Keysight TC721
DC–50 GHz Variable Attenuator: S–Parameters

Technical Overview

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Introduction

The TC721 is a voltage variable attenuator that operates from DC to 50 GHz. This application note consists of s–parameter data tables at the following attenuation levels:

– Minimum

– 7 dB

– 12 dB

– 17 dB

– 22 dB

– 27 dB Maximum

The s–parameters cover the frequency range of 1.5–26.5 GHz, and were obtained from on–wafer measurements.

Table 1. S–parameters (TA = 25 °C)[1]

Minimum Attenuation Setting

Freq. (GHz)	S_{11}			S_{21}			S_{12}			S_{22}		
	dB	Mag	Ang	dB	Mag	Ang	dB	Mag	Ang	dB	Mag	Ang
1.5	−32.4	0.024	−79.91	−0.9	0.900	−12.55	−0.9	0.900	−12.99	−32.2	0.024	−79.41
2.0	−28.3	0.038	−80.77	−0.9	0.906	−16.98	−0.9	0.906	−17.43	−28.7	0.037	−80.83
2.5	−27.7	0.041	−91.93	−0.9	0.902	−20.94	−0.9	0.902	−21.32	−27.9	0.040	−90.45
3.0	−26.7	0.046	−106.79	−1.0	0.894	−25.08	−1.0	0.894	−25.45	−26.8	0.046	−107.55
3.5	−25.1	0.056	−105.68	−0.9	0.900	−29.30	−0.9	0.900	−29.65	−25.4	0.054	−106.02
4.0	−23.8	0.064	−114.10	−1.0	0.896	−33.59	−1.0	0.896	−33.91	−24.2	0.062	−114.64
4.5	−23.4	0.067	−122.48	−1.0	0.890	−37.53	−1.0	0.890	−37.86	−23.6	0.066	−123.20
5.0	−22.7	0.073	−125.90	−1.0	0.891	−41.60	−1.0	0.891	−41.93	−23.0	0.071	−128.27
5.5	−22.0	0.080	−133.64	−1.0	0.886	−45.72	−1.0	0.886	−46.05	−22.3	0.077	−135.06
6.0	−21.8	0.081	−138.35	−1.1	0.885	−49.62	−1.1	0.885	−49.92	−21.9	0.080	−139.75
6.5	−21.4	0.085	−141.58	−1.1	0.885	−53.57	−1.1	0.885	−53.87	−21.6	0.083	−145.06
7.0	−20.9	0.090	−146.84	−1.1	0.884	−57.71	−1.1	0.884	−57.99	−21.0	0.089	−148.97
7.5	−20.8	0.091	−150.80	−1.1	0.884	−61.65	−1.1	0.884	−61.88	−20.9	0.090	−153.07
8.0	−20.5	0.095	−156.01	−1.1	0.881	−65.73	−1.1	0.881	−65.94	−20.6	0.093	−158.61
8.5	−20.2	0.098	−159.27	−1.1	0.882	−69.88	−1.1	0.882	−70.09	−20.3	0.097	−162.51
9.0	−20.2	0.098	−162.75	−1.1	0.881	−73.72	−1.1	0.881	−73.91	−20.3	0.096	−166.86
9.5	−19.9	0.101	−166.92	−1.1	0.881	−77.71	−1.1	0.881	−77.88	−20.2	0.098	−171.38
10.0	−19.6	0.105	−169.81	−1.1	0.882	−81.91	−1.1	0.882	−82.08	−19.8	0.102	−174.32
10.5	−19.2	0.109	−173.53	−1.1	0.885	−86.16	−1.1	0.885	−86.32	−19.5	0.105	−176.50
11.0	−19.1	0.111	−178.96	−1.1	0.883	−90.49	−1.1	0.883	−90.60	−19.4	0.108	177.58
11.5	−19.2	0.110	176.41	−1.1	0.882	−94.58	−1.1	0.882	−94.71	−19.3	0.108	172.65
12.0	−19.2	0.110	170.54	−1.1	0.879	−98.78	−1.1	0.878	−98.90	−19.2	0.109	166.06
