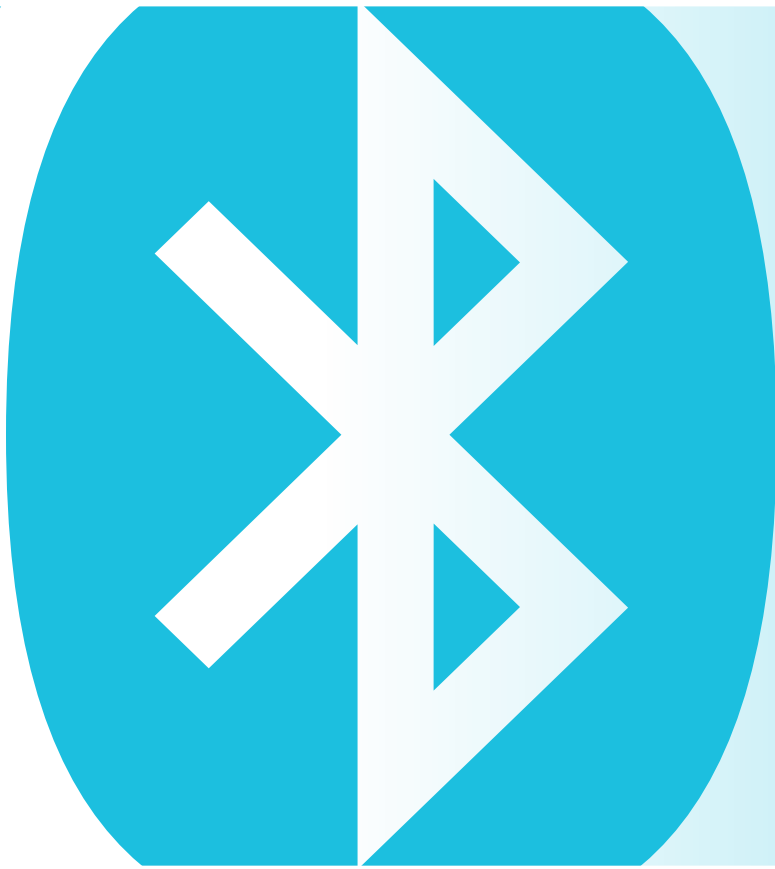# Internet of Things:
How to Select A Bluetooth Module

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Tektronix®

You will learn: The basic process of Bluetooth module integration, typical Bluetooth applications, selection of parameters for a Bluetooth module and how to select Bluetooth modules for different applications.

Contents

1. The Applications of Bluetooth in the Internet of Things

With the coming of the Internet of Things age, there are about 4.9 billion Internet-connected devices on the market by 2015, which is expected to grow to 25 billion by 2020. You can find the technology, concept and products regarding the Internet of Things are mentioned in almost every electronic journal or magazine when flipping through them. The Internet-connected devices have been everywhere in our life. At present, we can not only communicate with the content from the virtual Internet, but also begin to establish the conversation between increasingly tangible commodities. Living in such a smart city, our quality of life is improved with these interconnected wireless devices every day. The well-known virtual Internet becomes more and more tangible, promoting the whole world to officially enter the Internet of Things age. Typical applications include:

Smart City	Home Automation	Health Care
• Traffic control • Smart traffic lights • Smart water and electricity meters • Accident alarm	• Temperature and light control • Energy saving control • Smart electric appliance • Maintenance	• Remote nursing • Tracking of medical drugs • Access control • Tracking of ambulances
Automobiles	**Smart Manufacturing**	**Wearability**
• Communication between cars • Remote record • Replacement of wired communication • Multimedia entertainment	• Optimization of assembly lines • Real-time inventory • Tracking of parts • Security alarm	• Entertainment • Fitness • Smart watch • Positioning

Right now, the communication technologies widely used in the Internet of Things include the Wi-Fi, Bluetooth, ZigBee, Z-Wave, NFC and other kinds of mobile communication technologies, as well as the simple modulation methods similar to ASK and FSK for some non-standard industrial/scientific/medical (ISM) frequency bands. A developer of the Internet of Things needs to consider multiple factors when selecting a suitable wireless technology for its own application, such as the cost, power consumption, transmission range and safety, etc.

The Bluetooth technology was developed as the alternative of RS232 data cable in 1994. In a sense, the Bluetooth and the Wi-Fi are complementary with each other. There are billions of Bluetooth devices currently on the market, including mobile phones, tablet computer, personal computers, TV and even TV set top box and game consoles, and this number will still be increasing in the future. There are numerous versions of Bluetooth technology, from V1.0, V1.1, V1.2, V2.0 and V2.0 etc, to the latest V4.0, V4.1 and V4.2. Among the above, Bluetooth 4.0, also called Bluetooth Smart, has become the preferred choice for most applications not pursuing high-speed transmission in the Internet of Things. This is due to its low power consumption (90% reduced as compared to the earlier versions), with which makes it ideal for wearable devices.
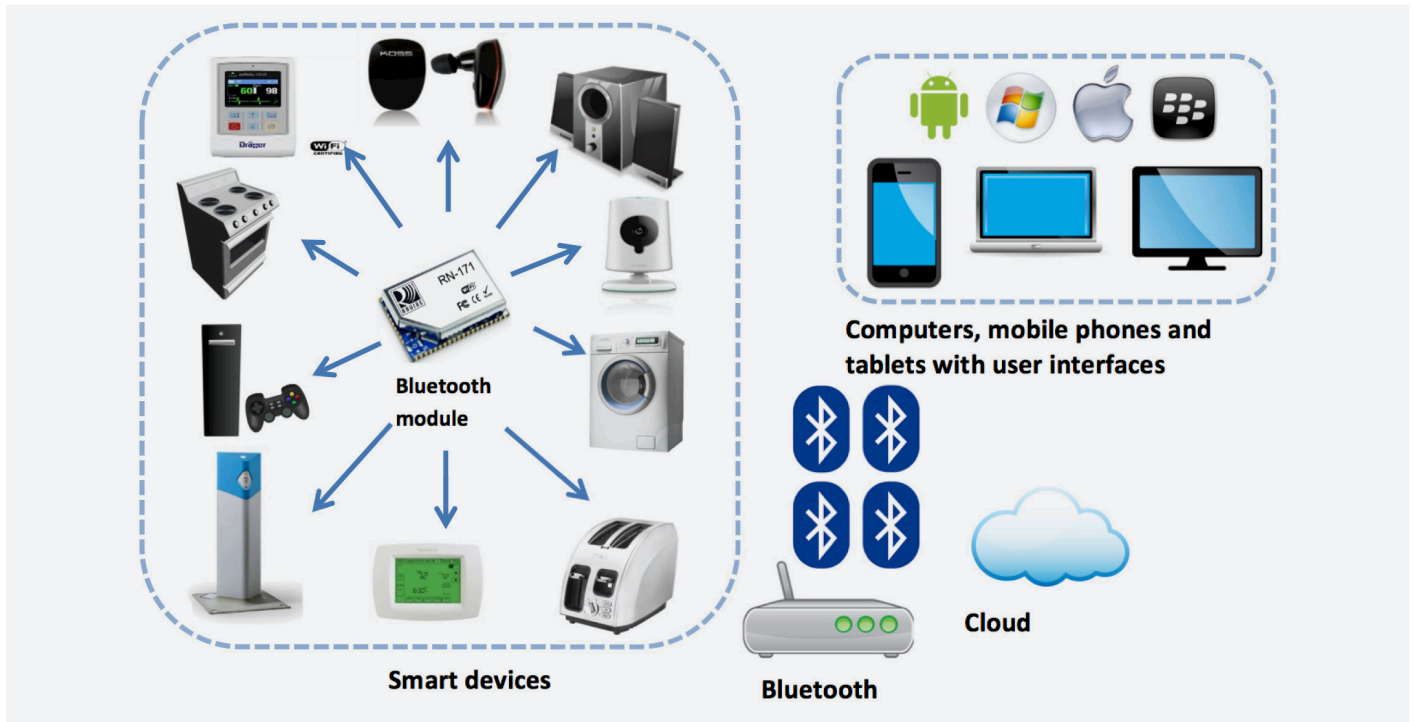
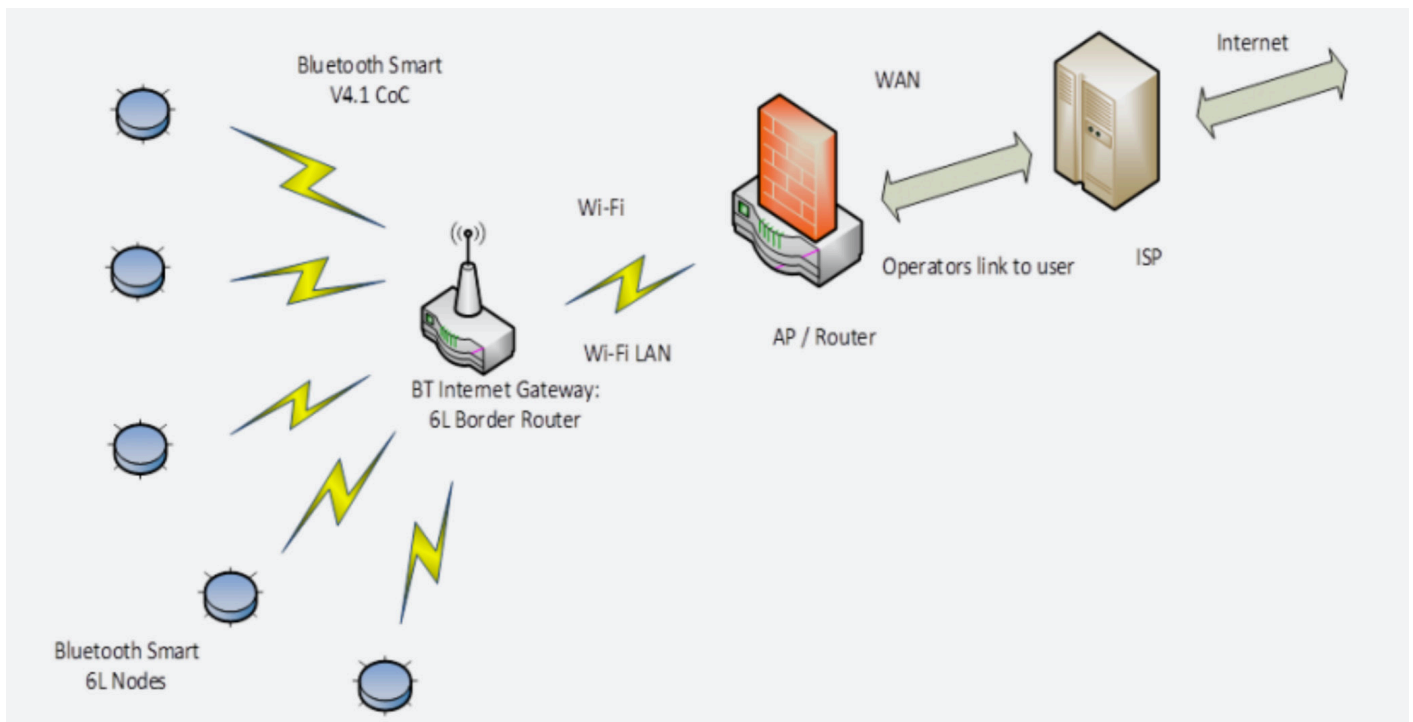**FIGURE 2.** Integration of Bluetooth Modules into Smart Devices.

