

WX5512-T0 FCC Directional Gain Proposal



HW RF

14/06/2022

Purpose

- Introduction a test method of FCC KDB 662911 correlated/Uncorrelated directional gain, it strictly follows the FCC directional gain calculation formula.
- With this method, the total directional gain result will more close to the MIMO system real operation scenario.

Agenda

- Directional gain test method introduction.
- SATIMO Microwave Anechoic Chamber environment introduction
- WX5512-T0 Antenna real test report and directional gain calculation

Directional gain test method introduction

FCC KDB 662911 Calculation formula of directional gain for correlated/uncorrelated

- (i) If transmit signals are *correlated*, then

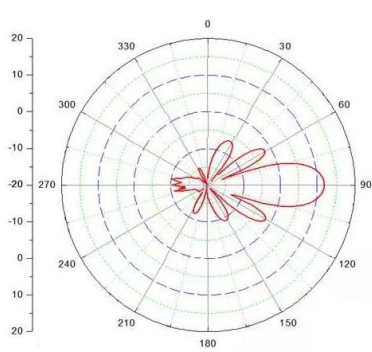
Directional gain = $10 \log[(10^{G_1/20} + 10^{G_2/20} + \dots + 10^{G_N/20})^2 / N_{\text{ANT}}]$ dBi [Note the “20”s in the denominator of each exponent and the square of the sum of terms; the object is to combine the signal levels coherently.]

- (ii) If all transmit signals are *completely uncorrelated*, then

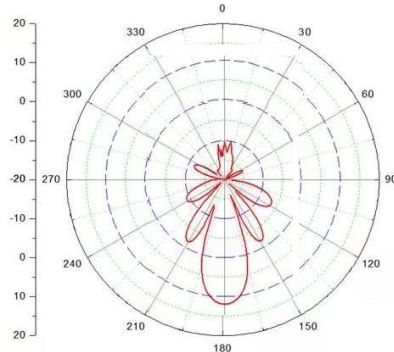
Directional gain = $10 \log[(10^{G_1/10} + 10^{G_2/10} + \dots + 10^{G_N/10}) / N_{\text{ANT}}]$ dBi

Based on FCC KDB 662911 Calculation formula of directional gain analyze

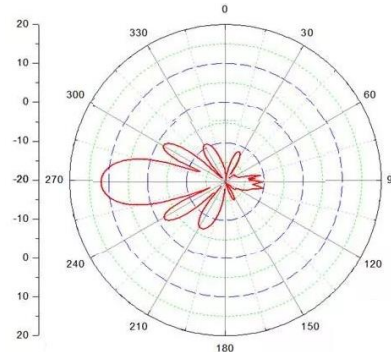
Antenna pattern example:



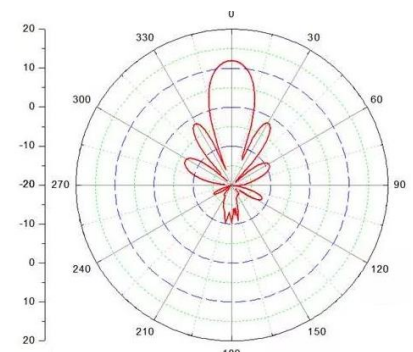
ANT0=3dBi



ANT1=-5dBi



ANT1=-3dBi



ANT1=-7dBi



X axis

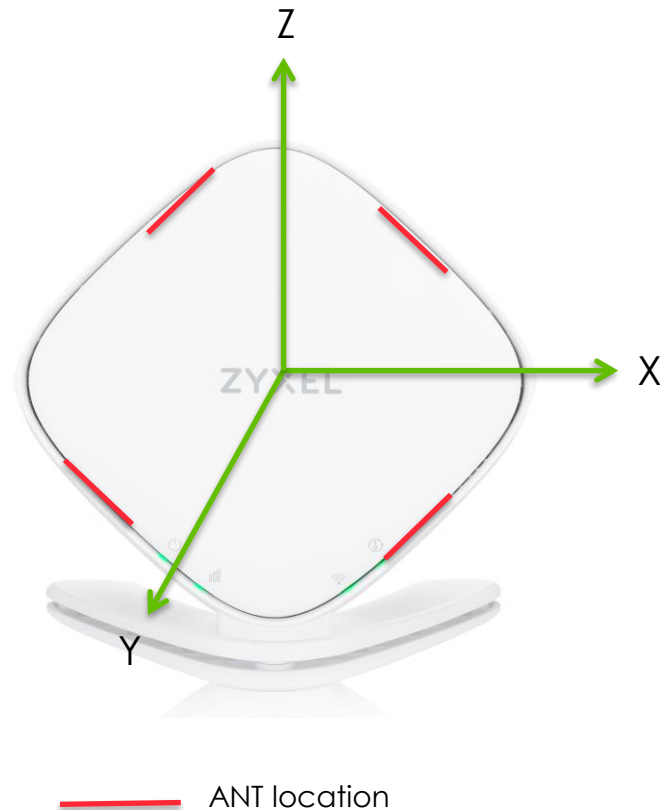
Based on above antenna pattern. The real Antennas gain is reasonable to calculate by each direction. It's the same with MIMO real operation mode. But not calculate with peak gain in different angle.

ZYXEL System introduction

Our product is 4x4 4T4R MIMO system with embedded antennas design

- The antennas are with different location and polarization
- The four antennas have it's own 3D gain data
- The four peak gains are not at the same direction.

So based on the real antenna's gain table, calculate the 4x4 Total Directional gain angle by angle, then select the peak gain as the system directional Gain.



MIMO System directional gain calculation example

For example: at the X axis positive(0 degree):

Ant0 Gain:3dBi

ANT1 Gain:-5dBi

ANT2 Gain:-3dBi

ANT3 Gain:-7dBi

So this directional gain:

Correlated directional gain $= 10 * \text{LOG}((10^{(3/20)} + 10^{(-5/20)} + 10^{(-3/20)} + 10^{(-7/20)})^2 / 4) = 3.9\text{dBi}$

Un-correlated directional gain $= 10 * \text{LOG}((10^{(3/10)} + 10^{(-5/10)} + 10^{(-3/10)} + 10^{(-7/10)}) / 4) = -1.2\text{dBi}$

With the same method, calculate the total 3D gain, then select the peak point as final directional gain.

SATIMO Microwave Anechoic Chamber environment introduction

OUTLINE

1、 Instrument introduction

1.1 SATIMO

1.2 Calibration antenna

1.3 software

2、 Calibration

2.1 Power on and test

2.2 calibration

3、 Measure

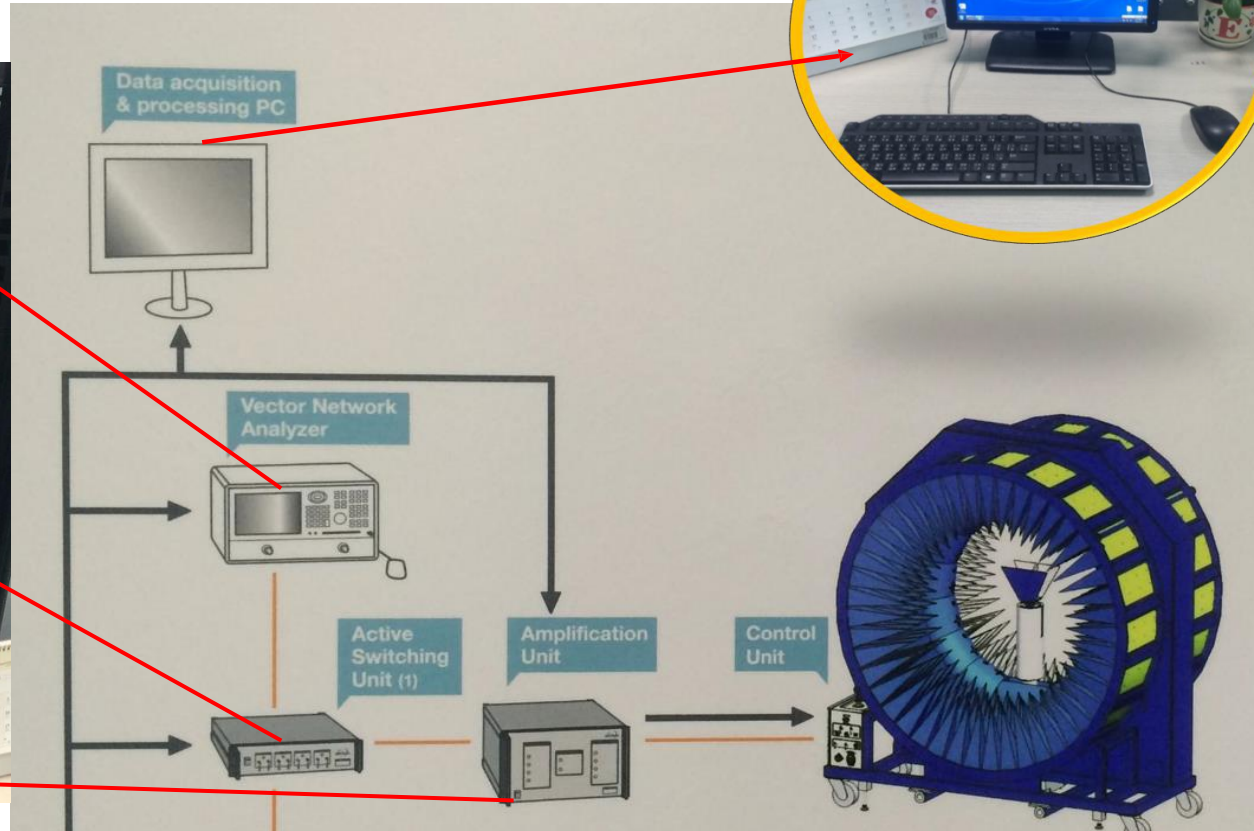
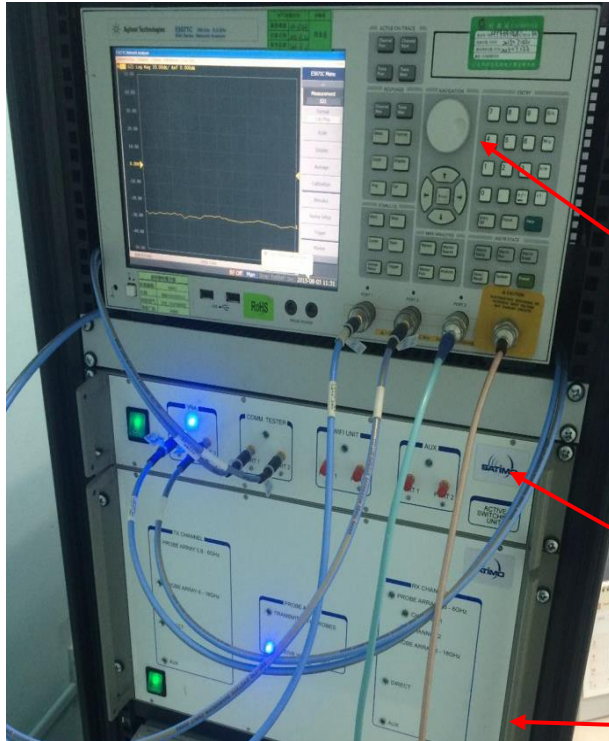
3.1 Place the sample to be tested

