Measurements G-S-S-G

Time domain

G-S-S-G transmission measurements were performed with a near symmetric 'field' configuration, mutual parameter determination was performed on all sites. 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:

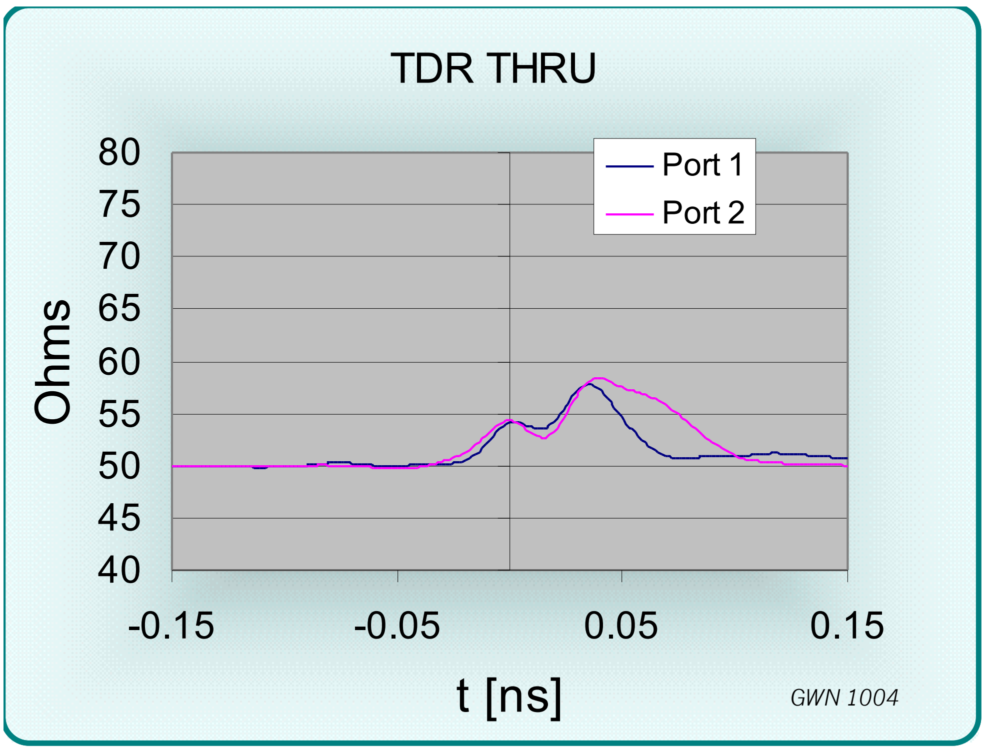

Figure 21 TDR through DUT into a terminated probe

The thru TDR measurement from port 1 to port 2 shows an inductive response. The low peak corresponds to a transmission line impedance of 57.7 Ohms. This is higher than in the G-S-G case since one of the adjacent pins is not grounded.

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

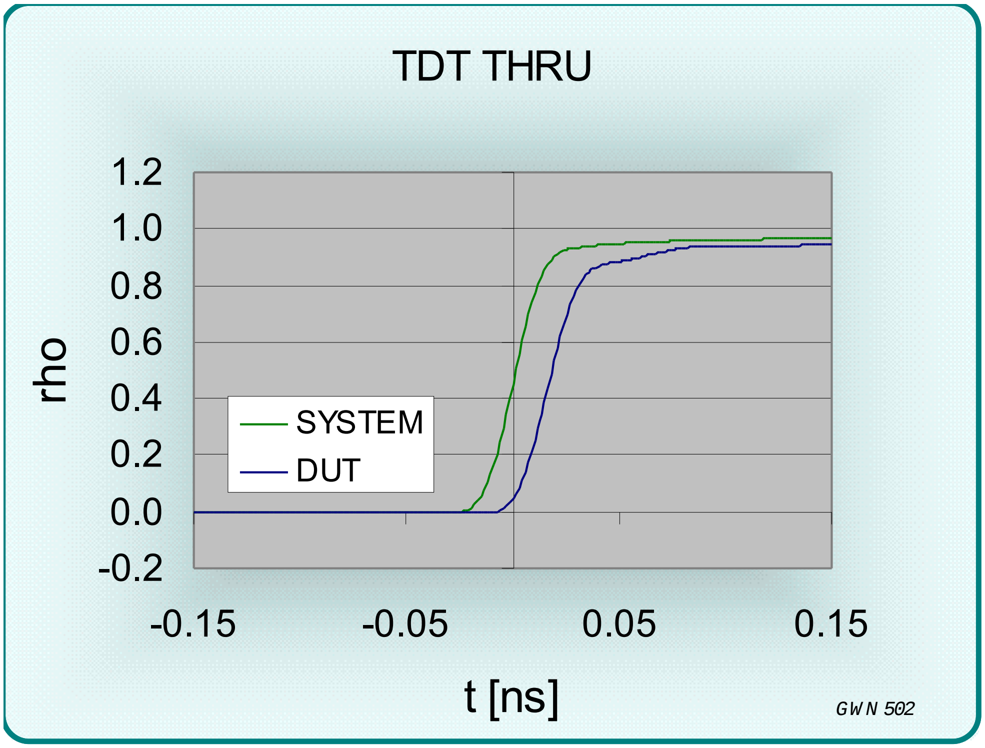

Figure 22 TDT measurement

The TDT measurements for transmission shows almost the same risetime from the pin array (10-90% RT = 33.0 ps) as the system risetime (28.5 ps). The added delay at the 50% point is 16.5 ps. The 20%-80% values are 19.5 ps and 18.0 ps, respectively.

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 (ports 1-4). As a result, the scattering parameters shown below were recorded for reflection and transmission through the contact array.

First, an insertion loss measurement is shown for port 1 to port 2.

