Limit Line Scaling

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CommScope

Supporters

- Val Maguire – The Siemon Company
- Mike Grimwood – Broadcom
- George Zimmerman – CME Consulting
- Sterling Vaden – OC
- Peter Wu - Marvell

Limit Line Scaling

- There are only a limited number of category 8 channel measurements available. While more will become available over time, it will always be a limited number. There is no assurance that this limited number of measurements captures a reasonable worst case.
- Would like to adjust the measured data to the worst case, for PHY development purposes.
- The result of this should be worse than the worst case, but the amount by which it is worse should be minimized.
- Using the channel limit at all frequencies is generally much worse than a realistic worst case.
- Methods to scale insertion loss, return loss, NEXT and FEXT are offered. Detailed equations and example results are included.

Insertion Loss scaling equations

1. Find the insertion loss of each of the four pairs as dB.
2. Find the scaling factor as a function of f:

$$SF(f) := \frac{ILLimit(f) - IL(f)}{\sqrt{f}}$$

Use the insertion loss limit as a function of channel length, patch cord length, patch cord de-rating factor, and number of connectors.

$$ILLimit(f) := \frac{L + (DF - 1)\cdot FL}{100}\cdot\left(1.8\cdot\sqrt{f} + .005\cdot f + \frac{.25}{\sqrt{f}}\right) + N\cdot COIL + .0324\cdot\sqrt{f}$$

$L :=$ total length of channel
$DF :=$ de – rating factor_(1.0, 1.2, 1.5)
$FL :=$ flexible length
$COIL :=$ connector insertion_loss
$N :=$ number_of_connectors

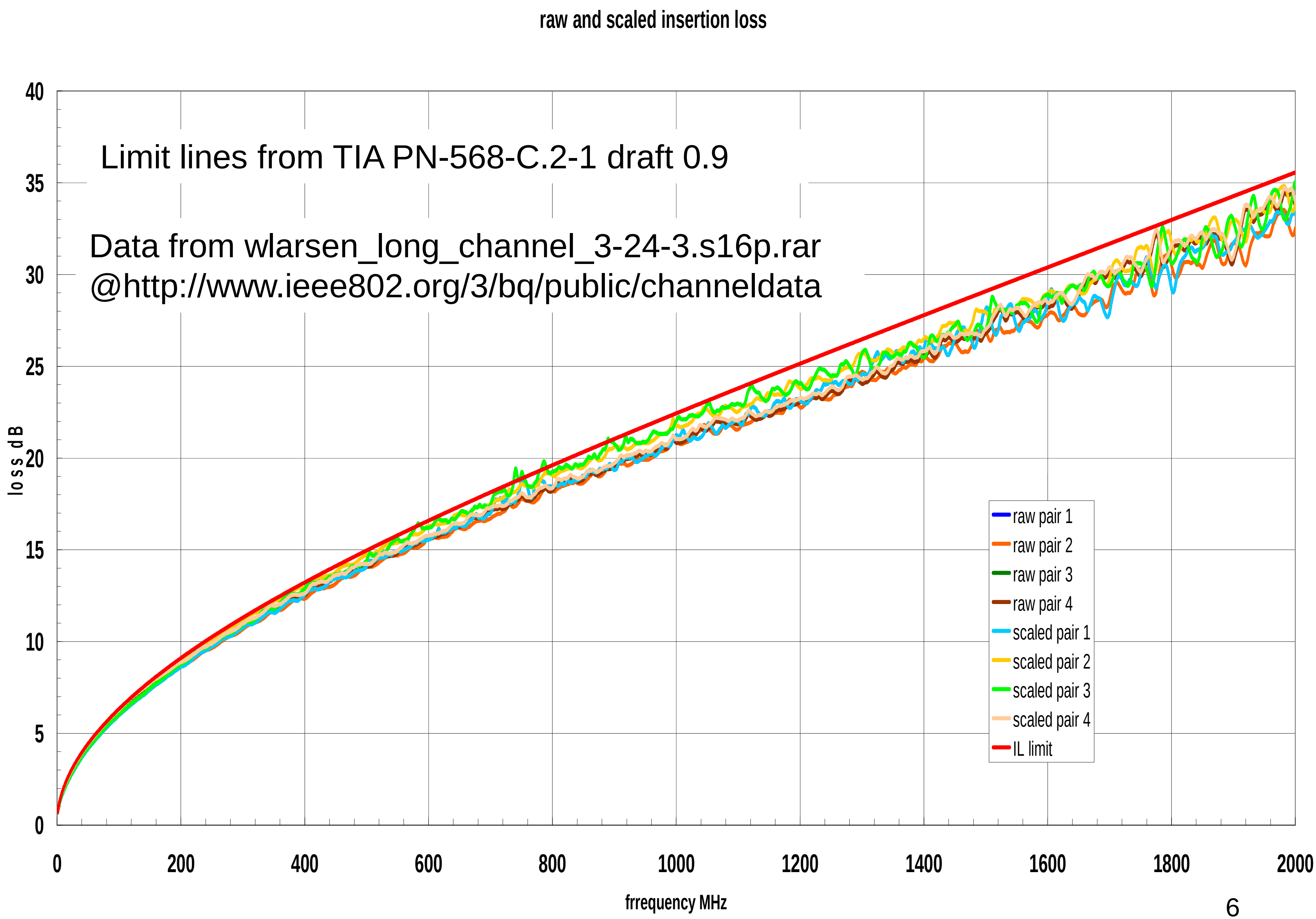
Ignoring the frequency range below 10 MHz, find min(SF(f)) for each pair. Replace any negative number with zero, since enhancing the performance is not allowed. This equation was adapted from the TIA category 8 draft.

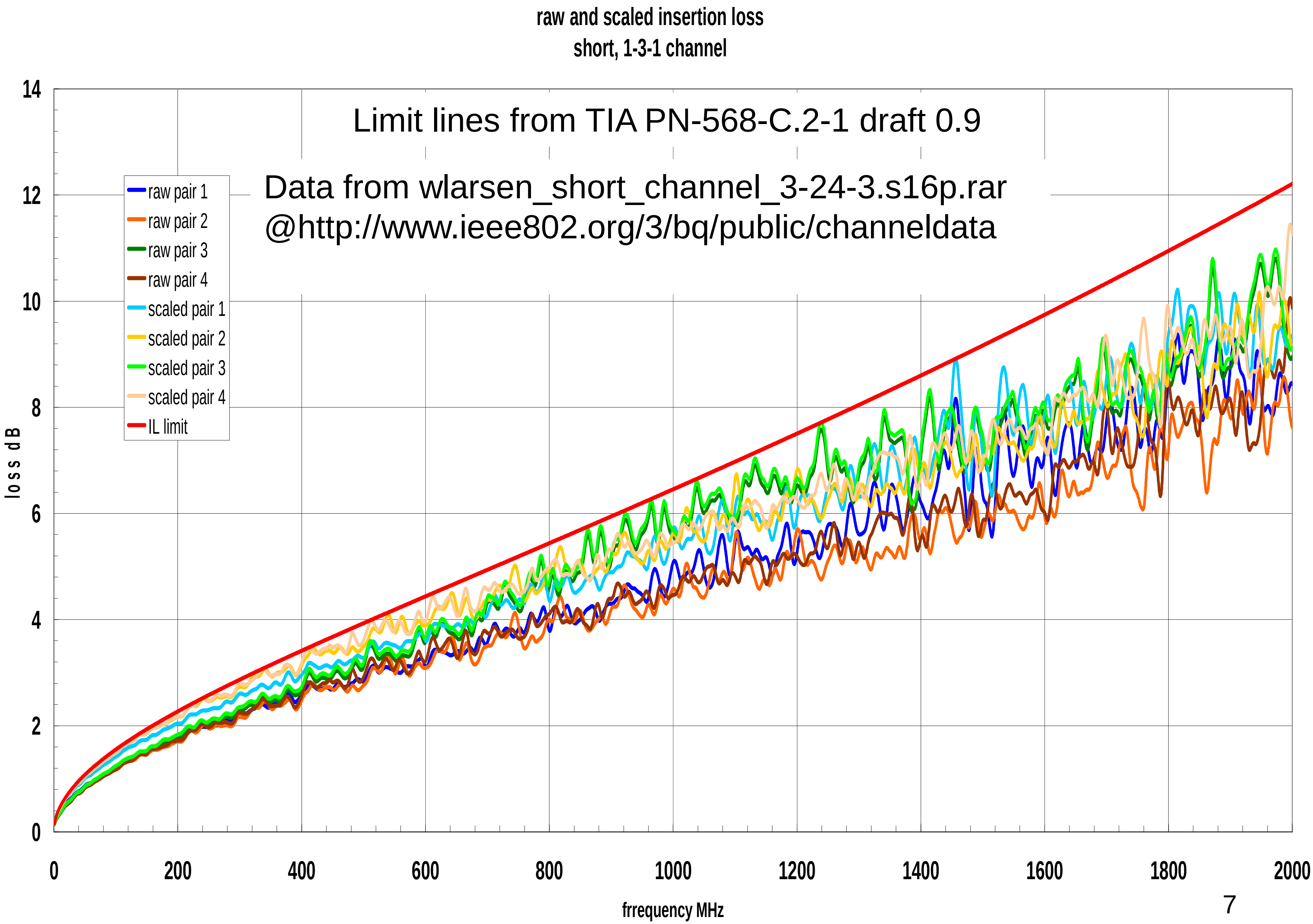
Insertion Loss Scaling Equations-2

3. Scale the insertion loss:

$$SIL(f) := IL(f) + \min(SF(f)) \cdot \sqrt{f}$$

4. Check the maximum margin of the scaled IL data against the limit line. If there is greater than 5 dB margin on any pair at any frequency point, the raw data is not suitable for scaling.


