

PCB ANTENNA SPECIFICATION SHEET

2.4 GHz ISM Band | Inverted-F Antenna (IFA)

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Revision	1.0
Date	2026-05-22
Frequency Range	2400 - 2480 MHz
Peak Gain	0.54 dBi
Status	Released

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1. General Description

This specification defines the electrical, mechanical, and environmental requirements for a 2.4 GHz ISM band PCB antenna designed for embedded wireless applications. The antenna is optimized for Bluetooth Low Energy (BLE), Wi-Fi (802.11 b/g/n), Zigbee, and other 2.4 GHz proprietary protocols.

The antenna is an Inverted-F Antenna (IFA) type implemented directly on the PCB substrate, requiring no external antenna component. It is designed for 50 Ω impedance matching and provides near-omnidirectional radiation characteristics suitable for general-purpose wireless communication.

2. Electrical Specifications

2.1 Key Electrical Parameters

Parameter	Specification	Condition
Frequency Range	2400 – 2480 MHz	ISM Band
Center Frequency	2440 MHz	—
Bandwidth (S11 $\leq$ -10 dB)	$\geq$ 150 MHz	Free Space
Peak Gain	0.54 dBi	@ 2440 MHz, Free Space
Average Gain	$\geq$ -1.5 dBi	Over 2400–2480 MHz
Radiation Efficiency	$\geq$ 45%	@ 2440 MHz
Impedance	50 Ω	Nominal
VSWR	$\leq$ 2.0:1	Over 2400–2480 MHz
Return Loss (S11)	$\leq$ -10 dB	Over 2400–2480 MHz
Polarization	Linear (Vertical)	—
Radiation Pattern	Near-Omnidirectional	H-Plane
Max Input Power	2 W (33 dBm)	Continuous
Front-to-Back Ratio	$\geq$ 3 dB	E-Plane

2.2 Gain Characteristics

Frequency (MHz)	Peak Gain (dBi)	Avg Gain (dBi)
2400	0.46	-1.6
2420	0.50	-1.4
2440	0.54	-1.2
2460	0.51	-1.3
2480	0.47	-1.5

2.3 VSWR Characteristics

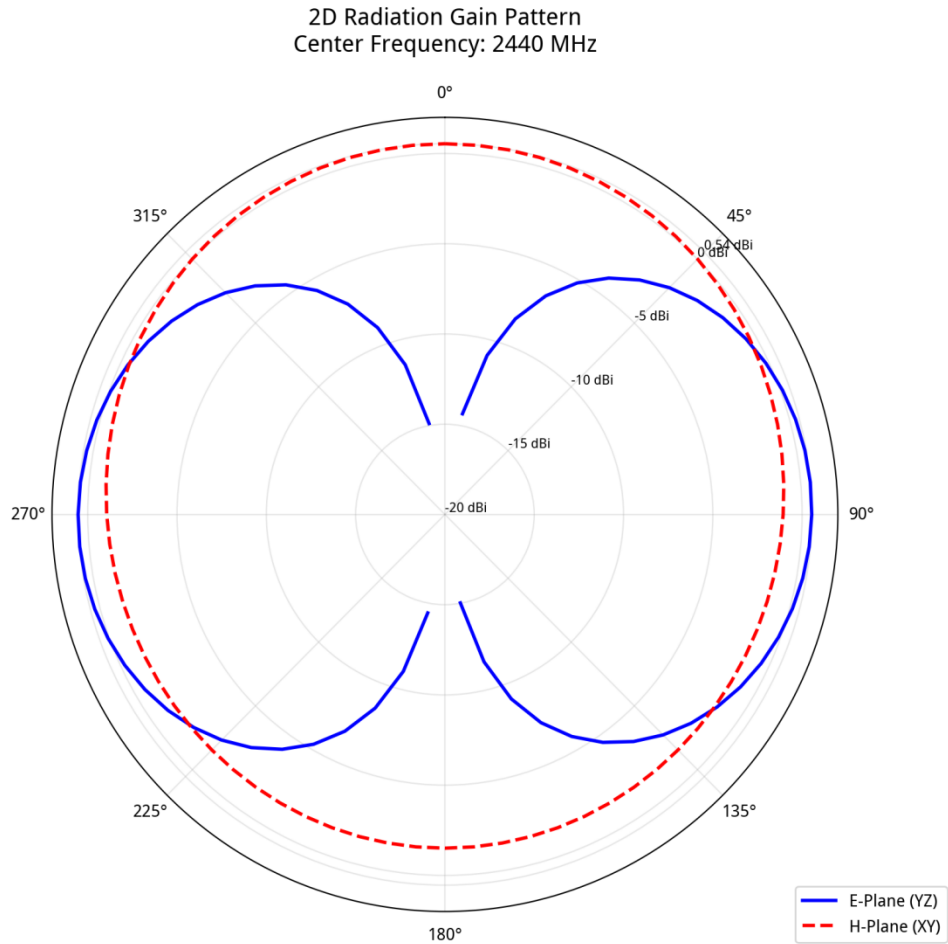
Frequency (MHz)	VSWR	Return Loss (dB)
2400	1.82	-9.8
2420	1.65	-12.1
2440	1.45	-15.3
2460	1.58	-13.0