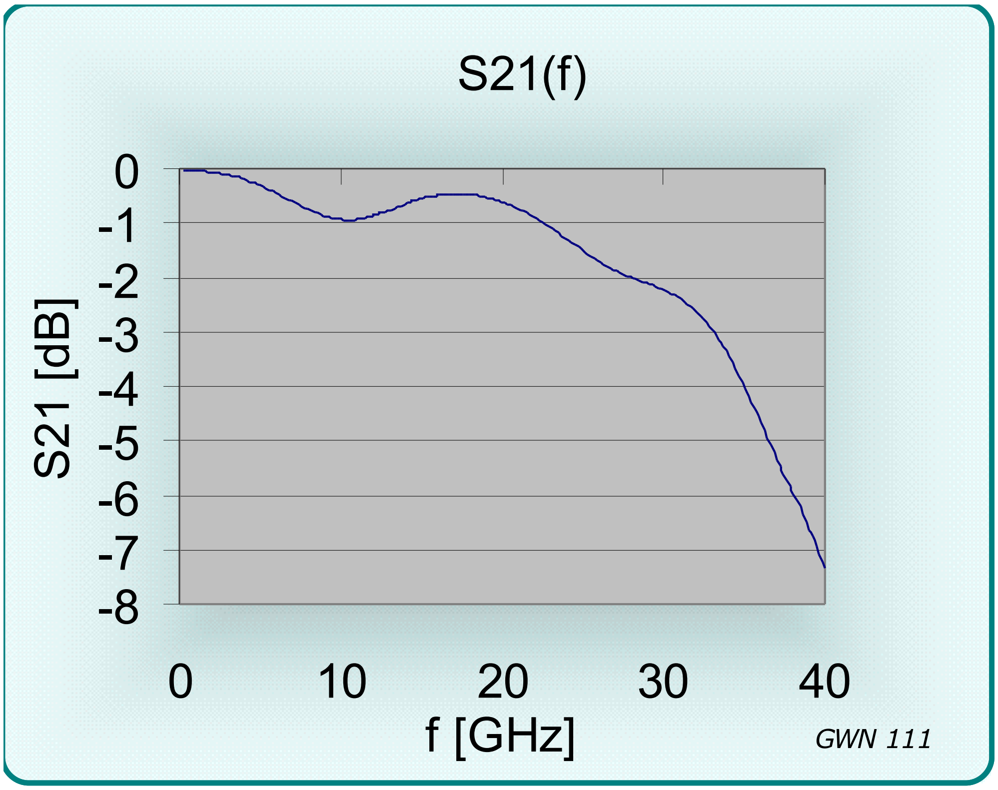

Figure 23 Insertion loss S21 (f)

Insertion loss is less than 1 dB to about 22.7 GHz. The 3 dB point is not reached before 33.3 GHz.

Insertion loss is higher than in the G-S-G case because of the diversion of some signal energy from the thru connection to the adjacent second signal pin.

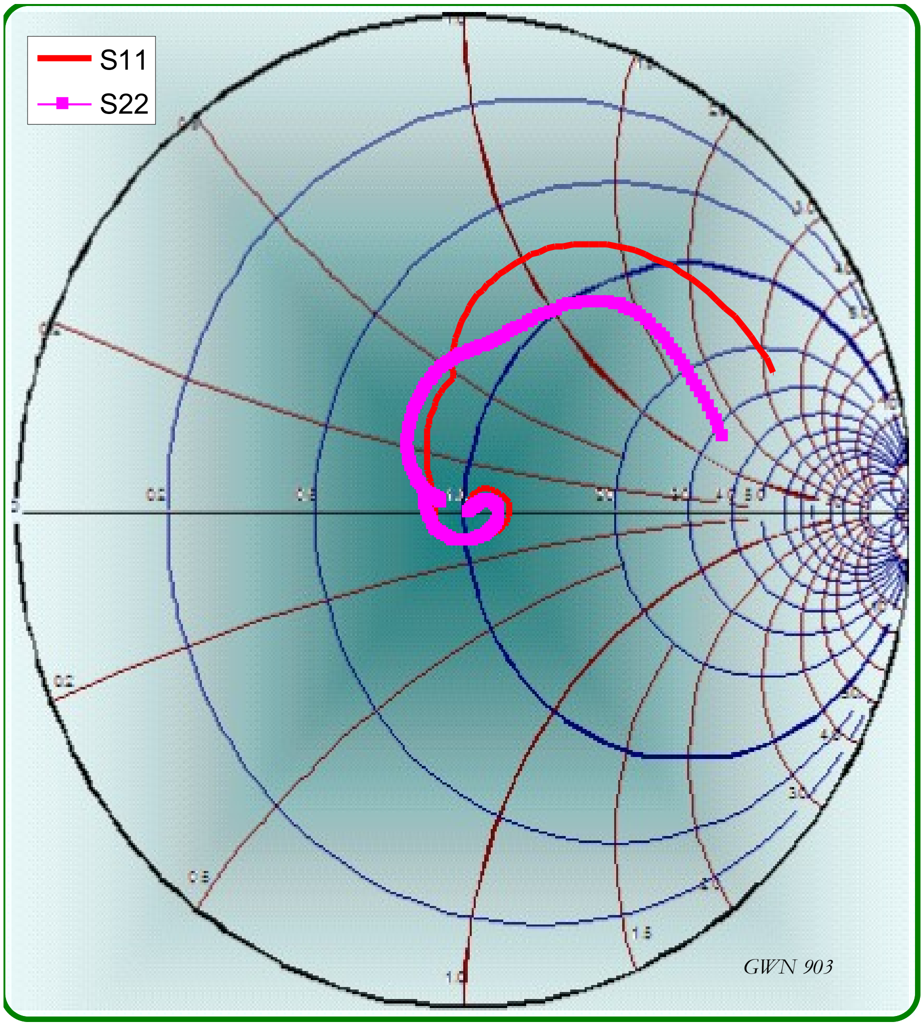

Figure 24 Smith chart for the thru measurement into a 50 Ohm probe

The Smith chart for the thru measurements shows a good match at low frequencies with some reactive components as frequency increases.

