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# ARIES ELECTRONICS

## BGA SOCKET
## (0.80MM TEST CENTER PROBE CONTACT)

# Final Report

**Electrical Characterization**
**0.05-5.05 GHz**

**Feburary 21, 2003**

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# Summary

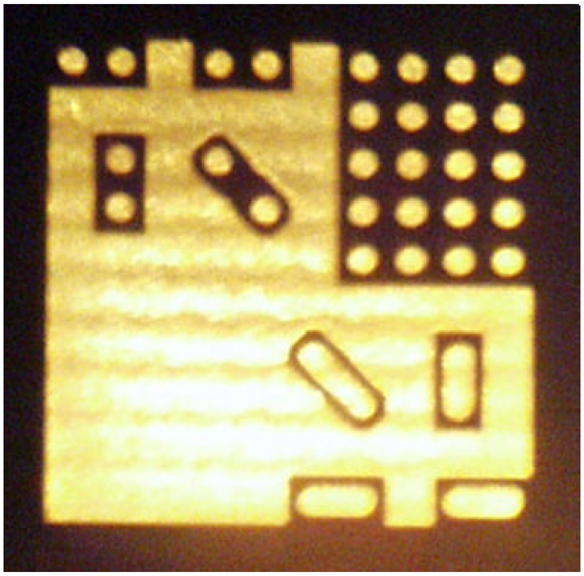
**Objective**

The Aries BGA (0.80mm Test Center Probe Contact) socket was measured at GigaTest Labs to assess its electrical performance. Also, its high-speed performance limits were determined.

**Methodology:**

A custom fixture (GTL 243-GT-001 rev A1) was first designed by GTL which allows the use of coplanar probes to make the measurements. A second fixture was fabricated to be placed inside each socket. It provides connections between the internal pins, so pairs of pins can be measured in different load conditions. This fixture is referred to as "surrogate package". Figure 1 shows a picture the surrogate package, while figure 2 shows the top and bottom side of the fixture.

## Figure 1: Surrogate Package



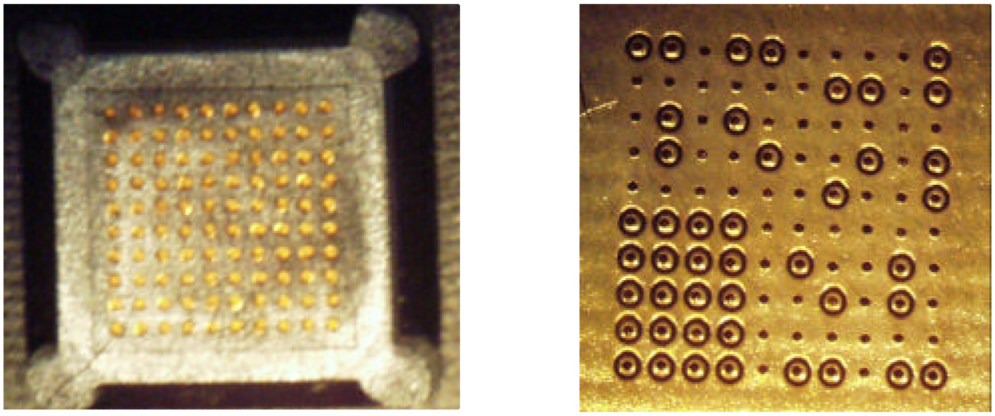


**Figure 2 – Socket Fixture**

There are three load conditions used on the signal pins:  the **open** measurement is performed on two pins with just unconnected surface pads on the surrogate package.  The **short** measurement is done with the pins shorted to the ground on the surrogate.  The **thru** is just the two pins connected together.  These are illustrated on figure 3.  The measured pins are denoted by the numbers 1 & 2. The adjacent pins to the measurement, usually the three nearest neighbors are grounded to the fixture ground and the surrogate package ground.

