Ironwood Electronics

BGA socket
1 mm pitch

Measurement Results

prepared by

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4/30/05

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Objective

The objective of these measurements is to determine the RF performance of a Ironwood Electronics BGA 1.0mm socket. For G-S-G configurations, a signal pin surrounded by grounded pins is selected for the signal transmission. For G-S-S-G configurations, two adjacent pins are used and all other pins are grounded. Measurements in both frequency and time domain form the basis for the evaluation. Parameters to be determined are pin capacitance and inductance of the signal pin, the mutual parameters, the propagation delay and the attenuation to 40 GHz.

Methodology

Capacitance and inductance for the equivalent circuits were determined through a combination of measurements in time and frequency domain. Frequency domain measurements were acquired with a network analyzer (HP8722C). The instrument was calibrated up to the end of the 0.022" diameter coax probes that are part of the test fixturing. The device under test (DUT) was then mounted to the fixture and the response measured from one side of the contact array. When the DUT pins terminate into an open circuit, a capacitance measurement results. When a short circuit compression plate is used, inductance can be determined.

Time domain measurements are obtained via Fourier transform from VNA tests. These measurements reveal the type of discontinuities at the interfaces plus contacts and establish bounds for digital system risetime and clock speeds.

Test procedures

To establish capacitance of the signal pin with respect to the rest of the array, a return loss calibration is performed. Phase angle information for S11 is selected and displayed. When the array is connected, a change of phase angle with frequency can be observed. It is recorded and will be used for determining the pin capacitance.

The self-inductance of a pin is found in the same way, except the BGA 1.0mm contact array is compressed by a metal plate instead of an insulator. Thus a short circuit at the far end of the pin array results. Again, the analyzer is calibrated and S11 is recorded. The inductance of the connection can be derived from this measurement.

Setup

Testing was performed with a test setup that consists of a brass plate that contains the coaxial probes. The DUT is aligned and mounted to that plate. The opposite termination is also a metal plate with coaxial probes, albeit in the physical shape of an actual device to be tested or a flat plate with embedded coaxial probes.

Figs. 1 and 2 show a typical arrangement base plate and DUT probe:

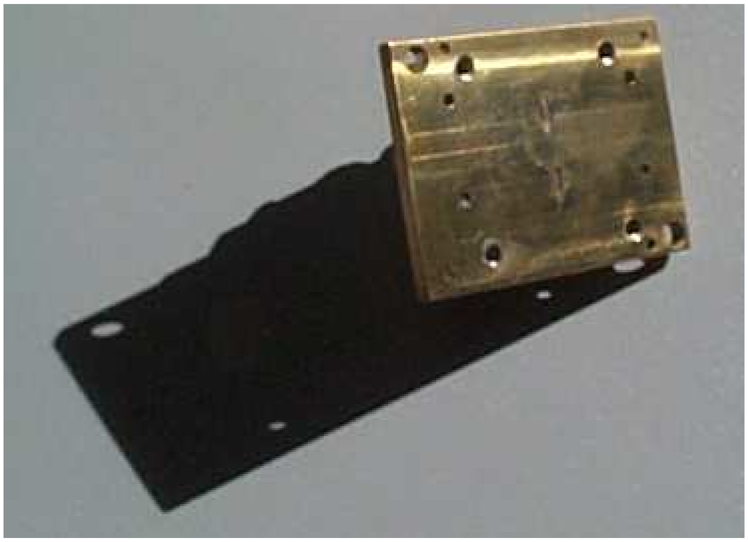


Figure 1 BGA 1.0mm socket base plate example

Figure 2 DUT plate

The BGA 1.0mm socket and base plate as well as the DUT plate are then mounted in a test fixture as shown below in Fig. 3:

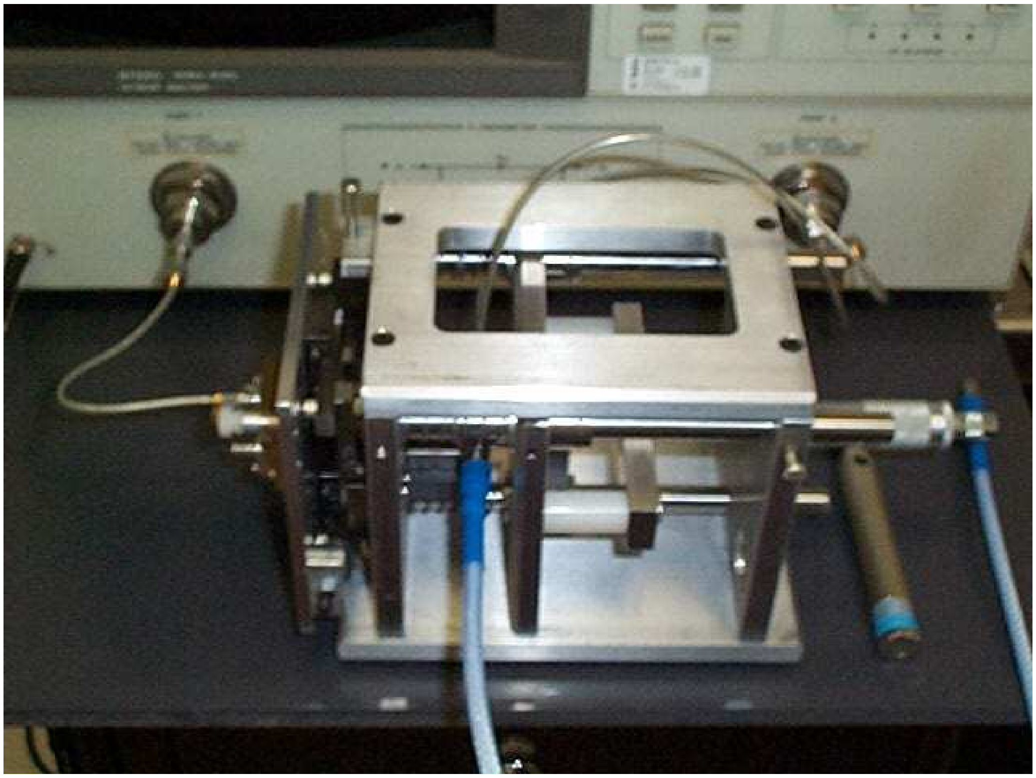
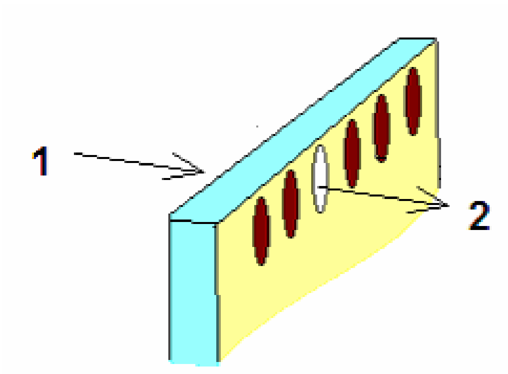


Figure 3 Test fixture

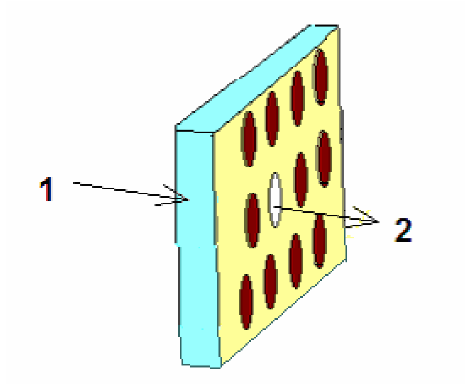
This fixture provides for independent X,Y and Z control of the components relative to each other. X, Y and angular alignment is established once at the beginning of a test series and then kept constant. Z (depth) alignment is measured via micrometer and is established according to specifications for the particular DUT.