raw and scaled insertion loss
Limit lines from TIA PN-568-C.2-1 draft 0.9
Data from wlarsen_long_channel_3-24-3.s16p.rar
@http://www.ieee802.org/3/bq/public/channeldata
loss dB
frrequency MHz
0
5
10
15
20
25
30
35
40
0
200
400
600
800
1000
1200
1400
1600
1800
2000
raw pair 1
raw pair 2
raw pair 3
raw pair 4
scaled pair 1
scaled pair 2
scaled pair 3
scaled pair 4
IL limit



raw and scaled insertion loss
short, 1-3-1 channel
Limit lines from TIA PN-568-C.2-1 draft 0.9
Data from wlarsen_short_channel_3-24-3.s16p.rar
@http://www.ieee802.org/3/bq/public/channeldata
raw pair 1
raw pair 2
raw pair 3
raw pair 4
scaled pair 1
scaled pair 2
scaled pair 3
scaled pair 4
IL limit
loss dB
0
2
4
6
8
10
12
14
0
200
400
600
800
1000
1200
1400
1600
1800
2000
frrequency MHz

Return Loss Scaling Equations

1. Find the return loss of each of the 4 pairs in both directions as dB.
2. Convert from dB to linear.

$$RLlin(f) := 10^{-\frac{RL(f)}{20}}$$

3. Smooth the RL over a 100 MHz apperture.

$$SMRLlin(f) := \frac{\sum_{f = minf}^{maxf} RLlin(f)}{number\_of\_points\_from\_minf\_to\_maxf}$$

4. Convert back into dB

$$SMRL(f) := -20 \cdot \log(SMRLlin(f))$$

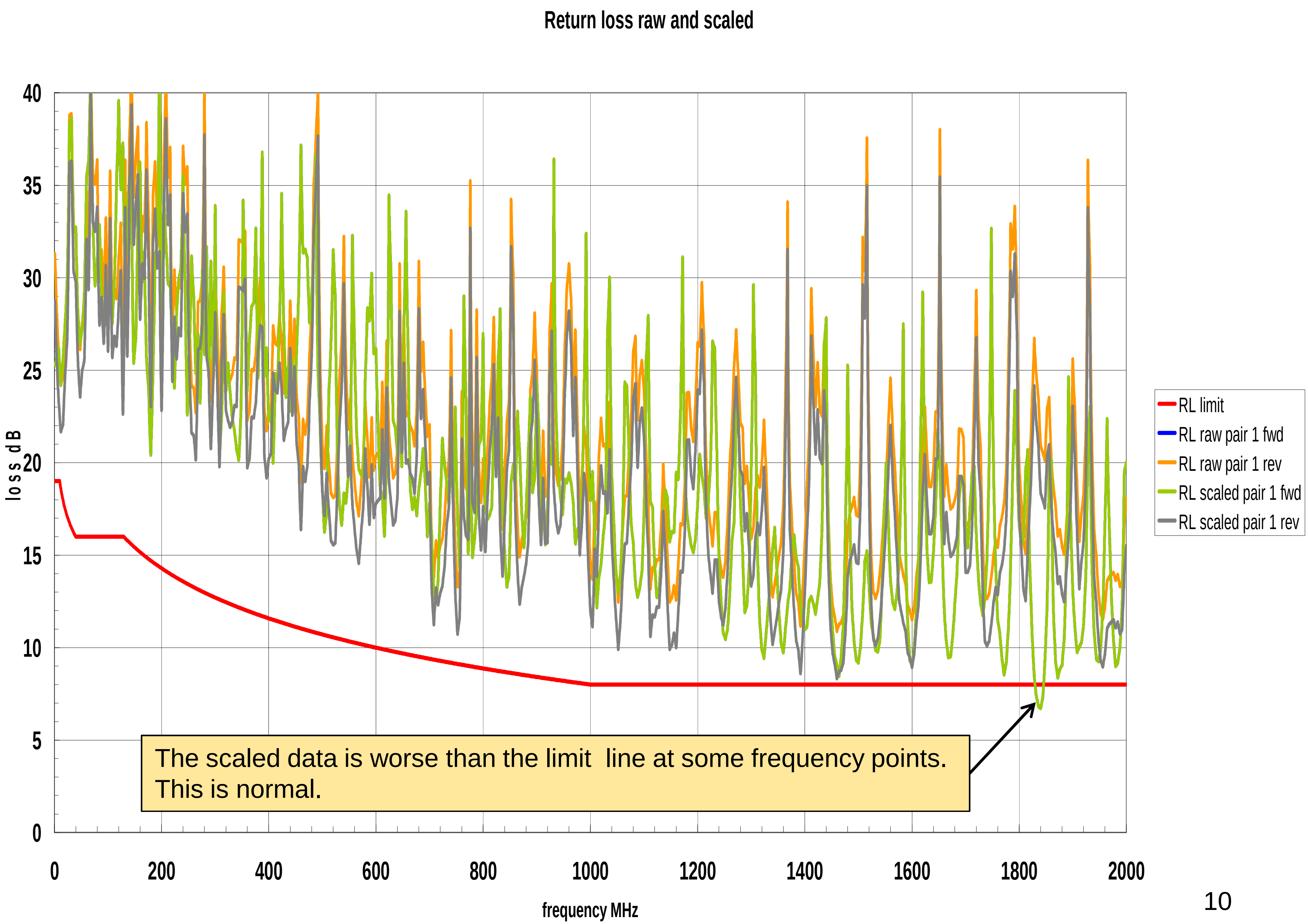
Return Loss Scaling Equations 2

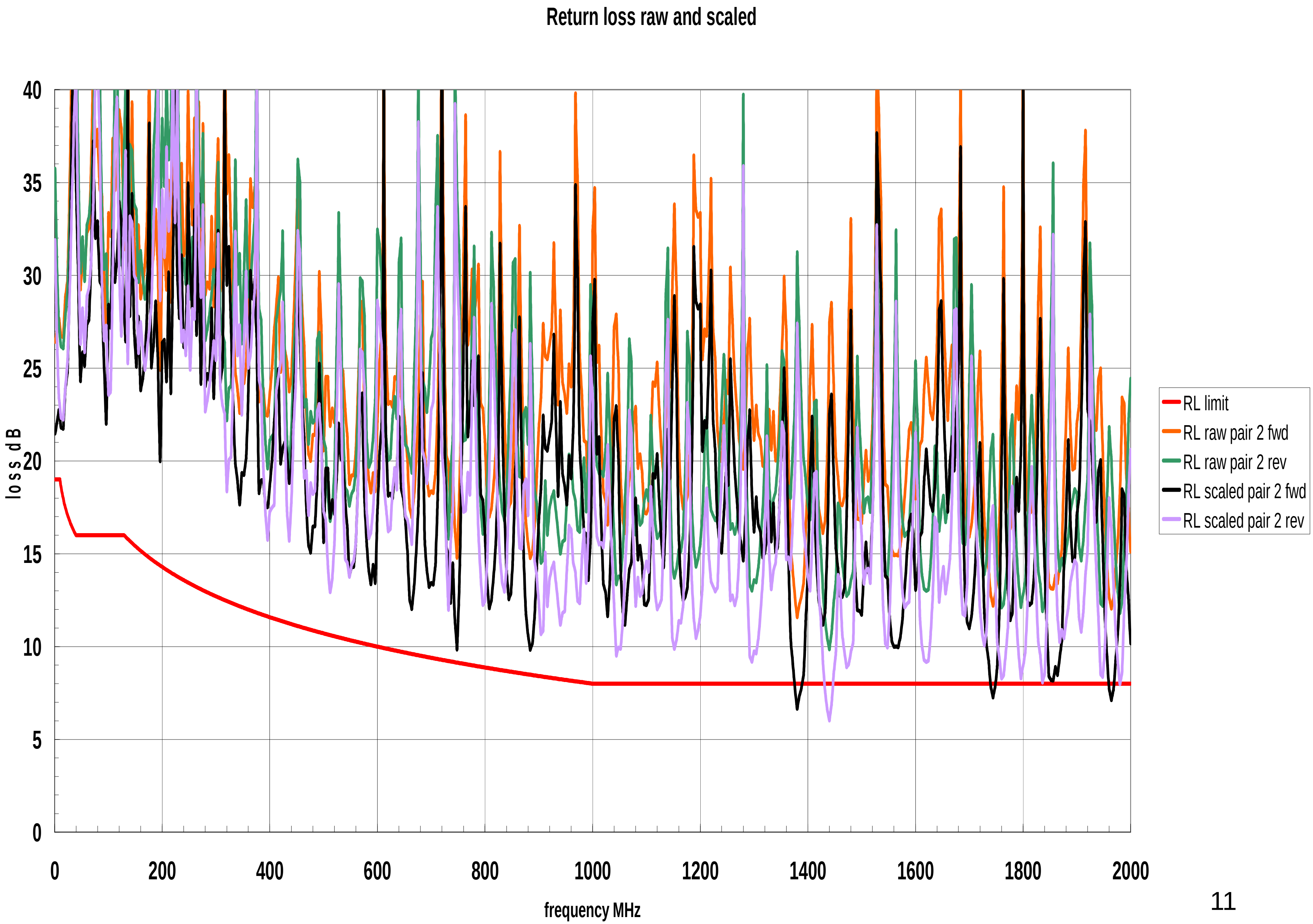
5. For each pair in each direction, find the minimum margin of the smoothed return loss to a limit 3 dB greater than the return loss channel limit. But if the result is negative, replace with zero, because enhancing the performance is not allowed.

