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

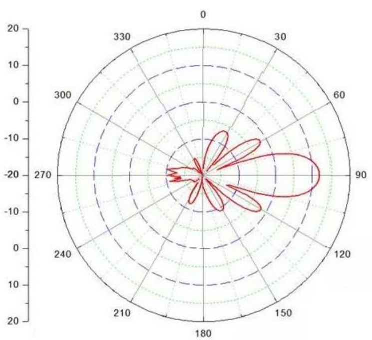
Directional gain = $10 \log[(10^{G1/20} + 10^{G2/20} + \ldots + 10^{GN/20})^2 / N_{ANT}]$ dBi [Note the "20"s in the denominator of each exponent and the square of the sum of terms; the object is to combine the signal levels coherently.]

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

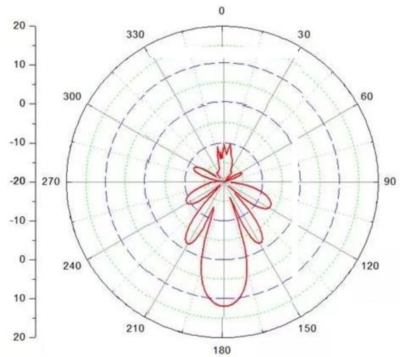
Directional gain = $10 \log[(10^{G1/10} + 10^{G2/10} + \ldots + 10^{GN/10})/N_{ANT}]$ dBi

Based on FCC KDB 662911 Calculation formula of directional gain analyze

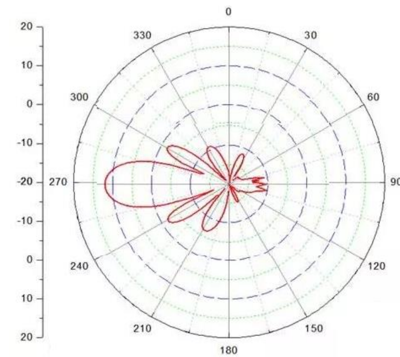
Antenna pattern example:



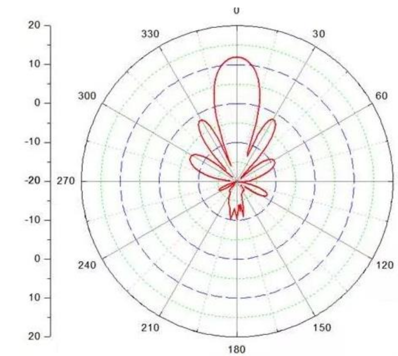
ANT0=3dBi



ANT1=-5dBi



ANT1=-3dBi



ANT1=-7dBi

X axis

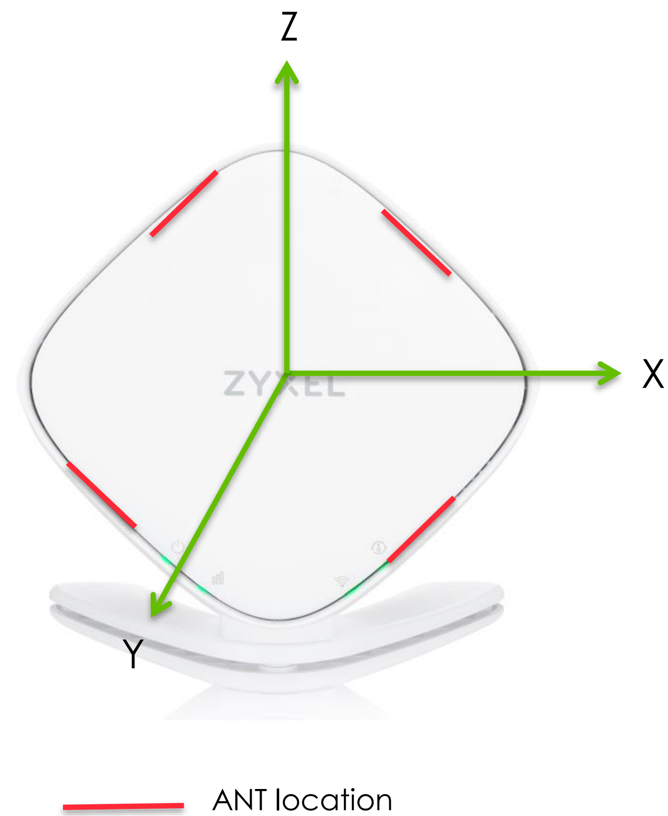
Based on above antenna pattern. The real Antennas gain is reasonable to calculate by each direction. It's the same with MIMO real operation mode. But not calculate with peak gain in different angle.

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*LOG((10^(3/20)+10^(-5/20)+10^(-3/20)+10^(-7/20))^2/4)=3.9dBi

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

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

SATIMO Microwave Anechoic Chamber environment introduction

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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

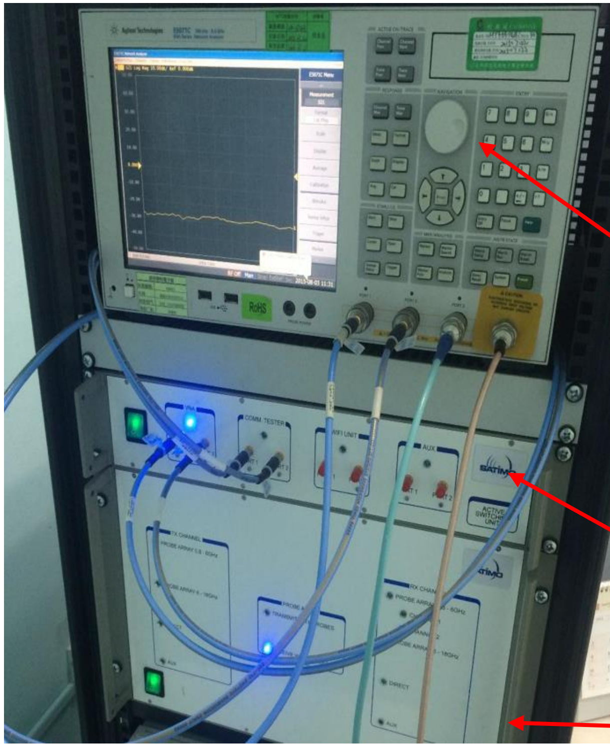
3.1 Place the sample to be tested

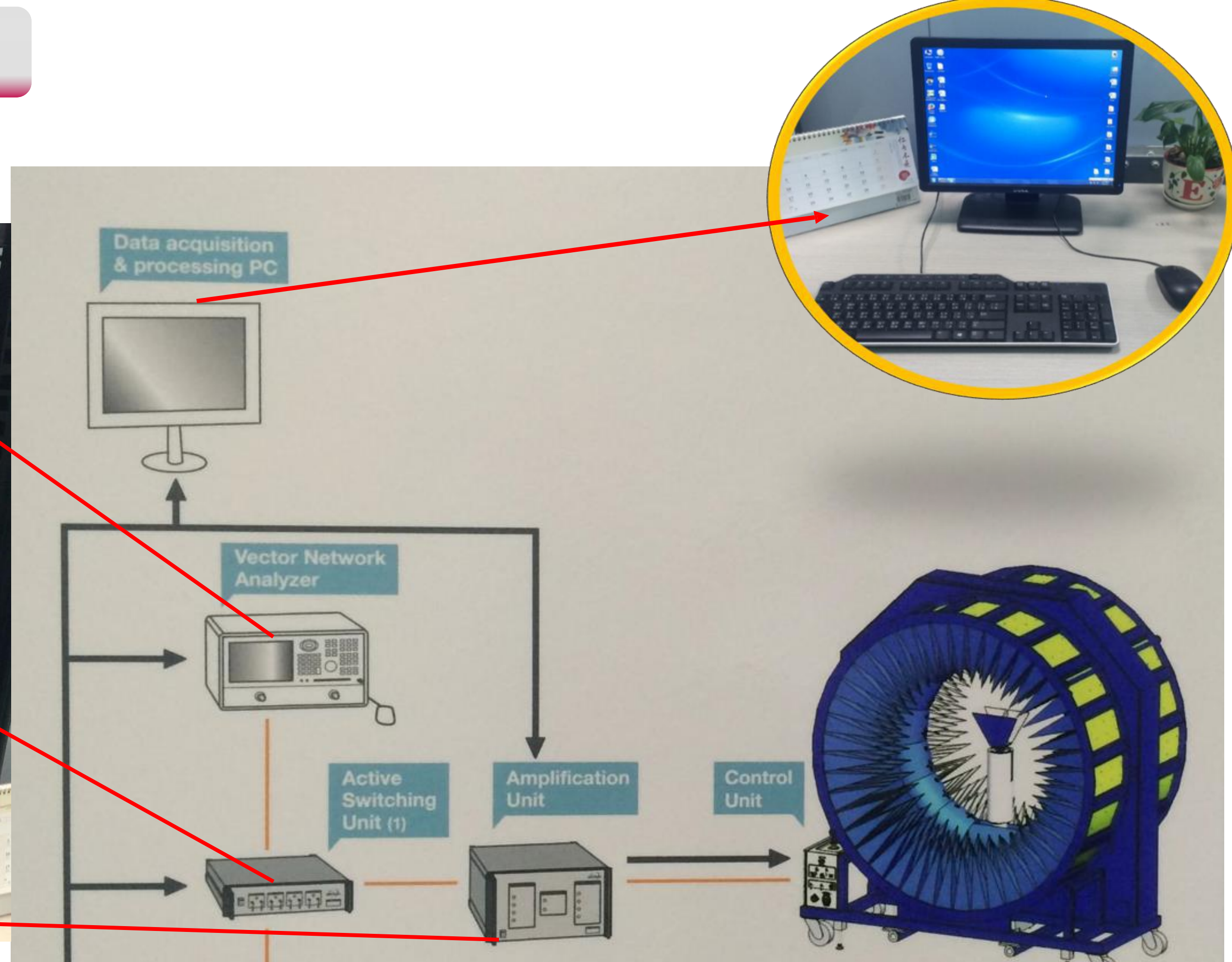
3.2 Reset network instrument

3.3 Measure and process data

1、 Instrument introduction

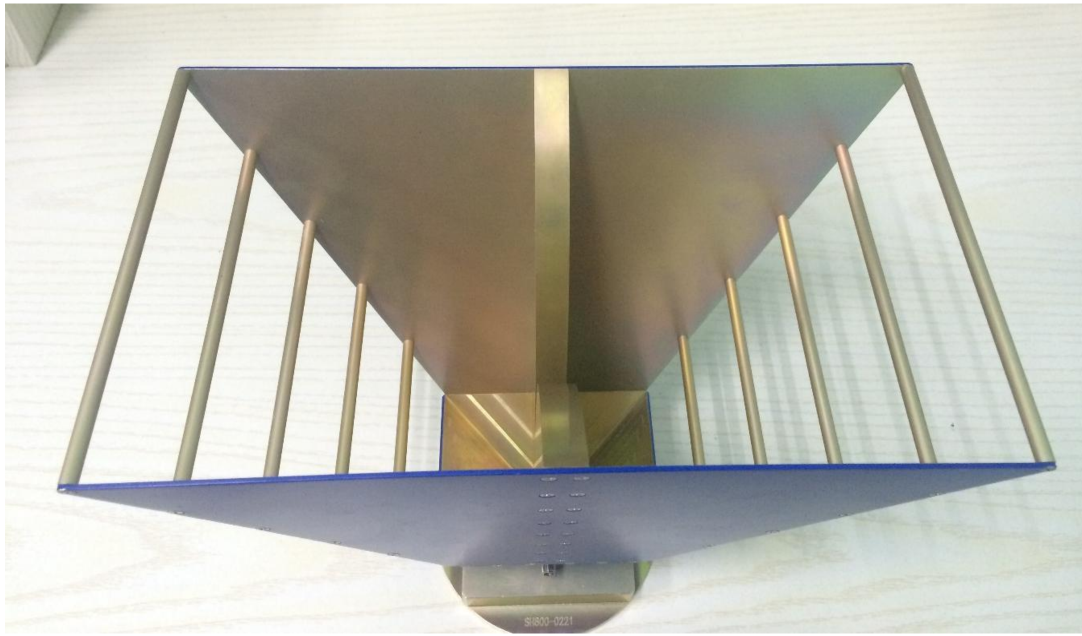
1.1 SATIMO Overview






Entity diagram
天线微波暗室
mvc

1.2 Calibration antenna-Horn antenna

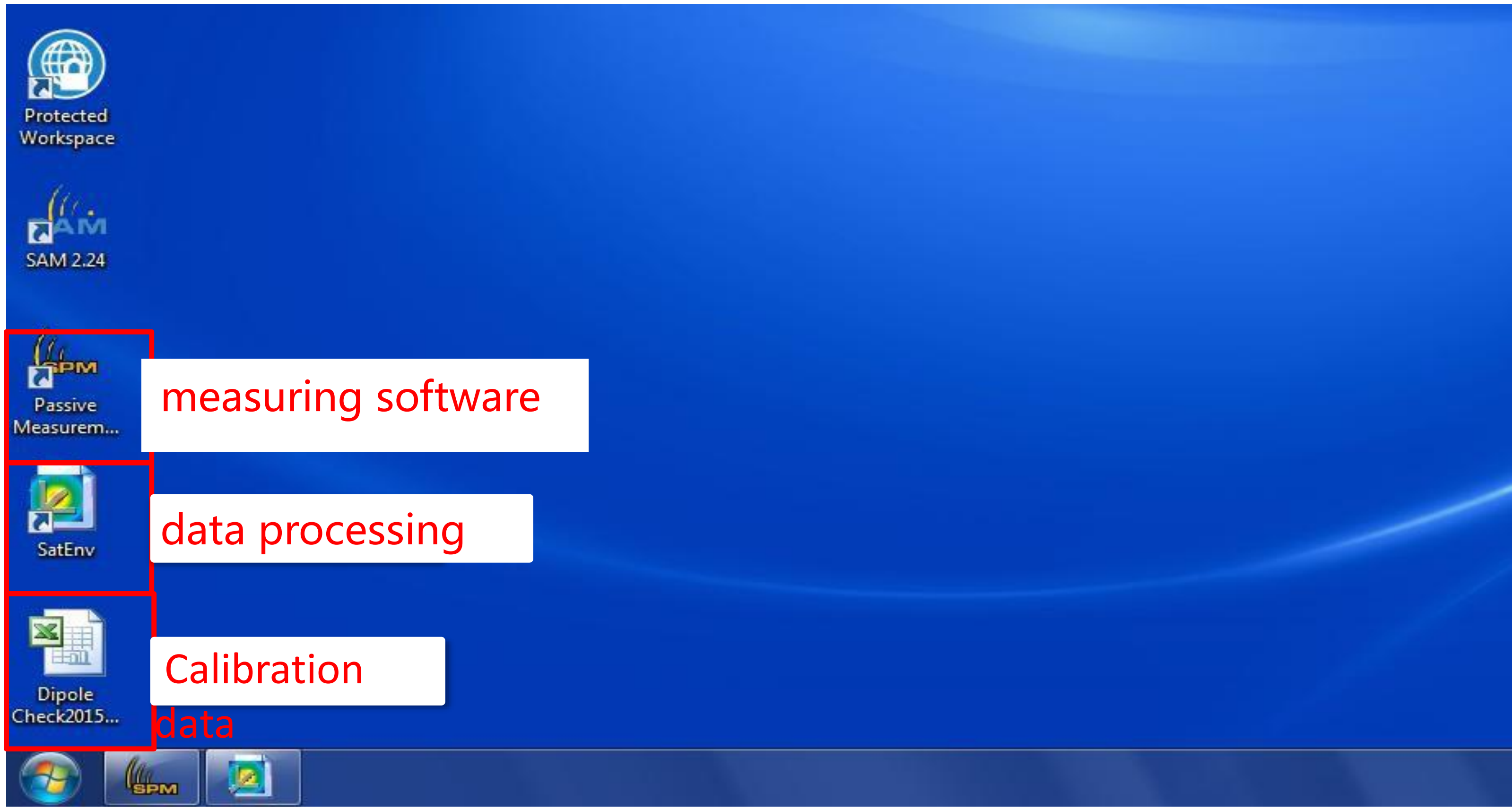


Horn antenna

1.2 Calibration antenna-Dipole antenna

Dipole antenna

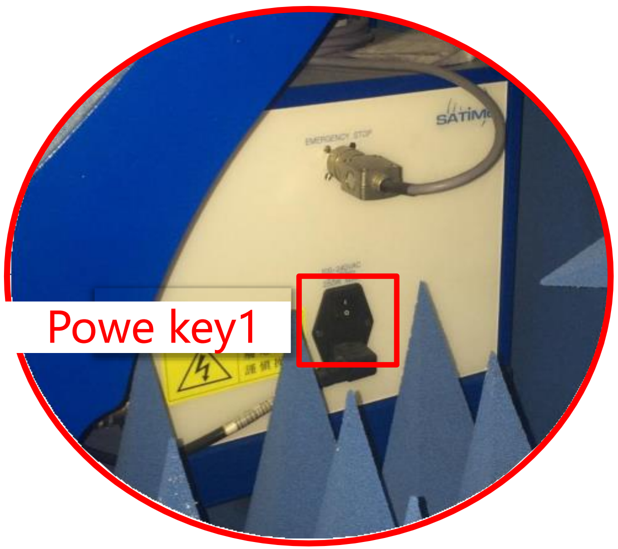
1.3 Software


Protected Workspace
SAM 2.24
Passive Measurem...
measuring software
SatEnv
data processing
Dipole Check2015...
Calibration
data