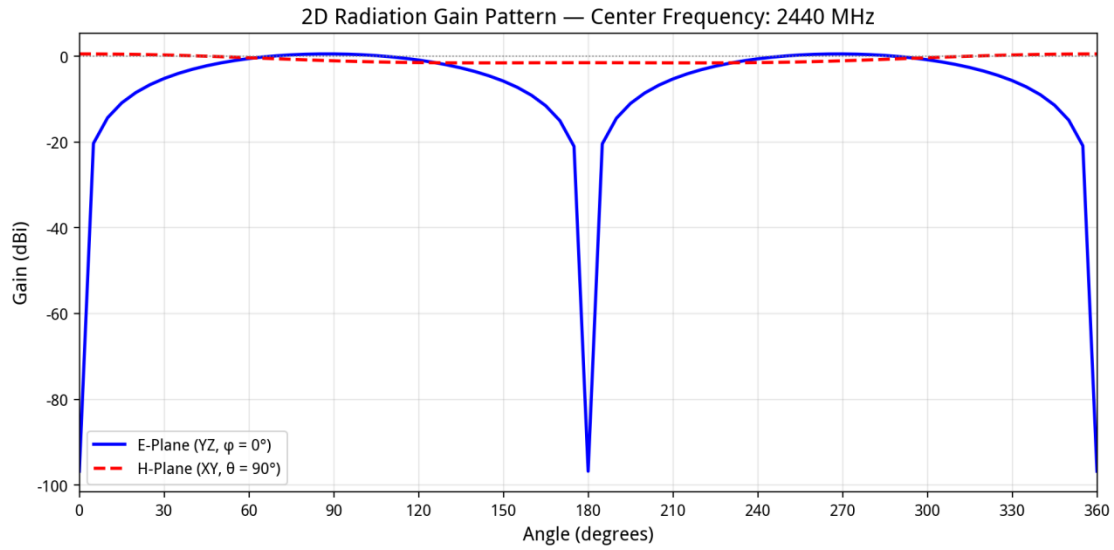
Frequency (MHz)	VSWR	Return Loss (dB)
2480	1.78	-10.5

3. Radiation Pattern

3.1 2D Radiation Gain Pattern

The following figures show the E-Plane (YZ , $\phi = 0^\circ$) and H-Plane (XY , $\theta = 90^\circ$) radiation gain patterns measured at the center frequency of 2440 MHz.





