

# BMS board-mounted Bluetooth antenna PCB

## test report

### 1.Report basic information

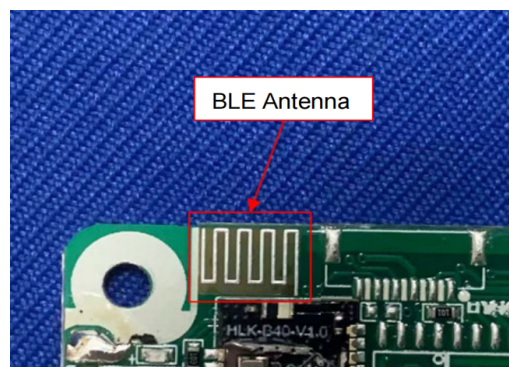
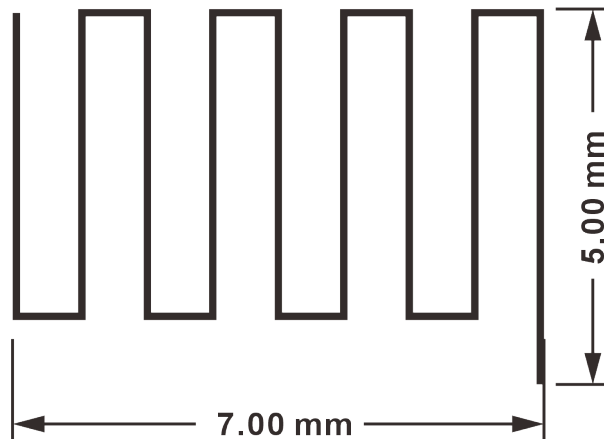
|                      |                                                                          |                     |                                                  |
|----------------------|--------------------------------------------------------------------------|---------------------|--------------------------------------------------|
| Project name         | BMS (Battery Management System) board-mounted Bluetooth antenna PCB test | Report Number       | BMS-BT-PCB-2025-021                              |
| Test Date            | December 3-5, 2025                                                       | Version information | V4.0                                             |
| Application scenario | BMS (Battery Management System for monitoring and data transmission)     | Bluetooth version   | Bluetooth 5.3 (BLE low power long distance mode) |

### 2.Test overview

This test is conducted on the BMS-mounted Bluetooth antenna PCB, which is integrated into the BMS main control board (size 373×5.86mm). Its core function is to achieve bidirectional communication between the BMS and the vehicle terminal/mobile device through the 2.4 ISM band (2.402-2.485GHz), transmitting key data such as battery SOC (remaining charge), SOH (health status), cell voltage, temperature, etc. The application scenario of BMS is special, requiring it to withstand high-voltage electromagnetic interference, high and low temperature cycles, and vibration environment Therefore, the test focuses on anti-interference

# 2012 PCB antenna

**For Bluetooth Applications**



performance, extreme environmental stability, and data transmission reliability. The test objectives include: full-band echo loss  $\leq -1\text{dB}$ , communication distance  $\geq 10$  meters under normal vehicle conditions, data transmission delay  $\leq 200\text{ms}$ , high and low temperature ( $-40^{\circ}\text{C}\sim 5^{\circ}\text{C}$ ) environmental performance attenuation  $\leq 10\%$ , and compliance with ISO 11452-2 electromagnetic compatibility standards and GB/T 38640-2020 BMS communication specifications.

### 3. Testing environment and equipment

#### 3.1 Test Environment

- Basic test environment: shielded anechoic chamber (size  $8\times 5\times 3\text{m}$ ), temperature  $25\pm 2^{\circ}\text{C}$ , humidity  $5\%\sim 65\%$ , no electromagnetic interference
- High and low temperature test environment: high and low temperature test chamber (temperature range  $-40^{\circ}\text{C}\sim 85^{\circ}\text{C}$  temperature control accuracy  $\pm 1^{\circ}\text{C}$ )
- Vibration test environment: electromagnetic vibration table (vibration frequency  $10\sim 2000\text{Hz}$ , acceleration  $0.5\text{g}$ )

