AN12243

NxH3670 dongle antenna

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Document information

Information	Content
Keywords	NxH36xx family, dongle antenna
Abstract	This document describes antenna design guidelines and evaluation methods using the NxH36xx.

Revision history

Rev	Date	Description
v.1	20181120	first issue

1 Introduction

This application note is intended as a practical guide to design and validate an antenna for a 2.4 GHz PC dongle application with radio ICs of the NxH36xx family. The aim is to provide the required guidelines to design such an application-specific antenna and to achieve the best performance for RF communication at 2.4 GHz.

Notes:

- As a prerequisite, it is assumed that the reader has a basic understanding on how to use a Radio IC of the NxH36xx family. This application note does not replace any of the relevant radio IC datasheets.
- As there are many parameters influencing the overall performance, a basic RF knowledge is required to design an RF antenna.
- Design hints on how to place the components on a PCB are not included.
- All antenna measurements must always be performed at the final mounting position to consider effects of incorporation into a product.

The guideline covers the following items:

- A description of the antenna structure.
- The antenna performance validation section describes the required tools and measuring setups to determine the antenna parameters obtained with a connected measurement and a radiated measurement in an anechoic room.

1.1 Reference documents

- Data sheet NxH3670 and NxH36xx family

1.2 Reference simulation tools

- CST Microwave Studio: 3D Electromagnetic Simulation Tool

2 Description of the antenna

The antenna is a planar helical antenna distributed on two layers of a printed circuit board. This printed circuit board conforms to the form factor of a laptop/PC dongle. The dimensions of the NXP dongle PCB are approximately 19.2 mm by 11.8 mm.

The helical antenna is printed at a location on the dongle PCB furthest away from the USB connector entering the laptop/PCB USB port for best performance. The printed circuit board also incorporates electronic components but at the position of the helical antenna no electronics are mounted and the intermediate layers should be copper free.

The helical antenna is formed by a copper trace which is partially on the top layer (green) and the bottom layer (blue) as shown in the top drawing in Figure 1. Via holes connect the subsections of the helical antenna on both layers as shown in the bottom drawing in Figure 1.

The antenna feeding port is given at the marking F1 in this unbalanced feeding configuration.

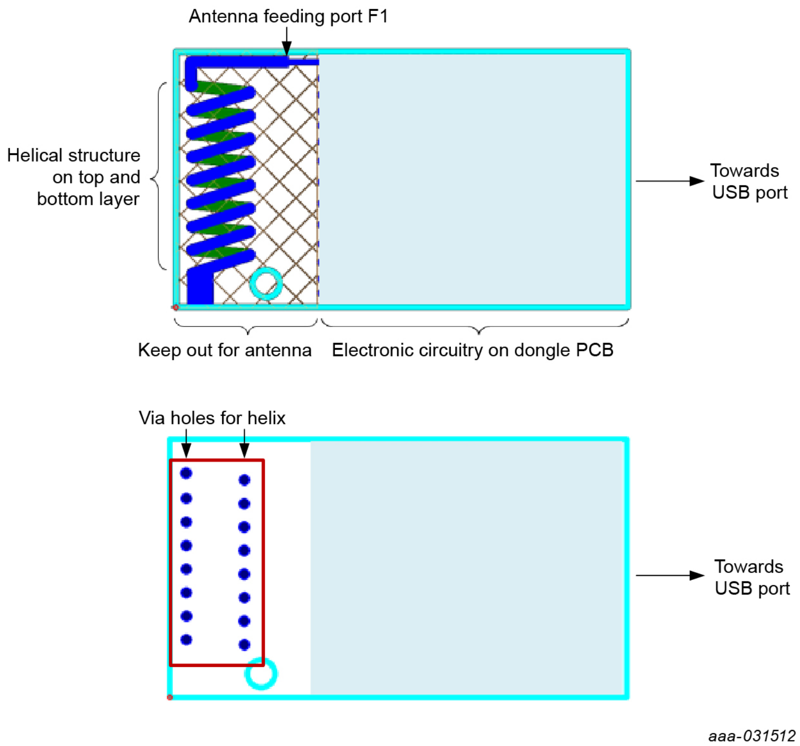


Figure 1. Drawings of the dongle antenna

2.1 Antenna layout

In what follows, reported values correspond to an antenna design on an FR4 substrate board of approximately 0.6 mm thickness and the stack up given in Section 2.2.5. When designing the helical antenna for an operation frequency of 2.45 GHz, the keep out area foreseen for the antenna is given a dimension of 6 mm by 11 mm approximately.