FIGURE 3. Connection of Household Appliances to Internet via Bluetooth Smart.

Frequency	CH	Frequency	CH	Frequency	CH	Frequency	CH	Frequency	CH
2.402 GHz	0	2.419 GHz	17	2.436 GHz	34	2.453 GHz	51	2.470 GHz	68
2.403 GHz	1	2.420 GHz	18	2.437 GHz	35	2.454 GHz	52	2.471 GHz	69
2.404 GHz	2	2.421 GHz	19	2.438 GHz	36	2.455 GHz	53	2.472 GHz	70
2.405 GHz	3	2.422 GHz	20	2.439 GHz	37	2.456 GHz	54	2.473 GHz	71
2.406 GHz	4	2.423 GHz	21	2.440 GHz	38	2.457 GHz	55	2.474 GHz	72
2.407 GHz	5	2.424 GHz	22	2.441 GHz	39	2.458 GHz	56	2.475 GHz	73
2.408 GHz	6	2.425 GHz	23	2.442 GHz	40	2.459 GHz	57	2.476 GHz	74
2.409 GHz	7	2.426 GHz	24	2.443 GHz	41	2.460 GHz	58	2.477 GHz	75
2.410 GHz	8	2.427 GHz	25	2.444 GHz	42	2.461 GHz	59	2.478 GHz	76
2.411 GHz	9	2.428 GHz	26	2.445 GHz	43	2.462 GHz	60	2.479 GHz	77
2.412 GHz	10	2.429 GHz	27	2.446 GHz	44	2.463 GHz	61	2.480 GHz	78
2.413 GHz	11	2.430 GHz	28	2.447 GHz	45	2.464 GHz	62		
2.414 GHz	12	2.431 GHz	29	2.448 GHz	46	2.465 GHz	63	Key	
2.415 GHz	13	2.432 GHz	30	2.449 GHz	47	2.466 GHz	64		
2.416 GHz	14	2.433 GHz	31	2.450 GHz	48	2.467 GHz	65	Inquiry Channel	
2.417 GHz	15	2.434 GHz	32	2.451 GHz	49	2.468 GHz	66	Not used as	
2.418 GHz	16	2.435 GHz	33	2.452 GHz	50	2.469 GHz	67	an Inquiry Channel	

FIGURE 4. Frequency Distribution for Classic Bluetooth.

2. Introduction to Bluetooth Technology

2.1 BLUETOOTH CLASSIFICATION

Based on the current market and the development trend of the Internet of Things in the future, versions of Bluetooth technology are classified into 2 types: classic and low-energy (LE). The classic Bluetooth assures the data transmission rate, so that it is suitable for applications such as the Bluetooth headset transmitting the high quality music. In the classic type, it is subdivided into the basic rate (BR) and the enhanced date rate (EDR). The low-energy Bluetooth focuses more on the simple information transmission, which tries to extend the endurance time of electronics as long as possible. However, Bluetooth LEis not suitable for the high-speed transmission of large data.

In response to the high demand for low-energy Bluetooth/ Bluetooth V4.0 application on the market of the Internet of Things, Bluetooth SIG provides 2 kinds of certification marks for the existing smart devices equipped with Bluetooth: Bluetooth Smart and Bluetooth Smart Ready.

Developers of Internet-of-Things devices will often struggle to select a suitable Bluetooth version but this decision depends largely on the specific type of application being sought. If the device needs to communicate with both the devices equipped with the latest version of low-energy Bluetooth and those equipped with the classic Bluetooth, the Bluetooth Smart ready will be a better choice. Otherwise the Bluetooth Smart with only low energy version support will be good enough. The definitions of the two Bluetooth SIG certification marks are shown as follows:

