RF Probe Simulations And Associated Physical Geometries For Interface Design

Michael Ricci
Principal Engineer

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Rika Denshi Group, LTD

- 57 years in business as a spring probe manufacturer
- HQ in Tokyo with factories in USA, Thailand and Japan
- Third generation family ownership
- Over 6000 Sq Ft of clean room
- RF lab, experience engineering staff
- Focused on RF/mmWave, High Temperature, Tight Pitch and Non-magnetic spring probes, test sockets and probe heads
Introduction

• We will share examples of how HFSS simulations are be used to optimize spring probe design and test array patterns for RF applications.

• HFSS by ANSYS is a 3D electromagnetic (EM) simulation software for designing and simulating high-frequency electronic products such as antennas, antenna arrays, RF or microwave components, high-speed interconnects, filters, connectors, IC packages and printed circuit boards.

• Both Magnitude and Phase can be simulated resulting in generation of S11 or Return Loss and S21 or Insertion loss parameters.

• Insertion loss = loss of signal power resulting from the insertion of a device (modeled structure or node) in a transmission line or optical fiber and is expressed in decibels (dB).

• Return loss = loss of power in the signal returned/reflected by a discontinuity in a transmission line or optical fiber. This discontinuity can be a mismatch with the terminating load or with a device inserted in the signal line. Return loss is usually expressed as a ratio in decibels (dB).
Application – 40 GHz Interface

- An example for Ka band (26GHz-40GHz) transceiver backplane interposer is shared.

- Both a 40 pin and 80 pin interposer were required to maintain a robust RF interface between Ka-band transceiver modules and COMM-SAT chassis backplane.

- Electrical requirements = > 40 GHz bandwidth with as close to 50 Ohm characteristic impedance as possible...while adhering to the mechanical design constraints.

- Mechanical requirements = must survive rocket launch (~20 Gs) and maintain RF performance during satellite lifecycle (5-8) years in temporary earth orbit.

- Operational temperature range -24C to 125C

- Insertion cycles = 1
Goals For SI Simulation

• Discover the optimum probe design; mechanical features, shape, location

• Discover the optimum working compression distance

• Discover the optimum SIG to GND probe pitch

• Discover the optimum plunger geometries
Simulating Pitch - Spring Probe - B1859-A1
Socket

Place 1 signal pin surrounded by 2 or 4 ground pins for measurement. Plastic housing was made in PEEK material for each size of probe.
B1859-A1
Measurement Report

- Pitch 0.80mm
- Pitch 0.90mm
- Pitch 1.15mm
B1859-A1

Measurement Report

- Pitch 0.80mm
- Pitch 0.90mm
- Pitch 1.15mm
B1859-A1

Measurement Report

4 GND
Standard Pitch 0.80mm
Various Pitches
0.90mm, 1.15mm... 1.3mm
Measuring Instruments

- Agilent E8364C VNA
  Frequency 10M - 50GHz

- Agilent 86100C DSO
  Frequency DC - 18GHz
Measurement Fixtures

RF Coupler ~ 50GHz

RF Measurement Fixture
Measuring Method

Inductance and Capacitance Measurement

S-parameter Measurement

C adapter (50Ω)

Fixture

Socket

Short tool
or

Open tool

Tool used for Calibration & Measurement

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S-parameter for B1859-A1

Pitch 0.80mm, GND2

0.80mm pitch

Signal-PROBE
GND-PROBE

S11 Return Loss

freq, GHz

dB(S(1,1))

16.5GHz

S21 Insertion Loss

freq, GHz

dB(S(2,1))

21.4GHz
S-parameter for B1859-A1

Pitch 0.90mm, GND2

![Diagram showing 0.90mm pitch with Signal-PROBE and GND-PROBE](image)

**S11 Return Loss**

![Graph showing S11 Return Loss with a peak at 30.4GHz](image)

**S21 Insertion Loss**

![Graph showing S21 Insertion Loss with a peak at 30.4GHz](image)
S-parameter for B1859-A1