3.2 Reset network instrument

3.3 Measure and process data

1、Instrument introduction

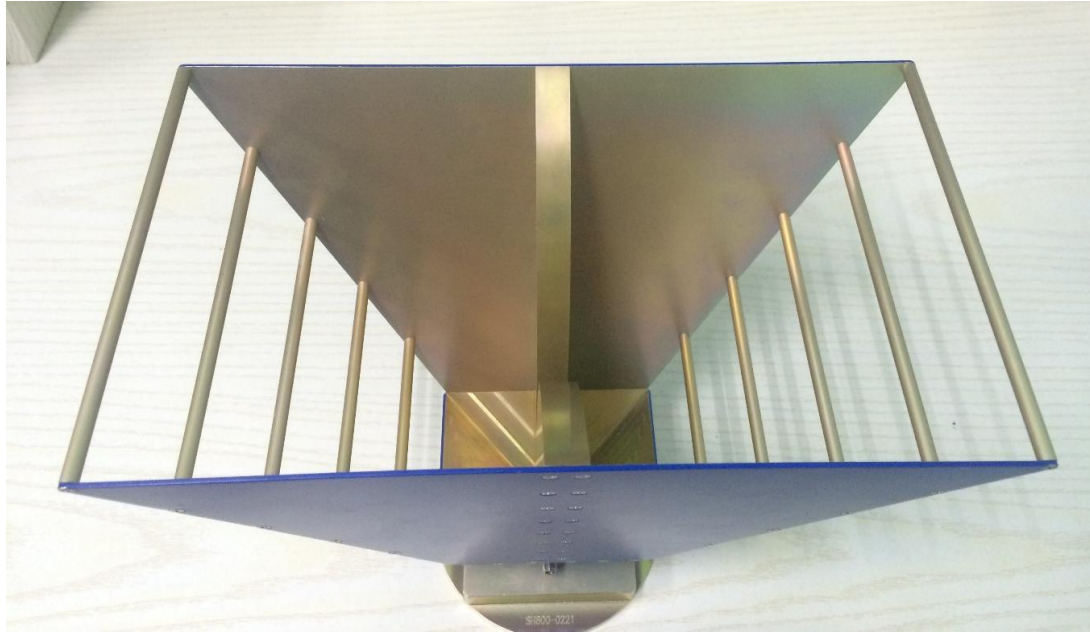
1.1 SATIMO Overview



Entity diagram



1.2 Calibration antenna-Horn antenna



Horn antenna

1.2 Calibration antenna-Dipole antenna

2450MHz

2600MHz

1575MHz

2050MHz

1900MHz

1800MHz

900MHz



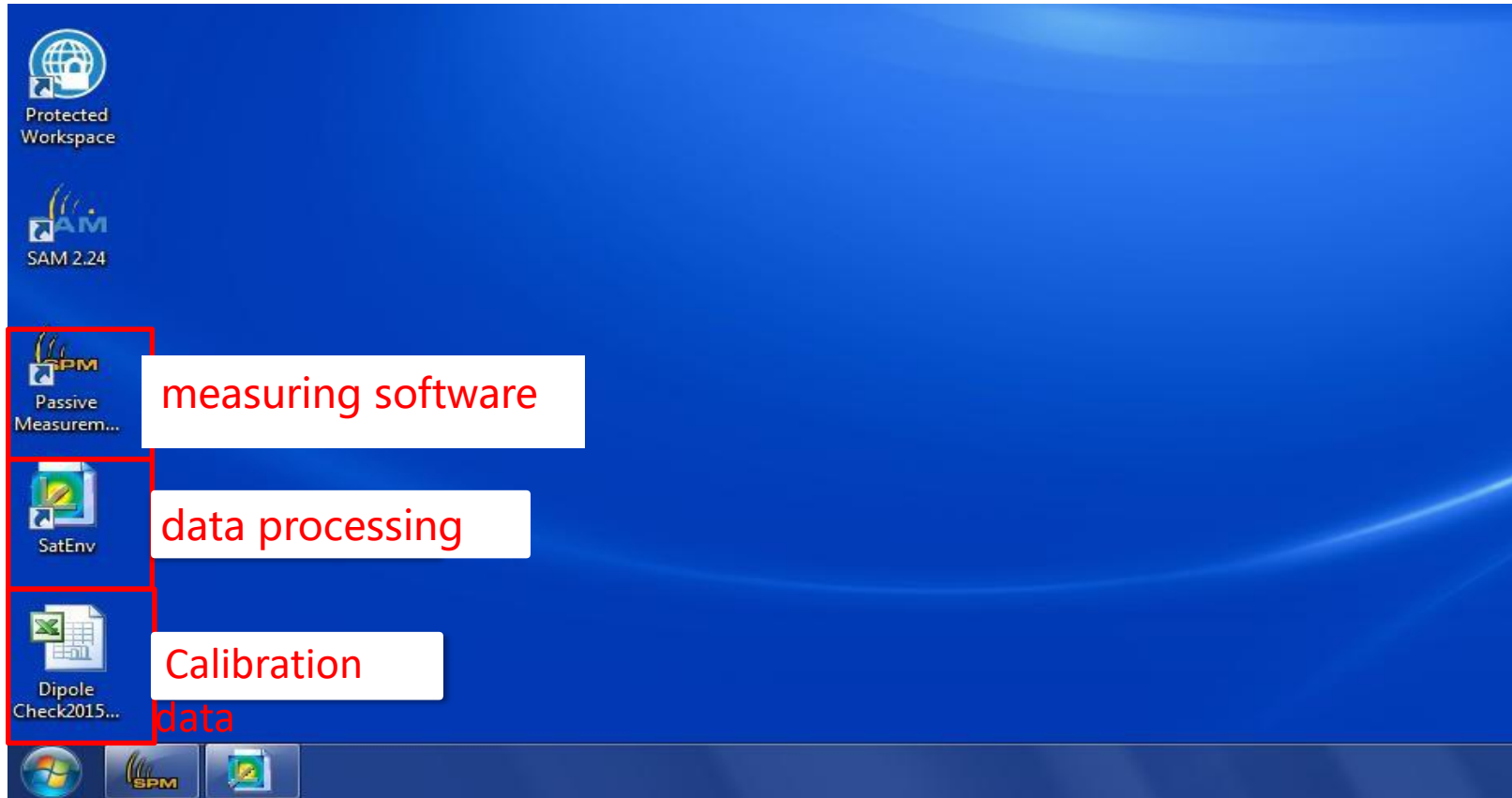
3600MHz

5150MHz

5650MHz

Dipole antenna

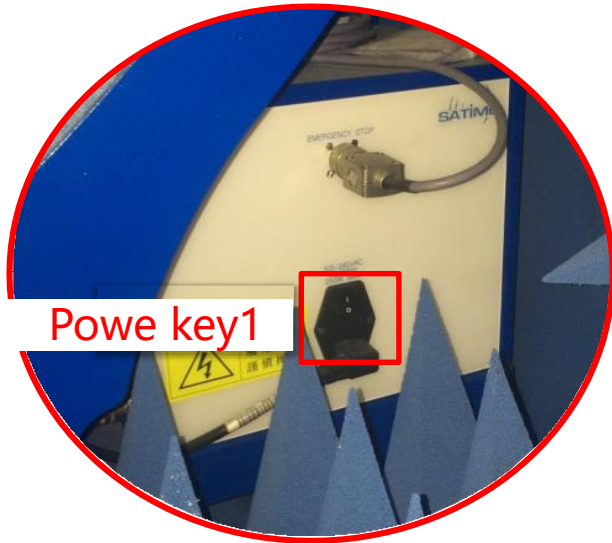
1.3 Software



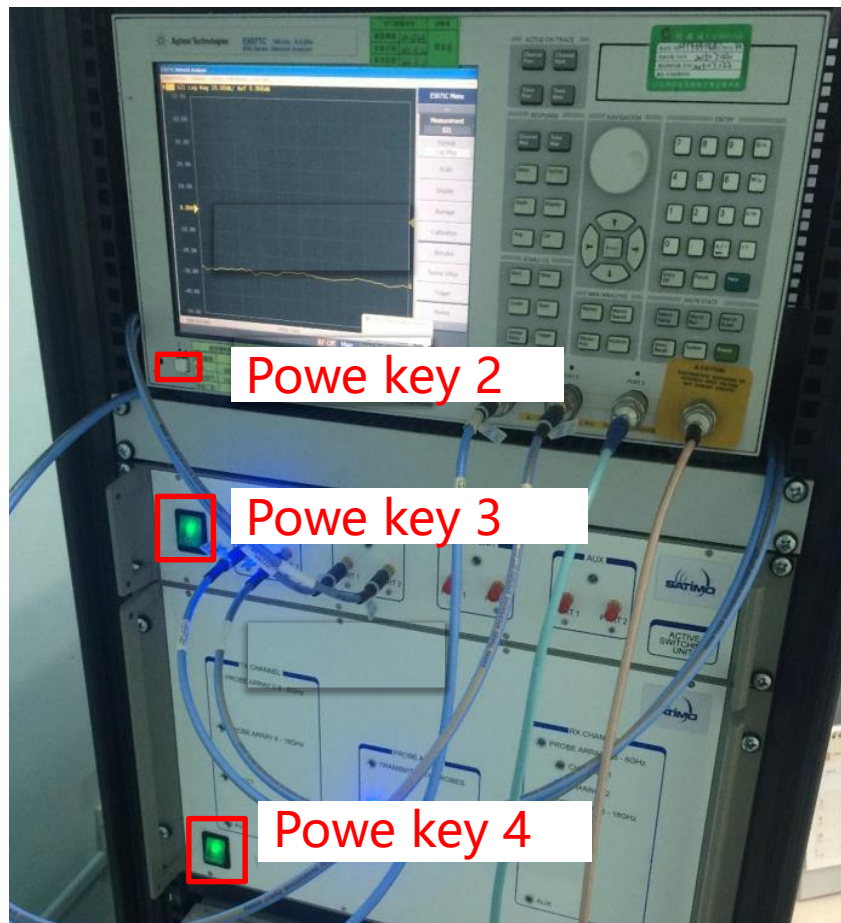
2、Calibration

2.1.1 Open Power

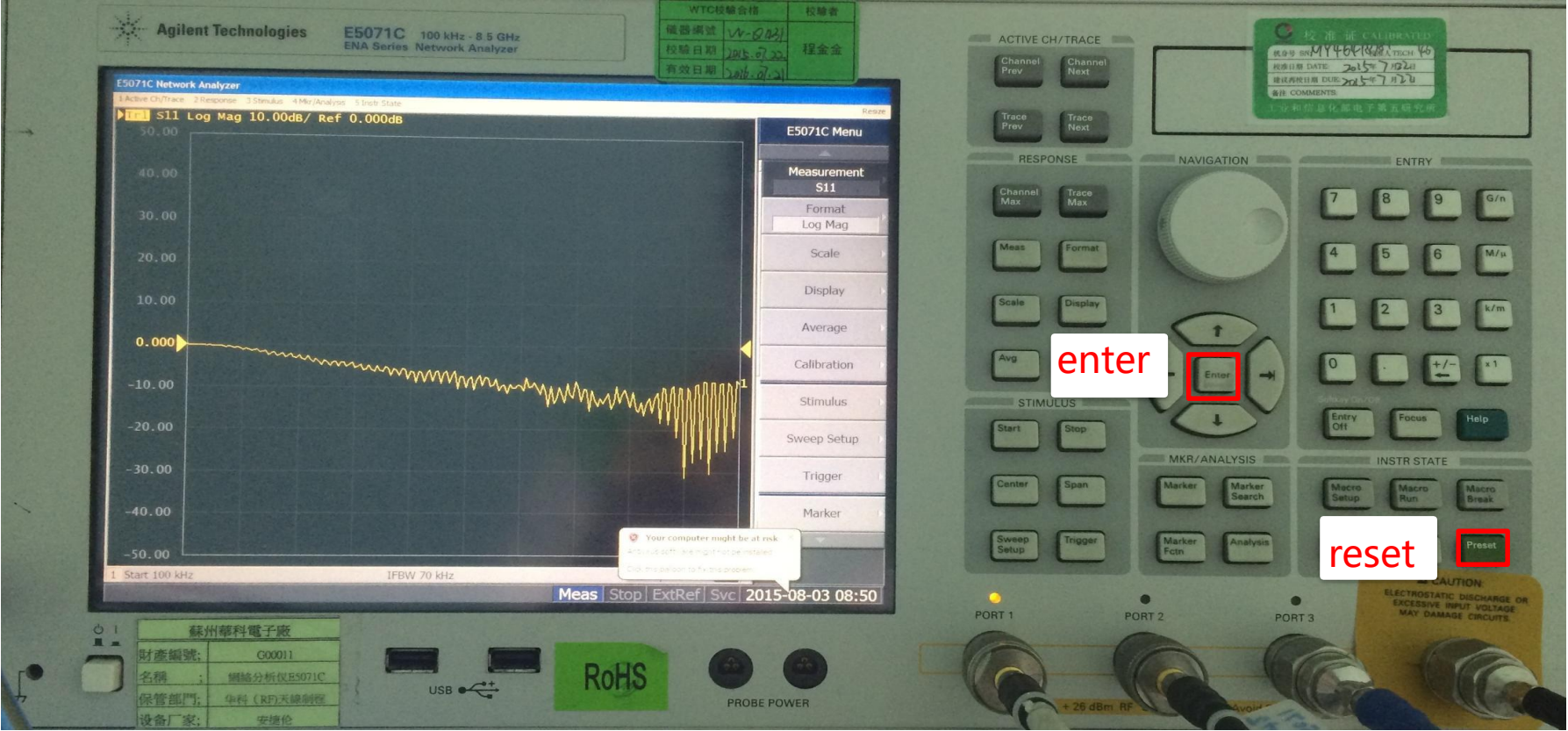
Turn on the power in turn 1, 2, 3, 4, 5



2.1.1 Open Power

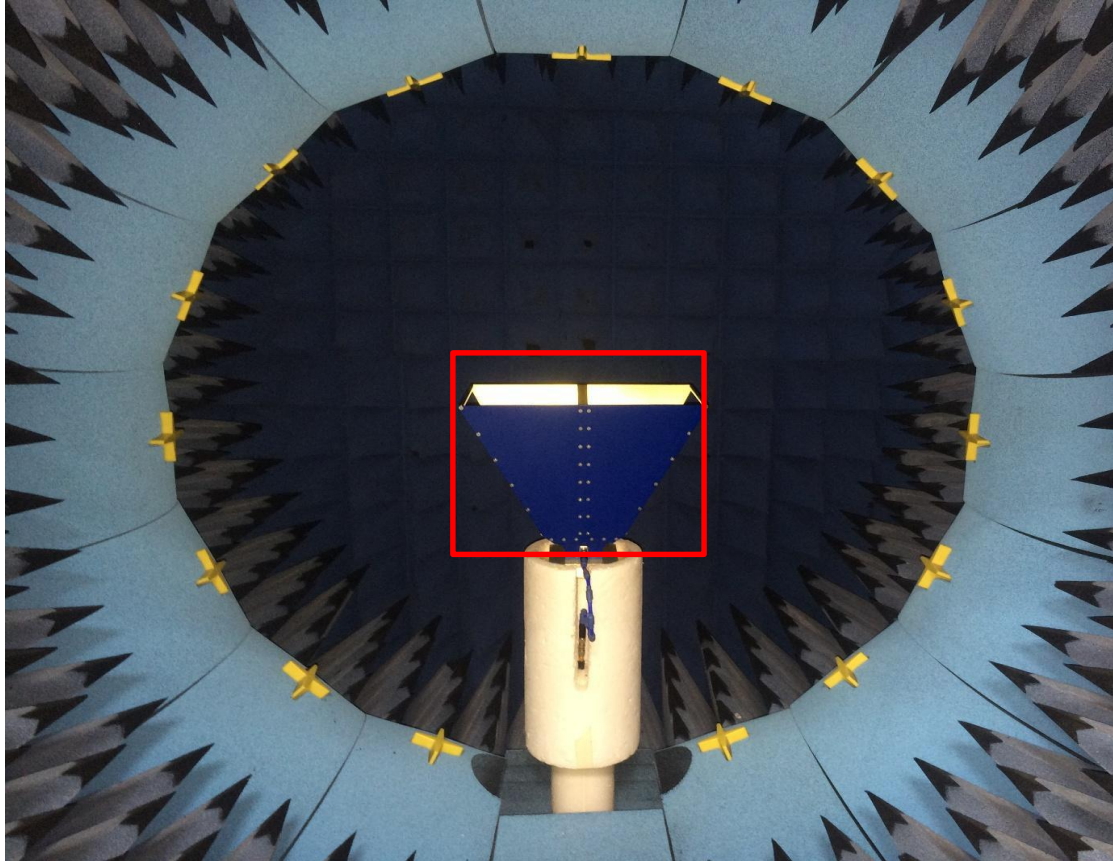


2.1.2 Reset network analyzer

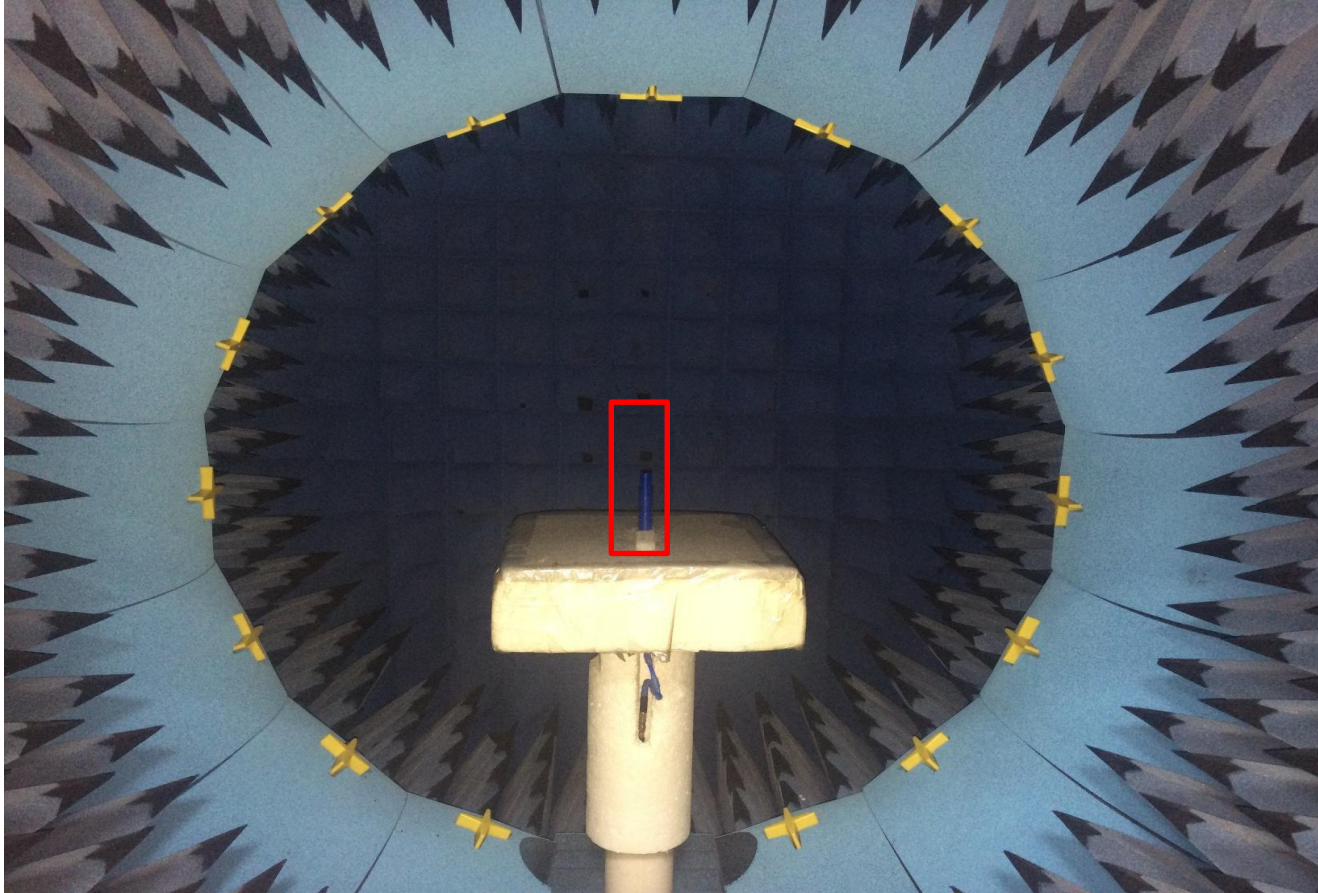


2.2 Calibration

2.2.1. Horn antenna schematic diagram of placement position :



2.2.2 Dipole antenna schematic diagram of placement position :



2.2.3 Open the measurement software, set parameters and start measurement

Start a measurement

Copy data

Magnitude Scale

Legend

Markers

Manage system calibrations

Back to RealTime

Frequency : 2280 MHz

Azimuth : 0

Markers

Double click on a marker to change its position

Elevation -157.5°

Bh -30.2 dB

Ev -27.4°

-13.3 dB

57.2°

Display on plot

Elevation -90°

Bh -30.9 dB

Ev -118.9°

-6.4 dB

71.5°

Display on plot

Elevation -45°

Bh -25.8 dB

Ev -42.1°

-8.5 dB

58.9°

Display on plot

Elevation 0°

Bh -31.0 dB

Ev -71.9°

-38.3 dB

43.3°

Display on plot

Elevation 45°

Bh -29.2 dB

Ev -32.5°

-9.0 dB

-118.7°

Display on plot

Elevation 90°

Bh -32.3 dB

Ev -119.7°

-6.3 dB

-105.0°

Display on plot

Elevation 157.5°

Bh -28.3 dB

Ev -69.3°

-12.8 dB

-124.9°

Display on plot

Magnitude (dB) vs Elevation (°)

