ISP4520
Application note AN200601

INSIGHTSIP

LoRa Range versus PCB size and module position

LoRa Alliance™ Bluetooth® SMART

Scope

This application note describes the performance of the LoRa antenna, embedded in the ISP4520, as a function of the size of the application PCB and the position of the module on the PCB. The results are based on 3D electromagnetic simulations using ANSYS HFSS tool.

Contents

Revision History

Revision	Date	Ref	Change Description
R0	05/02/2021	pg	Preliminary release
R1	09/06/2022	pd pg	Document layout update

1. Introduction

The performance of all antennas is strongly dependent on the immediate environment.

The following parameters have the strongest effect on antenna performance:

- Size and shape of the metal plane, commonly called "ground plane" to which the antenna is attached
- Position of the antenna relative to the "ground plane"
- Position and dielectric constant of non-conducting elements that are near to the antenna. This includes any PCB material that is directly under the antenna and any plastic enclosure around the antenna.
- Position of any other metal objects near the antenna

The ISP4520 contains an embedded LoRa antenna. The application PCB, on which the module is mounted, acts as the "ground plane". In this study the size of this application board and the position of the module on the board are considered to determine the tradeoffs between size and communication range.

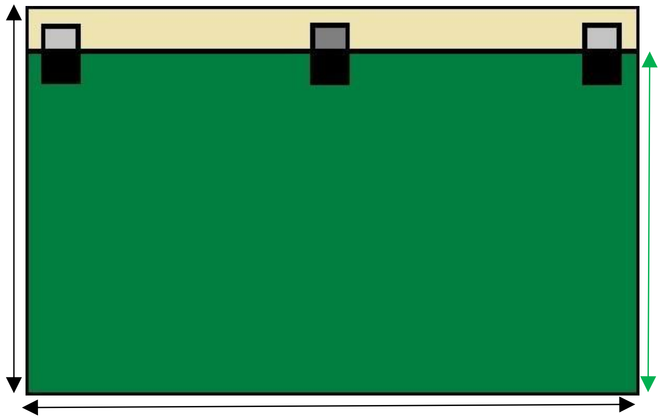
2. Simulations criteria

2.1. Simulation

The simulation model is shown below:

Length variation between 50mm and 130mm.

PCB material is typical FR4 with ϵ_r = 4.4 and loss factor 0.02 with thickness t=1 mm.

