

PEGATRON 和碩聯合科技

Antenna measurement data for HH4K 6E- F5689 project



Introduction

- ❖ Using PCBA SR1 REV:1.00 to measure antenna passive performance.
- ❖ Pegatron proposed :
Dual-Band off-board antenna*2 + 6G on-board antenna*3 + 5G on-board antenna*3 + 2.4G on-board antenna*3



- ❖ This report provides passive simulation results which include:
 - Return loss ; Isolation
 - Antenna Gain
 - Radiation Pattern

Contents

- ❖ Antenna specification
- ❖ Antenna placement and cable routing
- ❖ Measurement data
- ❖ Summary

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Antenna specification

❖ Antenna performance

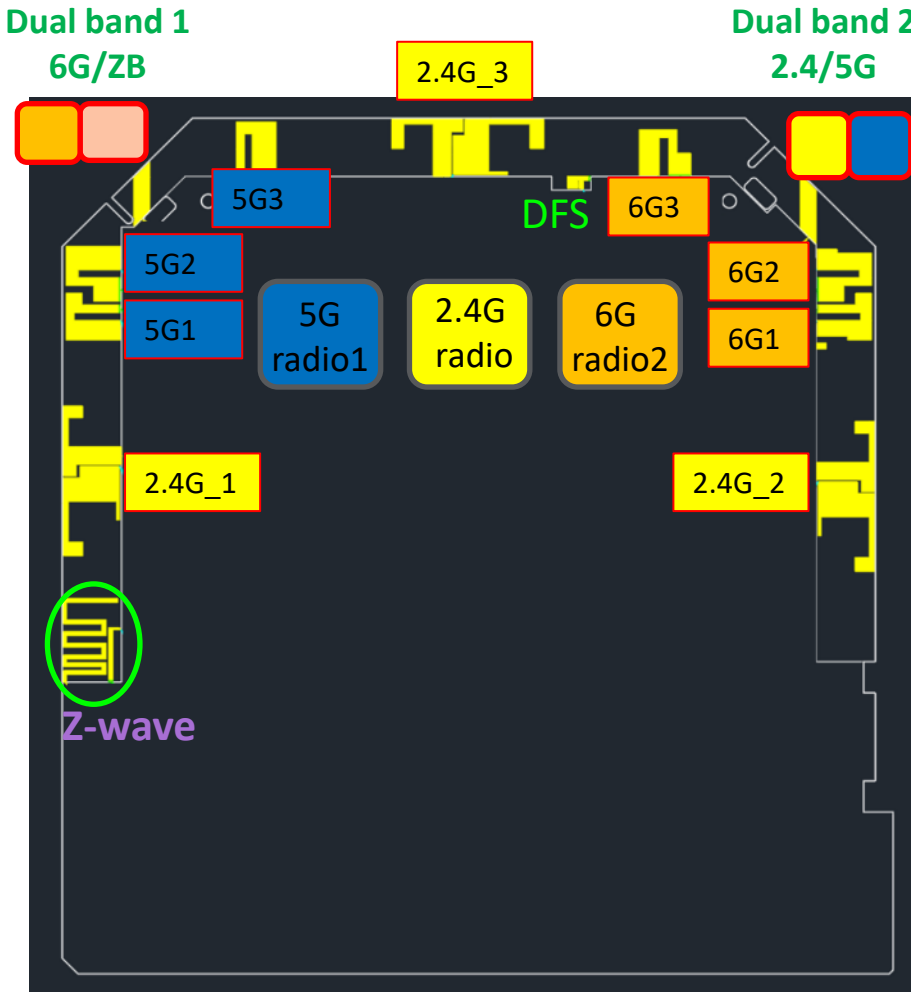


Antenna Proposal		
Wireless Function	■ Wi-Fi 2.4G antenna 4X4 ■ Wi-Fi 5G Radio#1 antenna 4X4 ■ Wi-Fi 6G Radio#2 antenna 4X4	
Antenna type	■ On-board : 2.4G antenna*3 ■ On-board : 5G antenna*3 ■ On-board : 6G antenna*3 ■ On-board : Z-wave antenna *1 ■ On-board : DFS antenna *1 ■ Off board : Dual Band antenna*2	
Speciation and measurement data		
	Customer spec	Measurement data
Return loss	< -10 dB	<-10 dB
Isolation	■ between 2.4G < -18 dB ■ between 5G/6G <-18 dB	■ between 2.4G < -28dB ■ between 5G & 6G <-20dB ■ 5G to 6G < -26 dB
Peak Gain	■ 2.4G: 4 dBi ■ 5G: 5dBi ■ 6G: 5dBi	■ 2.4G : 2.95 dBi ■ 5G : 4.89 dBi ■ 6G : 4.83 dBi
Antenna efficiency	■ 2.4G antenna > 65%. ■ 5G antenna > 60%	■ 2.4G antenna > 65%. ■ 5G antenna > 60 % ■ 6G antenna > 55 %

Contents

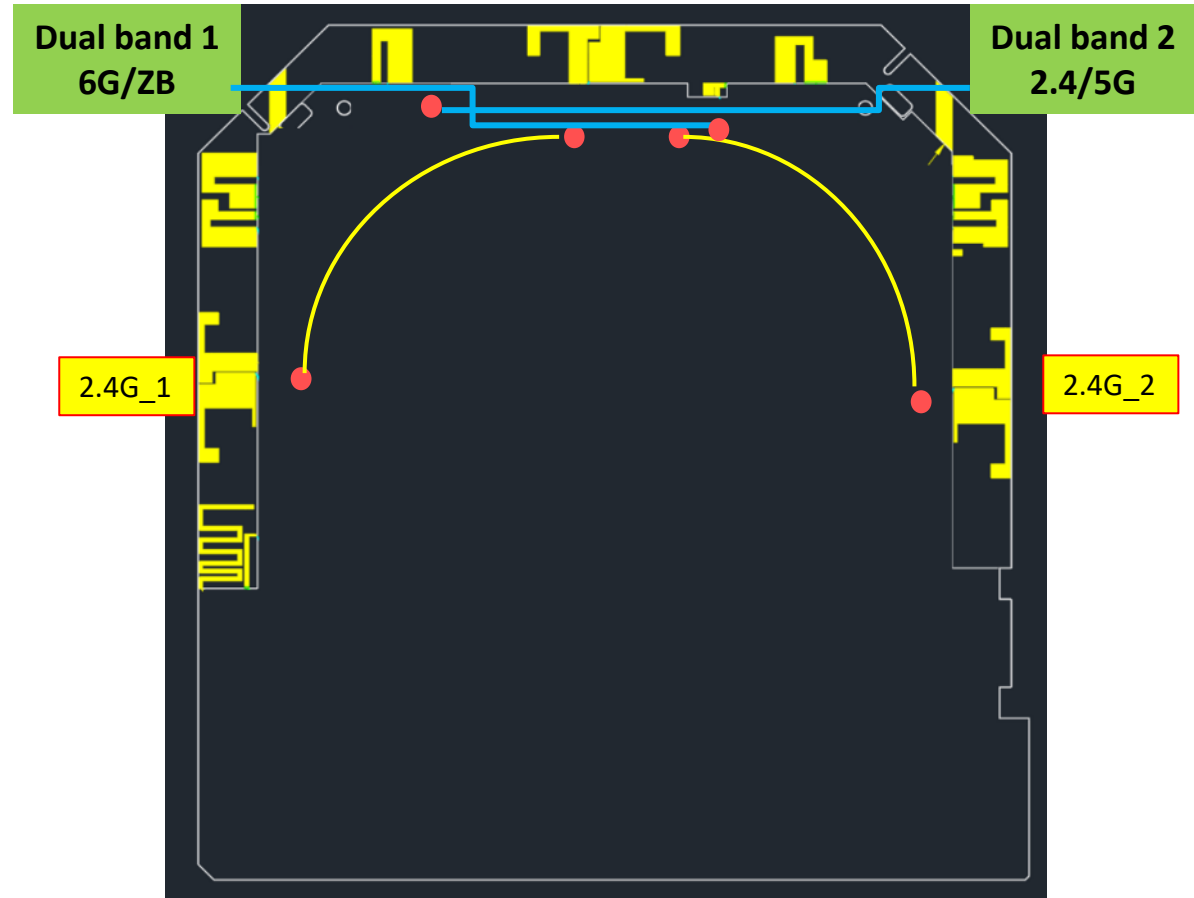
- ❖ Antenna specification
- ❖ Antenna placement and cable routing
- ❖ Measurement data
- ❖ Summary

Antenna placement & Antenna polarization



2.4G-1	2.4G-2	2.4G-3	DB-2 (2.4G)	5G-1	5G-2
Vertical (dipole)	Vertical (dipole)	Horizontal (dipole)	Horizontal (dipole)	Mix (PIFA)	Mix (PIFA)
5G-3	DB-2 (5G)	6G-1	6G-2	6G-3	DB-1 (6G)
Mix (PIFA)	Horizontal (dipole)	Mix (PIFA)	Mix (PIFA)	Mix (PIFA)	Horizontal (dipole)

Antenna placement & cable routing

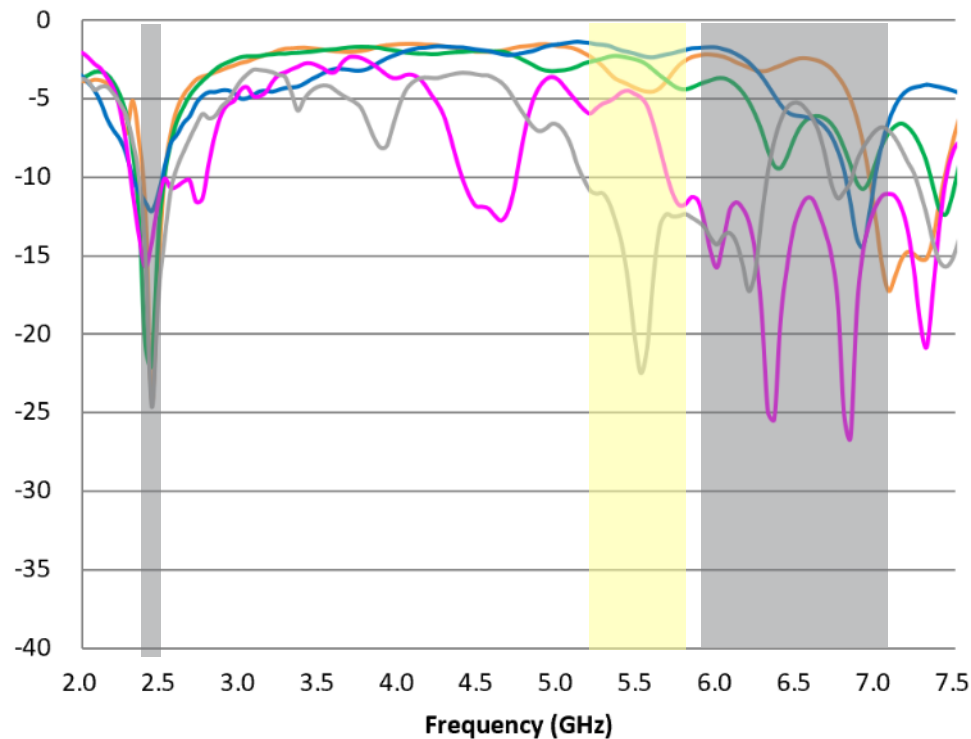


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- ❖ Antenna specification
- ❖ Antenna placement and cable routing
- ❖ Summary
- ❖ Measurement data
 - S-parameter(Return loss and Isolation)
 - Radiation pattern
 - Gain table& efficiency
- ❖ Summary