2.2 FREQUENCY BAND AND CHANNEL

Bluetooth is a short-distance wireless communication technology, that operates in a 2.4GHz ISM frequency band with a range from 2.400 GHz to 2.4835 GHz. frequency band is 2.4 GHz ISM, and the frequency range is from 2.400 GHz to 2.4835 GHz. For classic Bluetooth, there are 79 channels in total, and the band interval is 1 MHz. This includes the 2 MHz guard interval at 2.400 GHz (the bottom end) and 3.5 MHz at 2.4835 GHz (the top end). The most common transmission rate for Class II electronic devices is +4 dBm, and the sensitivity range of receiver is -90 dBm.
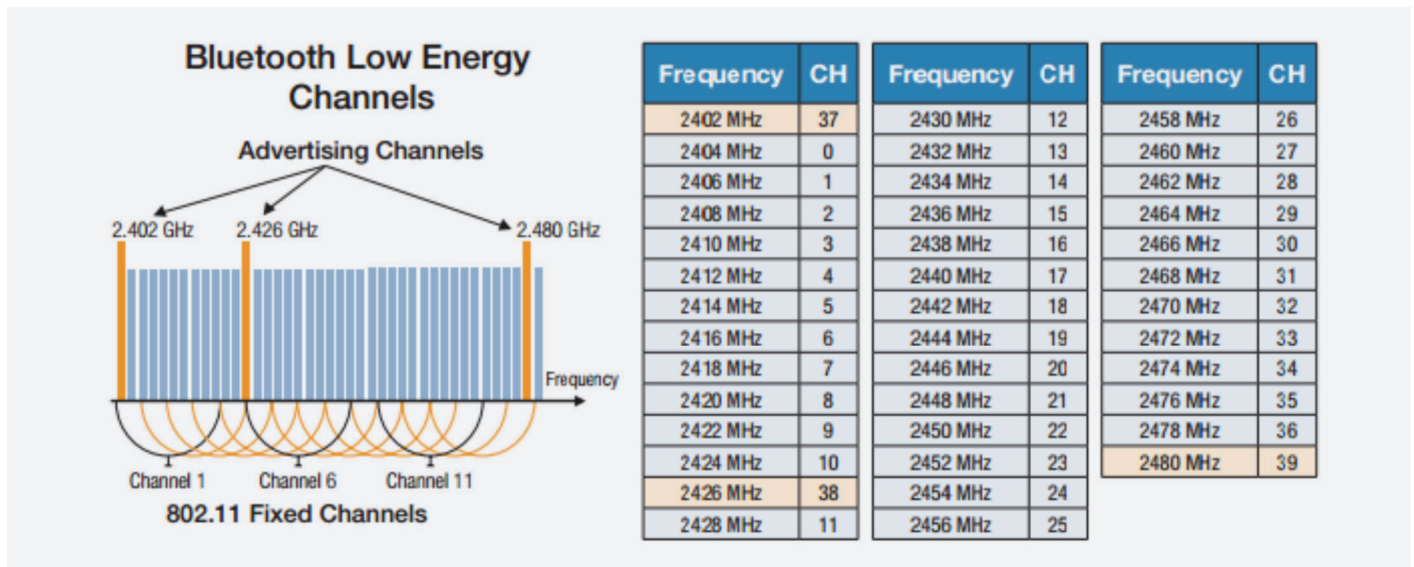
Bluetooth Low Energy Channels

Frequency	CH	Frequency	CH	Frequency	CH
2402 MHz	37	2430 MHz	12	2458 MHz	26
2404 MHz	0	2432 MHz	13	2460 MHz	27
2406 MHz	1	2434 MHz	14	2462 MHz	28
2408 MHz	2	2436 MHz	15	2464 MHz	29
2410 MHz	3	2438 MHz	16	2466 MHz	30
2412 MHz	4	2440 MHz	17	2468 MHz	31
2414 MHz	5	2442 MHz	18	2470 MHz	32
2416 MHz	6	2444 MHz	19	2472 MHz	33
2418 MHz	7	2446 MHz	20	2474 MHz	34
2420 MHz	8	2448 MHz	21	2476 MHz	35
2422 MHz	9	2450 MHz	22	2478 MHz	36
2424 MHz	10	2452 MHz	23	2480 MHz	39
2426 MHz	38	2454 MHz	24		
2428 MHz	11	2456 MHz	25		

FIGURE 5. Frequency Distribution for Low-energy Bluetooth (4.0).

The low energy Bluetooth (Bluetooth 4.0) focuses on reducing power consumption and cost, so that the requirement of the filter design is relatively low, and the modulation coefficient is reduced from 0.28-0.35 for class Bluetooth to 0.45-0.55. Therefore, the frequency interval increases to 2 MHz with a total of 40 channels.

2.3 FREQUENCY HOPPING

Frequency hopping is one of main characteristics in the Bluetooth standards. It is initially designed to resolve the coexistence of other signals in the crowded ISM frequency bands. Because the Bluetooth shares one same frequency band with the Wi-Fi, the signal carrier frequency needs to change often to avoid the interference with other signals on the same band. In other words, the Bluetooth signal can only be transmitted and stay in a fixed channel for a very short time. Once it finds itinterfered with other signals in the same channel, the Bluetooth transmission it will hop to another channel that has not been interfered for re-transmission. The Bluetooth hopping frequency is 1,600 times per second, posing a challenge to the research, development and testing of Bluetooth devices, especially obviously with the trend that more and more devices are both equipped with Wi-Fi and Bluetooth.
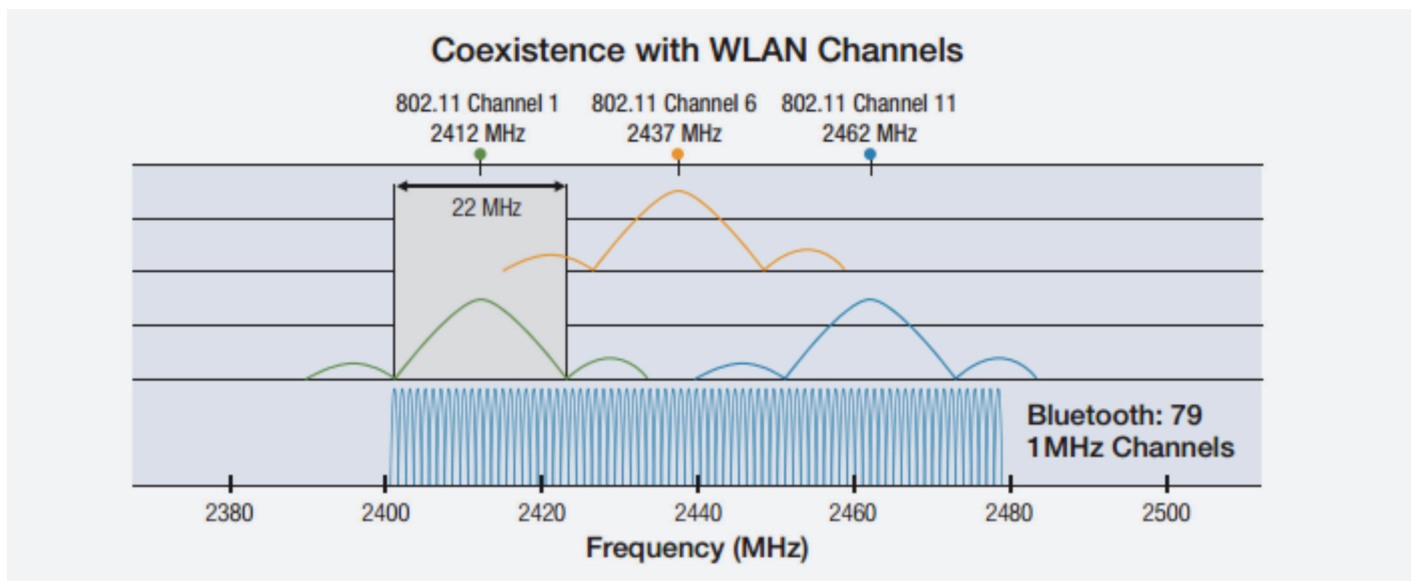

