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QN908x BLE Antenna Design Guide

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Document information

Info	Content
Keywords	QN9080, QN9083, BLE, USB dongle, PCB layout, MIFA, chip antenna, antenna simulation, gain pattern.
Abstract	This application note describes the QN908x antenna design and selection. It includes the antenna introduction and details on the simulation and design of the PCB and chip antenna solutions.

Revision history

Rev	Date	Description
1.0	06/2017	Public release.

Contact information

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1. Introduction

This document provides guidelines for the selection of antennas that are used for the QN908x Bluetooth Low Energy (BLE) device. There are some key factors to consider when choosing the antenna for your product:

- Size
- Frequency band
- Bandwidth
- Polarization
- Peak gain and average gain
- Radiation pattern

This document shows the PCB antenna and chip antennas used in the QN9080 USB dongle and QN908x module boards. These can be used as a sample reference design for your product's antenna.

2. PCB antenna

This section provides an overview of the QN9080 USB dongle and the module board antenna design. The PCB antenna is a Meandered Inverted F Antenna (MIFA). As a sample, the antenna design contains the antenna simulation and PCB layout.

This type of PCB antenna has these design features:

- Smaller size
- Easier integration on the PCB board
- Low-profile shape
- Low cost for mass production

For different application designs, it is helpful to understand the typical radiation pattern direction of a MIFA antenna so that the radiation in the desired direction can be maximized. The radiation direction is shown in Fig 1.

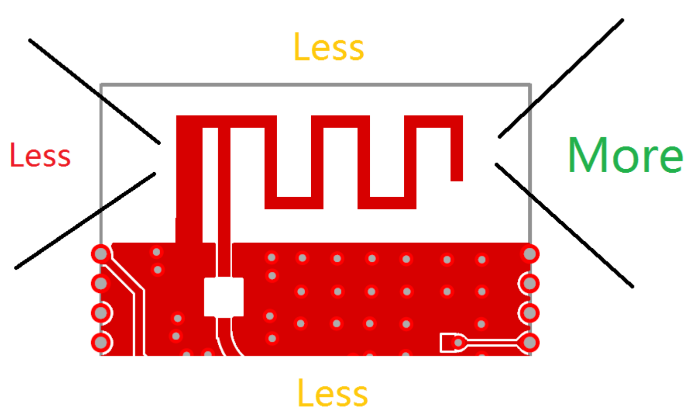


Fig 1. MIFA antenna radiation direction

2.1 Antenna used in the USB dongle

MIFA is a PCB antenna for low-cost, low-profile, and high-efficiency applications. The meander trace design effectively reduces antenna dimensions and is easily integrated.

NXP completed the antenna simulation with the housing removed. Although the USB dongle product is always sold in a housing to be considered a real product, the housing has an impact on the antenna performance. The RF matching helps to adjust the antenna's resonant frequency to the correct range.

EMPro is an electromagnetic simulation tool which can be used to perform the antenna simulation for PCB antennas. The simulation model is shown in Fig 2.

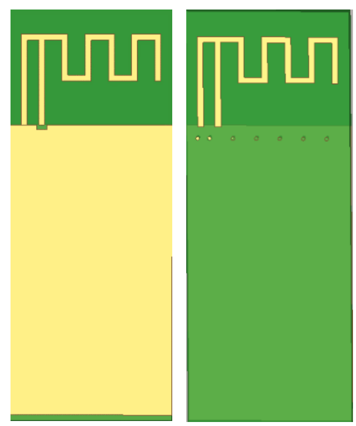


Fig 2. Dongle MIFA antenna simulation

Some of the simulation antenna parameters are shown in Table 1.

Table 1. Simulation antenna parameters

Antenna parameters	Value	Unit
PCB substrate permittivity	4.6	—
PCB substrate H	1.0	mm
Length of PCB substrate	35.5	mm
Width of PCB substrate	14	mm
Length of TOP PCB ground	25.5	mm
Width of TOP PCB ground	14	mm
Length of BOT PCB ground	25.5	mm
Width of BOT PCB ground	14	mm
Width of antenna trace	0.5	mm

2.1.1 S11 antenna

Fig 3 shows the S11 antenna simulation results, which is the antenna's return loss. The BLE frequency band ranges from 2402 to 2483.5 MHz. The return loss value is below -10 dB in the BLE frequency band.

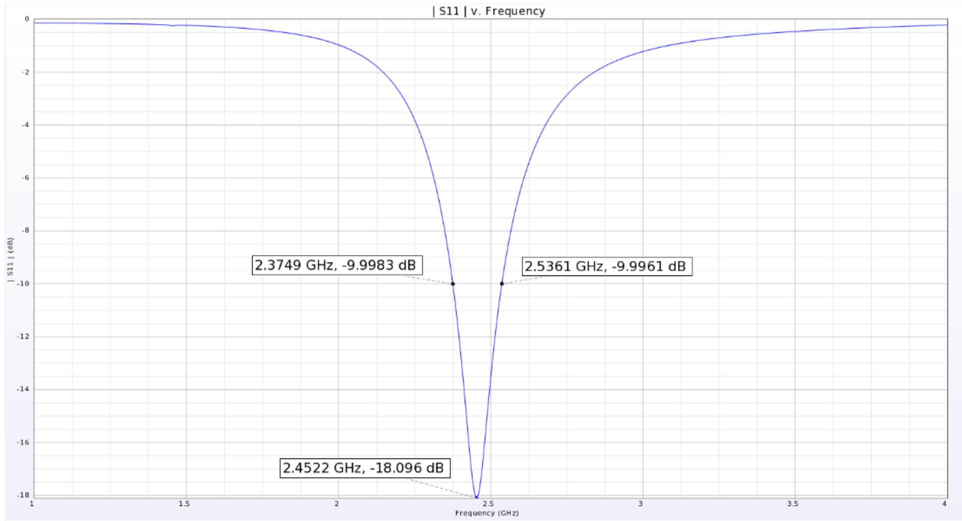


Fig 3. S11 antenna

2.1.2 Gain pattern

Fig 4 shows the simulation results for the antenna gain pattern at phi = 90^o.