12.5	−19.1	0.111	166.06	−1.1	0.876	−102.86	−1.1	0.876	−102.95	−19.1	0.111	160.48
13.0	−19.1	0.111	160.92	−1.2	0.875	−106.96	−1.2	0.874	−107.02	−19.0	0.112	155.03
13.5	−19.3	0.108	154.24	−1.2	0.872	−110.98	−1.2	0.872	−111.02	−19.2	0.109	149.54
14.0	−19.8	0.102	150.79	−1.2	0.872	−115.01	−1.2	0.871	−115.00	−19.4	0.107	145.92
14.5	−20.1	0.098	146.10	−1.2	0.873	−119.08	−1.2	0.872	−119.07	−19.7	0.104	141.11
15.0	−20.5	0.094	141.23	−1.2	0.873	−123.24	−1.2	0.872	−123.20	−20.6	0.093	134.72
15.5	−21.3	0.086	135.73	−1.2	0.873	−127.37	−1.2	0.872	−127.35	−21.1	0.088	130.51
16.0	−21.6	0.083	133.46	−1.2	0.872	−131.50	−1.2	0.872	−131.49	−21.3	0.086	124.23
16.5	−21.9	0.080	127.49	−1.2	0.872	−135.73	−1.2	0.872	−135.66	−22.2	0.077	117.24
17.0	−22.7	0.074	121.62	−1.2	0.873	−139.84	−1.2	0.872	−139.81	−22.8	0.073	117.36
17.5	−23.3	0.068	117.18	−1.2	0.872	−144.15	−1.2	0.872	−144.06	−22.9	0.072	112.91
18.0	−24.5	0.060	109.20	−1.2	0.872	−148.36	−1.2	0.872	−148.25	−24.5	0.059	103.88
18.5	−26.3	0.049	103.38	−1.2	0.872	−152.72	−1.2	0.872	−152.54	−26.2	0.049	103.19
19.0	−28.1	0.039	99.64	−1.2	0.871	−156.91	−1.2	0.870	−156.72	−26.9	0.045	95.31
19.5	−30.1	0.031	89.69	−1.2	0.872	−161.25	−1.2	0.872	−161.00	−28.9	0.036	75.49
20.0	−33.1	0.022	82.15	−1.2	0.872	−165.59	−1.2	0.872	−165.39	−31.3	0.027	71.08
20.5	−35.2	0.017	75.55	−1.2	0.870	−169.97	−1.2	0.870	−169.75	−31.5	0.027	66.08
21.0	−37.6	0.013	47.99	−1.2	0.868	−174.37	−1.2	0.867	−174.11	−34.7	0.018	40.82
21.5	−37.0	0.014	−21.01	−1.3	0.865	−178.66	−1.3	0.864	−178.40	−38.7	0.012	−16.47
22.0	−33.4	0.022	−67.73	−1.3	0.862	177.02	−1.3	0.861	177.30	−36.2	0.016	−73.89
22.5	−30.5	0.030	−84.67	−1.3	0.860	172.72	−1.3	0.860	173.03	−30.4	0.030	−85.37
23.0	−27.7	0.041	−93.23	−1.3	0.857	168.30	−1.3	0.857	168.64	−27.1	0.044	−92.81
23.5	−26.2	0.049	−102.67	−1.4	0.855	164.01	−1.4	0.854	164.38	−25.7	0.052	−98.65
24.0	−25.0	0.056	−105.38	−1.4	0.853	159.72	−1.4	0.854	160.03	−24.6	0.059	−103.15
24.5	−23.3	0.068	−110.85	−1.4	0.852	155.34	−1.4	0.851	155.75	−23.6	0.066	−111.08
25.0	−22.2	0.078	−118.27	−1.4	0.850	150.93	−1.4	0.849	151.37	−22.7	0.074	−120.04
25.5	−21.0	0.089	−119.77	−1.5	0.846	146.55	−1.5	0.845	146.97	−21.1	0.089	−125.82
26.0	−19.4	0.107	−124.67	−1.5	0.843	142.22	−1.5	0.842	142.69	−19.7	0.104	−128.84
26.5	−18.5	0.118	−133.37	−1.5	0.840	137.79	−1.5	0.838	138.34	−18.6	0.117	−135.28

