

ZYXEL

Your Networking Ally

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

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Directional gain test method introduction

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

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

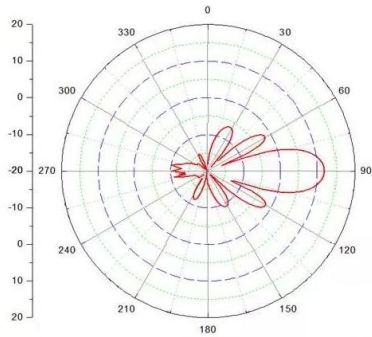
Directional gain = $10 \log[(10^{G_1/20} + 10^{G_2/20} + \dots + 10^{G_N/20})^2 / N_{\text{ANT}}]$ dBi [Note the “20”s in the denominator of each exponent and the square of the sum of terms; the object is to combine the signal levels coherently.]

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

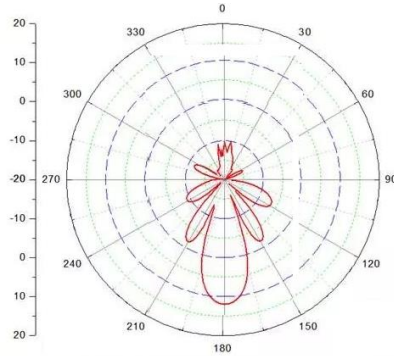
Directional gain = $10 \log[(10^{G_1/10} + 10^{G_2/10} + \dots + 10^{G_N/10}) / N_{\text{ANT}}]$ dBi

Based on FCC KDB 662911 Calculation formula of directional gain analyze

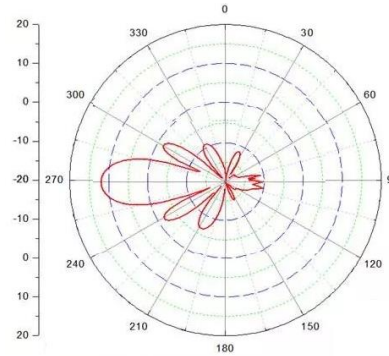
Antenna pattern example:



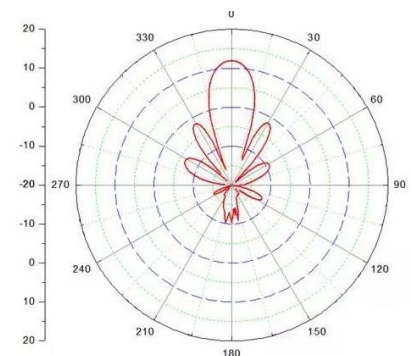
ANT0=3dBi



ANT1=-5dBi



ANT1=-3dBi



ANT1=-7dBi



X axis

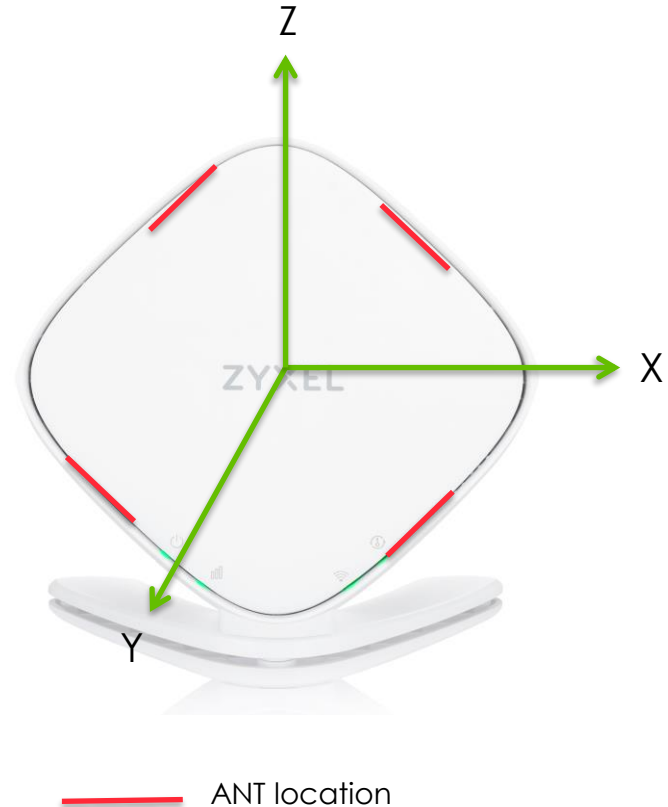
Based on above antenna pattern. The real Antennas gain is reasonable to calculate by each direction. It's the same with MIMO real operation mode. But not calculate with peak gain in different angle.

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

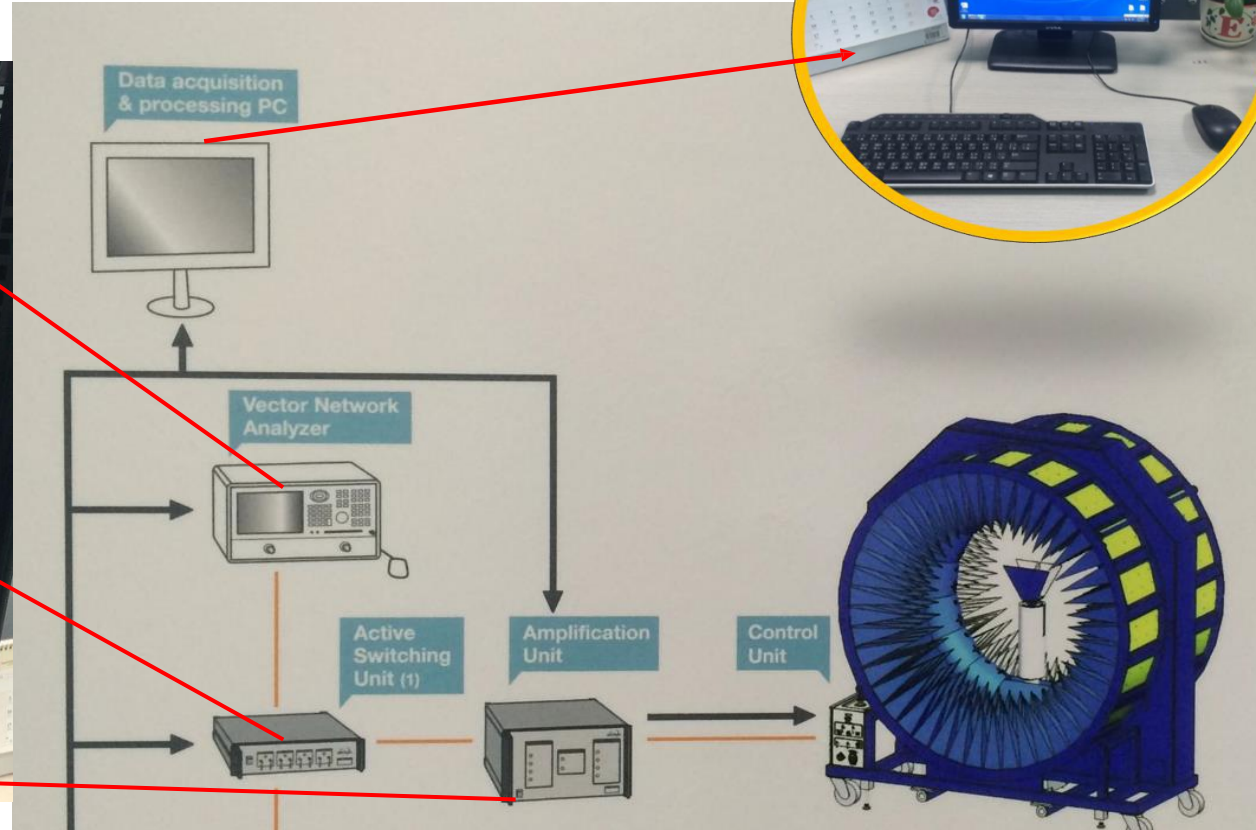
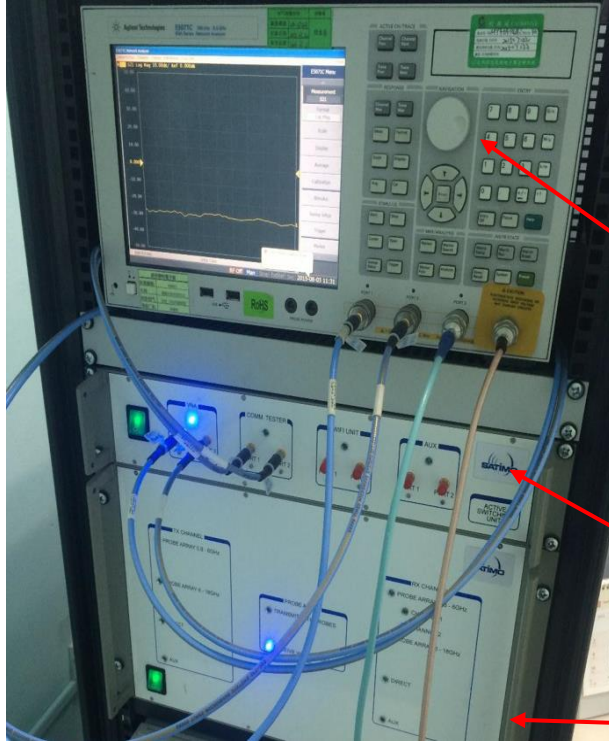
3.1 Place the sample to be tested