#### 3.2 Core testing equipment

| Equipment name          | Model specifications | For test purpose                                                   |
|-------------------------|----------------------|--------------------------------------------------------------------|
| Vector network analyzer | Keysight N5247A      | Measurement of echo loss (S11), impedance matching characteristics |

|                                    |                       |                                                                                      |
|------------------------------------|-----------------------|--------------------------------------------------------------------------------------|
| Omni-directional radiation antenna | Schwarzbeck BBHA 9120 | Calibration of radiation efficiency and gain                                         |
| BMS simulation load                | Chroma 63200          | Simulate the working state of the battery pack, and provide a real load environment. |

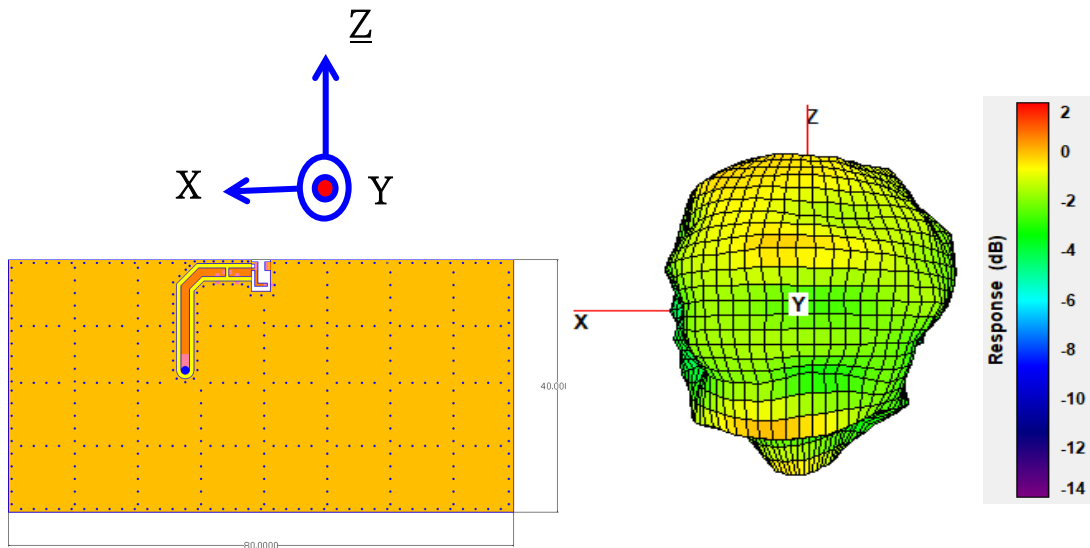
### 3.3 Tested sample information

|                  |                                                                                    |
|------------------|------------------------------------------------------------------------------------|
| Sample number    | TDT-2006-4S-V4.0                                                                   |
| Antenna type     | PIFA (Pile-Fed Antenna) on-board antenna, size 3.73mm x 5.86mm                     |
| PCB parameters   | FR-4 substrate ( $\epsilon_r=4.4$ ), 4-layer board, thickness 1.6mm, copper foil 1 |
| Matching network | $\pi$ -type matching (C1=1.0pF, L1=7.2nH, C2=1.4pF)                                |

