Bluetooth® Low Energy (V5.0) RF-Test for Internet of Things Applications
Application Note

Products:

- R&S®CMW500
- R&S®CMW290
- R&S®CMW270
- R&S®FSVxx
- R&S®FSVAxx
- R&S®FSWxx
- R&S®Forum

- R&S®SMW200A
- R&S®SMBV100A
- R&S®SMB100A
- R&S®SGT100A
- R&S®SGS100A
- R&S®SMC100A

More and more everyday items such as household appliances, vehicles, lights, etc. are now connected to the Internet, forming what is known as the "Internet of Things". Even clothing with sewn-in sensors to measure vital functions can now connect to the Internet and transmit data to cloud services. These different things use a variety of wireless technology standards to establish a connection. Due to its popularity, one of the most important standards is Bluetooth (or Bluetooth Low Energy). Before a new product with Bluetooth functionality can be launched, the qualification process defined by the Bluetooth SIG must be successfully completed. To save time and money, performance tests need to be performed in the development stage. This application note describes how to use the R&S CMW platform to perform the measurements defined in Bluetooth test specification version 5. As an alternative solution, we also cover how to perform almost all of the measurements with a spectrum analyzer and signal generator.

Note:

The latest version of this document is available on our homepage:
http://www.rohde-schwarz.com/appnote/1MA282.

This document has accompanying software. The software may have been updated even if the document version has not changed.

ROHDE & SCHWARZ

Contents

This application note uses the following abbreviations for Rohde & Schwarz instruments:

ı   The R&S® CMW radio communication tester platform is referred to as CMW.

ı   The R&S® SMBV100A vector signal generator is referred to as SMBV100A.

ı   The R&S® SGT100A SGMA vector RF source is referred to as SGT100A.

ı   The R&S® SGS100A SGMA RF source is referred to as SGS100A.

ı   The R&S® FSV signal and spectrum analyzer is referred to as FSV.

Note: For the Bluetooth LE receiver measurements with the SMBV100A, the option *R&S SMBV-K117 Bluetooth 5.0* required for this, is available in the second half of 2017.

1 The Internet of Things

A refrigerator orders more food when it is empty. A car informs the repair shop when work is needed. Vehicles share information about traffic jams and accidents using car-to-car communications (C2C) or car-to-infrastructure communications (C2I). Pacemakers provide an early warning about health problems and immediately send data to the doctor. Beacons guide us to our destinations in stadiums, museums and department stores via smartphone apps. In the future, an extremely wide range of items will be equipped with sensors and microprocessors and interconnected via the Internet. For example, miniature computers known as wearables with various sensors are now embedded directly into clothing. In contrast to the Internet, which allows people to communicate with one another and take advantage of offered services e.g. to exchange information or make online purchases, the Internet of Things (IoT) is based on the concept of IoT-enabled devices exchanging data with one another directly via machine-to-machine communications (M2M). Every device in the Internet of Things is uniquely identified by its address and can be addressed via the Internet and interact with connected information systems. IoT differentiates between concepts for industry concepts for consumers. Industry has its own Industrial Internet of Things (IIoT) and the field of telemedicine has the Internet of Medical Things (IoMT).

The vision behind the Internet of Things is not new. In his 1991 essay entitled "The Computer for the 21st Century", Mark Weiser spoke for the first time about a vision of internetworked devices. The term "Internet of Things" was used for the first time in 1999 by Kevin Ashton. The Internet of Things became widely known through the activities of the Auto-ID Labs. Fig. 1-1 shows a forecast by Ericsson and Cisco for the growth in IoT devices over the coming years. Whereas the number of mobile phones, PCs, laptops, etc. is more or less limited by the world population, the number of IoT devices is rapidly increasing.
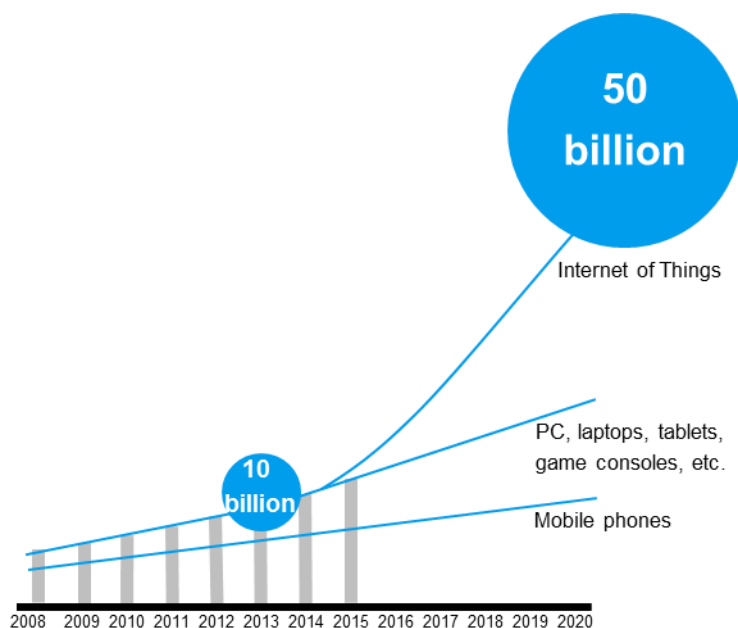

Fig. 1-1: Growth forecast for IoT devices

The Internet of Things (IoT) is evolving in the direction of an Internet of Everything (IoE) in which nearly everything is interconnected.

While the IoT does entail many opportunities and benefits, there are also certain disadvantages. For example, the interconnected infrastructure could be used for surveillance purposes or cyberattacks. There is also an increasing number of reports of huge numbers of IoT devices being exploited to create botnets that can be externally controlled for malicious purposes. By sending a massive number of simultaneous requests to servers of specific Internet services, it is possible to paralyze the servers for hours.
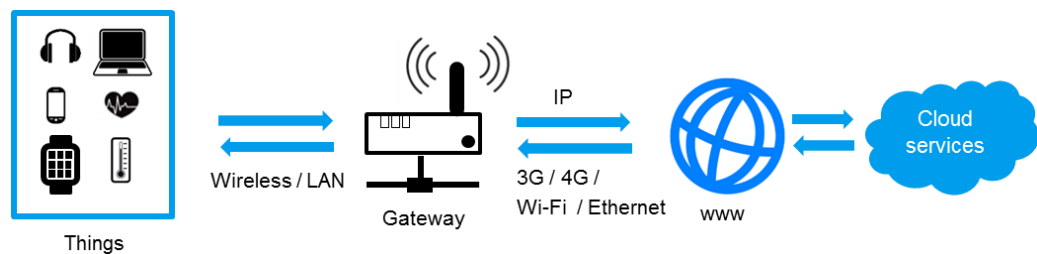
1.1 Connecting IoT Devices to the Internet

