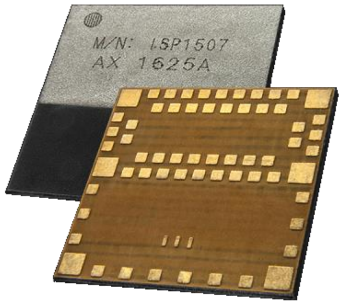
Application note AN210501

BLE Range versus Ground Plane Size and Module Position



Introduction

Scope

This document describes the performance of the BLE antenna, embedded in ISP1507, ISP1807 and ISP1907 modules, 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

1. Antenna area

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

The target is to have a clear understanding of the effects of different parameters on the antenna performance and consequently communication range of the ISP Module.

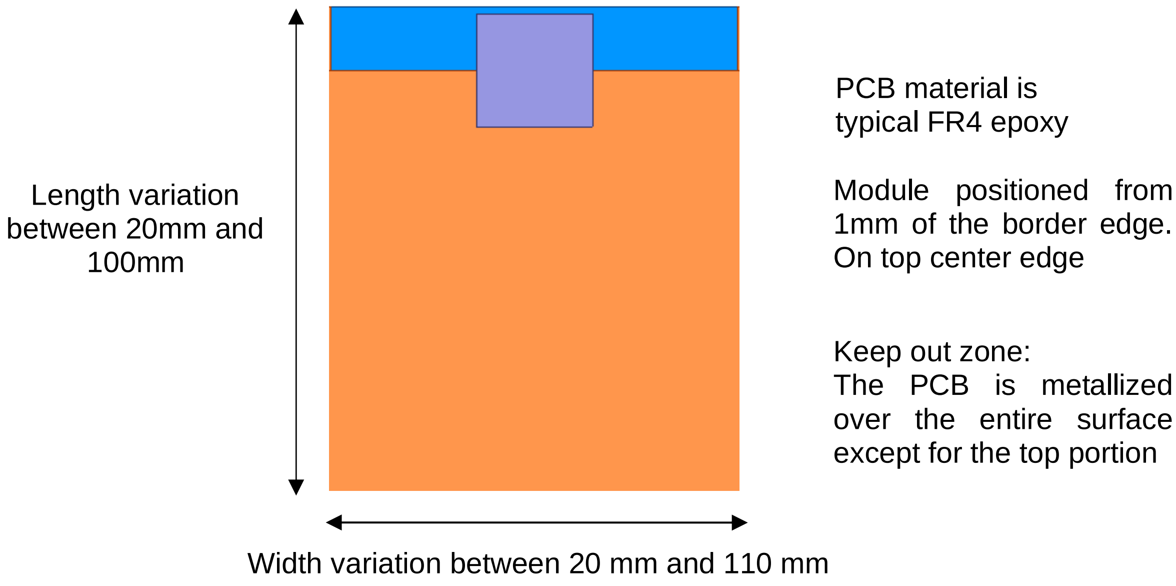
Specifically, the following effects have an influence on the antenna performance:

- Ground Plane size and module position on application PCB
- Manufacturing tolerances of the antenna
- Material property variations of the module and application PCB
- Position and dielectric constant of non-conducting elements that are near to the antenna
- Position of any others metal objects near to the antenna
- Change in permittivity of materials used for molding and PCB

In this application note, we focus on the ground plane size effects.
Manufacturing tolerances and material properties are under close control in our module.
The other effects are too dependent on the customer application to be analyzed in this application note.

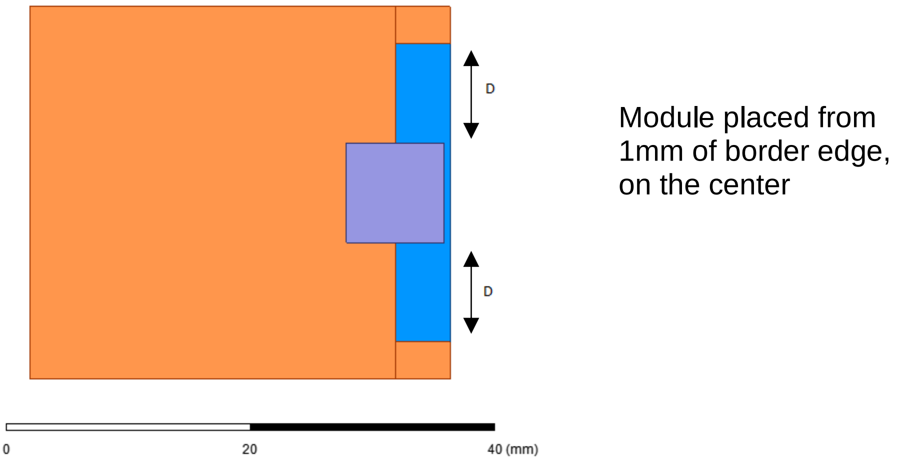
2. Simulation criteria

2.1. Simulation



In addition to the above, the module will be positioned on the left corner and the right corner into other simulations.

