# Agilent P-Series and EPM-P Power Meters for Bluetooth Testing

## Technical Overview and Self-Guided Demonstration

## Introduction

Bluetooth® is a technology specification designed for low-cost short-range radio communications between devices such as PCs, mobile phones, and other portable devices. On top of that, Bluetooth enables your devices to access the Internet.

Originally developed in Scandinavia, this technology that unites products has a code name that is inspired by a 10th century Danish Viking king, Harald Bluetooth, who united and controlled Denmark and Norway during an era when Scandinavian Europe was torn apart by wars and feuding clans.

Today, Bluetooth is administered by the Bluetooth Special Interest Group (SIG), whose members are leaders in the telecommunications, computing, networking, industrial automation, and automotive industries.

Agilent Technologies

## The Technology

Bluetooth operates within the industrial, scientific, and medical (ISM) band at 2.4 GHz. It is a short-range wireless communication standard defined as a cable replacement for a personal area network (PAN), an individual's own personal space.

A cable replacement standard has been defined because cables limit mobility. They are cumbersome to carry around and are easily lost or broken. It is frequently difficult to diagnose failure in the connectors, and they are often proprietary. Bluetooth counteracts these limitations by being light, portable, robust, and not limited to one manufacturer.

To serve effectively as a cable replacement, Bluetooth keeps its cost comparable to that of cable by operating in the license-free 2.4 GHz ISM band, while remaining backward compatible whenever possible to avoid upgrades. The relaxed radio specification also enables single-chip integrated circuit solutions.

## Frequency Hopping

The ISM band used by Bluetooth is available from 2.40 GHz to 2.4835 GHz in most countries, although there are restrictions in some countries. In this band, Bluetooth uses frequency-hopping spread spectrum (FHSS) techniques to mitigate interference.

In countries without restrictions, the radio signals hop in pseudorandom sequences around all 79 available channels with a channel spacing of 1 MHz. Starting at the base channel of 2402 MHz, the frequency of the channels can be expressed as below:

$$f = 2402 + n \text{ MHz}$$

where n is the channel number with an integer value in the range from 0 to 78.

In countries with restrictions, a limited frequency hopping scheme with just 23 channels is used and accounted for in the Bluetooth specification. Both hopping schemes have 1 MHz channel spacing. This allows a simple radio interface design, whereby the baseband only has to specify a channel number and the radio multiplies this up to the appropriate frequency offset.

In this FHSS scheme, there are 1,600 hops per second, which is a hop every 625 µs. Part of this hop timing is taken up by a guard time of 220 µs, allowing the synthesizer time to settle. The frequency hopping implements time division multiplexing graph is shown in Figure 1. During the first 625 µs slot, k, the master device transmits while the slave receives. In the following slot, the slave may transmit and the master listen.

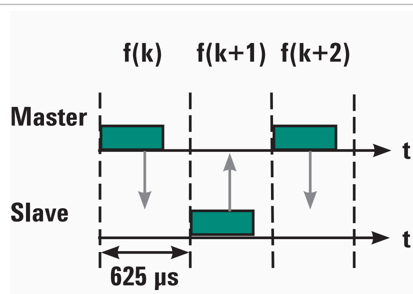


*Figure 1. Graph shows frequency hopping where master and slave interact on corresponding slots*

The radio must be able to be retuned and stabilized to a new frequency within tight time constraints. This is pushed further when establishing a connection; the hop rate is can be shortened to every 312.5 µs. As the radio is constantly hopping to different radio channels, this ensures that packets affected by interference on one channel can be retransmitted on another channel. To further enhance resilience, both automatic repeat request (ARQ) and forward error correction (FEC) form part of the specification.

## Protocol Stack

Figure 2 shows a configuration of the Bluetooth protocol stack with different basic layers. At the base of the Bluetooth protocol stack is the Bluetooth radio. It modulates data for transmitting and demodulating received data. This layer defines the physical characteristics a Bluetooth transceiver must have. The Baseband and Link Controller controls the physical links via the radio, assembling packets and controlling frequency hopping. Ascending the stack, the Link Manager converts host controller interface (HCI) commands into baseband-level operations. The Host Controller Interface handles communication between host and the module.

At the bottom of the software stack, Logical Link Control and Adaption is a multiplexer which adapts data from higher layers and converts between different packet sizes. The next layer consists of communication interfaces. The application layer provides profiles that determine how applications use the protocol stack to ensure interoperability at application level.

