Ansys INNOVATION CONFERENCE 2020

# Novel Skew Compensation Techniques for Reducing EMI from Differential Traces

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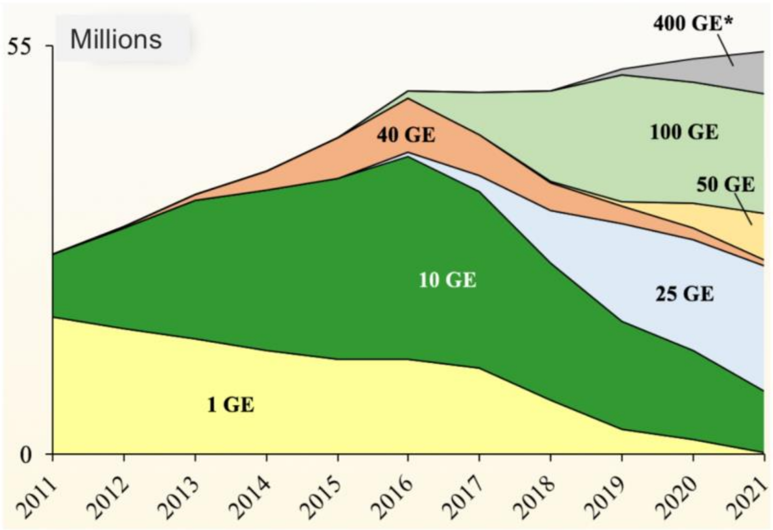
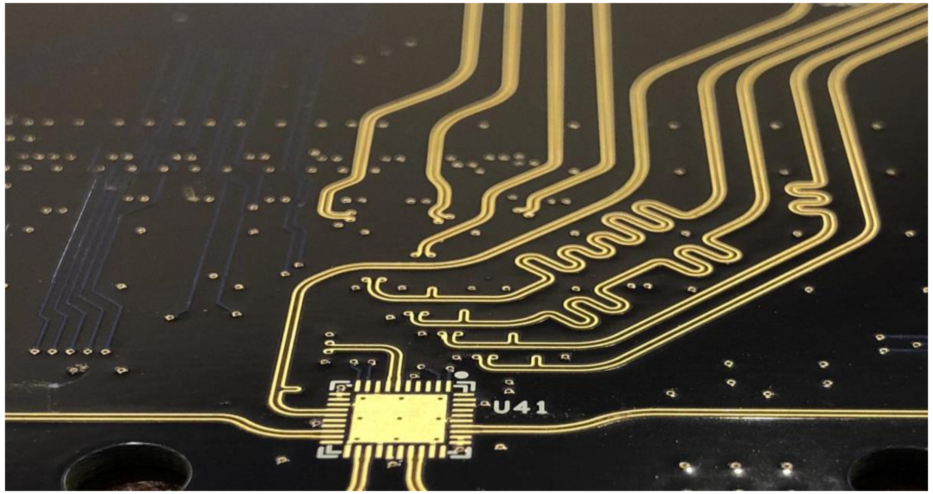
# Background

- The switch port speed goes higher to 100G, 400G, etc.
- Differential pairs are commonly used in high speed switch design
- EMI benefits diminish if there is any imbalance in differential routing
- The skew due to bend is the main imbalance
- Current skew compensation techniques are not optimized



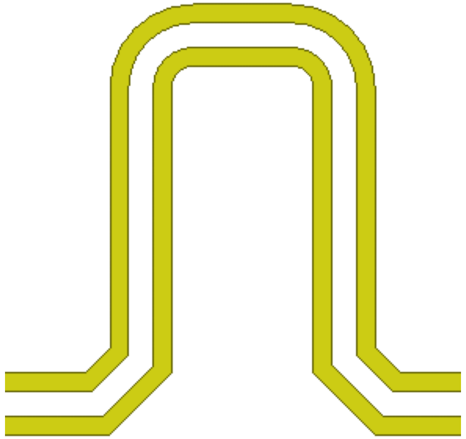

Source: DELL'ORO GROUP



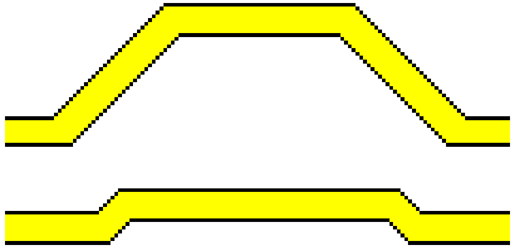
# Three Skew Compensation Techniques for Reducing EMI from Differential Traces

- Hybrid U Turn(HUT), Published in APEMC2017
- Asymmetric Dual Bend(ADB) structure for skew compensation,

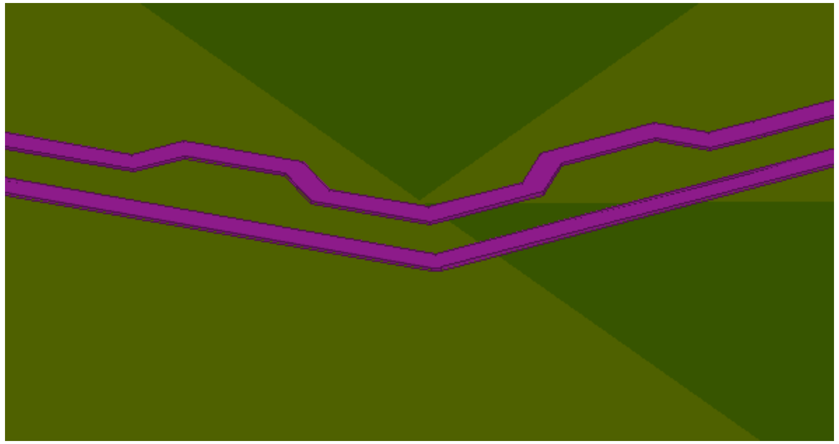
  Patent pending in USPTO, Paper accepted by 2020 IEEE International Symposium on EMC/SI/PI
- Localized skew compensation technique for reducing EMI(WBWC), **US Patent US 8835775 B2**



HUT



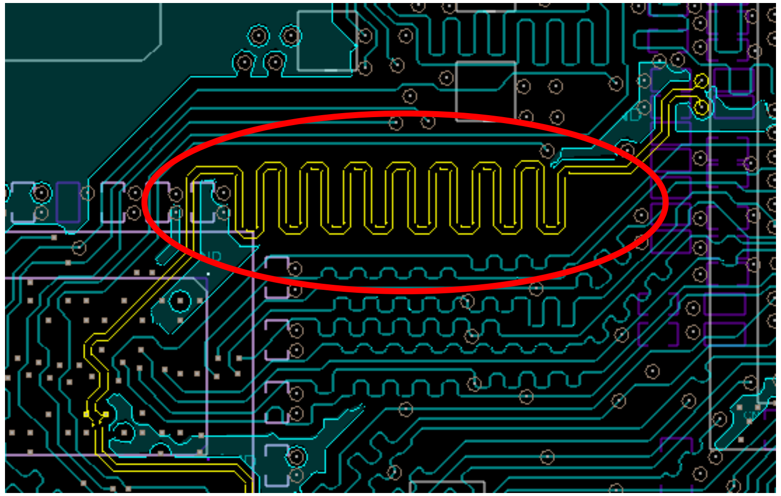
ADB



WBWC

# Hybrid U Turn ---- Background

1



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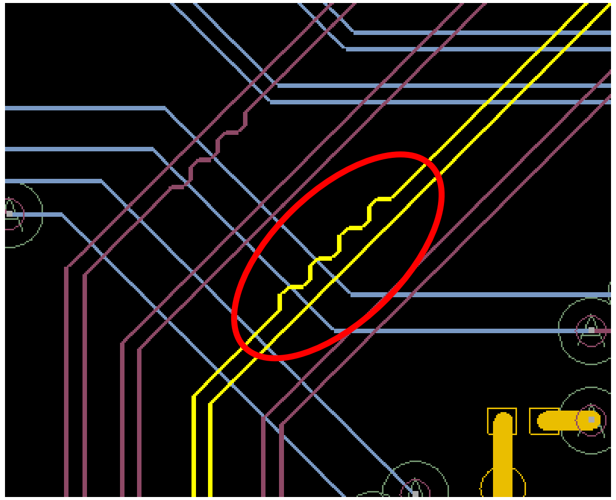

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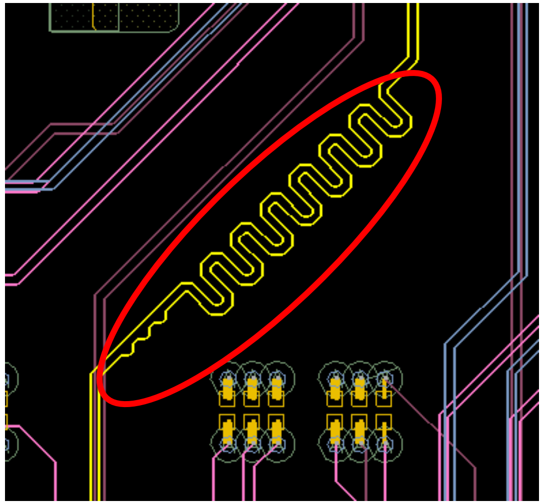
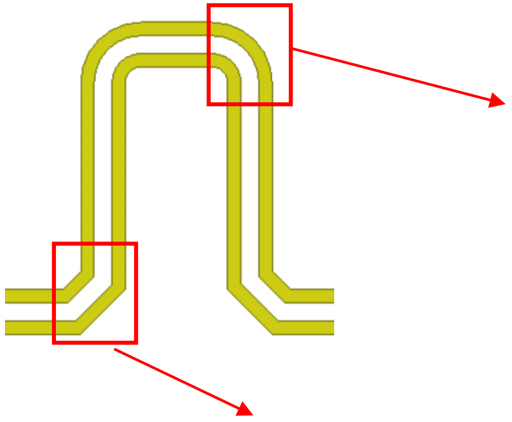
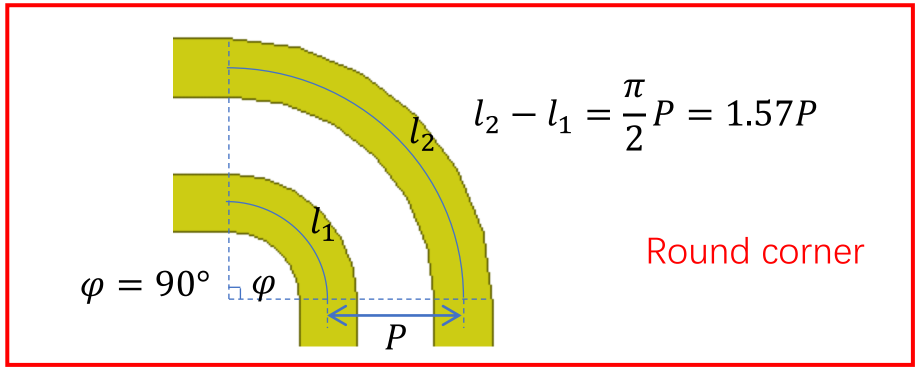
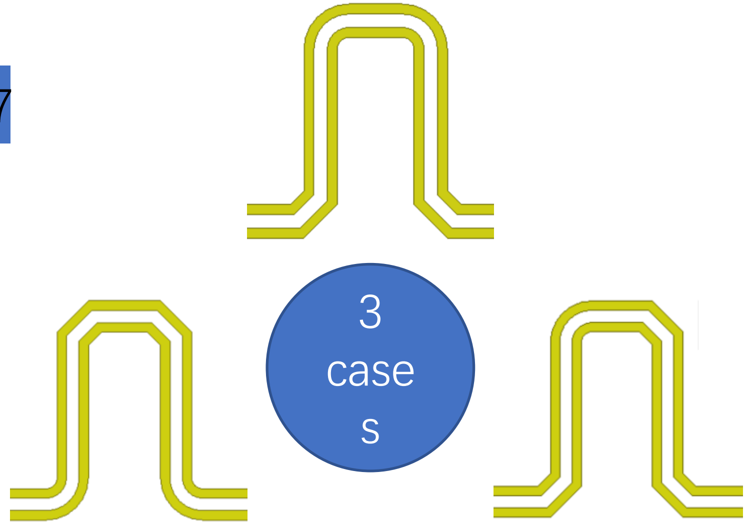


