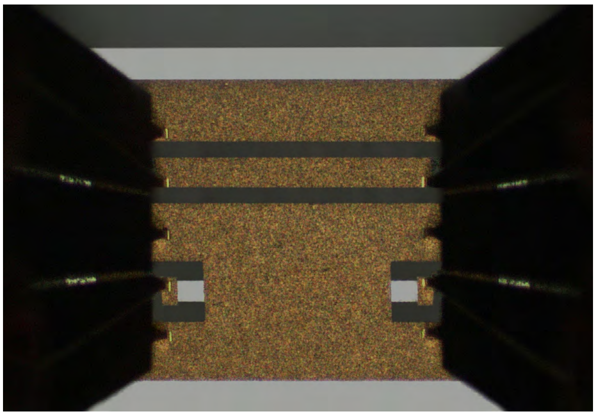
TCS-GSGSG-0150-0200 Calibration Substrate

The MPI TITAN™ TCS-GSGSG-0150-0200 Dual Calibration Substrate is designed to provide accurate probe tip calibration of MPI TITAN™ RF probes with ground-signal-ground-signal-ground (GSGSG) tips and the standard's layout is optimized implementing recommendations developed by the PlanarCal Consortium of twelve European organizations[1]. It supports the industry standard Short-Open-Load-Thru (SOLT/TOSM) calibration method, as well as advanced Thru-Match-Reflect (TMR/LRM), Thru-Match-Reflect-Reflect (TMRR) and the NIST multi-line Thru-Reflect-Line (mTRL) calibrations.

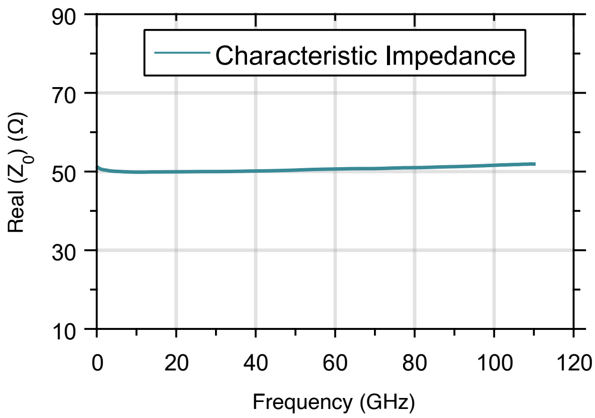
The TCS-GSGSG-0150-0200 contains the full set of coplanar transmission lines for mTRL calibrations up to 140 GHz.

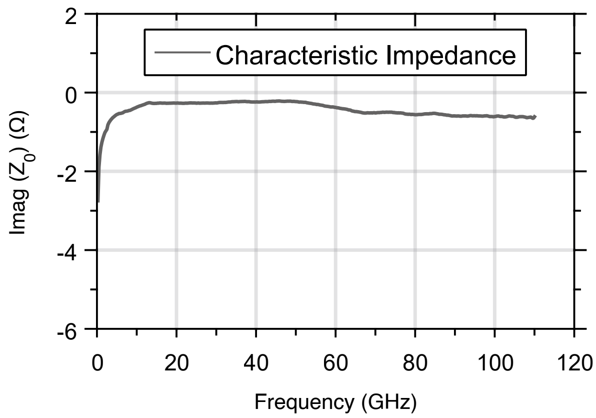


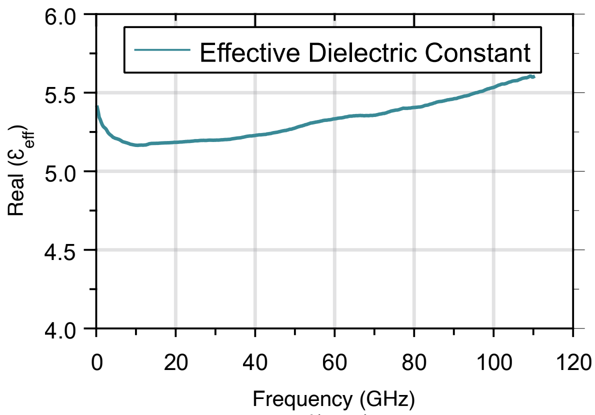
Two opposing GSGSG TITAN™ Dual Probes in separation after touching the Thru (Adj Load) Standard and using 10 µm vertical overtravel.