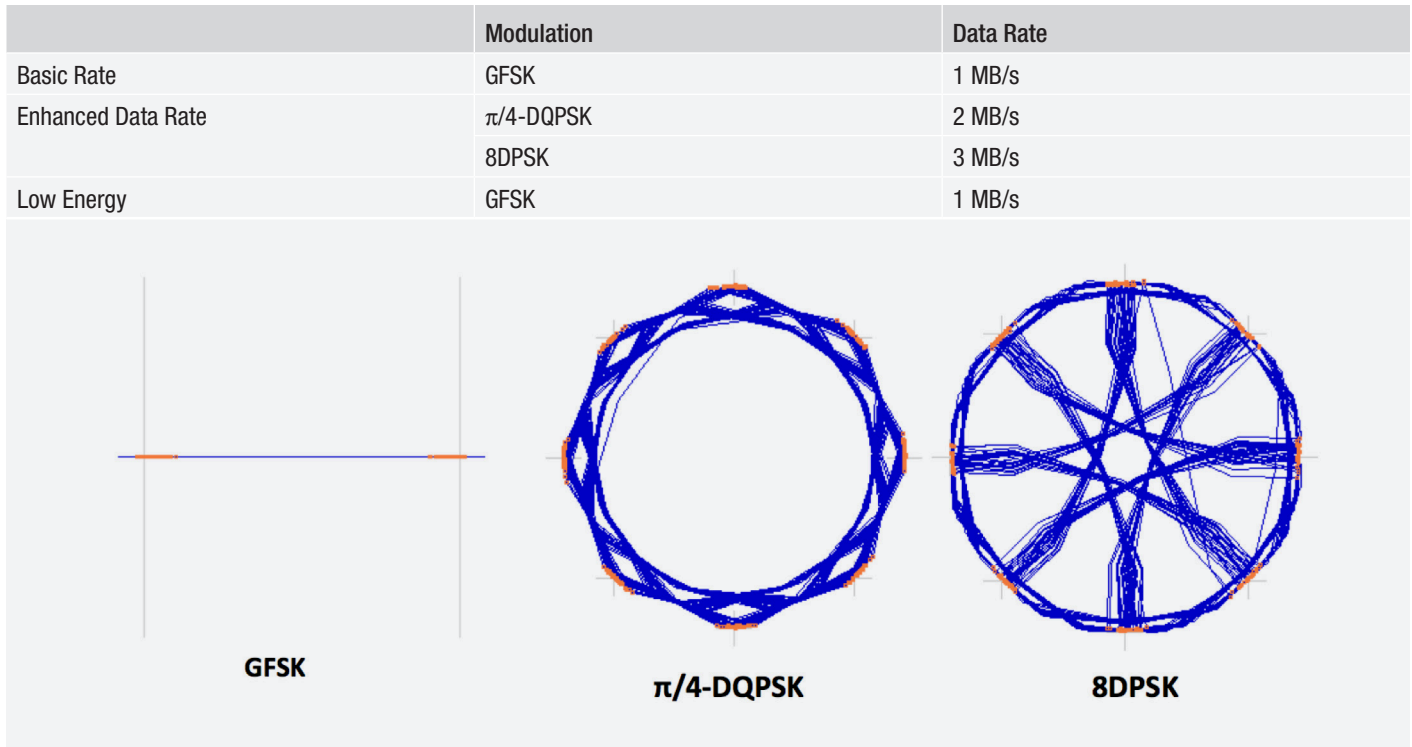**FIGURE 6.** Coexistence of Frequency Bands for Bluetooth and Wi-Fi.

	Modulation	Data Rate
Basic Rate	GFSK	1 MB/s
Enhanced Data Rate	π/4-DQPSK	2 MB/s
	8DPSK	3 MB/s
Low Energy	GFSK	1 MB/s

GFSK   **π/4-DQPSK**   **8DPSK**

FIGURE 7. Coexistence of Frequency Bands for Bluetooth and Wi-Fi.

2.4 MODULATION

In the Bluetooth standard, Gaussian frequency shift keying (GFSK) is used as the most basic modulation. As the name suggests, GFSK belongs to FSK technology. Before the original digital signal is sent through FSK modulation, a Gaussian low-pass filter is added to limit the spectrum width of modulated signal for the communication transmission and power consumption with limited spectrum width. With the Gaussian filter, the required bandwidth for Bluetooth signal is limited at 1 MHz, and the modulation coefficient is between 0.28 and 0.35. For low-energy Bluetooth, the required frequency interval becomes 2 MHz, and therefore the modulation coefficient is lowered to 0.45-0.55, which reduces the design cost and lowers the demand of electric power supply.

For the EDR Bluetooth, in order to increase signal transmission rate, the modulation method is upgraded from GFSK with low transmission rate and low power consumption to the two kinds of phase shift keying (PSK): π/4-DQPSK and 8DPSK. Therefore, although the symbol rate during transmission is still 1Ms/s, the data transmission rate can be increased to 2 Mbps with a higher order modulation such as π/4-DQPSK. With 8DPSK, it can be even increased to 3 Mbps. In this way, the data transmission rate for Bluetooth will be greatly improved.

3. The workflow of Bluetooth Module Integration

As the wire technology enters a new age of development, the traditional commodities are welcoming the new development trend. More and more traditional electric appliances such as coffee machine, the toothbrush and the air conditioner start to have the wireless functions integrated and become the smart appliances, so that users can use the applications in their mobile phones or other mobile devices to control these electric appliances at any time. These applications on the smart platforms are generally developed in a short time, but they greatly benefit users by allowing them to easily control the electric devices nearby they can think of at any time.

To successfully achieve the smart and wireless electric devices mentioned above, major manufacturers of traditional electric and startups developing new devices must learn how to integrate the wireless functions into their own products. There are many ways to integrate the Bluetooth function into the existing products, of which the most common way is to use a completely encapsulated Bluetooth module. Purchasing a Bluetooth module will greatly simplify the whole integration process but has many inherent challenges face many challenges. First, we will introduce the typical design process for integrating the Bluetooth module into the existing products and discuss the problems possibly occurring at each operation step.

If you wish to have your product equipped with the Bluetooth function, what do you need to do?

1. Select the proper wireless standard for the application, and decide whether the Bluetooth is the most suitable wireless technology for the product.

2. **Select a Bluetooth chip or module suitable for your product.**

3. Select the testing equipment or hire the RF design expert.

4. Integrate the Bluetooth chip or module into your product.

5. Test and optimize the antenna.

6. Conduct the electromagnetic radiation pretest required by the regulatory authority in the laboratory.
   - Find out any problems that may occur, and return to Step 4 and Step 5 for adjustment.

7. Submit the result of electromagnetic radiation test for certification by local wireless regulatory authority ($1-3K/day).
   - If the certification fails, return to Step 3.

8. Complete the integration of Bluetooth function.

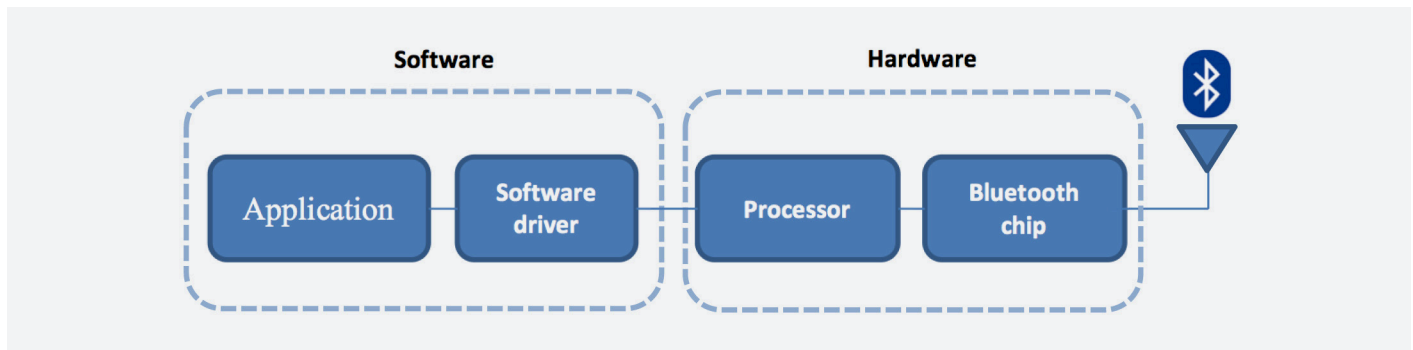In this application note, we will focus on Step two: how to select a Bluetooth chip or module.

FIGURE 8. Simplified Block Diagram of Bluetooth Module.

4. How to Select A Bluetooth Module

The Bluetooth module is a functional component and can only function completely when embedded into a proper system. When you select a Bluetooth module for your product, further consideration should be taken into hardware and software.

The hardware of a Bluetooth module consists of a Bluetooth chip and an application processor. Most products currently on the market are embedded with the Bluetooth modules equipped with the application processors. The application processor in the module has the internal or external flash memory, ROM and RAM. This kind of module also provides different I/O interfaces, including the time clock, serial communication interface, analog comparator, ADC, DAC, crystal oscillator and the debugging interface, etc.

Bluetooth modulesgenerally need the specific application software support to ensure the security and facilitate the user operation and developer management. As shown in the figure, the module software normally includes a drive program and a full-feature management and control program.

