Application Note :
Telink Antenna Design Guide

AN-16080500-E2

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Brief:

This document is the design guide for Telink common antennas.

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Revision History

Version	Major Changes	Date	Author
1.0.0	Initial release	2016/8	H.Z.F., L.X., Cynthia
2.0.0	Updated based on “AN_16080500-E1_Telink Antenna Design Guide” and “AN_A-PCB-E3_Common Antennas”. Added section 1 Overview, 2 Brief Introduction about Antenna, 3 Antenna Type, 4 Matching Bandwidth, RL with a Network Analyzer.	2018/12	L.X., Cynthia

Table of contents

Table of figures

1 Overview

Antenna is the most important component used in short-range device applications.

In this document, many important parameters, e.g. bandwidth, gain, impedance matching parameters, will be introduced.

It is very important to use a correct antenna pattern. In free space, wavelength (λ) is about 12cm~12.5cm.

2 Brief Introduction about Antenna

Antenna is an important component to transmit higher power and receive a weak signal.

A typical antenna used in consumer electronics is 1/4 wavelength antenna. And 1/2 wavelength dipole is usually used during initial design.

a) λ/2 dipole antenna

A dipole antenna is often designed as λ/2 wavelength. The Figure 1 shows the typical emission pattern.

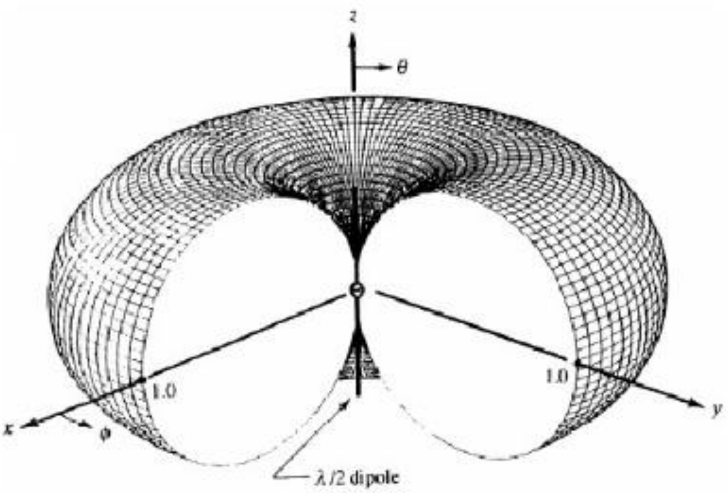


Figure 1 Typical emission pattern for λ/2 dipole antenna

The antenna is located in the Z plane. The most powerful energy is radiated out in the XY plane. The weakest points are on the Z plane.

b) Monopole (λ /4) antenna

A monopole antenna is often designed as λ /4 wavelength, and it's often used in applications including consumer electronics and IOT.

Since one antenna element is λ /4 wavelength and the GND plane acts as the other λ /4 wavelength, the λ /4 wavelength monopole antenna is equal to a λ /2 wavelength dipole antenna in fact.

Usually, a big solid ground is necessary for good antenna performance.

c) Voltage Standing Wave Ratio (VSWR)

In theory, when the source resistance is equal to the load resistance, the load will get the maximum power from the source.

$$Z0 = Zl$$

The complex reflection coefficient(Γ) is defined as below.

$$\Gamma = (Zl-Z0)/(Zl+Z0)$$

If Zl=Z0, Γ =0, then the load gets the maximum energy.

In antenna applications, VSWR and Return Loss (RL) are usually used.

$$VSWR=(1+|\Gamma|)/(1-|\Gamma|)$$

$$S11(db)=20\log((VSWR-1)/(VSWR+1))$$

VSWR and RL are used to check how well the antenna works. Usually, VSWR 0f 2.0(RL=9.5dB) is usually used as the limitation to define antenna's bandwidth. In real application design, it's recommended to adopt a pi-matching network.

Table 1 VSWR, RL and Γ

VSWR	Return Loss (dB)	Reflection Coefficient
1	∞	0
1.5	14	0.2
2	9.5	0.333

d) Antenna parameters

When choosing a correct antenna pattern, it's needed to consider many parameters, including:

i. Antenna location: Do not place antenna close to metal components, motor, battery and so on. Please place antenna face to free space.

ii. Ground plane: A big and solid ground is a fundamental design point to ensure good antenna performance.

iii. Matching network: A pi-matching network is optional in the design.

iv. Antenna gain: In consumer applications, omnidirectional antenna is a good choice.

v. Antenna bandwidth: The parameter is defined using Return Loss.

e) Friis transmission equation

Friis transmission equation is a primary formula to estimate power and distance.

$$P_r = P_t G_t G_r \left(\frac{\lambda}{4\pi R} \right)^2$$

λ = Wavelength in Meters
P_r = Received Power in dBm
P_t = Transmit Power in dBm
G_t = Transmit Antenna Gain in dBi
G_r = Receive Antenna Gain in dBi
R = Distance between Antennas in Meters

When the transmitted power increases by delta (unit: dBm), the communication distance will be the X multiple.

