Aries

QFP microstrip socket

Measurement and Model Results

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Objective

The objective of these measurements is to determine the rf performance of an Aries QFP microstrip 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 to. 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 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 probe's microstripline. The probe was then connected to the fixture and the response measured from the PCB side of the socket. When the pins terminate into an open circuit, a capacitance measurement results. When a short circuit compression plate is used on the socket's DUT side, 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 QFP microstrip socket 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 with a microstrip transmission line suitable for interfacing with the socket. The impedance of that line is slightly greater than 50 Ohms. This was done so that the combined impedance with the socket present will be as close to 50 Ohms as possible. The DUT is aligned and mounted to that plate. The opposite termination is a metal plate with coaxial probes in the physical shape of an actual device to be tested.

As will be seen later, the fact that the microstrip characteristic impedance necessarily changes when the socket is installed will, unfortunately, cause unavoidable calibration errors. Measurements for capacitance and inductance will be those of the immediate area near the DUT at the end of the microstrip. All other measurements apply to the entire length of the microstripline(s).

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

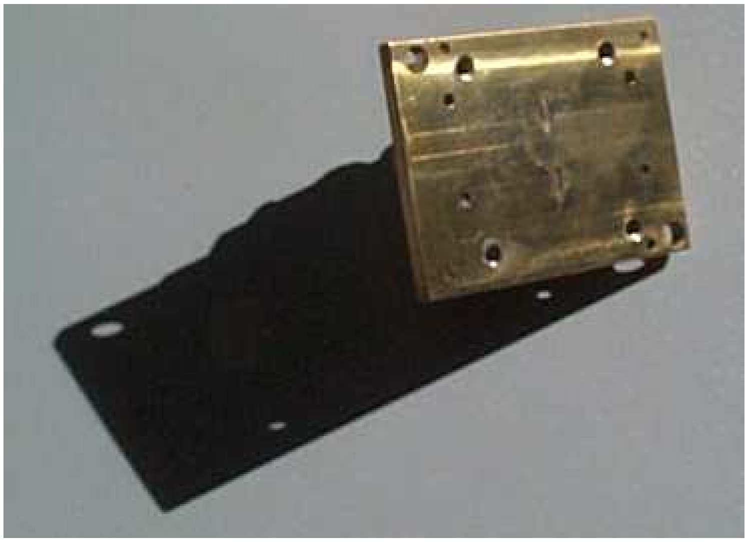

Figure 1 QFP microstrip socket base plate example

Figure 2 DUT plate

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

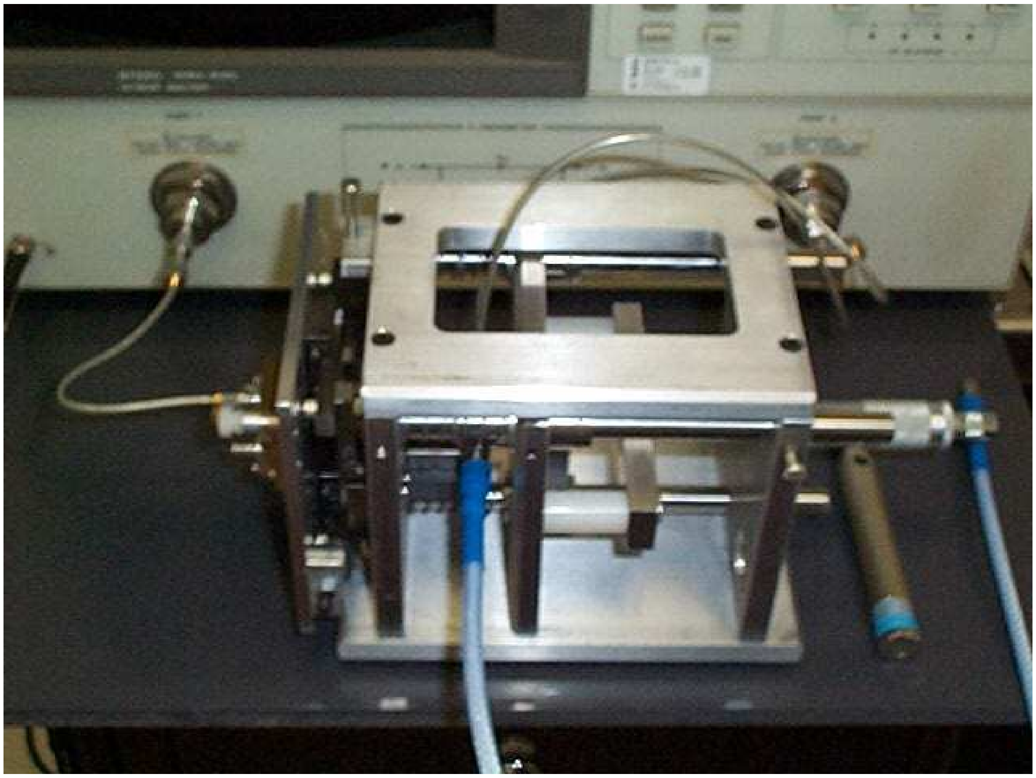

Figure 3 Test fixture

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

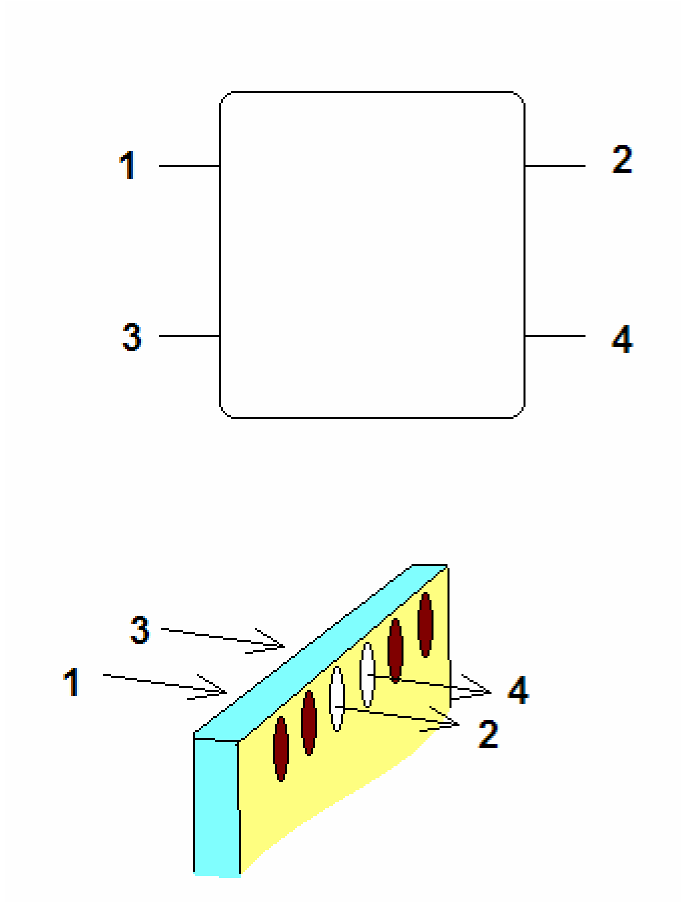

Figure 4 Ports for the G-S-S-G measurements

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 in Figs. 5 to 7.

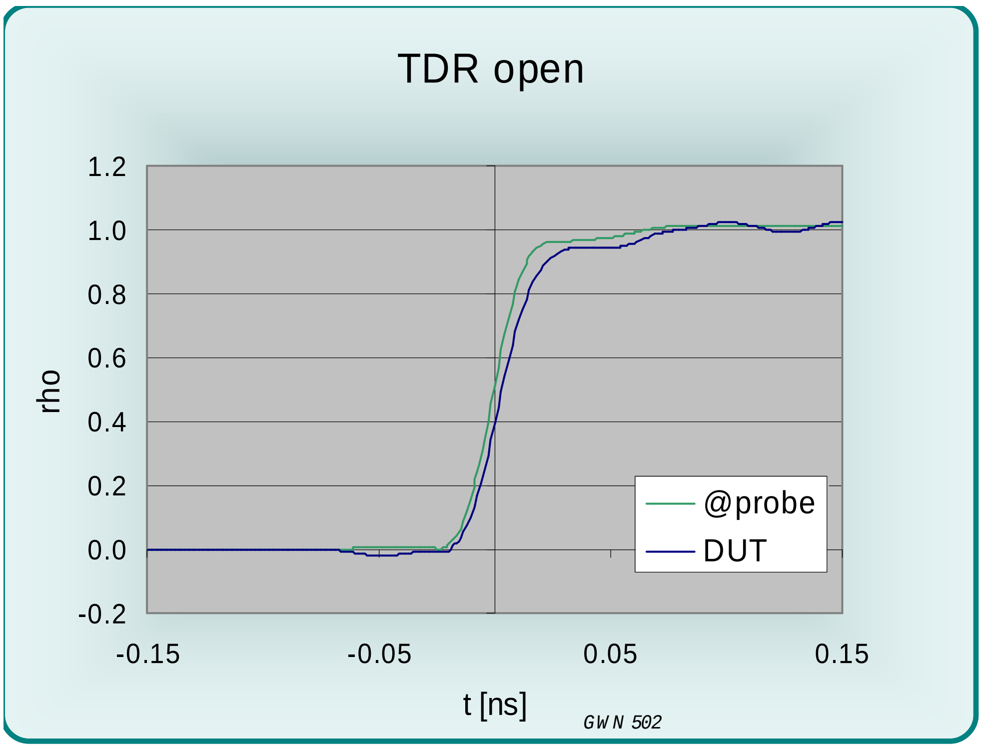

Figure 5 TDR signal from an OPEN circuited QFP microstrip socket

The reflected signal from the QFP microstrip socket (rightmost trace) shows only a small deviation in shape from the original waveform (leftmost trace). The risetime is about 36.0 ps and is only slightly larger than that of the system with the open probe (27.0 ps). Electrical pin length is about 2.3 ps one way.

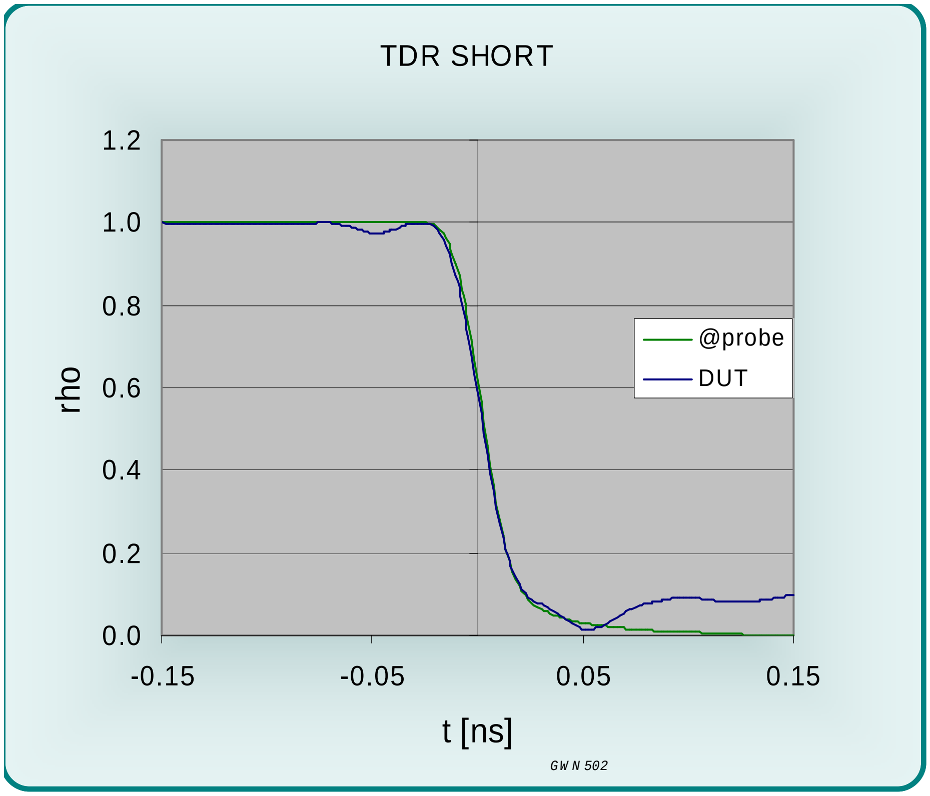

Figure 6 TDR signal from a SHORT circuited QFP microstrip socket

For the short circuited QFP microstrip socket the fall time is about 33.0 ps. This is an insignificant increase over the system risetime.