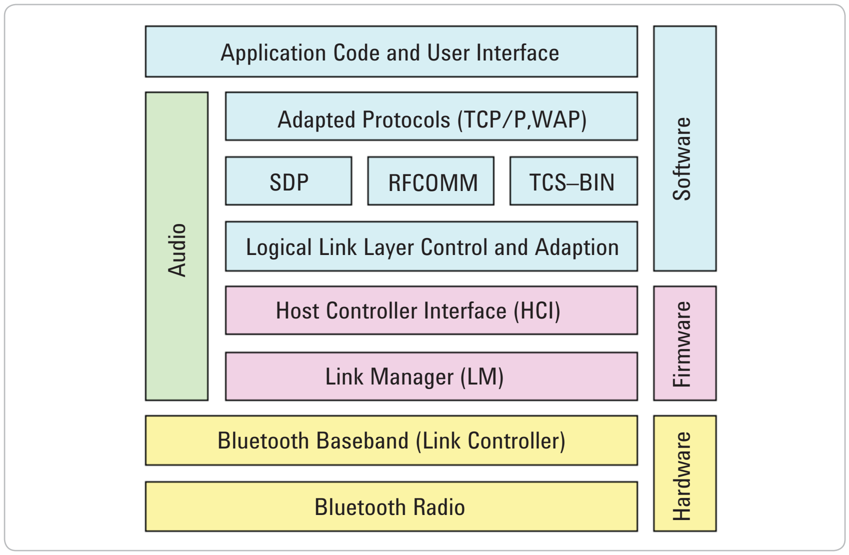


*Figure 2. The Bluetooth protocol stack*

## Agilent Power Meter and Sensor Solutions for Bluetooth Transmitter Test

The P-Series and EPM-P power meters fully meet the Bluetooth SIG specified Bluetooth certification test requirements for transmitter tests as listed in Table 1. These tests are relevant to a full functional Bluetooth devices, the transmitter, or even the RF components of the transmitter.

Table 1. Transmitter tests that can be measured with power meter and power sensor

| Transmitter test | Frequency hopping | Test mode | Packet type | Payload data | Measurement bandwidth |
|---|---|---|---|---|---|
| Output power TRM/CA/01/C | On | Loopback or Tx mode | DH5 or longest supported packet and payload | PRBS 9 | 3 Mhz RBW 3 MHz VBW |
| Power control TRM/CA/03/C | Off | Loopback or Tx mode | DH1 | PRBS 9 | 3 Mhz RBW 3 MHz VBW |

### Frequency hopping

Hopping is required for testing the functional capability of Bluetooth devices but is not essential for parametric tests. Frequency hopping is therefore turned off for a number of tests to reduce the number of variables and identify individual performance characteristics.

### Test mode

In test mode, the Bluetooth device is operating in a specific state. The implementation of test mode in Bluetooth devices is required to facilitate testing of transmitter and receiver performance of a device. By putting the device into test mode, different transmission and/or reception parameters can be controlled, such as frequency selection, transmit frequency, packet type and length, bit pattern, poll period, and power level.

### Payload data

PRBS9 is a pseudorandom bit sequence of period $2^9$–1 that is intended to simulate live traffic and so produces a modulated signal with a spectral distribution approximating that of a real signal.

### Test setup

A device under test (DUT) controller in Figure 3 allows the tester to put the device into test mode. The host will need to send a special command in order to prepare the device to enter test mode. The control can be performed by sending a protocol over a RF connection or by direct digital control of the device.

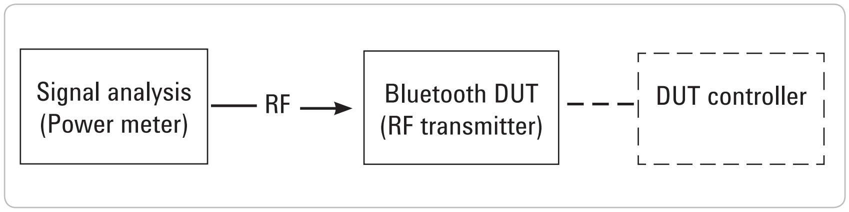


*Figure 3. Test setup for a Bluetooth transmitter with power meter*

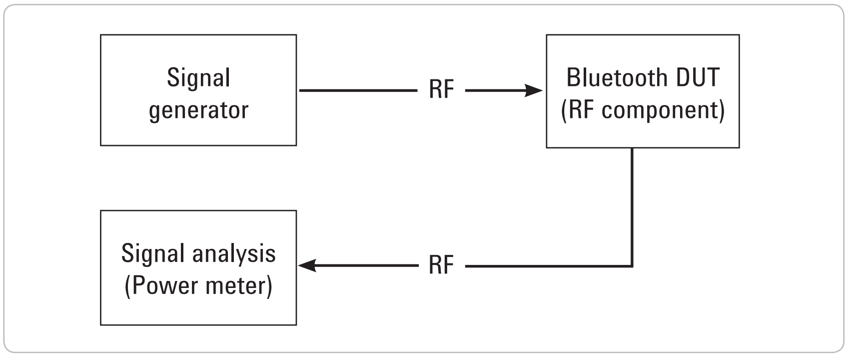


*Figure 4. Test setup for RF components of a Bluetooth transmitter with power meter*