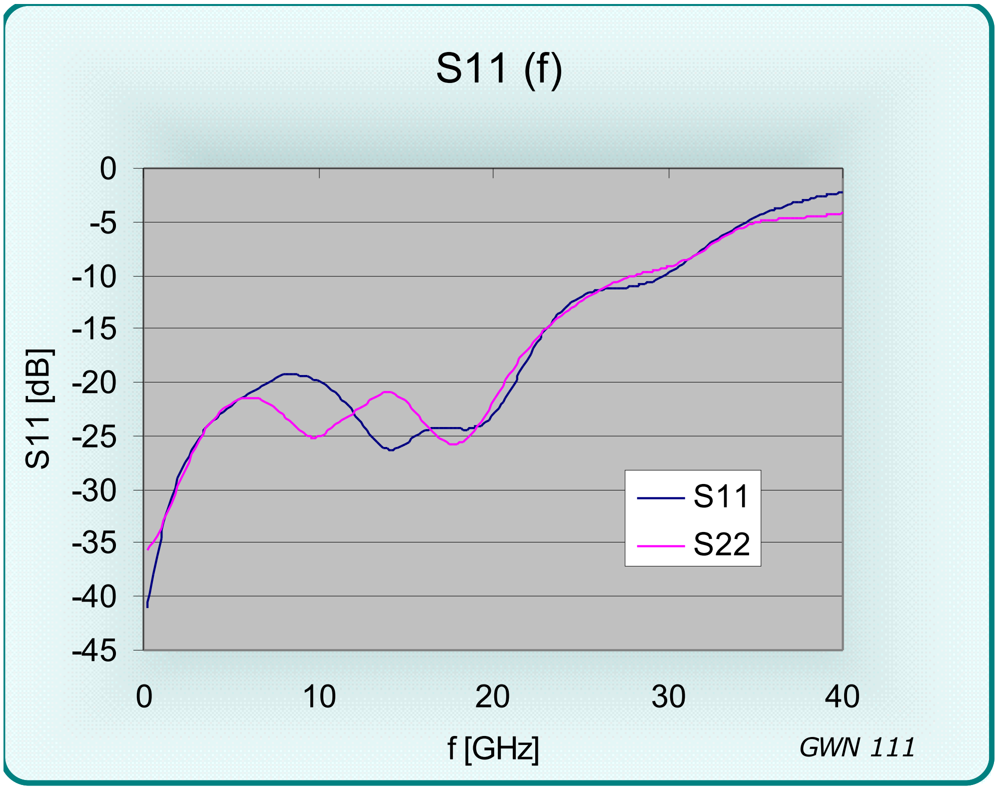

Figure 25 S11 magnitude (f) for the thru measurements into a 50 Ohm probe

The value of the return loss for the thru measurement reaches -20 dB at 7.2 GHz (S11) and 20.7 GHz (S22).

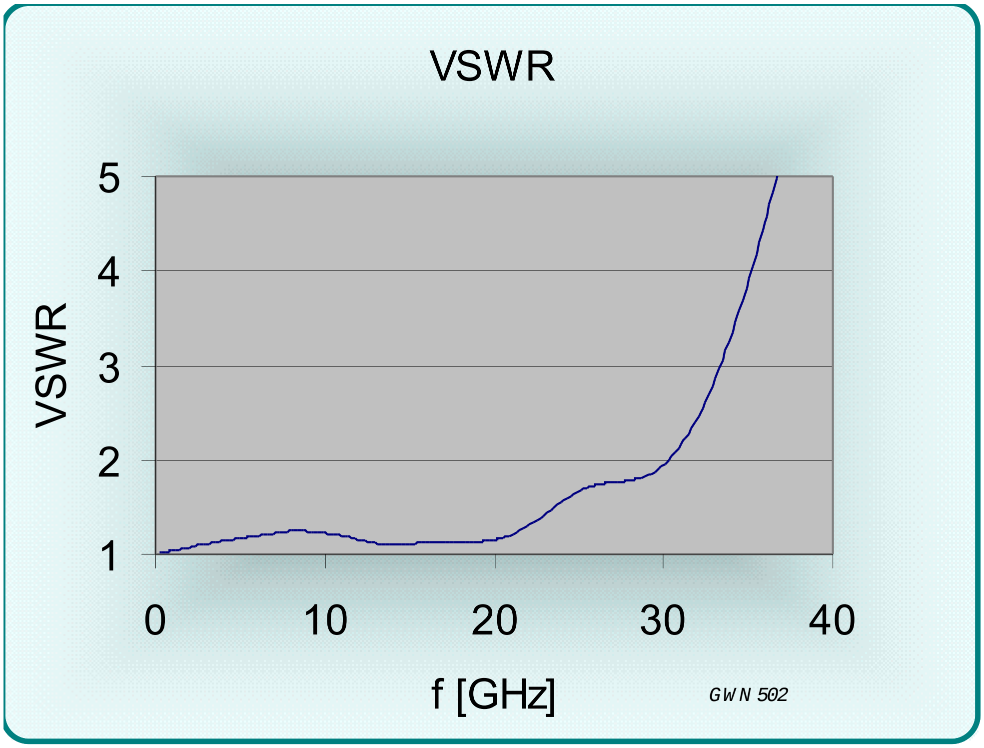

Figure 26 Standing wave ratio VSWR (f) [1 / div.]

The VSWR remains below 2 : 1 to a frequency of 30.3 GHz.