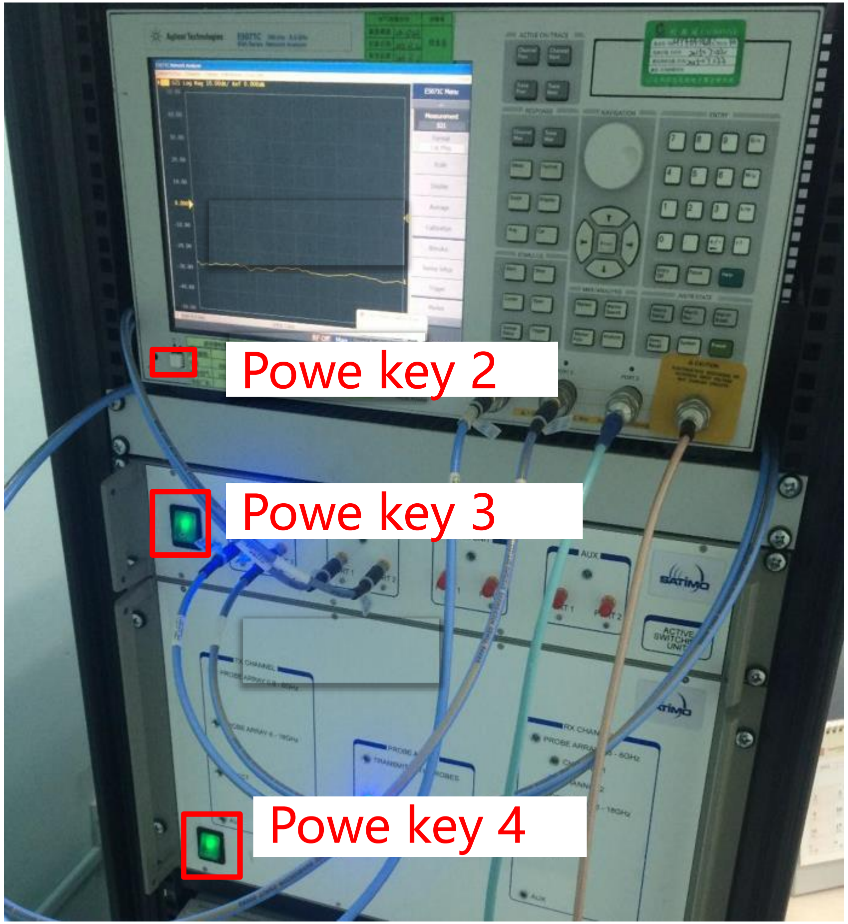
2、 Calibration

2.1.1 Open Power

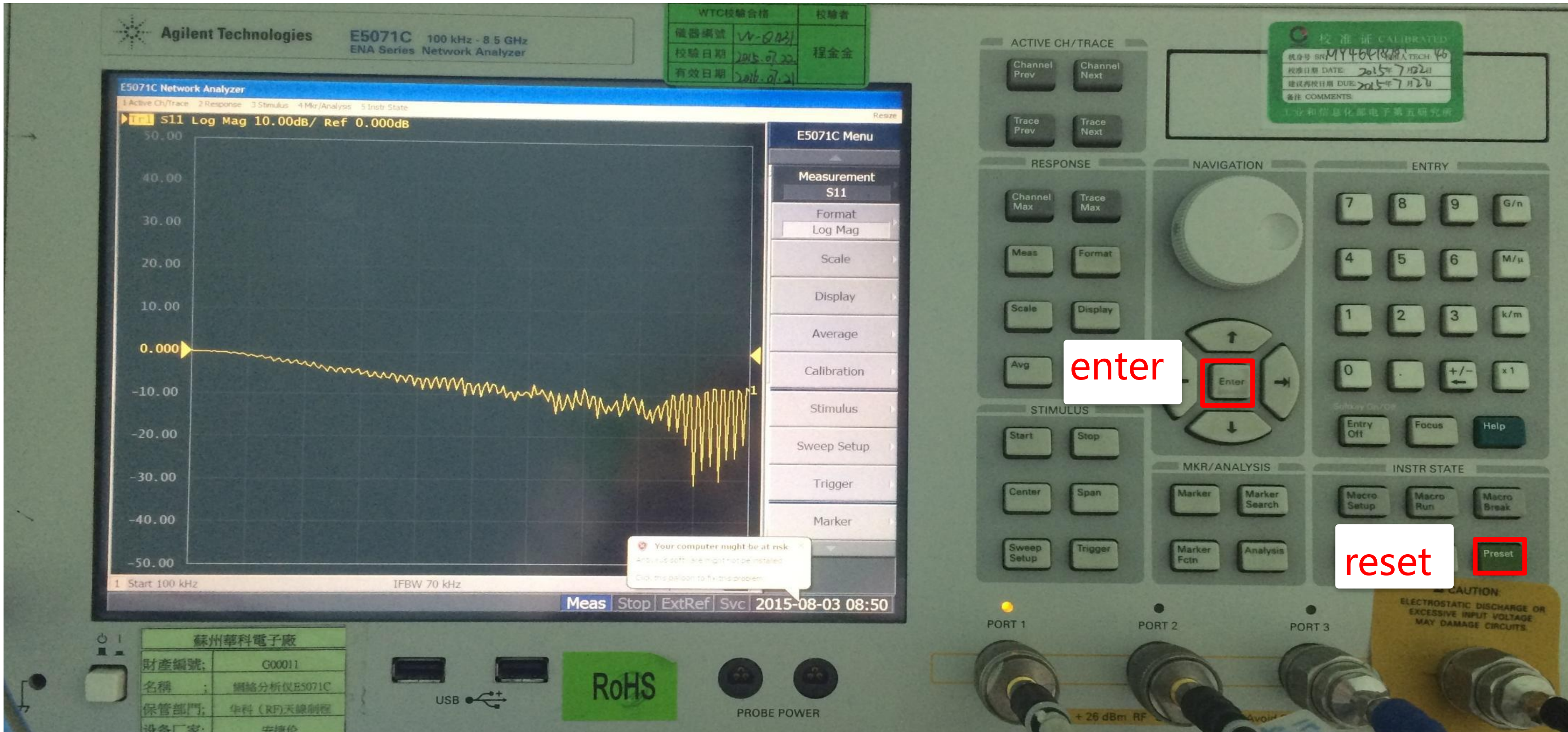
Turn on the power in turn 1、2、3、4、5



2.1.1 Open Power

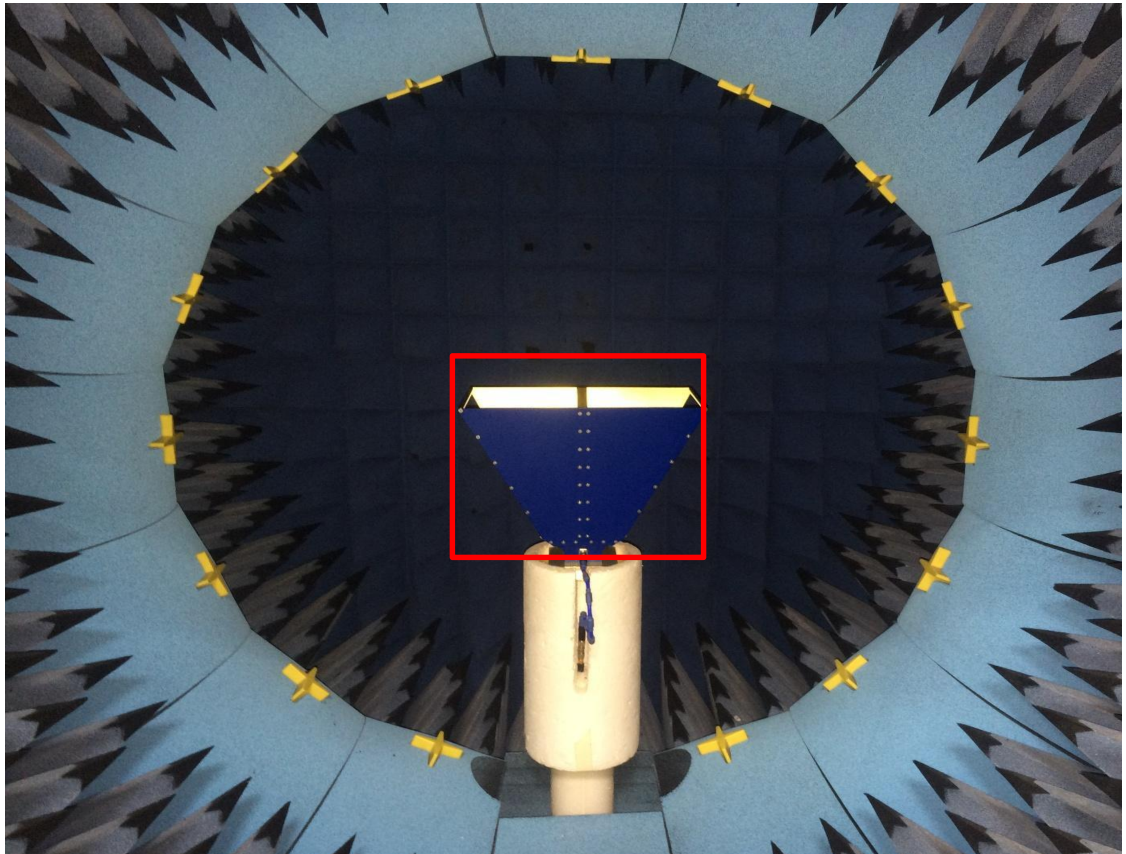


2.1.2 Reset network analyzer

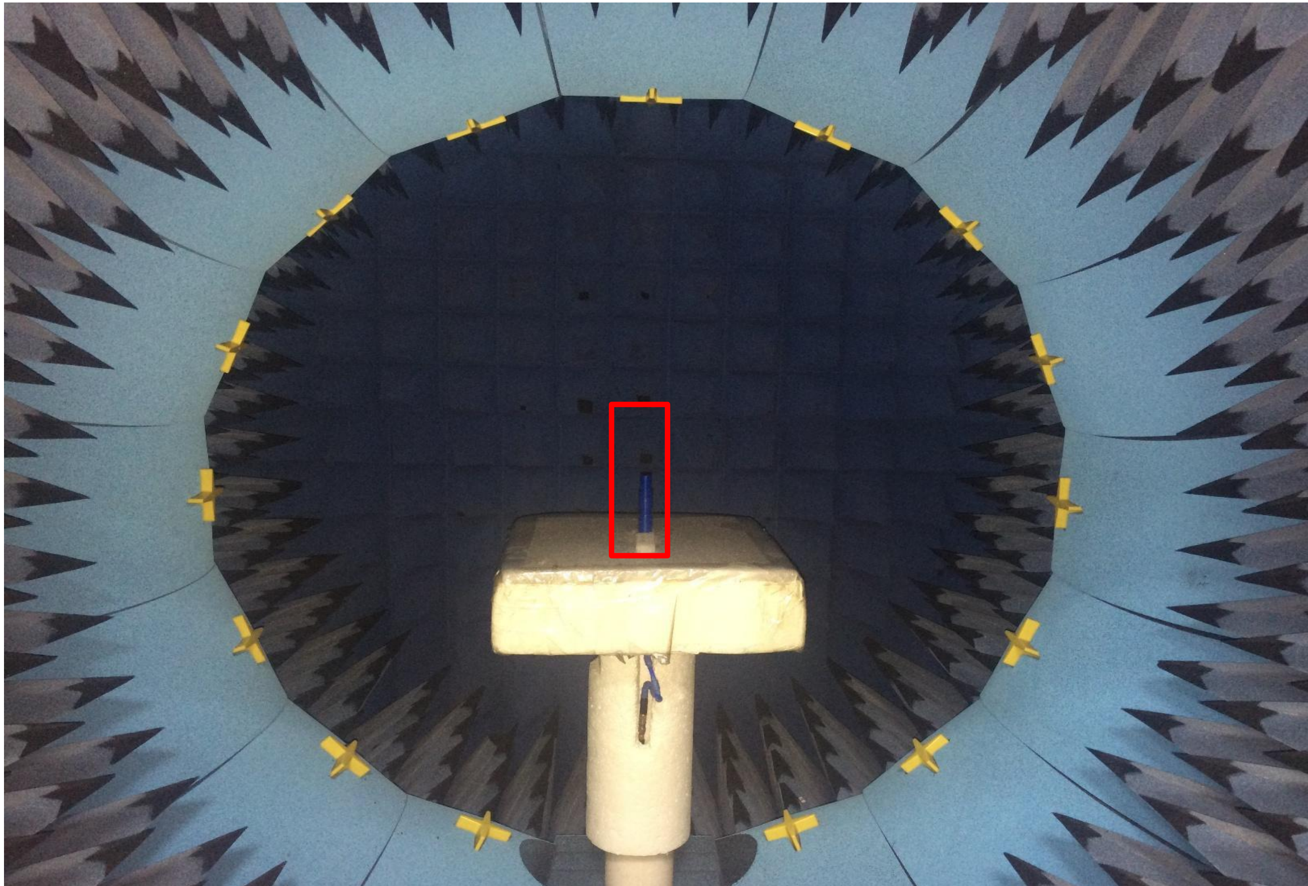


2.2 Calibration

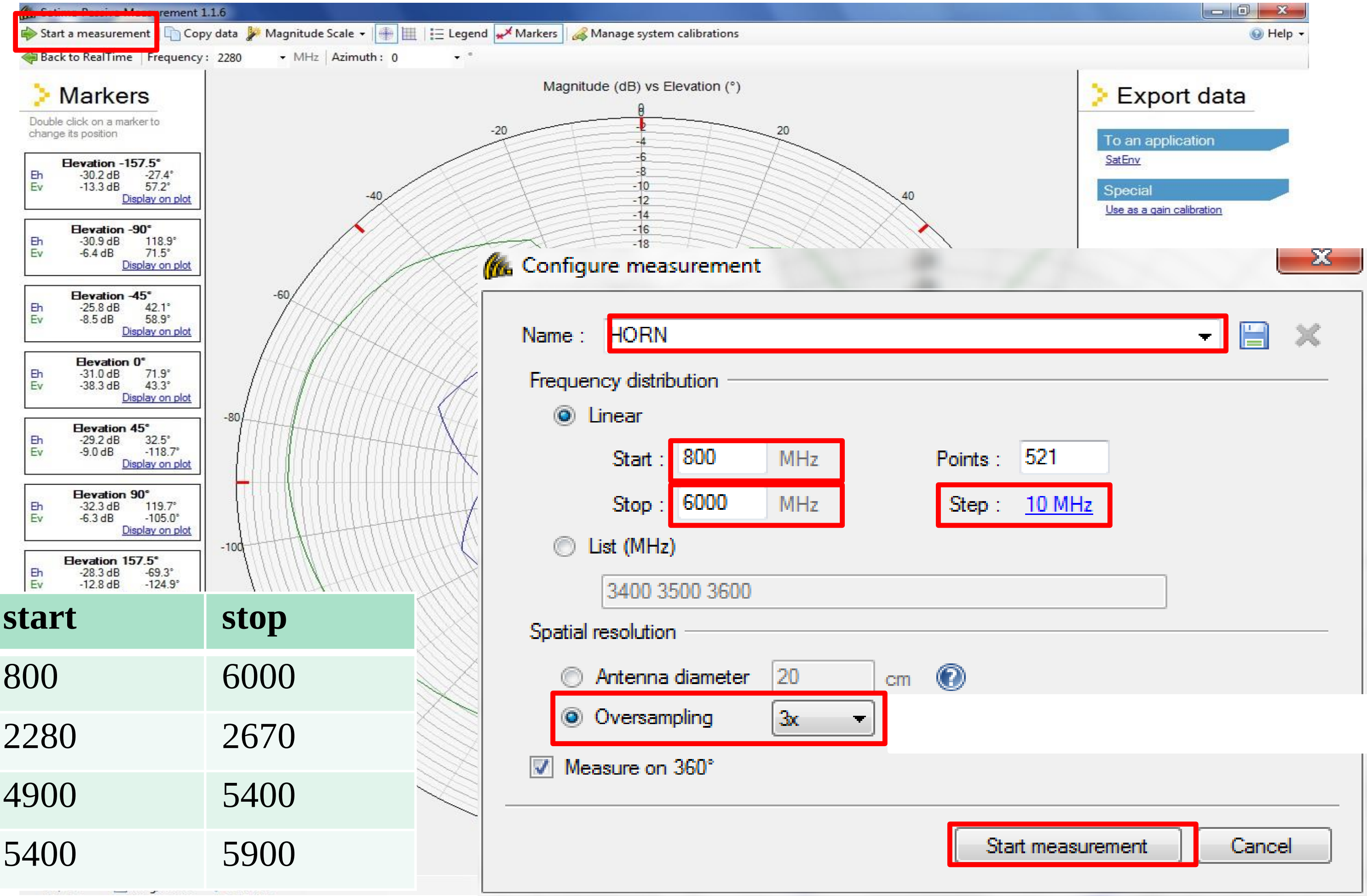
2.2.1. Horn antenna schematic diagram of placement position



