

EE3300-00 FCC Directional Gain Proposal



HW RF

10/14/2025

Purpose

- Introduction a test method of FCC KDB 662911 correlated/non-correlated 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
- EE3300-00 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

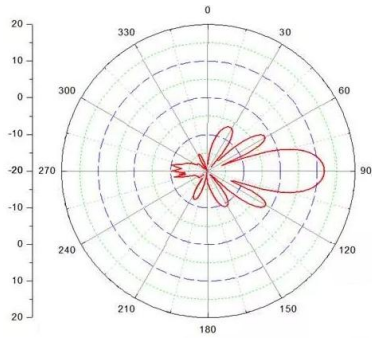
Directional gain = $10 \log[(10^{G_1/20} + 10^{G_2/20} + \dots + 10^{G_N/20})^2 / N_{\text{ANT}}]$ dBi [Note the “20”s in the denominator of each exponent and the square of the sum of terms; the object is to combine the signal levels coherently.]

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

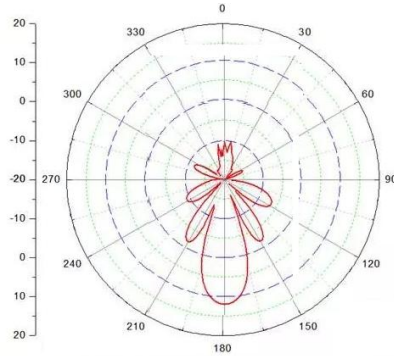
Directional gain = $10 \log[(10^{G_1/10} + 10^{G_2/10} + \dots + 10^{G_N/10}) / N_{\text{ANT}}]$ dBi

Based on FCC KDB 662911 Calculation formula of directional gain analyze

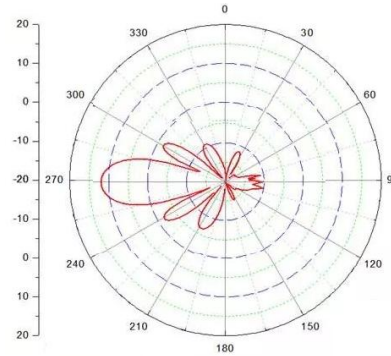
Antenna pattern example:



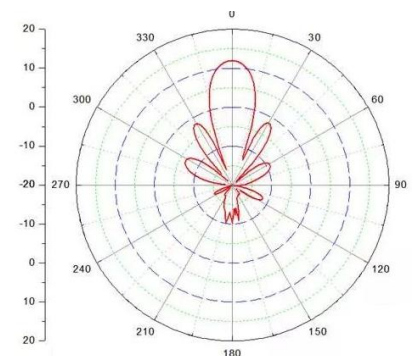
ANT0=3dBi



ANT1=-5dBi



ANT1=-3dBi



ANT1=-7dBi



X axis

Based on above antenna pattern, it is more realistic to get combine antenna gain of one by one direction. It's more consistent with MIMO real operation mode.

ZYXEL System introduction

Our product:

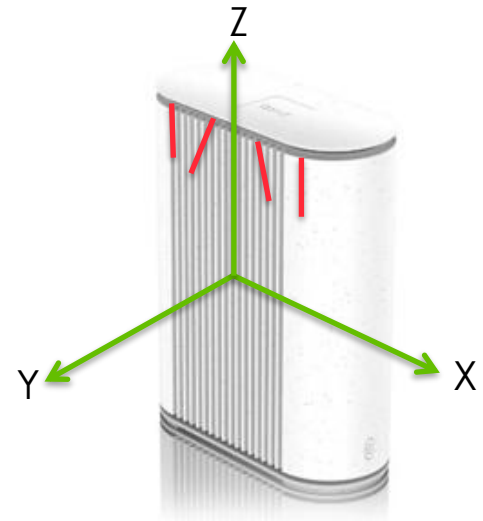
2.4G is 4x4 4T4R MIMO system with embedded antennas design

5G is 5x5 5T5R MIMO system with embedded antennas design

Take 4x4 4T4R MIMO system for example to calculate the directional Gain as below:

- The antennas are with different location and polarization
- The four antennas have it's own 3D gain data(Detail as Raw Data file)
- The four peak gains are at the different direction.

So based on the real antenna gain table, calculate the 4x4 Directional gain angle by angle, then select the max value as the system directional Gain.



— ANT location

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

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 with the raw data, then select the max value as final directional gain(uncorrelated& correlated sheet of Raw Data file)

SATIMO Microwave Anechoic Chamber environment introduction

OUTLINE

1、 Instrument introduction

1.1 SATIMO Overview

1.2 Equipment list & Calibration info

2、 Measure

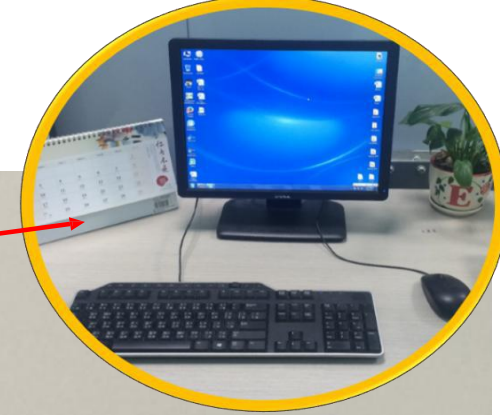
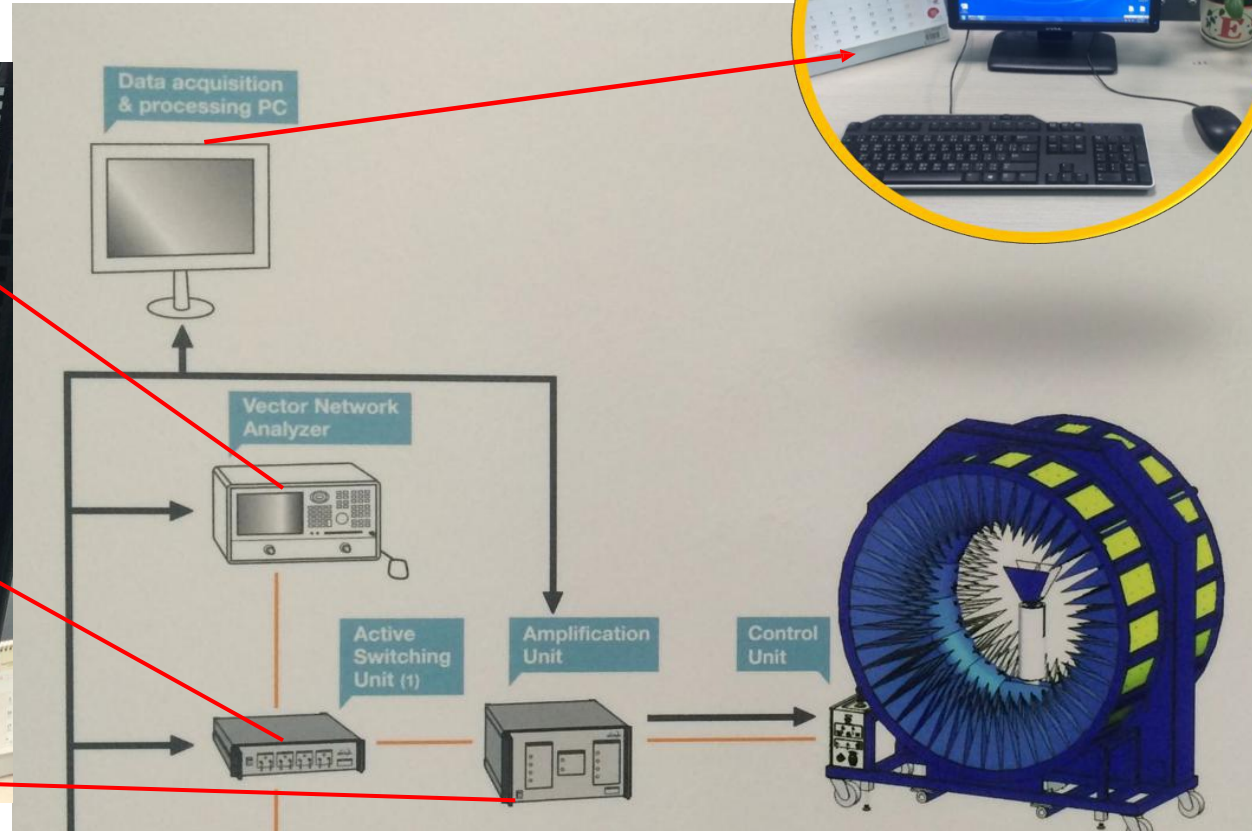
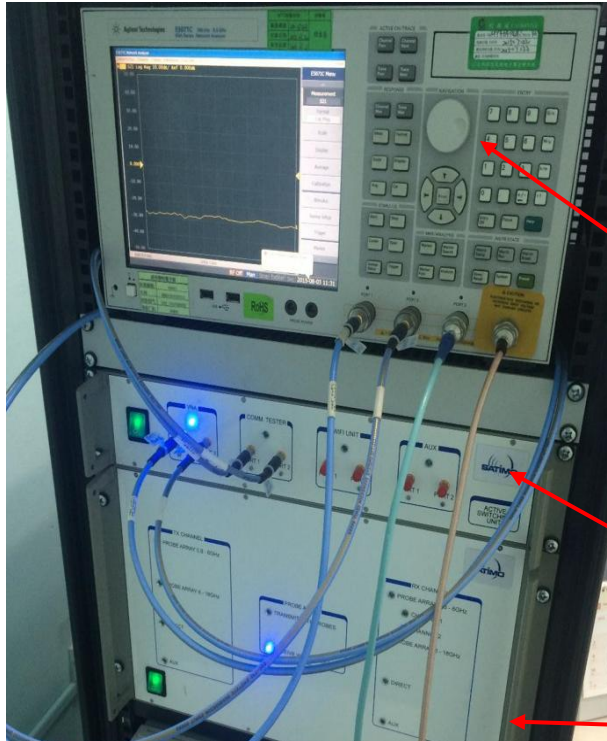
3.1 DUT in test bed

3.2 Software initial

3.3 Measure and process data

1、Instrument introduction

1.1 SATIMO Overview



Entity diagram

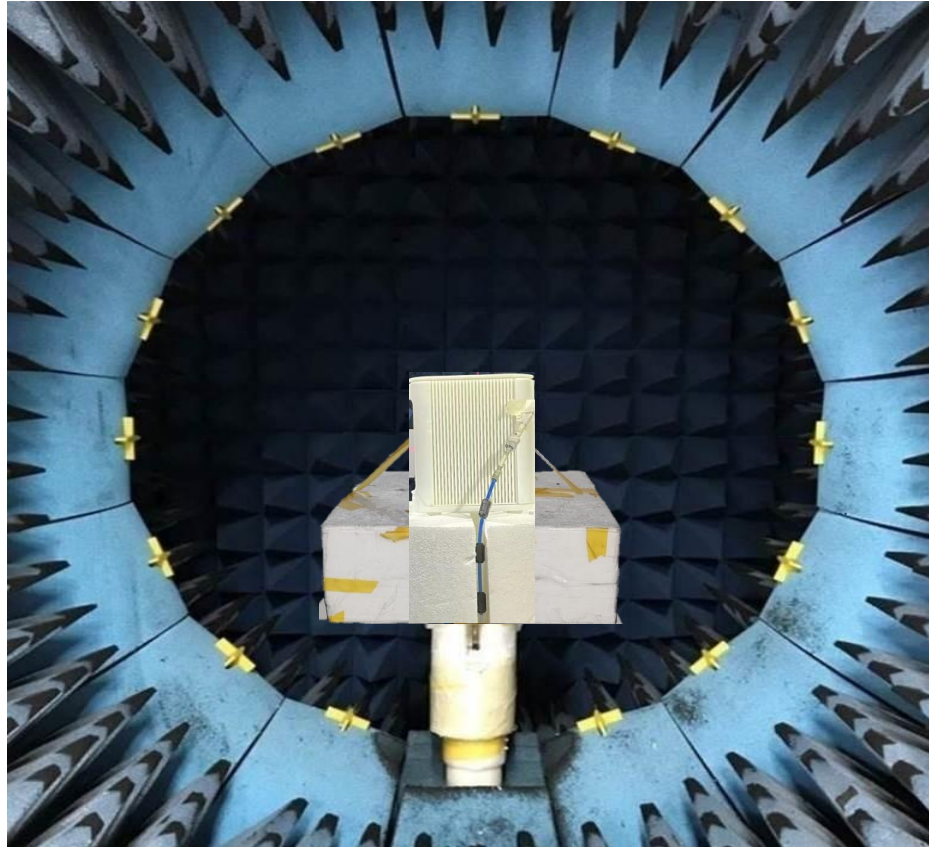
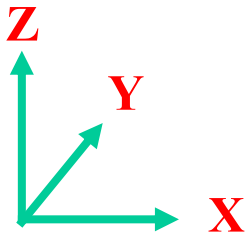


