Antenna Composite Gain Test Report

FCC ID	I88EE6510-10
Equipment	Tri-Band Wireless BE18000 10G Ethernet Gateway
Brand Name	ZYXEL
Model Name	EE6510-10
Applicant	Zyxel Communications Corporation No.2 Industry East RD. IX, Hsinchu Science Park, Hsinchu 30075, Taiwan
Manufacturer	Zyxel Communications Corporation No.2 Industry East RD. IX, Hsinchu Science Park, Hsinchu 30075, Taiwan, R.O.C
Standard	KDB662911 D03 v01
Sample Received	May 31, 2024
Start Test Date	Jun. 06, 2024
Final Test Date	Jun. 06, 2024

Approved by: Sam Chen

Sporton International Inc. Hsinchu Laboratory

No.8, Ln. 724, Bo'ai St., Zhubei City, Hsinchu County 302010, Taiwan (R.O.C.)

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History of this test report

Report No.	Version	Description	Issued Date
AP453021	01	Initial issue of report	Dec. 04, 2024

1. Operation Mode and Antenna Information

Antenna Position	RF Port	Brand Name	Model Name	Ant. Type	Connector	Modes of Operation
2G Ant1	1	INPAQ	RFPCA351506IMAB401	PCB	I-Pex	2.4GHz
2G Ant2	2	INPAQ	RFPCA351510IMAB401	PCB	I-Pex	2.4GHz
2G Ant3	3	INPAQ	RFPCA351511IMAB404	PCB	I-Pex	2.4GHz
5G Ant1	1	INPAQ	RFPCA201022IM5B901	PCB	I-Pex	5GHz UNII 1~3
5G Ant2	2	INPAQ	RFPCA201022IM5B902	PCB	I-Pex	5GHz UNII 1~3
5G Ant3	3	INPAQ	RFPCA201027IM5B903	PCB	I-Pex	5GHz UNII 1~3
5G Ant4	4	INPAQ	RFPCA201026IM5B903	PCB	I-Pex	5GHz UNII 1~3
6G Ant1	1	INPAQ	RFDPA100510IM6B902	TUBE	I-Pex	6GHz UNII 5~8
6G Ant2	2	INPAQ	RFDPA100509IM6B902	TUBE	I-Pex	6GHz UNII 5~8
6G Ant3	3	INPAQ	RFDPA100509IM6B903	TUBE	I-Pex	6GHz UNII 5~8
6G Ant4	4	INPAQ	RFDPA100509IM6B904	TUBE	I-Pex	6GHz UNII 5~8

Note:

2.4GHz Operation Mode (3TX/3RX)

2G Ant1~3 can be used as transmitting/receiving antenna.

2G Ant1~3 could transmit/receive simultaneously.

5GHz Operation Mode (4TX/4RX)

5G Ant1~4 can be used as transmitting/receiving antenna.

5G Ant1~4 could transmit/receive simultaneously.

6GHz Operation Mode (4TX/4RX)

6G Ant1~4 can be used as transmitting/receiving antenna.

6G Ant1~4 could transmit/receive simultaneously.

2. Test Frequency

The listed frequency of each bands are selected to represent each frequency bands

Band [MHz]	Test Frequency [MHz]
2400-2483.5	2400
	2450
	2483.5
5150-5250	5200
5250-5350	5300
5470-5725	5600
5725-5850	5785
5925-6425	6175
6425-6525	6475
6525-6875	6695
6875-7125	6995

3. Testing Location

Testing Location		
Sporton International Inc. Hsinhua Laboratory		
☒	HWA YA	ADD : No.13-1 & 14-1, Ln. 19, Wen 33rd St., Guishan Dist., Taoyuan City 333, Taiwan R.O.C.