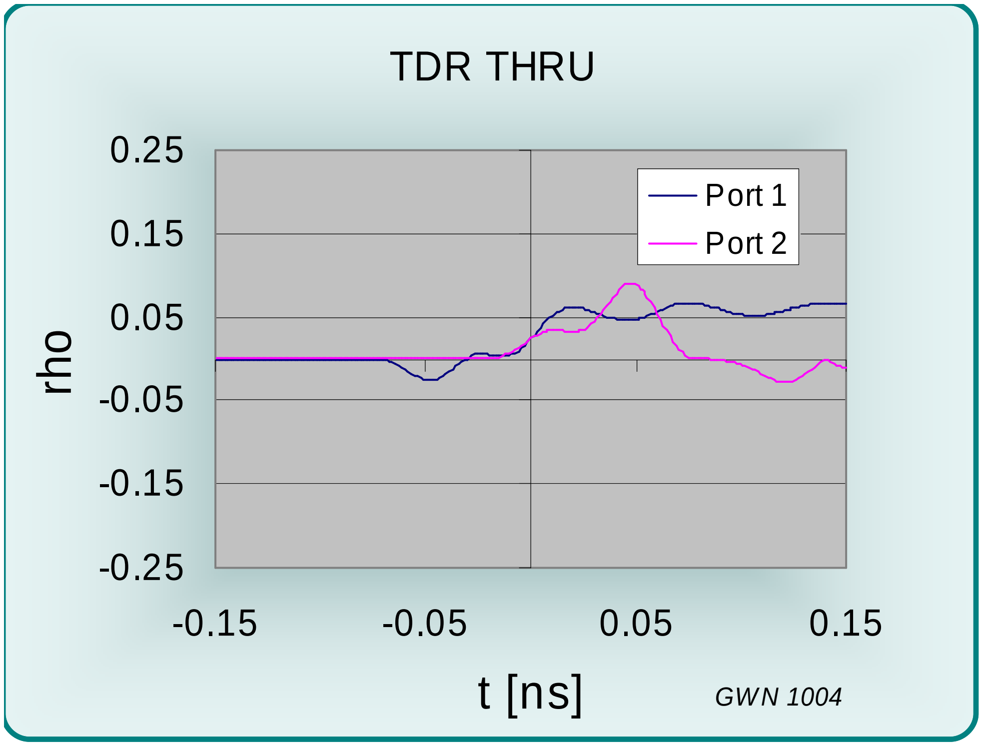

Figure 7 TDR measurement into a 50 Ohm probe

The thru TDR response shows both inductive and capacitive responses. The peak corresponds to a transmission line impedance of 57.2 Ohms, the dip to 47.5 Ohms. As in the case of the short circuit measurement, the dip is likely caused by the fixture's microstrip line coming close to the socket material, which causes capacitive loading.

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

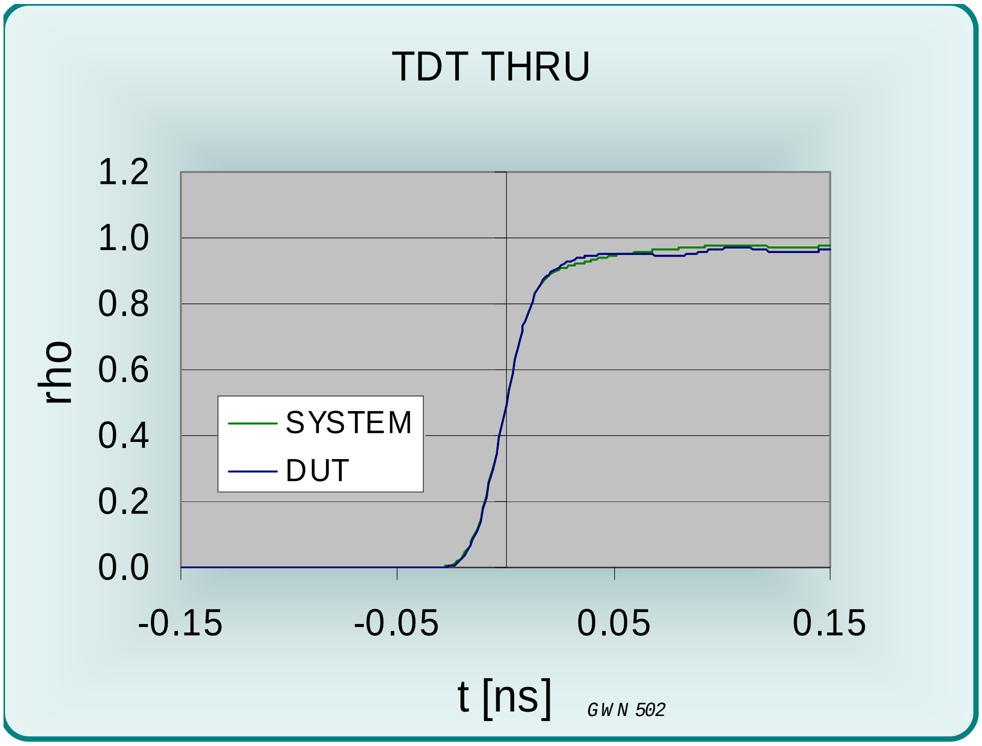

Figure 8 TDT measurement

The TDT measurements for transmission show no contribution to risetime from the pin array (10-90% RT = 31.5 ps, the system risetime is 33.0 ps). System risetime is larger than the risetime with DUT because of the missing capacitive loading from the socket during calibration. This results in a microstrip impedance greater than 50 Ohms during the calibration and produces a foot near the top of the rise, thus affecting the timing of the 90% level. If the 20%-80% values are extracted, the socket risetime is only 19.5 ps vs. 19.5 ps system risetime. The added delay at the 50% point is 1 ps. There is no significant signal distortion. Calibration in this case is performed at the end of the microstrip line.

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).

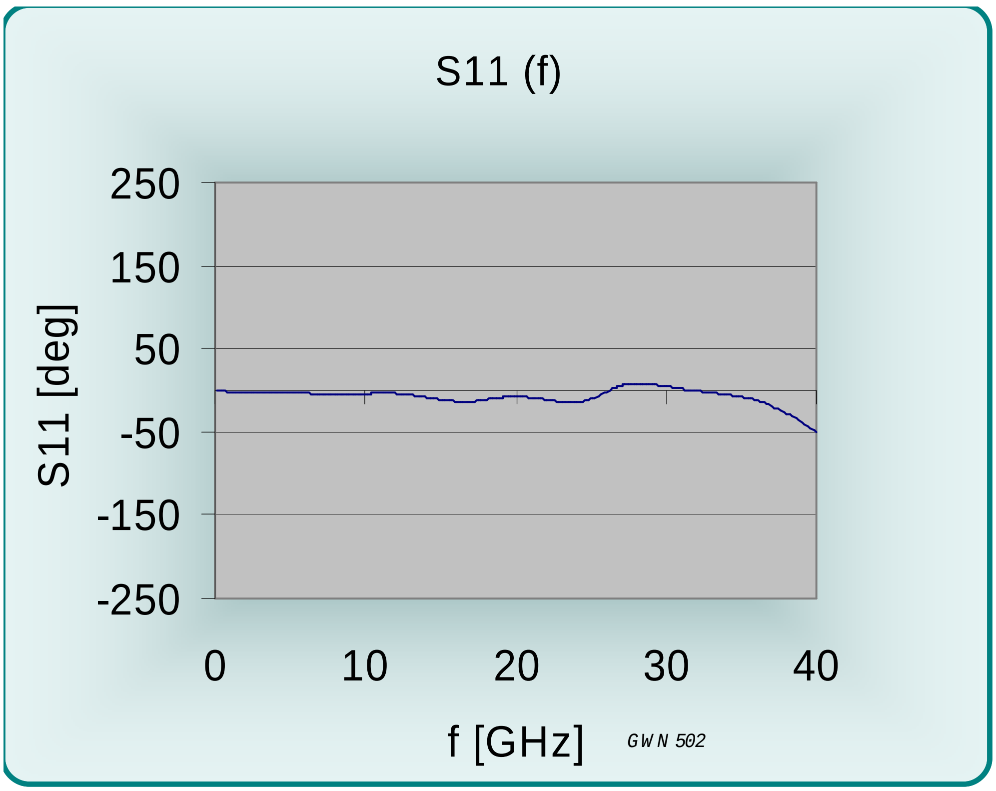

Figure 9 S11 phase (f) for the open circuited signal pin

Because of the impedance drop that is experienced over the entire length of the microstrip transmission line when the socket is placed over it, calibration accuracy is necessarily compromised when calibration to the end of the microstrip is attempted.