Fig. 1-2: Connecting IoT devices to the Internet

The type of connection used to connect IoT-enabled devices to the Internet depends on the application. Fig. 1-2 shows the basic concept for Internet access. The IoT device first establishes a connection to the gateway. The gateway is responsible for connecting networks with different network protocols and ultimately converting the data stream to the Internet protocol (IP). In other words, the gateway has the same function as the routers we use in our homes to connect to the Internet. When connecting via a cellular network, a smartphone can function as the gateway to the Internet, for example. When connecting IoT devices to the gateway, we distinguish between wired and wireless access. The most familiar and common type of cable connection is over the LAN or USB interface. This connection type is used for stationary IoT devices. It is less susceptible to disruptions than a wireless connection. For mobile devices (or when there is no LAN cable infrastructure), a wireless link is required. This is also known as Wireless Internet of Things (WIoT). WIoT can be used by miniature devices and wireless sensors to communicate via the Internet. There are various wireless technology standards that come into consideration for WIoT. Some of the different wireless technologies are shown in Fig. 1-3.
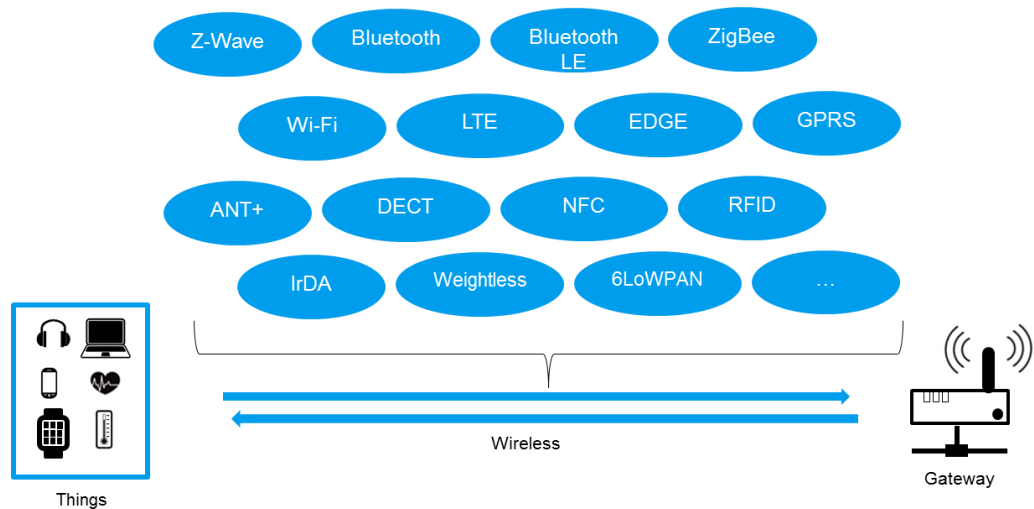
Fig. 1-3: Various technologies for wireless data transmission in IoT applications

Each of these technologies has advantages and disadvantages when used for IoT. The right technology can be selected by considering the application. The various wireless technologies differ in terms of their range, transmission speed, network capacity, power consumption, chip size and costs. The following comparison shows applications as well as basic differences between four wireless technology standards selected as examples:

ı   Wi-Fi (specified in the IEEE 802.11 standard) for classic WLAN Internet access Bluetooth BR/EDR (also known as "Bluetooth Classic") and Bluetooth Low Energy (BLE) for wireless personal area networks (WPAN) to connect audio applications as well as the data transmission of various sensors from the field of automotives, medical technology, consumer goods and smart wearables.

ı   The standard IEEE 802.15.4 low-rate wireless personal networks with its various technologies such as Zigbee, Thread, 6LoWPAN and others for sensor networks, home automation, lighting technologyZ-Wave for home automation.

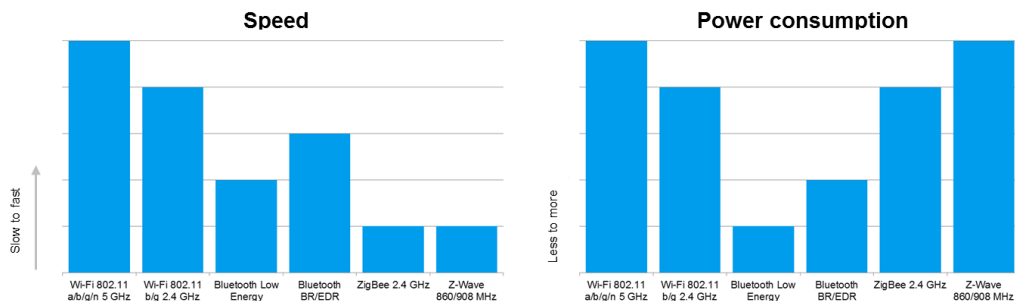See Fig. 1-4 to Fig. 1-6 for a qualitative comparison of key parameters for these wireless technology standards.

Fig. 1-4: Speed and power consumption for different wireless technologies
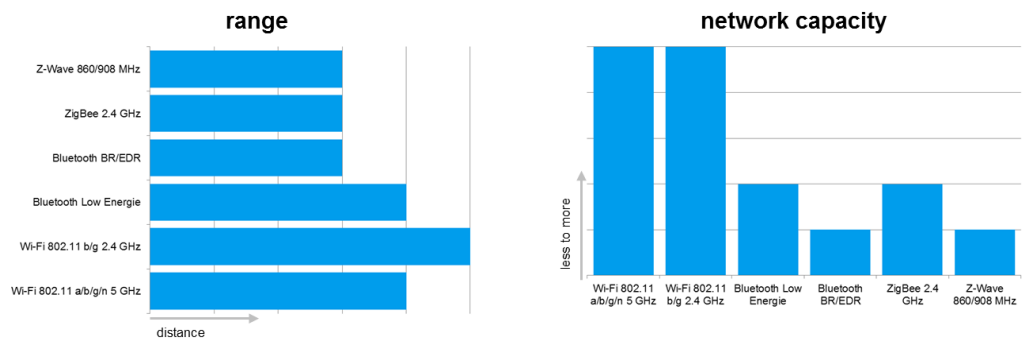
Fig. 1-5: Comparison of range and network capacity for different wireless technologies
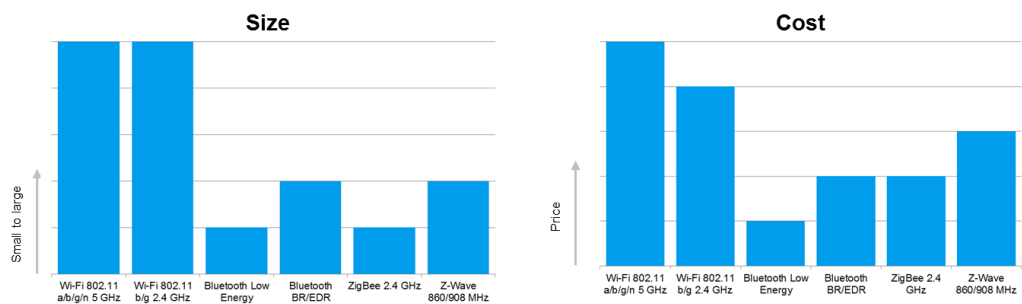
Fig. 1-6: Comparison of chip size and costs for different wireless technologies

Particularly for WIoT, an affordable and power-efficient solution based on battery power is one of the main requirements. Generally speaking, WIoT devices transmit fairly little data so high transmission capacity is not required. Based on these requirements together with the above comparison of different wireless technology standards, we can see that Bluetooth LE is well-suited for WIoT applications. Bluetooth also enjoys unrivaled market success. This wireless technology standard is now used in practically every mobile phone, PC, tablet, newer car, etc. According to Bluetooth Special Interest Group (SIG), over 8 billion Bluetooth devices are in use today.

2 Bluetooth Briefly Explained

In 1989, Ericsson Mobile in Sweden began developing a wireless technology for transmitting data between devices over short distances. This technology later became known as Bluetooth. This technology can be used to wirelessly connect mobile phones to a PC or headphones, for example. "Bluetooth" is an Anglicized version of the Danish Blåtand (Old Norse Blátǫnn) in honor of the Danish King Harald Bluetooth (born around 910 in Denmark; died November 1, 987) who united dissonant tribes in Norway and Denmark. Just as King Bluetooth once united large parts of Denmark and Norway, Bluetooth wireless technology brings together the computer and telecommunications worlds and replaces a variety of different connectors. The Bluetooth logo is a monogram combining the Old Norse runes for H and B. The wireless technology standard was originally specified as IEEE 802.15, but it is no longer maintained. The standard was taken over in 1998 by the new Bluetooth Special Interest Group (SIG) originally founded by Ericsson, IBM, Intel, Nokia and Toshiba. In 1999, 3Com, Lucent, Microsoft and Motorola joined SIG. Today, Bluetooth SIG has more than 26,000 member companies with an interest in the further development and proliferation of Bluetooth technology. Apple, Ericsson, Lenovo, Nokia, Toshiba, Intel and Microsoft are the Promoter member companies with a seat on the Board of Directors. Bluetooth SIG is the owner of the Bluetooth trademark and the publisher of the Bluetooth specification.