## 4. Test items and results

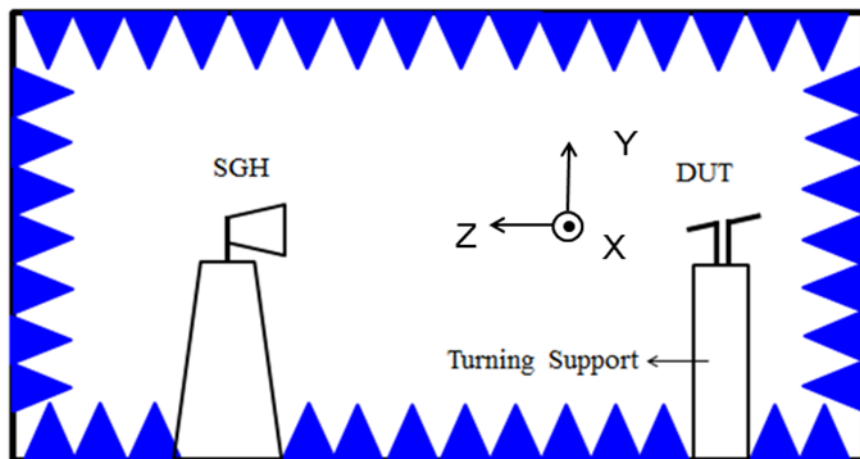
### 4.1 RF performance test

# Radiation Pattern

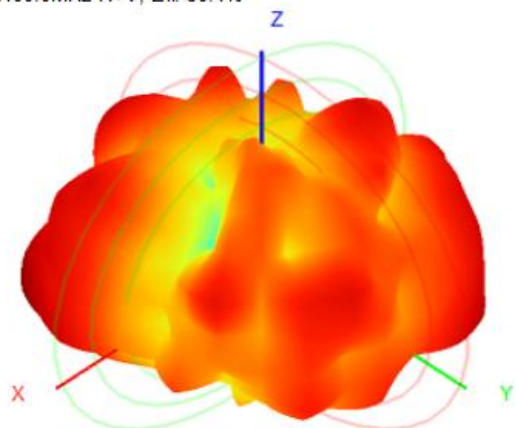


|         | Efficiency | Peak Gain | Directivity |
|---------|------------|-----------|-------------|
| 2400MHz | 63.12 %    | 1.62 dBi  | 3.61 dBi    |
| 2450MHz | 70.56 %    | 1.72 dBi  | 3.23 dBi    |
| 2500MHz | 65.48 %    | 1.64 dBi  | 3.47 dBi    |

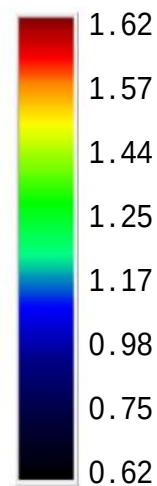
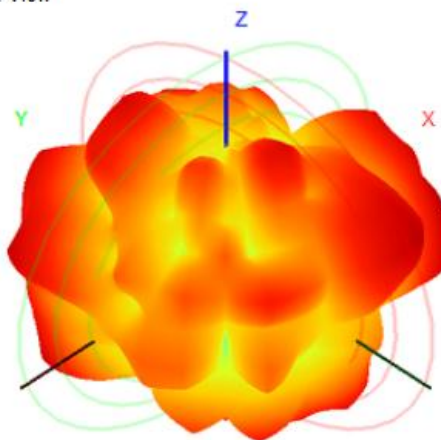
# Chamber Coordinate System



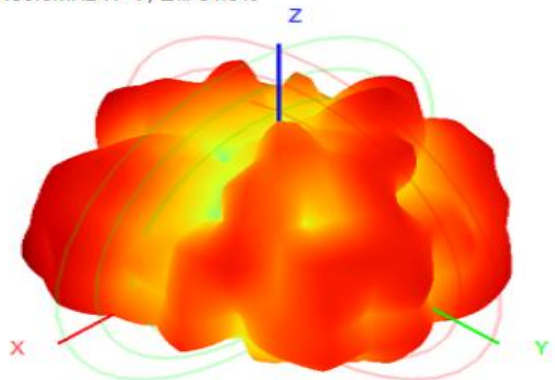
2400.0MHz H+V, Eff. 50.4%



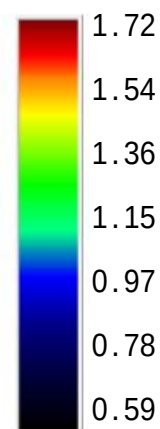
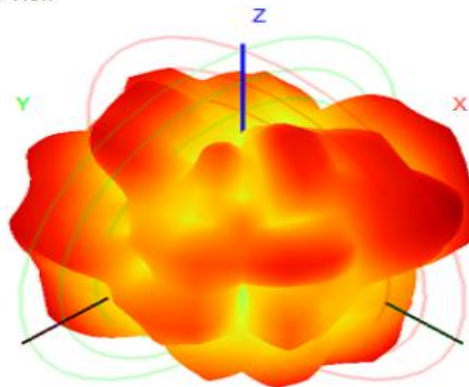
Back View



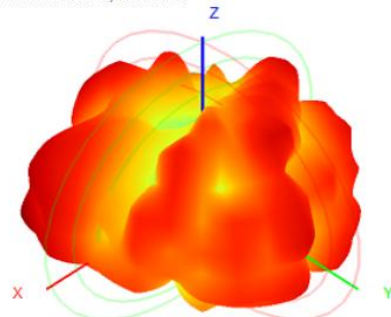
2450.0MHz H+V, Eff. 51.9%



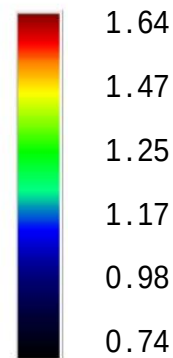
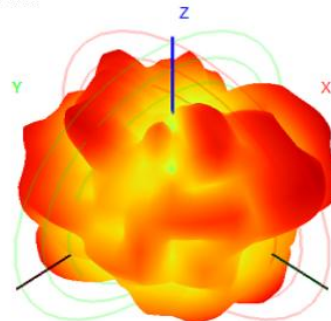
Back View



