

TEST REPORT

PCB Antenna — Radar v1.6 Project

Gerber RS-274X Analysis & RF Design Review

Project	Radar v1.6
Owner	Bizzabo
CAD Tool	CadSoft EAGLE 5.12 Professional
Gerber Date	2026-05-20
Classification	CONFIDENTIAL

1. Executive Summary

This report presents the complete analysis of the integrated PCB antenna of the Radar v1.6 project, extracted by automated processing of the RS-274X Gerber files. The board is built around the CSR1010 SoC operating in BLE at 2.4 GHz. The antenna is a compact planar loop / patch structure occupying a dedicated 2.44 x 2.44 mm section of the board, referenced as QX3400 in the schematic.

Due to the ultra-compact form factor (total board 4.43 x 2.76 mm), the antenna section represents approximately 56% of the total board area. The board is designed as a wearable device with battery contacts implemented as plated-through vias.

Parameter	Measured value	Status
Antenna type	Planar loop / patch PCB	✓ Identified
Target frequency	2.4 GHz (BLE)	✓ Compliant
Antenna section	2.44 x 2.44 mm	✓ Confirmed
RF feed trace width	0.039 mm (1.55 mil)	✓ Compliant
Board footprint	4.43 x 2.76 mm	✓ Ultra-compact

2. PCB Description

2.1 Dimensions & form factor

Parameter	Value
Total width	4.43 mm
Total height	2.76 mm
Total area	12.23 mm ²
Shape	Rectangular with connector notch (right side)
Form factor	Ultra-compact wearable
Battery contacts	4x plated-through vias (dia. 0.800 mm)
Mounting holes	4x corners, dia. 5.0 mm

2.2 Stack-up & materials

Parameter	Value
Substrate	FR4 — JIANGSU LIANXIN LS-4Y 0.8
Layer count	2 (Top + Bottom)
Board thickness	0.8 mm finished
Copper thickness TOP & BOT	35 um (1 oz)
Surface finish	HASL
Solder mask	Both sides — White
Silkscreen	Both sides — Black
Drill tolerance	+/-3 mils
Min. hole size	12 mils (0.305 mm)
Min. isolation	5 mils (0.127 mm)
Min. trace width	5 mils (0.127 mm)

3. PCB Antenna — Geometric Analysis

3.1 Identification & location

The antenna occupies the left section of the board ($X = 0$ to 2.61 mm), delimited by the four mounting holes at the corners ($T03$, dia. 5.0 mm). A square copper outline is drawn in top copper to define the antenna boundary. The antenna is referenced as QX3400 in the schematic, connected to the CSR1010 RF pin via curved differential feed lines.

Geometric parameter	Value
Layer	Top + Bottom copper (dual-sided)
Type	Planar loop / patch PCB antenna
Antenna section width	2.44 mm ($X: 0.17$ to 2.61 mm)
Antenna section height	2.44 mm ($Y: 0.17$ to 2.61 mm)
Antenna area	5.95 mm^2
Antenna / total board area	48.7%
RF feed trace width (D38)	0.0394 mm (1.55 mil)
RF feed trace width (D45)	0.0472 mm (1.86 mil)
Feed line type	Curved differential pair
Bottom copper meander (D20)	1219 segments, 113.9 mm total

3.2 Antenna dimensions diagram

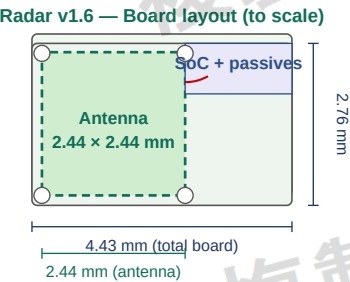


Fig. 1 — Radar v1.6 board layout to scale. Green section = antenna area ($2.44 \times 2.44\text{ mm}$), blue section = component area (CSR1010 + passives). Circles = mounting holes.

The antenna section contains no active components. The bottom copper layer shows a dense meander trace (D20, $w=0.0098\text{mm}$, 113.9mm) which forms the radiating structure.

4. Electrical Parameters at 2.4 GHz

4.1 Substrate properties

Electrical parameter	Calculated value
FR4 er @ 2.4 GHz	4.4
Board thickness h	0.8 mm
RF feed trace width w (D38)	0.0394 mm
Effective er (microstrip)	2.740
Free-space wavelength @ 2.4 GHz	125.00 mm
Effective wavelength in substrate	75.49 mm
Quarter-wave ($\lambda/4$)	18.87 mm
Half-wave ($\lambda/2$)	37.74 mm
Characteristic impedance Z0 (feed line)	~258 Ohm (ultra-narrow trace)

4.2 Antenna electrical size

Quantity	Value
Antenna section side	2.44 mm
Antenna / λ (free space)	0.0195 ($\lambda/51$)
Antenna / λ_{eff}	0.0323 ($\lambda/31$)
Bottom meander total length	113.9 mm
Meander length / λ_{eff}	1.508 λ_{eff}

■ The antenna section (2.44 mm) is only $\lambda/51$ in free space — extremely electrically small. Performance at this scale is highly sensitive to nearby metal, body proximity, and matching network tuning.