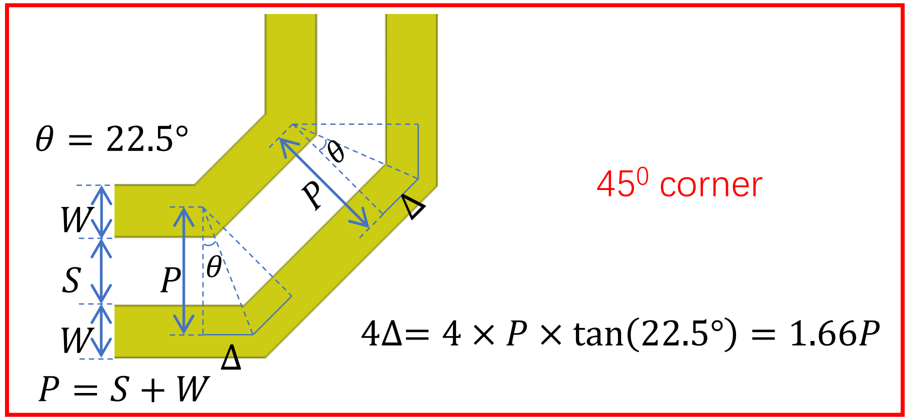
# Hybrid U Turn ---- illustration

Published in APEMC2017



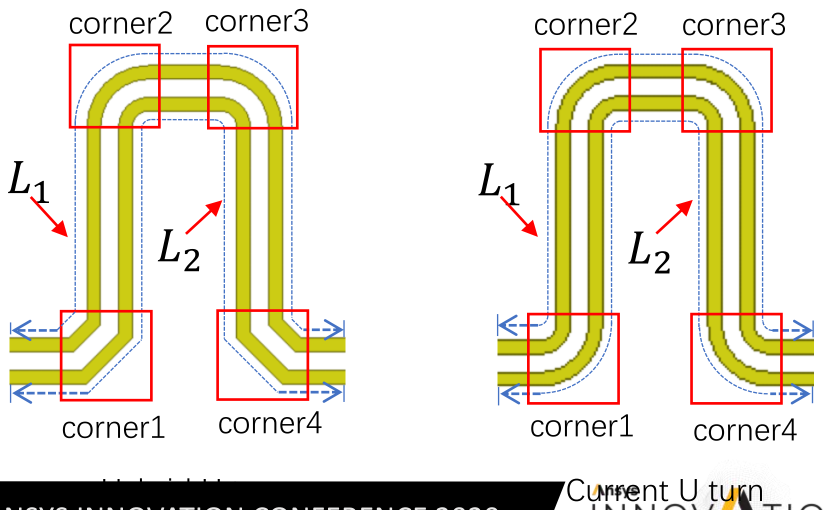


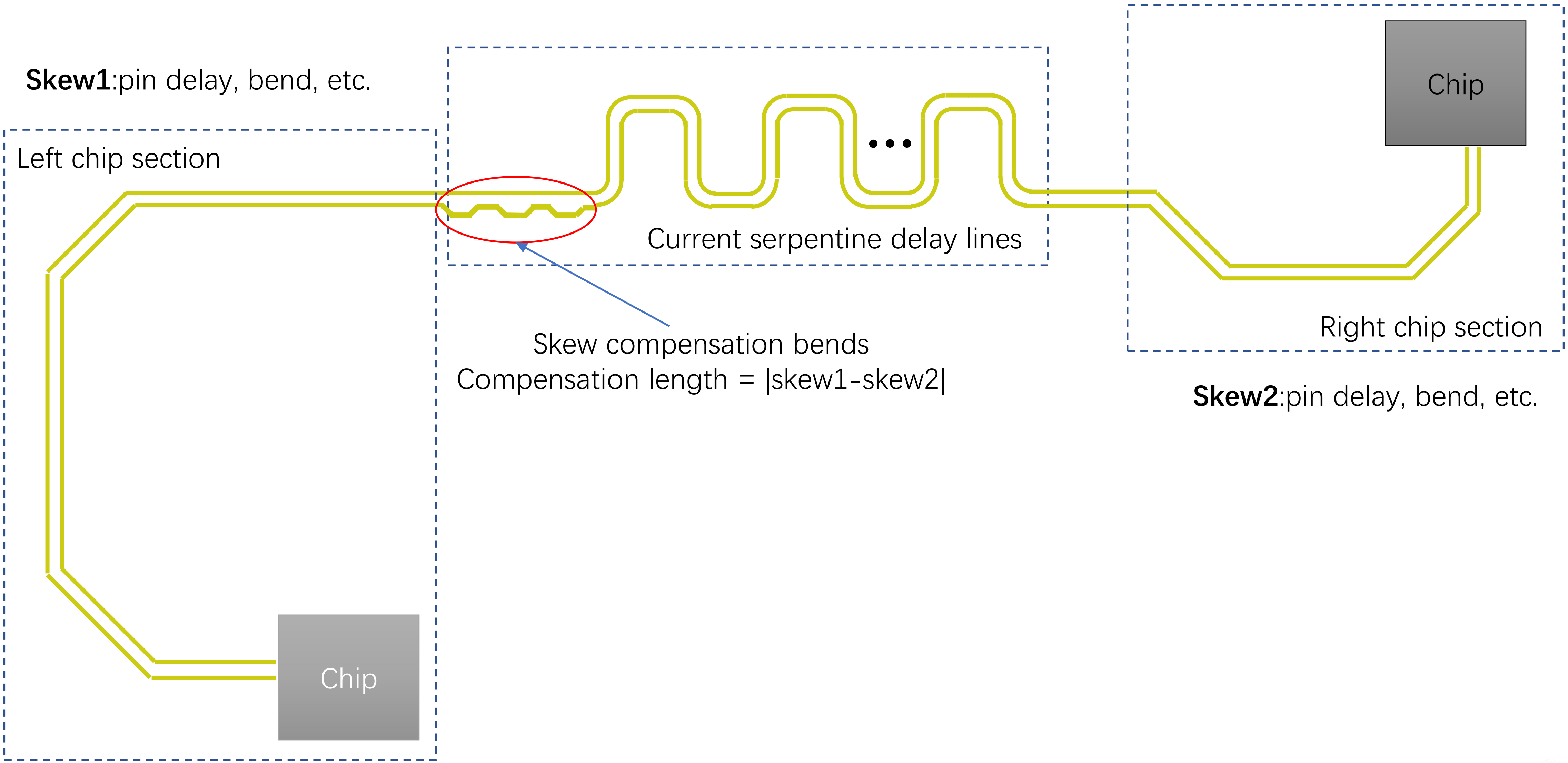




Two functions in one symbol:

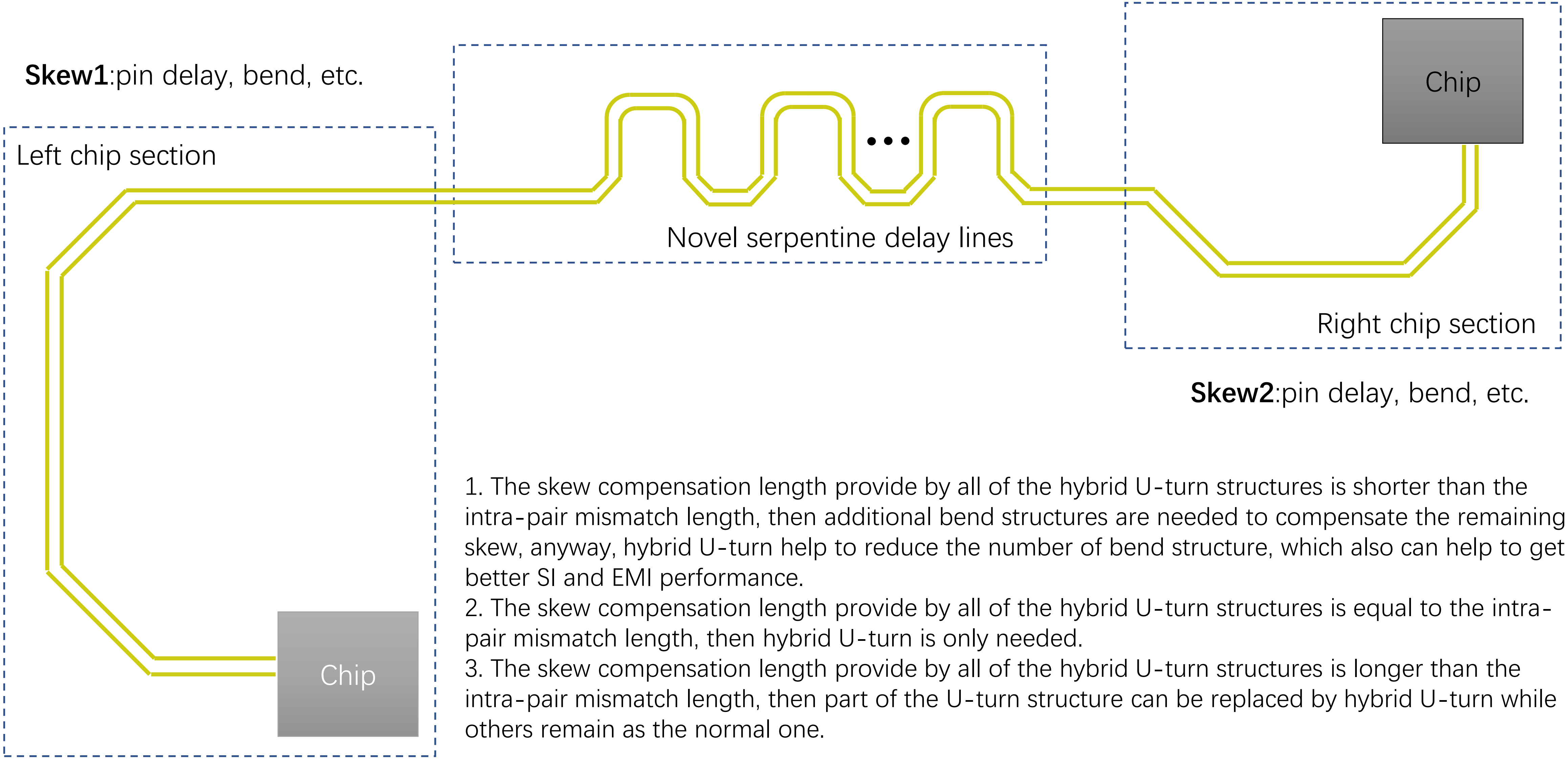
1. Tune time budget or keep the same length with other channels
2. Mitigate skew in its channel, one symbol get $0.18P$ skew compensation



