



Antenna Composite Gain Test Report

Equipment	802.11ax 6E Wireless Access Point
Brand Name	Juniper
Model Name	AP45
Applicant	Juniper Networks, Inc. 1133 Innovation Way Sunnyvale, California 94089 USA
Manufacturer	Juniper Networks, Inc. 1133 Innovation Way Sunnyvale, California 94089 USA
Sample Received	Sep. 24, 2021
Start Test Date	Mar. 10, 2022
Final Test Date	Mar. 15, 2022



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1. Operation Mode and Antenna Information

Antenna Position	Brand Name	Model Name	Ant. Type	Connector
2G 5GAnt1	Juniper	AP45	PIFA	I-PEX
2G 5GAnt2	Juniper	AP45	PIFA	I-PEX
2G 5GAnt3	Juniper	AP45	PIFA	I-PEX
2G 5GAnt4	Juniper	AP45	PIFA	I-PEX
5G Ant1	Juniper	AP45	PIFA	I-PEX
5G Ant2	Juniper	AP45	PIFA	I-PEX
5G Ant3	Juniper	AP45	PIFA	I-PEX
5G Ant4	Juniper	AP45	PIFA	I-PEX

Note:

Operation Mode (4TX/4RX)

2G 5GAnt1~2G 5GAnt4 can be used as transmitting/receiving antenna.

2G 5GAnt1~2G 5GAnt4 could transmit/receive simultaneously.

5G Ant1~5G Ant4 can be used as transmitting/receiving antenna.

5G Ant1~5G Ant4 could transmit/receive simultaneously.

Antenna operation of 2G 5GAnt1~2G 5GAnt4 and 5G Ant1~5G Ant4 have two kinds of operation mode:

Operation mode 1: 5GHz UNII 1~UNII 3 (2G 5GAnt1~2G 5GAnt4)+2.4GHz(2G 5GAnt1~2G 5GAnt4): The antenna operation was limited to the same 4x4 MIMO.

Operation mode 2: 5GHz UNII 2C, UNII 3 (2G 5GAnt1~2G 5GAnt4)+5GHz UNII 1, UNII 2A (5G Ant1~5G Ant4): The antenna operation was limited to the 4x4 MIMO.

2. Test Frequency

The middle frequency of each bands are selected to represent each frequency bands.

Band [MHz]	Test Frequency [MHz]
2400-2483.5	2450
5150-5250	5200
5250-5350	5300
5470-5725	5600
5725-5850	5785

3. Testing Location

Testing Location		
<input checked="" type="checkbox"/>	HWA YA	ADD : No.13-1 & 14-1, Ln. 19, Wen 33rd St., Guishan Dist., Taoyuan City 333, Taiwan R.O.C.

Test Condition	Test Site No.	Test Engineer	Test Environment (°C / %)	Test Date
Radiated	05CH03-HY	Rex Liao	23.5-24.5 / 50-55	Mar. 10, 2022~Mar. 15, 2022

Note:

Testing Site Information

Brand Name: TDK

Dimension: 11m*6m*6m

Characteristic: Fully Anechoic Chamber

4. Test Facility and Configuration

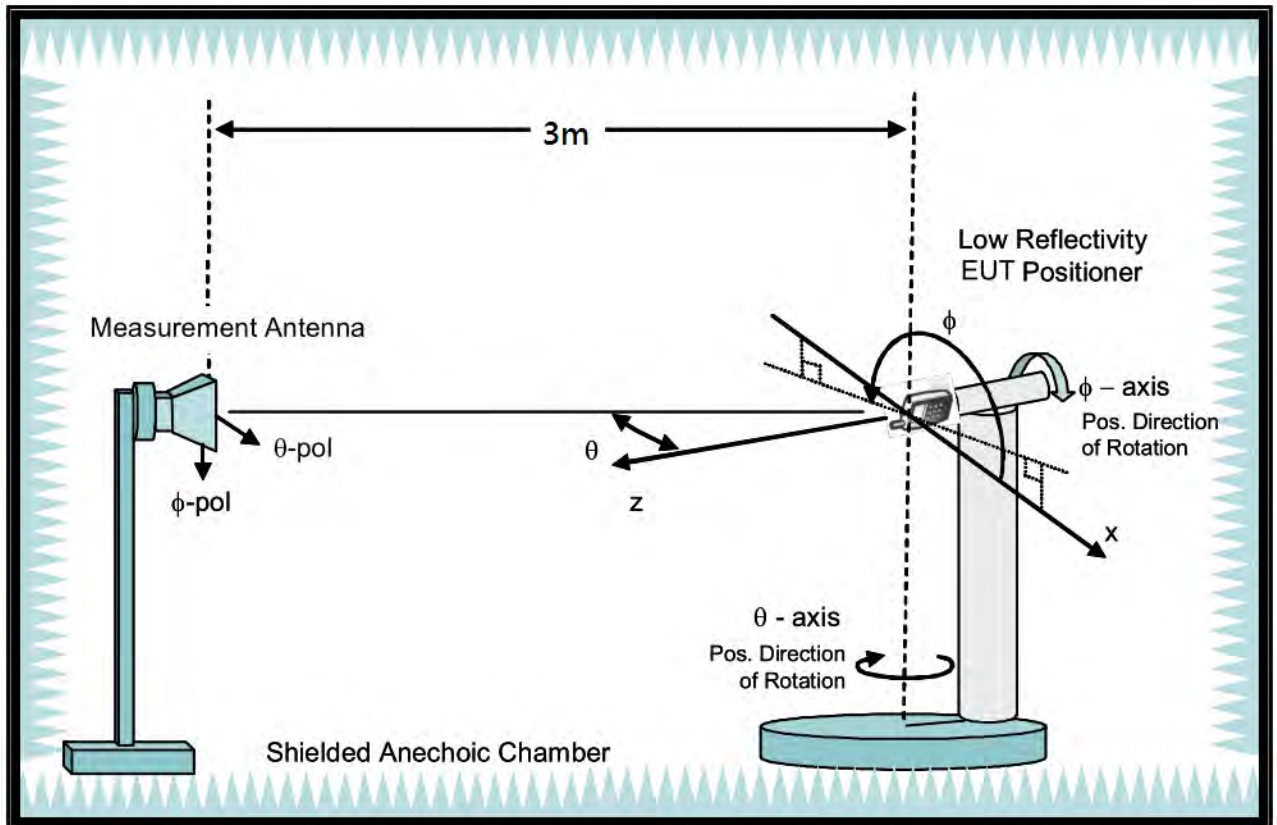
Test configuration: Reference to CITA OTA distributed-axes system configuration.

Chamber: Fully Anechoic Chamber.

Measurement antenna: Single Polarization Horn antenna calibrated according to ANSI C63.5.

Turntable: Multi-axis positioner (Theta and Phi angle).

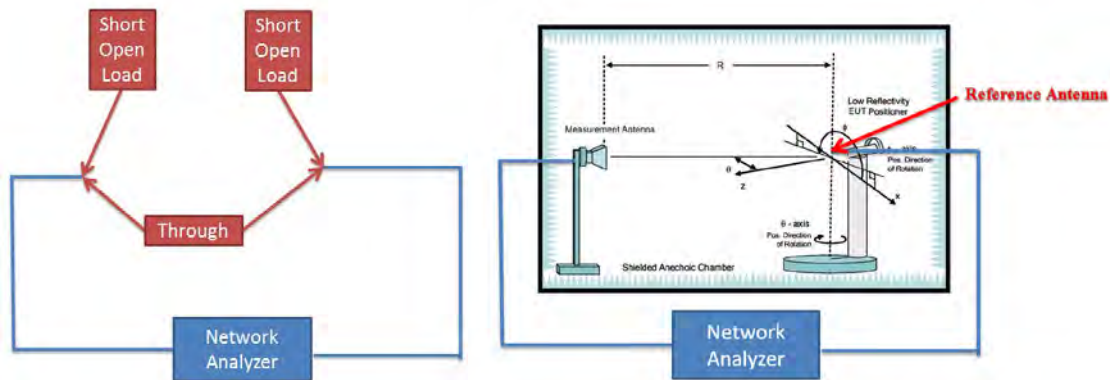
#Reference to CTIA “ctia-test-plan-for-wireless-device-over-the-air-performance-ver-3-7-1”



5. Reference Calibration

Connected cables to VNA calibration kit and use network analyzer internal function to do calibration. Do short, open and load to each side. Then connect through to both side and calibrate S21 values. The cable loss is calibrated and set inside the network analyzer.