3.2 Reset network instrument

3.3 Measure and process data

1. Instrument introduction

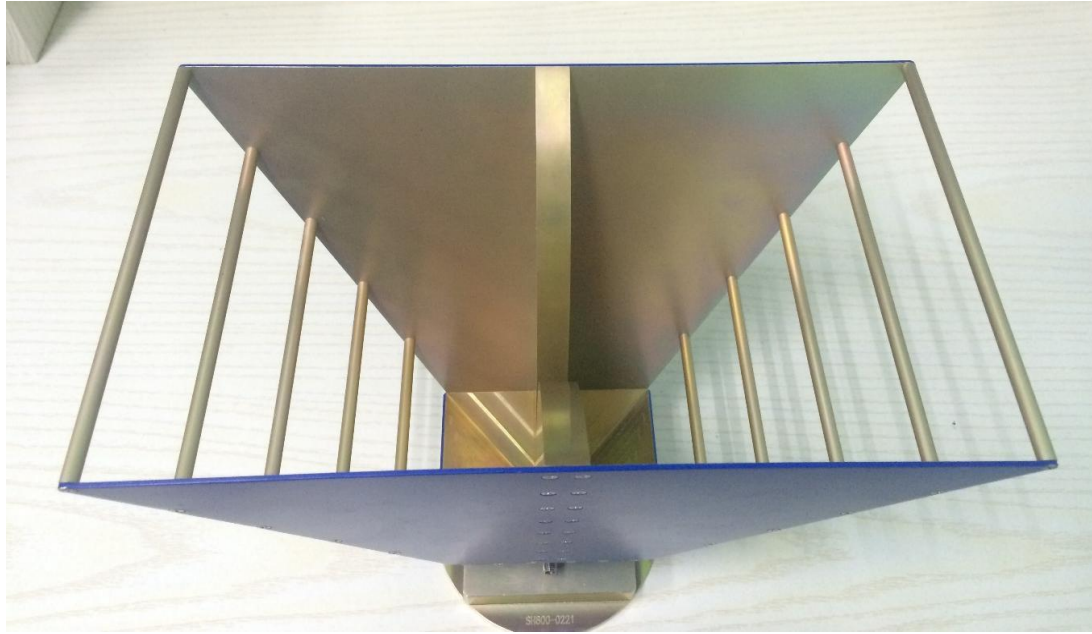
1.1 SATIMO Overview



Entity diagram



1.2 Calibration antenna-Horn antenna



Horn antenna

1.2 Calibration antenna-Dipole antenna

2450MHz

2600MHz

1575MHz



2050MHz

1900MHz

1800MHz

900MHz

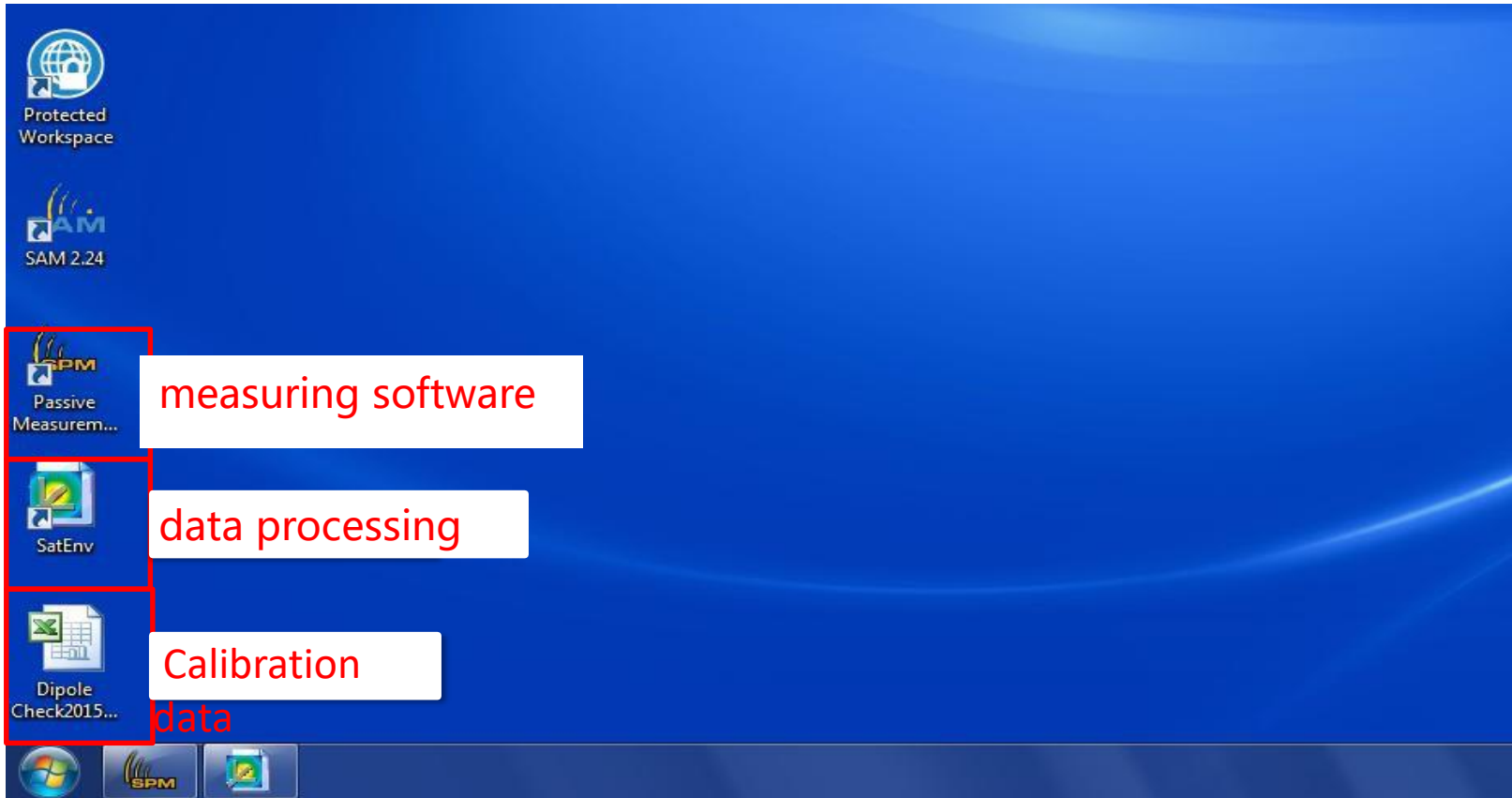
3600MHz

5150MHz

5650MHz

Dipole antenna

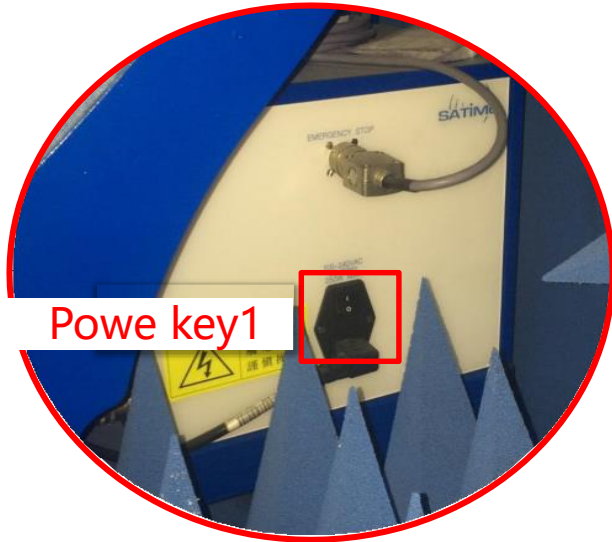
1.3 Software



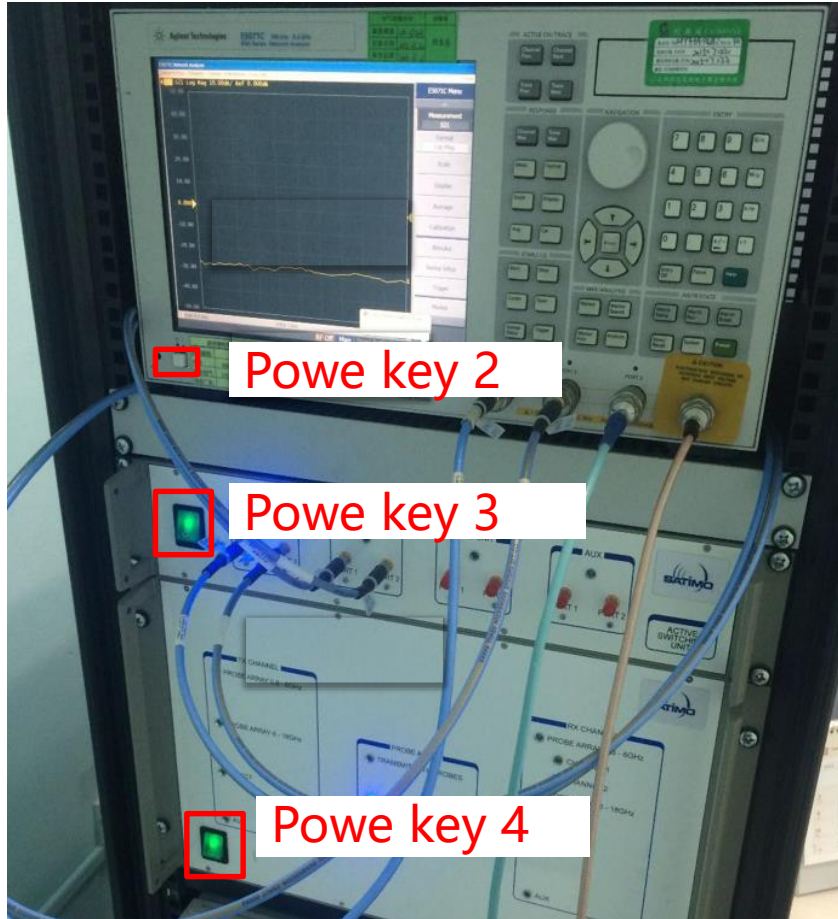
2、 Calibration

2.1.1 Open Power

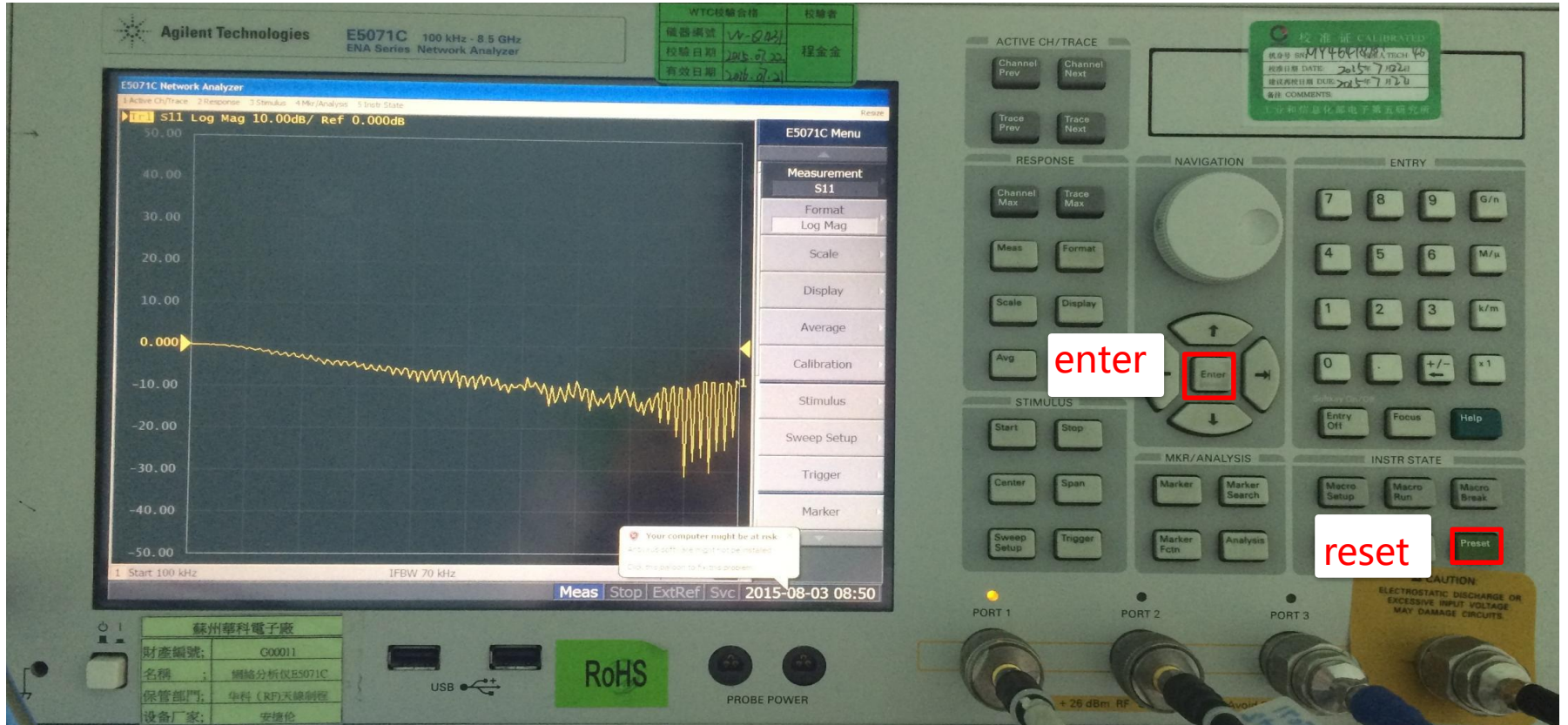
Turn on the power in turn 1, 2, 3, 4, 5



2.1.1 Open Power

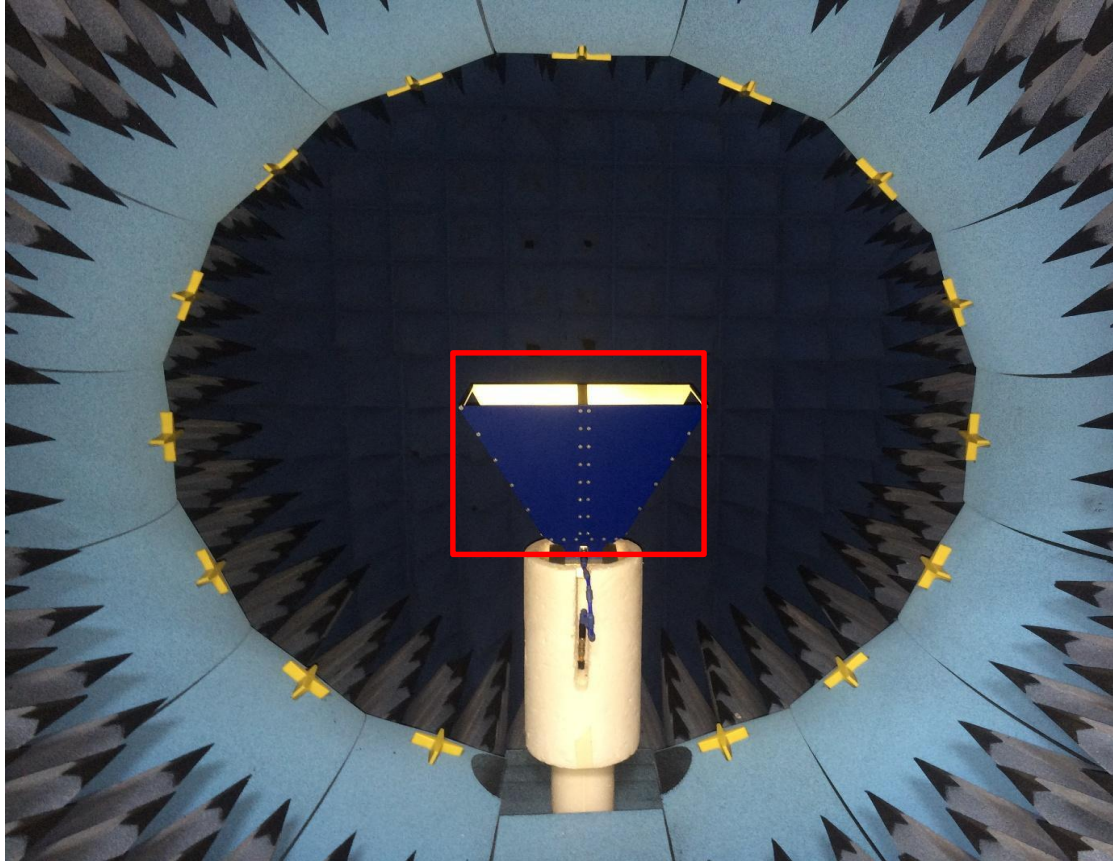


2.1.2 Reset network analyzer

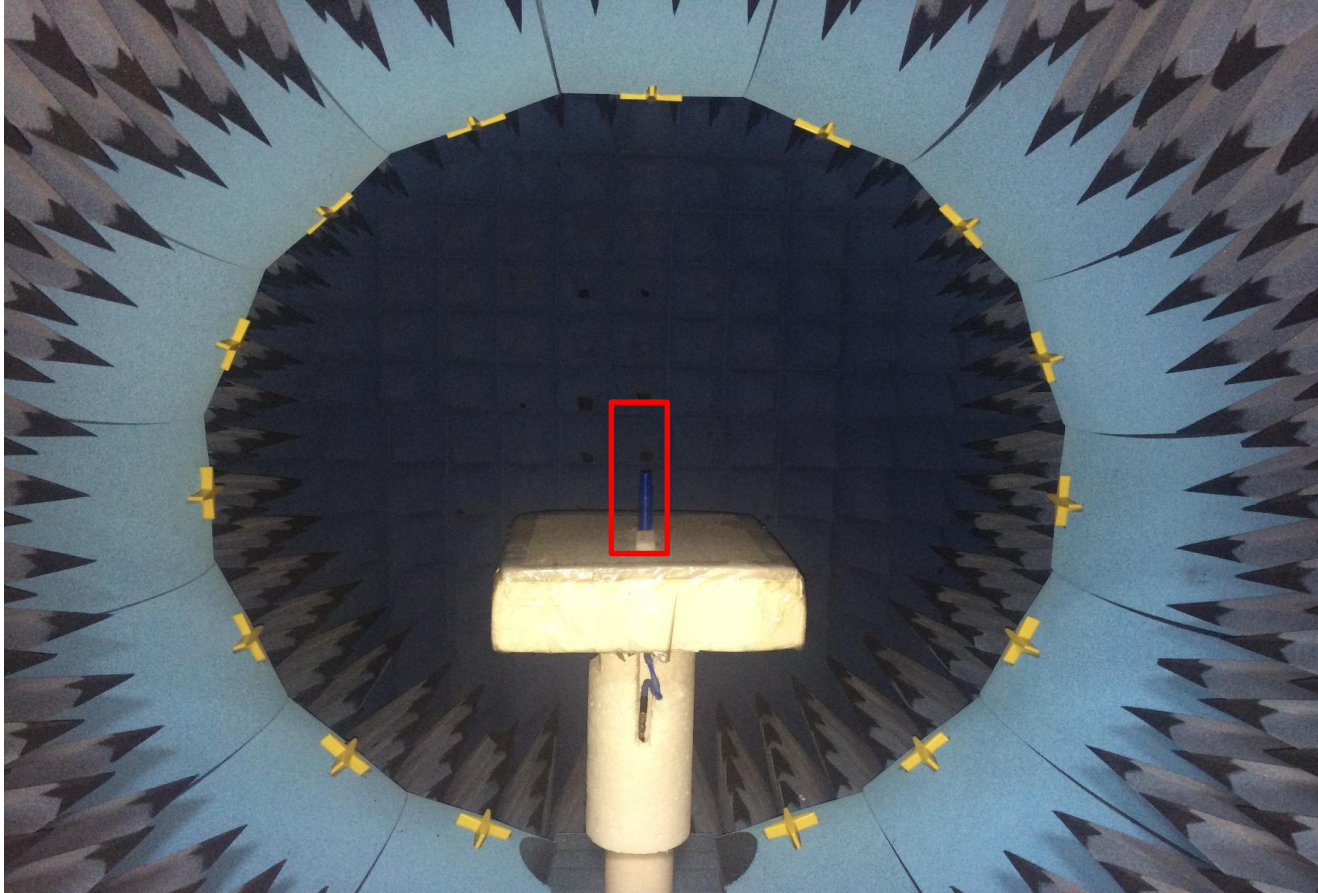


2.2 Calibration

2.2.1. Horn antenna schematic diagram of placement position :



2.2.2 Dipole antenna schematic diagram of placement position :

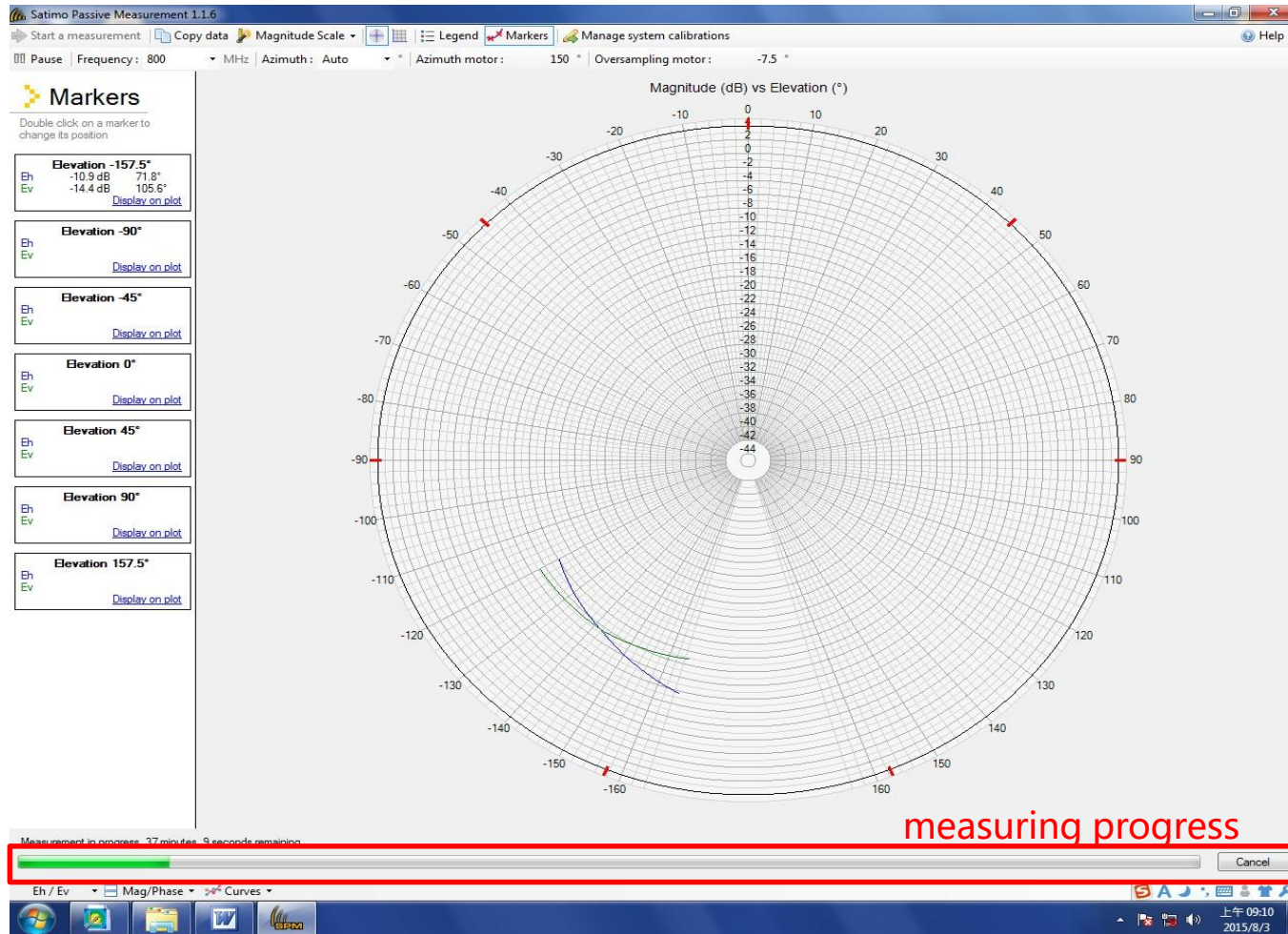


2.2.3 Open the measurement software, set parameters and start measurement

The screenshot shows the Measurement 1.1.6 software interface. The 'Start a measurement' button is highlighted in red. A 'Configure measurement' dialog box is open, showing settings for Name: HORN, Frequency distribution: Linear (Start: 800 MHz, Stop: 6000 MHz, Step: 10 MHz), Spatial resolution: Oversampling 3x, and Measure on 360° checked. The 'Start measurement' button in the dialog is also highlighted in red. The background shows a magnitude vs elevation plot and a markers list.

type	start	stop
Horn	800	6000
Dipple2450	2280	2670
Dipple5150	4900	5400
Dipple5650	5400	5900

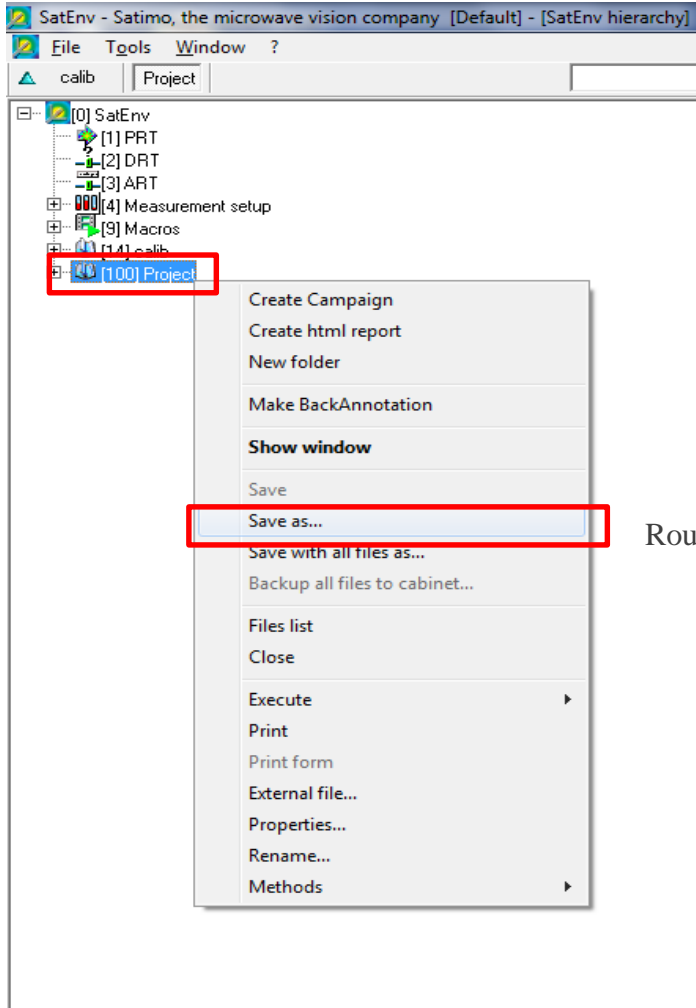
Measuring processing



2.2.4 Open data processing software to create project

The screenshot displays the SatEnv software interface. The main window title is "SatEnv - Satimo, the microwave vision company [Default] - [SatEnv hierarchy]". The menu bar includes "File", "Tools", and "Window". The "Project" menu is open, showing options like "Create", "Open...", "List of Administrators...", "List of Creators...", "Execute", "Print", "Print form", "External file...", "Properties...", "Rename...", and "Methods". The "Create" option is highlighted. A red box highlights the "Create" option in the menu. A red arrow points from the "Create" option to the "Project setup" dialog box. The dialog box has a header with the Satimo logo and the text "The microwave vision company". It contains several fields for project information, including "Date", "File name", "Project