For example, when increasing power by 6dBm, the communication distance will double.

△(dBm)	X (Multiple)
3	1.4
6	2

3 Antenna Type

Size and cost are parameters that should be considered together when choosing antenna.

Table 2 Advantage and disadvantage for different antenna types

Antenna Type	Advantage	Disadvantage
PCB antenna	low cost; small size at high frequencies; wide bandwidth available when designed well	large size at low frequencies
Chip antenna	small size	high cost; narrow bandwidth
Whip antenna	high performance	high cost; large volume

4 Matching Bandwidth, RL with a Network Analyzer

a) Mounting cable for S11 measurement

It is very important to use semi-rigid cables when doing RF measurement.

Solder the outer of the cable to ground plane, and solder the inner of the cable to the feed point.

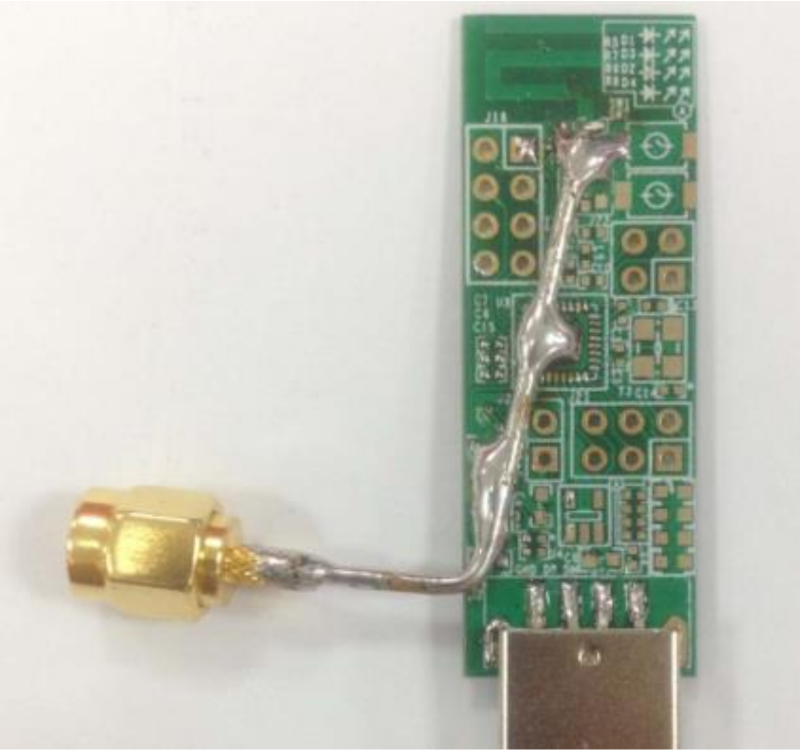


Figure 2 Mounting cable

b) Calibration

It is important to calibrate the network analyzer before doing RF measurement. We usually do it like this.

i. Choose a suitable calibration kit.

ii. Set the correct frequency range.

iii. Set several markers.

iv. Connect three known terminations, 50 ohm load, short and open, to the connector.

v. Move the calibration plane to the feed point by using calibration extension function.

And ferrites **MUST** be used to reduce the influence from current running at the outer of the cable. This point is very important, and it's highly recommended to follow it.

Figure 3 Calibrate vector network analyzer

c) Antenna under test

The antenna should be placed in the real case when measuring return loss.

For example, if the device is a remote controller, you should measure return loss with the actual usage case. Since remote controller is handhold, it's recommended to take it by your hand when measuring.

d) Impedance matching

Usually Vector network analyzer (VNA) is used to tune an antenna.

Antenna type, ground size, and distance from antenna to ground are the parameters that can affect the impedance. By changing them, it is possible to improve the impedance.

Discreet components can also be used to tune antenna by smith chart on VNA.

5 Antenna Simulation Sample 1

5.1 Module figure

Figure 4 shows dimensions of a module board (Dual-layer FR4, board thickness is 1mm) and combined antenna.

The maximum gain for this antenna is 3dBi or so.

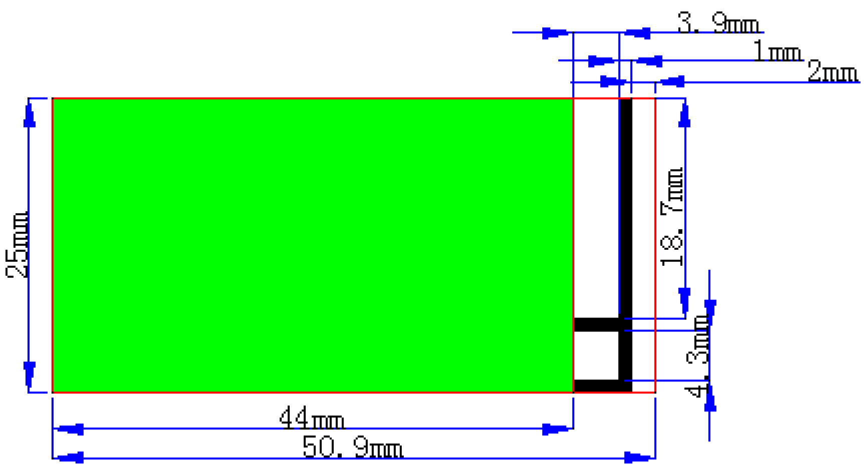


Figure 4 Module figure 1

5.2 S11 figure

Figure 5 shows S11 figure.

