

# LoRa Range versus PCB size and module position



## Application Note AN200601



### 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

<b>1. Introduction .....</b>	<b>2</b>
<b>2. Simulations criteria .....</b>	<b>2</b>
2.1. Simulation .....	2
2.2. Key results from the simulation .....	3
<b>3. Simulation results .....</b>	<b>5</b>
3.1. ISP4520 on top center edge .....	5
3.2. ISP4520 on top right corner .....	6
3.3. ISP4520 on the top left corner .....	7
3.4. ISP4520 on Top Center Edge of the PCB with extra length .....	8
3.5. Radiation pattern of the ISP4520 .....	9
<b>4. About this project .....</b>	<b>9</b>

## 1. Introduction

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

The following parameters have the strongest effect on antenna performance:

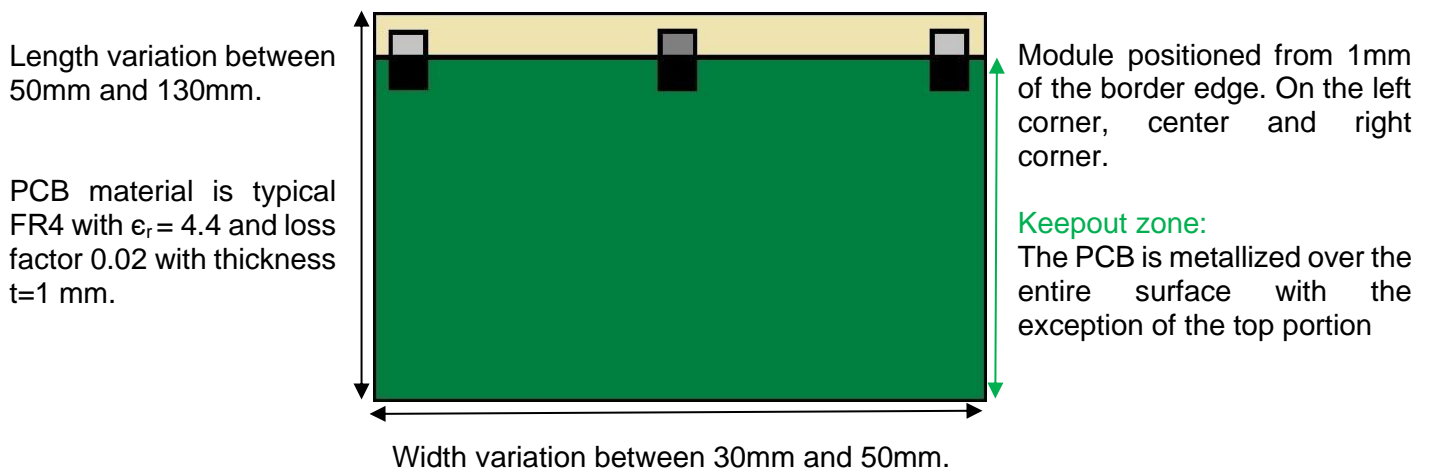
- Size and shape of the metal plane, commonly called “ground plane” to which the antenna is attached
- Position of the antenna relative to the “ground plane”
- Position and dielectric constant of non-conducting elements that are near to the antenna. This includes any PCB material that is directly under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

