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Trace Design For Crosstalk Reduction

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INTRODUCTION

- Crosstalk requirements review
  - Tx-to-Tx
  - Rx-to-Rx
  - Tx-to-Rx
- Stripline
- Dual-Stripline
- Microstrip

Forward and Reverse Crosstalk

Forward Crosstalk

- $Kf = \frac{1}{2}\left(\frac{Cm}{Ctotal} - \frac{Lm}{Ltotal}\right)$

Backward (Reverse) crosstalk

- $Kb = \frac{1}{4}\left(\frac{Cm}{Ctotal} + \frac{Lm}{Ltotal}\right)$

- Cm = Mutual Capacitance
- Lm = Mutual Inductance
- Ctotal = Total Capacitance
- Ltotal = Total Inductance

In mode-balanced transmission lines (i.e. stripline) the ratio of Cm/Ctotal and Lm/Ltotal are equal, canceling all forward crosstalk, and leaving only reverse crosstalk to contend with.

For microstrip, inductance and capacitance are not balanced, due to mode separation. As a result, forward crosstalk can be significant.

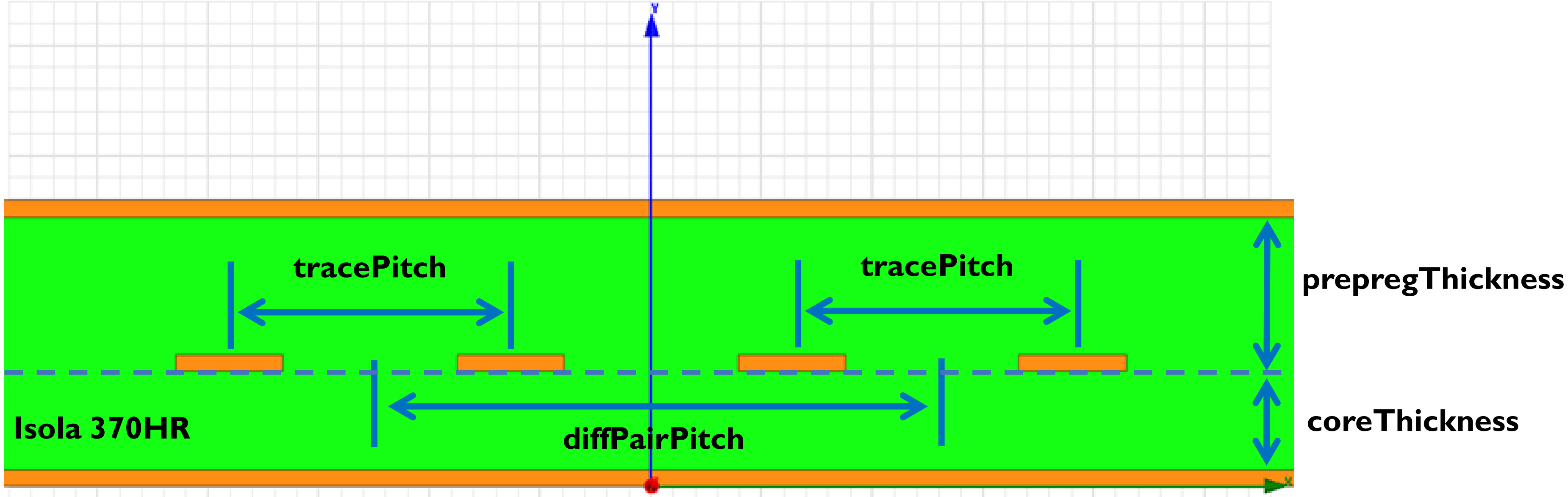
Kf = Forward crosstalk = Forward traveling wave. Kf scales with length and risetime

FEXT = Crosstalk received at far end of line. This is a combination of forward crosstalk and reflected reverse crosstalk.

Kb = Backward crosstalk = Reverse traveling wave. Amplitude reaches maximum at risetime. Area under curve increases with length.