Furthermore, the small application board 30 x 30 mm^2 is simulated with metal layers implemented on both sides of the board (on top corners), as shown in the diagram below. Its width is varied from 1 mm to 10 mm.



Width and length are 30mm

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 0.5 db is lost. A return loss of 6 dB 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 efficiency of an antenna concerns the power delivered to the antenna and the power radiated or dissipated in the antenna. The efficiency is very often quoted in terms of percentage, for example, an efficiency of 0.5 is the same as 50%. Antenna efficiency is also often quoted in decibels (dB), an efficiency of 0.1 is10% or (-10 dB), and an efficiency of 0.5 or 50% is 3dB.

- The radiation patterns show the directionality of the antenna system.

- Bluetooth Low Energy (BLE) is an emerging low-power wireless technology developed for short-range control and monitoring applications that is expected to be integrated into billions of devices over the next few years.

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

- The Received Sensitivity: is defined in BLE as the signal level at the receiver for which a Binary Error Rate (BER) of $10^{-3}$is obtained. The BLE specification imposes a sensitivity better than or equal to -70 dBm. The coverage range is typically several tens of meters.

- The B.E.R: abbreviation for Bit Error Rate, is a value, relative to the error rate, measured at the reception of a digital transmission, relative to the level of attenuation and/or disturbance of a transmitted signal.

- Transmit power: The following formula was used to determine 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 to actual maximum communication range it is necessary to use an algorithm that relates the two parameters.

The module is near to the ground, the transmission is not considered in free space, the Transmission Loss empirical formula is:

$$TRLoss(dB) = 10Log\,[(\frac{\lambda}{4\pi R})^{2.6}]$$

The calculations were done using the ISP Module, what means that the resonance frequency Fr=2.4GHz, adding that the maximum output power of the module is Pin=4dBm.

In order to calculate the attenuation, the sensitivity is used as Receive power. The module has sensitivity of -96dBm when we use 1Mbits/s.

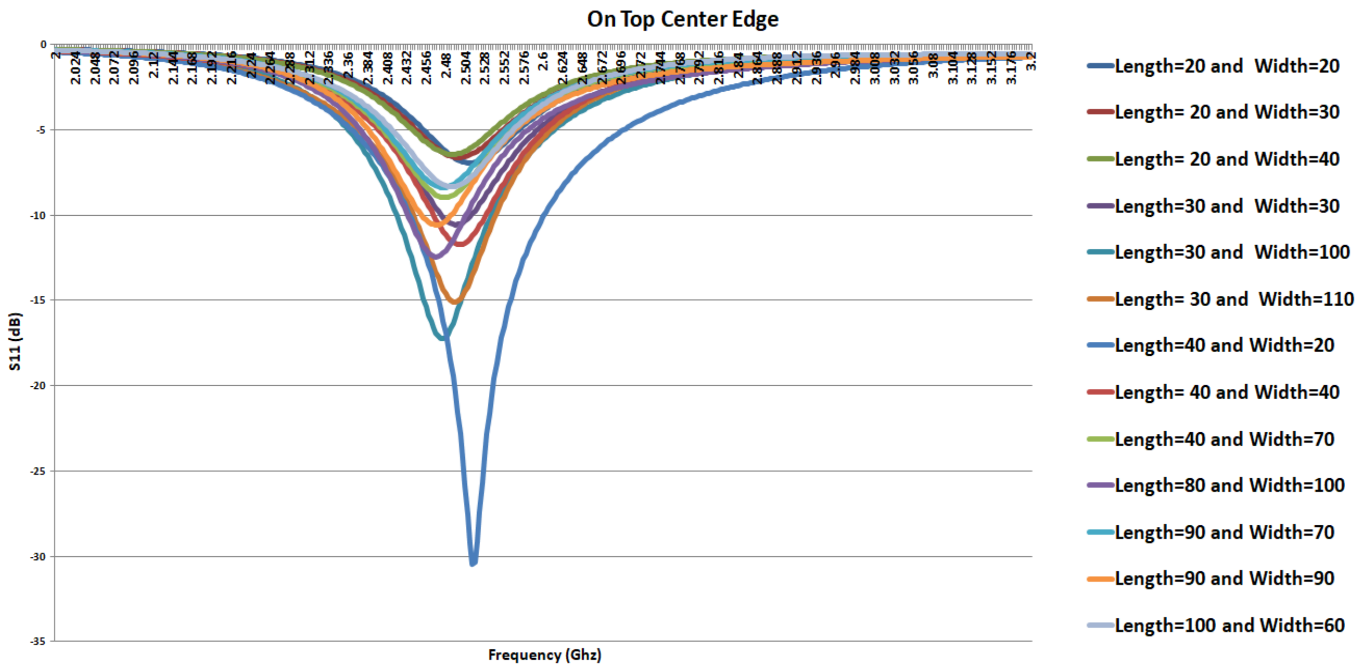
The module is capable of different data rate which can affect the sensitivity level. In this study we will use the 1Mbit/s.

