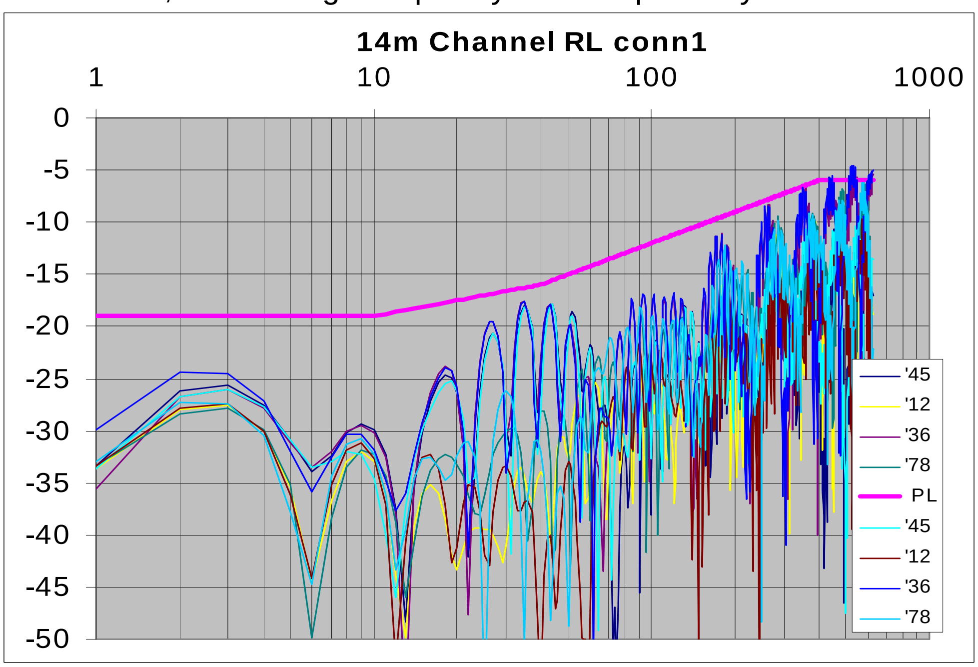
100m Channel insertion loss for Conn1



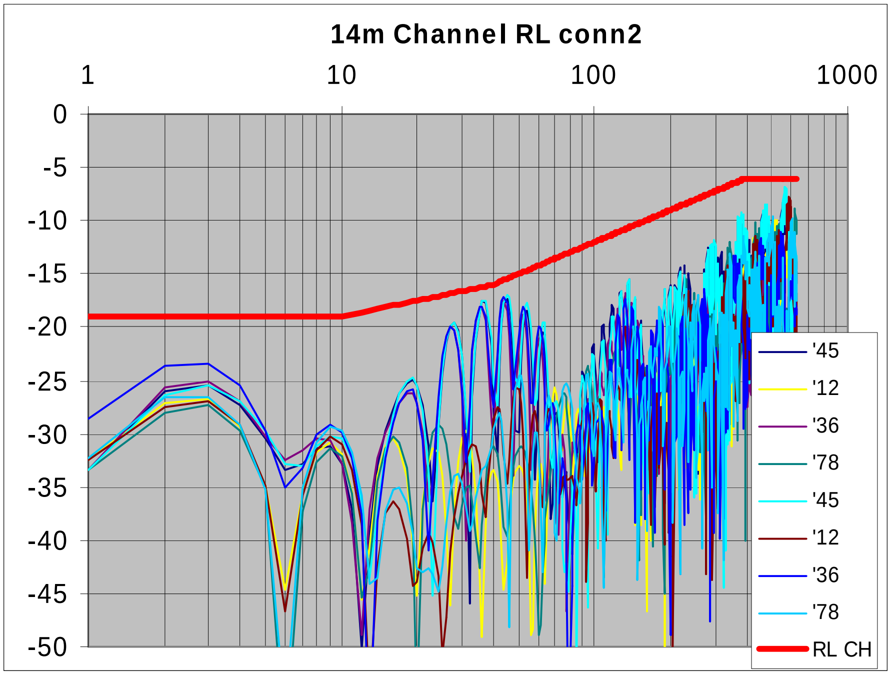
100m Channel insertion loss for Conn2

Return loss:

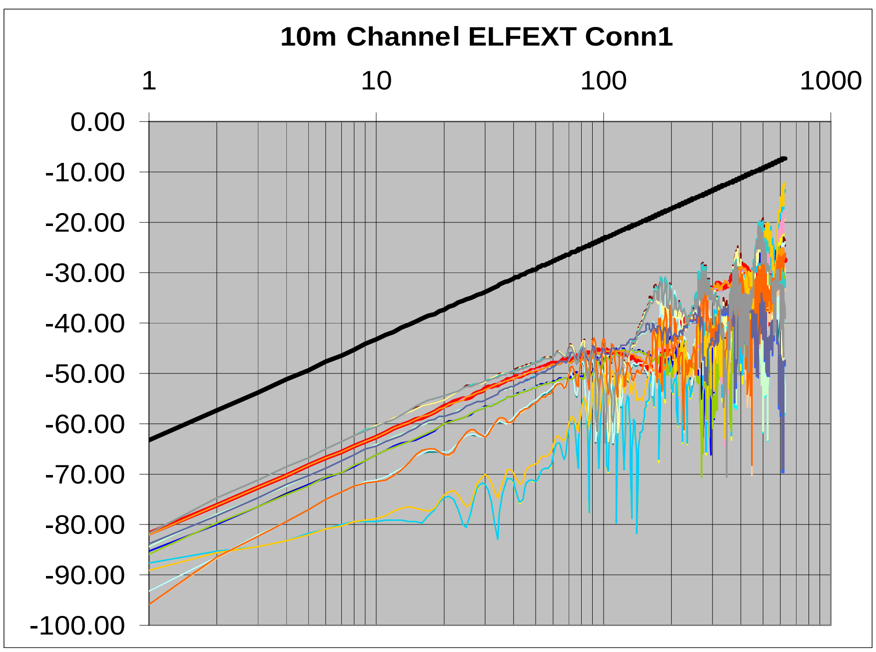
The return loss of the channel is also typically the worst case (at certain frequencies) for the short channel configuration. In this case, there is predicted a bump in the 20 to 60 MHz region and the response approaches the current limit line as the frequency increases. The mid frequency bump is due to patch cord Return loss effect, and the high frequency effect is primarily due to connector RL.



14m Channel Return Loss conn1 with WC RL compared to extended Cat6 limit



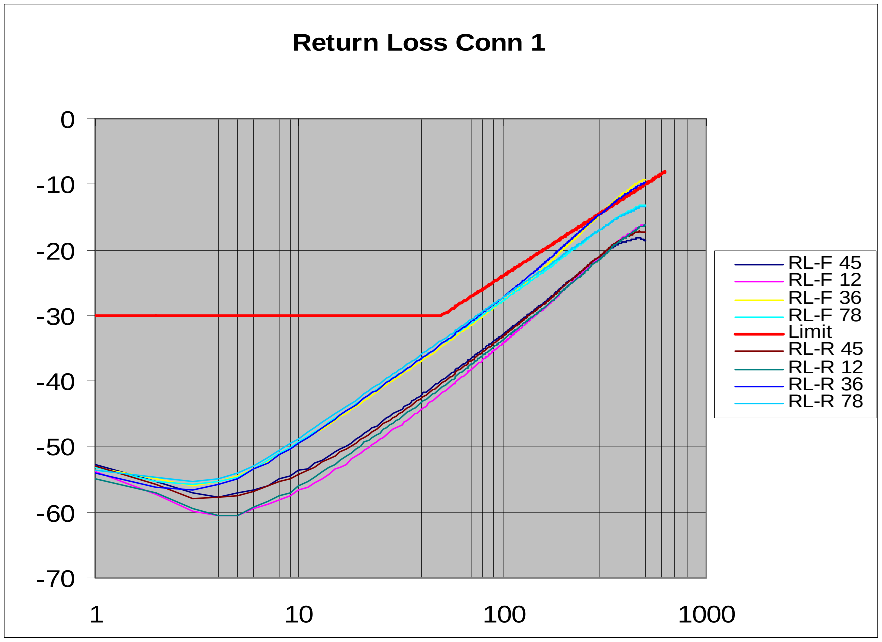
14m Channel Return Loss conn2 with 30 dB RL compared to extended Cat6 limit