1. Data obtained from on–wafer measurements. T_{chuck} = 25 °C

Table 2. S–parameters (TA = 25 °C)[1]

7 dB Setting

Freq. (GHz)	S_{11}			S_{21}			S_{12}			S_{22}		
	dB	Mag	Ang	dB	Mag	Ang	dB	Mag	Ang	dB	Mag	Ang
1.5	−31.7	0.026	−133.48	−7.0	0.445	−12.45	−7.1	0.442	−12.87	−34.2	0.020	−62.83
2.0	−29.4	0.034	−124.60	−7.0	0.448	−16.94	−7.0	0.446	−17.33	−31.2	0.027	−70.54
2.5	−28.0	0.040	−126.77	−7.0	0.446	−20.85	−7.0	0.445	−21.19	−30.9	0.028	−83.54
3.0	−26.5	0.047	−133.28	−7.1	0.440	−24.92	−7.1	0.441	−25.27	−30.4	0.030	−102.95
3.5	−25.3	0.054	−132.40	−7.1	0.444	−29.13	−7.0	0.444	−29.47	−28.9	0.036	−102.02
4.0	−24.0	0.063	−136.46	−7.1	0.444	−33.45	−7.1	0.443	−33.71	−27.5	0.042	−108.92
4.5	−23.3	0.068	−142.66	−7.1	0.442	−37.33	−7.1	0.440	−37.60	−27.0	0.045	−117.20
5.0	−22.6	0.074	−145.50	−7.1	0.443	−41.38	−7.1	0.441	−41.66	−26.3	0.048	−124.45
5.5	−21.8	0.081	−151.09	−7.1	0.440	−45.42	−7.1	0.439	−45.71	−25.8	0.051	−133.32
6.0	−21.4	0.085	−155.51	−7.1	0.440	−49.26	−7.1	0.440	−49.51	−25.3	0.054	−139.91
6.5	−21.0	0.090	−159.52	−7.1	0.440	−53.22	−7.1	0.440	−53.50	−24.9	0.057	−145.93
7.0	−20.5	0.094	−164.29	−7.1	0.442	−57.30	−7.1	0.441	−57.52	−24.5	0.059	−149.84
7.5	−20.3	0.097	−168.87	−7.1	0.443	−61.19	−7.1	0.442	−61.36	−24.3	0.061	−155.13
8.0	−19.9	0.101	−173.67	−7.1	0.443	−65.26	−7.1	0.442	−65.43	−24.1	0.063	−161.85
8.5	−19.7	0.104	−177.88	−7.1	0.443	−69.32	−7.1	0.443	−69.51	−23.8	0.064	−167.87
9.0	−19.5	0.106	177.51	−7.1	0.444	−73.16	−7.1	0.444	−73.35	−23.7	0.065	−173.83
9.5	−19.3	0.108	173.02	−7.0	0.445	−77.19	−7.0	0.445	−77.30	−23.6	0.066	179.78
10.0	−19.1	0.111	169.14	−7.0	0.448	−81.35	−7.0	0.448	−81.47	−23.5	0.067	175.92
10.5	−18.9	0.114	164.39	−6.9	0.452	−85.58	−6.9	0.451	−85.68	−23.4	0.067	171.85
11.0	−18.8	0.115	159.09	−6.9	0.453	−89.87	−6.9	0.452	−89.96	−23.4	0.068	165.31
11.5	−18.7	0.116	153.20	−6.9	0.454	−94.05	−6.9	0.453	−94.13	−23.4	0.067	157.56
12.0	−18.7	0.116	147.52	−6.8	0.455	−98.29	−6.8	0.455	−98.38	−23.4	0.067	149.38
12.5	−18.7	0.116	142.06	−6.8	0.457	−102.52	−6.8	0.456	−102.59	−23.3	0.068	143.29
13.0	−18.8	0.115	136.75	−6.8	0.459	−106.82	−6.8	0.458	−106.81	−23.0	0.071	136.07
13.5	−18.8	0.115	130.29	−6.7	0.461	−111.04	−6.7	0.460	−111.07	−23.3	0.068	129.08
14.0	−19.1	0.111	124.35	−6.7	0.464	−115.38	−6.7	0.462	−115.30	−23.6	0.066	124.16
14.5	−19.4	0.108	118.25	−6.6	0.466	−119.70	−6.6	0.465	−119.65	−23.8	0.064	114.91
15.0	−19.5	0.105	110.93	−6.6	0.469	−124.19	−6.6	0.468	−124.13	−24.8	0.058	102.14
15.5	−20.0	0.100	103.55	−6.5	0.472	−128.74	−6.5	0.472	−128.67	−25.5	0.053	93.19
16.0	−20.3	0.096	97.82	−6.5	0.474	−133.33	−6.5	0.474	−133.22	−25.1	0.056	81.73
16.5	−20.5	0.095	90.04	−6.4	0.477	−138.01	−6.4	0.476	−137.88	−25.5	0.053	66.45
17.0	−21.0	0.089	81.14	−6.4	0.480	−142.68	−6.4	0.478	−142.56	−26.7	0.046	60.41
17.5	−21.5	0.084	73.80	−6.3	0.482	−147.51	−6.4	0.481	−147.35	−26.6	0.047	51.29
18.0	−21.9	0.080	63.47	−6.3	0.484	−152.27	−6.3	0.483	−152.17	−26.6	0.047	29.19
18.5	−22.6	0.074	51.21	−6.3	0.485	−157.27	−6.3	0.484	−157.05	−27.2	0.044	9.98
19.0	−23.4	0.068	40.08	−6.3	0.485	−162.14	−6.3	0.485	−161.92	−26.3	0.048	0.34
19.5	−23.5	0.067	26.90	−6.3	0.486	−167.11	−6.3	0.485	−166.87	−24.4	0.060	−14.48
20.0	−23.8	0.064	12.23	−6.3	0.485	−172.15	−6.3	0.485	−171.81	−24.2	0.061	−27.73
20.5	−24.4	0.060	−0.21	−6.3	0.485	−177.14	−6.3	0.484	−176.93	−24.1	0.063	−35.42
21.0	−24.3	0.061	−13.13	−6.3	0.484	177.71	−6.3	0.483	178.04	−23.0	0.071	−46.75
21.5	−23.7	0.065	−29.11	−6.3	0.483	172.49	−6.3	0.481	172.98	−21.9	0.080	−62.94
22.0	−23.5	0.067	−45.90	−6.4	0.481	167.49	−6.4	0.479	167.95	−21.2	0.087	−73.73
22.5	−23.1	0.070	−58.05	−6.4	0.478	162.50	−6.4	0.477	162.90	−20.0	0.100	−81.17
23.0	−22.2	0.078	−69.50	−6.5	0.475	157.38	−6.5	0.473	157.77	−19.0	0.112	−88.97
23.5	−21.8	0.081	−81.43	−6.5	0.472	152.44	−6.6	0.470	152.84	−18.6	0.117	−94.78
24.0	−21.4	0.085	−88.79	−6.6	0.468	147.42	−6.6	0.467	147.86	−18.4	0.121	−99.91
24.5	−20.5	0.094	−97.89	−6.7	0.464	142.38	−6.7	0.463	142.82	−18.1	0.124	−107.23
25.0	−20.0	0.100	−107.42	−6.7	0.460	137.44	−6.8	0.459	137.84	−17.7	0.131	−114.95
25.5	−19.3	0.108	−113.04	−6.8	0.456	132.31	−6.8	0.455	132.85	−17.0	0.141	−121.42
26.0	−18.3	0.122	−120.78	−6.9	0.451	127.52	−6.9	0.451	127.93	−16.2	0.154	−126.40
26.5	−17.9	0.127	−130.62	−7.0	0.448	122.42	−7.0	0.447	123.25	−15.8	0.162	−133.60

