Custom Interconnects

Fuzz Button Coax interconnect

Ø.010 RF Layout 50ohms

Measurement and Model Results

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7/8/14

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Objective

The objective of these measurements is to determine the RF performance of a Custom Interconnects Fuzz Button Coax interconnect. A signal pin surrounded by grounded pins is selected for the signal transmission. 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 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 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 in 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.

Inductance of a pin is found in the same way, except the Fuzz Button Coax interconnect 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 coaxial probes. The DUT is aligned and mounted to that plate. The opposite termination is also a metal plate with embedded coaxial probes.

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

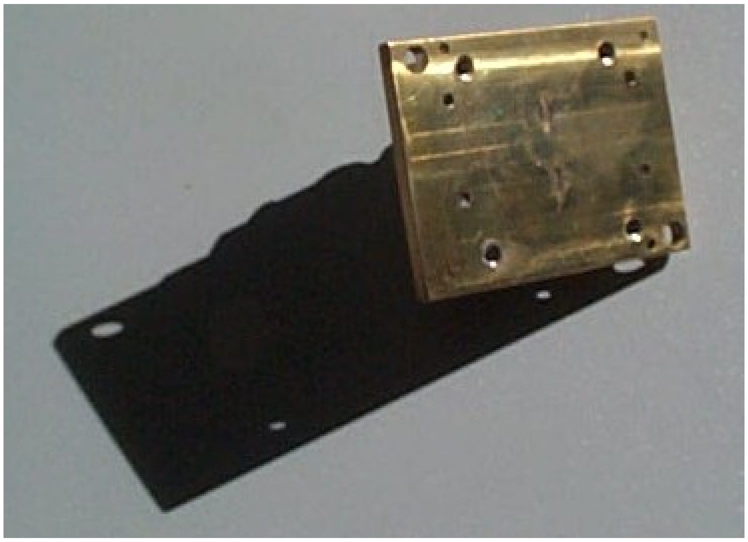

Figure 1 Coax interconnect base plate example

Figure 2 DUT plate example

The Coax interconnect and base plate as well as the DUT plate are then mounted in a test fixture as shown below in Fig. 3:

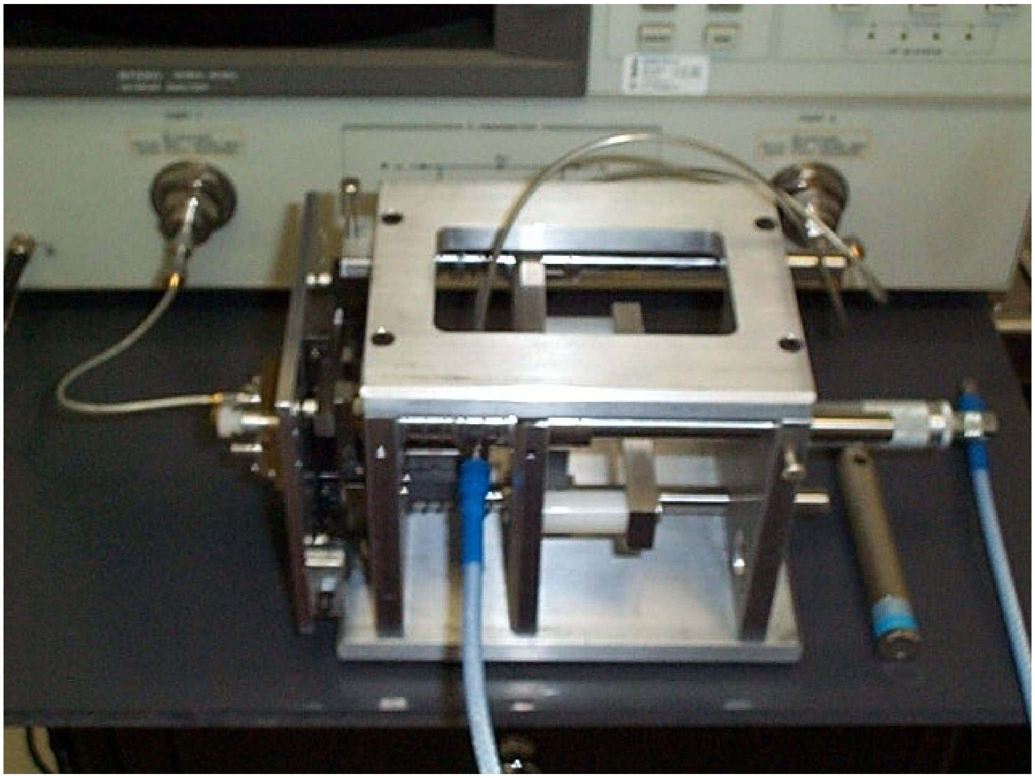

Figure 3 Test fixture example

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.

Figure 4 Ø0.010 Fuzz Button Interconnect Configuration

The signal is routed through the center contact, all other contacts are grounded.

Measurements

Time domain

The time domain measurements will be presented first. TDR reflection measurements are shown below:

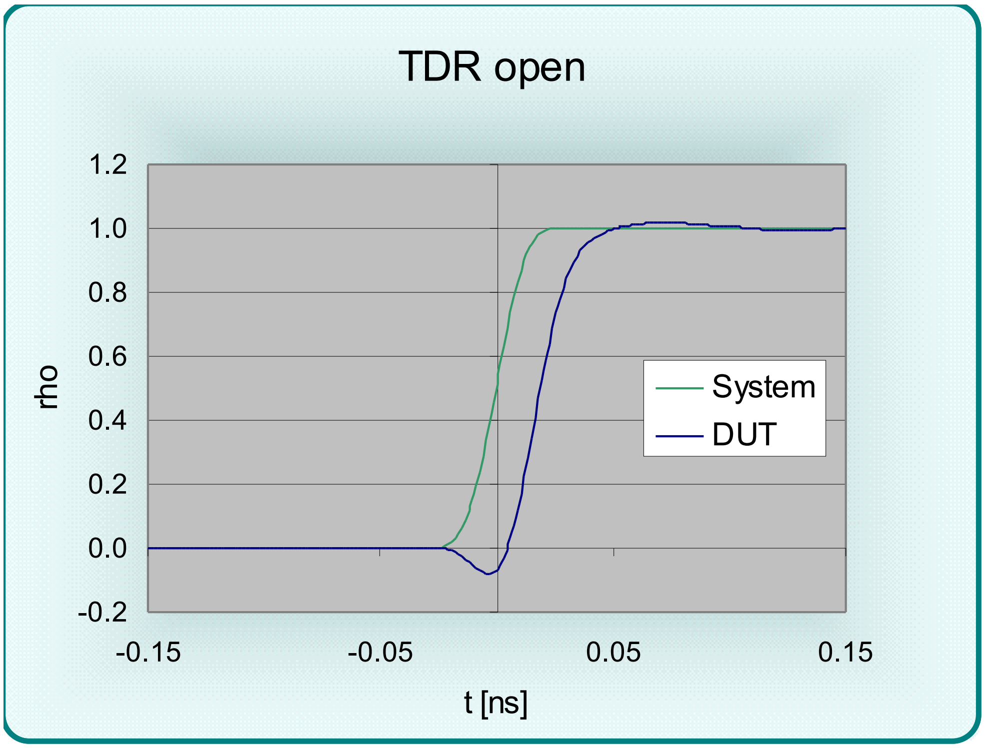

Figure 5 TDR signal from an OPEN circuited Coax interconnect

The reflected signal from the Fuzz Button Coax interconnect (right trace) shows only a small deviation in shape from the original waveform (left trace). The risetime is 25.5 ps and is almost the same as that of the system with the open probe (24.0 ps). Electrical open circuit pin length is 9.8 ps (one way).