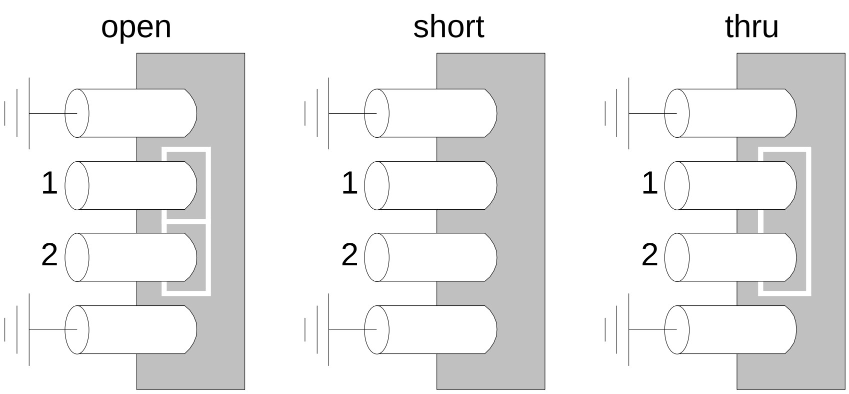



**Figure 3 – Signal pin load conditions**

The fixture was measured separately to extract its parasitics, so they could later be de-embedded from the overall measurement.

The Agilent 8510C network-analyzer was used to measure two-port s-parameters.  The frequency range was 100 MHz – 40.1 GHz.  From the s-parameter data, a SPICE-compatible equivalent circuit was derived using Agilent ADS version 2002.

**Measurement system**

All measurements were taken using a high-frequency measurement system. This consists of a Agilent 8510C network analyzer & GGB Picoprobes™ 450 µm pitch. The Agilent 8510C network analyzer is a frequency domain instrument. The measurements are taken as scattering parameters (a.k.a. s-parameters). The HP8510C has great calibration capabilities, which make it the most accurate high-frequency instrument available. For this work the short-open-load-thru (SOLT) calibration was used. The GGB Picoprobes provide a high-quality 50 Ω path from the network analyzer and cables to the DUT.

**Equivalent-circuit model**

Figure 4 shows the topology used to model the BGA socket (0.80mm Test Center Probe Contact). Please note that only two pins are shown in this schematic, however there will be similar mutual elements ($M_{21}$, $C_{21A}$ and $C_{21B}$) to **ALL the surrounding pins**. Therefore, to implement the model for one pin, the user needs to describe it and all the pins surrounding it (a total of 9 pins). By the same reasoning, to implement two pins, then the models for 12 pins will be needed.

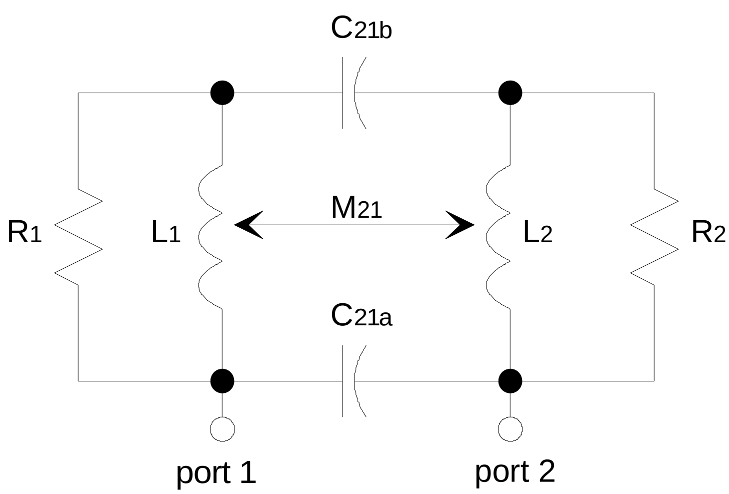



**Figure 4 - BGA socket equivalent-circuit diagram**

**Element definitions**

| | |
|---|---|
| **$L_1$, $L_2$:** | pin effective inductance |
| **$M_{21}$:** | mutual inductance between adjacent pins |
| **$R_1$, $R_2$:** | shunt-resistance of inductors $L_1$ and $L_2$, used to model high-frequency loss due to skin effect and dielectric loss |
| **$C_{21a}$:** | mutual-capacitance between adjacent pins (PCB side) |
| **$C_{21b}$:** | mutual-capacitance between adjacent pins (BGA side) |