The helical trace is designed to have a width of 0.5 mm and is composed of 8 turns each of 6 mm length. The L-shaped trace connecting the feeding port F1 to the first helical turn is approximately 5 mm long. The spacing between the helical antenna and the PCB ground plane is approximately 2.6 mm. The distance between the via holes of the helical antenna is 1 mm vertically and 2.5 mm horizontally from center to center. At the end of the helical antenna, a copper rectangle is foreseen for top loading of 1 mm × 1.3 mm.

The connecting trace that passes the signal from the balun - connecting to the NxH36xx - to the feeding port F1 of the helical structure is highlighted as an orange dotted line in Figure 2. Provisions for matching are foreseen to be populated along this trace if necessary.

Since the helical antenna is in a horizontal plane, it predominantly supports horizontally polarized antenna radiation as is demonstrated later.

As the dongle PCB is used to mount electronic components as well, following guidelines must be considered. When more than 2 layers are used in the PCB design, the keep-out area of the spiral antenna must be respected on all intermediate layers. At the location of the electronic circuitry on the top layer and the bottom layer, a ground fill is in place.

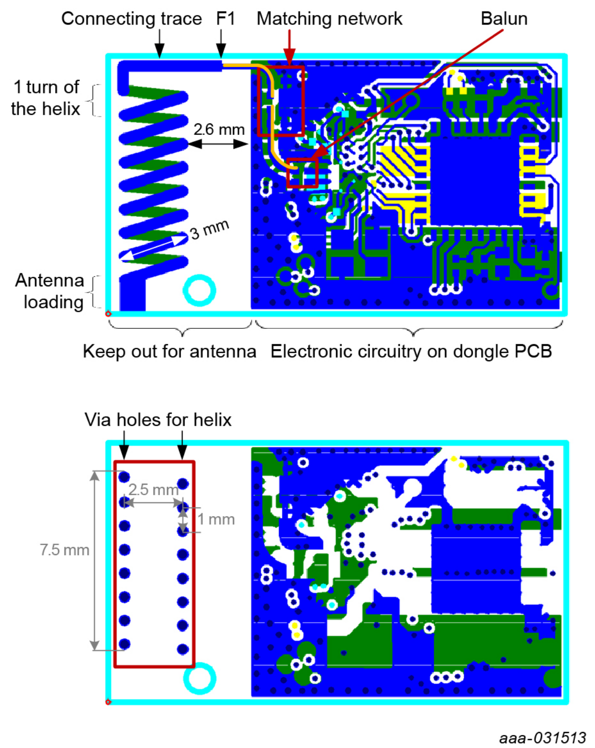


Figure 2. Schematic drawing of the antenna

2.2 Design guidelines

2.2.1 Assumptions

- Carrier frequency: 2402 MHz to 2480 MHz
- Radio IC: NxH3670

2.2.2 Design targets

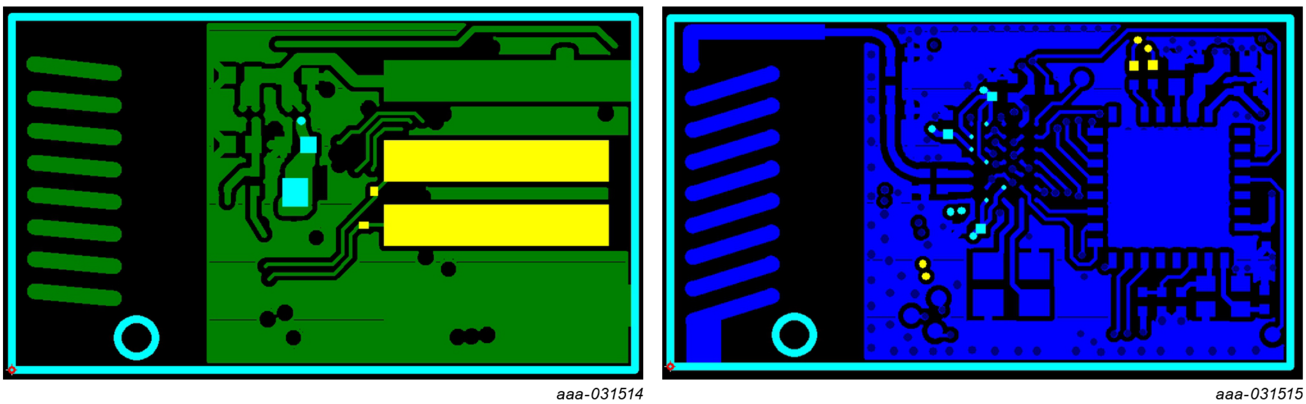
- Return Loss |S11| ≤ −10 dB from 2402 MHz to 2480 MHz
- Bandwidth ≥ 80 MHz
- Maximum gain ≥ 0 dBi for the horizontal polarization