Only products that are licensed by SIG may use the Bluetooth trademark. To receive a license, the company must be a member of the Bluetooth SIG. SIG also manages the Bluetooth SIG qualification process, i.e. the certification procedure that represents another licensing prerequisite for any product that uses Bluetooth wireless technology.

Versions

Bluetooth has gone through a number of versions over its development history. Table 2-1 shows an overview of the main versions. Officially, all versions from V2.1 (including basic rate) are valid. Although development of the high speed mode has been discontinued, the specification remains valid. The versions up to and including version 3 are known as Bluetooth "Classic", while the versions starting with version 4 are called Bluetooth Low Energy (BLE). BLE is optimized for low power consumption in battery-powered devices that require very long battery life. Bluetooth LE (starting with V4) is not backwards-compatible. Some devices such as smartphones and tablets now support both types of Bluetooth in "dual mode". Bluetooth Classic and Bluetooth Low Energy are similar, but they are not compatible (Fig. 2-1).

Bluetooth versions				
Version	Attribute	Description	Year	Designation
1	Basic rate (BR)	Conventional BT, low data rate	1999-2003	Classic
2	Enhanced data rate (EDR)	Higher transmission speed	2004-2007	
3	High speed (HS)	High speed mode	2009	
4	Low energy (LE)	Low power consumption for IoT	2010-2014	Low energy
5	Improvements for LE	Higher data rate, greater range, higher throughput	2016	

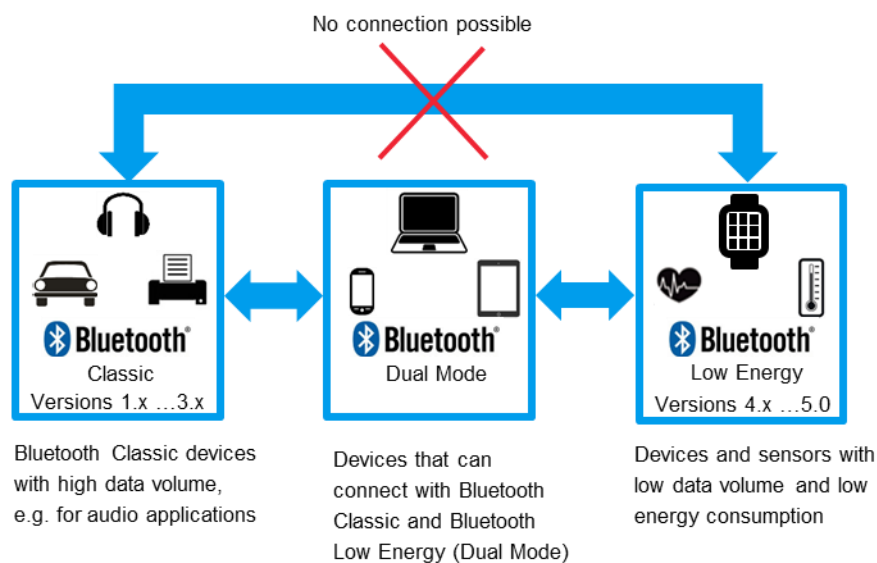**Table 2-1: Overview of the main Bluetooth versions**

Fig. 2-1: Overview of the different Bluetooth types

Here are some examples of device classes and the corresponding Bluetooth version:

ı   Bluetooth LE USB dongle: almost all such devices support both versions (dual mode)

ı   Most wearables (fitness wristbands, sportswear with integrated heart rate monitor, etc.): Bluetooth Low Energy to save power

ı   Mobile phones must be able to connect to BT devices with different data transfer requirements. Thus, Bluetooth Classic allows a data transfer of up to 2.1 Mbps, which is used, for example, for wireless headphones. The LE technology up to 4.2 provides data rates up to approx. 300 kbps, which is sufficient for the data transmission of sensors.

Frequency band

Bluetooth uses the industrial, scientific and medical (ISM) band which is designated for unlicensed use worldwide in the 2.4 GHz band. ISM devices such as microwave ovens, WLAN routers, DECT telephones and wireless remote controllers only require a general authorization from the national frequency allocation authority. To avoid

collisions with other wireless services, Bluetooth does not use just a single frequency channel. Data is transmitted using the frequency hopping spread spectrum (FHSS) technique. Transmitters and receivers constantly change frequencies in an agreed sequence. FHSS thus has low susceptibility to interference since any single carrier frequency is only used for transmitting over a short period of time. If a frequency happens to have interference from another transmitter, only a small part of the data sequence will be impacted by this interference, and this can mostly be corrected (or at least detected) using suitable error correction techniques.

Architecture

A Bluetooth device basically consists of a host and a Bluetooth controller. The host is the computing unit in a BT chip. The host has the Bluetooth stack (software) and the actual application running on it. The baseband (frequency signal of the wanted signal) can support either Bluetooth Classic (BR/EDR) or BLE. Both communicate via the host controller interface (HCI) (Fig. 2-2). The following communications take place via the HCI:

ı   Commands from host to baseband (BB)

ı   Events from BB to host
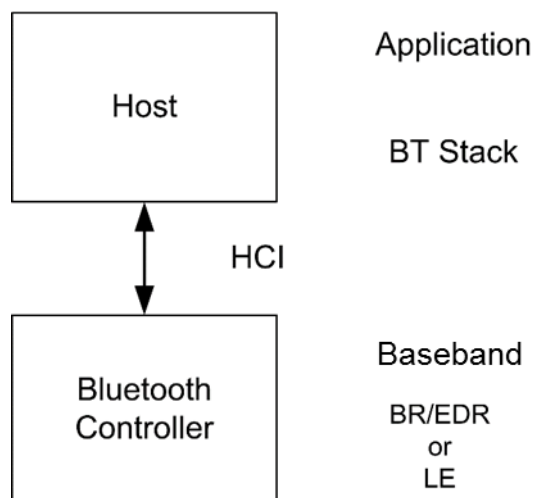
ı   Data

Fig. 2-2: Basic Bluetooth architecture

Dual-mode devices implement two controllers: one for BR/EDR and one for LE (Fig. 2-3).
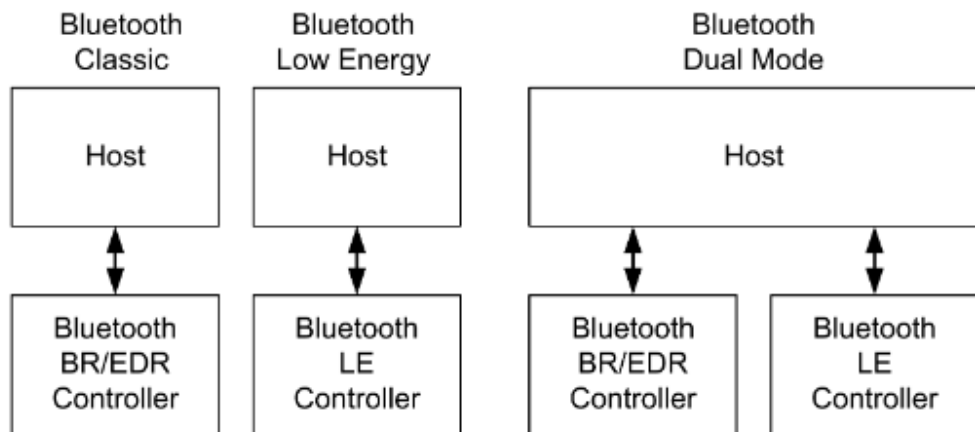
Fig. 2-3: Architecture for Bluetooth Classic, Bluetooth Low Energy and Bluetooth Dual Mode

Addressing

Every Bluetooth device has its own fixed 48-bit address that also contains a special manufacturer ID.

Profiles

Bluetooth only provides the physical capability to transfer data without a cable. From the user's perspective, however, there are certain expectations or use cases (e.g. "Transfer a file from my PC to my mobile phone") that must be fulfilled. For such use cases, Bluetooth defines certain profiles, i.e. scripts for how a specific scenario should be implemented (in keeping with the above example, a file transfer profile (FTP)).

Some profiles are universally applicable and must be supported in every Bluetooth device. Others appear only in certain devices or versions, depending on their purpose (e.g. the handsfree profile makes sense in headsets, but not in smartphones).