Magnitude Scale

Legend

Markers

Manage system calibrations

Help

Export data

To an application

SetEnv

Special

Use as a gain calibration

Configure measurement

Name : HORN

Frequency distribution

Linear

Start : 800 MHz

Points : 521

Stop : 6000 MHz

Step : 10 MHz

List (MHz)

3400 3500 3600

Spatial resolution

Antenna diameter

20 cm

Oversampling

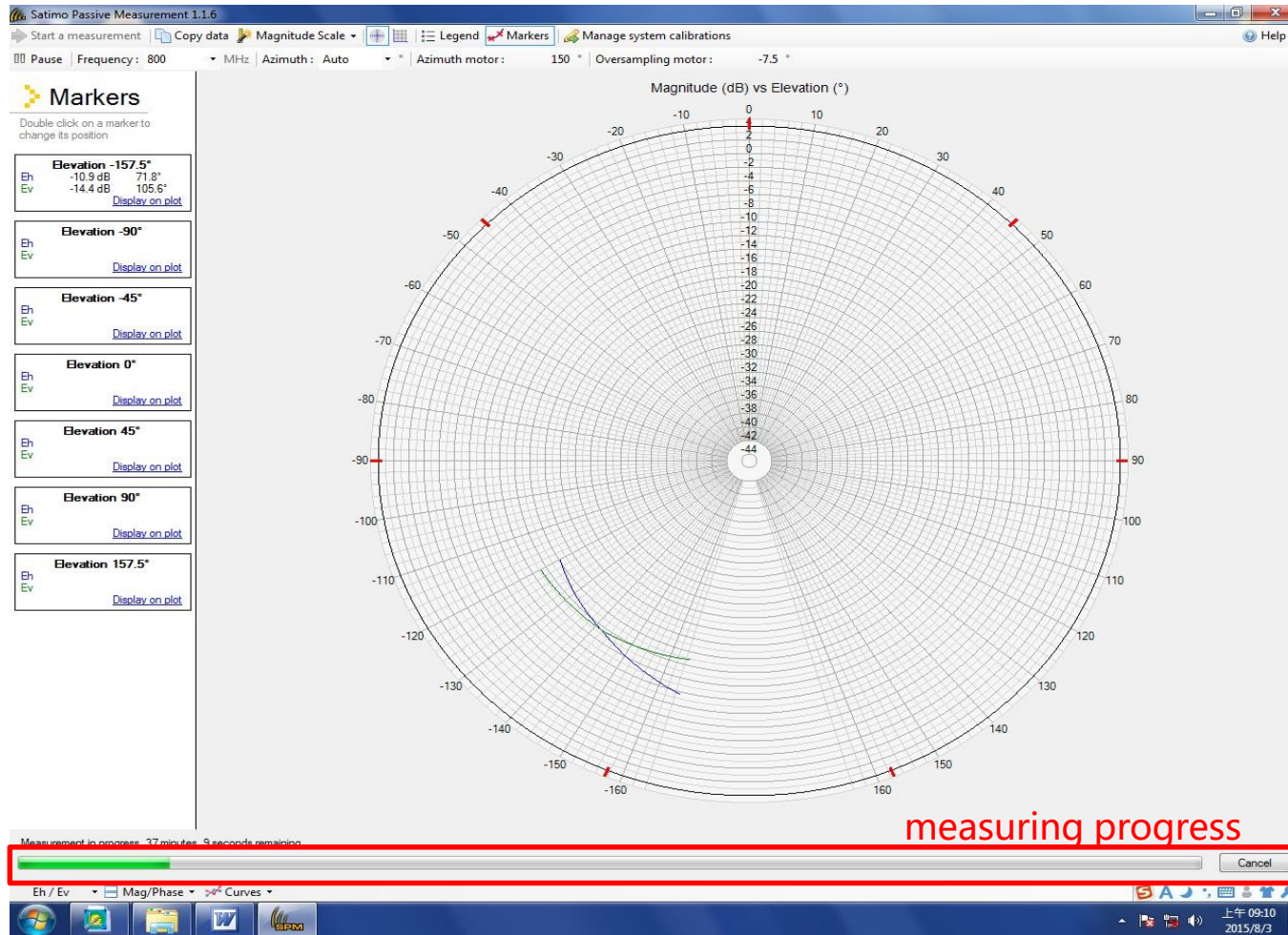
3x

Measure on 360°

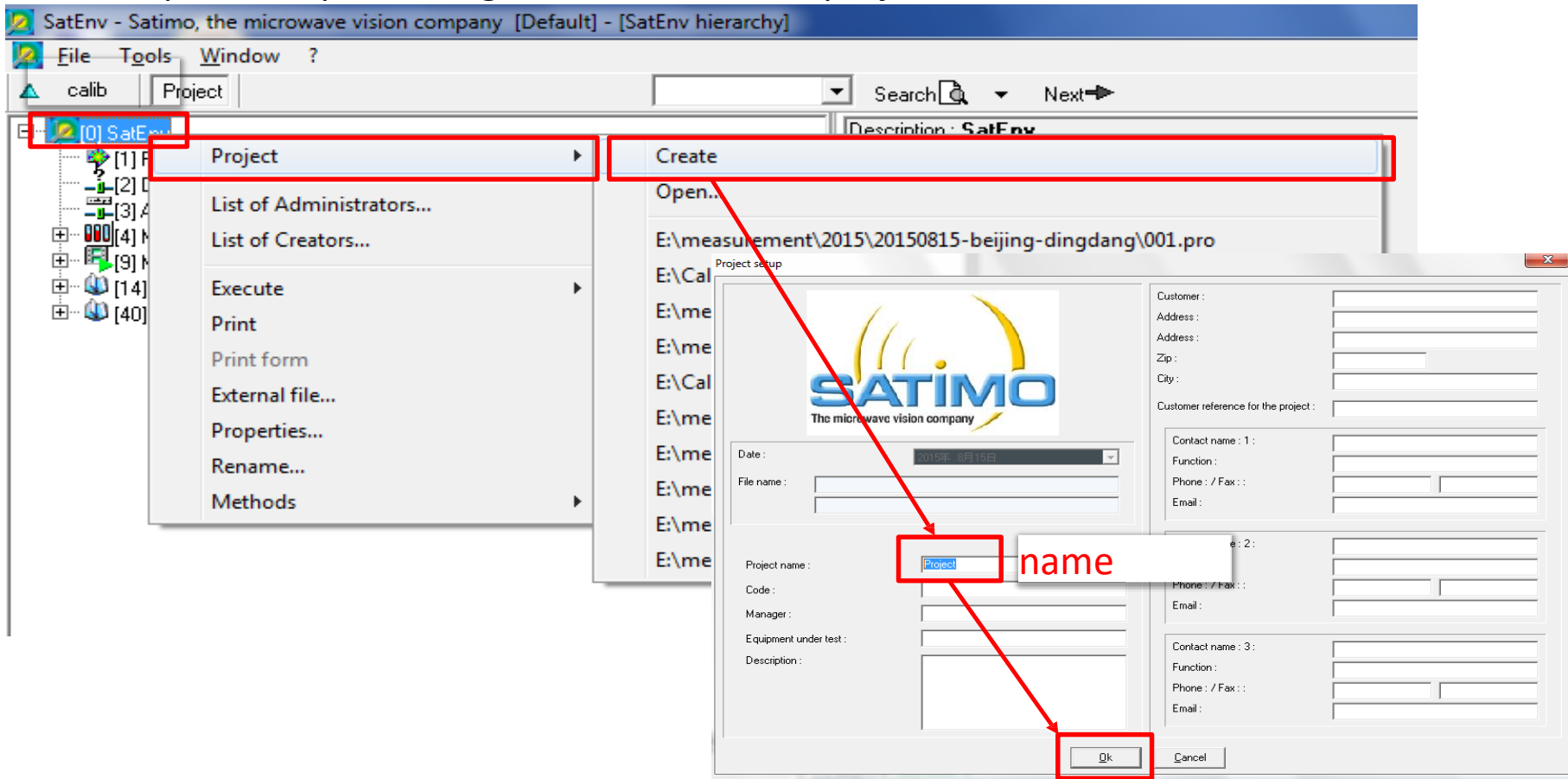
Start measurement

Cancel

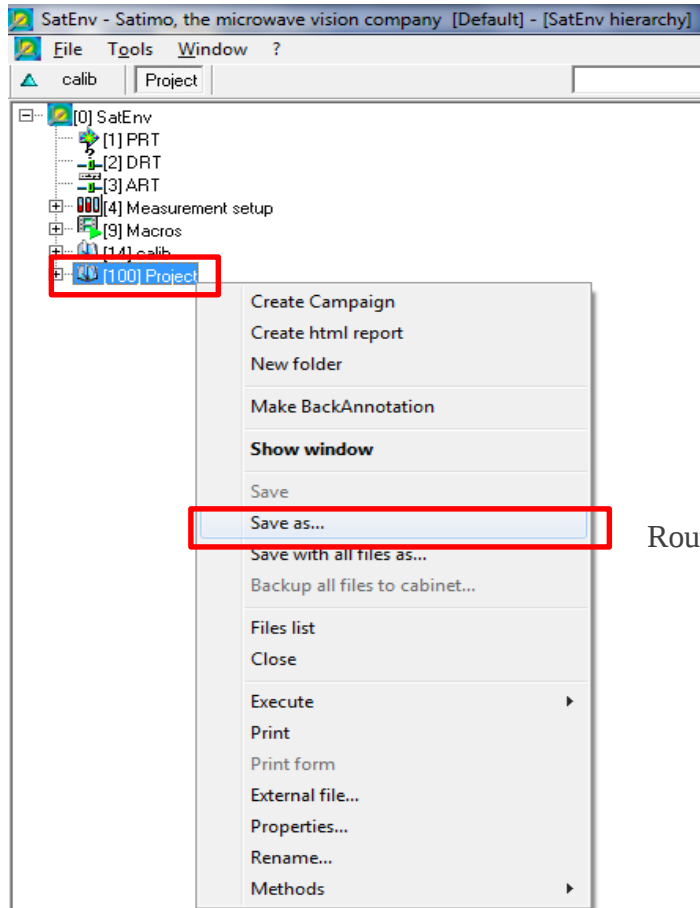
Measuring processing



2.2.4 Open data processing software to create project



2.2.5 Save Route



Route E:\Calib\2015\passive calibration

2.2.6 Export data to data processing software

Satimo Passive Measurement 1.1.6

Start a measurement | Copy data | Magnitude Scale | Legend | Markers | Manage system calibrations

Back to RealTime | Frequency: 2280 MHz | Azimuth: 0

Markers

Double click on a marker to change its position

Elevation	Bh	Ev
-157.5°	-31.3 dB	-42.1°
-90°	-29.7 dB	120.0°
-45°	-25.3 dB	53.1°
0°	-30.3 dB	83.5°

Export data

- Test application
- Set Env
- Special
- Use as a gain calibration

Gain Calibration

Reference file: ...

Antenna type: Horn

Calibration type: Efficiency

☐ Append to previous calibration

Cancel | Ok

Open

Organize | New folder

Search Reference Antenna Data

Name	Date modified	Type
Data D900-12.txt	2010/10/4 下午 06:...	Text Document
Data D1575-4.txt	2010/10/4 下午 06:...	Text Document
Data D1800-45.txt	2010/10/21 下午 1:...	Text Document
Data D1900-21.txt	2010/10/4 下午 06:...	Text Document
Data D2050-36.txt	2010/10/4 下午 06:...	Text Document
Data D2450-32.txt	2010/10/4 下午 06:...	Text Document
Data D2600-0.txt	2010/10/4 下午 06:...	Text Document
Data D3600-17.txt	2010/10/4 下午 06:...	Text Document
Data D5150-19.txt	2010/10/4 下午 06:...	Text Document
Data D5650-40.txt	2010/10/4 下午 06:...	Text Document
Data H800-21.satref	2010/10/4 下午 05:...	SATREF File
Data H2000-49.satref	2010/10/11 下午 0:...	SATREF File

File name: | Reference files (*.ref;*.txt;*.satref)

Open | Cancel

Gain Calibration

Reference file: C:\Calib\Ref\Reference Antenna Data\...