**Element values**

The BGA socket (0.80mm Test Center Probe Contact) model is valid from DC to 5.05 GHz. The measured and modeled transmission response agrees within 1 dB. Models were extracted for four types of pins: adjacent field pins, corner pins, field diagonal pins and edge adjacent pins.

**Table 1 – BGA socket (0.80mm Test Center Probe Contact) element values**

| **Pins** | **$L_1$ & $L_2$ (nH)** | **$M_{21}$ (nH)** | **$R_1$ & $R_2$ (W)** | **$C_{21a}$ (pF)** | **$C_{21b}$ (pF)** |
|---|---|---|---|---|---|
| Field adjacent | 0.56 | 0.08 | 200 | 0.033 | 0.033 |
| Corner adjacent | 0.76 | 0.17 | 300 | 0.043 | 0.043 |
| Field diagonal | 0.51 | 0.01 | 300 | 0.007 | 0.007 |
| Edge adjacent | 0.65 | 0.12 | 200 | 0.040 | 0.040 |

**Conclusions**

**1.** The bandwidth for the BGA socket (0.80mm Test Center Probe Contact) was determined from a loop-thru measurement on two adjacent pins with varying numbers of surrounging pins grounded (please see figure 5 and table 2).

**Table 2 – BGA socket (0.80mm Test Center Probe Contact) 1dB loop-thru bandwidth**

| **Pins** | **1dB BW (GHz)** |
|---|---|
| Field adjacent (1:5 signal to gnd ratio) | 7.8 |
| Corner adjacent (1:2 signal to gnd ratio) | 7.1 |
| Field diagonal (1:7 signal to gnd ratio) | 10.1 |
| Edge adjacent (1:3 signal to gnd ratio) | 8.5 |

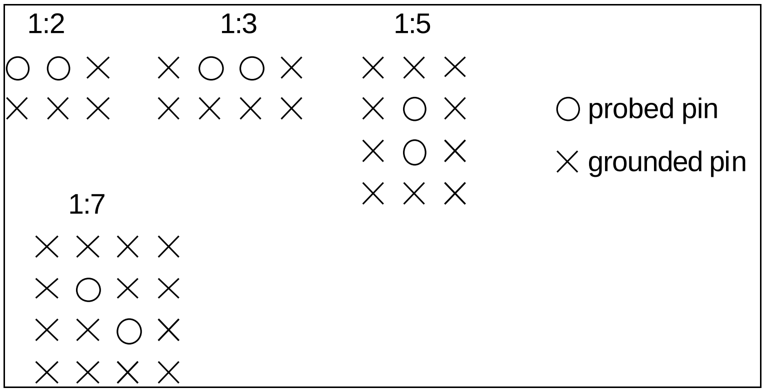



**Figure 5 – Signal to ground ratio setup**

Since the surrogate packages were routed out to fit into the socket cavity, we believe there was a small misalignment on the field adjacent THRU standard. This issue is probably responsible for the low field adjacent bandwidth. We attempted this measurement twice, with no better result. In reality, the field adjacent 1 dB bandwidth should be in the 9-10 GHz range.