Two devices that want to exchange data must support the same profile.

3 Bluetooth Low Energy for IoT

Bluetooth Low Energy, Bluetooth LE or simply BLE is the name for special enhancements starting in version 4 that reduce power consumption. Versions 4.1 and 4.2 provide minor enhancements/improvements. In order to handle increasing numbers of devices on the Internet, for example, version 4.2 added support for IPv6 (increasing the IP address space from $4.3 \cdot 10^9$ in IP4 to $3.4 \cdot 10^{38}$) to the BLE protocol stack. Compared to Bluetooth Classic, BLE has much lower current consumption. This is achieved by keeping a device in sleep mode most of the time (99.9 % of the time). IoT applications require relatively low data rates. BLE also offers faster connection setup. Version 5 introduces basic improvements such as higher data rate and greater range. Bluetooth LE is not technically backwards-compatible. Bluetooth devices must provide additional support for the LE protocol stack in order to connect.

3.1 Advances in Version 5

ı   Doubling of the data rate to 2 Mbit/s with a new modulation type (see 3.4.3)

ı   Four times the range thanks to special coding (LE long range)

ı   Eight times the broadcast capacity through an extension of the advertising procedures (LE advertising extension)

ı   Higher available transmit power (up to +20 dBm) (see 3.4.2)

ı   The implementation of a stable modulation index SMI additional to the standard modulation index. This feature improves the link budget by up to 3 dB, which means the extension of the range of the Bluetooth connection.

Stable modulation index	0.495 … 0.505
Standard modulation index	0.450 … 0.550

For more details on version 5, see the White Paper 1MA108_2e "Bluetooth physical layer evolution: From cable replacement to the IoT".

3.2 Advertising and Data Transmission

Bluetooth LE recognizes different types of communications:

ı   Information transmission only (broadcast)

ı   Data reception only

ı   Mixed transmission and reception of data

Bluetooth LE introduced "advertising". All communications is initially handled via three (or more starting in version 5) special channels known as "advertising channels"; see 3.4.1). A device transmits information on this channel, while one or more other devices listen (scanning). Even though a device is expected to save power, it still has to draw attention to itself at regular intervals. For example, a fitness wristband wakes up every ten seconds and sends a "Hello, here I am" message on an advertising channel. It then

listens briefly on the same channel to see if there is a response. If there is no response, it tries again on the other two channels and then the processor goes back to sleep. To save power, devices can also refrain from communicating in the scanning process. This is implemented using a white list filter. This means the Bluetooth controller will set up a connection with a device address only if it matches an address stored in the white list.

Low data volumes can be exchanged directly between devices via an advertising channel. For large volumes, an additional connection can be set up in response to a request by a device (initiator). Both agree to meet on a channel at a certain time and then resume frequency hopping. This corresponds to a piconet from Bluetooth Classic with master and slave operation. The fitness wristband as a BLE device is then connected, for example, to a smartphone and is no longer visible to other devices. Since it can only set up one connection simultaneously, advertising no longer makes any sense either. Simply stated, BLE devices only know three states: off, advertising and connected.

Version 5 brought an enhancement to advertising. Data channels can now also be used as auxiliary channels. In advertising mode, data is transmitted on the data channels using auxiliary packets (AUX), and no true connection is set up. This is called offloading. Offloading serves to reduce the load on the three advertising channels.

3.3 Profiles and Services

Bluetooth LE defines services and profiles. A service describes one or more features that characterize the behavior of a peripheral device. A profile describes how a service can be used for a specific application on a Gateway (smartphone or tablet).

Fig. 3-1 compares services and profiles. The thermometer in this example offers temperature measurement as a service. It transmits at a set time interval in the advertising channel. As a dual-mode device, the tablet functions as a scanner or initiator and uses a profile to read data from the thermometer.
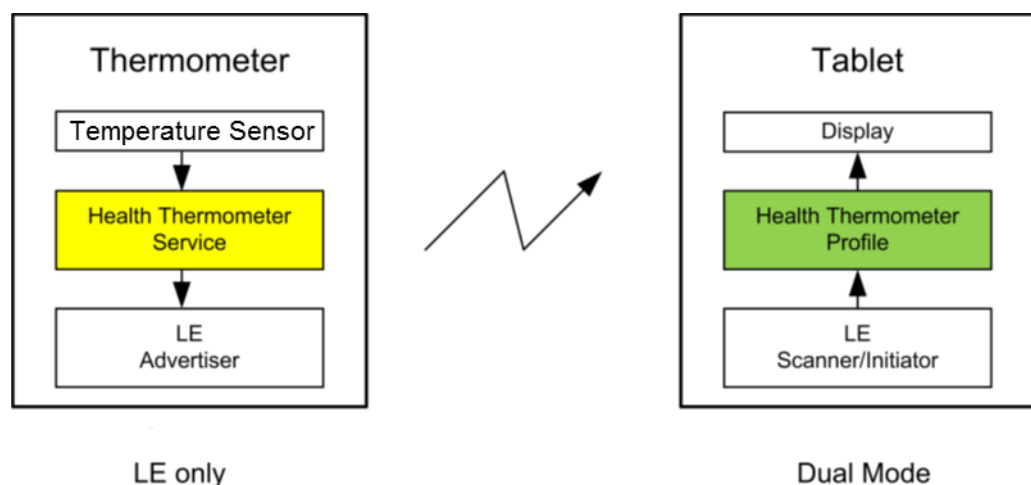

Fig. 3-1: Usage of service and profile

From the perspective of central devices (tablet , smartphone), Bluetooth LE devices always connect via the generic attribute profile (GATT). GATT is for sensor data and in general it optimizes the power-efficient transmission of low data volumes. It defines a sort of framework for profile development, i.e. profiles can derive a specific architecture from GATT.

Examples of services and profiles:

ι BAS – battery service

ι BLP – blood pressure profile

ι BLP – blood pressure service

ι GLP – glucose profile

ι HRP – heart rate profile

ι HRS – heart rate service

ι LNP – location and navigation profile

ι RSCP – running speed and cadence profile

ι WSP – weight scale profile

3.4 Wireless Interface

3.4.1 Channels, Frequencies and Frequency Hopping

BLE uses 40 channels with a channel spacing of 2 MHz in the 2.4 GHz ISM band. This band ranges from 2402 MHz (channel 0, logical channel 37) to 2480 MHz (channel 39, logical channel 39). Logical channels 37, 38 and 39 are the advertising channels and channels 0 to 36 are the data channels. The three advertising channels are arranged in the frequency band so they cannot be disrupted by Wi-Fi channels 1, 6 and 11, which share the ISM band (Fig. 3-2). Frequency hopping is not used until a connection has been set up between two devices. Since advertising and data transfer in advertising do not use frequency hopping, the European Telecommunications Standards Institute (ETSI) does not classify Bluetooth LE as a frequency hopping system.
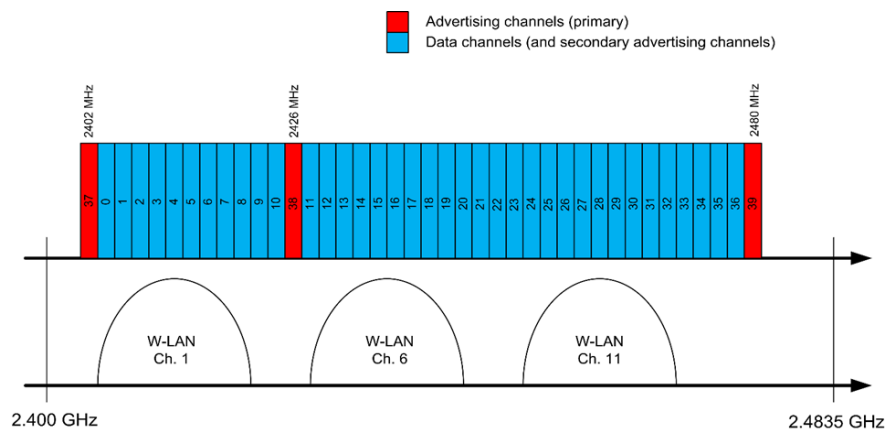

Fig. 3-2: Bluetooth LE channels; red: advertising channels; blue: data channels

3.4.2 Transmit Power

The transmit power in BLE lies between –20 dBm (0.01 mW) and 20 dBm (10 mW). In order to optimize power consumption or minimize interference for other devices, separate power management can be implemented in a device. The following power classes have been defined:

Class	Maximum output power (dBm)
1	+20
1.5	+10
2	+4
3	0

Table 3-1: BLE power classes

3.4.3 Modulation

To keep Bluetooth LE simple, there is only one single, robust modulation mode. Like in the Bluetooth Classic basic rate, Gaussian frequency shift keying (GFSK) is used for modulation. The frequency deviation is ±250 kHz, allowing a gross data rate of 1 Mbit/s.