1.2 Equipment list & Calibration info

Instrument	Manufacture	Model No	Cali. Interval	Cali. Due Date
ENA series Network Analyzer	Agilent	E5071C	1 year	2026-08-15
Microwave Anechoic Chamber	MVG	MG-16	1 year	2026-08-15

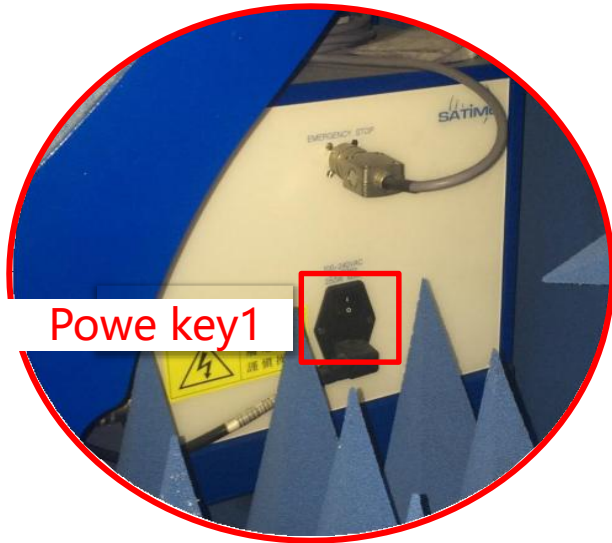
2、Measure

2.1 DUT in test bed

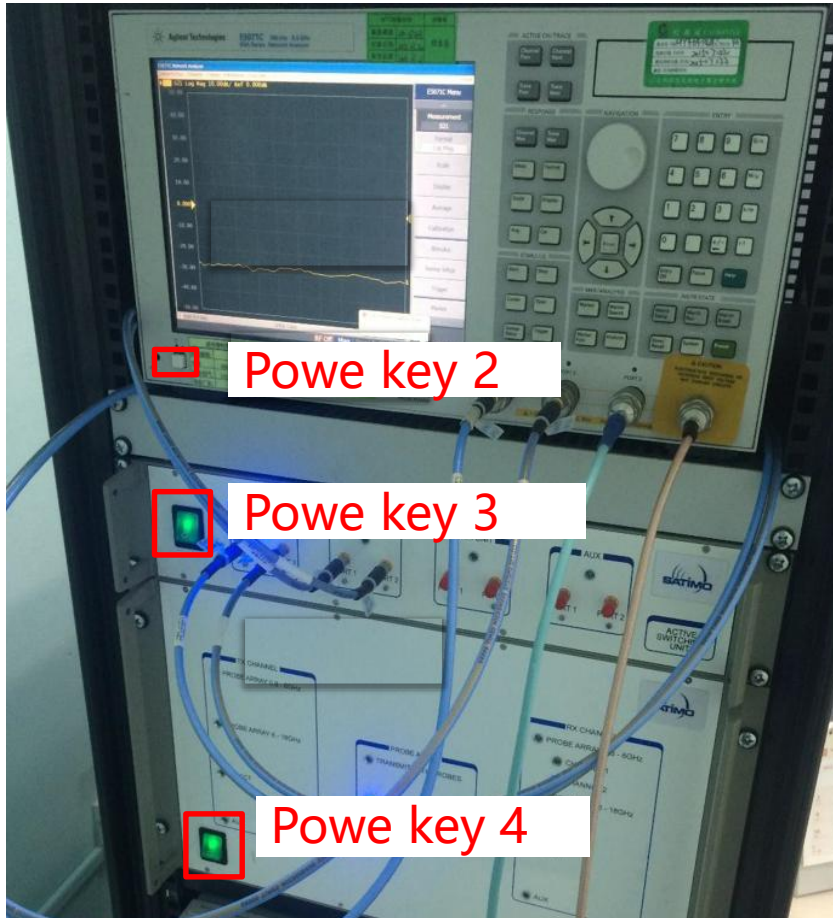


2.1.1 Open Power

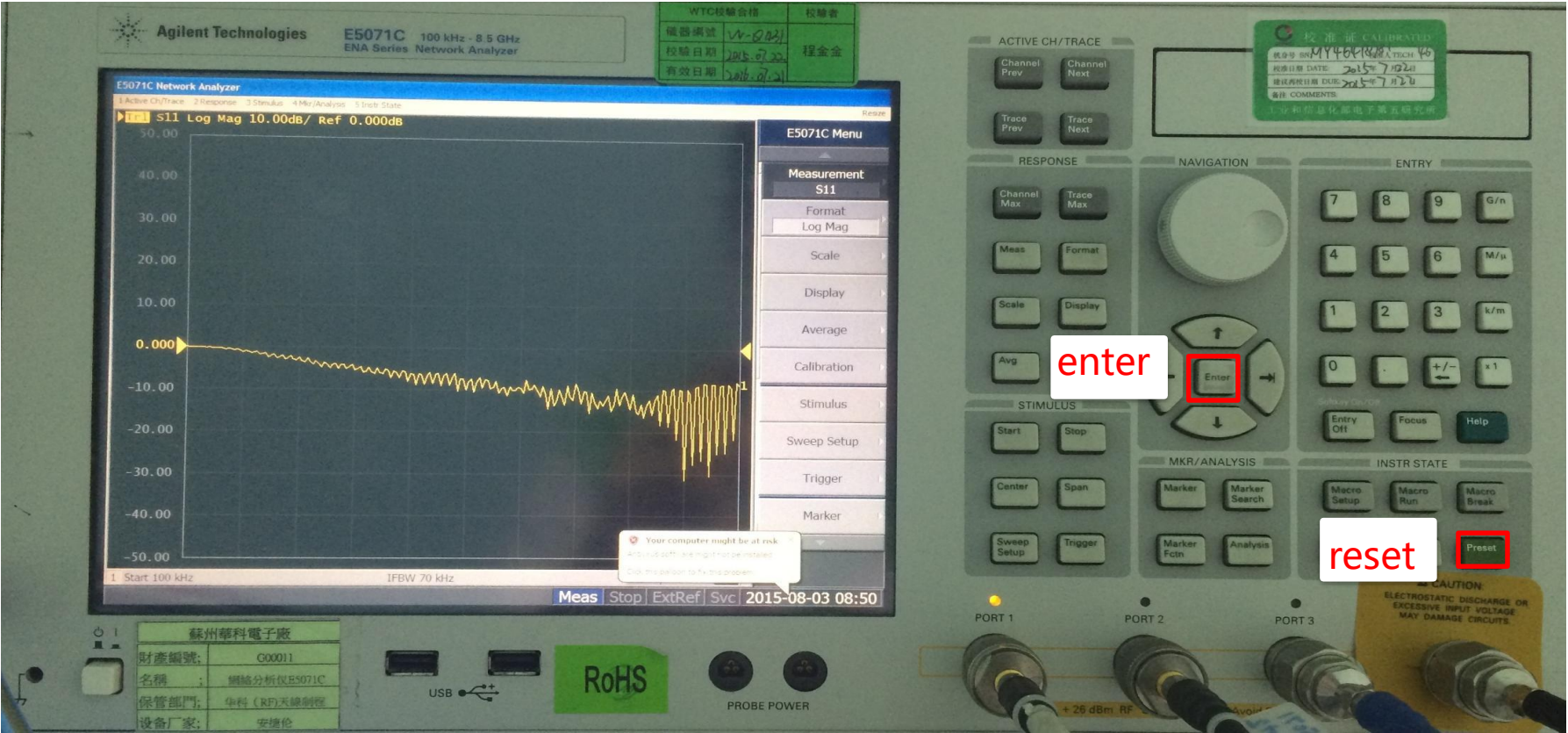
Turn on the power in turn 1、2、3、4、5



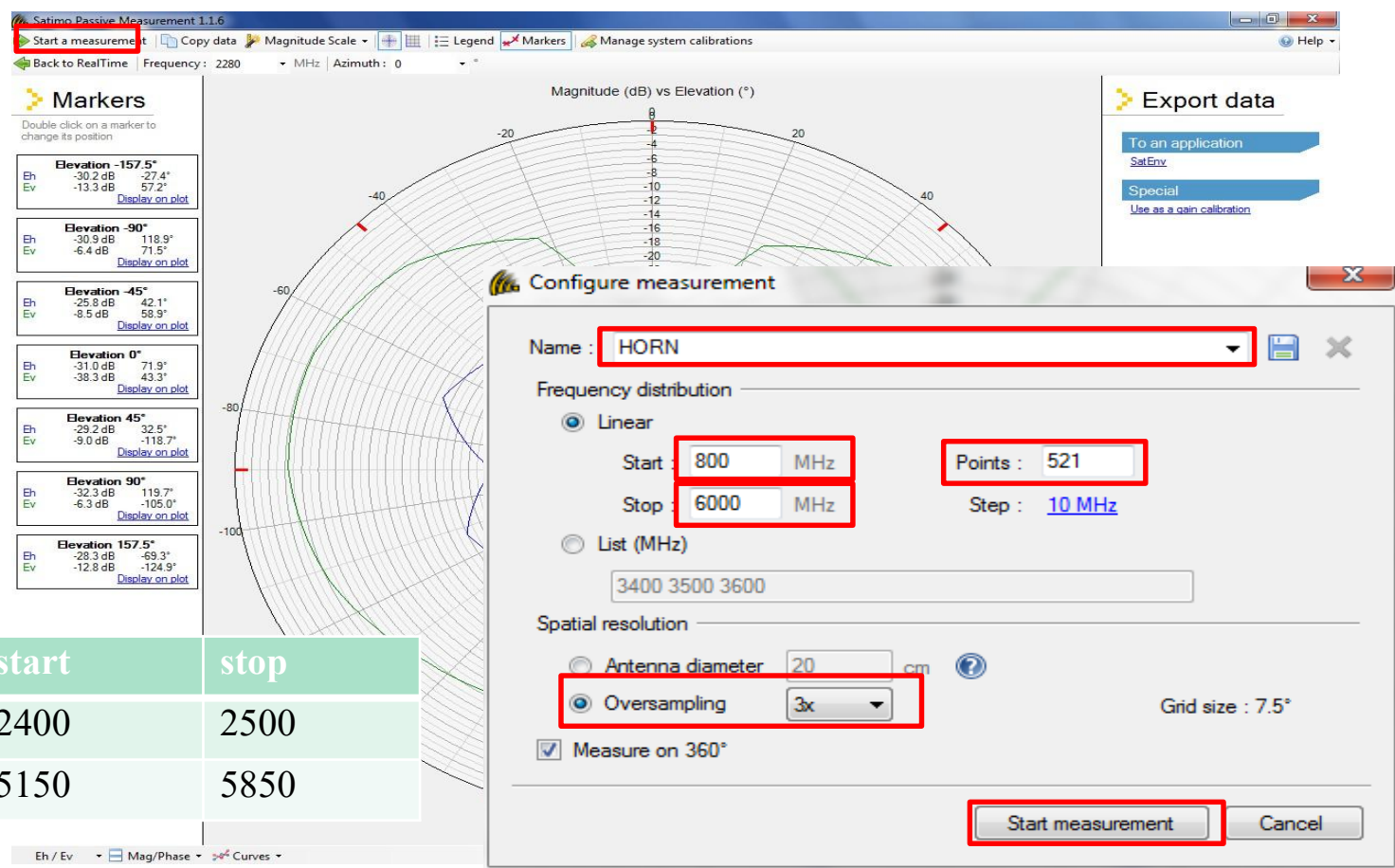
2.1.1 Open Power



2.1.2 Reset network analyzer

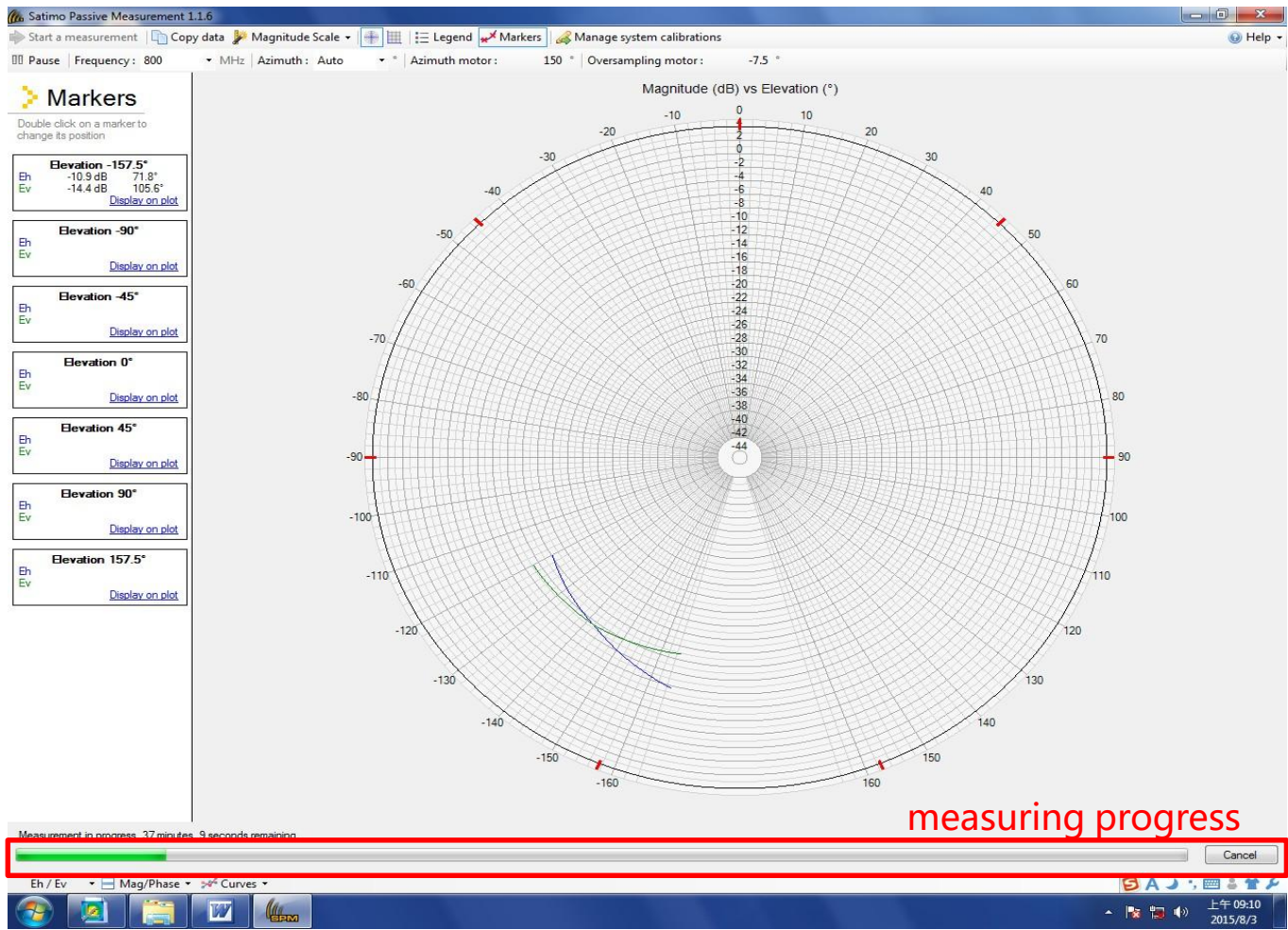


2.2 Software initial, set parameters and start measurement

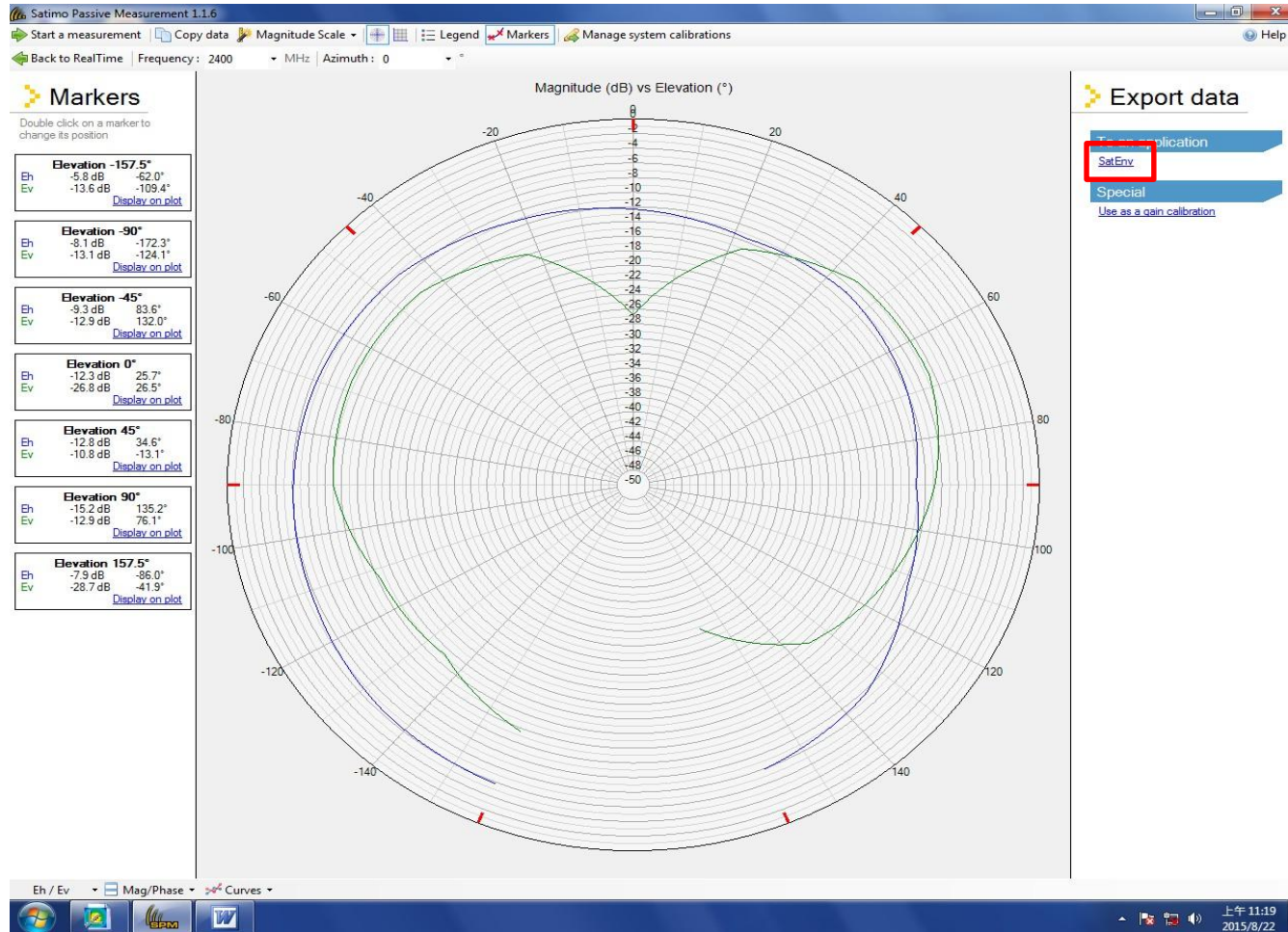


type	start	stop
2.4G	2400	2500
5G	5150	5850

Measuring processing



2.3 Export data to data processing software



2.3.1 Export Peak Gain

The screenshot displays the SatEnv software interface. On the left, a project hierarchy tree shows the following structure:

- [0] SatEnv
 - [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
 - [109] NF to FF transform (highlighted with a red box)
 - [115] NF to FF transform
 - [116] NF to FF transform

A right-click context menu is open over the highlighted [109] NF to FF transform node. The menu options are:

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

The main panel on the right displays the details for the selected 'NF to FF transform Id=109':