E-Plane (YZ Plane) Key Data

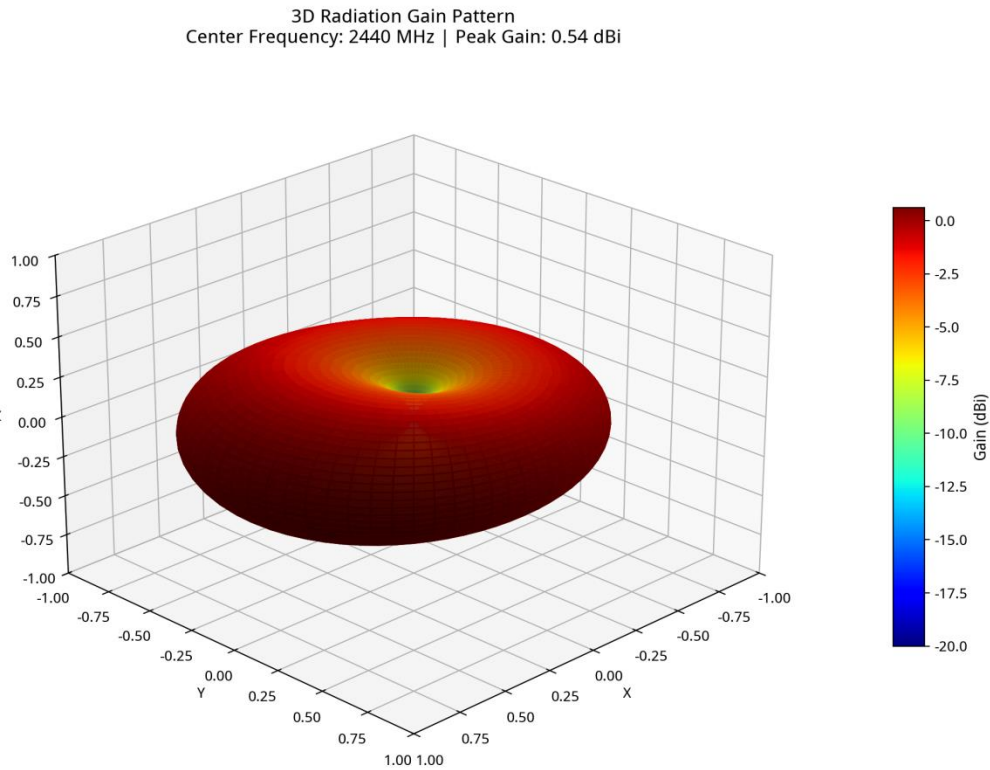
Angle (θ)	Gain (dBi)
0°	-18.2
30°	-3.8
60°	0.32
90° (Peak)	0.54
120°	0.28
150°	-4.5
180°	-19.0
270°	0.48

H-Plane (XY Plane) Key Data

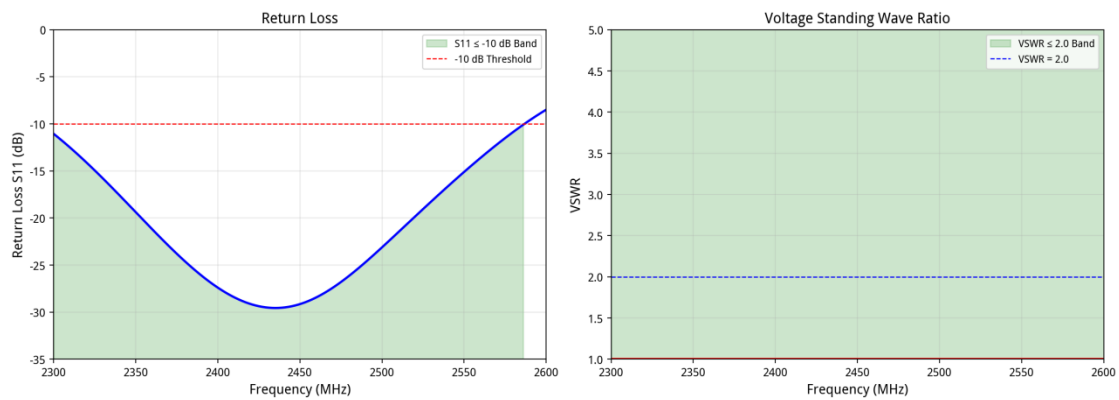
Angle (ϕ)	Gain (dBi)
0° (Peak)	0.54
45°	0.38
90°	-0.15
135°	0.10
180°	0.42
225°	0.12
270°	-0.25
315°	0.35