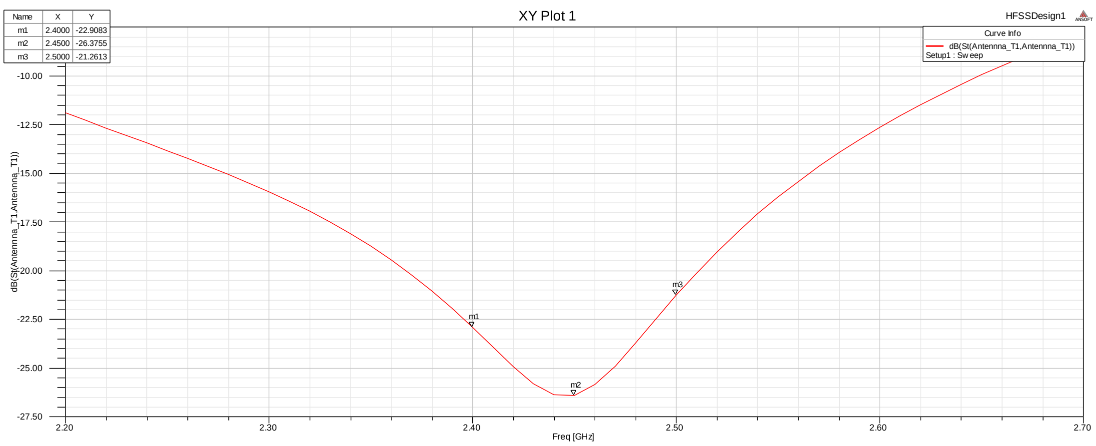


Figure 5 S11 figure 1

5.3 Radiation figure

Figure 6 shows radiation figure.

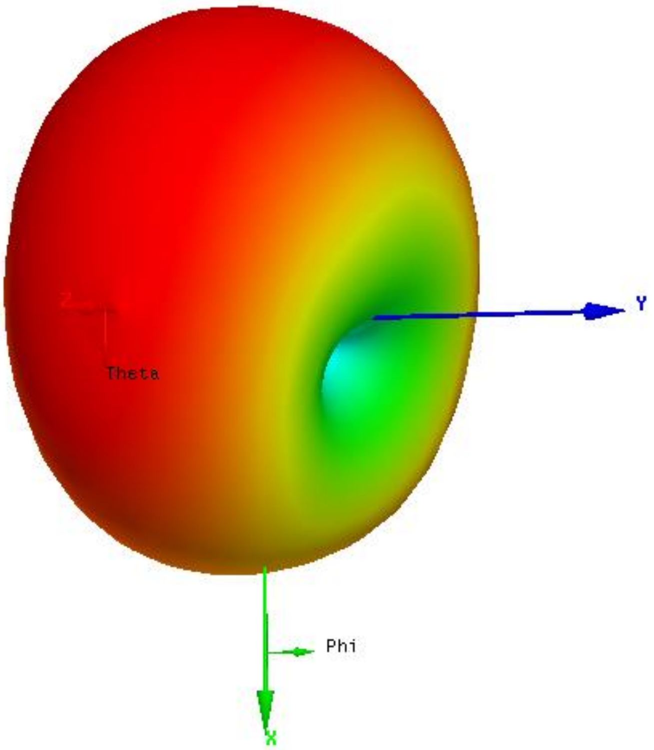
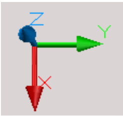