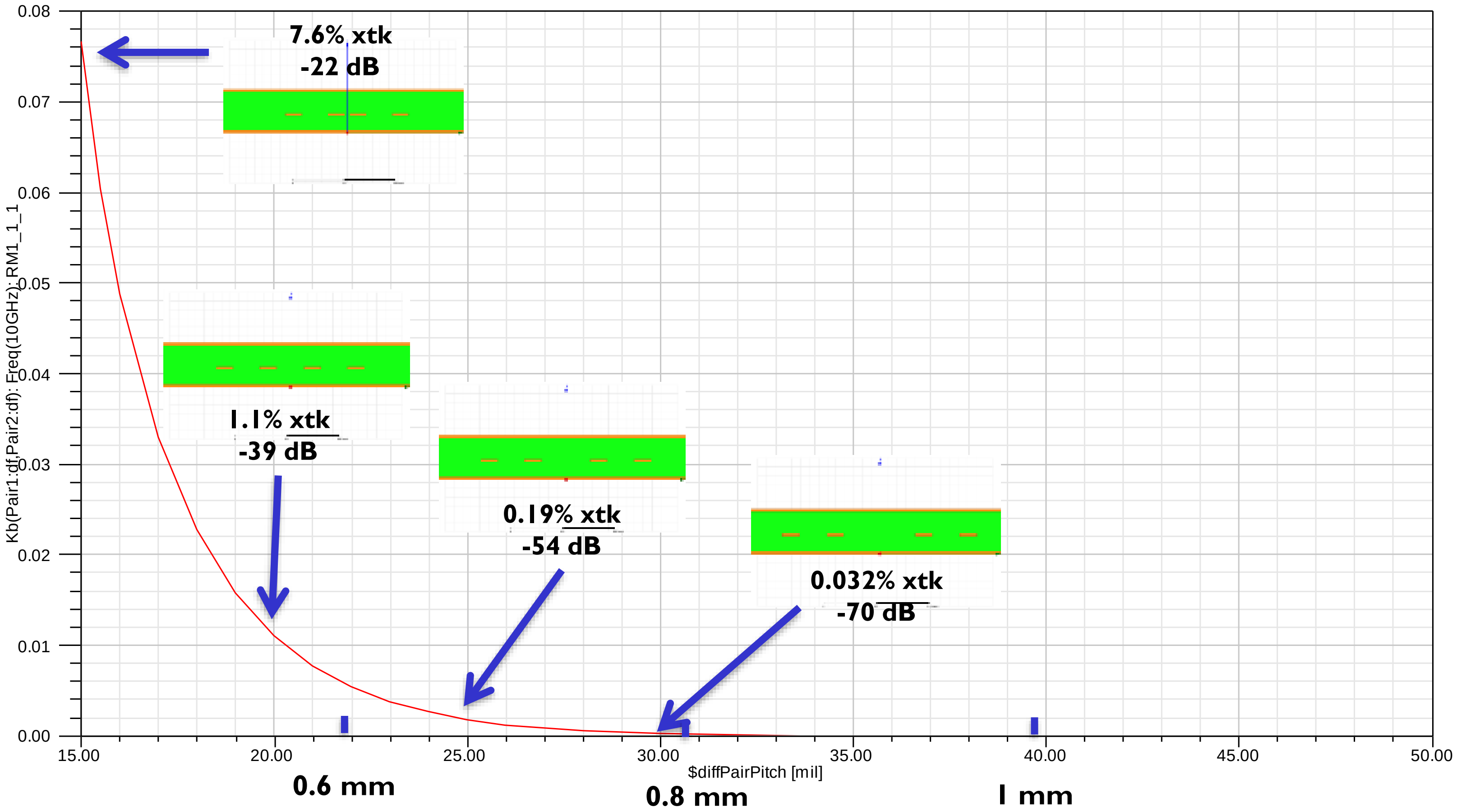
NEXT = Crosstalk received at near end of line. This is predominantly reverse crosstalk.