# Hybrid U Turn ---- Current routing scheme

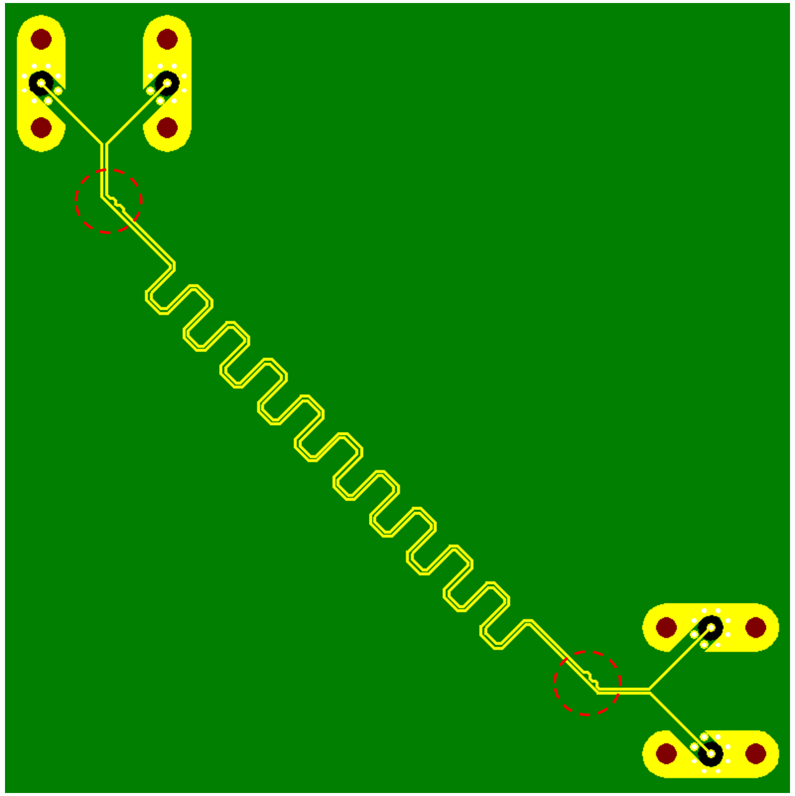


# Hybrid U Turn ---- Routing with Hybrid U-Turn

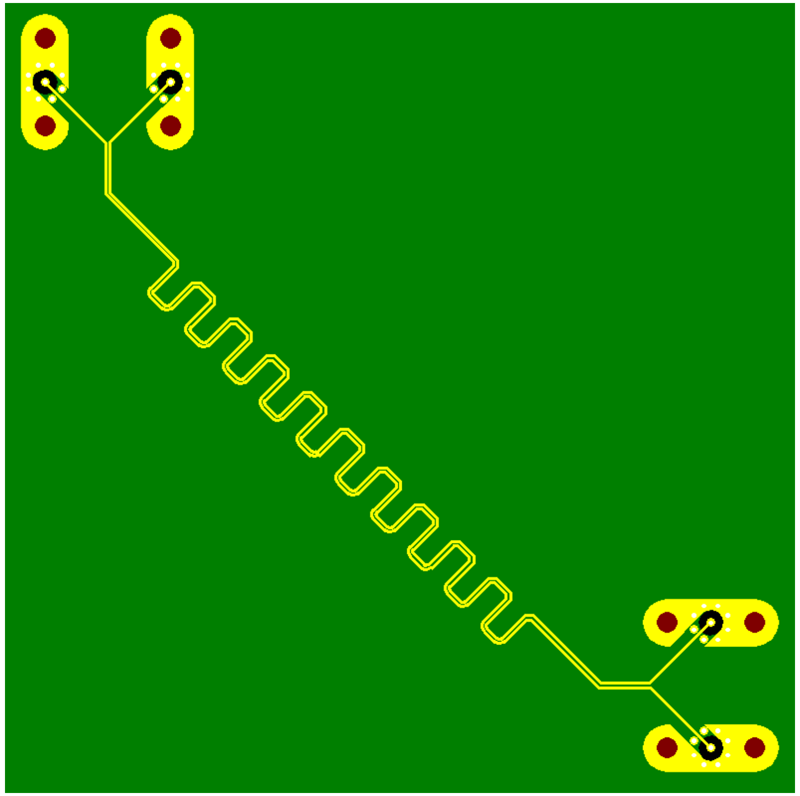



1. The skew compensation length provide by all of the hybrid U-turn structures is shorter than the intra-pair mismatch length, then additional bend structures are needed to compensate the remaining skew, anyway, hybrid U-turn help to reduce the number of bend structure, which also can help to get better SI and EMI performance.
2. The skew compensation length provide by all of the hybrid U-turn structures is equal to the intra-pair mismatch length, then hybrid U-turn is only needed.
3. The skew compensation length provide by all of the hybrid U-turn structures is longer than the intra-pair mismatch length, then part of the U-turn structure can be replaced by hybrid U-turn while others remain as the normal one.