Connections to the VNA are made with high quality coaxial cables with K connectors.

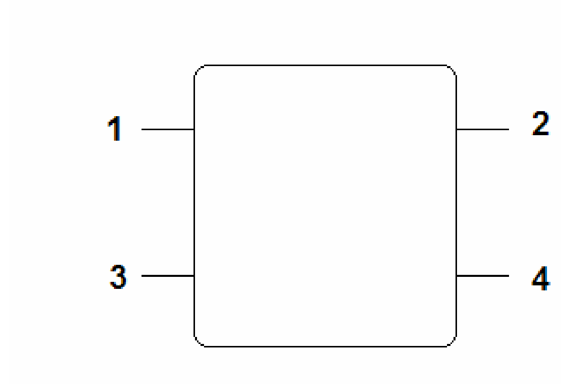
For G-S-G and G-S-S-G measurements, the ports are named as follows:



Single row DUTs



Multi-row DUTS



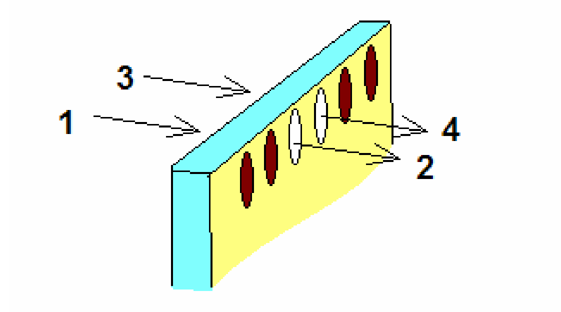


Figure 4 Ports for the G-S-G and G-S-S-G measurements

Signals are routed though two adjacent connections (light areas), unused connections are grounded (dark areas).

Measurements G-S-G

Time domain

The time domain measurements will be presented first because of their significance for digital signal integrity. TDR reflection measurements are shown below:

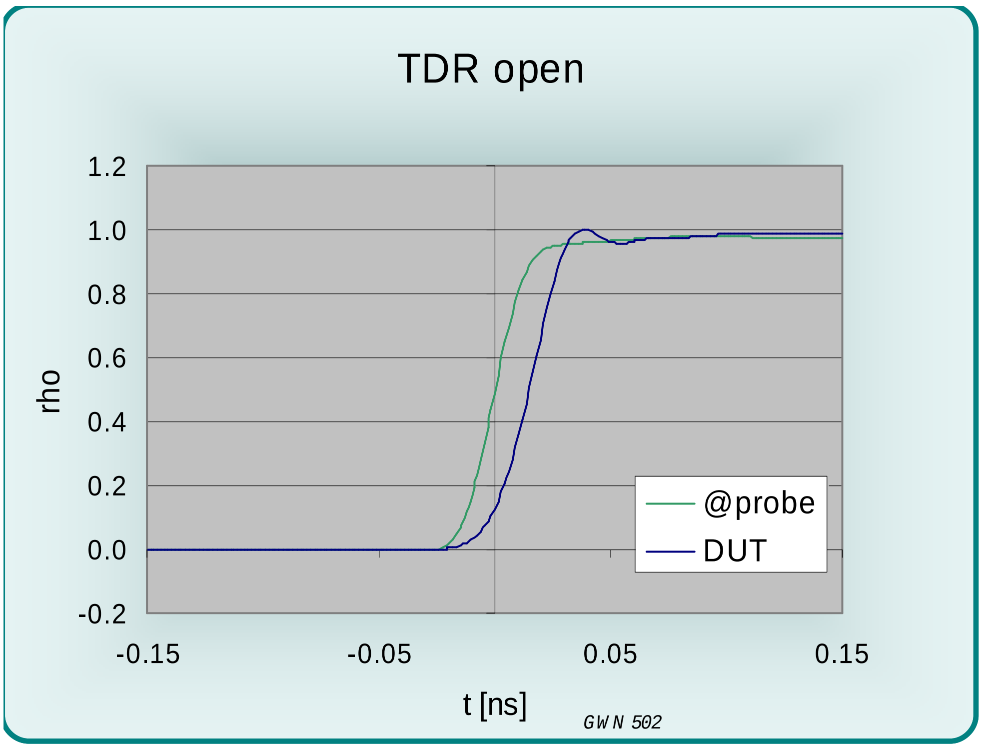


Figure 5 TDR signal from an OPEN circuited BGA 1.0mm socket

The reflected signals from the BGA 1.0mm socket (rightmost traces) show only a small deviation in shape from the original waveform (leftmost trace). The risetime is about 30.0 ps and is almost the same as that of the system with the open probe (27.0 ps). Electrical pin length is about 7.5 ps one way.

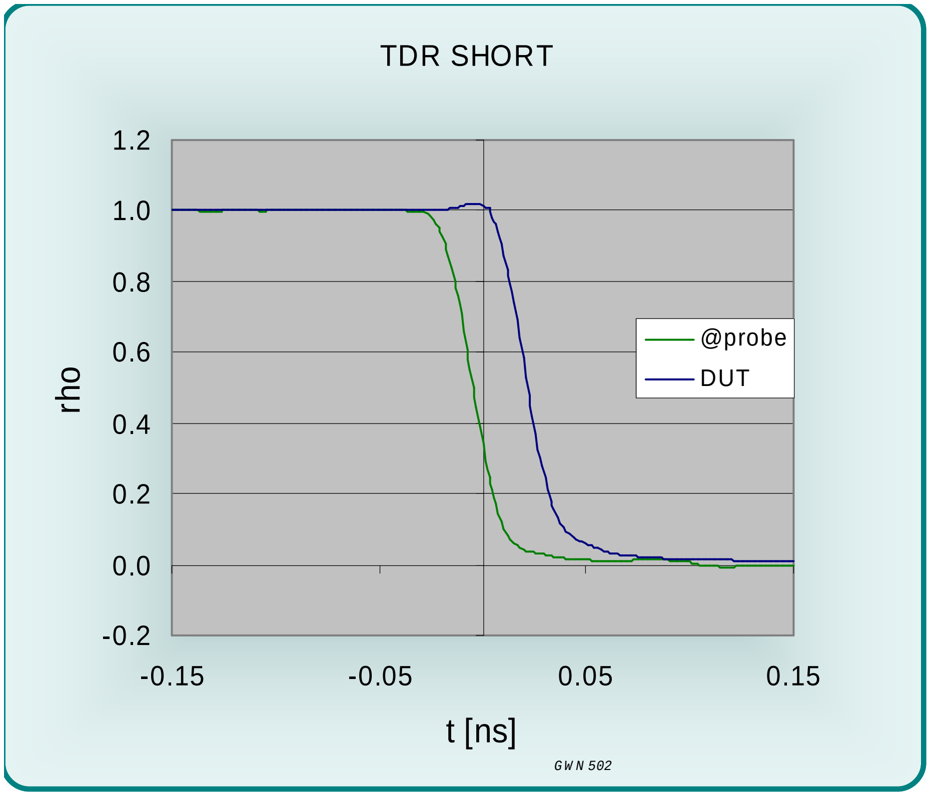


Figure 6 TDR signal from a SHORT circuited BGA 1.0mm socket

For the short circuited BGA 1.0mm socket the fall time is about 30.0 ps. There is an insignificant increase over the system risetime of 27.0 ps.