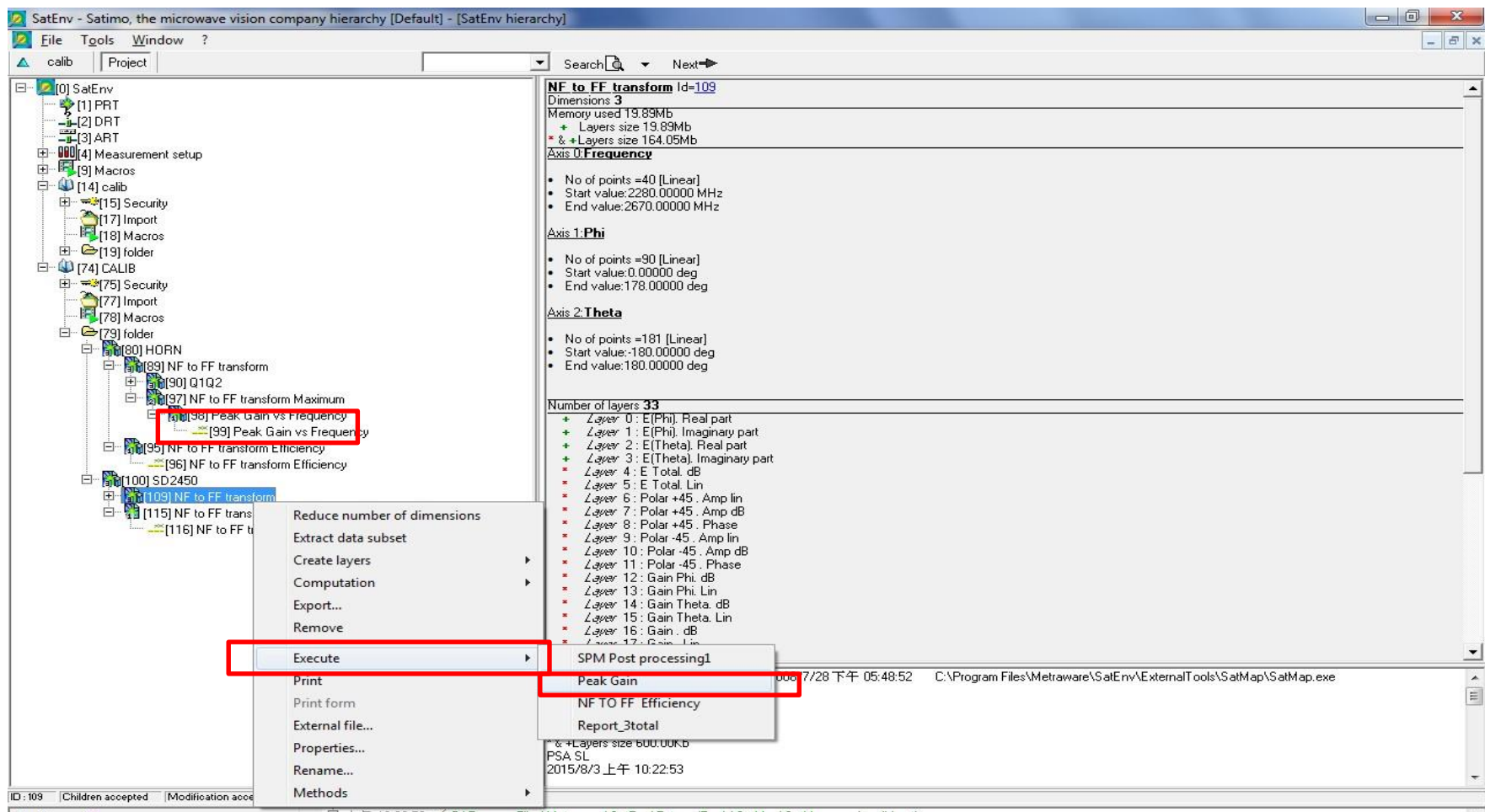
Antenna type: Dipole

Calibration type: Efficiency

☒ Append to previous calibration

Cancel | Ok

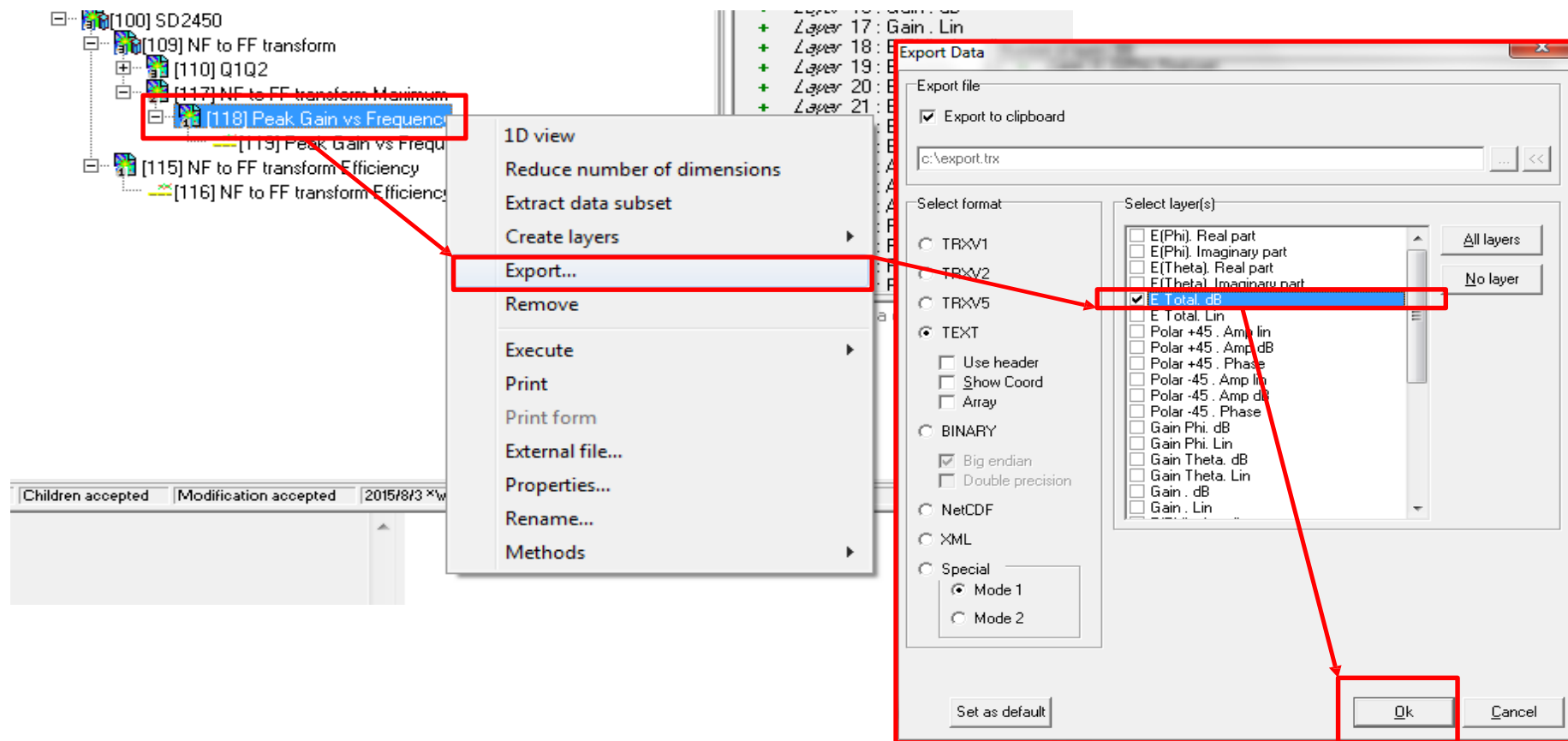
2.2.6.1 Export Peak Gain



2.2.6.2 Get Peak Gain



2.2.6.3 Export E-Total



2.2.6.4 Get E-Total

Microsoft Excel - Dipole Check20150319.xls

檔案(F) 編輯(E) 檢視(V) 插入(I) 格式(O) 工具(T) 資料(D) 視窗(W) 說明(H)

輸入需要解答的問題

H29 1.73400690430778

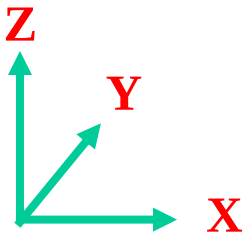
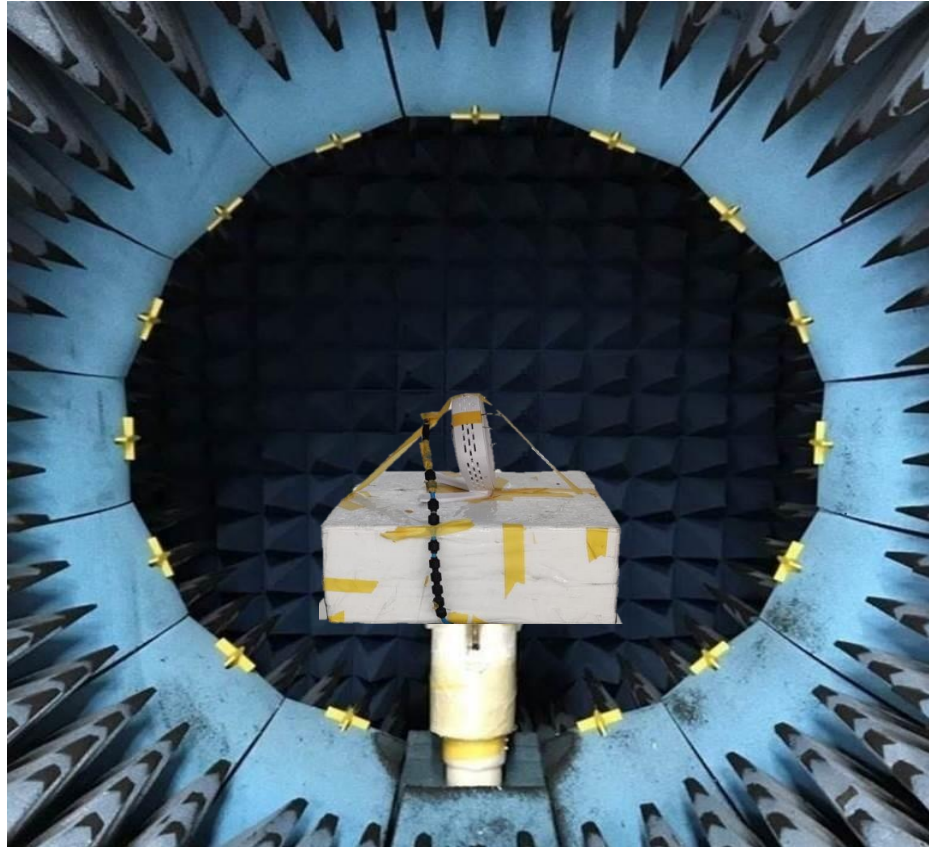
Measure Peak Gain [dBi] - 5071C - Eff Method

	F	G	H	I	J	K
19	Measure Peak Gain [dBi] - 5071C - Eff Method					
20						
21						
22						
23						
24						
25						
26						
27	Agilent 5071C					
28	Measure Efficiency[%] - 5071C - Eff Method	Measure Efficiency[dB] - 5071C	Measure Peak Gain [dBi] - 5071C - Eff Method	Compare Efficiency(%)	Compare Peak Gain(dB)	Compare Efficiency(dB)
29	88%	-0.58	1.73	-1%	-0.08	-0.029
30	89%	-0.53	1.76		-0.04	-0.030
31	89%	-0.52	1.75		-0.01	-0.031
32	89%	-0.52	1.75		-0.02	-0.032
33	89%	-0.52	1.76		0.01	-0.033
34	90%	-0.47	1.81		-0.04	-0.034
35	90%	-0.47	1.81		-0.05	-0.034
36	90%	-0.47	1.84		-0.08	-0.034
37	90%	-0.47	1.86		-0.16	-0.034
38	90%	-0.47	1.88		-0.21	-0.034
39	91%	-0.42	1.95		-0.21	-0.034
40	91%	-0.42	1.97		-0.19	-0.034
41	91%	-0.42	1.97		-0.17	-0.034
42	91%	-0.42	1.95		-0.14	-0.035
43	91%	-0.42	1.94		-0.14	-0.035
44	91%	-0.42	1.91		-0.13	-0.036
45	91%	-0.42	1.88		-0.13	-0.036
46	92%	-0.37	1.92		-0.15	-0.037
47	92%	-0.37	2.00		-0.19	-0.037
48	92%	-0.37	2.01		-0.12	-0.037
49	92%	-0.37	2.02		-0.10	-0.036
50	92%	-0.37	2.03	-1%	-0.10	-0.037
51	91%	-0.42	2.00	-1%	-0.07	-0.036
52	91%	-0.42	2.02	-1%	-0.09	-0.036
53	92%	-0.37	2.08	-1%	-0.14	-0.036
54	91%	-0.42	2.04	-1%	-0.16	-0.037
55	91%	-0.42	2.05	-1%	-0.24	-0.037
56	91%	-0.42	2.06	-1%	-0.24	-0.038
57	91%	-0.42	2.06	-1%	-0.20	-0.040
58	91%	-0.42	2.07	-1%	-0.20	-0.041
59	91%	-0.41	2.09	-1%	-0.19	-0.043
60	91%	-0.41	2.10	-1%	-0.19	-0.045
61	90%	-0.46	2.06	-1%	-0.17	-0.047
62	91%	-0.41	2.09	-1%	-0.20	-0.049
63	90%	-0.45	2.05	-1%	-0.18	-0.052
64	90%	-0.45	2.05	-1%	-0.22	-0.051

剪下(S) 複製(C) 貼上(P) 選擇性貼上(O)... 插入(I)... 刪除(D)... 清除內容(U) 插入註解(M) 儲存格式(F)... 從下拉式清單挑選(O)... 新增監看式(W) 建立清單(C)... 超連結(H)... 查詢(L)...

SD900 / SD1575 / SD1800 / SD1900 / SD2050 / SD2450 / SD2600 / SD3600 / SD5150 / SD5650 /

3、Measure



3.1 Open the measurement software, set parameters and start measurement

Satimo Passive Measurement 1.1.6

Start a measurement Copy data Magnitude Scale Legend Markers Manage system calibrations

Back to RealTime Frequency : 2280 MHz Azimuth : 0

Magnitude (dB) vs Elevation (°)

Markers

Double click on a marker to change its position

Elevation -157.5°	Eh -30.2 dB	Ev -27.4°	-13.3 dB	57.2°
Elevation -90°	Eh -30.9 dB	Ev 118.9°	-6.4 dB	71.5°
Elevation -45°	Eh -25.8 dB	Ev 42.1°	-8.5 dB	58.9°
Elevation 0°	Eh -31.0 dB	Ev 71.9°	-38.3 dB	43.3°
Elevation 45°	Eh -29.2 dB	Ev 32.5°	-118.7°	-9.0 dB
Elevation 90°	Eh -32.3 dB	Ev 119.7°	-105.0°	-6.3 dB
Elevation 157.5°	Eh -28.3 dB	Ev -69.3°	-124.9°	-12.8 dB

Export data

To an application

SetEnv

Special

Use as a gain calibration

Configure measurement

Name : HORN

Frequency distribution

Linear

Start 800 MHz

Stop 6000 MHz

Points : 521

Step : 10 MHz

List (MHz)