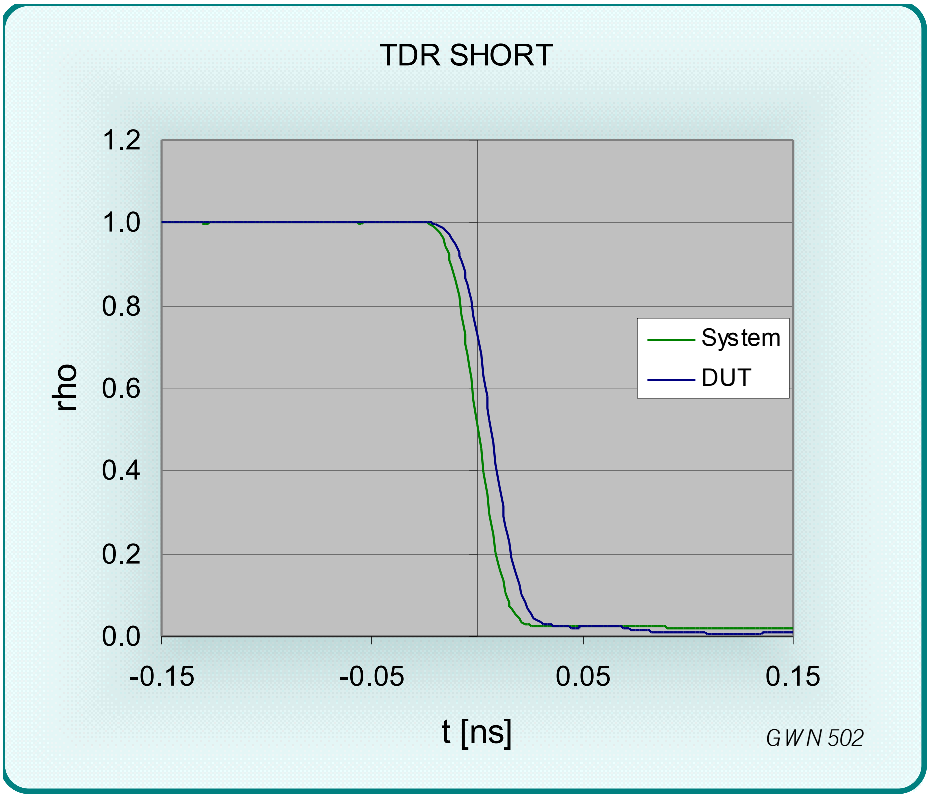

Figure 6 TDR signal from a SHORT circuited Fuzz Button Coax interconnect

For the short circuited Fuzz Button Coax interconnect the fall time is 28.5 ps. There is an insignificant increase over the system risetime of 25.5 ps caused by the contact impedance levels.

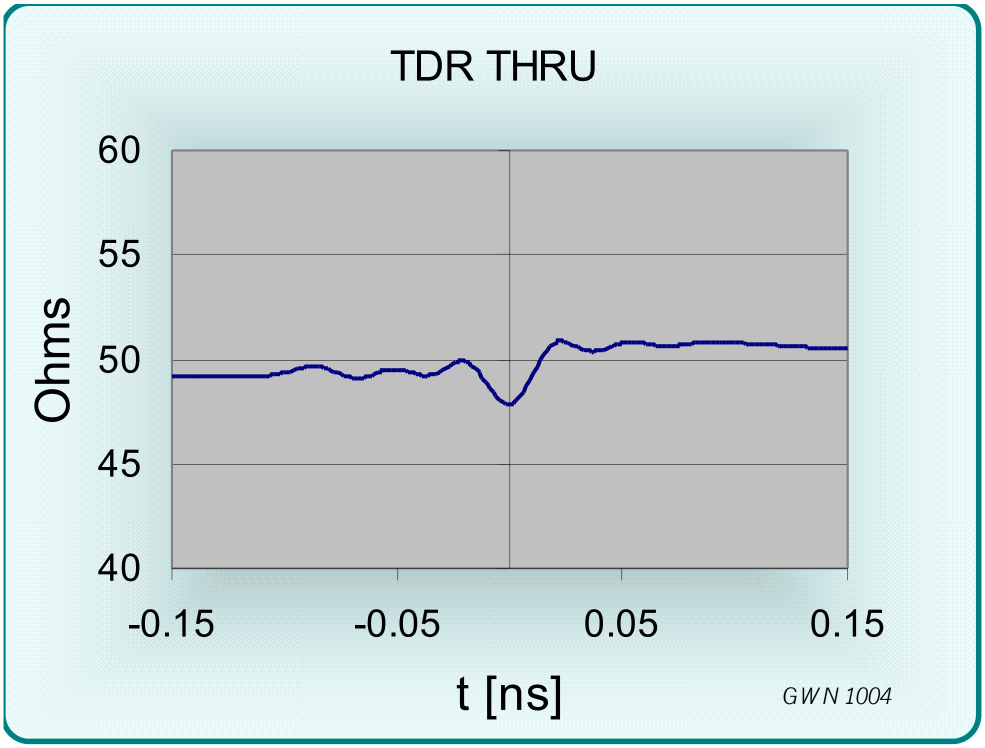

Figure 7 TDR measurement into a 50 Ohm probe

The thru TDR response shows primarily no perturbation to the signal. The peak corresponds to an impedance of 50.9 Ohms. The dips below the 0 line go to 47.8 Ohms.

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

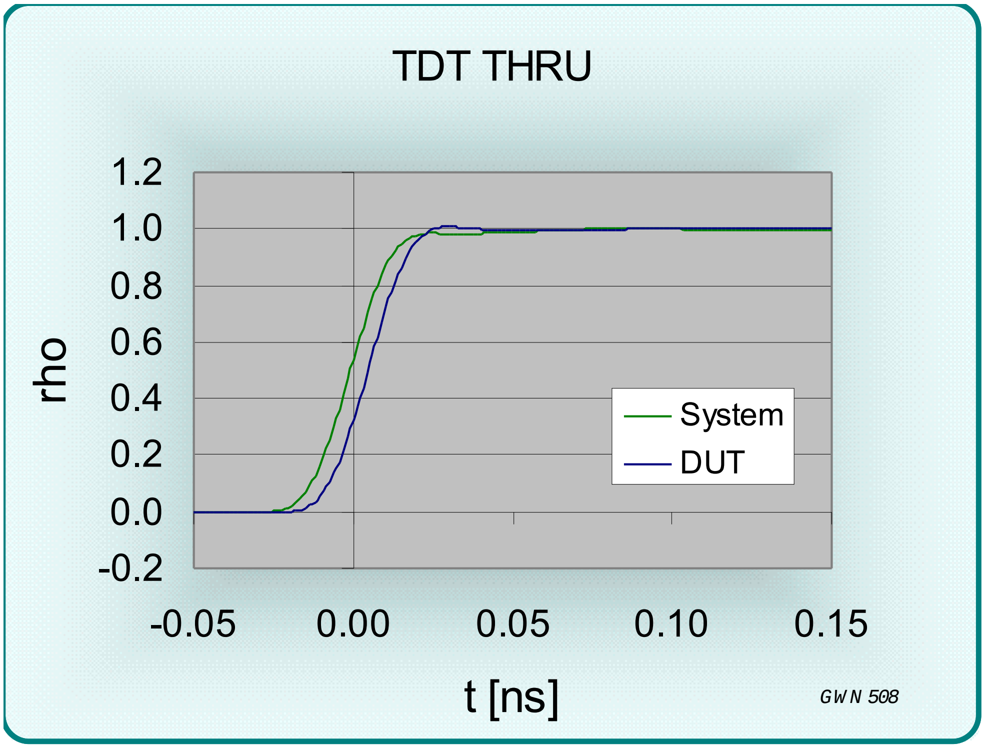

Figure 8 TDT measurement

The TDT measurements for transmission show almost the same risetime from the pin array (10-90% RT = 25.5 ps, the system risetime is 24.0 ps). The added delay at the 50% point is 5.5 ps. There is a small plateau because of the low impedance level. If the 20%-80% values are extracted, the risetime is only 16.5 ps vs. 18.0 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).