2.2.2 Dipole antenna schematic diagram of placement position：

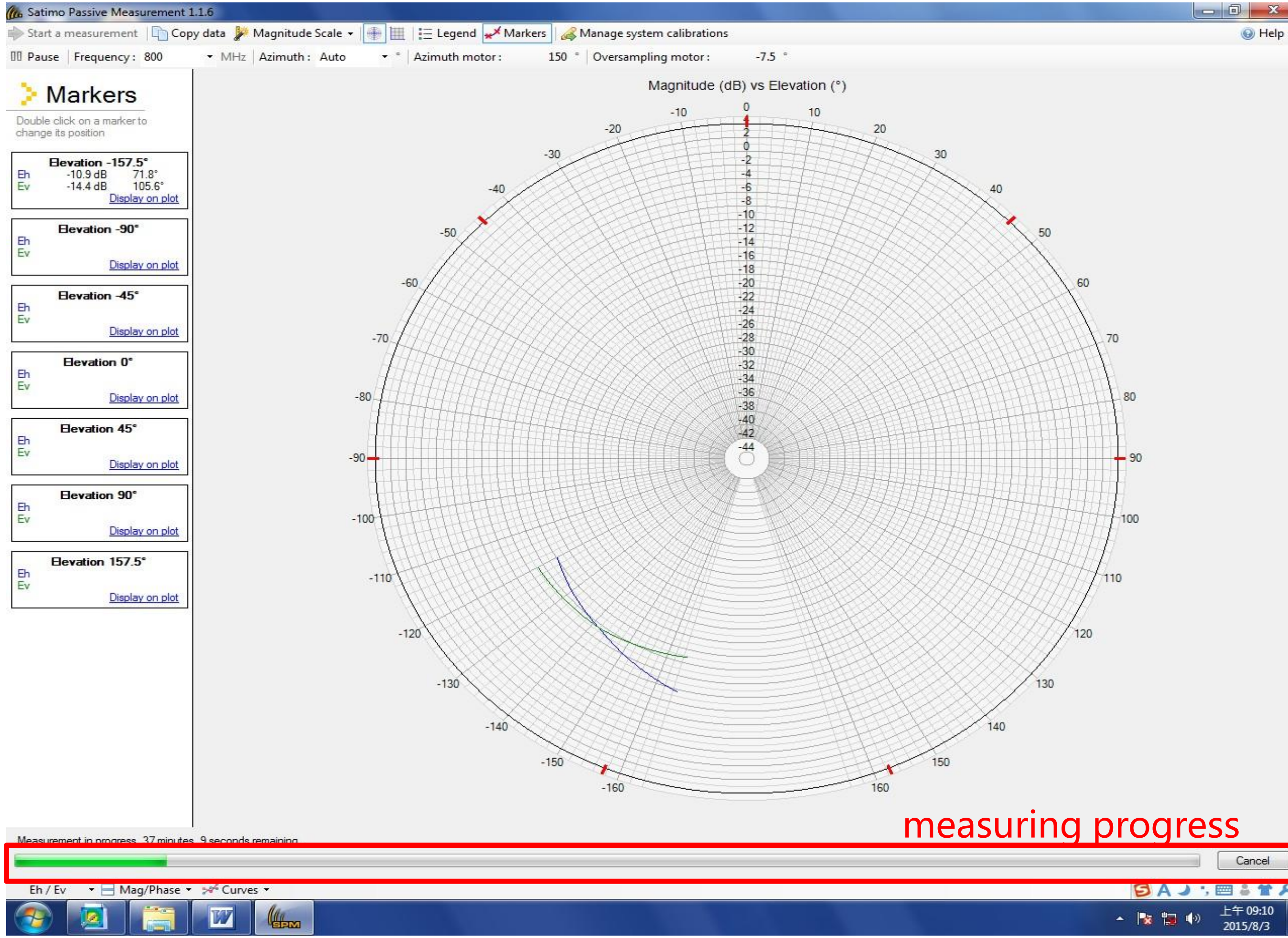


2.2.3 Open the measurement software, set parameters and start measurement

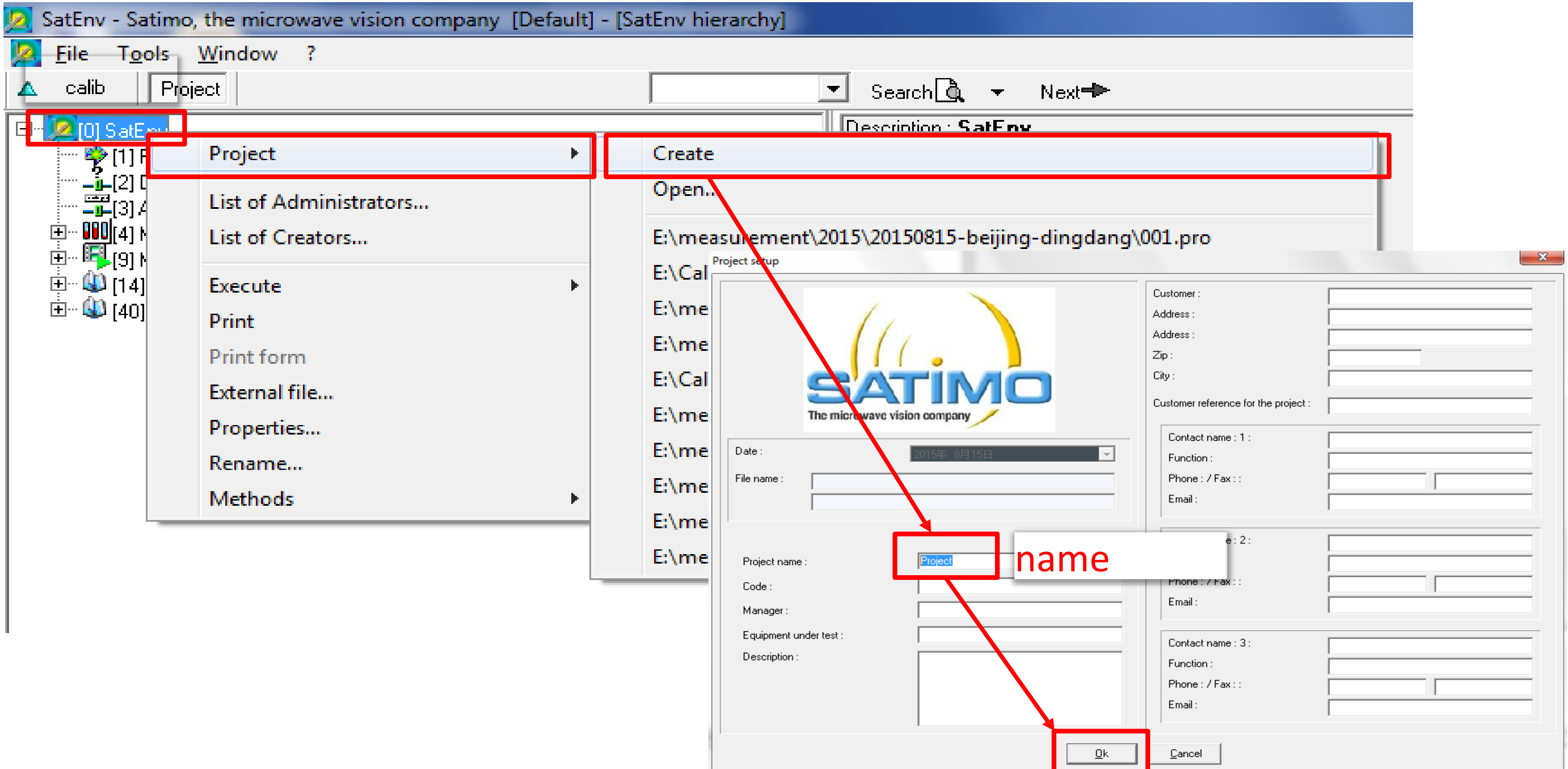


type	start	stop
Horn	800	6000
Dipple2450	2280	2670
Dipple5150	4900	5400
Dipple5650	5400	5900

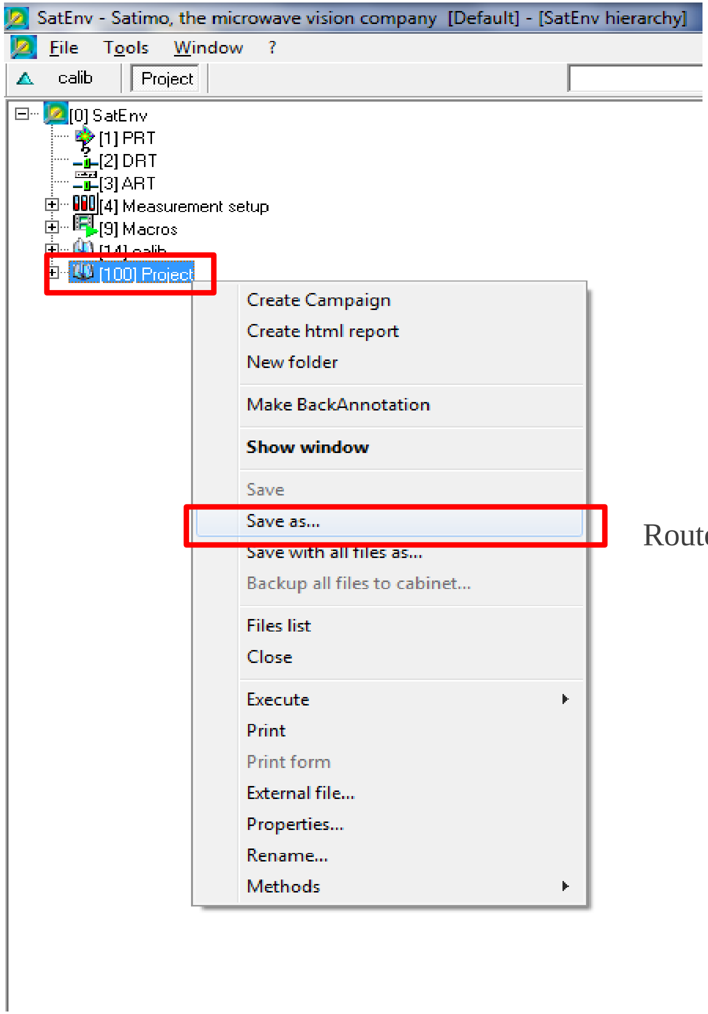
Measuring processing



2.2.4 Open data processing software to create project

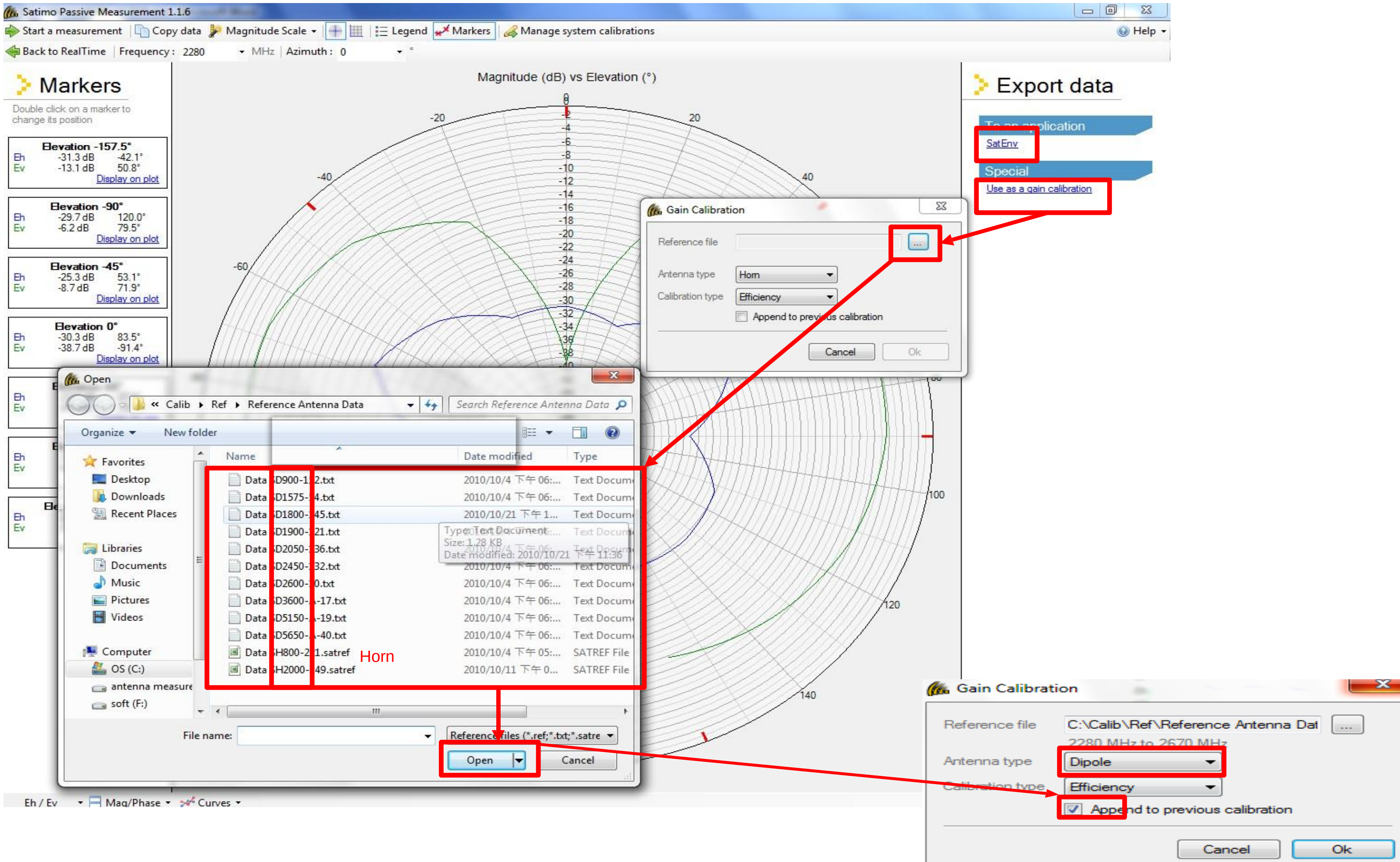


2.2.5 Save Route

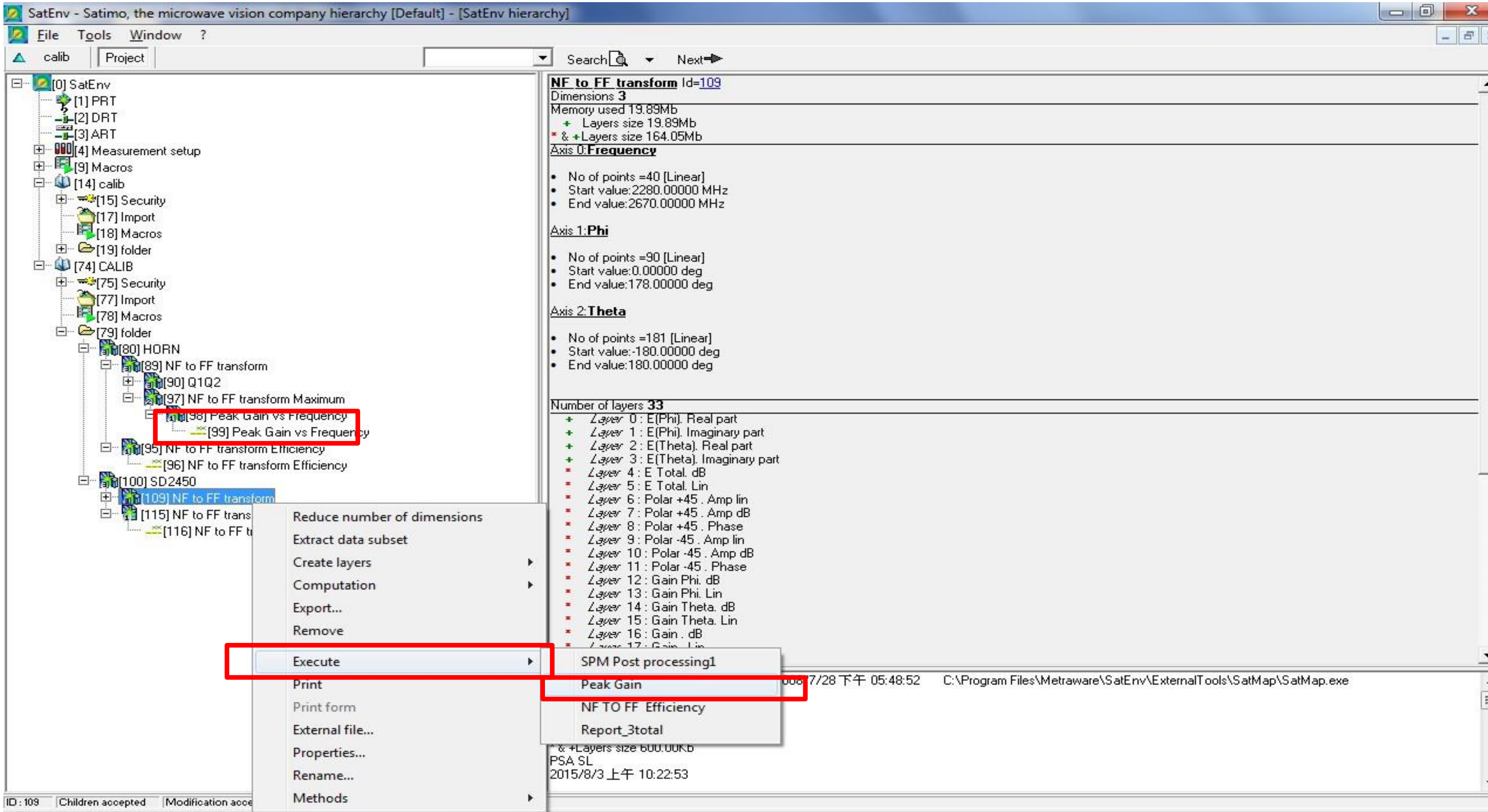


Route E:\Calib\2015\passive calibration

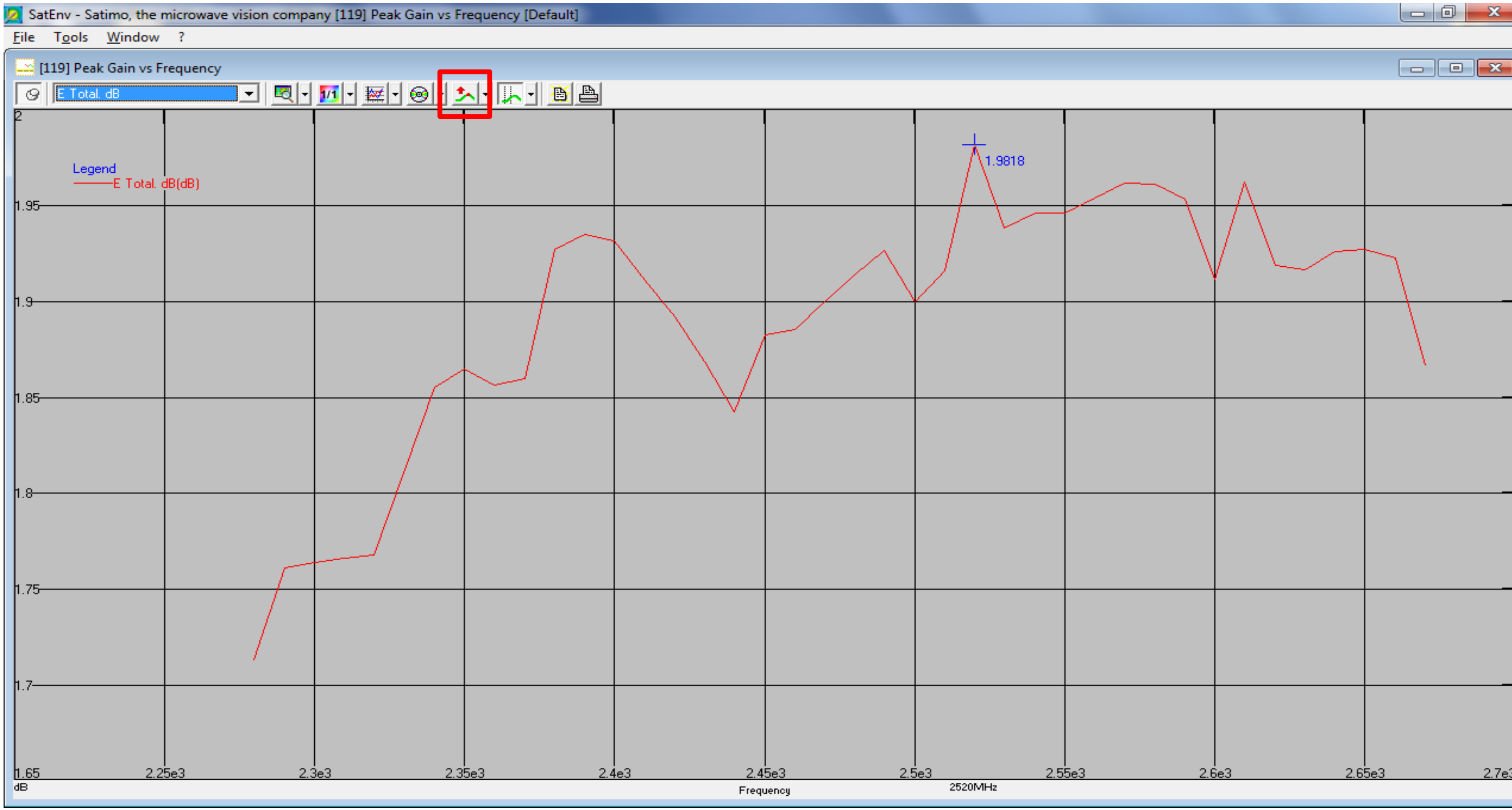
2.2.6 Export data to data processing software