Measurement data

❖ S-parameter : Return loss



— 2G-1
— 2G-2
— 2G-3
— DB-1(ZB+6G)
— DB-2

Frequency (MHz)	2G-1	2G-2	2G-3	DB-1 (ZB)	DB-2
2400	-11.96	-20.76	-11.60	-15.71	-14.82
2450	-24.33	-22.04	-12.18	-14.14	-24.64
2500	-16.41	-14.06	-11.12	-11.62	-17.86

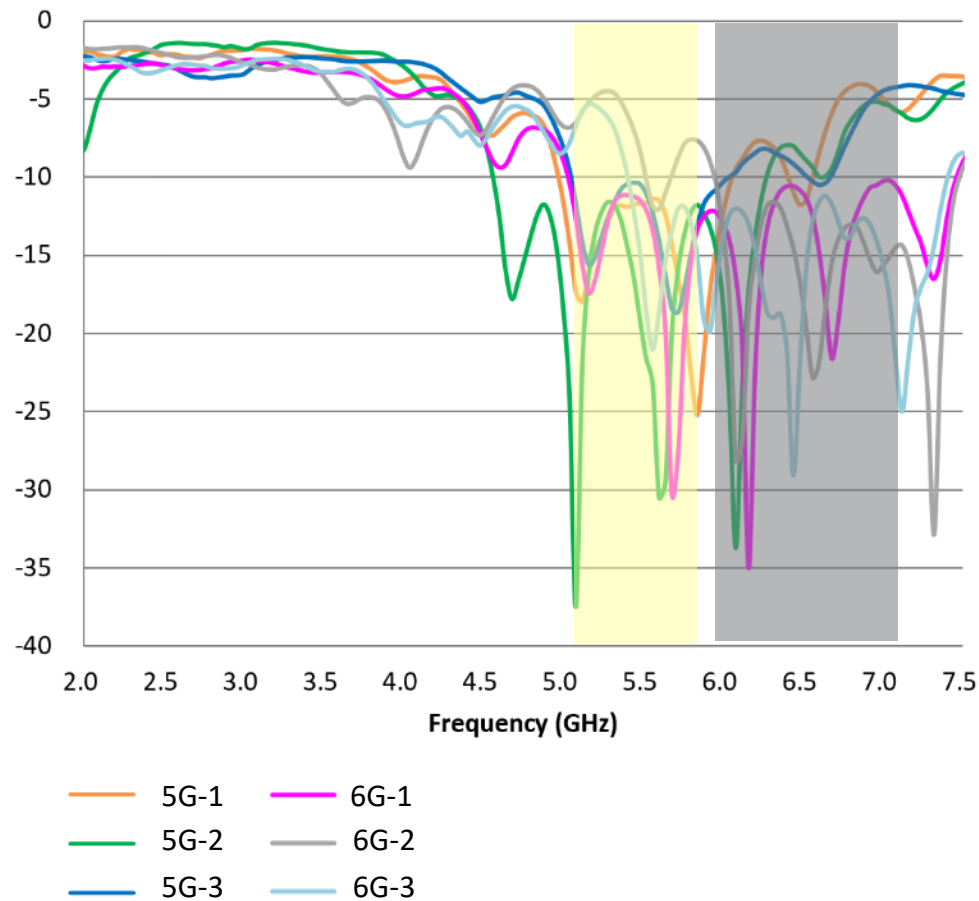
Frequency (MHz)	DB-1 (6G)
5925	-12.85
6325	-24.91
6675	-13.46
6925	-14.65
7125	-11.20

Frequency (MHz)	DB-2 (5G)
5150	-10.13
5350	-12.80
5470	-20.09
5725	-12.52
5850	-12.59

Unit: dB

Measurement data

❖ S-parameter : Return loss



Frequency (MHz)	5G-1	5G-2	5G-3
5150	-16.16	-16.15	-15.60
5350	-11.79	-12.68	-10.80
5470	-11.64	-19.08	-10.44
5725	-16.49	-15.82	-18.62
5850	-25.18	-11.77	-13.01

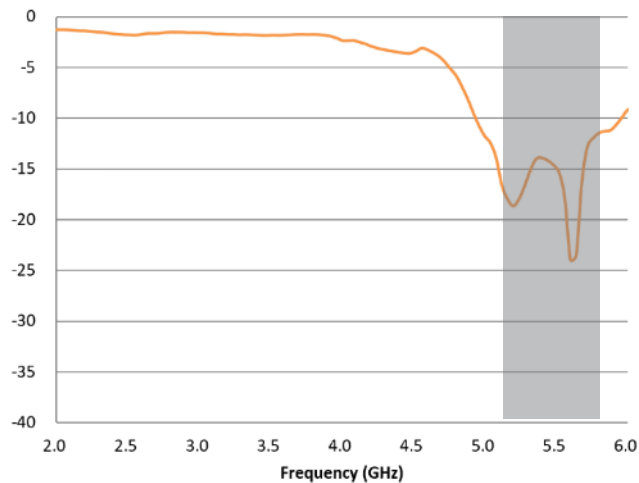
Frequency (MHz)	6G-1	6G-2	6G-3
5925	-12.15	-10.04	-19.87
6325	-11.63	-11.62	-18.99
6675	-21.59	-15.50	-11.74
6925	-10.66	-15.31	-13.07
7125	-11.17	-14.37	-25.00

Unit: dB

Measurement data

❖ S-parameter : Return loss

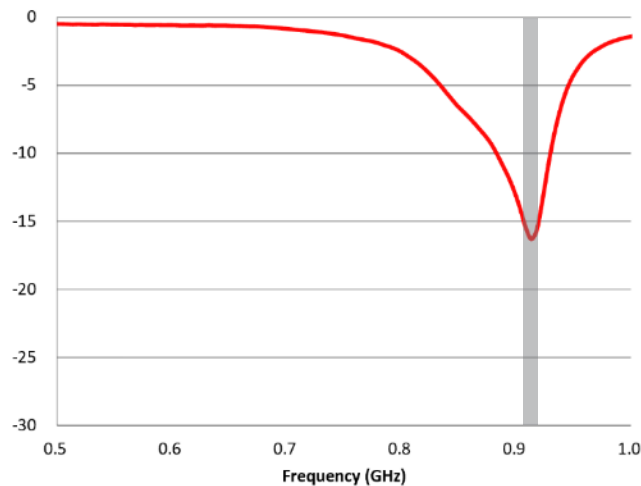
DFS



Frequency (MHz)	DFS
5150	-17.98
5350	-14.01
5470	-14.60
5725	-12.74
5850	-11.27

Unit: dB

Z-wave

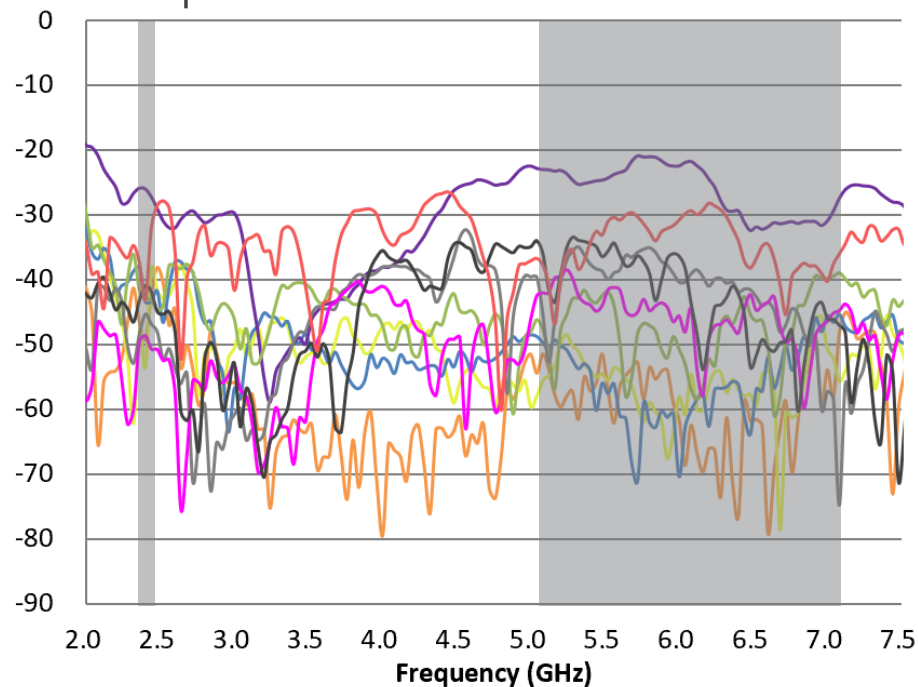


Frequency (MHz)	Z-wave
908	-15.42
913	-16.29
916	-15.54

Unit: dB

Measurement data

❖ S-parameter : Isolation



- 2G-1 to 2G-2
- 2G-1 to 2G-3
- 2G-2 to 2G-3
- 5G-1 to 5G-2
- 5G-1 to 5G-3
- 5G-1 to 6G-1
- 5G-1 to 6G-2
- 5G-1 to 6G-3
- DB-1 to DB-2

Frequency (MHz)	2G-1 to 2G-2	2G-1 to 2G-3	2G-2 to 2G-3
2400	-49.16	-53.48	-43.42
2450	-42.17	-38.32	-43.32
2500	-38.12	-41.68	-41.75