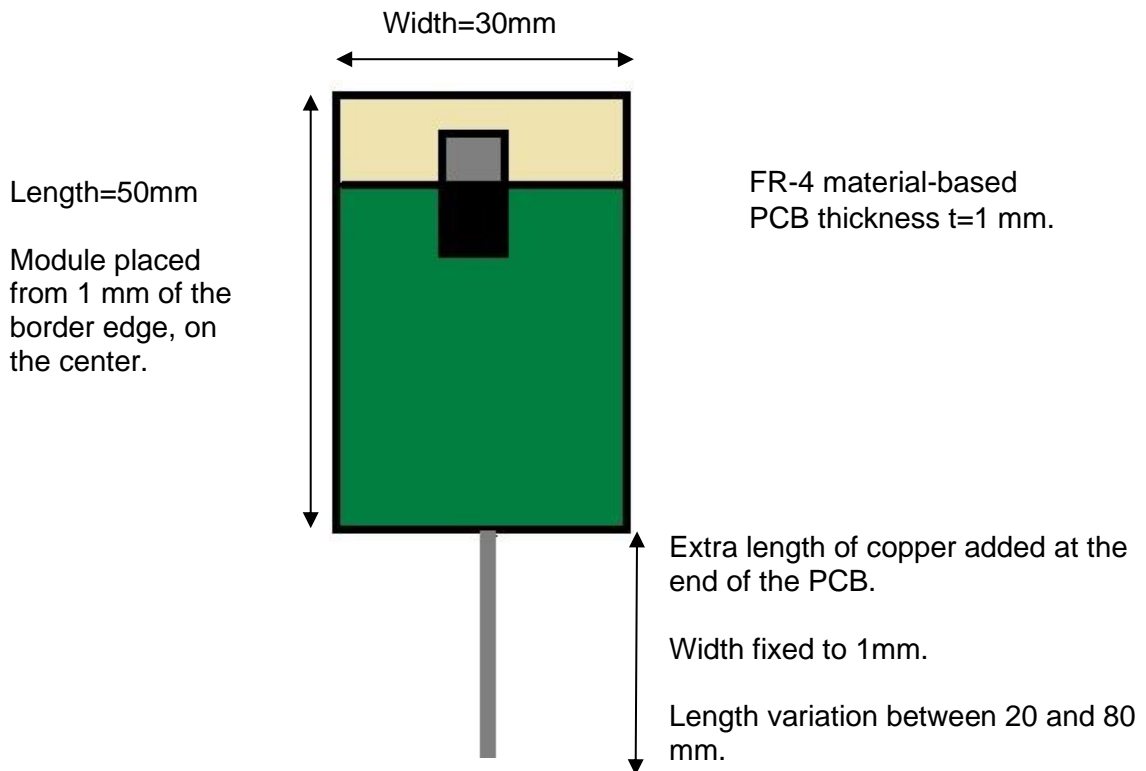
### 2.1. Simulation

The simulation model is shown below:





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  $G_r$  (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:

$$Pr(dBm) = Pin(dBm) + Gin(dBi) + Gr(dBi) + TRLoss(dB)$$

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 in free space, the Transmission Loss empirical formula is:

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

The calculations were done using the European version of the ISP4520 module, what means that the resonance frequency  $f_r=868$  MHz, adding that the input power of the module is  $P_{in}=14$  dBm.

In order to calculate the attenuation, the sensitivity is used as Receive power  $P_r=-124$  dBm or  $-137$  dBm 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.