2.2.3 Material

- Dielectric material = FR4 S1000H
- Dielectric constant = 4.2
- Manufacturer: Shenzhen Multilayer PCB Technology Co, Ltd.
- Total board thickness: 0.6 mm ± 0.1 mm
- Multilayer printed circuit board
- Cu thickness: 12 µm
- Plated through hole vias at the spiral antenna of 0.5 mm diameter
- via copper thickness: 0.1 mm
- drill size: 0.3 mm

2.2.4 Planar outline

For the sake of completeness, one can find in Figure 3 an outline of the top and bottom layer separately.



a. Top layer

b. Bottom layer

Figure 3. Example outline of the helical antenna PCB

2.2.5 Stack up

The reference design is using a multilayer PCB with the following stack up. The total board thickness is 0.6 mm ± 0.1 mm. As mentioned before, at the position of the spiral antenna the intermediate layers should be copper free.

Table 1. Multilayer PCB stack for dongle antenna PCB with electronics consisting of 4 copper layers and 3 material layers

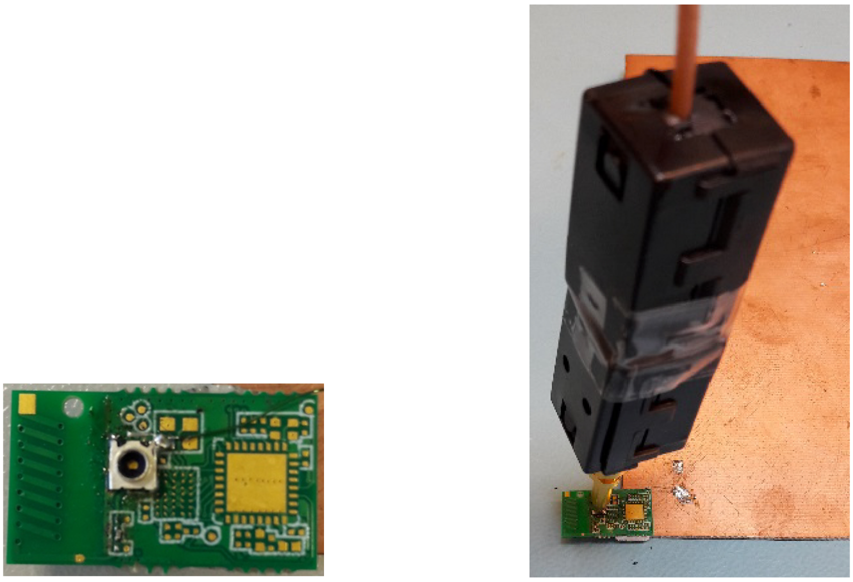
NO.	Stackup			Thickness [mm]
1	GTL			0.012
2	PP			0.09
3	L2-L3		S1000H 3313 FR4 S1000H S1000H 3313	0.3
4	PP			0.09
5	GBL			0.012

3 Antenna parameters validation

3.1 Conductive measurement

The measurement of the return loss or the $|S_{11}|$ is done in a connected manner. To retrieve the matching components to provide a 50 Ohm antenna input connection, a microwave coaxial cable connector (MM8130-2600) was soldered at the position of the balun as can be seen in Figure 4.

Since the helical antenna is small regarding the wavelength at 2.5 GHz, special attention must be paid to the cabling. Common mode cable currents can contribute to the antenna radiation and must be attenuated for accurate measurement of the S-parameters. An absorbing clamp (black enclosure in Figure 4) was developed to reduce the radiation by the cable at 2.5 GHz significantly. Additionally, the adapter and coaxial cable are kept perpendicular regarding the planar helical antenna PCB to avoid them further from contributing to the radiation of the antenna.



aaa-031519

a. PCB with connector to feed the antenna signal to an SMA cable with absorbing casing at 2.5 GHz

aaa-031520

b. Dongle soldered to a larger GND plane

Figure 4. Dongle antenna

A large copper PCB (20 cm × 20 cm) was connected to the ground of the helical antenna PCB to mimic the laptop/PC where the dongle is plugged into in the final application. A large conductive structure can influence the S-parameters. Figure 4 shows part of the copper plane.