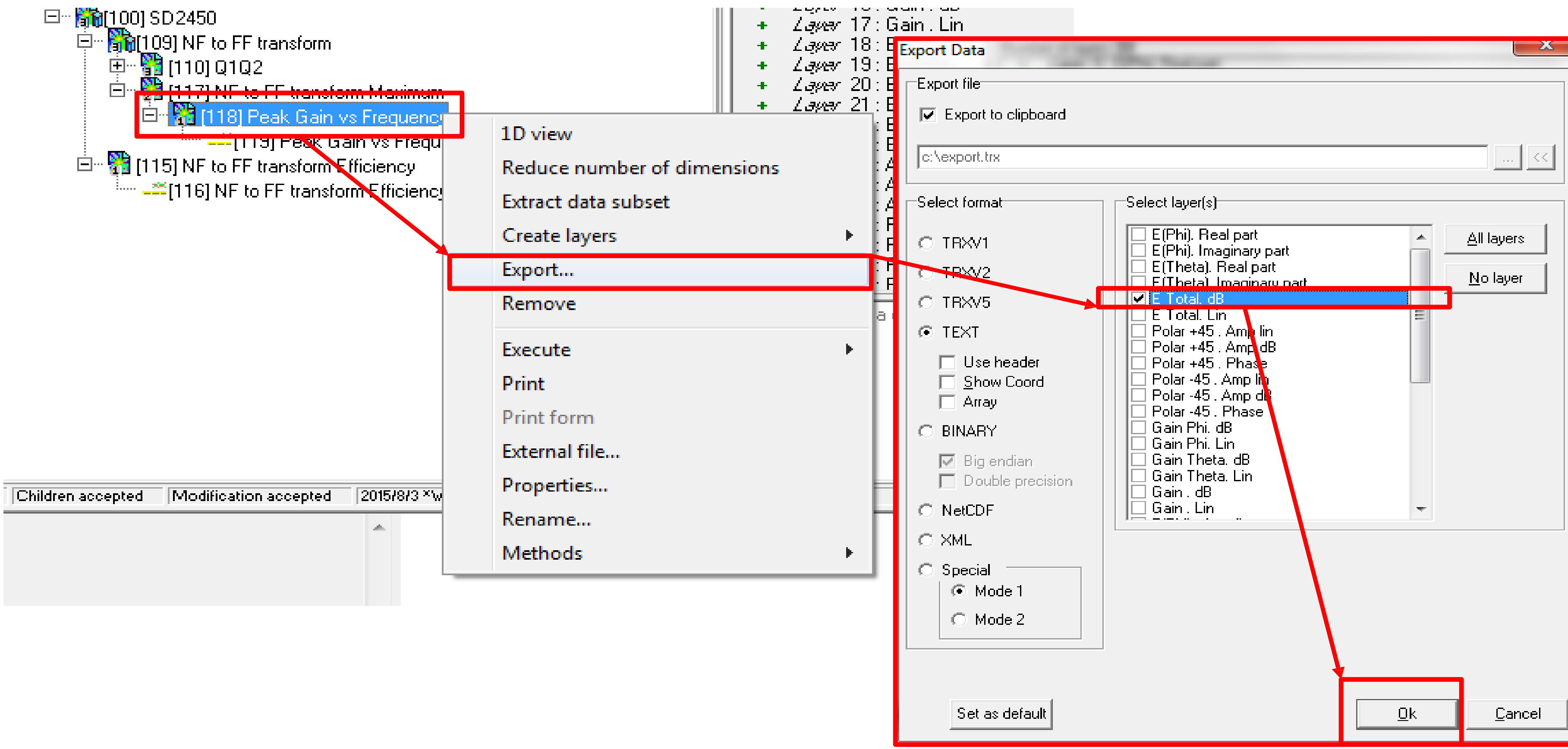
2.2.6.1 Export Peak Gain



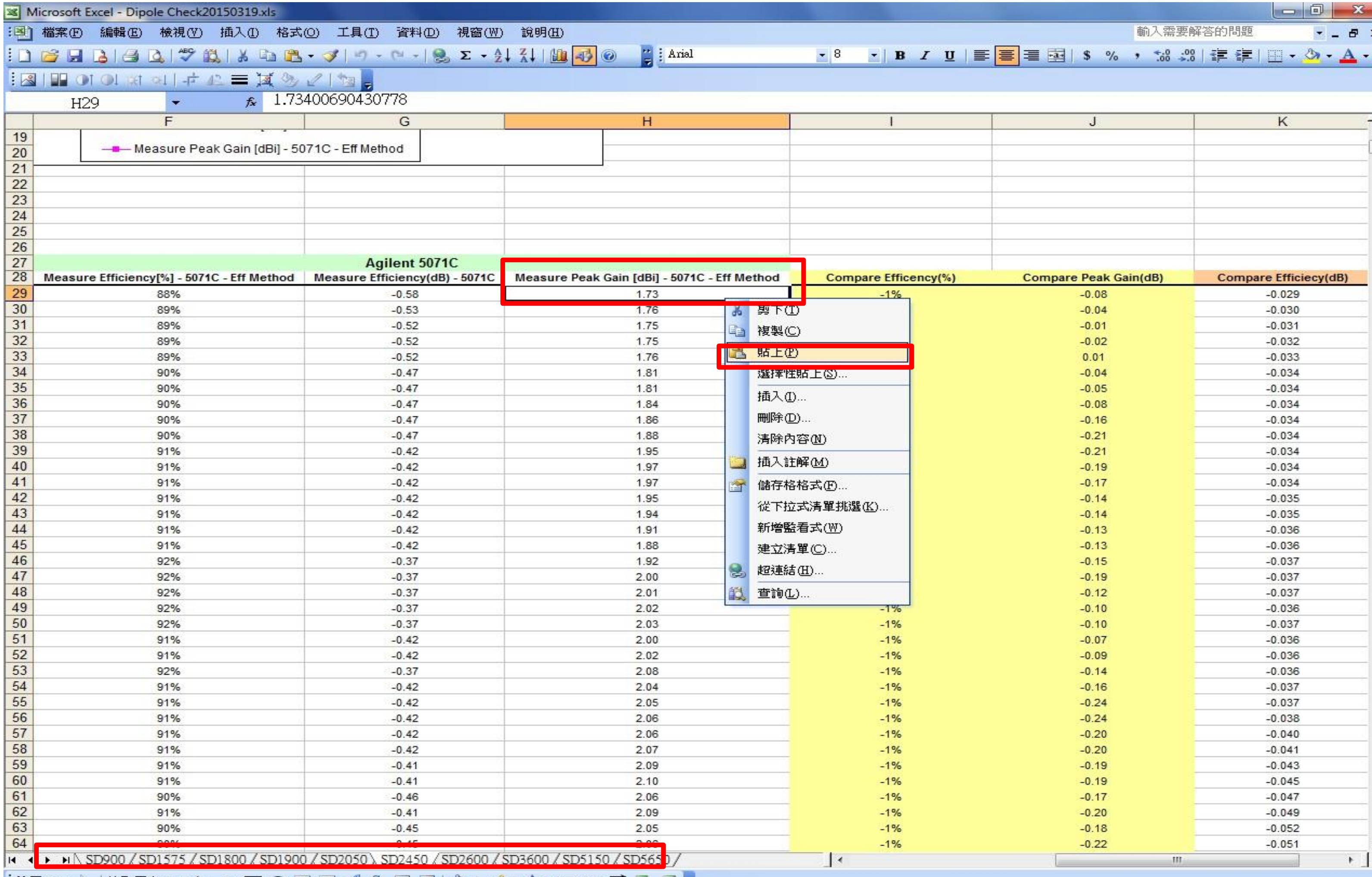
2.2.6.2 Get Peak Gain



2.2.6.3 Export E-Total

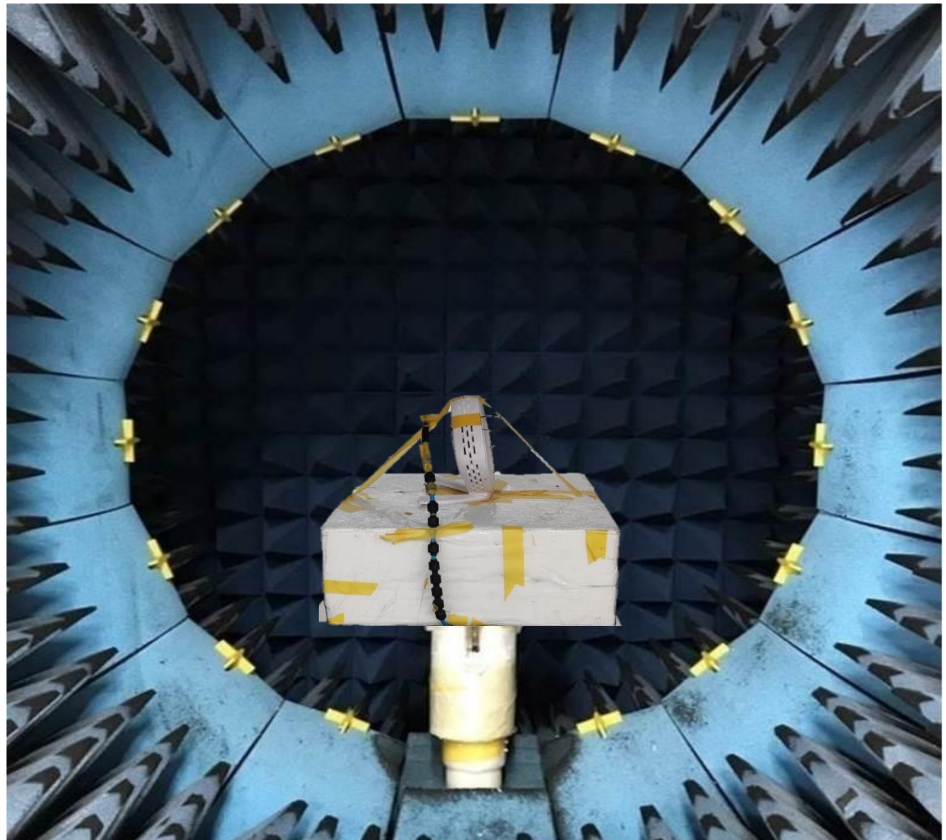


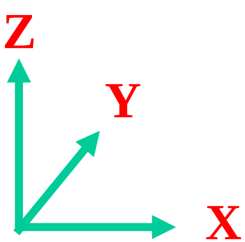
2.2.6.4 Get E-Total



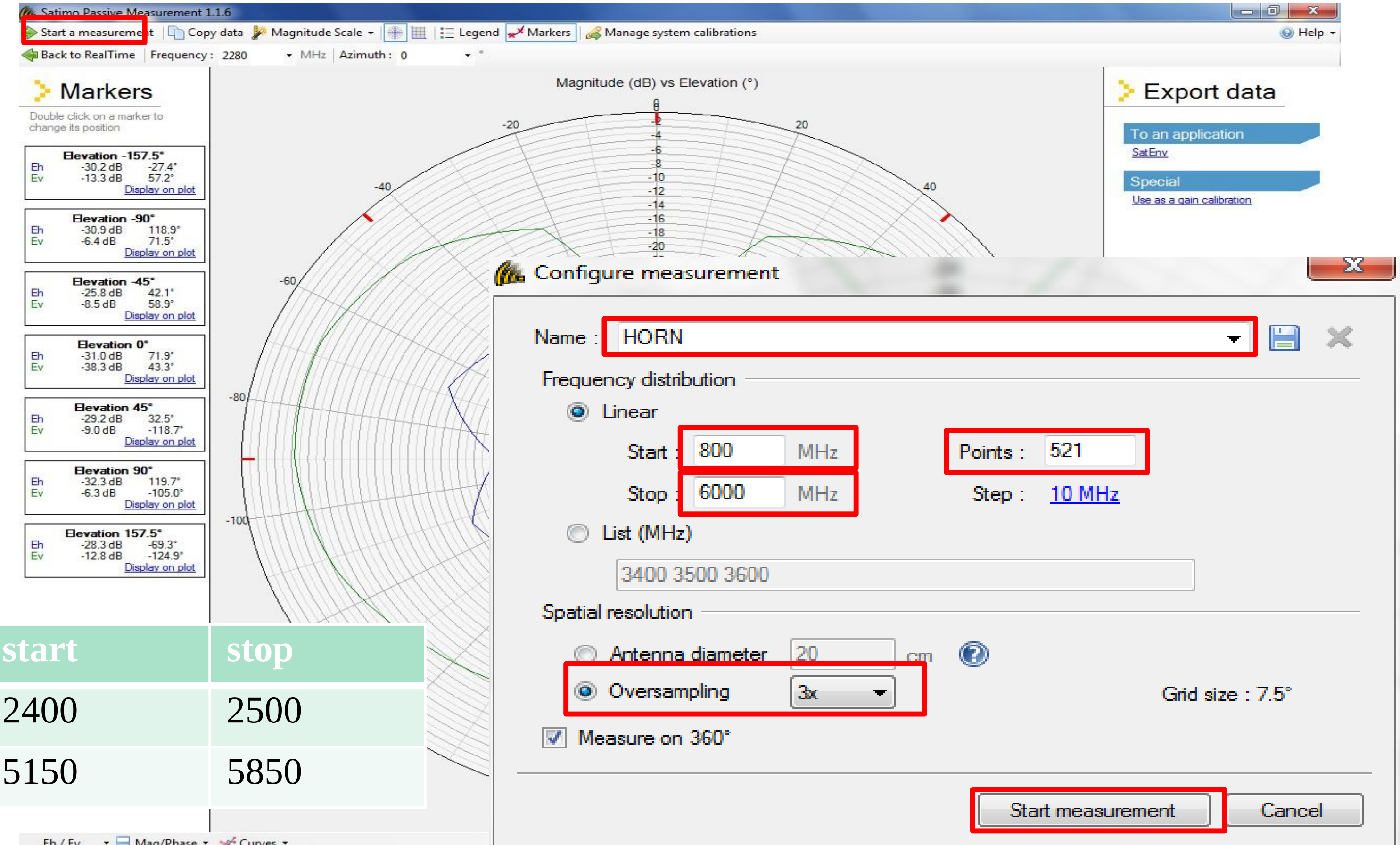
	F	G	H	I	J	K
27	Agilent 5071C					
28	Measure Efficiency[%] - 5071C - Eff Method	Measure Efficiency(dB) - 5071C	Measure Peak Gain [dBi] - 5071C - Eff Method	Compare Efficency(%)	Compare Peak Gain(dB)	Compare Efficiecy(dB)
29	88%	-0.58	1.73	-1%	-0.08	-0.029
30	89%	-0.53	1.76		-0.04	-0.030
31	89%	-0.52	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	-1%	-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	[illegible]	[illegible]	[illegible]	-1%	-0.22	-0.051