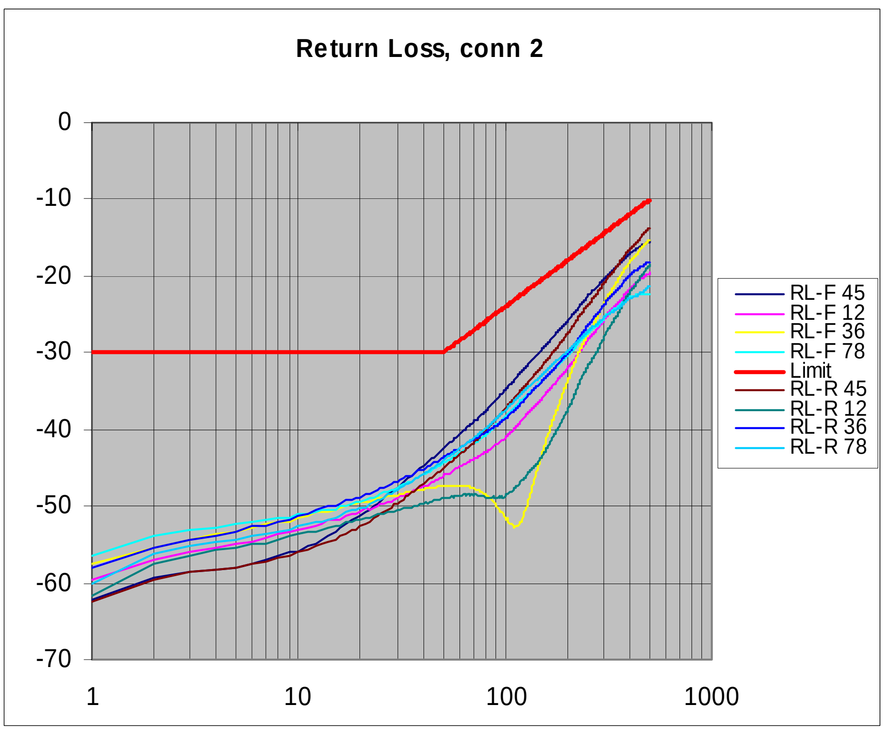
14 meter channel ELFEXT measurement

ELFEXT measurement of the channel is shown for reference, there is some problem with the calculations at high frequencies where the FEXT is very low and is swamped out by the attenuation of the cable. It is not proposed to change the Cat6 of Class E extended limits for FEXT and ELFEXT.

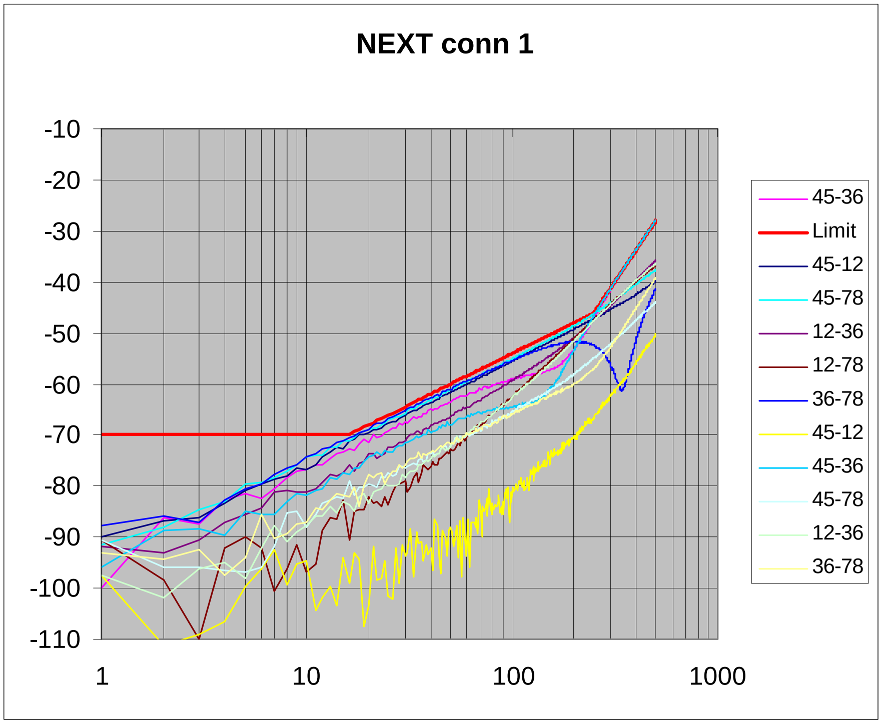
Further measurements for reference:



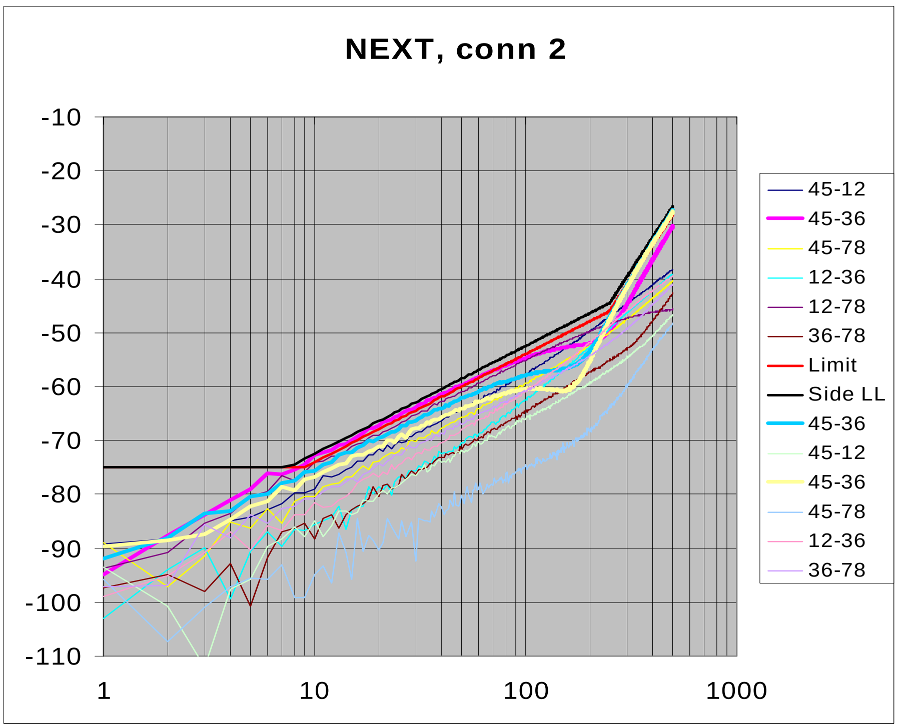
Connector1 Return Loss Measurement



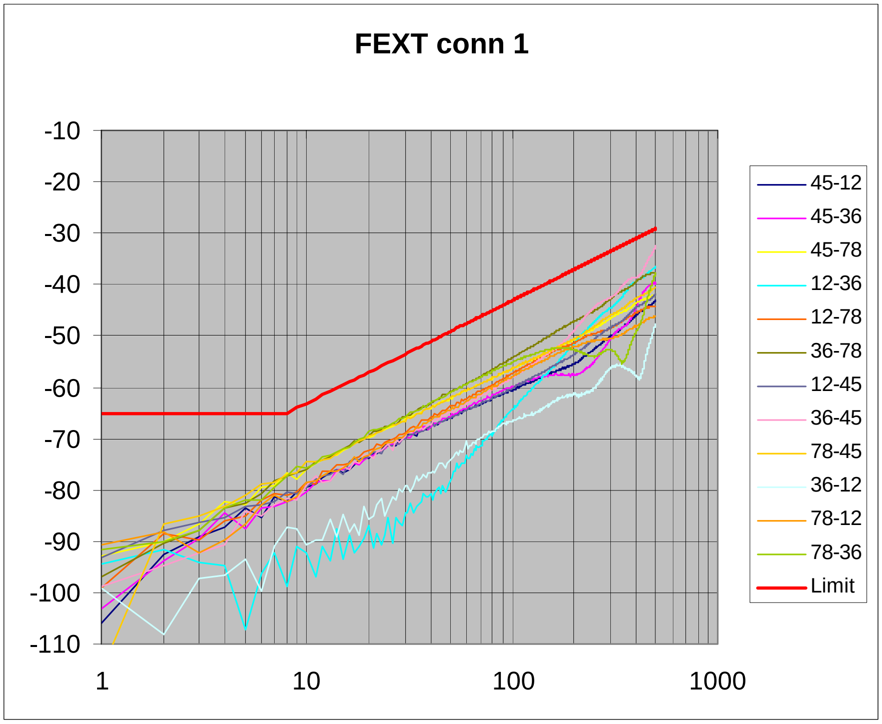
Connector2 Return Loss Measurement



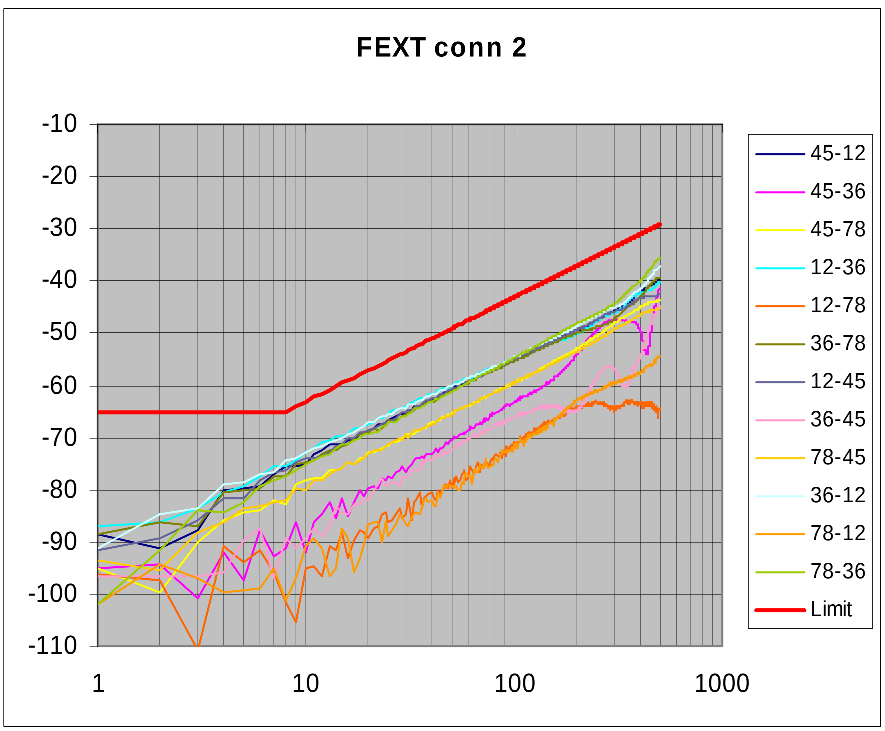
Connector1 NEXT Measurement



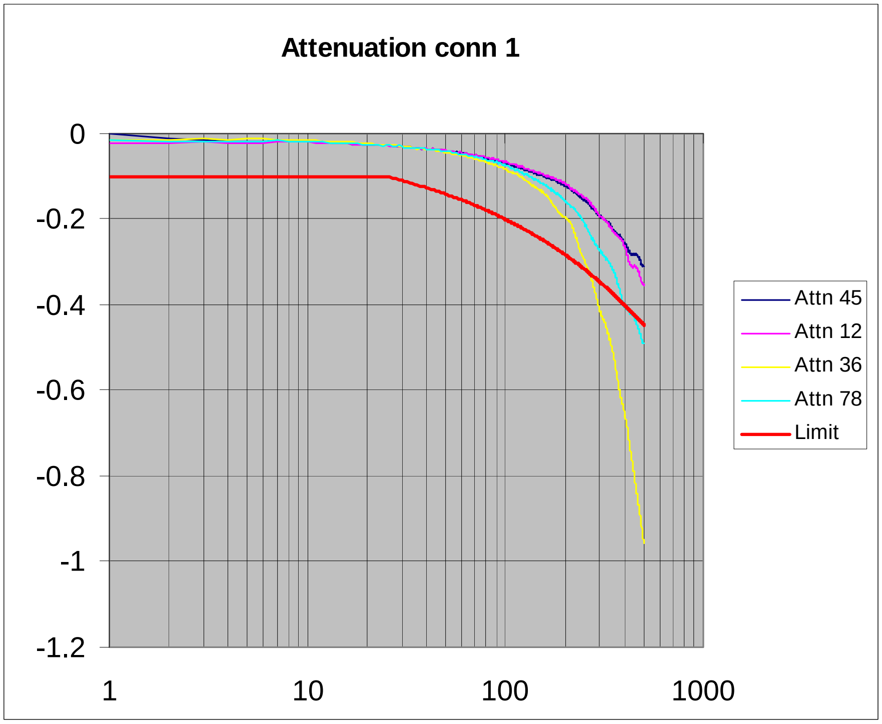
Connector2 NEXT Measurement



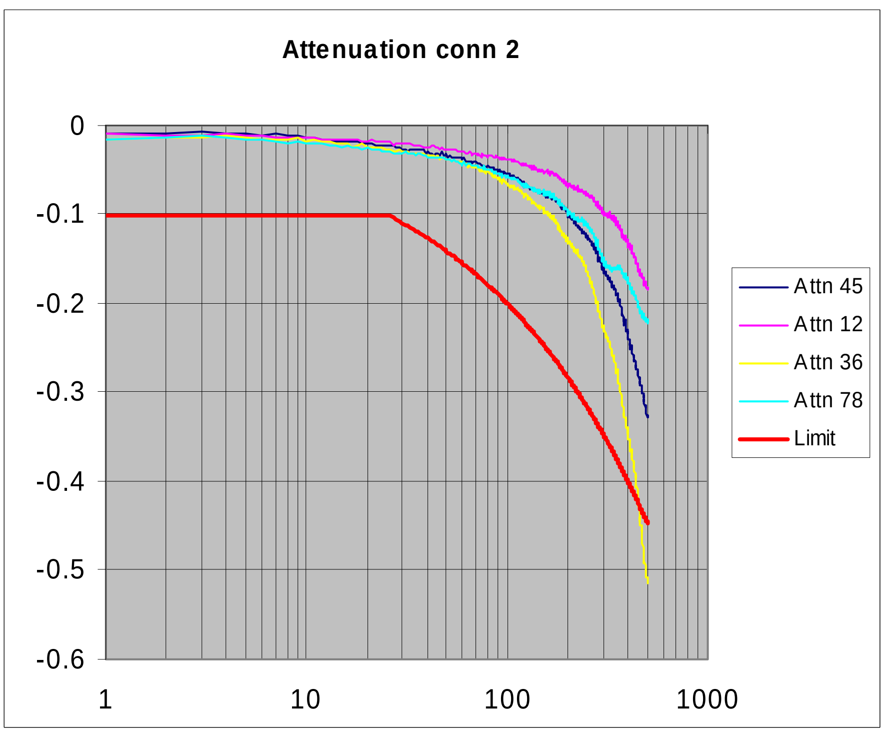
Connector1 FEXT Measurement



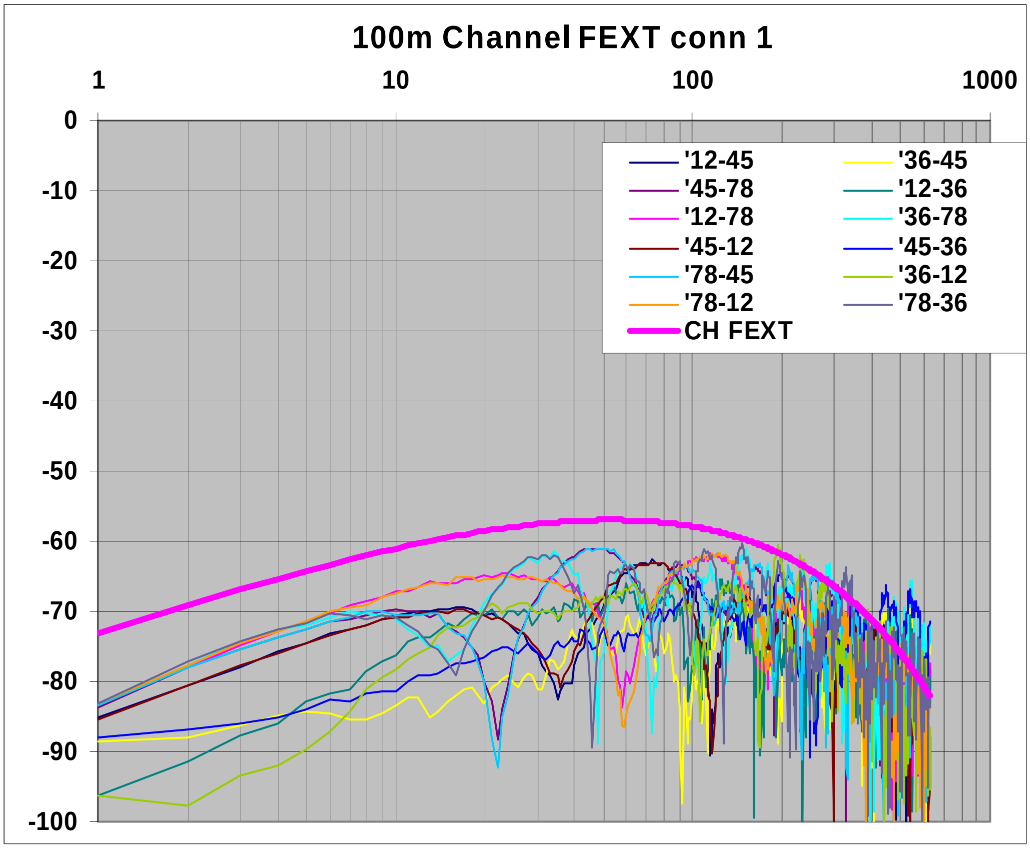
Connector 2 FEXT Measurement



Connector 1 Insertion Loss Measurement



Connector 2 Insertion Loss Measurement



100 meter channel FEXT measurement

Note that there may be some issues with FEXT compliance to limit at high frequencies as the channel insertion loss becomes very high. The connector insertion loss is not compliant with the limit at the high frequencies due to the connector return loss. This may be as much a measurement error due to low insertion loss of the measurement configuration. A typical measurement solution is to add attenuators to the measurement setup to increase the insertion loss and reduce the reflections from the terminations.

The data for these and other similar measurements can be made available to interested parties for modeling of channel behavior.

