APPENDIX J

: ANTENNA SPECIFICATION

ANT #1
PCB pattern antenna

Mobile Station Over the Air Passive Performance

EUT	PCB pattern antenna
Test Date	Mon 17/Jul/2017 18:58:01
Event Status	
Serial Number	
Hardware Version	

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Frequency(MHz)	**2400**	**2405**	**2410**	**2415**	**2420**	**2425**	**2430**	**2435**	**2440**	**2445**	**2450**	**2455**	**2460**	**2465**	**2470**	**2475**	**2480**	**2485**	**2490**	**2497**
Efficiency(dB)	**-5.77**	**-5.50**	**-5.31**	**-5.03**	**-4.72**	**-4.21**	**-4.00**	**-3.80**	**-3.56**	**-3.19**	**-3.03**	**-2.89**	**-2.74**	**-2.69**	**-2.73**	**-2.72**	**-2.87**	**-2.89**	**-2.97**	**-3.27**
Efficiency(%)	**26.49**	**28.18**	**29.46**	**31.38**	**33.71**	**37.96**	**39.84**	**41.71**	**44.03**	**47.94**	**49.79**	**51.41**	**53.21**	**53.86**	**53.39**	**53.43**	**51.60**	**51.42**	**50.49**	**47.10**
TRG(dB)	**-5.77**	**-5.50**	**-5.31**	**-5.03**	**-4.72**	**-4.21**	**-4.00**	**-3.80**	**-3.56**	**-3.19**	**-3.03**	**-2.89**	**-2.74**	**-2.69**	**-2.73**	**-2.72**	**-2.87**	**-2.89**	**-2.97**	**-3.27**
TRG_{Theta}(dB)	-8.64	-8.35	-8.10	-7.89	-7.59	-7.11	-6.78	-6.60	-6.37	-6.04	-5.86	-5.74	-5.60	-5.58	-5.58	-5.60	-5.81	-5.81	-5.90	-6.26
TRG_{Phi}(dB)	-8.92	-8.68	-8.55	-8.21	-7.88	-7.33	-7.25	-7.02	-6.78	-6.38	-6.23	-6.07	-5.90	-5.82	-5.90	-5.87	-5.96	-5.99	-6.05	-6.30
UHRG(dB)	-9.30	-9.00	-8.77	-8.52	-8.13	-7.58	-7.42	-7.17	-6.95	-6.56	-6.44	-6.31	-6.18	-6.15	-6.17	-6.19	-6.34	-6.34	-6.42	-6.68
UHRG/TRG(%)	44.35	44.68	45.08	44.75	45.64	45.97	45.51	45.98	45.83	46.05	45.63	45.48	45.29	45.09	45.23	45.01	44.99	45.20	45.18	45.56
H-Plane	-10.60	-10.21	-9.89	-9.75	-9.32	-8.87	-8.53	-8.23	-8.03	-7.83	-7.54	-7.51	-7.42	-7.43	-7.44	-7.57	-7.83	-7.82	-8.12	-8.37
E1-Plane, AVG(dB)	-15.50	-14.92	-15.03	-14.90	-14.45	-13.96	-13.68	-13.57	-13.34	-12.76	-12.57	-12.62	-12.39	-12.29	-12.25	-12.36	-12.35	-12.44	-12.43	-12.66
E2-Plane, AVG(dB)	-5.53	-5.19	-4.96	-4.74	-4.44	-3.96	-3.55	-3.45	-3.08	-2.83	-2.74	-2.54	-2.41	-2.38	-2.36	-2.37	-2.65	-2.62	-2.67	-3.12
Peak Gain(dB)	-2.94	-2.61	-2.54	-2.21	-1.99	-1.50	-1.31	-0.99	-0.64	-0.18	-0.05	0.06	0.22	0.19	0.09	0.14	-0.08	0.03	-0.12	-0.44
Directivity(dB)	2.83	2.89	2.76	2.82	2.73	2.70	2.69	2.81	2.92	3.02	2.98	2.95	2.96	2.88	2.81	2.87	2.79	2.92	2.85	2.83
Minimum Gain(dB)	-14.72	-15.60	-15.25	-13.78	-13.97	-13.44	-13.37	-12.51	-12.23	-11.46	-12.10	-11.06	-10.83	-10.29	-10.39	-10.66	-10.90	-11.01	-10.55	-10.98
Test Condition	FS																			
Antenna Type																				

FS=Free Space, BHR=Beside Head Right Side, BHL=Beside Head Left Side, HR=Hand Right, HL=Hand Left, BHHR=Beside Head and Hand Right Side, BHHL=Beside Head and Hand Left Side, NB=Notebook

Average Efficiency	**-3.58 dB, 43.82 %**

Comment

ANT #2
Dipole antenna

2.2.2 Passive Gain & 3D Pattern

2G_5G Antenna Passive Gain Data

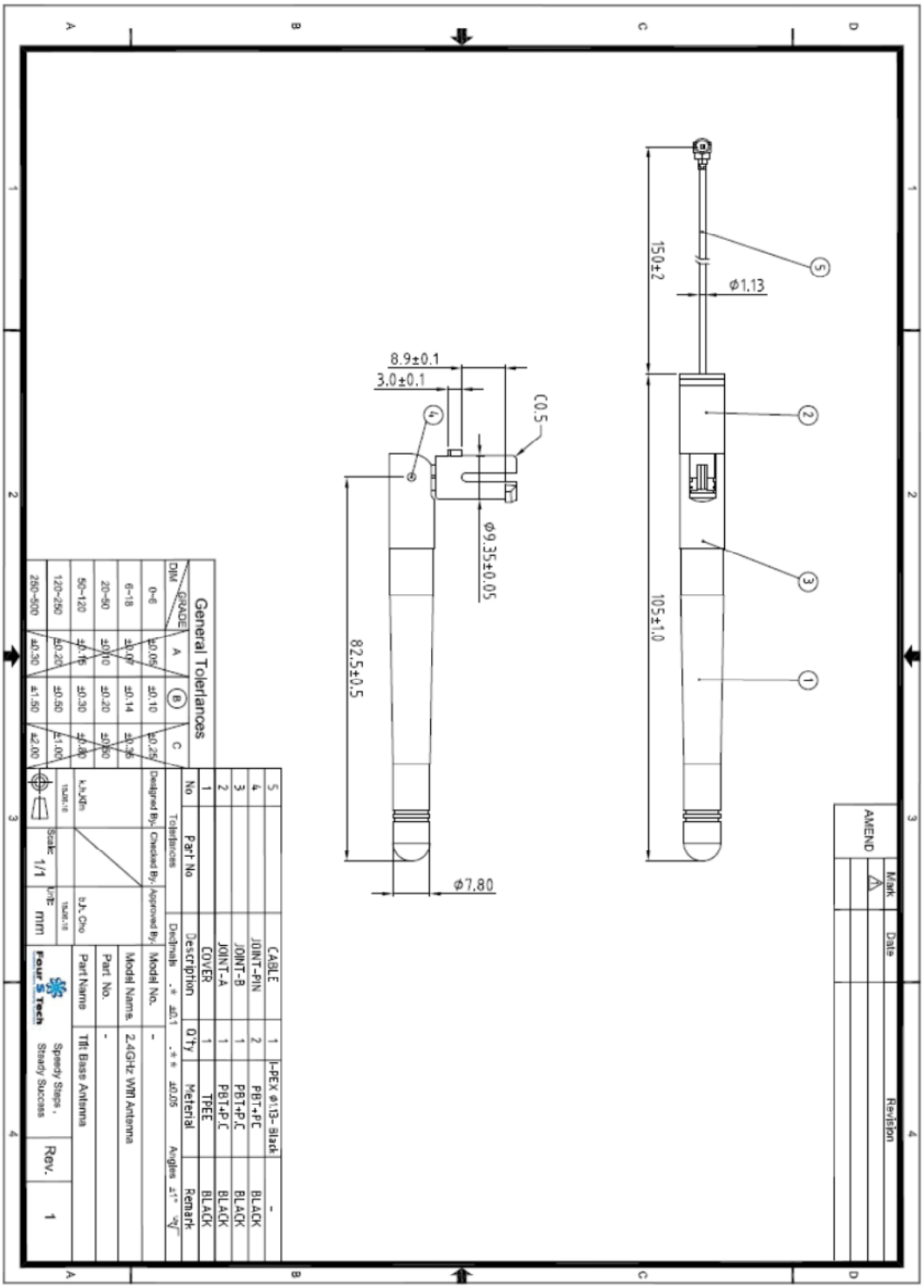
Frequency	Efficiency	Average Gain			Max Gain			Max Position
		Ver	Hor	Total	Ver	Hor	Total	
2,400,000,000 Hz	93.2 %	-8.3 dBi	-1.0 dBi	-0.3 dBi	-0.1 dBi	2.9 dBi	3.7 dBi	Theta105/Pie225
2,420,000,000 Hz	91.9 %	-9.1 dBi	-1.0 dBi	-0.4 dBi	-0.6 dBi	2.8 dBi	3.6 dBi	Theta105/Pie225
2,440,000,000 Hz	88.3 %	-9.9 dBi	-1.1 dBi	-0.5 dBi	-1.2 dBi	2.6 dBi	3.4 dBi	Theta105/Pie225
2,460,000,000 Hz	91.8 %	-10.6 dBi	-0.8 dBi	-0.4 dBi	-1.7 dBi	2.6 dBi	3.5 dBi	Theta105/Pie225
2,480,000,000 Hz	88.1 %	-11.6 dBi	-0.9 dBi	-0.5 dBi	-2.8 dBi	2.4 dBi	3.1 dBi	Theta105/Pie225
2,500,000,000 Hz	85.9 %	-12.5 dBi	-1.0 dBi	-0.7 dBi	-4.0 dBi	2.5 dBi	2.6 dBi	Theta105/Pie225
5,200,000,000 Hz	143.8 %	-9.8 dBi	1.3 dBi	1.6 dBi	-2.4 dBi	5.4 dBi	5.5 dBi	Theta105/Pie210
5,320,000,000 Hz	152.1 %	-9.1 dBi	1.5 dBi	1.8 dBi	-1.3 dBi	5.8 dBi	5.8 dBi	Theta90/Pie285
5,440,000,000 Hz	145.4 %	-9.2 dBi	1.2 dBi	1.6 dBi	-0.9 dBi	5.5 dBi	5.6 dBi	Theta90/Pie285
5,560,000,000 Hz	119.1 %	-10.2 dBi	0.4 dBi	0.8 dBi	-1.8 dBi	4.3 dBi	4.4 dBi	Theta90/Pie285
5,680,000,000 Hz	107.8 %	-10.4 dBi	-0.1 dBi	0.3 dBi	-2.9 dBi	4.0 dBi	4.1 dBi	Theta90/Pie270
5,800,000,000 Hz	125.3 %	-9.3 dBi	0.6 dBi	1.0 dBi	-1.7 dBi	4.5 dBi	4.6 dBi	Theta90/Pie270