Measurement Antenna is connected to port1 of Network analyzer and reference antenna connected to port 2 of Network Analyzer. Record S21 values and used with reference antenna gain to calculate gain factor.



Frequency (MHz)	2400	2450	2500	5150	5200	5300	5600	5750	5800	5900	6000	6500	7000	7500
S21 values (dBi)	-31.4	-31.4	-31.3	-31.3	-31	-30.7	-30.1	-30.5	-30.5	-30.8	-31.3	-32.8	-34.4	-35.4
Reference gain (dBi)	10.2	10.4	10.6	12.4	12.8	13.4	13.4	13.3	13.3	13.1	13.2	12.3	11.7	11.1
Factor (dB)	41.63	41.81	41.89	43.72	43.78	44.12	43.5	43.78	43.76	43.88	44.45	45.14	46.08	46.51



6. Test Method

EUT set on multi-axis positioner and adjust EUT's physical center to measurement reference center. Measurement antenna set at phi polarization and 1.5 meter height. Port 1 of Network analyzer connect to antenna 1 of EUT. Record S21 value every 15 degree from 0 to 345 degree on Phi angle and 0 to 180 on theta angle of multi-axis positioner. Then set measurement antenna to theta polarization and repeat process. Repeat process to each antenna of EUT.



7. Measured Values and Calculation of Maximum Gain Positions

For 2G 5GAnt.1, 2G 5GAnt.2, 2G 5GAnt.3, 2G 5GAnt.4

DG_1SS Max Value Position

Frequency (Hz)	2.45G	5.2G	5.3G	5.6G	5.785G
Ant. 1 (dBi)	-8.88	2.68	-2.56	3.43	0.02
Ant. 2 (dBi)	-1.16	0.74	2.25	1.17	1.52
Ant. 3 (dBi)	1.27	-0.07	0.55	1.06	1.23
Ant. 4 (dBi)	-1.29	-2.44	0.66	-1.77	-0.3
DG [1SS] (dBi)	4.23	6.44	6.41	7.19	6.67
Polarization	Theta	Theta	Theta	Theta	Theta
$\Theta(^{\circ})$	70	60	65	60	65
$\Phi(^{\circ})$	355	345	355	90	355

Note: The DG 1SS max value position is the maximum value of section 11 table DG 1SS Result.

DG_1SS Max Value Position Calculation

Frequency (Hz)	2.45G	5.2G	5.3G	5.6G	5.785G
Ant. 1 [$10^{(G/20)}$]	$10^{(-8.88/20)}$	$10^{(2.68/20)}$	$10^{(-2.56/20)}$	$10^{(3.43/20)}$	$10^{(0.02/20)}$
Ant. 2 [$10^{(G/20)}$]	$10^{(-1.16/20)}$	$10^{(0.74/20)}$	$10^{(2.25/20)}$	$10^{(1.17/20)}$	$10^{(1.52/20)}$
Ant. 3 [$10^{(G/20)}$]	$10^{(1.27/20)}$	$10^{(-0.07/20)}$	$10^{(0.55/20)}$	$10^{(1.06/20)}$	$10^{(1.23/20)}$
Ant. 4 [$10^{(G/20)}$]	$10^{(-1.29/20)}$	$10^{(-2.44/20)}$	$10^{(0.66/20)}$	$10^{(-1.77/20)}$	$10^{(-0.3/20)}$
Ant. 1 [$10^{(G/20)}$] value	0.36	1.361	0.745	1.484	1.002
Ant. 2 [$10^{(G/20)}$] value	0.875	1.089	1.296	1.144	1.191
Ant. 3 [$10^{(G/20)}$] value	1.157	0.992	1.065	1.13	1.152
Ant. 4 [$10^{(G/20)}$] value	0.862	0.755	1.079	0.816	0.966
Sum All Antenna [Amax]	3.254	4.197	4.185	4.574	4.312
DG [$10 \cdot \log(A_{max}^2/N_{ant})$]	4.23	6.44	6.41	7.19	6.67

Note:

Directional Gain (1SS) is the max value of every look angle. Each position value is calculated by KDB662911 D01 d) (i).