## Output Power Test TRM/CA/01/C

Power meters can measure output power at a lower cost compared to spectrum analyzers and vector signal analyzers. Both the P-Series and EPM-P Series power meters have predefined Bluetooth setup stored in non-volatile memory. The gate setup and control function allow closer analysis of the Bluetooth signal.

## Power Control TRM/CA/03/C

Power control test allows testing or calibration to be performed on the level control circuitry. This test is only needed for devices that support power control. It is performed in the same manner as the average power measurement, but at the three discrete channels — lowest, mid, and highest operating frequencies (2402, 2441, and 2480 GHz). The power control test verifies power levels and power control step sizes to ensure they are within specified ranges.

# Bluetooth Measurements Using P-Series Power Meter and N1921A Power Sensor

## Internal zeroing and calibration

Before performing any measurement, a power meter and power sensor must be zeroed and calibrated for correct measurements. Zeroing will remove residual DC offset on the power meter and power sensor combination. Calibration will establish a 0.0 dBm reference that is traceable to the National Institute of Standards and Technology (NIST).

The P-Series power sensor is the first power sensor to provide “internal zeroing and calibration,” and thereby eliminate the need for calibration using an external reference source. Agilent’s patent-pending technology integrates a DC reference source and switching circuits into each power sensor so that zeroing and calibration can be done while still connected to a DUT.

This feature reduces test time, measurement uncertainty, and wear and tear on connectors. It is especially useful in manufacturing and automated test environments where every second and every connection counts. Sensors can be embedded within test fixtures without the need to switch in reference signals.

When a P-Series power sensor is connected to the power meter, it automatically performs a zero and a calibration routine. To initiate another zeroing and calibration routine without disconnecting and reconnecting the sensor, press **[Cal] > Zero + Cal**. A “Please Wait” message will be displayed during both zeroing and calibration.

## Preset

The P-Series power meter has a series of measurement configurations, suitable for common wireless communication and radar formats. The configurations are saved as instrument presets when used with P-Series or E-Series E9320 power sensors. To access the presets, press **[Preset]**. Use the arrow keys to highlight the preset for Bluetooth, press [**Select**] > **Confirm** as shown in Figure 5.

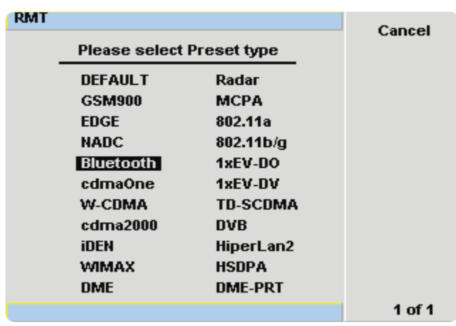


*Figure 5. Available preset settings*

## Configuring the signal source

The E4438C is used as the signal source in this demonstration.

| Instructions | Descriptions |
|---|---|
| 1. Connect the sensor to the 50 Ω RF output of Signal Generator. | |
| 2. Set the frequency to 2.4 GHz. | Press [**Frequency**] 2.4 > **GHz** |
| 3. Set the amplitude to –10 dBm. | Press [**Amplitude**] –10 > **dBm** |
| 4. Select the Bluetooth signal. | Press [**Mode**] > **More** > **Wireless Networking** > **Bluetooth.** Toggle **Bluetooth** to **ON** |
| 5. Activate the Bluetooth signal. | Toggle [**RF On/Off**] and [**Mod On/Off**] to **ON**. See Figure 6. |

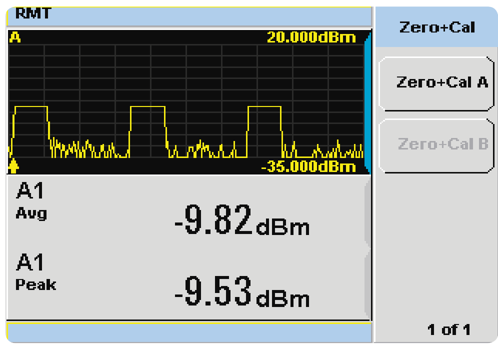


*Figure 6. The Bluetooth signal with average and peak power*

| Instructions | Descriptions |
|---|---|
| 6. View the Gate Control screen. | Press [ ]. On the display is the pulse trace with delta time, delta average, delta peak, and delta peak-to-average power ratio for Gate 1. See Figure 7. |