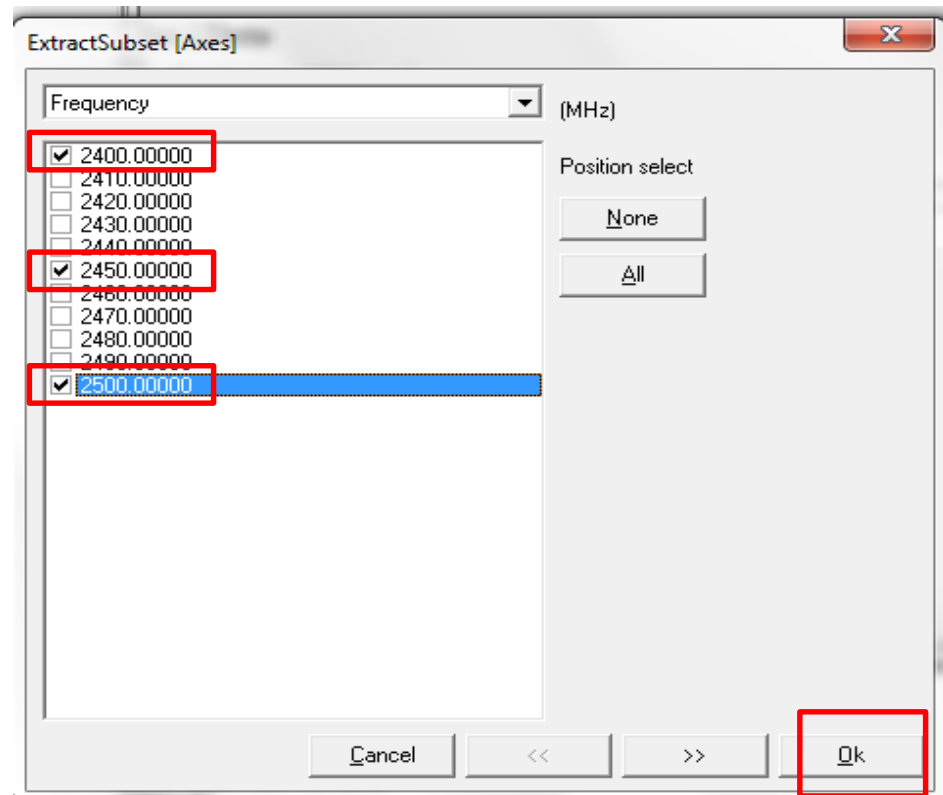
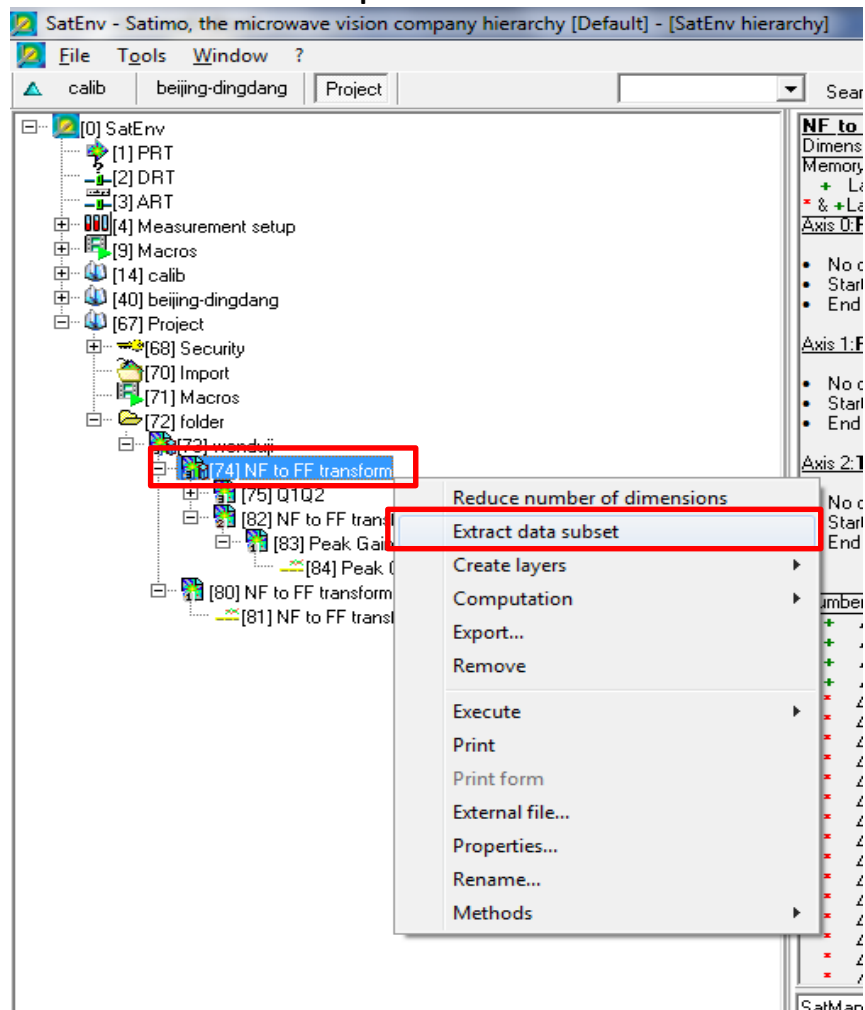
- Dimensions 3**
- Memory used 19.89Mb
 - + Layers size 19.89Mb
 - + Layers size 164.05Mb
- Axis 0: Frequency**
 - No of points =40 [Linear]
 - Start value:2280.00000 MHz
 - End value:2670.00000 MHz
- Axis 1: Phi**
 - No of points =90 [Linear]
 - Start value:0.00000 deg
 - End value:178.00000 deg
- Axis 2: Theta**
 - No of points =181 [Linear]
 - Start value:-180.00000 deg
 - End value:180.00000 deg
- Number of layers 33**
 - Layer 0: E(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 | Modification accepted