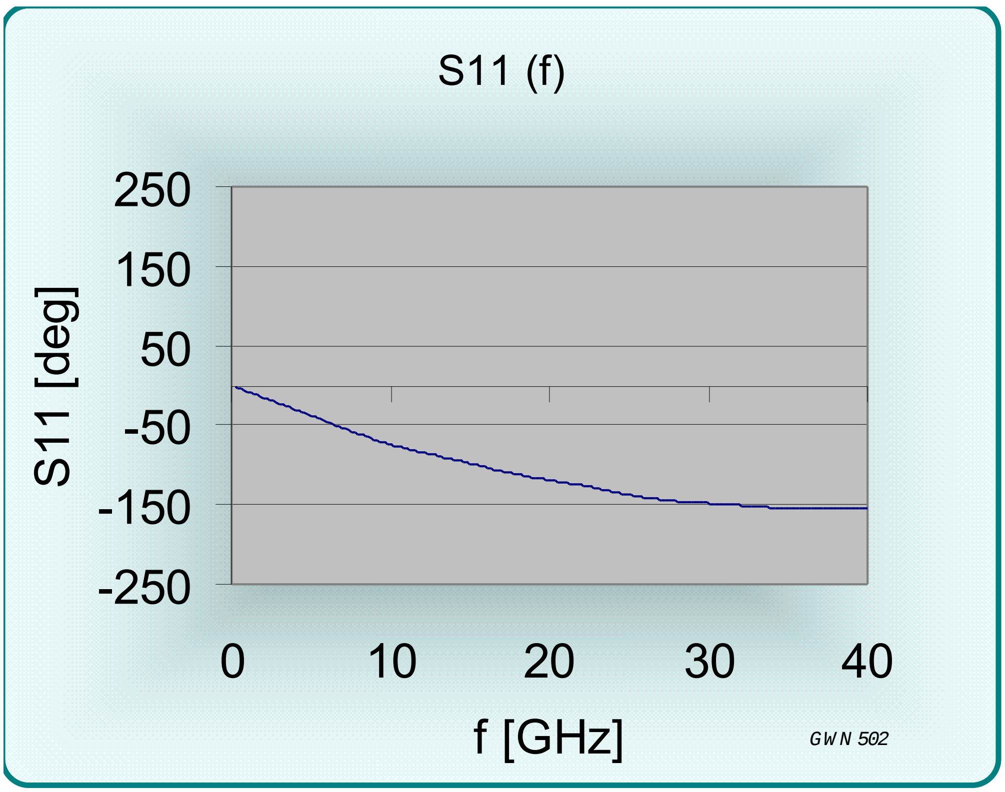

Figure 9 S11 phase (f) for the open circuited signal pin

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.

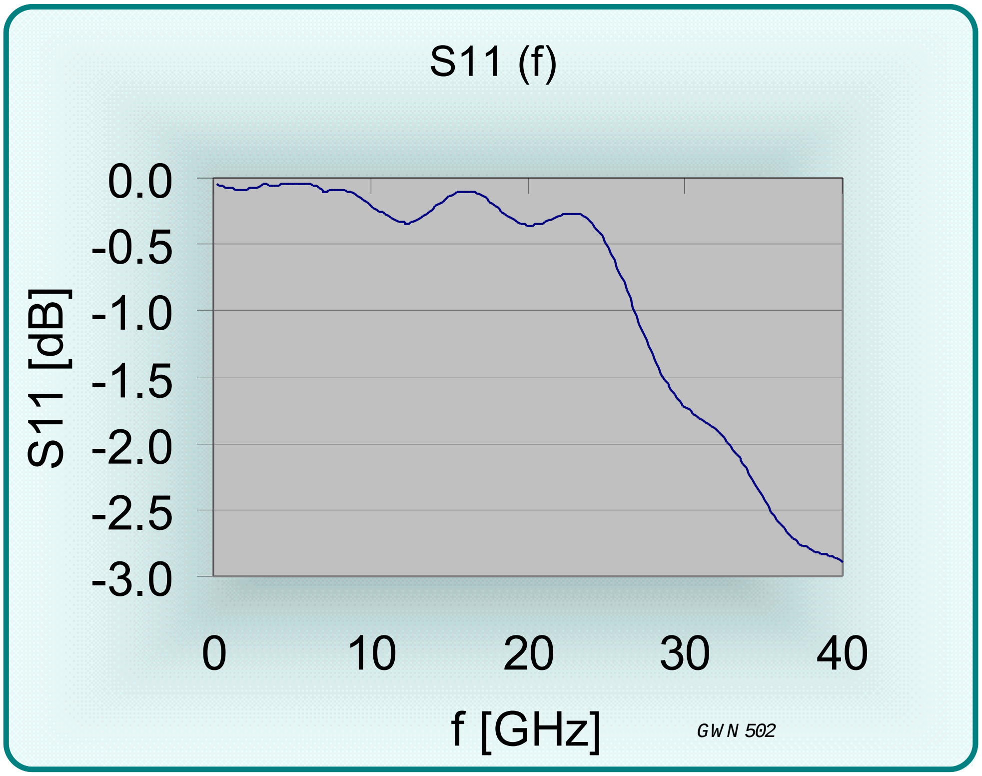

Figure 10 S11 magnitude (f) for the open circuited signal pin

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.

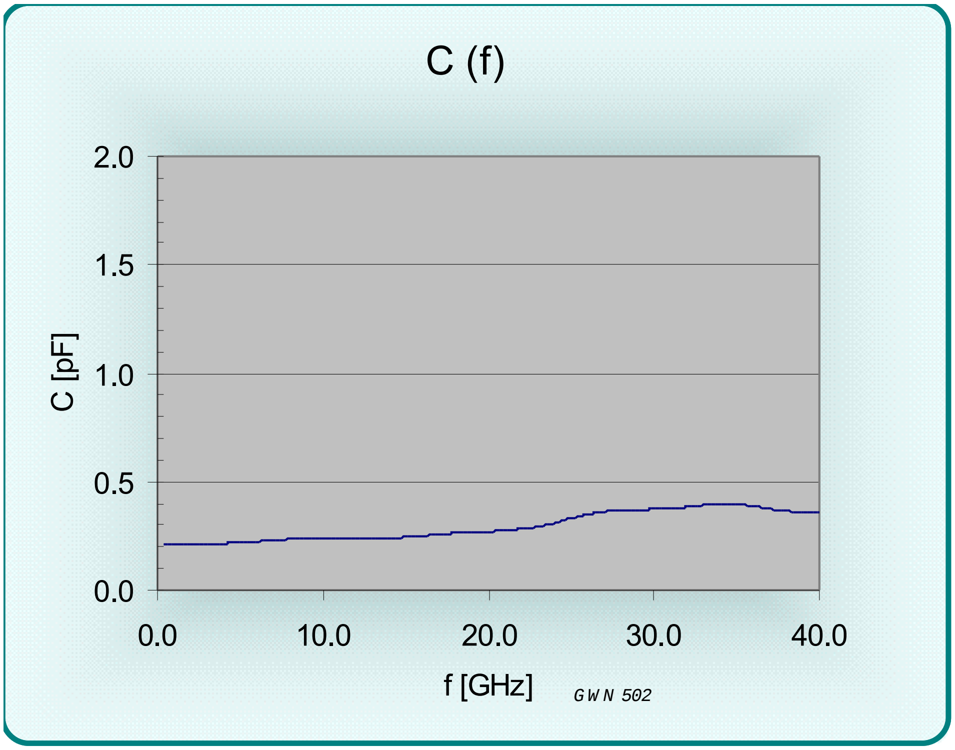

Figure 11 C(f) for the open circuited signal pin

Capacitance is 0.21 pF at low frequencies. The rise in capacitance toward 27 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. A small amount of loss is present. The Smith chart covers frequencies to 40 GHz.