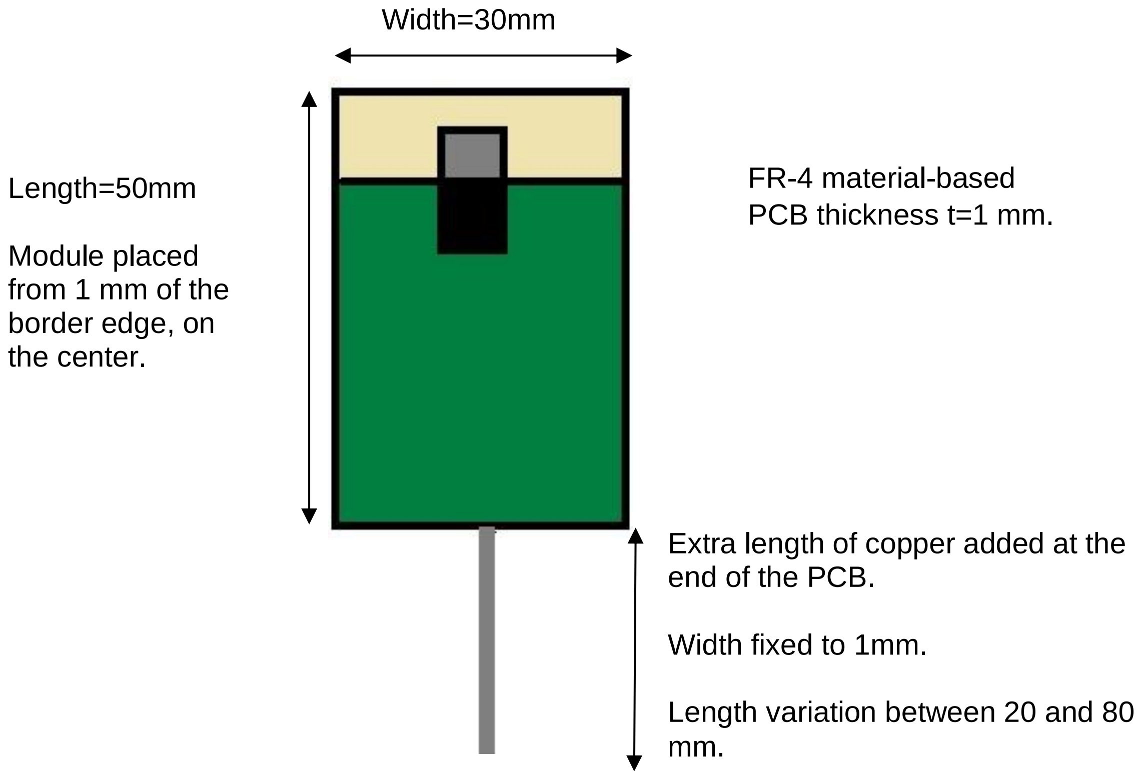


Module positioned from 1mm of the border edge. On the left corner, center and right corner.

Keepout zone:
The PCB is metallized over the entire surface with the exception of the top portion

Width variation between 30mm and 50mm.

In addition to the above, the smallest application board 50 x 30 mm is simulated with a central tail as shown in the diagram below. The tail could be implemented by a wire or other piece of metal in a practical case. The total length of the board plus tail L' is varied from 50 to 130mm.



2.2. Key results from the simulation

The electromagnetic simulations provide a large number of results. The results that are used to determine the overall performance of the antenna are described below:

- S11 – Return Loss (dB). This parameter measures the energy that is reflected by the antenna due to mismatch. A return loss of 10 dB implies that 90% of the energy is transmitted and consequently 0.5dB is "lost". A return loss of 6dB implies that 75% of the energy is transmitted and consequently 1.25 dB is "lost". This parameter is often used as the sole factor of merit for an antenna, but in the case of small antennas on small ground planes antenna efficiency is often more important.

- The total peak realised antenna Gain Gr (dBi). This is the key parameter that defines the overall performance of the antenna. This parameter includes the effects due to return loss, antenna efficiency and directivity. For a given transmitter power it describes the maximum power received at a fixed distance compared to that received from an isotropic radiator.

- 3D radiation patterns show the directionality of the antenna system

In order to assess how antenna performance impacts communication range for a LoRa system two key system parameters have to be taken into account:

- Receive sensitivity. This describes the minimum power level at which LoRa packets can be successfully received. A maximum packet error rate of 1% is taken as the limit. LoRa uses sophisticated coding to improve sensitivity by reducing actual data rates; this is defined by a “spreading factor” SF that can be varied between 7 and 12.

- Transmit power.

The following formula was used to determine the maximum transmission loss (TrLoss) for a given set of antenna and system parameters:

$$Pr(dBm) = Pin(dBm) + Gin(dBi) + Gr(dBi) + \mathrm{TRLoss}(dB)$$

Where

$Pr(dBm)$ is received signal strength
$Pin(dBm)$ is transmitter power
$Gin(dBi)$ is transmitter realised antenna gain
$Gr(dBi)$ is receiver realised antenna gain
$TRLoss(dB)$ is loss due to transmission

In order to equate maximum transmission loss to actual maximum communication range it is necessary to use an algorithm that relates the two parameters.

The module is near the ground, the transmission isn’t considered infree space, the Transmissions Loss empirical formula is:

$$TRLoss(dB) = 10Log[\left(\frac{\lambda}{4\pi R}\right)^2 \frac{1}{R}]$$

The calculations were done using the European version of the ISP4520 module, what means that the resonance frequency Fr=868 MHz, adding that the input power of the module is Pin=14dBm.

In order to calculate the attenuation, the sensitivity is used as Receive power Pr=-124 dBm or -137dBm depending of the spreading factor, the sensitivity is the minimal receive power, after what the receiver doesn’t receive the data. We remind that the ISP4520 using the protocol LoRa, it means that it has a spreading factor SF (7-12) with bandwidth=125kHz.