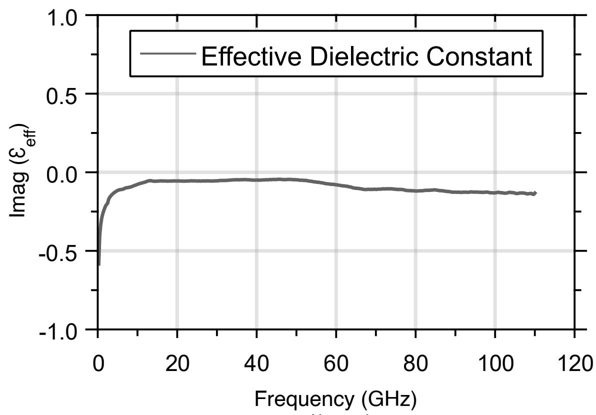
The unique approach of terminating idle RF probe ports by an Adjacent Load element implemented for MPI's TCS dual calibration substrates family drastically improves calibration accuracy at the mmW frequency range[2].

TYPICAL ELECTRICAL FIGURES









SUBSTRATE CHARACTERISTICS

Material	Alumina
Size	16.7 mm x 12.7 mm
Thickness	254 µm
Design or standards	Coplanar
Probe configuration	GSGSG
Supported probe pitch	150 to 200 µm
Number of calibration and verification lines	3
Calibration verification elements	yes
Supported calibration methods	TOSM (SOLT), TMR, LRM, SOLR, TMRR, TRL and mTRL
Typical resistance of the load	50 Ω
Typical load trimming accuracy error	± 0.3 %
Open standard	Au pads on substrate
Recommended overtravel for TITAN™ probes	10 µm

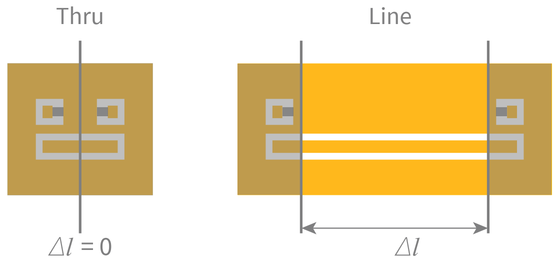
ELECTRICAL CHARACTERISTICS OF CPW LINE STANDARDS

Nominal capacitance per unit length, pF/cm	1.51
Nominal characteristic impedance @20 GHz	50 Ω
Effective dielectric constant @20 GHz, real part	5.19
Velocity factor @20 GHz	0.439
Parameters of the simplified model of line losses	
Reference loss, dB	0.31
Reference delay, ps	30
Reference frequency, GHz	30
Electrical length of line, ps	
Thru (Adj Load)	5.70
Thru (Adj Load) 1 (0201,0206)	8.28
Thru (Adj Load) 2 (0301,0306)	13.38
Thru (Adj Load) 3 (0401,0406)	28.65
Dual Thru (0103, 0104, 0203, 0204)	5.80
Vertical Thru (0502 - 0505)	3.12

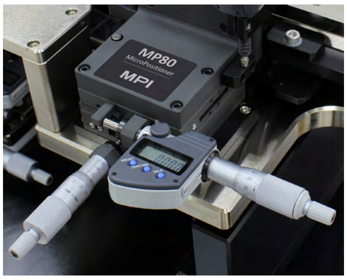
CALIBRATION ACCURACY USING NIST MULTILINE THRU-REFLECT-LINE (mTRL) PROCESS

The mTRL calibration kit can be easily designed and fabricated using the same semiconductor process as the DUT. Customized ”On-wafer“ mTRL calibration kits eliminate the need for de-embedding the DUT measurement results from parasitic impedances of the device contact pads. The mTRL is the only method that delivers trustable calibration results at measurement frequencies above 220 GHz.

The mTRL algorithm requires multiple Line standards of different physical lengths and always treats the first Line (the "Thru") standard as a zero-length line. As a result, the length of each subsequent Line standard, Delta-l, is defined with respect to the length of the Thru (the first line).



The TRL definition of the Δl for line standards



The MP80-DX MicroPositioner with the digital micrometer on the X axes.