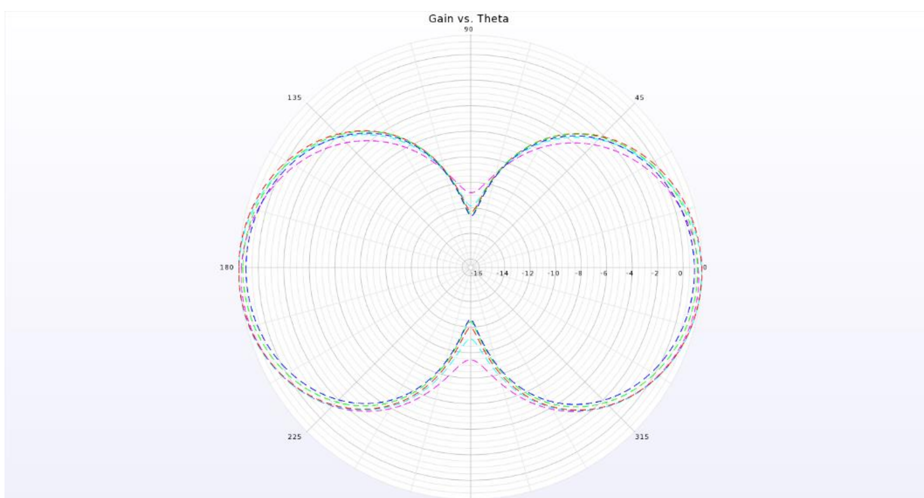


Fig 4. Antenna gain pattern @ phi = 90^o

Fig 5 shows the simulation results for the antenna gain pattern @ phi = 0^o.

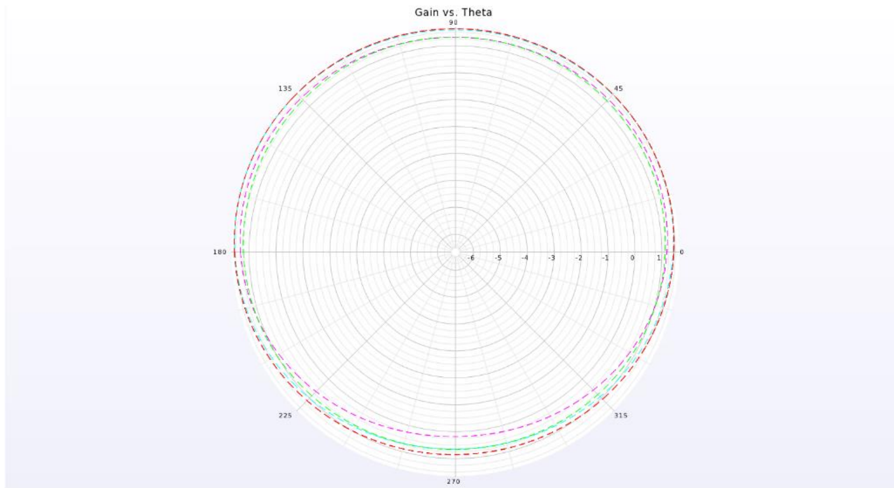


Fig 5. Antenna gain pattern @ phi = 0^o

2.1.3 3D gain pattern

Fig 6 shows the antenna 3D gain pattern simulation results.

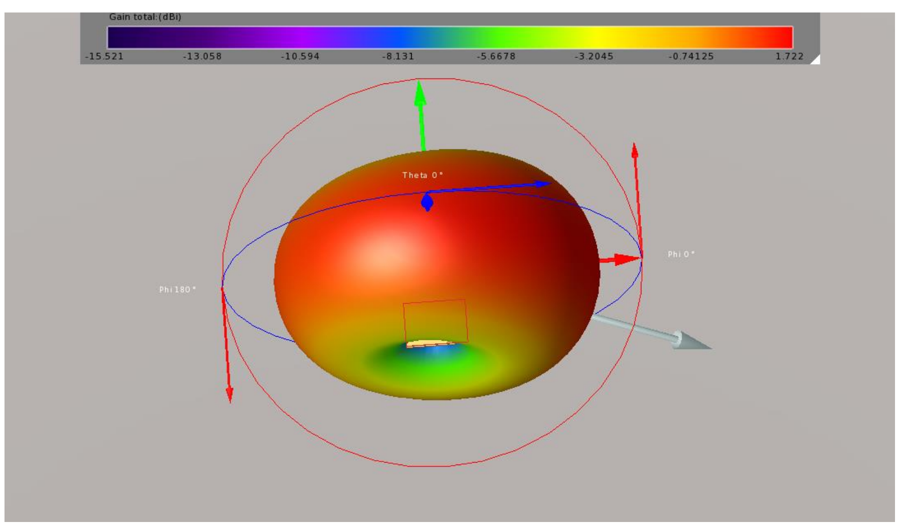


Fig 6. 3D antenna gain pattern

2.1.4 Antenna efficiency

Table 2. Antenna efficiency simulation results

Frequency (GHz)	Available power (W)	Input power (W)	Radiated power (W)	System efficiency	Radiation efficiency
1	0.0025	8.02E-05	1.27E-05	0.51 %	15.81 %
1.3	0.0025	9.78E-05	3.43E-05	1.37 %	35.10 %
1.36	0.0025	1.05E-04	4.17E-05	1.67 %	39.81 %
1.42	0.0025	1.15E-04	5.10E-05	2.04 %	44.35 %
1.72	0.0025	2.04E-04	1.39E-04	5.57 %	68.20 %
1.96	0.0025	4.31E-04	3.51E-04	14.06 %	81.46 %
2.08	0.0025	6.94E-04	5.94E-04	23.77 %	85.67 %
2.44	0.0025	2.46E-03	2.23E-03	89.00 %	90.64 %
2.83	0.0025	9.49E-04	8.40E-04	33.61 %	88.58 %
3.22	0.0025	3.94E-04	3.27E-04	13.07 %	82.98 %
4	0.0025	1.23E-04	6.81E-05	2.72 %	55.32 %

2.1.5 PCB layout

To provide a low-cost design for the QN9080 USB dongle, a two-layer stack, 1.0-mm PCB board is recommended. The dielectric material of the PCB is standard FR-4. The relative permittivity is 4.6.