$$Pr = -137dBm \text{ with SF12 and Bandwidth} = 125kHz.$$

$$Pr = -124dBm \text{ with SF7 and Bandwidth} = 125kHz.$$

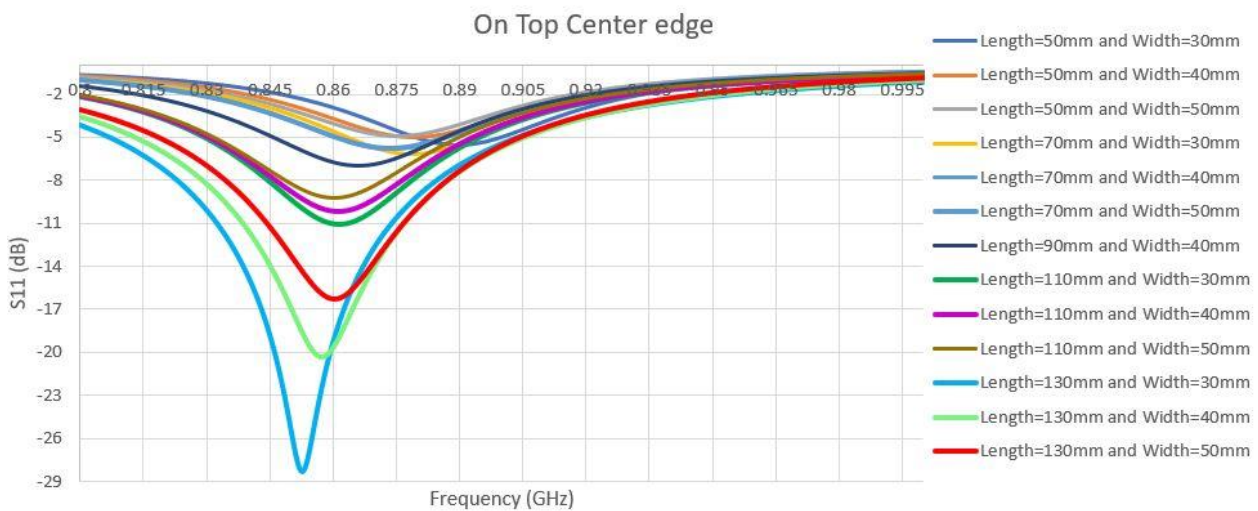


### 3. Simulation results

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  $t=1\text{mm}$  with different sizes in length and width.



The table shows the different criteria referred to above for a resonance frequency  $F_r=868\text{Hz}$ .

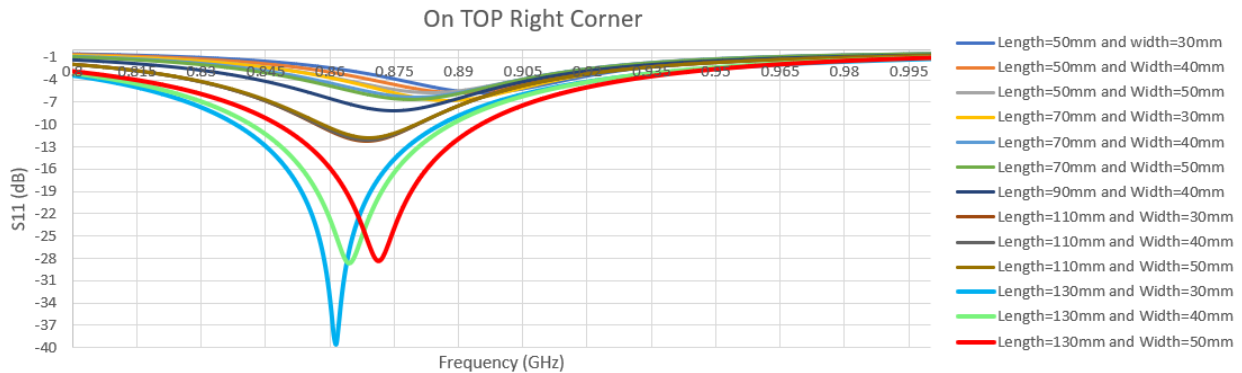
PCB Size (mm <sup>2</sup> )	S11 (dB)	Maximum Realised gain (dBi)	TRLoss <sup>(1)</sup> For SF12 (dB)	Distance D0 <sup>(1)</sup> (km)	TRLoss <sup>(2)</sup> For SF7 (dB)	Distance D1 <sup>(2)</sup> (km)
L=50 W=30	-3.7	-6	145	6	132	2
L=50 W=40	-4.5	-6	145	6	132	2
L= 50 W=50	-4.7	-5.9	145.1	6	132.1	2
L=70 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  $P_r=-137\text{dBm}$  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  $P_r=-124\text{dBm}$  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  $t=1\text{mm}$  with different sizes in length and width.