3. Simulations results

The simulations are done with different sizes of the PCB. The basic states are described below:

3.1. ISP Module on top center edge

The graph represents the results of a simulation of ISP Module on the top center edge for a PCB with thickness of t=1mm with different sizes in length and width.



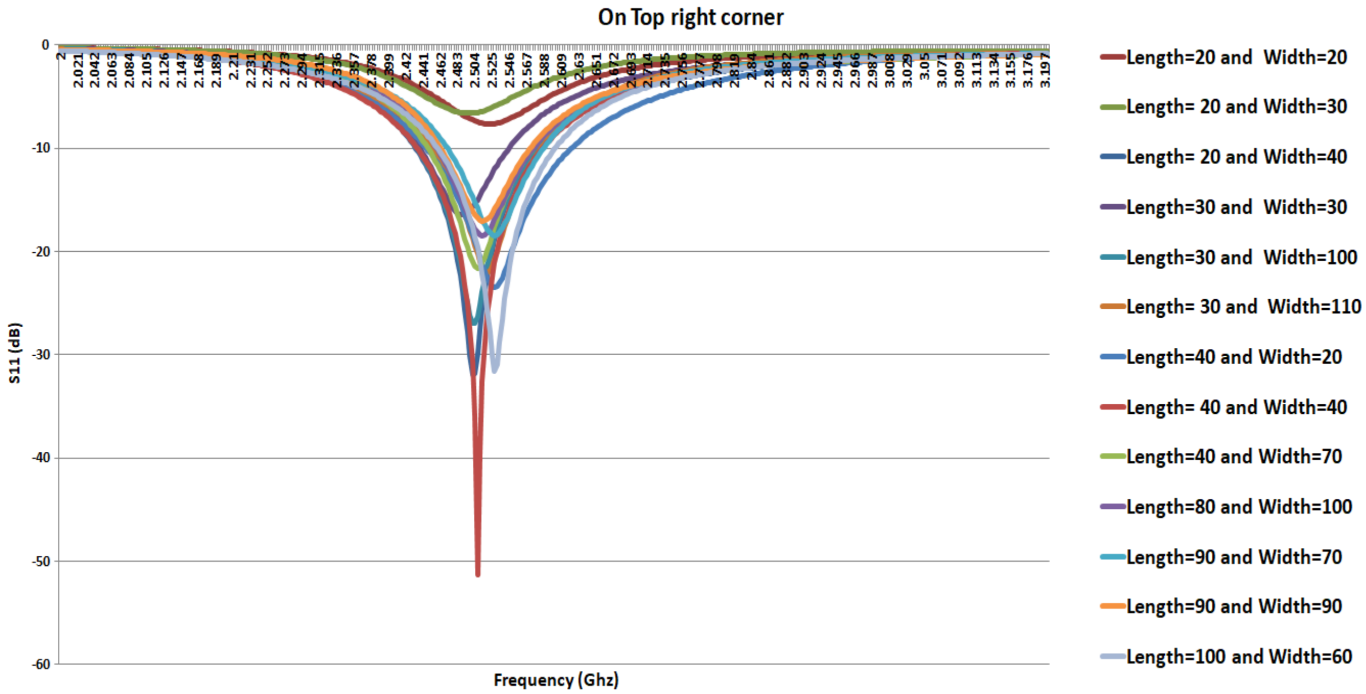
The following table shows the different criteria referred to above for a resonance frequency Fr=2.4 GHz.

