

Antenna Overview and Specification

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1. Antenna Overview

This antenna is a 2.4 GHz Bluetooth-band Monopole Inverted-F Antenna (IFA), implemented as a printed-circuit-board (PCB) antenna and placed along the edge of the product main board. This type of antenna features a low profile, controllable cost, and easy integration, and is widely used in BLE and 2.4G wireless communication modules. The antenna body consists of a feed point, a shorting point, a radiating stub, and a ground-plane reference; it is formed directly by PCB traces and requires no additional antenna component.

2. Antenna PCB Layout Diagram

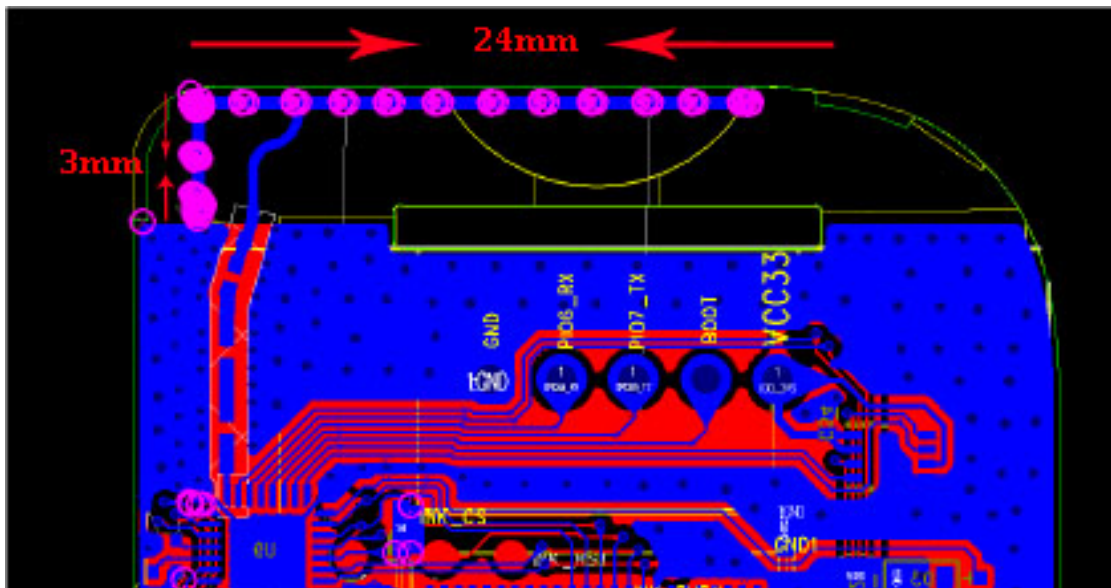


Figure 1: PCB Antenna Layout Diagram (2.4G Printed PCB Antenna)

3. Antenna Specifications

Antenna Type	PCB Antenna	

Operating Band	2400 MHz ~ 2483.5 MHz	Bluetooth / 2.4G ISM Band
Center Frequency	2442 MHz (typical)	BLE Common Channel Center
Impedance Matching	50 Ω	Matched to RF Front-End
Max Gain	0 dBi (typical)	Affected by structure / clearance
Polarization	Linear Polarization	Typical monopole antenna polarization
Dimensions	See antenna dimension drawing	Measure per actual layout
Antenna Clearance	No copper pour / routing beneath antenna area	Ensure antenna radiation efficiency
S11 (Return Loss)	≤ -6 dB (recommended) / ≤ -10 dB (preferred)	Lower center frequency is better
Antenna Efficiency	$\geq 40\%$ (typical recommendation)	Affected by whole-device environment
Test Conditions	Free space / standard jig	Actual whole-device requires calibration

4. Antenna Dimensions

Antenna dimensions must be measured from the actual PCB layout file and dimensional drawing.

Typical IFA design dimensions include:

1. Total length of radiating stub: approximately $\lambda/4$ (about 31.25 mm at 2.4G, subject to correction per dielectric constant).
2. Feed point width: designed for the 50 Ω matching line, typically 0.5 mm ~ 1.0 mm (depending on PCB material and stack-up).
3. Shorting point position: determines the antenna resonant frequency and impedance matching, and must be optimized through simulation or VNA tuning.
4. Antenna clearance area: reserve a clearance of ≥ 3 mm around and beneath the antenna trace to avoid copper pouring or signal lines crossing.
5. Distance from board edge: the antenna body should be placed close to the PCB edge to ensure radiation performance into free space.

5. Antenna Return Loss S11

S11 (return loss / reflection coefficient) characterizes the impedance matching between the antenna and the RF front-end. A smaller S11 indicates less reflected power and more power fed into the antenna.