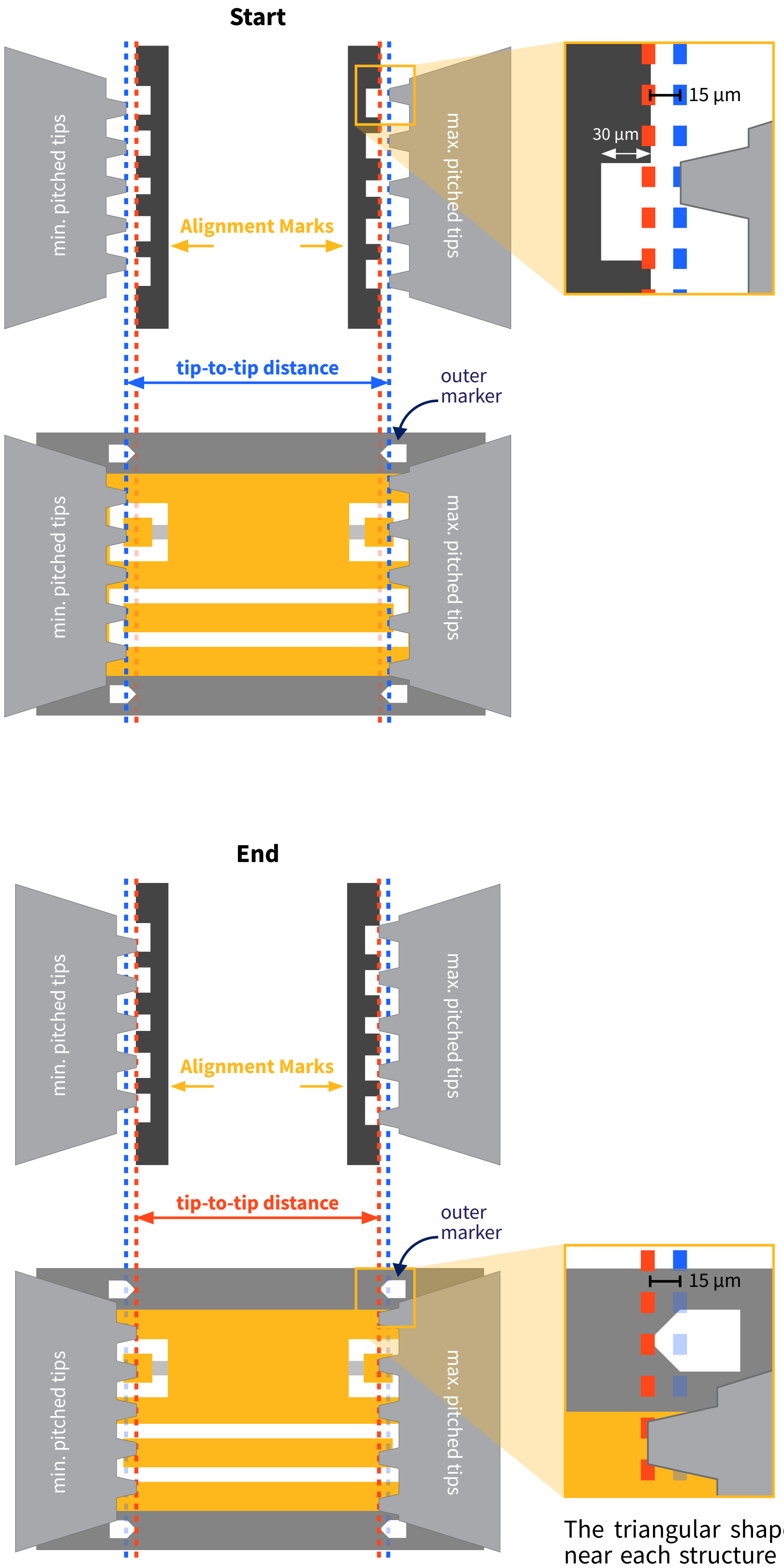
Standard type, (Name)	Physical length, µm	Effective length l, µm	Δl, µm
Thru (Adj Load)	800	750	0
Thru (Adj Load) Line 1 (0201,0206)	1140	1090	340
Thru (Adj Load) Line 2 (0301,0306)	1810	1760	1010
Thru (Adj Load) Line 3 (0401,0406)	3820	3770	3020