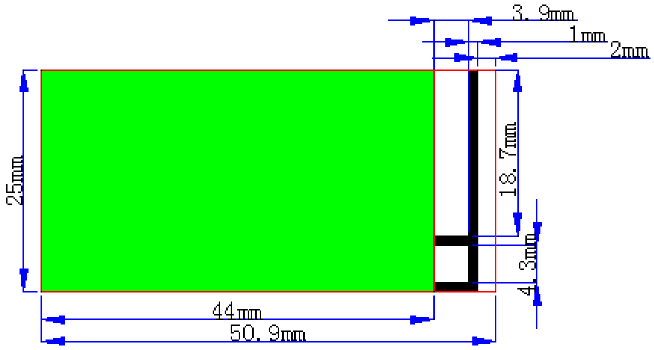
Figure 6 Radiation figure 1

5.4 Antenna description log

1. External view drawing

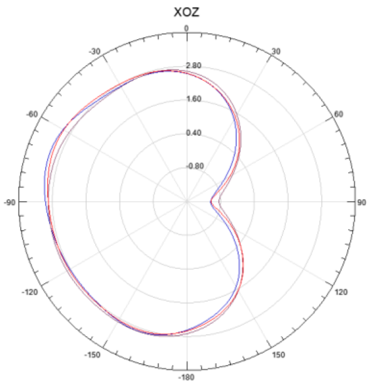
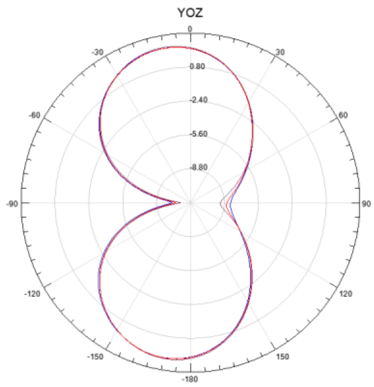
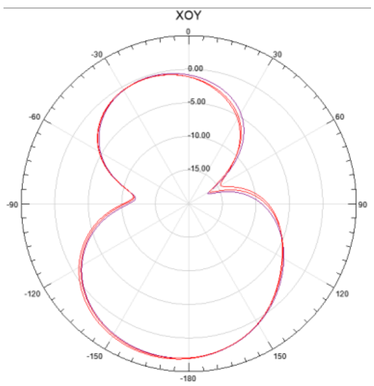
Picture of antenna





2. Antenna Radiation Pattern

	ZX plane		ZY plane		XY plane	
Frequency	Max Value	Average	Max Value	Average	Max Value	Average
[MHz]	[dBi]	[dBi]	[dBi]	[dBi]	[dBi]	[dBi]
2400	3.09	1.77	2.84	-2.5	3.12	-3.71
2450	2.95	1.82	2.92	-2.59	3.06	-3.75
2500	3.18	1.71	2.83	-2.42	3.28	-3.55

Radiation Pattern XOZ	Radiation Pattern YOZ	Radiation Pattern XOY
		

6 Antenna Simulation Sample 2

6.1 Module figure

Figure 7 shows dimensions of a module board (Dual-layer FR4, board thickness is 1mm) and combined antenna.

The maximum gain for this antenna is 2dBi or so.

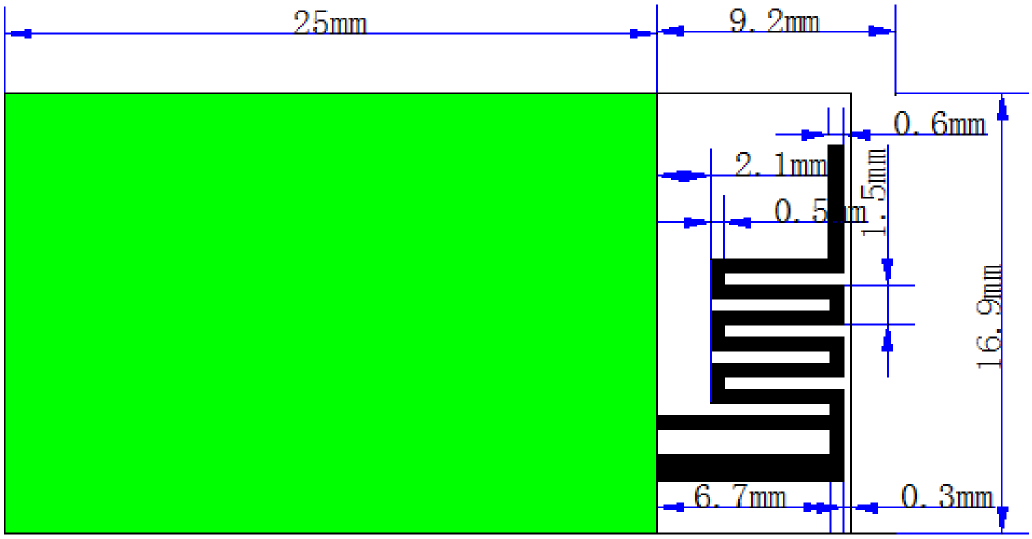


Figure 7 Module figure 2

6.2 S11 figure

Figure 8 shows S11 figure.

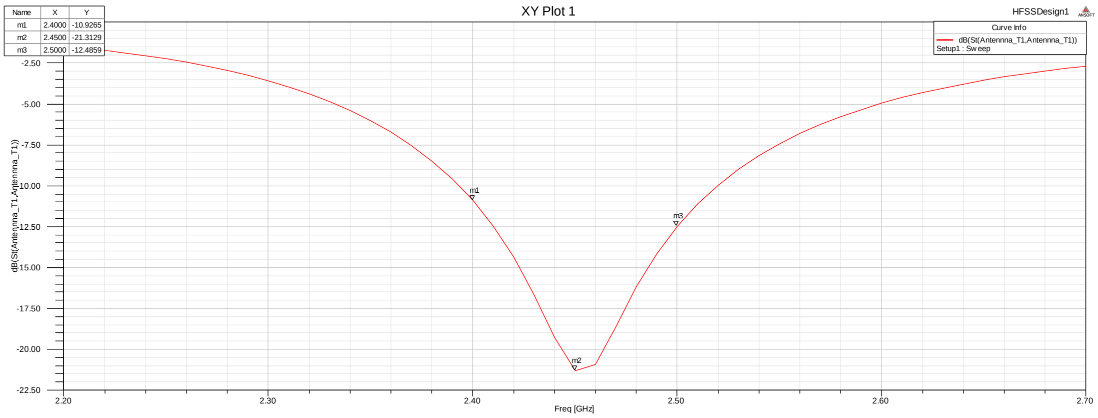


Figure 8 S11 figure 2

6.3 Radiation figure

Figure 9 shows radiation figure.