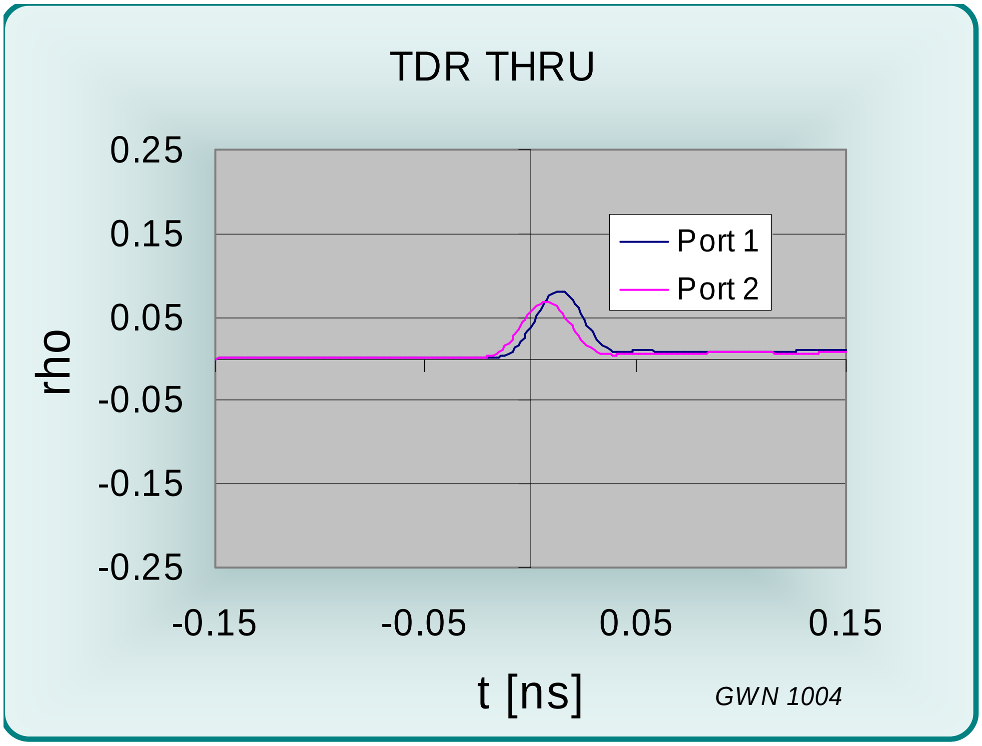


Figure 7 TDR measurement into a 50 Ohm probe

The thru TDR response shows an inductive response. The peak corresponds to an impedance of 58.8 Ohms and is noticeably larger than 50 Ohms. The dip goes to 50.0 Ohms, a value that is almost the same as the system impedance.

The TDT performance for a step propagating through the contact arrangement was also recorded:

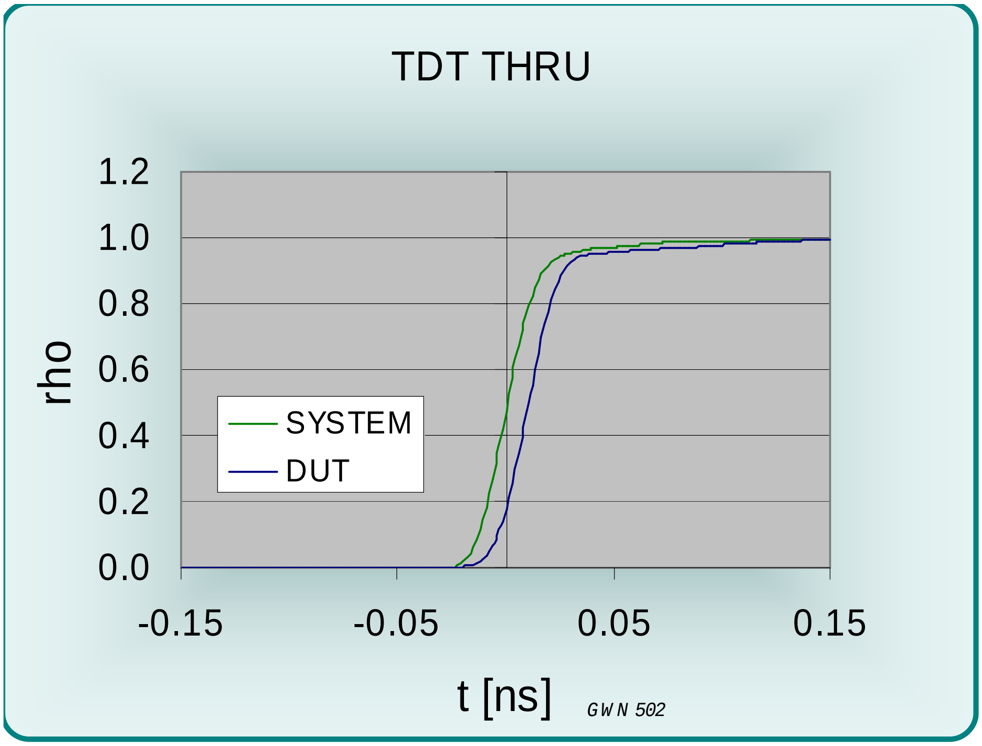


Figure 8 TDT measurement

The TDT measurements for transmission show an identical risetime from the pin array (10-90% RT = 30.0 ps, the system risetime is 30.0 ps). The added delay at the 50% point is 9.0 ps. There is no significant signal distortion. If the 20%-80% values are extracted, the risetime is only 19.5 ps vs. 19.5 ps system risetime.

Frequency domain

Network analyzer reflection measurements for a single sided drive of the signal pin with all other pins open circuited at the opposite end were performed to determine the pin capacitance. The analyzer was calibrated to the end of the probe and the phase of S11 was measured. From the curve the capacitance of the signal contact to ground can be determined (see Fig. 10).