2. The model bandwidth is DC-5.05 GHz, which will easily handle signals with 200 ps edges.

# Appendix

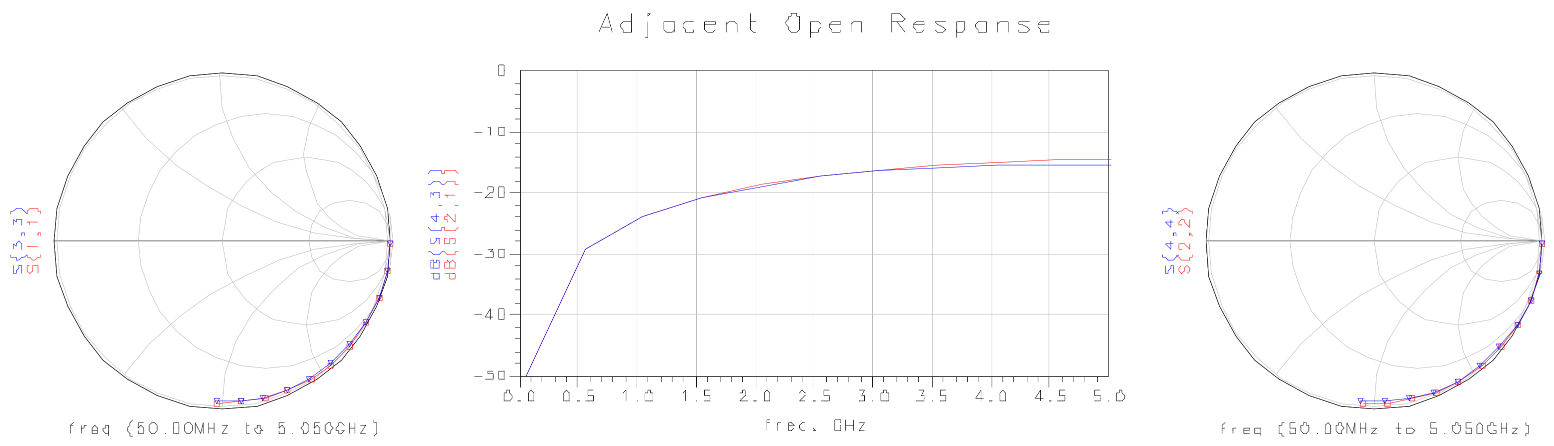
The appendix shows the measured and simulated output data.

**Measured and simulated data** **page**

Open measurement on adjacent pins ........................................................9
Shorted measurement on adjacent pins ...............................................10
Loop-thru measurement on adjacent pins.............................................11
Loop-thru bandwidth measurement (40 GHz).................................... 12-15

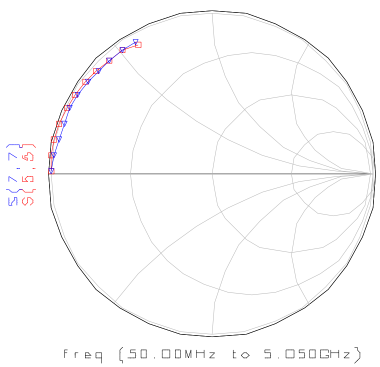
# Adjacent pins open

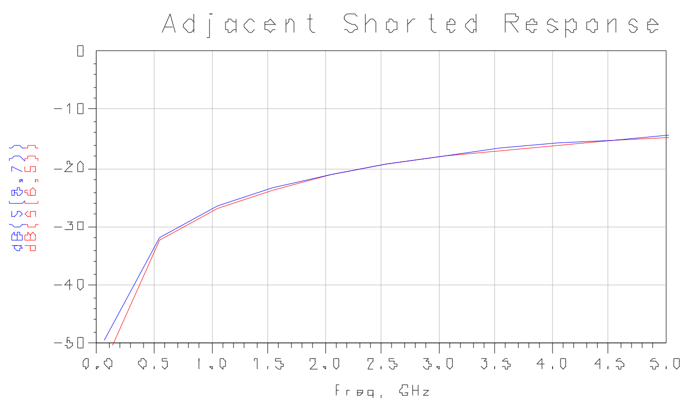
Measured s-parameters in blue, simulated s-parameters in red