3、 Measure



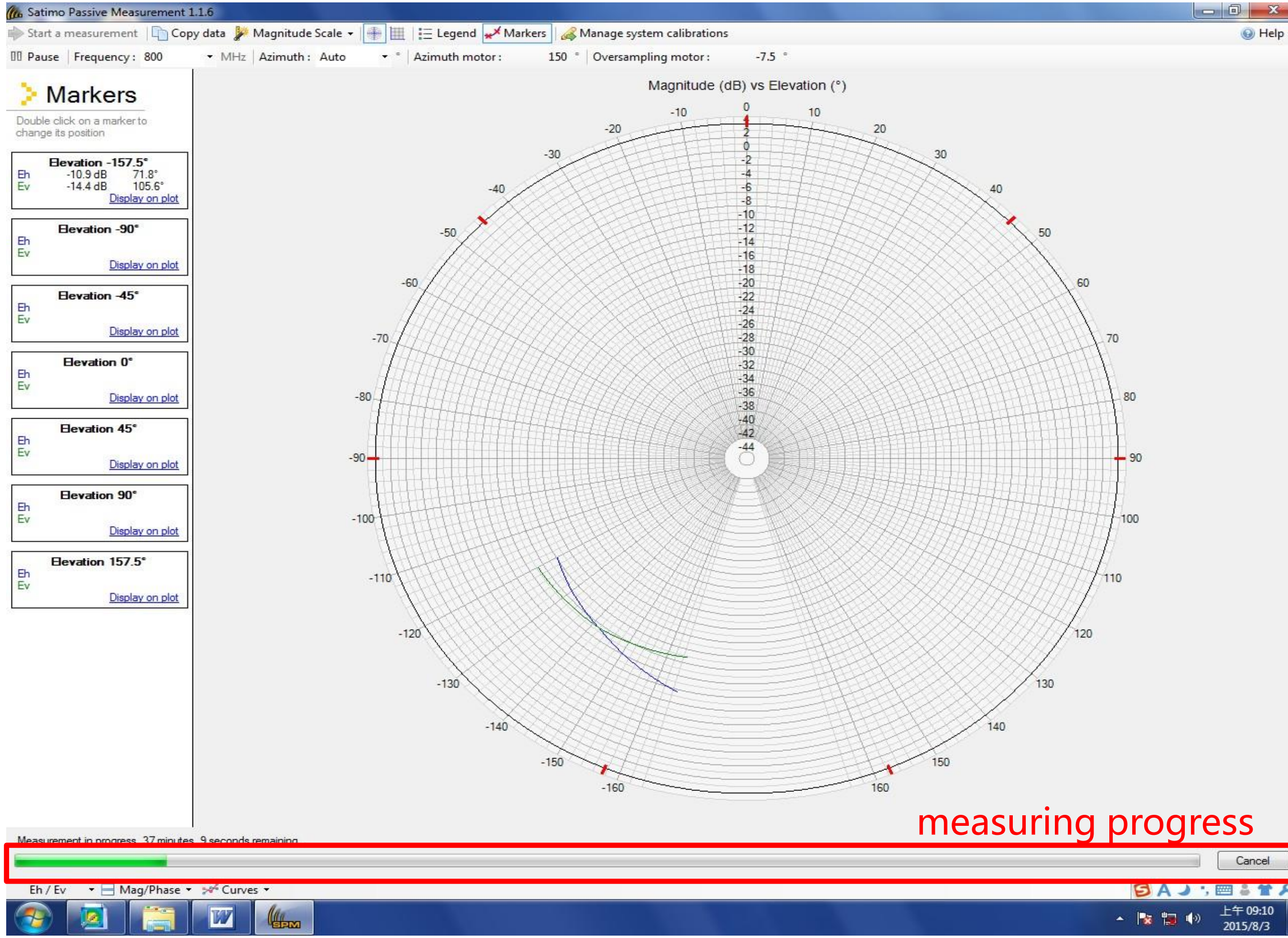


3.1 Open the measurement software, set parameters and start measurement

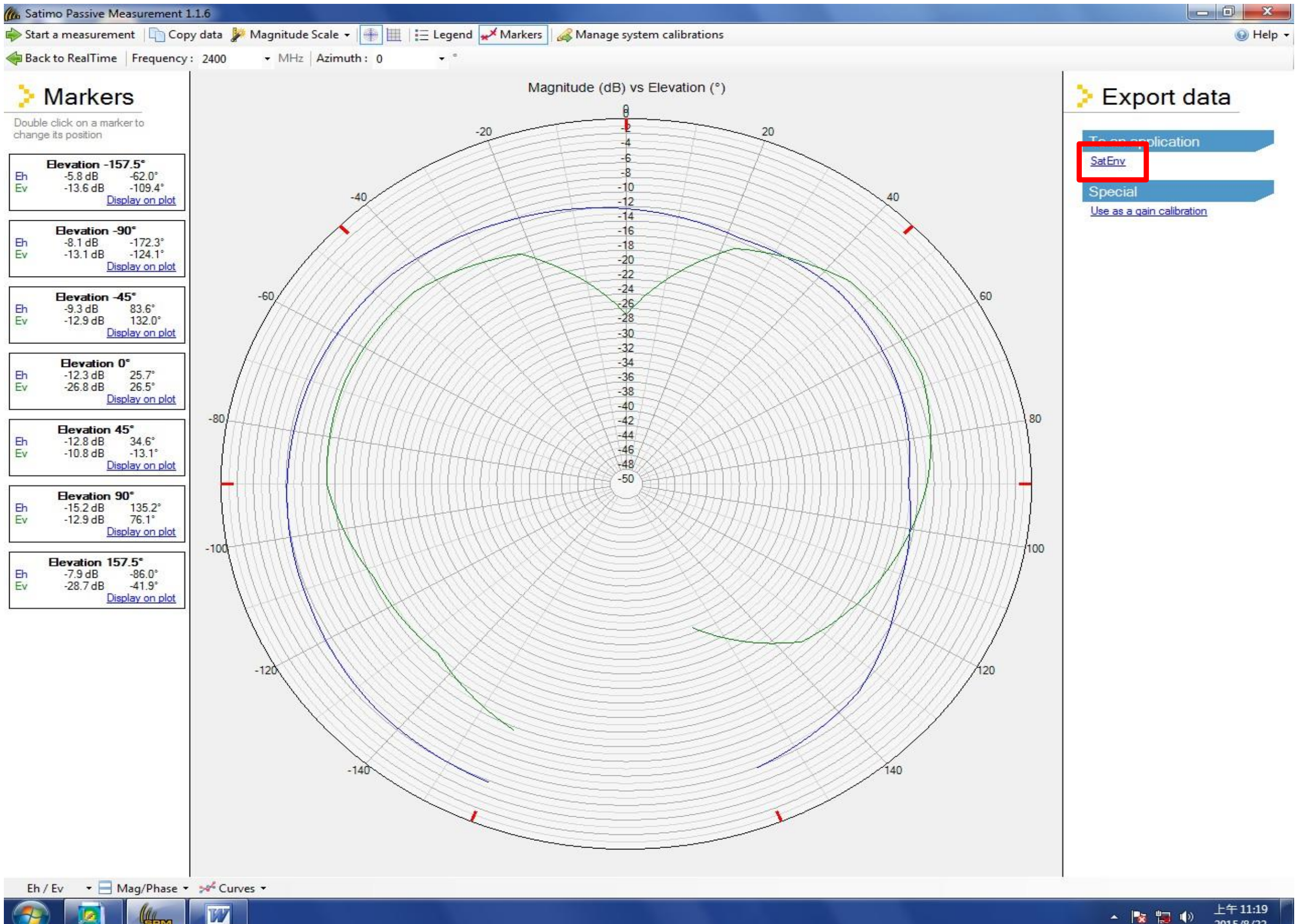


type	start	stop
2.4G	2400	2500
5G	5150	5850

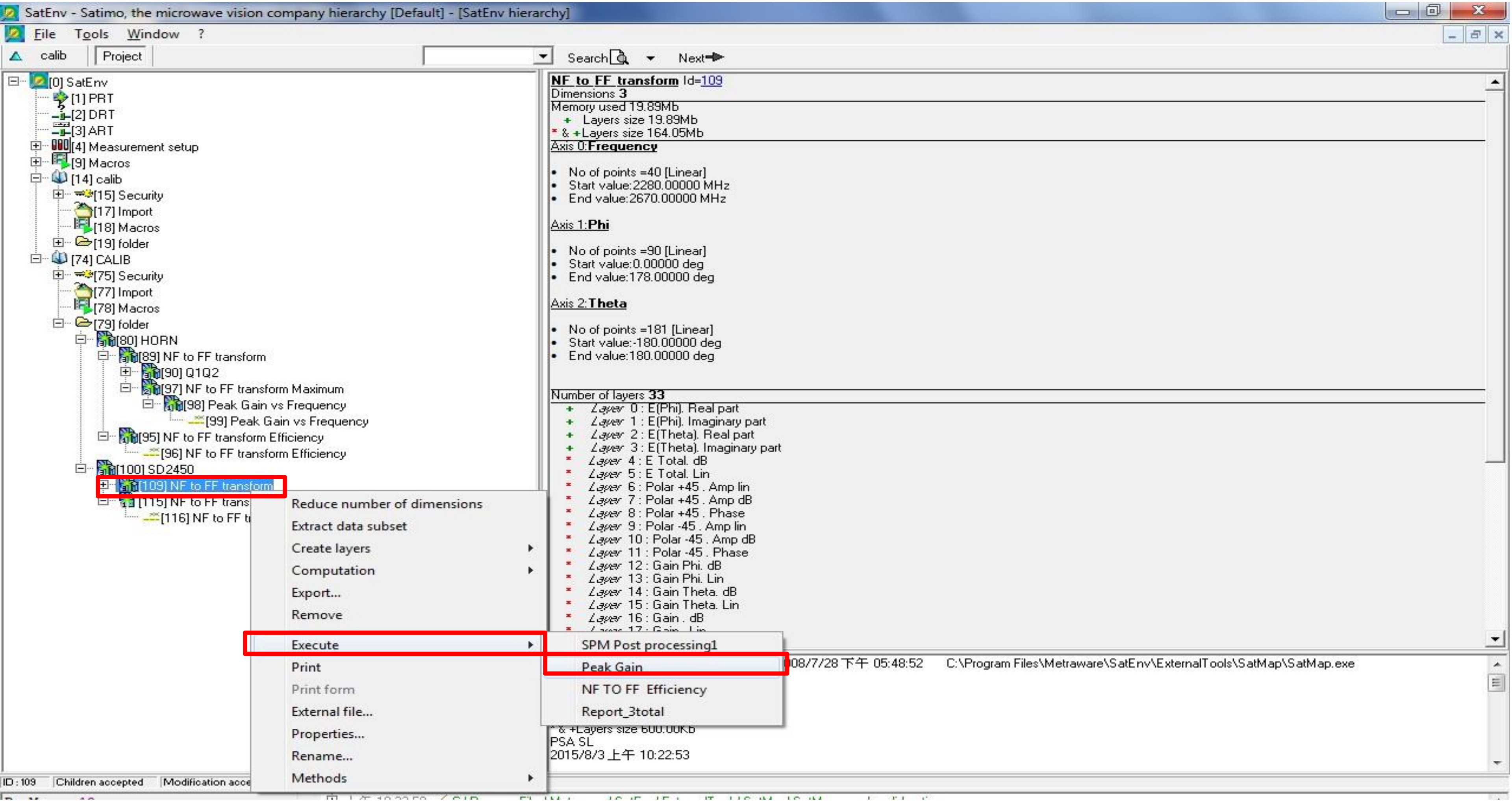
Measuring processing



3.2 Export data to data processing software

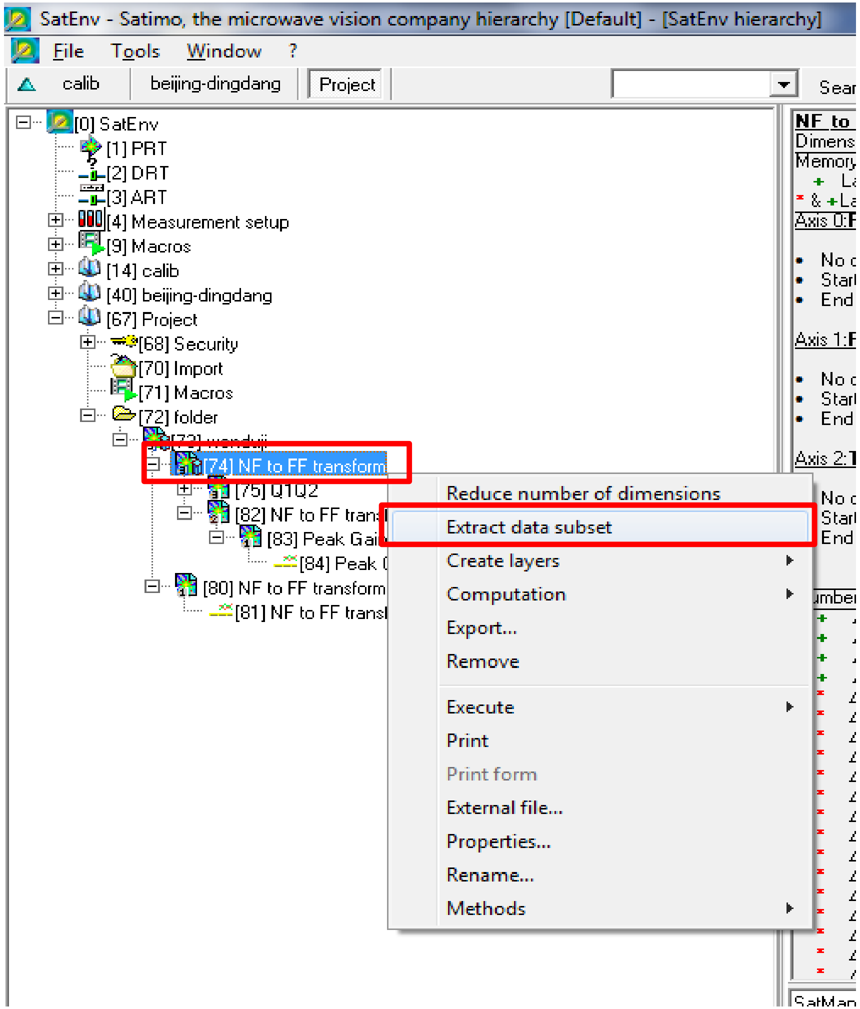


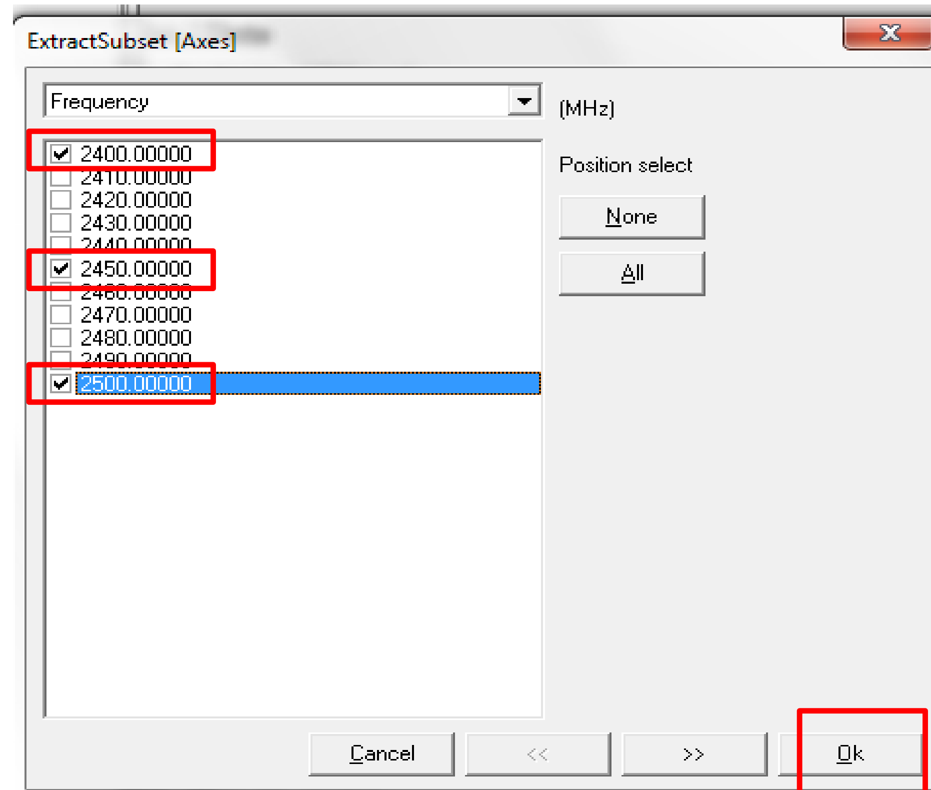
3.2.1 Export Peak Gain



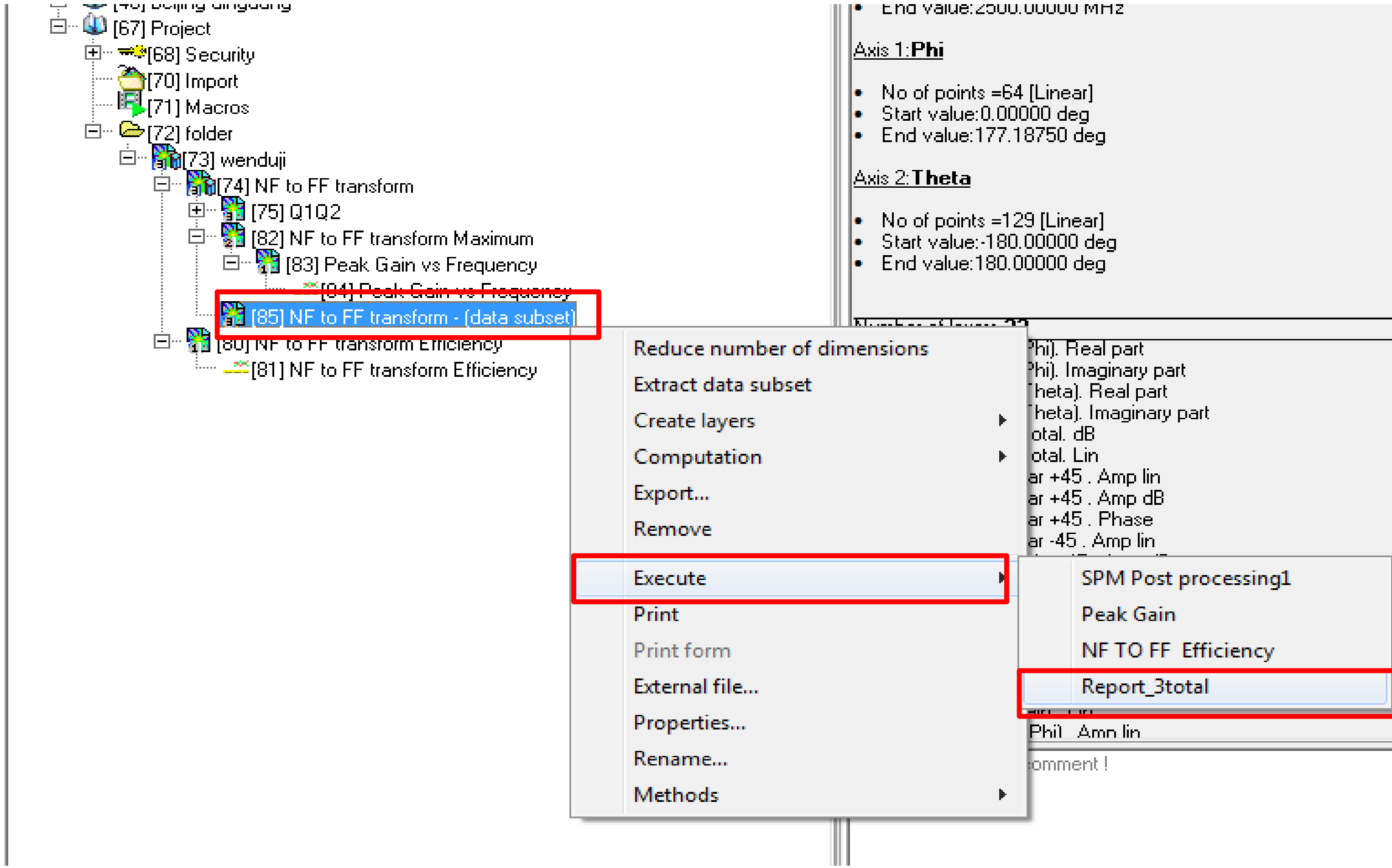
3.2.2 Get Peak Gain

3.2.3 Solve 2D field pattern