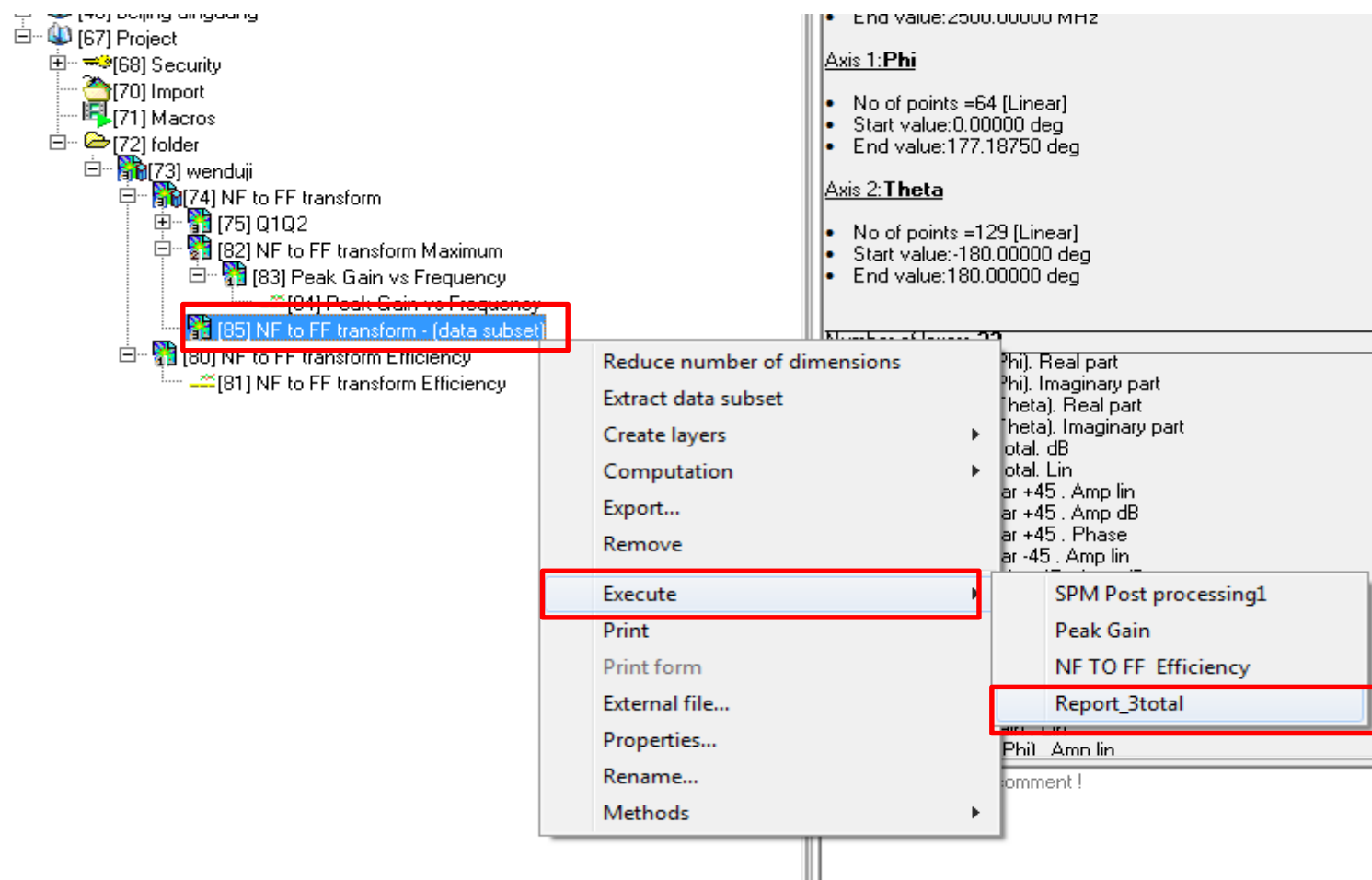
2.3.2 Get Peak Gain



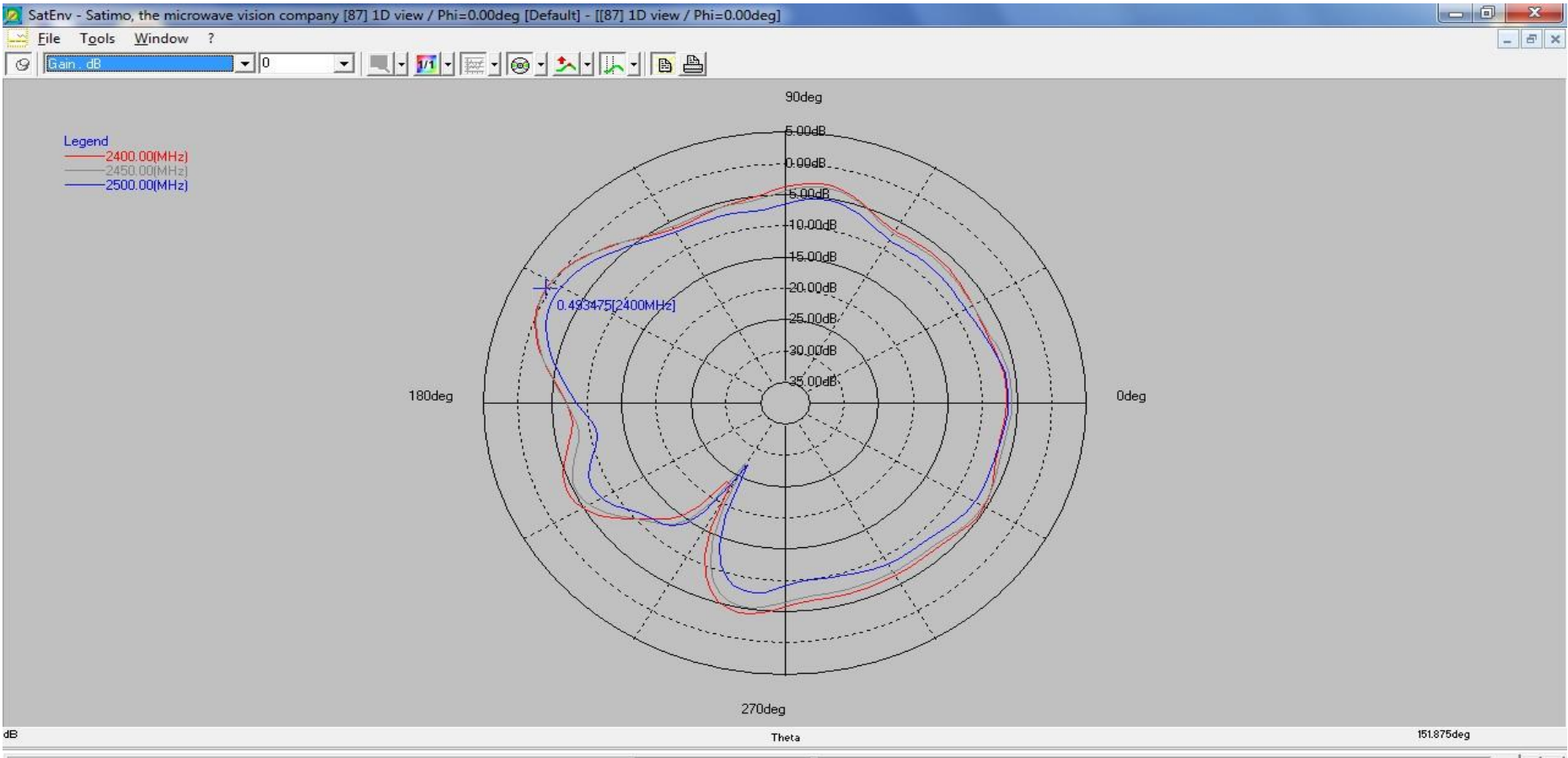
2.3.3 Solve 2D field pattern



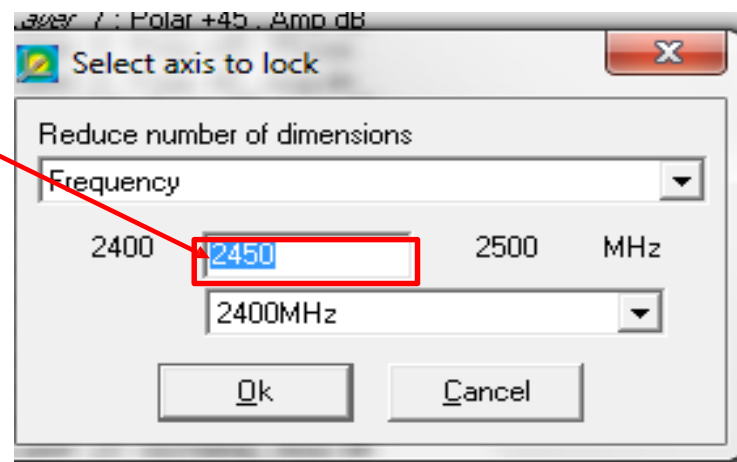
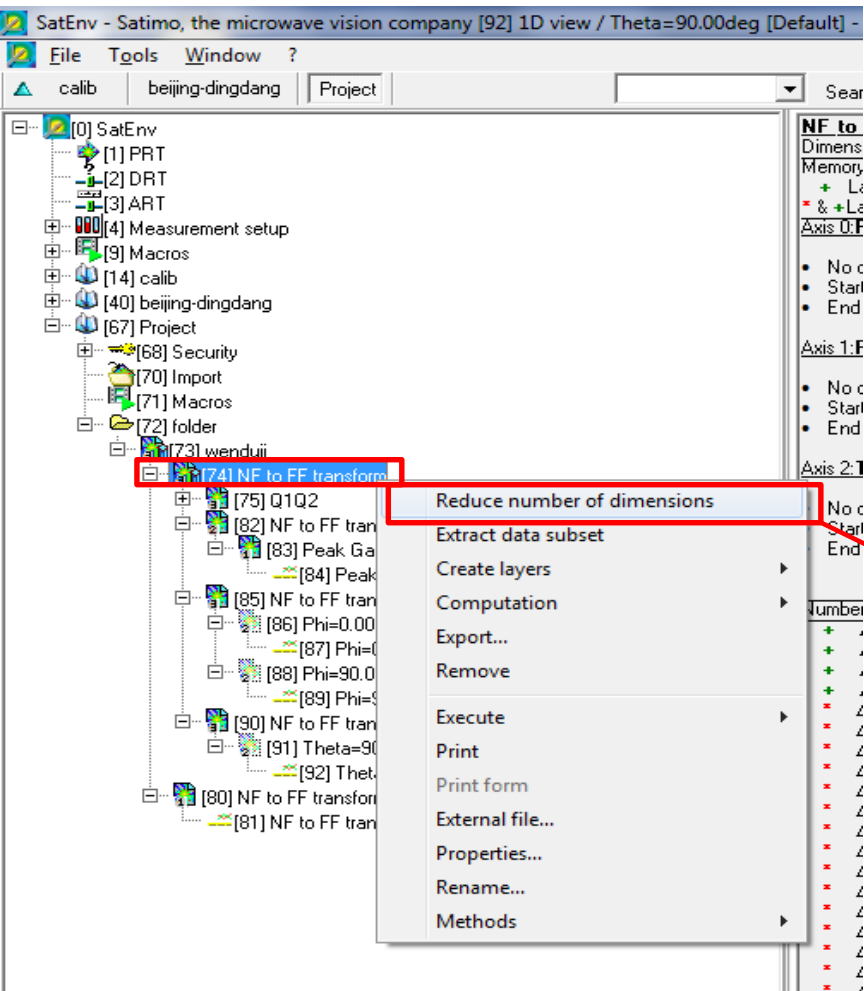
2.3.3 Solve 2D field pattern



2.3.4 Get 2D field pattern



2.3.5 Solving 3D field pattern



2.3.5 Solving 3D field pattern

The screenshot illustrates the steps to solve a 3D field pattern in a simulation software. The main window shows a project tree on the left with various simulation steps. The right pane displays the 'Axis 1: Theta' settings and a list of 33 layers. A context menu is open over the 'Frequency=2450.00MHz' layer, with 'Special' and '3D OpenGL Viewer' highlighted. The 'Layers configuration' dialog box is also open, showing a list of layers with 'E Total. dB' selected.