3400 3500 3600

Spatial resolution

Antenna diameter 20 cm

Oversampling 3x

Measure on 360°

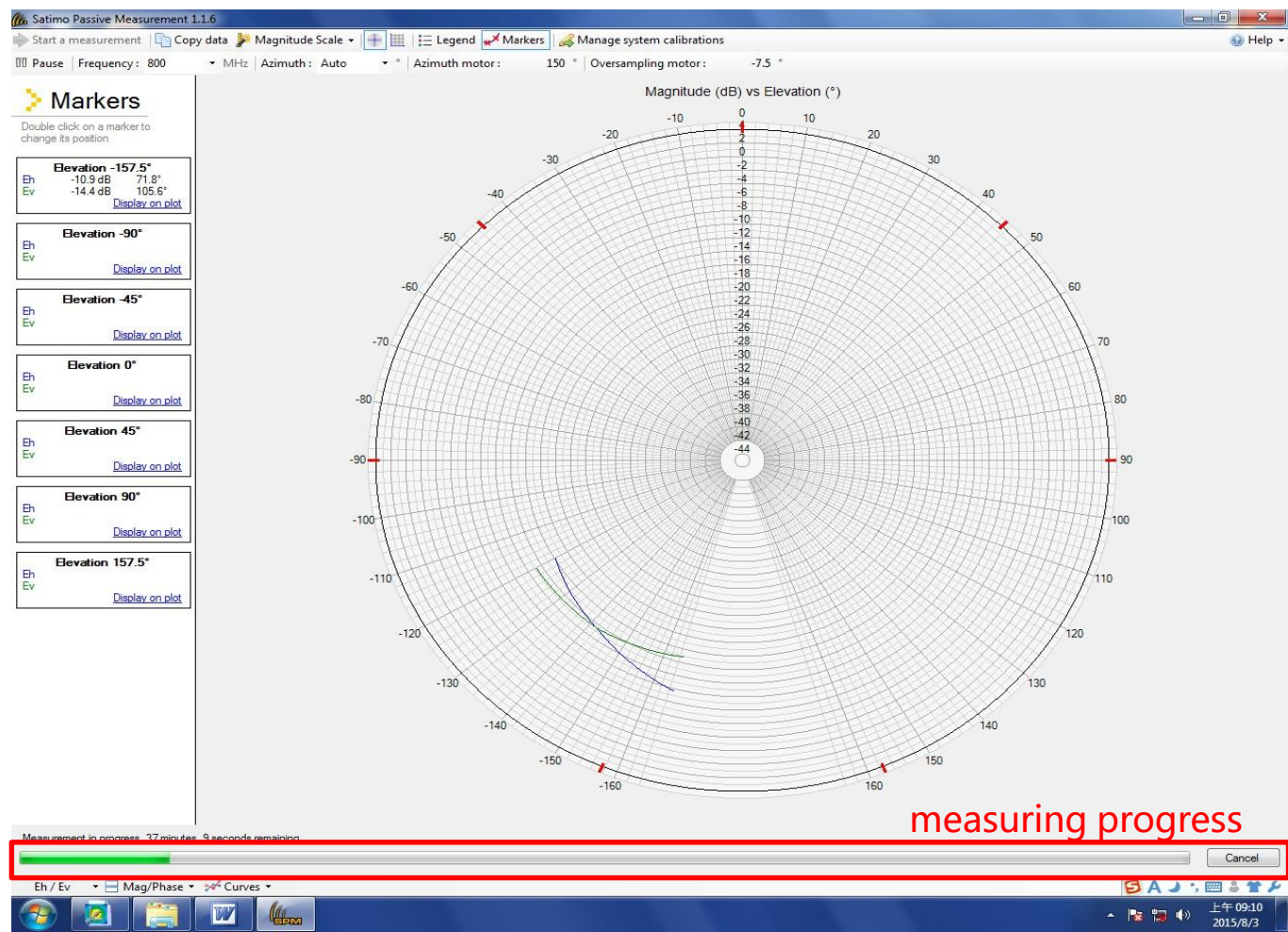
Grid size : 7.5°

Start measurement

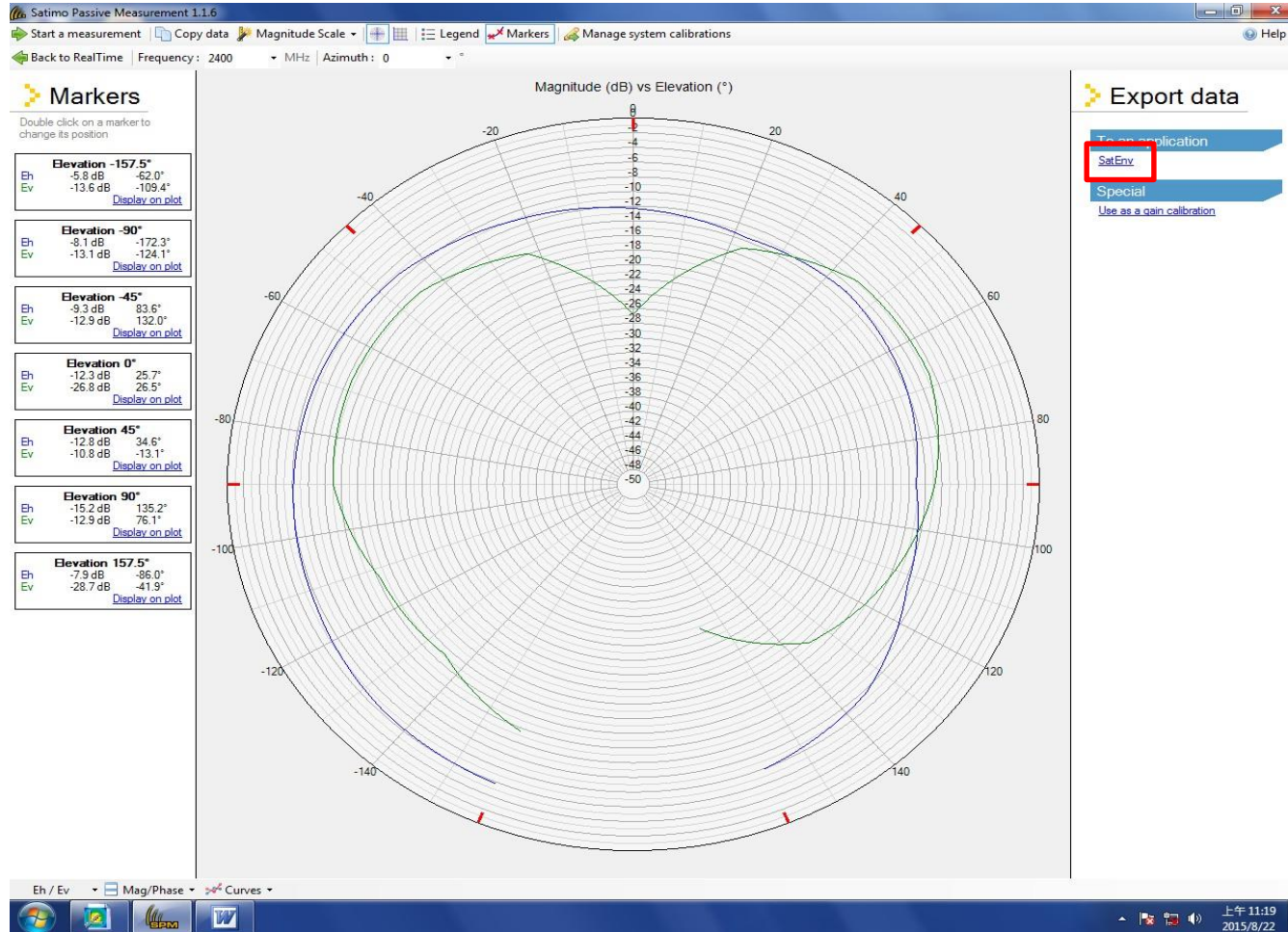
Cancel

type	start	stop
2.4G	2400	2500
5G	5150	5850

Measuring processing



3.2 Export data to data processing software



3.2.1 Export Peak Gain

The screenshot displays the SatEnv software interface. The left pane shows a project hierarchy for '[0] SatEnv', with sub-items including '[1] PRT', '[2] DRT', '[3] ART', '[4] Measurement setup', '[9] Macros', '[14] calib', '[15] Security', '[17] Import', '[18] Macros', '[19] folder', '[74] CALIB', '[75] Security', '[77] Import', '[78] Macros', '[79] folder', '[80] HORN', '[89] NF to FF transform', '[90] Q1Q2', '[97] NF to FF transform Maximum', '[98] Peak Gain vs Frequency', '[99] Peak Gain vs Frequency', '[95] NF to FF transform Efficiency', '[96] NF to FF transform Efficiency', '[100] SD2450', and '[109] NF to FF transform'. The '[109] NF to FF transform' item is selected and highlighted with a red box.

A context menu is open over the selected item, listing the following options: 'Reduce number of dimensions', 'Extract data subset', 'Create layers', 'Computation', 'Export...', 'Remove', 'Execute', 'Print', 'Print form', 'External file...', 'Properties...', 'Rename...', and 'Methods'. The 'Execute' option is highlighted with a red box, and a sub-menu is visible showing the following options: 'SPM Post processing1', 'Peak Gain', 'NF TO FF Efficiency', and 'Report_3total'. The 'Peak Gain' option is highlighted with a red box.

The right pane displays the details for the 'NF to FF transform Id=109' project. It shows the following information:

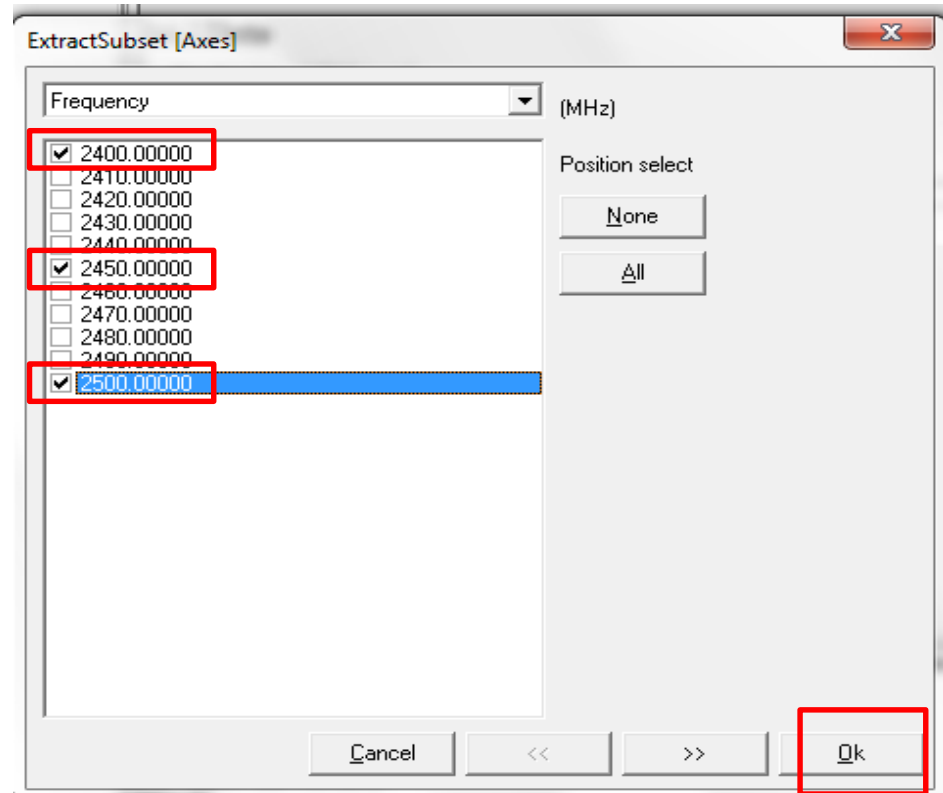
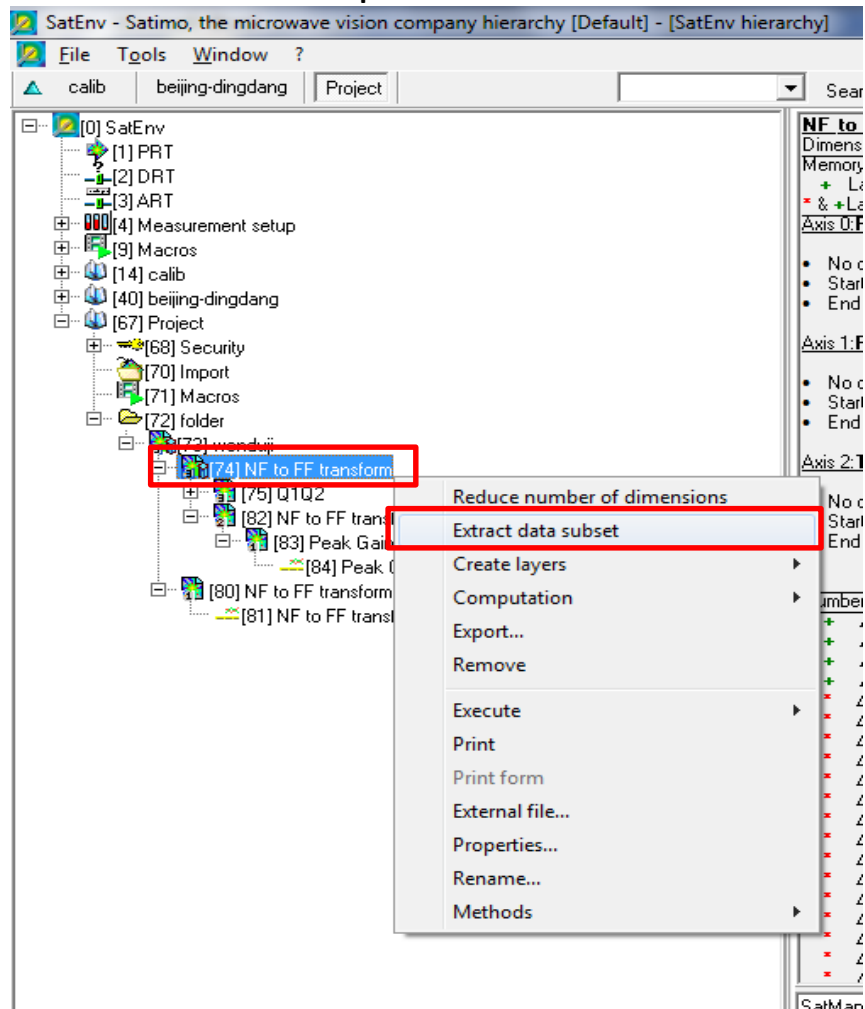
- Dimensions 3
- Memory used 19.89Mb
 - + Layers size 19.89Mb
 - + Layers size 164.05Mb
- Axis 0: **Frequency**
 - No of points =40 [Linear]
 - Start value:2280.00000 MHz
 - End value:2670.00000 MHz
- Axis 1: **Phi**
 - No of points =90 [Linear]
 - Start value:0.00000 deg
 - End value:178.00000 deg
- Axis 2: **Theta**
 - No of points =181 [Linear]
 - Start value:-180.00000 deg
 - End value:180.00000 deg
- Number of layers 33
 - + Layer 0: E(PHI). Real part
 - + Layer 1: E(PHI). Imaginary part
 - + Layer 2: E(Theta). Real part
 - + Layer 3: E(Theta). Imaginary part
 - + Layer 4: E Total. dB
 - + Layer 5: E Total. Lin
 - + Layer 6: Polar +45 . Amp lin
 - + Layer 7: Polar +45 . Amp dB
 - + Layer 8: Polar +45 . Phase
 - + Layer 9: Polar -45 . Amp lin
 - + Layer 10: Polar -45 . Amp dB
 - + Layer 11: Polar -45 . Phase
 - + Layer 12: Gain Phi. dB
 - + Layer 13: Gain Phi. Lin
 - + Layer 14: Gain Theta. dB
 - + Layer 15: Gain Theta. Lin
 - + Layer 16: Gain . dB
 - + Layer 17: Gain . Lin
- + Layers size 600.00Kb
- PSA SL
- 2015/8/3 上午 10:22:53

The status bar at the bottom shows 'ID: 109', 'Children accepted', and 'Modification accepted'. The bottom right corner of the window displays the date and time '08/7/28 下午 05:48:52' and the file path 'C:\Program Files\Metraware\SatEnv\ExternalTools\SatMap\SatMap.exe'.