The antenna layout trace dimensions are shown in Fig 7.

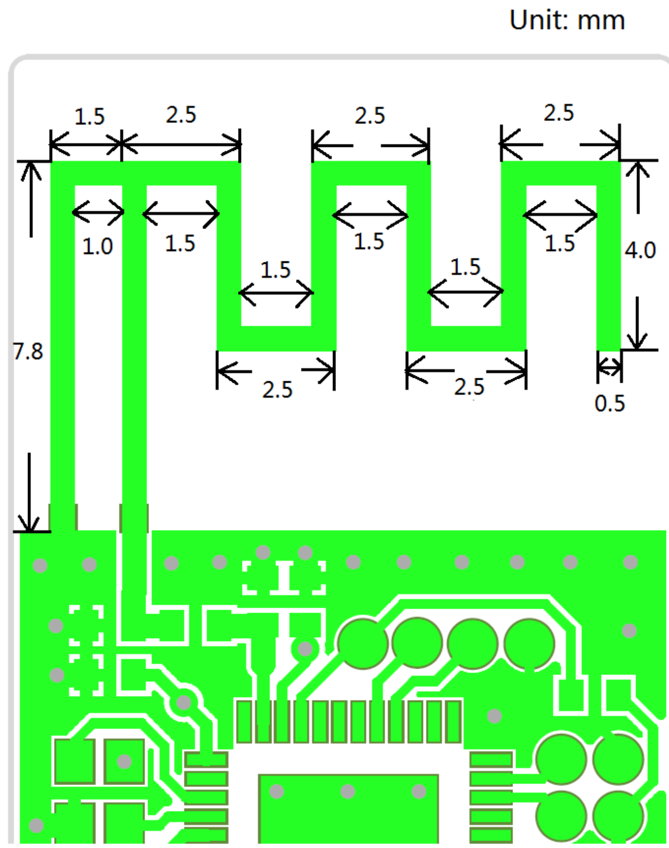


Fig 7. QN9080 USB dongle MIFA antenna dimensions

The reference PCB layout is shown in Fig 8 and Fig 9.

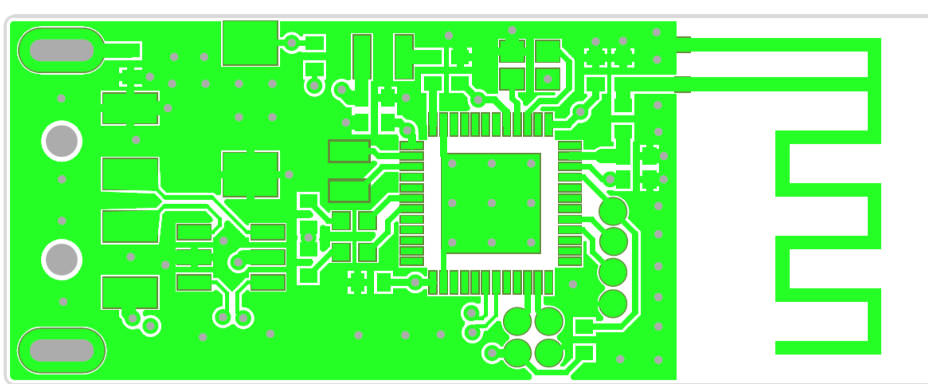


Fig 8. QN9080 USB dongle PCB layout top layer

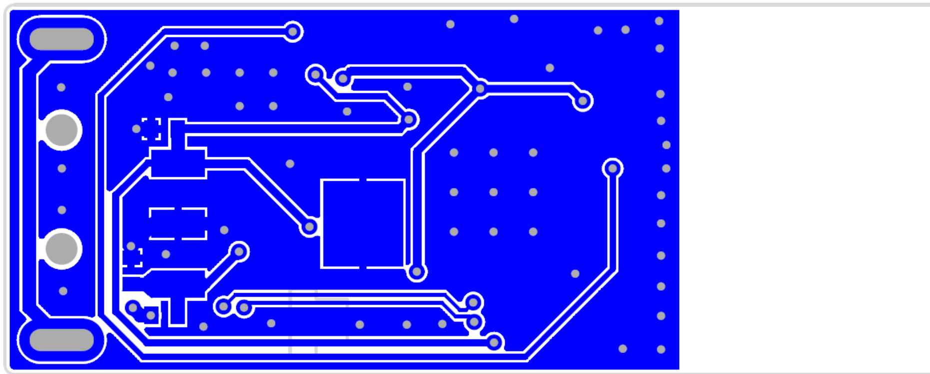


Fig 9. QN9080 USB dongle PCB layout bottom layer

For more information about the PCB design, contact your local NXP representative.

2.2 QN9080 development board module antenna

There are two different modules that are based on the QN9080 QFN and QN9083 WLCSP packages. Both can be mounted on the QN908x DK board to develop a BLE product based on the QN908x device.

The MIFA simulation model is created in the EMPro simulation software and shown in Fig 10.

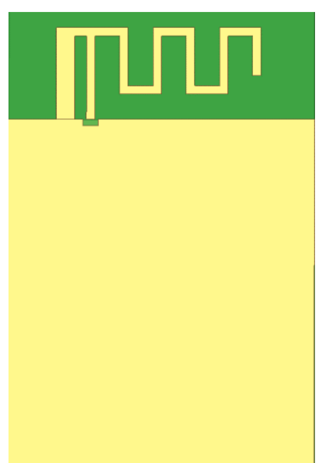


Fig 10. Module board MIFA simulation

Some of the simulation antenna parameters are shown in Table 3.