Antenna Cable 150mm 기준

Model	Type	Rev.	포에스텍	IR
FS-WFDB-SI	Dipole		오성전자	A

3. Mechanical Specification

3.1 Assy Drawing



ANT #3
PCB antenna

Approval Sheet

Product : 2.4GHz WiFi PCB Antenna

Date: March 16, 2017

Customer Applied Model	TDC-7100		
Customer	SeoRin Electronics Co., Ltd.		
Customer Part No.			
Supplier	Four S tech Co., Ltd.		
Supplier Part No.	FPW201-7100-138		
Customer	By designed	By checked	By approved
Supplier	By Designed	By checked	By approved
			
	Kim S.H	Cho B.H	Kim Y.W

Four S tech Co., Ltd.

Address : #202-402~403, Bucheon Techno Park Ssangyong Ⅲ, 36-1
Samjeong-Dong , Ohjeong-Gu, Bucheon-City, Gyeonggi-Do, Korea
Phone No. : TEL 82-32-624-0317~8, FAX 82-32-624-0319

■ Revision History

Revision No	Originator	Description of changes	Date of changes
1	Kim S.H	Initial release	2017.03.16
2			
3			
4			
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7			
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10			
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12			

Table of Contents

1. General

1.1 The Product

Customer Model	TDC-7100
Antenna Type	PCB Antenna
Applications	2.4GHz WiFi

1.2 Electrical Properties

Frequency Range	2.401 ~ 2.4835 GHz
VSWR	Less than 1.5 : 1
Peak Gain	4.9 dBi
Radiation Pattern	Omni-directional
Polarization	Linear

1.3 Mechanical Properties

Dimension	See page 14
Operational Temperature	-20°C ~ +70°C
Storage Temperature	-30°C ~ +80°C
Connector Type	UFL

2. Electrical Properties

2.1 Frequency Band

Band / Freq	2.4GHz WiFi
TX/RX	2.401 ~ 2.4835 GHz

2.2 Impedance

2.2.1 Normal Value

50Ω ± Normal

2.2.1 Measuring Method

The impedance over the frequency bands shall be as close as possible to 50Ω after matching. Both free space and talk position are considered.

2.3 VSWR

The impedance matching should be optimized in the more critical talk position.

2.3.1 Maximum values in free space

SERVICE	2.4GHz WiFi
	TX/RX
VSWR	1.5:1

2.3.2 Measuring Method

A 50Ω coaxial cable is connected(soldered) to the 50Ω point, at the duplex-filter on the main PCB. The connection of the coaxial cable shall be done to introduce a minimum of mismatch. As much as possible the coaxial cable arrangement shall prevent influences from induced currents on the cable. In the other end, the coaxial cable is connected to a network analyzer. The measurement is performed at room temperature. The handset, including the PCB, must not in any significant way differ from the mass production, i.e. the antenna feeding network has to be equivalent to the feeding network in mass production. The specification shall be met in the entire frequency band.

2.4 Gain (dBi)

2.4.1 Measuring Method

The connection is done according to 2.3.2.
Radiation patterns are measured at 3 different Plane
The antenna is measured according to the Figure 1 below.

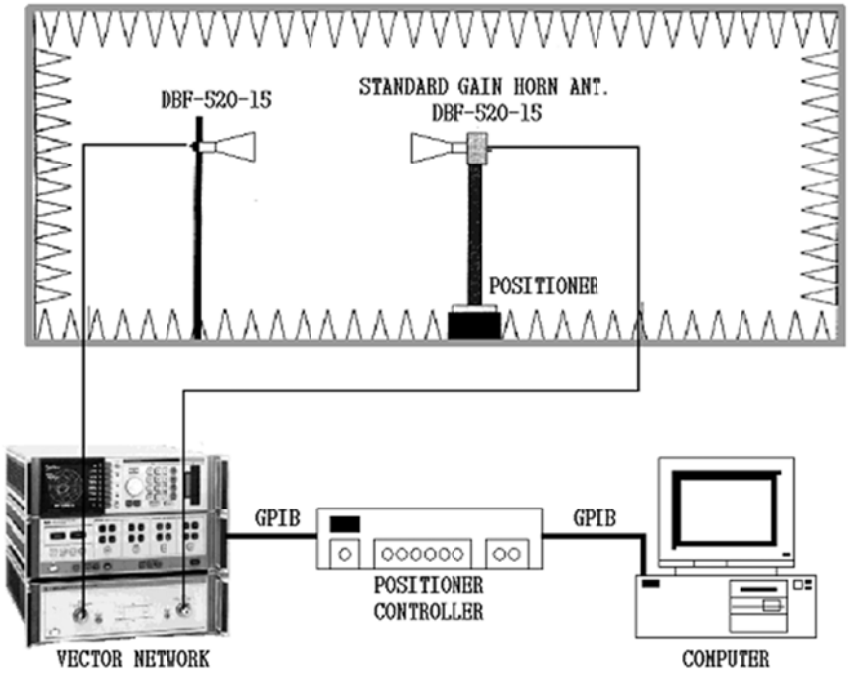


Figure 1

2.4.2 Typical values in maximum direction

2.4.2.1 Passive Gain

		PwrSum					H(θ=90)				E1(φ=0)				E2(φ=90)			
No.	Freq.	Eff.[%]	Avg.[dBi]	Peak[dBi]	θ[deg]	φ[deg]	Avg.[dBi]	Peak[dBi]	φ[deg]	BW[deg]	Avg.[dBi]	Peak[dBi]	θ[deg]	BW[deg]	Avg.[dBi]	Peak[dBi]	θ[deg]	BW[deg]
1	2401.0000	81.62	-0.88	4.42	90.00	150.00	-0.38	4.42	150.00	104.17	-0.48	3.29	-150.00	120.59	-0.94	2.27	75.00	117.82
2	2412.0000	87.65	-0.57	4.78	90.00	150.00	-0.06	4.78	150.00	103.62	-0.23	3.59	-150.00	121.62	-0.60	2.58	75.00	118.70
3	2462.0000	90.43	-0.44	4.94	90.00	150.00	0.15	4.94	150.00	107.69	-0.42	3.42	-150.00	122.33	-0.44	2.84	90.00	115.06
4	2472.0000	73.83	-1.32	4.02	90.00	135.00	-0.75	4.02	135.00	108.45	-1.38	2.47	-150.00	121.99	-1.26	2.11	-180.00	999.00
5	2483.5000	64.40	-1.91	3.52	90.00	135.00	-1.33	3.52	135.00	107.24	-2.04	1.83	-150.00	121.08	-1.80	1.59	-180.00	999.00

3. Mechanical Properties

3.1 Appearance

The appearance shall be according to the specification drawing on page 15.
The antenna shall have no cuts, abrasion or other mechanical damages.

3.2 Drop

3.2.1 Drops

1 drop in retracted mode (3cycles)

3.2.2 Drop Height

1.5m

3.2.3 Drop Angle

180°

3.2.4 Actual handset applied

3.2.5 Demands

The original shape shall be possible to restore. The antenna shall satisfy the electrical demands, according to 2.4.1, after the test.

3.2.6 Measuring Method

The antenna is placed in the handset or an equivalent test fixture.
The handset is dropped with the antenna downwards onto a metal plate.