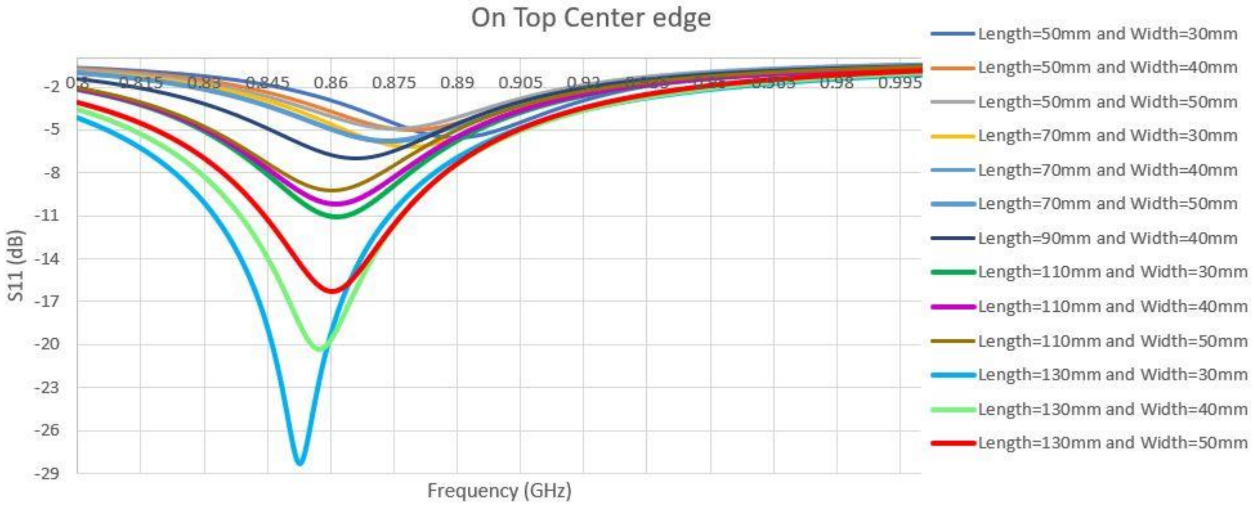
$$Pr = -137dBm\ with\ SF12\ and\ Bandwith = 125kHz.$$
$$Pr = -124dBm\ with\ SF7\ and\ Bandwidth = 125kHz.$$

3. Simulation results

The simulations are done with different sizes of the PCB, and are referred according to their position.

3.1. ISP4520 on top center edge

The chart represents the results of a simulation of ISP4520-EU module on the top center edge for a PCB with a thickness of t=1mm with different sizes in length and width.



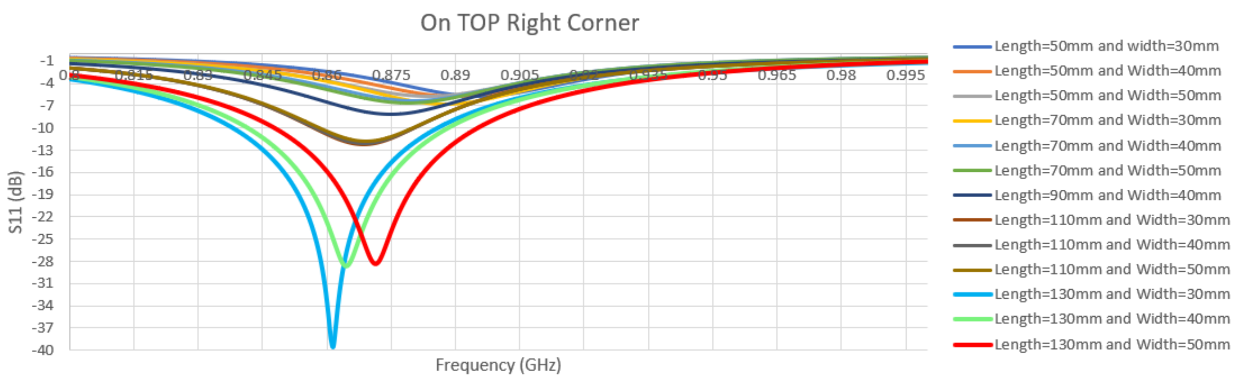
The table shows the different criteria referred to above for a resonance frequency Fr=868Hz.