When you are selecting a Bluetooth or the other RF module, you may find many more solutions available on the market than you imagine. Module manufacturers or suppliers will normally classify the modules by the transmission rate, transmission distance, frequency band, certification, packaging size, etc. Here we will briefly introduce the possible parameters that may impact your search for the suitable Bluetooth module for you.

Considerations	Description
Protocols/standards	There are many versions of Bluetooth standards since the Bluetooth development, among which the common ones currently on the market include: the basic rate (BR), enhanced date rate (EDR) and latest low energy (LE).
	Each wireless standard and its versions have advantages and disadvantages Each of them has different specifications, so that you need to consider the pros and cons before selecting a module with suitable data transmission rate, required power consumption and other parameters for your application. The continuous evolution of wireless standards enables more advanced technologies, faster rates and lower power consumption. But on the other hand, more mature standards are advantageous with more extensive market share and better compatibility.
	For instance, when selecting a Bluetooth module, you also need to consider other factors like whether the same module supports other standards or not. As the Bluetooth module runs at 2.4 GHz band, mostly it supports the Wi-Fi to meet the demand of high speed transmission.
Frequency band	From 2.400 GHz to 2.4835 GHz, there are 79 channels for classic Bluetooth in total, and the frequency band interval is 1 MHz. The low-energy Bluetooth (Bluetooth 4.0) focuses on reducing the power consumption and cost, so that the design of wave filter is less demanding, the channel interval is increased to 2 MHz, and 40 channels are included in total.
	If you wish to combine the Bluetooth and the Wi-Fi into one function, the operating frequency band for Wi-Fi has to be considered, i.e. 802.11b/g/n operating at 2.4 GHz same as the Bluetooth. However, if the Wi-Fi of other versions is needed such as 802.11a/h/j/n/ac/p, this kind of Bluetooth module must support 5 GHz band, which may also increase the module design cost.
Transmission distance	The Bluetooth network has a limited distance like any other wireless technologies. The transmission distance varies with different versions and will be longer for low energy Bluetooth (Bluetooth 4.0). In one same version, the transmission distance supported also varies with different power classes.
	The greater the power class is, the farther the place can be reached by the transmission. The specific classification is shown as follows: • Class 3: 1 meter radiation distance at maximum, applicable for extra-short distance transmission • Class 2: 10 meter radiation distance at maximum, under which most mobile devices fall • Class 1: 100 meter radiation distance at maximum, mainly applicable for industry
	The real valid distance of signal transmission varies with specific real environmental conditions, such as the transmission conditions, material, production deviation, antenna and battery, etc.
Transmission output power and operating current/voltage	High power means that greater range can be reached. The power requirements for Bluetooth are shown in the table below:

Power Classification	Maximum Power (dBm)	Power Control Requirement
1	20	Mandatory
2	4	Not Mandatory
3	0	Not Mandatory

Besides the requirements specified in the Bluetooth standards, the equipment also needs to meet the power requirements specified by the spectrum regulatory authority under the local government. As the Bluetooth device is generally powered by the battery, the operating current/voltage of equipment will also become an important consideration as it directly determines the charging cycle and battery life.

Considerations	Description
Micro-processor/ micro-controller	The micro-processor/micro-controller is like the brain of a RF module. It optimizes the hardware functions, receives the wireless data, and integrates and processes signals at high speed. The important considerations for selecting a processor include the price, dimensions, memory capability, power consumption, peripheral extensibility and computing speed.
Operating system (drive support)	Android, iPhone/iPad, Linux, and WinCE support of Bluetooth modules allows the end users to use the smart platforms more and more, so that the Bluetooth connection can be quickly set up and its application can be monitored. If you need to enable your product with this function, the operating system and its drive support should be considered.
Transmission rate	Theoretically, the transmission rate of low energy Bluetooth will not support its own maximum band width (1 MHz), because the low energy Bluetooth is not standardized to assure the transmission rate but focuses on the simple information transmission. If the data is transmitted at a high rate, the low energy Bluetooth will consume greater power, which is contradictory to the original design concept. If the high speed transmission is needed, the EDR Bluetooth or Wi-Fi with higher rate can be considered. Any rate increase will almost definitely consume huge power.

	Modulation	Data Rate
Basic Rate	GFSK	1 MB/s
Enhanced Data Rate	π/4-DQPSK	2 MB/s
	8DPSK	3 MB/s
Low Energy	GFSK	1 MB/s

Considerations	Description
Antennas and interfaces	The antennas for Bluetooth modules are mainly classified into 2 types - omnidirectional antennae and directional antennae. • An omnidirectional antenna can radiate the signals to a 360° range to maximize the signal coverage rate. Its typical applications include the network coverage of the home or office environment. • The directional antenna only sends signals in a specific direction. Its typical applications include the point-to-point transmission. The antenna interfaces can be classified into U.FL interfaces with respect to chip-fixed antenna and outside antenna. The former is a new technology that just has been popular in recent yearsThe whole module can be minimally sized to about 8 *5 * 2.5 mm. The latter one is more flexible and suitable for applications less demanding on these dimensions. Moreover, whether the antenna has been successfully certified by the regulatory authority is also one of important prerequisites for selection. If the module and antenna both have been certified, your product can be free from certification in some countries.
Normal operating temperature	The most common operating temperature of a Bluetooth module is -40°C to 85°C. At present, most Bluetooth modules are designed for commercial use at non-extreme temperatures. Some modules are marked to be able to operate at extreme temperatures ifprotective devices such a fan or insulation chamber are installed during use.
Hardware interfaces	The most common data interfaces include the serial UART connection, security digital I/O card (SDIO), serial peripheral interface (SPI) or USB. SDIO, SPI and USB interfaces are essential to the high speed transmission of data. The digital interface is used to connect the equipment and the processor.
Other functions	Other functions refer to the appearance and dimensions, the packaging, PCB design, real-time stamp, automatic sleep/ activation, wireless firmware upgrade, demo board, user programming interface, etc.
Regulatory Compliance: EMI/EMC Certification	Modules manufacturers market their products as pre-certified or tested, which implies that no further standards testing is required. **The question then becomes:if I buy this kind of certified module, does the integrated product still need to be certified or tested again as specified by the regulatory authority?** The answer is yes.The integrated product still needs to be certified and tested as specified by the regulatory agency because most spectrum regulatory authorities over the world do not have the related laws and regulations on the exemption from certification, such as ESTI/CE in Europe. That is to say, the certification and testing must be based on the product not the module. If you want to know more details, please refer to *Tektronix Application Guide: Spectrum Pre-compliance for Wireless LAN Regulatory Testing.*

Of all of the characteristics of a Bluetooth module, the 3 key factors are the transmission rate, the coverage range and the power consumption. Over the past 10 to 20 years, scientific and technological workers have continuously made an effort to transmit the data more quickly in a wireless way, which makes not only the multiplexing, encoding and modulation of wireless communication systems more and more complicated, but also increases the cost and power consumption for processing and computing at the same time. The Bluetooth technology itself is not an expert in high-speed transmission. If you require a high speed in the application, it is suggested to consider the high-speed Wi-Fi protocols such as 802.11n and 802.11ac. Most modules can also be embedded with the Bluetooth function at the same to expand your equipment compatibility. On the contrary, if your application only focuses on the connectivity, such as the health monitoring and safety monitoring, etc., you may first consider the power consumption index.
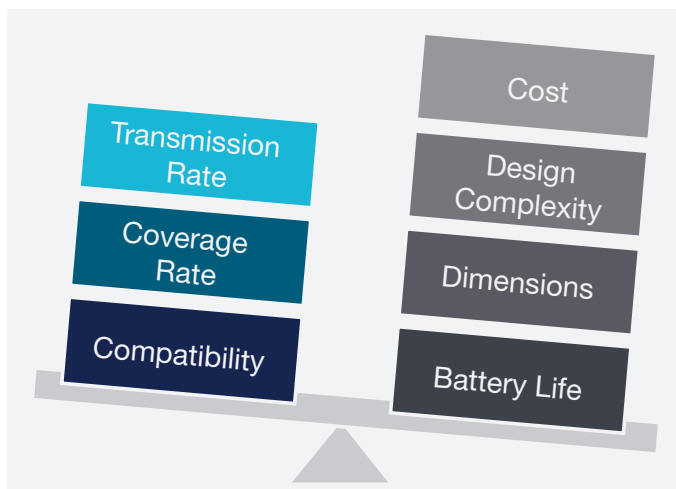

FIGURE 9. Trade-off during Selection of Bluetooth Module.