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)
 - [86] Phi=0.00deg
 - [87] Phi=0.00deg
 - [88] Phi=90.00deg
 - [89] Phi=90.00deg
 - [90] NF to FF transform - (data subset) Expanded
 - [91] Theta=90.00deg
 - [92] Theta=90.00deg
 - [93] Frequency=2450.00MHz
 - [94] NF to FF transform Efficiency
 - [81] NF to FF transform Efficiency

Axis 1: Theta (Right):

- End value: 177.18750 deg
- No. of points = 129 [Linear]
- Start value: -180.00000 deg
- End value: 180.00000 deg

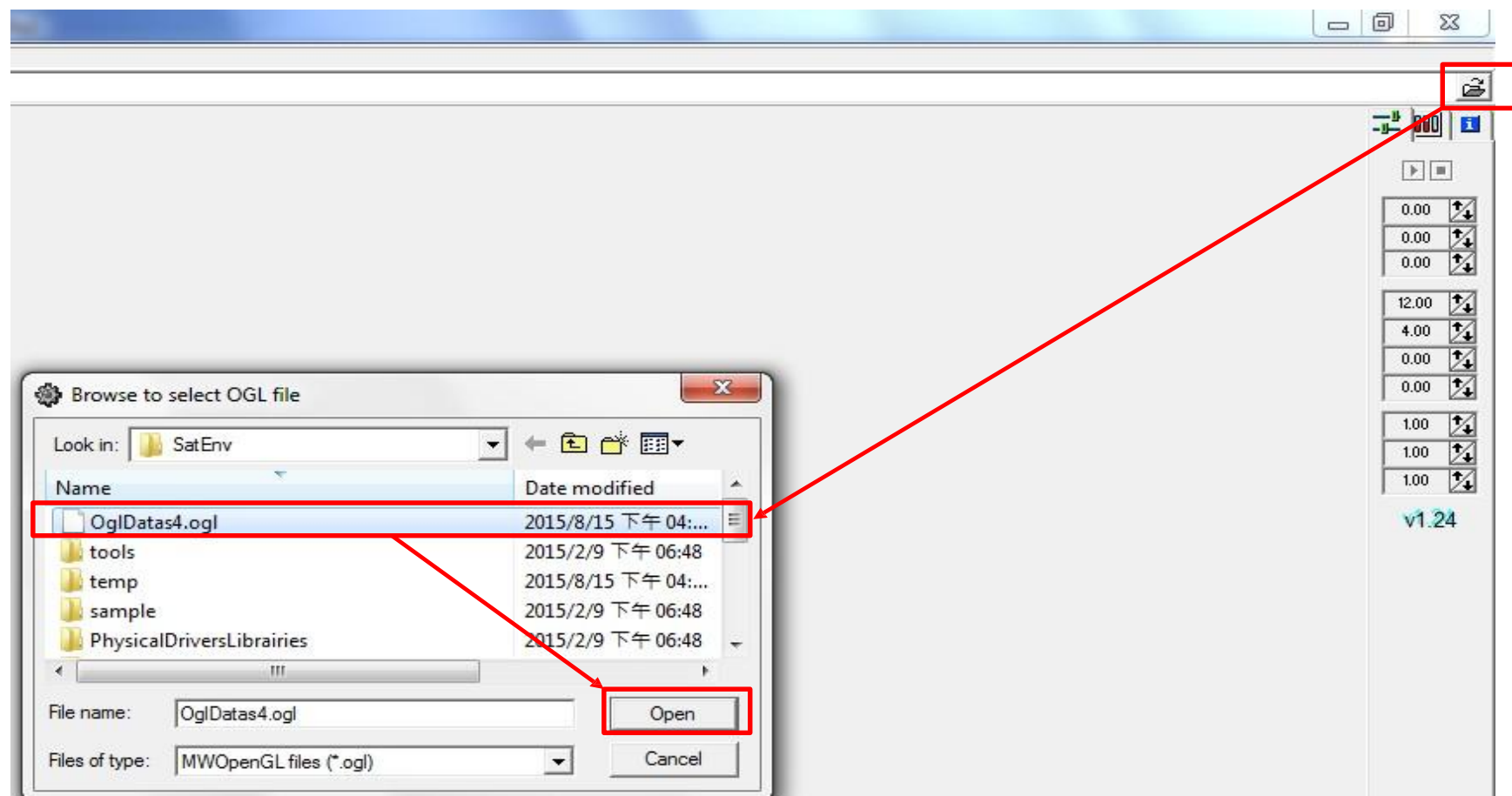
Number of layers: 33

- 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

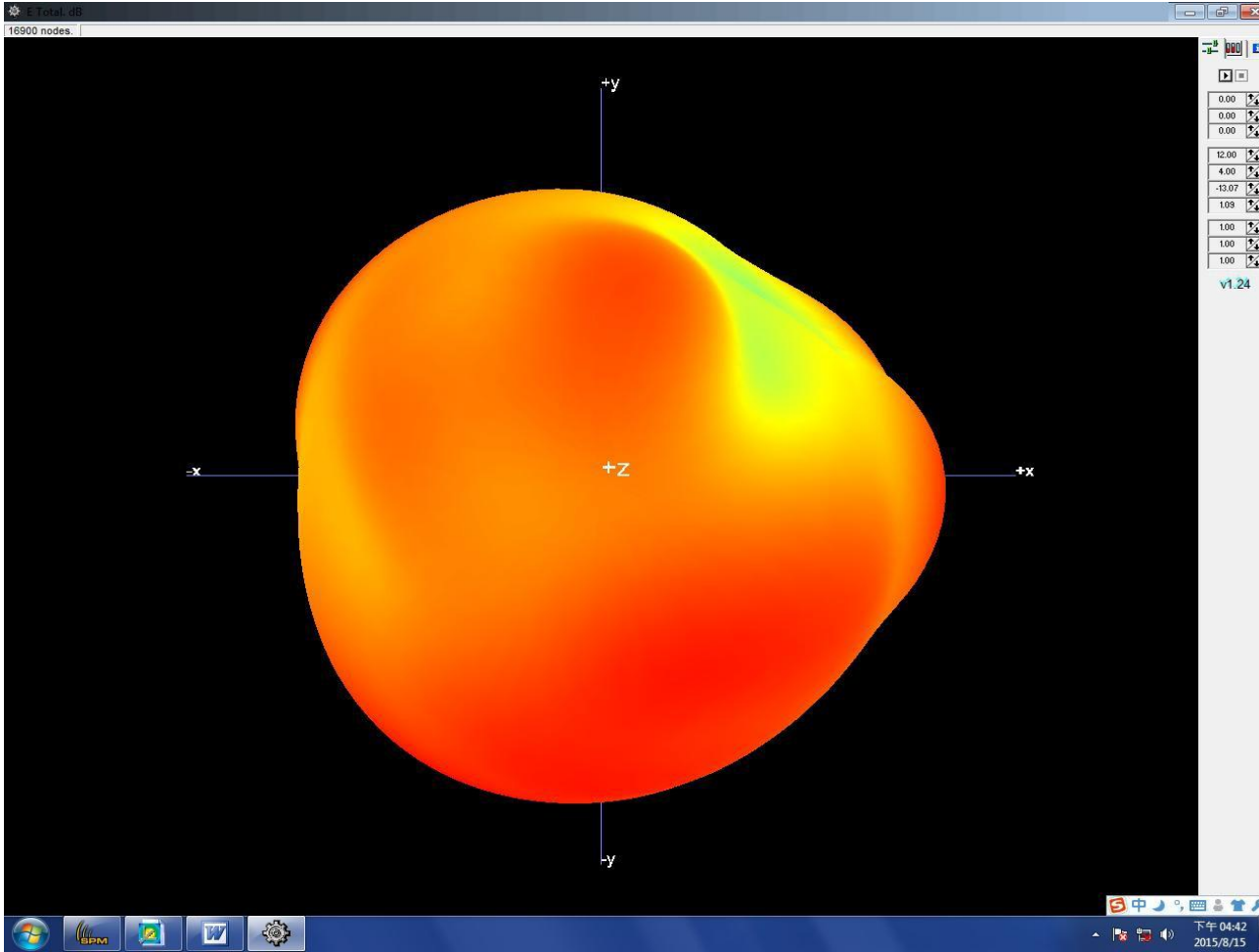
Layers configuration (Dialog Box):

