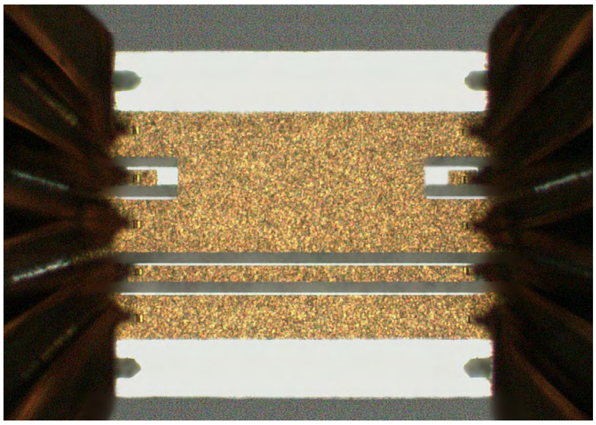
TCS-GSGSG-0075-0075 Calibration Substrate

The MPI TITAN™ TCS-GSGSG-0075-0075 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.

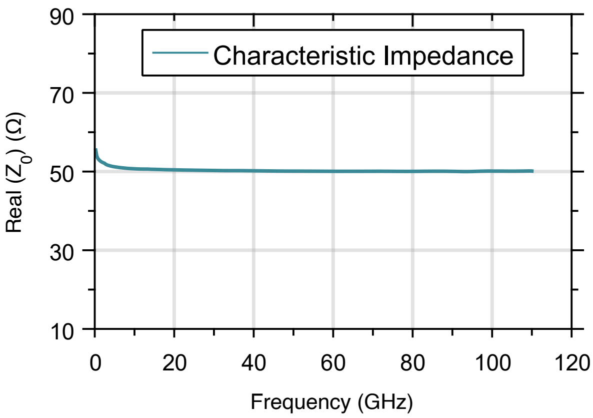
The TCS-GSGSG-0075-0075 contains the full set of coplanar transmission lines for mTRL calibrations up to 325 GHz.

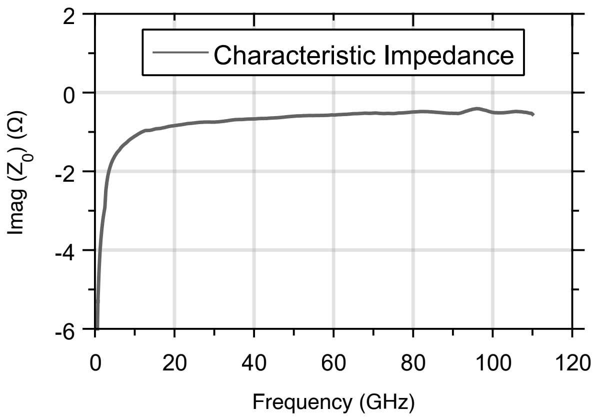


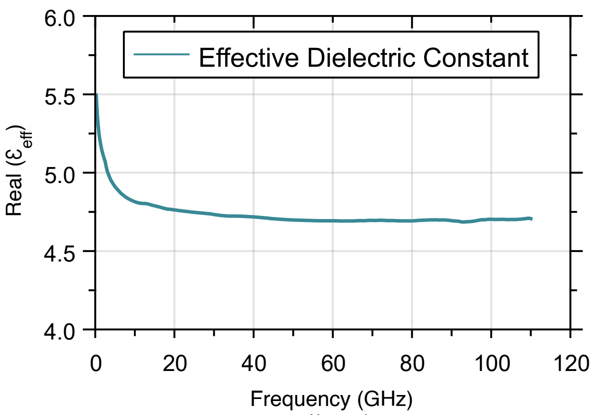
Two opposing GSGSG TITAN™ Dual Probes in separation after touching the Thru (Adj Load) Standard and using 10 µm vertical over-travel.