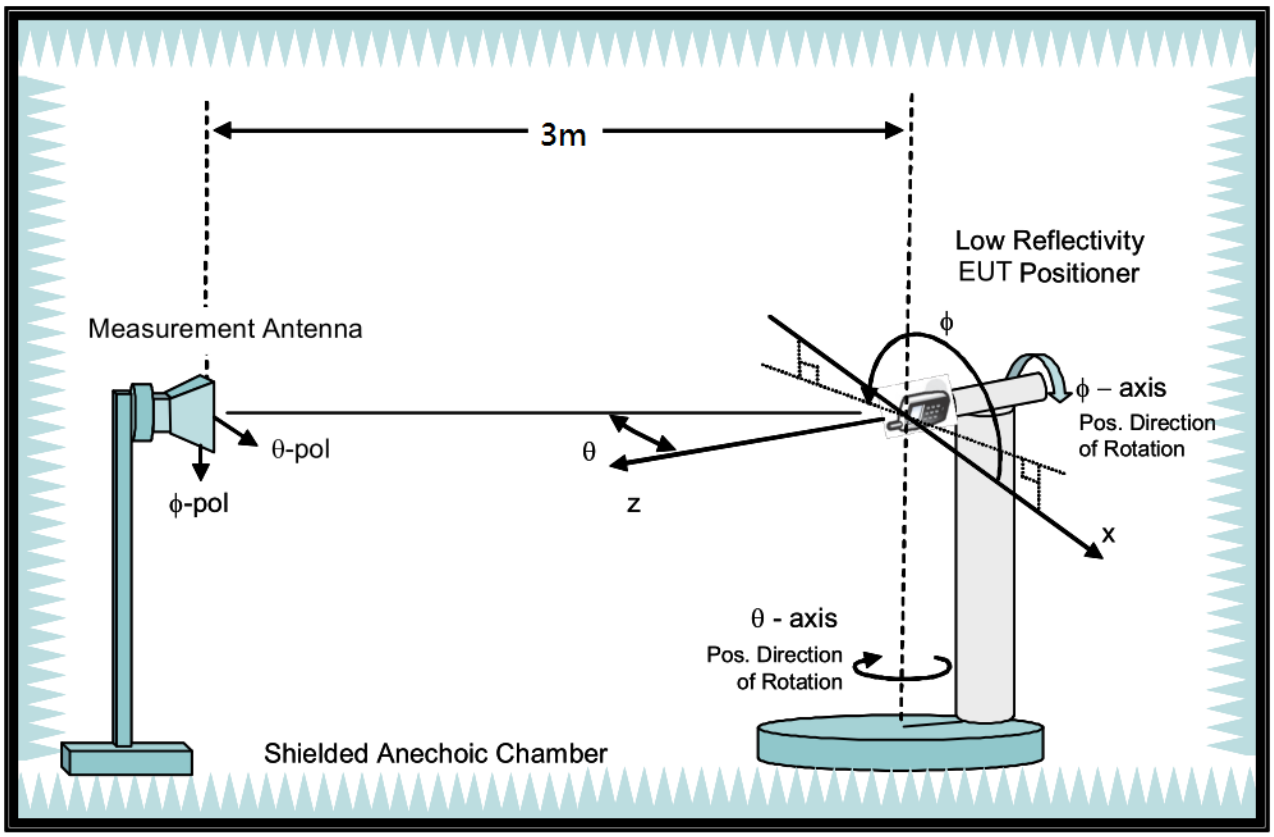
Test Condition	Test Site No.	Test Engineer	Test Environment (°C / %)	Test Date
Radiated	05CH03-HY	Rofy Chen	23.5~24.5 / 45~55	Jun. 06, 2024

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: Dual Polarization Horn antenna
Turntable: Multi-axis positioner (Theta and Phi angle).

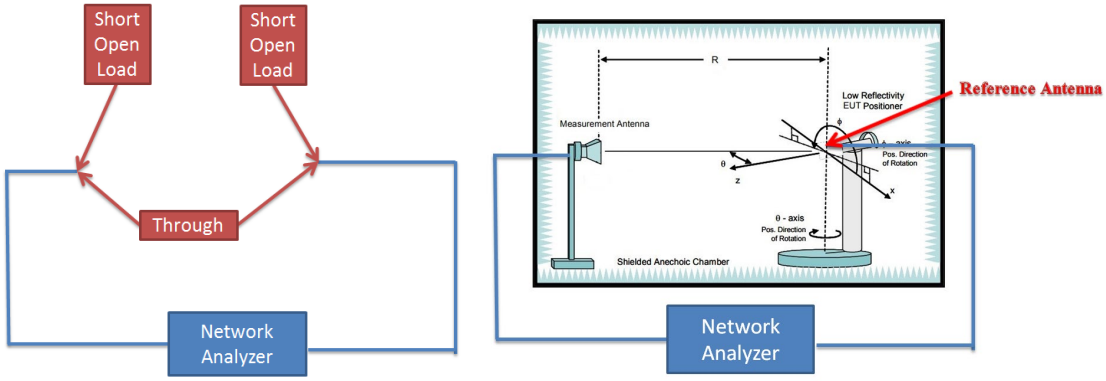
#Reference to CTIA “ctia-test-plan-for-wireless-device-over-the-air-performance-ver-3-7-1”