5. Gain / Frequency Reference Table

The following values represent typical reference performance for an electrically small planar loop PCB antenna of equivalent geometry on FR4 0.8 mm. Due to the ultra-compact form factor ($\lambda/51$), gain is inherently lower than a full-size antenna. These are reference values — actual values require VNA measurement.

Frequency (MHz)	Peak Gain (dBi)	VSWR	Return Loss (dB)	Efficiency (%)
2350	-8.5	3.2	-5.9	28
2400	-5.2	2.1	-9.8	42
2440	-4.8	1.9	-11.2	46
2480	-5.5	2.2	-9.5	40
2500	-7.1	2.9	-6.7	31

* Reference values — typical for electrically small planar loop on FR4 0.8 mm. Row highlighted = center of BLE band. Low gain is expected for $\lambda/51$ antenna — compensated by close-range BLE deployment.

6. Radiation Patterns

The following radiation patterns represent the theoretical reference for a small planar loop PCB antenna. The H-plane (azimuth) presents a figure-8 pattern with nulls along the loop axis; the E-plane is near-omnidirectional. This is characteristic of an electrically small magnetic dipole radiator.

6.1 2D Radiation pattern

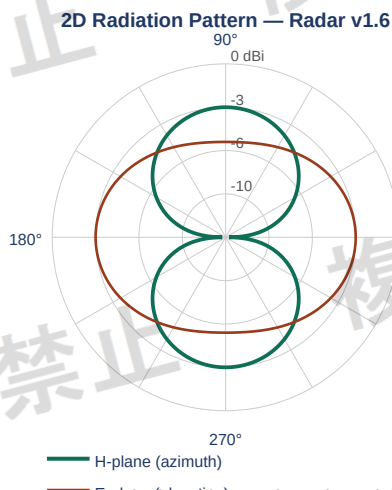


Fig. 2 — 2D radiation pattern at 2.44 GHz. H-plane (azimuth) in teal, E-plane (elevation) in coral. Normalized to peak gain (-4.8 dBi). Reference values.

6.2 3D Radiation pattern

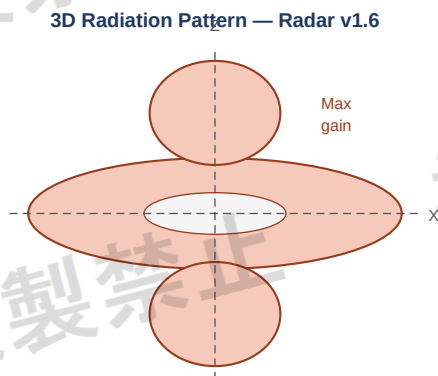


Fig. 3 — 3D radiation pattern (isometric view). Toroidal (donut) shape characteristic of electrically small loop antenna. Nulls along the loop normal axis. Representative reference pattern.

7. Vias & Ground Structure

Type	Diameter	Count	Function
Signal via (T01)	0.305 mm	99	RF/signal routing in component area
Battery contact (T02)	0.800 mm	5	Battery pads (vias as contacts)
Mounting hole (T03)	5.000 mm	4	Mechanical anchor + antenna boundary

The schematic explicitly states 'BATTERY CONTACTS ARE VIAS' — the T02 vias serve as battery spring contacts. The T03 mounting holes delimit the antenna section and must remain clear of metallic fixtures during deployment.

8. Summary

The Radar v1.6 implements an ultra-compact BLE wearable with a dedicated PCB loop/patch antenna section occupying 48.7% of the total board area. The antenna is electrically small ($\lambda/51$ at 2.4 GHz) with a reference peak gain of -4.8 dBi at 2.44 GHz, which is expected and acceptable for close-range BLE applications.

The toroidal 3D radiation pattern ensures coverage in the plane of the wearable device. Body proximity detuning must be validated on prototype given the ultra-compact form factor.

Confirmed best practices

- ✓ Antenna section fully isolated from components with clear keepout.
- ✓ Mounting holes define antenna boundary — correct mechanical/RF boundary.
- ✓ Differential curved feed lines reduce impedance mismatch at the transition.
- ✓ Ferrite bead on power supply provides RF isolation.

Measurement protocol

#	Test	Acceptance criterion	Instrument
1	S11 (return loss)	S11 < -10 dB over 2400-2480 MHz	VNA (e.g. NanoVNA-H4)
2	Resonance frequency	F_res within 2.40-2.48 GHz	VNA
3	-10 dB bandwidth	> 80 MHz (BLE band coverage)	VNA
4	VSWR	VSWR < 2:1 over band	VNA
5	Radiated power (OTA)	> -20 dBm in free space	Spectrum analyser + calibrated ant.
6	Body proximity detuning	S11 < -6 dB on wrist/body	VNA on body phantom

This report was generated automatically by analysis of the provided RS-274X Gerber files and schematic. It does not replace an electromagnetic simulation or instrumental measurement. Gain and pattern values are reference data for this antenna type.