$$\text{Directional gain (1SS)} = 10 \cdot \log(10^{(G_{ant1}/20)} + 10^{(G_{ant2}/20)} + 10^{(G_{ant3}/20)} + 10^{(G_{ant4}/20)} + \dots)^2 / N_{ant}$$



DG_4SS Max Value Position

Frequency (Hz)	2.45G	5.2G	5.3G	5.6G	5.785G
Ant. 1 (dBi)	-8.88	2.68	0.34	3.43	0.02
Ant. 2 (dBi)	-1.16	0.74	1.52	1.17	1.52
Ant. 3 (dBi)	1.27	-0.07	2.19	1.06	1.23
Ant. 4 (dBi)	-1.29	-2.44	-3.58	-1.77	-0.3
DG [4SS] (dBi)	-1.28	0.6	0.6	1.35	0.69
Polarization	Theta	Theta	Theta	Theta	Theta
$\Theta(^{\circ})$	70	60	70	60	65
$\Phi(^{\circ})$	355	345	345	90	355

Note: The DG 4SS max value position is the maximum DG 4SS value calculated from section 11 table Gain Result.

DG_4SS Max Value Position Calculation

Frequency (Hz)	2.45G	5.2G	5.3G	5.6G	5.785G
Ant. 1 $((10^{(G/20)})^2)$	0.1294	1.8535	1.0814	2.2029	1.0046
Ant. 2 $((10^{(G/20)})^2)$	0.7656	1.1858	1.4191	1.3092	1.4191
Ant. 3 $((10^{(G/20)})^2)$	1.3397	0.984	1.6558	1.2764	1.3274
Ant. 4 $((10^{(G/20)})^2)$	0.743	0.5702	0.4385	0.6653	0.9333
Sum All Antenna	2.9777	4.5935	4.5948	5.4538	4.6843
DG $[10*\log(\text{sum all}/N_{\text{ant}})]$	-1.28	0.6	0.6	1.35	0.69

Note: Directional Gain (4SS) is the max value of all position. Each position value is calculated by KDB662911 D01 (e) (ii).

$$g_{j,k} = 10^{(G/20)}$$

$$\text{Directional Gain (4SS)} = 10*\log((10^{(G_{\text{ant}1}/20)})^2+(10^{(G_{\text{ant}2}/20)})^2+ (10^{(G_{\text{ant}3}/20)})^2 +(10^{(G_{\text{ant}4}/20)})^2+.....)/N_{\text{ant}})$$



For 5G Ant.1, 5G Ant.2, 5G Ant.3, 5G Ant.4

DG_1SS Max Value Position

Frequency (Hz)	5.2G	5.3G
Ant. 1 (dBi)	2.48	2.1
Ant. 2 (dBi)	1.64	0.69
Ant. 3 (dBi)	1.2	2.72
Ant. 4 (dBi)	1.36	2.89
DG [1SS] (dBi)	7.7	8.16
Polarization	Phi	Phi
$\Theta(^{\circ})$	50	55
$\Phi(^{\circ})$	320	140

Note: The DG 1SS max value position is the maximum value of section 11 table DG 1SS Result.

DG_1SS Max Value Position Calculation

Frequency (Hz)	5.2G	5.3G
Ant. 1 [10^(G/20)]	10^(2.48/20)	10^(2.1/20)
Ant. 2 [10^(G/20)]	10^(1.64/20)	10^(0.69/20)
Ant. 3 [10^(G/20)]	10^(1.2/20)	10^(2.72/20)
Ant. 4 [10^(G/20)]	10^(1.36/20)	10^(2.89/20)
Ant. 1 [10^(G/20)] value	1.33	1.274
Ant. 2 [10^(G/20)] value	1.208	1.083
Ant. 3 [10^(G/20)] value	1.148	1.368
Ant. 4 [10^(G/20)] value	1.169	1.395
Sum All Antenna [Amax]	4.856	5.119
DG [10*log(Amax^2/Nant)]	7.7	8.16

Note:

Directional Gain (1SS) is the max value of every look angle. Each position value is calculated by KDB662911 D01 d) (i).

$$\text{Directional gain (1SS)} = 10 \cdot \log(10^{(G_{ant1}/20)} + 10^{(G_{ant2}/20)} + 10^{(G_{ant3}/20)} + 10^{(G_{ant4}/20)} + \dots)^{2/N_{ant}}$$



DG_4SS Max Value Position

Frequency (Hz)	5.2G	5.3G
Ant. 1 (dBi)	2.48	2.1
Ant. 2 (dBi)	1.64	0.69
Ant. 3 (dBi)	1.2	2.72
Ant. 4 (dBi)	1.36	2.89
DG [4SS] (dBi)	1.7	2.18
Polarization	Phi	Phi
$\Theta(^{\circ})$	50	55
$\Phi(^{\circ})$	320	140

Note: The DG 4SS max value position is the maximum DG 4SS value calculated from section 11 table Gain Result.