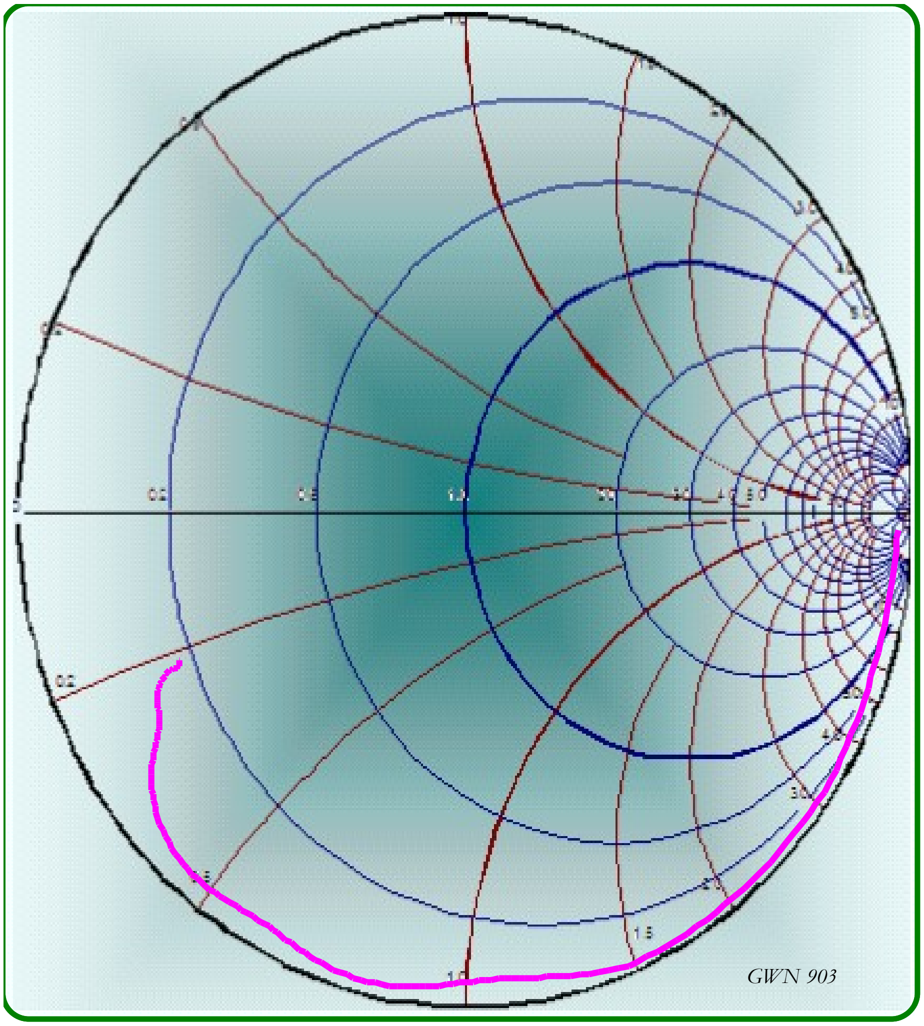

Figure 12 Reflections from the open circuited Fuzz Button Coax interconnect

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 Fuzz Button Coax interconnect. Calibration was established with a short placed at the end of the coax probe.