PROBE TIP POSITIONING AND ALIGNMENT MARKS

Consistent and accurate placement of the probe tips on calibration structures is critical for accurate and repeatable system calibration. The MPI TITAN™ TCS calibration substrate simplifies correct probe-tip-to-structure-alignment by providing special pre-alignment structures for the end user. The pre-alignment structures (Alignment Marks) enable the user to contact the Short, Open, Load and Thru structures in the correct location for consistent calibration results. For the Short, Open and Load, correct alignment is at the middle of each pad (Y-axis or relative to the direction of probe tip skate). For the Thru/Line elements, the correct alignment is 10-15 µm inward from each end of line so the two opposing probes are apart by the specified distance that corresponds to the effective length of the element.

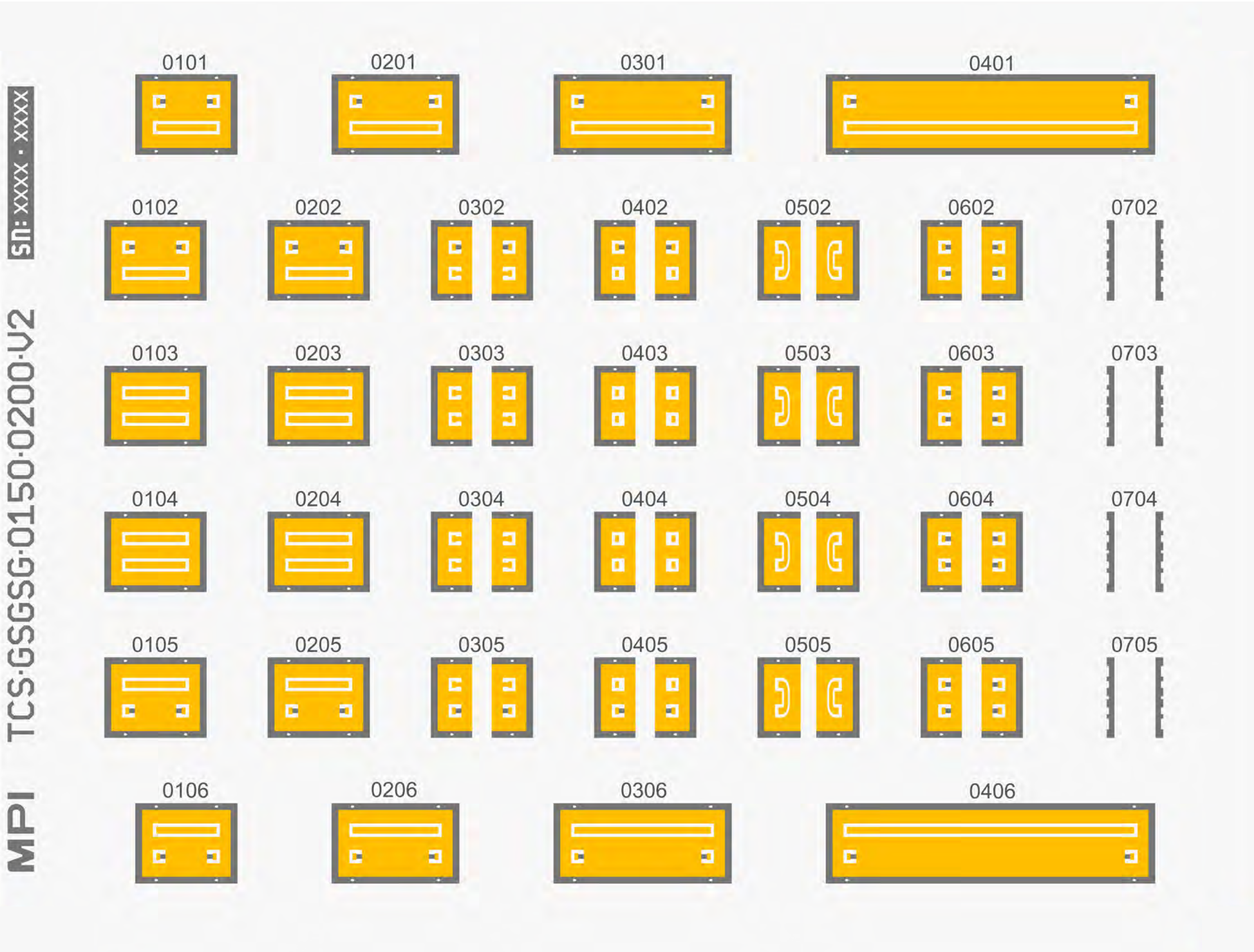
The unique saw-tooth like Alignment Marks (structures # 0702-0705) and cone-shaped Outer Marker found on the TCS calibration substrate are designed for proper probe-tip-to-calibration-structure edge adjustment. The edge of the Alignment Marks (as highlighted by the red dashed line in Figure below) corresponds to the endpoint on a Short, Open, Load or Thru/Line structure when the proper amount of probe overtravel and resulting 10-15 µm of probe tip skate has been used. Skate begins from the moment the probe tips first make contact to the substrate (See the blue dashed line in Figure below) where initial tip contact should occur.