3.1.1 S-parameter measurement

The return loss or $|S_{11}|$ measurement of the antenna in air is given in Figure 5 when the available matching network is populated with a series capacitor (Murata 3 pF GRM0335C1H3R0BA01) as a matching component.

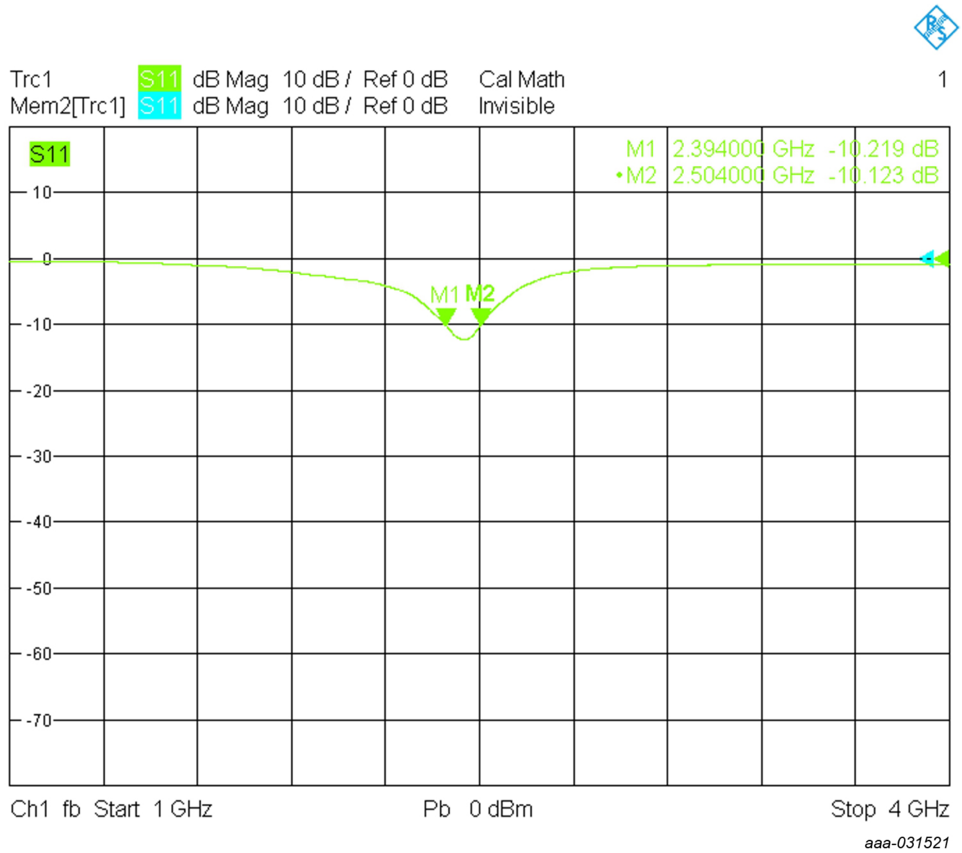


Figure 5. Return loss of the helical antenna

$|S_{11}| < -10$ dB for 2.394 GHz to 2.504 GHz, i.e. a bandwidth of approximately 110 MHz. Hence, the design target is achieved. When the helical antenna dongle is plugged into a laptop, the return loss characteristic may vary a bit and the bandwidth of the antenna is further evaluated in a radiated measurement in Section 3.2.

The Smith Chart in Figure 6 shows that $Z_{IN} = (34 + 21j)\ \Omega$ at 2.4 GHz.