PCB size (mm2)	S11 (dB)	Max gain (dBi)	TR loss (dB)	Distance (m)
L=20 W=20	-6.90	-4.10	-91.80	33.77
L=20 W=30	-6.60	-4.00	-92.00	34.37
L=20 W=40	-6.40	-3.70	-92.60	36.24
L=30 W=30	-10.50	-0.70	-98.60	61.66
L=30 W=100	-17.20	0.50	-101.00	76.26
L=30 W=110	-15.10	0.60	-101.20	77.63
L=40 W=20	-30.30	1.10	-102.20	84.81
L=40 W=40	-36.30	0.02	-100.04	70.05
L=40 W=70	-8.90	-0.60	-98.80	62.76
L=80 W=100	-12.40	0.40	-100.80	74.92
L=90 W=70	-8.30	-0.70	-98.60	61.66
L=90 W=90	-10.50	-0.10	-99.80	68.57
L=100 W=60	-8.30	-0.20	-99.60	67.37

TR Loss refers to the attenuation calculated with Pr=-96dBm and Pin=4dBm
Distance refers to the distance calculated with result of TR Loss and received sensibility.

3.2. ISP Module on top right corner

The graph represents the results of a simulation of ISP Module on the top center edge for a PCB with thickness of t=1mm with different sizes in length and width.

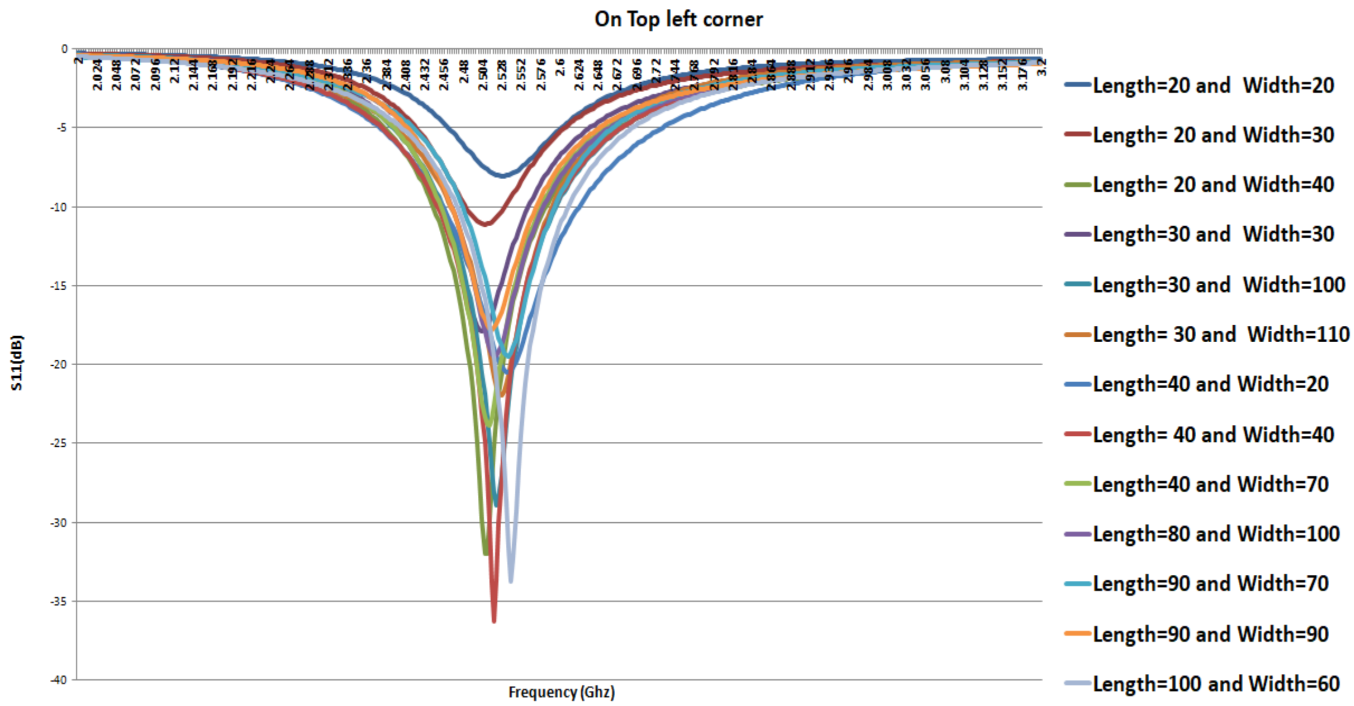


The table shows the different criteria referred to above for a resonance frequency Fr=2.4 GHz.