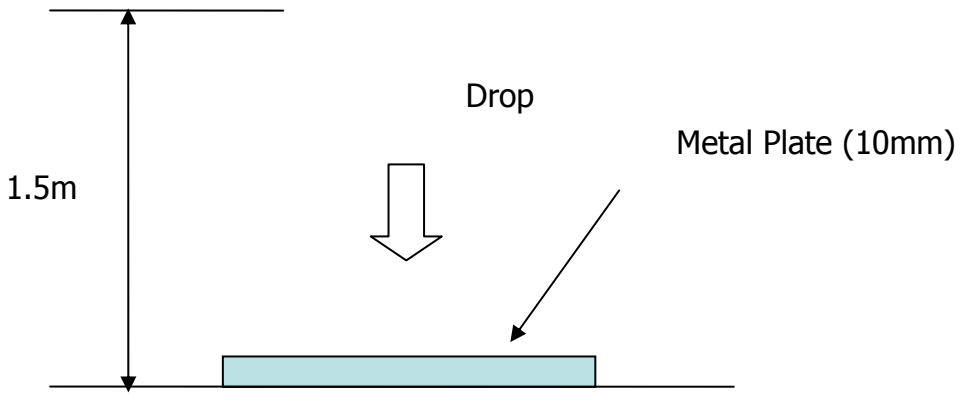


Figure3. Drop Test

4. Environment Resistance Properties

4.1 Operational Temperature

4.1.1. Low Operational Temperature

TLO = -20°C

4.1.2 High Operational Temperature

THO = +70°C

4.1.3 Demands

No visual deterioration shall occur, and the antenna shall satisfy the electrical demands, according to 2.4.1, during the test.

4.1.4 Measuring Method

The antenna is placed in a climatic chamber at temperature TLO.
The antenna is taken out after 1 hour, and VSWR is immediately measured.
The antenna is placed in a climatic chamber at temperature THO.
The antenna is taken out after 1 hour, and VSWR is immediately measured.

4.2 Temperature Cycling

4.2.1 Low Cycling Temperature

TLC = -20°C

4.2.2 High Cycling Temperature

THC = +70°C

4.2.3 Demands

No visual deterioration shall occur during the test. The antenna shall satisfy the electrical demands, according to 2.4.1.

4.2.4 Measuring Method

The antenna is placed in a climatic chamber. The temperature is cycled as follows: The temperature is kept constantly at TLC for 1 hour, increased to THC during 1 hour, kept constantly at THC for 1 hour, and then decreased to TLC during 1 hour.
This procedure is repeated 10 times, ending at room temperature according to Figure 4 below.

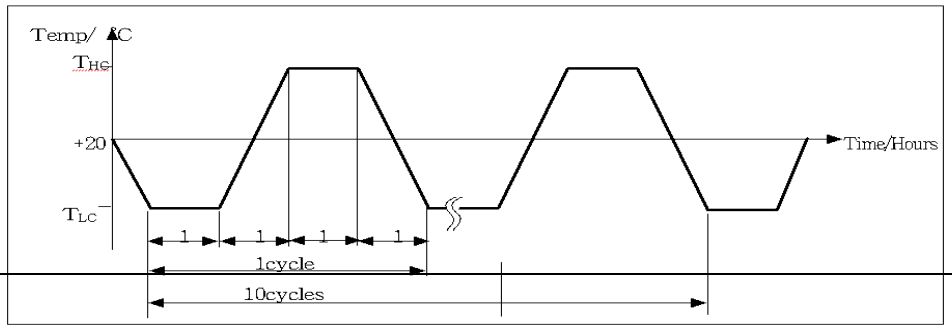


Figure 4. Temperature Cycling

4.3 humidity

4.3.1 Relative Humidity

95%

4.3.2 Temperature

+55°C

4.3.3 Demands

No visual deterioration shall occur during the test. The antenna shall satisfy the electrical demands, according to 2.4.1, after the test.

4.3.4 Measuring Method

The antenna is placed in a climatic chamber for 24 hours. The antenna is taken out from the chamber and measured after another 24 hours in room temperature.

4.4 Sinusoidal Vibration

4.4.1 Vibration Frequencies

10-55-10Hz (1cycle)

4.4.2 Sweep Rate

1 octave/min (logarithmic)

4.4.3 Maximum Amplitude

A = 1.52mm

4.4.4 Maxim Acceleration

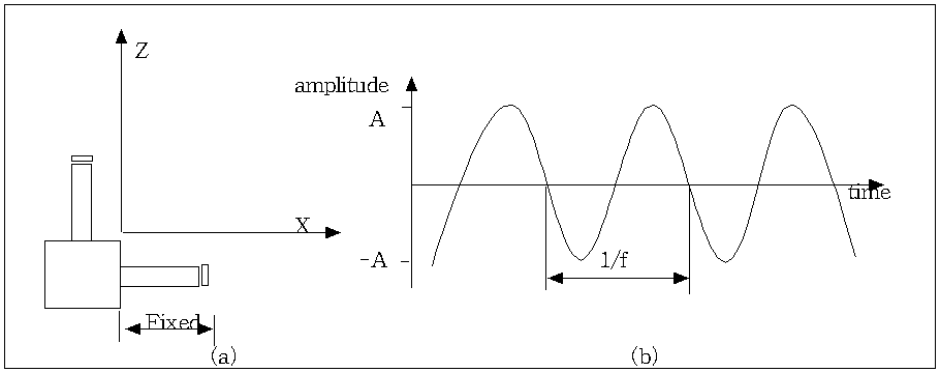
2g

4.4.5 Crossover Frequency

18.2Hz

4.4.7 Measuring Method

The fixed antenna is assembled in the test equipment. The vibration is done both in x-and z-directions, according to Figure 5(a), with a duration of 1 hour in each direction.