DG_4SS Max Value Position Calculation

Frequency (Hz)	5.2G	5.3G
Ant. 1 $((10^{(G/20)})^2)$	1.7701	1.6218
Ant. 2 $((10^{(G/20)})^2)$	1.4588	1.1722
Ant. 3 $((10^{(G/20)})^2)$	1.3183	1.8707
Ant. 4 $((10^{(G/20)})^2)$	1.3677	1.9454
Sum All Antenna	5.9149	6.61
DG $[10*\log(\text{sum all}/N_{\text{ant}})]$	1.7	2.18

Note: Directional Gain (4SS) is the max value of all position. Each position value is calculated by KDB662911 D01 (e) (ii).

$g_{j,k} = 10^{(G/20)}$

Directional Gain (4SS) = $10*\log((10^{(G_{\text{ant}1}/20)})^2+(10^{(G_{\text{ant}2}/20)})^2+ (10^{(G_{\text{ant}3}/20)})^2 +(10^{(G_{\text{ant}4}/20)})^2+.....)/N_{\text{ant}})$



8. Summary of Test Result

For 2G 5G Ant.1, 2G 5G Ant.2, 2G 5G Ant.3, 2G 5G Ant.4

Freq(Hz)	2.45G	5.2G	5.3G	5.6G	5.785G
Ant. 1 Max Gain (dBi)	2.01	2.89	3.7	3.46	2.39
Ant. 2 Max Gain (dBi)	0.66	2.61	2.55	3.04	3.8
Ant. 3 Max Gain (dBi)	2.04	1.94	2.2	2.82	2.54
Ant. 4 Max Gain (dBi)	1.17	3.27	4.06	2.87	2.17
Ant. 1 Polarization/ $\Theta(^{\circ})/\Phi(^{\circ})$	Theta/65/255	Theta/60/340	Theta/60/100	Theta/60/95	Theta/85/195
Ant. 2 Polarization/ $\Theta(^{\circ})/\Phi(^{\circ})$	Theta/60/210	Theta/55/105	Theta/75/355	Theta/65/190	Theta/70/255
Ant. 3 Polarization/ $\Theta(^{\circ})/\Phi(^{\circ})$	Theta/80/5	Theta/70/275	Theta/65/345	Theta/60/340	Theta/70/340
Ant. 4 Polarization/ $\Theta(^{\circ})/\Phi(^{\circ})$	Theta/105/90	Theta/65/175	Theta/65/175	Theta/60/180	Theta/75/105
Max Gain (dBi)	2.04	3.27	4.06	3.46	3.8
DG [1SS] (dBi)	4.23	6.44	6.41	7.19	6.67
DG [2SS] (dBi)	2.04	3.44	4.06	4.19	3.8
DG [4SS] (dBi)	-1.28	0.6	0.6	1.35	0.69

Note:

1. Directional Gain (2SS) = Directional Gain (1SS) – 3dB. If directional gain is less than max gain, use max gain as directional gain.
2. Each antenna max gain is the max value of measurement S21 of theta and phi through all measurement angles.
3. The max gain is the max value of all antennas.