name", "Code", "Manager", "Equipment under test", "Description", "Customer", "Address", "Zip", "City", "Customer reference for the project", "Contact name", "Function", "Phone / Fax", and "Email". The "Project name" field is highlighted with a red box and contains the text "Project". A red box also highlights the "Ok" button at the bottom right of the dialog box. A white box with the text "name" is positioned next to the "Project" text in the "Project name" field.

2.2.5 Save Route



Route E:\Calib\2015\passive calibration

2.2.6 Export data to data processing software

The screenshot illustrates the process of exporting data from Satimo Passive Measurement 1.1.6. The main window shows a plot of Magnitude (dB) vs Elevation (°). The 'Export data' panel on the right has two buttons highlighted: 'Set Env' and 'Use as a gain calibration'. A 'Gain Calibration' dialog box is open, with a file selection button highlighted. An 'Open' file dialog shows a list of files, with 'Data H2000-49.satref' highlighted and labeled 'Horn'. A second 'Gain Calibration' dialog box shows the selected file path and 'Dipole' antenna type.

Export data panel:

- Set Env
- Use as a gain calibration

Gain Calibration dialog (top):

- Reference file: ...
- Antenna type: Horn
- Calibration type: Efficiency
- Append to previous calibration

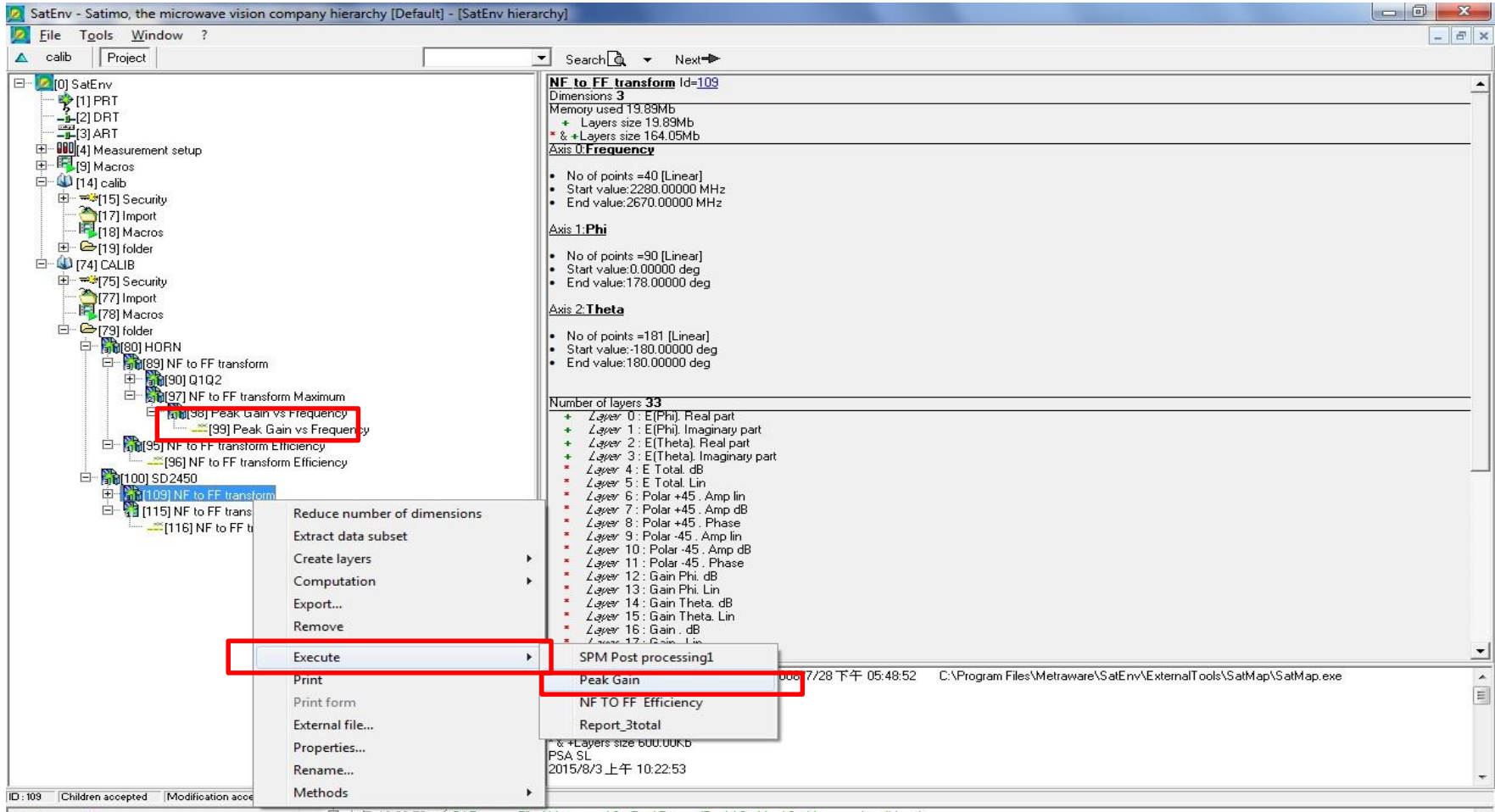
Open dialog (file list):

Name	Date modified	Type
Data D900-1-2.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

Gain Calibration dialog (bottom):

- Reference file: C:\Calib\Ref\Reference Antenna Data\...
- Antenna type: Dipole
- Calibration type: Efficiency
- Append to previous calibration

2.2.6.1 Export Peak Gain



NF to FF transform Id=109
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(PPhi). Real part
- Layer 1: E(PPhi). 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

- Reduce number of dimensions
 - Extract data subset
 - Create layers
 - Computation
 - Export...
 - Remove
 - Execute
 - Print
 - Print form
 - External file...
 - Properties...
 - Rename...
 - Methods
- SPM Post processing1
 - Peak Gain
 - NF TO FF Efficiency
 - Report_3total

2015/7/28 下午 05:48:52 C:\Program Files\Metroware\SatEnv\ExternalTools\SatMap\SatMap.exe

& + Layers size 600.00KB
PSA SL
2015/8/3 上午 10:22:53

2.2.6.2 Get Peak Gain



2.2.6.3 Export E-Total

The screenshot illustrates the steps to export E-Total data from a simulation project. The process involves navigating through a project tree, opening a context menu, and configuring the 'Export Data' dialog.