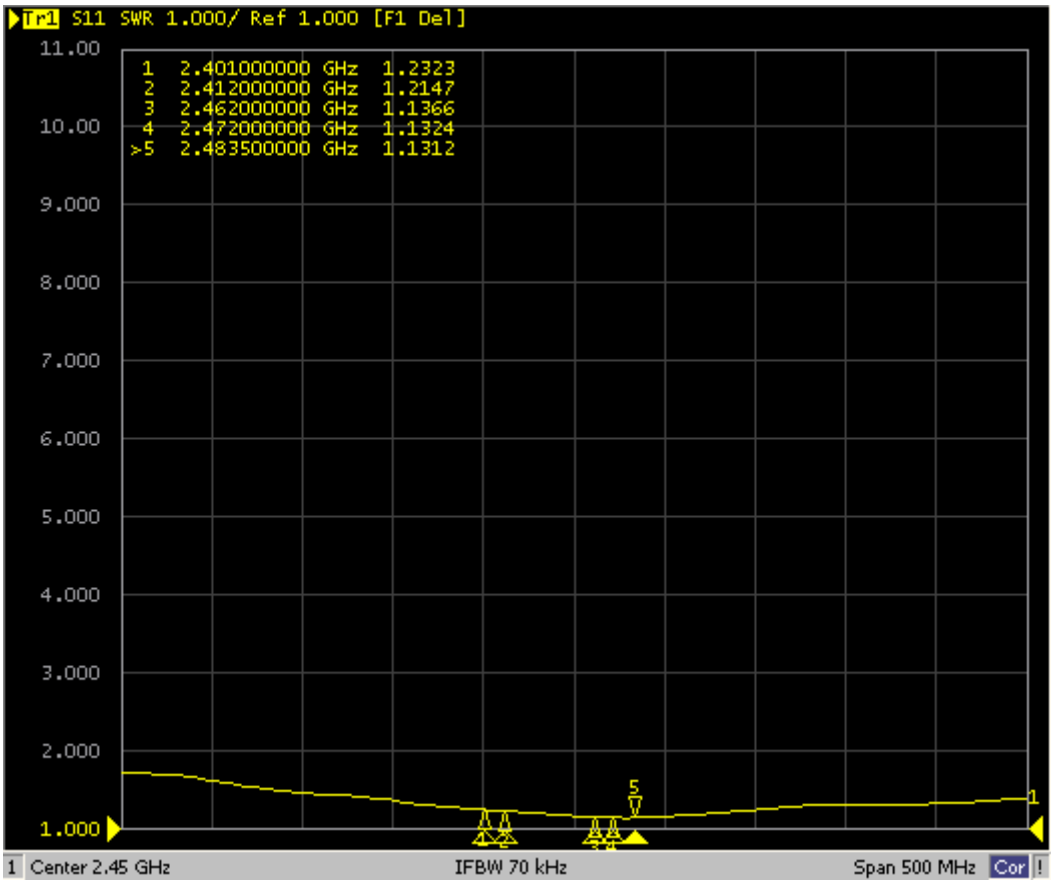


(a) Vibration directions (b) Vibration form

Figure 5. Sinusoidal Vibrator

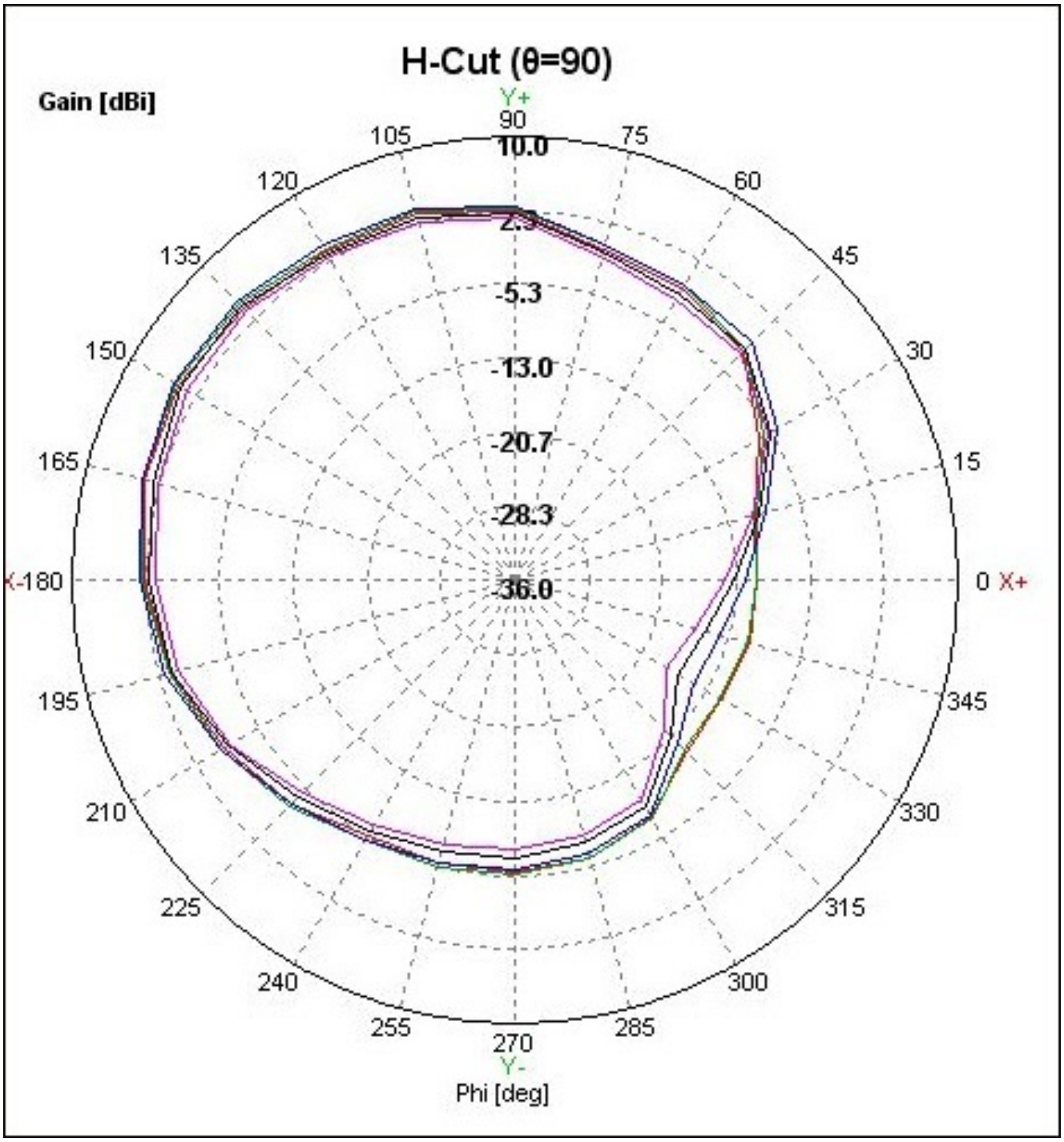
5. Test Data

5.1 Network Data

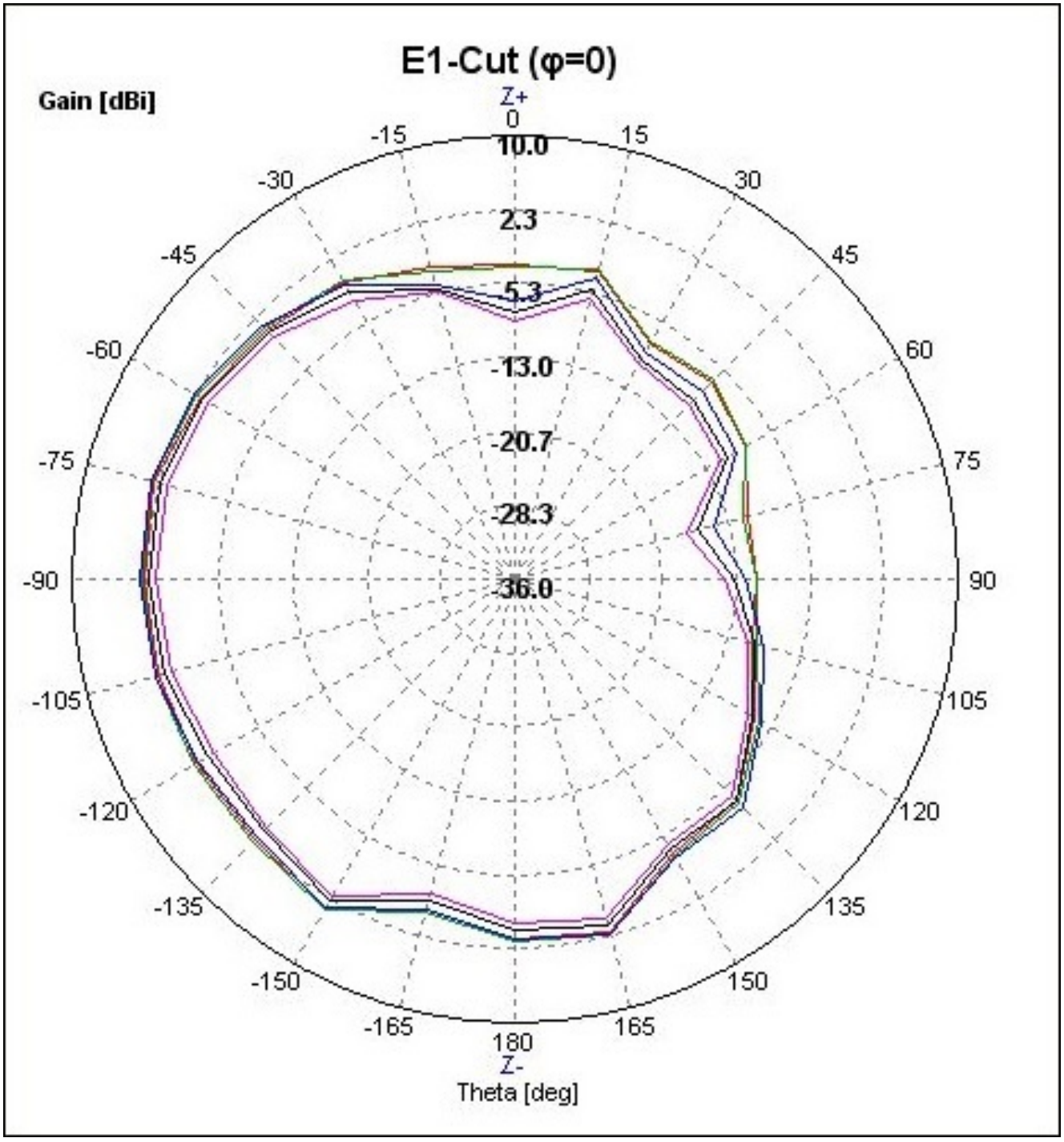


5.2 Radiation Pattern

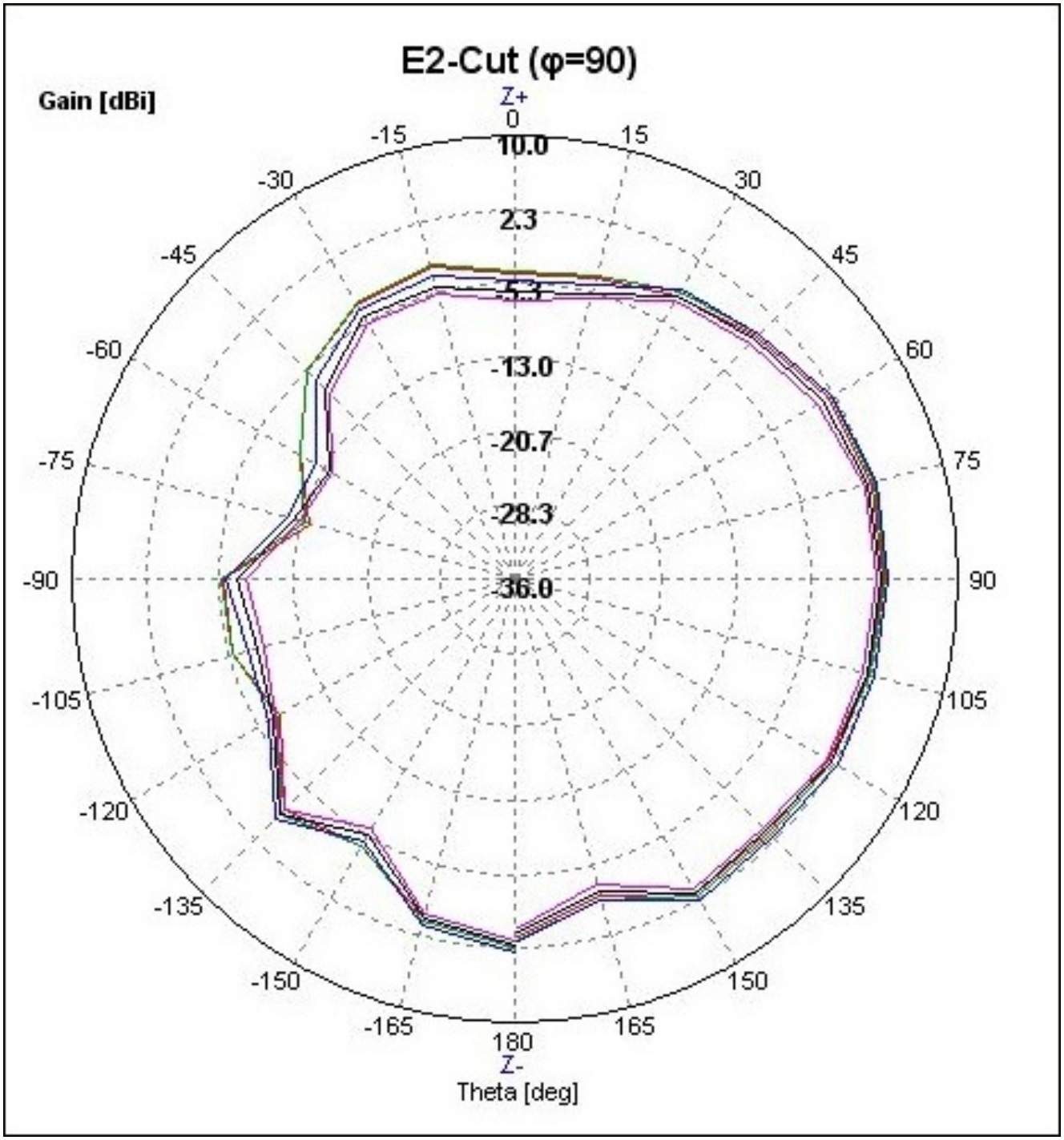
5.2.1 XY – Plane



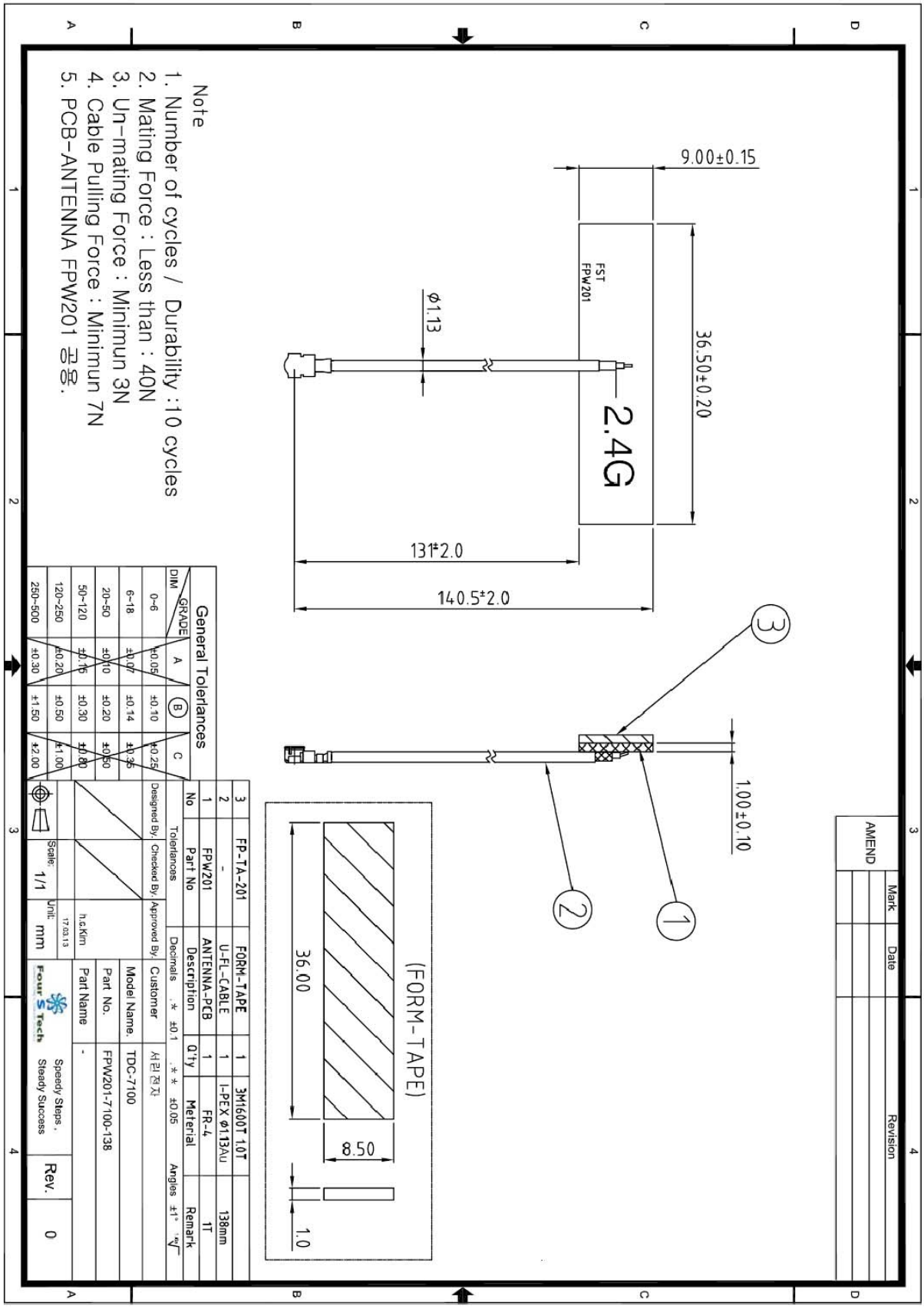
5.2.2 YZ - Plane


E1-Cut (φ=0)
Gain [dBi]
Z+
0
-15
15
-30
30
-45
45
-60
60
-75
75
-90
90
-105
105
-120
120
-135
135
-150
150
-165
165
180
Z-
10.0
2.3
-5.3
-13.0
-20.7
-28.3
-36.0
Theta [deg]

5.2.3 XZ – Plane


E2-Cut (φ=90)
Gain [dBi]
Z+
0
-15
15
-30
30
-45
45
-60
60
-75
75
-90
90
-105
105
-120
120
-135
135
-150
150
-165
165
180
Z-
10.0
2.3
-5.3
-13.0
-20.7
-28.3
-36.0
Theta [deg]

6. Mechanical Drawing

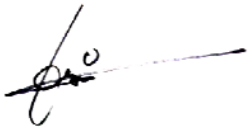


ANT #4
PCB antenna

Approval Sheet

Product : 2.4GHz WiFi PCB Antenna

Date :June 03, 2020

Customer Applied Model			
Customer	SeoRin Electronics Co., Ltd.		
Customer Part No.			
Supplier	Four S Tech Co., Ltd.		
Supplier Part No.	FPW201-1200		
Customer	By designed	By checked	By approved
Supplier	By Designed	By checked	By approved
			
	Lee J.H	Cho B.H	Kim Y.W

Four S tech Co., Ltd.