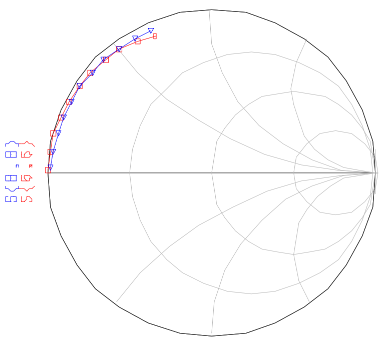


# Adjacent pins shorted to ground

Measured s-parameters in blue, simulated s-parameters in red

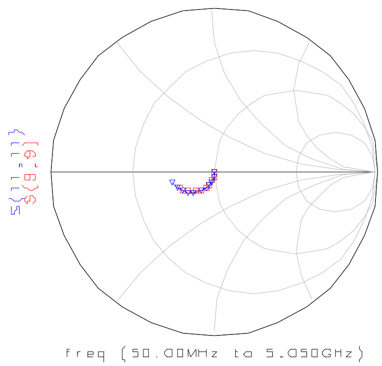


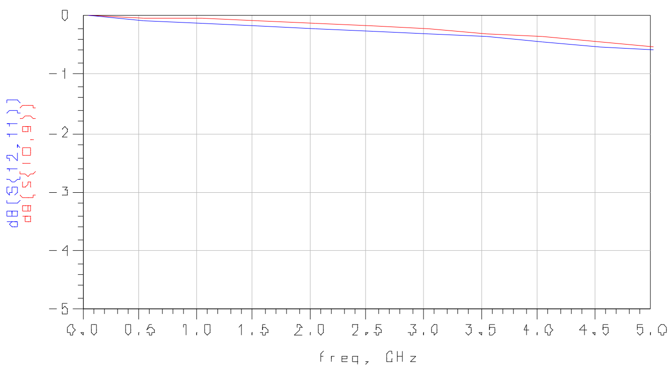



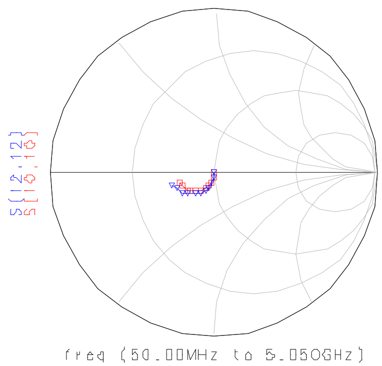



# Adjacent pins connected together (loop-thru)

Measured s-parameters in blue, simulated s-parameters in red