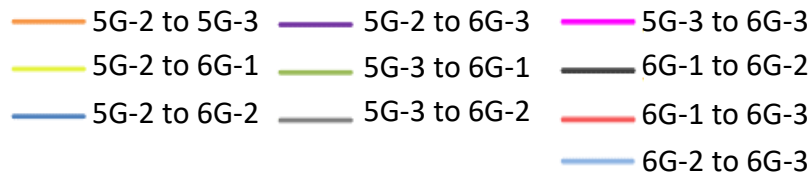
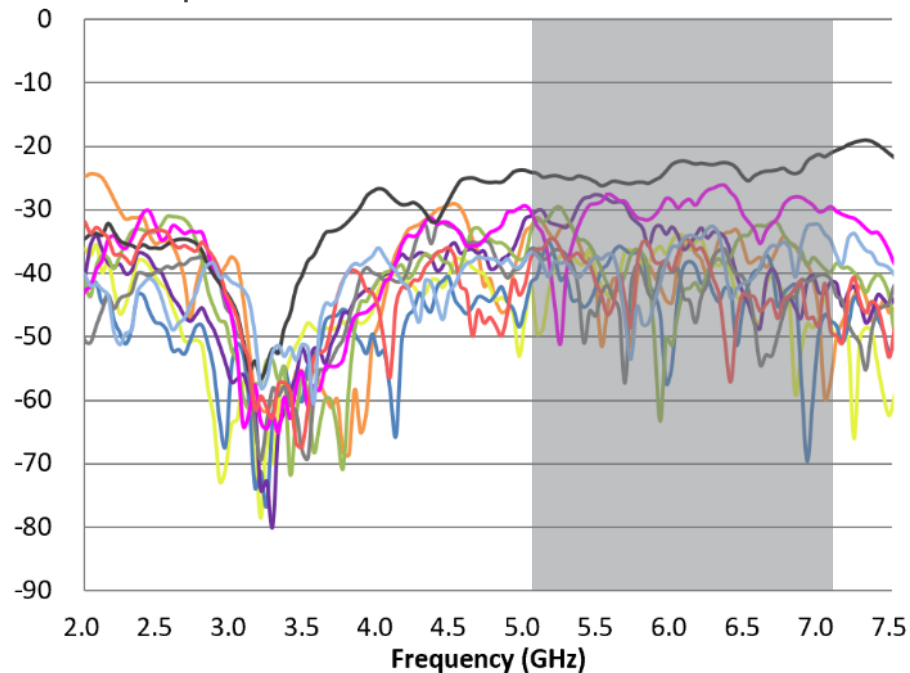
Frequency (MHz)	5G-1 to 5G-2	5G-1 to 5G-3	5G-1 to 6G-1	5G-1 to 6G-2	5G-1 to 6G-3
5150	-23.24	-56.92	-46.44	-39.75	-43.47
5470	-24.63	-42.46	-38.67	-44.05	-36.42
5850	-22.08	-47.91	-35.76	-44.04	-43.22
6325	-29.25	-45.61	-40.55	-46.19	-42.73
6675	-31.37	-58.15	-48.08	-47.20	-49.73
6925	-31.05	-39.40	-48.70	-48.56	-44.31
7125	-26.08	-39.84	-56.18	-43.75	-48.13

Frequency (MHz)	DB-1 to DB-2
2400	-43.07
2450	-31.91
2500	-28.54
5150	-46.92
5470	-33.09
5850	-34.00
6325	-30.31
6675	-40.70
6925	-37.91
7125	-34.50

Unit: dB

Measurement data

❖ S-parameter : Isolation



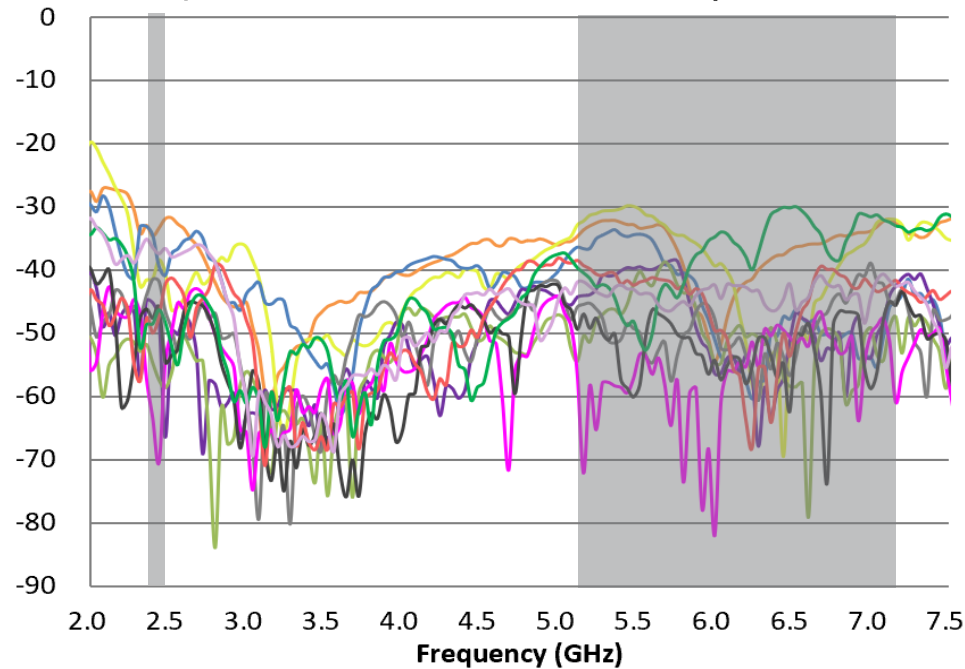
Frequency (MHz)	5G-2 to 5G-3	5G-2 to 6G-1	5G-2 to 6G-2	5G-2 to 6G-3
5150	-33.61	-42.95	-35.02	-31.87
5470	-41.77	-40.08	-42.31	-27.60
5850	-38.58	-38.39	-41.47	-35.66
6325	-34.65	-38.77	-44.44	-33.63
6675	-37.88	-40.57	-38.88	-39.27
6925	-38.48	-48.03	-69.57	-41.31
7125	-50.13	-50.21	-48.26	-41.61

Frequency (MHz)	5G-3 to 6G-1	5G-3 to 6G-2	5G-3 to 6G-3	6G-1 to 6G-2	6G-1 to 6G-3	6G-2 to 6G-3
5150	-31.22	-37.37	-37.80	-24.74	-34.76	-40.60
5470	-37.32	-46.70	-29.05	-25.64	-41.29	-37.35
5850	-39.91	-43.14	-31.58	-25.83	-35.44	-47.81
6325	-37.73	-36.42	-26.19	-22.66	-43.40	-33.99
6675	-31.98	-52.97	-32.21	-23.85	-44.18	-35.65
6925	-38.80	-41.35	-28.63	-22.36	-46.98	-32.62
7125	-38.44	-43.59	-30.25	-21.02	-49.87	-37.22

Unit:dB

Measurement data

❖ S-parameter : Isolation (2G to 5G/6G)



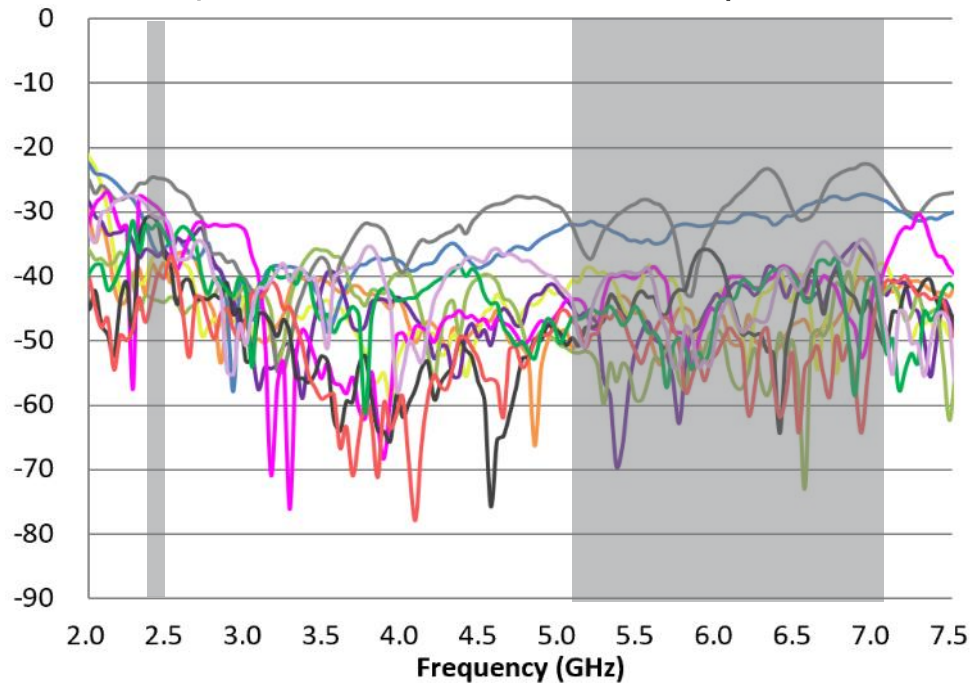
— 2G-1 to 5G-1 — 2G-1 to 6G-1 — 2G-2 to 5G-1 — 2G-2 to 6G-1
— 2G-1 to 5G-2 — 2G-1 to 6G-2 — 2G-2 to 5G-2 — 2G-2 to 6G-2
— 2G-1 to 5G-3 — 2G-1 to 6G-3 — 2G-2 to 5G-3 — 2G-2 to 6G-3

Frequency (MHz)	2G-1 to 5G-1	2G-1 to 5G-2	2G-1 to 5G-3	2G-1 to 6G-1	2G-1 to 6G-2	2G-1 to 6G-3
2400	-34.59	-41.37	-34.49	-45.17	-54.72	-41.43
2450	-33.33	-38.36	-39.42	-47.70	-57.39	-41.76
2500	-31.85	-40.46	-40.84	-66.44	-58.63	-46.45
5150	-33.63	-32.22	-36.61	-44.02	-50.44	-45.43
5470	-32.80	-29.90	-34.40	-39.72	-42.21	-49.25
5850	-43.11	-35.21	-40.94	-45.27	-43.63	-49.41
6325	-39.01	-56.03	-57.29	-58.58	-51.74	-53.34
6675	-35.81	-44.47	-50.14	-54.33	-50.08	-47.41
6925	-34.05	-36.39	-53.93	-47.40	-58.14	-40.74
7125	-31.93	-31.95	-45.86	-44.06	-49.06	-45.06

Frequency (MHz)	2G-2 to 5G-1	2G-2 to 5G-2	2G-2 to 5G-3	2G-2 to 6G-1	2G-2 to 6G-2	2G-2 to 6G-3
2400	-63.52	-47.60	-49.96	-31.11	-48.51	-36.46
2450	-70.48	-45.87	-47.31	-34.00	-46.30	-37.41
2500	-54.47	-54.59	-42.17	-35.01	-48.32	-36.56
5150	-72.12	-46.95	-39.28	-31.84	-40.44	-41.85
5470	-57.14	-60.08	-42.39	-52.20	-48.13	-43.05
5850	-59.44	-50.77	-43.82	-30.59	-39.30	-45.61
6325	-49.36	-50.71	-55.37	-22.45	-33.82	-45.46
6675	-46.62	-59.30	-39.39	-21.06	-34.33	-40.86
6925	-63.84	-47.17	-42.83	-21.85	-31.18	-43.90
7125	-51.25	-45.01	-42.40	-25.64	-32.40	-41.64

Measurement data

❖ S-parameter : Isolation (2G to 5G/6G)