Address : #202-402~403, Bucheon Techno Park Ssangyong Ⅲ, 397
Seokcheon-ro , Ohjeong-Gu, Bucheon-City, Gyeonggi-Do, Korea

Phone No. : TEL 82-32-624-0317~8, FAX 82-32-624-0319

■ Revision History

Revision No	Originator	Description of changes	Date of changes
1	Lee J.H	Initial release	2020.06.03
2			
3			
4			
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6			
7			
8			
9			
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12			

Table of Contents

1. General

1.1 The Product

Customer Model	FPW201-1200
Antenna Type	Dipole Antenna
Applications	2.4GHz WiFi

1.2 Electrical Properties

Frequency Range	2.401 ~ 2.4835 GHz
VSWR	Less than 2.5 : 1
Peak Gain	5.21dBi
Radiation Pattern	Omni-directional
Polarization	Linear

1.3 Mechanical Properties

Dimension	See page 14
Operational Temperature	-30°C ~ +80°C
Connector Type	I-PEX / U_FL Conn’

2. Electrical Properties

2.1 Frequency Band

Band / Freq'	WiFi
TX/RX	2.401 ~ 2.4835 GHz

2.2 Impedance

2.2.1 Normal Value

50Ω ± Normal

2.2.1 Measuring Method

The impedance over the frequency bands shall be as close as possible to 50Ω after matching. Both free space and talk position are considered.

2.3 VSWR

The impedance matching should be optimized in the more critical talk position.