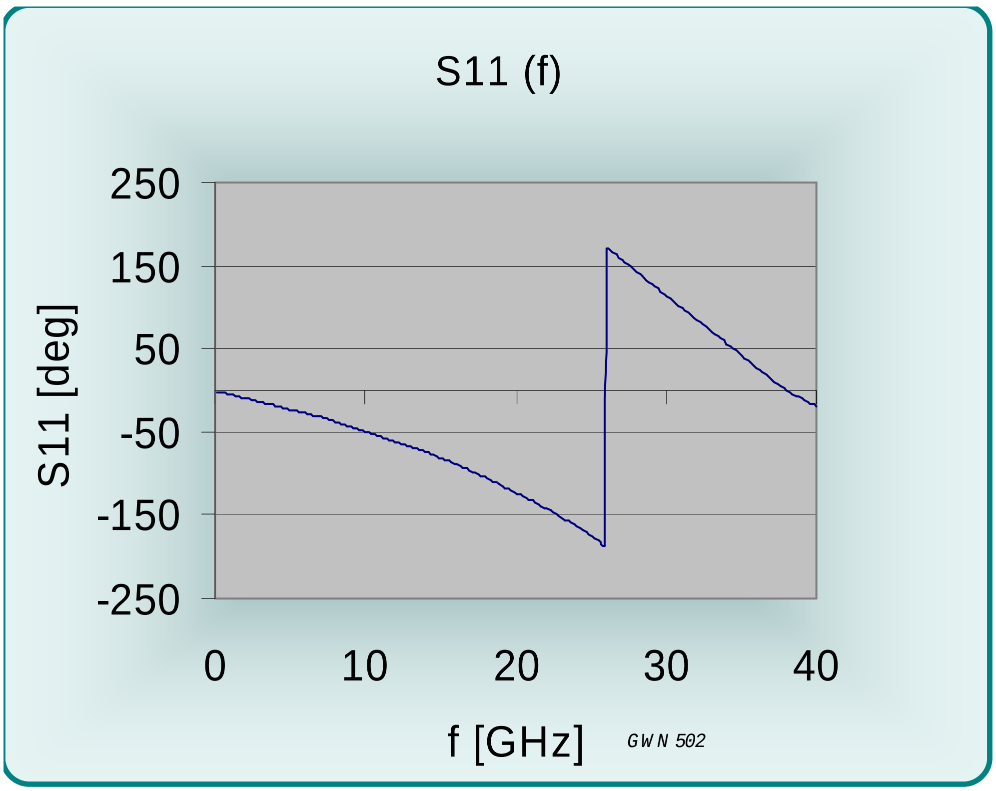


Figure 9 S11 phase (f) for the open circuited signal pin

There are no aberrations in the response. The 360 degree jump is due to the network analyzer data presentation which does not allow for values greater than +/- 180 degrees.

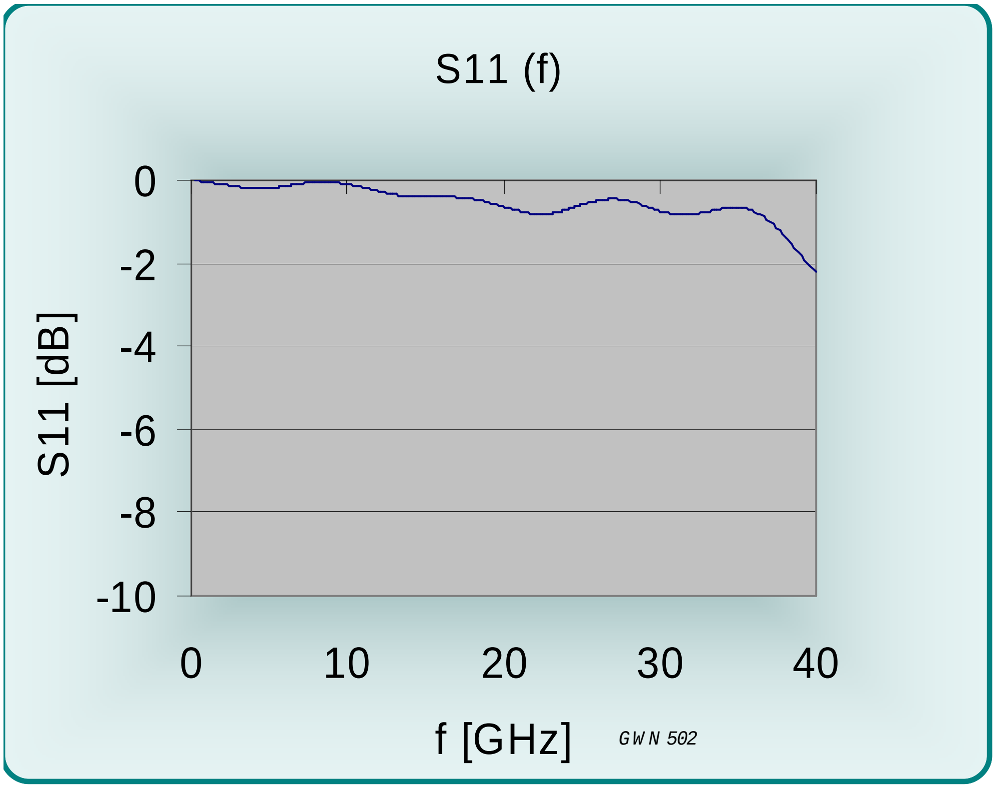


Figure 10 S11 magnitude (f) for the open circuited signal pin

While ideally the magnitude of S11 should be unity (0 dB), minimal loss and radiation in the contact array are likely contributors to S11 (return loss) for the open circuited pins at elevated frequencies.