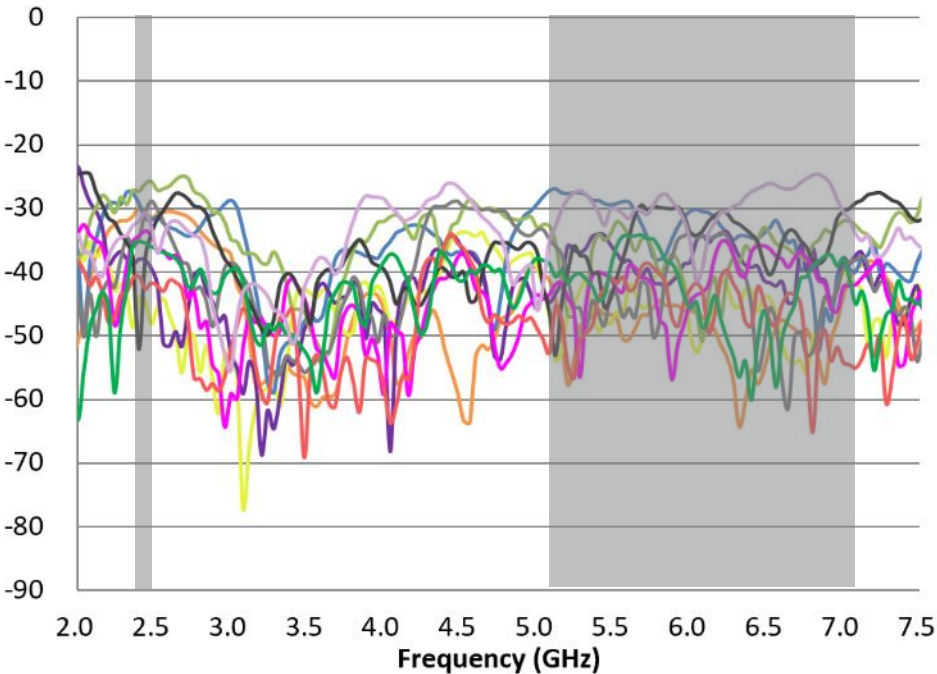
— 2G-3 to 5G-1 — 2G-3 to 6G-1 — 2G-1 to DB-1 — 2G-2 to DB-2
— 2G-3 to 5G-2 — 2G-3 to 6G-2 — 2G-1 to DB-2 — 2G-3 to DB-1
— 2G-3 to 5G-3 — 2G-3 to 6G-3 — 2G-2 to DB-1 — 2G-3 to DB-2

Frequency (MHz)	2G-3 to 5G-1	2G-3 to 5G-2	2G-3 to 5G-3	2G-3 to 6G-1	2G-3 to 6G-2	2G-3 to 6G-3
2400	-38.14	-37.37	-34.74	-36.19	-43.52	-24.63
2450	-39.54	-36.51	-36.48	-36.90	-43.77	-24.76
2500	-37.88	-37.08	-35.78	-36.00	-44.02	-24.90
5150	-48.67	-38.86	-31.89	-45.59	-51.63	-36.58
5470	-45.68	-43.52	-34.46	-51.68	-59.07	-28.79
5850	-45.75	-49.99	-32.00	-48.84	-51.74	-42.97
6325	-51.07	-42.43	-30.97	-38.63	-58.49	-23.32
6675	-47.63	-47.69	-28.37	-44.40	-49.18	-26.85
6925	-40.13	-36.52	-27.27	-35.86	-45.40	-22.62
7125	-42.39	-40.79	-29.13	-40.70	-41.44	-26.81

Frequency (MHz)	2G-1 to DB-1	2G-1 to DB-2	2G-2 to DB-1	2G-2 to DB-2	2G-3 to DB-1	2G-3 to DB-2
2400	-28.65	-30.72	-43.61	-32.01	-32.64	-30.41
2450	-29.42	-31.82	-39.65	-29.38	-31.80	-30.92
2500	-30.85	-36.66	-40.23	-28.98	-33.30	-30.98
5150	-44.61	-48.04	-51.14	-61.59	-46.22	-50.90
5470	-40.31	-43.37	-51.62	-41.29	-44.64	-39.60
5850	-54.21	-38.48	-55.86	-65.86	-54.45	-49.12
6325	-40.66	-51.66	-48.10	-39.42	-39.97	-46.77
6675	-39.92	-45.86	-55.50	-35.02	-37.48	-34.61
6925	-52.63	-45.84	-64.30	-39.32	-46.73	-34.25
7125	-35.77	-45.51	-40.84	-43.14	-49.78	-55.16

Measurement data

❖ S-parameter : Isolation (2G to 5G/6G)



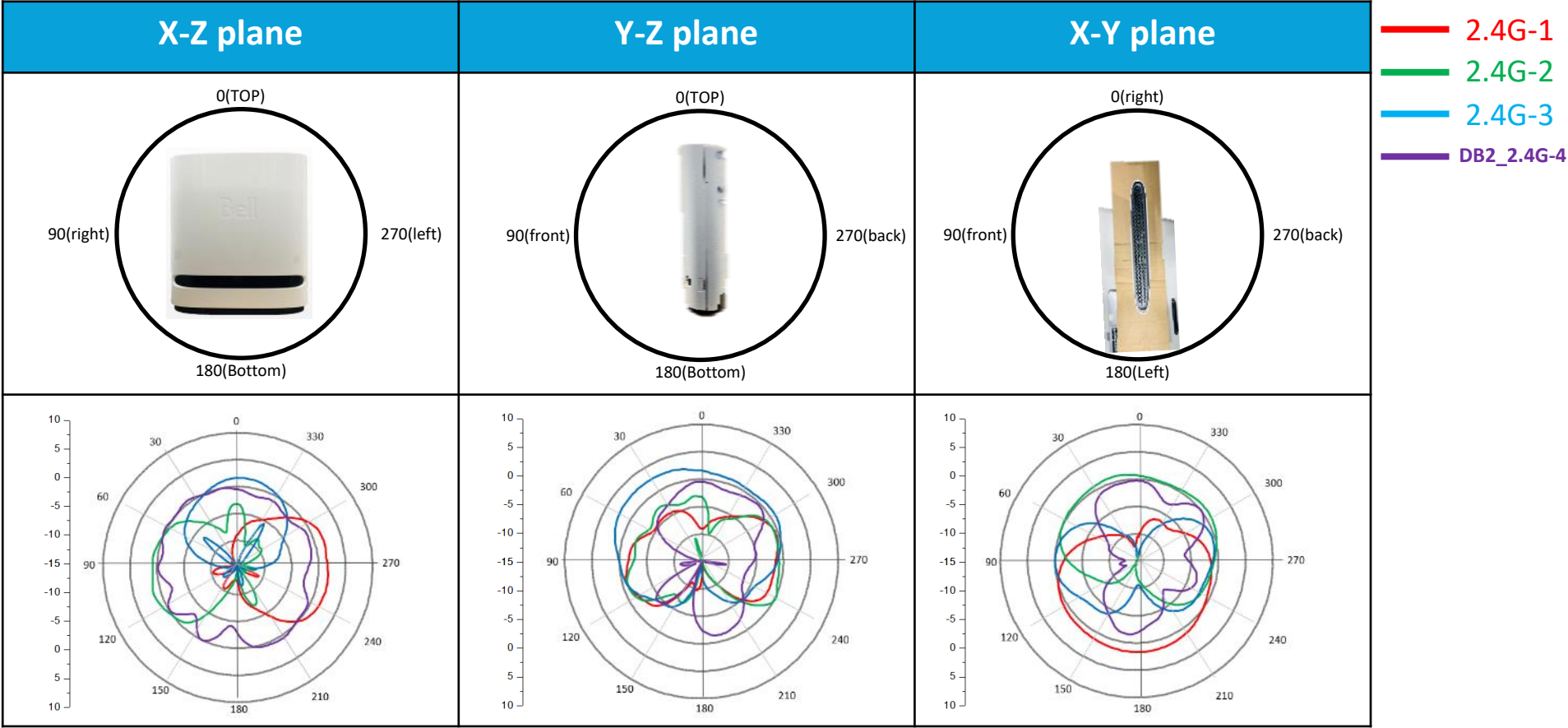
5G-1 to DB-1 5G-2 to DB-2 6G-1 to DB-1 6G-2 to DB-2
5G-1 to DB-2 5G-3 to DB-1 6G-1 to DB-2 6G-3 to DB-1
5G-2 to DB-1 5G-3 to DB-2 6G-2 to DB-1 6G-3 to DB-2

Frequency (MHz)	5G-1 to DB-1	5G-1 to DB-2	5G-2 to DB-1	5G-2 to DB-2	5G-3 to DB-1	5G-3 to DB-2
2400	-29.92	-44.11	-29.27	-37.97	-27.32	-34.63
2450	-30.76	-44.50	-31.50	-38.11	-26.14	-30.70
2500	-31.44	-48.17	-31.87	-39.45	-25.77	-28.87
5150	-50.20	-52.55	-27.53	-41.40	-41.41	-37.22
5470	-46.67	-48.13	-29.44	-35.76	-33.98	-43.17
5850	-45.24	-41.58	-37.24	-42.21	-38.67	-40.05
6325	-64.29	-45.50	-34.30	-37.53	-38.59	-39.41
6675	-48.92	-54.32	-35.14	-44.50	-37.19	-50.21
6925	-50.82	-44.16	-47.56	-44.51	-33.78	-44.78
7125	-38.84	-42.73	-37.73	-36.92	-33.65	-37.50

Frequency (MHz)	6G-1 to DB-1	6G-1 to DB-2	6G-2 to DB-1	6G-2 to DB-2	6G-3 to DB-1	6G-3 to DB-2
2400	-34.33	-52.12	-40.69	-38.93	-35.20	-32.00
2450	-33.51	-37.89	-42.65	-43.13	-35.45	-30.62
2500	-34.17	-34.01	-41.70	-44.88	-36.04	-32.91
5150	-41.72	-44.88	-47.44	-29.14	-39.84	-30.20
5470	-40.94	-44.16	-40.86	-28.38	-39.34	-30.15
5850	-48.65	-29.96	-41.91	-31.75	-38.28	-27.74
6325	-40.21	-32.48	-43.59	-32.70	-56.52	-29.34
6675	-37.82	-33.59	-43.57	-28.83	-45.19	-26.78
6925	-45.82	-35.18	-53.92	-27.15	-37.33	-26.31
7125	-40.98	-28.71	-53.70	-32.05	-43.02	-35.07