# Hybrid U Turn ---- Simulation model

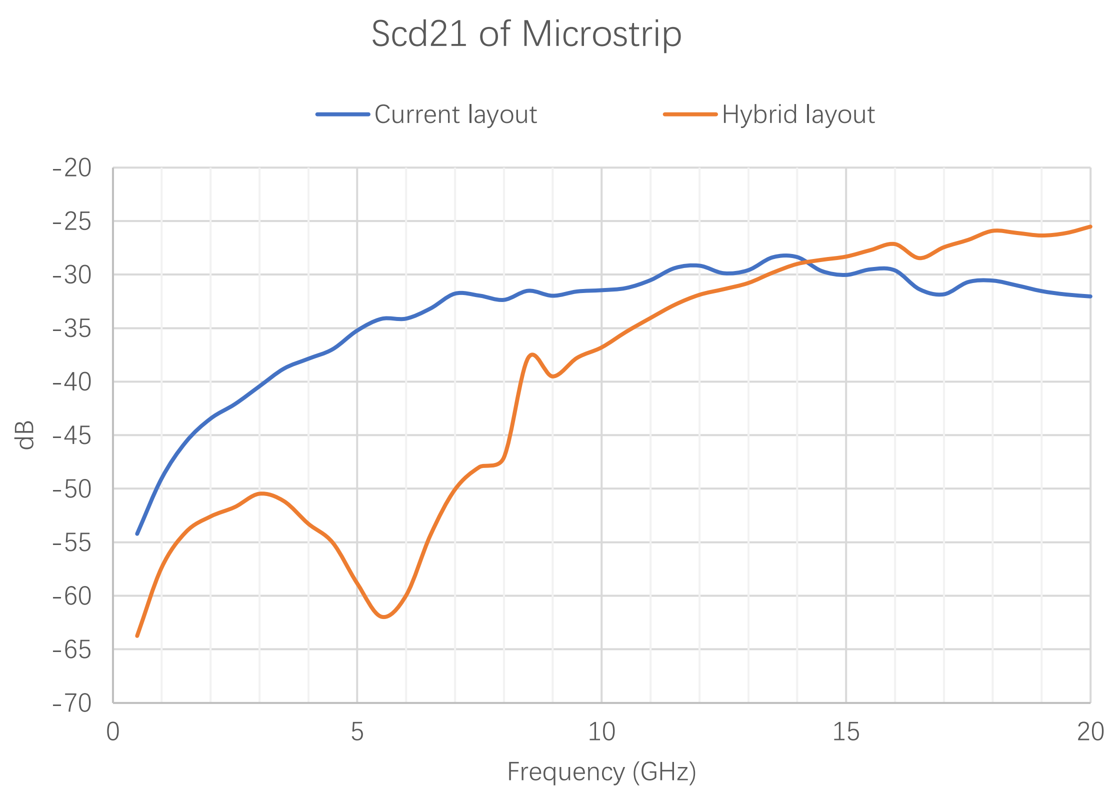


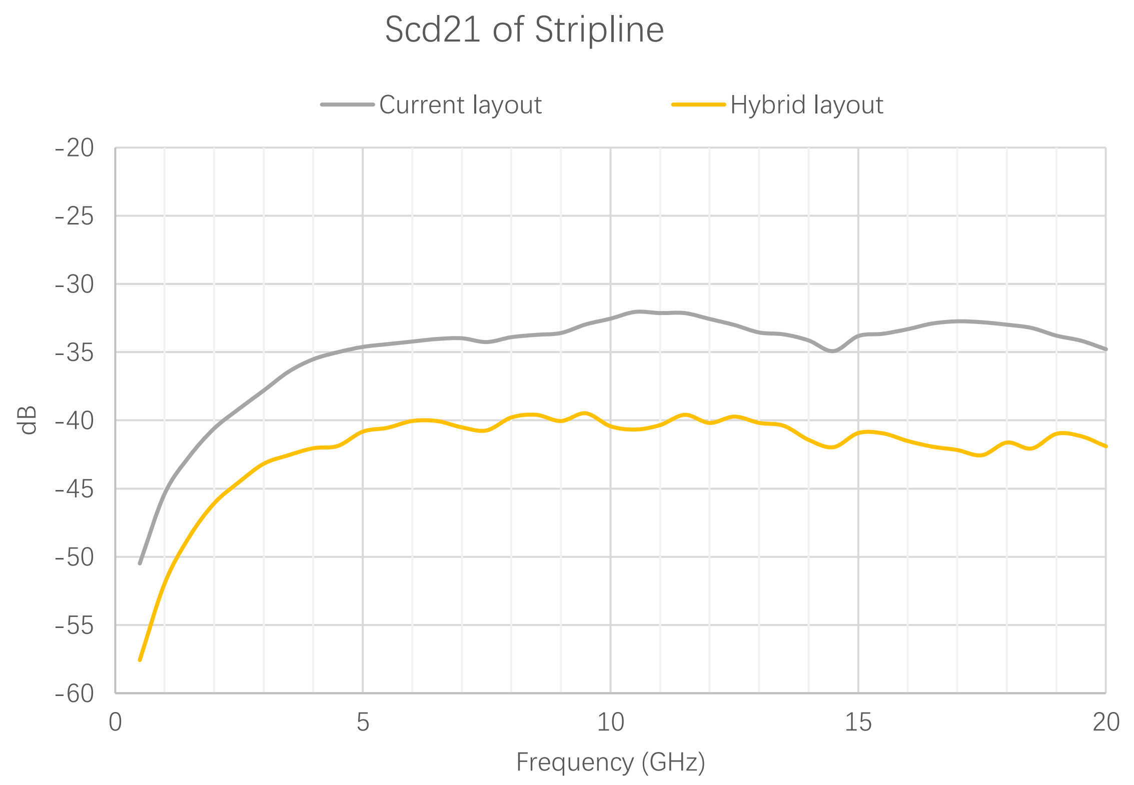
Current layout



Hybrid layout

# Hybrid U Turn ---- Scd21

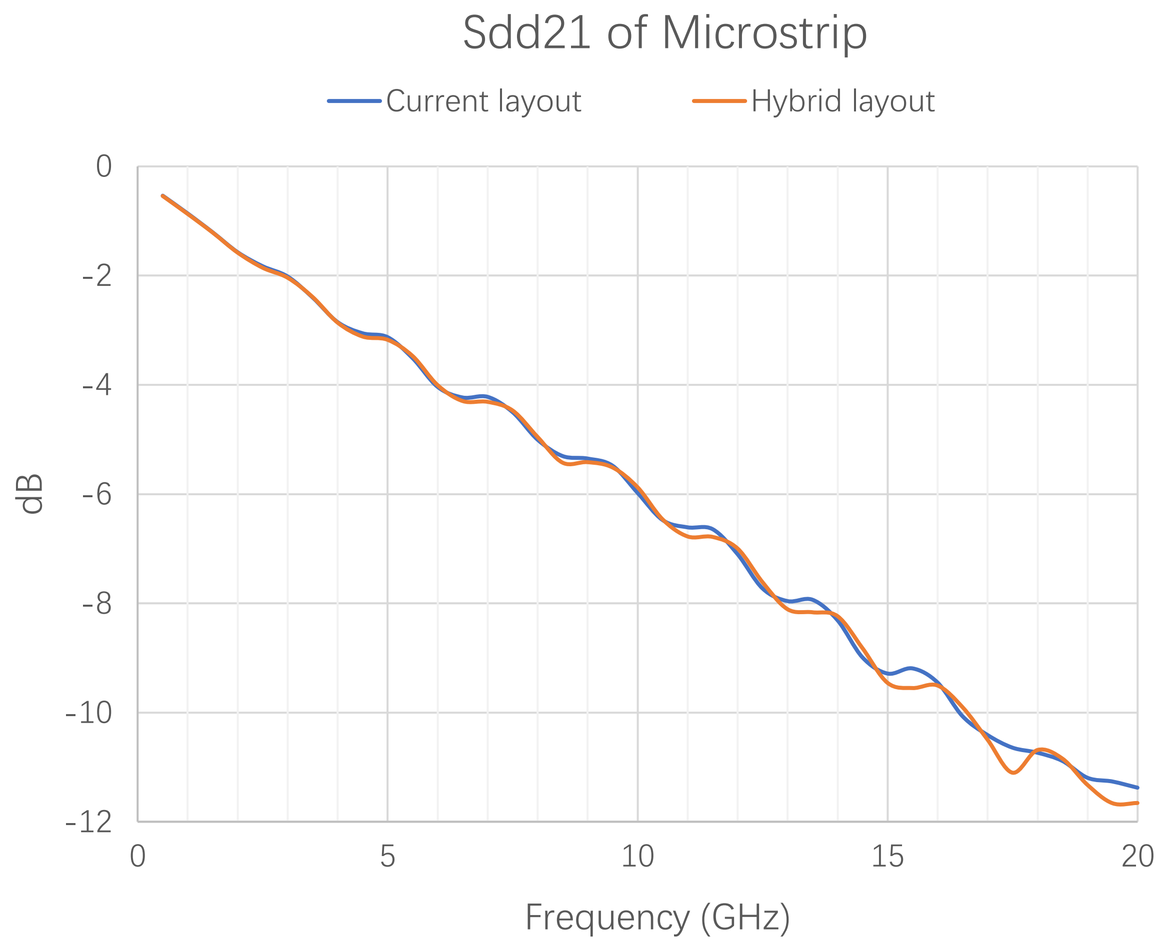


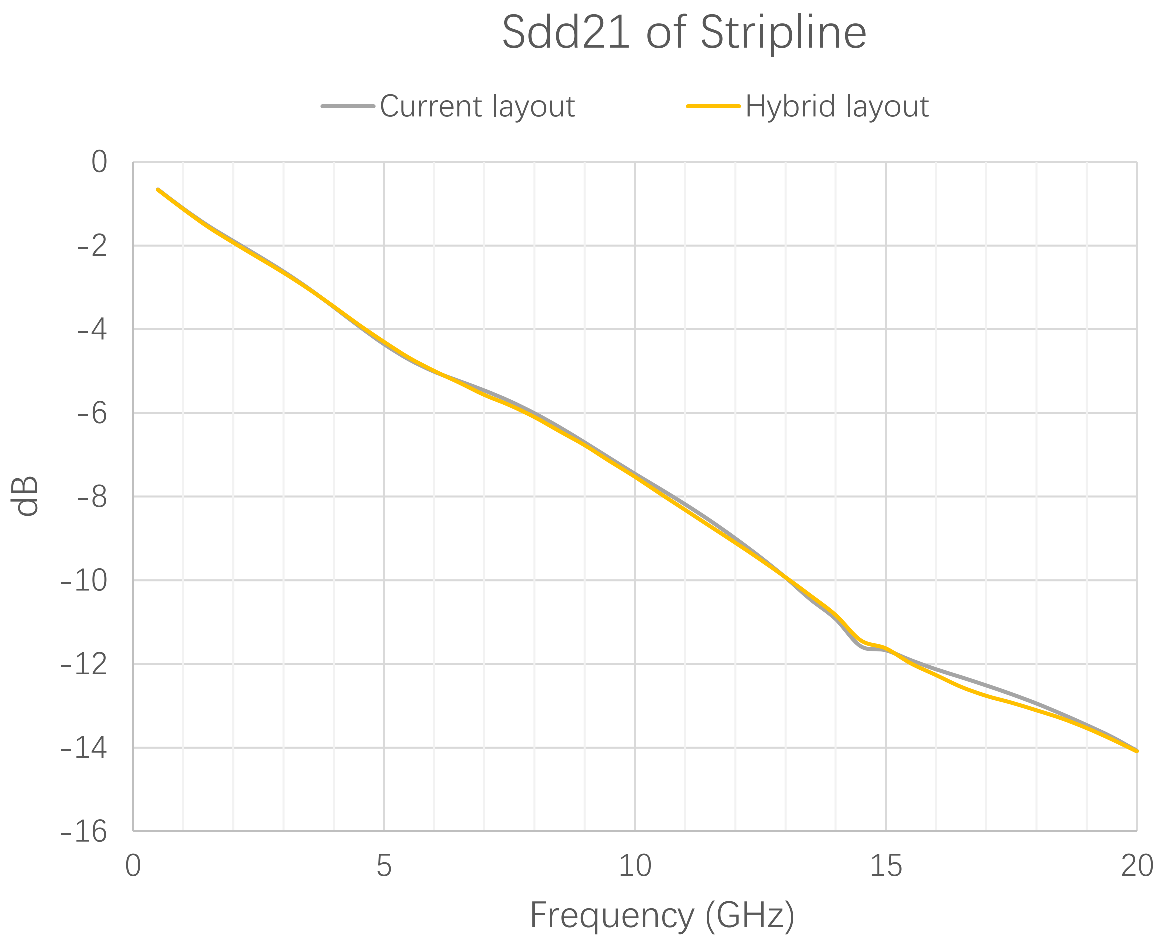




$$V_{common.MAX} = \frac{V_{in}}{4t_r} \cdot min\{2\tau, \Delta t\}, \Delta t = T_{even} - T_{odd}$$

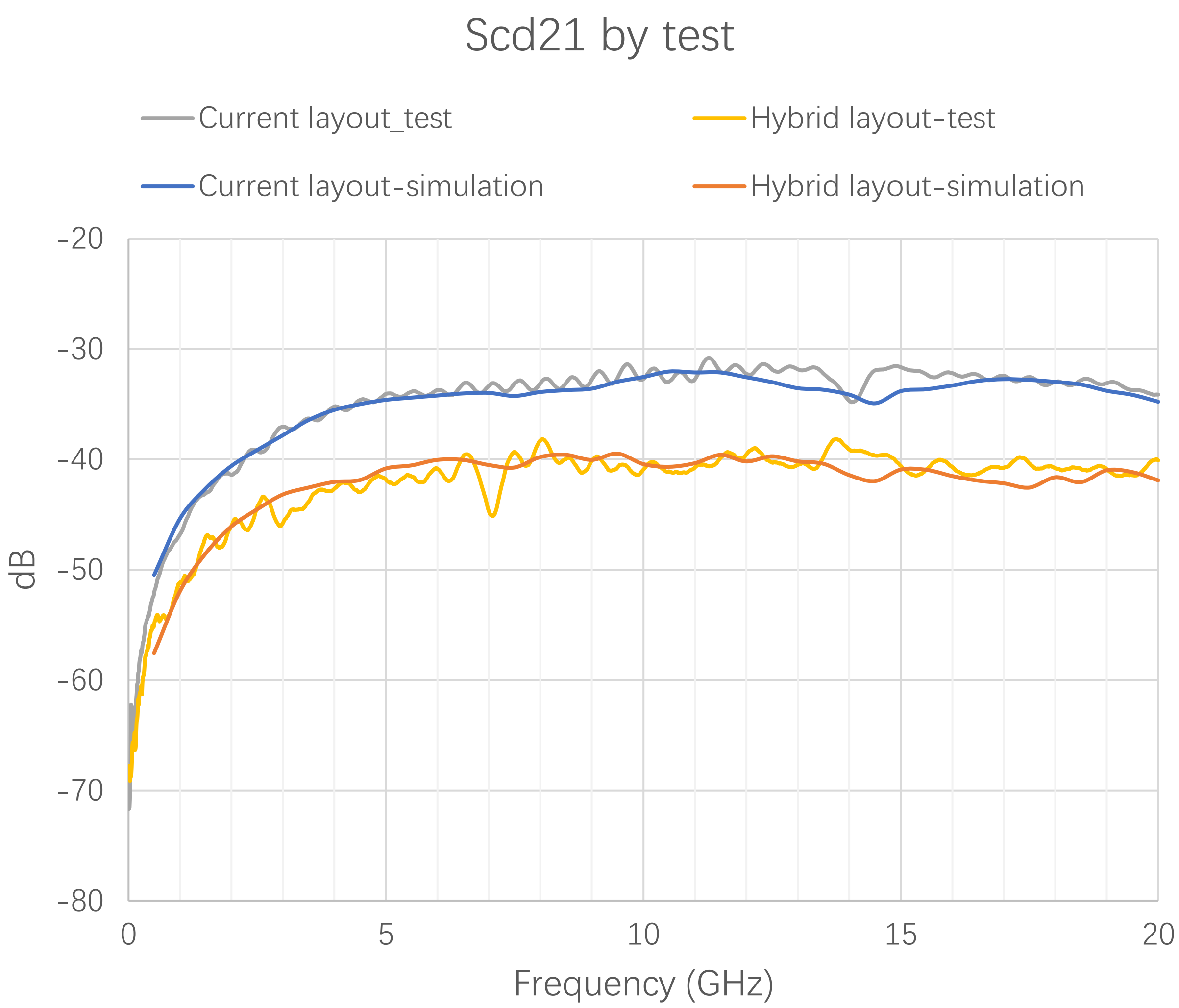
1. Hybrid U-turn structures are farther from skew bend than current compensation scheme
2. The propagation constant of even mode and odd mode in microstrip are different

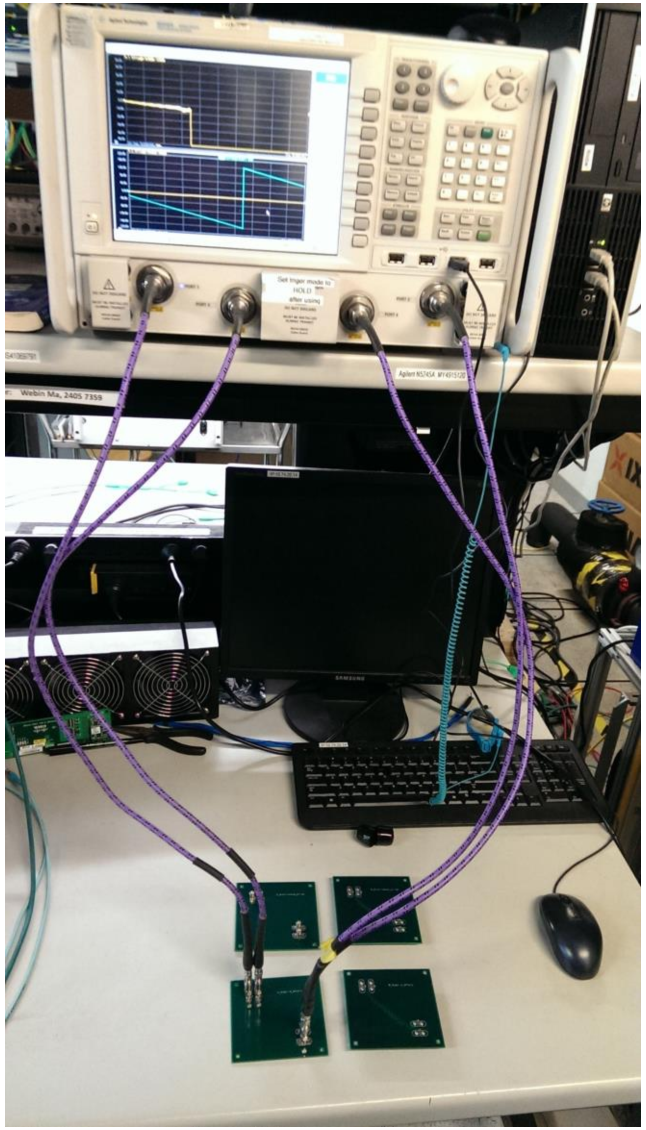
# Hybrid U Turn ---- Sdd21



# Hybrid U Turn ---- Scd21 verification

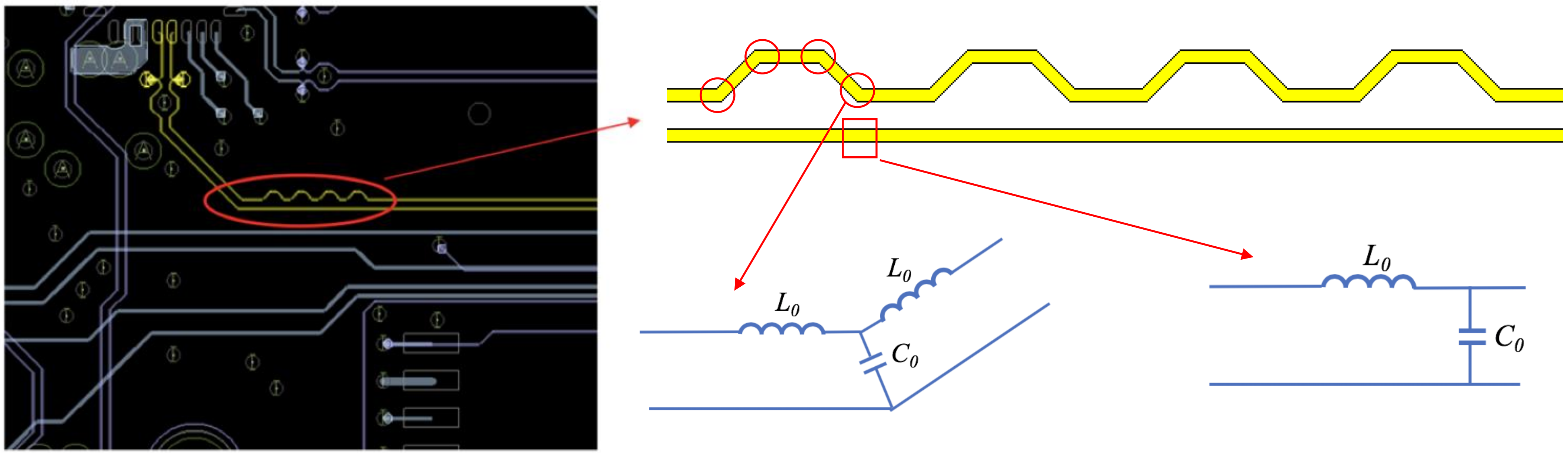


# Hybrid U Turn ---- Conclusion

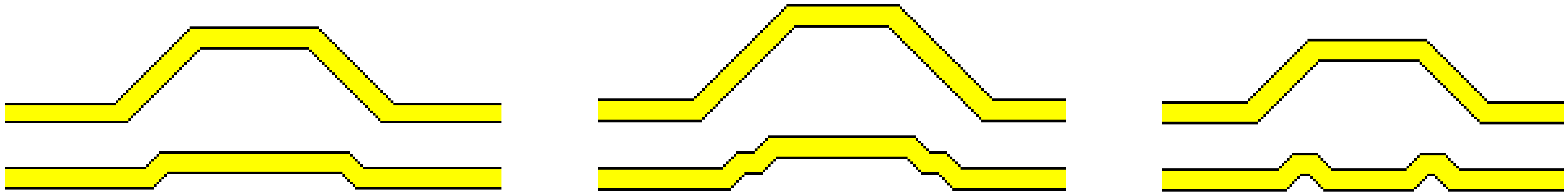
- A novel differential serpentine delay line is proposed which have both inter and intra-pair length matching function
- 5-15dB reduction in differential to common mode conversion