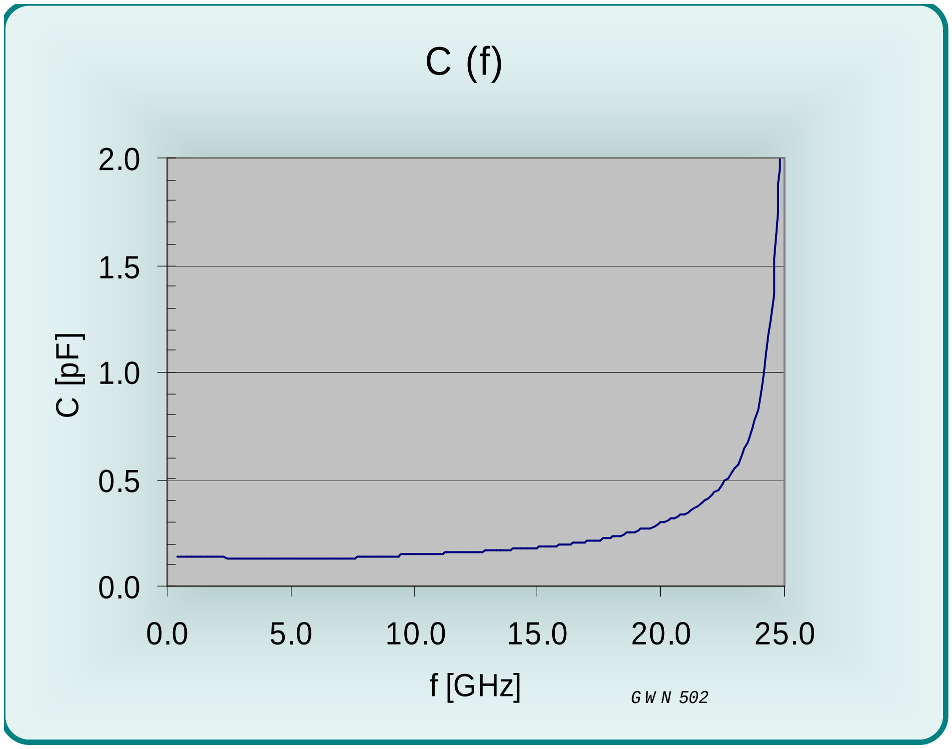


Figure 11 C(f) for the open circuited signal pin

Capacitance is 0.14 pF at low frequencies. The rise in capacitance toward 23 GHz is due to the fact that the pins form a transmission line with a length that has become a noticeable fraction of the signal wavelength. The lumped element representation of the transmission environment as a capacitor begins to become invalid at these frequencies and so does the mathematical calculation of capacitance from the measured parameters. This merely means the model is not valid anymore. As is evident from time domain and insertion loss measurements this does not imply that the DUT does not perform at these frequencies.

The Smith chart measurement for the open circuit shows no resonances for frequencies to 40 GHz. A small loss is present.

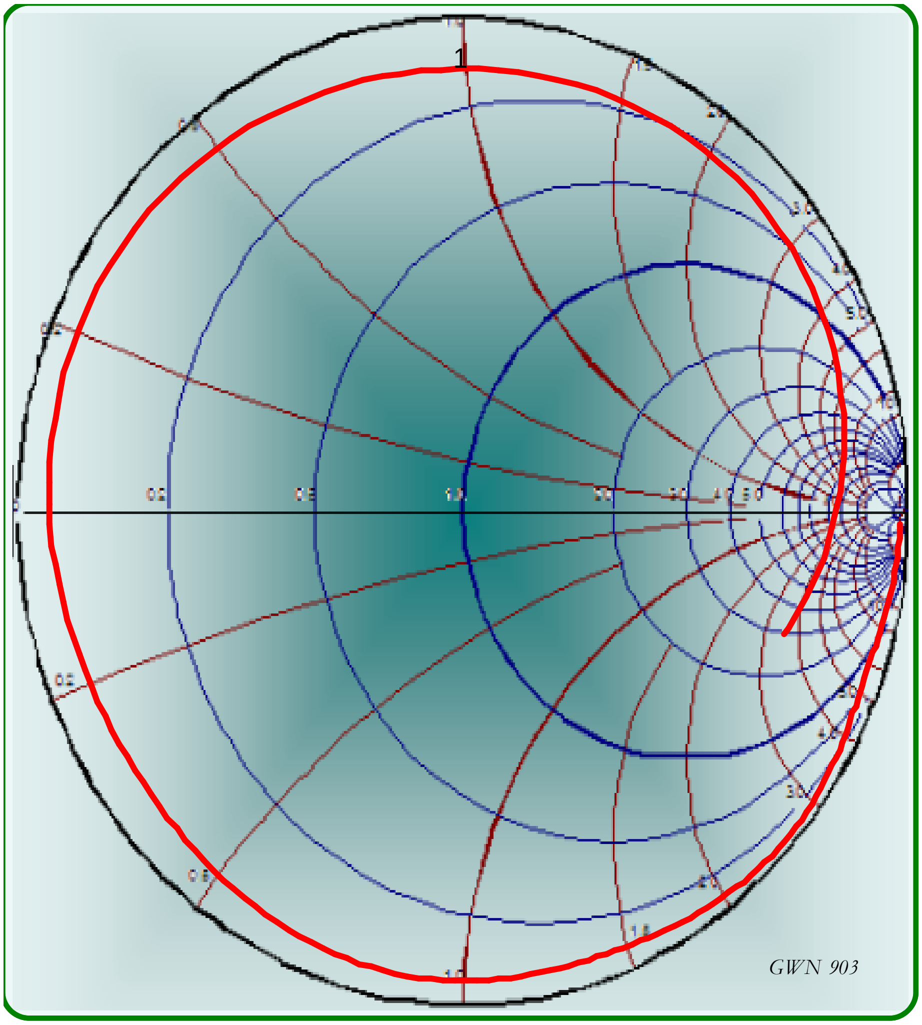


Figure 12 Reflections from the open circuited BGA 1.0mm socket

To extract pin inductance, the same types of measurements were performed with a shorted pin array. Shown below is the change in reflections from the BGA 1.0mm socket. Calibration was established with a short placed at the end of the coax probe.