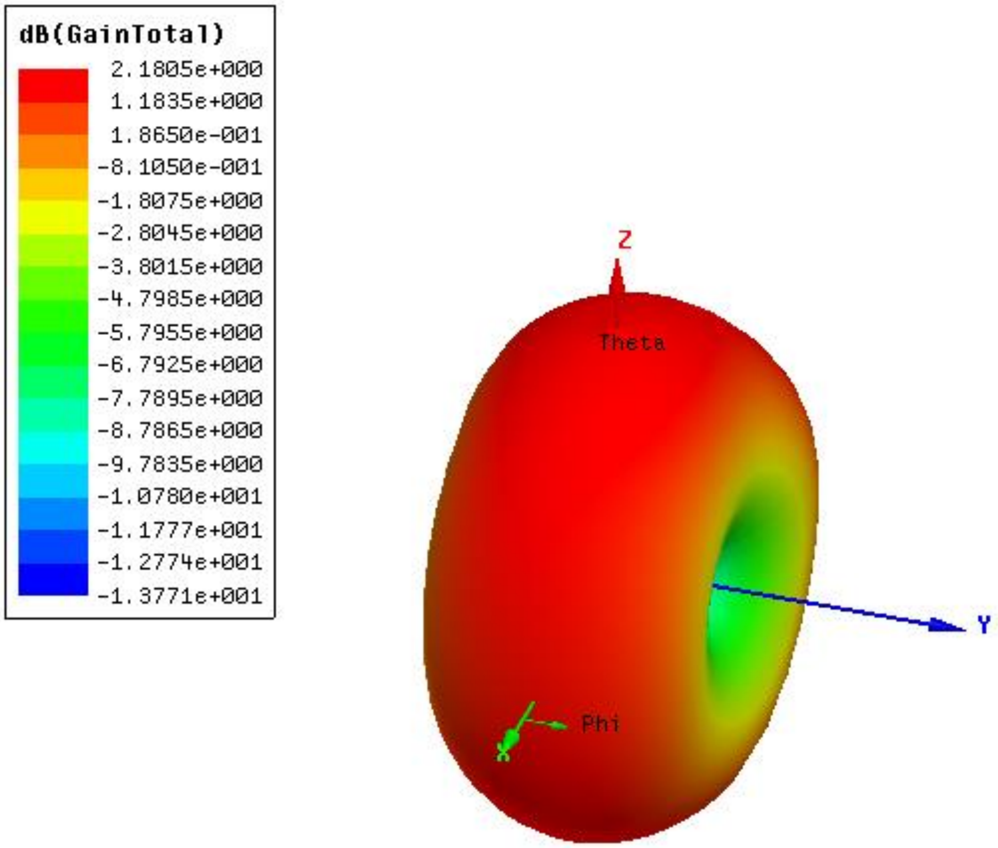
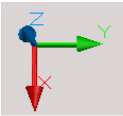