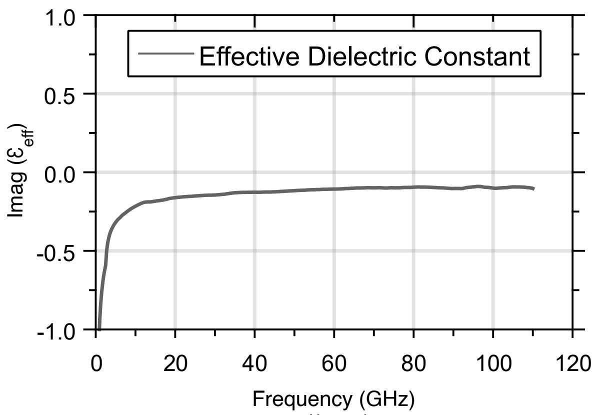
The unique approach of terminating idle RF probe ports by an Adjacent Load element implemented for MPI's TCS dual calibration substrates family drastically improves calibration accuracy at the mmW frequency range[2].

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	75 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

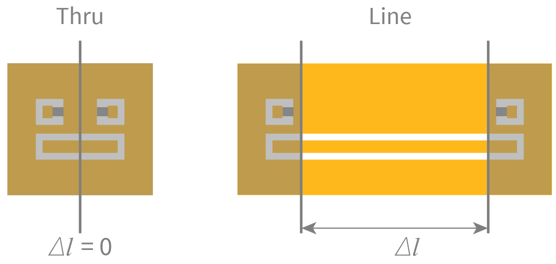
ELECTRICAL CHARACTERISTICS OF CPW LINE STANDARDS

Nominal capacitance per unit length, pF/cm	1.455
Nominal characteristic impedance @20 GHz	50 Ω
Effective dielectric constant @20 GHz, real part	4.75
Velocity factor @20 GHz	0.459
Parameters of the simplified model of line losses	
Reference loss, dB	0.22
Reference delay, ps	10
Reference frequency, GHz	30
Electrical length of line, ps	
Thru (Adj Load)	3.63
Line (Adj Load) 1 (0201, 0209)	4.72
Line (Adj Load) 2 (0301, 0309)	8.65
Line (Adj Load) 3 (0401, 0409)	26.52
Dual Thru (0105, 0205)	3.68
Vertical Thru (0702 - 0708)	1.65

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 axis.

Standard type, (Name)	Physical length, µm	Effective length l, µm	Δl, µm
Thru (Adj Load)	550	500	0
Line (Adj Load) 1 (0201, 0209)	700	650	150
Line (Adj Load) 2 (0301, 0309)	1240	1190	690
Line (Adj Load) 3 (0401, 0409)	3700	3650	3150

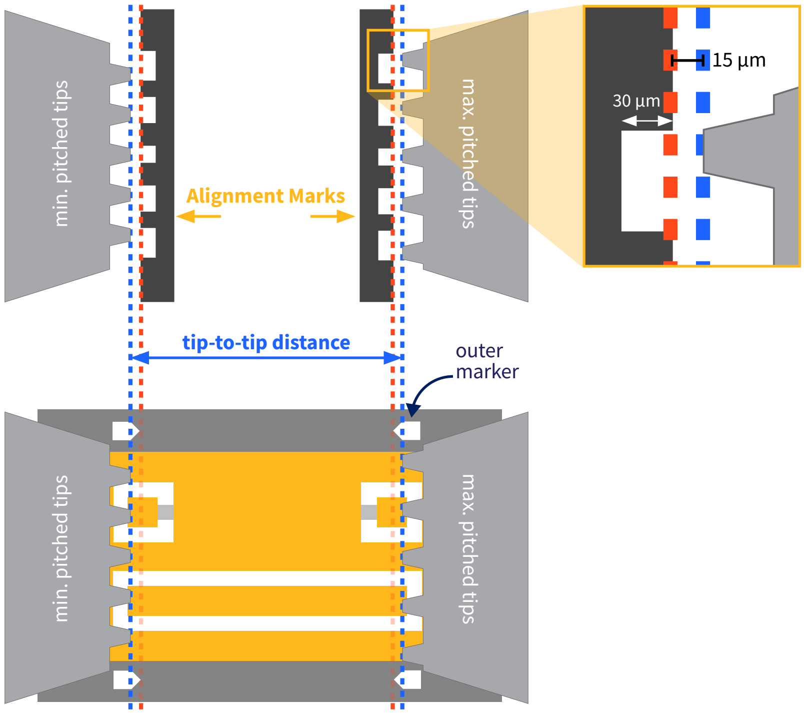
PROBE TIP POSITIONING AND ALIGNMENT MARKS

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.