# Asymmetric Dual Bend ---- Background



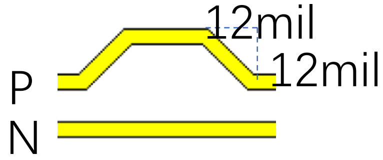

The bends can help to compensate the skew between two traces of differential pair, additionally, each bend also introduces four corners in one trace while the other trace is still straight, which may bring imbalance between two trace and lead to differential to common mode conversion

# Asymmetric Dual Bend ---- 3 new bends



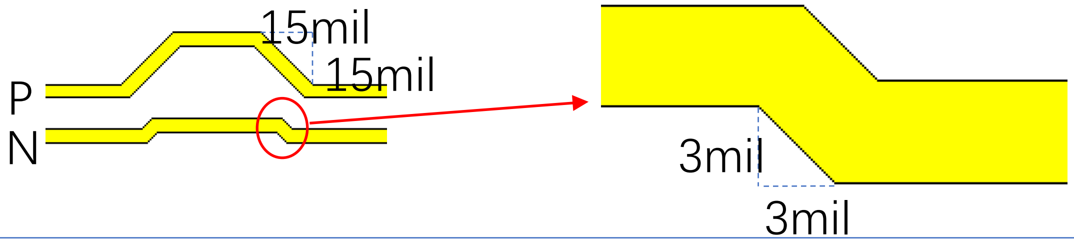
Patent pending in USPTO
Paper accepted by 2020 IEEE International Symposium on EMC/SI/PI

# Asymmetric Dual Bend ---- Skew compensation length of each bend

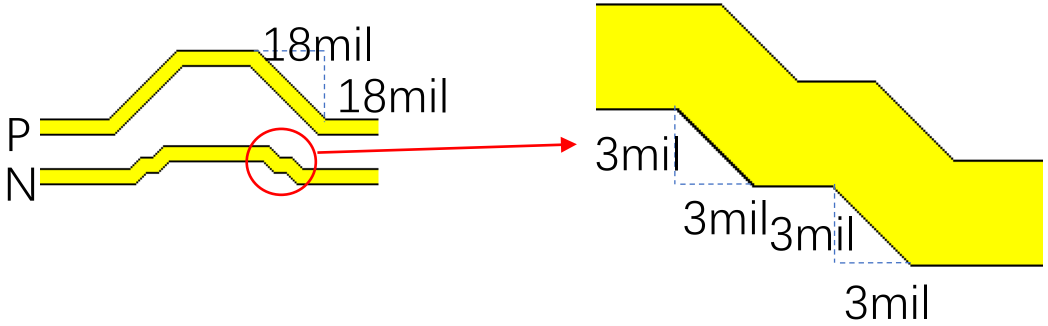



$$\Delta length\ between\ P\ and\ N\ trace:$$

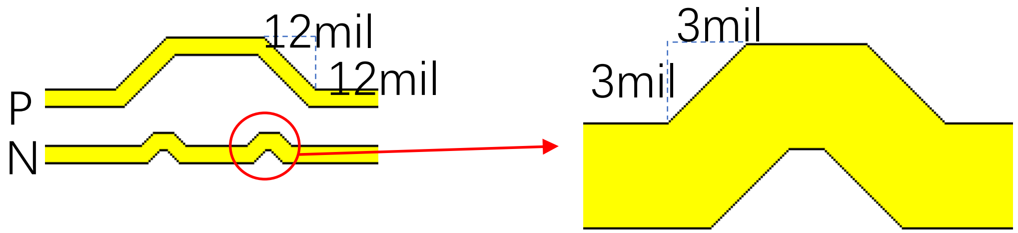
$$12 \times \left(\sqrt{2} - 1\right) \times 2 = 9.95mil$$




$$15 \times \left(\sqrt{2} - 1\right) \times 2 - 3 \times \left(\sqrt{2} - 1\right) \times 2 = 9.95mil$$

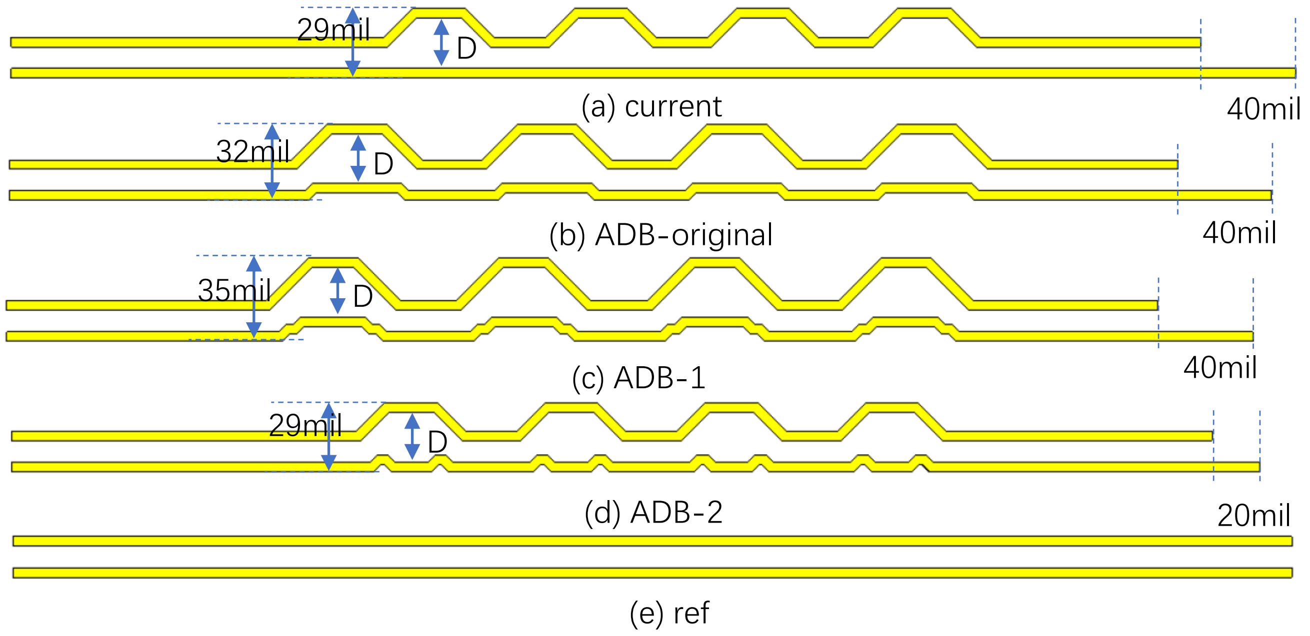


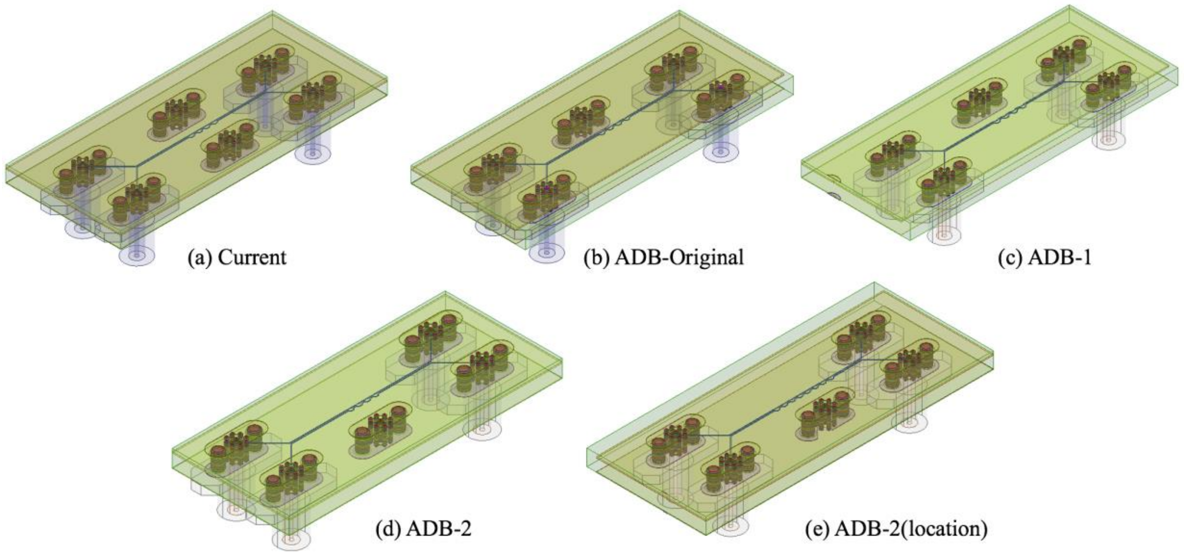

$$18 \times \left(\sqrt{2} - 1\right) \times 2 - 6 \times \left(\sqrt{2} - 1\right) \times 2 = 9.95mil$$



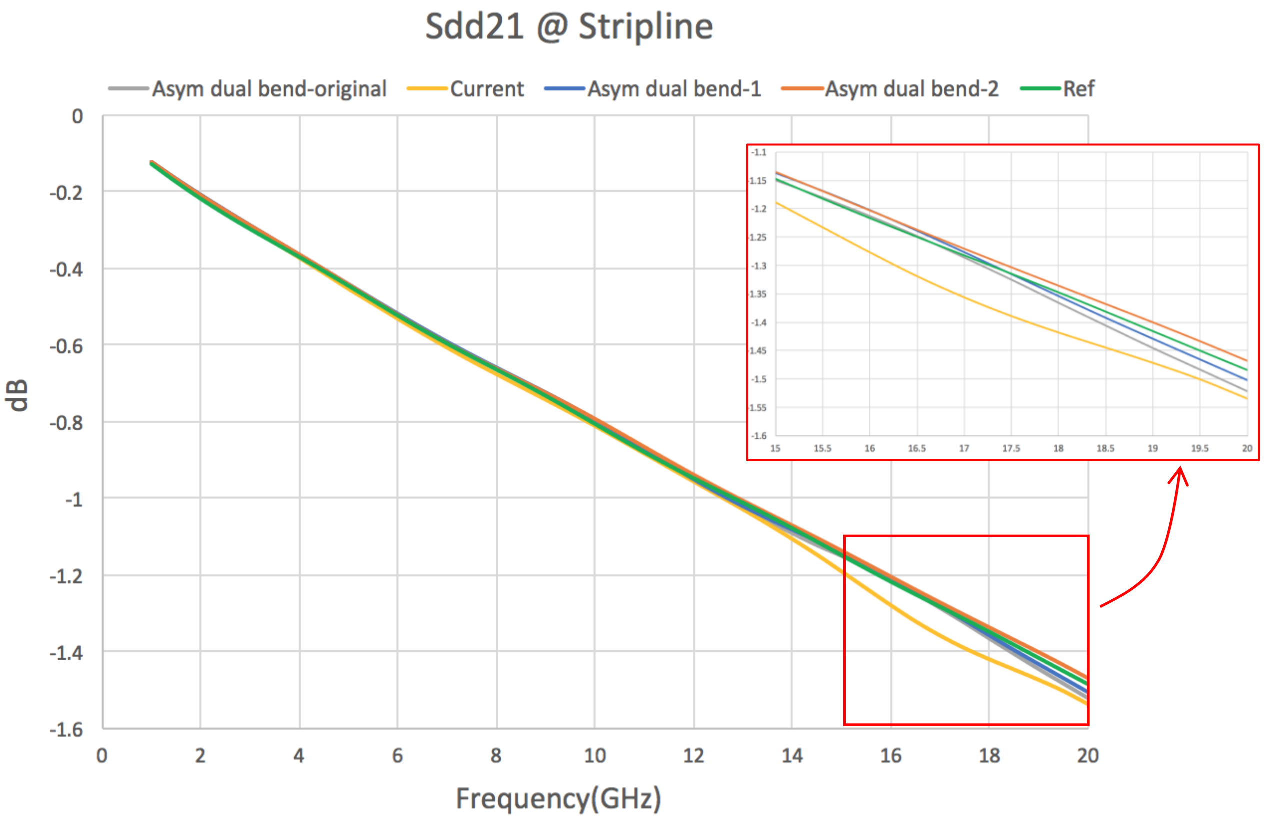

$$12 \times \left(\sqrt{2} - 1\right) \times 2 - 3 \times \left(\sqrt{2} - 1\right) \times 4 = 4.97mil$$