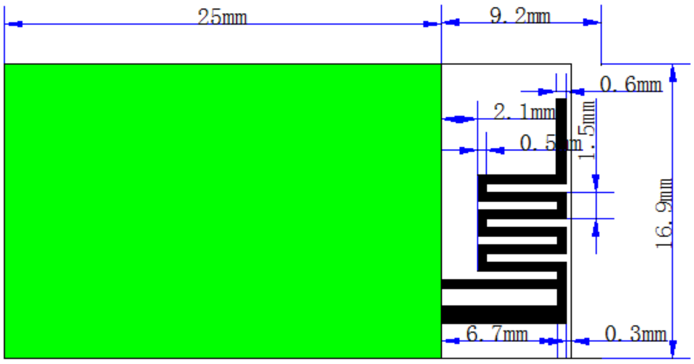
Figure 9 Radiation figure 2

6.4 Antenna description log

1. External view drawing:

Picture of antenna

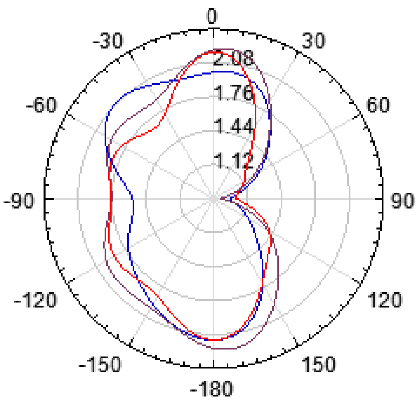




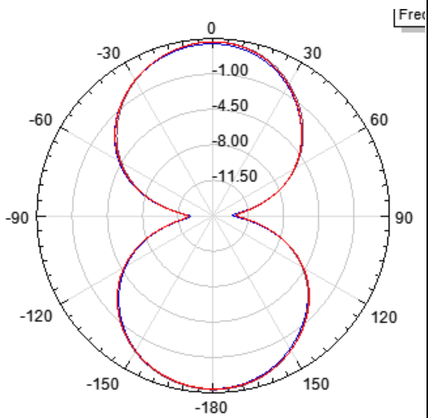
3. Antenna Radiation Pattern

	ZX plane		ZY plane		XY plane	
Frequency	Max Value	Average	Max Value	Average	Max Value	Average
[MHz]	[dBi]	[dBi]	[dBi]	[dBi]	[dBi]	[dBi]
2400	2.18	1.68	2.18	-3.17	1.78	-3.43
2450	2.23	1.77	2.21	-3.18	1.78	-3.46
2500	2.13	1.70	2.13	-3.27	1.58	-3.52

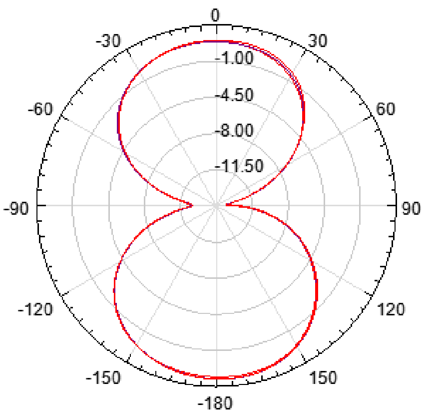
Radiation Pattern XOZ



Radiation Pattern YOZ



Radiation Pattern XOY



7 Antenna Simulation Sample 3

7.1 Module figure

Figure 10 shows dimensions of a module board (Dual-layer FR4, board thickness is 1mm) and combined antenna.

The maximum gain for this antenna is 3dBi or so.

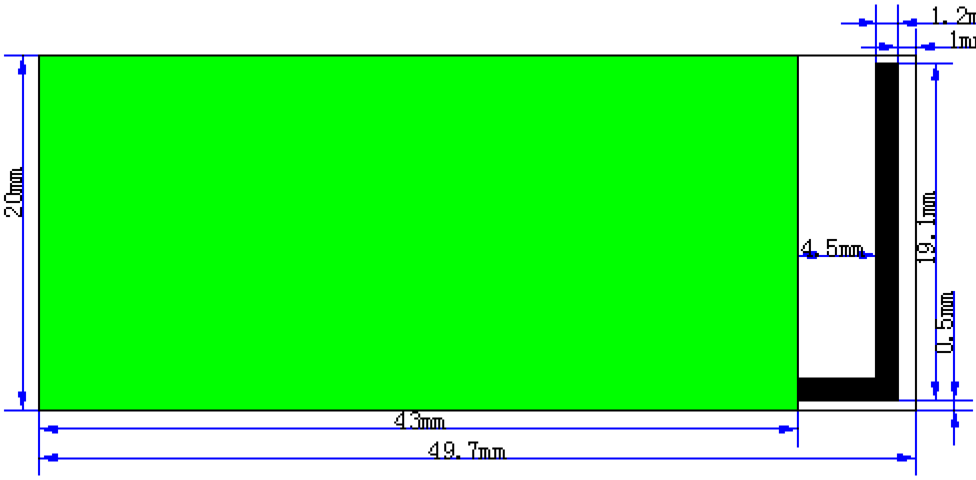


Figure 10 Module figure 3

7.2 S11 figure

Figure 11 shows S11 figure.

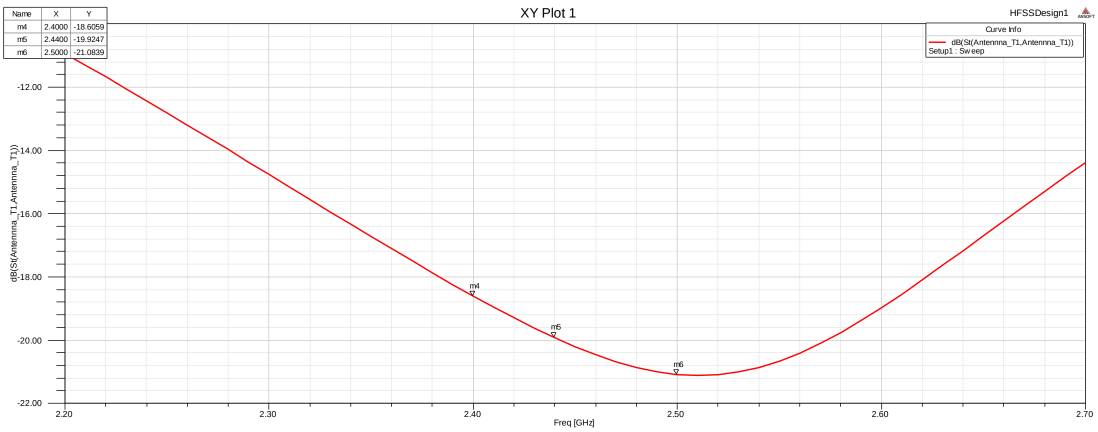


Figure 11 S11 figure 3

7.3 Radiation figure

Figure 12 shows radiation figure.