For higher data rates, version 5 introduces an optional physical layer (PHY) with twice the frequency deviation (±500 kHz). This corresponds to a gross data rate of 2 Mbit/s.

The stable modulation index (SMI) is also optional. With SMI, devices guarantee a modulation index between 0.495 and 0.505. This makes the frequency deviation more precise and increases the possible range. This is possible for all PHYs.

Version 5 introduces new technologies on the lower layers. As a result, it is now possible to define three different physical layers (PHYs). They have different frequency deviations, coding and net data rates. The coding is used for forward error correction and ultimately helps to increase the range up to four times. S=8 indicates that eight symbols code one bit; correspondingly S=2 means two symbols are equal to one bit. LE1M is mandatory and is backwards-compatible with V4.

Table 3-2 shows an overview of the three PHYs.

PHY	Bluetooth LE	Frequency deviation/ gross data rate	Coding		Net data rate
			Access header	Payload	
LE1M	Required	250 kHz/ 1 Msymbols/s	Uncoded		1 Mbit/s
LE2M	Optional	500 kHz/ 2 Msymbols/s	Uncoded		2 Mbit/s
LE coded	Optional	250 kHz/ 1 Msymbols/s	S=8	S=2 S=8	500 kbit/s 125 kbit/s

Table 3-2: Overview of the three physical layers

3.5 Summary

Table 3-3 summarizes the main characteristics of Bluetooth LE.

Application	Automotive, smartwatches, sports & fitness, home electronics, automation, industry 4.0, healthcare, smartphones, etc.
Audio	No
Frequency band (ISM)	2.4 GHz
Power consumption	50 % to 99 % less than Bluetooth Classic
Coverage	≥ 10 m
Output power	max. +20 dBm
Connection setup	Via advertising
Connection time	6 ms
RF channels	40 with 2 MHz spacing 3 advertising channels 37 data channels (+ secondary advertising channels)
Modulation	GFSK Frequency deviation: 250 kHz or 500 kHz Modulation index: 0.45 to 0.55 Stable modulation index: 0.495 to 0.505
Gross data rate	1 Mbit/s to 2 Mbit/s
Net data rate	0.2 Mbit/s to 0.6 Mbit/s

Table 3-3: BLE characteristics

3.6 Bluetooth SIG Qualification

During the development of a new product that uses a new wireless connectivity protocol, one important factor to consider is time to market. This issue can be addressed by understanding the Bluetooth qualification process.

How to get your Bluetooth product to market

Two main sets of approval requirements must be addressed before products using Bluetooth technology can legally be placed on the market. The aim of the Bluetooth qualification program defined by the Bluetooth SIG is to protect the value of Bluetooth technology and the brand. The Bluetooth SIG compliance program is intended to ensure that a product complies with the Bluetooth specification and will successfully interoperate with other products that support the same Bluetooth profile. First, any company using Bluetooth wireless technology in their products and services must become a member of Bluetooth SIG. Depending on the developed product, the qualification process requires different test cases, such as RF conformance testing, protocol and profile conformance testing and profile interoperability testing. After a product "passes" all required test cases and its compliance is declared, companies are able to sell and brand their products with Bluetooth trademarks. National type approval requirements also apply to Bluetooth products and are a primary requirement for market entry. In general, three product certification requirements apply to Bluetooth products:

- The radio type approval or RF transmitter/transceiver unit

- The EMC certification of the RF part, usually when installed within the host unit and   relative to normal configuration and conditions of usage

- Safety certification, usually dependent upon the operating voltage of the product and any associated power supplies

If RF conformance testing and national radio type approval is needed, testing is generally required at a test laboratory accredited by the Bluetooth SIG and by the country of interest. In order to be sure that the product will pass the conformance test, it would make sense to perform an in-house preconformance test. Any problems can be detected and corrected quickly before the conformance test. This will save time and money on the way to launching a new product. In the following, RF PHY pre-conformance testing will be described.
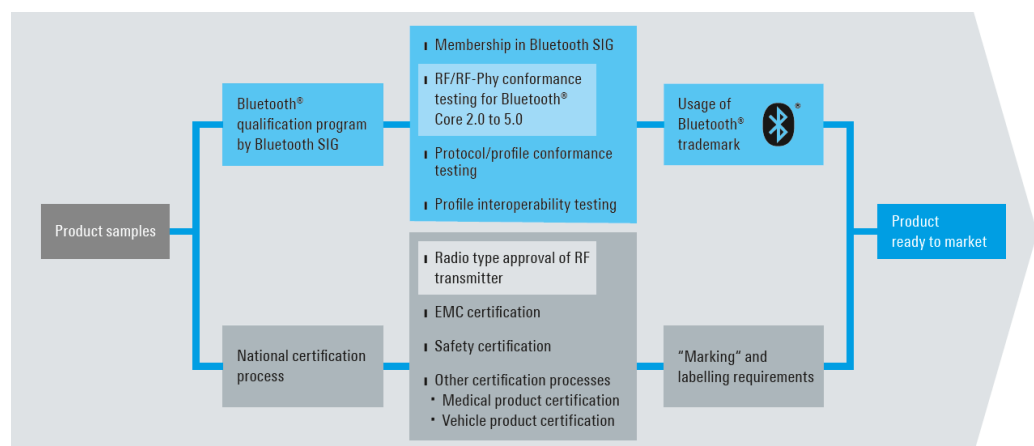

Fig. 3-3: Bluetooth qualification process

4 RF Measurements on a Bluetooth LE Device in Accordance with the Specification

The Bluetooth Special Interest Group (SIG) defines the measurements to be performed on the radio interface as part of the qualification process. All Bluetooth devices must prove they satisfy the specification requirements in a Bluetooth qualification and test facility (BQTF). For Bluetooth Low Energy devices, the test specification that is relevant is the Bluetooth test specification: (RF) // RF-PHY.TS.5.0.0 [3].

A distinction is made between transmitter (TX) and receiver (RX) tests. Since various chips with various applications exist in Bluetooth only a subset of the tests may be relevant in some cases. Beacons for example transmit only, but cannot receive.

The test specification [3] defines some fundamental tests that must be performed depending on the PHY.

 RF transmitter measurements

- Output power

- In-band emissions

- Modulation characteristics

- Carrier frequency offset and drift

RF receiver tests

- Receiver sensitivity

- C/I and receiver selectivity performance

- Blocking performance

- Intermodulation performance

- Maximum input signal level

- PER report integrity

These fundamental tests are repeated for the various PHYs. Table 4-1 and Table 4-2 provide an overview. The transmitter tests are designated as **TP/TRM-LE/CA/BV-xx-C** and the receiver tests as **TP/RCV-LE/CA/BV-xx-C**. The corresponding numerals in the different tables must be inserted. All tests listed below are nonhopping and must be performed on single RF channels. SMI is the abbreviation for stable modulation index.