Table 3. Simulation antenna parameters

Antenna parameters	Value	Unit
PCB substrate permittivity	4.6	—
PCB substrate H	1.0	mm
Length of the PCB substrate	27.8	mm
Width of the PCB substrate	18.45	mm
Length of the TOP PCB ground	21.3	mm
Width of the TOP PCB ground	18.45	mm
Length of the BOT PCB ground	21.3	mm
Width of the BOT PCB ground	18.45	mm
Width of the antenna trace	0.5	mm

2.2.1 S11 antenna

Fig 11 shows the S11 antenna parameter simulation results. The BLE frequency band ranges from 2402 to 2483.5 MHz. The return loss value is below -10 dB in the BLE frequency band.

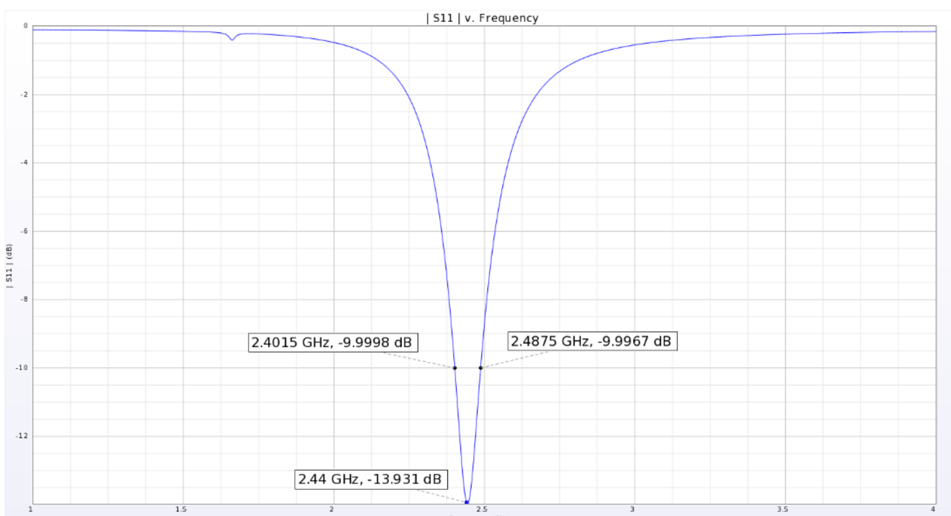


Fig 11. S11 antenna

2.2.2 Gain pattern

Fig 12 shows the antenna gain pattern @ phi = 90^o simulation results.

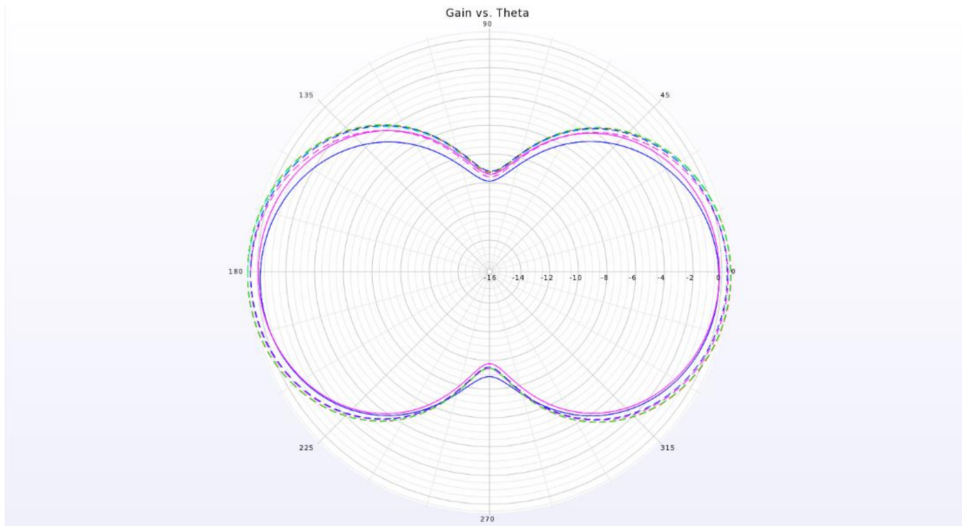


Fig 12. Antenna gain pattern @ phi = 90^o

Fig 13 shows the antenna gain pattern @ phi = 0^o simulation results.

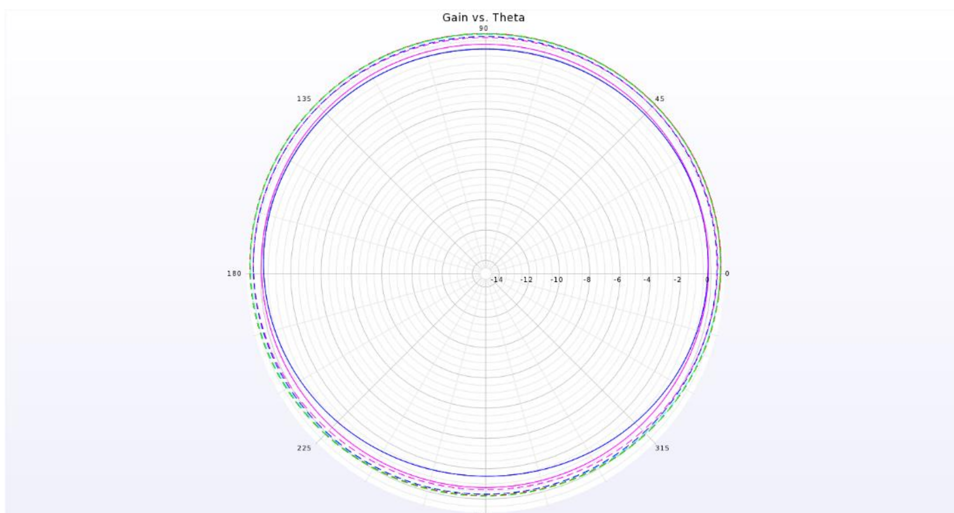


Fig 13. Antenna gain pattern @ phi = 0^o

2.2.3 3D gain pattern

Fig 14 shows the 3D antenna gain pattern simulation results.