3.2.2 Get Peak Gain



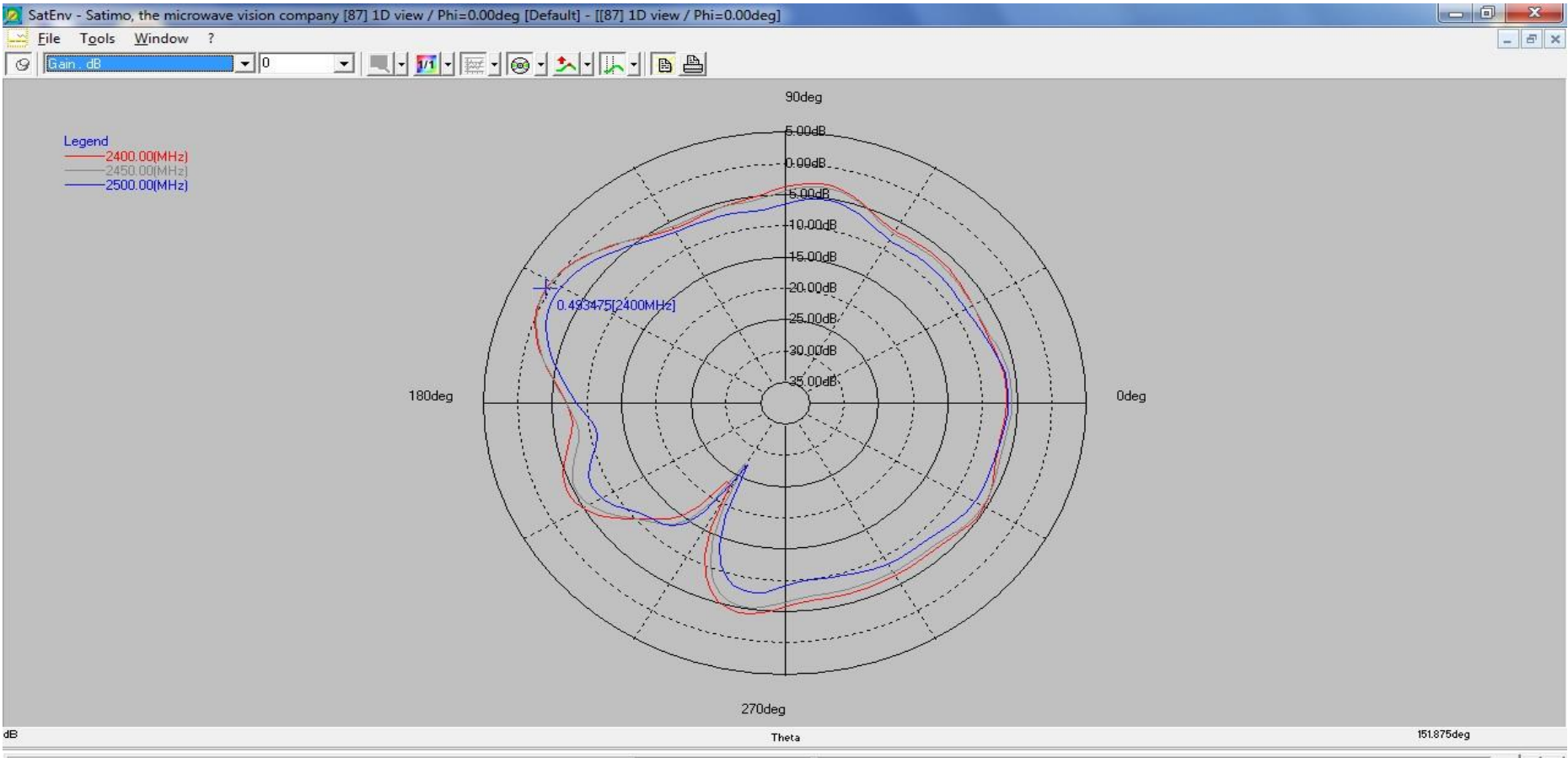
3.2.3 Solve 2D field pattern



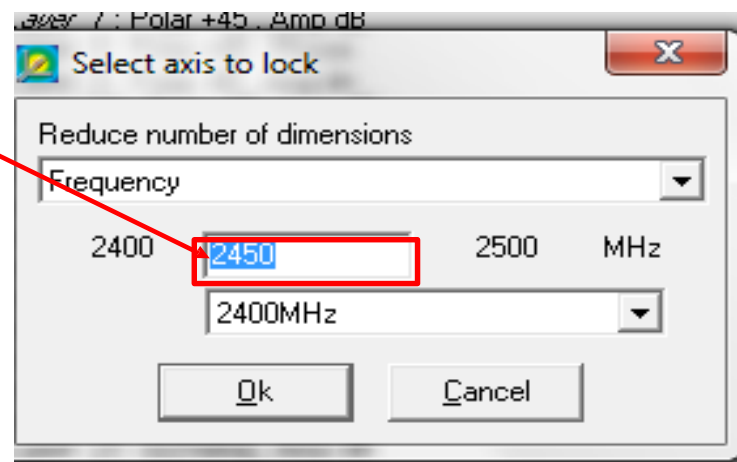
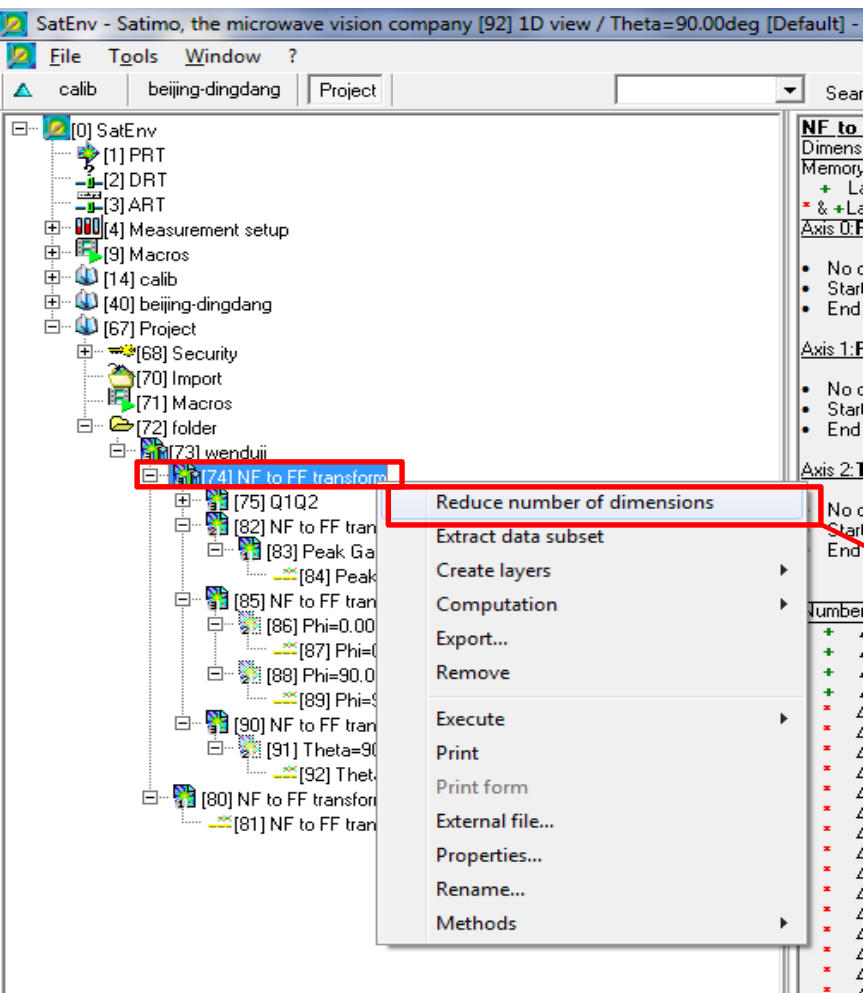
3.2.3 Solve 2D field pattern

The screenshot displays the HSPICE GUI interface. On the left, a project tree shows a hierarchy of items: [67] Project, [68] Security, [70] Import, [71] Macros, [72] folder, [73] wenduji, [74] NF to FF transform, [75] Q1Q2, [82] NF to FF transform Maximum, [83] Peak Gain vs Frequency, [84] Peak Gain vs Frequency, [85] NF to FF transform - (data subset), [80] NF to FF transform Efficiency, and [81] NF to FF transform Efficiency. Item [85] is selected, and a context menu is open over it. The menu options are: Reduce number of dimensions, Extract data subset, Create layers, Computation, Export..., Remove, Execute (highlighted with a red box), Print, Print form, External file..., Properties..., Rename..., and Methods. A sub-menu is open for 'Execute', showing options: SPM Post processing1, Peak Gain, NF TO FF Efficiency, and Report_3total (highlighted with a red box). On the right, a parameter list for 'Axis 1: Phi' and 'Axis 2: Theta' is visible, showing values for 'No of points', 'Start value', and 'End value'.

3.2.4 Get 2D field pattern



3.2.5 Solving 3D field pattern

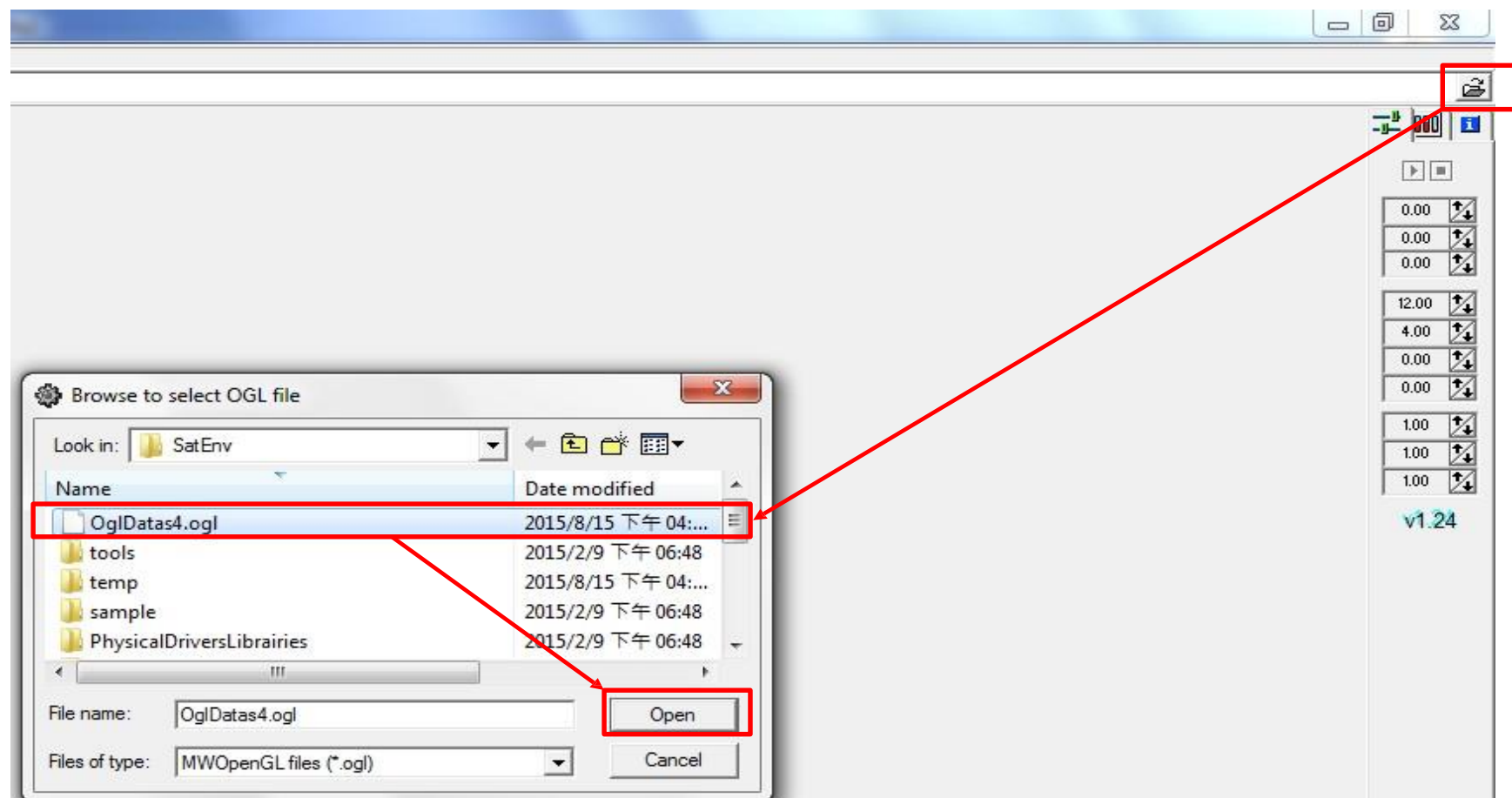


3.2.5 Solving 3D field pattern

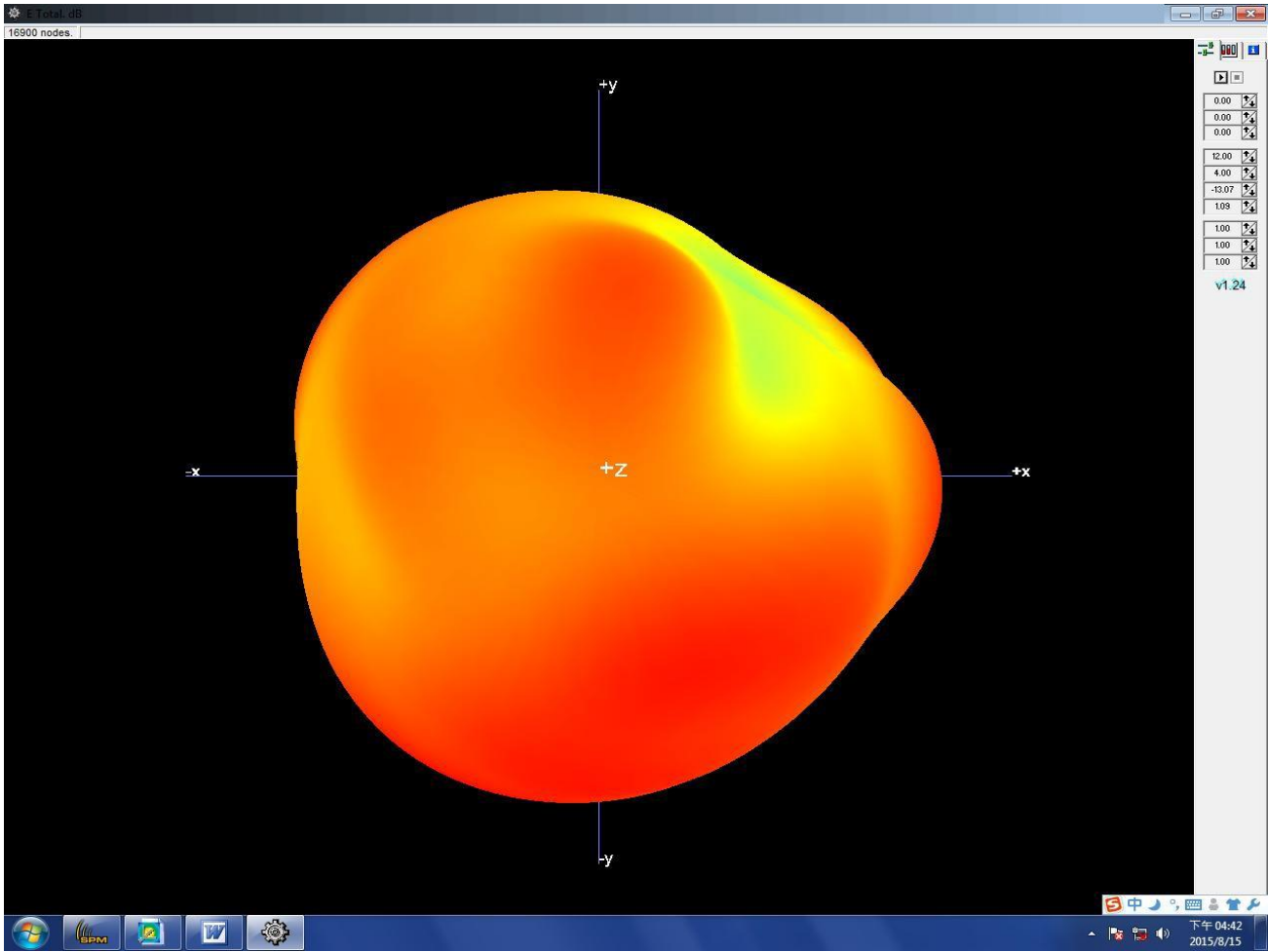
The screenshot illustrates the steps to solve a 3D field pattern in a software application. The interface is divided into several sections:

- Project Tree (Left):** A hierarchical list of project items. Item [93] "Frequency=2450.00MHz" is highlighted with a red box.
- Main Workspace (Center):** Displays a list of layers for "Axis 1: Theta". The layers include:
 - Layer 0: E(Phi). Real part
 - Layer 1: E(Phi). Imaginary part
 - Layer 2: E(Theta). Real part
 - Layer 3: E(Theta). Imaginary part
 - Layer 4: E Total. dB
 - Layer 5: E Total. Lin
 - Layer 6: Polar +45 . Amp lin
 - Layer 7: Polar +45 . Amp dB
 - Layer 8: Polar +45 . Phase
 - Layer 9: Polar -45 . Amp lin
 - Layer 10: Polar -45 . Amp dB
 - Layer 11: Polar -45 . Phase
 - Layer 12: Gain Phi. dB
 - Layer 13: Gain Phi. Lin
 - Layer 14: Gain Theta. dB
 - Layer 15: Gain Theta. Lin
 - Layer 16: Gain . dB
 - Layer 17: Gain . Lin
 - Layer 18: E(Phi) . Amp lin
 - Layer 19: E(Theta) . Amp lin
- Context Menu (Center):** A right-click menu is open over the project tree. The "Special" option is selected, and the "3D OpenGL Viewer" option is highlighted with a red box.
- Layers configuration Dialog (Right):** A dialog box titled "Layers configuration" is open. It contains a list of layers with checkboxes. The "E Total. dB" layer is checked and highlighted with a red box. The "Ok" button is also highlighted with a red box.