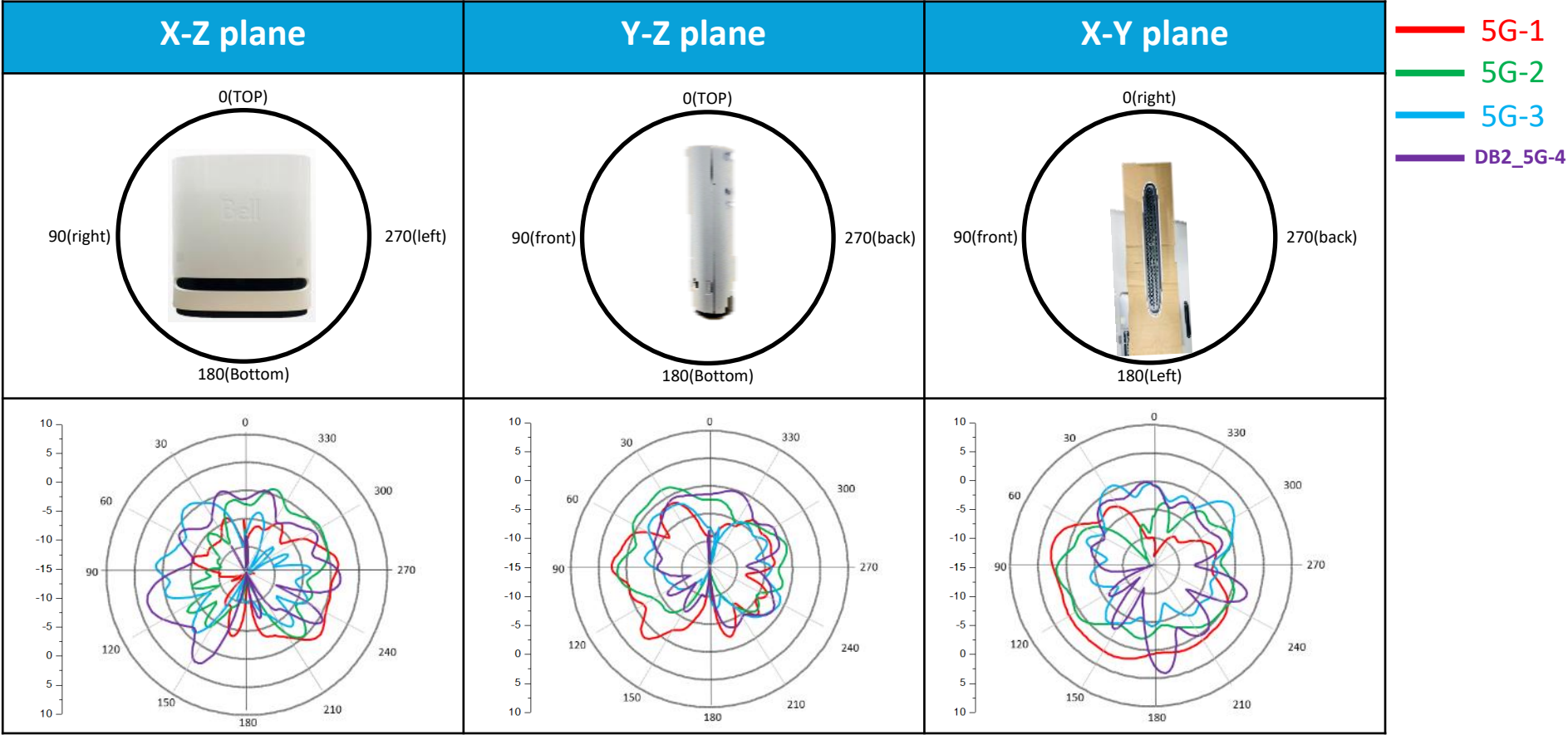
Measurement data

Radiation pattern – 2.45G



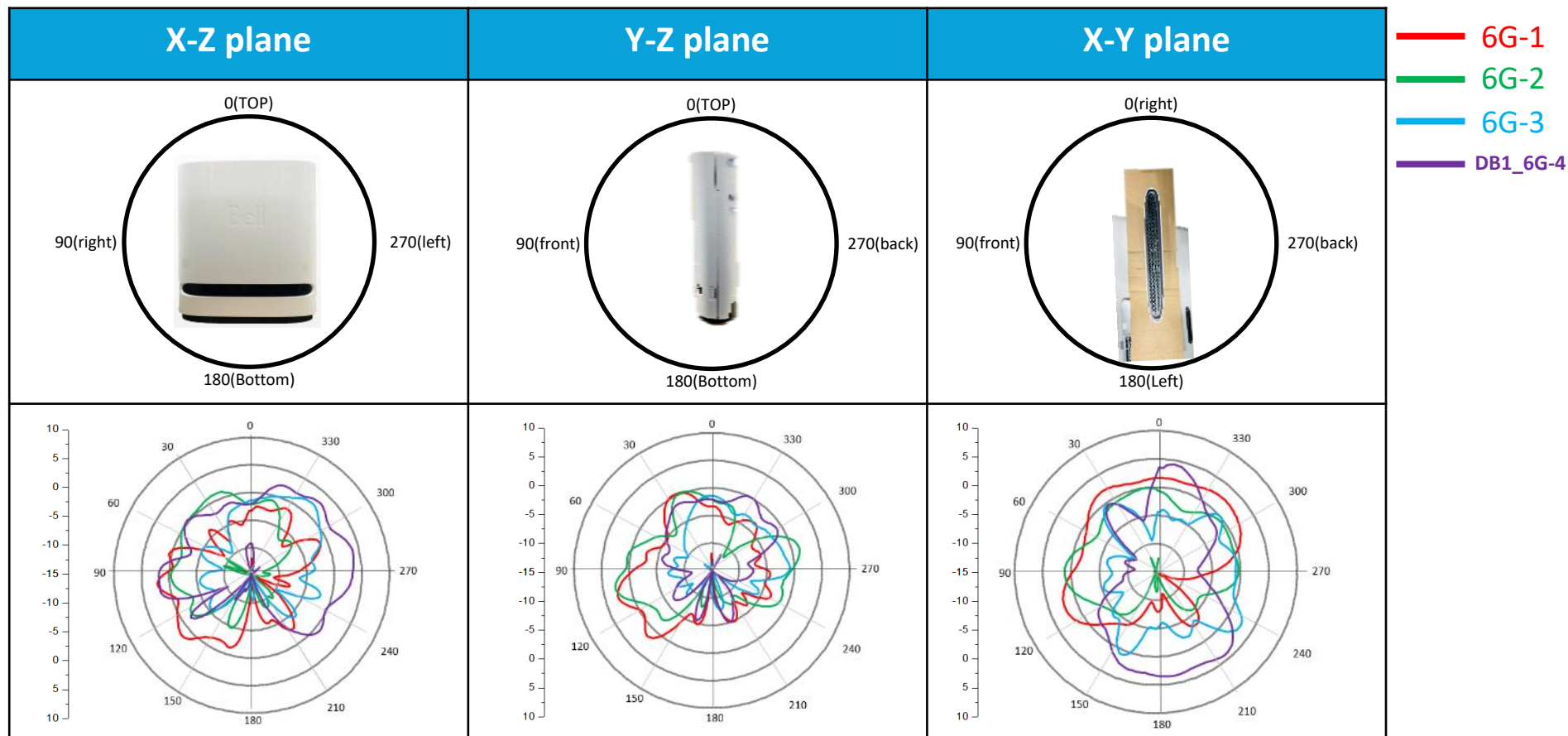
Measurement data

Radiation pattern – 5G Radio#1



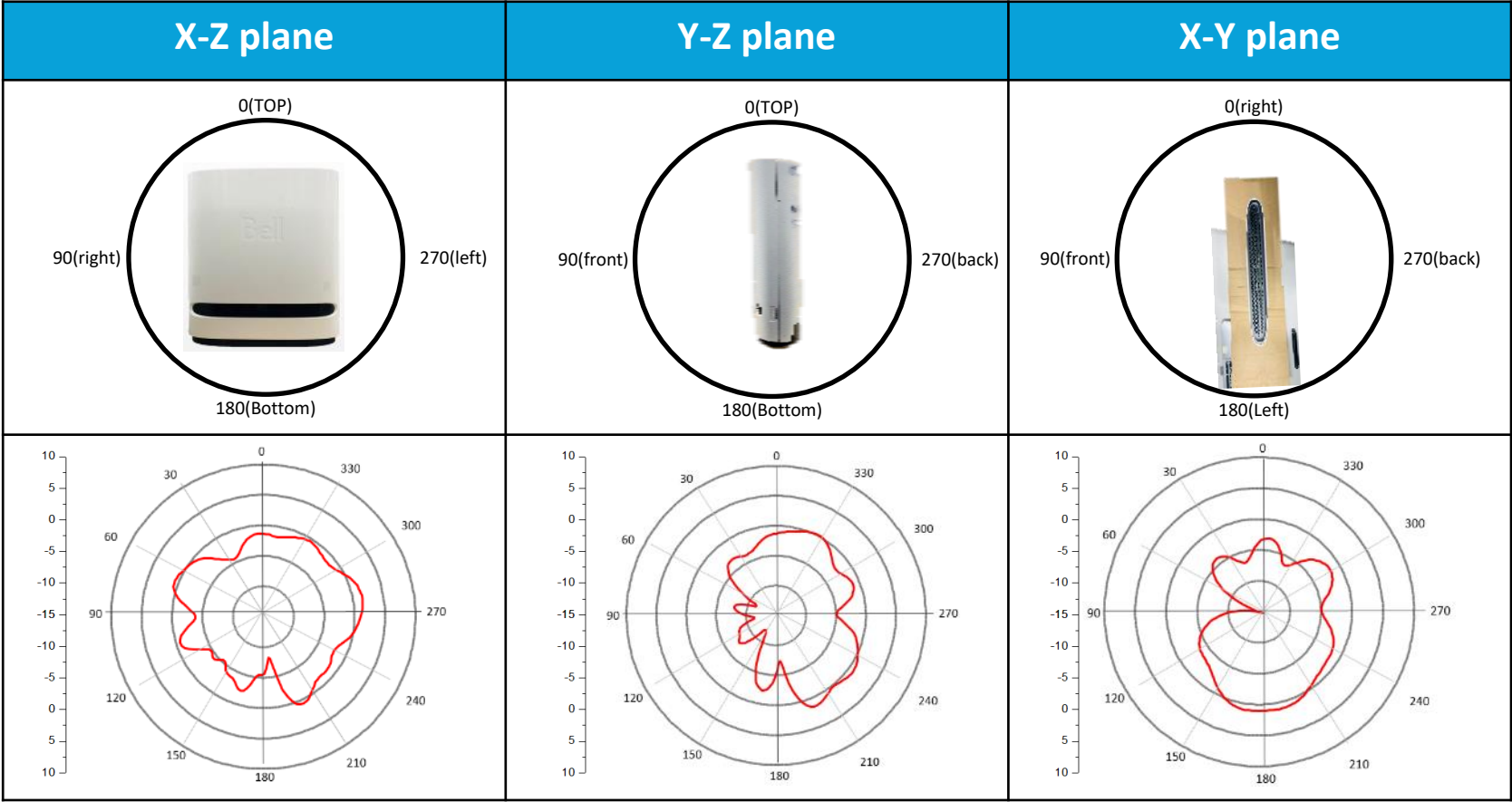
Measurement data

Radiation pattern – 6G Radio#2



Measurement data

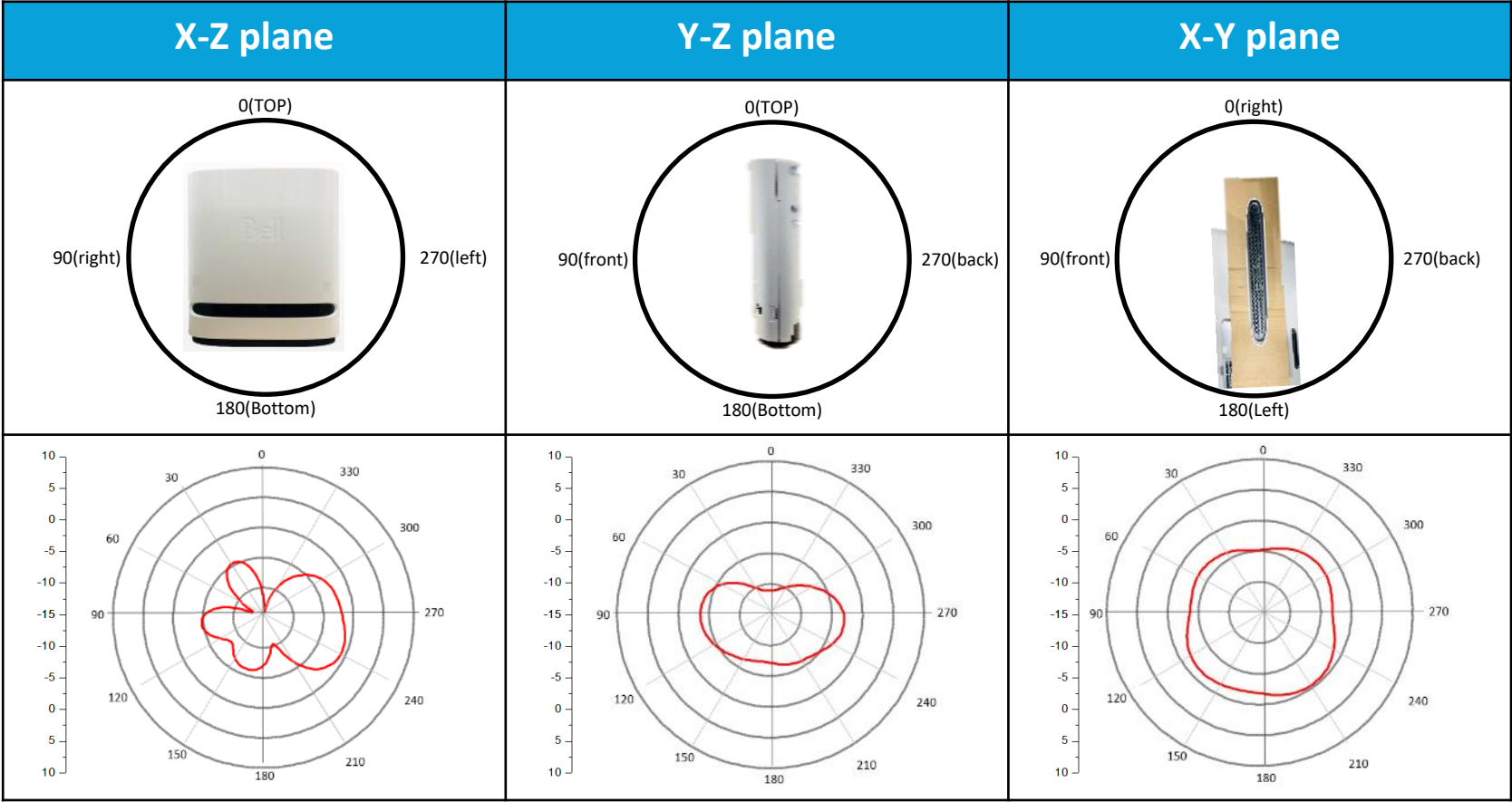
Radiation pattern – Zigbee



— Zigbee

Measurement data

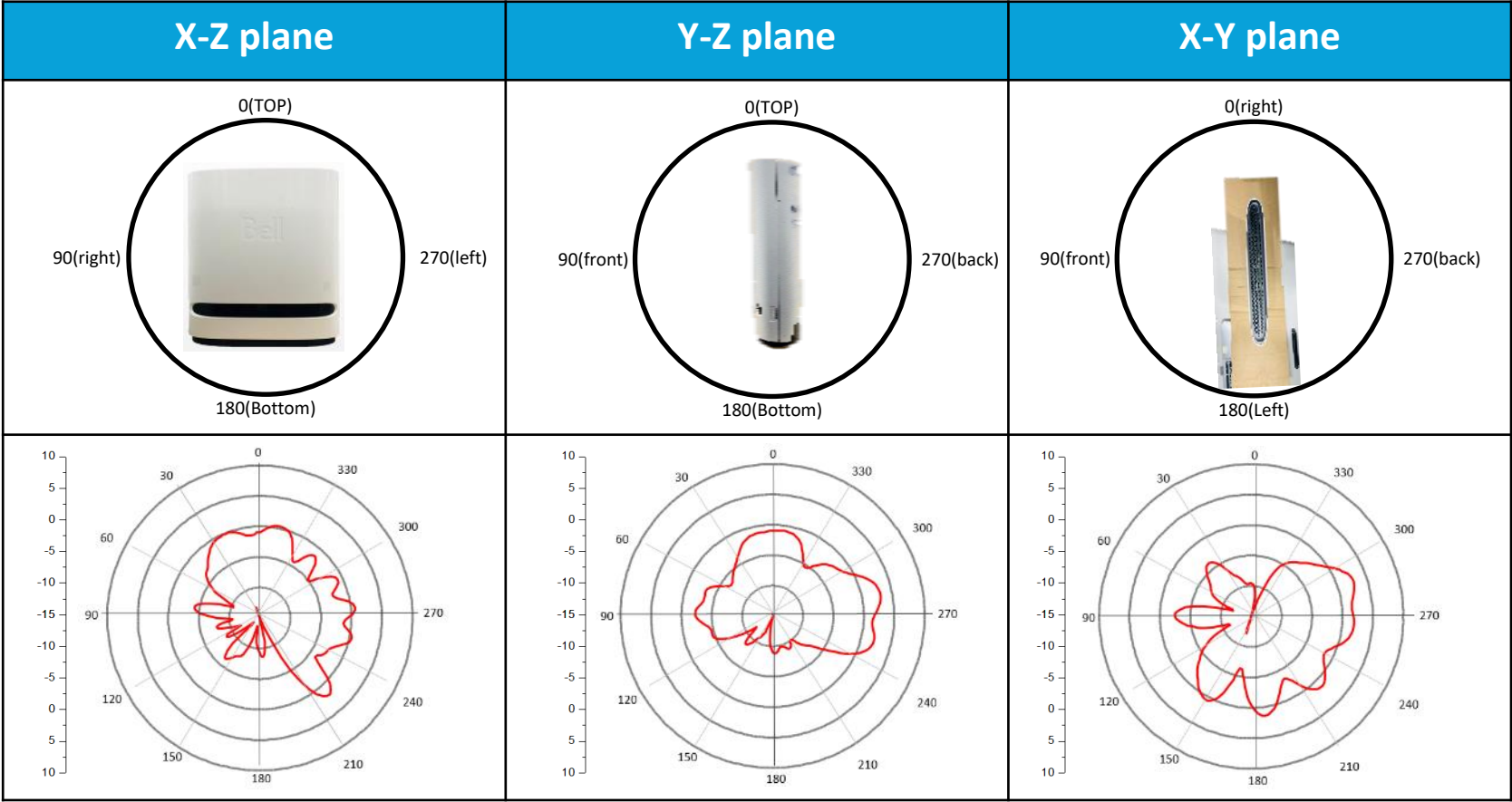
Radiation pattern – Z-wave



— Z-wave

Measurement data

Radiation pattern – DFS



— DFS

Measurement data

❖ Gain table: 2G-1 antenna

Frequency (MHz)	XZ plane		YZ plane		XY plane		E-total (dBi)	Efficiency (%)
	Peak Gain (dBi)	Average Gain (dBi)	Peak Gain (dBi)	Average Gain (dBi)	Peak Gain (dBi)	Average Gain (dBi)		
2400	2.23	-5.54	-0.59	-4.5	1.71	-2.1	2.38	67%
2450	1.88	-5.46	-0.46	-4.41	1.67	-2.15	1.90	66%
2500	1.62	-5.72	-0.4	-4.55	1.3	-2.45	1.63	65%

Measurement data

❖ Gain table: 2G-2 antenna

Frequency (MHz)	XZ plane		YZ plane		XY plane		E-total (dBi)	Efficiency (%)
	Peak Gain (dBi)	Average Gain (dBi)	Peak Gain (dBi)	Average Gain (dBi)	Peak Gain (dBi)	Average Gain (dBi)		
2400	1.91	-5.75	0.16	-4	1.18	-2.05	1.91	65%
2450	1.35	-5.69	0.13	-3.96	1.02	-2.39	1.44	66%
2500	0.58	-5.89	0.23	-4.11	0.47	-2.72	1.50	64%