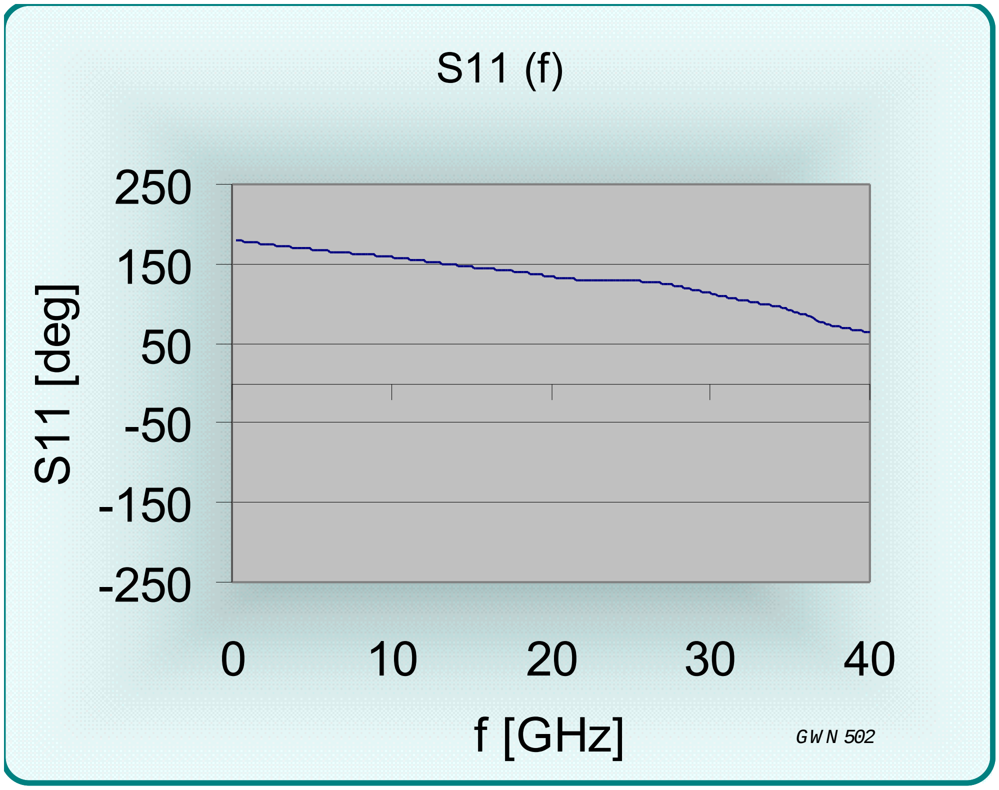

Figure 13 S11 phase (f) for the short circuited case

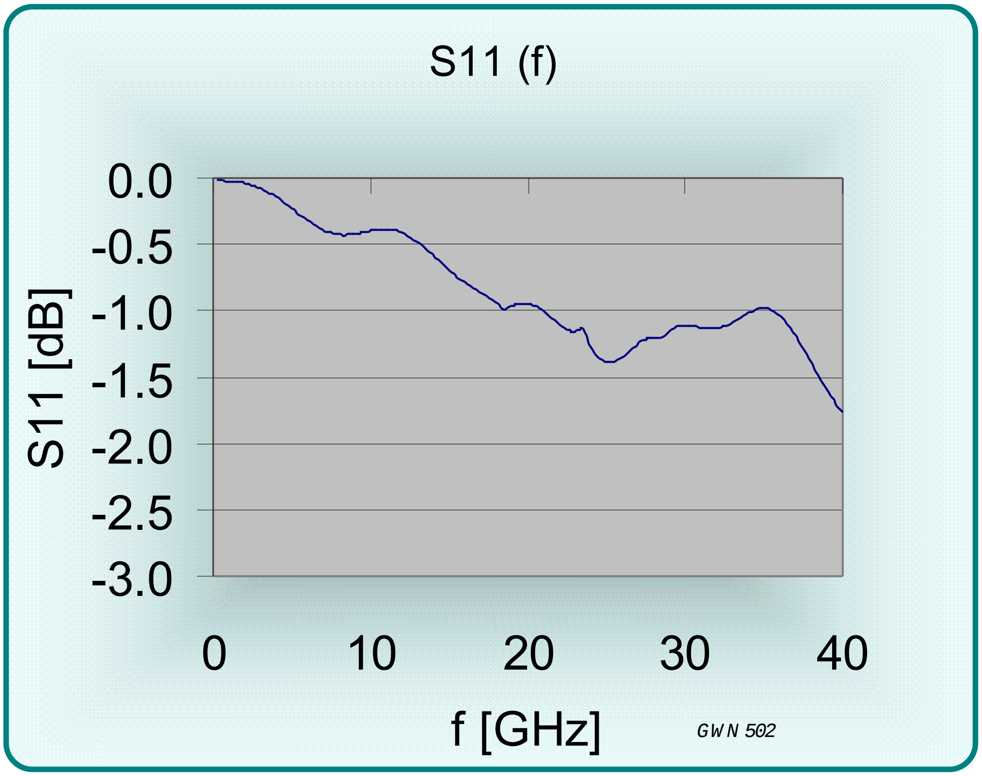

Figure 14 S11 magnitude (f) for the short circuited case

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

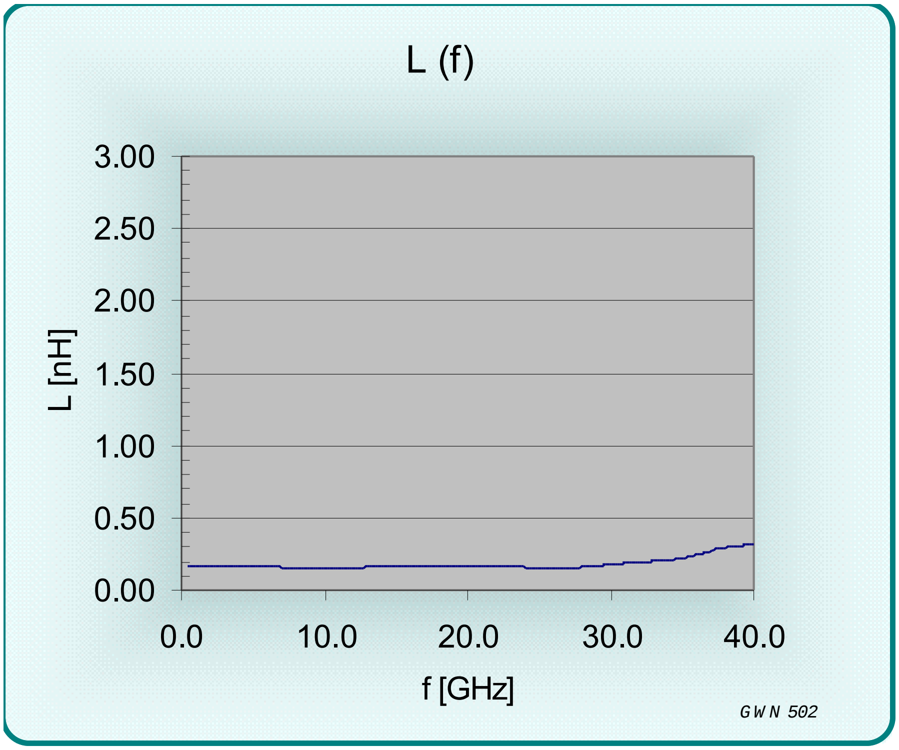

Figure 15 L(f) for the Coax interconnect

The phase change corresponds to an inductance of 0.17nH at low frequencies. Toward 12 GHz inductance increases.   At these frequencies, the transmission line nature of the arrangement must be taken into account.

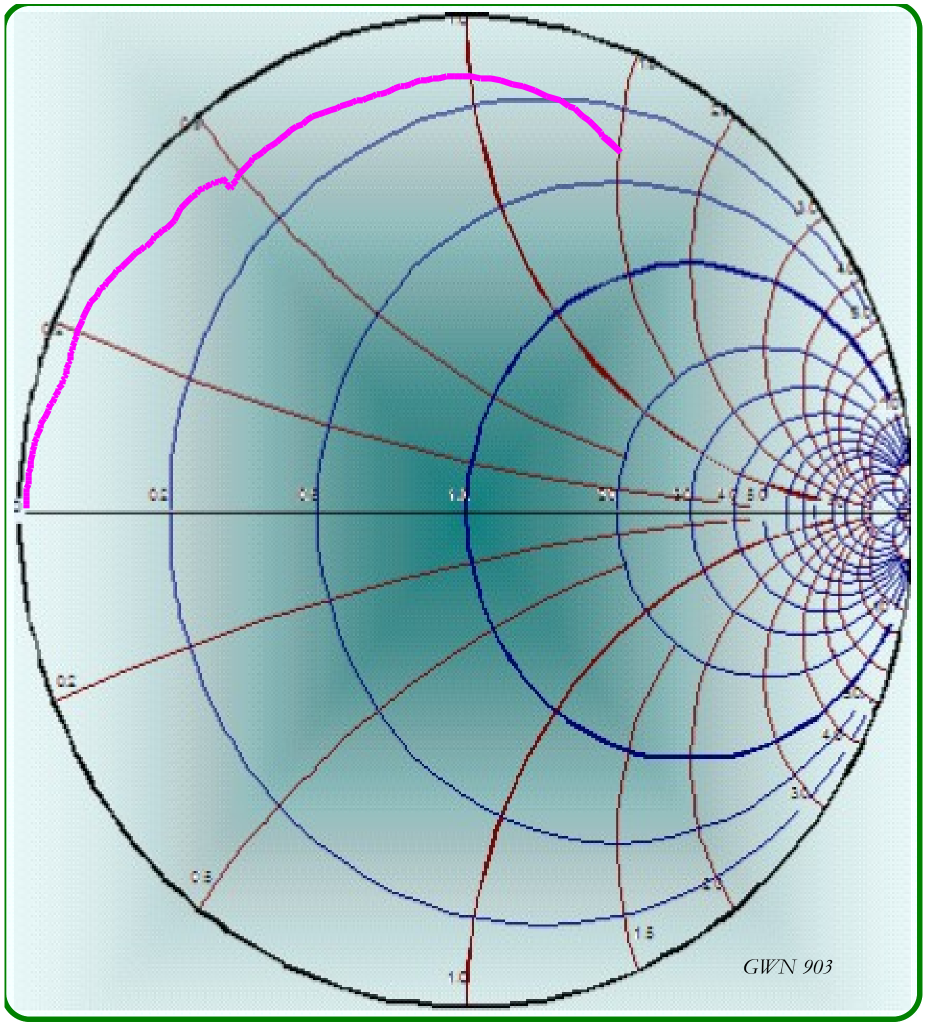

Figure 16 Short circuit response in the Smith chart

Only a small amount of loss is noticeable in the Smith chart for the short circuit condition. The Smith chart covers frequencies to 40 GHz.

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

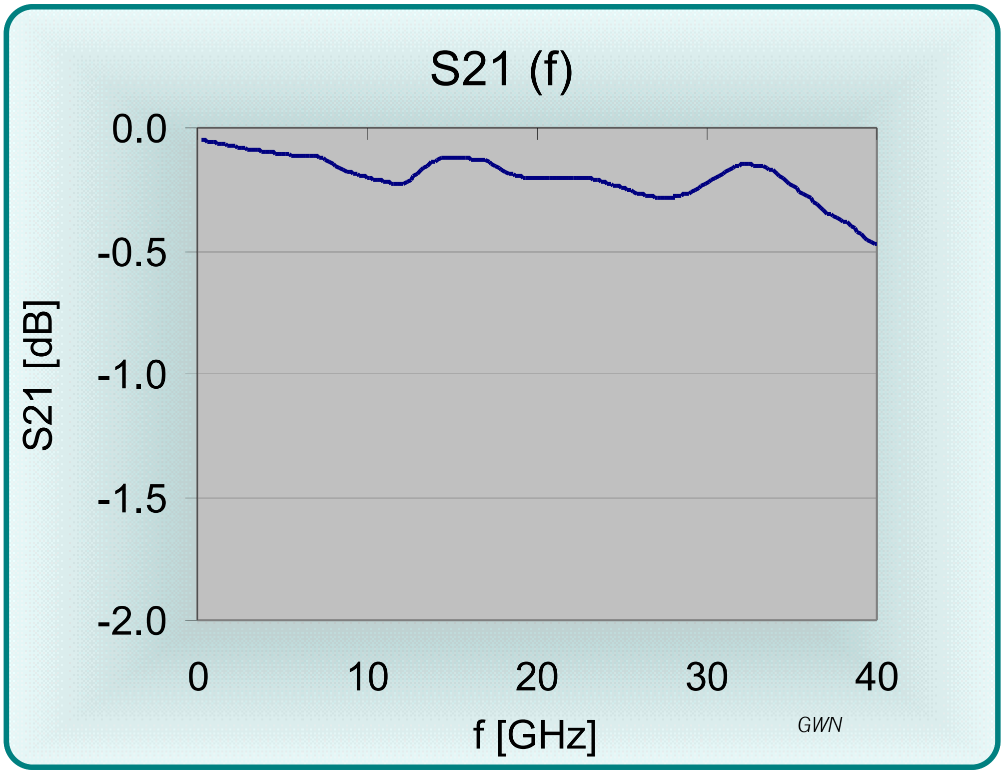

Figure 17 Insertion loss S21 (f)

Insertion loss is less than -0.2 dB to 9.8 GHz. The 1 dB point is not reached before 40 GHz.