3.2.5 Solving 3D field pattern



3.2.6 Get 3D field pattern



WX5512-T0 Antenna real test report and directional gain calculation

OUTLINE

WX5512-T0 Antenna Test Report

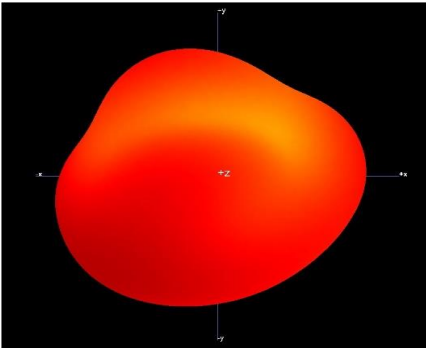
- 1.1 3D Pattern & E-Total Gain Table & 2D Radiation Patterns
- 1.2 Peak Gain of 3D Directional pattern

1.1.1 E-Total Gain Formula

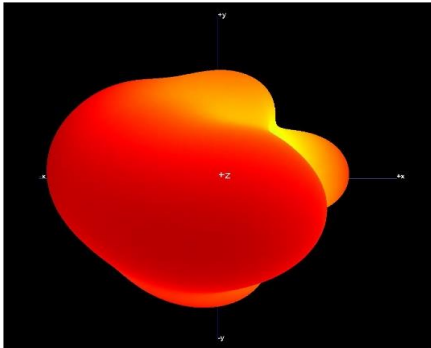
	Formula	Remarks
E-Total	Satimo darkroom data solution =MAX(XX:XX)	The maximum value in the original data of angle by angle and with frequency

1.1.2 3D Pattern & E-total Table of 2.4G

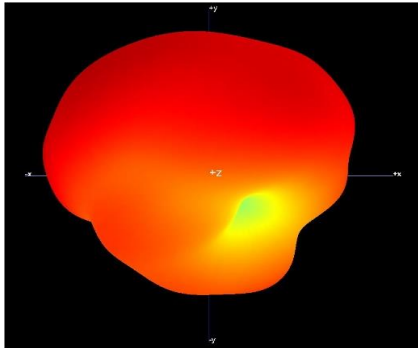
2.4G-1_2450MHz



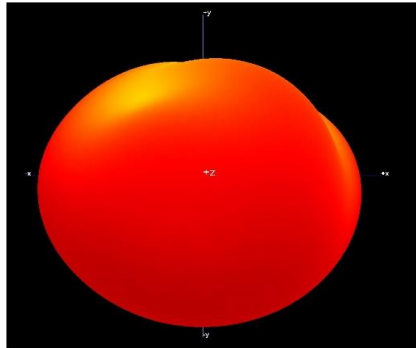
2.4G-2_2450MHz



2/5G-1_2450MHz



2/5G-2_2450MHz

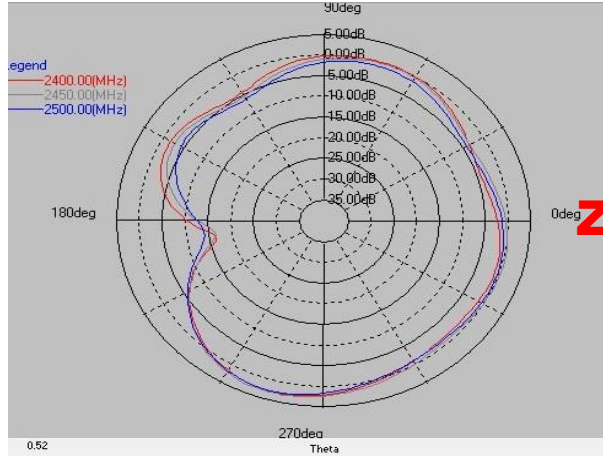


Frequency [MHz]	2.4G-1	2.4G-2	2/5G-1-2.4G	2/5G-2-2.4G
	E-total [dBi]	E-total [dBi]	E-total [dBi]	E-total [dBi]
2400	2.86	3.30	2.88	3.21
2450	3.54	3.12	3.54	3.02
2500	3.26	3.40	3.31	2.87

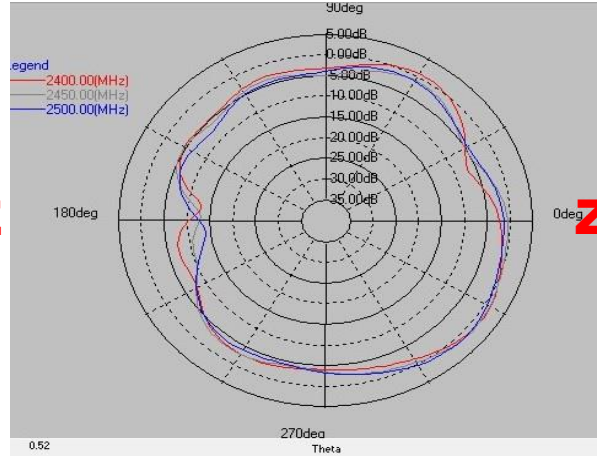
1.1.3 2D Radiation Patterns---2.4G-Ant 1



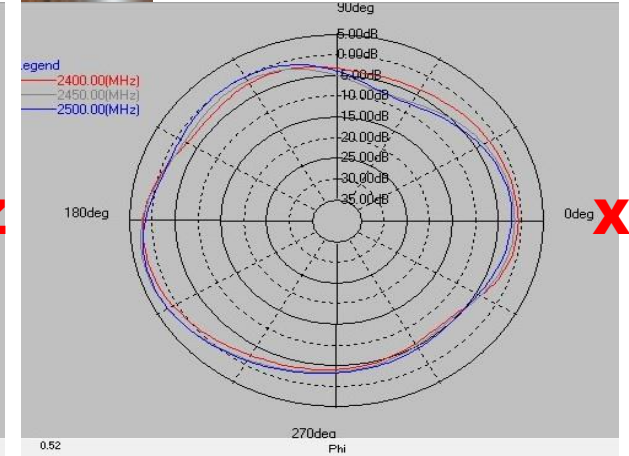
X



Y



Y

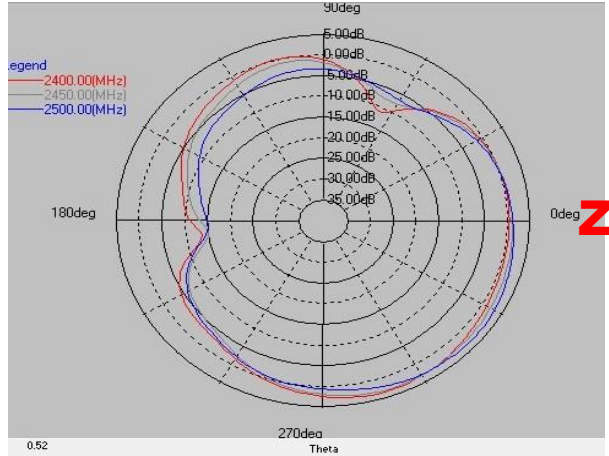


	ZX plane		ZY plane		XY plane	
Frequency [MHz]	Max Value [dBi]	Average [dBi]	Max Value [dBi]	Average [dBi]	Max Value [dBi]	Average [dBi]
2400	2.55	-1.43	1.48	-2.77	2.19	-1.81
2450	2.86	-1.18	1.49	-2.88	3.10	-1.64
2500	2.41	-1.87	1.22	-3.10	2.75	-1.59

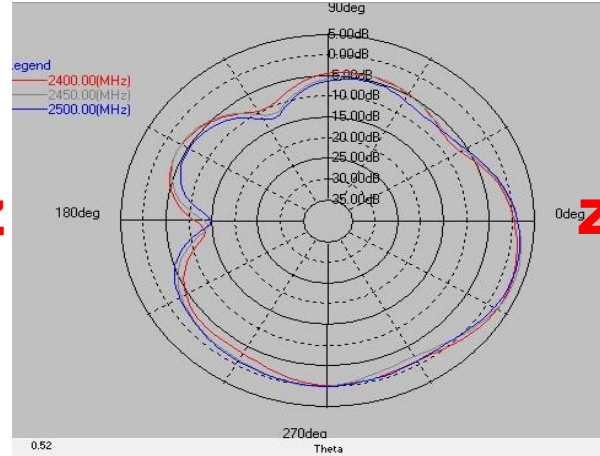
1.1.3 2D Radiation Patterns---2.4G-Ant 2



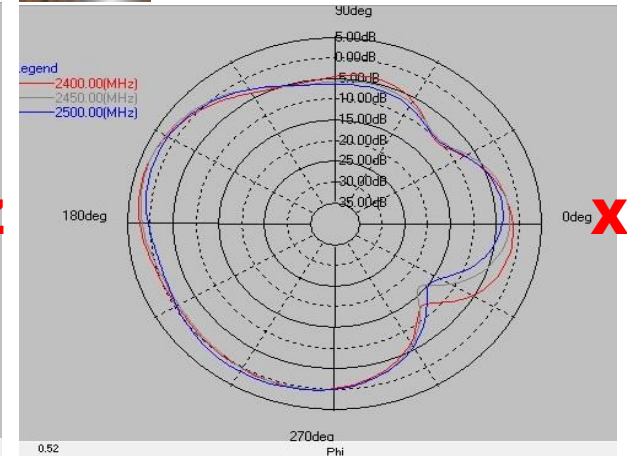
X



Y



Y

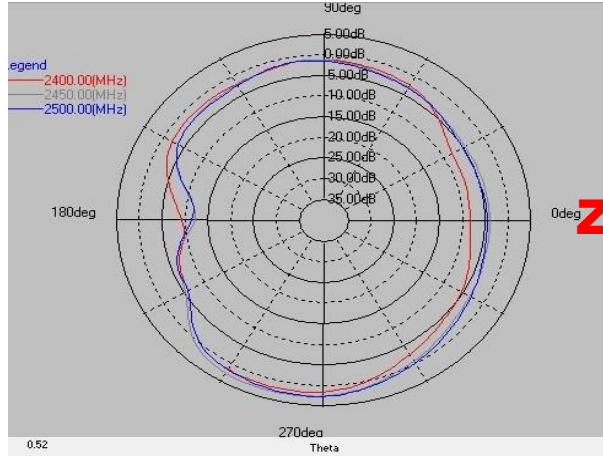


	ZX plane		ZY plane		XY plane	
Frequency [MHz]	Max Value [dBi]	Average [dBi]	Max Value [dBi]	Average [dBi]	Max Value [dBi]	Average [dBi]
2400	3.30	-0.84	2.65	-2.45	2.98	-1.51
2450	2.97	-1.05	3.03	-2.26	2.84	-1.73
2500	3.18	-1.32	2.55	-2.42	1.93	-2.05

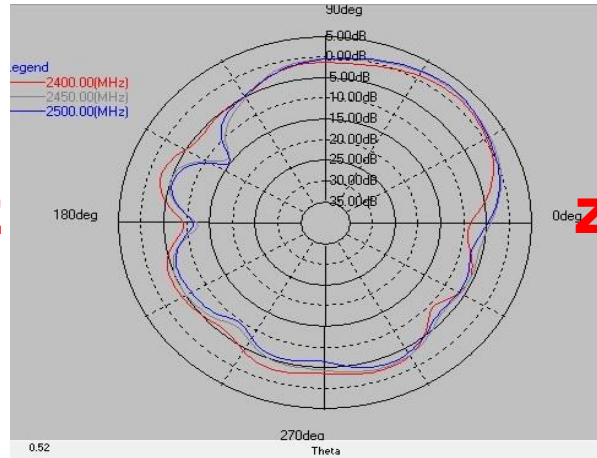
1.1.3 2D Radiation Patterns---2.4G-Ant 3



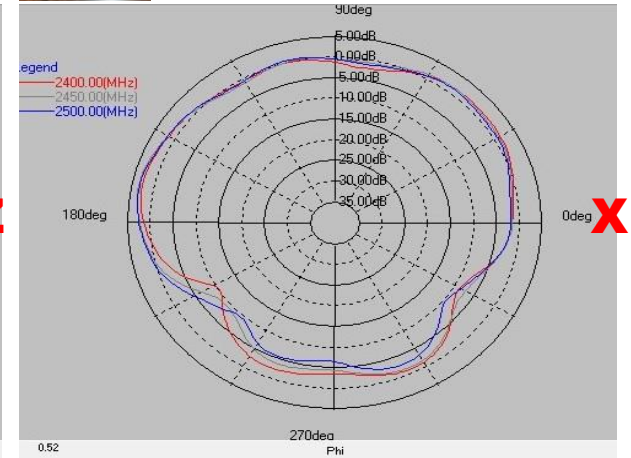
X



Y



Y

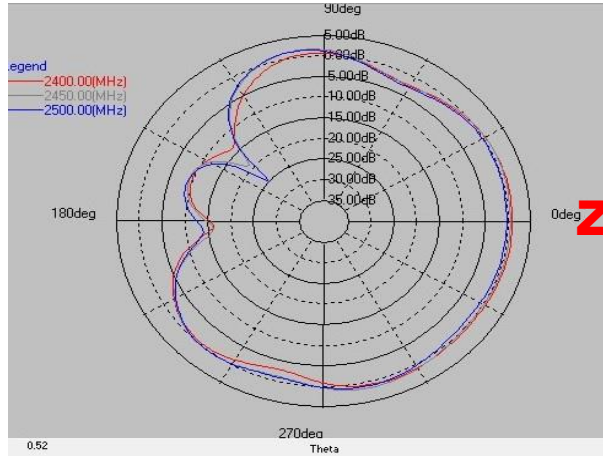


	ZX plane		ZY plane		XY plane	
Frequency [MHz]	Max Value [dBi]	Average [dBi]	Max Value [dBi]	Average [dBi]	Max Value [dBi]	Average [dBi]
2400	1.63	-2.56	1.51	-3.08	2.69	-0.98
2450	2.62	-1.78	2.23	-2.86	3.41	-0.84
2500	2.49	-1.99	2.50	-3.09	3.26	-1.08

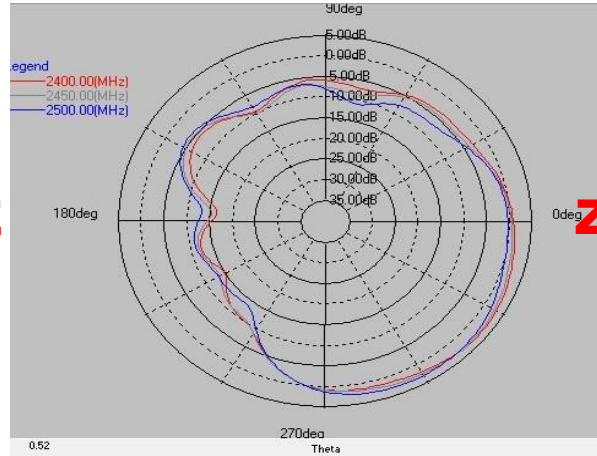
1.1.3 2D Radiation Patterns---2.4G-Ant 4



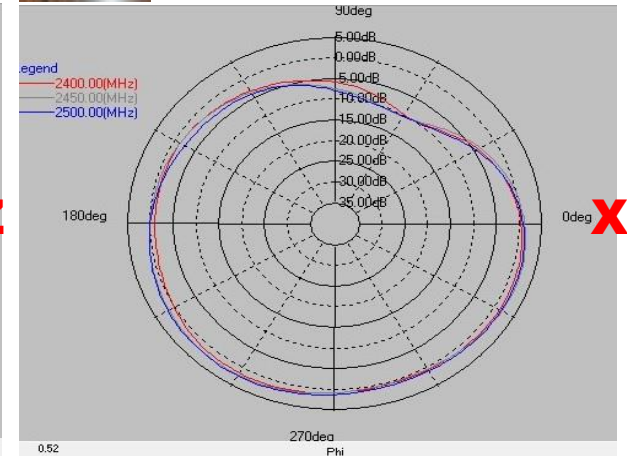
X



Y



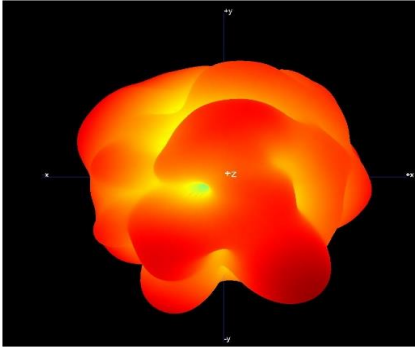
Y



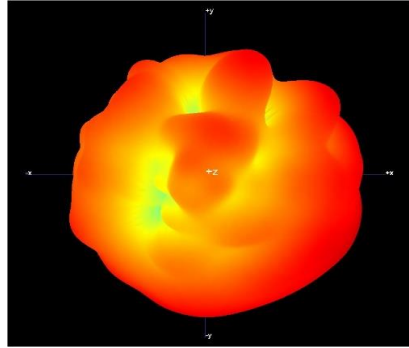
	ZX plane		ZY plane		XY plane	
Frequency [MHz]	Max Value [dBi]	Average [dBi]	Max Value [dBi]	Average [dBi]	Max Value [dBi]	Average [dBi]
2400	0.93	-1.38	3.21	-2.06	1.46	-0.85
2450	1.48	-1.04	3.00	-2.18	2.09	-0.40
2500	1.33	-1.47	2.87	-2.38	2.19	-0.42