PCB size (mm2)	S11 (dB)	Max gain (dBi)	TR loss (dB)	Distance (m)
L=20 W=20	-7.60	-3.70	-92.60	36.24
L=20 W=30	-10.50	-1.30	-97.40	55.44
L=20 W=40	-31.90	1.02	-102.04	83.62
L=30 W=30	-16.50	0.40	-100.80	74.92
L=30 W=100	-26.90	2.00	-104.00	99.47
L=30 W=110	-21.90	1.40	-102.80	89.44
L=40 W=20	-23.40	0.90	-101.80	81.86
L=40 W=40	-51.20	1.60	-103.20	92.67
L=40 W=70	-21.60	1.30	-102.60	87.87
L=80 W=100	-18.40	1.50	-103.00	91.04
L=90 W=70	-18.40	1.00	-102.00	83.33
L=90 W=90	-17.00	0.90	-101.80	81.86
L=100 W=60	-31.50	1.80	-103.60	96.01

3.3. ISP Module on top left corner

The graph represents the results of a simulation of ISP Module on the top center edge for a PCB with thickness of t=1mm with different sizes in length and width.

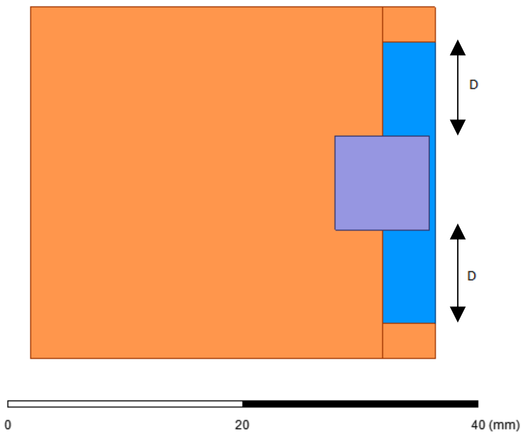


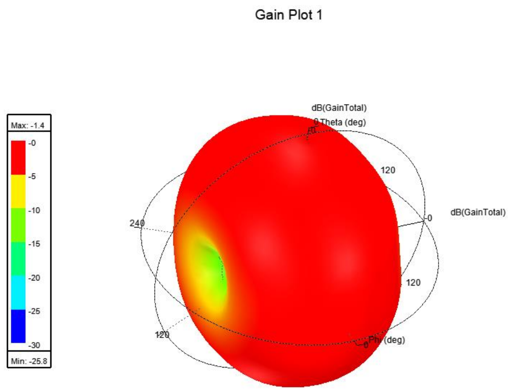
The table shows the different criteria referred to above for a resonance frequency Fr=2.4 GHz.

PCB size (mm2)	S11 (dB)	Max gain (dBi)	TR loss (dB)	Distance (m)
L=20 W=20	-8.00	-3.80	-92.40	35.61
L=20 W=30	-11.10	-1.60	-96.80	52.57
L=20 W=40	-31.90	0.30	-100.60	73.61
L=30 W=30	-17.80	-0.09	-99.82	68.70
L=30 W=100	-28.80	1.20	-102.40	86.33
L=30 W=110	-21.90	0.80	-101.60	80.43
L=40 W=20	-20.40	0.70	-101.40	79.01
L=40 W=40	-36.30	1.10	-102.20	84.81
L=40 W=70	-23.80	0.90	-101.80	81.86
L=80 W=100	-19.40	0.90	-101.80	81.86
L=90 W=70	-19.40	0.90	-101.80	81.86
L=90 W=90	-17.70	0.90	-101.80	81.86
L=100 W=60	-34.05	1.70	-103.40	94.32