Test Conditions:

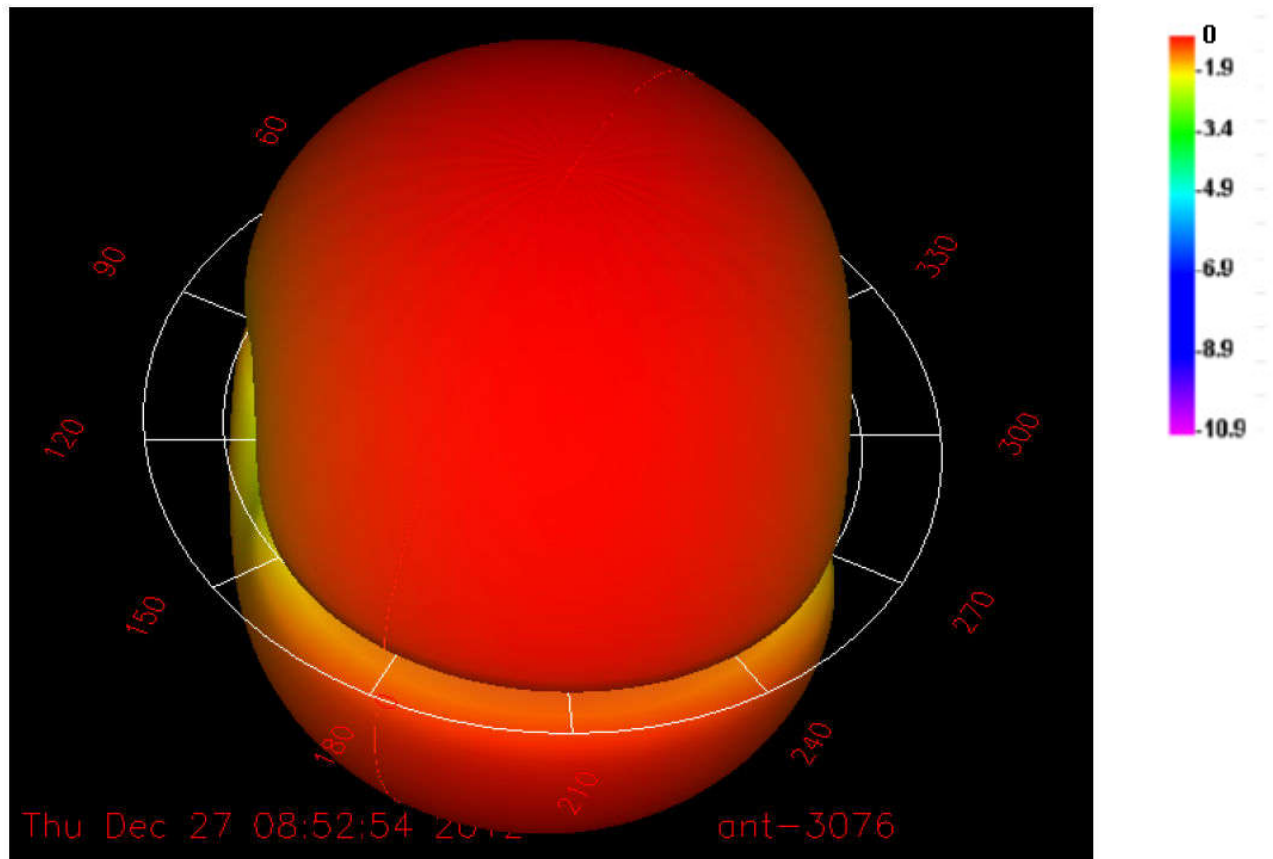
1. Test equipment: Vector Network Analyzer (VNA) or antenna test system.
2. Test environment: anechoic environment or standard jig.
3. Frequency range: 2400 MHz ~ 2483.5 MHz.

Acceptance Criteria:

- Across the entire 2.4G Bluetooth band (2400 ~ 2483.5 MHz), S11 is recommended to be ≤ -6 dB.
- Near the center channel (about 2442 MHz), S11 is preferably ≤ -10 dB.
- If the S11 curve shows an obvious frequency shift or insufficient notch depth within the target band, adjust the antenna trace length, shorting point position, or matching network.

6. Antenna Radiation Pattern

The antenna radiation pattern describes the distribution of radiated power in different spatial directions.