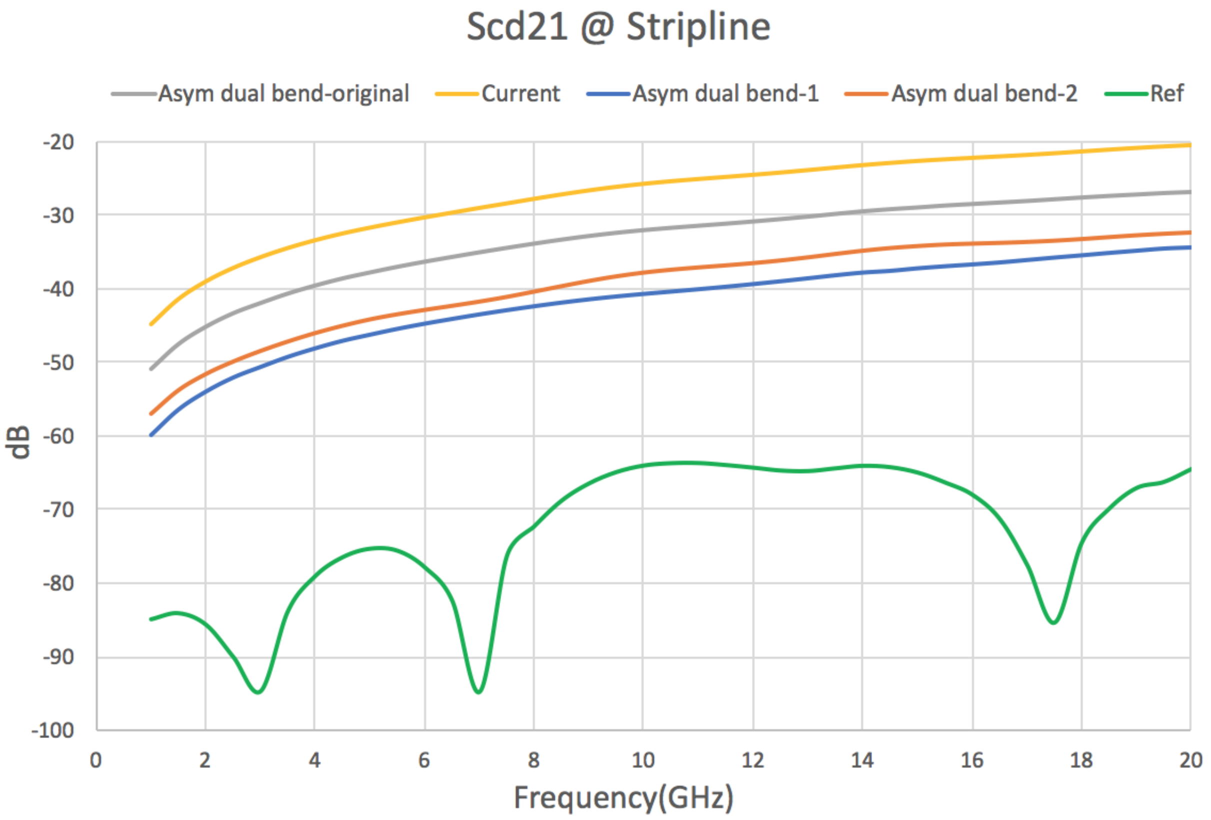
# Asymmetric Dual Bend ---- Simulation cases



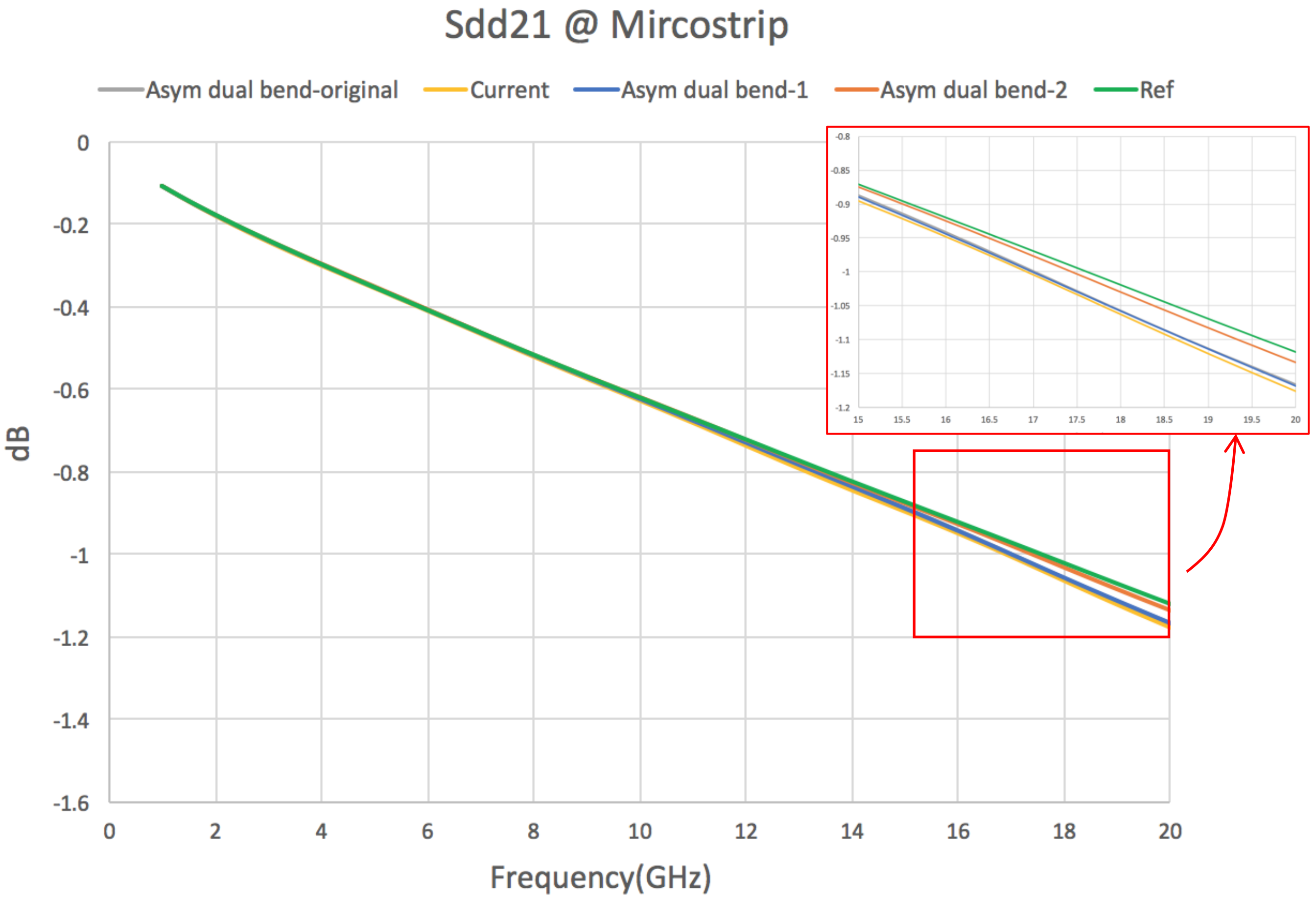



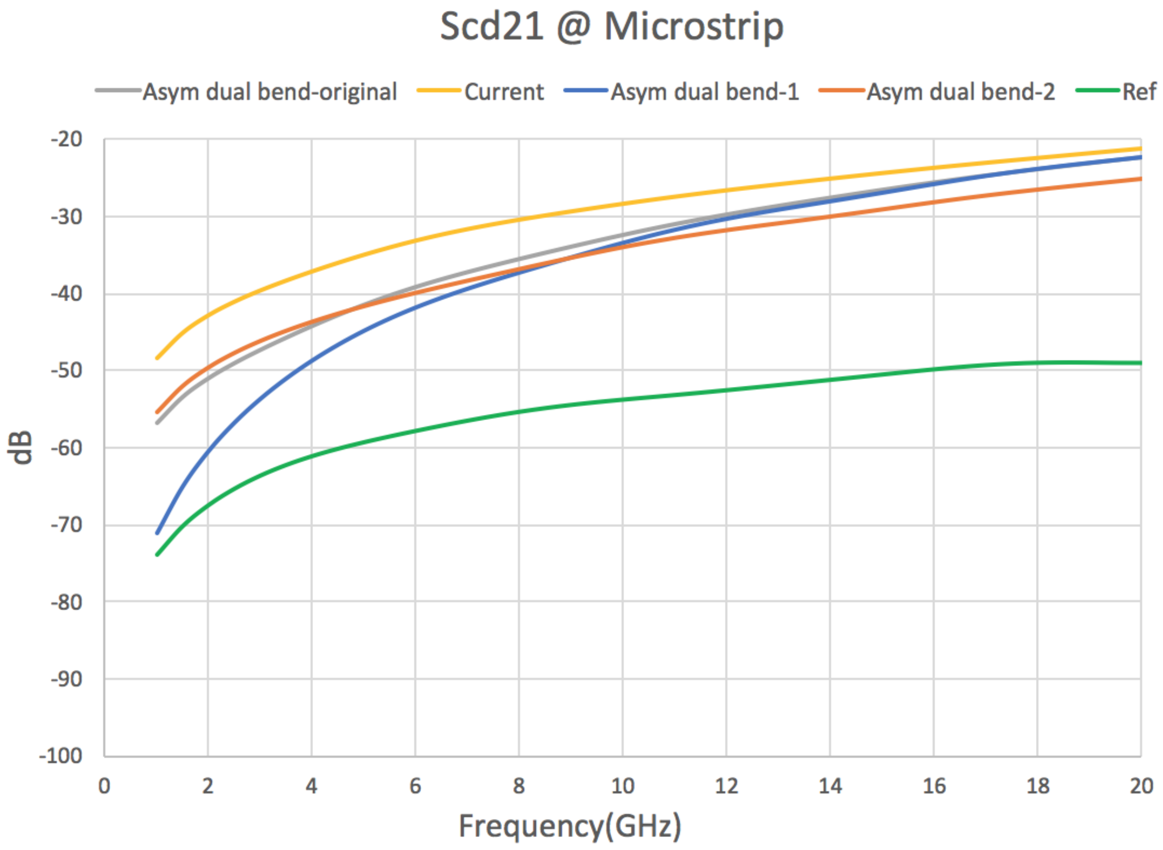
# Asymmetric Dual Bend ---- Stripline simulation