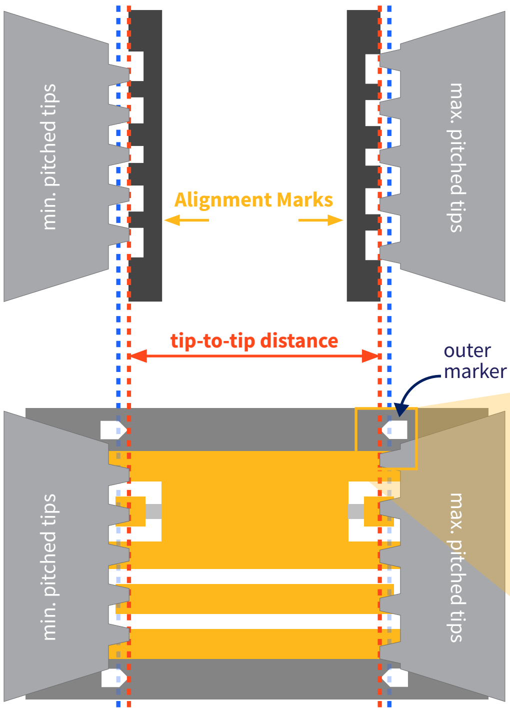
The unique saw-tooth like Alignment Marks (structures # 0902 - 0908) and cone-shaped Outer Marker found on the TCS calibration substrate are designed for proper probe-tip-to-calibration-structure edge adjustment. The edge of the Alignment Marks (as highlighted by the red dashed line in Figure below) 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.

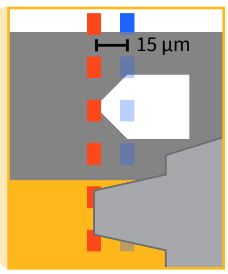
The operator should aim for and use the blue dashed line and cone of the Outer Marker as a visual reference/starting point for 10-15 µm of probe tip skate. Minimal vertical overtravel (less than 20 µm typically) is needed so the tips skate from the blue dashed line (outside saw tooth opening) to the 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).