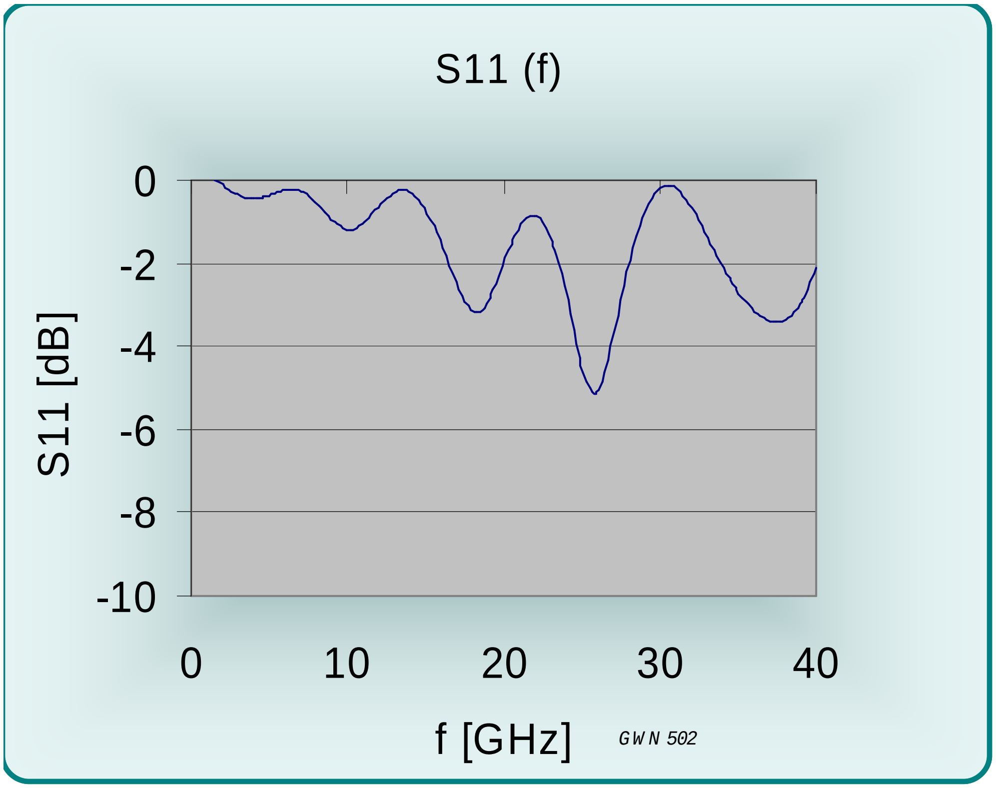

Figure 10 S11 magnitude (f) for the open circuited signal pin

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

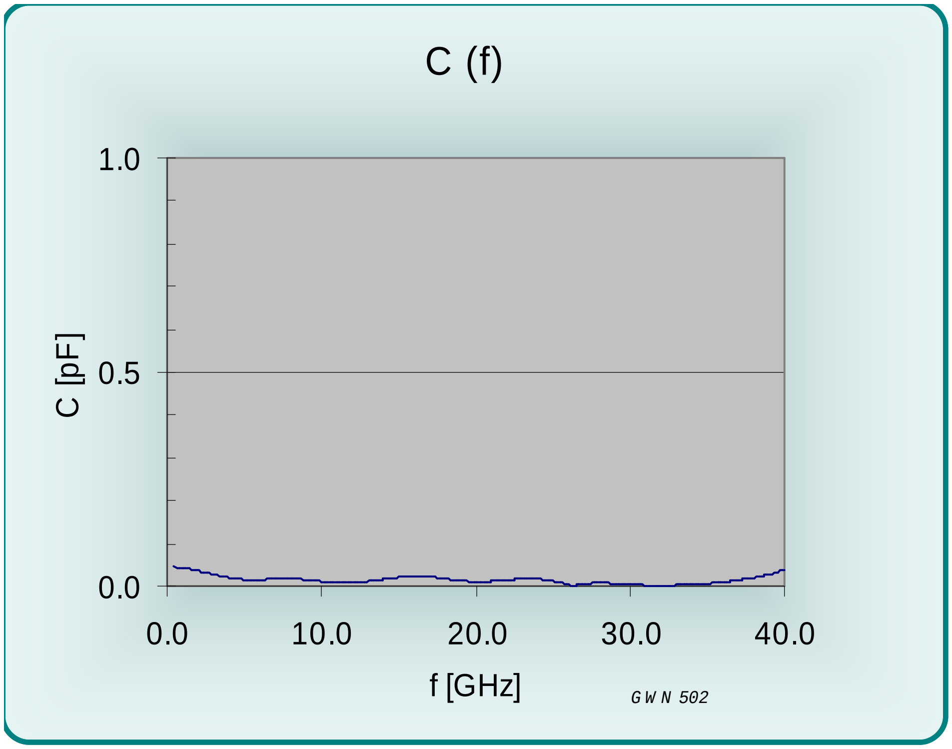

Figure 11 C(f) for the open circuited signal pin

Capacitance is 0.04 pF at low frequencies. Again, the calibration is adversely affected by the presence of the socket over the microstrip line during test. It effectively alters the transmission line properties and thereby also the measurement results.

The Smith chart measurement for the open circuit shows some resonances toward the upper frequency limit of 40 GHz. Also, a small loss term is present.

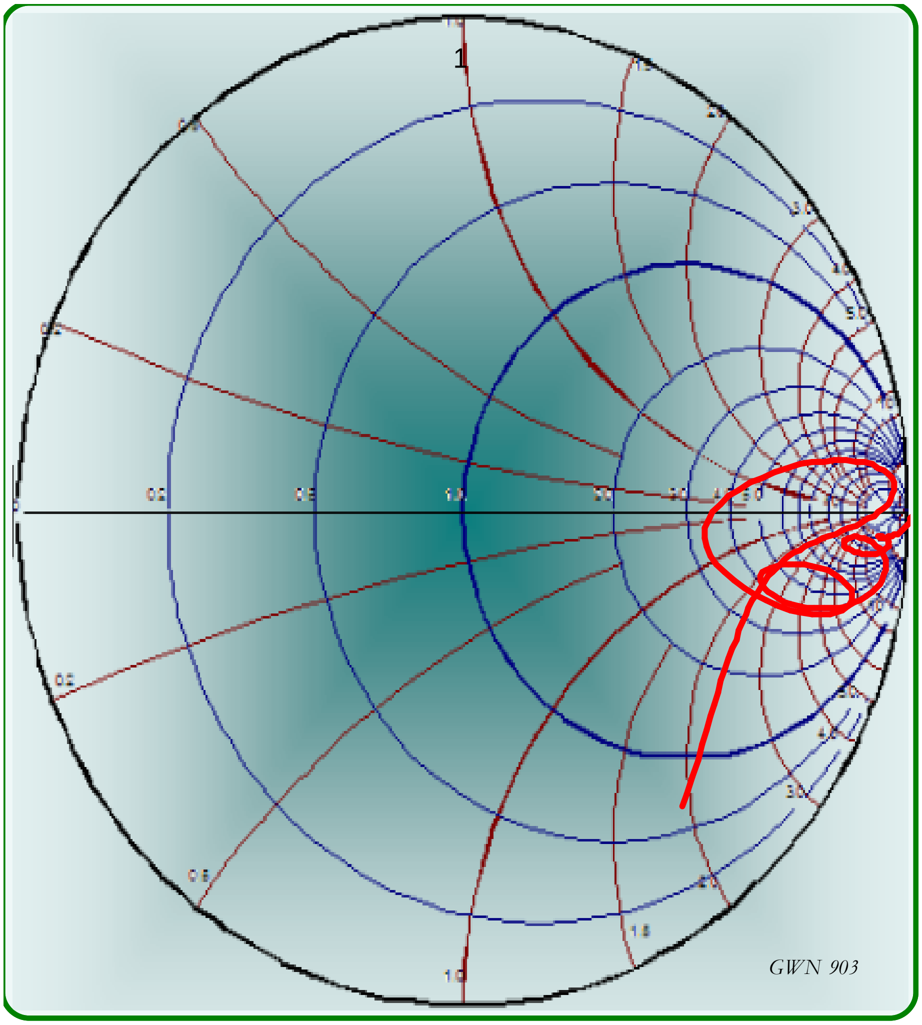

Figure 12 Reflections from the open circuited QFP microstrip socket

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

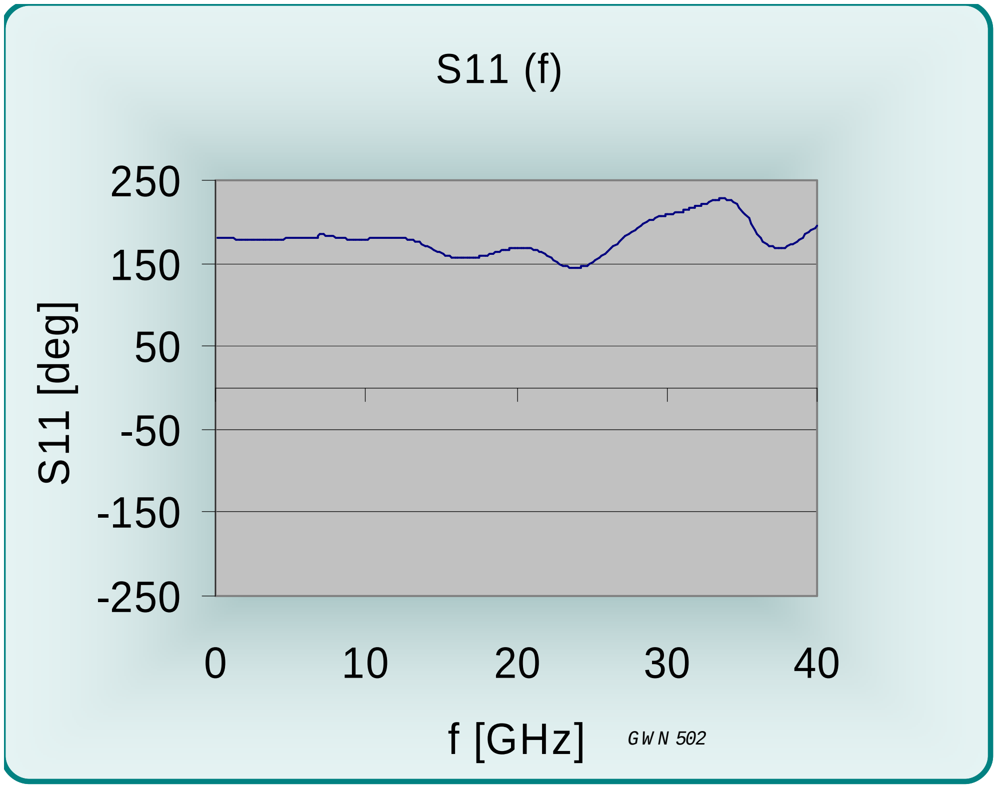

Figure 13 S11 phase (f) for the short circuited case

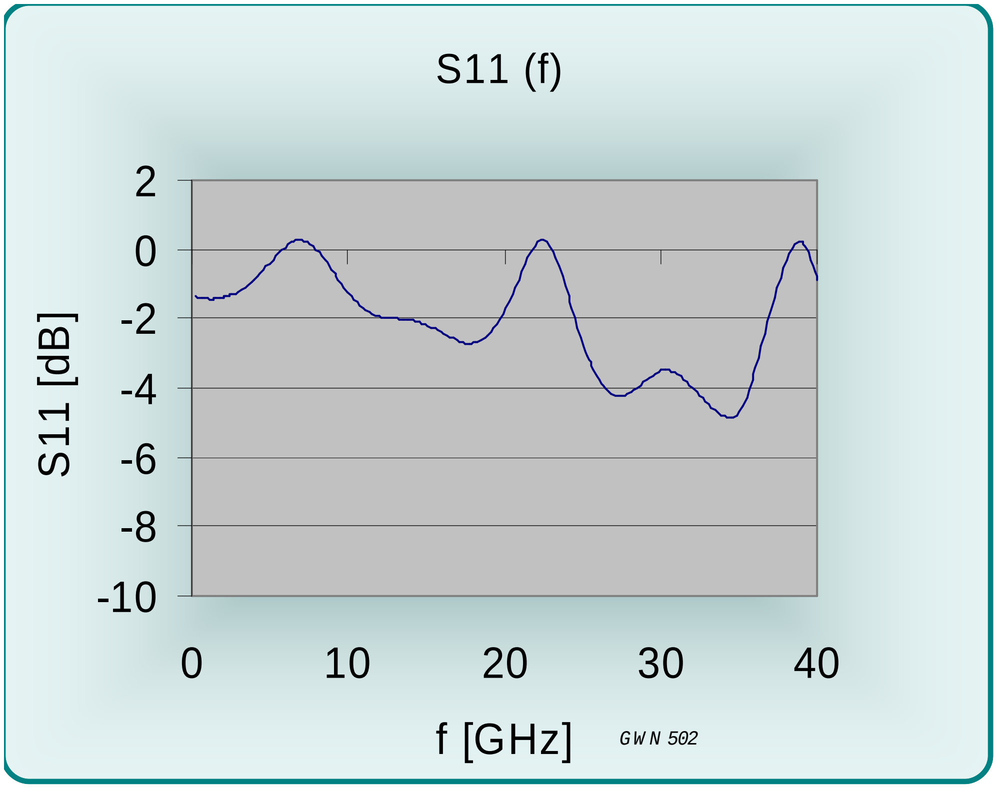

Figure 14 S11 magnitude (f) for the short circuited case

Some loss exists, likely the result of radiation and dielectric loss. The loss at low frequencies is likely the result of the aforementioned calibration difficulties in the absence of the socket.

The phase change corresponds to an inductance of 0.05 nH at low frequencies (see Fig. below).