Transmitter tests								
Test	LE1M 1 Ms/s	LE2M 2 Ms/s	LE1M 1 Ms/s SMI	LE2M 2 Ms/s SMI	Coded 1 Ms/s S=2	Coded 1 Ms/s S=8	Coded 1 Ms/s SMI S=2	Coded 1 Ms/s SMI S=8
Output power	01							
In-band emissions	03	08						
Modulation characteristics	05	10	09	11	13			
Carrier frequency offset and drift	06	12			14			

Table 4-1: RF transmitter tests for Bluetooth LE according to [3]

Receiver tests								
Test	LE1M 1 Ms/s	LE2M 2 Ms/s	LE1M 1 Ms/s SMI	LE2M 2 Ms/s SMI	Coded 1 Ms/s S=2	Coded 1 Ms/s S=8	Coded 1 Ms/s SMI S=2	Coded 1 Ms/s SMI S=8
Receiver sensitivity	01	08	14	20	26	27	32	33
C/I and receiver sensitivity	03	09	15	21	28	29	34	35
Blocking performance	04	10	16	22				
Intermodulation performance	05	11	17	23				
Maximum input signal level	06	12	18	24				
PER report integrity	07	13	19	25	30	31	36	37

Table 4-2: RF receiver tests for Bluetooth LE according to [3]

4.1 Direct Test Mode

The core specification defines a "direct test mode" (DTM) for Bluetooth LE. The DTM allows testing the physical layer (PHY) by sending and receiving test packet sequences. For example it can be used to send direct commands to the DUT and return reports such as the PER. This mode is often used in development, production and pre-conformance tests. The DTM skips the host stack and communicates directly with the PHY. Since direct test mode is part of the specification, every Bluetooth device should support this mode for conformance tests. It simplifies device control since it is not necessary to support every proprietary protocol, which is the case, for example, for W-LAN.

Control is via special commands for the host controller interface (HCI). Physically, a serial bus (UART or USB) is used. A PC or measuring instrument can therefore control the DUT.

The core specification also defines special test packets (coded and uncoded) to simplify the tests and make them reproducible. For the different tests, various bit patterns in the payload are supported, including:

- Pseudorandom bit pattern with a length of $2^9 - 1$ (PRBS9) or $2^{15} - 1$ (PRBS15)

- Alternating bit sequence: 01010101…

- All zeros or ones: 00000000 or 11111111

4.2 Measurements on the Bluetooth LE Transmitter

During transmitter tests, the DUT transmits and the test instrument measures the characteristics of the signal. Using direct test mode, the signal parameters are set either by the tester or via a PC with control software from the DUT manufacturer.
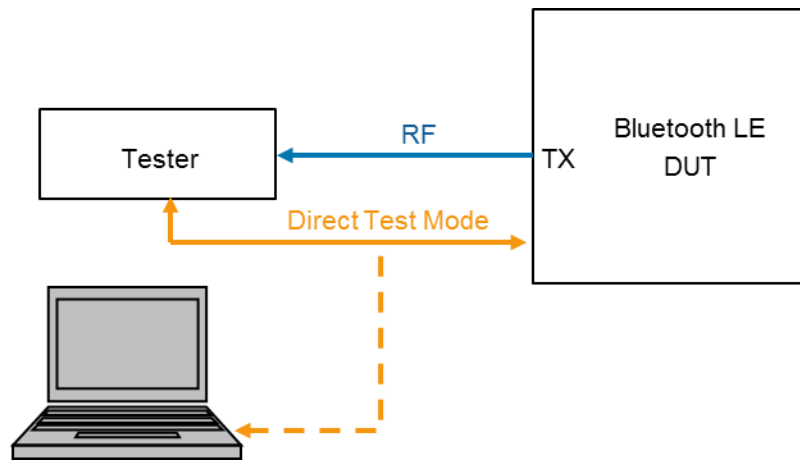

Fig. 4-1: Basic setup for transmitter tests. The tester or a PC controls the DUT via direct test mode. The tester measures the transmitter characteristics

All transmitter tests are performed on three frequency channels: one in the lower range, one in the middle range and one in the upper range of the ISM spectrum. The channel numbers differ based on the device classes as follows:

- Peripheral and central devices (connectible)

- Broadcaster and observer devices (non-connectible)

The channels are defined in the test specification.

Output power

One important characteristic of a transmitter is its output power. In the case of Bluetooth, the maximum output power may not exceed a specified value in order to make sure it does not interfere with other wireless communications services.

In-band emissions

A transmitter in the wanted channel produces interference on adjacent channels. This interference may not exceed a certain limit in order to minimize interference on other channels. The performance is measured on all Bluetooth channels (Bluetooth Classic channel spacing of 1 MHz) within the ISM band.

Modulation characteristics

The signal quality is important in order for the transmitter and receiver to understand each other. This test measures the signal quality based on the modulation.

Carrier frequency offset and drift

This test also measures the signal quality. The transmitter and receiver must operate on the same frequency. This test measures the difference between the transmitter frequency and the nominal frequency as well as the additional deviation of the center frequency during transmission of a complete packet.

4.3 Measurements on the Bluetooth LE Receiver

During receiver tests, the test instrument transmits a signal that is received by the DUT. Using direct test mode, the signal parameters are set either by the tester or via a PC with control software from the DUT manufacturer. The criterion used for the receiver test is the packet error rate (PER), or the data throughput which is derived from the PER. Normally, the DUT calculates the PER and sends the value back to the tester or the PC.
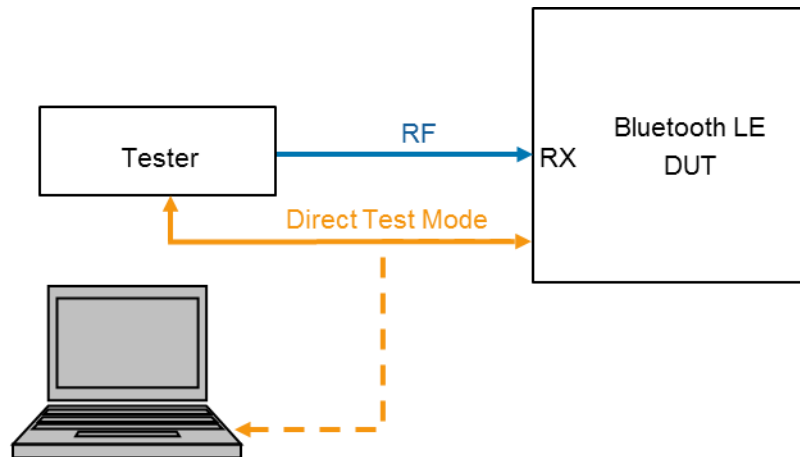
Fig. 4-2: General setup for receiver tests. The tester transmits test packets. The receiver settings are transferred to the DUT by the tester or PC. The DUT determines the PER and sends it back to the tester or PC for evaluation

All but two receiver tests are performed on three frequency channels (top, middle and bottom of ISM band). The blocking performance and PER integrity tests only require one channel in the middle of the range. The channel numbers differ based on the device classes as follows:

▪ Peripheral and central devices (connectible)

▪ Broadcaster and observer devices (non-connectible)

The channels are defined in the test specification [3].

Receiver sensitivity

The most important characteristic of the receiver is its sensitivity, i.e. just how weak a signal can the receiver successfully understand. In Bluetooth tests, a malfunctioning ("dirty") transmitter is also simulated.

C/I and receiver selectivity performance

In the ISM band, multiple Bluetooth transmissions can take place simultaneously between different devices. Different channels are used for this purpose. In this test, the receiver performance is measured in the presence of interference from other Bluetooth LE transmissions in adjacent channels.

Blocking performance

Various wireless systems such as mobile communications networks, satellite communications systems, satellite-based and radar-based navigation systems also transmit signals outside the ISM band. In this test, the receiver performance is checked in the presence of interference from other wireless transmissions outside the ISM band.

Intermodulation performance

Due to nonlinearities, two or more transmitters can produce new, additional interferers on specific frequencies. In this test, the receiver performance is measured in the presence of interference due to intermodulation.

Maximum input signal level

How the receiver behaves in response to weak signals is tested under receiver sensitivity. In Bluetooth, relatively strong signals can occur due to the spatial proximity of the devices. This test tests the receiver performance in the presence of strong signals.