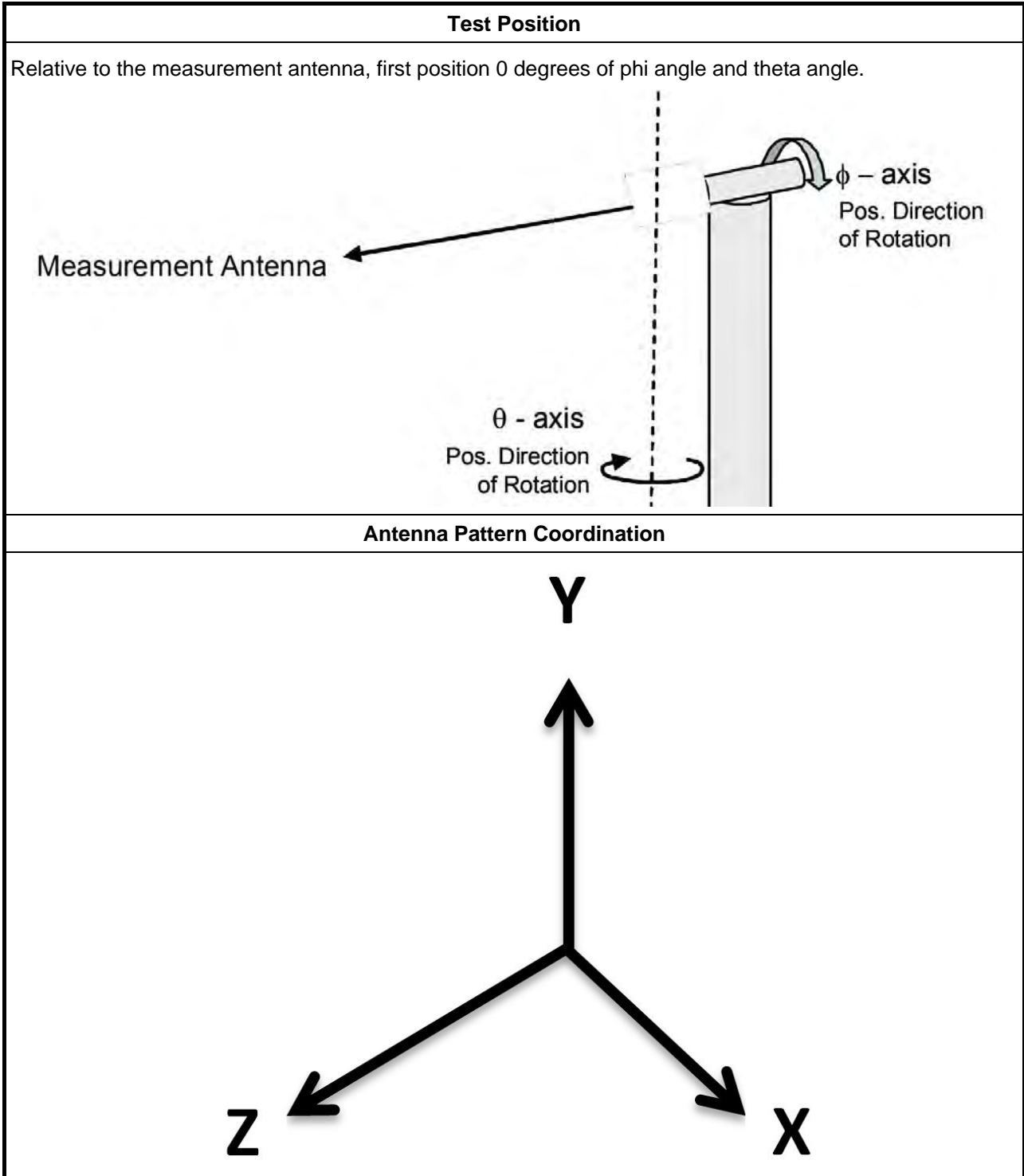
For 5G Ant.1, 5G Ant.2, 5G Ant.3, 5G Ant.4

Freq(Hz)	5.2G	5.3G
Ant. 1 Max Gain (dBi)	3.2	3.56
Ant. 2 Max Gain (dBi)	2.85	3.77
Ant. 3 Max Gain (dBi)	3.37	3.23
Ant. 4 Max Gain (dBi)	3.11	3.68
Ant. 1 Polarization/ $\Theta(^{\circ})/\Phi(^{\circ})$	Phi/45/305	Phi/55/230
Ant. 2 Polarization/ $\Theta(^{\circ})/\Phi(^{\circ})$	Phi/55/330	Phi/60/335
Ant. 3 Polarization/ $\Theta(^{\circ})/\Phi(^{\circ})$	Phi/50/140	Phi/40/215
Ant. 4 Polarization/ $\Theta(^{\circ})/\Phi(^{\circ})$	Phi/55/215	Phi/45/315
Max Gain (dBi)	3.37	3.77
DG [1SS] (dBi)	7.7	8.16
DG [2SS] (dBi)	4.7	5.16
DG [4SS] (dBi)	1.7	2.18

Note:

1. Directional Gain (2SS) = Directional Gain (1SS) – 3dB. If directional gain is less than max gain, use max gain as directional gain.
2. Each antenna max gain is the max value of measurement S21 of theta and phi through all measurement angles.
3. The max gain is the max value of all antennas.