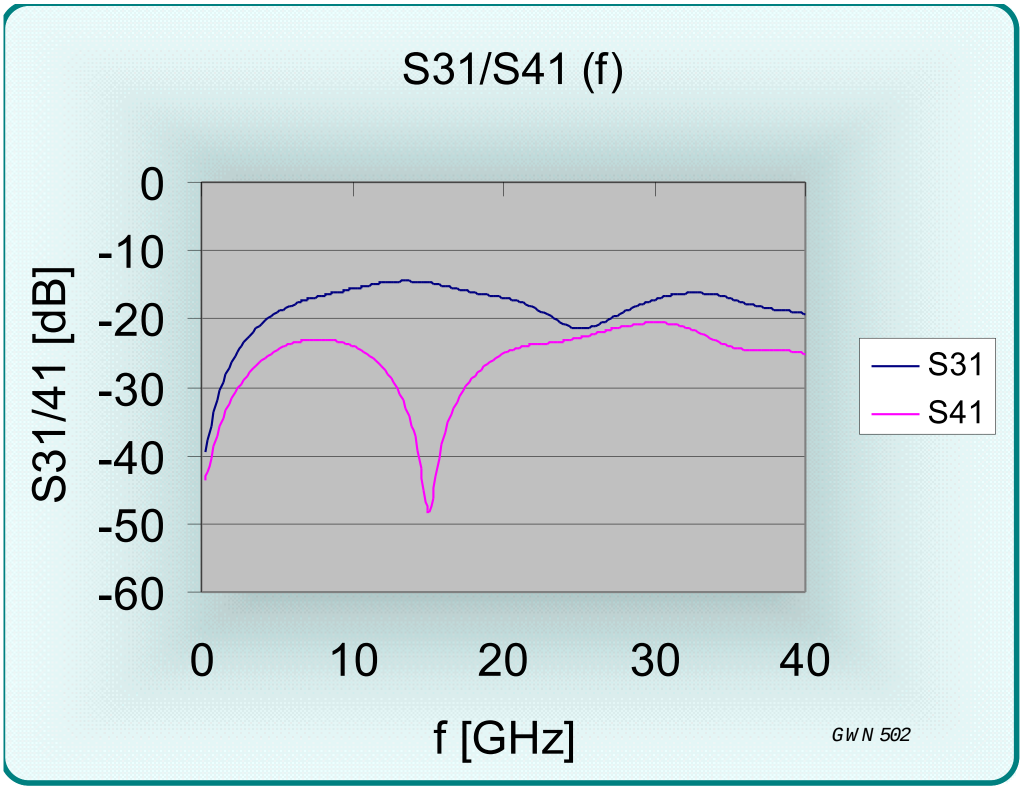

Figure 27 Crosstalk as a function of frequency

The graph shows forward crosstalk from port 1 to port 4 (S41, far end crosstalk {FEXT}) and backward crosstalk from port 1 to the adjacent terminal (port 3, S31, near end crosstalk {NEXT}). The -20 dB point is reached at 4.2 GHz (S31) and not before 40.0 GHz (S41).

For the purpose of model development the open circuit and short circuit backward crosstalk S31 is also recorded. It is shown below for the different sites. Model development yields a mutual capacitance of 0.079, 0.069, 0.058 and 0.025 pF and a mutual inductance of 0.42, 0.32, 0.22 and 0.158 nH for corner, edge field and diagonal sites, respectively.