2.3.1 Maximum values in free space

SERVICE	2.401 ~ 2.4835 GHz
VSWR	Less than 2.5:1

2.3.2 Measuring Method

A 50Ω coaxial cable is connected(soldered) to the 50Ω point, at the duplex-filter on the main PCB. The connection of the coaxial cable shall be done to introduce a minimum of mismatch. As much as possible the coaxial cable arrangement shall prevent influences from induced currents on the cable. In the other end, the coaxial cable is connected to a network analyzer. The measurement is performed at room temperature. The handset, including the PCB, must not in any significant way differ from the mass production, i.e. the antenna feeding network has to be equivalent to the feeding network in mass production. The specification shall be met in the entire frequency band.

2.4 Gain (dBi)

2.4.1 Measuring Method

The connection is done according to 2.3.2.

Radiation patterns are measured at 3 different Plane

The antenna is measured according to the Figure 1 below.

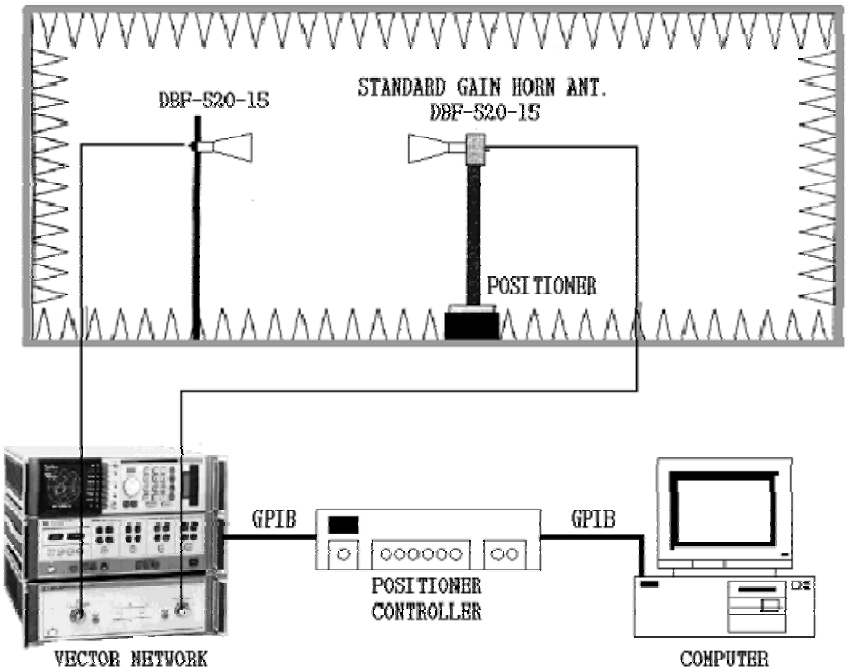


Figure 1

2.4.2 Typical values in maximum direction

2.4.2.1 Passive Gain

		PwrSum					H(θ=90)				E1(φ=0)				E2(φ=90)			
No.	Freq.	Eff.[%]	Avg.[dBi]	Peak[dBi]	θ[deg]	φ[deg]	Avg.[dBi]	Peak[dBi]	φ[deg]	BW[deg]	Avg.[dBi]	Peak[dBi]	θ[deg]	BW[deg]	Avg.[dBi]	Peak[dBi]	θ[deg]	BW[deg]
1	2401.0000	97.48	-0.11	4.61	105.00	255.00	-0.04	3.26	240.00	79.33	-1.79	3.05	150.00	13.23	1.42	4.06	-120.00	64.61
2	2412.0000	95.09	-0.22	4.70	105.00	255.00	-0.08	3.25	240.00	79.54	-1.87	2.96	150.00	13.22	1.34	4.14	-120.00	62.23
3	2462.0000	93.59	-0.29	5.15	105.00	255.00	0.02	3.31	270.00	75.56	-1.76	3.86	180.00	999.00	1.32	4.37	-120.00	53.26
4	2472.0000	90.14	-0.45	5.08	105.00	255.00	-0.14	3.20	270.00	74.34	-2.00	3.80	180.00	999.00	1.18	4.39	-120.00	51.01
5	2483.5000	90.81	-0.42	5.21	105.00	255.00	-0.13	3.29	270.00	71.88	-2.09	3.93	180.00	999.00	1.21	4.53	-120.00	48.49

3. Mechanical Properties

3.1 Appearance

The appearance shall be according to the specification drawing on page 15.
The antenna shall have no cuts, abrasion or other mechanical damages.

3.2 Drop

3.2.1 Drops

1 drop in retracted mode (3cycles)

3.2.2 Drop Height

1.5m

3.2.3 Drop Angle

180°

3.2.4 Actual handset applied

3.2.5 Demands

The original shape shall be possible to restore. The antenna shall satisfy the electrical demands, according to 2.4.1, after the test.

3.2.6 Measuring Method

The antenna is placed in the handset or an equivalent test fixture.
The handset is dropped with the antenna downwards onto a metal plate.

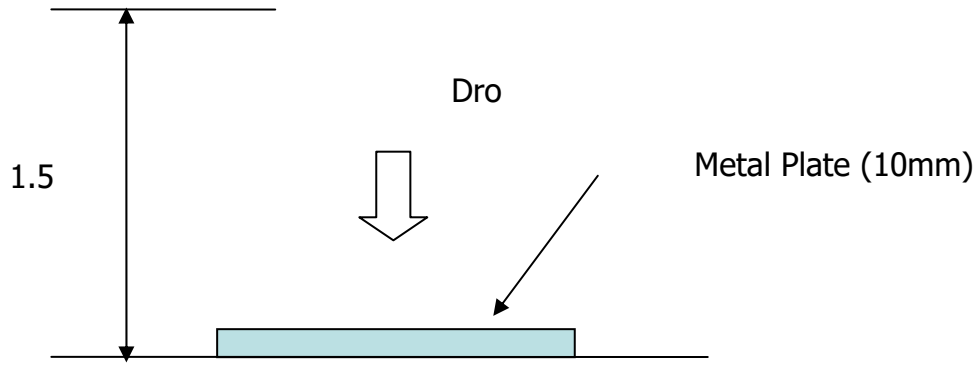


Figure3. Drop Test

4. Environment Resistance Properties

4.1 Operational Temperature

4.1.1. Low Operational Temperature

TLO = -30°C

4.1.2 High Operational Temperature

THO = +80°C

4.1.3 Demands

No visual deterioration shall occur, and the antenna shall satisfy the electrical demands, according to 2.4.1, during the test.

4.1.4 Measuring Method

The antenna is placed in a climatic chamber at temperature TLO.
The antenna is taken out after 1 hour, and VSWR is immediately measured.
The antenna is placed in a climatic chamber at temperature THO.
The antenna is taken out after 1 hour, and VSWR is immediately measured.

4.2 Temperature Cycling

4.2.1 Low Cycling Temperature

TLC = -30°C

4.2.2 High Cycling Temperature

THC = +80°C

4.2.3 Demands

No visual deterioration shall occur during the test. The antenna shall satisfy the electrical demands, according to 2.4.1.

4.2.4 Measuring Method

The antenna is placed in a climatic chamber. The temperature is cycled as follows: The temperature is kept constantly at TLC for 1 hour, increased to THC during 1 hour, kept constantly at THC for 1 hour, and then decreased to TLC during 1 hour.
This procedure is repeated 10 times, ending at room temperature according to Figure 4 below.

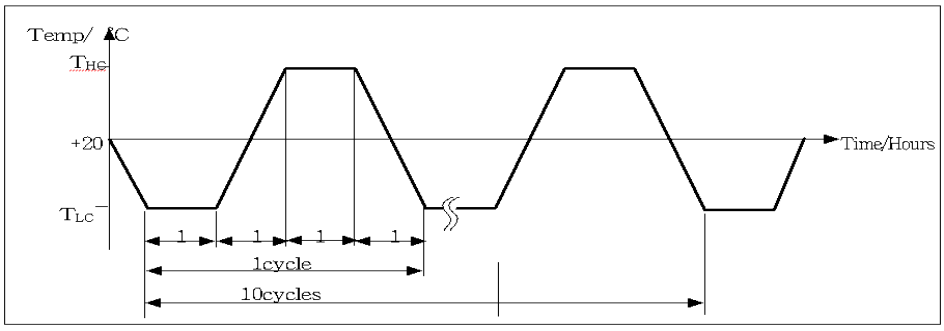


Figure 4. Temperature Cycling

4.3 humidity

4.3.1 Relative Humidity

95%

4.3.2 Temperature

+55°C

4.3.3 Demands

No visual deterioration shall occur during the test. The antenna shall satisfy the electrical demands, according to 2.4.1, after the test.

4.3.4 Measuring Method

The antenna is placed in a climatic chamber for 24 hours. The antenna is taken out from the chamber and measured after another 24 hours in room temperature.