1. Data obtained from on–wafer measurements. T_{chuck} = 25 °C

Table 3. S–parameters (TA = 25 °C)[1]

12 dB Setting

Freq. (GHz)	S_{11}			S_{21}			S_{12}			S_{22}		
	dB	Mag	Ang	dB	Mag	Ang	dB	Mag	Ang	dB	Mag	Ang
1.5	–33.6	0.021	–53.93	–12.1	0.249	–10.07	–12.1	0.249	–10.51	–25.8	0.051	–22.77
2.0	–31.6	0.026	–64.99	–12.0	0.251	–13.80	–12.0	0.251	–14.24	–25.3	0.055	–30.51
2.5	–30.8	0.029	–72.88	–12.0	0.251	–16.91	–12.0	0.251	–17.25	–25.6	0.053	–37.04
3.0	–29.8	0.032	–83.92	–12.0	0.250	–20.39	–12.0	0.250	–20.71	–26.1	0.050	–45.87
3.5	–28.5	0.038	–89.43	–11.9	0.253	–23.84	–11.9	0.253	–24.14	–25.4	0.054	–51.16
4.0	–27.5	0.042	–97.44	–11.9	0.254	–27.43	–11.9	0.253	–27.76	–24.9	0.057	–58.78
4.5	–26.9	0.045	–105.04	–11.9	0.254	–30.68	–11.9	0.254	–31.02	–24.9	0.057	–65.78
5.0	–26.2	0.049	–111.06	–11.8	0.256	–34.09	–11.9	0.256	–34.39	–24.9	0.057	–72.37
5.5	–25.5	0.053	–118.16	–11.8	0.257	–37.64	–11.8	0.256	–37.89	–25.0	0.056	–80.12
6.0	–25.2	0.055	–123.23	–11.8	0.258	–40.89	–11.8	0.258	–41.14	–25.1	0.056	–87.51
6.5	–24.7	0.058	–128.32	–11.7	0.261	–44.31	–11.7	0.261	–44.59	–25.0	0.056	–93.98
7.0	–24.3	0.061	–133.95	–11.6	0.264	–47.88	–11.6	0.263	–48.16	–24.7	0.058	–98.33
7.5	–24.1	0.063	–138.86	–11.5	0.266	–51.32	–11.5	0.266	–51.54	–24.7	0.058	–103.93
8.0	–23.7	0.065	–144.00	–11.4	0.268	–54.97	–11.4	0.268	–55.21	–24.7	0.058	–110.28
8.5	–23.5	0.067	–148.78	–11.3	0.272	–58.72	–11.3	0.272	–58.92	–24.9	0.057	–115.72
9.0	–23.3	0.068	–153.11	–11.2	0.274	–62.34	–11.2	0.275	–62.50	–25.1	0.056	–122.37
9.5	–23.1	0.070	–158.11	–11.1	0.278	–66.09	–11.1	0.278	–66.20	–25.2	0.055	–128.38
10.0	–22.9	0.071	–162.19	–11.0	0.282	–69.91	–11.0	0.282	–70.09	–25.2	0.055	–132.67
10.5	–22.7	0.073	–167.22	–10.9	0.286	–73.89	–10.9	0.286	–74.04	–25.2	0.055	–136.05
11.0	–22.7	0.073	–172.08	–10.7	0.290	–78.07	–10.7	0.290	–78.21	–25.5	0.053	–140.96
11.5	–22.7	0.073	–178.23	–10.7	0.293	–82.20	–10.7	0.293	–82.28	–25.9	0.051	–147.32
12.0	–22.9	0.072	176.38	–10.5	0.297	–86.40	–10.5	0.297	–86.49	–26.5	0.047	–154.19
12.5	–23.0	0.070	171.00	–10.4	0.300	–90.68	–10.4	0.300	–90.71	–26.6	0.047	–161.11
13.0	–23.2	0.069	166.58	–10.3	0.304	–94.96	–10.3	0.304	–94.99	–26.8	0.046	–170.40
13.5	–23.4	0.068	160.64	–10.3	0.307	–99.31	–10.3	0.307	–99.30	–27.6	0.042	–174.67
14.0	–23.9	0.064	155.79	–10.2	0.310	–103.66	–10.2	0.310	–103.64	–27.9	0.040	–176.74
14.5	–24.4	0.060	151.23	–10.0	0.315	–108.10	–10.1	0.314	–108.10	–29.2	0.035	177.17
15.0	–25.0	0.056	144.29	–9.9	0.318	–112.71	–10.0	0.318	–112.72	–32.1	0.025	178.33
15.5	–26.1	0.050	138.76	–9.8	0.322	–117.43	–9.9	0.322	–117.38	–33.7	0.021	–178.19
16.0	–26.7	0.046	135.21	–9.8	0.324	–122.12	–9.8	0.324	–122.08	–36.8	0.014	166.10
16.5	–27.4	0.043	126.61	–9.7	0.327	–127.03	–9.7	0.327	–126.87	–46.0	0.005	–161.69
17.0	–29.0	0.036	119.83	–9.6	0.330	–131.82	–9.6	0.329	–131.77	–39.6	0.010	–132.92
17.5	–30.6	0.030	117.13	–9.6	0.332	–136.82	–9.6	0.331	–136.72	–41.1	0.009	–125.88
18.0	–32.7	0.023	107.40	–9.5	0.333	–141.68	–9.6	0.333	–141.63	–35.2	0.017	–82.10
18.5	–37.6	0.013	93.67	–9.5	0.334	–146.84	–9.5	0.334	–146.66	–31.2	0.028	–86.33
19.0	–44.9	0.006	74.04	–9.5	0.334	–151.84	–9.5	0.335	–151.58	–30.1	0.031	–82.48
19.5	–43.9	0.006	–15.07	–9.5	0.336	–156.87	–9.5	0.335	–156.58	–27.5	0.042	–74.44
20.0	–37.2	0.014	–60.95	–9.5	0.335	–161.91	–9.5	0.334	–161.61	–26.1	0.049	–83.47
20.5	–34.2	0.020	–81.46	–9.5	0.334	–167.06	–9.5	0.334	–166.83	–25.9	0.050	–87.49
21.0	–31.7	0.026	–88.61	–9.5	0.334	–172.15	–9.6	0.333	–171.90	–24.3	0.061	–91.17
21.5	–28.8	0.036	–92.93	–9.6	0.332	–177.23	–9.6	0.332	–176.87	–22.4	0.076	–100.05
22.0	–26.8	0.046	–103.07	–9.6	0.330	177.77	–9.6	0.330	178.02	–21.5	0.084	–106.22
22.5	–25.7	0.052	–108.68	–9.7	0.328	172.66	–9.7	0.329	173.17	–20.4	0.096	–108.46
23.0	–24.4	0.060	–112.93	–9.7	0.326	167.59	–9.8	0.325	168.05	–19.6	0.105	–112.20
23.5	–23.4	0.068	–119.81	–9.8	0.324	162.56	–9.8	0.323	163.07	–19.1	0.110	–116.22
24.0	–22.9	0.071	–123.47	–9.9	0.321	157.82	–9.9	0.321	158.21	–19.2	0.110	–119.75
24.5	–21.9	0.080	–127.14	–9.9	0.319	152.93	–9.9	0.318	153.23	–18.7	0.116	–126.15
25.0	–21.3	0.086	–133.52	–10.0	0.316	147.87	–10.0	0.315	148.25	–18.3	0.121	–131.70
25.5	–20.6	0.093	–136.20	–10.1	0.313	143.14	–10.1	0.314	143.41	–17.8	0.129	–135.59
26.0	–19.5	0.106	–139.82	–10.2	0.310	138.03	–10.2	0.310	138.60	–17.0	0.141	–139.73
26.5	–19.0	0.112	–147.80	–10.3	0.306	133.00	–10.2	0.307	133.97	–16.5	0.150	–143.85