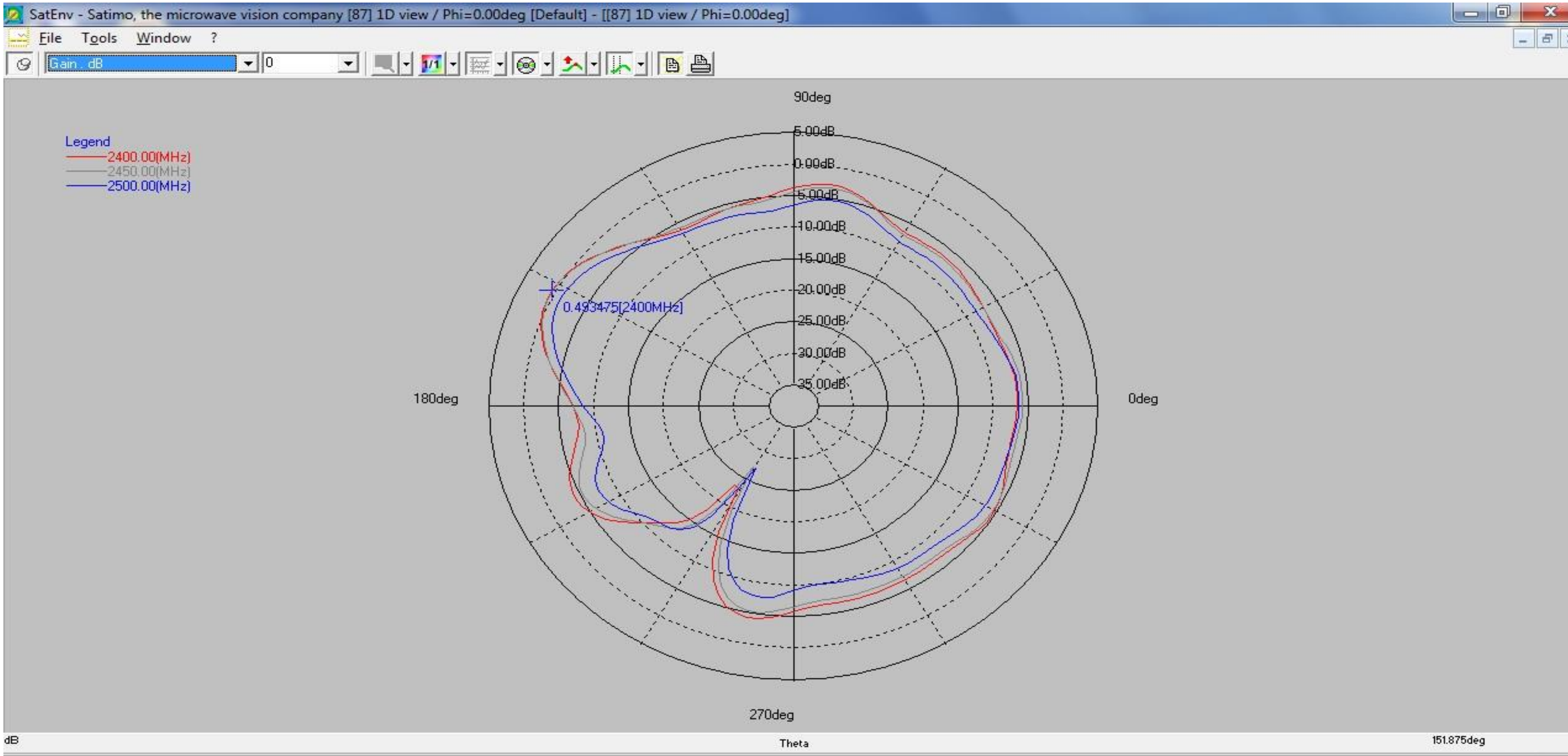




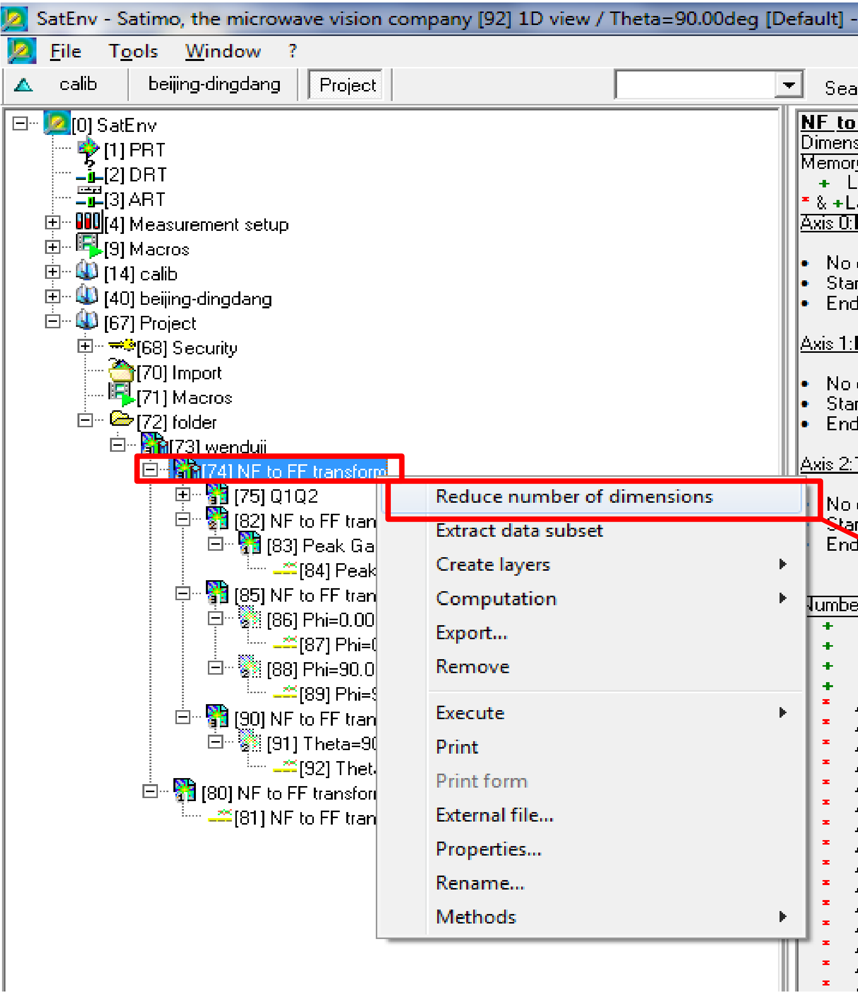
3.2.3 Solve 2D field pattern

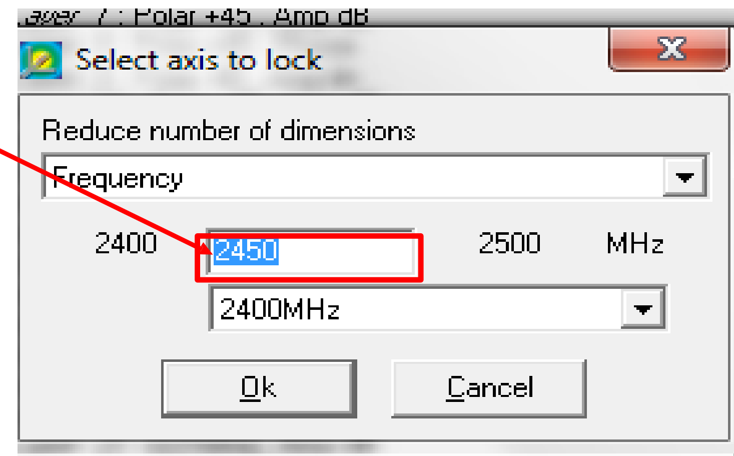


3.2.4 Get 2D field pattern

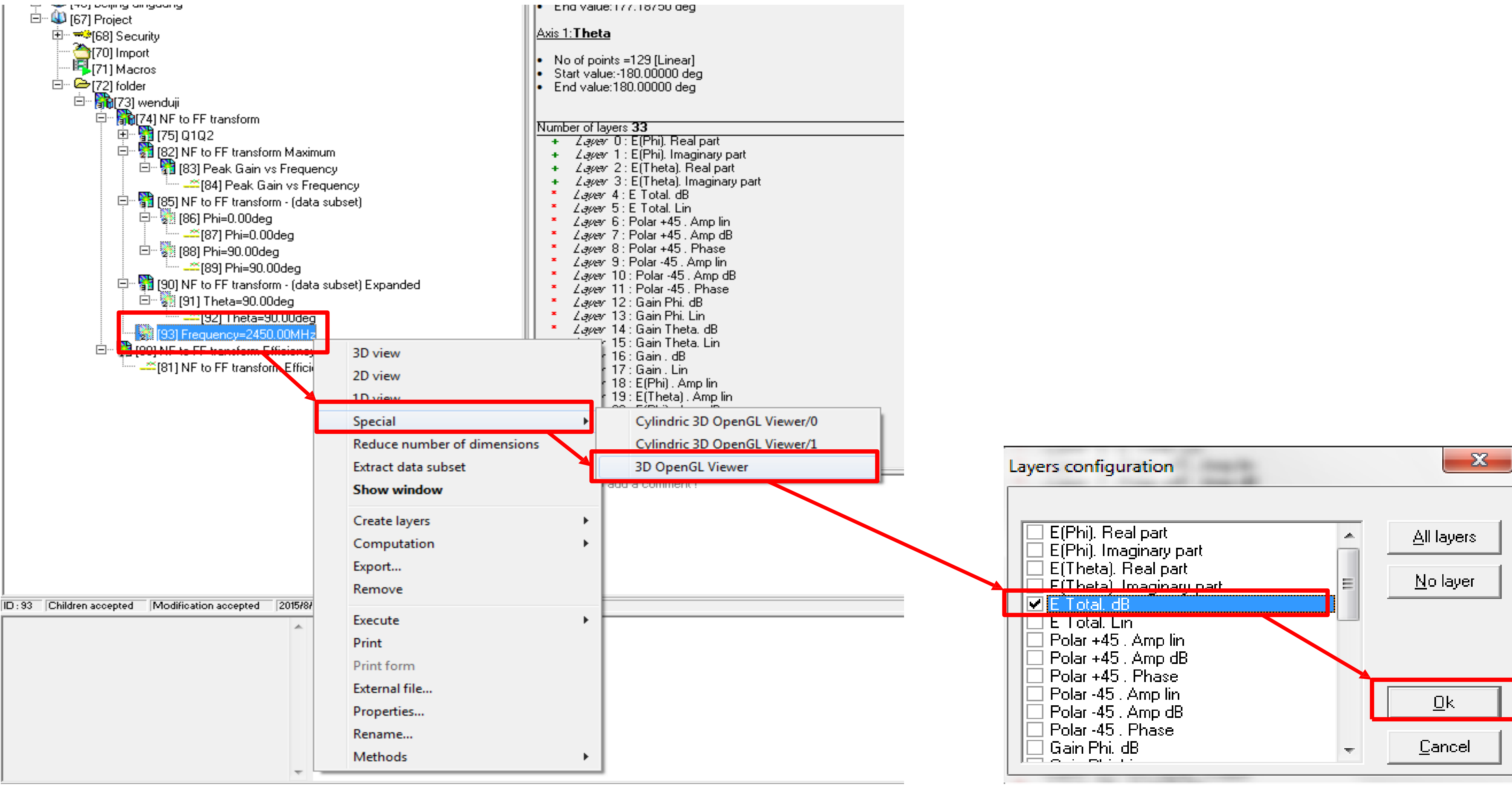


3.2.5 Solving 3D field pattern

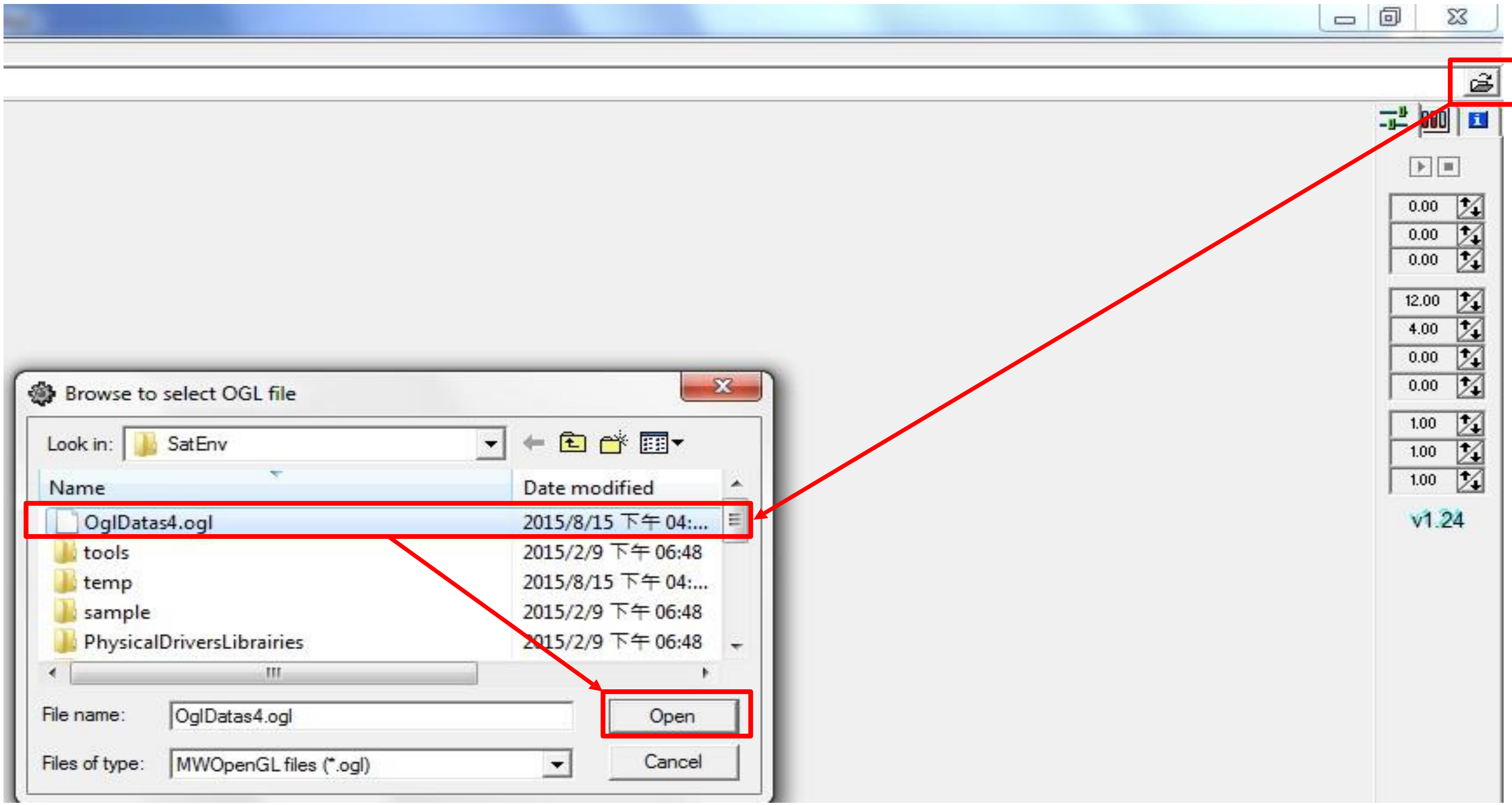




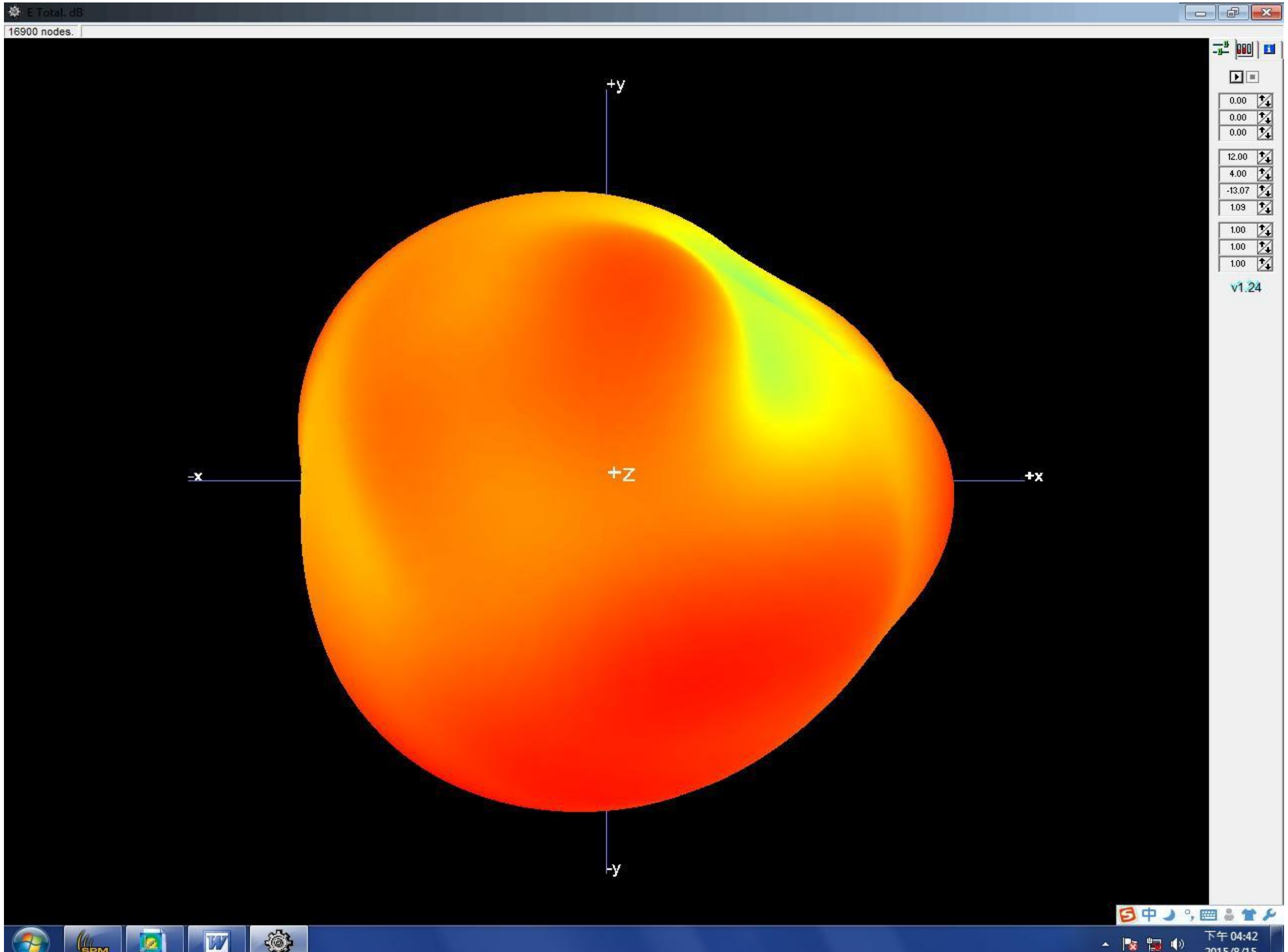
3.2.5 Solving 3D field pattern



3.2.5 Solving 3D field pattern



3.2.6 Get 3D field pattern



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WX5512-T0 Antenna real test report and directional gain calculation