Project Tree:

- [100] SD2450
 - [109] NF to FF transform
 - [110] Q1Q2
 - [117] NF to FF transform Maximum
 - [118] Peak Gain vs Frequency
 - [119] Peak Gain vs Frequency
 - [115] NF to FF transform Efficiency
 - [116] NF to FF transform Efficiency

Context Menu:

- 1D view
- Reduce number of dimensions
- Extract data subset
- Create layers
- Export...**
- Remove
- Execute
- Print
- Print form
- External file...
- Properties...
- Rename...
- Methods

Export Data Dialog:

- Export file: c:\export.txt
- Export to clipboard
- Select format:
 - TRXV1
 - TRXV2
 - TRXV5
 - TEXT
 - Use header
 - Show Coord
 - Array
 - BINARY
 - Big endian
 - Double precision
 - NetCDF
 - XML
 - Special
 - Mode 1
 - Mode 2
- Select layer(s):
 - E(Phi). Real part
 - E(Phi). Imaginary part
 - E(Theta). Real part
 - E(Theta). Imaginary part
 - E Total, dB
 - E Total, Lin
 - Polar +45, Amp, lin
 - Polar +45, Amp, dB
 - Polar +45, Phase
 - Polar -45, Amp, lin
 - Polar -45, Amp, dB
 - Polar -45, Phase
 - Gain Phi, dB
 - Gain Phi, Lin
 - Gain Theta, dB
 - Gain Theta, Lin
 - Gain, dB
 - Gain, Lin

- Buttons: Set as default, **OK**, Cancel

2.2.6.4 Get E-Total

Microsoft Excel - Dipole Check20150319.xls

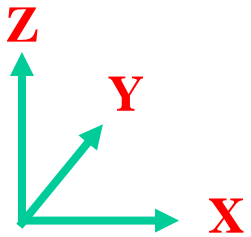
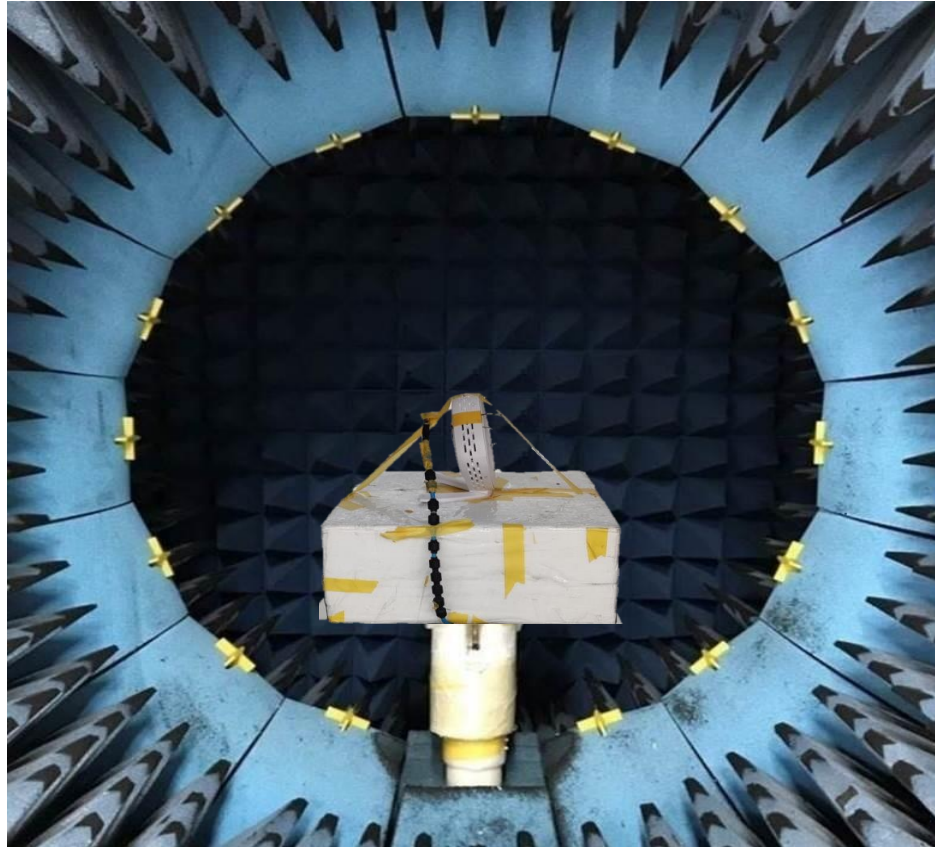
輸入需要解答的問題

H29 1.73400690430778

	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

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

3、 Measure



3.1 Open the measurement software, set parameters and start measurement

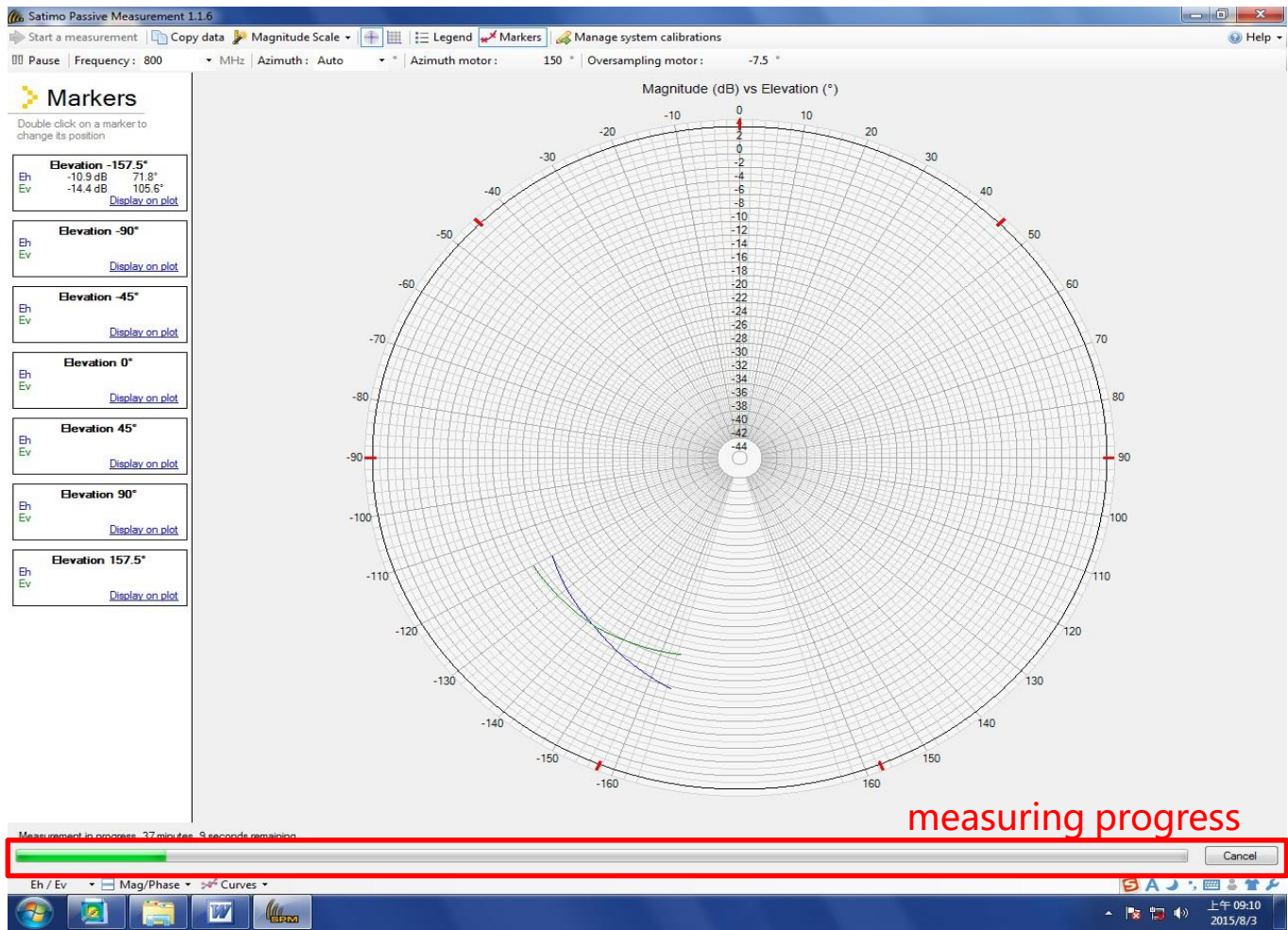
The screenshot shows the Satimo Passive Measurement 1.1.6 software interface. The main window displays a plot of Magnitude (dB) vs Elevation (°). A 'Configure measurement' dialog box is open, showing the following settings:

- Name: HORN
- Frequency distribution: Linear
 - Start: 800 MHz
 - Stop: 6000 MHz
 - Points: 521
 - Step: 10 MHz
- List (MHz): 3400 3500 3600
- Spatial resolution: Oversampling (3x)
- Antenna diameter: 20 cm
- Grid size: 7.5°
- Measure on 360°: checked

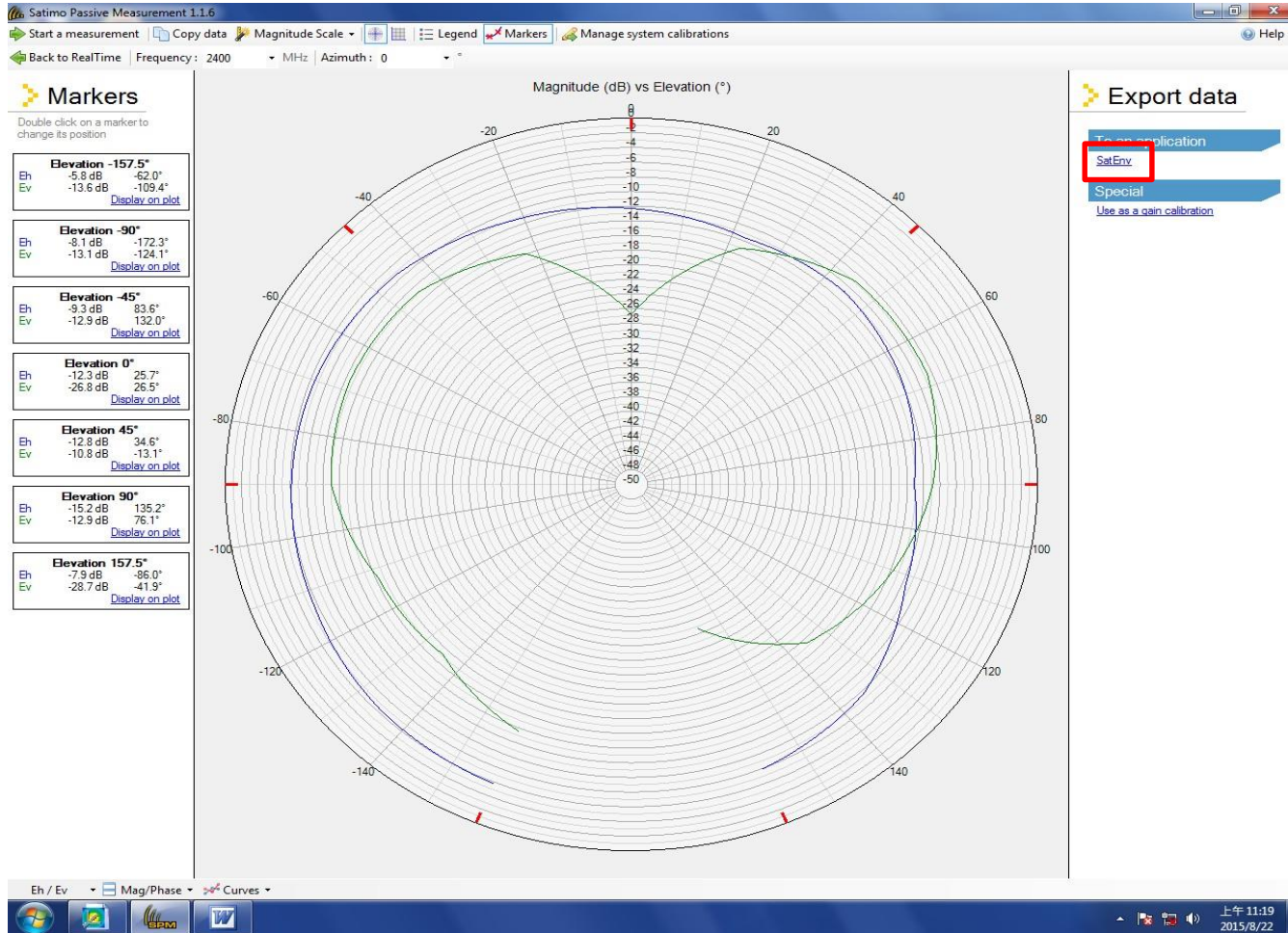
The 'Start measurement' button is highlighted in red. A table in the bottom left corner shows the frequency ranges for 2.4G and 5G.