1. Data obtained from on–wafer measurements. T_{chuck} = 25 °C

Table 4. S–parameters (TA = 25 °C)[1]

17 dB Setting

Freq. (GHz)	S_{11}			S_{21}			S_{12}			S_{22}		
	dB	Mag	Ang	dB	Mag	Ang	dB	Mag	Ang	dB	Mag	Ang
1.5	–32.4	0.024	–50.09	–17.2	0.138	–8.27	–17.2	0.138	–8.74	–26.1	0.049	–26.48
2.0	–30.8	0.029	–60.95	–17.1	0.140	–11.45	–17.1	0.140	–11.98	–25.6	0.052	–34.56
2.5	–29.9	0.032	–69.35	–17.1	0.140	–14.05	–17.0	0.140	–14.41	–25.8	0.051	–42.67
3.0	–28.9	0.036	–78.53	–17.0	0.140	–17.13	–17.0	0.140	–17.49	–26.0	0.050	–51.92
3.5	–27.7	0.041	–84.43	–16.9	0.142	–20.14	–16.9	0.142	–20.37	–25.3	0.054	–57.49
4.0	–26.7	0.046	–91.79	–16.9	0.143	–23.28	–16.9	0.143	–23.61	–24.7	0.058	–65.09
4.5	–26.0	0.050	–98.45	–16.8	0.144	–26.12	–16.8	0.144	–26.48	–24.3	0.061	–72.34
5.0	–25.3	0.054	–104.73	–16.7	0.146	–29.17	–16.7	0.146	–29.50	–24.2	0.062	–79.31
5.5	–24.6	0.059	–110.45	–16.6	0.147	–32.36	–16.6	0.147	–32.71	–24.1	0.063	–86.87
6.0	–24.1	0.062	–115.51	–16.5	0.149	–35.32	–16.5	0.149	–35.73	–23.8	0.064	–94.13
6.5	–23.6	0.066	–120.30	–16.4	0.151	–38.59	–16.4	0.151	–38.91	–23.6	0.066	–100.64
7.0	–23.1	0.070	–125.22	–16.3	0.154	–41.99	–16.3	0.154	–42.18	–23.2	0.069	–104.82
7.5	–22.8	0.072	–129.81	–16.2	0.156	–45.22	–16.1	0.156	–45.46	–23.0	0.071	–110.19
8.0	–22.4	0.076	–134.22	–16.0	0.158	–48.75	–16.0	0.158	–48.97	–22.9	0.072	–116.22
8.5	–22.1	0.078	–138.17	–15.9	0.160	–52.41	–15.9	0.161	–52.52	–22.8	0.073	–121.27
9.0	–21.9	0.081	–142.39	–15.8	0.163	–55.95	–15.8	0.163	–56.13	–22.7	0.074	–127.42
9.5	–21.6	0.084	–146.56	–15.6	0.166	–59.74	–15.6	0.166	–59.83	–22.6	0.074	–132.64
10.0	–21.3	0.086	–150.33	–15.5	0.169	–63.50	–15.5	0.169	–63.67	–22.4	0.076	–136.28
10.5	–21.1	0.088	–154.47	–15.3	0.171	–67.47	–15.3	0.172	–67.53	–22.3	0.076	–140.08
11.0	–21.0	0.089	–158.18	–15.2	0.175	–71.68	–15.2	0.174	–71.69	–22.4	0.076	–144.18
11.5	–20.9	0.090	–162.73	–15.1	0.177	–75.84	–15.0	0.177	–75.98	–22.4	0.076	–149.25
12.0	–20.9	0.090	–166.58	–15.0	0.179	–80.11	–14.9	0.179	–80.20	–22.5	0.075	–154.15
12.5	–20.9	0.090	–170.28	–14.8	0.181	–84.55	–14.8	0.181	–84.44	–22.4	0.076	–159.37
13.0	–20.8	0.091	–173.07	–14.7	0.183	–88.85	–14.7	0.183	–88.74	–22.3	0.077	–165.55
13.5	–20.8	0.091	–177.07	–14.7	0.185	–93.13	–14.7	0.185	–93.13	–22.4	0.076	–168.58
14.0	–20.9	0.090	–179.58	–14.6	0.187	–97.65	–14.6	0.187	–97.67	–22.2	0.077	–170.46
14.5	–21.0	0.090	177.58	–14.5	0.189	–102.08	–14.5	0.189	–102.02	–22.6	0.074	–174.30
15.0	–21.1	0.088	173.89	–14.4	0.190	–106.71	–14.4	0.190	–106.76	–23.5	0.067	–174.42
15.5	–21.4	0.086	171.92	–14.4	0.192	–111.41	–14.3	0.192	–111.41	–23.5	0.067	–175.32
16.0	–21.3	0.086	169.86	–14.3	0.194	–116.14	–14.3	0.193	–116.05	–23.9	0.064	178.56
16.5	–21.4	0.085	165.87	–14.2	0.194	–120.95	–14.3	0.194	–120.81	–24.7	0.058	178.31
17.0	–21.8	0.082	164.18	–14.2	0.194	–125.48	–14.2	0.194	–125.48	–23.9	0.064	179.37
17.5	–21.8	0.082	163.30	–14.2	0.195	–130.45	–14.2	0.195	–130.35	–23.8	0.064	174.95
18.0	–22.0	0.079	160.82	–14.2	0.195	–135.22	–14.2	0.195	–135.04	–24.5	0.060	177.57
18.5	–22.4	0.076	161.14	–14.2	0.195	–140.25	–14.2	0.195	–139.93	–24.2	0.062	–178.49
19.0	–22.6	0.074	160.61	–14.2	0.195	–144.93	–14.2	0.195	–144.64	–24.6	0.059	177.34
19.5	–23.0	0.071	158.54	–14.2	0.195	–149.78	–14.2	0.194	–149.53	–25.7	0.052	179.18
20.0	–23.2	0.069	159.63	–14.3	0.194	–154.60	–14.3	0.194	–154.22	–25.2	0.055	–179.54
20.5	–22.9	0.072	159.74	–14.3	0.193	–159.30	–14.3	0.193	–159.01	–24.9	0.057	174.28
21.0	–23.0	0.071	158.31	–14.4	0.192	–164.51	–14.4	0.191	–164.02	–25.1	0.056	176.83
21.5	–23.1	0.070	159.42	–14.4	0.191	–169.07	–14.4	0.190	–168.65	–24.0	0.063	–177.68
22.0	–22.6	0.074	161.06	–14.5	0.189	–173.87	–14.5	0.189	–173.56	–23.4	0.067	–177.57
22.5	–22.7	0.073	158.65	–14.5	0.188	–178.60	–14.5	0.188	–178.42	–23.5	0.067	–173.66
23.0	–22.7	0.073	159.39	–14.6	0.187	176.65	–14.6	0.185	176.76	–23.1	0.070	–172.30
23.5	–22.4	0.076	158.48	–14.7	0.184	171.40	–14.7	0.184	172.15	–23.0	0.071	–174.91
24.0	–22.4	0.076	155.14	–14.8	0.182	166.94	–14.8	0.182	167.46	–23.3	0.068	179.85
24.5	–22.4	0.076	156.00	–14.9	0.180	162.07	–14.9	0.179	162.83	–22.9	0.072	176.96
25.0	–22.0	0.079	155.01	–14.9	0.179	157.43	–15.0	0.179	158.05	–22.4	0.076	175.05
25.5	–22.4	0.076	153.82	–15.1	0.176	152.75	–15.1	0.176	153.00	–22.0	0.080	176.11
26.0	–22.0	0.079	158.21	–15.2	0.174	148.05	–15.2	0.174	148.77	–21.5	0.084	177.06
26.5	–21.4	0.085	155.00	–15.3	0.172	142.97	–15.3	0.172	144.30	–20.8	0.091	177.45

1. Data obtained from on–wafer measurements. T_{chuck} = 25 °C

Table 5. S–parameters (TA = 25 °C)[1]