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 G 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 G 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	7200
G(theta) reading (dB)	-33.55	-33.38	-32.91	-32.29	-32.48	-32.25	-32.33	-32.85	-32.67	-33.37	-32.53	-33.75	-34.72	-35.33
G(phi) reading (dB)	-33.11	-32.68	-32.48	-32.45	-32.85	-31.35	-32.76	-32.68	-32.57	-32.81	-32.85	-33.62	-34.33	-35.29
Reference gain (dBi)	10.3	10.3	10.1	11.1	11.3	11.7	12.1	11.5	11.2	11.1	11.3	11	11.1	10.5
Factor(theta) (dB)	43.85	43.68	43.01	43.39	43.78	43.95	44.43	44.35	43.87	44.47	43.83	44.75	45.82	45.83
Factor(phi) (dB)	43.41	42.98	42.58	43.55	44.15	43.05	44.86	44.18	43.77	43.91	44.15	44.62	45.43	45.79

Note:

G reading (dB) =20*log(V2/V1)=10*log(P2/P1)

V2 is the voltage of VNA port2 is measured, V1 is the voltage of VNA port1 is the reference source.

P2 is the power of VNA port2 is measured, P1 is the power of VNA port1 is the reference source.

Factor = gain factor + power gain conversion= (Reference antenna gain)-(G reading)

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 G value every 7.5 degree from 0 to 352.5 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.

DG steps:

1. Each Phi and Theta polarization antenna gain are measured for all test angles.
2. Composite Phi and Theta antenna gain are computed, using formula in KDB662911 D01 d) (i) and e) (ii), for all angles.
3. Composite antenna gain are examined for all angles to determine max gain and Phi/Theta position. Max gain and phi/theta position are listed in section 7 tables.

Note: Antenna gain = G reading + factor, The factor of chapter five includes reference antenna gain factor and power gain conversion.

7. Measured Values and Calculation of Maximum Gain Positions

DG_1SS max value position

Frequency (Hz)	2.4G	2.45G	2.4835G
Ant. 1 (dBi)	1.93	-0.49	0.63
Ant. 2 (dBi)	-4.23	-2.32	-6.58
Ant. 3 (dBi)	2.45	2.38	3.13
DG [1SS] (dBi)	5.3	4.85	4.71
Polarization	Phi	Phi	Phi
Θ(°)	82.5	82.5	90
Φ(°)	52.5	60	60

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)	2.4G	2.45G	2.4835G
Ant. 1 [10^(G/20)]	10^(1.93/20)	10^(-0.49/20)	10^(0.63/20)
Ant. 2 [10^(G/20)]	10^(-4.23/20)	10^(-2.32/20)	10^(-6.58/20)
Ant. 3 [10^(G/20)]	10^(2.45/20)	10^(2.38/20)	10^(3.13/20)
Ant. 1 [10^(G/20)] value	1.249	0.945	1.075
Ant. 2 [10^(G/20)] value	0.614	0.766	0.469
Ant. 3 [10^(G/20)] value	1.326	1.315	1.434
Sum All Antenna [Amax]	3.189	3.026	2.978
DG [10*log(Amax^2/Nant)]	5.3	4.85	4.71

Note:

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

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

DG_1SS max value position

Frequency (Hz)	5.2G	5.3G	5.6G	5.785G
Ant. 1 (dBi)	-1.06	-3.7	2.45	1.47
Ant. 2 (dBi)	-12.8	0.99	-2.08	2.51
Ant. 3 (dBi)	-3.35	-0.62	-2.43	-5.67
Ant. 4 (dBi)	1.69	-4.38	-2.62	-6.44
DG [1SS] (dBi)	3.55	4.37	5.13	4.9
Polarization	Theta	Theta	Theta	Theta
Θ(°)	157.5	97.5	97.5	90
Φ(°)	345	292.5	300	232.5

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	5.6G	5.785G
Ant. 1 [10^(G/20)]	10^(-1.06/20)	10^(-3.7/20)	10^(2.45/20)	10^(1.47/20)
Ant. 2 [10^(G/20)]	10^(-12.8/20)	10^(0.99/20)	10^(-2.08/20)	10^(2.51/20)
Ant. 3 [10^(G/20)]	10^(-3.35/20)	10^(-0.62/20)	10^(-2.43/20)	10^(-5.67/20)
Ant. 4 [10^(G/20)]	10^(1.69/20)	10^(-4.38/20)	10^(-2.62/20)	10^(-6.44/20)
Ant. 1 [10^(G/20)] value	0.885	0.653	1.326	1.184
Ant. 2 [10^(G/20)] value	0.229	1.121	0.787	1.335
Ant. 3 [10^(G/20)] value	0.68	0.931	0.756	0.521
Ant. 4 [10^(G/20)] value	1.215	0.604	0.74	0.476
Sum All Antenna [Amax]	3.009	3.309	3.608	3.516
DG [10*log(Amax^2/Nant)]	3.55	4.37	5.13	4.9

Note:

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

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

DG_1SS max value position

Frequency (Hz)	6.175G	6.475G	6.695G	6.995G
Ant. 1 (dBi)	-0.24	-12.37	0.29	-3.62
Ant. 2 (dBi)	2.43	3.87	-2.93	1.27
Ant. 3 (dBi)	1.66	-4.6	1.02	-3.05
Ant. 4 (dBi)	-1.38	2.19	2.61	0.58
DG [1SS] (dBi)	6.77	5.29	6.49	5.08
Polarization	Theta	Phi	Theta	Phi
Θ(°)	105	97.5	75	97.5
Φ(°)	127.5	262.5	180	240

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)	6.175G	6.475G	6.695G	6.995G
Ant. 1 [10^(G/20)]	10^(-0.24/20)	10^(-12.37/20)	10^(0.29/20)	10^(-3.62/20)
Ant. 2 [10^(G/20)]	10^(2.43/20)	10^(3.87/20)	10^(-2.93/20)	10^(1.27/20)
Ant. 3 [10^(G/20)]	10^(1.66/20)	10^(-4.6/20)	10^(1.02/20)	10^(-3.05/20)
Ant. 4 [10^(G/20)]	10^(-1.38/20)	10^(2.19/20)	10^(2.61/20)	10^(0.58/20)
Ant. 1 [10^(G/20)] value	0.973	0.241	1.034	0.659
Ant. 2 [10^(G/20)] value	1.323	1.561	0.714	1.157
Ant. 3 [10^(G/20)] value	1.211	0.589	1.125	0.704
Ant. 4 [10^(G/20)] value	0.853	1.287	1.351	1.069
Sum All Antenna [Amax]	4.359	3.678	4.223	3.59
DG [10*log(Amax^2/Nant)]	6.77	5.29	6.49	5.08

Note:

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

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

8. Summary of Test Result

Frequency (Hz)	2.4G	2.45G	2.4835G
Ant. 1 Max Gain (dBi)	4.6	4.82	4.21
Ant. 2 Max Gain (dBi)	2.28	2.32	2.08
Ant. 3 Max Gain (dBi)	3.99	3.32	3.68
Ant. 1 Polarization/Θ(°)/Φ(°)	Phi/75/0	Phi/75/0	Phi/75/352.5
Ant. 2 Polarization/Θ(°)/Φ(°)	Phi/135/240	Phi/150/240	Phi/150/240
Ant. 3 Polarization/Θ(°)/Φ(°)	Phi/45/262.5	Phi/82.5/270	Phi/82.5/270
Max Gain (dBi)	4.6	4.82	4.21
DG [1SS] (dBi)	5.3	4.85	4.71
DG [2SS] (dBi)	4.6	4.82	4.21
DG [3SS] (dBi)	4.6	4.82	4.21