$$\mathrm{SMRLM}(f) := \mathrm{SMRL}(f) - \mathrm{RLLimit}(f) - 3\mathrm{dB}$$

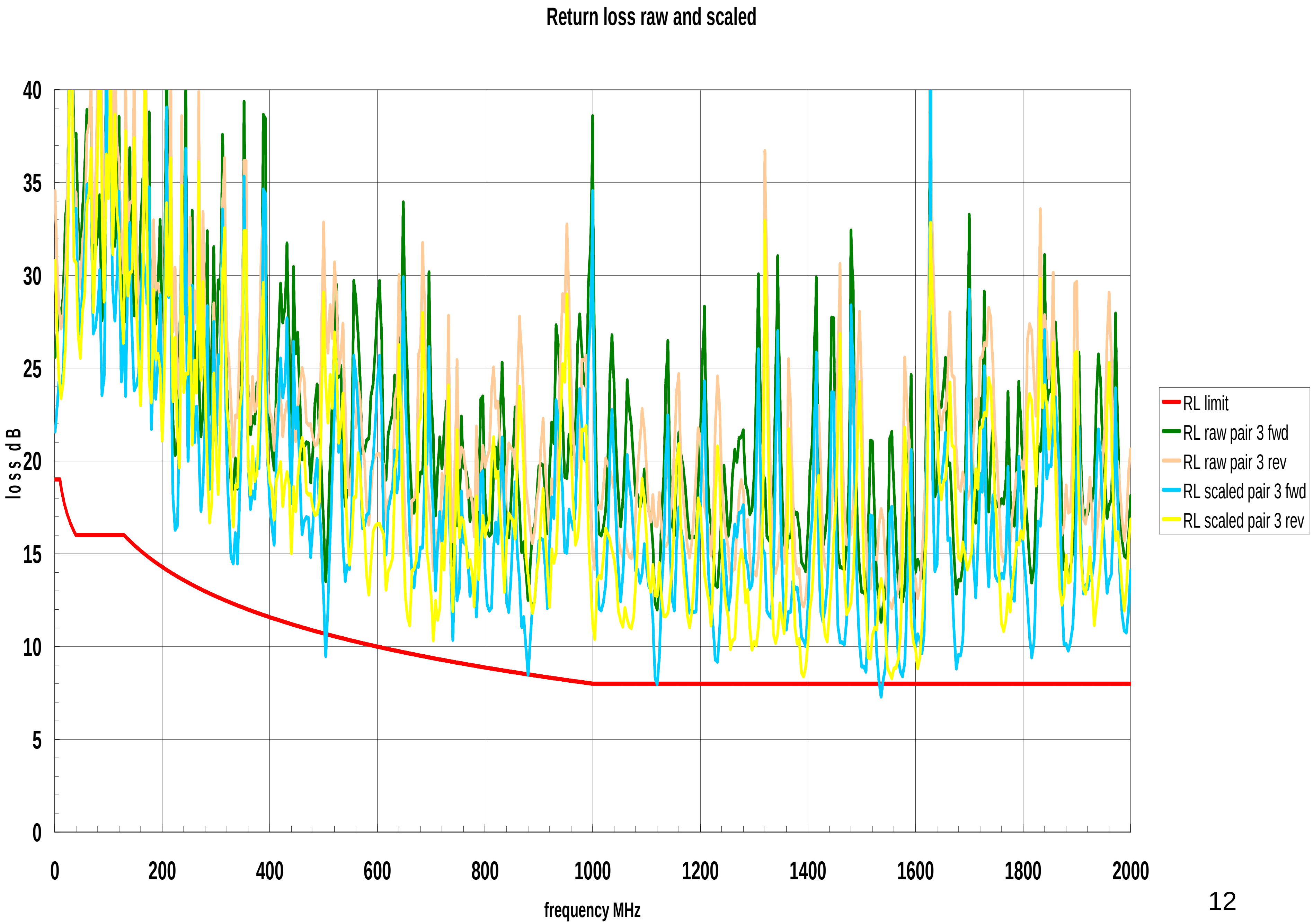
6. Scale the raw data by the minimum

$$\mathrm{SRL}(f) := \mathrm{RL}(f) - \min(\mathrm{SMRLM}(f))$$

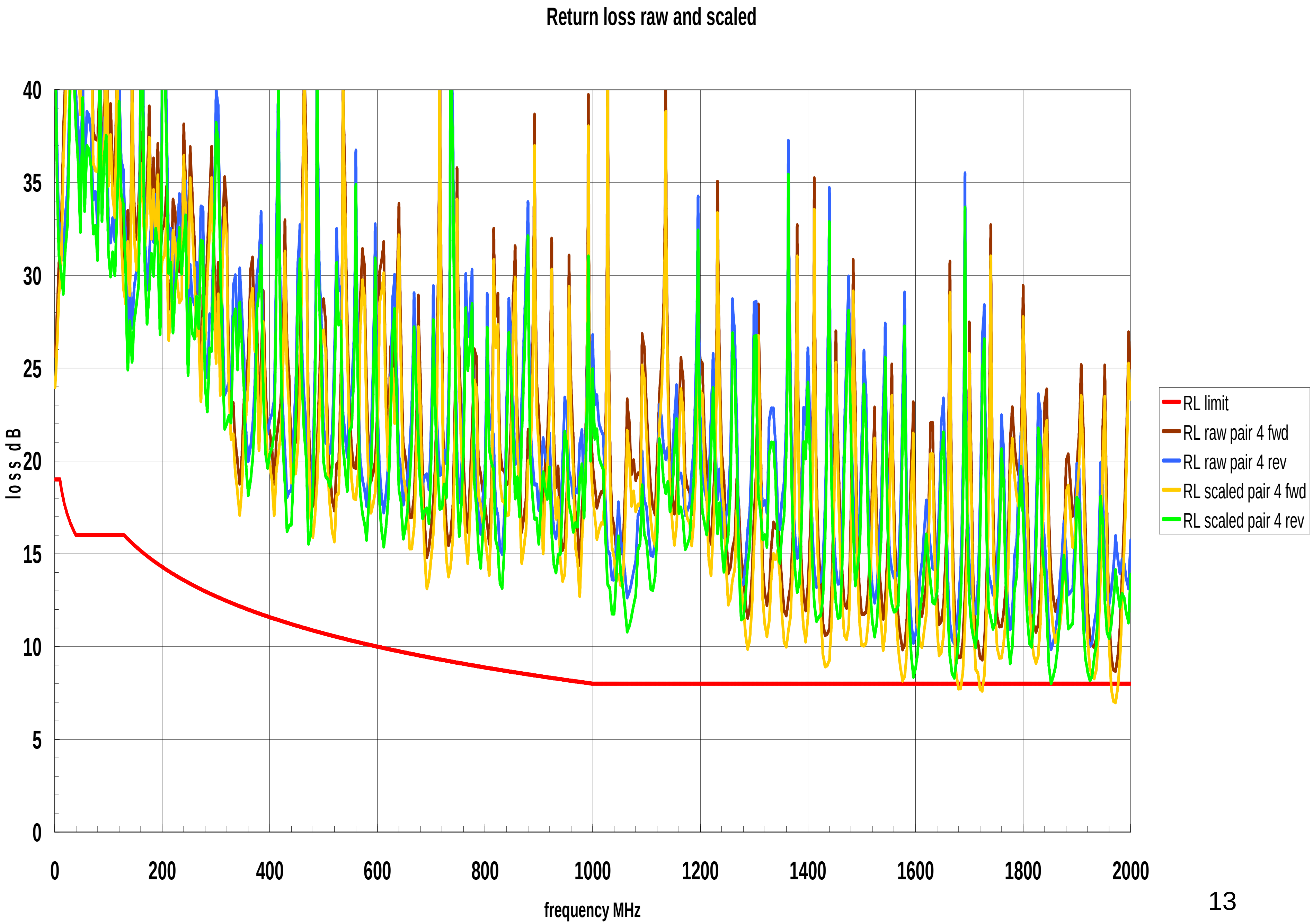

Return loss raw and scaled
40
35
30
25
20
15
10
5
0
loss dB
0
200
400
600
800
1000
1200
1400
1600
1800
2000
frequency MHz
RL limit
RL raw pair 1 fwd
RL raw pair 1 rev
RL scaled pair 1 fwd
RL scaled pair 1 rev
The scaled data is worse than the limit line at some frequency points.
This is normal.