22 dB setting

Freq. (GHz)	S11			S21			S12			S22		
	dB	Mag	Ang	dB	Mag	Ang	dB	Mag	Ang	dB	Mag	Ang
1.5	−34.2	0.020	−90.85	−21.9	0.080	−8.60	−21.9	0.081	−9.05	−29.9	0.032	−45.15
2.0	−31.6	0.026	−94.43	−21.8	0.081	−12.11	−21.8	0.082	−12.50	−28.7	0.037	−55.32
2.5	−29.9	0.032	−98.90	−21.8	0.082	−14.63	−21.8	0.082	−15.12	−28.2	0.039	−66.51
3.0	−28.3	0.038	−103.35	−21.8	0.082	−17.98	−21.8	0.082	−18.29	−27.5	0.042	−77.07
3.5	−26.9	0.045	−106.22	−21.7	0.082	−21.01	−21.7	0.082	−21.41	−26.4	0.048	−81.88
4.0	−25.7	0.052	−110.32	−21.7	0.082	−24.21	−21.7	0.083	−24.70	−25.3	0.055	−88.04
4.5	−24.6	0.059	−114.56	−21.7	0.082	−27.26	−21.6	0.083	−27.88	−24.4	0.060	−94.56
5.0	−23.8	0.064	−118.94	−21.6	0.084	−30.39	−21.6	0.084	−30.78	−23.8	0.064	−101.07
5.5	−23.0	0.071	−122.80	−21.5	0.084	−33.90	−21.5	0.084	−34.26	−23.3	0.068	−107.27
6.0	−22.4	0.076	−126.33	−21.5	0.084	−36.91	−21.5	0.084	−37.20	−22.7	0.074	−113.36
6.5	−21.7	0.082	−129.77	−21.4	0.085	−40.23	−21.4	0.085	−40.50	−22.1	0.078	−118.64
7.0	−21.2	0.087	−133.58	−21.3	0.086	−43.68	−21.3	0.086	−43.93	−21.6	0.084	−122.04
7.5	−20.7	0.092	−137.11	−21.3	0.086	−46.82	−21.2	0.087	−47.19	−21.1	0.088	−126.26
8.0	−20.3	0.097	−140.34	−21.2	0.087	−50.56	−21.2	0.087	−50.76	−20.7	0.092	−130.95
8.5	−19.9	0.101	−143.61	−21.1	0.088	−54.04	−21.1	0.088	−54.32	−20.4	0.096	−135.22
9.0	−19.5	0.106	−146.68	−21.1	0.088	−57.56	−21.1	0.088	−57.99	−20.0	0.100	−139.80
9.5	−19.1	0.111	−150.15	−21.0	0.089	−61.29	−21.0	0.089	−61.35	−19.7	0.103	−143.95
10.0	−18.7	0.116	−153.26	−20.9	0.090	−64.93	−20.9	0.090	−65.11	−19.4	0.107	−147.09
10.5	−18.4	0.120	−156.65	−20.8	0.091	−68.82	−20.8	0.091	−68.97	−19.1	0.111	−150.53
11.0	−18.1	0.124	−159.79	−20.8	0.091	−72.66	−20.8	0.091	−72.85	−18.9	0.114	−154.03
11.5	−17.9	0.127	−163.24	−20.7	0.092	−76.85	−20.7	0.092	−76.97	−18.7	0.117	−157.98
12.0	−17.7	0.130	−166.53	−20.7	0.092	−80.99	−20.7	0.092	−81.01	−18.5	0.119	−162.01
12.5	−17.5	0.133	−169.58	−20.7	0.092	−84.74	−20.7	0.092	−85.08	−18.1	0.124	−166.07
13.0	−17.3	0.136	−172.16	−20.7	0.092	−89.06	−20.7	0.092	−88.79	−17.8	0.128	−170.87
13.5	−17.1	0.140	−175.55	−20.7	0.093	−92.99	−20.7	0.092	−93.03	−17.7	0.131	−173.68
14.0	−16.9	0.142	−178.31	−20.7	0.093	−97.16	−20.7	0.093	−97.06	−17.4	0.136	−175.87
14.5	−16.7	0.146	179.00	−20.6	0.093	−101.02	−20.7	0.092	−100.96	−17.3	0.136	−179.60
15.0	−16.6	0.148	175.56	−20.6	0.093	−105.32	−20.7	0.093	−105.31	−17.5	0.134	178.27
15.5	−16.5	0.149	172.93	−20.6	0.093	−109.36	−20.6	0.093	−109.59	−17.3	0.137	175.91
16.0	−16.3	0.154	170.22	−20.7	0.093	−113.98	−20.7	0.092	−113.70	−17.2	0.138	170.75
16.5	−16.1	0.156	166.31	−20.7	0.092	−118.04	−20.7	0.092	−117.93	−17.3	0.136	168.25
17.0	−16.1	0.156	163.75	−20.7	0.092	−122.28	−20.7	0.092	−122.26	−16.8	0.144	166.91
17.5	−15.9	0.160	161.45	−20.8	0.091	−126.91	−20.8	0.092	−126.57	−16.5	0.150	162.32
18.0	−15.9	0.161	157.96	−20.8	0.091	−131.11	−20.8	0.091	−130.94	−16.7	0.146	160.22
18.5	−15.9	0.161	155.75	−20.9	0.090	−135.14	−20.9	0.090	−135.19	−16.5	0.149	159.08
19.0	−15.8	0.162	152.85	−21.0	0.090	−139.64	−21.0	0.089	−139.43	−16.5	0.150	154.40
19.5	−15.8	0.162	149.38	−21.0	0.089	−143.72	−21.1	0.089	−143.73	−16.8	0.144	150.83
20.0	−15.8	0.162	147.03	−21.1	0.088	−148.16	−21.2	0.087	−148.03	−16.6	0.148	148.55
20.5	−15.6	0.165	144.67	−21.2	0.087	−152.46	−21.2	0.087	−152.23	−16.3	0.154	143.80
21.0	−15.5	0.167	141.31	−21.2	0.087	−157.06	−21.3	0.086	−156.71	−16.4	0.152	141.05
21.5	−15.6	0.166	138.85	−21.4	0.085	−161.15	−21.3	0.086	−160.57	−16.3	0.153	141.09
22.0	−15.4	0.169	136.95	−21.5	0.084	−165.43	−21.5	0.085	−165.18	−16.2	0.155	139.16
22.5	−15.4	0.171	133.52	−21.6	0.083	−169.61	−21.6	0.083	−169.40	−16.4	0.151	136.62
23.0	−15.5	0.169	130.57	−21.7	0.082	−174.34	−21.7	0.082	−173.93	−16.5	0.150	134.79
23.5	−15.4	0.171	127.93	−21.7	0.082	−178.65	−21.9	0.080	−178.10	−16.5	0.149	130.57
24.0	−15.3	0.171	123.85	−21.9	0.080	177.42	−22.0	0.079	178.47	−16.4	0.152	125.38
24.5	−15.4	0.169	121.52	−22.1	0.078	173.41	−22.1	0.078	173.79	−16.3	0.153	122.27
25.0	−15.3	0.171	118.60	−22.3	0.077	169.50	−22.2	0.077	169.52	−16.2	0.154	119.55
25.5	−15.5	0.167	115.22	−22.4	0.076	164.97	−22.5	0.075	165.50	−16.3	0.153	117.91
26.0	−15.7	0.164	114.56	−22.6	0.074	160.76	−22.5	0.075	162.00	−16.5	0.149	117.27
26.5	−15.5	0.168	111.85	−22.3	0.076	155.73	−22.8	0.073	156.61	−16.6	0.148	116.14

1. Data obtained from on–wafer measurements. T_{chuck} = 25 °C

Table 6. S–parameters (TA = 25 °C)[1]