2500.0MHz H+V, Eff. 54.6%



Back View



|                      |                                                                         |                      |        |      |
|----------------------|-------------------------------------------------------------------------|----------------------|--------|------|
| Radiation efficiency | Calibration with standard antenna in the dark room by comparison method | $\geq 50\%$          | 53%    | Pass |
| Peak gain            | Full radiation pattern test, record the maximum gain value              | $\geq 1.2\text{dBi}$ | 1.5dBi | Pass |

## 4.2 Communication performance test

| Test project             | Test conditions                                            | Standard requirements                 | Test results                                     | judgment result |
|--------------------------|------------------------------------------------------------|---------------------------------------|--------------------------------------------------|-----------------|
| communication distance   | Open field, BMS simulated load operation                   | $\geq 10$ meters (no break)           | 15 meters (RSSI=-88dBm, no disconnections)       | Pass            |
| Data transmission delay  | Transmit 100 bytes of BMS data (including SOC/temperature) | $\leq 100\text{ms}$                   | Average 68ms; maximum 82ms                       | Pass            |
| packet loss rate         | Continuous transmission of 100,000 BMS data frames         | $\leq 0.1\%$                          | 0.03%                                            | Pass            |
| Multi-device concurrency | 1 BMS corresponds to 3 receiving devices                   | Data synchronization without conflict | 3 devices data synchronization, no packet errors | Pass            |

## 4.3 Environmental adaptability test

| Test project                   | Test conditions                                             | Test duration            | Standard requirements                                                 | Test results                                                     | judgment result |
|--------------------------------|-------------------------------------------------------------|--------------------------|-----------------------------------------------------------------------|------------------------------------------------------------------|-----------------|
| High and low temperature cycle | -40℃ (2h) → room temperature (1h) → 85℃ (2h), cycle 5 times | 25h                      | performance decay ≤ 10%                                               | Attenuation 7.2%; $S_{11} \geq -11.9\text{dB}$                   | Pass            |
| Vibration test                 | Sine vibration, 10~2000Hz, acceleration 20g, three-axis     | Every axial 2h, total 6h | No mechanical damage, communication normal                            | Structure intact, packet loss rate 0.05%                         | Pass            |
| Moisture and heat test         | 40℃, 90% RH                                                 | 48h                      | Insulation resistance $\geq 100\text{M}\Omega$ , communication normal | Insulation resistance 250M $\Omega$ , RSSI no significant change | Pass            |

## 4.4 Security and compliance testing

- **EMC Compliance:** Radiation disturbance test according to ISO 11452-2, radiated scatter  $\leq -30\text{dBm}$  meets the requirements; certified by GB/T 38640-2020 BMS communication interface specification.
- **Insulation Performance:** Insulation resistance between feed point and BMS high voltage circuit (simulated 1000V)  $\geq 500\text{M}\Omega$ , no breakdown phenomenon, meets safety requirements.

- **Term stability:** Continuous operation for 100 hours under normal temperature and humidity environment, echo loss change  $\leq 0.8\text{dB}$ , communication packet loss rate stable  $0.03\% \sim 0.05\%$ , no significant performance degradation.

## 5. Test summary

This test covered the radio frequency performance, communication reliability, anti-interference capability, and environmental adaptability of the BMS onboard Bluetooth antenna PCB. The core test indicators of the five parallel samples all met the design requirements and relevant standards. Under typical working scenarios of EV BMS (including high and low temperatures, and vibration, the antenna can stably achieve communication over 10 meters, with low data transmission latency and low packet loss rate, and can accurately transmit key data of battery status. Test results show that the design of the BMS onboard Bluetooth antenna PCB is reasonable, the matching network and EMC optimization measures are effective, and it has the conditions for mass and vehicle application. It is recommended to implement improvement suggestions for high temperature and extreme interference scenarios to further improve product reliability.

Date: December 5, 202