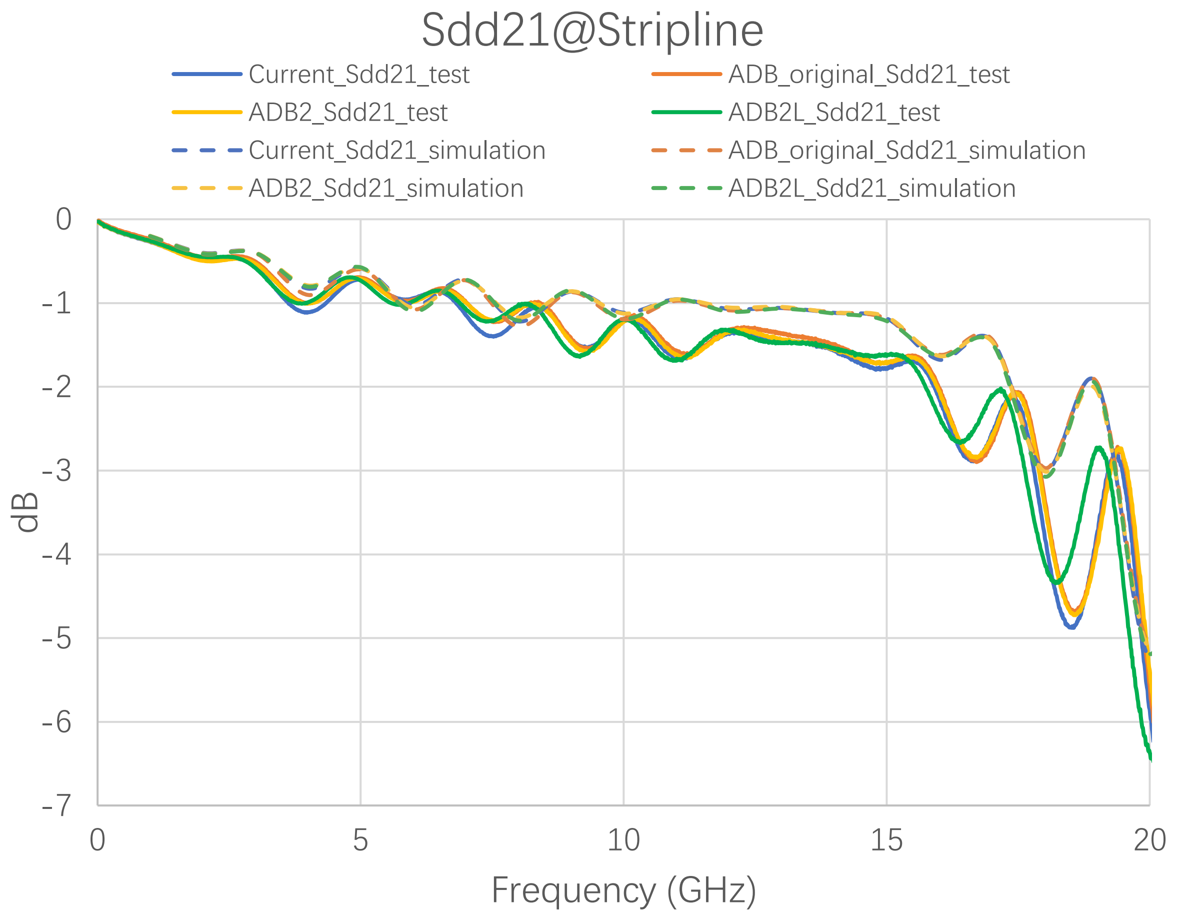



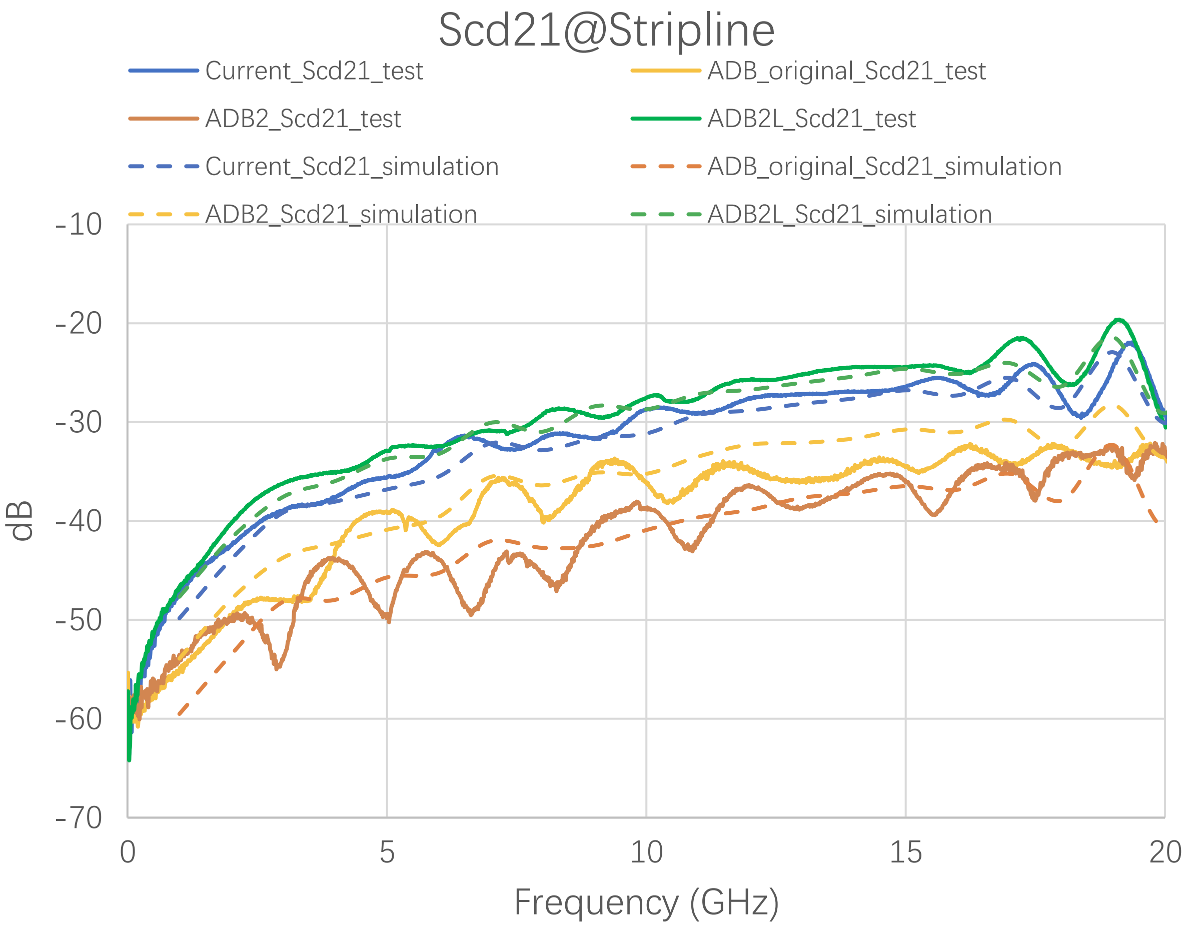
# Asymmetric Dual Bend ---- Microstrip simulation



# Asymmetric Dual Bend ---- Simulation Vs Measurement

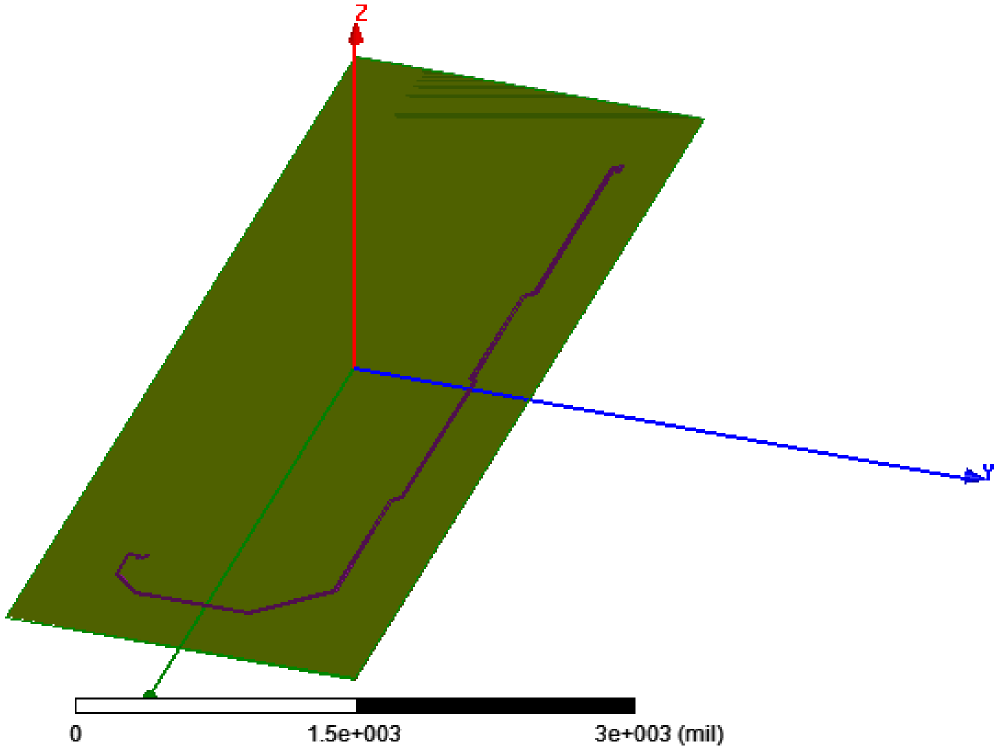


# Asymmetric Dual Bend ---- Conclusion

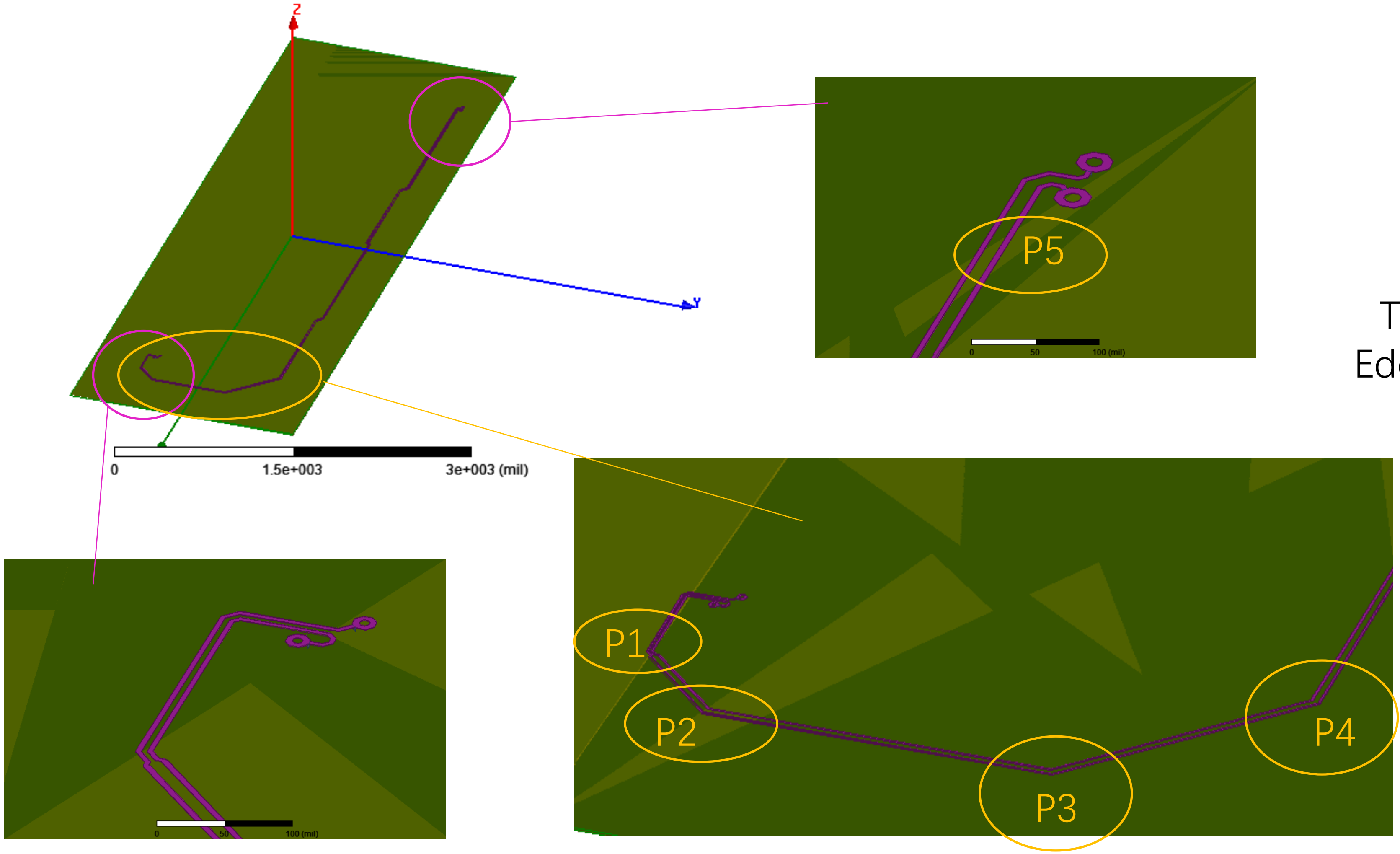
- Asymmetric dual bend (ADB) introduces bends in both P and N traces of differential pair to compensate the skew
- ADB provides 10+ dB improvement for Scd21 in stripline layout and nearly 5dB improvement for microstrip layout

# Localized skew compensation technique ---- Background



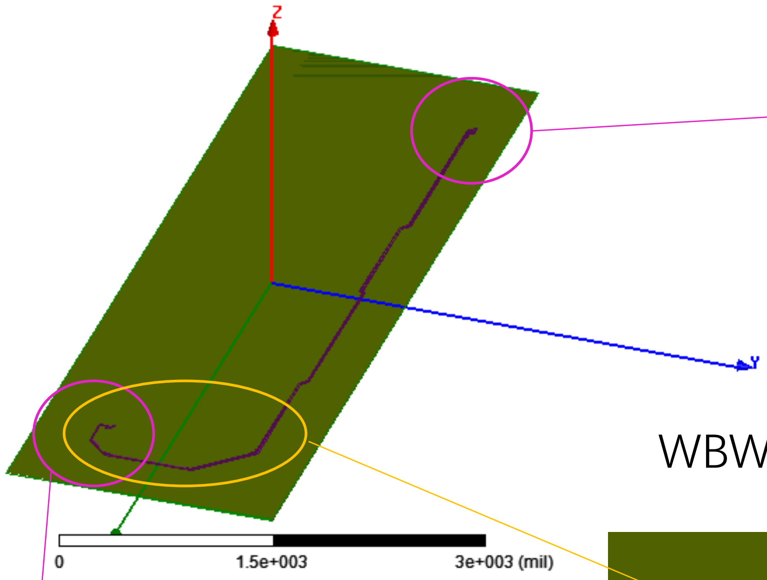

- Bend layout introduce skew of differential pair
- Differential pair is required to have an equal length for signal integrity concerns. Therefore bends are added on the shorter trace.
- In practical PCB routing, CAD engineers usually count the length of trace pairs at the final stage, and then put a few bends to de-skew the pair length wherever there is a space. Does randomly placing the bends impact the EMI performance?