- ☐ 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

2.3.5 Solving 3D field pattern



2.3.6 Get 3D field pattern



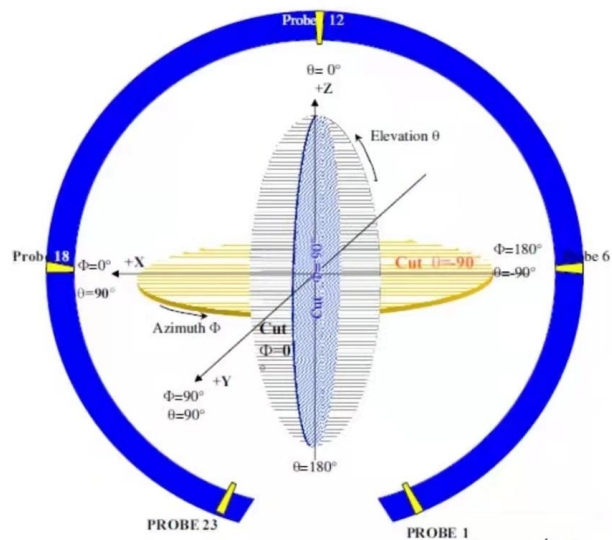
EE3300-00 Antenna real test report and directional gain calculation

OUTLINE

EE3300-00 Antenna Test Report

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

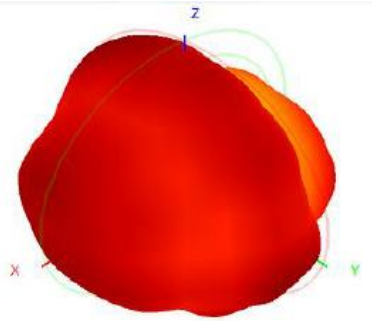
1.1.1 E-Total Gain Formula



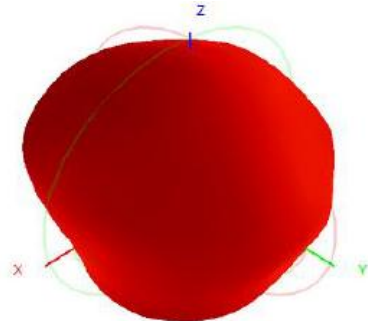
	Formula	Remarks
3D E-Total Gain	=MAX(Satimo darkroom data)	The maximum value in the original data of angle by angle for each frequency
2D XZ Plane Gain	=MAX(Satimo darkroom Phi=0 degree plane data)	Maximum value of Phi=0 degree plane for each frequency
2D YZ Plane Gain	=MAX(Satimo darkroom Phi=90 degree plane data)	Maximum value of Phi=90 degree plane for each frequency
2D XY Plane Gain	=MAX(Satimo darkroom Theta=90&Theta=-90 degree plane data)	Maximum value of Theta=90&Theta=-90 degree plane for each frequency

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

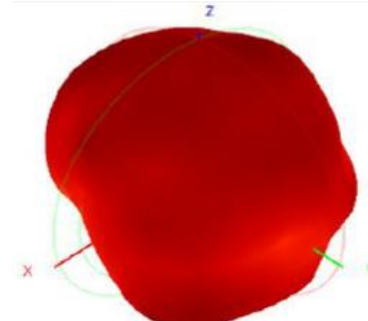
2.4G-1_2450MHz



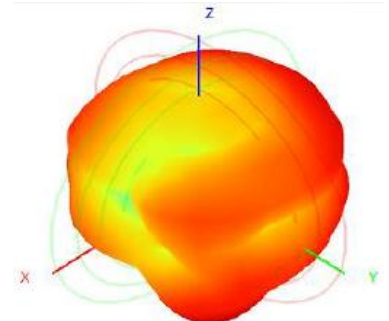
2.4G-2_2450MHz



2.4G-3_2450MHz

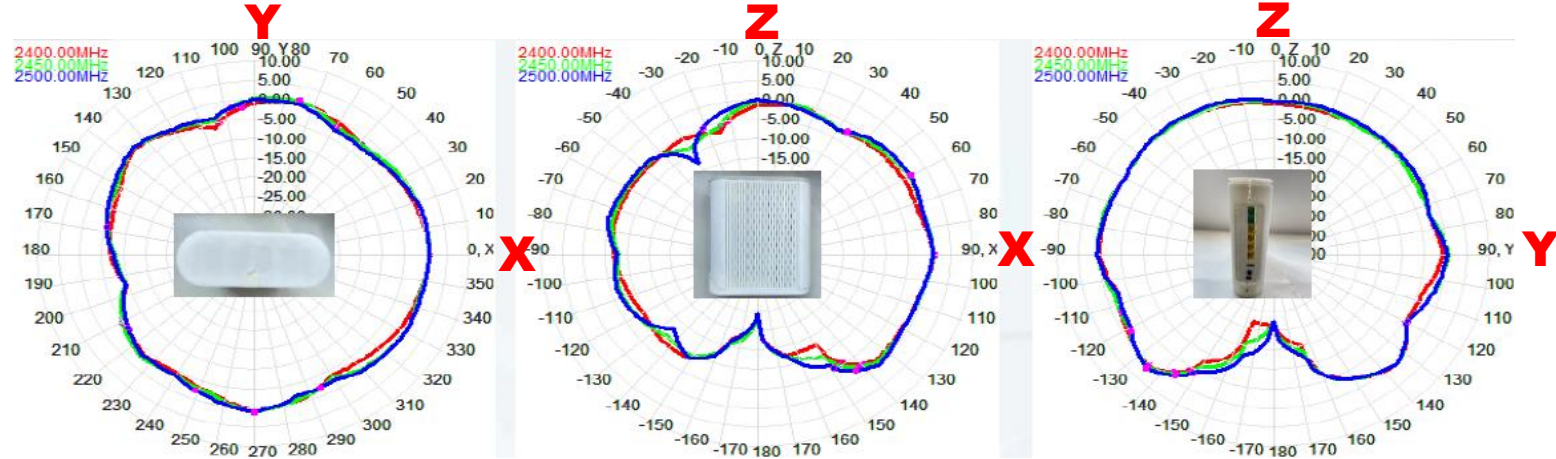


2.4G-4_2450MHz



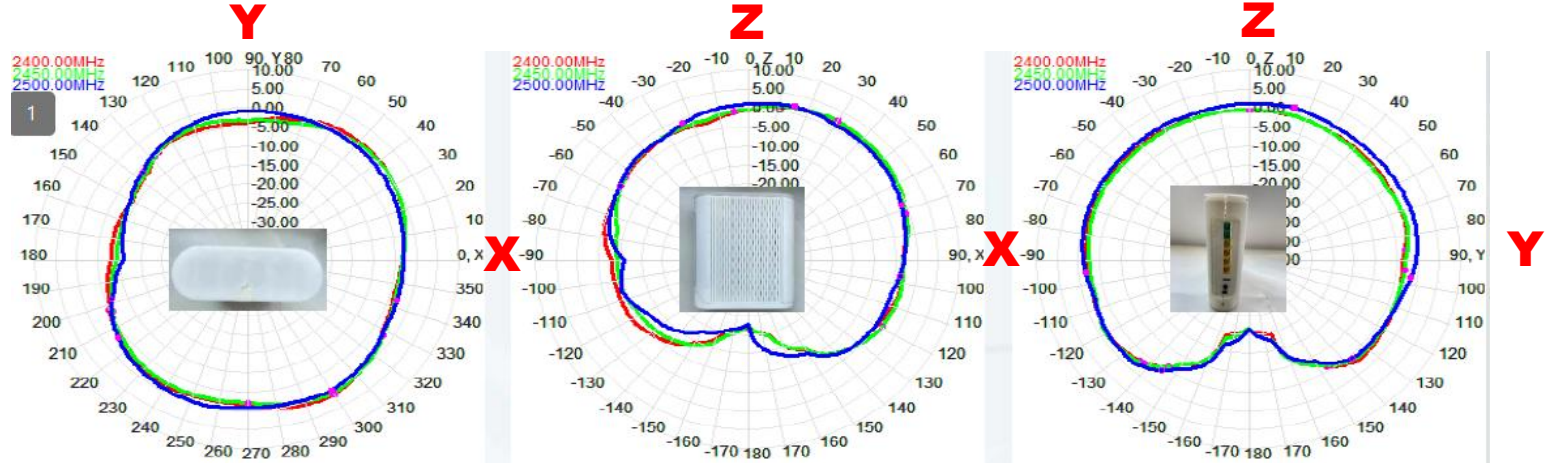
Frequency [MHz]	2.4G-1	2.4G-2	2.4G-3	2.4G-4
	E-total [dBi]	E-total [dBi]	E-total [dBi]	E-total [dBi]
2400	1.45	2.09	2.59	3.28
2450	1.48	2.19	1.67	4.04
2500	1.45	1.83	2.07	4.03