5. The Key RF Performance Tests for Bluetooth Module

Direct purchase of Bluetooth module = no need of RF engineer?

One of the biggest obstacles for non-traditional RF manufacturers who want to integrate the wireless module into their products is the lack of RF development experience. Fortunately, module producers have begun to provide more and more wireless connection solutions for Internet of Things. They self-develop and test the wireless modules, and become the experts in the RF field. When you feel bewildered about RF technology, these manufacturer can be a great help.

However, it is not realistic to pin the hope on the module manufacturers to help engineers solve all the problems possibly occurring in the RF design by participating in the specific product integration. A RF expert is still needed during the wireless integration of the Internet of Things devices to make sure the products are ready to be put on the market. This kind of technical support may come from hiring a consultant specializing in the RF field or relying on professional institutions or professional RF testing equipment companies such as Tektronix.

The great majority of Bluetooth devices currently on the market of the Internet of Things are just simply tested for connectivity or inspected by the Bluetooth protocol analyzer for the transmission quality. Although the protocol analyzer is connected to the diagnosis network and can inspect the possible problems in the application layer very efficiently, the problems are more likely to occur in a more complicated physical layer during the integration design, so that the spectrum analyzer is an essential tool to the Bluetooth test. The spectrum analyzer can not only be used for tests with standard specifications, but can also be used for the radiation requirement test specified by the certification authority to find the interference from different domains and different parts of electric circuits, etc.

There is a wide variety of spectrum analyzers on the market right now. While many spectrum analyzers are designed for the high-end testing and many other low-end solutions focused on basic metering, USB real time spectrum analyzers like the RSA306B and SignalVu-PC software offer an inexpensive, powerful, and portable alternative created for wireless device designers and manufacturers. Unlike low-end spectrum analyzers that cannot _, the Tektronix RSAs are cover the demands of both Wi-Fi and Bluetooth with 40MHz of bandwidth and higher sampling frequencies. In contrast to the expensive and unwieldy high-end boxes, the RSA306B is about one tenth the price of a traditional unit and small enough to hold in your hand. The PC-based software provides 17 measurements and views for free, with options specifically tailored for Bluetooth and Wi-Fi testing.

The Bluetooth analysis option of Tektronix SignalVu-PC Software will help you verify that whether the RF signal sent by the equipment complies with the V4.1 standard released by SIG. This option can test and analyze 3 kinds of main Bluetooth standards: basic rate (BR), enhanced date rate (EDR) and latest low energy (LE). The test items for each standard include different Presets, such as the power, frequency deviation and spectrum, etc. It also provides the pass/fail display of all kinds of tests as specified by the standard, so that users can run the one-button test without needing to comprehensively understanding the Bluetooth standard. We will use the RSA306B and SignalVu for the screenshots and test set ups in the following sections.

Introduction to Required Tests:

The Bluetooth analysis option of Tektronix SignalVu-PC Software includes multiple different tests. We will basically introduce various kinds of required tests for Bluetooth. Users can briefly learn about the Bluetooth tests in this section to select necessary tests as required and effectively verify whether their own devices comply with standard requirements in the future.

5.1 MODULATION CHARACTERISTICS

The test of modulation characteristics can verify whether the transmitting signal has a correct modulation function. Most Bluetooth standards use FSK as the modulation method, therefore they focus more on inspecting the FSK modulation quality with the frequency deviation, unlike other complicated modulation methods (QPSK and QAM) by observing the EVM value.

According to the Bluetooth standards, the test of modulation characteristics is suggested to be conducted at a fixed frequency or a non-frequency-hopping environment. For testing the modulation characteristics of Bluetooth, 2 kinds of special data pattern needs to be sent: 10101010 and 11110000, so as to test the peak and average values of frequency deviation. The real data transmission can be simulated by transmitting a pseudo-random sequence during test, but sending special bit type such as 10101010 provides more information for the test of filter in the Bluetooth modulation characteristics and also changes the spectrum appearance. After the bit type data 11110000 continuously sends out four 1s and four 0s, the signal output will reach the maximum range value of frequency and thus can detect the Gaussian filtering function. These 2 kinds of special bit type data are specified by the standard and provide better guidance for troubleshooting.

For EDR Bluetooth, higher-order PSK is used as the modulation method, therefore the eye diagram and the constellation diagram can more intuitively show the modulation condition and EVM becomes a measure of modulation quality.
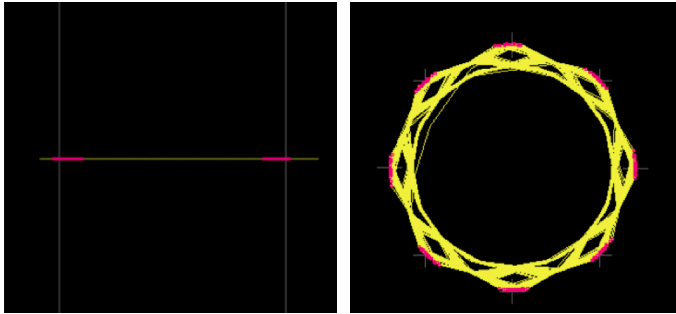
GFSK   8DPSK

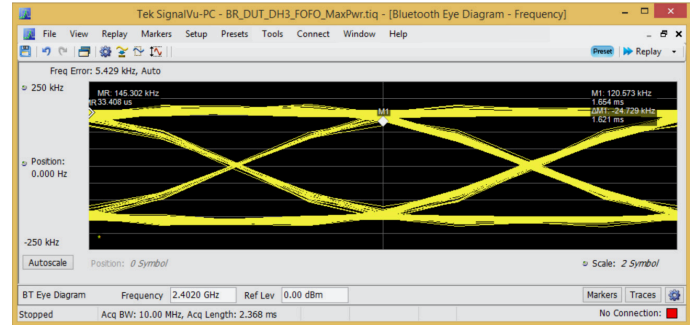**FIGURE 10.** Test of High Frequency Deviation in Bluetooth Signal at Standard Rate (10101010) signal (high deviation).

FIGURE 11. Test of Low Frequency Deviation in Bluetooth Signal at Standard Rate (11110000) signal (high deviation).

FIGURE 12. Test of High Frequency Deviation in Bluetooth Signal at Standard Rate (10101010) signal (high deviation).

FIGURE 13. Test of Low Frequency Deviation in Bluetooth Signal at Standard Rate (11110000) signal (high deviation).
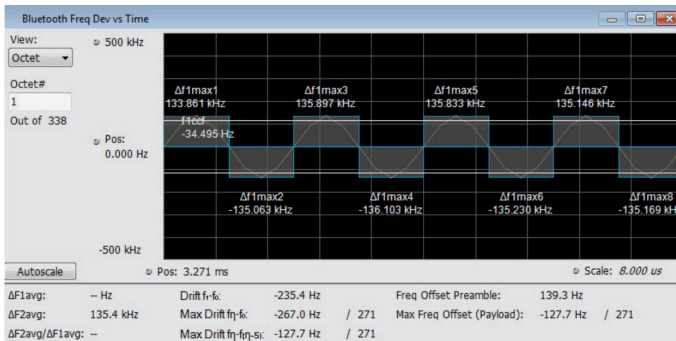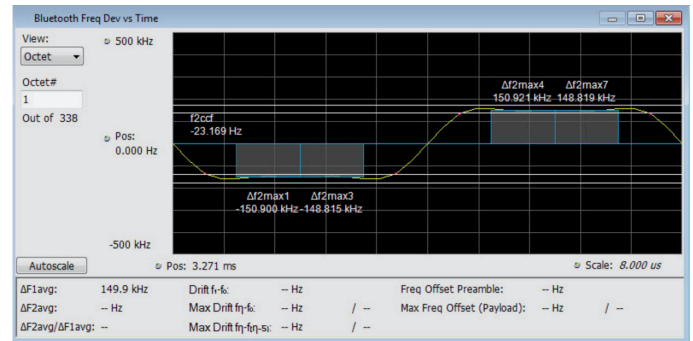
5.2 CARRIER FREQUENCY OFFSET AND DRIFT