Start



End





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

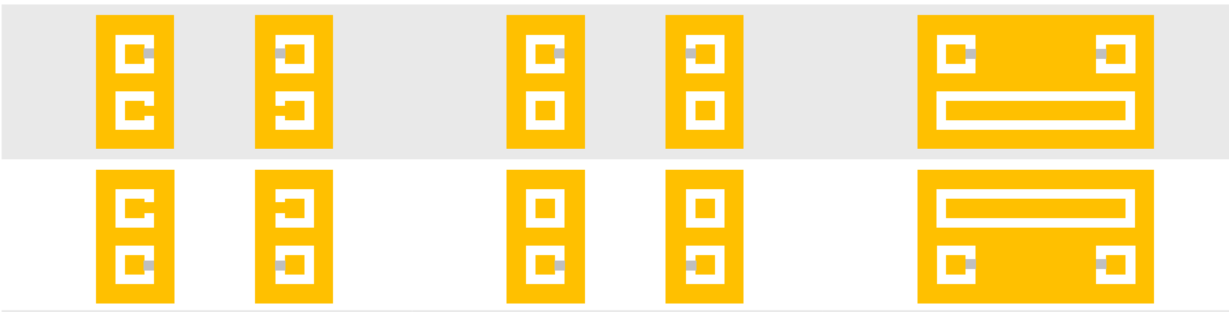
SUBSTRATE LAYOUT

**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**

Dual Load **Vertical Thru** **Alignment Mark**

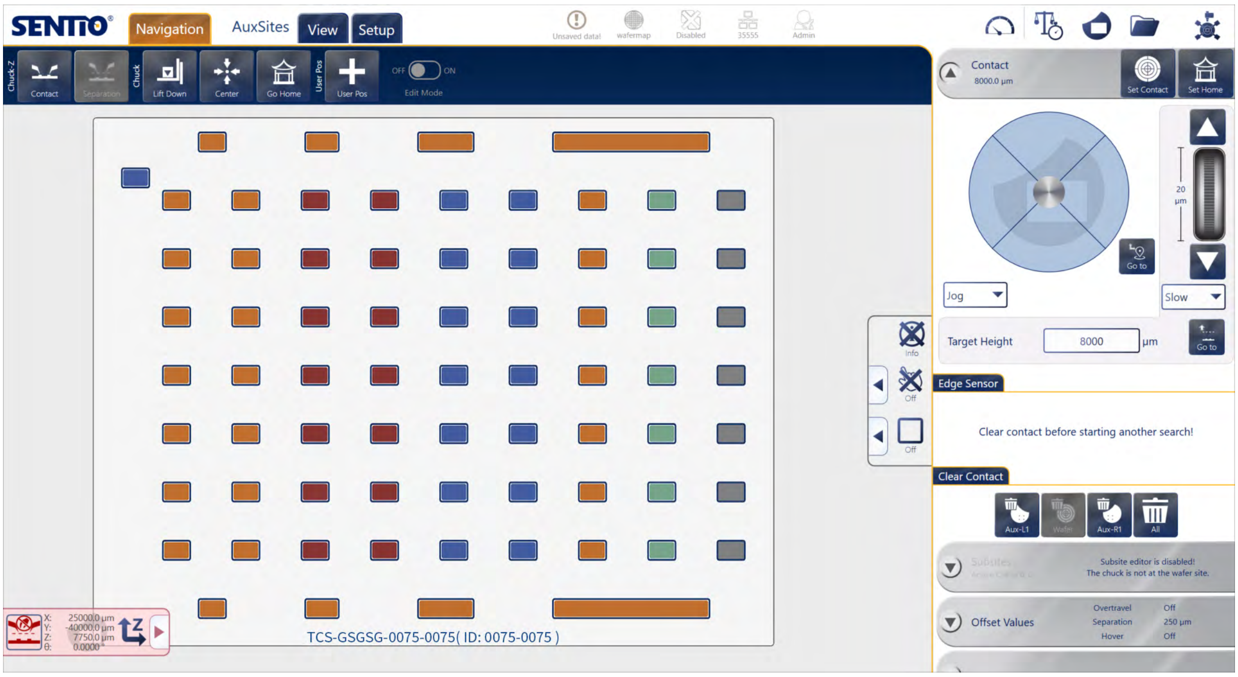
AUTOMATED NAVIGATION IN SENTIO®

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-0075-0075 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	500
0103	Thru (Adj Load)	0	-1300	500
0104	Thru (Adj Load)	0	-2600	500
0202	Thru (Adj Load)	1690	0	500
0203	Thru (Adj Load)	1690	-1300	500
0204	Thru (Adj Load)	1690	-2600	500
0106	Thru (Adj Load)	0	-5200	500
0107	Thru (Adj Load)	0	-6500	500
0108	Thru (Adj Load)	0	-7800	500
0206	Thru (Adj Load)	1690	-5200	500
0207	Thru (Adj Load)	1690	-6500	500
0208	Thru (Adj Load)	1690	-7800	500
0101	Thru (Adj Load)	860	1300	500
0109	Thru (Adj Load)	860	-9100	500

Line Standards with Adjacent Load

Name	Type	X µm	Y µm	Spacing µm
0201	Line1 (Adj Load)	3450	1300	660
0301	Line2 (Adj Load)	6200	1300	1210
0401	Line3 (Adj Load)	9500	1300	3660
0209	Line1 (Adj Load)	3450	-9100	660
0309	Line2 (Adj Load)	6200	-9100	1210
0409	Line3 (Adj Load)	9500	-9100	3660