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



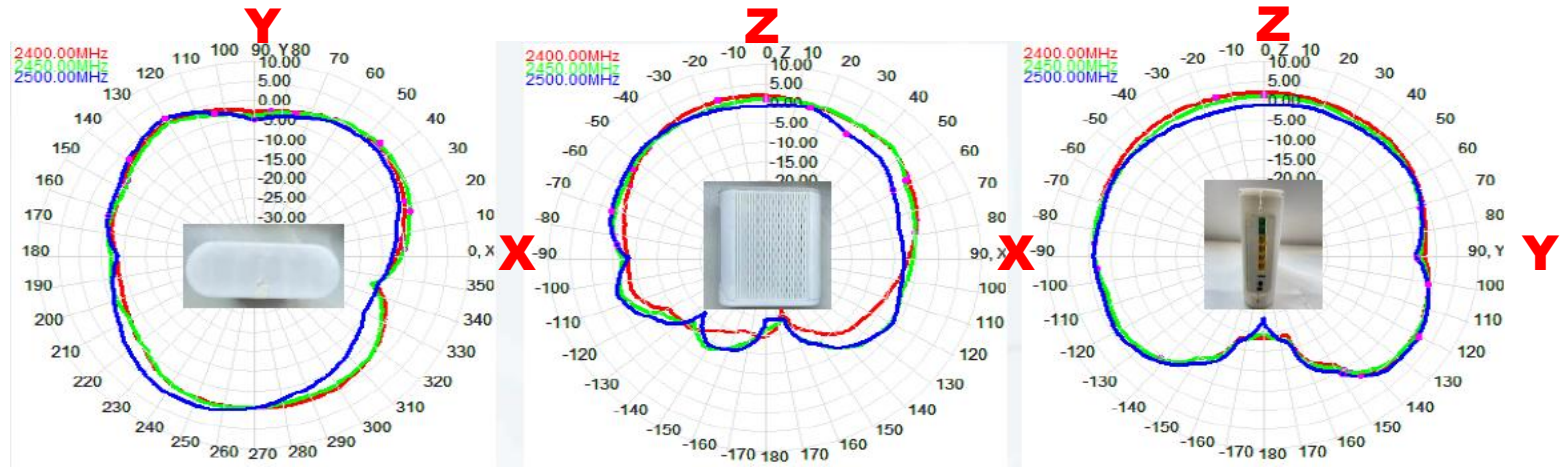
	XY plane	XZ plane	YZ plane
Frequency [MHz]	Gain(Max Value) [dBi]	Gain(Max Value) [dBi]	Gain(Max Value) [dBi]
2400	0.62	0.75	0.87
2450	0.50	1.11	1.02
2500	0.77	1.33	0.59

1.1.4 2D Radiation Patterns---2.4G-2



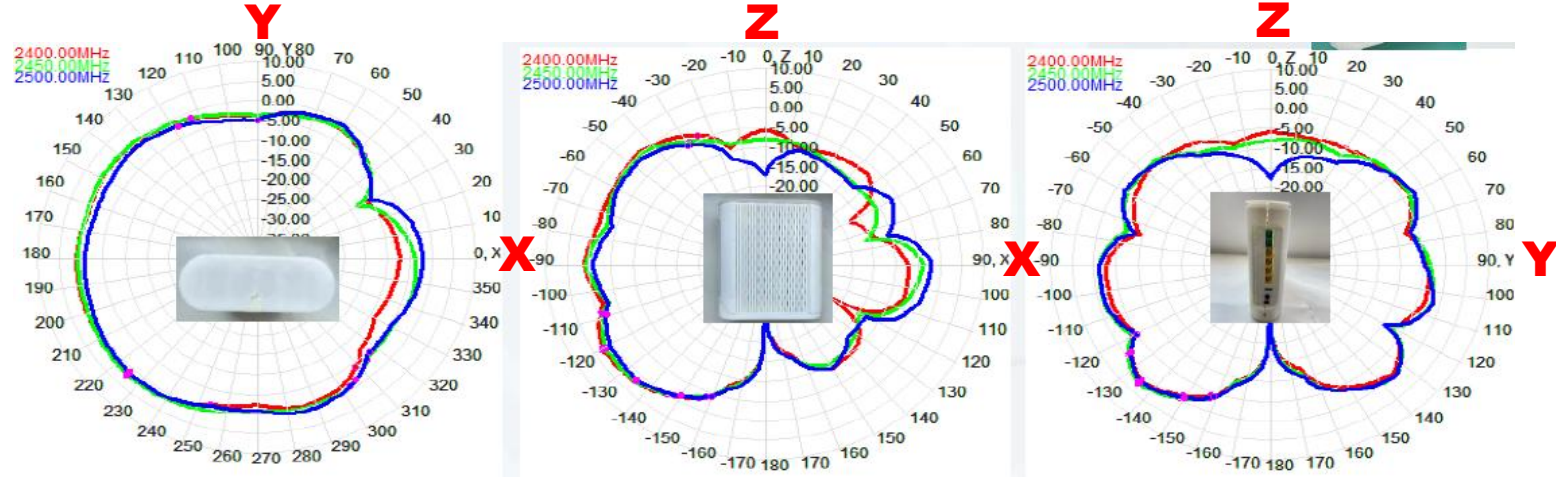
	XZ plane	YZ plane	XY plane
Frequency [MHz]	Gain(Max Value) [dBi]	Gain(Max Value) [dBi]	Gain(Max Value) [dBi]
2400	1.86	-0.24	0.91
2450	2.18	-0.41	0.47
2500	1.83	1.38	-0.37

1.1.5 2D Radiation Patterns---2.4G-3



	XZ plane	YZ plane	XY plane
Frequency [MHz]	Gain(Max Value) [dBi]	Gain(Max Value) [dBi]	Gain(Max Value) [dBi]
2400	2.11	2.08	0.48
2450	1.19	1.21	0.91
2500	0.22	1.35	0.91

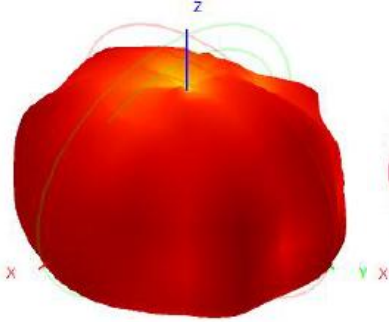
1.1.6 2D Radiation Patterns---2.4G-4



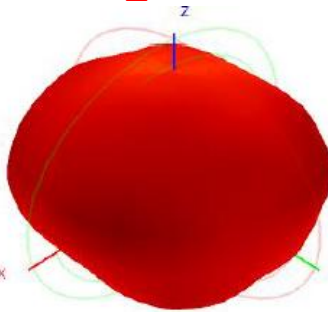
	XZ plane	YZ plane	XY plane
Frequency [MHz]	Gain(Max Value) [dBi]	Gain(Max Value) [dBi]	Gain(Max Value) [dBi]
2400	2.60	1.51	1.64
2450	1.91	2.47	1.71
2500	1.29	1.80	1.08

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

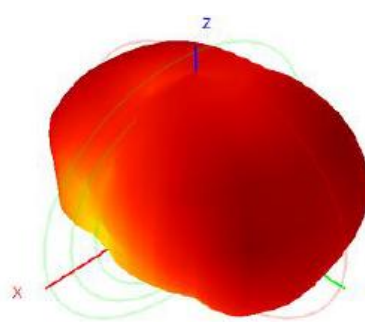
5G-1_5500MHz



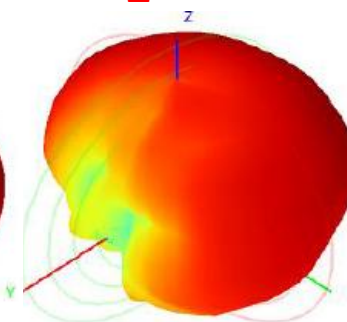
5G-2_5500MHz



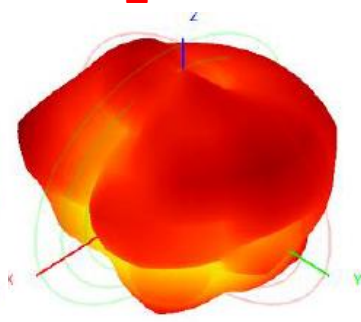
5G-3_5500MHz



5G-4_5500MHz

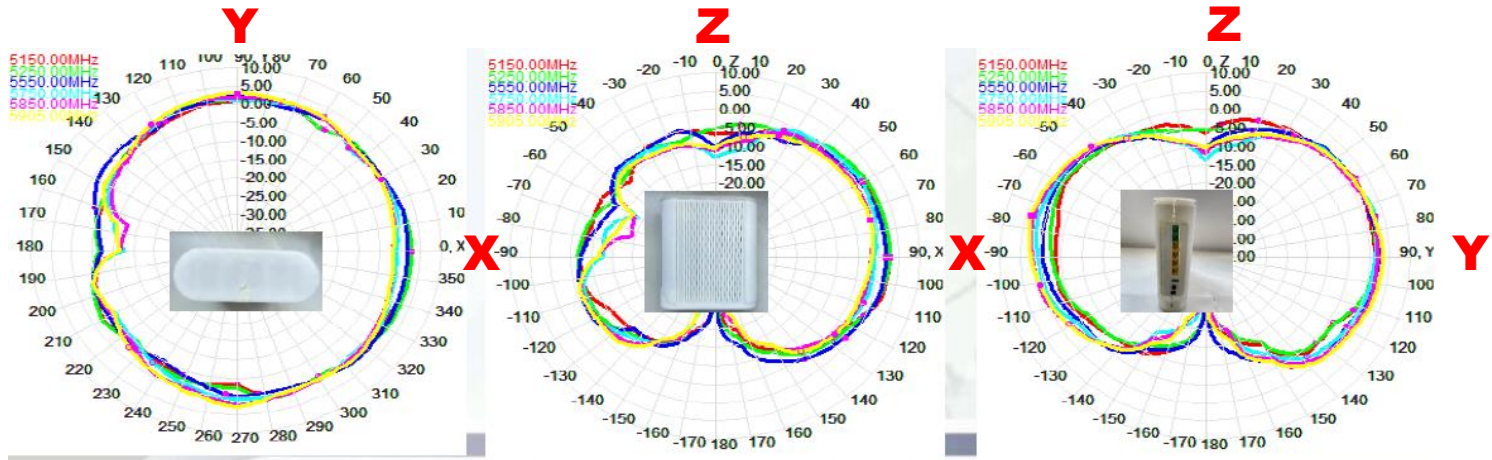


5G-5_5500MHz



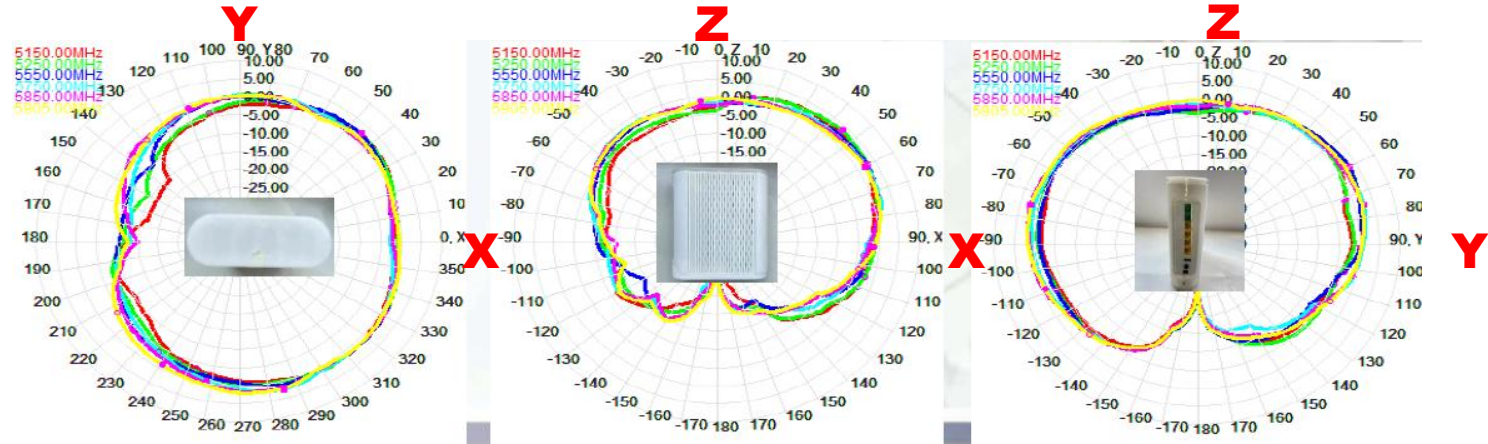
Frequency [MHz]	5G-1	5G-2	5G-3	5G-4	5G-5
	E-total [dBi]	E-total [dBi]	E-total [dBi]	E-total [dBi]	E-total [dBi]
5150	2.26	4.65	4.02	2.70	0.93
5250	2.47	4.39	4.49	3.84	0.99
5550	2.13	4.06	3.68	3.80	2.12
5750	3.39	3.83	3.76	2.88	1.01
5850	3.25	3.11	3.92	1.96	1.00
5905	3.78	3.21	4.09	1.59	1.66