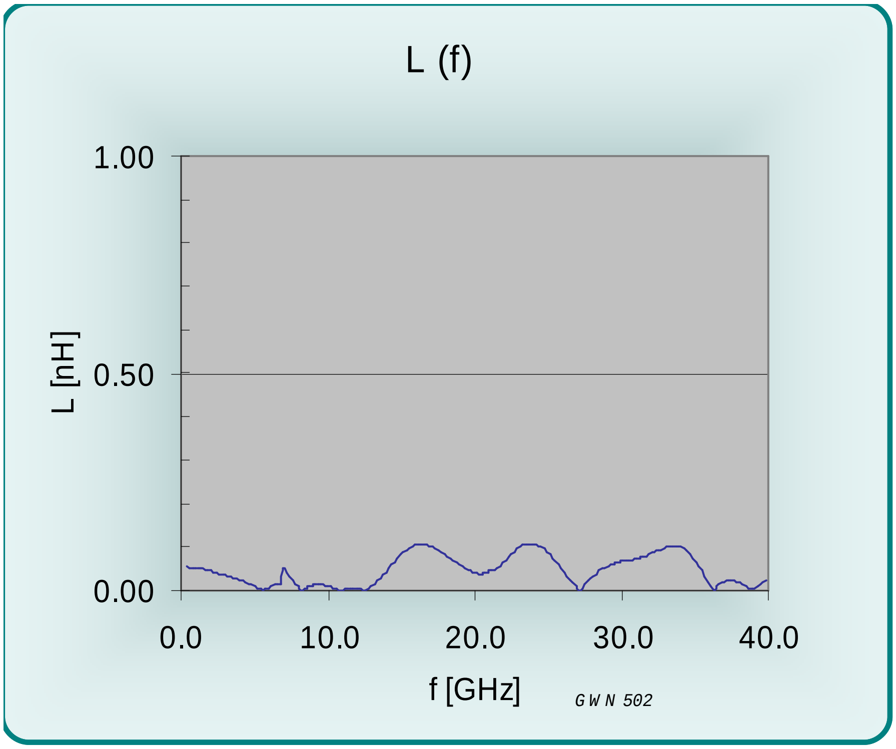

Figure 15 L(f) for the QFP microstrip socket

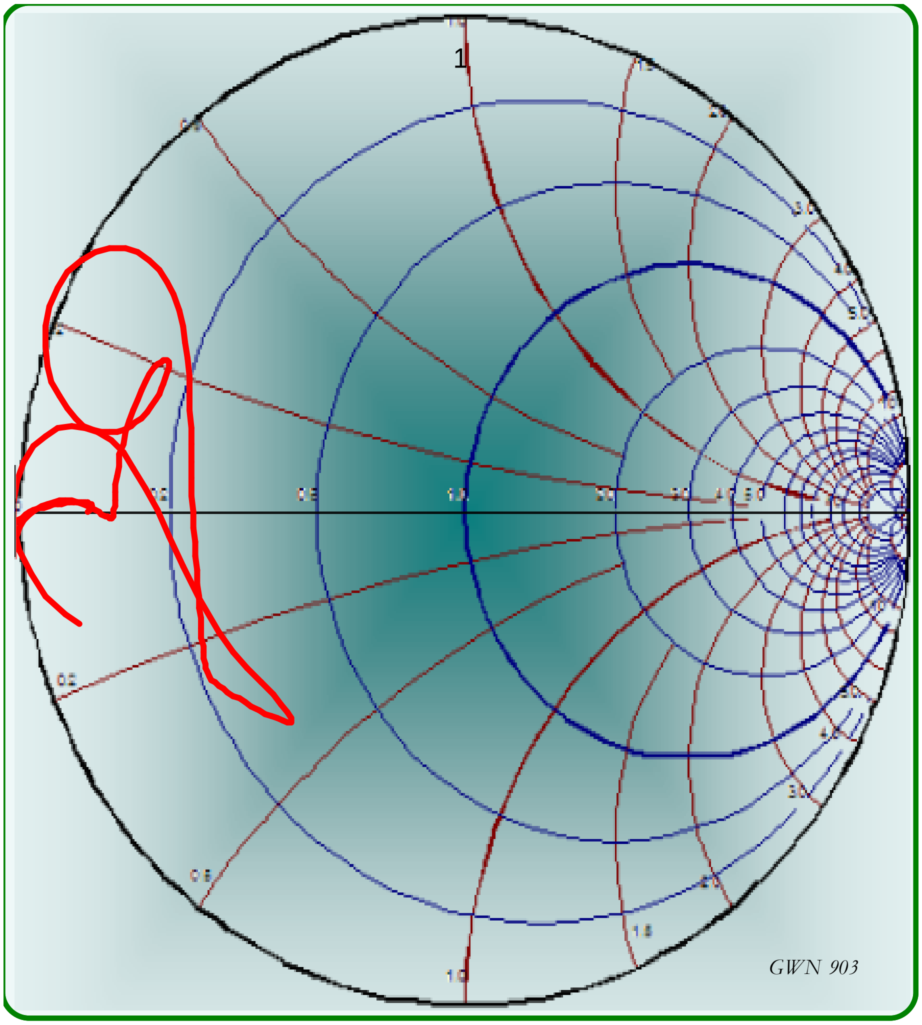

Figure 16 Short circuit response in the Smith chart

The Smith chart illustrates the difficulties of achieving an accurate calibration..

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

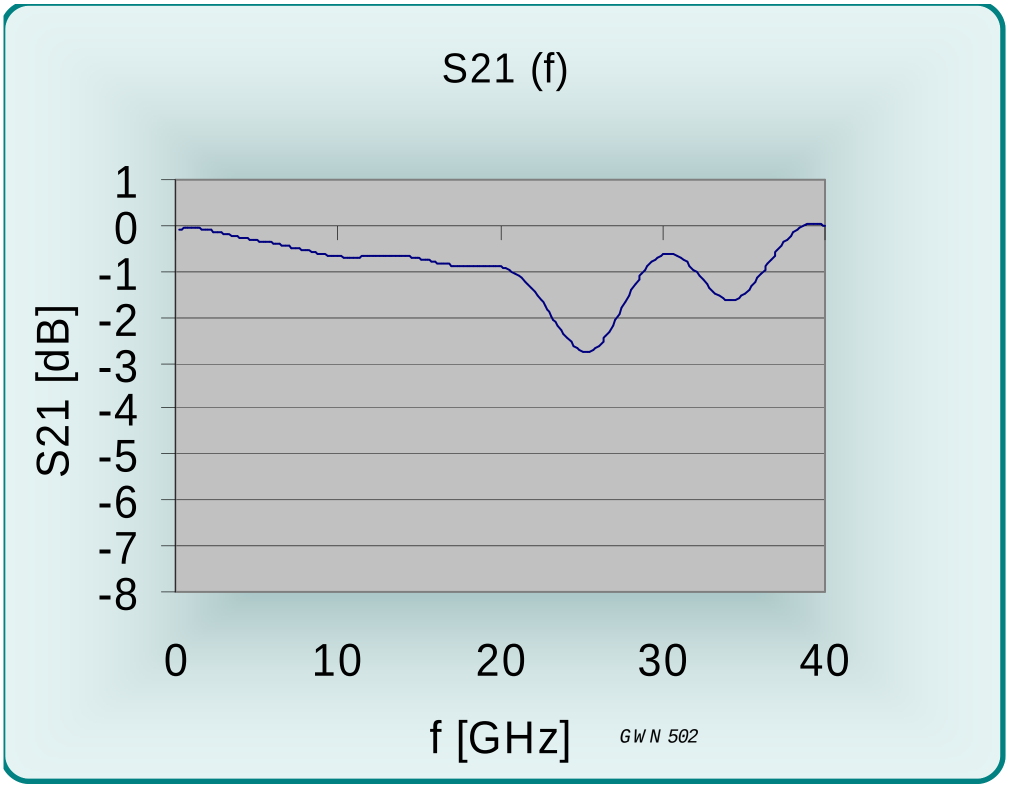

Figure 17 Insertion loss S21 (f)

Insertion loss is less than 1 dB to about 20.7 GHz. The 3 dB point is not reached before 40.0 GHz. The resonance at 25 GHz is the result of coupling to adjacent transmission lines.