Measurement data

❖ Gain table: 2G-3 antenna

Frequency (MHz)	XZ plane		YZ plane		XY plane		E-total (dBi)	Efficiency (%)
	Peak Gain (dBi)	Average Gain (dBi)	Peak Gain (dBi)	Average Gain (dBi)	Peak Gain (dBi)	Average Gain (dBi)		
2400	1.42	-6.48	2.48	-1.19	0.14	-3.85	2.62	66%
2450	1.61	-6.48	2.58	-1.24	-0.04	-4.02	2.75	65%
2500	2.22	-6.42	2.84	-1.06	0.63	-3.71	2.95	67%

Measurement data

❖ Gain table: Dual-Band 2 (2.4G) antenna

Frequency (MHz)	XZ plane		YZ plane		XY plane		E-total (dBi)	Efficiency (%)
	Peak Gain (dBi)	Average Gain (dBi)	Peak Gain (dBi)	Average Gain (dBi)	Peak Gain (dBi)	Average Gain (dBi)		
2400	1.55	-1.05	0.46	-4.3	0.77	-3.77	1.64	68%
2450	1.38	-0.77	0.89	-4.1	0.22	-3.98	2.58	65%
2500	0.59	-0.84	-0.38	-4.46	0.02	-4.15	2.79	66%

Measurement data

❖ Gain table: 5G-1 antenna

Frequency (MHz)	XZ plane		YZ plane		XY plane		E-total (dBi)	Efficiency (%)
	Peak Gain (dBi)	Average Gain (dBi)	Peak Gain (dBi)	Average Gain (dBi)	Peak Gain (dBi)	Average Gain (dBi)		
5150	1.68	-6.01	3.09	-4.21	3.06	-2.54	3.53	64%
5350	1.37	-5.66	2.75	-3.91	2.98	0.18	3.25	63%
5470	1.85	-5.91	2.66	-3.82	2.9	-0.34	3.88	65%
5725	1.46	-6.17	2.45	-3.53	2.19	-1.37	3.02	63%
5850	1.55	-4.94	2.05	-3.27	1.73	-2.19	3.25	64%