3.2 3D Radiation Gain Pattern

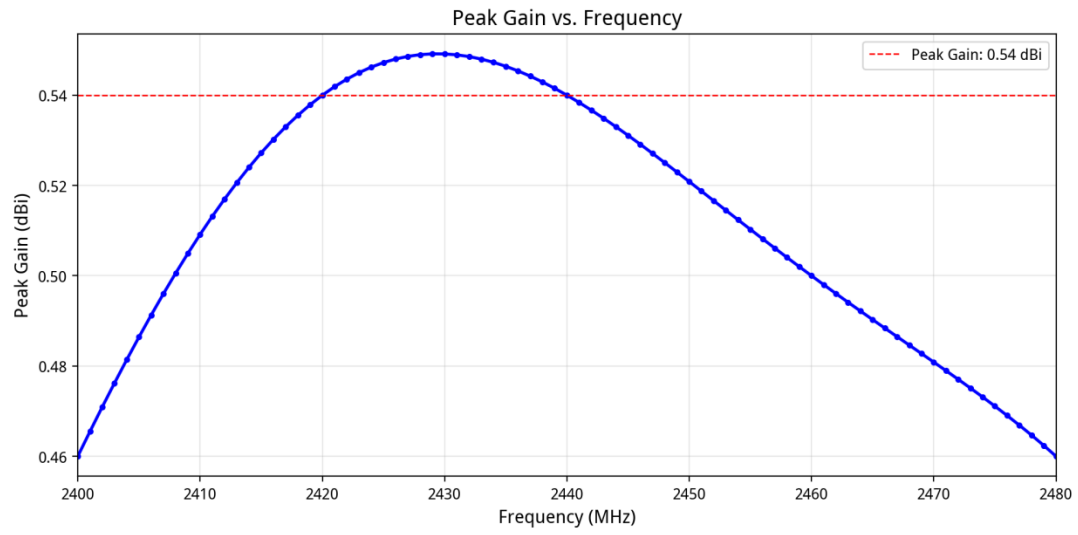
The 3D radiation pattern illustrates the spatial distribution of the antenna gain. The peak gain of 0.54 dBi is observed at $\theta = 90^\circ$, $\phi = 0^\circ$.



3.3 Return Loss & VSWR



3.4 Gain vs. Frequency



4. Mechanical Specifications

4.1 Antenna Dimensions

Parameter	Value	Tolerance
Radiating Arm Length (L1)	15.2 mm	± 0.2 mm
Radiating Arm Width (W1)	0.9 mm	± 0.1 mm
Feed Arm Length (L2)	2.7 mm	± 0.1 mm
Feed Arm Width (W2)	0.5 mm	± 0.1 mm
Shorting Arm Length (L3)	5.0 mm	± 0.1 mm
Shorting Arm Width (W3)	0.5 mm	± 0.1 mm
Ground Clearance	0.5 mm (min)	—
Keep-out Zone	15.2 × 5.7 mm	—

4.2 PCB Substrate Requirements

Parameter	Specification
Material	FR-4
Dielectric Constant (ϵ_r)	4.4 ± 0.2
Loss Tangent ($\tan \delta$)	≤ 0.02
PCB Thickness	1.6 mm (± 0.1 mm)
Copper Weight	1 oz (35 μ m)
Surface Finish	ENIG (Recommended)
Number of Layers	≥ 2

4.3 Feed Line Requirements

Parameter	Specification
Characteristic Impedance	50 Ω
Microstrip Line Width	3.0 mm (for 1.6 mm FR-4)
Max Feed Line Length	< 12 mm ($\lambda/10$)
Ground Via Spacing	≤ 5 mm ($\lambda/20$)

4.4 Matching Network

A PI-type matching network is recommended near the antenna feed point. Start with default values (0 Ω series, 0 pF shunt) and adjust based on VNA measurements.