Offset Differential Stripline



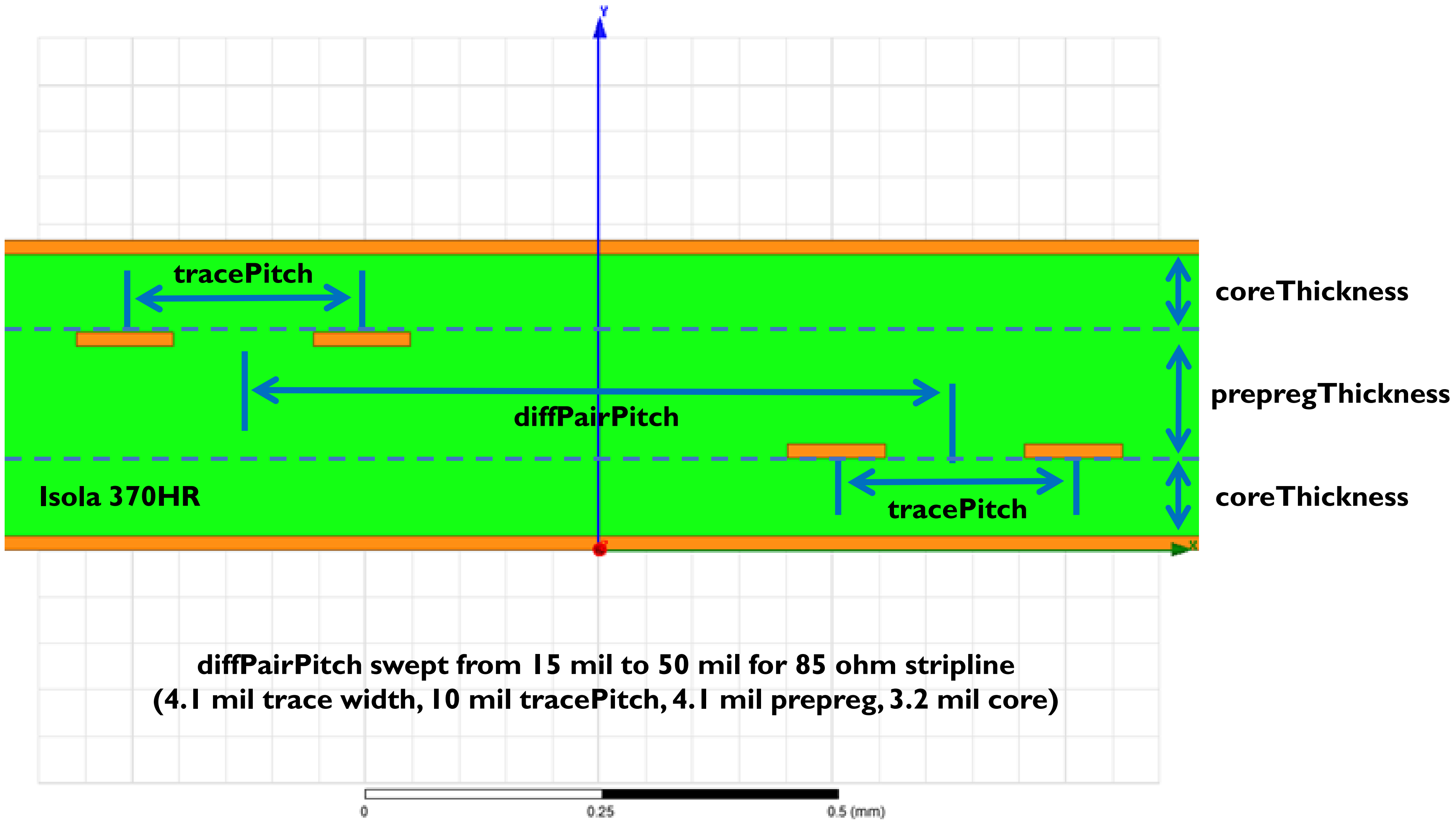
diffPairPitch swept from 15 mil to 50 mil for 85 ohm stripline in Ansys 2D quasi-static FEM solver.
(3.8 mil trace width, 10 mil tracePitch, 4.9 mil prepreg, 3.5 mil core)

Offset Stripline
Reverse Crosstalk vs Differential Pair Pitch



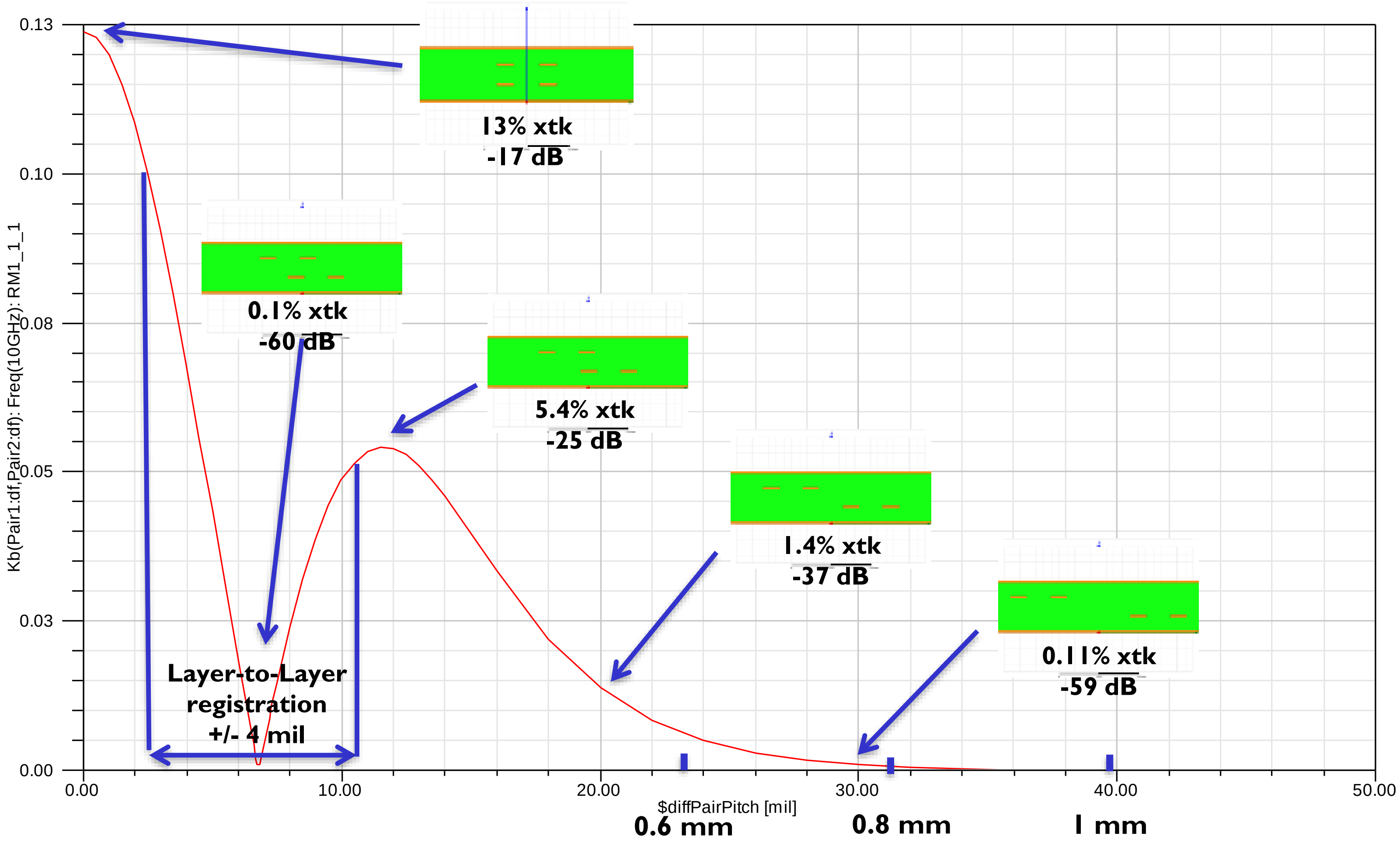
diffPairpitch swept from 0 mil to 50 mil for 85 ohm stripline in Ansys 2D quasi-static FEM solver.
(4.1 mil trace width, 10 mil tracePitch)