4.4 Sinusoidal Vibration

4.4.1 Vibration Frequencies

10-55-10Hz (1cycle)

4.4.2 Sweep Rate

1 octave/min (logarithmic)

4.4.3 Maximum Amplitude

A = 1.52mm

4.4.4 Maxim Acceleration

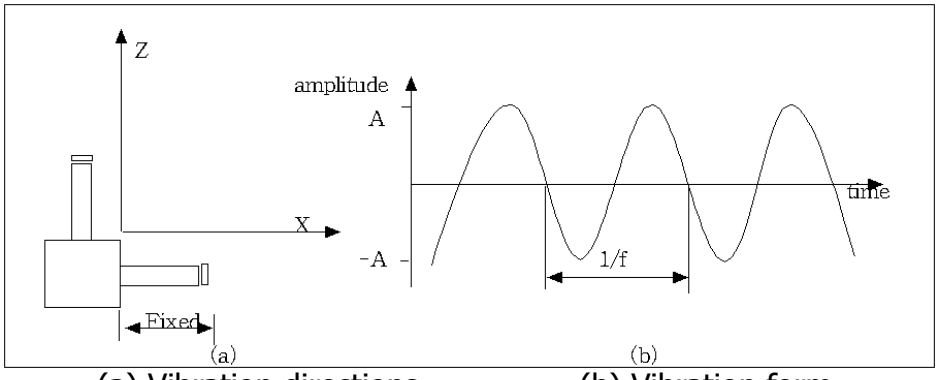
2g

4.4.5 Crossover Frequency

18.2Hz

4.4.7 Measuring Method

The fixed antenna is assembled in the test equipment. The vibration is done both in x-and z-directions, according to Figure 5(a), with a duration of 1 hour in each direction.



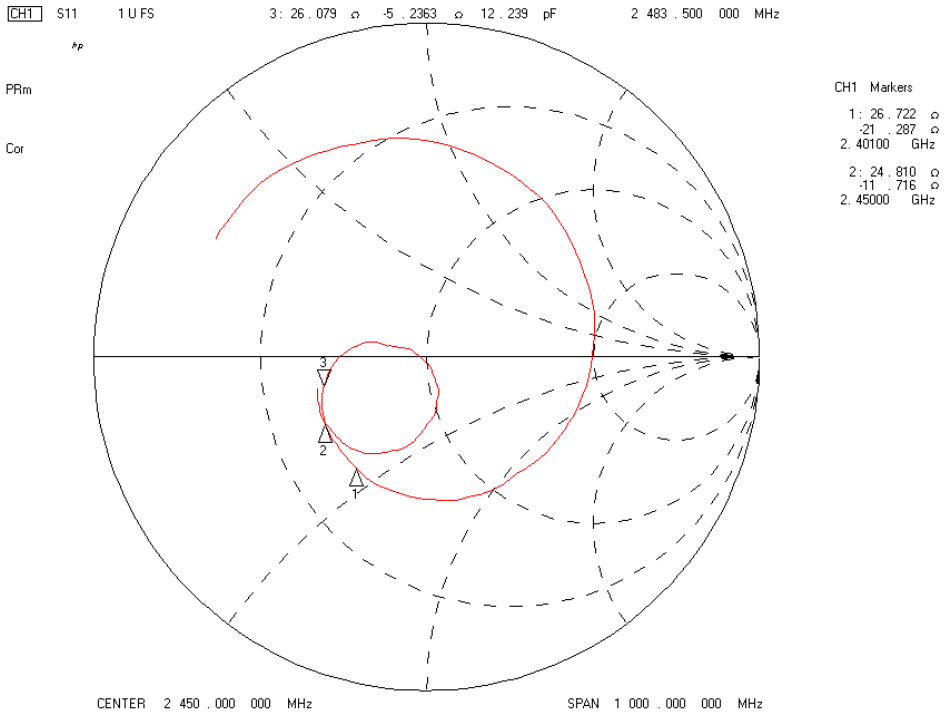
(a) Vibration directions (b) Vibration form