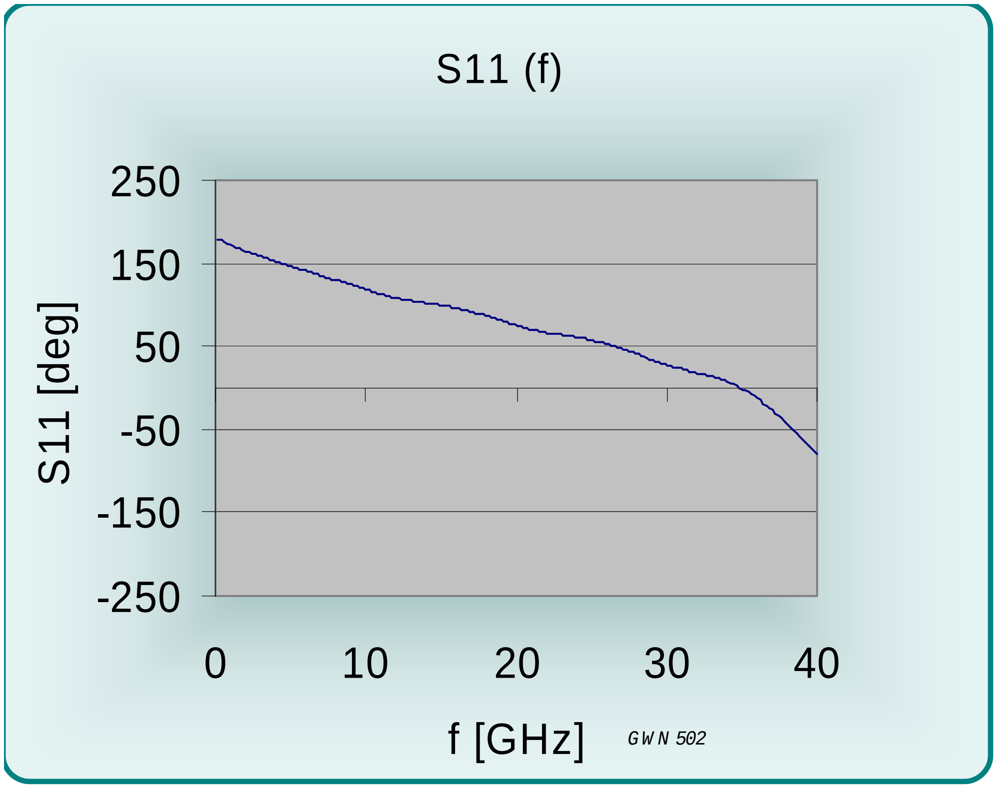


Figure 13 S11 phase (f) for the short circuited case

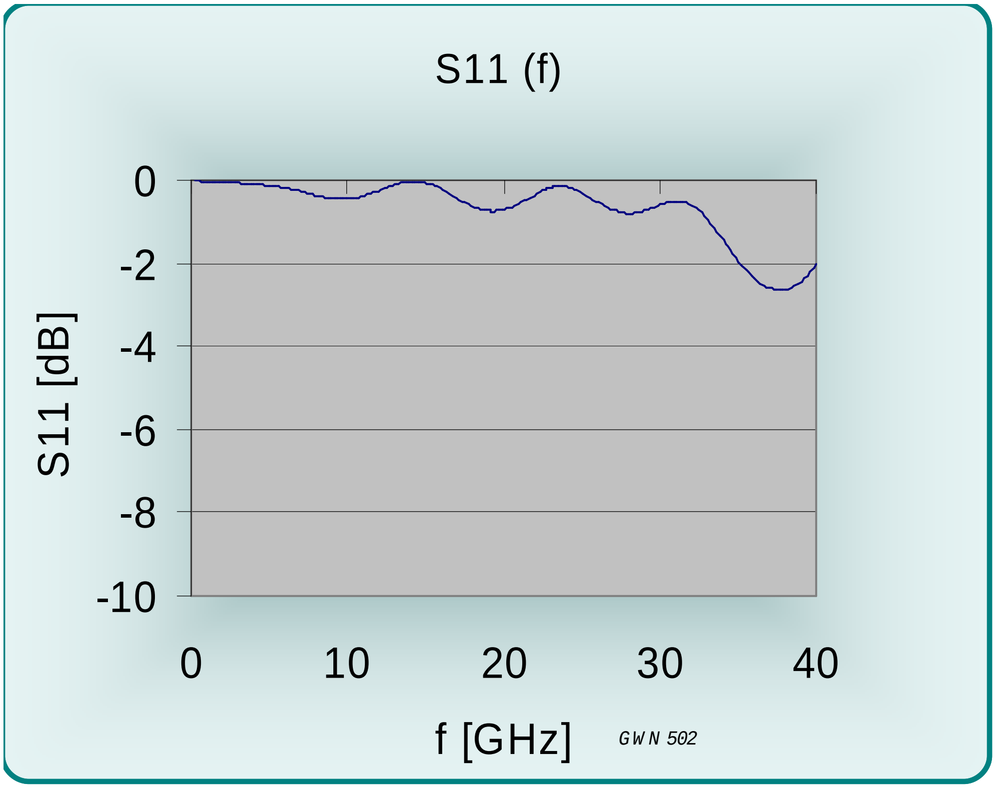


Figure 14 S11 magnitude (f) for the short circuited case

Only a small S11 return loss exists, likely the result of minimal loss and radiation.

The phase change corresponds to an inductance of 0.54 nH at low frequencies (see Fig. below). Toward 33 GHz inductance increases. At these frequencies, the transmission line nature of the arrangement must be taken into account.