PCB Size (mm²)	S11 (dB)	Maximum Realised gain (dBi)	TRLoss(1) For SF12 (dB)	Distance D0(1) (km)	TRLoss(2) For SF7(dB)	Distance D1(2) (km)
L=50 W=30	-3.7	-6	145	6	132	2
L=50 W=40	-4.5	-6	145	6	132	2
L= 50 W=50	-4.7	-5.9	145.1	6	132.1	2
L=70 W=30	-5.5	-3.4	147.6	7.5	134.6	3
L=70 W=40	-5.6	-3.4	147.6	7.5	134.6	3
L=70 W=50	-5.6	-3.4	147.6	7.5	136.3	3
L=90 W=40	-7	-1.7	149.3	8.5	132.6	3.5
L=110 W=30	-10.4	-0.4	150.6	9.5	137.6	3.5
L=110 W=40	-9.6	-0.2	150.8	9.5	137.8	3.5
L=110 W=50	-8.6	-0.1	150.9	10	137.9	3.5
L=130 W=30	-13.8	0.7	151.7	10.5	138.7	4
L=130 W=40	-14.8	0.8	151.8	10.5	138.9	4
L=130 W=50	-14.3	1	152	10.5	139	4

(1) TRLoss for SF12 refers to the attenuation calculated with Pr=-137dBm FOR SF12 and bandwidth=125kHz. distance D0 refers to the distance calculated with the result of TRLoss for SF12.
(2) TRLoss for SF7 refers to the attenuation calculated with Pr=-124dBm for SF7 and bandwidth=125kHz. distance D1 refers to the distance calculated with the result of TRLoss for SF7.

3.2. ISP4520 on top right corner

The chart represents the results of a simulation of ISP4520-EU module on the top of a PCB with a thickness of t=1mm with different sizes in length and width.

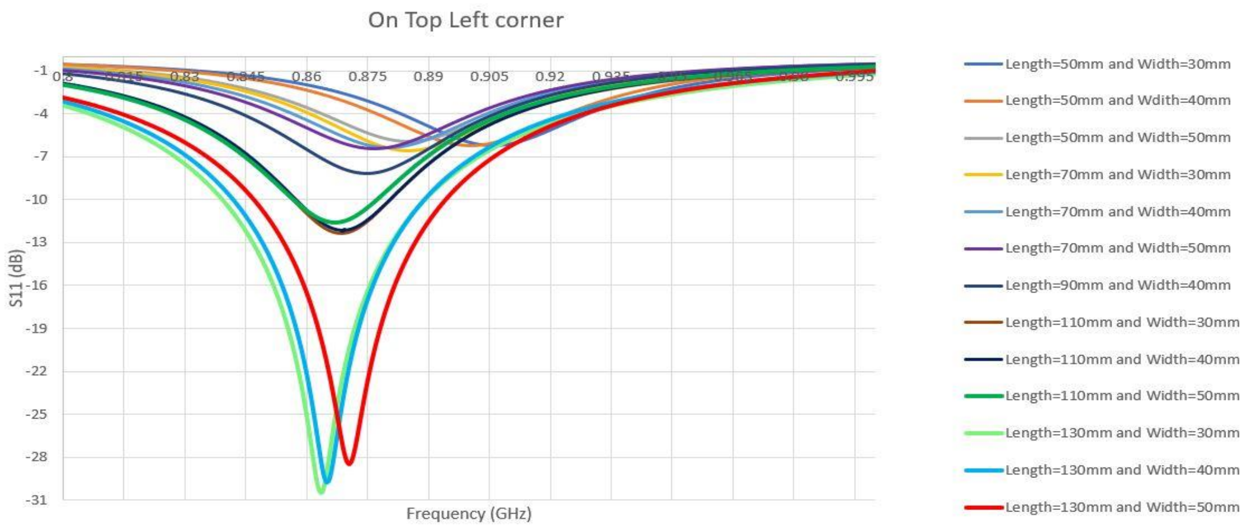


The table shows the different criteria referred to above for a resonance frequency Fr=868Hz.

PCB Size (mm^2)	S11(dB)	Realized Gain (dBi)	TRLoss for SF12 (dB)	Distance D0 (km)	TRLoss for SF7 (dB)	Distance D1 (km)
L=50 W=30	-2.5	-5.6	145.4	6.5	132.4	2.5
L=50 W=30	-3	-5	146	6.5	133	2.5
L=50 W=50	-4.5	-5.8	145.2	6.5	132.2	2.5
L=70 W=30	-5	-3.5	147.5	7.5	134.5	3
L=70 W=40	-5.5	-3.4	147.6	7.5	134.6	3
L=70 W=50	-6	-3.3	147.7	7.5	134.7	3
L=90 W=40	-7.8	-1.7	149.3	8.5	136.3	3
L=110 W=30	-12.3	-0.4	150.6	9.5	137.6	3.5
L=110 W=40	-12.1	-0.2	150.8	9.5	137.8	3.5
L=110 W=50	-11.5	0	151	10	138	3.5
L=130 W=30	-23.4	0.7	151.7	10.5	138.7	4
L=130 W=40	-25.2	0.9	151.9	10.5	138.9	4
L=130 W=50	-26.1	1	152	10.5	139	4