Pitch 1.15mm, GND2

1.15mm pitch

Signal-PROBE
GND-PROBE

S11 Return Loss

S21 Insertion Loss

37.8GHz

23.6GHz
**_B1859-A1_ - GND2**

**DIMENSIONS ARE INCHES [MM REF]**

<table>
<thead>
<tr>
<th>SPRING FORCE (g)</th>
<th>20</th>
</tr>
</thead>
<tbody>
<tr>
<td>OPERATING POSITION (mm)</td>
<td>2.0</td>
</tr>
<tr>
<td>GND PROBE (pcs)</td>
<td>2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pitch (mm)</th>
<th>0.80</th>
<th>0.90</th>
<th>1.15</th>
</tr>
</thead>
<tbody>
<tr>
<td>Return Loss (dB)</td>
<td><a href="mailto:-10dB@16.5GHz">-10dB@16.5GHz</a></td>
<td><a href="mailto:-10dB@30.4GHz">-10dB@30.4GHz</a></td>
<td><a href="mailto:-10dB@37.8GHz">-10dB@37.8GHz</a></td>
</tr>
<tr>
<td>Insertion Loss (dB)</td>
<td><a href="mailto:-1dB@21.4GHz">-1dB@21.4GHz</a></td>
<td><a href="mailto:-1dB@30.4GHz">-1dB@30.4GHz</a></td>
<td><a href="mailto:-1dB@23.6GHz">-1dB@23.6GHz</a></td>
</tr>
<tr>
<td>Inductance (nH)</td>
<td>0.60</td>
<td>0.70</td>
<td>0.82</td>
</tr>
<tr>
<td>Capacitance (pF)</td>
<td>0.28</td>
<td>0.26</td>
<td>0.23</td>
</tr>
<tr>
<td>Characteristic Impedance (Ω)</td>
<td>46.0</td>
<td>52.0</td>
<td>59.8</td>
</tr>
</tbody>
</table>

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S-parameter for B1859-A1

Pitch 0.80mm, GND4

S11 Return Loss

S21 Insertion Loss

8.1GHz

14.4GHz

0

-10

-20

-30

-40

-50

0

-1

-2

-3

-4

-5

0

10

20

30

40

50

freq, GHz

freq, GHz
S-parameter for B1859-A1

Pitch 0.90mm, GND4

S11 Return Loss  
-10dB(S11) at 14.1GHz

S21 Insertion Loss  
-1dB(S21) at 19.3GHz
S-parameter for B1859-A1

Pitch 1.15mm, GND4

S11 Return Loss

31.8GHz

S21 Insertion Loss

36.3GHz
(B1859-A1 • GND4)

DIMENSIONS ARE INCHES [MM REF]

<table>
<thead>
<tr>
<th>Pitch (mm)</th>
<th>0.80</th>
<th>0.90</th>
<th>1.15</th>
</tr>
</thead>
<tbody>
<tr>
<td>Return Loss (dB)</td>
<td><a href="mailto:-10dB@8.1GHz">-10dB@8.1GHz</a></td>
<td><a href="mailto:-10dB@14.1GHz">-10dB@14.1GHz</a></td>
<td><a href="mailto:-10dB@31.8GHz">-10dB@31.8GHz</a></td>
</tr>
<tr>
<td>Insertion Loss (dB)</td>
<td><a href="mailto:-1dB@14.4GHz">-1dB@14.4GHz</a></td>
<td><a href="mailto:-1dB@19.3GHz">-1dB@19.3GHz</a></td>
<td><a href="mailto:-1dB@36.3GHz">-1dB@36.3GHz</a></td>
</tr>
<tr>
<td>Inductance (nH)</td>
<td>0.48</td>
<td>0.56</td>
<td>0.70</td>
</tr>
<tr>
<td>Capacitance (pF)</td>
<td>0.40</td>
<td>0.32</td>
<td>0.26</td>
</tr>
<tr>
<td>Characteristic Impedance (Ω)</td>
<td>34.8</td>
<td>41.7</td>
<td>52.4</td>
</tr>
</tbody>
</table>

SPRING FORCE (g) 20
OPERATING POSITION (mm) 2.0
GND PROBES (pcs) 4
Signal to GND Probe in Socket

Top view

1.52mm pitch

GND1

1.52mm pitch

GND2

1.52mm pitch

GND3

1.52mm pitch

GND4

Socket height: 2.0mm to 2.3mm
PEEK (ε=3.3)

Signal-PROBE
GND-PROBE

Place 1 signal pin surrounded by 1 ~ 4 ground pins for measurement. Plastic housing was made in PEEK material for each size of probes. Using different height sockets for each operating lengths of probes.