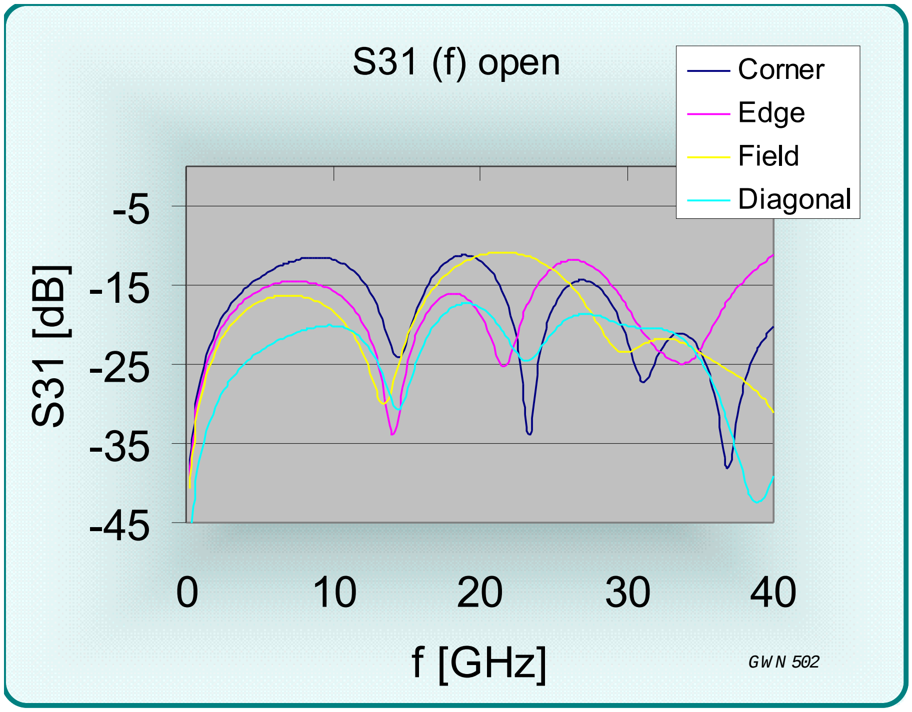

Figure 28 Open circuit crosstalk from port 1 to port 3

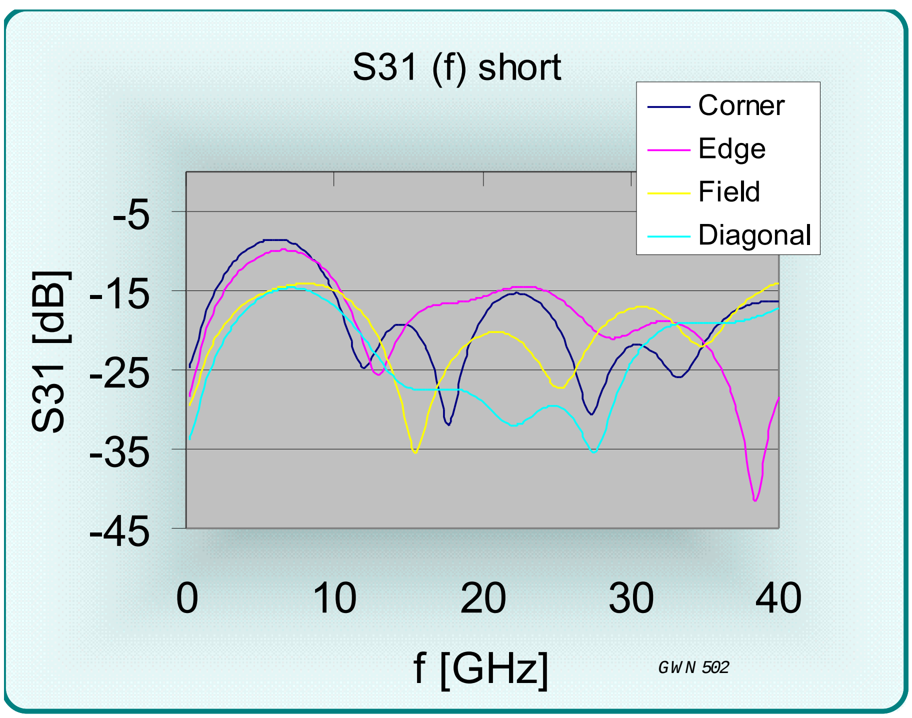

Figure 29 Short circuit crosstalk from port 1 to port 3

SPICE Models

A lumped element SPICE model for the Ironwood P-P204A test socket in G-S-G configuration is shown below:

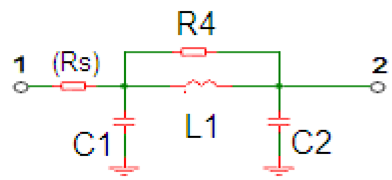

Figure 30 Lumped element SPICE model

The resistance value (R4) approximates the loss term encountered. The series resistance Rs is very small and does not significantly impact S-parameters. It can be determined by DC measurements but is not included in this model.

The values for the elements are

Site	Cg=C1+C2			L1		R4	
Corner		0.246	pF	1.25	nH	1000	Ohms
Edge		0.273	pF	0.99	nH	2000	Ohms
Field		0.296	pF	0.92	nH	2000	Ohms
Diagonal		0.296	pF	0.92	nH	2000	Ohms

Toward the cutoff frequency of the Pi section the lumped element model becomes invalid. This happens above 13 GHz for the above model. Accuracy of the model is better than 0.5 dB up to 9.6, 11.2 and 11.8 GHz for C,E,F. The second model developed is a transmission line model:

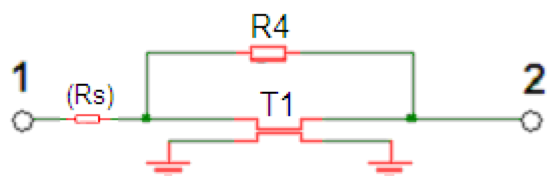

Figure 31 Transmission line model for the P-P204A test socket

Again, R4 describes loss and the series resistance Rs is very small and not included. The array configuration with signal pins surrounded by ground pins provides a transmission line environment with the following parameters:

	Zo		L		R4	
Corner	71.4	Ω	17.57	ps	2000	Ω
Edge	60.2	Ω	16.41	ps	10000	Ω
Field	55.8	Ω	16.53	ps	10000	Ω

Values computed here are generally lower than those measured by TDR. A possible cause is a more complex equivalent circuit with short sections of low impedance transmission line that cannot be resolved by the limited risetime TDR measurement.

Accuracy for S21 is better than 0.5 dB to 14.7, 22.9 and 23.9 GHz for C,E,F.

The lumped model does not remain valid at high frequencies. Alternatives are to split this model into multiple sections with the same total capacitance and inductance or to use a transmission line model. For models that are more accurate at high frequencies it is recommended to use a multi-pole SPICE subcircuit representation or sNp Touchstone S-parameters.

Time domain

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

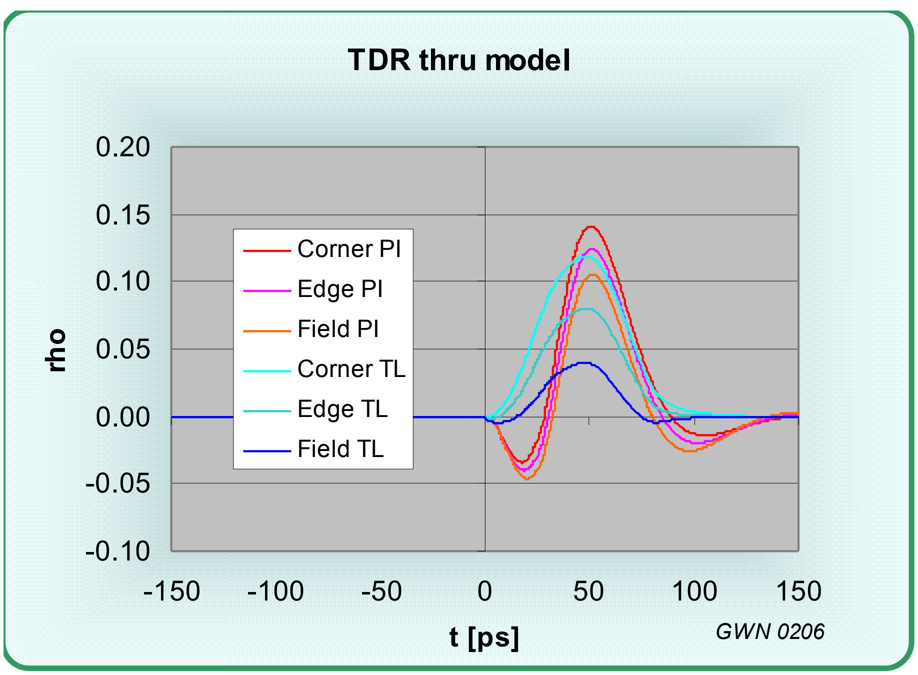

Figure 32 TDR model results

TMline TDR simulation results indicate a response comparable to that observed in measurements (see TDR THRU). However, simple lumped element models do not agree as well for fast risetimes. Just as in the frequency domain for better approximation at higher speeds, a transmission line model, more detailed multi-section LC model or sNp parameters should be used. Since these responses are computed from the model result, not the TDR result, the previously mentioned different computed impedance values are reflected in a divergent model from the TDR measurement.