3.3. ISP4520 on the top left corner

The chart represents the results of a simulation of ISP4520-EU module on the top of a pcb with a thickness of t=1mm with differentes sizes in length and width.

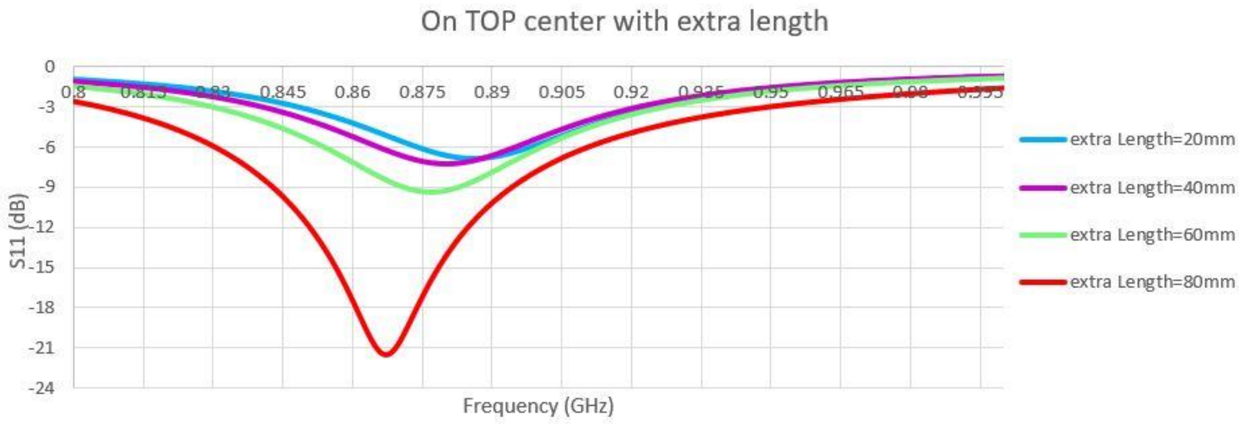


The table shows the different criteria referred to above for a resonance frequency Fr=868Hz.

PCB Size (mm²)	S11(dB)	Maximum Realized Gain (dBi)	TRLoss for SF12 (dB)	Distance D0 (km)	TRLoss for SF7 (dB)	Distance D1 (km)
L=50 W=30	-3.1	-6.5	144.5	6	131.5	2
L=50 W=40	-3.8	-5.5	145.6	6.5	132.5	2.5
L=50 W=50	-4.6	-4.1	147	7	134	2.5
L=70 W=30	-4.8	-3.1	148	8	135	3
L=70 W=40	-5.5	-3	148	8	135	3
L=70 W=50	-6	-2.4	148.6	8	135.6	3
L=90 W=40	-7.7	-1	149.9	9	136.9	3.5
L=110 W=30	-12.3	0.2	151.2	10	138.2	3.5
L=110 W=40	-12.1	0.2	151.2	10	138.2	3.5
L=110 W=50	-11.8	0.2	151.2	10	138.2	3.5
L=130 W=30	-20.5	1.2	152.2	11	139.2	4
L=130 W=40	-24	1.1	152.1	11	139.1	4
L=130 W=50	-24.6	1.1	151.1	11	139.1	4

3.4. ISP4520 on Top Center Edge of the PCB with extra length

In the case, the PCB has a fixed small size, the solution is to add a length of copper at the end of the PCB. The simulation was done on the criteria mentioned above, and the results are presented in the following chart.