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Measuring Method

Inductance and Capacitance Measurement

S-parameter Measurement

C adapter (50Ω)

Fixture

Socket

Short tool or

Open tool

Tool used for Calibration & Measurement
### S-parameter for B1859-A1 (Operating position 2.0mm)

<table>
<thead>
<tr>
<th></th>
<th>Return Loss (S11)</th>
<th>Insertion Loss (S21)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>GND3</strong></td>
<td><img src="image1" alt="Graph" /></td>
<td><img src="image2" alt="Graph" /></td>
</tr>
<tr>
<td>dB(S1(1,1))</td>
<td></td>
<td></td>
</tr>
<tr>
<td>freq, GHz</td>
<td>27.4GHz</td>
<td>24.0GHz</td>
</tr>
<tr>
<td><strong>GND4</strong></td>
<td><img src="image3" alt="Graph" /></td>
<td><img src="image4" alt="Graph" /></td>
</tr>
<tr>
<td>dB(S1(1,1))</td>
<td></td>
<td></td>
</tr>
<tr>
<td>freq, GHz</td>
<td>41.2GHz</td>
<td>38.4GHz</td>
</tr>
</tbody>
</table>
• RI-037LA-02-A2 Spring Probe
• Barrel Length Comparison
• RF Simulations – HFSS
Overview

- HFSS simulation of probes with different length of barrel
- Area of optimization is RED dimension bellow

<table>
<thead>
<tr>
<th>Length of Barrel</th>
<th>Operating length</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.165</td>
<td>0.75</td>
<td>-0.50</td>
</tr>
<tr>
<td>0.415</td>
<td>1.00</td>
<td>-0.25</td>
</tr>
<tr>
<td><strong>0.665</strong></td>
<td><strong>1.25</strong></td>
<td><strong>0 (Original)</strong></td>
</tr>
<tr>
<td>0.915</td>
<td>1.50</td>
<td>+0.25</td>
</tr>
<tr>
<td>1.165</td>
<td>1.75</td>
<td>+0.50</td>
</tr>
<tr>
<td>1.415</td>
<td>2.00</td>
<td>+0.75</td>
</tr>
</tbody>
</table>
Simulation Models

- These are models for the RF simulation

Overall: 2.00mm

Overall: 1.25mm

Overall: 0.75mm

Minimum

Original

Maximum

Probe layout

0.5mmPitch

G

S

G

Simulator: HFSS
Simulation Results (Return Loss)

- Shorter probes have better Return loss
• Simulation for retaining feature shape and location
Simulation Of Falcon Probe Features

- Probe model includes a retention feature (collar) with right angles.
- Simulation results analyzed to understand if tapered collar would improve RF performance.
- Simulation results analyzed to understand if collar location on barrel would improve RF performance.

<table>
<thead>
<tr>
<th>GND probe : 2pcs</th>
<th>Flange</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Normal</td>
</tr>
<tr>
<td>Plunger A</td>
<td>No.1</td>
</tr>
<tr>
<td>Crown</td>
<td></td>
</tr>
<tr>
<td>Conical</td>
<td>No.3</td>
</tr>
</tbody>
</table>
About simulation

- RF simulation for optimum collar location moved up and down. (Upper: up to 0.3mm, Lower: down to 0.1mm)
Result (Crown / Normal, Taper)

- Simulation results for collar position.

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Result (Crown / -0.1mm, +0.3mm)

- Simulation result for flange position.

T01_03_Ricci_06-02-2019_Rev1.0

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Simulation result for flange position.
Result (Conical / -0.1mm, +0.3mm)

- Simulation result for flange position.

S11

S21

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## Simulation result (S21)

- Simulation result of S21.

<table>
<thead>
<tr>
<th>GND probe : 2pcs</th>
<th>Flange Normal</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-0.1</td>
</tr>
<tr>
<td>Crown</td>
<td><a href="mailto:-1dB@44.9GHz">-1dB@44.9GHz</a></td>
</tr>
<tr>
<td></td>
<td><a href="mailto:-3dB@89.9GHz">-3dB@89.9GHz</a></td>
</tr>
<tr>
<td>Plunger A</td>
<td><a href="mailto:-1dB@42.7GHz">-1dB@42.7GHz</a></td>
</tr>
<tr>
<td></td>
<td><a href="mailto:-3dB@74.5GHz">-3dB@74.5GHz</a></td>
</tr>
</tbody>
</table>

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Notes

• RF Simulations are a software prediction that should be validated with physical measurements.

• Do not be surprised if simulation results do not immediately correlate with physical measurements.

• Simulation models can be optimized and simulation parameters can be altered to archive more accurate results by applying the knowledge learned from physical measurement results.

• RF measurements are difficult to repeat; follow RF test lab best practices such as calibrating instruments, taking care of cables, using proper tools, knowing torque specs for each connector type...brass requires less torque than SS connectors, keep everything clean.

• Maintain appropriate lab conditions; temp, humidity, ESD, vibration control.
Thank You? Your questions are welcome...

Michael Ricci
Principal Engineer