9. Test Setup



Note:

Photos of Test Position: Please refer to the test photos in the appendix.



10. Test Equipment and Calibration Data

Instrument	Brand	Model No.	Serial No.	Characteristics	Calibration Date	Calibration Due Date
Horn Antenna	SCHWARZBECK	BBHA9120D	BBHA 9120D-1292	1GHz~18GHz	Aug. 04, 2021	Aug. 03, 2022
ENA Series Network Analyzer	AGILENT	E5071C	MY46419201	100kHz~8.5GHz	Feb. 21, 2022	Feb. 20, 2023
Test Software	SPORTON	SENSE-RDG	V1.0.6	-	N.C.R.	N.C.R.

Note: Calibration Interval of instruments listed above is one year.

NCR means Non-Calibration required.



11. Test Results

Please refer to the appendix.

Appendix A – Radiated Composite Gain of 2G 5GAnt.1~2G 5GAnt.4Page 16
Appendix B – Radiated Composite Gain of 5G Ant.1~5G Ant.4.....Page 29
Appendix C – Antenna Pattern of 2G 5GAnt.1~2G 5GAnt.4.....Page 35
Appendix D – Antenna Pattern of 5G Ant.1~5G Ant.4..... Page 43
Appendix E – Test Photos..... Page 51



Freq(Hz)	2.45G	5.2G	5.3G	5.6G	5.785G
Ant. 1 Max Gain (dBi)	2.01	2.89	3.7	3.46	2.39
Ant. 2 Max Gain (dBi)	0.66	2.61	2.55	3.04	3.8
Ant. 3 Max Gain (dBi)	2.04	1.94	2.2	2.82	2.54
Ant. 4 Max Gain (dBi)	1.17	3.27	4.06	2.87	2.17
Ant. 1 Polarization/ θ (°)/ ϕ (°)	Theta/65/255	Theta/60/340	Theta/60/100	Theta/60/95	Theta/85/195
Ant. 2 Polarization/ θ (°)/ ϕ (°)	Theta/60/210	Theta/55/105	Theta/75/355	Theta/65/190	Theta/70/255
Ant. 3 Polarization/ θ (°)/ ϕ (°)	Theta/80/5	Theta/70/275	Theta/65/345	Theta/60/340	Theta/70/340
Ant. 4 Polarization/ θ (°)/ ϕ (°)	Theta/105/90	Theta/65/175	Theta/65/175	Theta/60/180	Theta/75/105
Max Gain (dBi)	2.04	3.27	4.06	3.46	3.8
DG [1SS] (dBi)	4.23	6.44	6.41	7.19	6.67
DG [2SS] (dBi)	2.04	3.44	4.06	4.19	3.8
DG [4SS] (dBi)	-1.28	0.6	0.6	1.35	0.69



Freq(Hz)	5.2G	5.3G
Ant. 1 Max Gain (dBi)	3.2	3.56
Ant. 2 Max Gain (dBi)	2.85	3.77
Ant. 3 Max Gain (dBi)	3.37	3.23
Ant. 4 Max Gain (dBi)	3.11	3.68
Ant. 1 Polarization/ $\theta(^{\circ})/\Phi(^{\circ})$	Phi/45/305	Phi/55/230
Ant. 2 Polarization/ $\theta(^{\circ})/\Phi(^{\circ})$	Phi/55/330	Phi/60/335
Ant. 3 Polarization/ $\theta(^{\circ})/\Phi(^{\circ})$	Phi/50/140	Phi/40/215
Ant. 4 Polarization/ $\theta(^{\circ})/\Phi(^{\circ})$	Phi/55/215	Phi/45/315
Max Gain (dBi)	3.37	3.77
DG [1SS] (dBi)	7.7	8.16
DG [2SS] (dBi)	4.7	5.16
DG [4SS] (dBi)	1.7	2.18