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



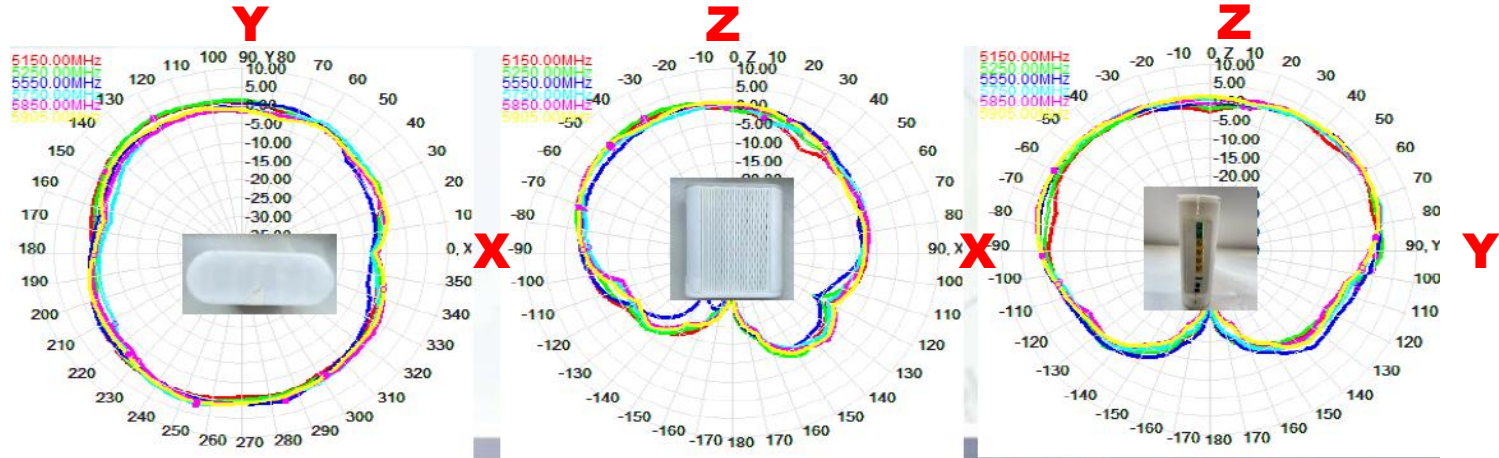
	XZ plane	YZ plane	XY plane
Frequency [MHz]	Gain(Max Value) [dBi]	Gain(Max Value) [dBi]	Gain(Max Value) [dBi]
5150	1.96	2.25	2.20
5250	2.42	1.45	2.47
5550	1.44	1.99	2.12
5750	1.04	2.61	2.44
5850	-0.86	3.24	2.19
5905	-0.98	3.78	3.-05

1.1.9 2D Radiation Patterns---5G-2



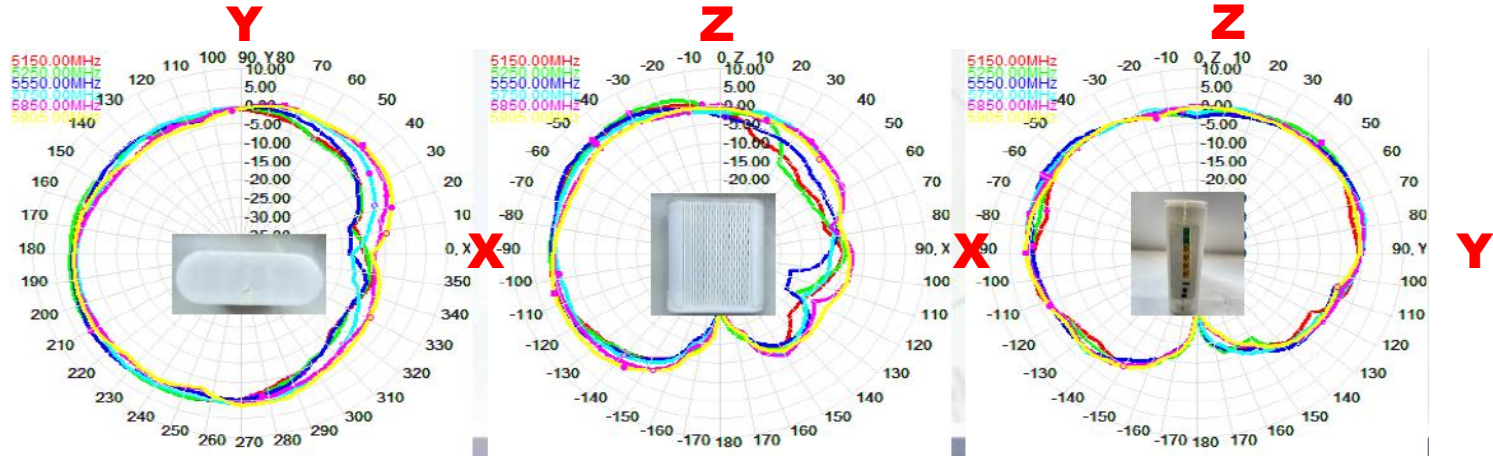
	XZ plane	YZ plane	XY plane
Frequency [MHz]	Gain(Max Value) [dBi]	Gain(Max Value) [dBi]	Gain(Max Value) [dBi]
5150	2.57	1.14	2.35
5250	3.51	1.47	2.29
5550	2.68	3.01	2.27
5750	2.28	2.18	2.14
5850	1.96	2.49	1.62
5905	1.83	2.19	1.85

1.1.10 2D Radiation Patterns---5G-3



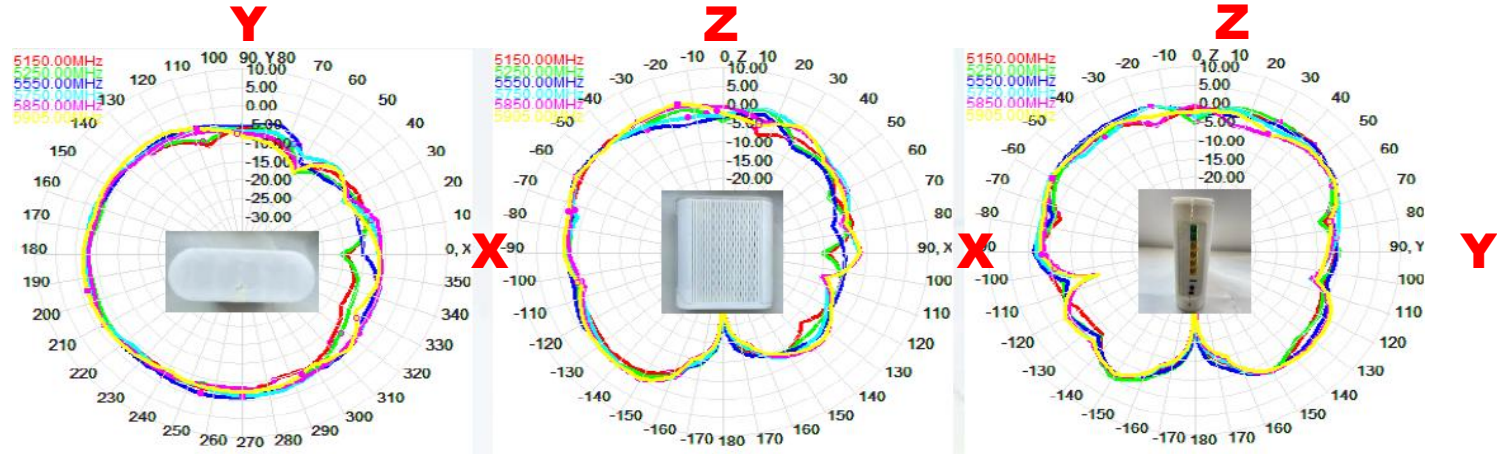
	XZ plane	YZ plane	XY plane
Frequency [MHz]	Gain(Max Value) [dBi]	Gain(Max Value) [dBi]	Gain(Max Value) [dBi]
5150	1.71	2.61	1.96
5250	2.26	2.45	2.24
5550	0.31	2.97	1.09
5750	0.45	3.02	2.00
5850	1.32	2.95	1.03
5905	1.54	2.98	1.54

1.1.11 2D Radiation Patterns---5G-4



	XZ plane	YZ plane	XY plane
Frequency [MHz]	Gain(Max Value) [dBi]	Gain(Max Value) [dBi]	Gain(Max Value) [dBi]
5150	2.64	0.65	1.54
5250	3.67	2.37	1.56
5550	3.14	2.44	1.49
5750	1.89	1.76	0.87
5850	0.38	1.34	1.45
5905	1.15	0.93	1.59

1.1.12 2D Radiation Patterns---5G-5



	XZ plane	YZ plane	XY plane
Frequency [MHz]	Gain(Max Value) [dBi]	Gain(Max Value) [dBi]	Gain(Max Value) [dBi]
5150	0.59	0.62	-2.01
5250	0.97	0.58	-2.04
5550	0.91	0.56	-1.06
5750	0.49	0.57	-1.64
5850	0.66	-0.35	-1.63
5905	1.65	-0.28	-1.43

1.2.1 Directional Gain for Correlated and Uncorrelated Formula

	Formula	Remarks
Correlated Gain	Correlated Directional gain angle by $\text{angle} = 10 \cdot \log_{10}(((10^{G1/20}) + 10^{(G2/20)} + 10^{(G3/20)} + 10^{(G4/20)})^2 / 4)$ Correlated peak gain = MAX(XX:XX)	1. Calculate the correlated gain angle by angle through the formula for each frequency 2. Use MAX to get the maximum value for each frequency
Uncorrelated Gain	Uncorrelated Directional gain angle by $\text{angle} = 10 \cdot \log_{10}((10^{G1/10}) + 10^{(G2/10)} + 10^{(G3/10)} + 10^{(G4/10)}) / 4)$ Uncorrelated peak gain = MAX(XX:XX)	1. Calculate the uncorrelated gain angle by angle through the formula for each frequency 2. Use MAX to get the maximum value for each frequency

1.2.2 Directional Gain for Correlated and Uncorrelated Table

Peak Gain of 3D Directional pattern		
Frequency (MHz)	Correlated	Uncorrelated
2400	6.13	0.33
2450	5.99	0.56
2500	6.29	0.68
5150	8.11	1.32
5250	8.43	1.76
5550	8.71	1.83
5750	8.66	1.81
5850	8.63	1.84
5905	8.62	1.82

1.3 Antenna Info

Antenna Info		
Model Number	Dimension	Manufacture
C1597-510769-A	150*34.5*1.0mm	Dongguan Aeon Tech. Co., Ltd. (Address: No. 7, Dalingshan Lake Road, Dalingshan Town, Dongguan City, Guangdong Province)