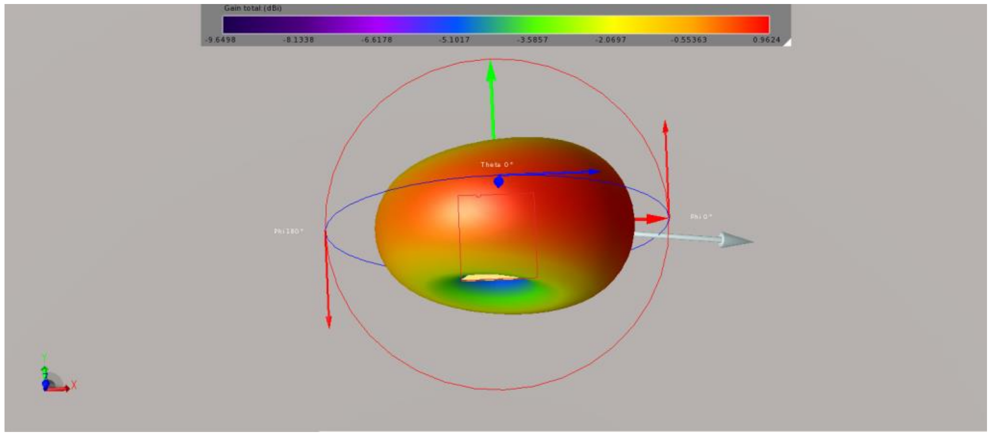


Fig 14. 3D antenna gain pattern

2.2.4 Antenna efficiency

Table 4. Antenna efficiency simulation results

Frequency (GHz)	Available power (W)	Input power (W)	Radiated power (W)	System efficiency	Radiation efficiency
1	0.0025	6.09E-05	4.24E-06	0.17 %	6.96 %
1.6	0.0025	1.00E-04	3.23E-05	1.29 %	32.19 %
1.66	0.0025	2.22E-04	6.56E-05	2.63 %	29.51 %
1.72	0.0025	1.22E-04	4.94E-05	1.98 %	40.35 %
2.08	0.0025	3.67E-04	2.46E-04	9.84 %	67.07 %
2.26	0.0025	1.02E-03	7.63E-04	30.50 %	74.76 %
2.44	0.0025	2.40E-03	1.86E-03	74.44 %	77.58 %
2.54	0.0025	1.85E-03	1.43E-03	57.32 %	77.41 %
2.64	0.0025	1.12E-03	8.54E-04	34.17 %	76.35 %
2.83	0.0025	4.83E-04	3.50E-04	14.00 %	72.46 %
3.22	0.0025	1.91E-04	1.18E-04	4.70 %	61.58 %
4	0.0025	8.62E-05	3.18E-05	1.27 %	36.87 %

2.2.5 PCB layout

The QN908x module board is a four-layer stack, 1-mm PCB board. The PCB dielectric material is standard FR-4. The relative permittivity is 4.6.

The antenna layout trace dimensions are shown in Fig 15.

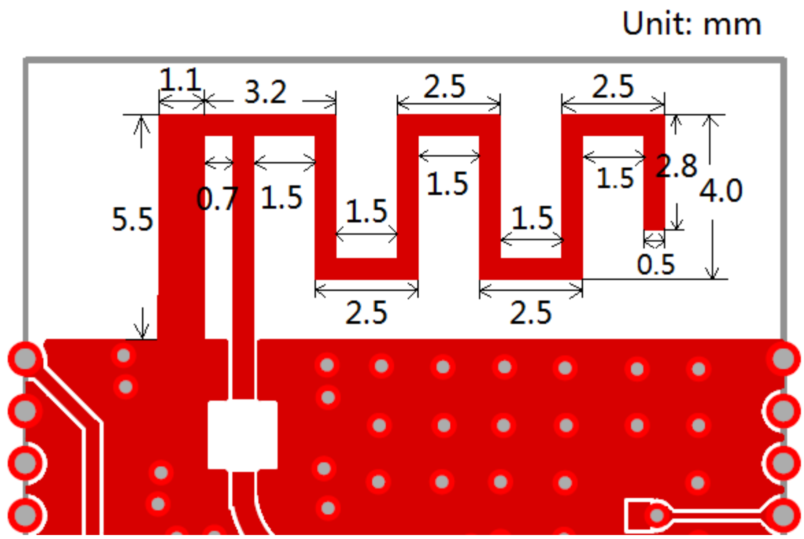


Fig 15. QN908x module MIFA dimensions

The reference PCB layout is shown in Fig 16 and Fig 17.