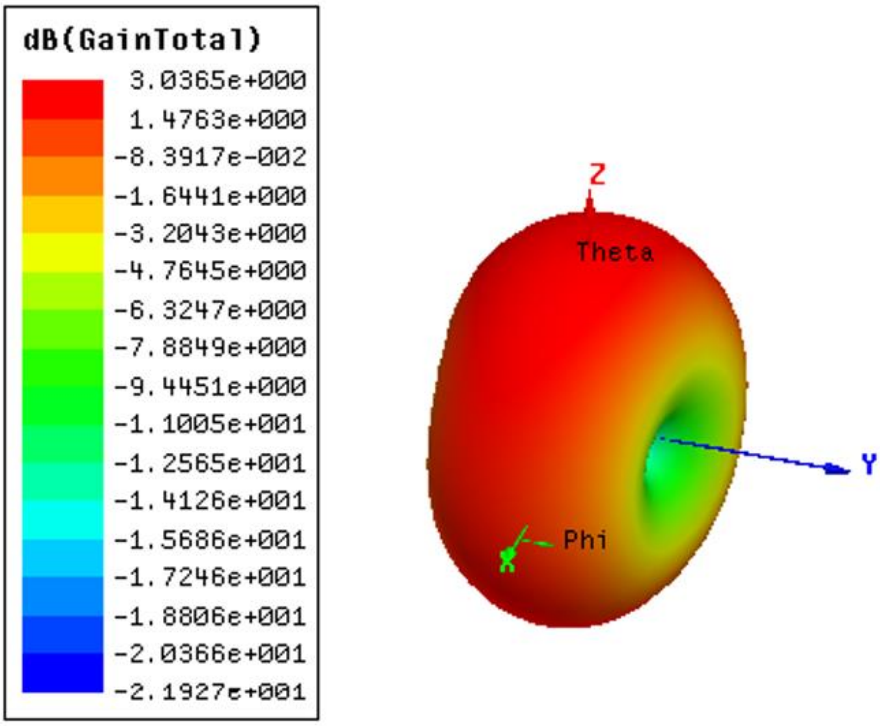
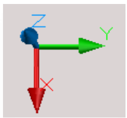


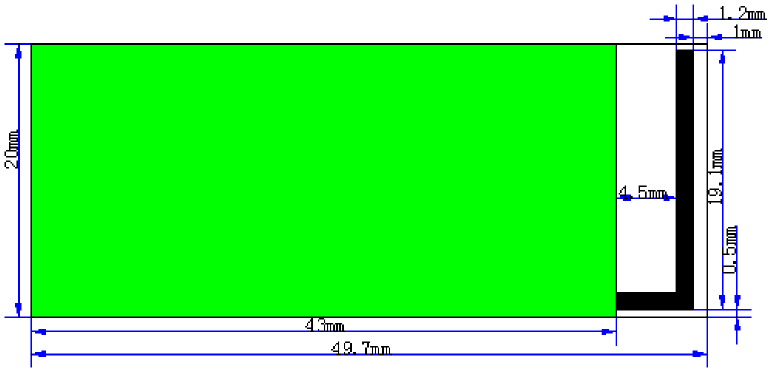
Figure 12 Radiation figure 3

7.4 Antenna description log

1.External view drawing:

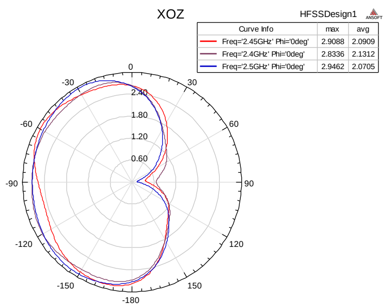
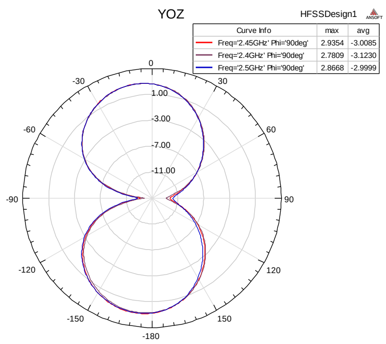
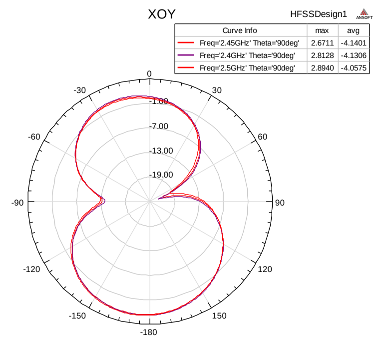
Picture of antenna