The carrier frequency offset and drift test is to verify whether the carrier frequency of transmitting signal from the transmitter is controlled within the specified range, so as to assure the transmitting frequency stability. This test can be conducted at fixed transmitting frequency, hopping frequency or in the direct transmitting mode, for which the transmitting data needed is the bit pattern 10101010. Once the carrier frequency offset and drift test of SignalVu-PC is done, following test results will be shown at last:

- Preamble frequency deviation (initial carrier frequency deviation)

- Maximum spectrum deviation of data (and data position where the maximum deviation occurs)

- Frequency drift from preamble to former 10 bits of data

- Maximum spectrum deviation of data and preamble (fn-f0) (and data position where the maximum deviation occurs)

- Maximum drift once every 10 bits of data in a 50us interval (and data position where the maximum deviation occurs)

Limits Interval#	fn (-150.0kHz to +150.0kHz)	fn-f0(-40.00kHz to +40.00kHz) f1-f0(-20.00kHz to +20.00kHz)	fn-f(n-5) (-20.00kHz to +20.00kHz)
0 (Preamble)	139.2751		
1	-96.15504	-235.4302	
2	7.167774	-132.1074	
3	-0.01093826	-139.2861	
4	0.01212997	-139.263	
5	-0.003742599	-139.2789	
6	0.007567215	-139.2676	96.16261
7	-0.002672958	-139.2778	-7.170447
8	-0.007925415	-139.2831	0.003012847
9	-0.01031799	-139.2855	-0.02244797
10	0.001925278	-139.2732	0.005667877
11	0.001144409	-139.274	-0.006422806
12	-0.004858398	-139.28	-0.00218544
13	0.001594162	-139.2736	0.009519577
14	-0.001327515	-139.2765	0.008990479
15	0.01260147	-139.2625	0.01067619
16	0.008859253	-139.2663	0.007714843
17	-0.003403854	-139.2785	0.001454544
18	-0.0007839203	-139.2759	-0.002378082
19	0.001569366	-139.2736	0.002896881
20	0.007740402	-139.2674	-0.004861068
21	-0.001542282	-139.2767	-0.01040153
22	0.009552765	-139.2656	0.01295662
23	-0.006316376	-139.2815	-0.005532456
24	-0.001724243	-139.2769	-0.00329361
25	-0.01467628	-139.2898	-0.02241669
26	-0.004405975	-139.2796	-0.002863693
27	0.0005382538	-139.2746	-0.009014511
28	-0.01394348	-139.2891	-0.007627105

Marker: MR   Time: 3.133 ms   Interval# 0   Value: 139.2

Freq Offset Preamble: 139.3 Hz
Max Freq Offset (Payload):   -127.7 Hz   / 271

Drift fn-fk: -235.4 Hz
Max Drift fn-fk: -267.0 Hz   / 271

Max Drift fn-fn-5:   -127.7 Hz   / 271

FIGURE 14. List of Test Results on Carrier Frequency Offset and Drift in Bluetooth Signal at Standard Rate signal (high deviation).

5.3 IN–BAND SPURIOUS EMISSIONS

The test of in-band spurious emissions is to verify whether the spectrum spurious signal on the Bluetooth transmitting band is within the range specified by the standard. According to the Bluetooth standard, this test is suggested to be conducted in a hopping frequency environment, so that the integrated power on each 1 MHz band across 80 channels from 2401 MHz to 2481 MHz can be tested. During the test, the integrated power values of adjacent channels will be calculated (except 3 channels near the transmitting center frequency) and compared with the power limit specified by the standard.

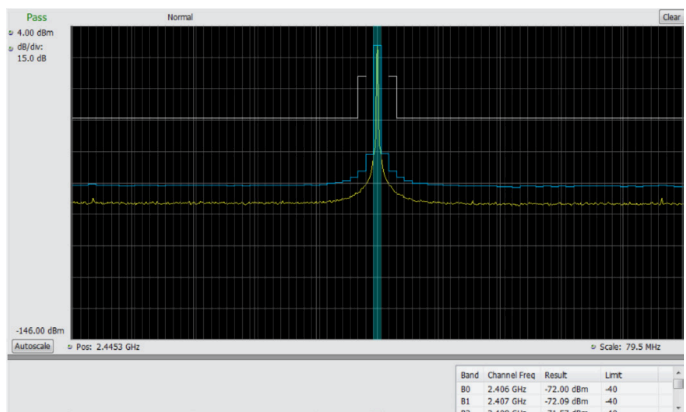This test also corresponds to ACPR test in the Bluetooth RF specification.

FIGURE 15. Test of In-band Emissions of Bluetooth Basic Rate Signals signal (high deviation).

5.4 OUTPUT POWER

As mentioned above, there are 3 kinds of different power classes for Bluetooth devices, each of which is strictly specified with a power limit. The output power test is to obtain the maximum peak power and the average power of the test device. According to the standard, PRBS signal is suggested to be transmitted for output power test, and the time length of test signal needs to cover the preamble and a burst. The transmitting mode is suggested at a fixed frequency.

5.5 20 DB BANDWIDTH

20 dB band width test is to verify whether the radiation frequency range of transmitting signal complies with the standard requirement. The transmitting mode is suggested at a fixed frequency. 20 dB bandwidth refers to the frequency range in case the signal transmitted by the test device is lower than the peak at 20 dB. For basic rate, 20 dB bandwidth should not be greater than 1.0 MHz as specified, otherwise the signals of other channels will be interfered.
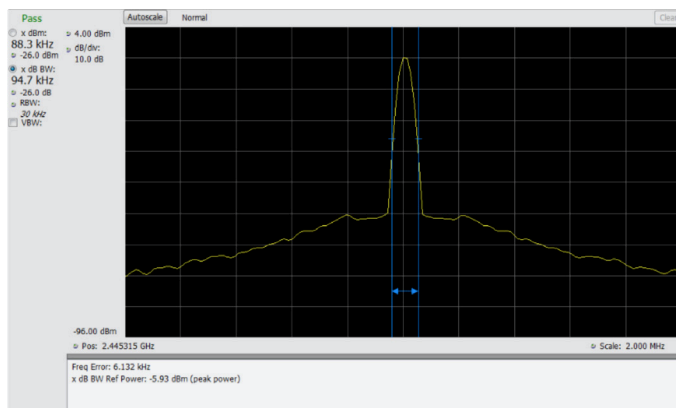

FIGURE 16. Test of In-band Emissions in Bluetooth Signal at Basic Rate signal (high deviation).

5.6 FREQUENCY RANGE

Similar to the 20 dB bandwidth test, the frequency range test is to make sure the power of transmitting signal on the band is within certain limit range. This test is performed in 2 steps at a non-hopping fixed frequency. Firstly, test the low-band (2399 MHz to 2405 MHz) spectrum of Bluetooth, and then test its high-band (2475 MHz to 2485 MHz) spectrum. fL refers to the low frequency on low band in case the power is lower than the center frequency peak at 30 dBm. fH refers to the high frequency on high band in case the power is lower than the center frequency peak at 30 dBm. fH - fL is the frequency range. This is one of tests required for basic rate Bluetooth standard.

5.7 POWER DENSITY

The power density test is to verify whether the maximum transmitted RF output power complies with the standard requirement. Bluetooth SIG specifies that any modulation modes of any power classes must not have the power greater than 100 mW per 100 kHz (20 dBm). In addition, even though the device meets the Bluetooth standard, you also need to check the spectrum management regulations specified by the local government, so as to make sure the power density meets the related requirements. For instance, European ETSI specifies that the power density must not exceed 20 dBW per 1 MHz (10mW).

FIGURE 17. Example of Spurious Emission Test in FCC 15.247 signal (high deviation).

5.8 OUT–OF–BAND SPURIOUS EMISSIONS

The out-of-band spurious emissions refer to the energy leakage outside of the transmitting band for various reasons (mostly caused by hardware design), which will cause the potential interference to other signals or devices. Similar to the EMC radiation test, this concept more focuses on the EMI test of intentional radiators. Generally the out-of-band spurious emissions are tested by the national and local spectrum regulatory authorities, and there are no specific requirements on this test in the Bluetooth standards. The Spurious measurement in SignalVu-PC is customized for this and is free to all users.