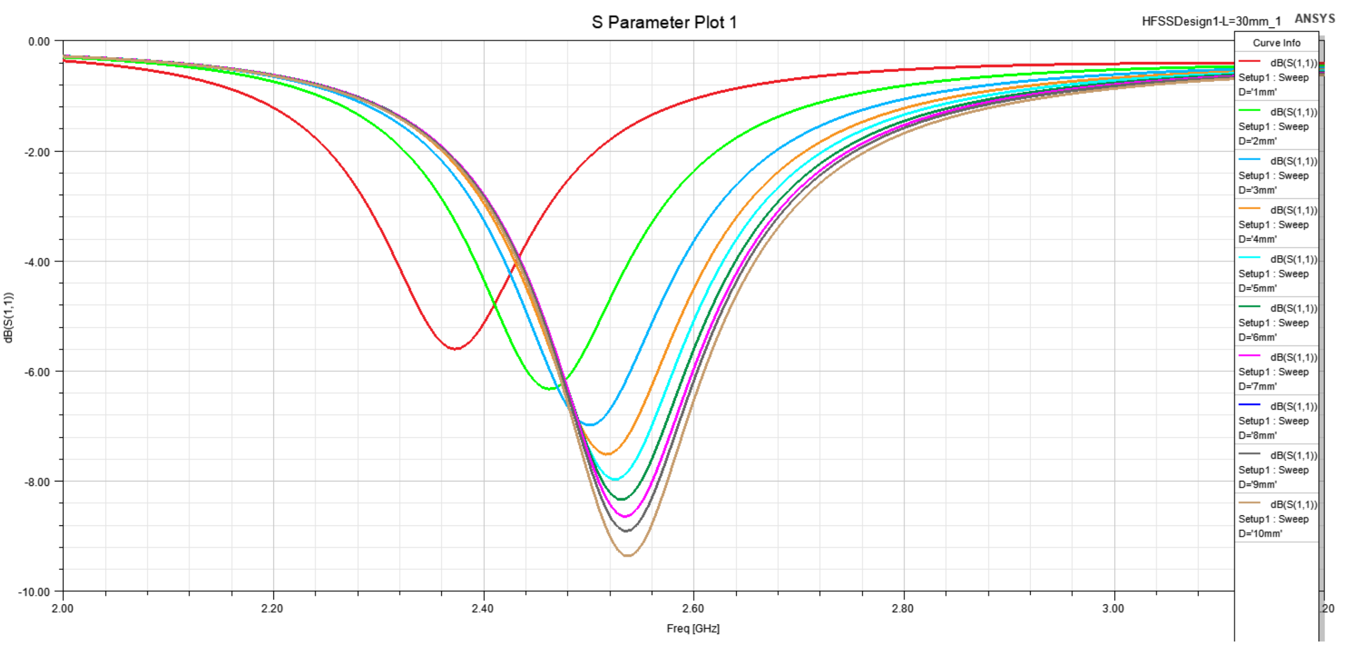
3.4. ISP Module on top center edge of the PCB with metal layers on corners

The graph represents the results of a simulation of ISP Module on the top center edge for a PCB with thickness of t=1mm with different sizes copper layers on both sides of the PCB.





The graph represents the results of a simulation of ISP Module on the top center edge for a PCB with thickness of t=1mm with different sizes copper layers on both sides of the PCB, D distance vary from 1mm to 10 mm and PCB size is W=30mm, L=30mm.



The frequency and S11 parameters decrease gradually by increasing the width of the metal layer on the left side while keeping the right side fixed.

When the D distance (keep out zone) is increased to 1 mm more, the resonance frequency increases.

It gives the same results if you reverse the roles: If we increase the width of the metal layer for both left and right sides with the same value by adding 1 mm simultaneously and gradually, S11 parameters and frequency decrease.

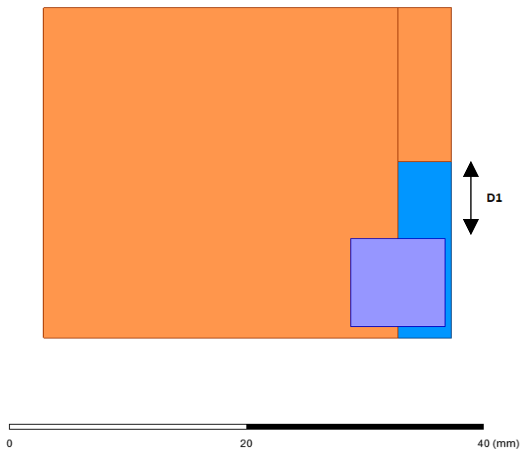
The table shows the different criteria referred to above for a resonance frequency Fr=2.4 GHz.