Measurement data

❖ Gain table: 5G-2 antenna

Frequency (MHz)	XZ plane		YZ plane		XY plane		E-total (dBi)	Efficiency (%)
	Peak Gain (dBi)	Average Gain (dBi)	Peak Gain (dBi)	Average Gain (dBi)	Peak Gain (dBi)	Average Gain (dBi)		
5150	1.04	-5.86	2.38	-4.06	2.27	-2.19	3.51	67%
5350	1.52	-6.17	1.77	-4.10	1.44	-2.30	3.02	62%
5470	1	-5.44	1.65	-4.61	1.82	-2.91	2.86	65%
5725	1.13	-6.42	2.01	-3.88	3.17	-2.87	3.46	62%
5850	1.2	-6.27	3.38	-4.62	1.36	-3.10	3.43	60%

Measurement data

❖ Gain table: 5G-3 antenna

Frequency (MHz)	XZ plane		YZ plane		XY plane		E-total (dBi)	Efficiency (%)
	Peak Gain (dBi)	Average Gain (dBi)	Peak Gain (dBi)	Average Gain (dBi)	Peak Gain (dBi)	Average Gain (dBi)		
5150	0.45	-5	-1.04	-5.74	2.47	-3.09	4.41	64%
5350	1.2	-4.68	-0.86	-5.52	2.76	-2.82	3.61	62%
5470	2.33	-4.8	-1.44	-5.43	3.13	-2.68	4.07	63%
5725	3.22	-4.75	1.46	-4.18	3.65	-2.07	4.04	64%
5850	3.5	-4.54	0.13	-5.08	2.46	-2.06	4.53	67%

Measurement data

❖ Gain table: Dual Band 2 (5G) antenna

Frequency (MHz)	XZ plane		YZ plane		XY plane		E-total (dBi)	Efficiency (%)
	Peak Gain (dBi)	Average Gain (dBi)	Peak Gain (dBi)	Average Gain (dBi)	Peak Gain (dBi)	Average Gain (dBi)		
5150	2.88	-2.77	-1.72	-6.45	0.6	-4.87	3.37	62%
5350	1.98	-2.89	0.88	-5.11	1.12	-3.40	4.87	62%
5470	2.69	-2.97	1.29	-4.86	4.3	-2.47	4.73	67%
5725	3.36	-3.30	-0.2	-4.86	4.24	-3.48	4.24	65%
5850	3.24	-2.40	1.39	-3.88	4.36	-2.80	4.89	68%

Measurement data

❖ Gain table: 6G-1 antenna

Frequency (MHz)	XZ plane		YZ plane		XY plane		E-total (dBi)	Efficiency (%)
	Peak Gain (dBi)	Average Gain (dBi)	Peak Gain (dBi)	Average Gain (dBi)	Peak Gain (dBi)	Average Gain (dBi)		
5925	2.18	-4.42	2.64	-4.17	2.65	-2.28	3.73	64%
6425	2.05	-6.09	0.42	-5.21	-0.6	-3.81	2.5	60%
6525	1.44	-6.25	1.16	-4.40	-1.81	-5.45	3.9	62%
6875	0.94	-5.95	2.48	-3.80	-0.22	-5.85	2.77	62%
7125	1.45	-6.17	4.09	-3.93	-2.15	-7.66	4.13	61%

Measurement data

❖ Gain table: 6G-2 antenna

Frequency (MHz)	XZ plane		YZ plane		XY plane		E-total (dBi)	Efficiency (%)
	Peak Gain (dBi)	Average Gain (dBi)	Peak Gain (dBi)	Average Gain (dBi)	Peak Gain (dBi)	Average Gain (dBi)		
5925	-1.18	-7.55	1.09	-3.88	2.77	-3.36	2.89	56%
6425	0.02	-6.13	1.14	-3.60	2.22	-2.66	2.28	57%
6525	1.16	-6.34	2.36	-4.20	1.48	-3.49	2.52	59%
6875	1.17	-6.91	2.74	-4.61	1.14	-4.20	2.74	60%
7125	1.2	-7.04	2.33	-4.52	0.04	-4.51	2.52	56%

Measurement data

❖ Gain table: 6G-3 antenna

Frequency (MHz)	XZ plane		YZ plane		XY plane		E-total (dBi)	Efficiency (%)
	Peak Gain (dBi)	Average Gain (dBi)	Peak Gain (dBi)	Average Gain (dBi)	Peak Gain (dBi)	Average Gain (dBi)		
5925	2.07	-5.08	-0.79	-6.48	2.76	-3.09	3.58	57%
6425	2.1	-6.50	1.56	-5.90	1.77	-3.57	2.60	58%
6525	1.76	-6.90	1.65	-5.81	1.6	-3.66	3.44	55%
6875	2.72	-6.94	-0.79	-7.98	3.09	-4.03	4.51	57%
7125	2.03	-5.98	1.08	-7.03	1.07	-3.48	3.04	56%

Measurement data

❖ Gain table: Dual Band 1 (6G) antenna

Frequency (MHz)	XZ plane		YZ plane		XY plane		E-total (dBi)	Efficiency (%)
	Peak Gain (dBi)	Average Gain (dBi)	Peak Gain (dBi)	Average Gain (dBi)	Peak Gain (dBi)	Average Gain (dBi)		
5925	3.85	-3.17	0.09	-6.90	4.29	-2.30	4.49	68%
6425	2.58	-2.95	0.31	-7.45	3.93	-3.06	4.72	64%
6525	2.84	-2.52	0.31	-6.71	4.39	-3.33	4.83	63%
6875	3.89	-2.96	1.42	-6.20	3.26	-4.02	3.92	60%
7125	2.97	-3.15	3.03	-4.92	2.42	-3.66	3.64	61%

Measurement data

❖ Gain table: Zigbee antenna

Frequency (MHz)	XZ plane		YZ plane		XY plane		E-total (dBi)	Efficiency (%)
	Peak Gain (dBi)	Average Gain (dBi)	Peak Gain (dBi)	Average Gain (dBi)	Peak Gain (dBi)	Average Gain (dBi)		
2400	1.53	-1.86	1.55	-4.06	1.07	-3.94	2.62	65%
2450	1.54	-2.13	0.19	-4.70	0.93	-3.17	2.78	64%
2500	2.85	-1.97	1.44	-3.74	0.99	-3.40	2.98	66%

Measurement data

❖ Gain table: Z-wave antenna

Frequency (MHz)	XZ plane		YZ plane		XY plane		E-total (dBi)	Efficiency (%)
	Peak Gain (dBi)	Average Gain (dBi)	Peak Gain (dBi)	Average Gain (dBi)	Peak Gain (dBi)	Average Gain (dBi)		
908	-0.82	-5.68	-2.87	-6.26	-0.46	-2.58	-0.34	47%
913	-0.97	-5.73	-2.88	-6.42	-0.57	-2.7	-0.44	48%
916	-1.3	-5.95	-3.1	-6.72	-0.86	-3	-0.73	46%

Measurement data

❖ Gain table: DFS antenna

Frequency (MHz)	XZ plane		YZ plane		XY plane		E-total (dBi)	Efficiency (%)
	Peak Gain (dBi)	Average Gain (dBi)	Peak Gain (dBi)	Average Gain (dBi)	Peak Gain (dBi)	Average Gain (dBi)		
5150	1.63	-3.78	1.25	-5.44	3.15	-2.38	3.44	52%
5350	1.21	-4.05	2.86	-4.68	1.97	-3.58	3.14	56%
5470	1.96	-3.84	3.11	-3.7	2.78	-2.77	3.25	53%
5725	2.81	-4.33	3.91	-2.72	3.54	-2.87	4.12	52%
5850	2.53	-5.11	4.74	-2.73	4.02	-3.86	4.83	53%

Directional Gain Equation

Refer to FCC KDB 662911 D01 Multiple Transmitter Output, unequal antenna gains, with equal transmit powers. For antenna gains given by $G_1, G_2, \dots, G_N$ dBi

Basic methodology with N_{ANT} transmit antennas, each with the same directional gain G_{ANT} dBi, being driven by N_{ANT} transmitter outputs of equal power. Directional gain is to be computed as follows:

If all antennas have the same gain, G_{ANT} , Directional gain = G_{ANT} + Array Gain, where Array Gain is as follows.

For power spectral density (PSD) measurements on all devices,
Array Gain = $10 \log(N_{ANT}/N_{SS})$ dB.

For power measurements on IEEE 802.11 devices,
Array Gain = 0 dB (i.e., no array gain) for $N_{ANT} \leq 4$;
Array Gain = 0 dB (i.e., no array gain) for channel widths ≥ 40 MHz for any N_{ANT} ;

If transmit signals are correlated, then

Directional gain = $10 \log[(10^{G_1/20} + 10^{G_2/20} + \dots + 10^{G_N/20})^2 / N_{ANT}]$ dBi [Note the “20”s in the denominator of each exponent and the square of the sum of terms; the object is to combine the signal levels coherently.]

Used the OTA test site to test site to test the antenna gain with each angle, and calculated the directional antenna gain per each angle, and searched out the highest directional antenna gain.