OUTLINE

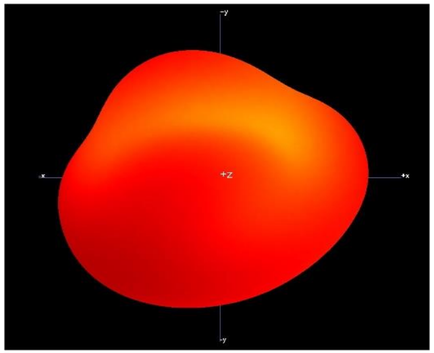
WX5512-T0 Antenna Test Report

1.1.1 E-Total Gain Formula

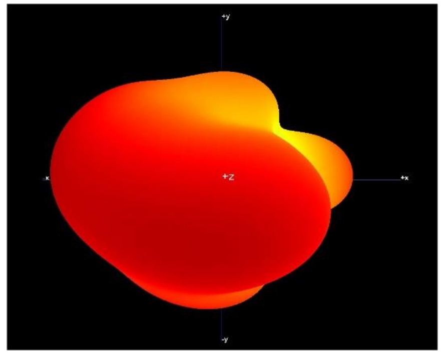
	Formula	Remarks
E-Total	Satimo darkroom data solution =MAX(XX:XX)	The maximum value in the original data of angle by angle and with frequency

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

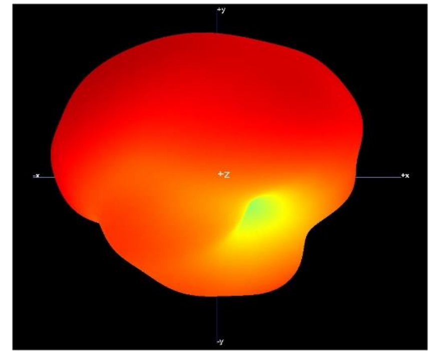
2.4G-1_2450MHz



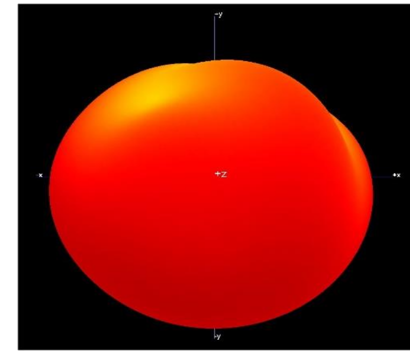
2.4G-2_2450MHz



2/5G-1_2450MHz

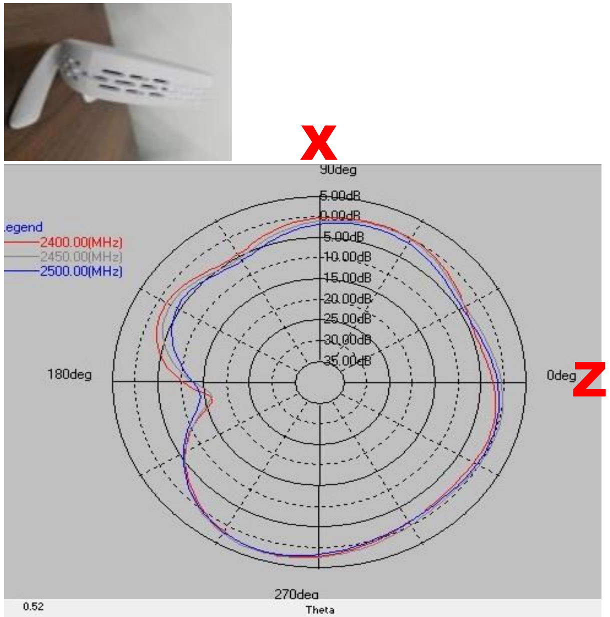


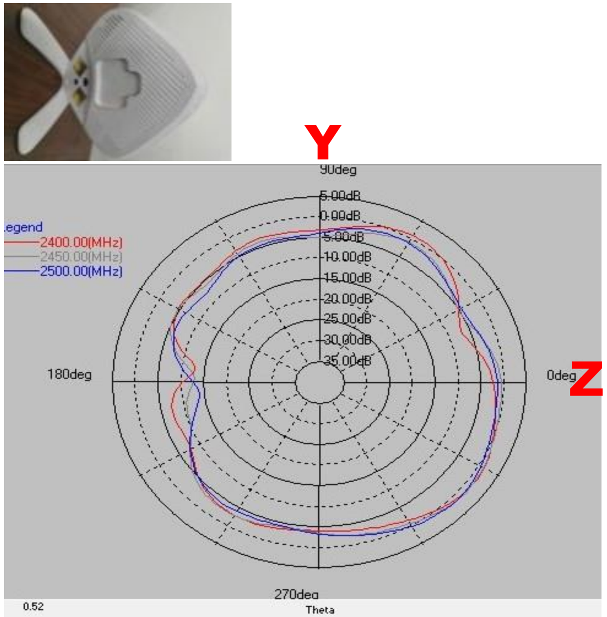
2/5G-2_2450MHz

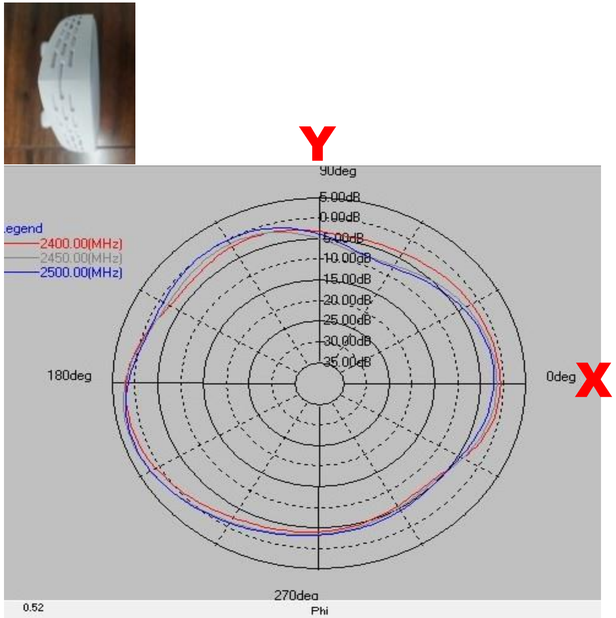


Frequency [MHz]	2.4G-1	2.4G-2	2/5G-1-2.4G	2/5G-2-2.4G
	E-total [dBi]	E-total [dBi]	E-total [dBi]	E-total [dBi]
2400	2.86	3.30	2.88	3.21
2450	3.54	3.12	3.54	3.02
2500	3.26	3.40	3.31	2.87

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

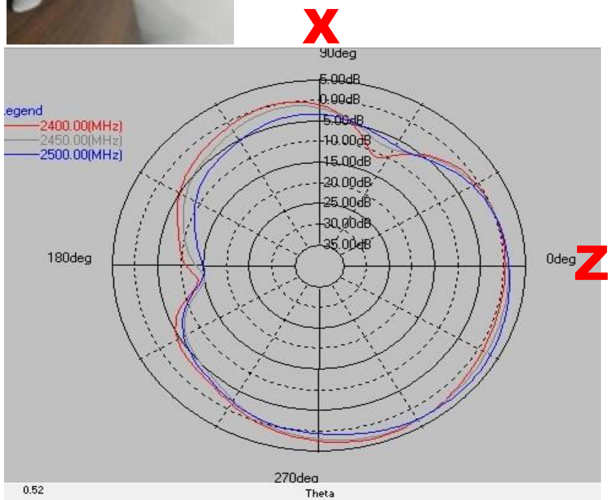


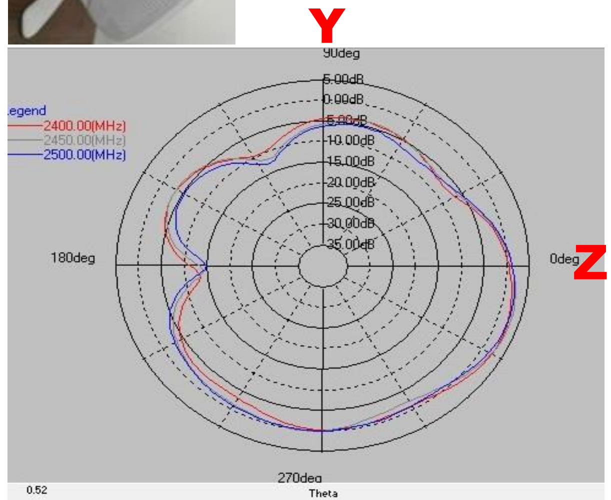


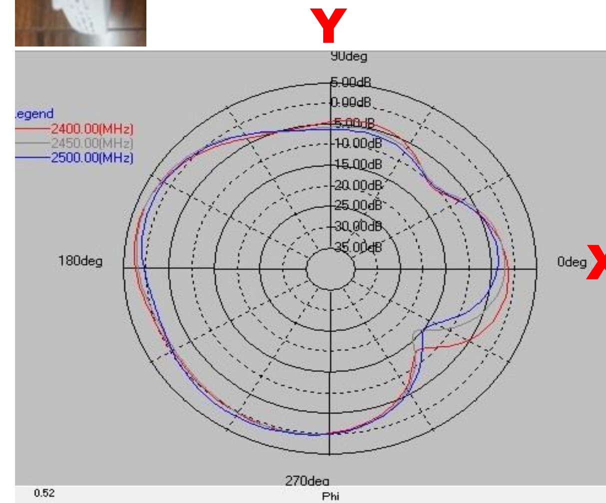


	ZX plane		ZY plane		XY plane	
Frequency [MHz]	Max Value [dBi]	Average [dBi]	Max Value [dBi]	Average [dBi]	Max Value [dBi]	Average [dBi]
2400	2.55	-1.43	1.48	-2.77	2.19	-1.81
2450	2.86	--1.18	1.49	-2.88	3.10	-1.64
2500	2.41	-1.87	1.22	-3.10	2.75	-1.59

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

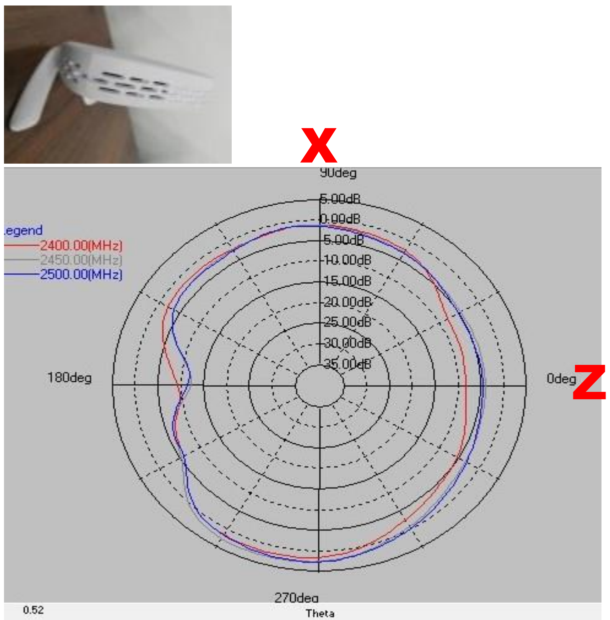


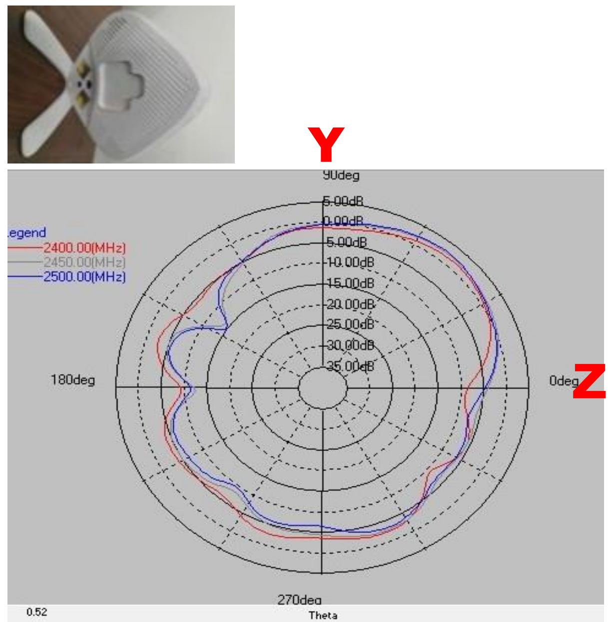


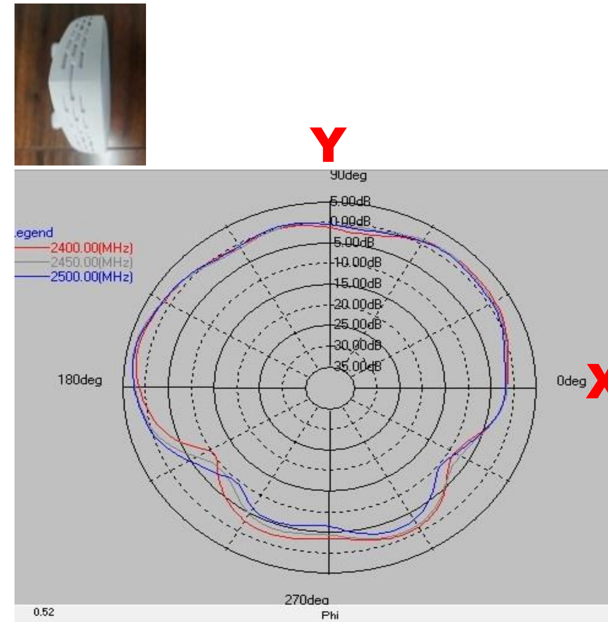


	ZX plane		ZY plane		XY plane	
Frequency [MHz]	**Max Value [dBi]**	**Average [dBi]**	**Max Value [dBi]**	**Average [dBi]**	**Max Value [dBi]**	**Average [dBi]**
2400	3.30	-0.84	2.65	-2.45	2.98	-1.51
2450	2.97	-1.05	3.03	-2.26	2.84	-1.73
2500	3.18	-1.32	2.55	-2.42	1.93	-2.05

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

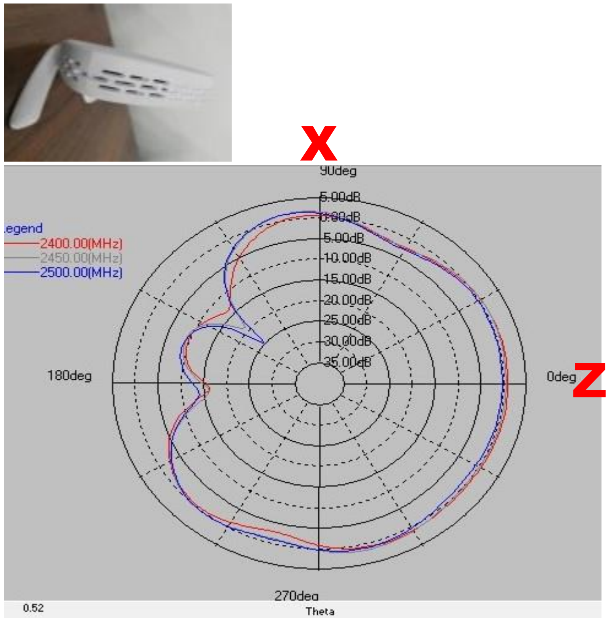


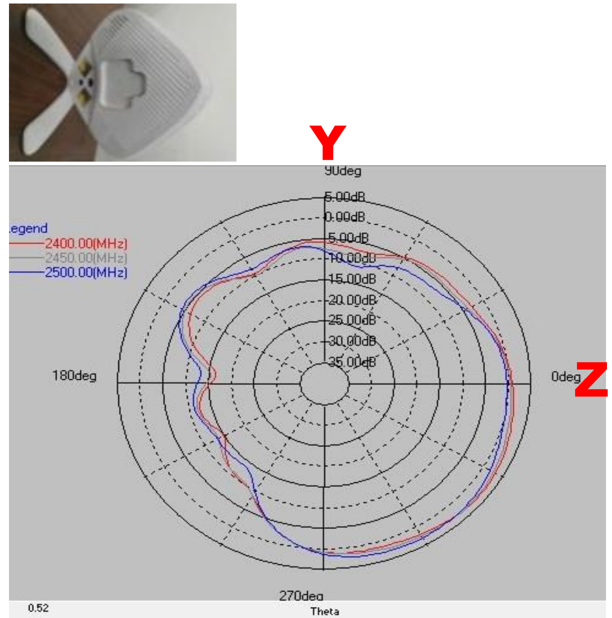


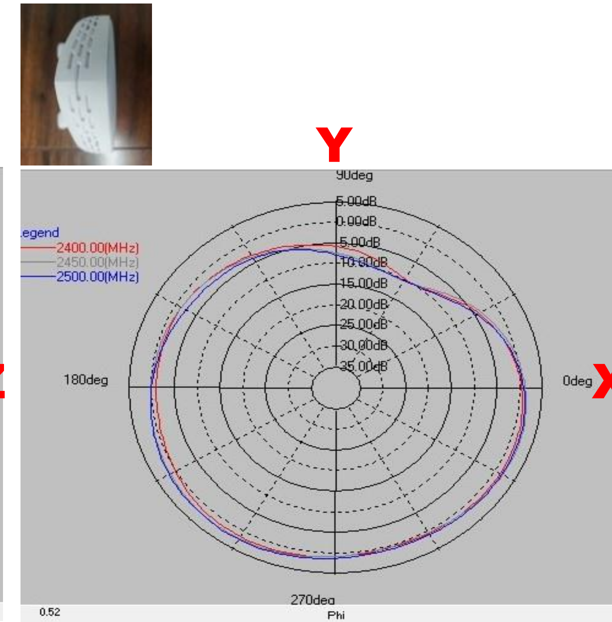


	ZX plane		ZY plane		XY plane	
Frequency [MHz]	**Max Value [dBi]**	**Average [dBi]**	**Max Value [dBi]**	**Average [dBi]**	**Max Value [dBi]**	**Average [dBi]**
2400	1.63	-2.56	1.51	-3.08	2.69	-0.98
2450	2.62	-1.78	2.23	-2.86	3.41	-0.84
2500	2.49	-1.99	2.50	-3.09	3.26	-1.08