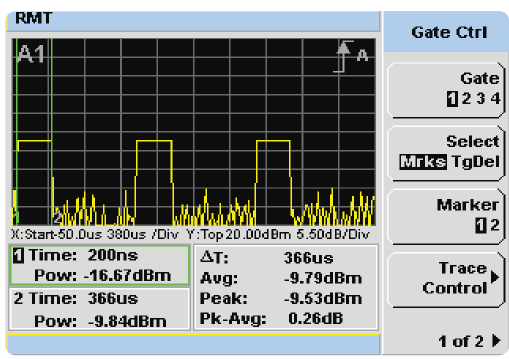


*Figure 7. Gate Control display*

| Instructions | Descriptions |
|---|---|
| 7. Set up more gates. | Toggle **Gate** to select another gate and use the arrow keys to position the gates. Then, toggle **Marker** to switch from Marker 1 to Marker 2 and vice versa. Adjust the gate for measurements of the second pulse. |

| Instructions | Descriptions |
|---|---|

8. Switch to Trace Control for time measurements.

Press **Trace Control**. The eight available measurements are rise time, fall time, time to positive occurrence, time to negative occurrence, pulse period, pulse width, duty cycle, and pulse repetitive frequency. See Figure 8.

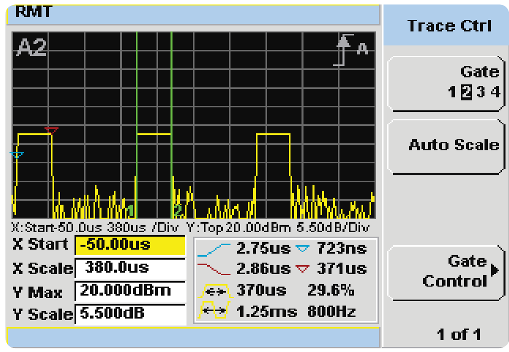


*Figure 8. Trace Control display*

9. View a full screen display.

Press [ ]. See Figure 9.

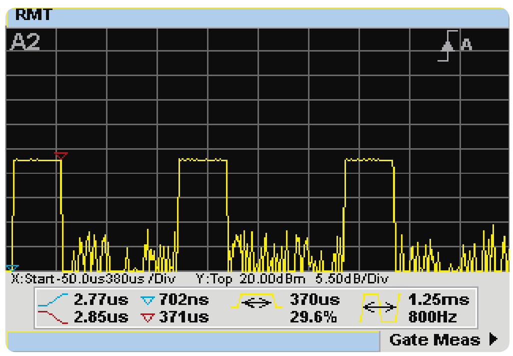


*Figure 9. Trace Control display in full screen*

10. View a full screen display of the Gate Control.

Press **Gate Meas**, or press [ ] twice. See Figure 10.

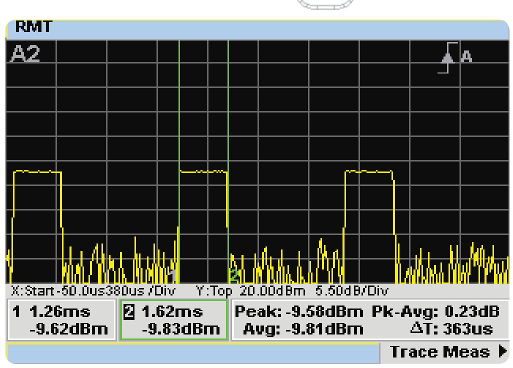


*Figure 10. Gate Control display in full screen*

# Bluetooth Measurements Using EPM-P Series Power Meter and E3296A Power Sensor

The demonstration in this guide requires an Agilent EPM-P Series power meter, either E4416A or E4417A, and an E9326A peak and average power sensor.