type	start	stop
2.4G	2400	2500
5G	5150	5850

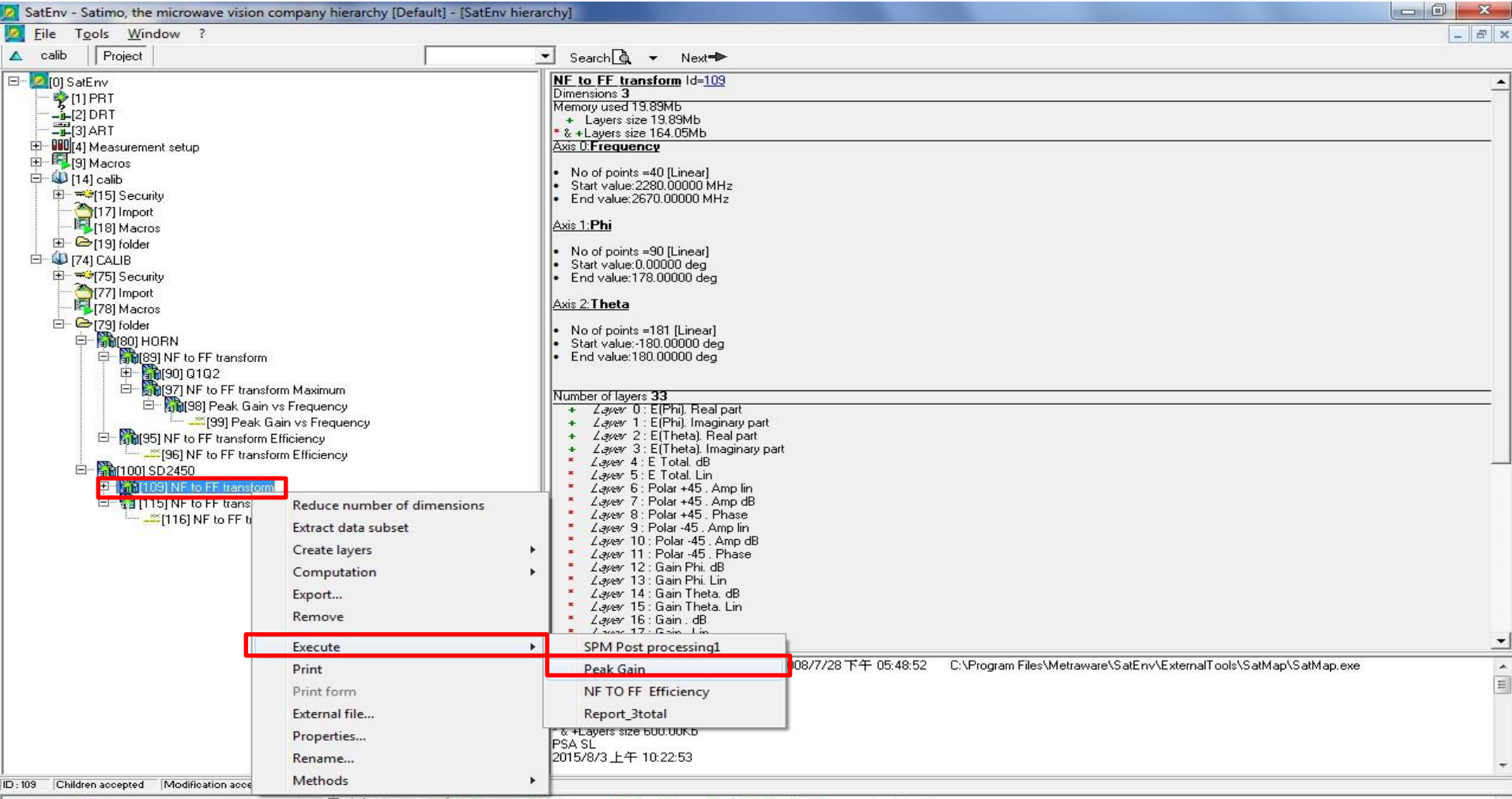
Measuring processing



3.2 Export data to data processing software



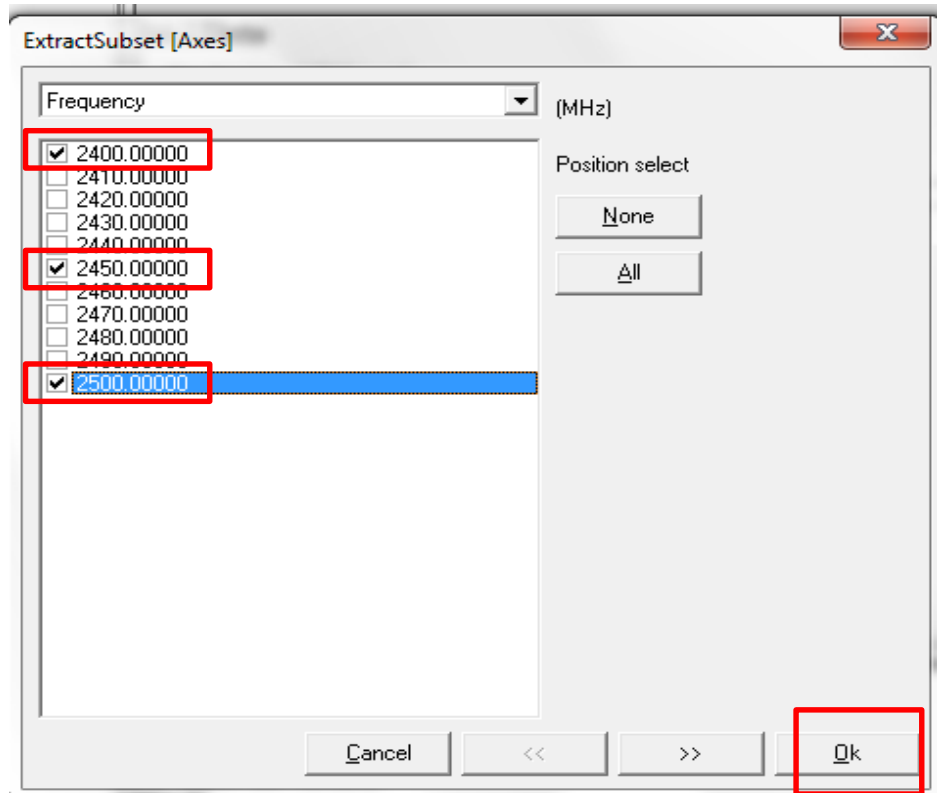
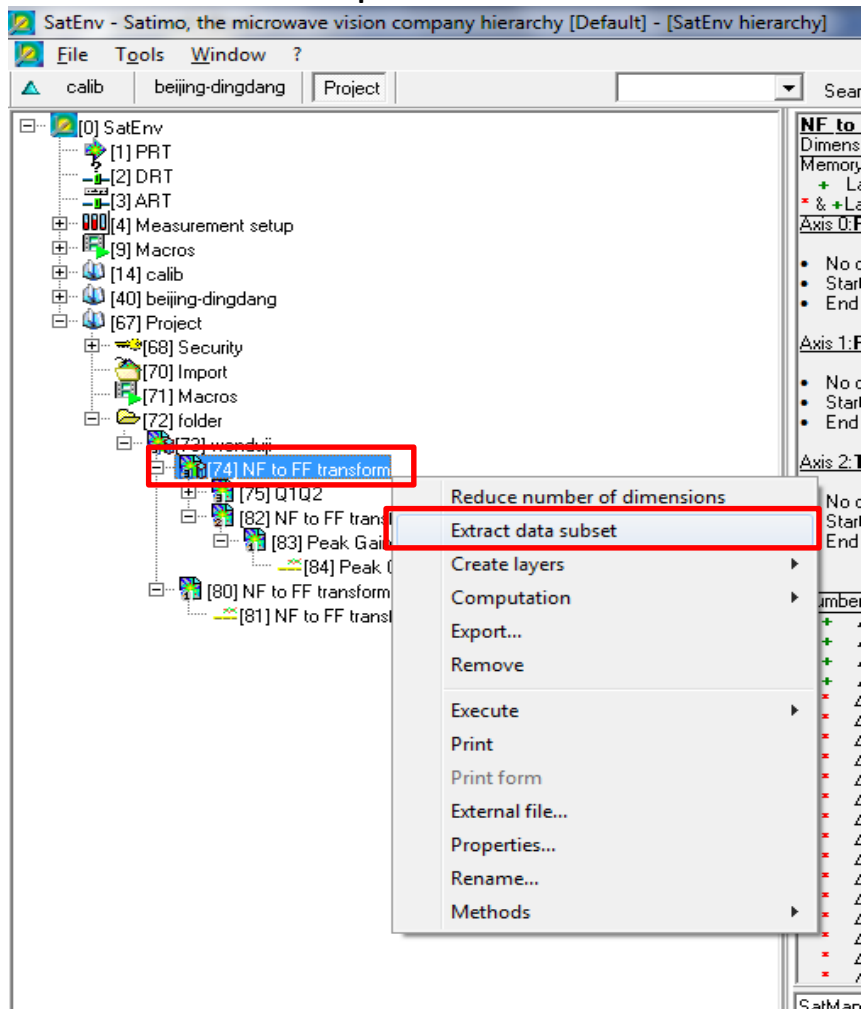
3.2.1 Export Peak Gain



3.2.2 Get Peak Gain



3.2.3 Solve 2D field pattern



3.2.3 Solve 2D field pattern

The screenshot displays a software interface with a project tree on the left, a parameter table on the top right, and a context menu on the bottom right.

Project Tree (Left):

- [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
 - [81] NF to FF transform Efficiency

• End value: 2000.00000 MHz

Axis 1: Phi

- No of points =64 [Linear]
- Start value:0.00000 deg
- End value:177.18750 deg

Axis 2: Theta

- No of points =129 [Linear]
- Start value:-180.00000 deg
- End value:180.00000 deg

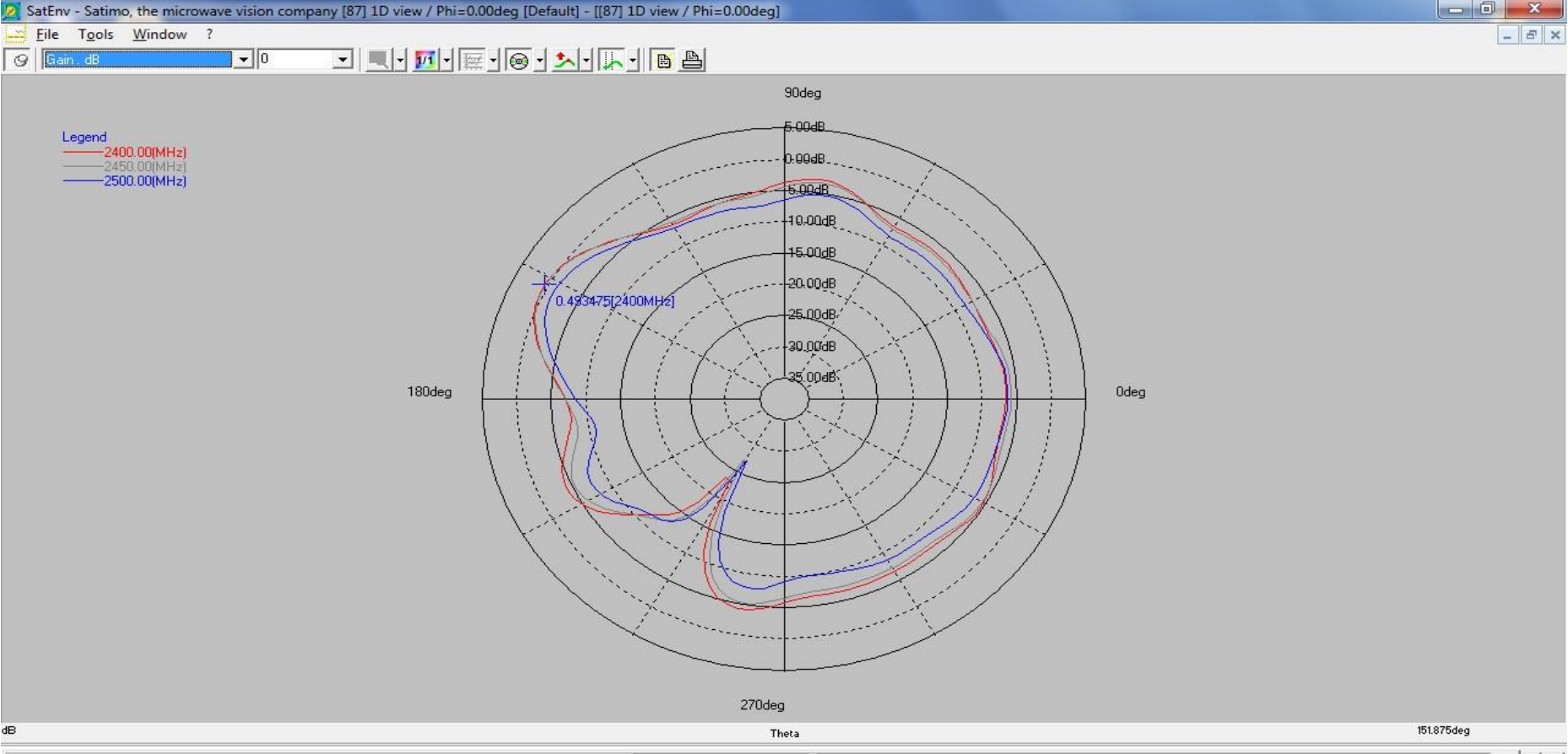
Context menu options:

- Reduce number of dimensions
- Extract data subset
- Create layers
- Computation
- Export...
- Remove
- Execute**
- Print
- Print form
- External file...
- Properties...
- Rename...
- Methods