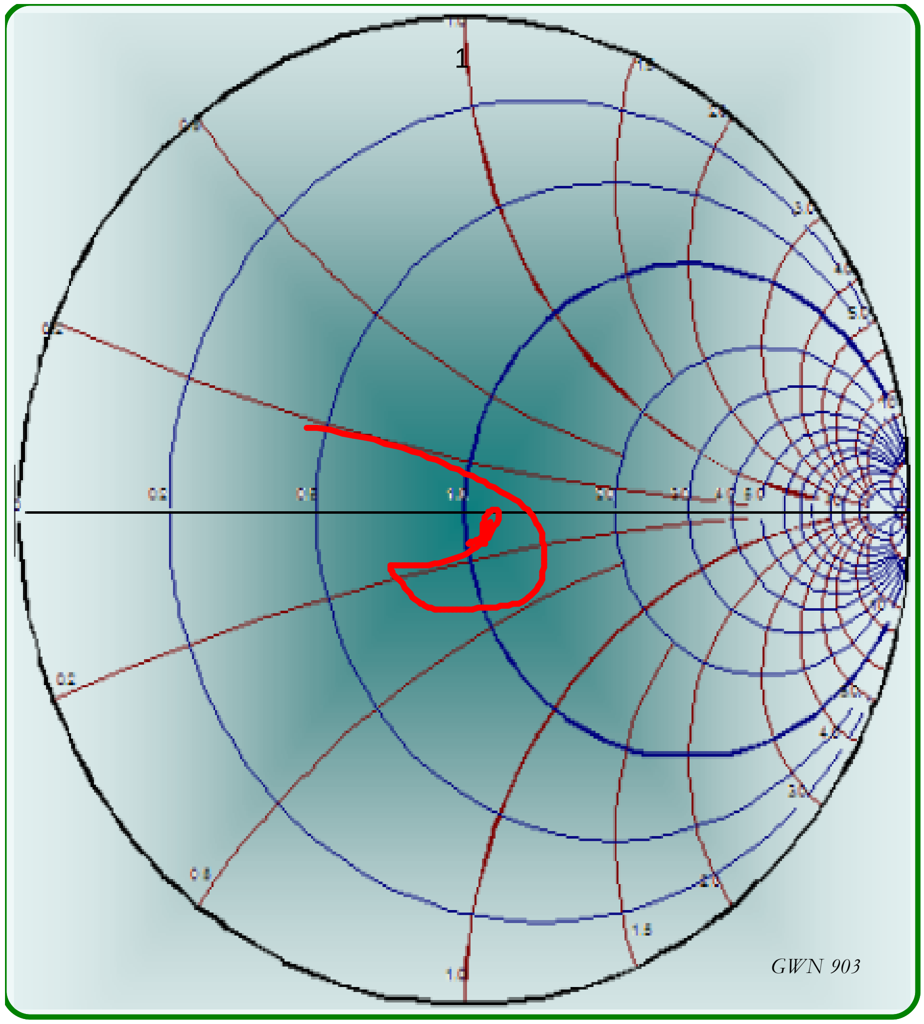

Figure 18 Smith chart for the thru measurement into a 50 Ohm probe

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

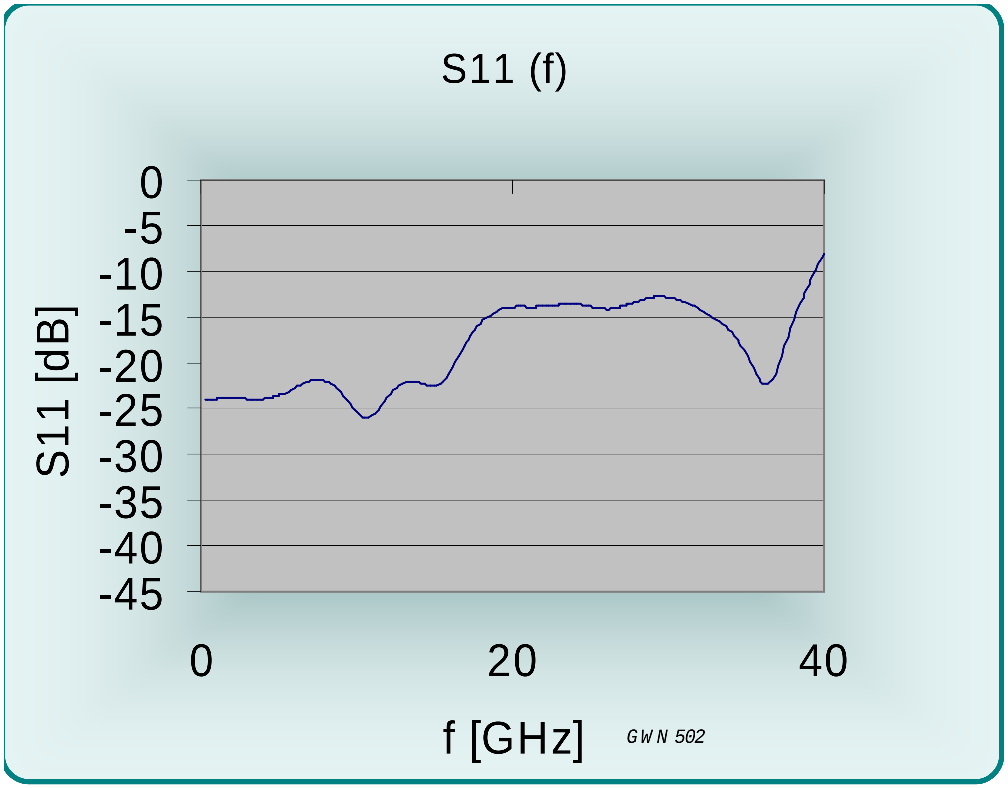

Figure 19 S11 magnitude (f) for the thru measurement into a 50 Ohm probe

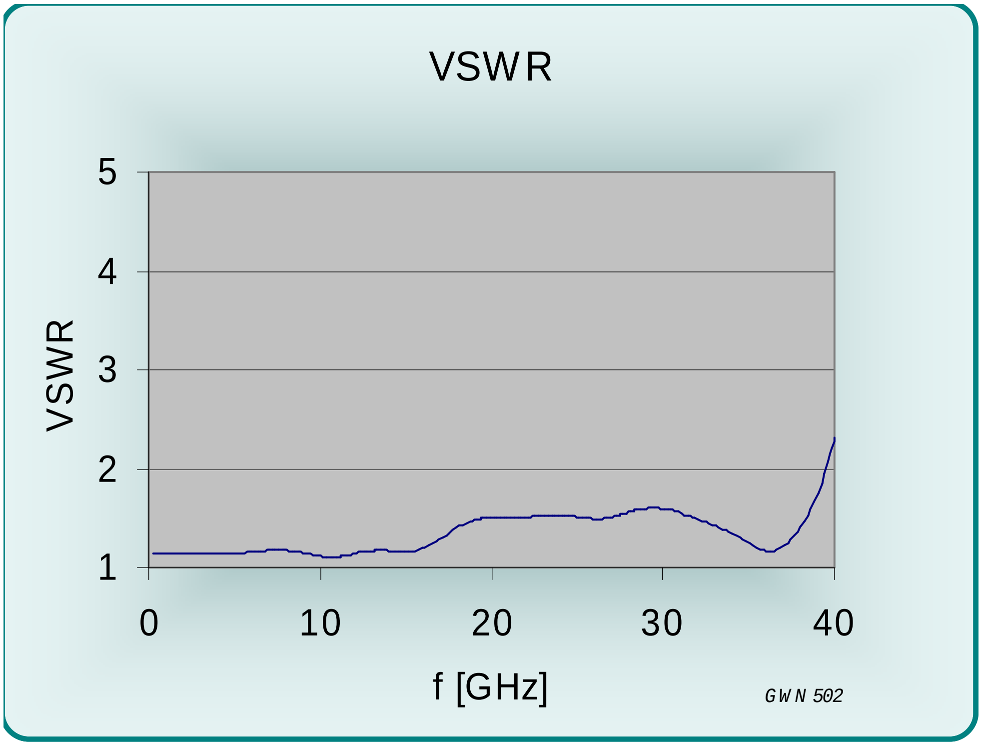

Figure 20 Standing wave ratio VSWR (f) [1 / div.]

The VSWR remains below 2 : 1 to a frequency of 39.5 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 modeling and are also listed in that section.

Measurements G-S-S-G

Time domain

Again, the time domain measurements will be presented first. A TDR reflection measurement is shown in Fig. 21 for the thru case at port 1 to port 2:

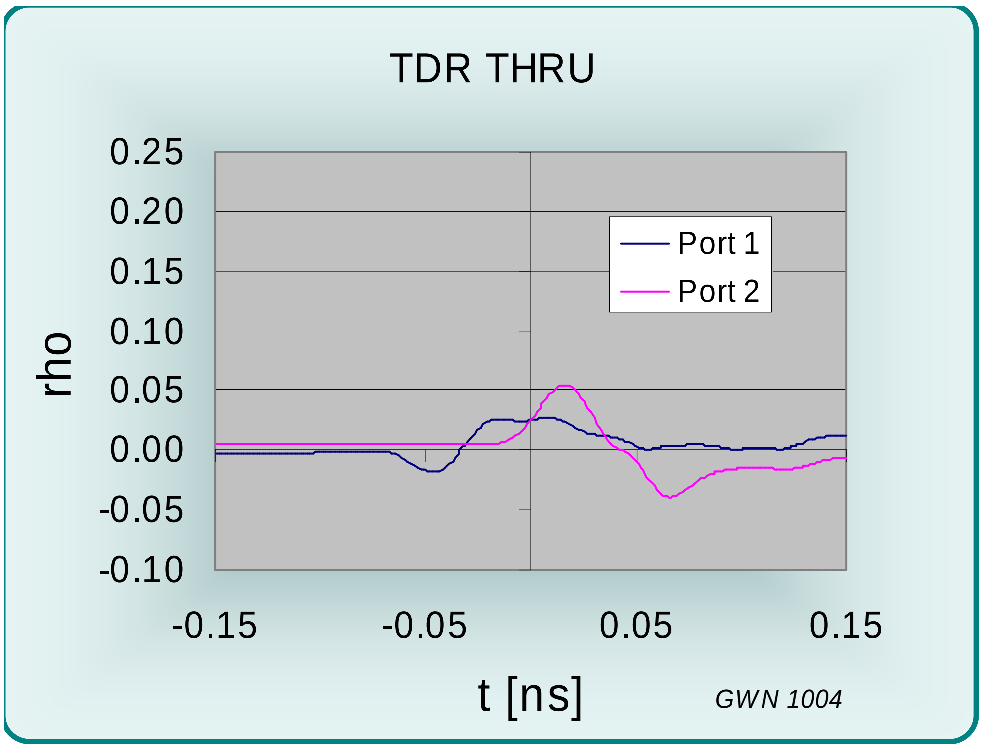

Figure 21 TDR through DUT into a terminated probe

The thru TDR response shows primarily inductive responses. The peak corresponds to a transmission line impedance of 55 Ohms.

The TDT performance for a step propagating through the G-S-S-G pin arrangement was also recorded:

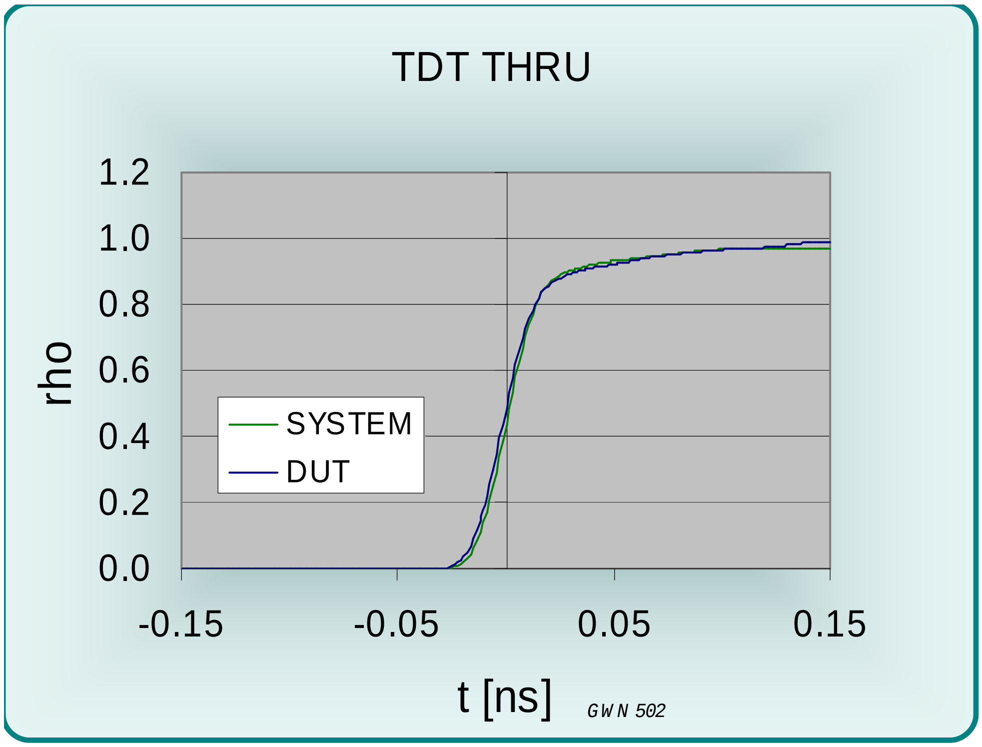

Figure 22 TDT measurement

The TDT measurements for transmission show a small contribution to risetime from the pin array (10-90% RT = 35.0 ps, the system risetime is 34.5 ps). The likely source is the elevated impedance of the pin array. The added delay at the 50% point is insignificant.

Frequency domain

Network analyzer reflection measurements for the G-S-S-G case were taken with all except the pins under consideration terminated into 50 Ohms. As a result, the scattering parameters shown below were recorded for reflection and transmission through the contact array.

First, insertion loss measurements (S21 and S12) are shown for port 1 to port 2.

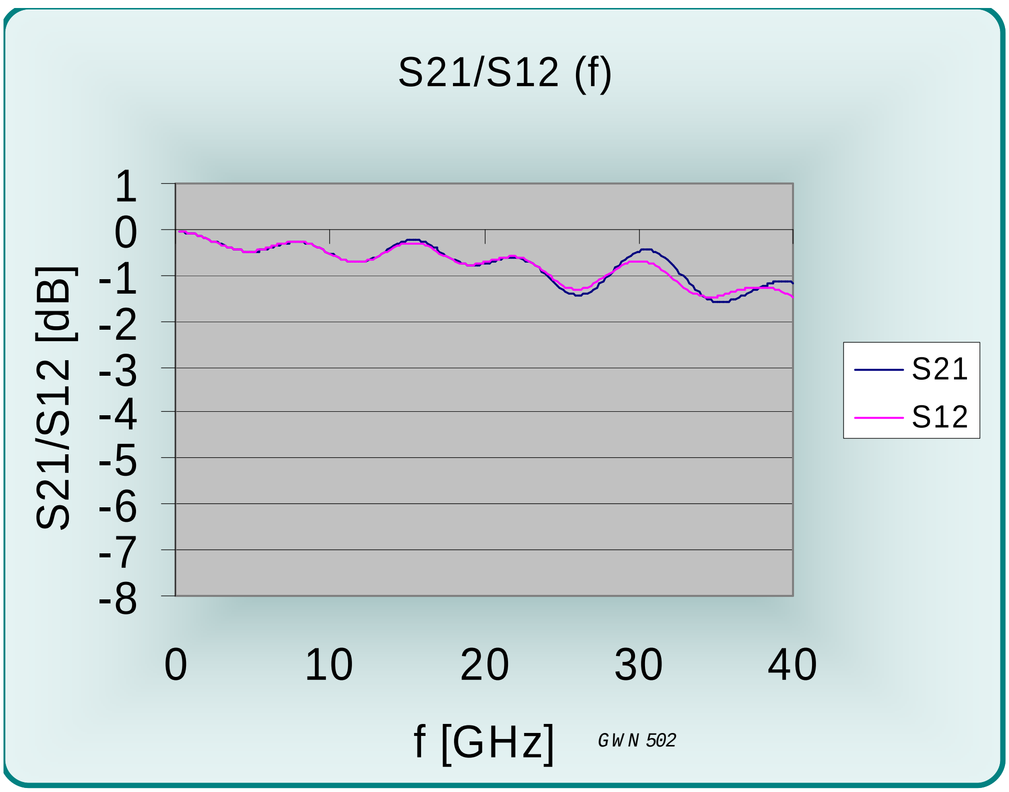

Figure 23 Insertion loss S21 (f) and S12 (f)

Insertion loss is less than 1 dB to about 23.9 GHz and 24.1 GHz for S21 and S12, respectively. The 3 dB point is not reached before 40.0 GHz (S21 and S12).