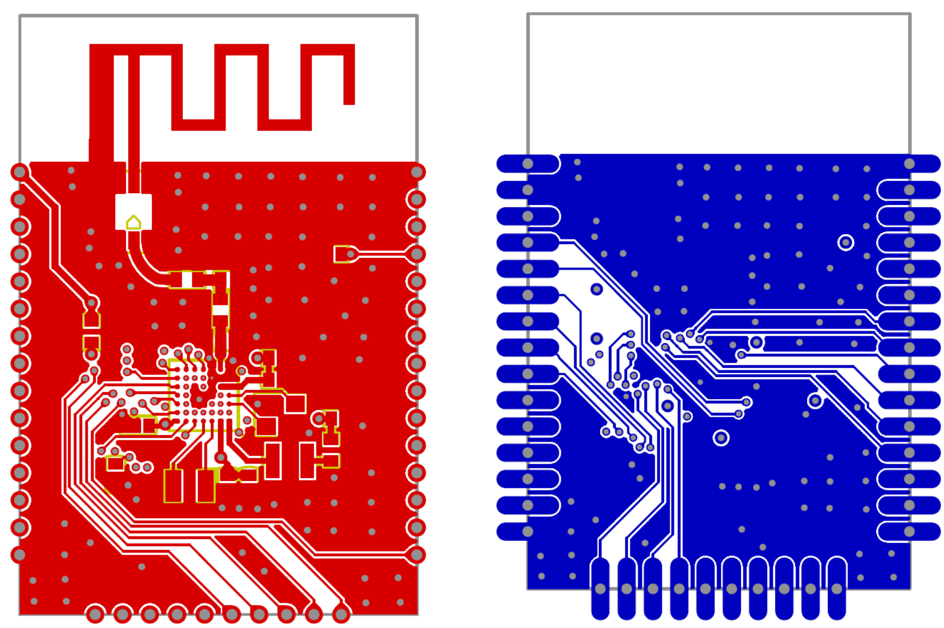


Fig 16. QN9083 WLCSP module board PCB layout top and bottom layers

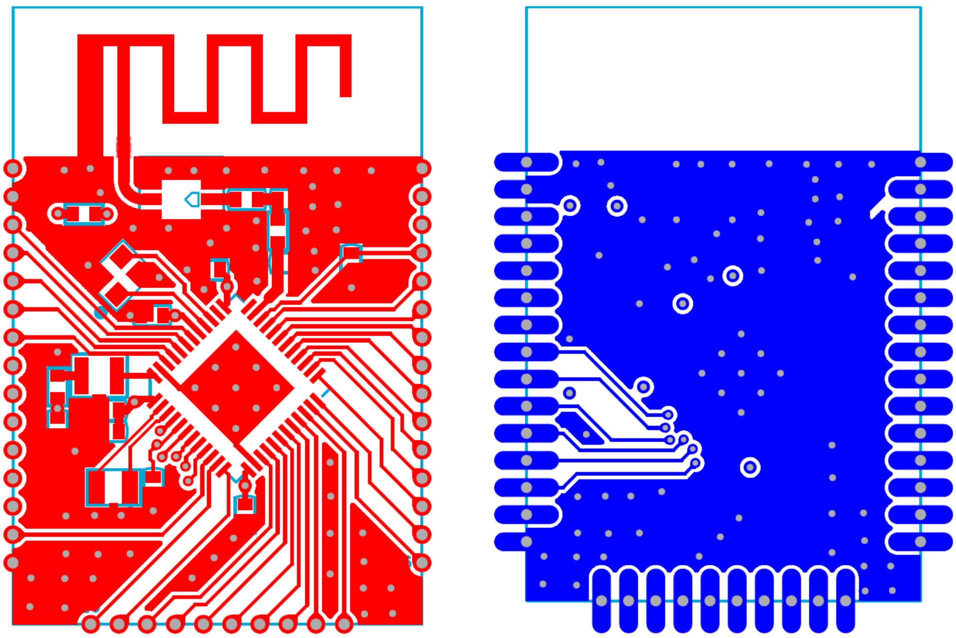


Fig 17. QN9080 QFN module board PCB layout top and bottom layers

For more information about the PCB design, contact your local NXP representative.

2.3 Antenna-matching circuit

The RF front-end pin of QN908x is already matched to 50 Ω by an internal matching circuit. Therefore, there is no need to add any matching circuits on the RF front-end pin on the reference designs.

A π-type circuit network is designed for antenna RF matching. If your antenna has a precise input impedance, leave the shunt capacitor as it is and use a suitable capacitor instead of a series resistor.

3. Chip antenna

The chip antenna is a high-frequency ceramic solution for 2.45-GHz antenna applications. The chip antenna is an ideal solution when the board space is limited. This type of antenna provides smaller size and acceptable cost. If an external matching circuit is used, the chip antenna performs better. The matching circuit, antenna placement, and ground layout are all important factors that affect the chip antenna performance.

In this section, the chip antenna is shown as an example used on the QN9080 small module board. The module dimensions are 10x10 mm. The chip antenna is a good solution for this module due to its small size. The chip antenna chosen is manufactured by Johanson Technology.

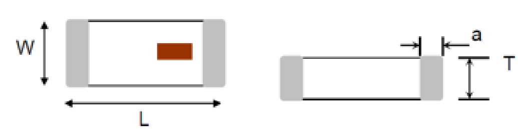
Table 5 lists some of the key parameters.

Table 5. General specifications

Part number	2450AT18A100
Frequency range	2400 to 2500 MHz
Peak gain	0.5 dBi typ. (XZ-V)
Average gain	-0.5 dBi typ (XZ-V)
Return loss	9.5 dB min.
Input power	2 W max. (CW)
Impedance	50 Ω
Operating temperature	-40 to +125 °C
Reel quantity	3000

Table 6 lists the mechanical dimensions of the chip antenna:

Table 6. Mechanical dimensions

—	in.	mm	
L	0.126 ± 0.008	3.20 ± 0.20	
W	0.063 ± 0.008	1.60 ± 0.20	
T	0.051 + 004/- 008	1.30 + 0.1/ 0.2	
a	0.020 ± 0.012	0.50 ± 0.30	

3.1 Antenna performance

The test data below was provided by the chip manufacturer (Johanson) for part number 2450AT18A100. If you have any questions related to this chip antenna, ask the manufacturer (Johanson Technology).