Broadside Dual-Differential Stripline



diffPairPitch swept from 15 mil to 50 mil for 85 ohm stripline
(4.1 mil trace width, 10 mil tracePitch, 4.1 mil prepreg, 3.2 mil core)

Broadside Dual-Differential Stripline Reverse Crosstalk vs Differential Pair Pitch



diffPairpitch swept from 0 mil to 50 mil for 85 ohm stripline (4.1 mil trace width, 10 mil tracePitch)

Broadside Dual-Differential Stripline Crosstalk Isolation

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Broadside stripline seen in stackups with dual-stripline layers have increased crosstalk coefficients due to coupling from larger cross-sectional area.

- This creates the potential for extremely high crosstalk.

In addition, PCB manufacturing tolerance exacerbates the problem, as traces on dual-stripline layers can be mis-registered by as much as +/- 4 mil.

- As a result, spacing to meet crosstalk requirements must be guard banded by 4 mil for broadside coupled dual-stripline layers.

System Crosstalk Requirements
Tx-to-Rx Crosstalk Isolation (Reverse Direction)

Reverse Crosstalk of a Maximum Amplitude Driver Against an Attenuated Receive Signal

- For most long reach standards, -60 dB is the acceptable level of received crosstalk allowed at the receiver. (YMMV)
- Since traces are not the only source of crosstalk in a system, we would like to set our allowable trace-to-trace crosstalk to 4 times lower (-72 dB), to account for 2 aggressors, and additional sources of noise in packages, vias, and connectors.

System Crosstalk Requirements Tx-to-Tx and Rx-to-Rx Crosstalk Isolation (Forward Direction)

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Forward crosstalk for differential stripline is essentially negligible.

- When there is forward crosstalk due to anisotropy, reflected near end crosstalk generally dominates.