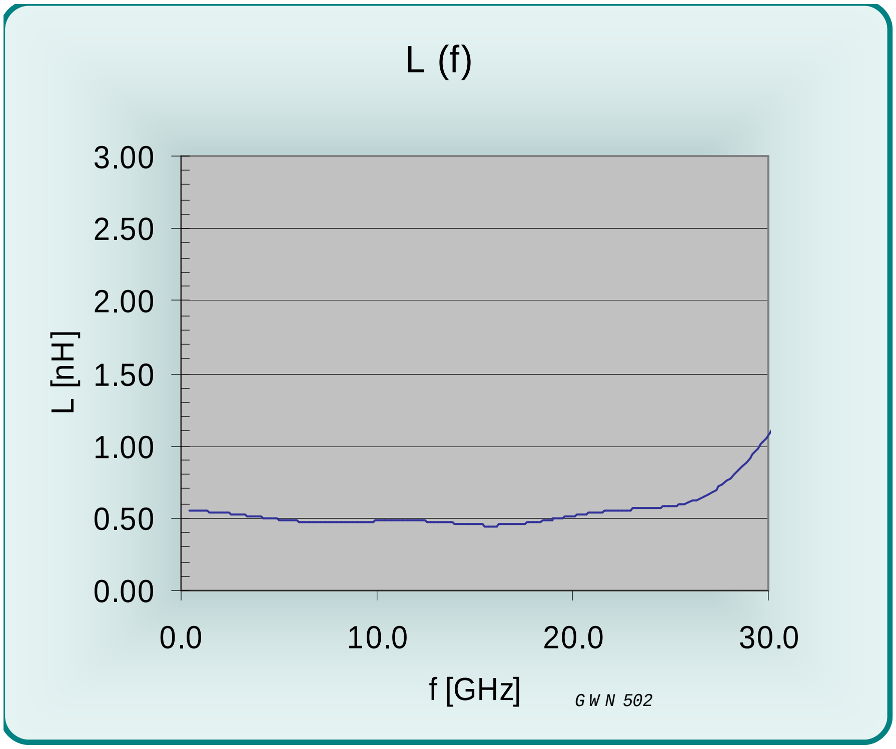


Figure 15 L(f) for the BGA 1.0mm socket

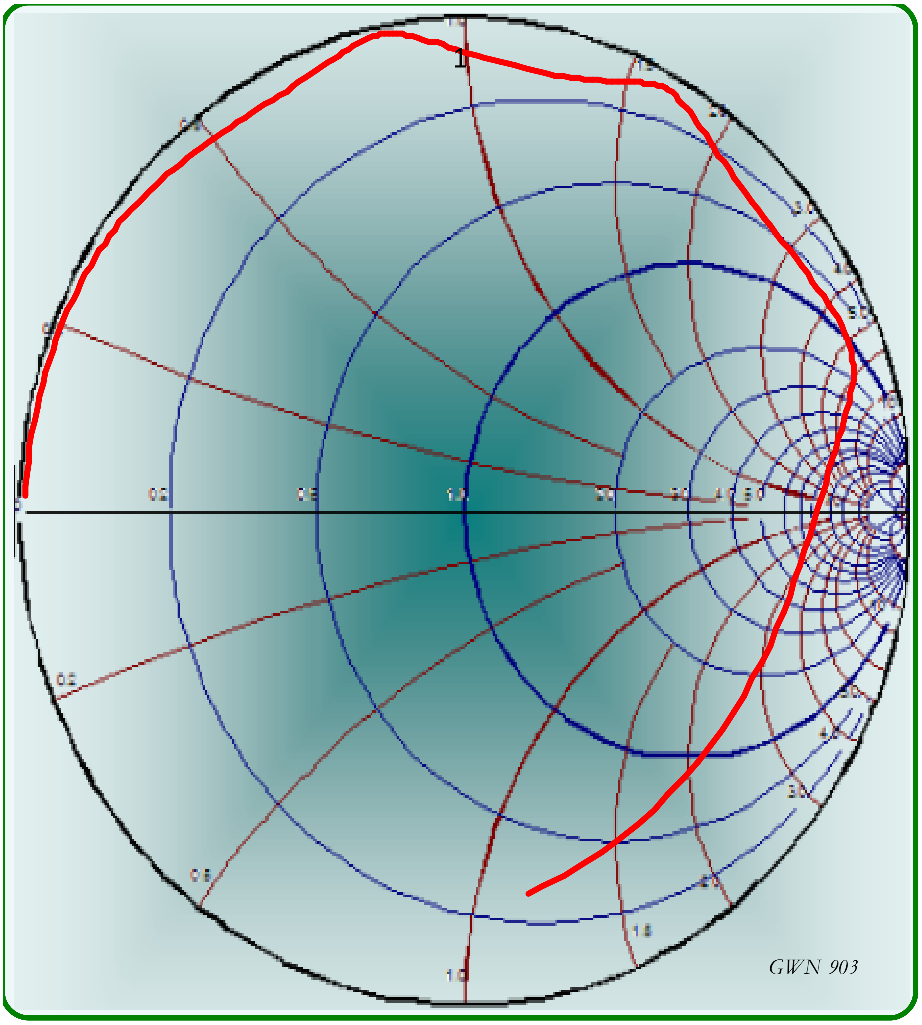


Figure 16 Short circuit response in the Smith chart

Only a small amount of loss and no resonances are noticeable to 40 GHz in the Smith chart for the short circuit condition.

An insertion loss measurement is shown below for the frequency range of 50 MHz to 40 GHz.

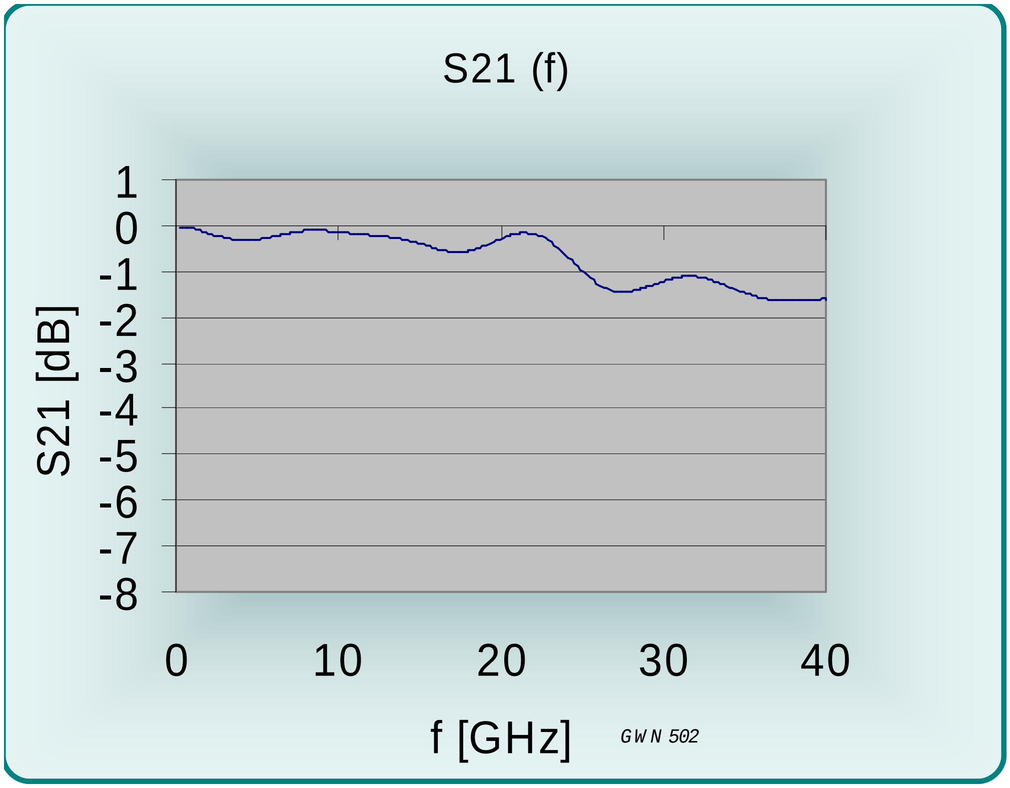


Figure 17 Insertion loss S21 (f)

Insertion loss is less than 1 dB to about 24.9 GHz. The 3 dB point is not reached before 40.0 GHz.

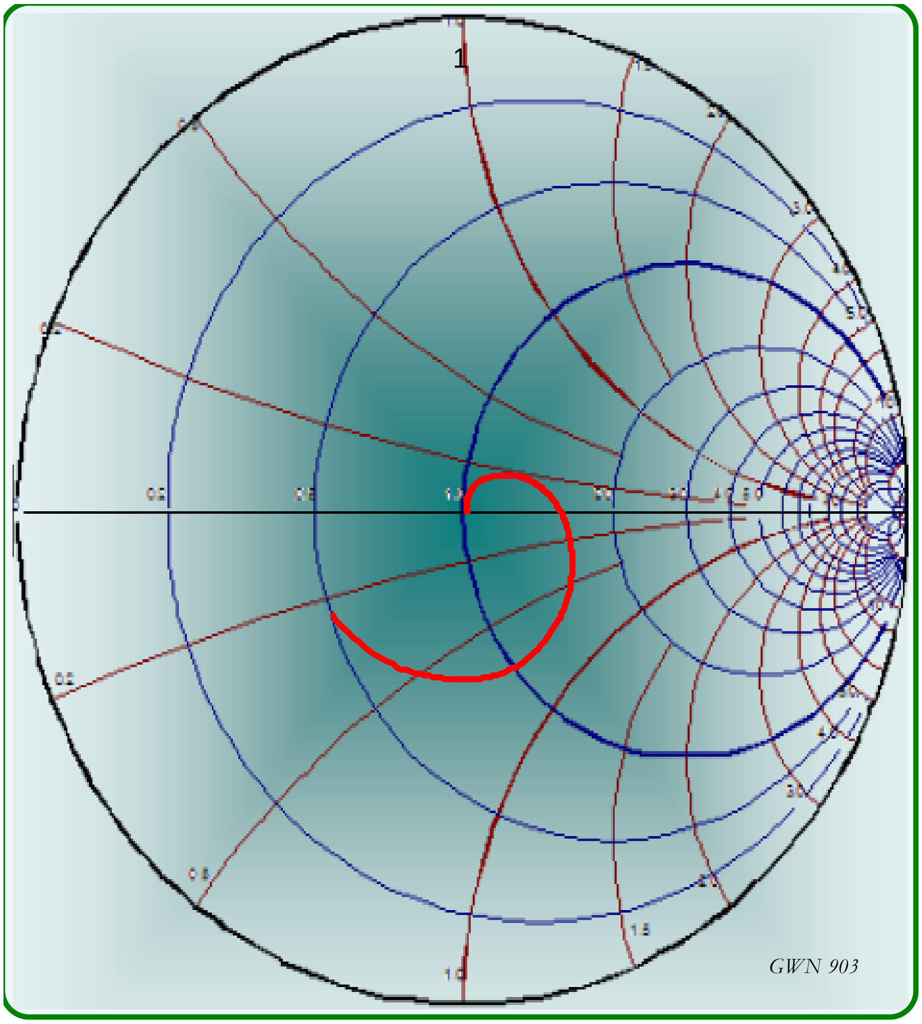


Figure 18 Smith chart for the thru measurement into a 50 Ohm probe

The Smith chart for the thru measurements shows a reasonable match with some reactive components toward 40 GHz.