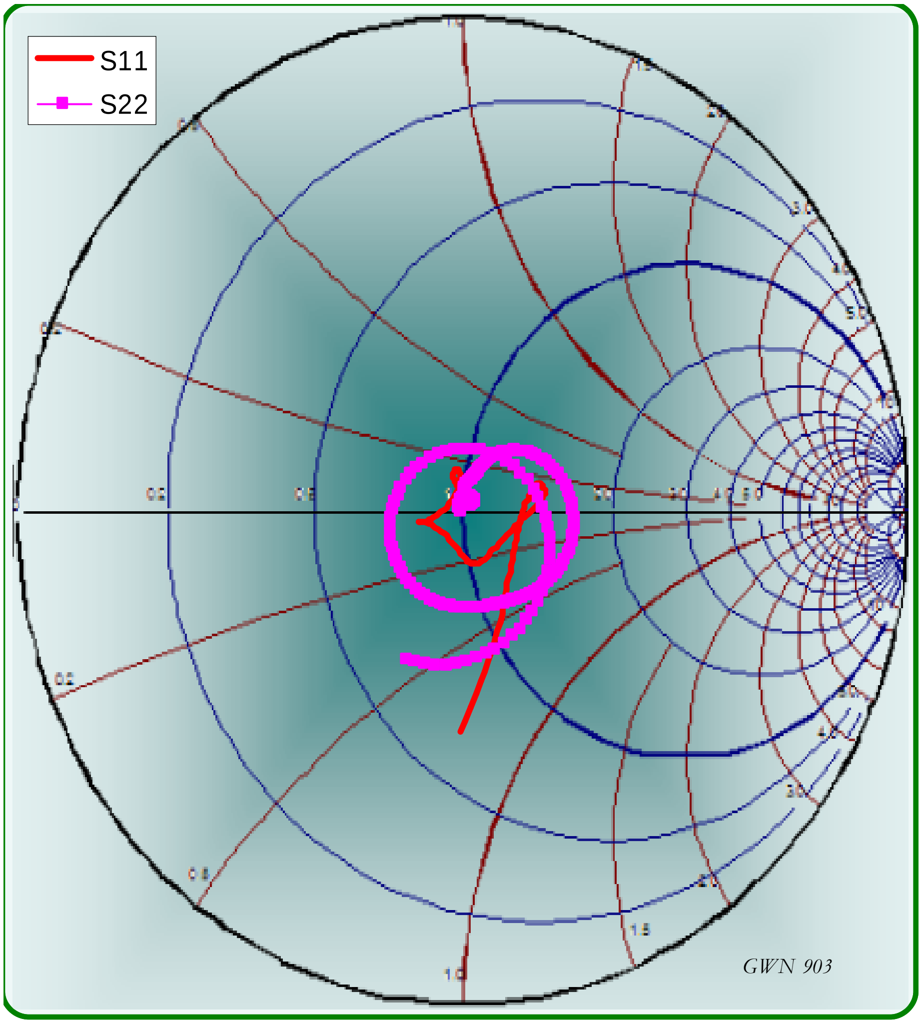

Figure 24 Smith chart for the thru measurement into a 50 Ohm probe

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

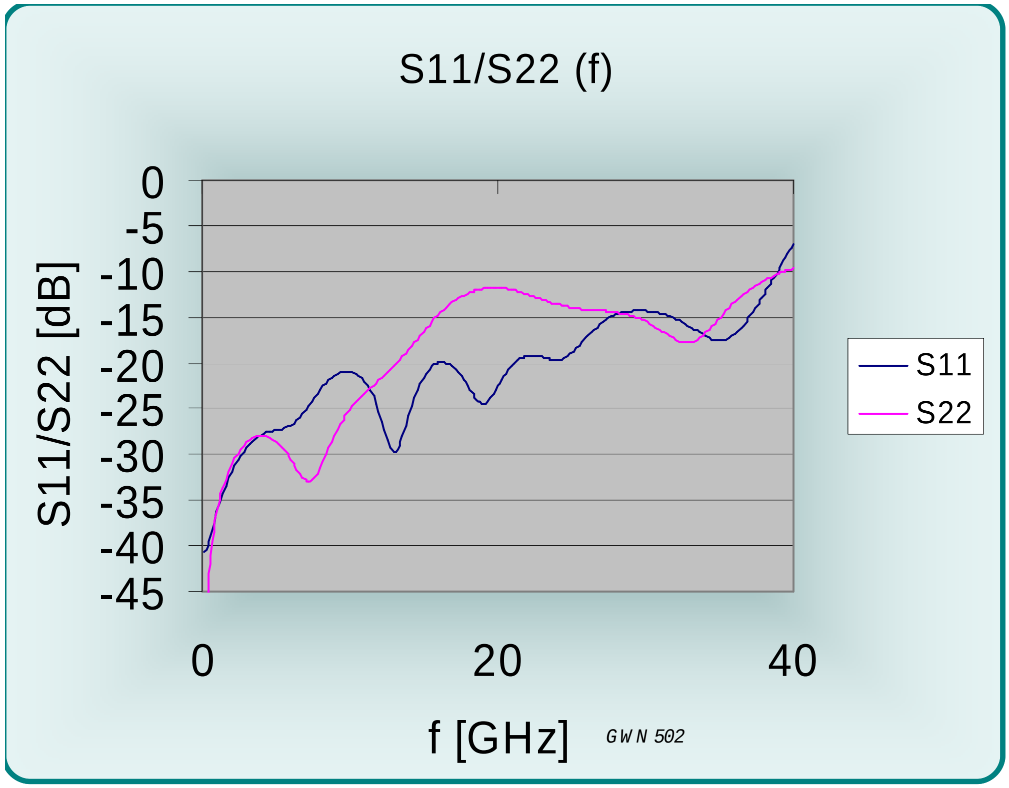

Figure 25 S11 magnitude (f) for the thru measurements into a 50 Ohm probe

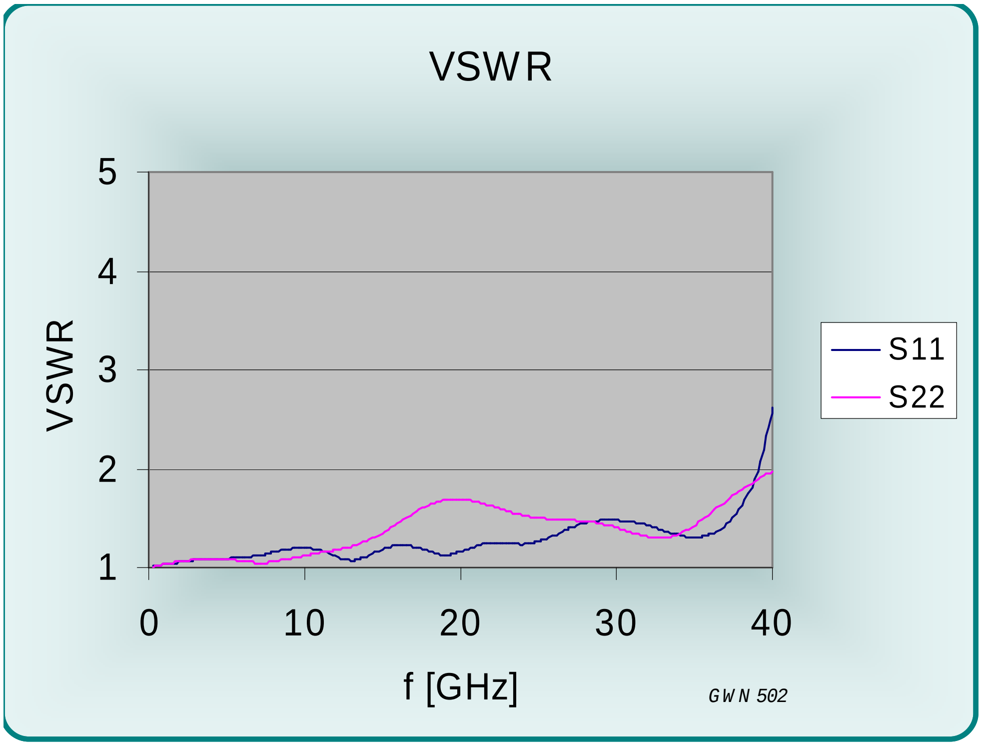

Figure 26 Standing wave ratio VSWR (f) [1 / div.]

The VSWR remains below 2 : 1 to a frequency of 39.1 GHz for S11 and 40.0 GHz for S22.

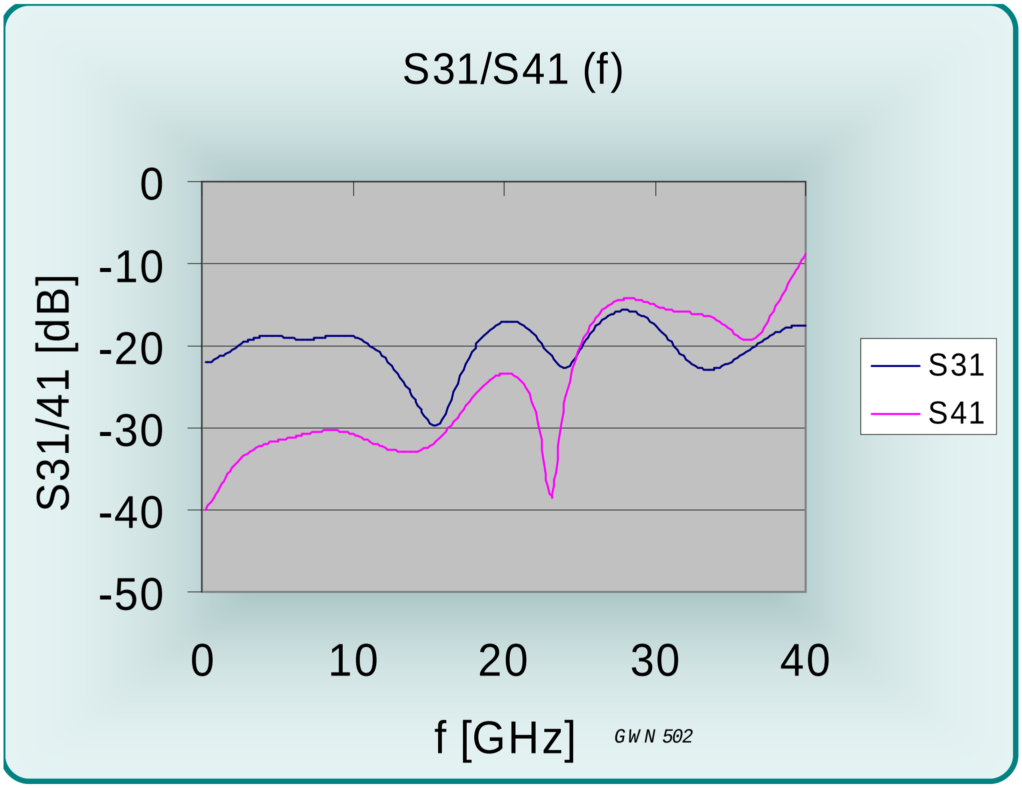

Figure 27 Crosstalk as a function of frequency

The graph shows forward crosstalk from port 1 to port 4 (S41) and backward crosstalk from port 1 to the adjacent terminal (port 3, S31). The -20 dB point is reached at 2.4 GHz (S31) and 24.9 GHz (S41). At 10.2 GHz (S31) and not before 39.5 GHz (S41) the level of signal reaches -10 dB.

For the purpose of model development the open circuit and short circuit backward crosstalk S31 is also recorded. It is shown below. It is important to realize that this measurement yields the mutual elements for the entire microstrip structure underneath the socket. Model development yields a mutual capacitance of 0.12 pF and a mutual inductance of 0.24 nH over the entire length of the microstrip line. Values are large due to the long coupled regions of microstrip line.