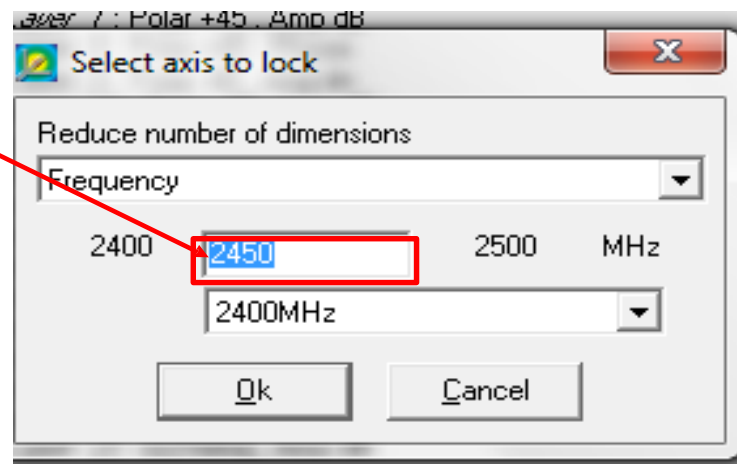
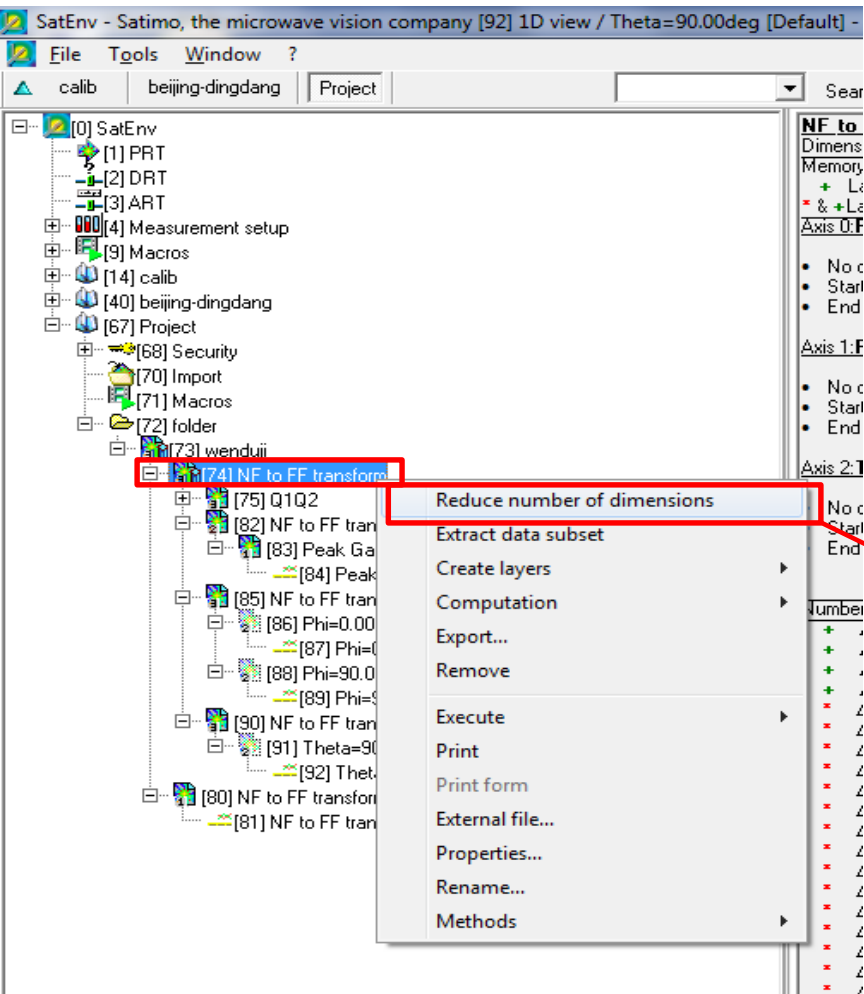
Sub-menu options (under Execute):

- SPM Post processing1
- Peak Gain
- NF TO FF Efficiency
- Report_3total**

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. The project tree on the left shows a hierarchy of simulation steps, with [93] Frequency=2450.00MHz highlighted. The top right panel lists parameters for Axis 1: Theta, including the number of layers (33) and a list of layer types. The context menu is open over the selected item, with 'Special' and '3D OpenGL Viewer' highlighted. The 'Layers configuration' dialog box is open, showing a list of layers with 'E Total. dB' selected and highlighted.

End value: 177.16750 deg

Axis 1: **Theta**

- No. of points = 129 [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
- Layer 18: E(Phi) . Amp lin
- Layer 19: E(Theta) . Amp lin

3D view
2D view
1D view
Special
Reduce number of dimensions
Extract data subset
Show window
Create layers
Computation
Export...
Remove
Execute
Print
Print form
External file...
Properties...
Rename...
Methods

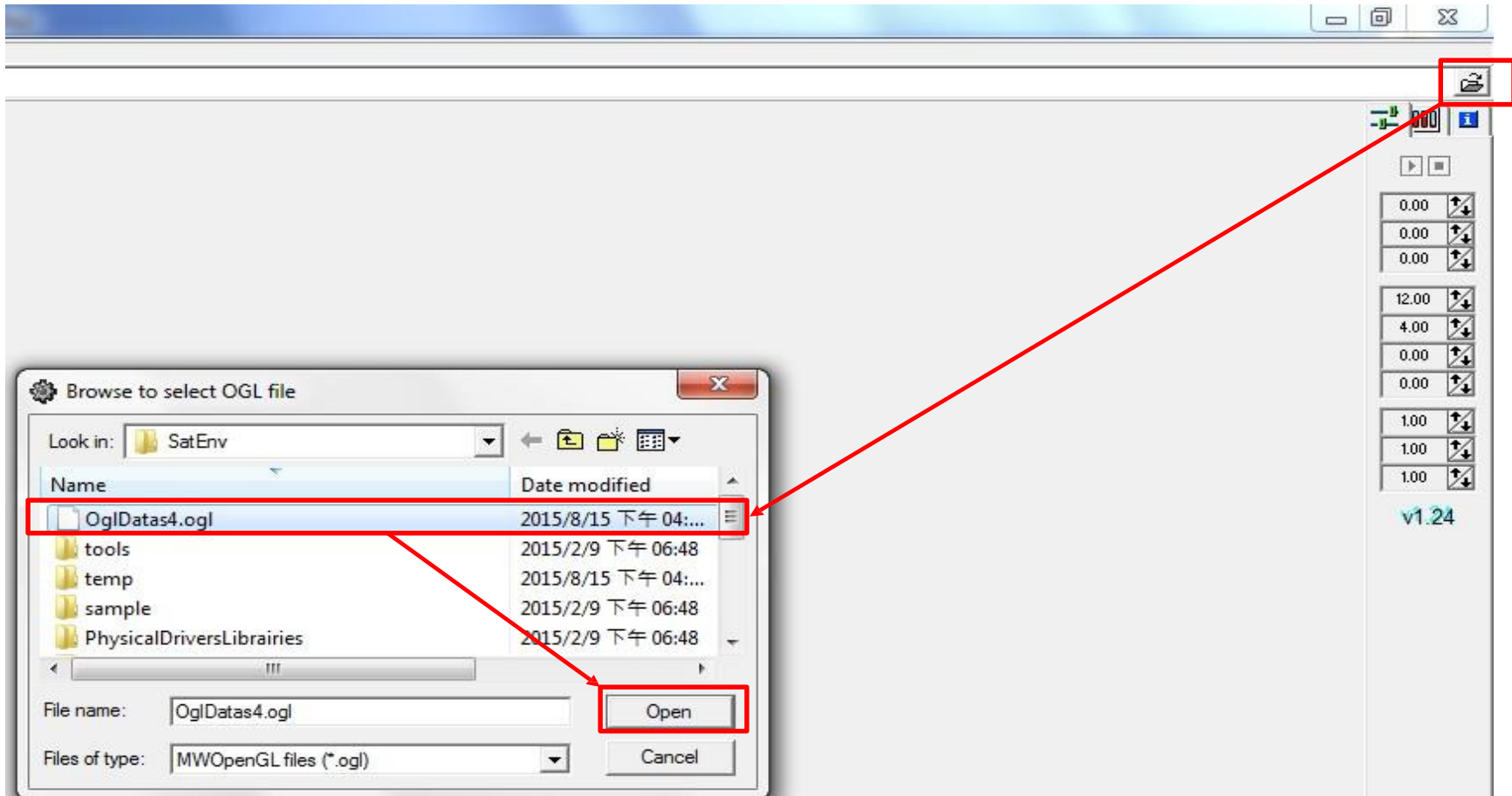
Cylindric 3D OpenGL Viewer/0
Cylindric 3D OpenGL Viewer/1
3D OpenGL Viewer

Layers configuration

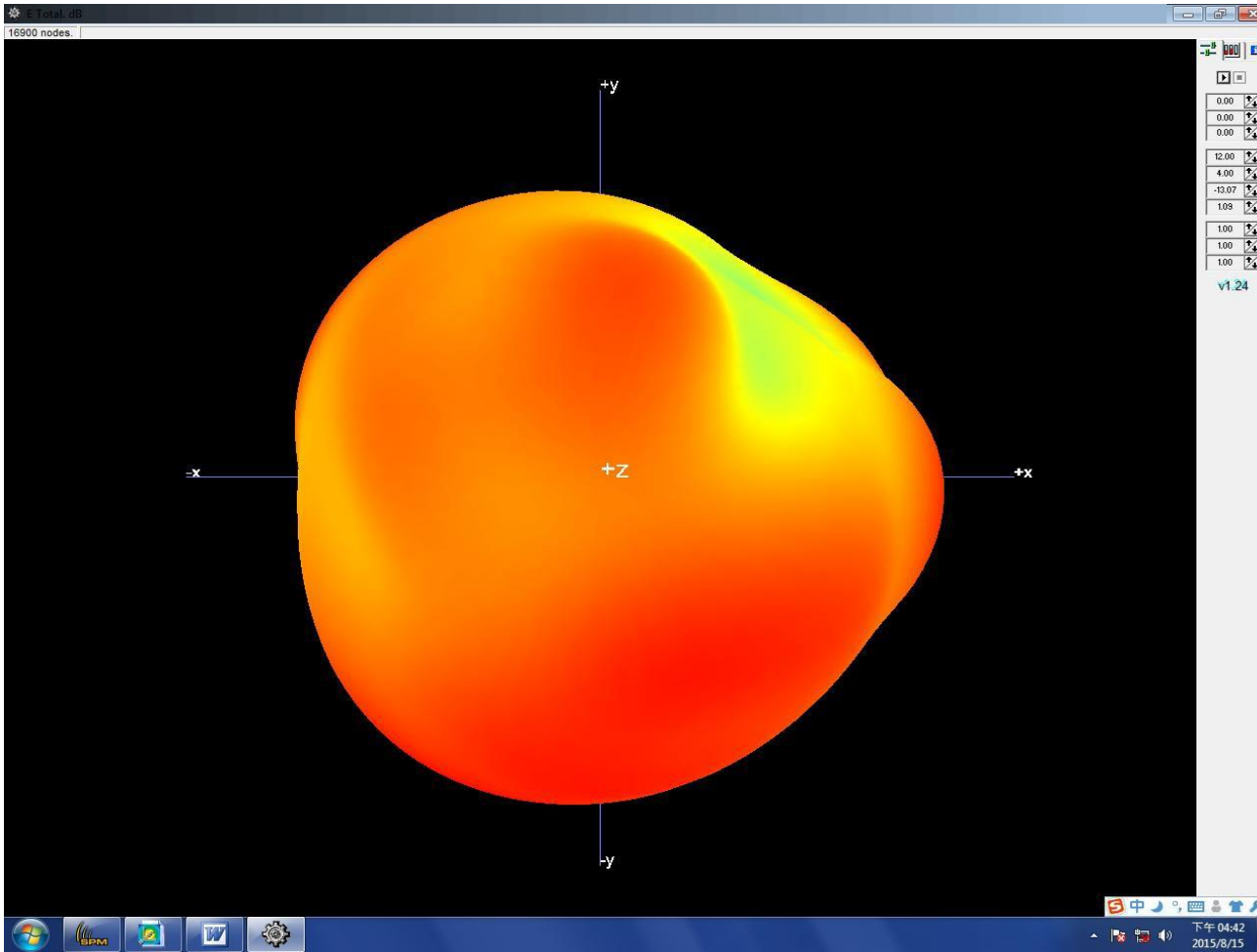
- E(Phi). Real part
- E(Phi). Imaginary part
- E(Theta). Real part
- E(Theta). Imaginary part
- E Total. dB**
- E Total. Lin
- Polar +45 . Amp lin
- Polar +45 . Amp dB
- Polar +45 . Phase
- Polar -45 . Amp lin
- Polar -45 . Amp dB
- Polar -45 . Phase
- Gain Phi. dB

All layers
No layer
Ok
Cancel

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

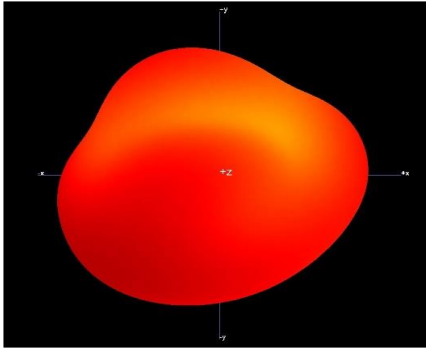
- 1.1 3D Pattern & E-Total Gain Table & 2D Radiation Patterns
- 1.2 Peak Gain of 3D Directional pattern

1.1.1 E-Total Gain Formula

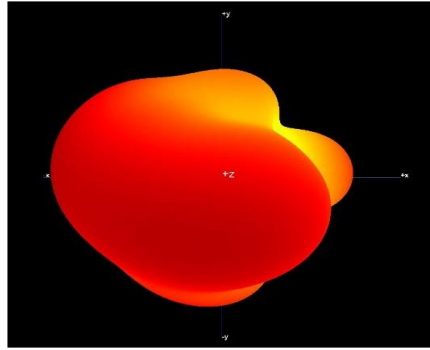
	Formula	Remarks
E-Total	Satimo darkroom data solution =MAX(XX:XX)	The maximum value in the original data of angle by angle and with frequency