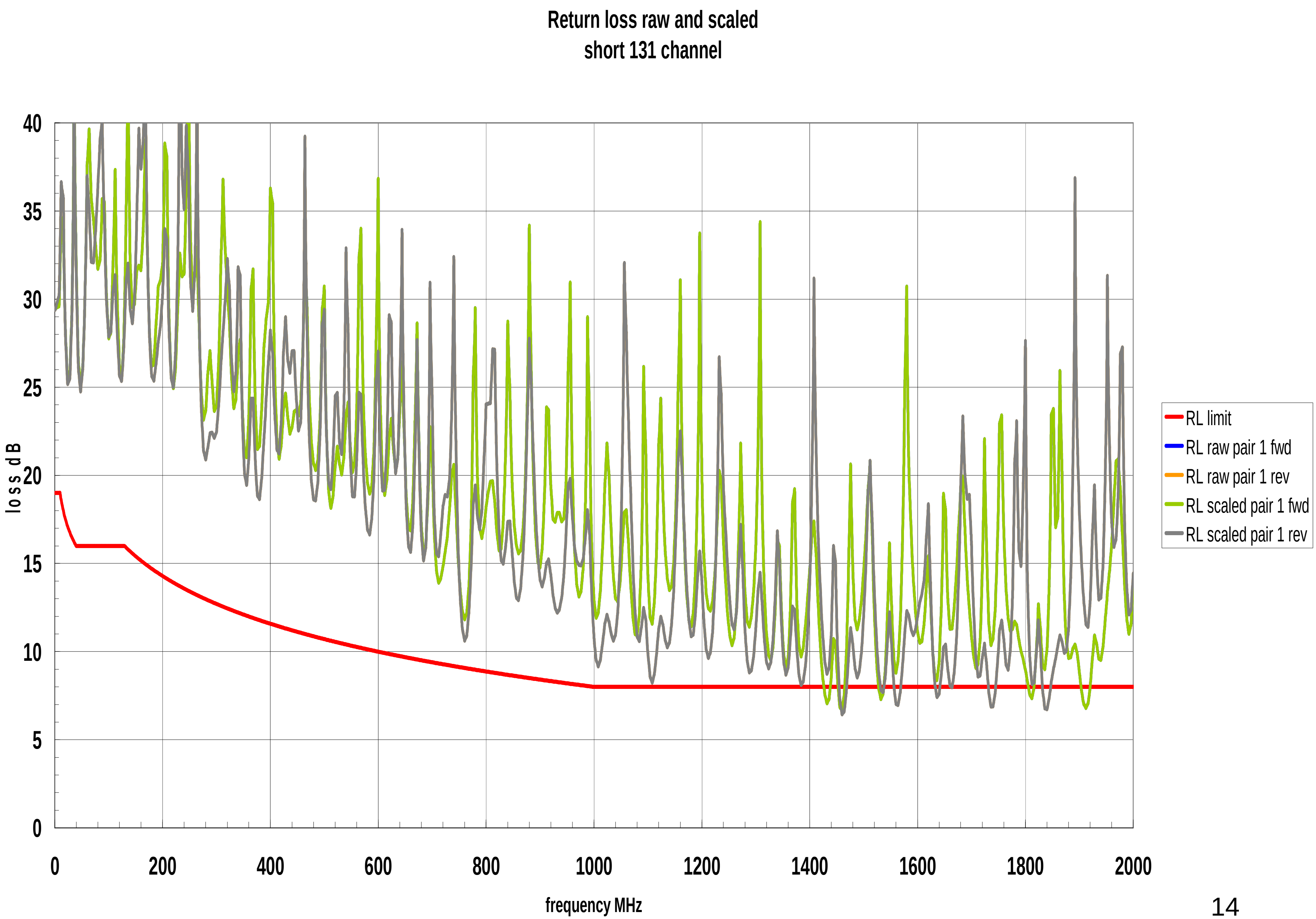


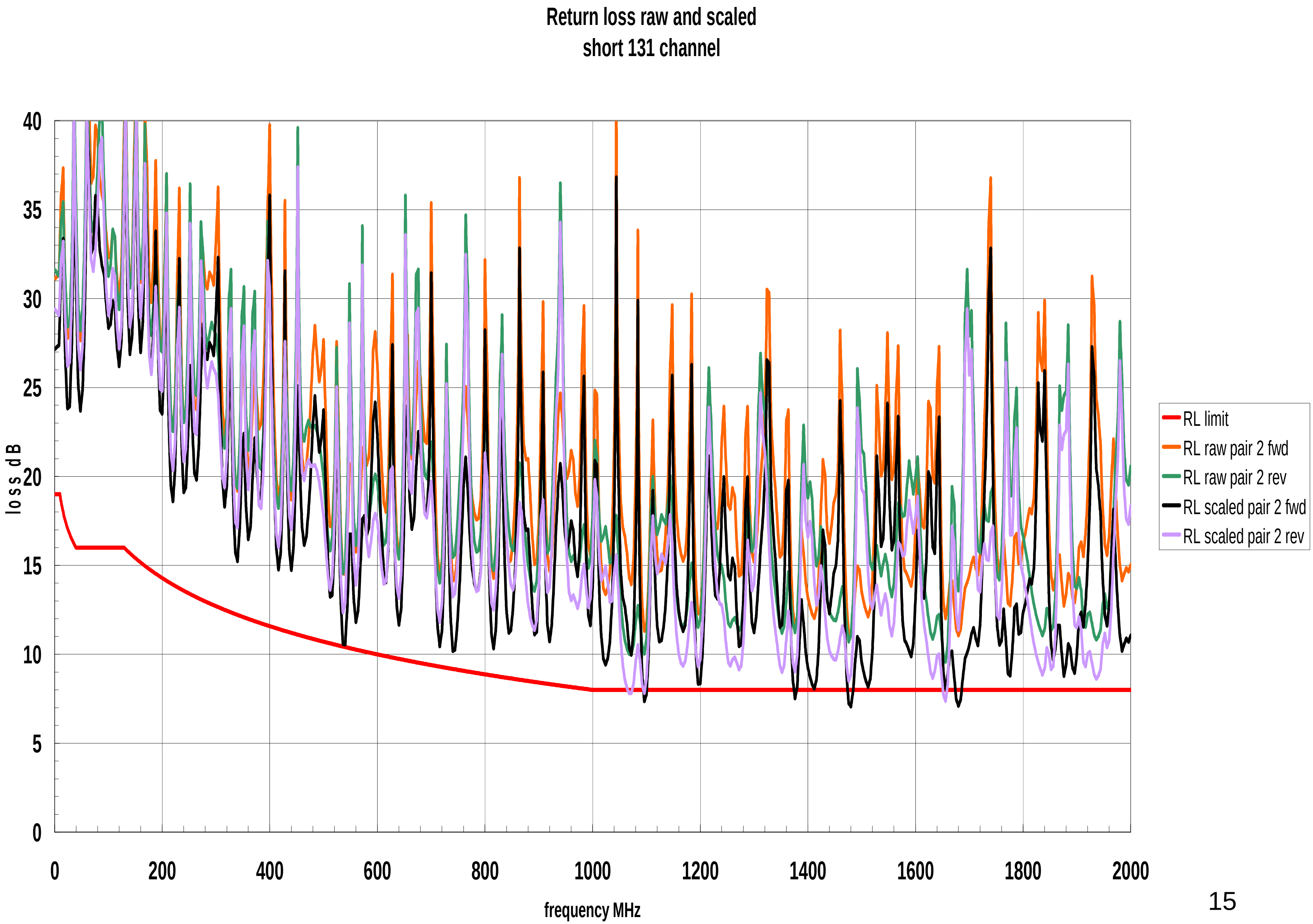
Return loss raw and scaled
40
35
30
25
20
15
10
5
0
loss dB
0
200
400
600
800
1000
1200
1400
1600
1800
2000
frequency MHz
RL limit
RL raw pair 2 fwd
RL raw pair 2 rev
RL scaled pair 2 fwd
RL scaled pair 2 rev



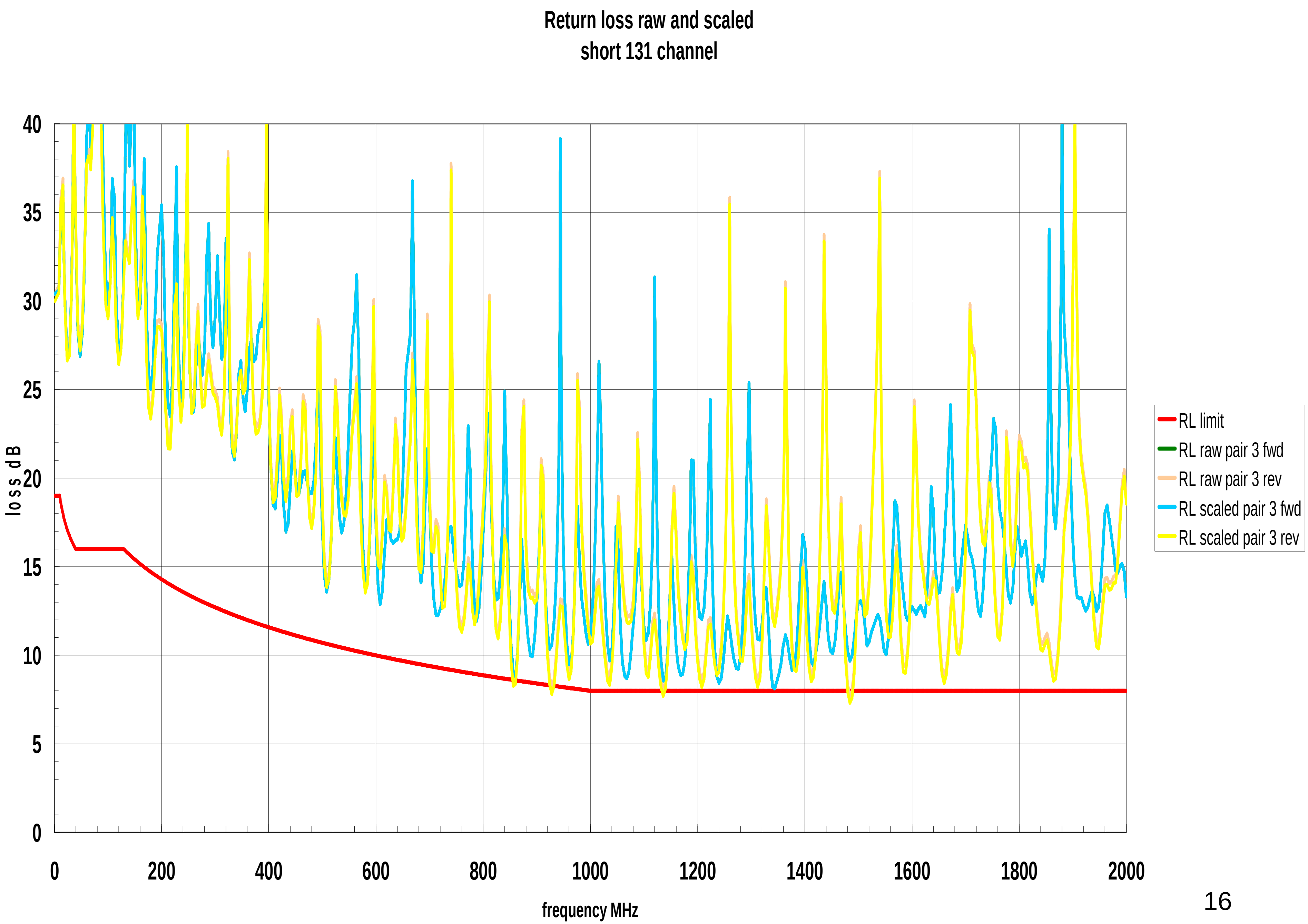
Return loss raw and scaled
40
35
30
25
20
15
10
5
0
loss dB
0
200
400
600
800
1000
1200
1400
1600
1800
2000
frequency MHz
RL limit
RL raw pair 3 fwd
RL raw pair 3 rev
RL scaled pair 3 fwd
RL scaled pair 3 rev