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

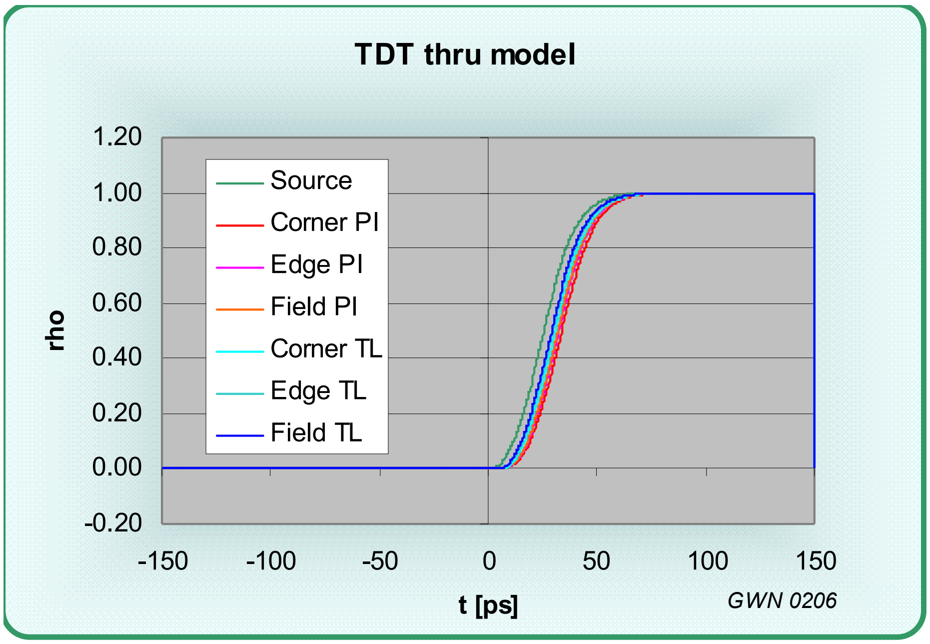

Figure 33 TDT model

Risetimes are comparable to that obtained in the measurement.

Frequency domain

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

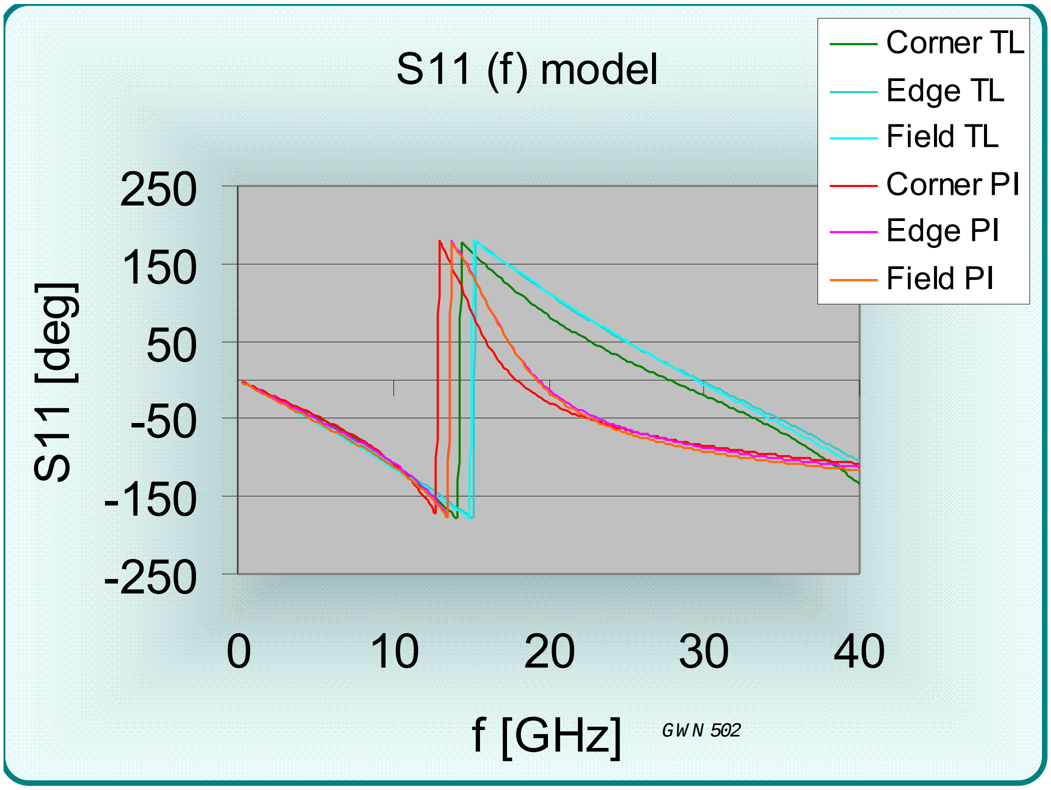

Figure 34 S11 phase (f) for open circuited case

The evolution of phase with frequency is comparable to that measured.
The lumped element model has a cutoff frequency of about 13 GHz.