27 dB Setting

Freq. (GHz)	S_{11}			S_{21}			S_{12}			S_{22}		
	dB	Mag	Ang	dB	Mag	Ang	dB	Mag	Ang	dB	Mag	Ang
1.5	−29.7	0.033	−54.14	−26.6	0.047	−10.26	−26.6	0.047	−10.81	−28.4	0.038	−45.02
2.0	−28.2	0.039	−65.10	−26.6	0.047	−14.58	−26.6	0.047	−15.05	−27.2	0.044	−55.34
2.5	−26.9	0.045	−73.49	−26.6	0.047	−17.47	−26.6	0.047	−17.90	−26.4	0.048	−64.94
3.0	−25.7	0.052	−80.80	−26.7	0.046	−21.59	−26.7	0.046	−21.84	−25.5	0.053	−73.76
3.5	−24.5	0.060	−86.75	−26.7	0.046	−25.12	−26.7	0.046	−25.45	−24.5	0.060	−79.61
4.0	−23.4	0.068	−92.82	−26.8	0.046	−28.65	−26.8	0.046	−29.04	−23.4	0.067	−86.47
4.5	−22.5	0.075	−98.22	−26.9	0.045	−32.25	−26.8	0.046	−32.59	−22.6	0.074	−92.85
5.0	−21.7	0.082	−103.35	−26.9	0.045	−35.42	−26.9	0.045	−35.77	−21.9	0.080	−98.79
5.5	−20.9	0.090	−108.48	−27.0	0.045	−38.91	−27.0	0.045	−39.44	−21.2	0.087	−104.13
6.0	−20.3	0.096	−112.61	−27.1	0.044	−42.22	−27.1	0.044	−42.42	−20.6	0.094	−109.43
6.5	−19.6	0.104	−116.77	−27.2	0.044	−45.33	−27.1	0.044	−45.91	−20.0	0.100	−114.52
7.0	−19.1	0.111	−121.01	−27.2	0.044	−48.63	−27.2	0.044	−49.04	−19.4	0.107	−118.30
7.5	−18.6	0.118	−124.88	−27.3	0.043	−51.98	−27.2	0.044	−52.34	−18.9	0.114	−122.59
8.0	−18.1	0.125	−128.74	−27.3	0.043	−55.33	−27.3	0.043	−55.64	−18.4	0.120	−126.93
8.5	−17.6	0.131	−132.38	−27.3	0.043	−58.61	−27.3	0.043	−58.79	−18.0	0.126	−130.85
9.0	−17.2	0.138	−135.93	−27.5	0.042	−62.19	−27.4	0.042	−61.95	−17.5	0.133	−135.11
9.5	−16.7	0.146	−139.61	−27.5	0.042	−65.01	−27.5	0.042	−65.38	−17.1	0.139	−139.03
10.0	−16.3	0.153	−143.20	−27.6	0.042	−68.68	−27.6	0.042	−68.37	−16.7	0.146	−142.60
10.5	−16.0	0.159	−146.88	−27.6	0.042	−71.77	−27.6	0.042	−71.87	−16.4	0.152	−146.10
11.0	−15.6	0.165	−150.33	−27.6	0.042	−75.38	−27.6	0.042	−75.21	−16.1	0.157	−149.65
11.5	−15.3	0.171	−153.99	−27.7	0.041	−78.66	−27.7	0.041	−78.91	−15.7	0.163	−153.54
12.0	−15.1	0.176	−157.48	−27.8	0.041	−82.35	−27.8	0.041	−82.39	−15.5	0.168	−157.52
12.5	−14.8	0.181	−160.82	−27.9	0.040	−85.43	−27.9	0.040	−85.83	−15.1	0.176	−161.62
13.0	−14.5	0.188	−163.97	−28.0	0.040	−88.91	−28.0	0.040	−89.08	−14.8	0.183	−166.21
13.5	−14.2	0.194	−167.57	−28.1	0.039	−92.10	−28.1	0.039	−92.04	−14.5	0.188	−169.35
14.0	−14.0	0.200	−170.77	−28.1	0.039	−95.36	−28.2	0.039	−95.40	−14.2	0.196	−171.93
14.5	−13.7	0.206	−173.98	−28.2	0.039	−98.81	−28.2	0.039	−98.89	−14.0	0.200	−175.66
15.0	−13.5	0.210	−177.56	−28.4	0.038	−102.01	−28.3	0.038	−102.45	−14.0	0.200	−178.31
15.5	−13.4	0.215	179.35	−28.4	0.038	−106.00	−28.4	0.038	−106.13	−13.7	0.206	178.89
16.0	−13.1	0.222	176.01	−28.5	0.038	−109.62	−28.5	0.038	−108.91	−13.5	0.210	174.14
16.5	−12.9	0.226	171.85	−28.6	0.037	−113.05	−28.5	0.037	−113.14	−13.5	0.211	171.03
17.0	−12.8	0.229	168.93	−28.7	0.037	−117.04	−28.8	0.036	−116.73	−13.1	0.222	168.64
17.5	−12.6	0.235	165.97	−28.8	0.036	−120.46	−28.8	0.036	−119.86	−12.7	0.230	164.12
18.0	−12.5	0.238	162.30	−28.9	0.036	−123.37	−28.9	0.036	−122.88	−12.8	0.230	161.35
18.5	−12.4	0.240	159.32	−29.0	0.036	−126.93	−29.1	0.035	−127.24	−12.5	0.236	159.31
19.0	−12.2	0.244	156.23	−29.2	0.035	−130.42	−29.4	0.034	−130.48	−12.4	0.240	154.76
19.5	−12.2	0.246	152.35	−29.4	0.034	−134.67	−29.3	0.034	−134.11	−12.5	0.236	150.89
20.0	−12.1	0.248	149.38	−29.6	0.033	−136.99	−29.6	0.033	−137.04	−12.3	0.242	148.07
20.5	−11.9	0.254	146.43	−29.7	0.033	−140.40	−29.7	0.033	−140.66	−12.1	0.250	143.38
21.0	−11.8	0.257	142.75	−29.7	0.033	−143.73	−29.9	0.032	−143.44	−12.1	0.250	140.17
21.5	−11.7	0.259	139.93	−29.9	0.032	−147.71	−30.0	0.032	−147.56	−11.9	0.253	138.70
22.0	−11.6	0.264	137.10	−30.0	0.032	−151.37	−30.1	0.031	−151.05	−11.8	0.258	135.76
22.5	−11.5	0.267	133.38	−30.1	0.031	−155.38	−30.2	0.031	−155.32	−11.9	0.255	132.62
23.0	−11.5	0.267	130.08	−30.4	0.030	−159.18	−30.5	0.030	−158.50	−11.9	0.254	129.84
23.5	−11.4	0.271	126.94	−30.9	0.028	−163.11	−30.8	0.029	−162.47	−11.8	0.258	125.60
24.0	−11.3	0.273	122.73	−31.1	0.028	−163.24	−31.0	0.028	−162.98	−11.7	0.261	121.01
24.5	−11.3	0.273	119.45	−31.1	0.028	−167.40	−31.2	0.027	−167.44	−11.5	0.265	117.55
25.0	−11.2	0.276	116.26	−31.3	0.027	−170.26	−31.4	0.027	−169.27	−11.5	0.267	114.68
25.5	−11.3	0.274	112.67	−31.4	0.027	−172.12	−31.6	0.026	−172.77	−11.5	0.268	111.78
26.0	−11.4	0.270	110.68	−31.3	0.027	−175.30	−31.5	0.026	−174.71	−11.5	0.265	109.39
26.5	−11.2	0.277	107.68	−31.8	0.026	−179.15	−31.6	0.026	179.62	−11.5	0.265	107.35

1. Data obtained from on–wafer measurements. T_{chuck} = 25 °C

Table 7. S–parameters (TA = 25 °C)[1]