Component	Default Value	Adjustment Range
C1	0 pF (open)	0 – 1.5 pF
L (Series)	0 Ω (short)	0 – 3.0 nH
C2	0 pF (open)	0 – 1.0 pF
C3	0 pF (open)	0 – 1.0 pF

5. Layout Guidelines

5.1 Keep-out Zone

- Antenna area: No copper traces, ground pours, or components allowed within the keep-out zone (15.2 × 5.7 mm) on all PCB layers.
- Minimum clearance: ≥ 3 mm from antenna to any metal object, battery, or conductive enclosure.
- Top and bottom layers: Both must be clear of copper under the antenna.

5.2 Ground Plane Requirements

- Minimum ground plane size: ≥ 40 mm × 15 mm for optimal performance.
- Ground plane should extend beneath the feed point and shorting arm.
- Use via stitching along ground plane edges (≤ 2 mm spacing).
- Avoid ground plane discontinuities near the antenna.

5.3 Placement Recommendations

- Place antenna at the edge of the PCB (corner placement preferred).
- Ensure the radiating arm extends toward the PCB edge.
- Avoid placing antenna near high-speed digital traces, power supply circuits, motors, or metal enclosures.

5.4 Enclosure Considerations

Enclosure Material	Impact on Performance
Plastic (ABS, PC)	Minimal (< 1% frequency shift)
Metal	Significant — requires antenna redesign or RF window
Carbon-fiber composite	Moderate — verify with testing

6. Environmental Specifications

Parameter	Specification
Operating Temperature	-40 °C to +85 °C
Storage Temperature	-55 °C to +125 °C
Humidity	5% – 95% RH (non-condensing)
Soldering Temperature	260 °C max (10 sec) per IPC/JEDEC J-STD-020
Thermal Shock	-40 °C ↔ +85 °C, 100 cycles
Vibration	10–500 Hz, 0.5 g, 2 hrs/axis
RoHS Compliance	Compliant

7. Test Conditions

Parameter	Condition
Measurement System	Vector Network Analyzer (VNA)
Calibration	SOL at test cable end

Parameter	Condition
Test Frequency Range	2300 – 2600 MHz
Radiation Pattern Test	Anechoic chamber, far-field measurement
Test Distance	≥ 3 m (far-field condition)
Reference Antenna	Standard gain horn antenna

8. Coordinate System Definition

E-Plane (YZ): Vertical plane at $\phi = 0^\circ$ (contains the radiating arm axis)

H-Plane (XY): Horizontal plane at $\theta = 90^\circ$ (perpendicular to the radiating arm)

θ (Theta): Elevation angle from Z-axis (0° to 180°)

ϕ (Phi): Azimuth angle from X-axis in XY plane (0° to 360°)

9. Application Notes

- **Impedance Matching:** The antenna is designed for $50\ \Omega$ impedance at 2440 MHz. Always verify matching with VNA after PCB fabrication, as board thickness, copper weight, and surrounding components can affect impedance.
- **Ground Plane Size:** Antenna performance is directly influenced by the ground plane dimensions. A ground plane of at least $\lambda/4 \times \lambda/4$ (~30 mm $\times$ 30 mm) at 2.44 GHz is recommended for stable performance.
- **Cable Effect:** During testing, use ferrite chokes on the test cable to minimize cable radiation effects. Position the cable perpendicular to the antenna for at least 20 cm.
- **Production Tuning:** For mass production, verify antenna performance across multiple board lots. FR-4 dielectric constant can vary ± 0.2 between batches, potentially causing frequency shift of up to ± 50 MHz.
- **Certification Support:** This antenna design is suitable for FCC Part 15.247, ETSI EN 300 328, and ARIB STD-T66 regulatory compliance. Final certification testing must be performed on the complete product assembly.
- **Hand/Body Effect:** When used in wearable or handheld devices, expect 1–3 dB gain reduction due to body proximity. Consider this in link budget calculations.

10. Revision History

Rev.	Date	Description	Author
1.0	2026-05-22	Initial release	Engineering

Disclaimer

This specification is provided for reference only. Actual antenna performance may vary depending on PCB layout, ground plane size, enclosure design, and surrounding components. It is strongly recommended to verify all parameters with actual measurements on the final product assembly. The manufacturer assumes no liability for performance deviations caused by implementation differences.

11.Dimension drawing

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