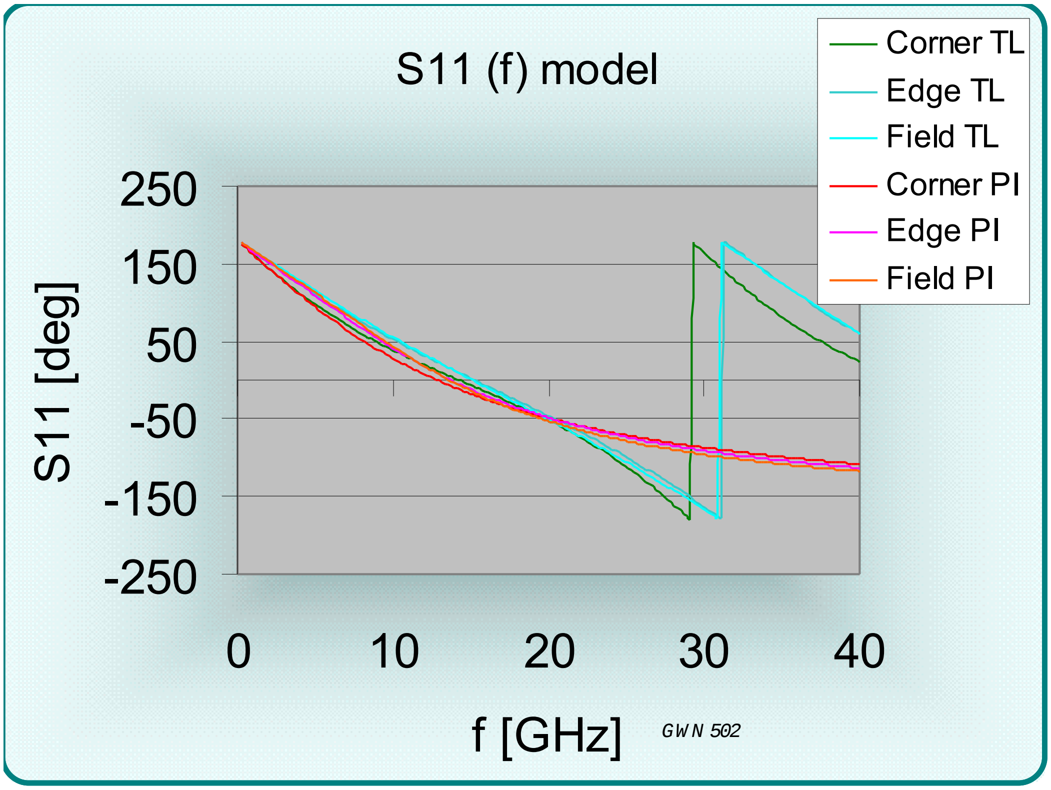

Figure 35 S11 phase response (short circuit)

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, insertion loss increases significantly. The transmission line model does not suffer from this shortcoming.

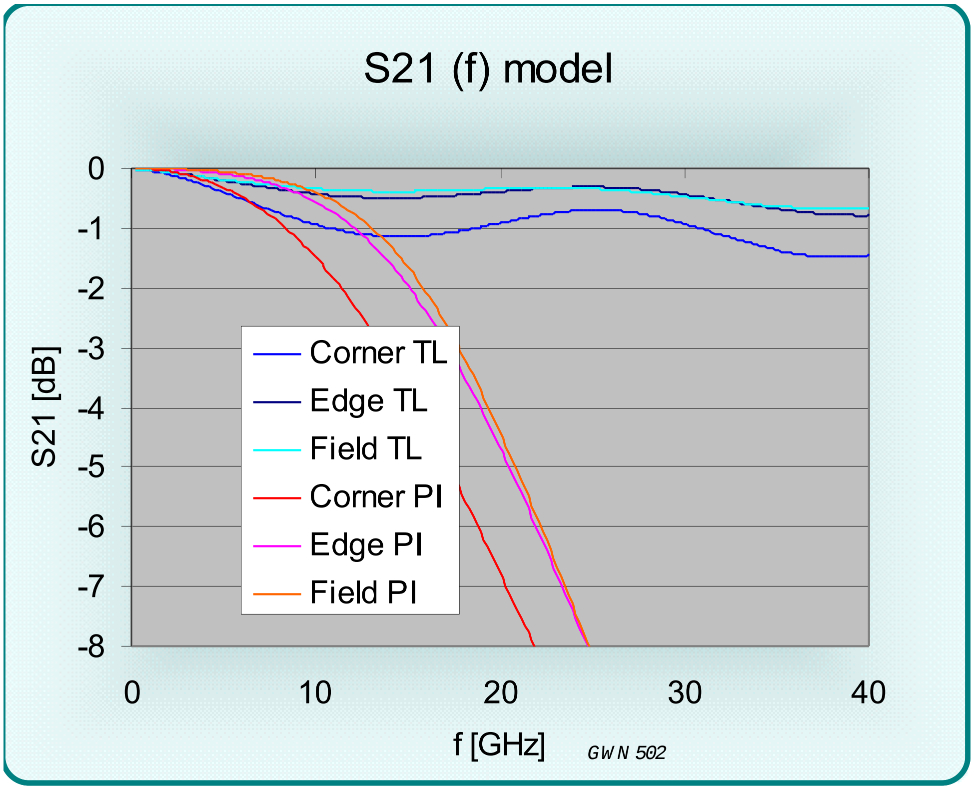

Figure 36 Insertion loss as a function of frequency

The lumped element frequency domain model used for evaluating the mutual elements also consists of the lumped model for the single pin plus a mutual inductance and two coupling capacitors. The model was used in configurations corresponding to the actual measurements. Contact resistance is again omitted because of negligible impact.