For designs that use the chip antenna, the radiation pattern direction is shown in Fig 18:

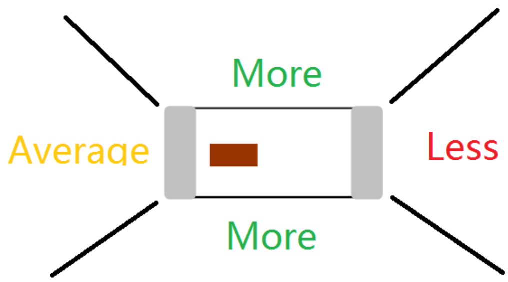


Fig 18. Chip antenna radiation direction

3.1.1 Chip antenna S11 and VSWR

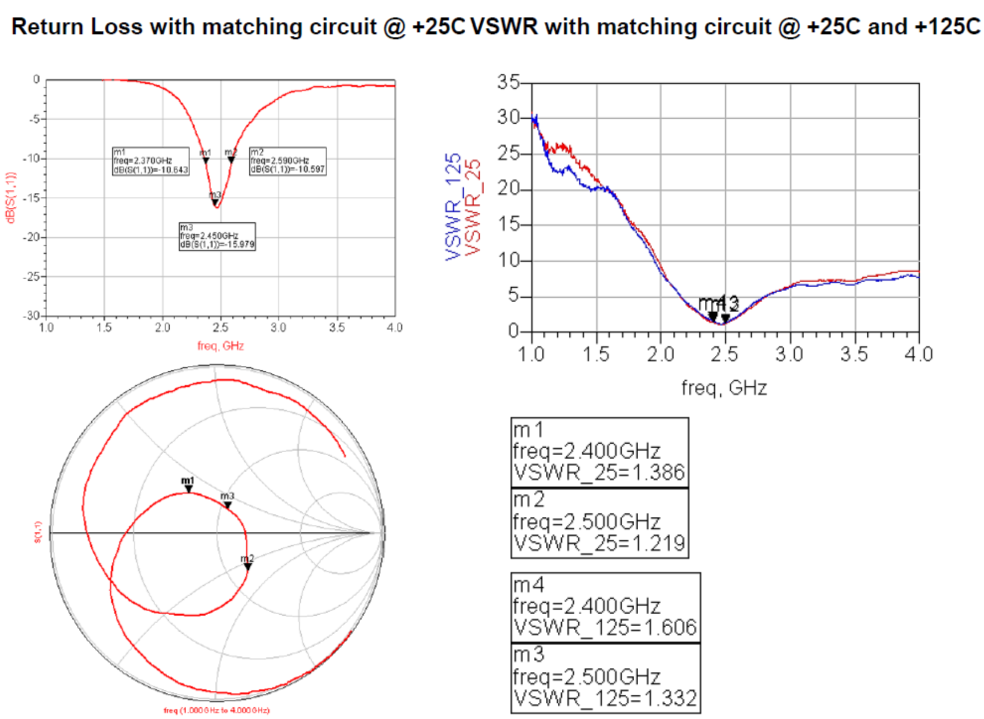


Fig 19. Chip antenna S11 and VSWR

3.1.2 Radiation pattern

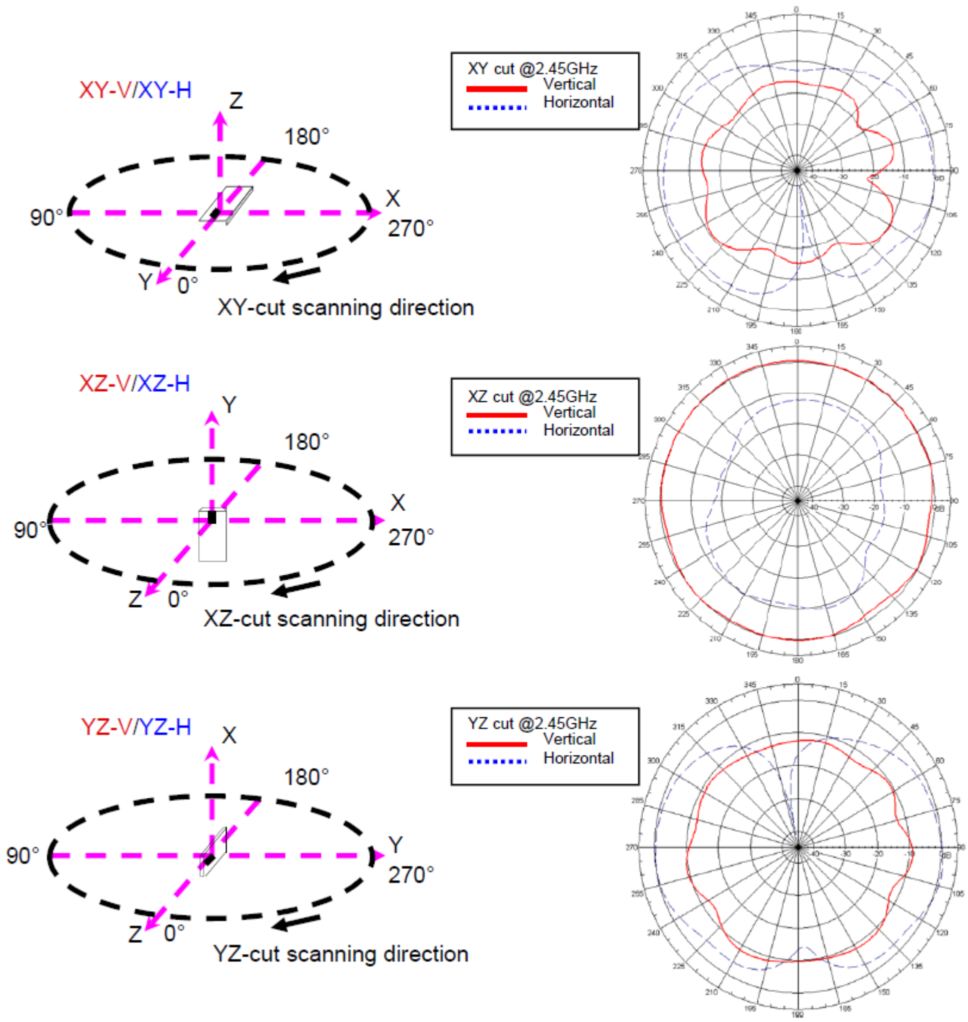


Fig 20. Chip antenna radiation pattern

3.2 Placement and PCB layout

The placement and layout of the chip antenna on the PCB board is very important. The antenna position on the PCB board, the size of the keep-out space, and the distance between the antenna and the reference ground plane affects the antenna resonance frequency, impedance, and efficiency. Some typical designs and placements are strongly recommended.