PER report integrity

This is actually not an RF test. Instead, the error correction software in the receiver is tested. The receiver has to properly handle packets with predefined errors that are artificially inserted.

5 Measurements with the CMW

The CMW family is the ideal platform for Bluetooth tests. It can perform all Bluetooth tests in line with the specification. This includes tests in development and production as well as precompliance tests (additional T&M instruments required for precompliance tests). It is also easy to perform co-existence tests with other wireless technology standards. The following test instruments in the CMW platform support Bluetooth:

- CMW500   - Flexible radio communication tester with all conventional wireless technology standards

- CMW270   - Wireless connectivity tester

- CMW290   - IoT tester

- CMW100   - Production solution (non-signaling)

The CMW500, 270 und 290 support the direct test mode defined in the Bluetooth specification [4]. The Direct Test Mode provides a selection of different RF test for Bluetooth Low Energy Devices including the Remote Control Commandos for the USB or R232 interface. All Bluetooth test cases can be covered with the the obove mentioned CMW models (see Table 5-1).

Bluetooth LE test cases	LE 1M 1 Ms/s	LE 2M 2 Ms/s	LE 1M 1 Ms/s SMI	LE 2M 2 Ms/s SMI	Coded 1 Ms/s S=2	Coded 1 Ms/s S=8	Coded 1 Ms/s SMI S=2	Coded 1 Ms/s SMI S=8
Transmitter Tests	**TP/TRM-LE/CA/BV-xx-C**							
Output power	01							
In-band emission	03	08						
Modulation characteristics	05	10	09	11		13		
Carrier frequency offset and drift	06	12				14		
Receiver Tests	**TP/RCV-LE/CA/BV-xx-C**							
Receiver sensitivity	01	08	14	20	26	27	32	33
C/I and receiver sensitivity	03	09	15	21	28	29	34	35
Blocking performance [1]	04	10	16	22				
Intermodulation performance [1]	05	11	17	23				
Maximum input signal level	06	12	18	24				
PER report integrity	07	13	19	25	30	31	36	37

[1] Requires an additional signal generator.

Table 5-1: All Bluetooth LE HF-test cases are supported by the MW500, 270 und 290

Test setup

Most of the tests (e.g. for development and production) can be performed with the CMW alone with the following test setup:
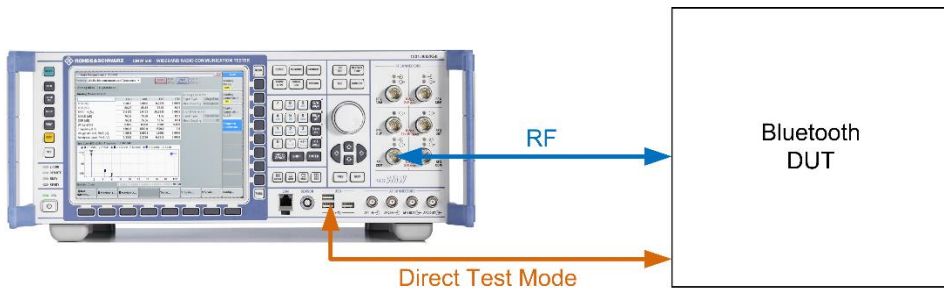
Fig. 5-1: The test setup with the CMW covers most transmitter and receiver tests. It also supports the direct test mode via USB

For all tests (preconformance), an additional signal generator is required:
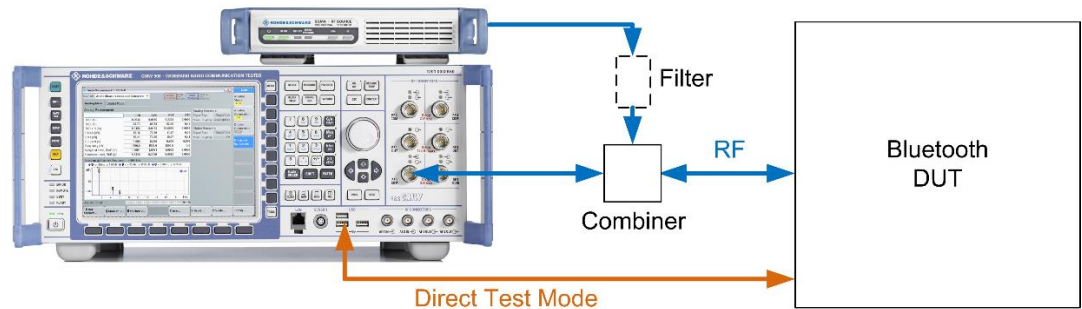
Fig. 5-2: This test setup with the CMW and an additional signal generator can be used to perform all transmitter and receiver tests in line with the specification. A filter suppresses any interference that might be produced by the CW generator in the Bluetooth band

5.1 Tests in Manual Operation

5.1.1 Initial Steps

For the Bluetooth tests, the following applications are required in the CMW firmware:

▮ Bluetooth Signaling

▮ Bluetooth Multi Evaluation

▮ Bluetooth RX Measurement

1. Use the SIGNAL GEN or MEASURE hardkeys to select the required applications. Go to the signaling application, e.g. by pressing TASKS.

2. Go to Bluetooth Signaling.
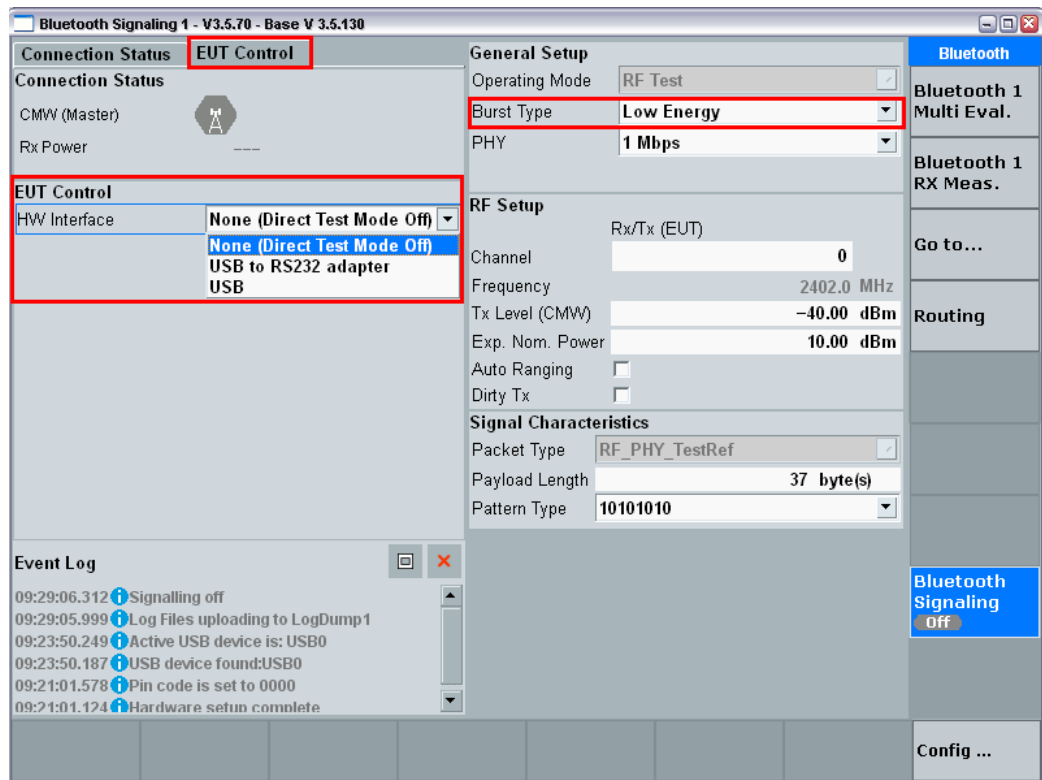
Fig. 5-3: The Bluetooth Signaling start screen. IoT tests run under Low Energy

3. IoT Bluetooth uses the *Low Energy* variant. Select *Low Energy* under **Burst Type**.

4. The CMW supports all three PHYs for Bluetooth version 5:

The three PHYs in the CMW	
LE1M	1 Mbps
LE2M	2 Mbps
LE coded	Long range

Table 5-2: Three PHYs in the CMW. Long Range supports coding schemes S=2 and S=8

5. On the left, select the type of connection to the DUT (**EUT Control**, **HW Interface**). Direct test mode is then automatically activated. Switch on the signaling. See application note 1C105 [xx] for more information on this topic.