The operator should aim for and use the blue dashed line and cone of the Outer Marker as a visual reference/starting point for 10-15 µm of probe tip skate. Minimal vertical overtravel (less than 20 µm typically) is needed so the tips skate from the blue dashed line (outside saw tooth opening) to the red dashed line (at the edge, but not into the saw tooth opening) as the stopping point. When done properly, two opposing probes are at the correct physical distance and rotational alignment when both are resting at the red dashed line in the example (at the edge of, but not inside, the saw tooth openings on the Alignment Marks).



The triangular shaped marker located near each structure provides a measurable visual reference for the 15 µm of skate and proper tip placement.

SUBSTRATE LAYOUT

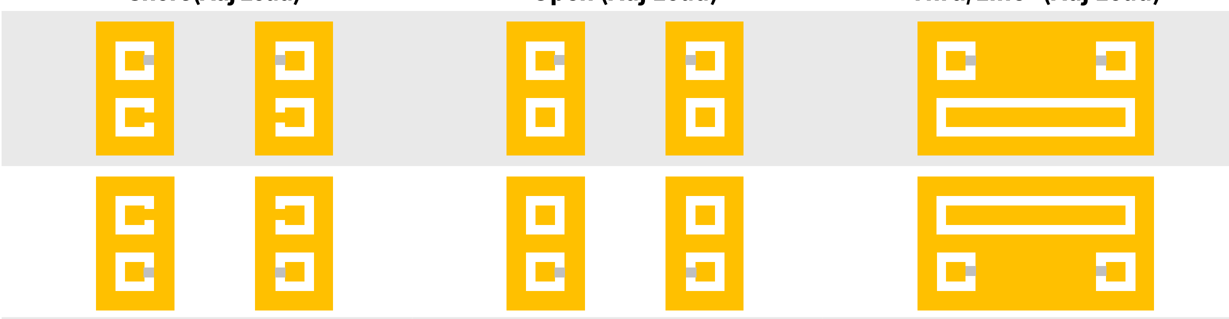


Location reference elements is 0102.

STANDARD ELEMENTS

Standards with adjacent loads

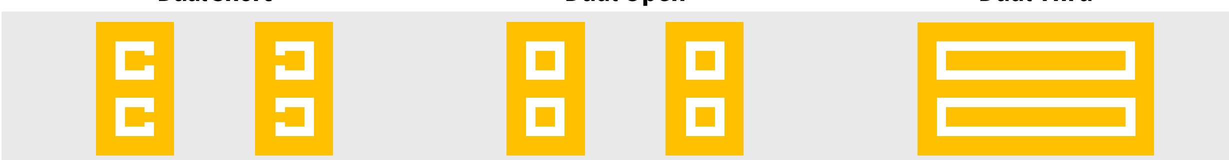
Short (Adj Load) | Open (Adj Load) | Thru/Line* (Adj Load)

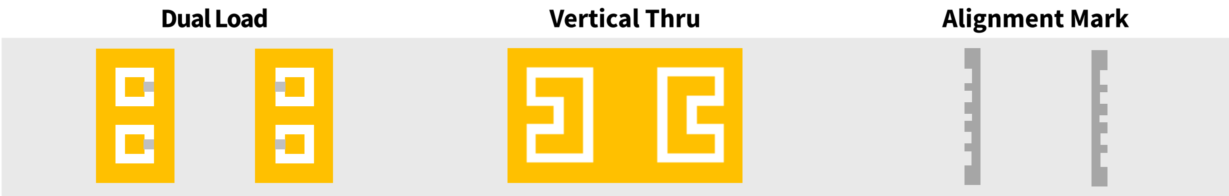


Lines: three choices of transmission lines provided, each with different physical and electrical lengths.