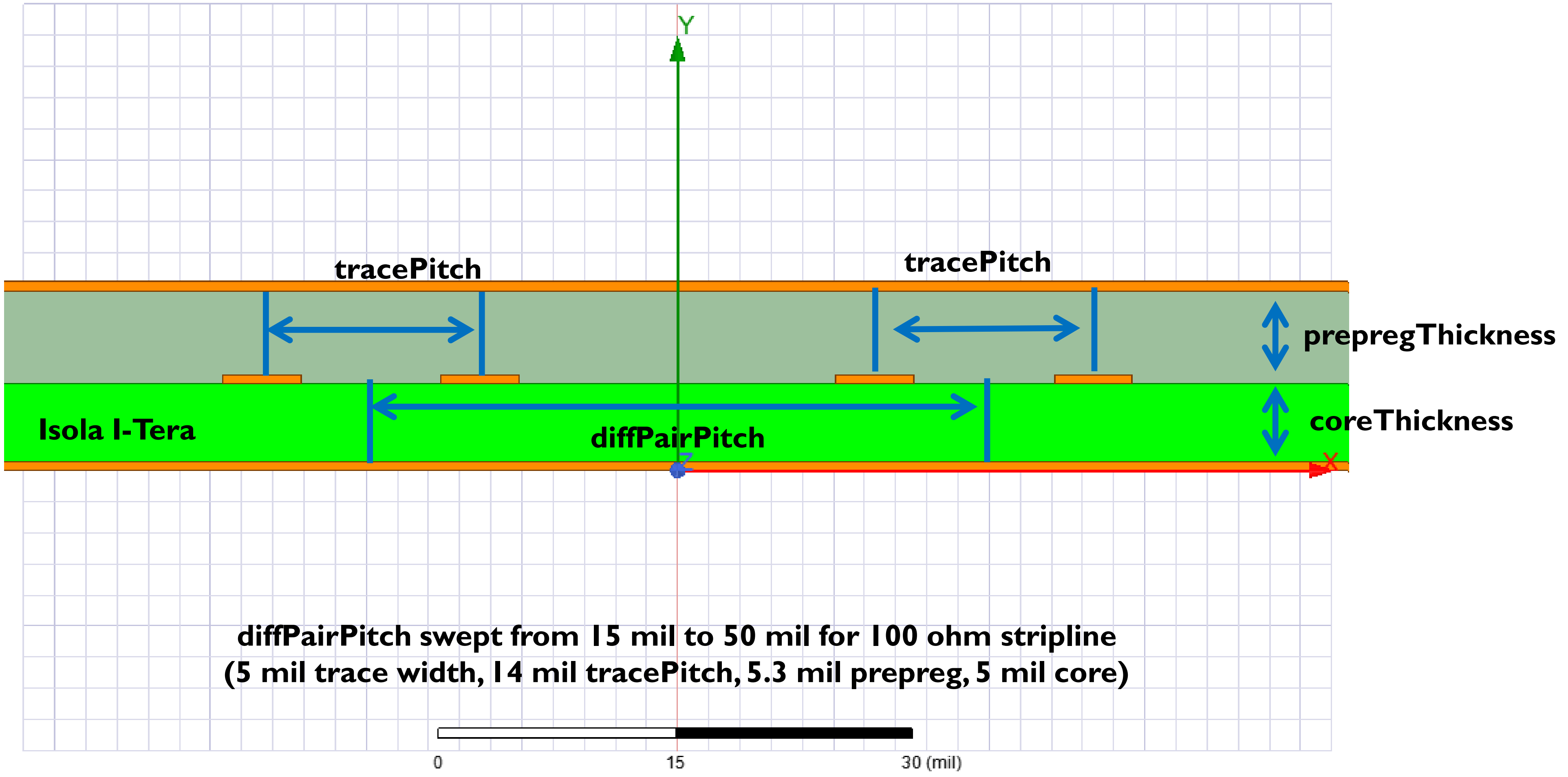
Reverse crosstalk is the important isolation parameter, and saturates (reaches a maximum magnitude) when the coupled section is one signal rise time long.

- For modern silicon this occurs within about 100 mils of trace length
- For Tx-to-Tx aggression, or Rx-to-Rx reverse crosstalk appears at the receiver as a result of reflection due to discontinuities and imperfect termination.
- Generally these reflections represent less than 10% of the signal energy (-20 dB).
- Reverse crosstalk for these "same direction" aggressors is therefore further attenuated by -20 dB, as seen by the receiver.

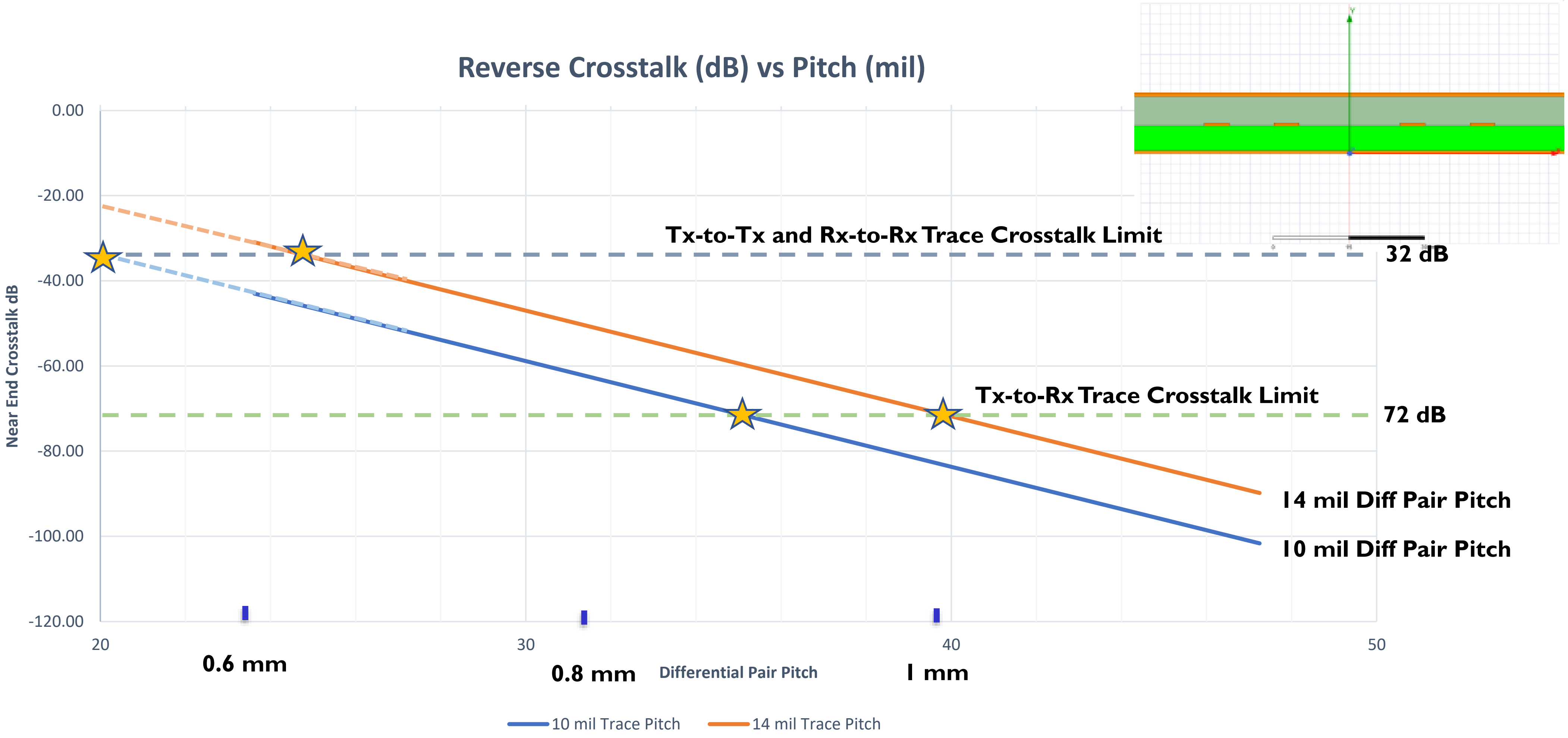
For most standards, -40 dB is the acceptable level of received crosstalk allowed at the receiver. (YMMV)