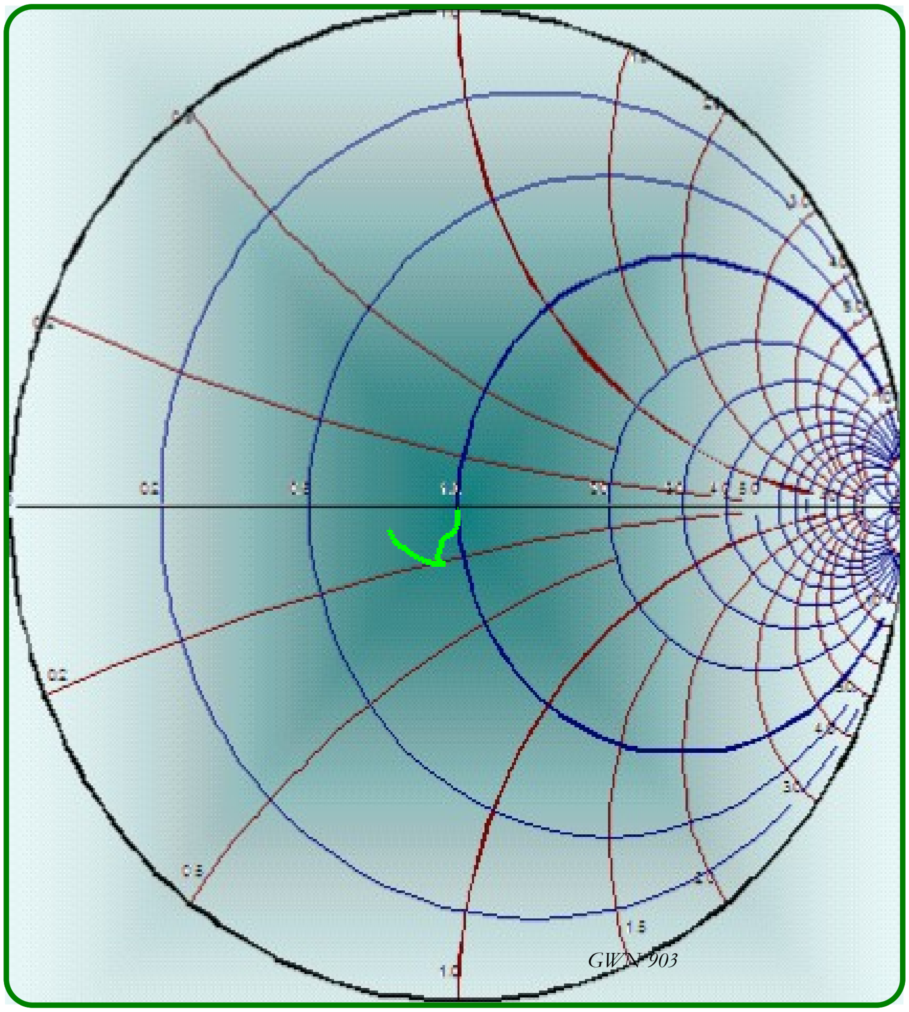

Figure 18 Smith chart for the thru measurement into a 50 Ohm probe

The Smith chart for the thru measurements shows some reactive components toward higher frequencies. The Smith chart covers frequencies to 40 GHz.

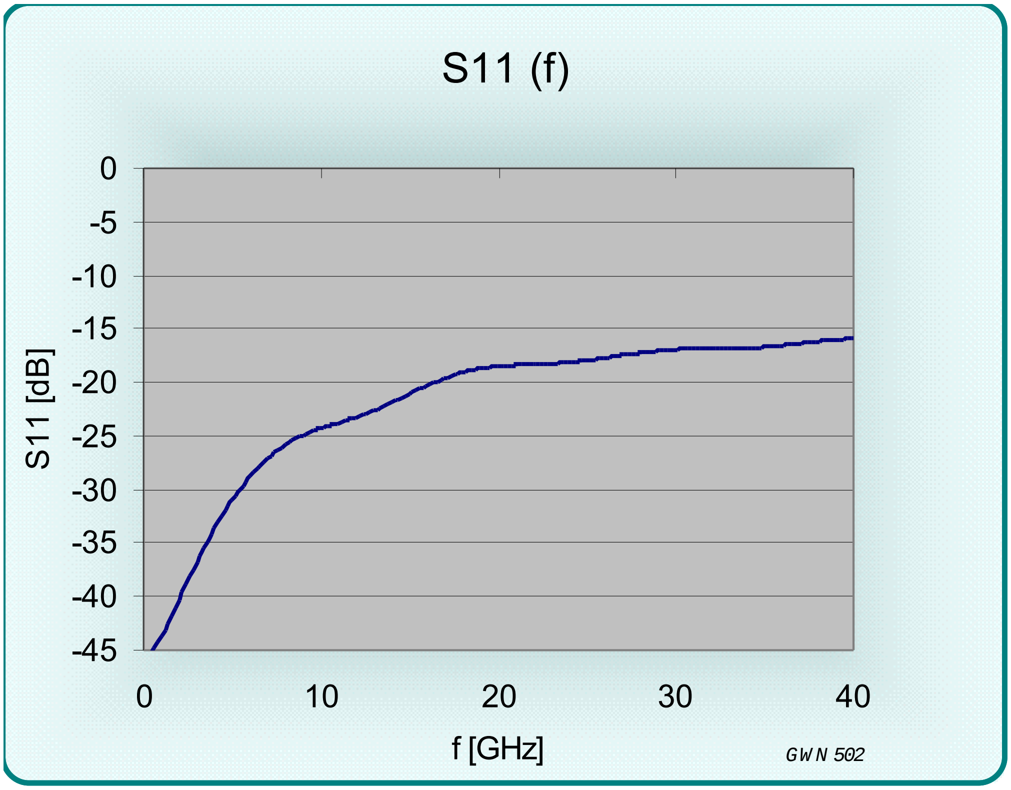

Figure 19 S11 magnitude (f) for the thru measurement into a 50 Ohm probe

The value of the return loss for the thru measurement reaches a level of -20 dB at a frequency of 16.3 GHz and -10 dB at >40.0 GHz.

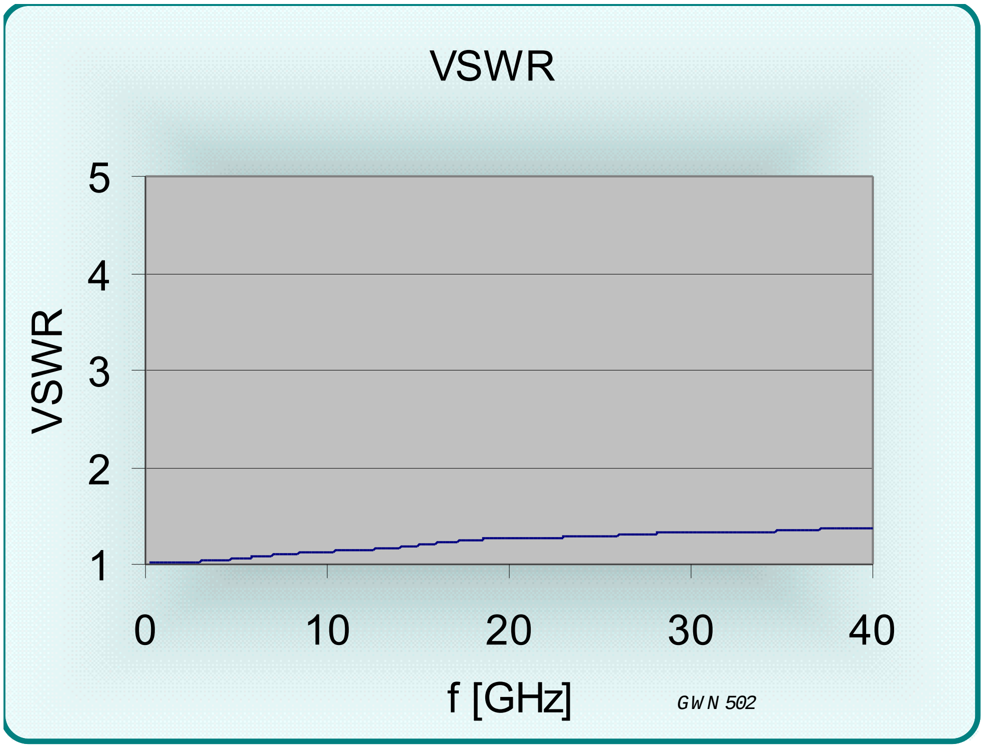

Figure 20 Standing wave ratio VSWR (f) [1 / div.]