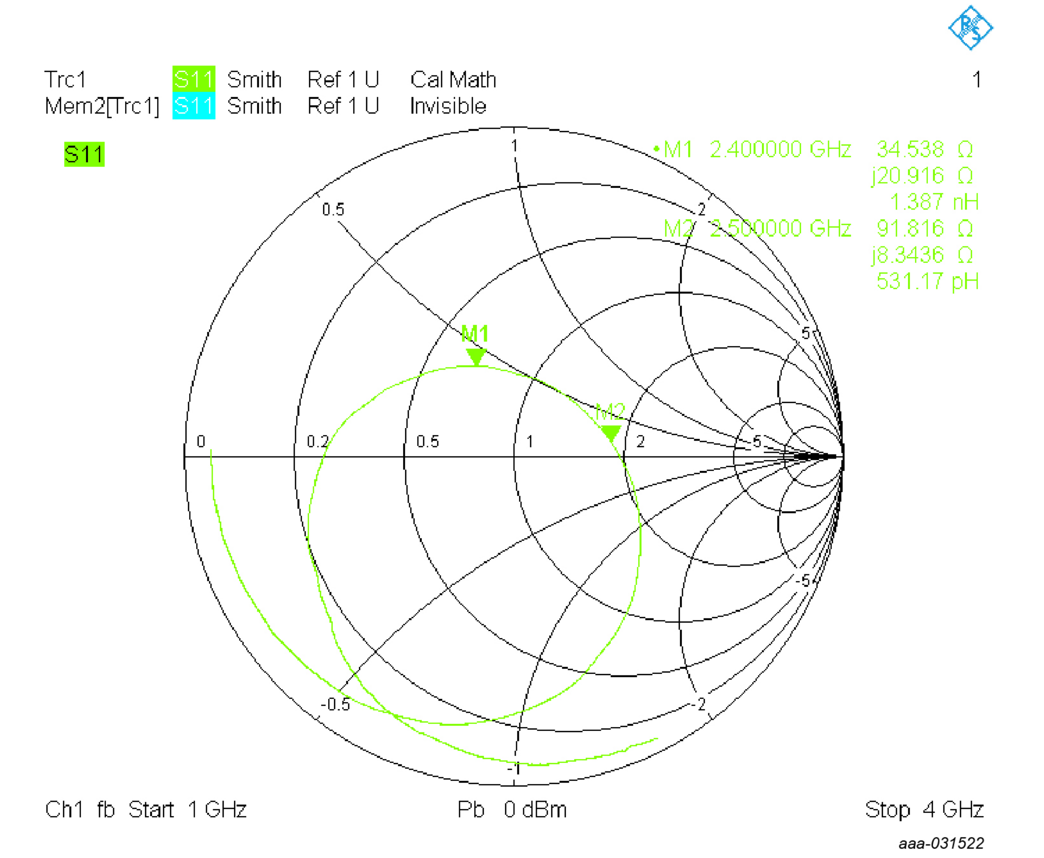


Figure 6. Smith Chart of S11 of the helical antenna

3.2 Radiated measurements

The performance of the antenna must be considered when it is integrated in an actual product. So, we have opted to measure the helical antenna PCB when plugged into the USB port of a laptop mounted in the anechoic room.

3.2.1 Radiated antenna bandwidth

Settings of the transceiver:

- Output power: 0 dBm
- Frequency: 2402 MHz to 2480 MHz
- Modulation: off
- Carrier: sweeping
- The antenna supports the required bandwidth from 2402 MHz to 2480 MHz (see Figure 7).