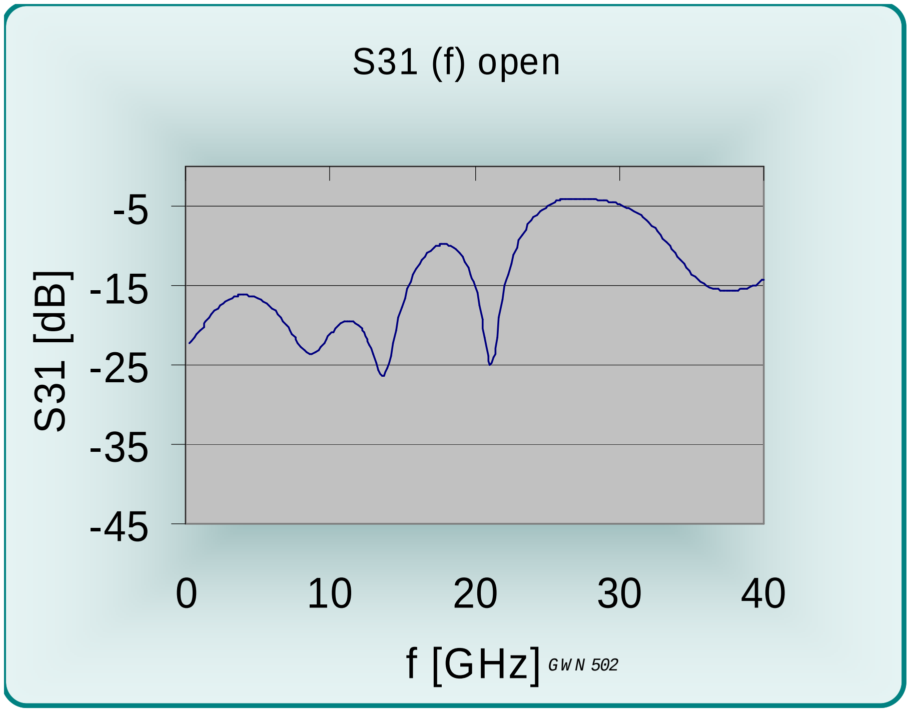

Figure 28 Open circuit crosstalk from port 1 to port 3

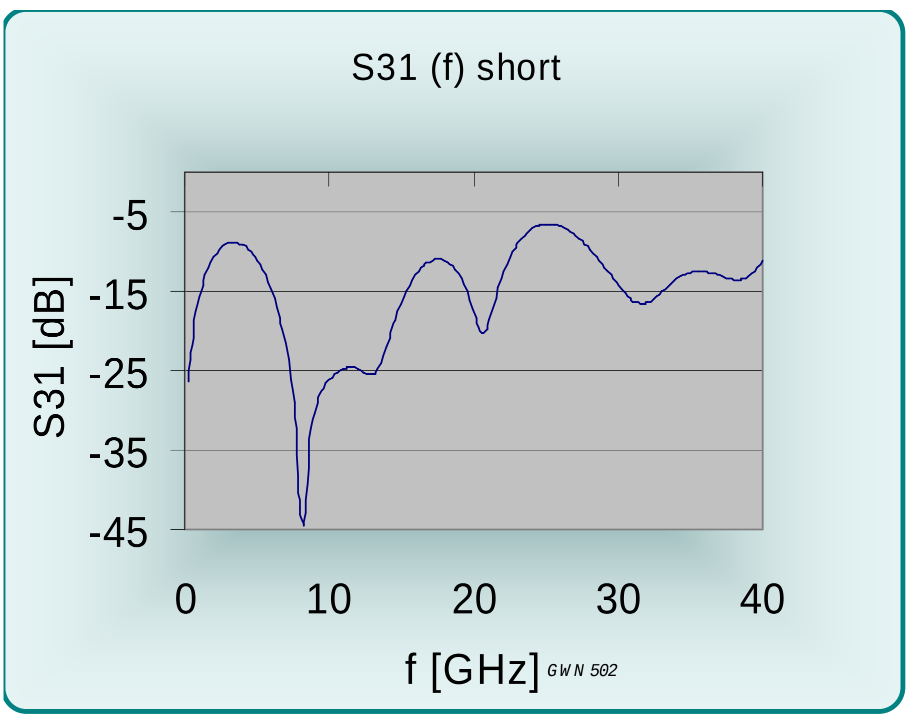

Figure 29 Short circuit crosstalk from port 1 to port 3

SPICE Models

A model for this type of interconnect requires careful consideration. Calibration to the end of the microstrip line underneath the socket allows extraction of parameters such as capacitance and inductance for the immediate area at the transmission line end. The SPICE model for the Aries QFP microstrip socket in G-S-G configuration is shown below:

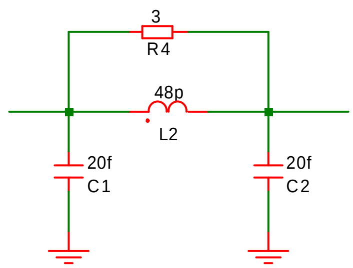

Figure 30 Lumped element SPICE model

The resistance value (R4) approximates the loss term encountered.

The second model developed is a transmission line model. It, too, models only the immediate vicinity of the microstripline end, not the entire microstripline:

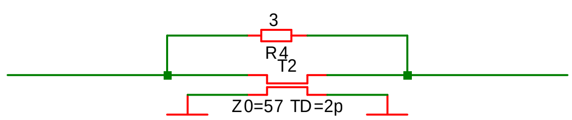

Figure 31 Transmission line model for the QFP microstrip socket

Since these models are the result of measurements that do NOT include the length of the microstripline, a direct comparison with measurements can be made only for open and short circuit conditions, where calibration to the end of the microstrip was performed.

These models apply only for the connection from the end of the microstripline to the DUT.

Time domain

The TDR simulation results indicate an inductive response just as the measurement (Fig. 5, TDR THRU).

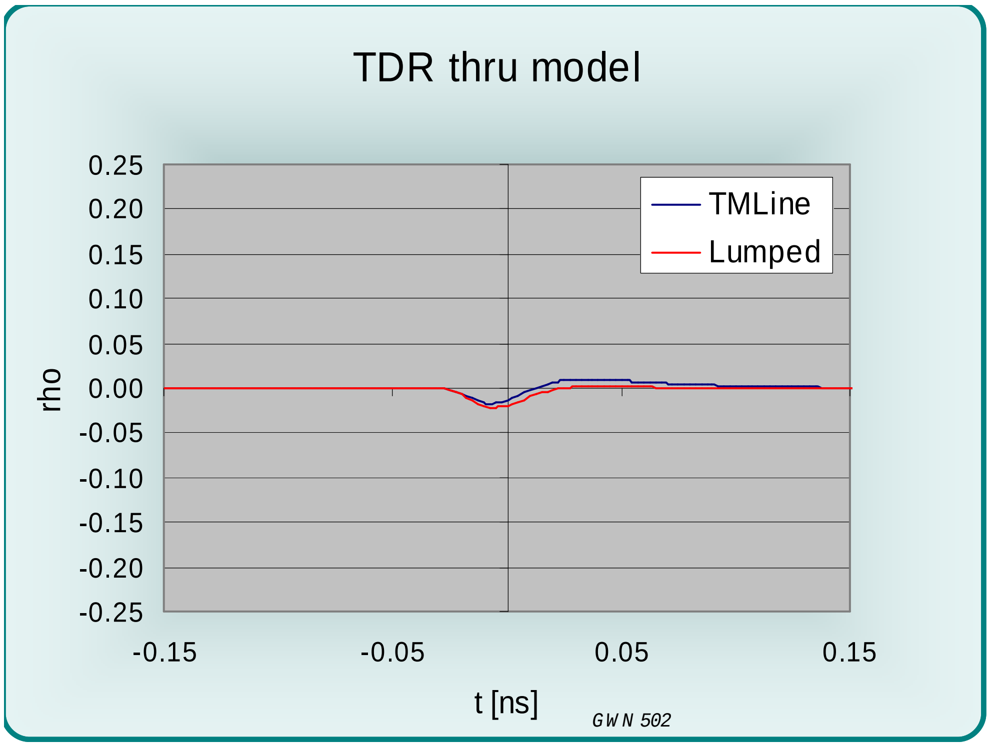

Figure 32 TDR model results

The transmission line model is better suited to the time domain simulation than the lumped element model since the latter is saddled with a larger capacitance compared to that of the transmission line model. The reason is the effective capacitance change that occurs when the socket comes into the proximity of the microstripline (the calibration is performed without any socket present).

The risetime contribution of a signal transmitted through the pin is shown below:

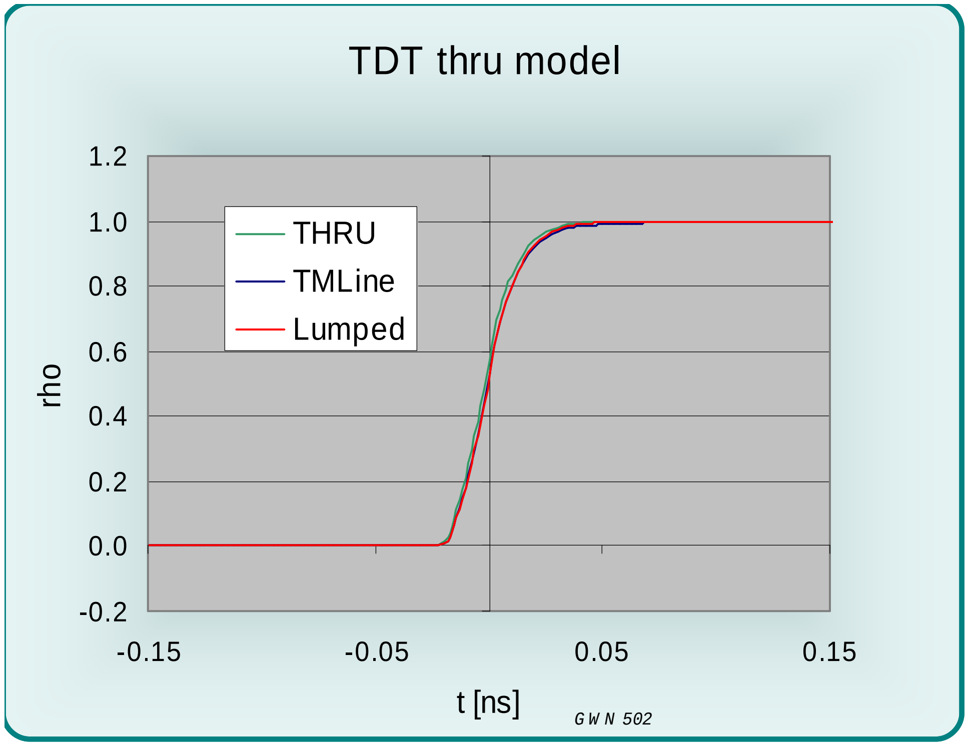

Figure 33 TDT model

The risetime for the transmission line case is 32.5 ps for all cases. This situation is comparable to that obtained in the measurement (Fig. 8).

Frequency domain

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

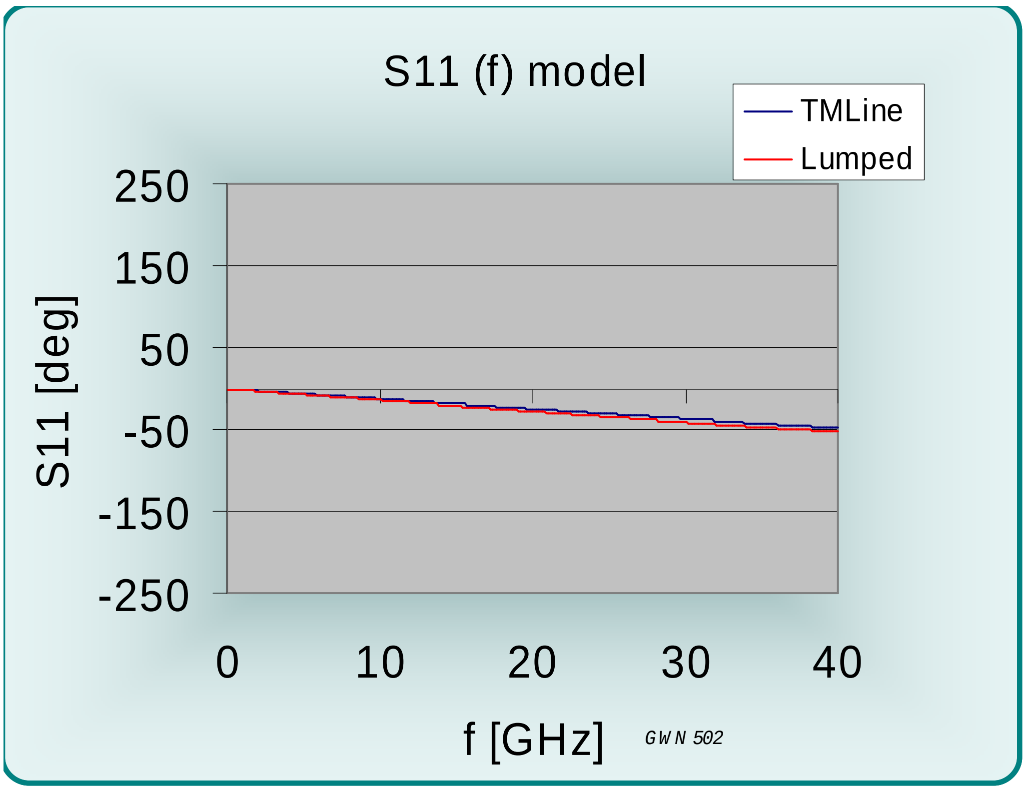

Figure 34 S11 phase (f) for open circuited case

The overall evolution of phase with frequency is comparable to that measured. Aberrations are likely absent because the measurement contains the effects of calibration changes due to the presence of the socket material to the microstripline.