1.1.7 3D Pattern & E-total Table of 5G

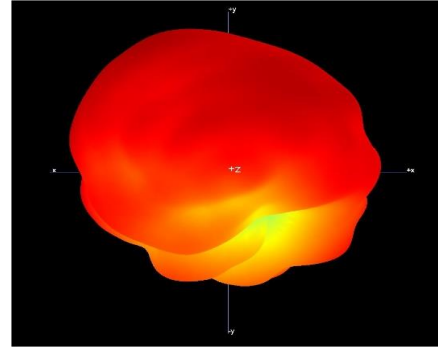
5G-1_5500MHz



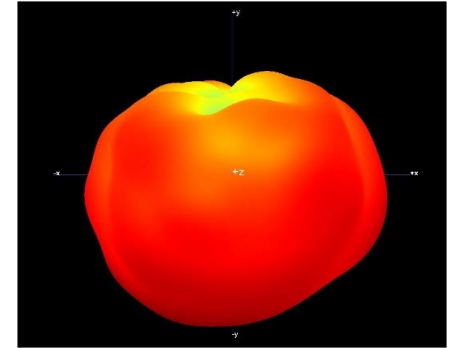
5G-2_5500MHz



2/5G-1_5500MHz

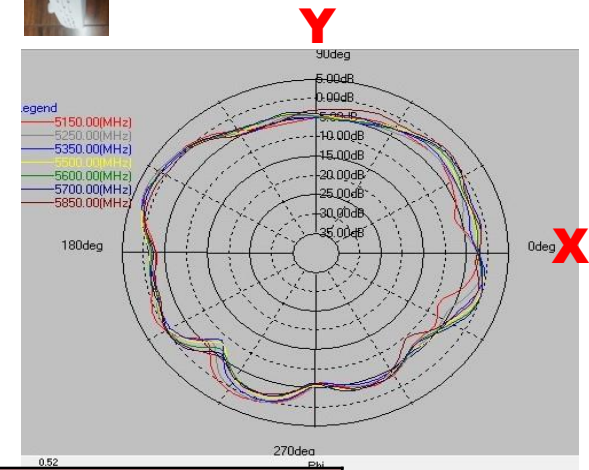
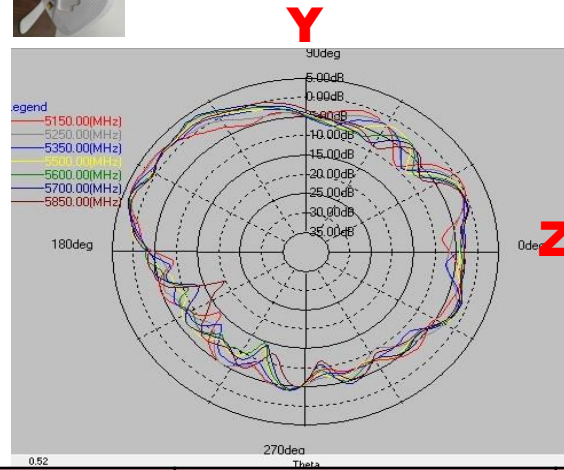
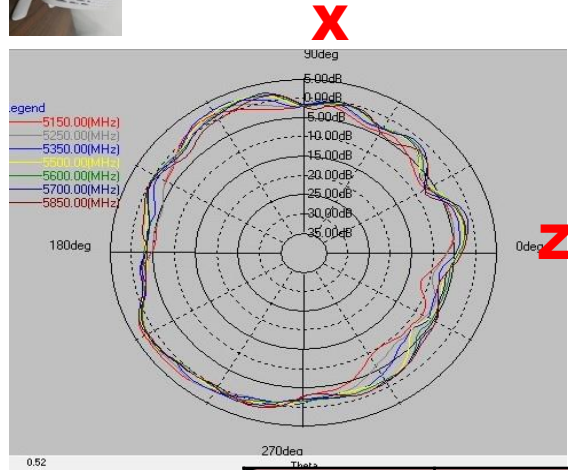


2/5G-2_5500MHz



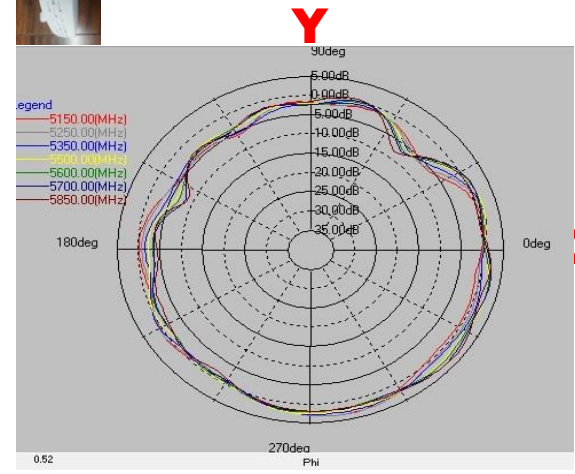
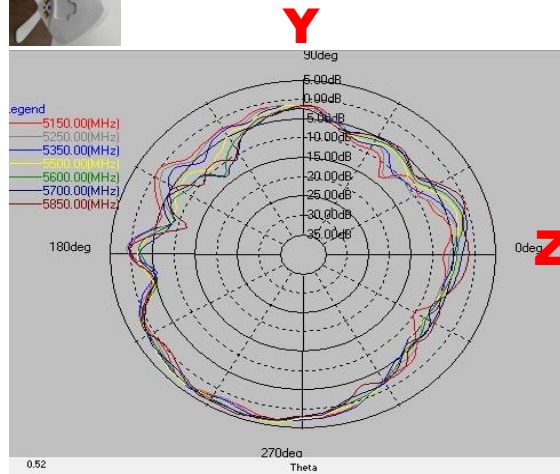
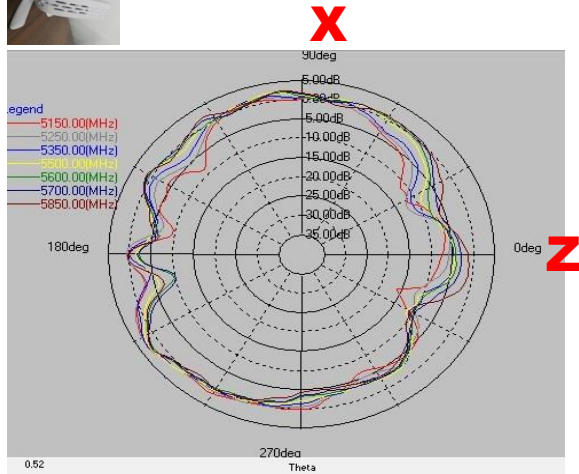
Frequency [MHz]	5G-1	5G-2	2/5G-1-5G	2/5G-2-5G
	E-total [dBi]	E-total [dBi]	E-total [dBi]	E-total [dBi]
5150	4.98	3.55	3.82	4.10
5250	4.94	3.74	3.82	4.00
5350	4.71	3.84	4.22	4.33
5500	4.21	3.75	4.00	4.89
5600	4.13	3.51	3.45	4.95
5700	4.58	3.95	3.31	4.85
5850	4.38	4.60	3.55	4.28

1.1.8 2D Radiation Patterns---5G-Ant 1



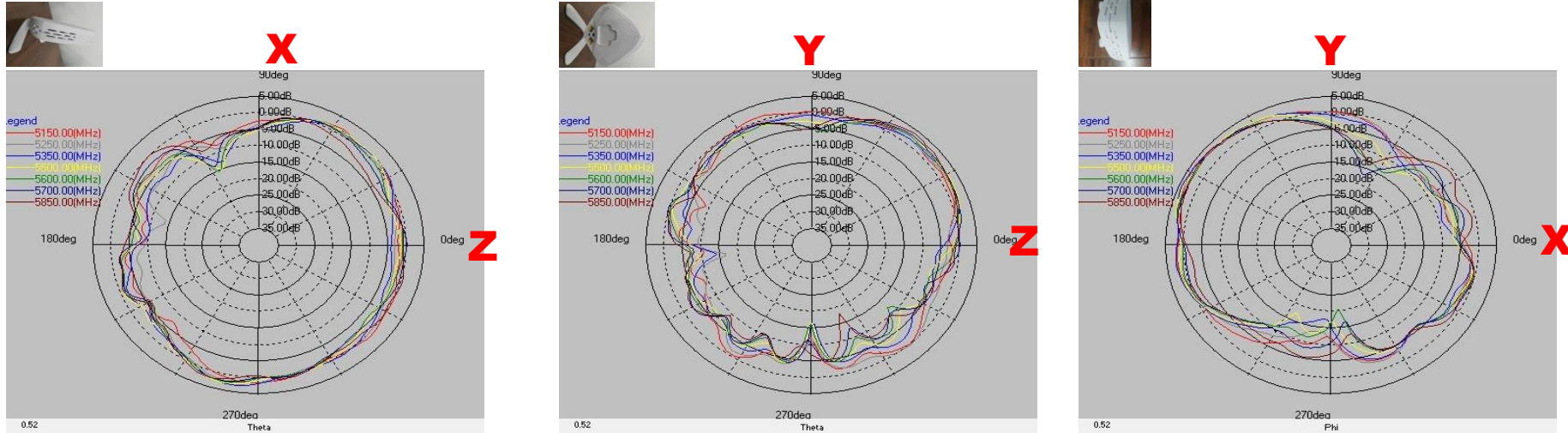
	ZX plane		ZY plane		XY plane	
Frequency [MHz]	Max Value [dBi]	Average [dBi]	Max Value [dBi]	Average [dBi]	Max Value [dBi]	Average [dBi]
5150	2.73	-2.10	3.49	-2.96	2.59	-2.24
5250	2.35	-1.88	3.29	-3.02	2.72	-2.20
5350	2.41	-1.54	3.33	-2.97	2.29	-2.34
5500	2.23	-1.31	2.98	-2.74	1.74	-2.11
5600	1.98	-1.35	3.11	-2.67	1.96	-2.10
5700	2.16	-1.13	3.29	-2.51	1.75	-1.85
5850	1.76	-1.51	2.39	-2.93	1.04	-2.18

1.1.8 2D Radiation Patterns---5G-Ant 2



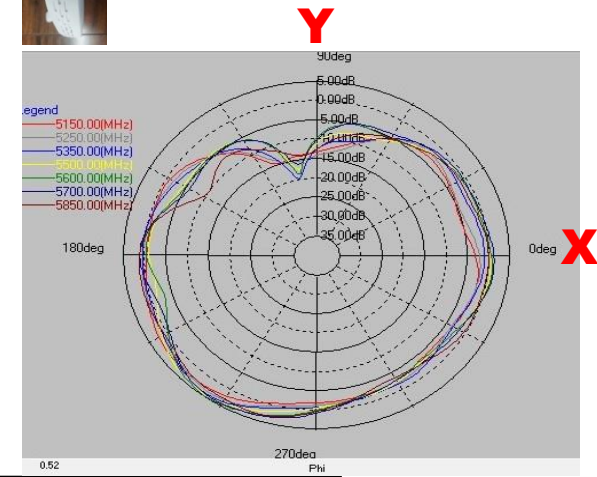
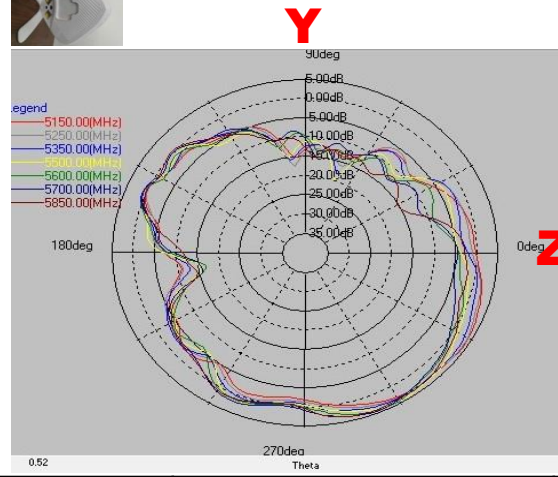
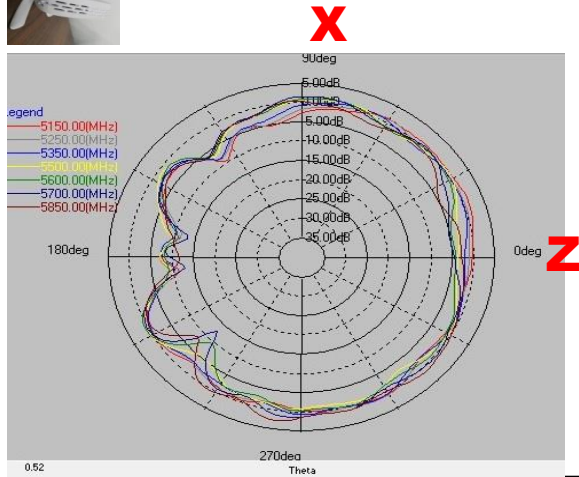
	ZX plane		ZY plane		XY plane	
Frequency [MHz]	Max Value [dBi]	Average [dBi]	Max Value [dBi]	Average [dBi]	Max Value [dBi]	Average [dBi]
5150	2.81	-2.16	3.34	-1.56	3.15	-0.69
5250	2.94	-1.76	3.52	-1.51	3.20	-0.48
5350	2.92	-1.67	3.73	-1.47	2.57	-0.49
5500	2.69	-1.37	3.73	-1.58	2.48	-0.16
5600	1.96	-1.60	3.41	-1.84	2.54	-0.40
5700	2.21	-1.41	3.54	-1.73	3.07	-0.36
5850	2.42	-1.19	3.89	-1.61	3.40	-0.44

1.1.8 2D Radiation Patterns---5G-Ant 3



	ZX plane		ZY plane		XY plane	
Frequency [MHz]	Max Value [dBi]	Average [dBi]	Max Value [dBi]	Average [dBi]	Max Value [dBi]	Average [dBi]
5150	1.55	-1.53	1.54	-1.84	3.77	-1.06
5250	2.29	-1.87	1.95	-1.99	3.66	-1.09
5350	2.68	-1.76	2.29	-2.46	4.07	-1.23
5500	2.38	-1.63	2.58	-2.26	3.63	-1.64
5600	2.02	-1.84	2.34	-2.39	3.05	-2.10
5700	1.82	-1.68	2.85	-1.93	3.30	-2.03
5850	1.87	-1.55	3.54	-1.84	3.17	-1.93

1.1.8 2D Radiation Patterns---5G-Ant 4



	ZX plane		ZY plane		XY plane	
Frequency [MHz]	Max Value [dBi]	Average [dBi]	Max Value [dBi]	Average [dBi]	Max Value [dBi]	Average [dBi]
5150	1.39	-1.51	4.10	-1.46	2.66	-1.95
5250	0.92	-1.56	3.97	-1.36	3.17	-1.68
5350	0.72	-1.67	3.43	-1.39	3.84	-1.29
5500	0.95	-1.88	4.31	-1.63	4.25	-1.07
5600	1.08	-2.00	4.14	-1.97	4.49	-1.02
5700	1.31	-1.56	4.17	-1.78	4.10	-0.74
5850	2.34	-1.47	3.80	-1.67	2.94	-1.20

1.2.1 Directional Gain for Correlated and Uncorrelated Formula

	Formula	Remarks
Correlated Gain	Correlated Directional gain angle by $\text{angle} = 10 \cdot \log_{10} \left(\frac{10^{(X-X')/20} + 10^{(X-X')/20} + 10^{(X-X')/20} + 10^{(X-X')/20}}{4} \right)$ Correlated peak gain = MAX(XX:XX)	1. Calculate the correlated gain angle by angle through the formula 2. Use MAX to get the maximum value
Uncorrelated Gain	Uncorrelated Directional gain angle by $\text{angle} = 10 \cdot \log_{10} \left(\frac{10^{(X-X')/10} + 10^{(X-X')/10} + 10^{(X-X')/10} + 10^{(X-X')/10}}{4} \right)$ Uncorrelated peak gain = MAX(XX:XX)	1. Calculate the uncorrelated gain angle by angle through the formula 2. Use MAX to get the maximum value

1.2.2 Directional Gain for Correlated and Uncorrelated Table

Peak Gain of 3D Directional pattern		
Frequency (MHz)	Correlated	Uncorrelated
2400	5.65	0.66
2450	5.82	0.80
2500	5.68	0.61
5150	5.64	1.05
5250	5.86	1.19
5350	5.72	1.05
5500	5.66	1.00
5600	5.80	1.04
5700	5.82	0.87
5850	5.89	1.09



Appendix

2.4G Ant 1 Raw Data