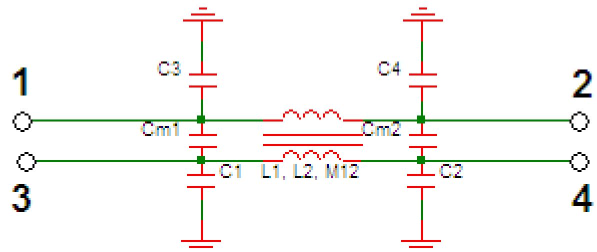

Figure 37 Equivalent circuit for G-S-S-G (mutual coupling)

The limitations for the G-S-S-G models are the identical to the G-S-G version.

The values for this model are:

Site	C1,2,3,4		Cm1,Cm2		L1, L2	M	
Corner	0.123		0.040	pF	1.25	0.423	nH
Edge	0.136		0.034	pF	0.99	0.317	nH
Field	0.148		0.029	pF	0.92	0.217	nH
Diagonal	0.148		0.012	pF	0.92	0.158	nH

The lumped model does not remain valid at high frequencies. Alternatives are a split of the lumped model into multiple sections, e.g. three sections with 1/3 the values for the total capacitance or inductance each or the use of a transmission line model with coupled transmission lines and added loss terms as shown below (field site only):

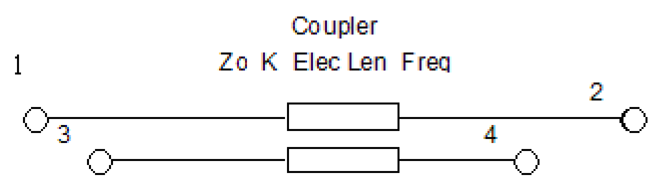

Figure 38 Transmission line equivalent circuit for crosstalk

The model shows two coupled transmission lines with the respective in- and outputs. Its elements are Z_o, L_{el}, k and $f_{(180deg)}$:

Field	55.2	Ω	16.0	ps	0.24	30.2	GHz

Simulations are performed like the measurements where S31 measures the backward crosstalk (NEXT), while ports 2 and 4 are terminated in 50 Ohms. Likewise, the forward crosstalk S41 (FEXT) is determined with ports 2 and 3 terminated into 50 Ohms.

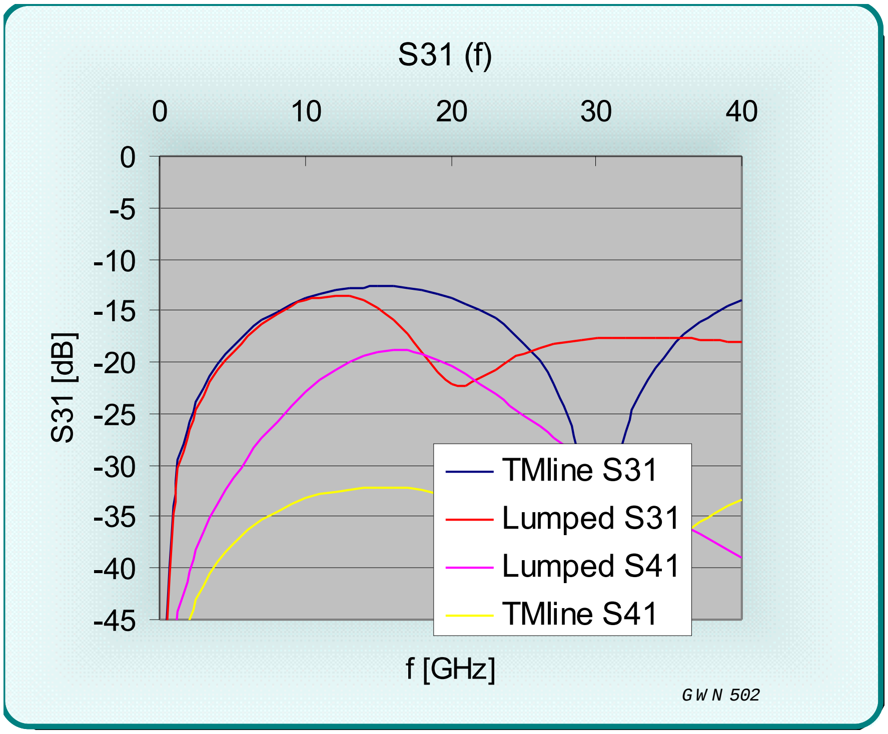

Figure 39 Crosstalk S31 and S41 [dB] as a function of frequency

The TM line model for S41 underestimates crosstalk. This is of little consequence, however, since the overall level of forward crosstalk is low to begin with. Again, model limit frequencies as noted in the G-S-G case apply. For fully accurate representations Touchstone parameters (SnP) or optional multi-pole representations should be used.

Summary sheet

Ironwood

P-P204A test socket
0.35 mm pitch

8/20/2015

Measurement results:

	Corner	Edge	Field	
Delay	16.6	16.3	16.0	ps
Risetime open	42	30	30	ps
Risetime short	120	123	72	ps
Risetime thru, 50Ω	34.5	30	30	ps
Insertion loss (1dB)	26.1	23.5	24.7	GHz
Insertion loss (3dB)	36.5	30.7	36.9	GHz
VSWR (2:1)	30.5	24.9	24.9	GHz

PI equivalent circuit component values:

Site	Cg=C1+C2			L1		R4	
Corner		0.246	pF	1.25	nH	1000	Ohms
Edge		0.273	pF	0.99	nH	2000	Ohms
Field		0.296	pF	0.92	nH	2000	Ohms
Diagonal		0.296	pF	0.92	nH	2000	Ohms

It should be noted that there are 2 capacitors in the PI equivalent circuit. Each of them has half the value listed here.
R4 is not the series resistance (Cres) but in parallel with L1; please see report for explanation.

Mutual component values:

Site		Cm		M	
Corner		0.079	pF	0.423	nH
Edge		0.069	pF	0.317	nH
Field		0.058	pF	0.217	nH
Diagonal		0.025	pF	0.158	nH

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:

Site	Zo		td	
Corner	66.6	Ω	16.6	ps
Edge	58.1	Ω	16.3	ps
Field	55.2	Ω	16.0	ps

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