Dual standards

Dual Short | Dual Open | Dual Thru





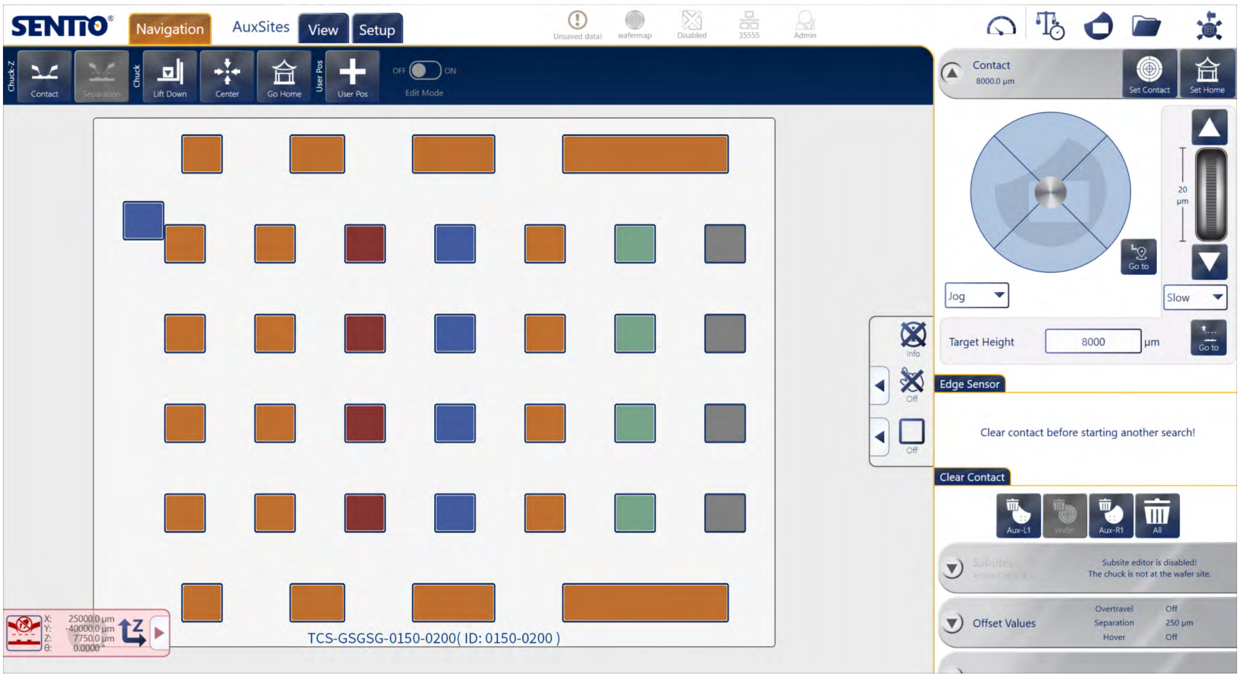
AUTOMATED NAVIGATION IN SENTIO®

SENTIO® probe station software from MPI Corporation is powerful Graphical User Interface (GUI) software to take your semiconductor testing to the next level. With unparalleled usability, multi-touch capabilities, and a customizable dashboard, SENTIO® software is designed to make your testing and microwave probe calibration processes more efficient and productive. Picture in Picture and QAlibria® inside provide advanced data analysis tools, while built-in intelligence streamlines your testing processes and keeps your probes and devices safe.

Connectivity and upgradability mean you're always connected and up to date with the latest features, while scalability ensures that SENTIO® software can grow with your business.

SENTIO® and QAlibria® integrate seamlessly with the structure mapping of your TCS calibration substrate, making standards navigation the calibration process automated and easy even for inexperienced operators.