Return loss raw and scaled
40
35
30
25
20
15
10
5
0
loss dB
0
200
400
600
800
1000
1200
1400
1600
1800
2000
frequency MHz
RL limit
RL raw pair 4 fwd
RL raw pair 4 rev
RL scaled pair 4 fwd
RL scaled pair 4 rev

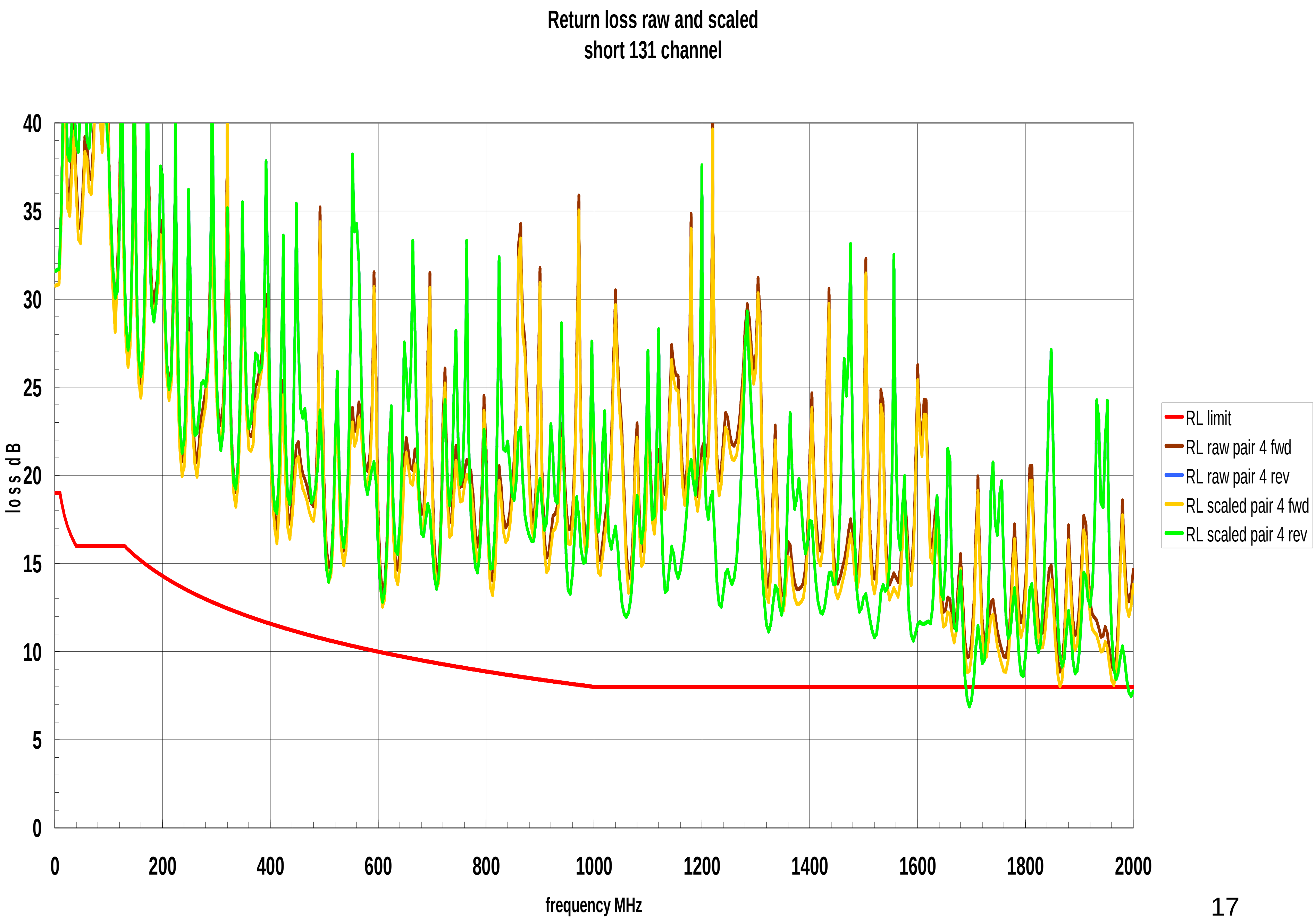

Return loss raw and scaled
short 131 channel
40
35
30
25
20
15
10
5
0
loss dB
0
200
400
600
800
1000
1200
1400
1600
1800
2000
frequency MHz
RL limit
RL raw pair 1 fwd
RL raw pair 1 rev
RL scaled pair 1 fwd
RL scaled pair 1 rev



Return loss raw and scaled
short 131 channel
40
35
30
25
20
15
10
5
0
loss dB
0
200
400
600
800
1000
1200
1400
1600
1800
2000
frequency MHz
RL limit
RL raw pair 2 fwd
RL raw pair 2 rev
RL scaled pair 2 fwd
RL scaled pair 2 rev



Return loss raw and scaled
short 131 channel
40
35
30
25
20
15
10
5
0
loss dB
0
200
400
600
800
1000
1200
1400
1600
1800
2000
frequency MHz
RL limit
RL raw pair 3 fwd
RL raw pair 3 rev
RL scaled pair 3 fwd
RL scaled pair 3 rev



Return loss raw and scaled
short 131 channel
40
35
30
25
20
15
10
5
0
l o s s d B
0
200
400
600
800
1000
1200
1400
1600
1800
2000
frequency MHz
RL limit
RL raw pair 4 fwd
RL raw pair 4 rev
RL scaled pair 4 fwd
RL scaled pair 4 rev

NEXT Scaling Equations

1. Find the NEXT of all 6 pair combinations in both directions, in dB.
2. Calculate the 8 PSNEXT values, 4 in each direction.
3. Convert to linear.

$$PSNEXTlin(f) := 10^{-\frac{PSNEXT(f)}{20}}$$

4. Smooth over a window 50 MHz wide.

$$SMPSMNEXTlin(f) := \frac{\sum_{f = minf}^{maxf} PSNEXTlin(f)}{number\_of\_points\_from\_minf\_to\_maxf}$$