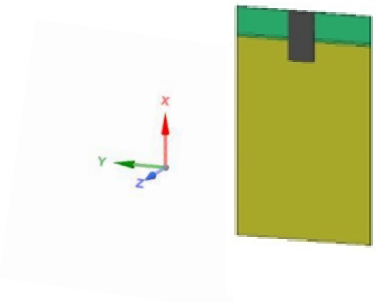


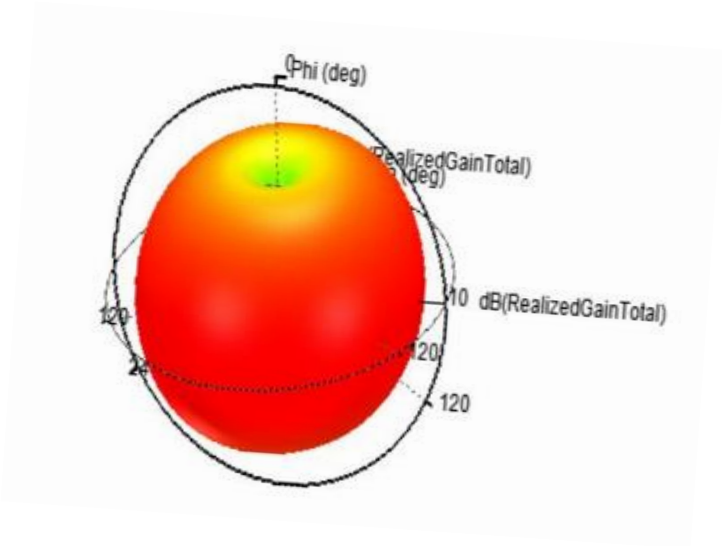
The table below represents the results of the simulation at the resonance frequency fr=868MHz, note that the length of the PCB is L=50mm and its width is fixed to 30mm.

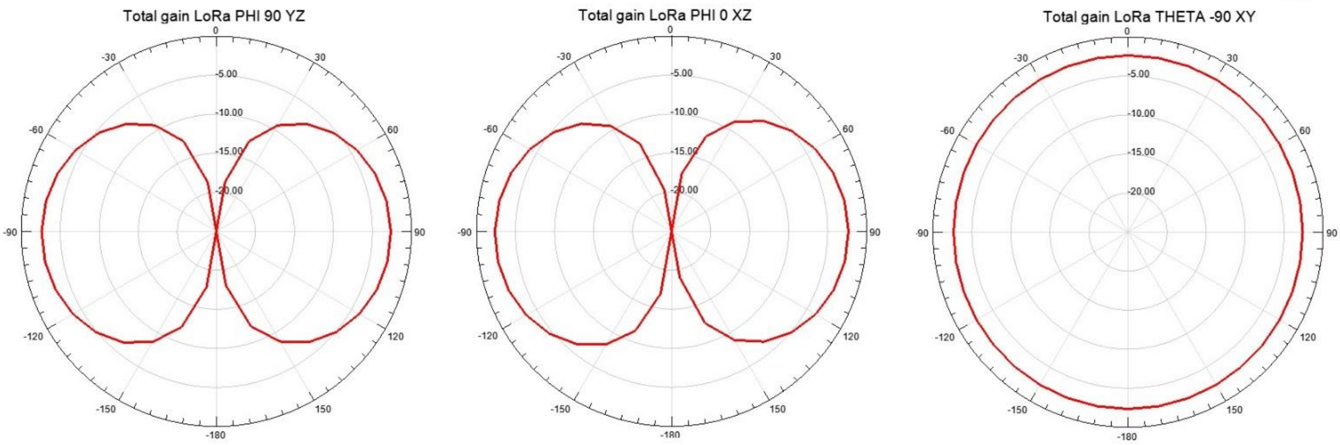
Extra length (mm)	S11(dB)	Maximum Realized Gain (dBi)	Attenuation A0 (dB)	Distance D0 (km)	Attenuation A1 (dB)	Distance D1 (km)
20	-5.3	-3.2	147.8	7.5	134.8	3
40	-6.4	-2.2	148.8	8.5	135.8	3
60	-8.6	-0.8	150.2	9	137.2	3.5
80	-21.4	0.8	151.8	10.5	138.2	4

3.5. Radiation pattern of the ISP4520

Here are shown the radiation pattern of the LoRa's antenna of the ISP4520 module at the resonance frequency Fr=868 MHz.







Note: The radiation pattern shape is the same in all the simulation, only the values will change with the PCB dimension.

4. About this project

This application has been built by the support team at Insight SIP, as a demo of some particular feature or use case.

Please post any questions about this project on https://www.insightsip.com/contact.