Figure 5. Sinusoidal Vibrator

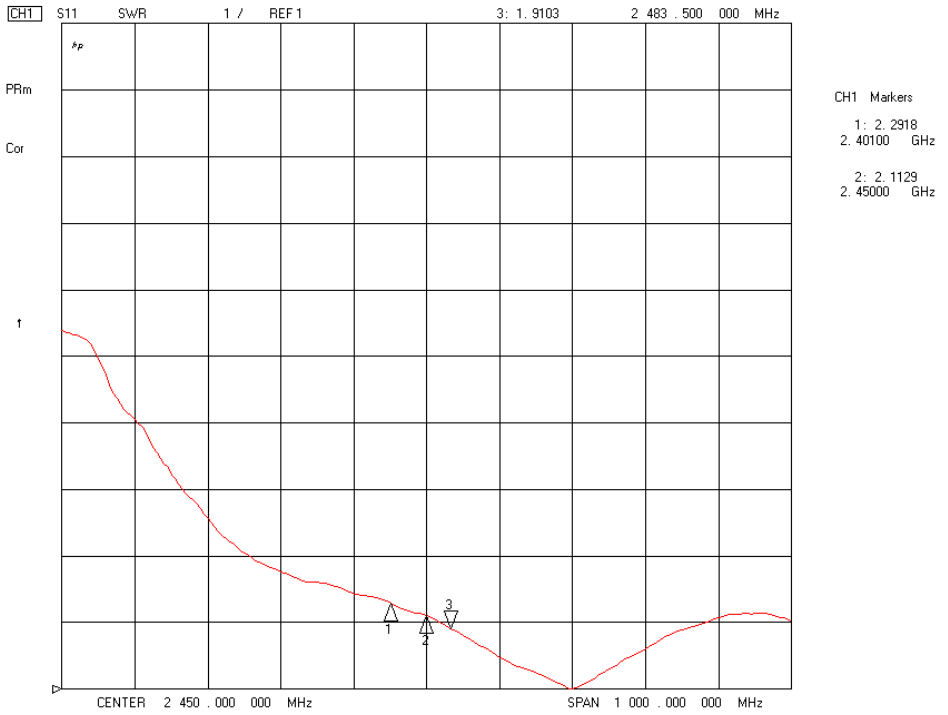
5. Test Data

5.1 Network Data

- Smith Chart

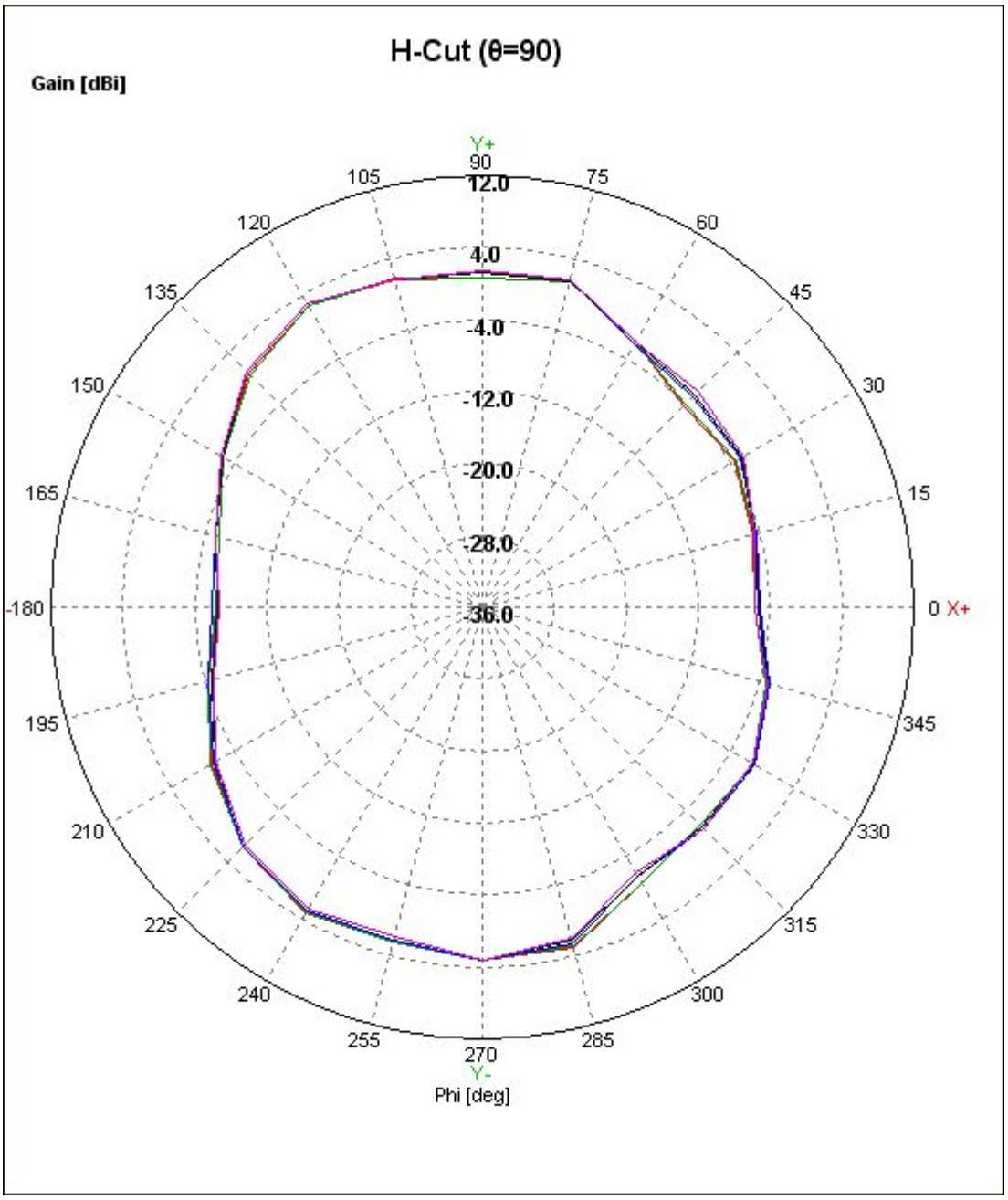


- VSWR

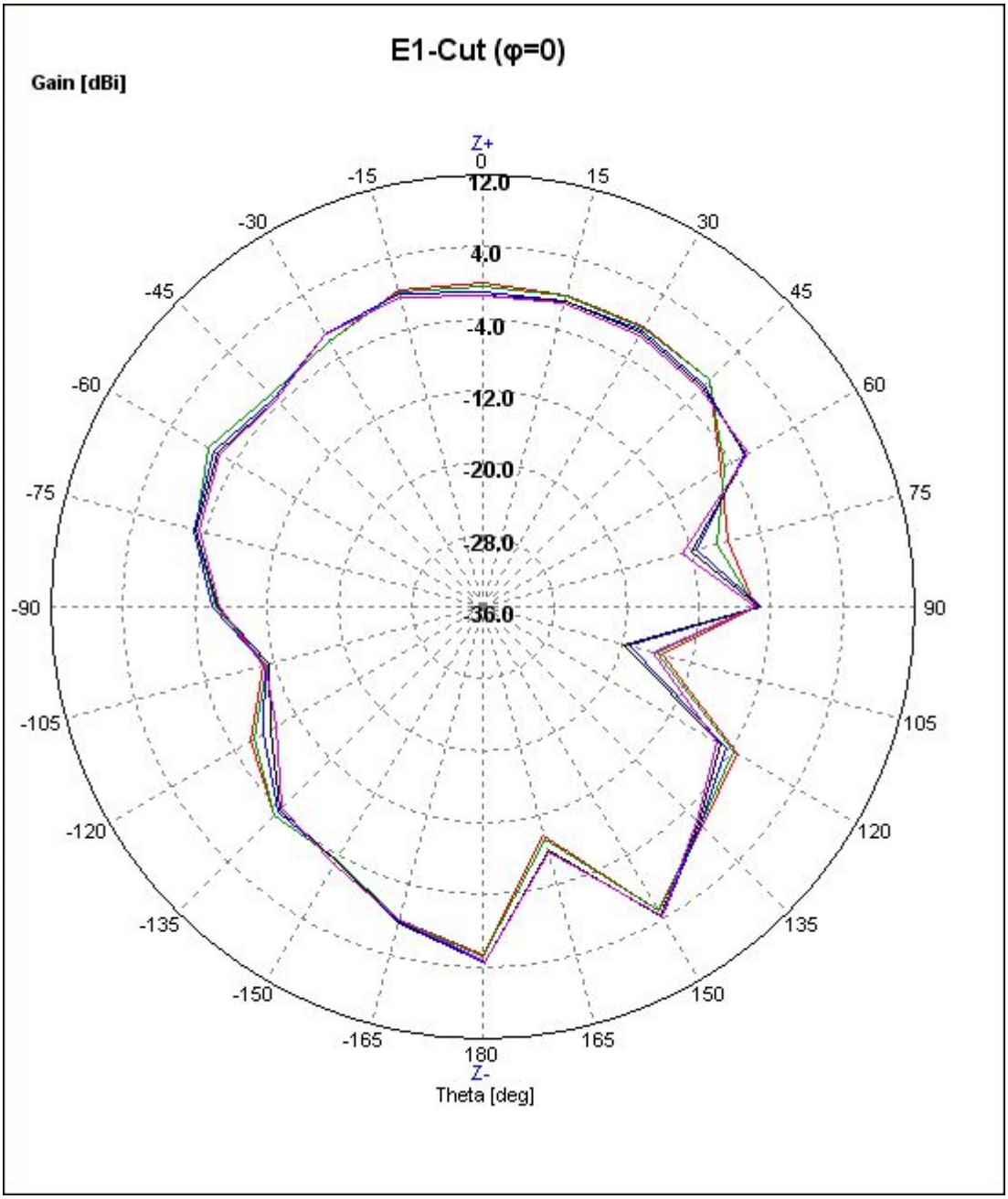


5.2 Radiation Pattern

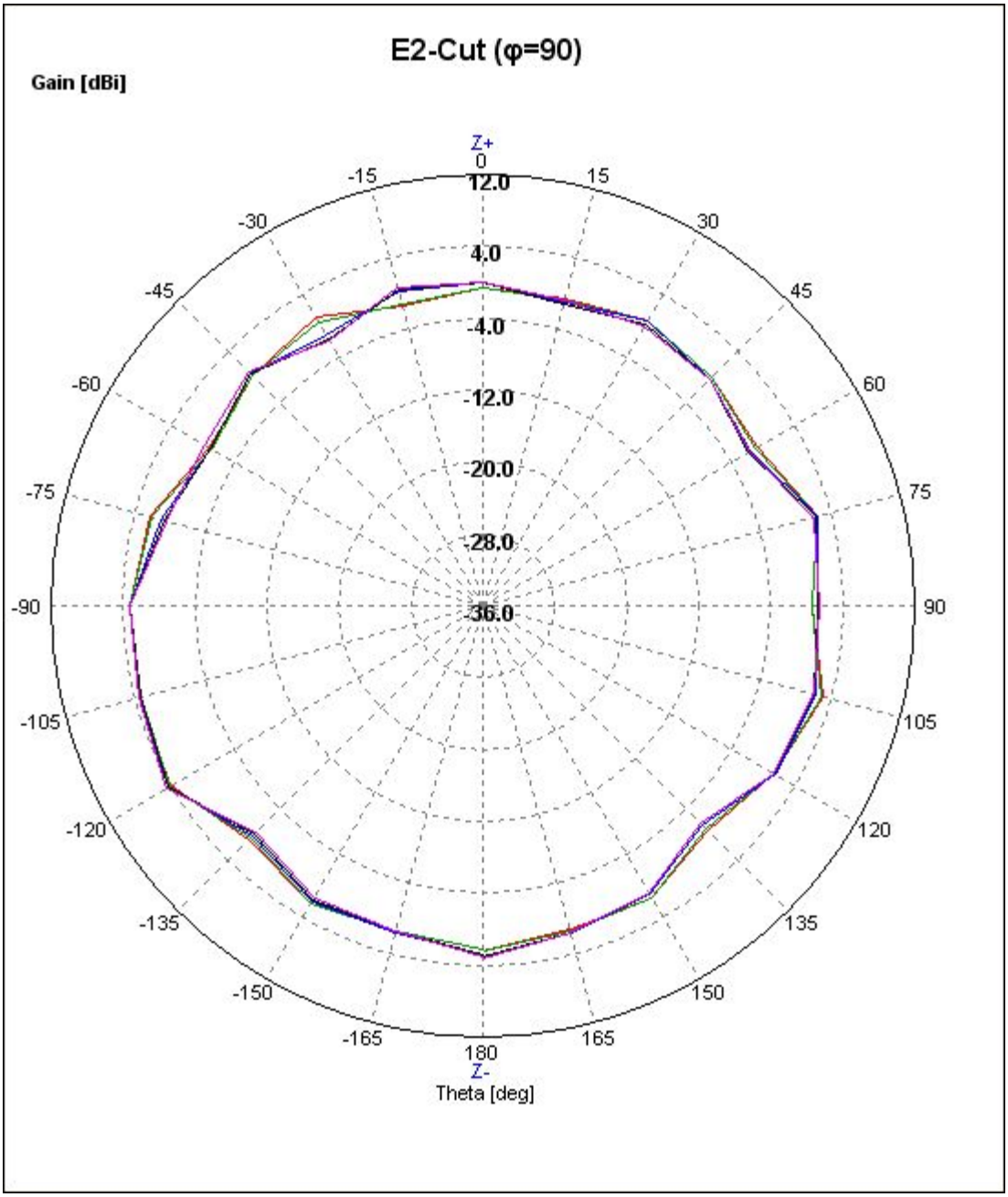
5.2.1 XY – Plane



5.2.2 YZ – Plane


E1-Cut (φ=0)
Gain [dBi]
Z+
0
15
30
45
60
75
90
105
120
135
150
165
180
Z-
-15
-30
-45
-60
-75
-90
-105
-120
-135
-150
-165
12.0
4.0
-4.0
-12.0
-20.0
-28.0
-36.0
Theta [deg]

5.2.3 XZ – Plane


E2-Cut (φ=90)
Gain [dBi]
Z+
0
15
30
45
60
75
90
105
120
135
150
165
180
Z-
-15
-30
-45
-60
-75
-90
-105
-120
-135
-150
-165
12.0
4.0
-4.0
-12.0
-20.0
-28.0
-36.0
Theta [deg]

6. Mechanical Drawing