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



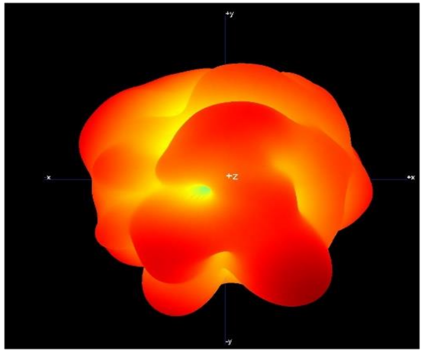




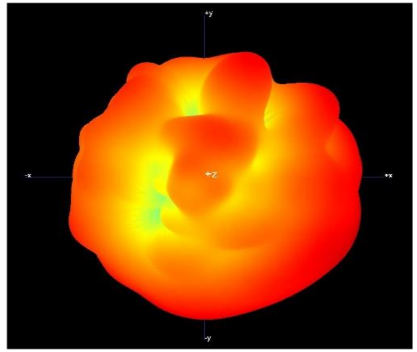
	ZX plane		ZY plane		XY plane	
Frequency [MHz]	**Max Value [dBi]**	**Average [dBi]**	**Max Value [dBi]**	**Average [dBi]**	**Max Value [dBi]**	**Average [dBi]**
2400	0.93	-1.38	3.21	-2.06	1.46	-0.85
2450	1.48	-1.04	3.00	-2.18	2.09	-0.40
2500	1.33	-1.47	2.87	-2.38	2.19	-0.42

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

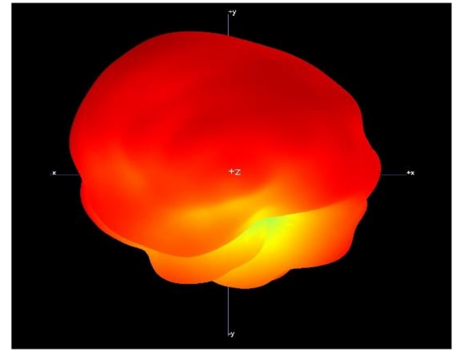
5G-1_5500MHz



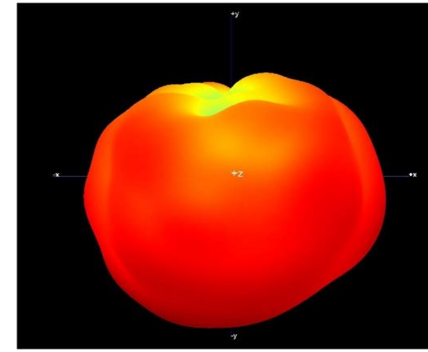
5G-2_5500MHz



2/5G-1_5500MHz

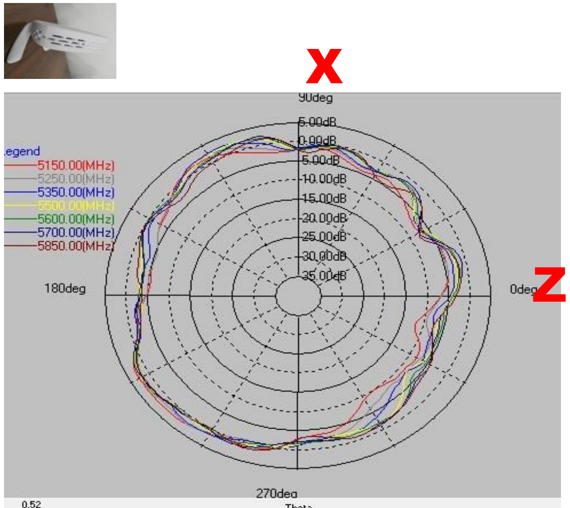


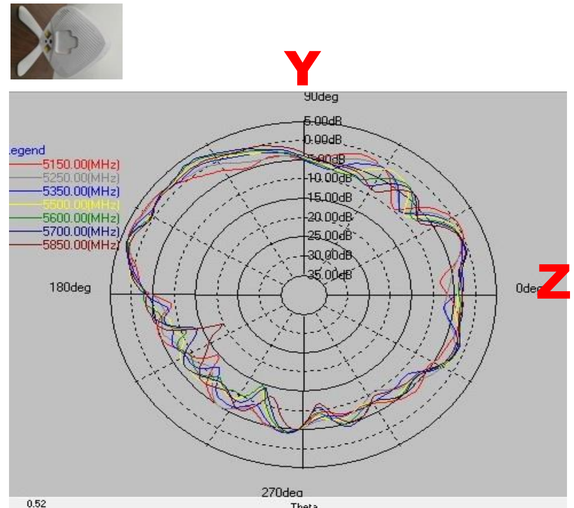
2/5G-2_5500MHz

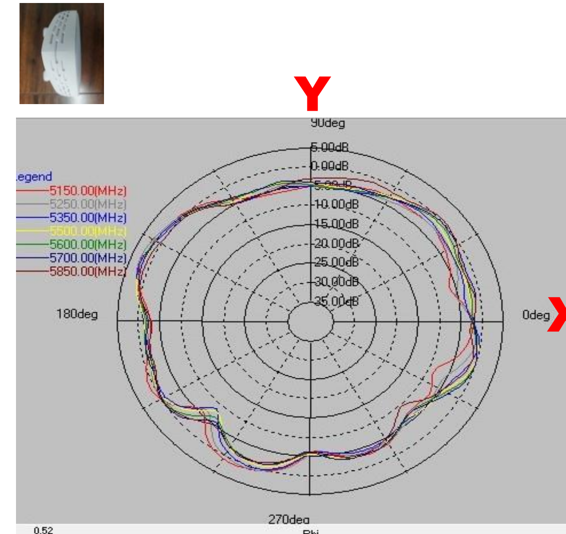


Frequency [MHz]	5G-1	5G-2	2/5G-1-5G	2/5G-2-5G
	E-total [dBi]	E-total [dBi]	E-total [dBi]	E-total [dBi]
5150	**4.98**	**3.55**	**3.82**	**4.10**
5250	**4.94**	**3.74**	**3.82**	**4.00**
5350	**4.71**	**3.84**	**4.22**	**4.33**
5500	**4.21**	**3.75**	**4.00**	**4.89**
5600	**4.13**	**3.51**	**3.45**	**4.95**
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

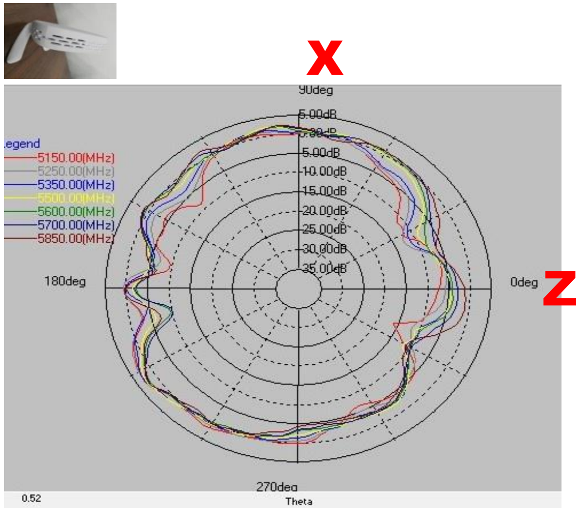


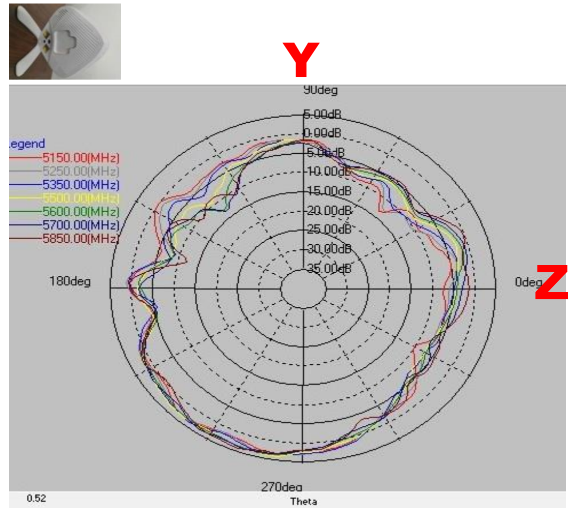




	ZX plane		ZY plane		XY plane	
Frequency [MHz]	**Max Value [dBi]**	**Average [dBi]**	**Max Value [dBi]**	**Average [dBi]**	**Max Value [dBi]**	**Average [dBi]**
5150	2.73	-2.10	3.49	-2.96	2.59	-2.24
5250	2.35	-1.88	3.29	-3.02	2.72	-2.20
5350	2.41	-1.54	3.33	-2.97	2.29	-2.34
5500	2.23	-1.31	2.98	-2.74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

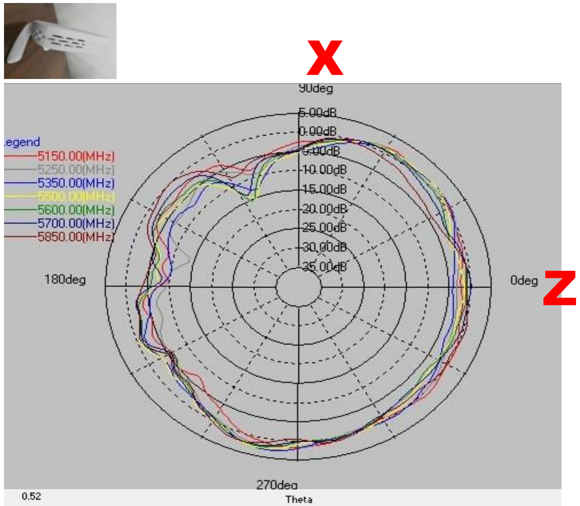
1.1.8 2D Radiation Patterns---5G-Ant 2

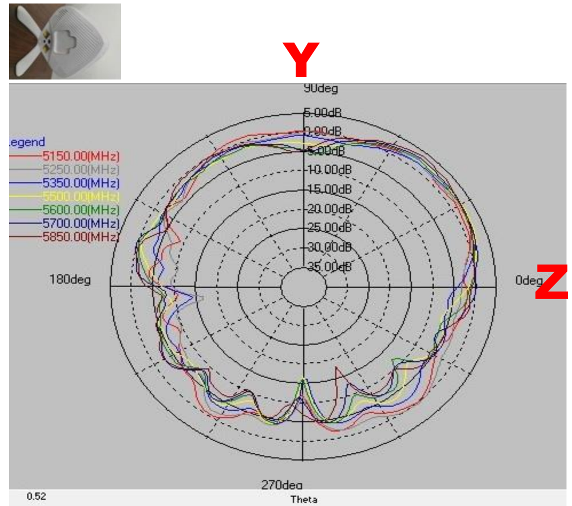


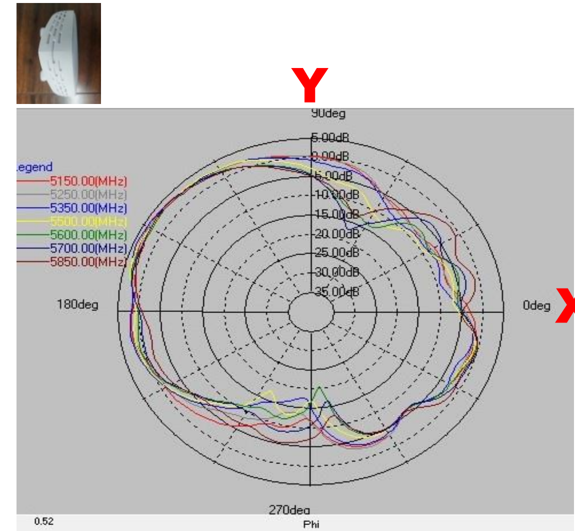


	ZX plane		ZY plane		XY plane	
Frequency [MHz]	Max Value [dBi]	Average [dBi]	Max Value [dBi]	Average [dBi]	Max Value [dBi]	Average [dBi]
5150	2.81	-2.16	3.34	-1.56	3.15	-0.69
5250	2.94	-1.76	3.52	-1.51	3.20	-0.48
5350	2.92	-1.67	3.73	-1.47	2.57	-0.49
5500	2.69	-1.37	3.73	-1.58	2.48	-0.16
5600	1.96	-1.60	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

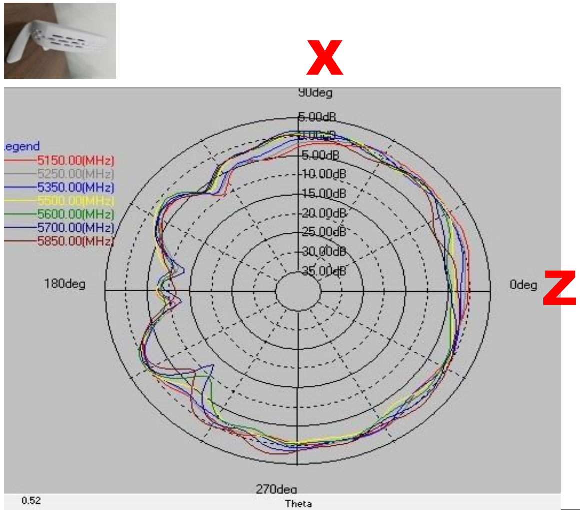


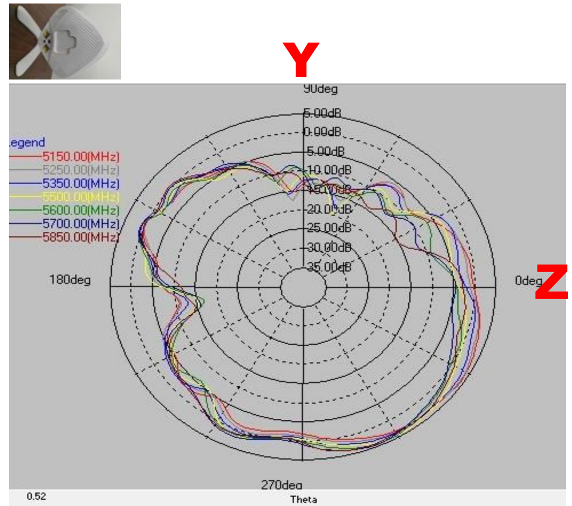


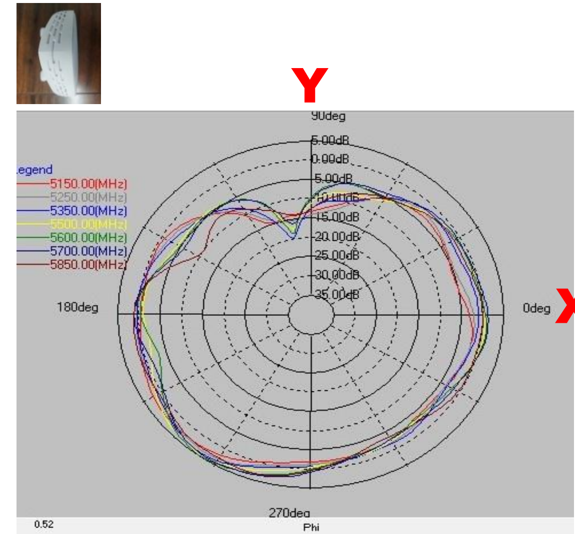


	ZX plane		ZY plane		XY plane	
Frequency [MHz]	Max Value [dBi]	Average [dBi]	Max Value [dBi]	Average [dBi]	Max Value [dBi]	Average [dBi]
5150	1.55	-1.53	1.54	-1.84	3.77	-1.06
5250	2.29	-1.87	1.95	-1.99	3.66	-1.09
5350	2.68	-1.76	2.29	-2.46	4.07	-1.23
5500	2.38	-1.63	2.58	-2.26	3.63	-1.64
5600	2.02	-1.84	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 angle=10*LOG10(((10^(‘X-X'!XX/20)+10^(‘X-X'!XX/20)+10^(‘X-X'!XX/20)+10^(‘X-X'!XX/20))^2)/4)** **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 angle=10*LOG10((10^(‘X-X'!XX/10)+10^(‘X-X'!XX/10)+10^(‘X-X'!XX/10)+10^(‘X-X'!XX/10))/4)** **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**

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Appendix
2.4G Ant 1 Raw Data