The VSWR remains below 2 : 1 to a frequency of 40.0 GHz.

SPICE Models

A lumped element SPICE model for the Custom Interconnects Fuzz Button Coax interconnect is shown below:

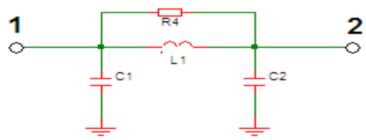

Figure 21 Lumped element SPICE model

The resistance value (R4) approximates the loss term encountered.
The values for the elements are

C1+C2		L1		R4	
0.213	pF	0.17	nH	1000	Ohms

Toward the cutoff frequency of the Pi section the lumped element model becomes invalid. This happens above 39 GHz for the above model. Hence, the second model developed is a transmission line model:

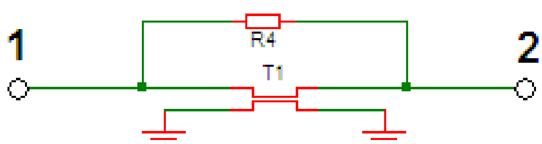

Figure 22 Transmission line model for the Fuzz Button Coax interconnect

The array configuration with signal pins surrounded by ground pins provides a transmission line environment with the following parameters:

Zo		L		R4	
47.8	Ω	5.5	ps	100000	Ω

Time domain

The TDR simulation results indicate a capacitive response just as observed in the measurement (see TDR THRU).

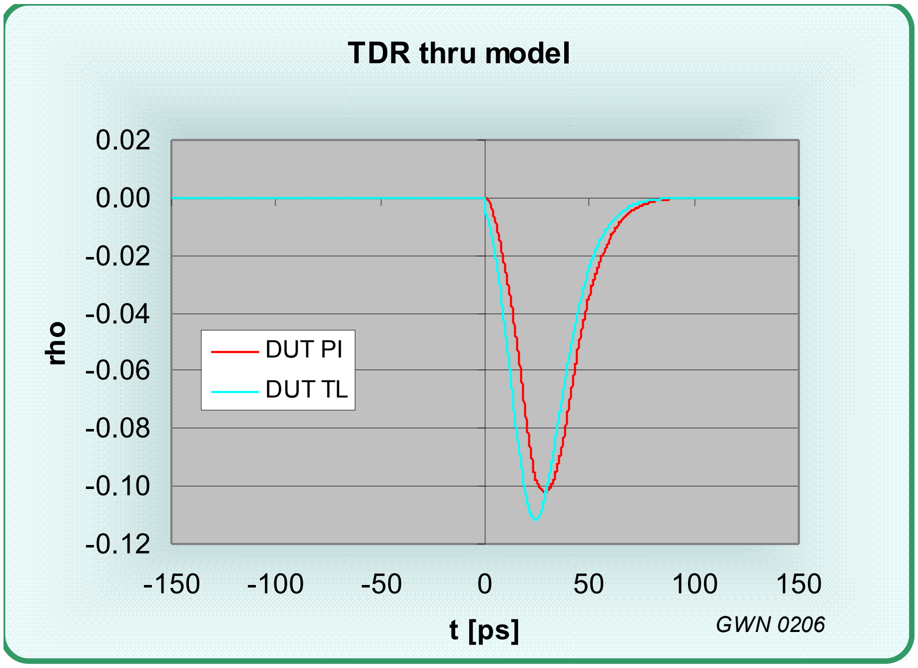

Figure 23 TDR model results

The transmission line models are better suited to the time domain simulation than the lumped element models since the latter cause a dual downward response from the two capacitors in the Pi section.

The risetime contributions of a signal transmitted through the pin are shown below:

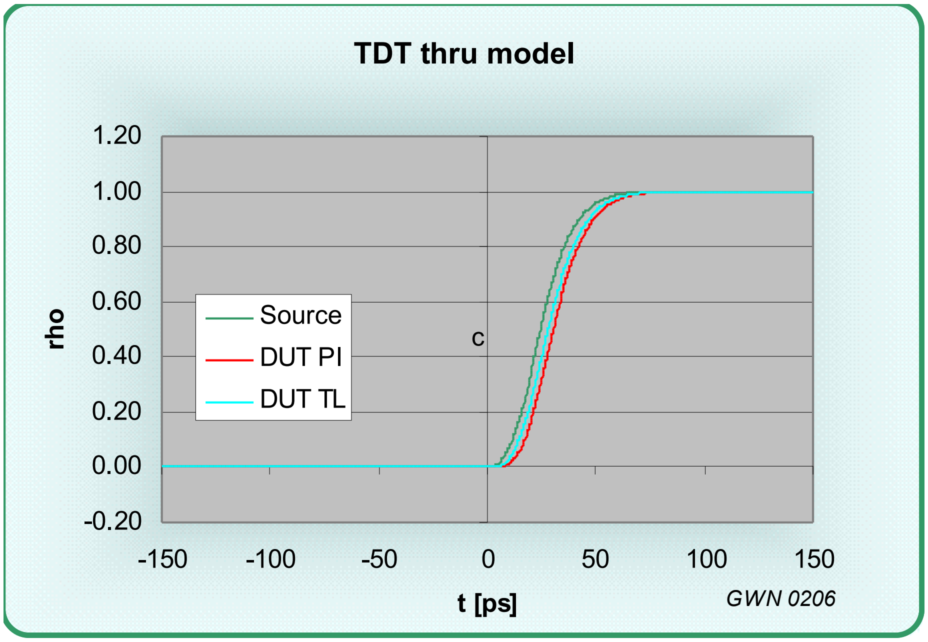

Figure 24 TDT model

Risetimes and signal waveform for the transmission line case are comparable to those measured.

Frequency domain

The model's phase responses are also divided into lumped element and transmission line equivalent circuits.