Short Standards with Adjacent Load

Name	Type	X µm	Y µm	Spacing µm
0302	Short (Adj Load)	3380	0	500
0303	Short (Adj Load)	3380	-1300	500
0304	Short (Adj Load)	3380	-2600	500
0402	Short (Adj Load)	5070	0	500
0403	Short (Adj Load)	5070	-1300	500
0404	Short (Adj Load)	5070	-2600	500
0306	Short (Adj Load)	3380	-5200	500
0307	Short (Adj Load)	3380	-6500	500
0308	Short (Adj Load)	3380	-7800	500
0406	Short (Adj Load)	5070	-5200	500
0407	Short (Adj Load)	5070	-6500	500
0408	Short (Adj Load)	5070	-7800	500

Open with Adjacent Load

Name	Type	X µm	Y µm	Spacing µm
0502	Open (Adj Load)	6760	0	500
0503	Open (Adj Load)	6760	-1300	500
0504	Open (Adj Load)	6760	-2600	500
0602	Open (Adj Load)	8450	0	500
0603	Open (Adj Load)	8450	-1300	500
0604	Open (Adj Load)	8450	-2600	500
0506	Open (Adj Load)	6760	-5200	500
0507	Open (Adj Load)	6760	-6500	500
0508	Open (Adj Load)	6760	-7800	500
0606	Open (Adj Load)	8450	-5200	500
0607	Open (Adj Load)	8450	-6500	500
0608	Open (Adj Load)	8450	-7800	500

Dual Calibration Standards

Name	Type	X µm	Y µm	Spacing µm
0105	Dual Thru	0	-3900	500
0205	Dual Thru	1690	-3900	500
0305	Dual Short	3380	-3900	500
0405	Dual Short	5070	-3900	500
0505	Dual Open	6760	-3900	500
0605	Dual Open	8450	-3900	500
0802	Dual Load	11830	0	500
0803	Dual Load	11830	-1300	500
0804	Dual Load	11830	-2600	500
0805	Dual Load	11830	-3900	500
0806	Dual Load	11830	-5200	500
0807	Dual Load	11830	-6500	500
0808	Dual Load	11830	-7800	500

Vertical (Loop-Back) Thru Standards

Name	Type	X µm	Y µm	Spacing µm
0702	Vertical Thru	10140	0	500
0703	Vertical Thru	10140	-1300	500
0704	Vertical Thru	10140	-2600	500
0705	Vertical Thru	10140	-3900	500
0706	Vertical Thru	10140	-5200	500
0707	Vertical Thru	10140	-6500	500
0708	Vertical Thru	10140	-7800	500

Probe Alignment Elements

Name	Type	X µm	Y µm	Spacing µm
0902	Alignment Mark	13520	0	500
0903	Alignment Mark	13520	-1300	500
0904	Alignment Mark	13520	-2600	500
0905	Alignment Mark	13520	-3900	500
0906	Alignment Mark	13520	-5200	500
0907	Alignment Mark	13520	-6500	500
0908	Alignment Mark	13520	-7800	500

CALIBRATION COEFFICIENTS FOR THE TITAN™ DUAL PROBES

GSGSG Configuration, 75 µm pitch

Model	C-Open, fF	L-Short, pH	L-Term, pH
26, 40, 50, 67 GHz, Reduced Contact Width (RC)	3	26	23
145 / 220 GHz	5.9	31	20

GSGSG Configuration, 75 µm pitch for the Keysight VNA

	Open	Short	Load*		
Model	C, fF	L, pH	R, Ohm	Offset Z_0, Ohm	Offset delay, ps
26, 40, 50, 67 GHz, Reduced Contact Width (RC)	3	26	50	500	0.046
145 / 220 GHz	5.9	31	50	500	0.040

**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.

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