NEXT scaling equations 2

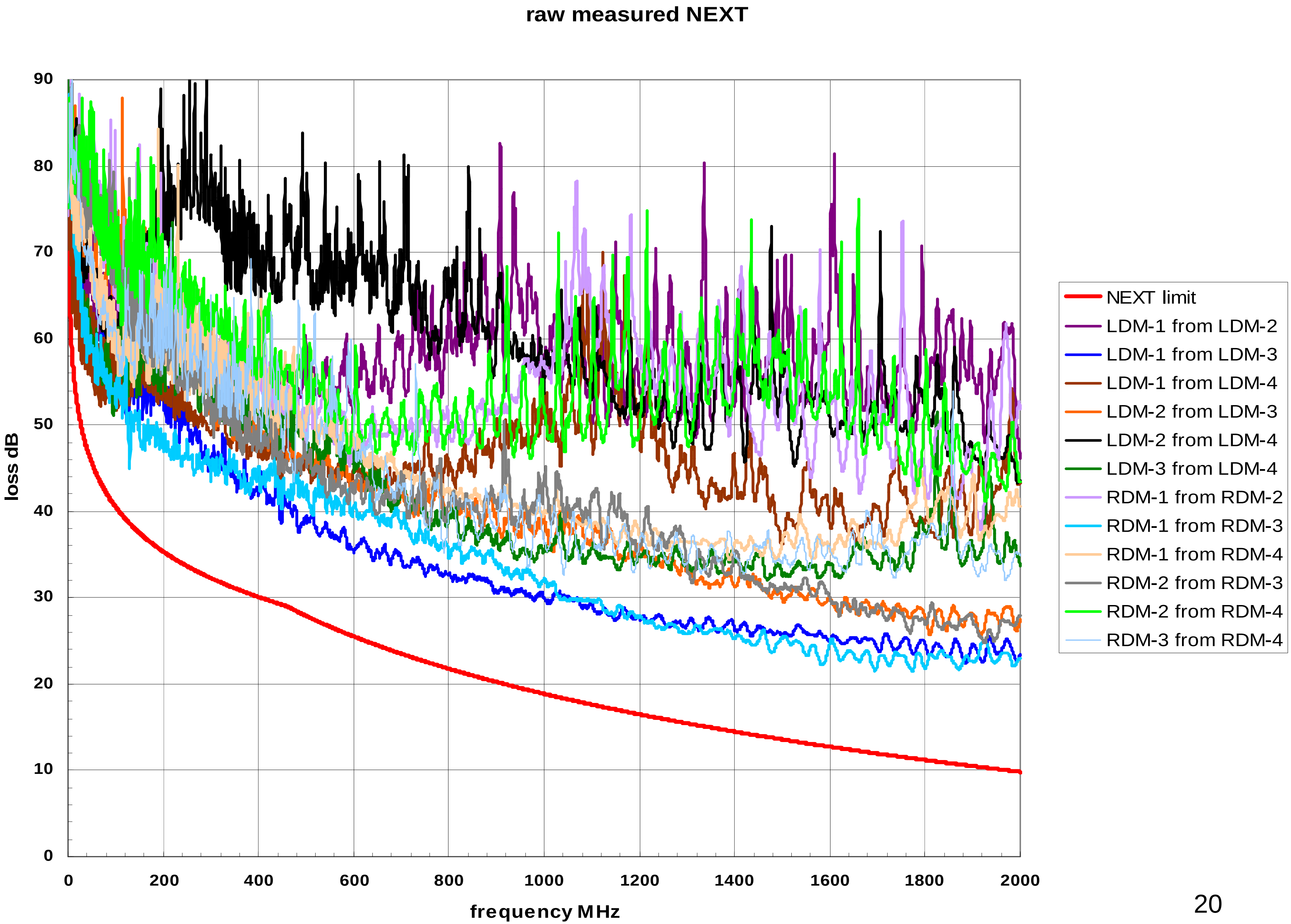
5. Convert back into dB

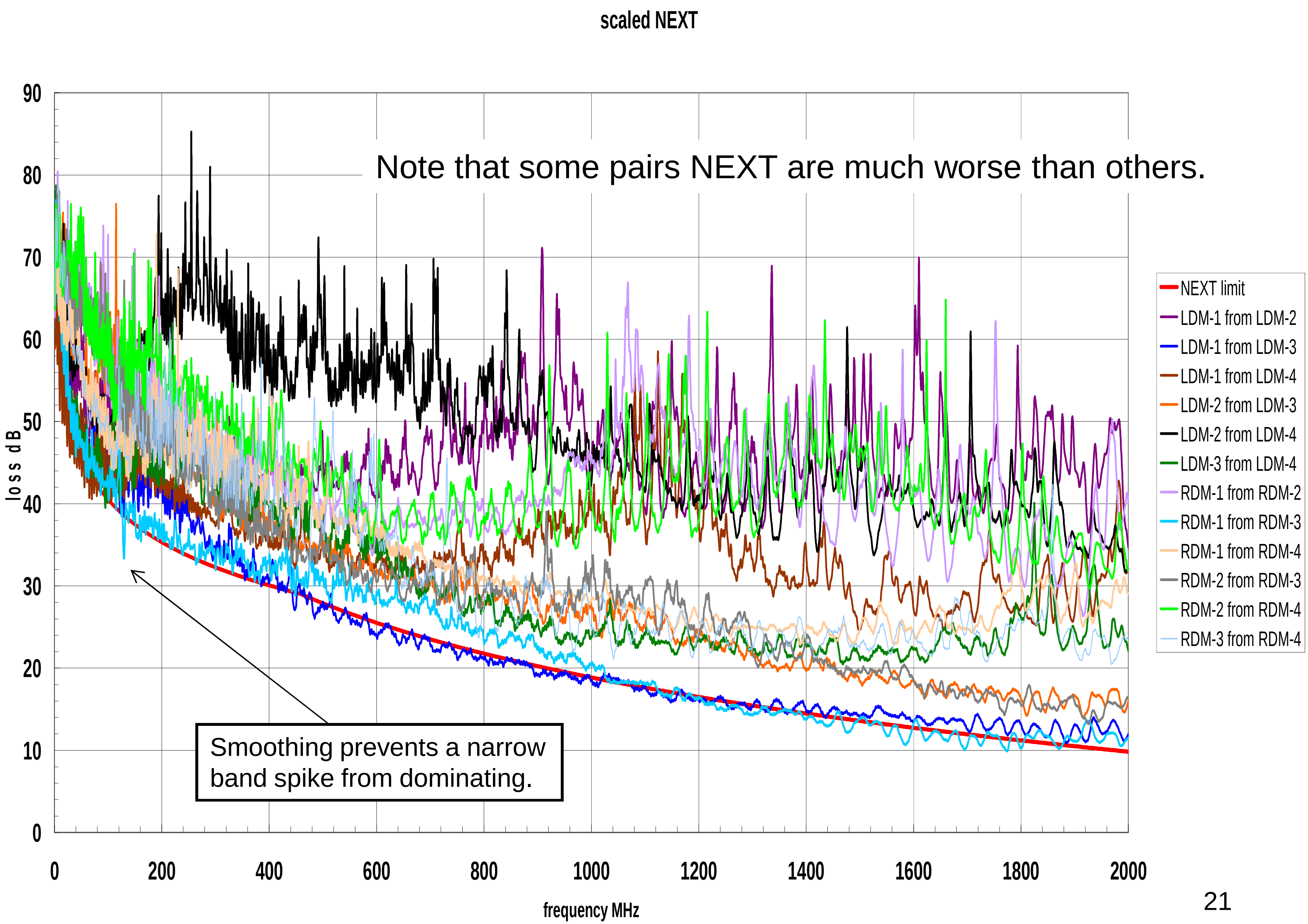
$$SMPSNEXT(f) := -20 \cdot \log(SMPSNEXTlin(f))$$

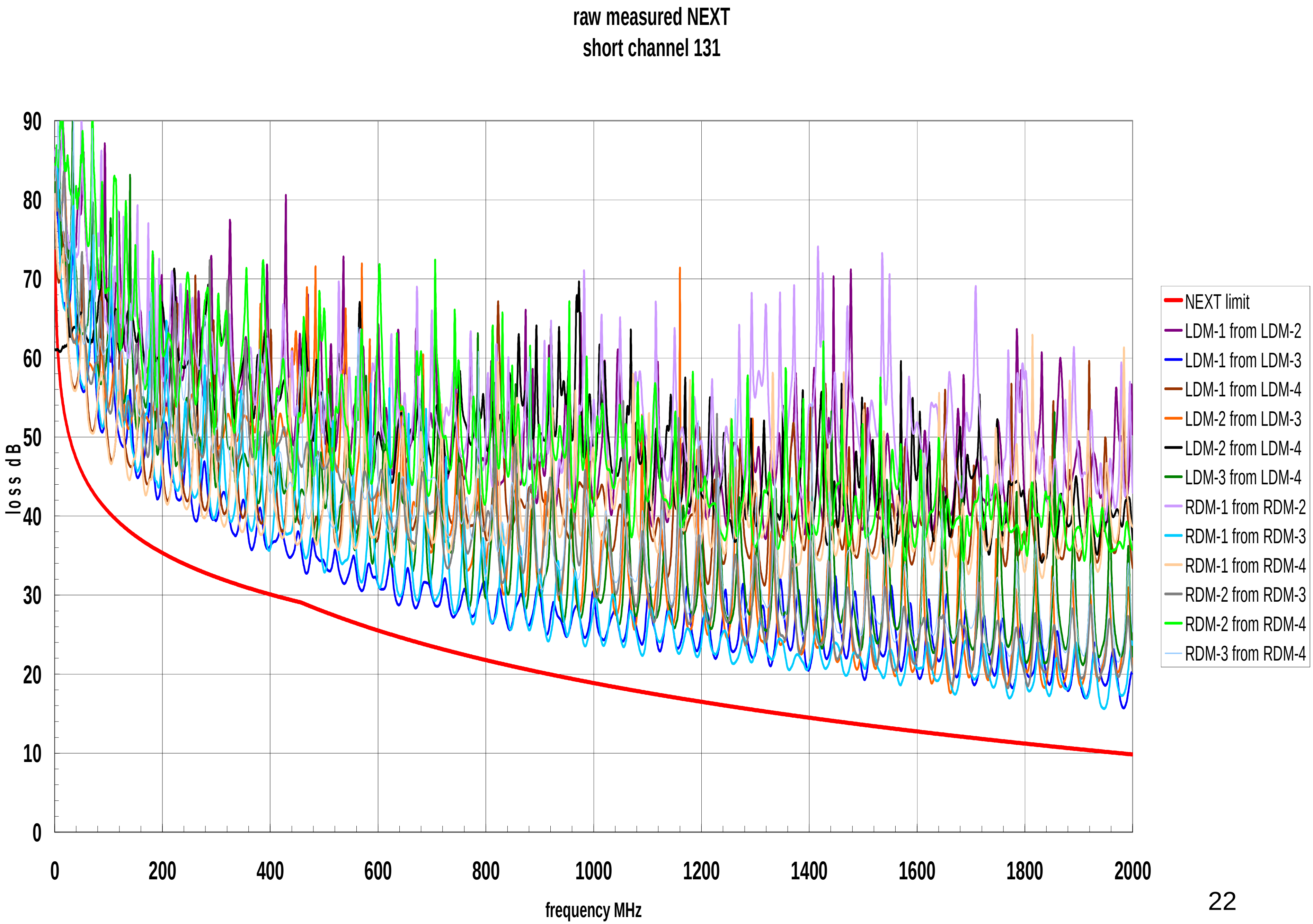
6. Find the minimum PSNEXT margin of the smoothed result, on any pair, to the PSNEXT liimit. Ignore the frequency range below 50 MHz, and replace any negative margins with zero.