Frequency (Hz)	5.2G	5.3G	5.6G	5.785G
Ant. 1 Max Gain (dBi)	2.08	2.09	2.45	2.12
Ant. 2 Max Gain (dBi)	2.02	2.11	2.64	2.51
Ant. 3 Max Gain (dBi)	2.12	2.31	3.78	3.46
Ant. 4 Max Gain (dBi)	3.42	4.1	4.6	4.37
Ant. 1 Polarization/Θ(°)/Φ(°)	Theta/120/337.5	Theta/60/217.5	Theta/97.5/300	Theta/112.5/52.5
Ant. 2 Polarization/Θ(°)/Φ(°)	Theta/52.5/300	Theta/112.5/15	Theta/82.5/270	Theta/90/232.5
Ant. 3 Polarization/Θ(°)/Φ(°)	Theta/135/247.5	Theta/135/255	Theta/135/255	Theta/135/255
Ant. 4 Polarization/Θ(°)/Φ(°)	Phi/172.5/270	Phi/172.5/285	Phi/172.5/285	Phi/172.5/285
Max Gain (dBi)	3.42	4.1	4.6	4.37
DG [1SS] (dBi)	3.55	4.37	5.13	4.9
DG [2SS] (dBi)	3.42	4.1	4.6	4.37
DG [4SS] (dBi)	3.42	4.1	4.6	4.37

Frequency (Hz)	6.175G	6.475G	6.695G	6.995G
Ant. 1 Max Gain (dBi)	2.67	3.01	3.78	3.22
Ant. 2 Max Gain (dBi)	3.25	4.65	2.61	4.19
Ant. 3 Max Gain (dBi)	3.91	2.75	2.19	2.95
Ant. 4 Max Gain (dBi)	2.99	2.38	3.08	2.28
Ant. 1 Polarization/Θ(°)/Φ(°)	Theta/135/157.5	Theta/97.5/270	Theta/105/262.5	Theta/105/255
Ant. 2 Polarization/Θ(°)/Φ(°)	Theta/127.5/180	Phi/97.5/270	Theta/97.5/247.5	Phi/97.5/270
Ant. 3 Polarization/Θ(°)/Φ(°)	Phi/75/337.5	Theta/97.5/262.5	Theta/82.5/180	Theta/37.5/112.5
Ant. 4 Polarization/Θ(°)/Φ(°)	Theta/60/165	Phi/90/262.5	Theta/67.5/172.5	Theta/142.5/7.5
Max Gain (dBi)	3.91	4.65	3.78	4.19
DG [1SS] (dBi)	6.77	5.29	6.49	5.08
DG [2SS] (dBi)	3.91	4.65	3.78	4.19
DG [4SS] (dBi)	3.91	4.65	3.78	4.19

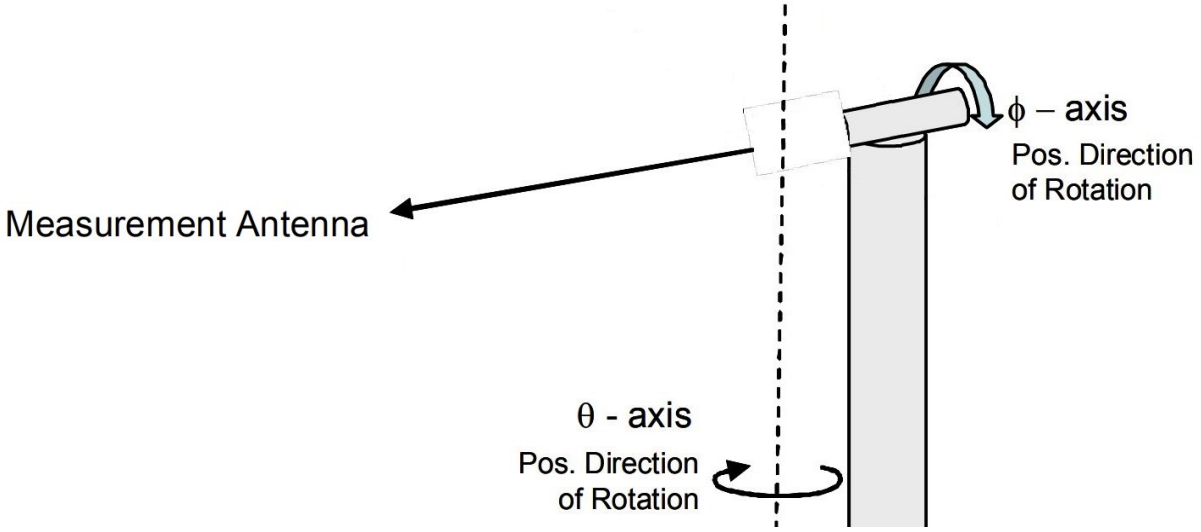
Note:

1. Antenna max gain is the max value of each individual antenna through all measurement angles.
2. The max gain is the max value of all antennas.
3. Directional Gain (2SS) = Directional Gain (1SS) – 3dB. If directional gain is less than max gain, use max gain as directional gain. Refer to KDB662911D01 (F) (2) (e) (ii)
4. Directional Gain (3SS) = Directional Gain (1SS) – 4.77dB. If directional gain is less than max gain, use max gain as directional gain. Refer to KDB662911D01 (F) (2) (e) (ii)
5. Directional Gain (4SS) = Directional Gain (1SS) – 6dB. If directional gain is less than max gain, use max gain as directional gain. Refer to KDB662911D01 (F) (2) (e) (ii)

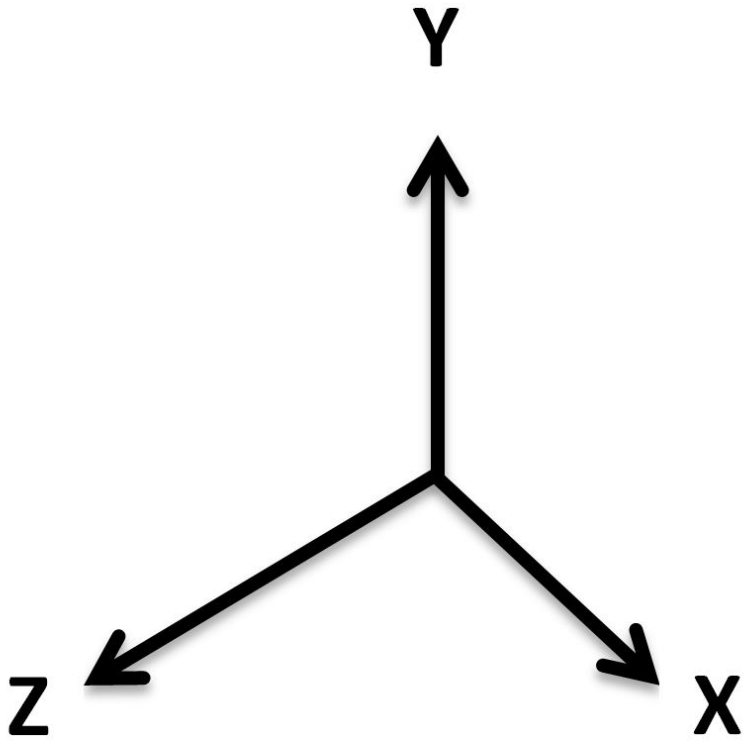
9. Test Setup

Test Position

Relative to the measurement antenna, first position 0 degrees of phi angle and theta angle.



Antenna Pattern Coordination



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-1531	1GHz~18GHz	Dec. 20, 2023	Dec. 19, 2024
Dual Polarization Horn Antenna	Sporton	S0209DP	S0209DP-001	2GHz~9GHz	N.C.R.	N.C.R.
ENA Series Network Analyzer	AGILENT	E5071C	MY46419477	100kHz~8.5GHz	Jul. 28, 2023	Jul. 27, 2024
VNA Calibration Kit	TS RF	TS85033E-F	-	DC~9GHz	N.C.R.	N.C.R.
Multi-axis positioner	Sporton	MAPS01	MAPS01-001	Theta / Phi axis	N.C.R.	N.C.R.
Test Software	SPORTON	SENSE-RDG	V1.0.8	-	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.