Nan Ya Plastics Corp.

The Signal Integrity Study with Fiber Weave Effect

Speaker: Peter Liang

Electro Material Div. Copper Clad Laminate Unit
Outline:

- Demand of High Data Rate For Transmission Line Design
  - What Influences Skew
  - How to Reduce Skew
  - Conclusion
Applications of High Speed Transition

Applications
- High-End Servers
- High-End Routers
- Switches
- Optical Transport
- High-End Datastorage
- Wireless Base Station

Challenge
- Higher Data Rate
  - 1-3 Gbps => 4 Gbps => 10 Gbps => Higher

Solution
- Rotate the image
- Spread glass cloth
- Low Dk cloth
- others

Demands
- Real time & Mass Data Transmission and Storage
## What is the Demand of High Speed Transmission

<table>
<thead>
<tr>
<th>Standard</th>
<th>Year 2006</th>
<th>Year 2009</th>
<th>In development / Next generation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethernet</td>
<td>1Gbps</td>
<td>10Gbps</td>
<td>40Gbps, 100Gbps</td>
</tr>
<tr>
<td>Fibre Channel</td>
<td>1,2,4 Gbps</td>
<td>8Gbps, 16Gbps</td>
<td>40Gbps</td>
</tr>
<tr>
<td>Fibre channel over Ethernet</td>
<td>N/A</td>
<td>10GFCoE</td>
<td>40GFCoE,</td>
</tr>
<tr>
<td>★SATA/SAS</td>
<td>1.5Gbps / 3Gbps</td>
<td>3Gbps / 6Gbps</td>
<td>6Gbps / 12Gbps</td>
</tr>
<tr>
<td>★PCI-Express</td>
<td>PCIe1.0 1Gbps</td>
<td>PCIe2.0 5Gbps</td>
<td>PCIe3.0 8Gbps</td>
</tr>
<tr>
<td>Infiniband</td>
<td>2.5Gbps</td>
<td>10Gbps</td>
<td>40Gbps</td>
</tr>
</tbody>
</table>
Skew Effect in Differential Line

Is the impedance variation always small enough in differential line for wide frequency range?

▲ Differential signals is out-of-phase ?
▲ Substrate material uniformity ?
▲ Signal coupling effect ?

From DesignCon 2005: The Impact of PCB Laminate Weave on the Electrical Performance of Differential Signaling at Multi-Gigabit Data Rates
An uniform group delay and a small phase difference result in a superior skew characteristic in the differential line, indicating a low time delay between the differential signals.
The Effect of Fibric

The traces at resin rich or resin poor have different Dk value. This may cause different impedance and reflection result.
Skew Effect

The trace with skew can make the signal differ from design.
The most popular way to reduce the skew effect is to rotate the image.

1. Higher cost
2. Material utility ratio become low
3. Hard to design
The other way to reduce the skew effect is to use spreading cloth.

How to gauge the fabric’s spread that is enough to solve skew effect?
Some Test Results by NanYa

Non-spreading glass cloth

\[ \Delta \text{Loss} = 4.244 \text{ dB} @ 20 \text{ GHz} \]

spreading glass cloth

\[ \Delta \text{Loss} = 2.665 \text{ dB} @ 20 \text{ GHz} \]

Using spreading glass cloth can minimize the gap between pattern 1 and pattern 2. But it also can’t ignore the FWE effect.
How to improve the effect of spreading for fabric?

<table>
<thead>
<tr>
<th>Style</th>
<th>1078</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spreading Level</td>
<td>Current Level</td>
</tr>
<tr>
<td>2 layer</td>
<td>60%</td>
</tr>
<tr>
<td>1 layer</td>
<td>37%</td>
</tr>
<tr>
<td>Interstice</td>
<td>3%</td>
</tr>
</tbody>
</table>

- Use different yarn style
- Denser Fabric

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Single Line Characteristics

- frequency independent $Dk$ and $Df$

$Dk$: 3.5~4.5 step 0.25
$Df$: 0.012

$Dk$: 3.9
$Df$: 0.002~0.02 step 0.005

Under 5 GHz operation, $Dk$ is the significant parameter for the impedance of transmission line.
The Dk variation in PCB board leads to the characteristic changes of impedance and group delay, and the jitter of eye diagram was also degraded.
The high-frequency response of material determines the loss for a wide frequency range. It also results in a worse performance in High/Low margin of eye diagram.
Outline:

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How to Mitigate FWE Effect

1. Rotate the trace with an angle

2. Use Low Dk glass cloth (glass Dk: 7.2 -> 5.5)

3. Increase the density of glass yarns
Experiment and Measurement (1)

On-wafer test
RF probe station

Frequency Domain
(up to 50 GHz)
(Network analyzer, Agilent E8363B)

• S parameter
  (loss, reflection, phase)
• Impedance

Time Domain
(up to 12.5 Gb/s)

Pulse pattern generator
Anritsu MP1763C

Sampling Oscilloscope
Agilent 86100C

• Waveforms (skew)
• Eye diagram (jitter, eye opening)
Experiment and Measurement (2)

Line width: 4, 6, 8, 10 mil.
Line length: 1, 2, 5 inch.
Line gap: 4, 6, 8, 10 mil.

Measurement Items:
- Through line: Dk/Df, phase, skew, impedance
- Loop line: Dk/Df and impedance with coupling effect
Experiment for Single Line

Parameters

Rotation

DK

Density

Impedance

Eye Diagram

S-parameter

Measurement

Evaluation

Frequency response
Impedance variation

Signal reflection
Eye opening
Jitter
Over or under shoot
Hi/Lo margin

Insertion loss
Return loss
Group delay
Construction B yarns v.s. C yarns per inch. (single line)

- The loss of the non-rotated transmission line can be reduced if yarns of glass is increased to C.
- A low loss transmission line can be achieved within 2 cases:
  1. rotate substrate from 0-degree to 45-degree, no matter it weaves by B or C yarns.
  2. direct using C-yarn substrate.
Eye Diagram Test

B yarns 0-degree

C yarns 0-degree

B yarns 45-degree

C yarns 45-degree
Experiment for Single Line

Parameter
- Rotation

Measurement
- Impedance
  - Frequency response
  - Impedance variation

Evaluation
- Impedance variation
  - Signal reflection
    - Eye opening
    - Jitter
    - Over or under shoot
    - Hi/Lo margin

Eye Diagram
- Insertion loss
  - Return loss
  - Group delay

S-parameter

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S parameter for different Dk (1)

- Trace places on fabric.

<table>
<thead>
<tr>
<th>Dk</th>
<th>W (mil)</th>
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<tbody>
<tr>
<td>4.5</td>
<td>6</td>
</tr>
<tr>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>3.5</td>
<td>6</td>
</tr>
</tbody>
</table>
Eye Diagram Test

10 Gb/s

Dk=3.5

Dk=4.5

A small sensitivity to Dk will be presented if MS line places on fabric of PCB.
S parameter for different Dk (2)

- Trace places on gaps and crosses.

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</tr>
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<td>6</td>
</tr>
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![Graph showing Loss (dB) vs Frequency (GHz) for different Dk values]

![Graph showing Return Loss (dB) vs Frequency (GHz) for different Dk values]
Eye Diagram Test

10 Gb/s

Dk=3.5

Dk=4.5

Dk=4

A large sensitivity to Dk will be presented if MS line places on gaps and crosses of PCB.
Experiment for Single Line
- Rotation
- DK
- Density

Parameter
- Impedance
- S-parameter
- Eye Diagram

Measurement
- Impedance variation
- Signal reflection
  - Eye opening
  - Jitter
  - Over or under shoot
  - Hi/Lo margin

Evaluation
- Frequency response
- Insertion loss
- Return loss
- Group delay

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• When the yarns of construction increased, the loss of transmission line will be reduced.
• 45 degree angle microstrip line shows the reliable performance compared to traditional vertical or lateral transmission line layout owing to a better distribution of glass fabric and glue beneath the microstrip line can be achieved.
• If the yarns less than B, the non-uniform of glass fabric and glue distribution caused a slow wave effect which resulted in the unstable transmission line for vertical and lateral layouts.
Eye Diagram Test

10 Gb/s

- C-yarns transmission line presents the performances of good 50-Ω impedance and low transmission loss.
- Due to small insertion and return losses for C-yarns transmission line, a low jitter and a low voltage variation in Hi/Lo level will be exhibited for 10-Gb/s eye diagram test.
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Conclusion:

In order to improve skew issue our next step are as follow:

1. New technique for better spread out the glass cloth.
2. Use denser fabric.
THANKS