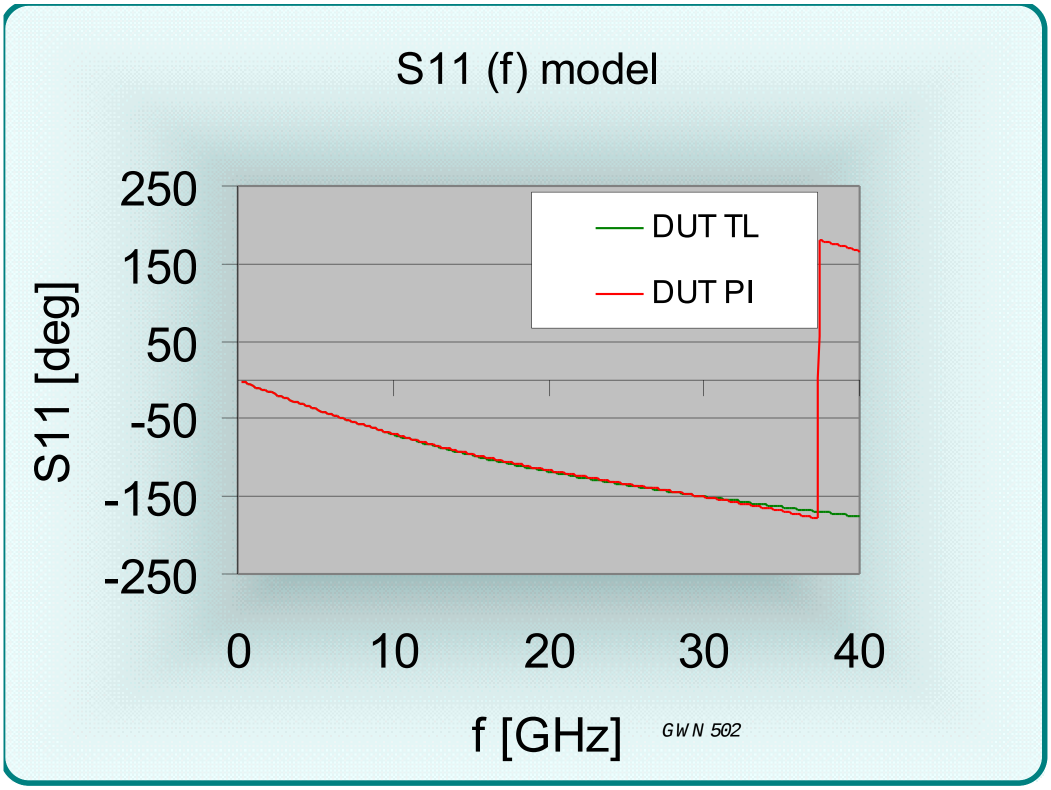

Figure 25 S11 phase (f) for open circuited case

The evolution of phase with frequency is comparable to that measured.

The response of the lumped element model illustrates that it is limited to a maximum frequency of 39 GHz.

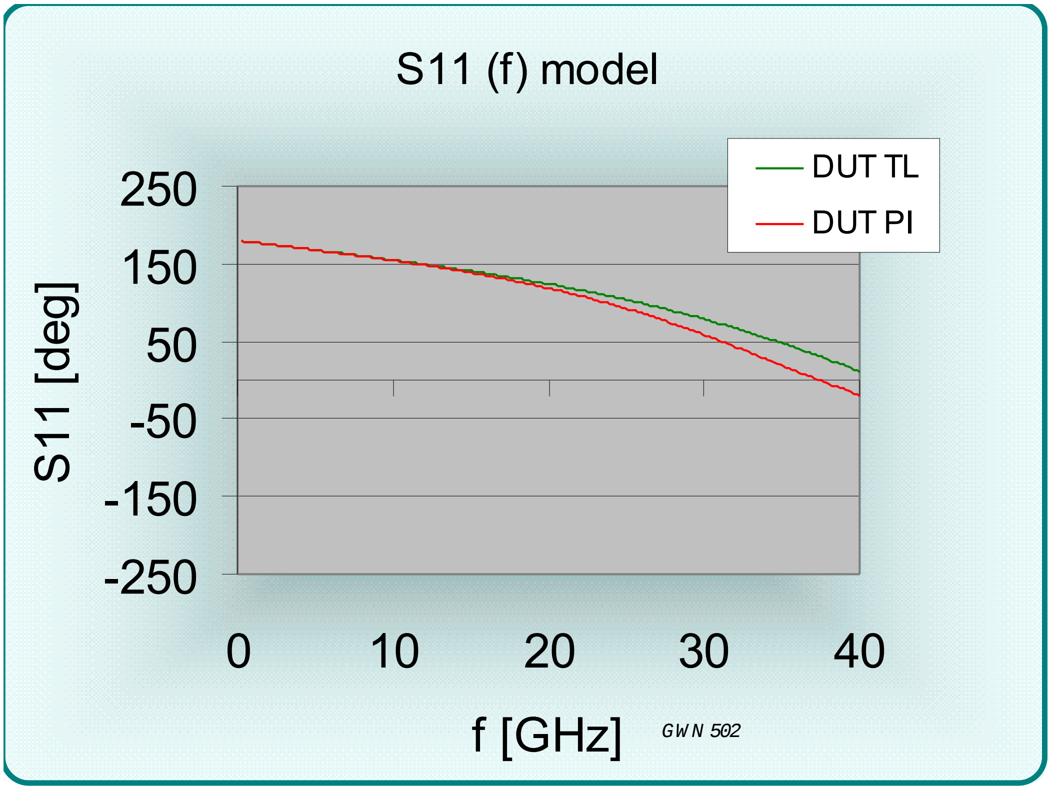

Figure 26 S11 phase response (short circuit)

The short circuit phase evolution with frequency is also comparable to that actually measured.

The insertion loss results below also clearly demonstrate the limits of the lumped element model. As the frequency approaches the cutoff frequency for the Pi section, the insertion loss increases significantly. This can be avoided by splitting the lumped element model into more than one section while keeping the sum of capacitances and inductances the same as for the single element. The transmission line model does not suffer from this shortcoming.

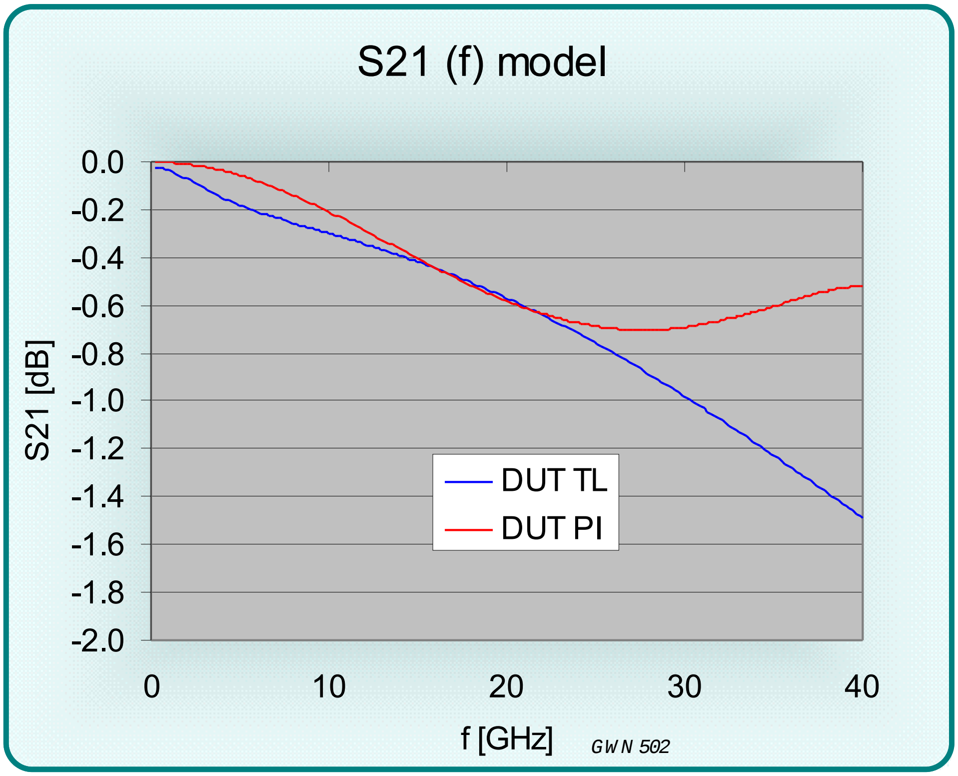

Figure 27 Insertion loss as a function of frequency

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Measurement results:

Delay	5.5	ps
Insertion loss (0.2dB)	9.8	GHz
Insertion loss (1dB)	>40	GHz
VSWR (2:1)	40.0	GHz

PI equivalent circuit component values:

C1+C2		L1		R4	
0.213	pF	0.17	nH	1000	Ohms

It should be noted that there are 2 capacitors in the PI equivalent circuit. Each of them has half the value listed here.

Transmission line equivalent circuit values:

Zo	47.8	Ω
td	5.5	ps

The impedance listed is that measured. It is different from that calculated from the measured L,C parameters because of the time domain signal risetime.