## 1. Zero and calibrations

| Instructions | Descriptions |
|---|---|
| 1. Connect the E9326A sensor and the E9288 cable to Channel A connector. | |
| 2. Connect the sensor to **Power Ref**. | |
| 3. Complete zero and calibration in one step. | Press **[Zero/Cal]** > **Zero+Cal**. During these processes, a "Please Wait" message will be displayed. |
| 4. Turn on the 0 dBm calibration reference. | Press **[Zero/Cal]** and toggle **Power Ref** to **ON**. |

## 2. Preset

Bluetooth is one of the available predefined setups for wireless standards in the EPM-P power meter.

| Instructions | Descriptions |
|---|---|
| 1. Access the list of predefined setups. | Press **[Preset/Local]**. Use the arrow keys to highlight the preset for Bluetooth and press **Confirm**. |

## 3. Configuring the signal source

The E4438C is used as the signal source in this demonstration. Connect the sensor to the 50 Ω RF output of the E4438C signal generator.

| Instructions | Descriptions |
|---|---|
| 1. Set the frequency to 2.4 GHz. | Press **[Frequency]** 2.4 > **GHz**. |
| 2. Set the amplitude to –10 dBm. | Press **[Amplitude]** –10 > **dBm**. |
| 3. Select the Bluetooth signal. | Press **[Mode] > More > Wireless Networking > Bluetooth**. Toggle **Bluetooth** to **ON**. |

| Instructions | Descriptions |
|---|---|
| 4. Activate the Bluetooth signal. | Toggle **[RF On/Off]** and **[Mod On/Off]** to **ON**. The screen of the power meter will show three active pulses of a Bluetooth DH1 data burst as shown in Figure 11. |

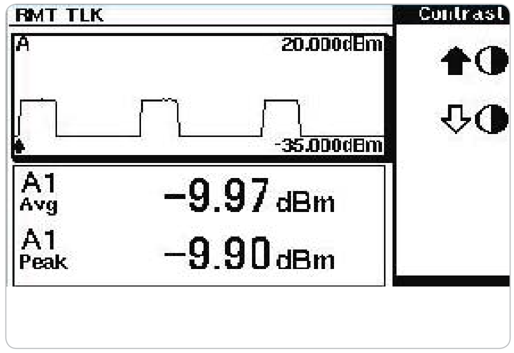


*Figure 11. The Bluetooth signal is shown in the upper window. Average and peak power in a single Bluetooth DH1 data burst appear in the lower window.*

## 4. View and set up gates

The Bluetooth predefined setup has Gate1 configured to measure the average and peak power across the first burst. The graphical gate setup and control of the power meter provide an easy method of configuring additional gates. Set up Gate 2 to measure average and peak power in second pulse or gate setup and control functions.

The gate setup and control functions allow closer analysis of the signal under test. The gate control screen shows the pulse trace, delta time, delta average, delta peak, and delta peak-to-average power ratio for the selected gate.

| Instructions | Descriptions |
|---|---|
| 1. View the Gate Control screen. | Press **[Channel]** > **Gates**.<br>Note that only Gate 1 is set up **Gate Control**. |
| 2. Decrease the horizontal length. | Press [ ] to zoom in, and the screen displays only the first and second pulses. Press **Trace Control**, use the arrow keys to highlight horizontal length, and select { } to decrease the length to –2 ms. |
| 3. Set up Gate 2 to measure the power across the second pulse. | Press **Gate Control**. Toggle **Gate** to highlight **2**. Use the arrow keys to move the marker to the rising edge of the second pulse (~1.3 ms) and toggle **Marker** to highlight **2**. Use the arrow keys to move Marker 2 to the falling edge of the second pulse (~6 ms). See Figure 12. |

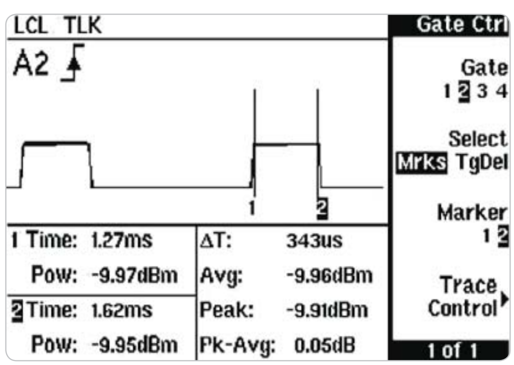


*Figure 12. Average and peak power of second pulse*

## Related Literature

Please refer to the publications below for further information.

| Publication title | Publication number |
|---|---|
| EPM-P Series Single and Dual Channel Power Meters Demo Guide | 5988-1605EN |
| Bluetooth® Measurement Fundamentals | 5988-3760EN |

## Related Web Resources

- For Bluetooth history, refer to the following URL:
  http://www.bluetomorrow.com/content/section/11/38/
- For Bluetooth RF Test Matrix, refer to the following URL:
  http://www.home.agilent.com/agilent/application.jspx?cc=US&lc=eng&nid=-35030.0.00
- For Definitive Internet Guide for Bluetooth® Designers, refer to the following URL:
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