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

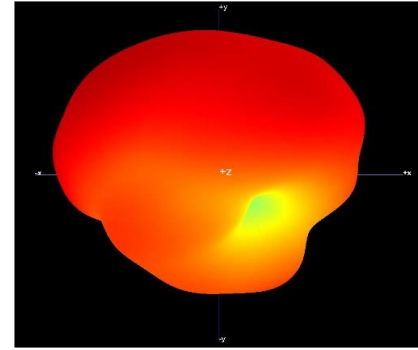
2.4G-1_2450MHz



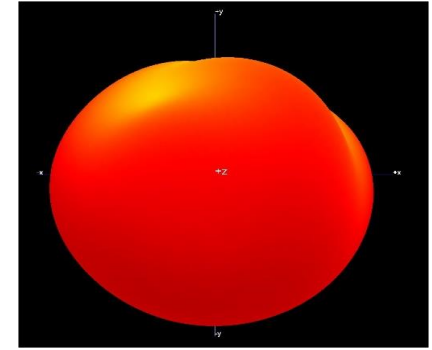
2.4G-2_2450MHz



2/5G-1_2450MHz



2/5G-2_2450MHz

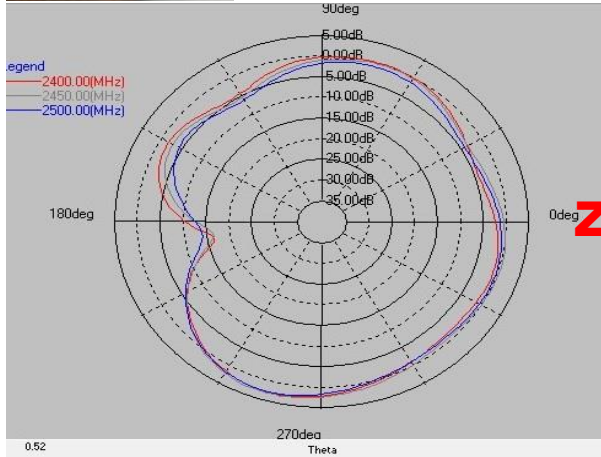


Frequency [MHz]	2.4G-1	2.4G-2	2/5G-1-2.4G	2/5G-2-2.4G
	E-total [dBi]	E-total [dBi]	E-total [dBi]	E-total [dBi]
2400	2.86	3.30	2.88	3.21
2450	3.54	3.12	3.54	3.02
2500	3.26	3.40	3.31	2.87

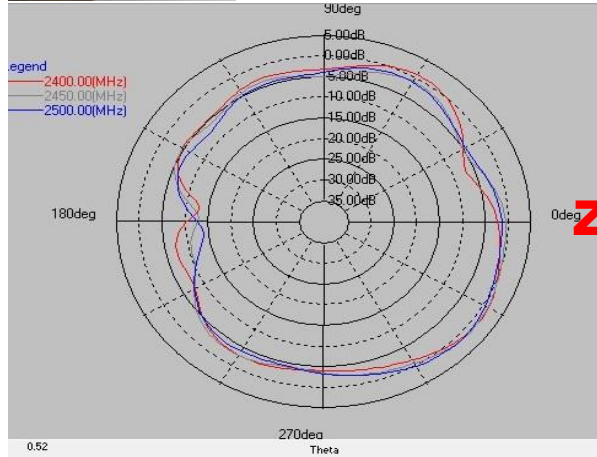
1.1.3 2D Radiation Patterns---2.4G-Ant 1



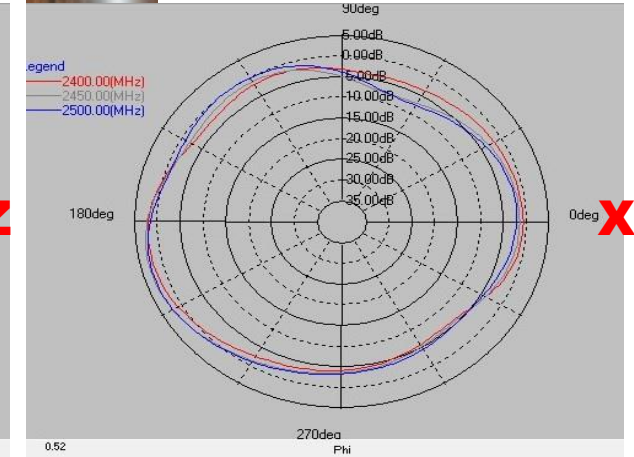
X



Y



Y

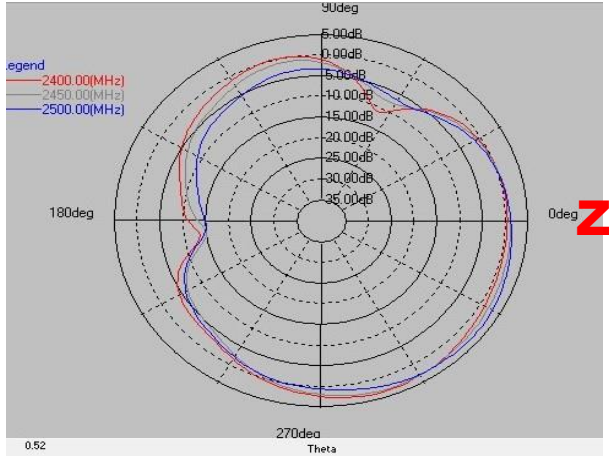


	ZX plane		ZY plane		XY plane	
Frequency [MHz]	Max Value [dBi]	Average [dBi]	Max Value [dBi]	Average [dBi]	Max Value [dBi]	Average [dBi]
2400	2.55	-1.43	1.48	-2.77	2.19	-1.81
2450	2.86	-1.18	1.49	-2.88	3.10	-1.64
2500	2.41	-1.87	1.22	-3.10	2.75	-1.59

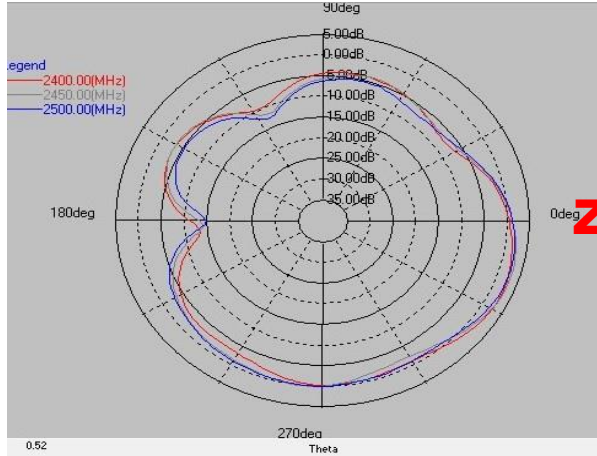
1.1.3 2D Radiation Patterns---2.4G-Ant 2



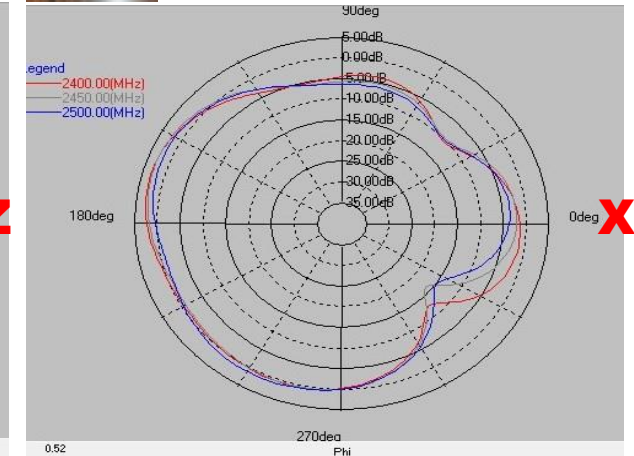
X



Y



Y

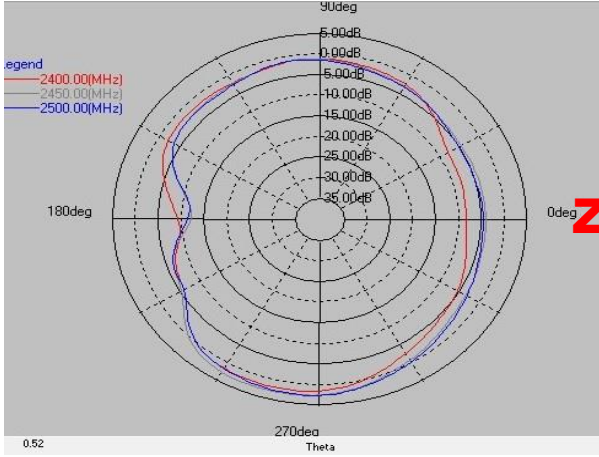


	ZX plane		ZY plane		XY plane	
Frequency [MHz]	Max Value [dBi]	Average [dBi]	Max Value [dBi]	Average [dBi]	Max Value [dBi]	Average [dBi]
2400	3.30	-0.84	2.65	-2.45	2.98	-1.51
2450	2.97	-1.05	3.03	-2.26	2.84	-1.73
2500	3.18	-1.32	2.55	-2.42	1.93	-2.05

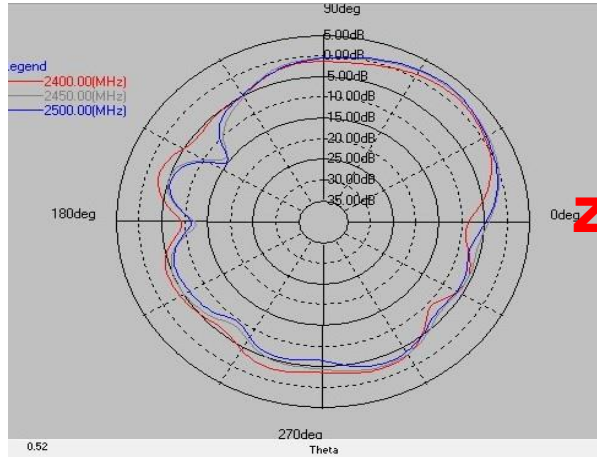
1.1.3 2D Radiation Patterns---2.4G-Ant 3



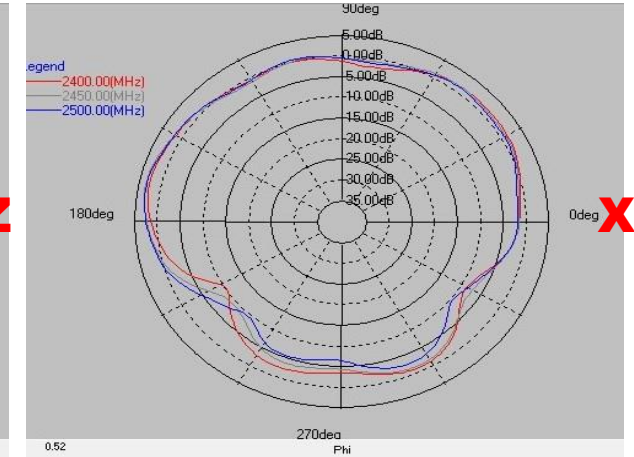
X



Y



Y

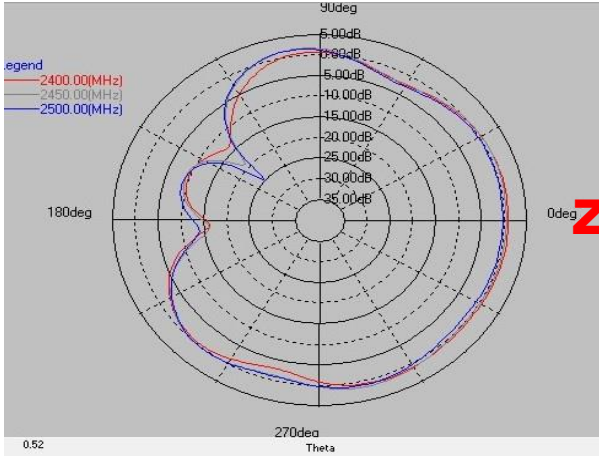


	ZX plane		ZY plane		XY plane	
Frequency [MHz]	Max Value [dBi]	Average [dBi]	Max Value [dBi]	Average [dBi]	Max Value [dBi]	Average [dBi]
2400	1.63	-2.56	1.51	-3.08	2.69	-0.98
2450	2.62	-1.78	2.23	-2.86	3.41	-0.84
2500	2.49	-1.99	2.50	-3.09	3.26	-1.08

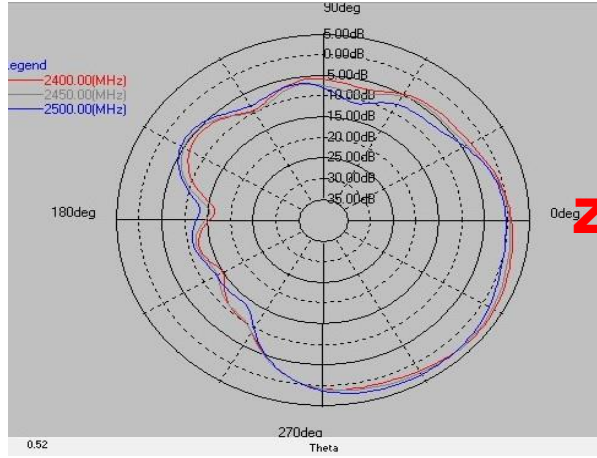
1.1.3 2D Radiation Patterns---2.4G-Ant 4