5.9 RECEIVER TESTS

The Bluetooth receiver tests are to make sure the Bluetooth receiver can receive the signals normally. The requirements specified by Bluetooth standards on the receiver test include: sensitivity test and blocking test, etc. Generally a calibrated signal generator of high accuracy should be used for the receiver testing.

TSG4100A series vector signal generator can generate high-quality Bluetooth signals, which is applicable for the Bluetooth product design, verification test and manufacture, etc. Tektronix TSG4100A series provides the mid-grade RF VSG performance indexes and rich vector signal modulation functions for customers at a lowprice, making it an ideal solution for Bluetooth receiver testing. By generating vector modulation signals at a range of 400 MHz - 6.0 GHz, and utilizing its built-in IQ baseband generator, the TSG4100A can produce various vector modulation methods to be widely applied in the IoT industry: ASK, QPSK, DQPSK, π/4 DQPSK, 8PSK, FSK, CPM, QAM (4 to 256), 8VSB and 16VSB, etc. Other built-in standard pulse shaping filters are classified into various types: raised cosine, root-raised cosine, Gaussian, rectangular, triangular, etc. The built-in IQ baseband generator can save 16M files at a 125 MHz/s sampling frequency, which is sufficient for users to conduct the receiver tests to the Bluetooth signals.
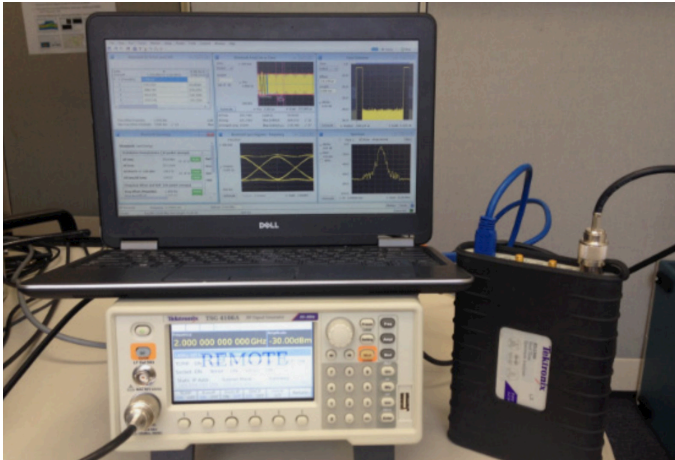
FIGURE 18. Demonstration of Bluetooth Low-energy Signal Transceiving by TSG4100A Vector Signal Generator and RSA306 Real-time Spectrum Analyzer.

TSG4100A can both manually and automatically generates various forms of Bluetooth signals. In the manual generation mode, users can easily set the frequency, the power class, the modulation mode (such as FSK and PSK) and the filter form (such as Gaussian filter) to directly output the required Bluetooth signal. For automatic generation of Bluetooth signals in cases such as production line test and environment test, etc., IQ waveform files complying with Bluetooth protocol requirements can be directly sent into the internal memory of TSG4100A and then called to generate the Bluetooth signals.

6. Tektronix Bluetooth Solution

Tektronix RSA 306B and RSA600 Spectrum Analyzers with SignalVu-PC option SV27
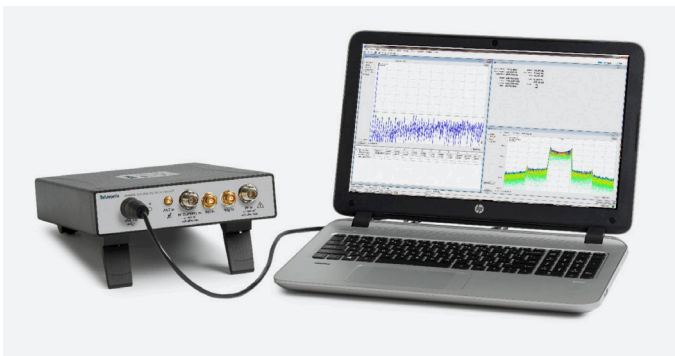

SignalVu PC Software
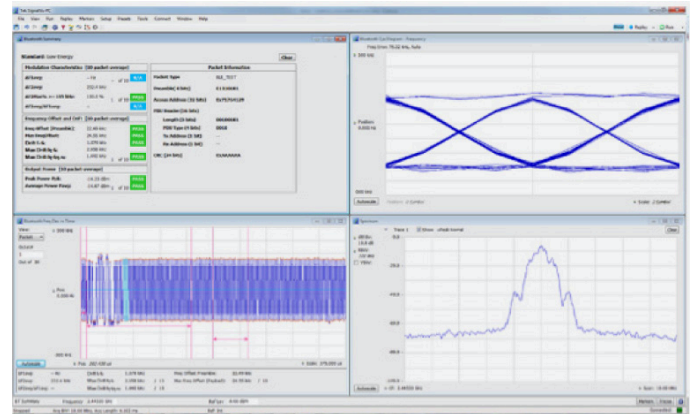
Use this powerful RF and Vector Signal Analysis software for all Tek RF products. SVPC comes free with 17 measurements and is instantly upgradable with options simplifiying Bluetooth measurements and troubleshooting. Take advantage of features like:

- Physical layer RF measurements for Bluetooth Basic and Bluetooth Low Energy, per the Bluetooth SIG specifications

- Demodulation and symbol information with simple presets for different test setups

- Automatic measurements for Bluetooth Low Energy and Basic Rate

- Detection for Bluetooth Enhanced Data Rate packets

Tektronix Real-time Spectrum Analyzers get you the design insight you need to get products to market. Choose the streamlined, no frills RSA306 or RSA600 Series spectrum analyzers measure and test Bluetooth signals at a fraction of the price of a benchtop spectrum analyzer.
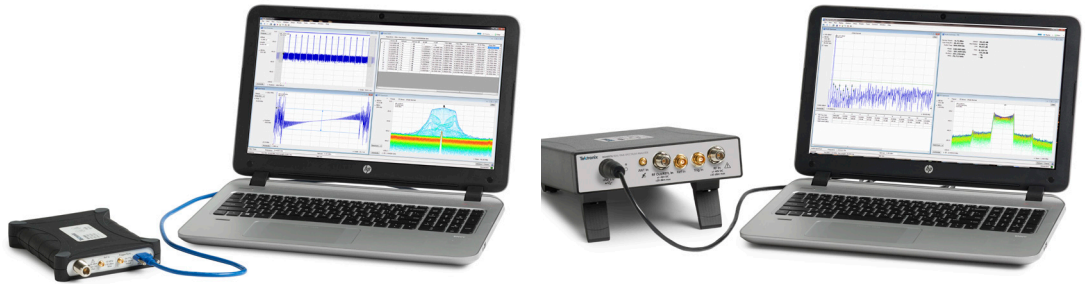
	RSA306B	RSA600
Power Source	USB 3.0	Battery or Line
Max Frequency Range	9 kHz - 6.2 GHz	9 kHz - 7.5 GHz
Max Acquisition Bandwidth	40 MHz	40 MHz
Noise Floor (DANL at 1 GHz, Preamp On, dBm/Hz)	-163	-164
Tracking Generator	No	Option
Modulation, pulse, wireless standards analysis	Option	Option
Weight	0.73 kg (1.6 lbs)	2.88 kg (6.35 lbs)

Learn more at www.tek.com/usb-spectrum-analyzer

Contact Information:

Australia* 1 800 709 465
Austria 00800 2255 4835
Balkans, Israel, South Africa and other ISE Countries +41 52 675 3777
Belgium* 00800 2255 4835
Brazil +55 (11) 3759 7627
Canada 1 800 833 9200
Central East Europe / Baltics +41 52 675 3777
Central Europe / Greece +41 52 675 3777
Denmark +45 80 88 1401
Finland +41 52 675 3777
France* 00800 2255 4835
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Italy 00800 2255 4835
Japan 81 (3) 6714 3010
Luxembourg +41 52 675 3777
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Mexico, Central/South America and Caribbean 52 (55) 56 04 50 90
Middle East, Asia, and North Africa +41 52 675 3777
The Netherlands* 00800 2255 4835
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