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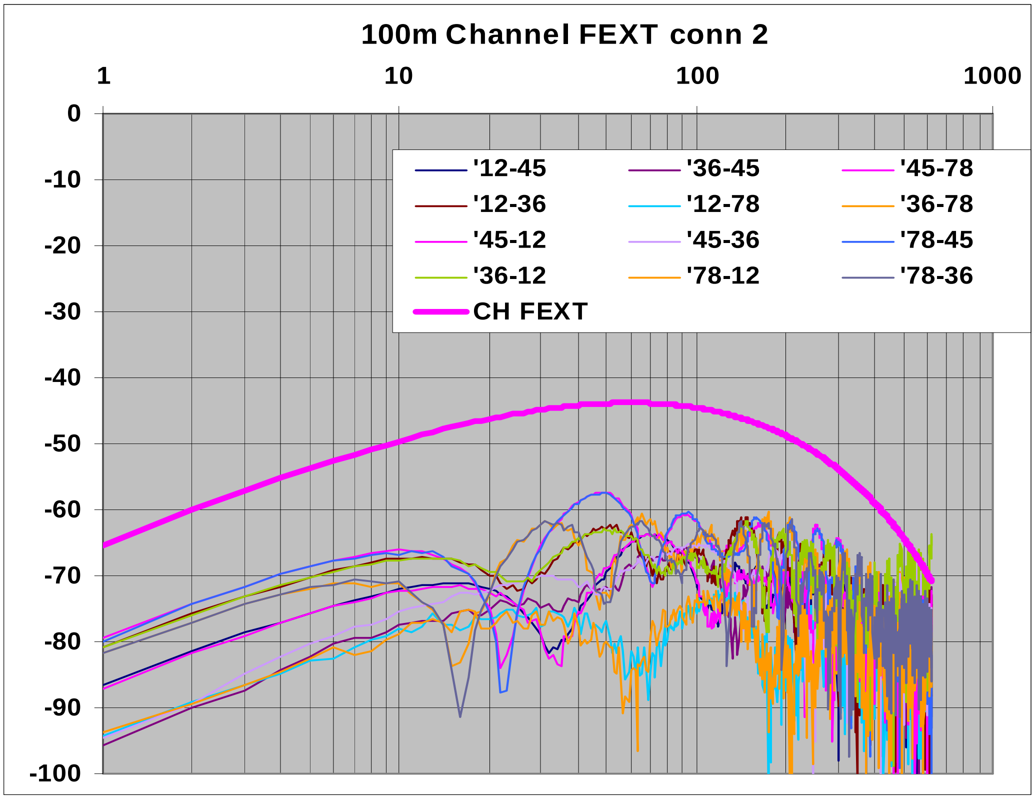
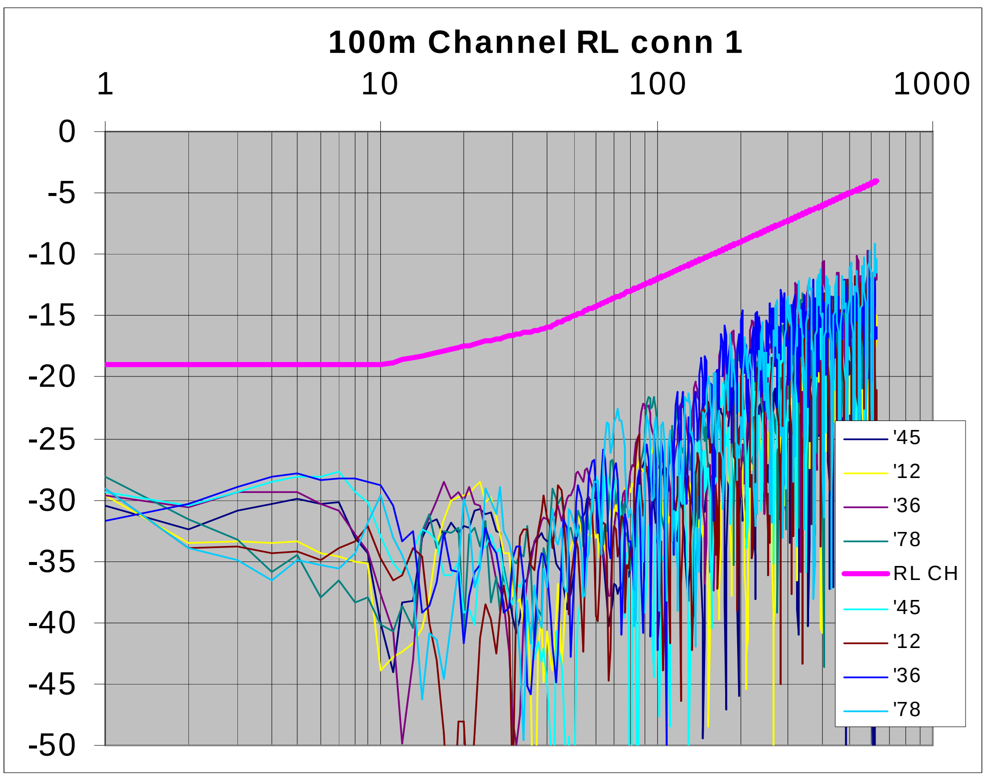
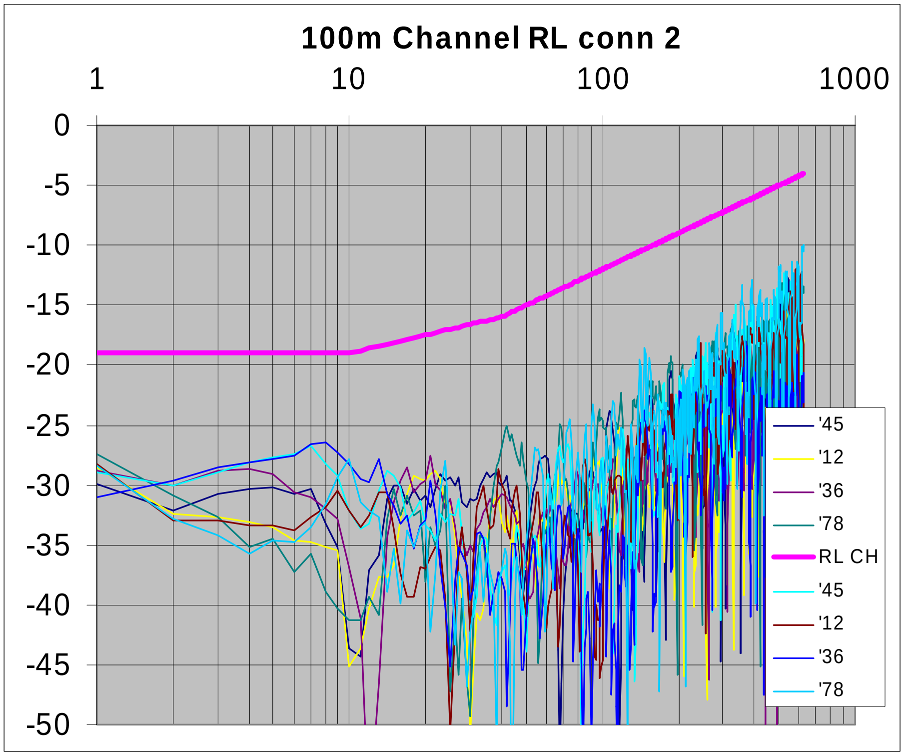
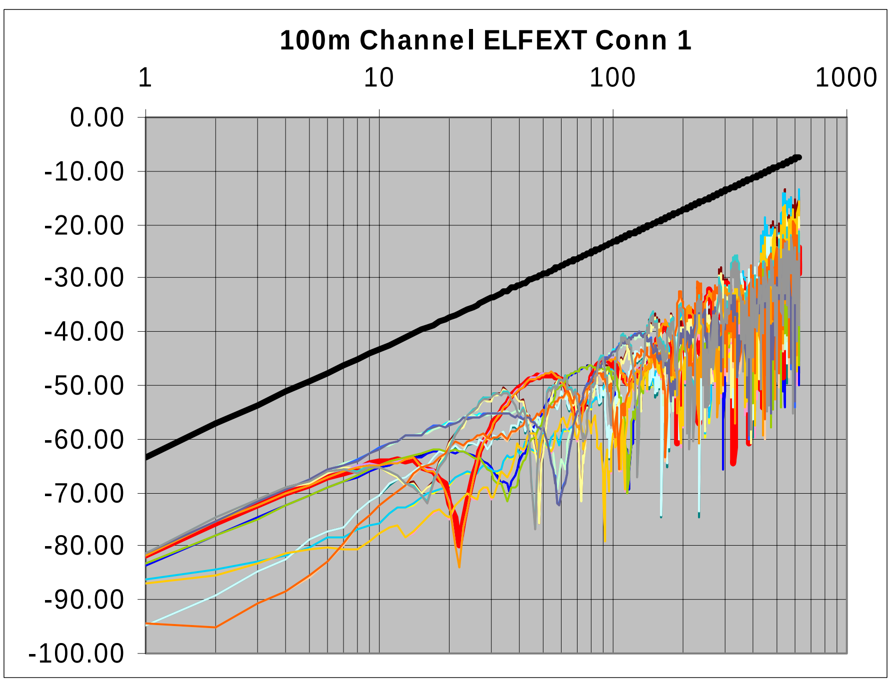
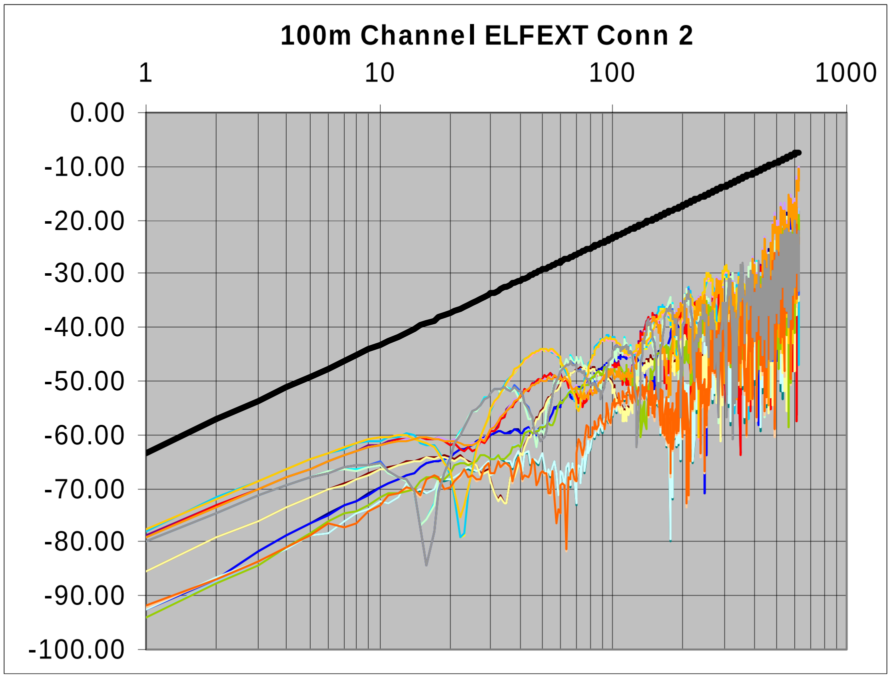

100m Channel FEXT conn 2
1
10
100
1000
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
'12-45
'36-45
'45-78
'12-36
'12-78
'36-78
'45-12
'45-36
'78-45
'36-12
'78-12
'78-36
CH FEXT


100m Channel RL conn 1
1
10
100
1000
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
'45
'12
'36
'78
RL CH
'45
'12
'36
'78





This chart shows that the mesured FEXT can be greater than predicted and still be well under the limit for ELFEXT


100m Channel ELFEXT Conn 2
1
10
100
1000
0.00
-10.00
-20.00
-30.00
-40.00
-50.00
-60.00
-70.00
-80.00
-90.00
-100.00