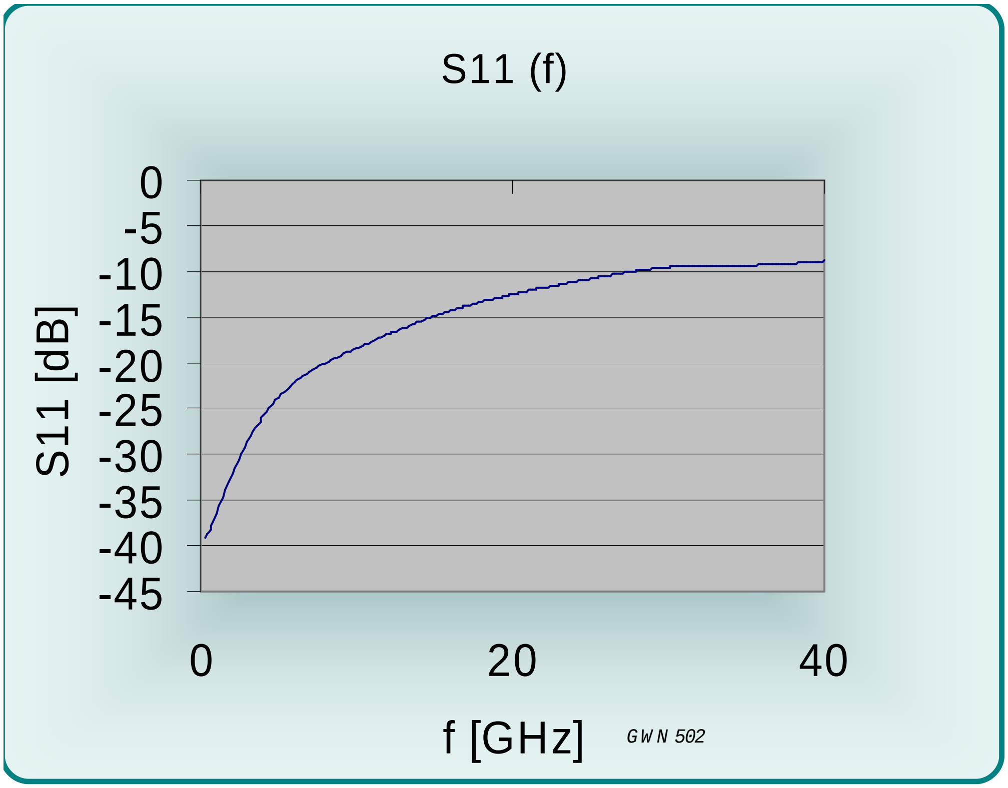


Figure 19 S11 magnitude (f) for the thru measurement into a 50 Ohm probe

The value of the return loss for the thru measurement reaches -20 dB at 8 GHz and exceeds -10 dB beyond 28 GHz.

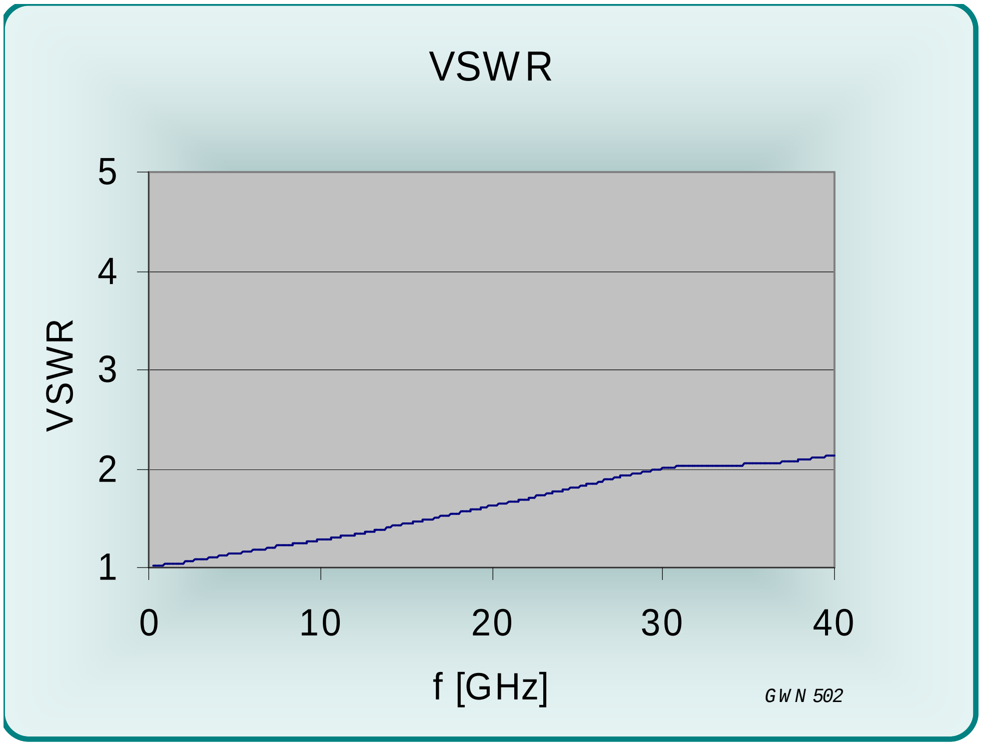


Figure 20 Standing wave ratio VSWR (f) [1 / div.]

The VSWR remains below 2 : 1 to a frequency of 29.9 GHz.

Crosstalk was measured in the G-S-S-G configuration by feeding the signal pin and monitoring the response on an adjacent pin. Measurement results can be found in the section on the G-S-S-G configuration.

The mutual capacitance and inductance values will be extracted from G-S-S-G models and are also listed in that section.

Ironwood Electronics

MLF 1.0mm

Report summary sheet

4/30/05

Socket test configuration:

All pins grounded in an 1 mm pitch array except for one signal pin (G-S-G) and two signal pins in the G-S-S-G configuration.

Performance:

Time domain:

Signal delay	=	9.0 ps
Risetime, open circuit	<	30.0 ps
Risetime, short circuit	<	30.0 ps
Risetime, thru 50 Ω	<	30.0 ps

Frequency domain:

Insertion loss	<	1 dB to 24.9 GHz , < 3 dB to 40.0 GHz
VSWR	<	2 :1 to 29.9 GHz

Equivalent circuit parameters:

Pin inductance	=	0.54 nH
Pin to ground capacitance	=	0.14 pF
Transmission line	=	Z0 = 58.8 Ω , L = 9 ps