- Since traces are not the only source of crosstalk in a system, we would like to set our allowable trace-to-trace crosstalk to 4 times lower (-32 dB), to account for 2 aggressors, and additional sources of noise in packages, vias, and connectors.
- For reflected reverse crosstalk, this amounts to a -32 dB effective limit.
- For forward crosstalk, -52 dB is still the limit.

Stripline

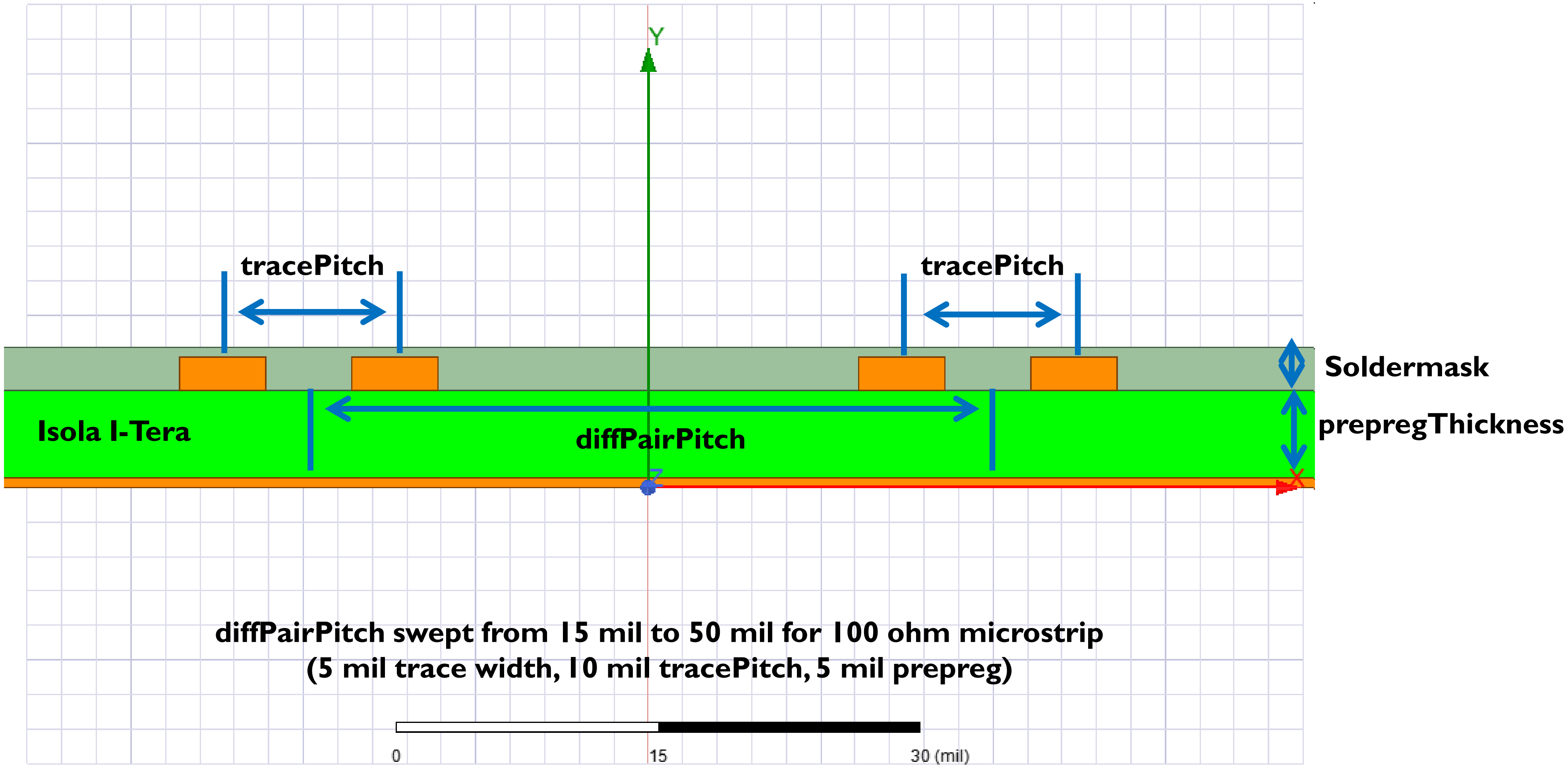

Y
tracePitch
tracePitch
prepregThickness
Isola I-Tera
diffPairPitch
coreThickness
X
diffPairPitch swept from 15 mil to 50 mil for 100 ohm stripline
(5 mil trace width, 14 mil tracePitch, 5.3 mil prepreg, 5 mil core)