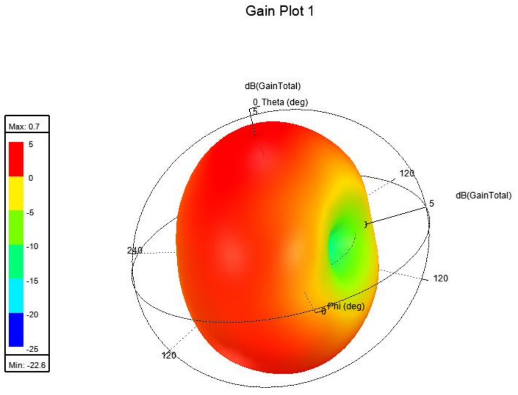
The communication distance calculates at 2.4 GHz frequency in. So, it should be kept out the antenna zone minimum 2mm from the module edge on the PCB to obtain a better the communication distance.

PCB size (mm2)	D distance (mm)	S11 (dB)	Max gain (dBi)	TR loss (dB)	Distance (m)
L=30 W=30	1	-3.38	-3.76	-92.48	35.86
L=30 W=30	2	-6.21	-3.55	-92.90	37.22
L=30 W=30	3	-5.37	-1.42	-97.16	54.28
L=30 W=30	4	-4.81	-1.42	-97.16	54.28
L=30 W=30	5	-4.68	-1.38	-97.24	54.66
L=30 W=30	6	-4.65	-1.25	-97.50	55.94
L=30 W=30	7	-4.66	-1.22	-97.56	56.24
L=30 W=30	8	-4.66	-1.21	-97.58	56.33
L=30 W=30	9	-4.65	-0.95	-98.10	58.99
L=30 W=30	10	-4.66	-0.81	-98.38	60.47

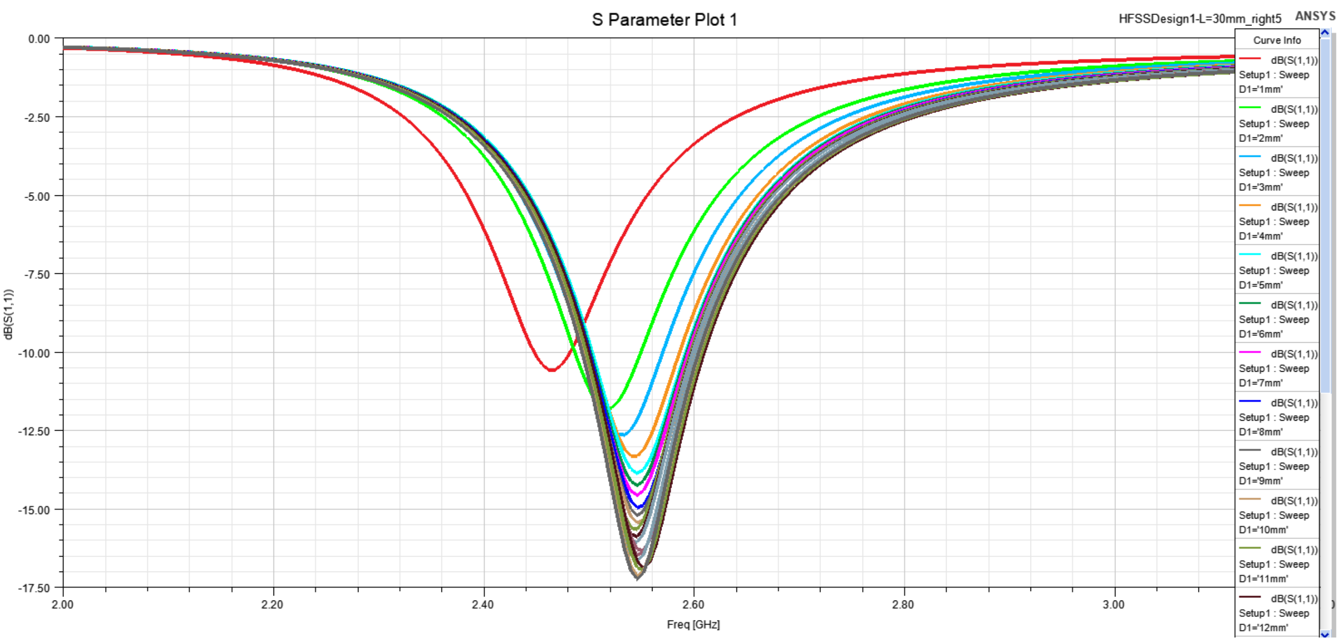
3.5. ISP Module on one corner of the PCB with metal layers on opposite corner

The last parametric study is the D1 distance (keep out zone at one side of the module which is put on the left or the right of the PCB corner).