Measurement data

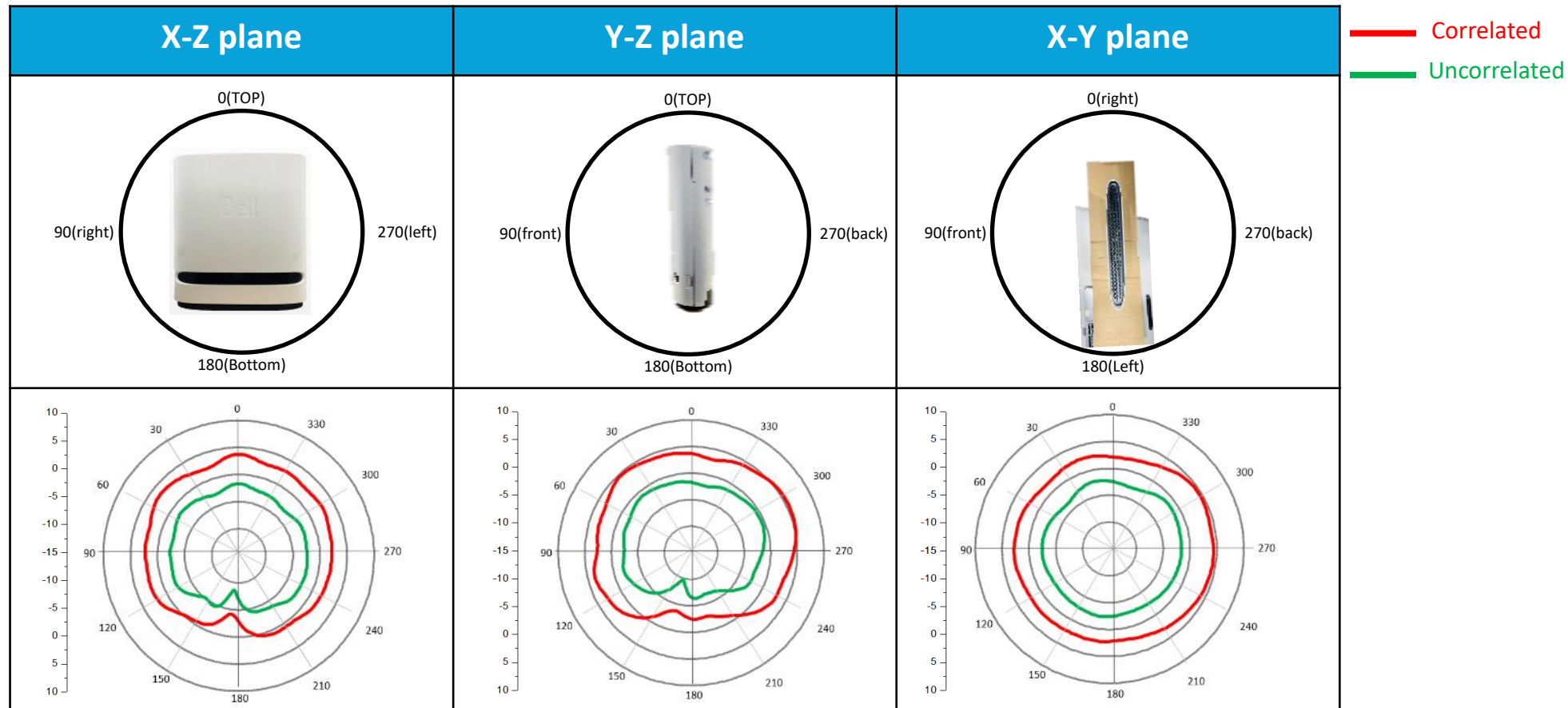
❖ Directional gain table

	Peak Gain of 3D Directional pattern				
	Correlated	Uncorrelated		Correlated	Uncorrelated
2400	6.00	0.04	-	-	-
2450	6.32	0.42	-	-	-
2500	6.40	0.53	-	-	-
	5G Radio#1			6G Radio#2	
5150	6.46	1.16	5925	7.03	1.11
5350	6.45	1.13	6425	6.20	0.75
5470	6.54	0.99	6525	5.99	0.58
5725	6.85	1.18	6875	6.18	0.79
5850	6.90	1.27	7125	6.04	0.12

Unit: dBi

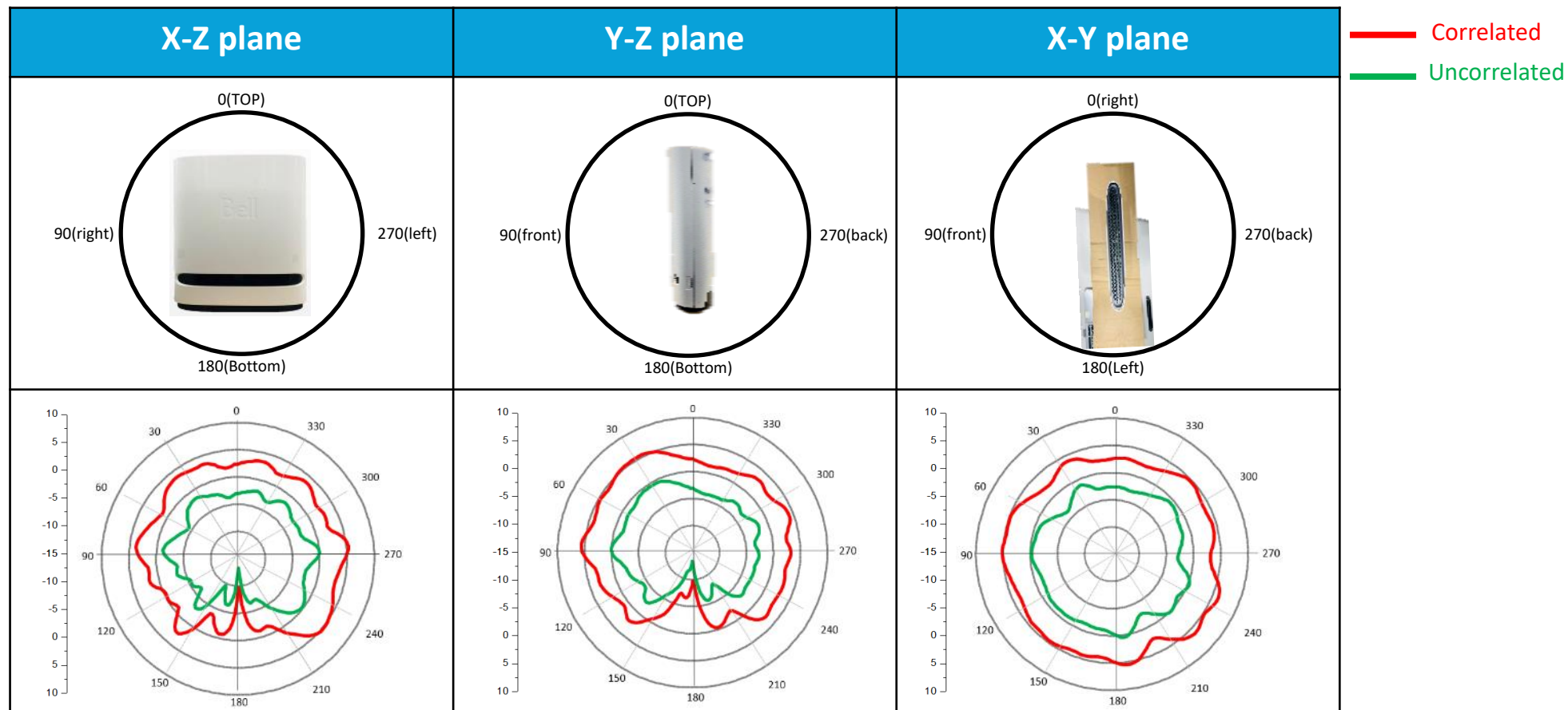
Measurement data

Radiation pattern – 2.4G Directional gain (Correlated &Uncorrelated)



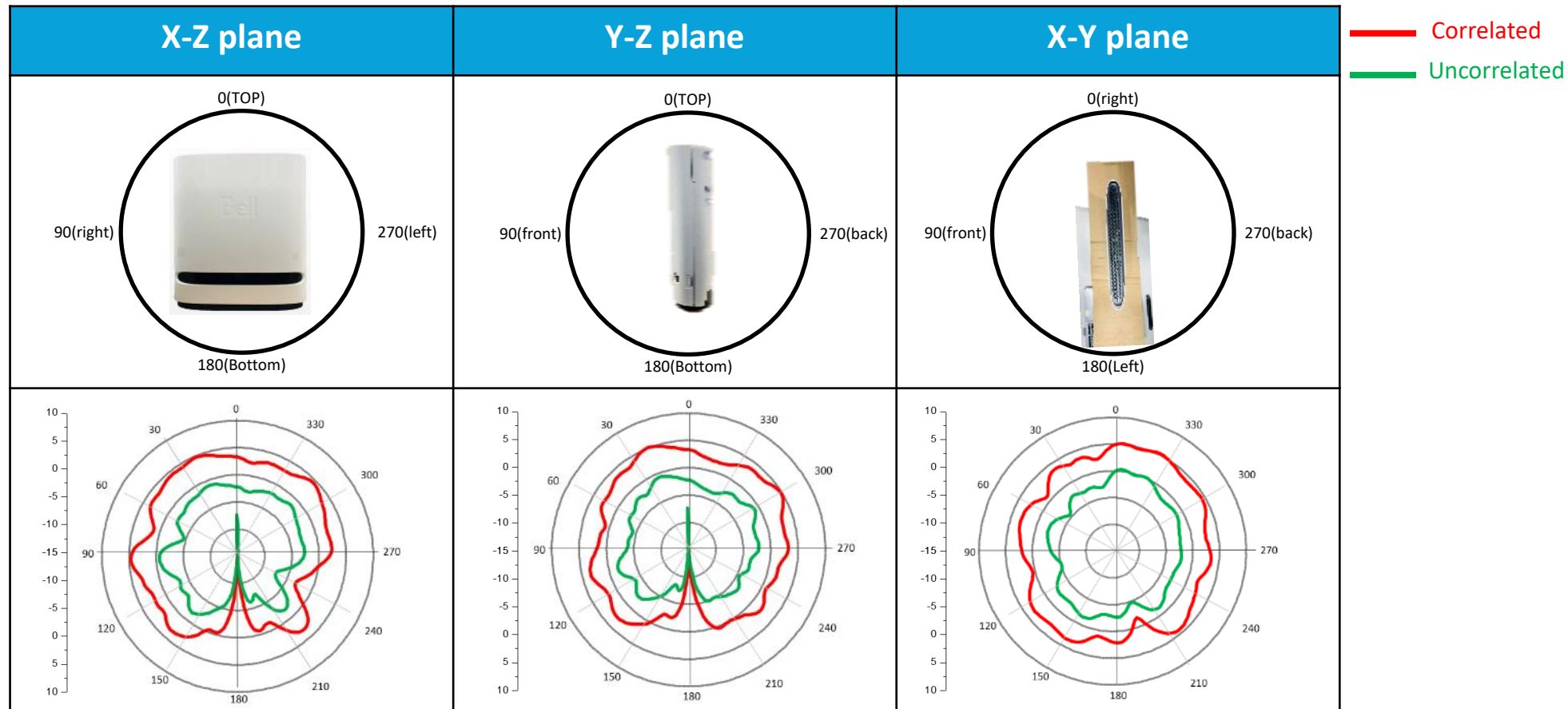
Measurement data

Radiation pattern – 5G Directional gain (Correlated &Uncorrelated)



Measurement data

Radiation pattern – 6G Directional gain (Correlated &Uncorrelated)



Contents

- ❖ Antenna specification
- ❖ Antenna placement and cable routing
- ❖ Measurement data
- ❖ Summary

Summary

◆ Return loss

- ▶ OK

◆ Isolation

- ▶ 5G to 6G isolation is under -26dB.
- ▶ 5G to 5G ,6G to 6G and 2.4G to 5G/6G are under -20dB.

◆ Peak gain & Radiation result

- ▶ 2.4G antennas peak gain can meet Spec(<4dBi). The **Uncorrelated** directional is under 2dBi.
- ▶ 5G/6G antennas peak gain can meet Spec(<5dBi). The **Uncorrelated** directional is under 3dBi.

Summary

◆ Efficiency

- ▶ 6G2 & 6G3 antenna have lower efficiency (55%) due to long RF trace .From path loss point of view , it is around 0.5dB loss .

From RF design point of view:

- ▶ Because of the Zigbee module, the RF path is too long due to space limitations.
- ▶ Considering the RF performance, the RF connector should be close to FEM.
- ▶ WiFi FEM close connector to reduce trace loss between FEM and connector and get good Tx power.