0
15
30 (mil)

Differential Stripline
Reverse Crosstalk vs Differential Pair Pitch



diffPairpitch swept from 22 mil to 48 mil for 100 ohm stripline.
(4.1 mil trace width, 10 mil tracePitch)

Differential Microstrip



diffPairPitch swept from 15 mil to 50 mil for 100 ohm microstrip (5 mil trace width, 10 mil tracePitch, 5 mil prepreg)

Differential Microstrip w/ Soldermask Reverse Crosstalk vs Differential Pair Pitch

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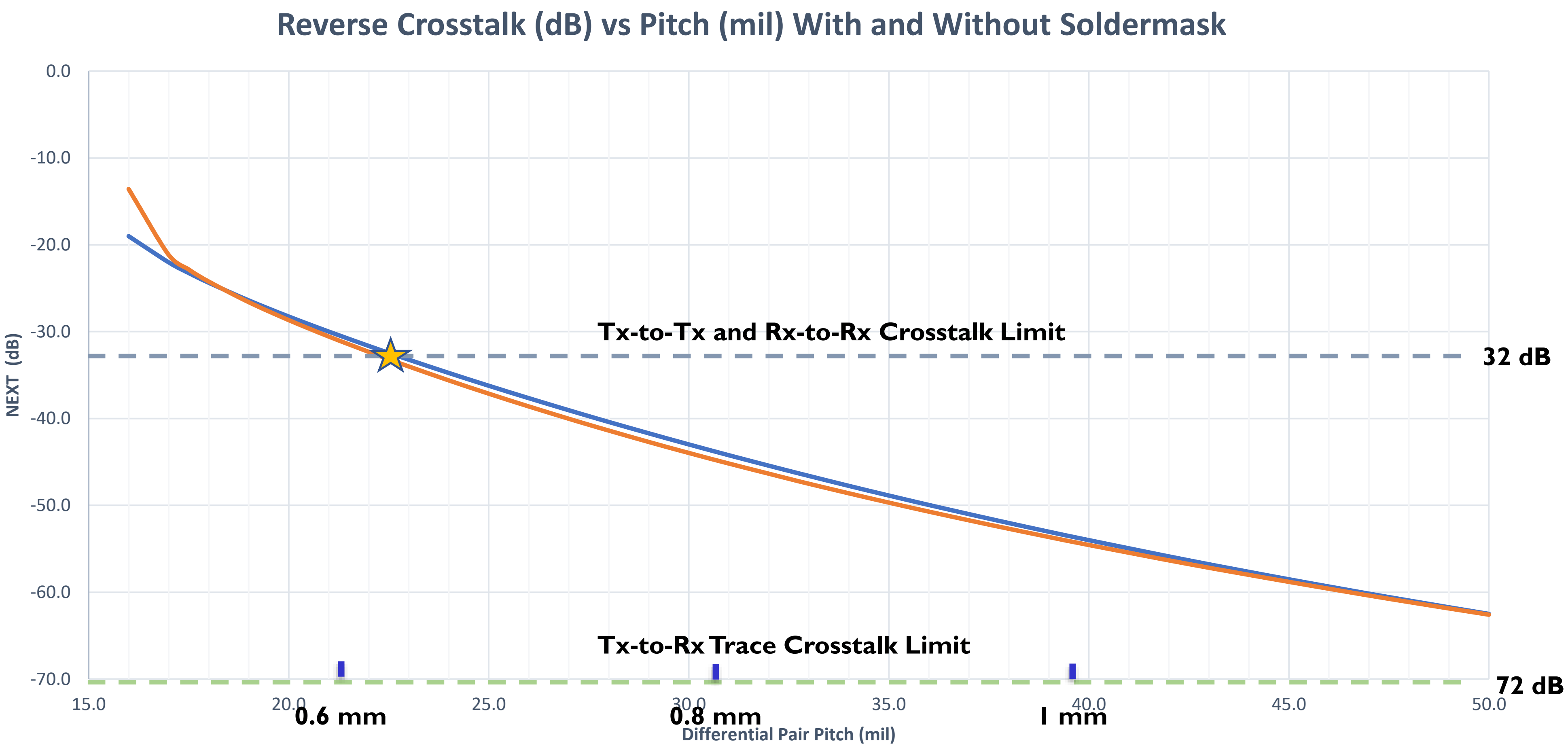

diffPairpitch swept from 16 mil to 58 mil for 100 ohm microstrip.
(5 mil Trace Width, 10 mil Trace Pitch)