Test Method:

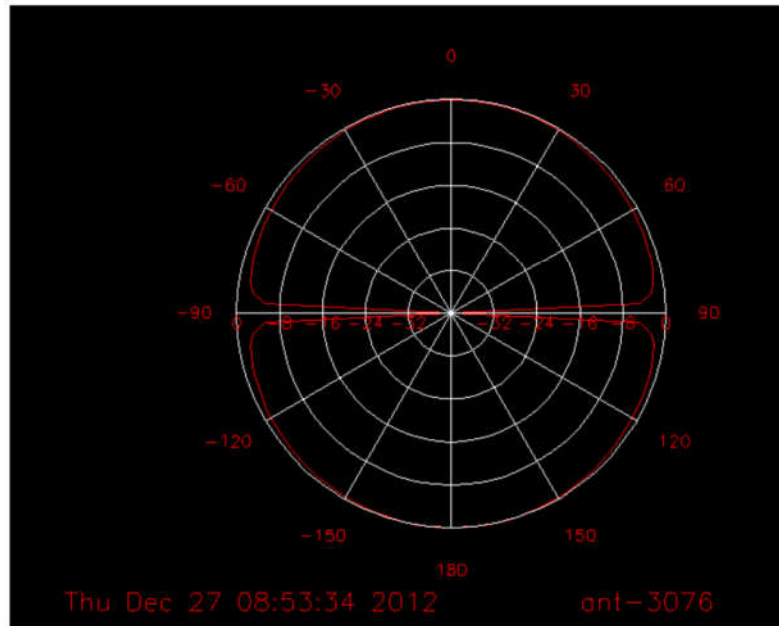
1. Measure in an anechoic chamber using the standard antenna method or near-field scanning.
2. Plot normalized radiation patterns on the E-plane (electric-field plane) and H-plane (magnetic-field plane) respectively.
3. Record the maximum-gain direction, half-power beamwidth (HPBW), and front-to-back ratio.

Typical Performance:

- The monopole IFA radiates strongly in the direction perpendicular to the PCB plane.
- Radiation is weak (with a null) in directions close to the ground plane (the PCB plane).
- Once the enclosure, battery, and metal parts are assembled, the radiation pattern changes; whole-device OTA testing is required.

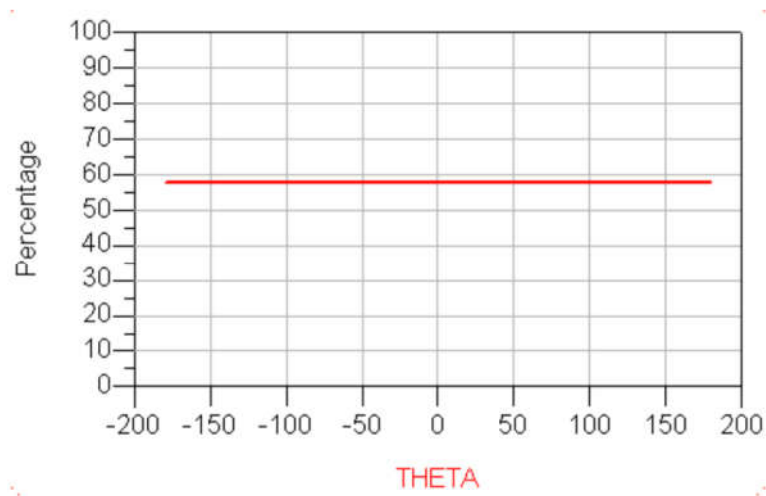
7. Antenna Efficiency

Antenna efficiency is the ratio of radiated power to input power, comprehensively reflecting the antenna matching loss and radiation loss.



2D图

5. 天线效率



Test Conditions:

1. Measure in an anechoic chamber or an active OTA test system.
2. Cover the entire 2.4G Bluetooth band (2400 ~ 2483.5 MHz).

3. Test typical usage scenarios separately: free space, hand-held, and head-worn.

Acceptance Criteria:

- Free-space antenna efficiency is recommended to be $\geq 40\%$.
- Whole-device efficiency is greatly affected by enclosure material, battery, metal structure, and human-body shadowing.
- If efficiency is low, check the antenna clearance, matching network, ground continuity, and board parameters.

8. Measured Data Record (Template)

S11	2.442	$\leq -6 \text{ dB} / \leq -10 \text{ dB}$	—	—	Insert measured curve plot
Peak Gain	2.442	about 0 dBi	—	—	Insert measured radiation pattern
Antenna Efficiency	2.442	$\geq 40\%$	—	—	Insert measured efficiency curve
Operating Band	2.400 ~ 2.4835	Covers full band	—	—	—
VSWR	2.442	$\leq 3.0 / \leq 2.0$	—	—	Derived from S11

9. Notes / Cautions

1. Copper pouring, trace routing, and component placement are strictly prohibited in the antenna area; keep the clearance to ensure radiation performance.
2. The antenna feed line should be as short as possible, designed as a 50Ω microstrip line, avoiding sharp-angle routing.
3. After whole-device assembly, S11, radiation pattern, and efficiency must be re-tested, because the enclosure, battery, and human body all cause significant impact.
4. If the antenna frequency deviates from the target band, optimize by adjusting the radiating stub length, shorting point position, or adding matching components.
5. It is recommended to complete whole-device passive and active OTA tests before certification to ensure compliance with FCC / CE / SRRC and other regulatory requirements.

Jiangxi Xingtai Technology Inc.
Jiqing Road, Jizhou District, Ji'an City, Jiangxi Province, China