7. Subtract this margin from the original raw NEXT dB, the same amount for all pair combinations and all frequencies.

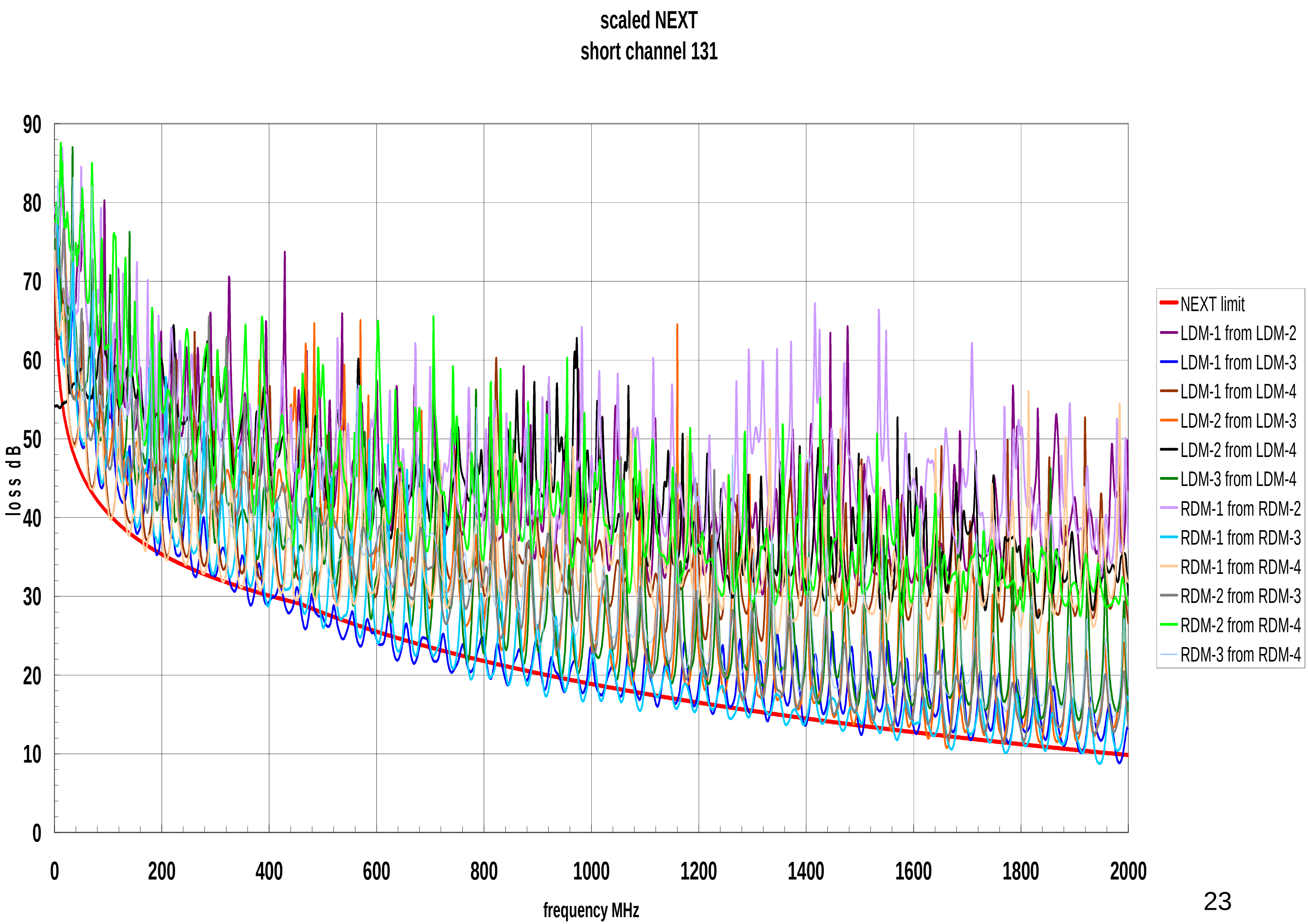
8. Combine the new magnitudes with the raw phase angles to make the scaled s-parameter result.


raw measured NEXT
loss dB
frequency MHz
0
10
20
30
40
50
60
70
80
90
0
200
400
600
800
1000
1200
1400
1600
1800
2000
NEXT limit
LDM-1 from LDM-2
LDM-1 from LDM-3
LDM-1 from LDM-4
LDM-2 from LDM-3
LDM-2 from LDM-4
LDM-3 from LDM-4
RDM-1 from RDM-2
RDM-1 from RDM-3
RDM-1 from RDM-4
RDM-2 from RDM-3
RDM-2 from RDM-4
RDM-3 from RDM-4


scaled NEXT
Note that some pairs NEXT are much worse than others.
Smoothing prevents a narrow band spike from dominating.
loss dB
frequency MHz
90
80
70
60
50
40
30
20
10
0
0
200
400
600
800
1000
1200
1400
1600
1800
2000
NEXT limit
LDM-1 from LDM-2
LDM-1 from LDM-3
LDM-1 from LDM-4
LDM-2 from LDM-3
LDM-2 from LDM-4
LDM-3 from LDM-4
RDM-1 from RDM-2
RDM-1 from RDM-3
RDM-1 from RDM-4
RDM-2 from RDM-3
RDM-2 from RDM-4
RDM-3 from RDM-4



raw measured NEXT
short channel 131
loss dB
frequency MHz
0
10
20
30
40
50
60
70
80
90
0
200
400
600
800
1000
1200
1400
1600
1800
2000
NEXT limit
LDM-1 from LDM-2
LDM-1 from LDM-3
LDM-1 from LDM-4
LDM-2 from LDM-3
LDM-2 from LDM-4
LDM-3 from LDM-4
RDM-1 from RDM-2
RDM-1 from RDM-3
RDM-1 from RDM-4
RDM-2 from RDM-3
RDM-2 from RDM-4
RDM-3 from RDM-4



scaled NEXT
short channel 131
loss dB
frequency MHz
90
80
70
60
50
40
30
20
10
0
0
200
400
600
800
1000
1200
1400
1600
1800
2000
NEXT limit
LDM-1 from LDM-2
LDM-1 from LDM-3
LDM-1 from LDM-4
LDM-2 from LDM-3
LDM-2 from LDM-4
LDM-3 from LDM-4
RDM-1 from RDM-2
RDM-1 from RDM-3
RDM-1 from RDM-4
RDM-2 from RDM-3
RDM-2 from RDM-4
RDM-3 from RDM-4

FEXT scaling

- Note: The ACRF and IL limit lines used for FEXT scaling are dependent on channel length.

FEXT scaling equations

1. Find the FEXT of all 12 pair combinations.
2. Calculate the 8 traces of PSFEXT, 4 in each direction.
3. Convert to linear.

$$PSFEXTlin(f) := 10^{-\frac{PSFEXT(f)}{20}}$$

4. Smooth over a window 50 MHz wide.

$$SMPSMfEXTlin(f) := \frac{\sum_{f = minf}^{maxf} PSfEXTlin(f)}{number\_of\_points\_from\_minf\_to\_maxf}$$

5. Convert back into dB

$$SMPSFEXT(f) := -20 \cdot \log(SMPSFEXTlin(f))$$

FEXT scaling equations 2

6. Calculate a length scaled PSACRF limit as follows:

$$PSACRFlim(f) := -20 \cdot \log\left(10^{\frac{A-3+10\cdot\log\left(\frac{30}{L}\right)-20\cdot\log\left(\frac{f}{100}\right)}{-20}} + 2\cdot 10^{\frac{B-3-20\cdot\log\left(\frac{f}{100}\right)}{-20}}\right)$$

Where A is the cable pair-to-pair ACRF requirement for a 30 m cable at 100 MHz, 39, and
B is the connector pair-to-pair FEXT requirement at 100 MHz, 43.1.
Both of these numbers are given in the TIA category 8 draft, and the equation above has been adapted from this draft.
In the above equation, the term

$$10\cdot\log\left(\frac{30}{L}\right)$$

scales the cable contribution for length, with L being the length. The cable and connector requirements are relaxed by 3 dB to account for power sum versus pair-to-pair effects.

FEXT Scaling Equations 3

7. Calculate the length dependant PSFEXT limit:

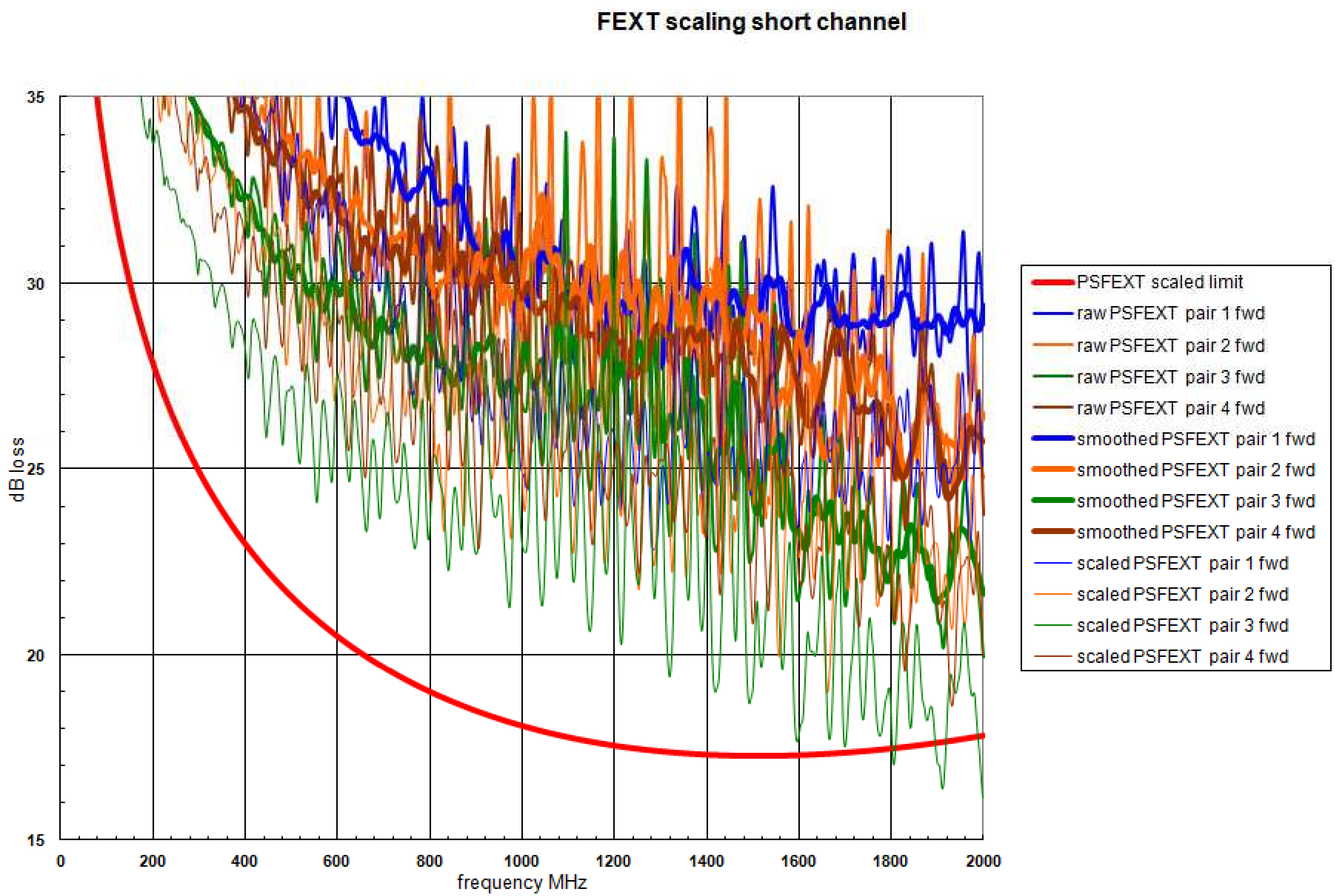
$$PSFEXTlim(f) := PSACRFlim(f) + ILLimit(f)$$