2.Antenna Radiation Pattern

	ZX plane		ZY plane		XY plane	
Frequency	Max Value	Average	Max Value	Average	Max Value	Average
[MHz]	[dBi]	[dBi]	[dBi]	[dBi]	[dBi]	[dBi]
2400	2.91	2.09	2.93	-3.00	2.67	-4.14
2450	2.83	2.13	2.78	-3.12	2.81	-4.13
2500	2.95	2.07	2.87	-3.00	2.89	-4.05

Radiation Pattern XOZ	Radiation Pattern YOZ	Radiation Pattern XOY
		

8 Small-Dimension Antennas

The two types of antennas shown in this section apply to applications with requirement for highly limited board size (e.g. dongle and module). In actual applications, as long as board size allows, it’s recommended to adopt antenna with larger area for better performance.

8.1 Sample 1

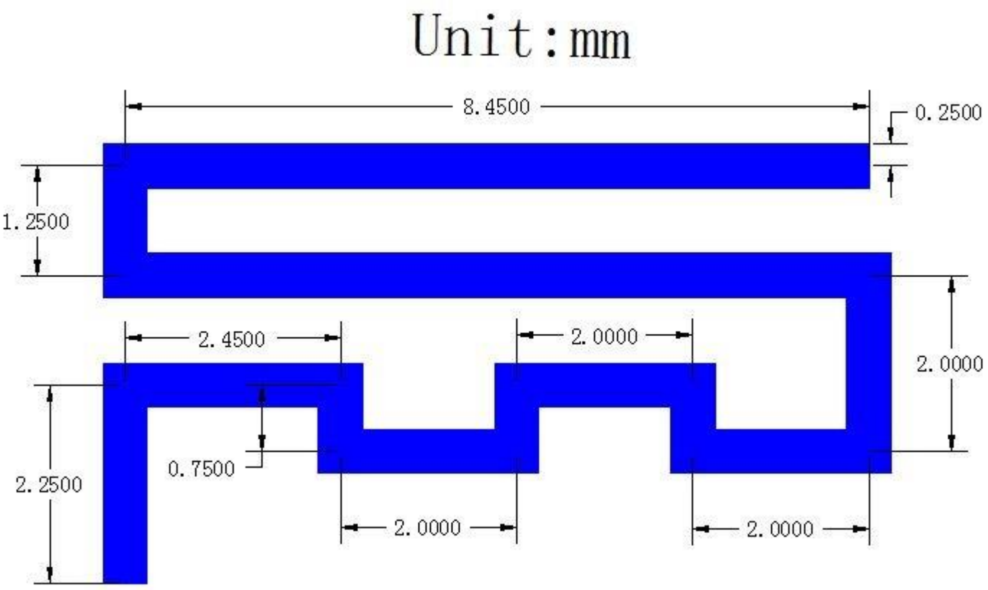


Figure 13 Sample 1

8.2 Sample 2

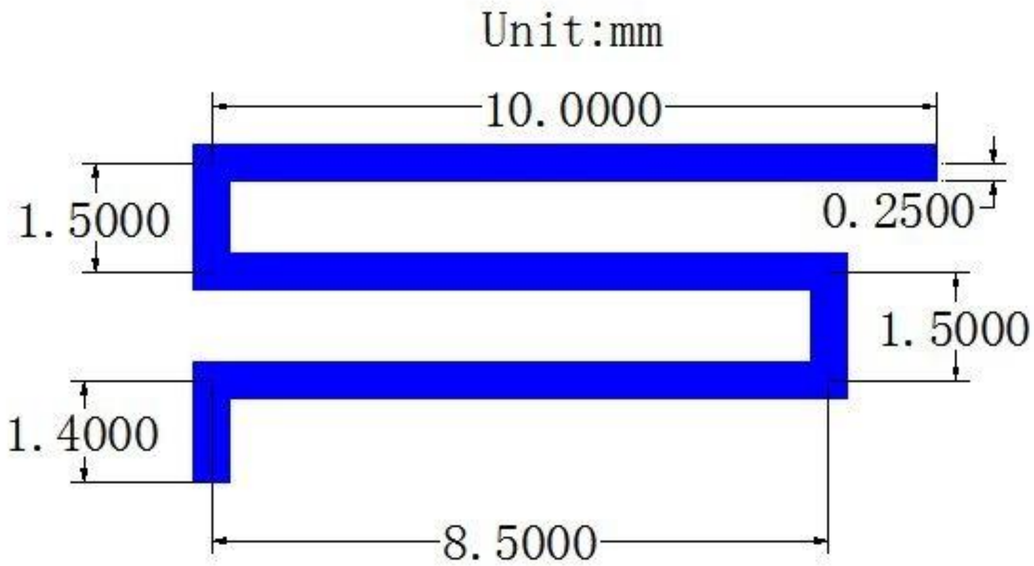


Figure 14 Sample 2