Differential Microstrip with Soldermask Forward Crosstalk vs Differential Pair Pitch

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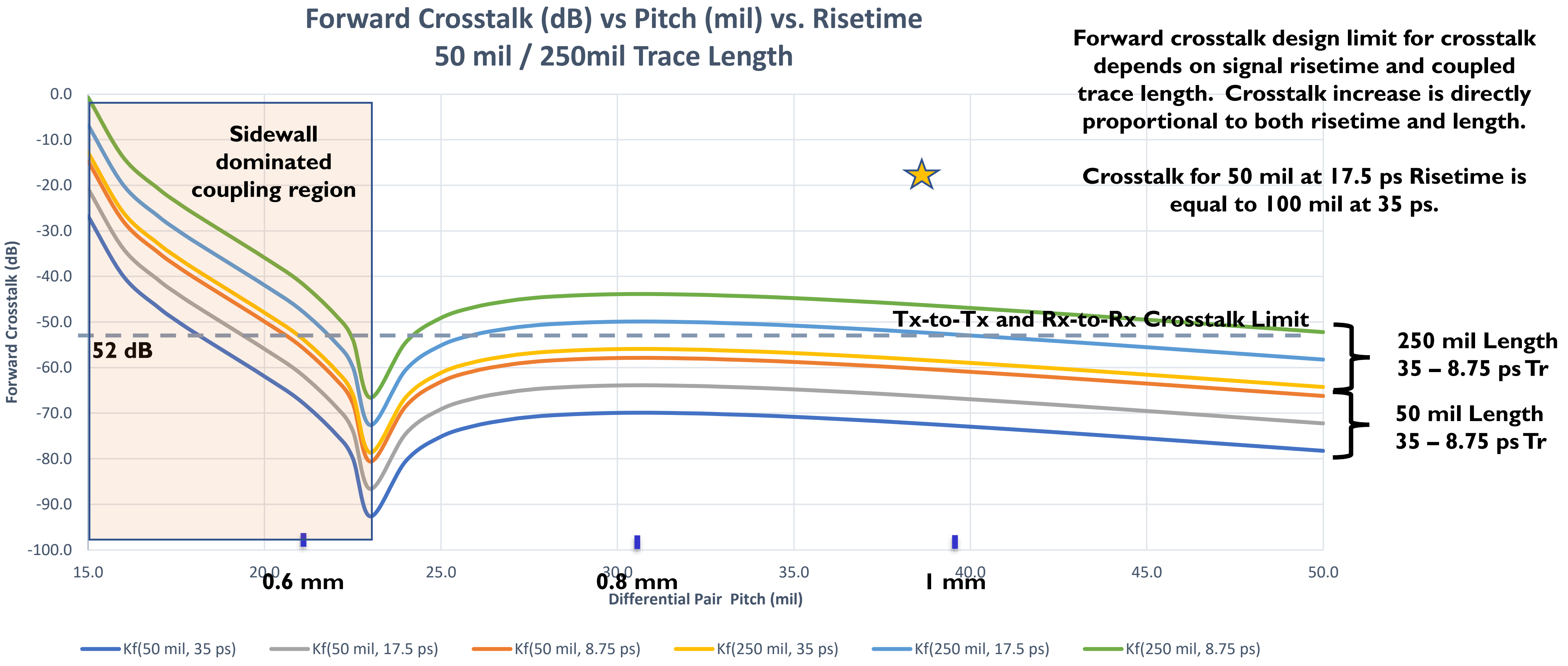

Forward crosstalk design limit for crosstalk depends on signal risetime and coupled trace length. Crosstalk increase is directly proportional to both risetime and length.

Crosstalk for 50 mil at 17.5 ps Risetime is equal to 100 mil at 35 ps.

diffPairpitch swept from 15 mil to 50 mil for 100 ohm microstrip.

Summary

For a robust trace crosstalk design limit pick a desired limit and add -12 dB to it to account for all sources.

For far end crosstalk control for -40 dB total.

- -52 dB forward crosstalk
- -32 dB reflected reverse crosstalk

For near end crosstalk control -60 dB total.

- -72 dB reverse crosstalk

Stripline crosstalk design is relatively straight forward, since reverse crosstalk dominates.

Microstrip crosstalk is much more difficult (and hideous), because both forward and reverse crosstalk are generated and are additive at the receiver.

- Maximum coupling length to achieve controlled forward crosstalk is quite small, limiting trace length in high performance system to breakout-only lengths.

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