The ILLimit is also length dependant, from above.

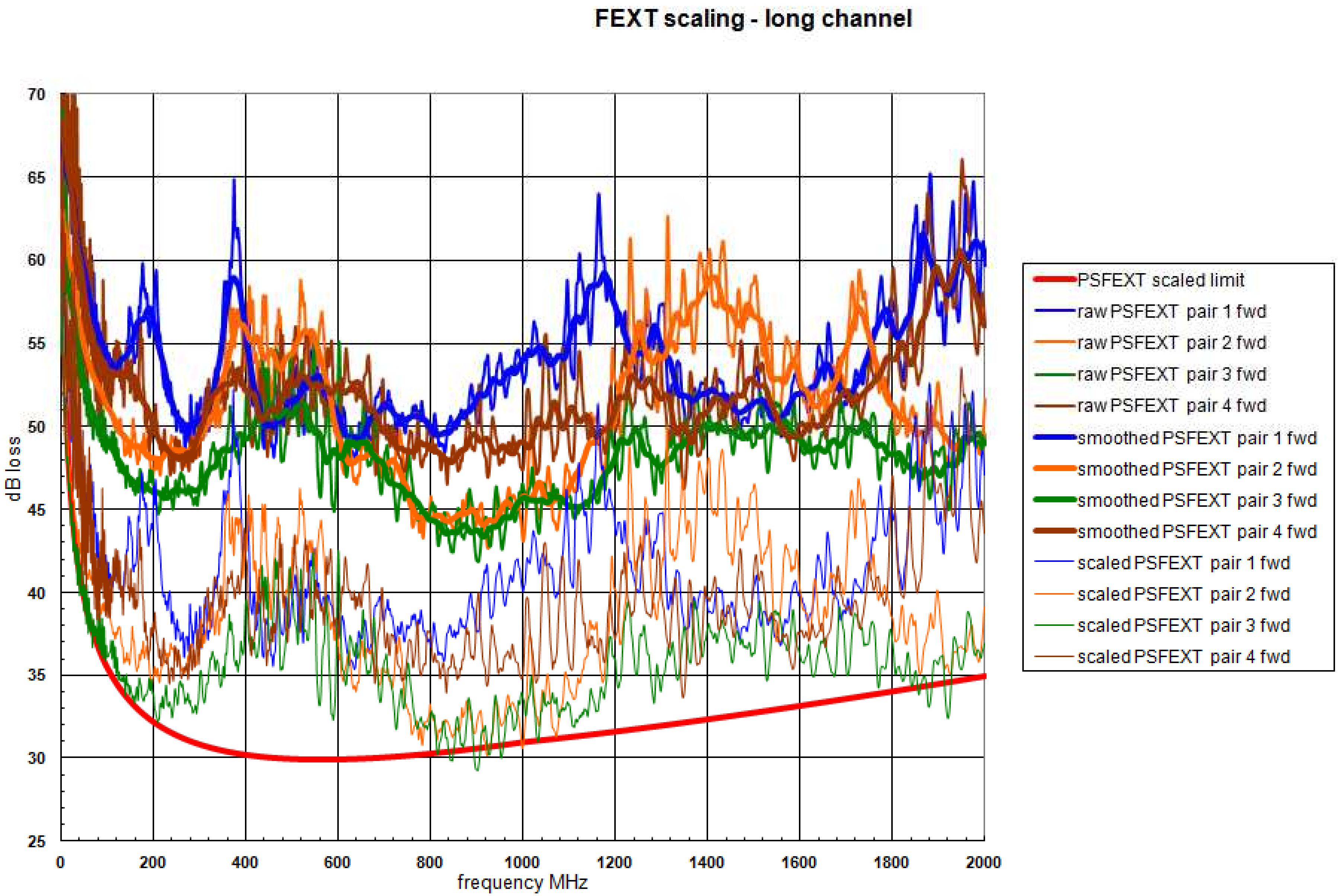
8. Calculate the minimum margin on any pair, at any frequency. Ignore frequencies below 50 MHz. Any negative margin shall be replaced with zero.

9. Adjust all 12 raw FEXT traces by subtracting this minimum margin from the magnitude in dB, same number for all pair combinations and all frequencies.

10. Combine this new magnitude with the raw measured phase to produce the scaled vector result.



FEXT scaling short channel
35
30
25
20
15
dB loss
0
200
400
600
800
1000
1200
1400
1600
1800
2000
frequency MHz
PSFEXT scaled limit
raw PSFEXT pair 1 fwd
raw PSFEXT pair 2 fwd
raw PSFEXT pair 3 fwd
raw PSFEXT pair 4 fwd
smoothed PSFEXT pair 1 fwd
smoothed PSFEXT pair 2 fwd
smoothed PSFEXT pair 3 fwd
smoothed PSFEXT pair 4 fwd
scaled PSFEXT pair 1 fwd
scaled PSFEXT pair 2 fwd
scaled PSFEXT pair 3 fwd
scaled PSFEXT pair 4 fwd



FEXT scaling - long channel
70
65
60
55
50
45
40
35
30
25
dB loss
0
200
400
600
800
1000
1200
1400
1600
1800
2000
frequency MHz
PSFEXT scaled limit
raw PSFEXT pair 1 fwd
raw PSFEXT pair 2 fwd
raw PSFEXT pair 3 fwd
raw PSFEXT pair 4 fwd
smoothed PSFEXT pair 1 fwd
smoothed PSFEXT pair 2 fwd
smoothed PSFEXT pair 3 fwd
smoothed PSFEXT pair 4 fwd
scaled PSFEXT pair 1 fwd
scaled PSFEXT pair 2 fwd
scaled PSFEXT pair 3 fwd
scaled PSFEXT pair 4 fwd

Summary

- A method has been described to scale measured data to a worst case, approximating the limit line
  - Uses length dependant limits for IL and ACRF
  - Uses smoothing to prevent large effects of narrow frequency spikes
- Given the limited number of measurements available, this method should be used for robust PHY analysis and development

Backup Material

Insertion Loss Scaling

Note: The limit line for insertion loss scaling is dependent on channel length.

1. Convert the IL data to dB.
2. Ignore data below 10 MHz.
3. Subtract the data from the length scaled limit line.
4. Divide the result by the square root of frequency.
5. Find the minimum value for each pair (the “scaling factor”).
6. Since enhancement of IL is not allowed, replace any values greater than zero with zero.
7. For each of the four pairs separately, multiply the scaling factor by the square root of frequency, and add to the insertion loss.
8. Combine this resulting insertion loss magnitude with the raw measured insertion loss phase to produce the scaled insertion loss.

Return Loss Scaling

1. Smooth the return loss response:
    1. Convert the RL to linear magnitude
    2. Average the RL over a window 100 MHz wide.
2. Convert the smoothed return loss to dB.
3. Add 3 dB to the return loss limit line, to take into account that the average return loss is greater than the minimum return loss.
4. Subtract the new limit line from the smoothed return loss.
5. Since enhancement is not allowed, replace any values greater than zero with zero.
6. For each pair in each direction, find the minimum margin at any frequency (total of 8 minima).
7. Subtract these margin (8 negative numbers) from the measured dB value of each measured (not smoothed) return loss.
8. Combine these magnitudes with the raw measured return loss phases to get the scaled return loss.

NEXT scaling

1. Find the power sum NEXT of each pair in each direction.
2. Smooth the PSNEXT:
    1. Convert to a linear amount.
    2. Average over a window 100 MHz wide.
    3. Convert back into dB.
3. Subtract the PSNEXT limit from the smoothed PSNEXT.
4. Since enhancement is not allowed, replace any values greater than zero with zero.
5. Ignoring frequencies below 50 MHz, find the minimum value of step 3 above for any pair at any frequency.
6. Subtract this margin (a negative number) from all the unsmoothed PSNEXT traces, the same adjustment for all traces. This results in scaled PSNEXT magnitudes.
7. Converting the measured NEXT to dB, also subtract this same margin from the raw measured NEXT.
8. Combine this with the raw measured NEXT phase to get the scaled NEXT.