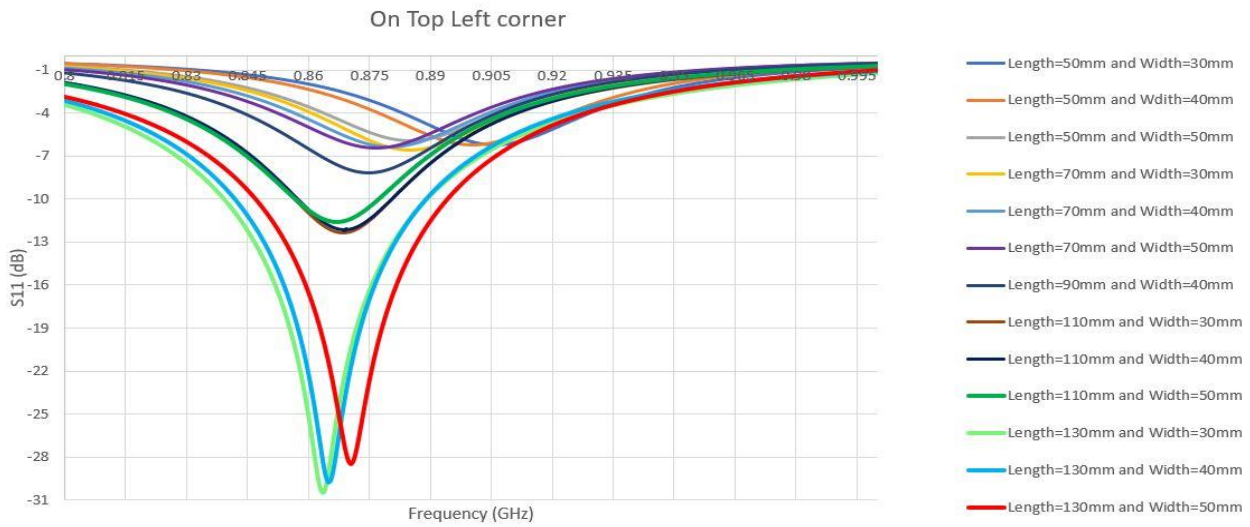
The table shows the different criteria referred to above for a resonance frequency  $F_r=868\text{Hz}$ .

PCB Size (mm <sup>2</sup> )	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.



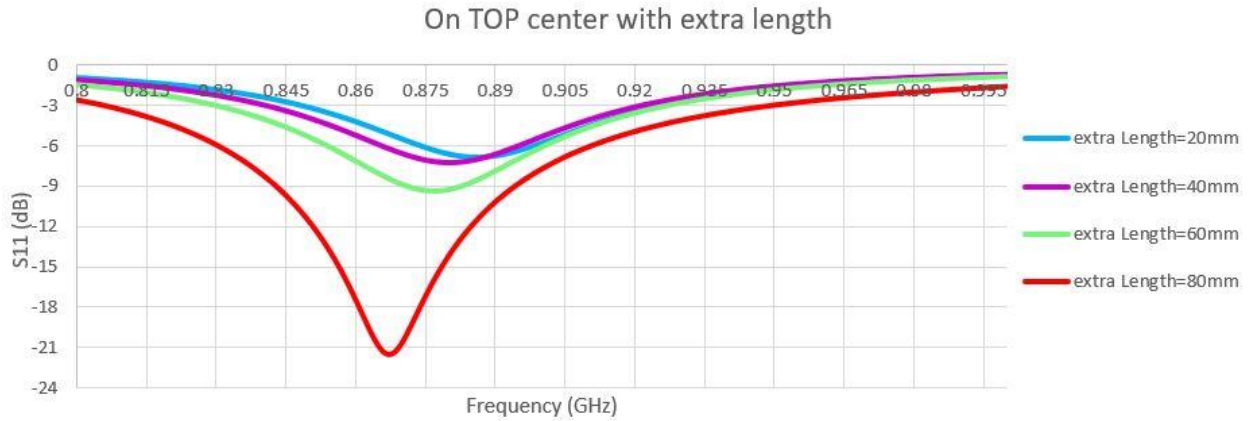
The table shows the different criteria referred to above for a resonance frequency  $F_r=868\text{Hz}$ .