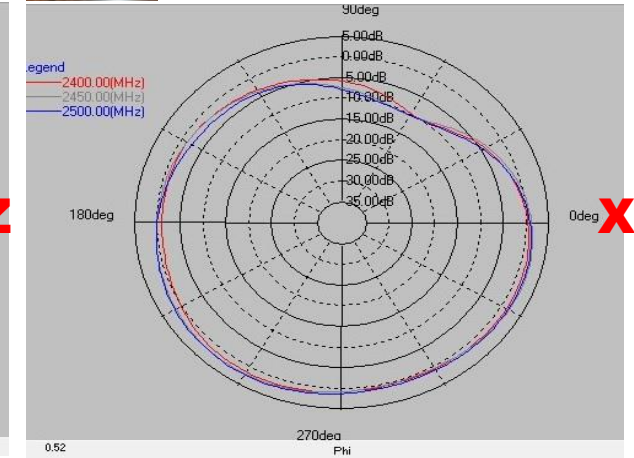
X



Y



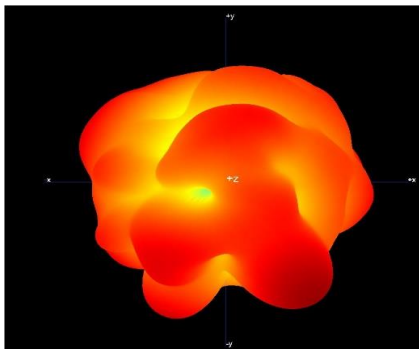
Y



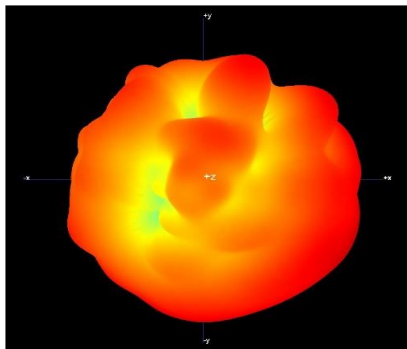
	ZX plane		ZY plane		XY plane	
Frequency [MHz]	Max Value [dBi]	Average [dBi]	Max Value [dBi]	Average [dBi]	Max Value [dBi]	Average [dBi]
2400	0.93	-1.38	3.21	-2.06	1.46	-0.85
2450	1.48	-1.04	3.00	-2.18	2.09	-0.40
2500	1.33	-1.47	2.87	-2.38	2.19	-0.42

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

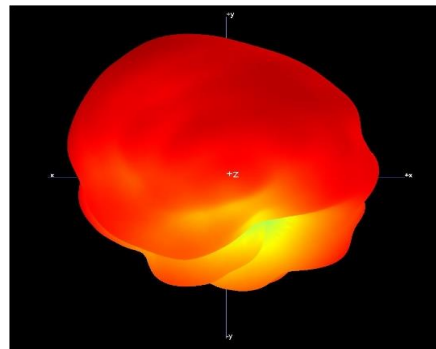
5G-1_5500MHz



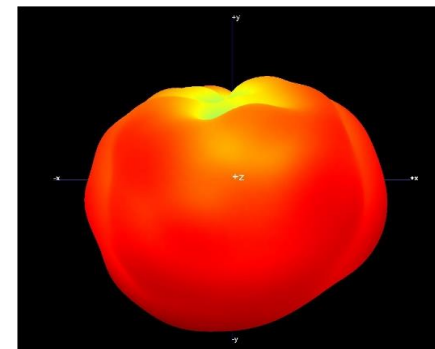
5G-2_5500MHz



2/5G-1_5500MHz



2/5G-2_5500MHz

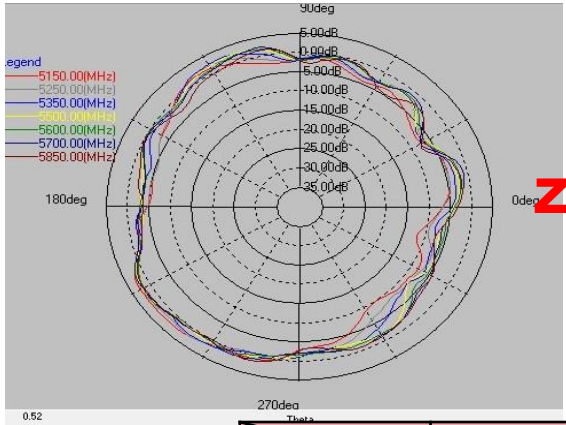


Frequency [MHz]	5G-1	5G-2	2/5G-1-5G	2/5G-2-5G
	E-total [dBi]	E-total [dBi]	E-total [dBi]	E-total [dBi]
5150	4.98	3.55	3.82	4.10
5250	4.94	3.74	3.82	4.00
5350	4.71	3.84	4.22	4.33
5500	4.21	3.75	4.00	4.89
5600	4.13	3.51	3.45	4.95
5700	4.58	3.95	3.31	4.85
5850	4.38	4.60	3.55	4.28

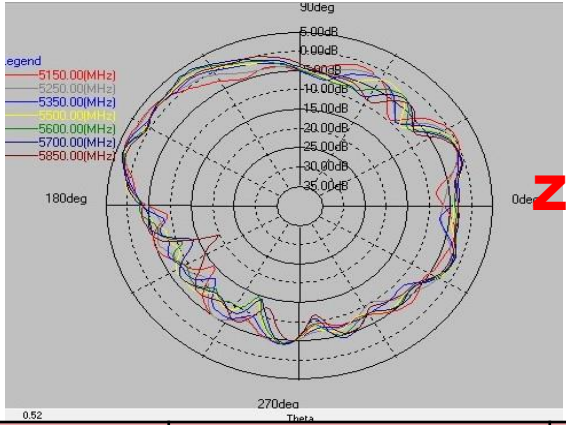
1.1.8 2D Radiation Patterns---5G-Ant 1



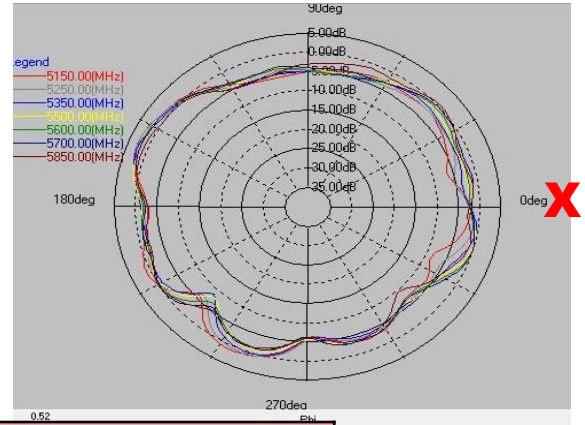
X



Y

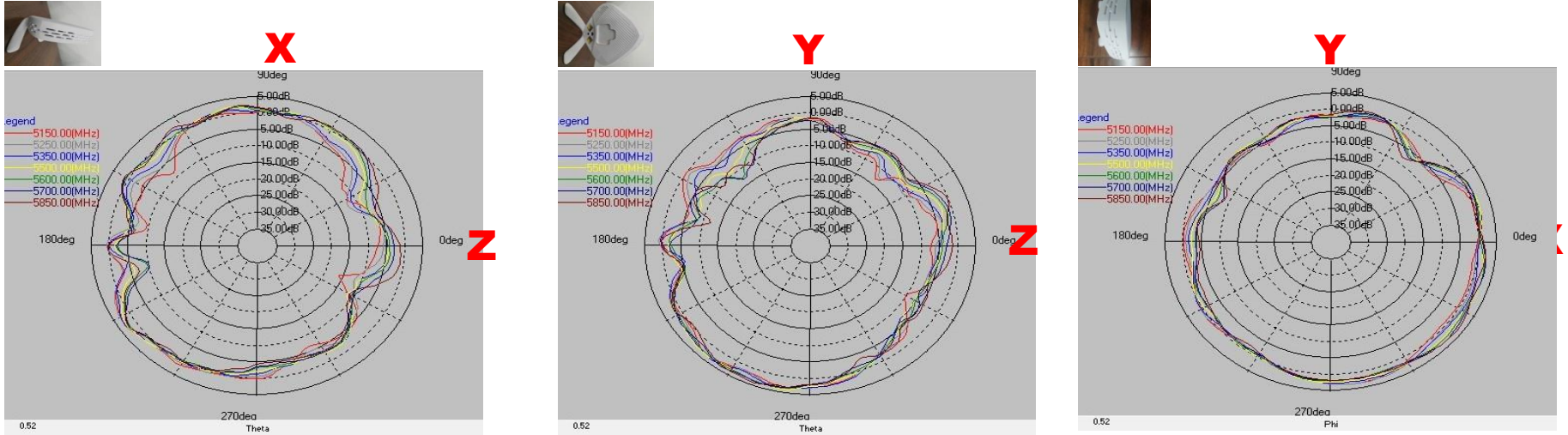


Y



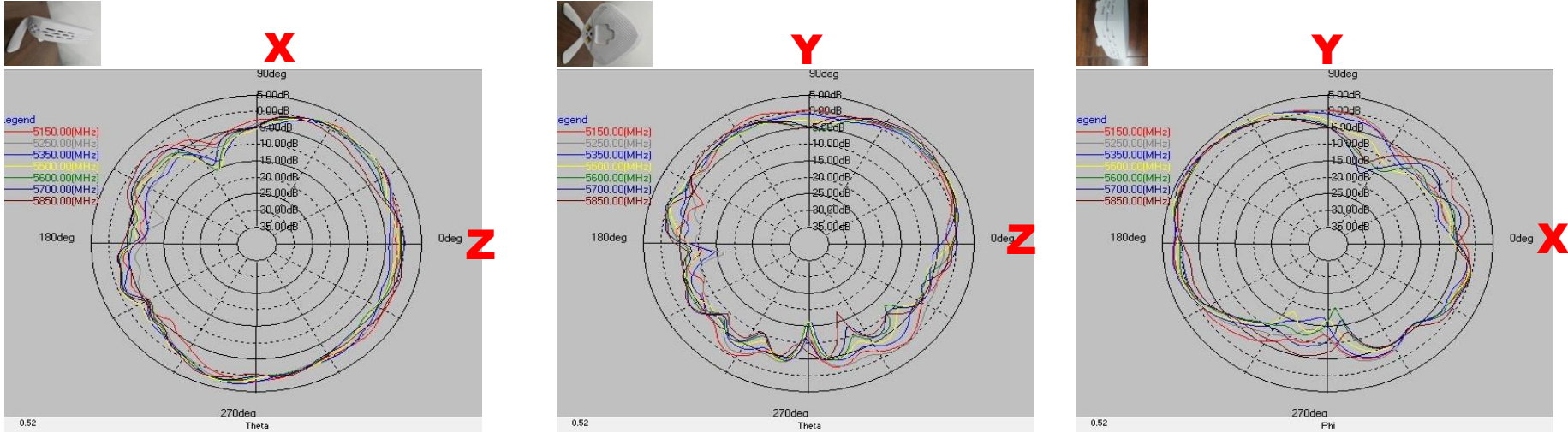
	ZX plane		ZY plane		XY plane	
Frequency [MHz]	Max Value [dBi]	Average [dBi]	Max Value [dBi]	Average [dBi]	Max Value [dBi]	Average [dBi]
5150	2.73	-2.10	3.49	-2.96	2.59	-2.24
5250	2.35	-1.88	3.29	-3.02	2.72	-2.20
5350	2.41	-1.54	3.33	-2.97	2.29	-2.34
5500	2.23	-1.31	2.98	-2.74	1.74	-2.11
5600	1.98	-1.35	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



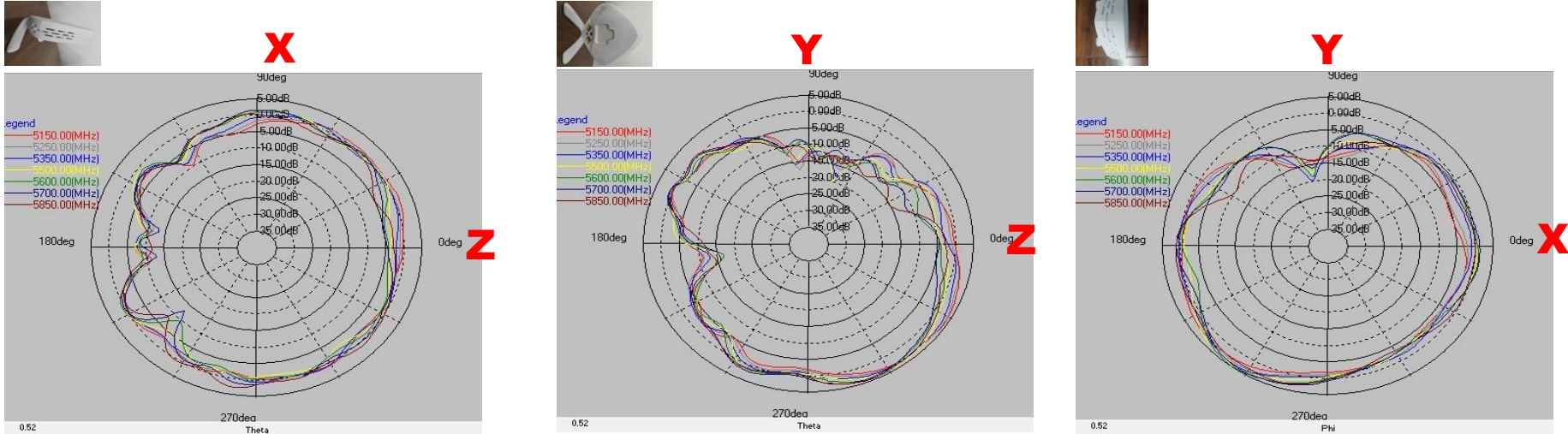
	ZX plane		ZY plane		XY plane	
Frequency [MHz]	Max Value [dBi]	Average [dBi]	Max Value [dBi]	Average [dBi]	Max Value [dBi]	Average [dBi]
5150	2.81	-2.16	3.34	-1.56	3.15	-0.69
5250	2.94	-1.76	3.52	-1.51	3.20	-0.48
5350	2.92	-1.67	3.73	-1.47	2.57	-0.49
5500	2.69	-1.37	3.73	-1.58	2.48	-0.16
5600	1.96	-1.60	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	<p>Correlated Directional gain angle by $\text{angle} = 10 \cdot \text{LOG}_{10} \left(\frac{10^{(X-X')XX/20} + 10^{(X-X')XX/20} + 10^{(X-X')XX/20} + 10^{(X-X')XX/20}}{4} \right)$</p> <p>Correlated peak gain = MAX(XX:XX)</p>	<ol style="list-style-type: none"> 1. Calculate the correlated gain angle by angle through the formula 2. Use MAX to get the maximum value
Uncorrelated Gain	<p>Uncorrelated Directional gain angle by $\text{angle} = 10 \cdot \text{LOG}_{10} \left(\frac{10^{(X-X')XX/10} + 10^{(X-X')XX/10} + 10^{(X-X')XX/10} + 10^{(X-X')XX/10}}{4} \right)$</p> <p>Uncorrelated peak gain = MAX(XX:XX)</p>	<ol style="list-style-type: none"> 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

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Appendix

2.4G Ant 1 Raw Data