Maximum Attenuation Setting

Freq. (GHz)	S_{11}			S_{21}			S_{12}			S_{22}		
	dB	Mag	Ang	dB	Mag	Ang	dB	Mag	Ang	dB	Mag	Ang
1.5	−35.5	0.017	−45.03	−34.2	0.019	−20.62	−34.2	0.019	−21.26	−34.5	0.019	−40.99
2.0	−33.7	0.021	−53.40	−34.4	0.019	−27.84	−34.4	0.019	−28.25	−33.0	0.022	−47.85
2.5	−32.4	0.024	−60.24	−34.9	0.018	−32.95	−34.8	0.018	−32.74	−32.0	0.025	−55.30
3.0	−30.8	0.029	−66.34	−35.4	0.017	−39.49	−35.3	0.017	−39.39	−30.7	0.029	−62.65
3.5	−29.3	0.034	−72.12	−35.8	0.016	−43.89	−35.8	0.016	−44.08	−29.4	0.034	−67.57
4.0	−28.1	0.039	−78.06	−36.4	0.015	−49.72	−36.4	0.015	−49.21	−28.2	0.039	−74.80
4.5	−27.0	0.045	−83.60	−36.9	0.014	−53.72	−36.9	0.014	−53.33	−27.2	0.044	−80.99
5.0	−26.0	0.050	−88.99	−37.5	0.013	−56.49	−37.6	0.013	−56.74	−26.4	0.048	−86.67
5.5	−25.2	0.055	−93.88	−38.1	0.012	−60.32	−38.2	0.012	−60.52	−25.6	0.053	−91.73
6.0	−24.5	0.060	−97.83	−38.7	0.012	−63.08	−38.7	0.012	−63.16	−24.7	0.058	−97.12
6.5	−23.7	0.065	−102.06	−39.4	0.011	−65.17	−39.3	0.011	−66.01	−24.0	0.063	−102.18
7.0	−23.0	0.070	−106.26	−39.8	0.010	−67.23	−39.7	0.010	−67.40	−23.3	0.068	−105.74
7.5	−22.4	0.076	−109.81	−40.4	0.010	−69.29	−40.3	0.010	−68.99	−22.7	0.073	−109.59
8.0	−21.8	0.081	−113.65	−40.8	0.009	−71.22	−40.9	0.009	−72.16	−22.1	0.078	−113.78
8.5	−21.3	0.086	−117.01	−41.3	0.009	−70.53	−41.3	0.009	−73.16	−21.6	0.083	−117.53
9.0	−20.7	0.092	−120.51	−41.6	0.008	−73.91	−41.9	0.008	−74.26	−21.0	0.089	−121.52
9.5	−20.2	0.098	−124.14	−42.2	0.008	−74.29	−42.3	0.008	−73.61	−20.5	0.094	−125.33
10.0	−19.7	0.103	−127.67	−42.4	0.008	−74.30	−42.6	0.007	−76.89	−20.1	0.099	−128.70
10.5	−19.3	0.109	−131.34	−42.6	0.007	−74.64	−42.9	0.007	−74.92	−19.6	0.105	−131.99
11.0	−18.9	0.114	−134.48	−43.1	0.007	−78.58	−43.0	0.007	−79.12	−19.2	0.110	−135.13
11.5	−18.5	0.119	−138.03	−43.3	0.007	−80.26	−43.3	0.007	−80.03	−18.8	0.115	−138.74
12.0	−18.2	0.123	−141.37	−44.0	0.006	−80.42	−44.0	0.006	−79.83	−18.4	0.120	−142.54
12.5	−17.9	0.128	−144.54	−44.0	0.006	−82.94	−44.4	0.006	−83.30	−17.9	0.127	−146.71
13.0	−17.4	0.135	−147.55	−44.6	0.006	−80.73	−44.9	0.006	−80.30	−17.5	0.133	−151.72
13.5	−17.1	0.140	−151.01	−45.0	0.006	−82.04	−45.0	0.006	−81.57	−17.2	0.138	−154.75
14.0	−16.7	0.146	−153.96	−45.2	0.006	−85.97	−45.7	0.005	−83.93	−16.7	0.146	−157.22
14.5	−16.4	0.152	−157.02	−45.4	0.005	−86.18	−45.5	0.005	−83.65	−16.5	0.150	−160.69
15.0	−16.1	0.156	−160.51	−45.5	0.005	−86.22	−45.7	0.005	−89.14	−16.4	0.152	−162.56
15.5	−15.8	0.161	−163.33	−46.2	0.005	−86.48	−45.7	0.005	−86.09	−16.0	0.159	−165.20
16.0	−15.5	0.169	−166.78	−46.0	0.005	−92.00	−46.4	0.005	−86.68	−15.8	0.163	−170.12
16.5	−15.2	0.173	−170.90	−46.6	0.005	−86.68	−46.6	0.005	−91.57	−15.7	0.165	−172.67
17.0	−15.0	0.178	−173.64	−47.1	0.004	−87.87	−47.3	0.004	−89.78	−15.0	0.178	−175.38
17.5	−14.7	0.184	−176.80	−47.5	0.004	−90.48	−48.0	0.004	−95.21	−14.6	0.186	179.92
18.0	−14.5	0.189	179.54	−48.0	0.004	−91.90	−47.7	0.004	−91.41	−14.5	0.188	177.66
18.5	−14.3	0.192	177.03	−48.4	0.004	−94.49	−48.0	0.004	−94.12	−14.1	0.196	175.61
19.0	−14.1	0.198	173.99	−49.1	0.004	−90.74	−49.1	0.004	−93.13	−14.0	0.200	170.91
19.5	−13.9	0.201	170.13	−50.2	0.003	−92.43	−49.4	0.003	−92.81	−14.1	0.198	167.58
20.0	−13.8	0.205	167.30	−50.8	0.003	−90.49	−50.5	0.003	−87.23	−13.7	0.206	164.58
20.5	−13.4	0.213	164.18	−50.8	0.003	−94.39	−49.6	0.003	−96.59	−13.4	0.214	159.59
21.0	−13.2	0.218	160.36	−50.8	0.003	−76.60	−52.0	0.002	−88.19	−13.2	0.218	156.61
21.5	−13.1	0.222	157.66	−50.2	0.003	−84.67	−50.8	0.003	−80.23	−12.9	0.226	155.12
22.0	−12.8	0.229	154.70	−51.7	0.003	−88.37	−50.2	0.003	−86.00	−12.6	0.233	152.24
22.5	−12.6	0.235	150.86	−51.1	0.003	−74.62	−52.4	0.002	−91.70	−12.6	0.234	149.17
23.0	−12.5	0.238	147.74	−52.0	0.002	−82.05	−52.8	0.002	−81.03	−12.5	0.236	146.52
23.5	−12.3	0.243	144.23	−55.4	0.002	−59.19	−55.4	0.002	−60.95	−12.3	0.242	142.37
24.0	−12.1	0.248	140.01	−52.8	0.002	−46.46	−51.4	0.003	−52.16	−12.2	0.246	137.36
24.5	−12.0	0.250	137.00	−53.2	0.002	−41.25	−49.1	0.004	−54.31	−12.0	0.253	133.76
25.0	−11.8	0.256	133.44	−50.5	0.003	−42.24	−48.2	0.004	−51.62	−11.7	0.260	130.40
25.5	−11.8	0.258	129.88	−47.1	0.004	−46.15	−47.5	0.004	−39.32	−11.6	0.263	127.67
26.0	−11.8	0.258	128.34	−47.1	0.004	−46.61	−46.4	0.005	−67.22	−11.5	0.265	125.32
26.5	−11.4	0.269	124.33	−45.4	0.005	−53.16	−46.6	0.005	−63.33	−11.4	0.269	122.97

1. Data obtained from on–wafer measurements. T_{chuck} = 25 °C

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