# Localized skew compensation technique ---- Old design

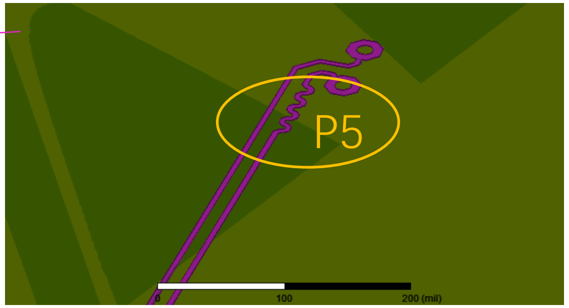


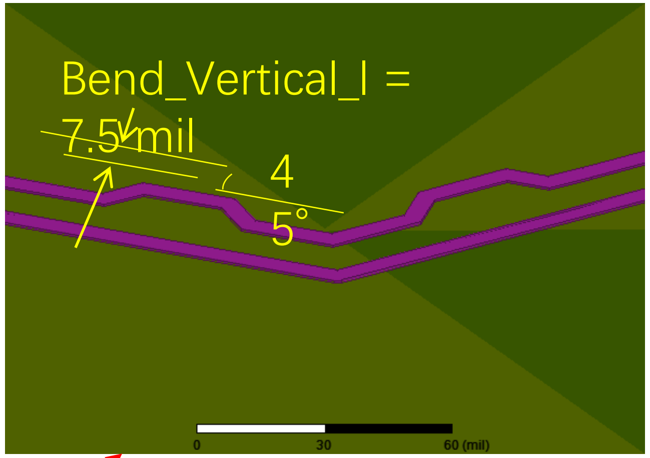

Length = 6376 mil
Trace width = 4.7 mil
Trace thickness = 0.65 mil
Edge to edge spacing = 10.3 mil
FR4 height = 3.6 mil
$\varepsilon_r$ = 4, tan δ= 0.02
$Z_0$ = 59.3 Ohm

# Localized skew compensation technique ---- Improved design

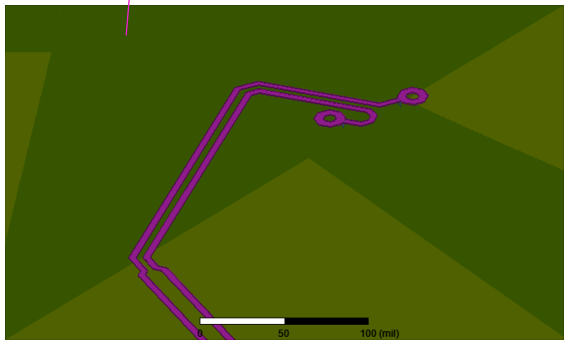


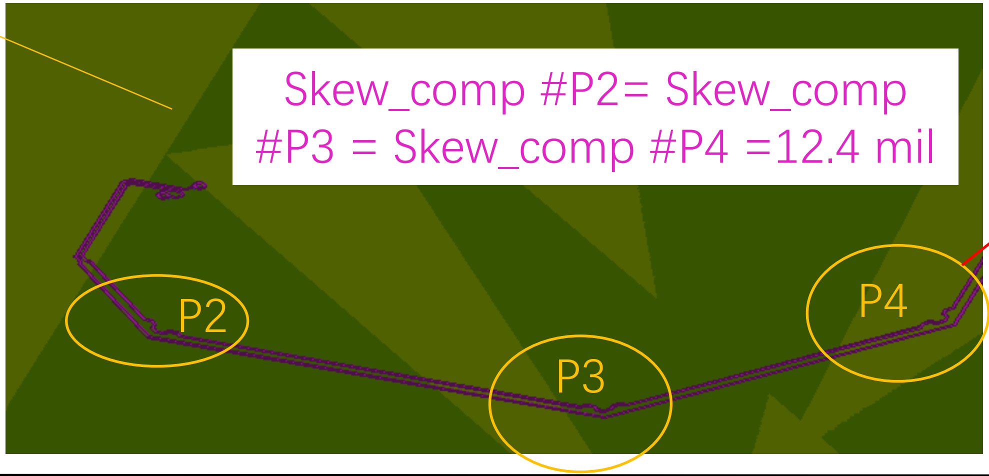

Skew_comp #P5 = -37 mil



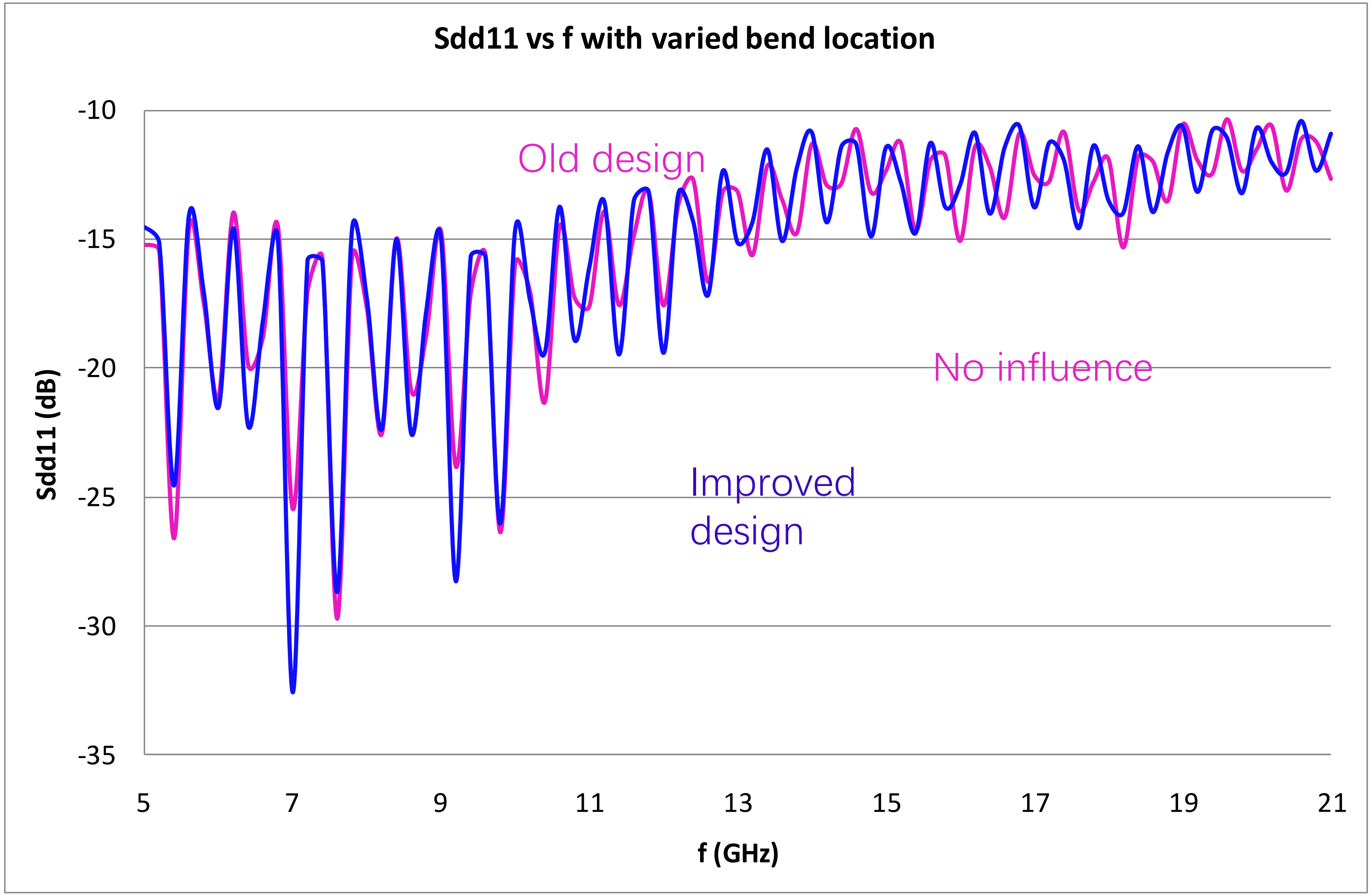

WBWC (where bent where compensated)



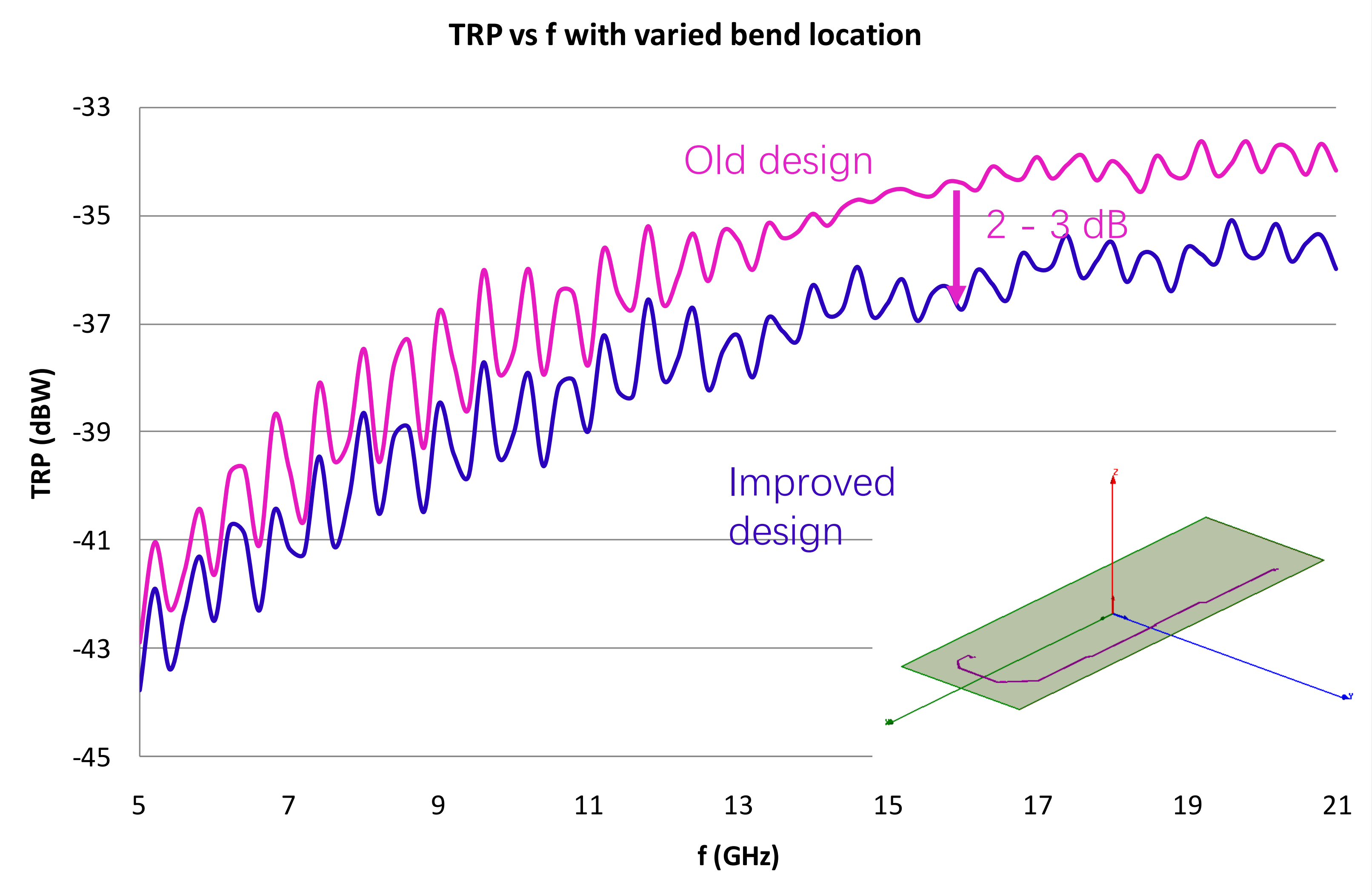

US Patent US 8835775 B2

# Localized skew compensation technique ---- Sdd11



# Localized skew compensation technique ---- Sdd21

# Localized skew compensation technique ---- TRP



# Localized skew compensation technique ---- Conclusion

- A new compensation approach named by 'WBWC (where bent where compensated)' is proposed here.
- No influence on reflection loss.
- 1 dB improvement on differential mode insertion loss.
- 2-3 dB reduction on Total radiated power(TRP)

# Summary

- Three skew compensation techniques for reducing EMI from differential traces are proposed
- The performance is simulated by Ansys HFSS, and shows good improvement
- The simulation results are verified by PCB coupon measurement

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