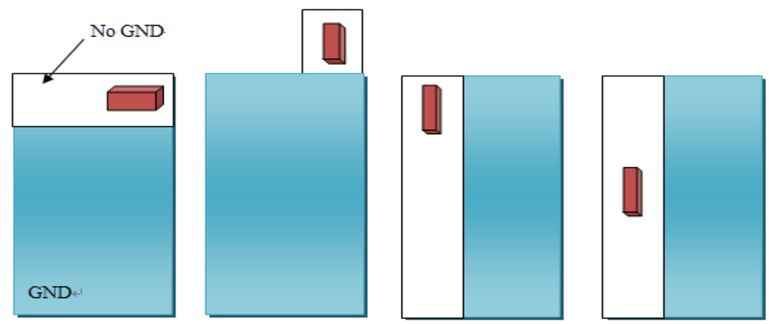


Fig 21. Excellent positions for a chip antenna

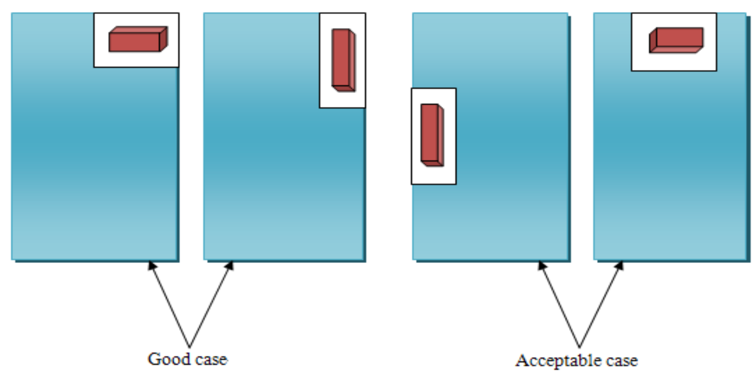


Fig 22. Acceptable positions for a chip antenna

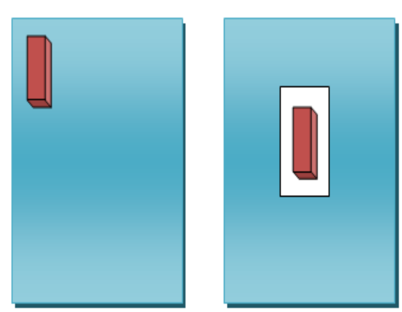


Fig 23. Unacceptable positions for a chip antenna

Here are some recommendations to follow:

- Do not put any metal objects (such as batteries) above or below the antenna clearance area. Keep any other metals as far from the clearance area as possible.
- Additional stitching vias around the ground plane near the antenna provide a better ground reflection for the antenna.
- Place the antenna-matching circuit components as close to the antenna feed port as possible.

For the antenna PCB layout, a 50-Ω feed line, matching circuit, and antenna clearance is all that is needed. A sample PCB layout is shown in Fig 24:

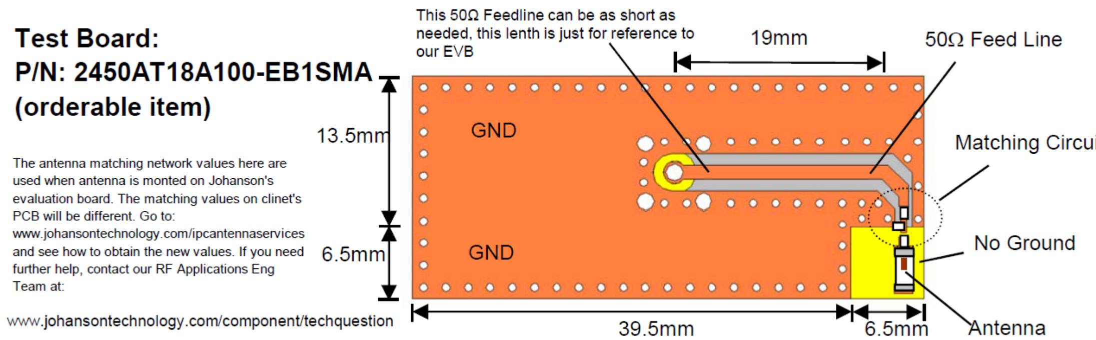


Fig 24. Chip antenna PCB layout from Johanson

3.3 Chip antenna list

There are many suppliers of ceramic chip antennas. When working on a design, the antenna size, price, and performance are the key factors to choose the antenna best suited for the needs of the design. Table 7 lists chip antennas from different suppliers that are tested with QN9080.

Table 7. Chip antenna list

Supplier	Tested	Main 2.4-GHz chip antenna products
JOHANSON TECHNOLOGY	Y	2450AT18B100, 2450AT18A100, 2450AT18D0100, 2450AT18E0100, 2450AT43D100, 2450AT43H0100, 2450AT45A100
Sunlord EXPERT IN PASSIVE PARTS	Y	SLDA31-2R800G-S1TF, SLDA52-2R350G-S1TF, SLDA72-2R470G-S1TF
RainSun	Y	AN3216, AN2051, AN6520, AN0835, AN9520
PSA	Y	RFANT5220110AT, RFANT3216120AT, RFECA3216060A1T, RGANT8010100A0T, RFGFRA9937380A3T, RGFRA1903041A1T
成電電子 ChengDian Electronic	Y	BTCA5020, BTCA4020, BTCA1206, BTCA0805
antenova m2m	Y	A10192, A5839, A5645, A6111, A6150, A10381

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