PCB Size (mm <sup>2</sup> )	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.



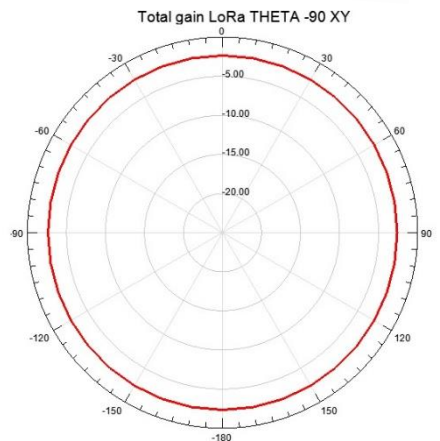
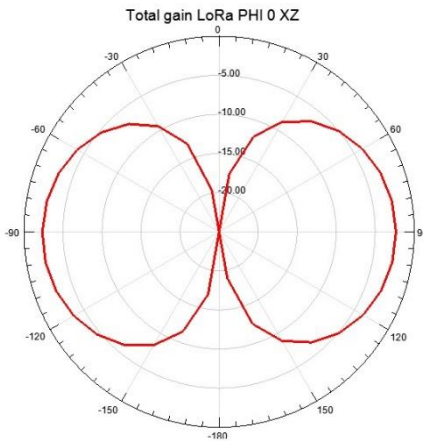
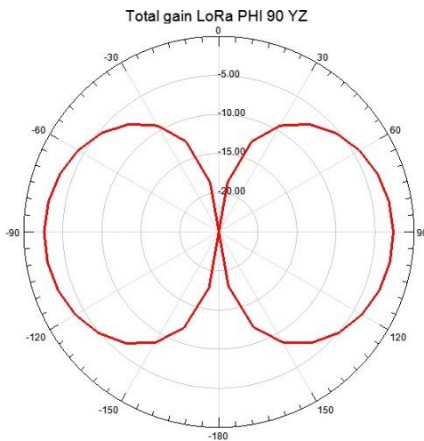
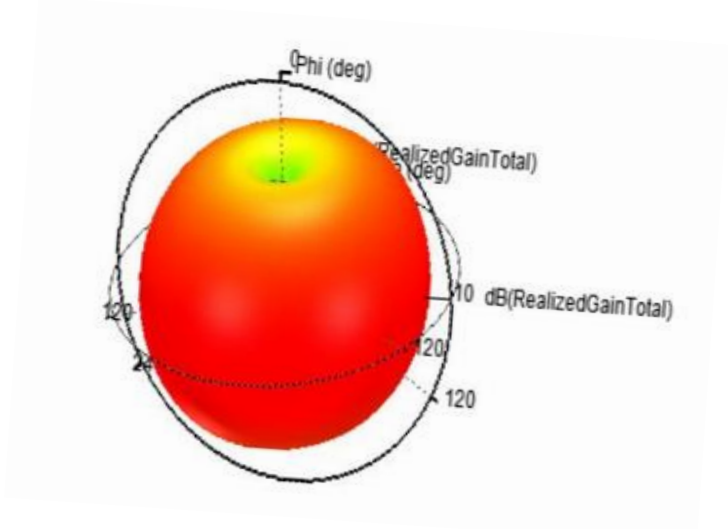
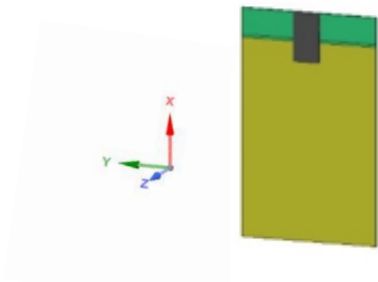
The table below represents the results of the simulation at the resonance frequency  $f_r=868\text{MHz}$ , note that the length of the PCB is  $L=50\text{mm}$  and its width is fixed to  $30\text{mm}$ .

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  $F_r=868$  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>.