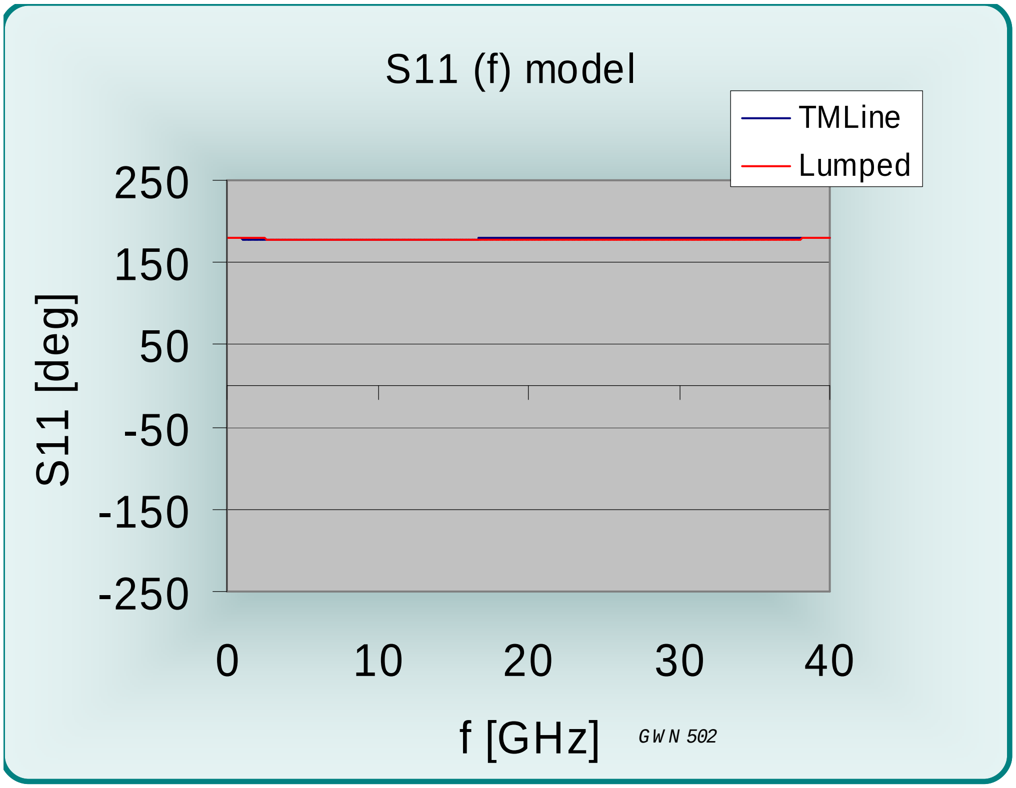

Figure 35 S11 phase response (short circuit)

The short circuit phase evolution with frequency is much smoother than that measured. Again, transmission line property changes that cannot be compensated for are at the root of the deviations.

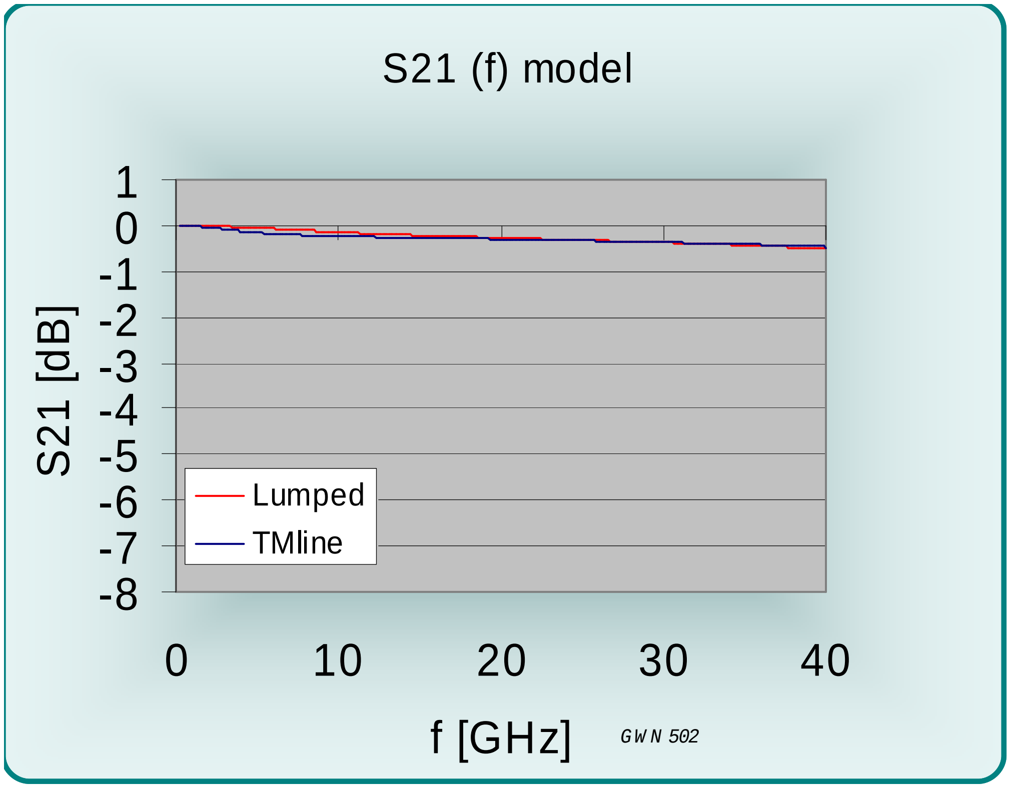

Figure 36 Insertion loss as a function of frequency

Neither of these models takes into account the changes that occur when the socket is placed over the microstrip transmission line. Hence, model results are better and smoother than actually measured values.

When modeling the mutual coupling, the entire length of the line was taken into account, however. This results in the following equivalent circuit parameters:

Ls=1.5nH, Lm=0.24nH, Cg=0.6pF, Cm=0.12pF.

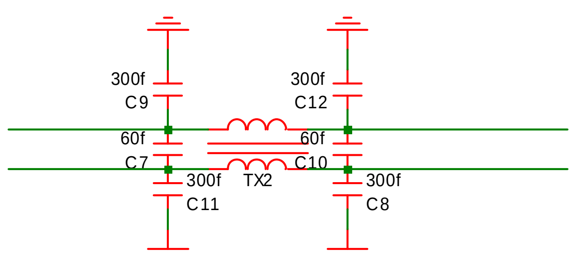

Figure 37 Equivalent circuit for mutual coupling

Since the lumped model does not remain valid at high frequencies, a transmission line model with coupled transmission lines and added loss terms was also established:

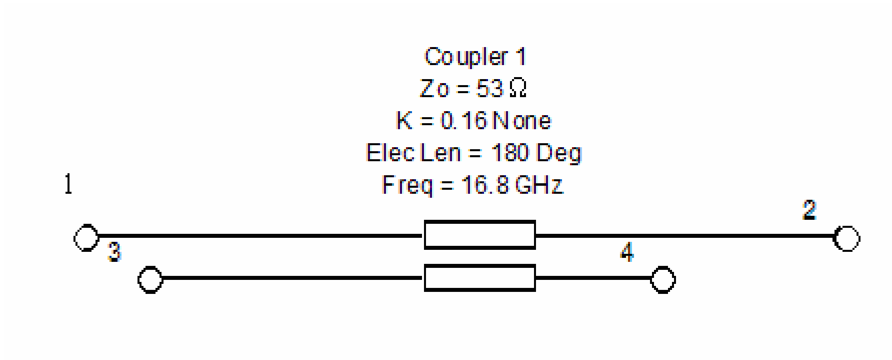

Figure 38 Transmission line equivalent circuit for crosstalk

The model shows two coupled transmission lines with the respective in- and outputs. When comparing the results with the measurements it should be kept in mind that the lumped model applies only at low frequencies. It is not clear why the transmission line model response for forward crosstalk is much lower than the measured values.

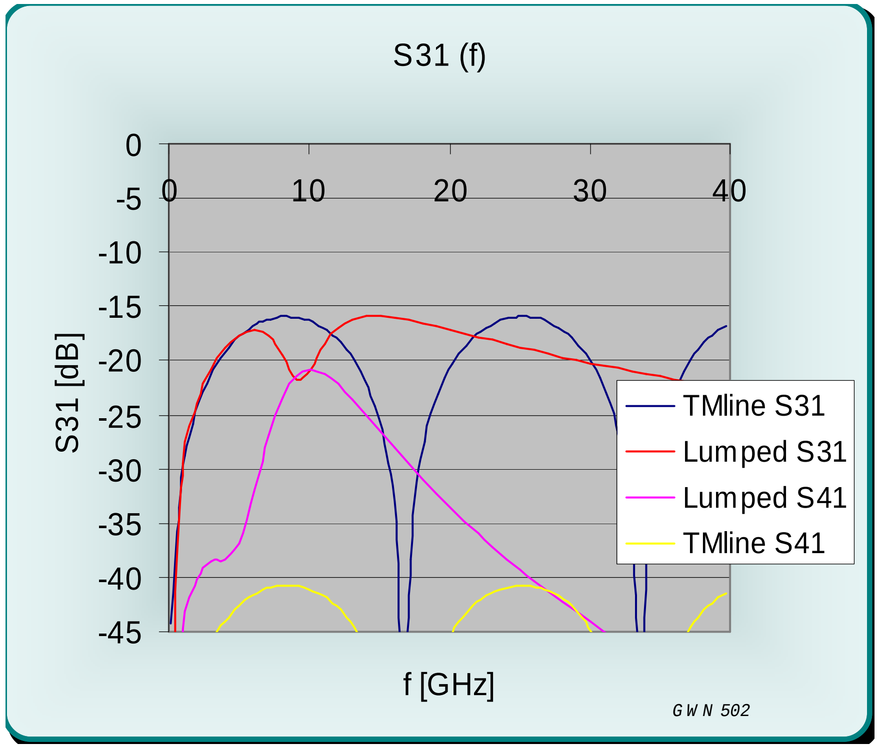

Figure 39 Crosstalk S31 and S41 [dB] as a function of frequency

Aries

QFP microstrip socket

Report summary sheet

2/18/05

Socket test configuration:

All pins grounded in an 0.4 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	=	1 ps
Risetime, open circuit	<	36.0 ps
Risetime, short circuit	<	33.0 ps
Risetime, thru 50 Ω	<	31.5 ps

Frequency domain:

Insertion loss	<	1 dB to 20.7 GHz , < 3 dB to 40.0 GHz
VSWR	<	2 :1 to 39.5 GHz

Equivalent circuit parameters:

Pin inductance	=	0.05 nH
Pin to ground capacitance	=	0.04 pF
Mutual inductance	=	0.24 nH
Mutual capacitance	=	0.12 pF
Transmission line	=	Z0 = 57.2 Ω , Tl = 2 ps