Minimal-reflection bends in micro-strip lines
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Overview

- Introduction
- De-embedding and elimination of reflection caused by 50-Ohm normalization
- Minimization of reflection from bend with chamfer
- Minimization of reflection from bend with rectangular cut-out
- Analysis of a simple channel with 10 regular and optimal bends
- Conclusion
Introduction

- Bends in micro-strip and strip lines are often discussed as a source of reflection in PCB interconnects (see SI list reflector http://www.freelists.org/archives/si-list/ - search for “bends”)
- It is practically impossible to detect the effect with TDR due to smallness of effect and not sufficient bandwidth and dynamic range of such measurements
- Precise frequency-domain measurements are required to detect the effect
  - The effect of bend may be hidden by the mismatch at the connectors or probes
  - Precise de-embedding is required that is hard to do on PCBs due to variations in dielectric properties
- Alternatively electromagnetic analysis with precise de-embedding can be used to reveal the effect and to minimize the reflection
- This example demonstrates how to do quick “what-if” experiments with Simbeor and provide design rules for PCB/packaging layout
- Simbeor 2008 built on September 9, 2008 has been used for all computations
Characteristic impedance of the micro-strip line is usually not exactly 50 Ohm: It is complex function and changing with the frequency as shown below.

8-mil micro-strip line on 4.5 mil substrate (see materials and stackup on page 7)
Removing normalization mismatch

- To eliminate the normalization mismatch we use generalized modal S-parameters normalized to the complex characteristic impedance of the micro-strip line.

S-parameters of 70 mil long 8-mil micro-strip line segment normalized to 50 Ohm

Reflection can interfere with the optimization!

Generalized S-parameters - no reflection ($|S_{11}|=0$)!
Original “reflective” bend

- Simple 4-layer stackup (only the first 2 layers are used in analysis of micro-strip structures)
- 8-mil micro-strip, reference planes are shifted 14 mil from the external corner of the bend

Cell size is 1 mil

S-parameters reference planes
The reflection is very small up to 25 GHz. Generalized S-parameters are necessary to detect the effect and to do the optimization.
Parameterized solution with chamfer

- 9 circuits with changing parameter $d$, mil attached to each circuit to plot the results as function of parameter
- Each parameterized circuit is simulated at 7 frequency points: 1, 5, 10, 20, 30 and 40 GHz

Simulations in Simbeor:

Bend4a geometry (nearly optimal)
Finding optimal chamfer position

- Plotting the reflection as function of the chamfer position allows us to find the minimum

Minimal reflection is somewhere between 9 and 10 mil cuts (d/w=1.1 – 1.25)

Reflection grows with the frequency
Chamfered optimal bend vs. the original

- Reflection from the optimal bend is reduced by about -20 dB
Are there other ways to reduce the reflection?

- Yes – anything that reduces the excessive capacitance and does not increase the inductance would work.
Optimization of bend with external corner cut

- Magnitude of the reflection coefficient $|S_{11}|$ as function of the cut size shows the minimum

![Graph showing the reflection with frequency and cut size]
Optimal bend with external cut vs. the original or regular

- Reflection from the optimal bend is reduced by about -20 dB almost as in the case with the chamfer.
Analysis of a simple channel with bends

- Micro-strip channel with 10 bends separated by 0.5 inch segments of micro-strip line is investigated with the regular and optimal chamfered bends.

Reflection loss with 10 regular bends is above 0 dB, while reflection loss with 10 optimal bends is below -30 dB!

Transmission is almost identical due to large losses in t-lines.
Conclusion

- The effect of the 90-degree bend is minor and only precise de-embedding and generalized S-parameters can be used to investigate and minimize the reflection.
- Chamfered bend with d/w=1.1-1.25 minimizes the reflection from 90-degree bends.
- Different shapes of cut-outs can be used to minimize the reflection.
- Electromagnetic models of the bends created with Simbeor can be used for accurate modeling of multi-gigabit data channels.
- Setting up all simulations and model building with Simbeor took approximately 1 hour.
Solutions and contact

- Simbeor solution files are available for download from the simberian web site
  - http://www.simberian.com/AppNotes/Solutions/BendsOptimization_2008_05.zip

- Send questions and comments to
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