The map of the TCS-GSGSG-0150-0200 substrate in SENTIO®



- Thru (Adj Load), Dual Thru, Vertical Thru, Line (Adj Load)
- Short (Adj Load), Dual Short
- Open (Adj Load), Dual Open, Open on bare ceramic or in Separation
- Dual Load
- Alignment Mark

STANDARDS

Thru Standards with Adjacent Load

Name	Type	X µm	Y µm	Spacing µm
0102	Thru (Adj Load)	0	0	750
0202	Thru (Adj Load)	2170	0	750
0105	Thru (Adj Load)	0	-5820	750
0205	Thru (Adj Load)	2170	-5820	750
0101	Thru (Adj Load)	410	1940	750
0106	Thru (Adj Load)	410	-7760	750

Line Standards with Adjacent Load

Name	Type	X µm	Y µm	Spacing µm
0201	Line1 (Adj Load)	3020	1940	1090
0301	Line2 (Adj Load)	5970	1940	1760
0401	Line3 (Adj Load)	9590	1940	3770
0206	Line1 (Adj Load)	3020	-7760	1090
0306	Line2 (Adj Load)	5970	-7760	1760
0406	Line3 (Adj Load)	9590	-7760	3770

Short Standards with Adjacent Load

Name	Type	X µm	Y µm	Spacing µm
0302	Short (Adj Load)	4340	0	750
0305	Short (Adj Load)	4340	-5820	750

Open with Adjacent Load

Name	Type	X µm	Y µm	Spacing µm
0402	Open (Adj Load)	6510	0	750
0405	Open (Adj Load)	6510	-5820	750

Dual Calibration Standards

Name	Type	X µm	Y µm	Spacing µm
0103	Dual Thru	0	-1940	750
0104	Dual Thru	0	-3880	750
0203	Dual Thru	2170	-1940	750
0204	Dual Thru	2170	-3880	750
0303	Dual Short	4340	-1940	750
0304	Dual Short	4340	-3880	750
0403	Dual Open	6510	-1940	750
0404	Dual Open	6510	-3880	750
0602	Dual Load	10850	0	750
0603	Dual Load	10850	-1940	750
0604	Dual Load	10850	-3880	750
0605	Dual Load	10850	-5820	750

Vertical (Loop-Back) Thru Standards

Name	Type	X µm	Y µm	Spacing µm
0502	Vertical Thru	8680	0	750
0503	Vertical Thru	8680	-1940	750
0504	Vertical Thru	8680	-3880	750
0505	Vertical Thru	8680	-5820	750

Probe Alignment Elements

Name	Type	X µm	Y µm	Spacing µm
0702	Alignment Mark	13020	0	750
0703	Alignment Mark	13020	-1940	750
0704	Alignment Mark	13020	-3880	750
0705	Alignment Mark	13020	-5820	750

CALIBRATION COEFFICIENTS FOR THE TITAN™ DUAL PROBES

GSGSG Configuration

Pitch	Model	C-Open, fF	L-Short, pH	L-Term, pH
150 µm	26, 40, 50, 67 GHz, Standard	8.1	58	43
200 µm	26, 40, 50, 67 GHz, Standard	7.2	55	48

GSGSG Configuration, for the Keysight VNA

		C-Open, fF	L-Short, pH	Load*		
Pitch	Model	C, fF	L, pH	R, Ohm	Offset Z_0, Ohm	Offset delay, ps
150 µm	26, 40, 50, 67 GHz, Standard	8.1	58	50	500	0.087
200 µm	26, 40, 50, 67 GHz, Standard	7.2	55	50	500	0.097

**Use both offset impedance and offset delay parameters.*

REFERENCES

[1] M. Spirito, U. Arz, G. N. Phung, F. J. Schmückle, W. Heinrich, and R. Lozar, "Guidelines for the design of calibration substrates, including the suppression of parasitic modes for frequencies up to and including 325 GHz," in "EMPIR 14IND02 – PlanarCal," Physikalisch-Technische Bundesanstalt (PTB), 2018.

[2] H.-C. Fu, K. Jung. “Improve RF Dual Probe Calibration Accuracy with Peer-Terminated Standard”, in 2024 IEEE / MTT-S International Microwave Symposium - IMS 2024, Washington, DC, USA, 16-24 June, 2024.

See MPI Corporation‘s Terms and Conditions of Sale for more details.

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