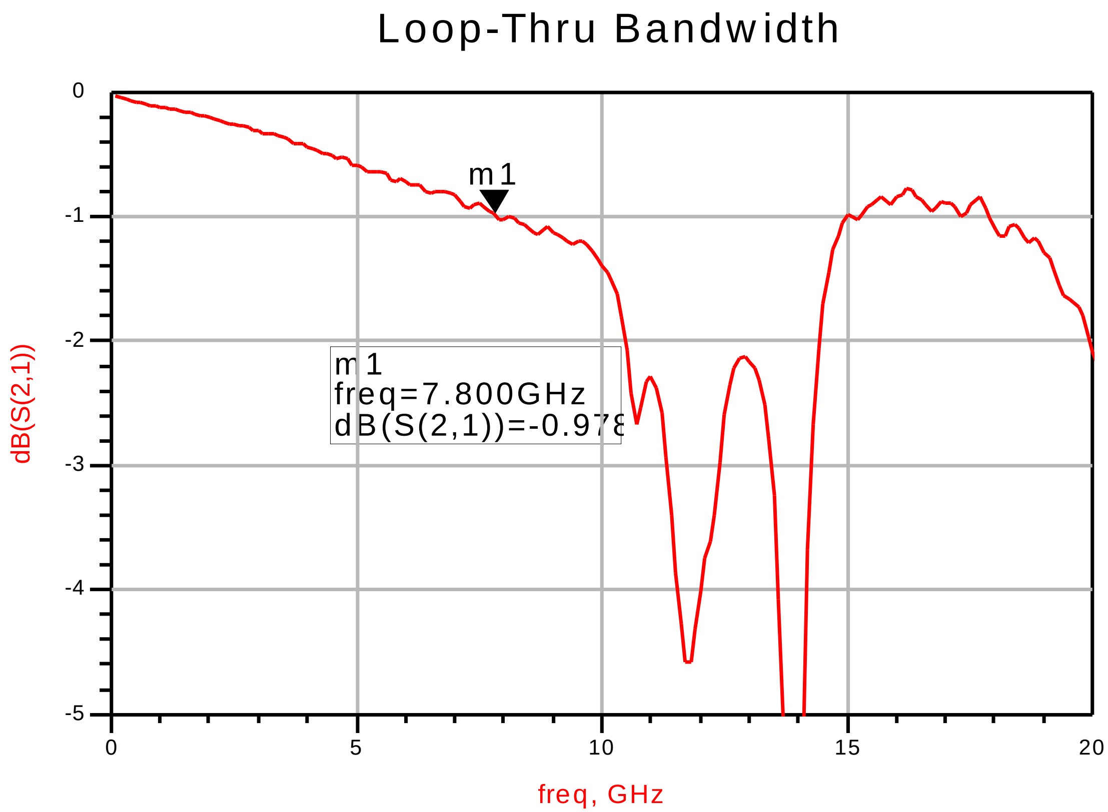



# Adjacent Loop-thru Bandwidth Measurement

**Measured insertion loss versus frequency for two pins in series**

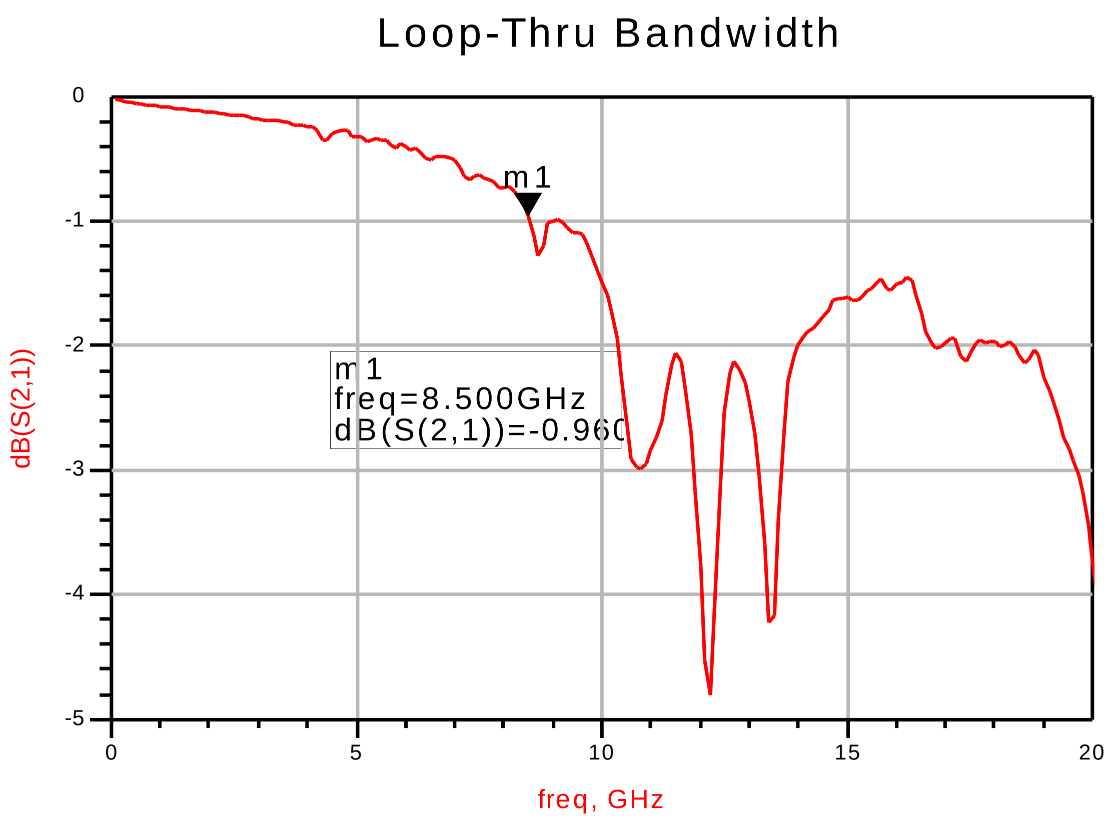
**“1:5 signal to ground ratio”**



# Edge Loop-thru Bandwidth Measurement

**Measured insertion loss versus frequency for two pins in series**

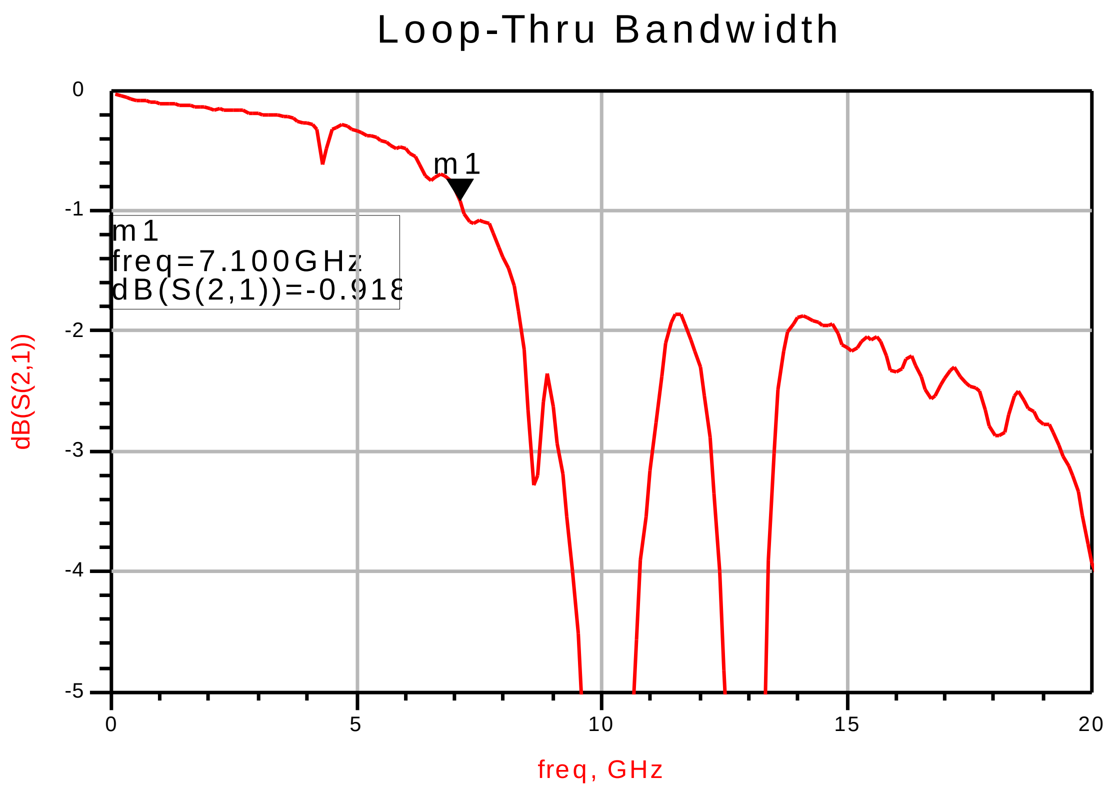
**“1:3 signal to ground ratio”**



# Corner Loop-thru Bandwidth Measurement

**Measured insertion loss versus frequency for two pins in series**

**“1:2 signal to ground ratio”**



# Diagonal Loop-thru Bandwidth Measurement

**Measured insertion loss versus frequency for two pins in series**

**“1:7 signal to ground ratio”**