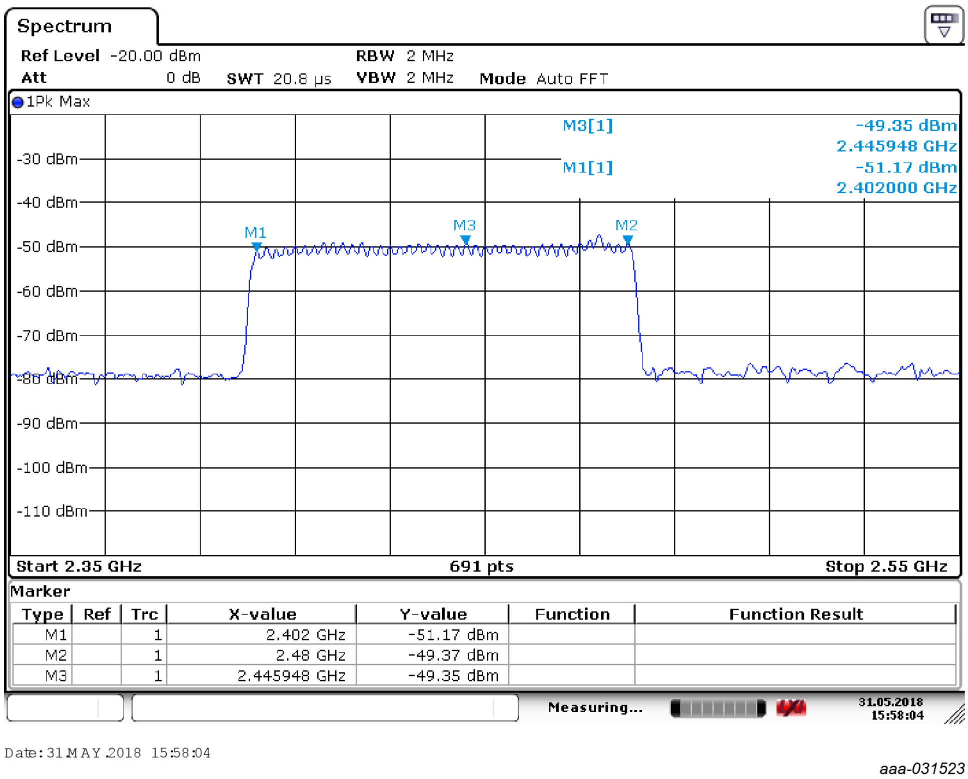


Figure 7. Received signal strength (dBm) versus frequency (MHz)

3.2.2 Antenna radiation pattern

The helical antenna PCB is plugged into the USB port at the right side of the bottom case assembly of the laptop.

Figure 8 depicts the amount of energy transmitted in the vertical and horizontal polarization by the helical antenna in such configuration as captured by a receiving horn antenna. The gray shape in Figure 8 represents the horizontal view of the laptop case and the red box represents the helical antenna PCB dongle. Antenna radiation patterns are measured in the horizontal plane.

The loss of measuring cables, the horn antenna gain, the path loss in the anechoic room and the input power of the IC are calibrated such that the received signal strength measured by the spectrum analyzer is a measure for the antenna gain in dBi[1] of the conductive plane antenna.

Both polarizations are transmitted and received of which the horizontal polarization is more dominant as can be observed in Figure 8 and in Table 2. The maximum gain and average gain are approximately 0 dBi and −6 dBi respectively, in the horizontal polarization.

Although the helical antenna is designed in a horizontal plane, therefore yielding predominantly horizontal polarization, there is also energy in the vertical polarization as the display of the laptop was in the upright position and contributes to the antenna radiation in the vertical polarization.

1 Antenna gain is here defined as the ratio of the power produced by the antenna to the power produced by a hypothetical lossless isotropic antenna, which is equally sensitive to signals from all directions. This ratio is expressed in "decibels-isotropic" or dBi.

Using other USB ports or different laptops during the measurement may result in slightly different radiation patterns.

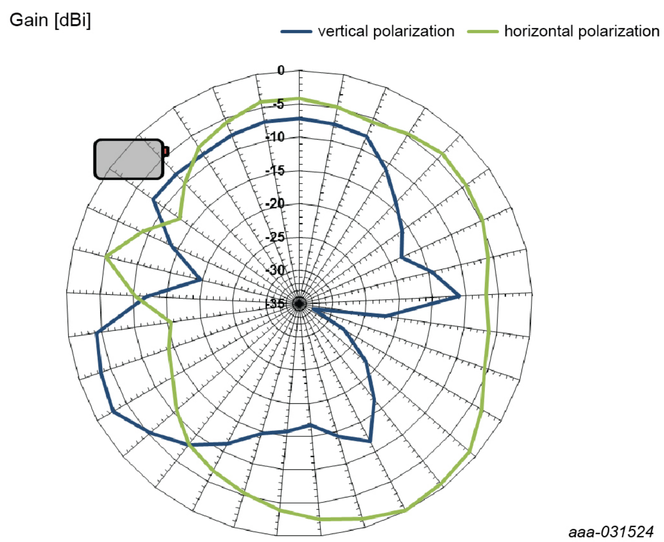


Figure 8. Antenna gain (dBi) in the horizontal plane rotated over 360 degrees

Table 2. Antenna gain (dBi) in the horizontal plane: maximum, minimum and average value over 360 degree rotating angle in the horizontal plane

Gain (dBi)	Vertical polarization	Horizontal polarization
maximum	−2.7	−0.2
minimum	−32.8	−15.5
average	−12.8	−6.3

3.3 Conclusions on the antenna validation

As observed in Section 3, the following antenna design targets were met:

- Return loss |S11| ≤ −10 dB from 2402 MHz to 2480 MHz
- Bandwidth ≥ 80 MHz
- Maximum Gain ≈ 0 dBi for the horizontal polarization

When incorporated in a USB port of a laptop with either a display in the upright position or another large conductive part positioned vertically, the antenna supports the vertical polarization to a limited extent.

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