In this case, the module is placed on the right corner of the PCB. We have the same result, when the D1 distance (keep out zone) is increased to 1 mm more, the resonance frequency increases.

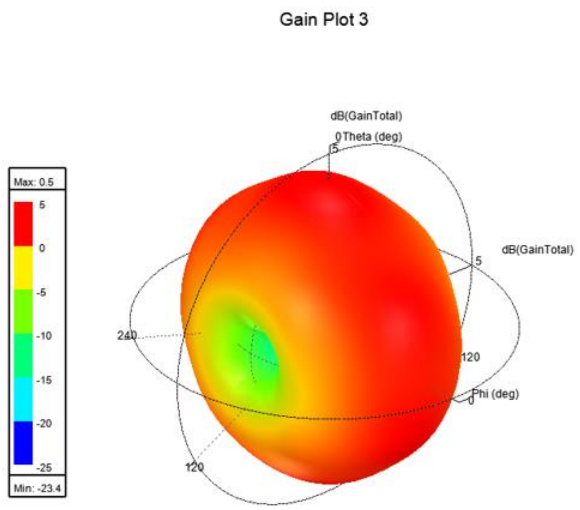


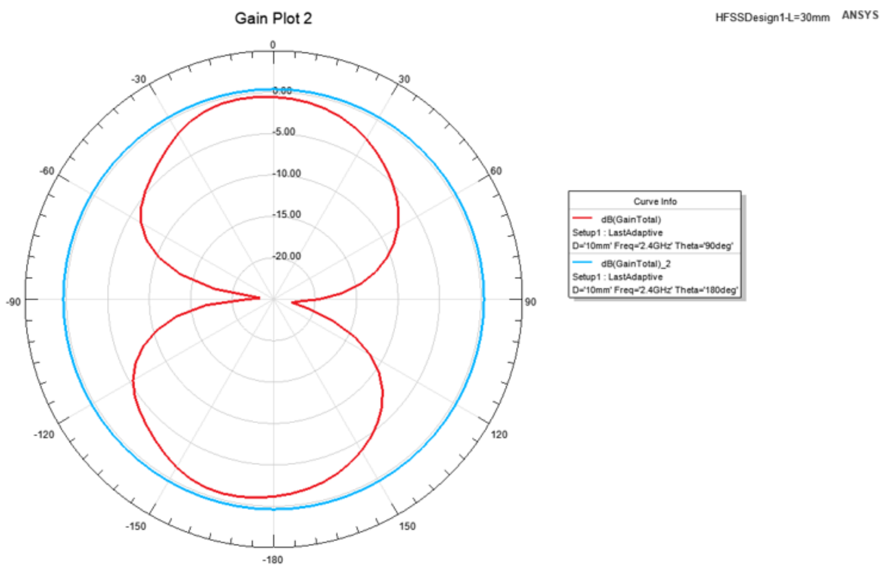
The table shows the different criteria referred to above for a resonance frequency Fr=2.4 GHz.

PCB size (mm2)	D distance (mm)	S11 (dB)	Max gain (dBi)	TR loss (dB)	Distance (m)
L=30 W=30	1	-10.14	-0.07	-99.86	68.94
L=30 W=30	3	-6.66	-0.05	-99.90	69.18
L=30 W=30	5	-5.86	0.02	-100.04	70.05
L=30 W=30	7	-5.54	0.12	-100.24	71.30
L=30 W=30	9	-5.5	0.15	-100.30	71.68
L=30 W=30	11	-5.45	0.25	-100.50	72.96
L=30 W=30	13	-5.43	0.38	-100.76	74.66
L=30 W=30	15	-5.41	0.45	-100.90	75.59
L=30 W=30	17	-5.45	0.56	-101.12	77.08
L=30 W=30	19	-5.42	0.65	-101.30	78.32

3.6. Radiation pattern of the ISP Module

Here are shown the Radiation pattern in 3 planes of the BLE's antenna of the ISP Module at the resonance frequency Fr=2.4 GHz.





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

4. About this project

This application has been built by the support team at Insight SIP, as a demo of some feature or use case. Any questions about this project please go on https://www.insightsip.com/contact.