6. The screen should now look like Fig. 5-4.

7. Click Connection Check at any time to verify the HCI connection to the DUT in direct test mode.
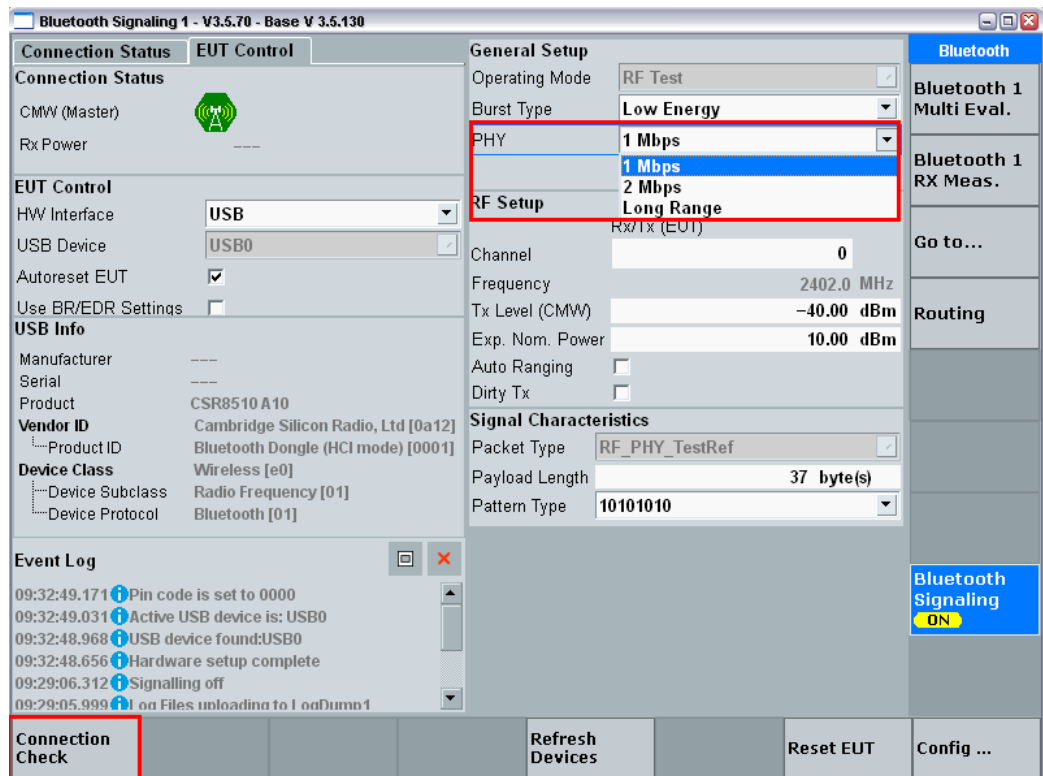
Fig. 5-4: Low energy and direct test mode are activated
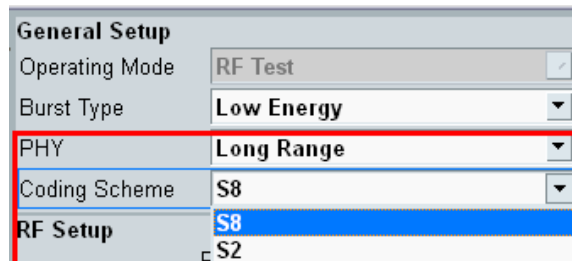
Fig. 5-5: Long range supports both coding schemes
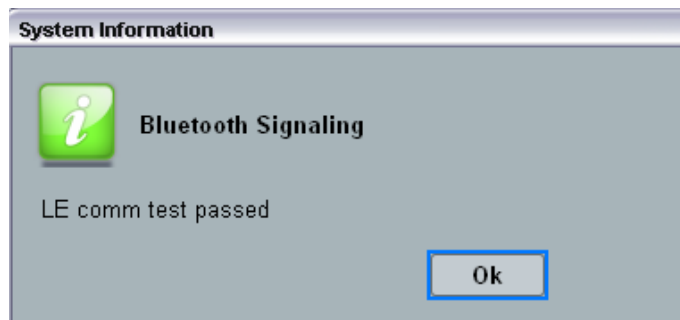
Fig. 5-6: Verification of the connection to the DUT in direct test mode

8. Click **Bluetooth Multi Eval.** (top right) to switch to the TX measurement screen. Activate the measurements by selecting **Multi Evaluation** (top right) and **ON**.
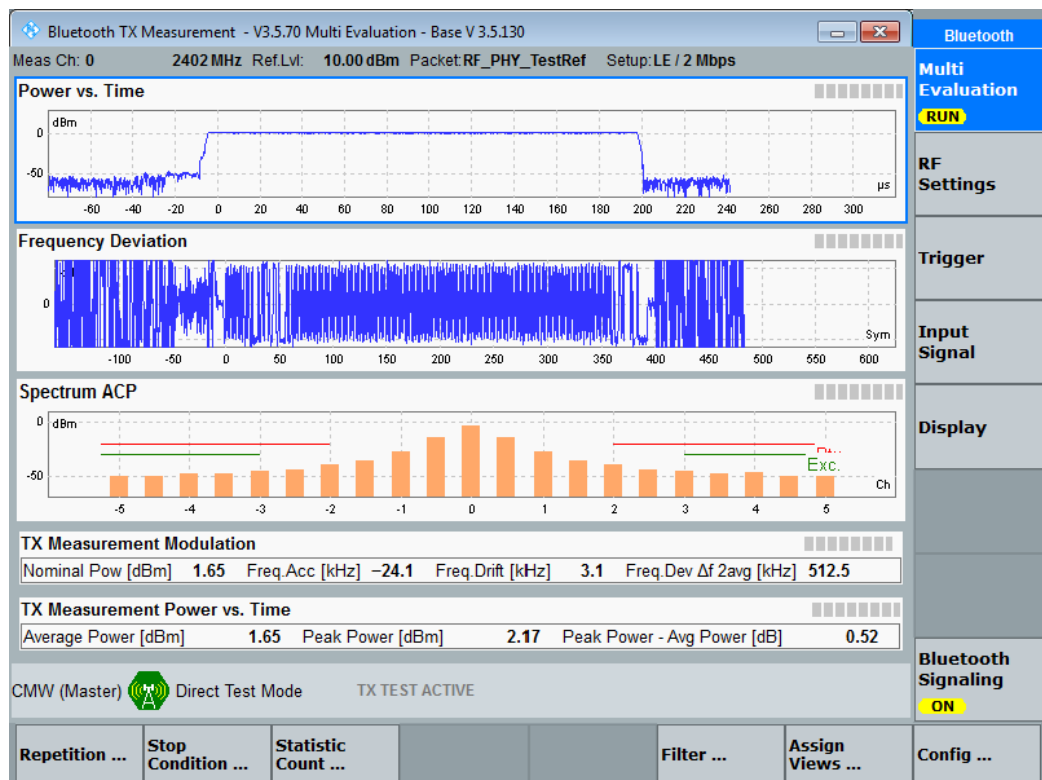
Fig. 5-7: The first LE TX measurement: overview of a TX measurement in the LE2M PHY at 2 Mbit/s

5.1.2 TX Tests

Multi Evaluation mode runs all of the transmitter tests. The parameters can be set in various places, e.g. in **Bluetooth Signaling** or directly in **Multi Evaluation**. Here, the parameters are always set in Multi Evaluation.

If the LE device supports the "Extended Packet Length" feature (from core specification 4.2), the maximum packet length supported by the DUT needs to be set under the **Payload Length**.

The parameters can be found under **Config** and the individual measurement views under **Display->Select View**.
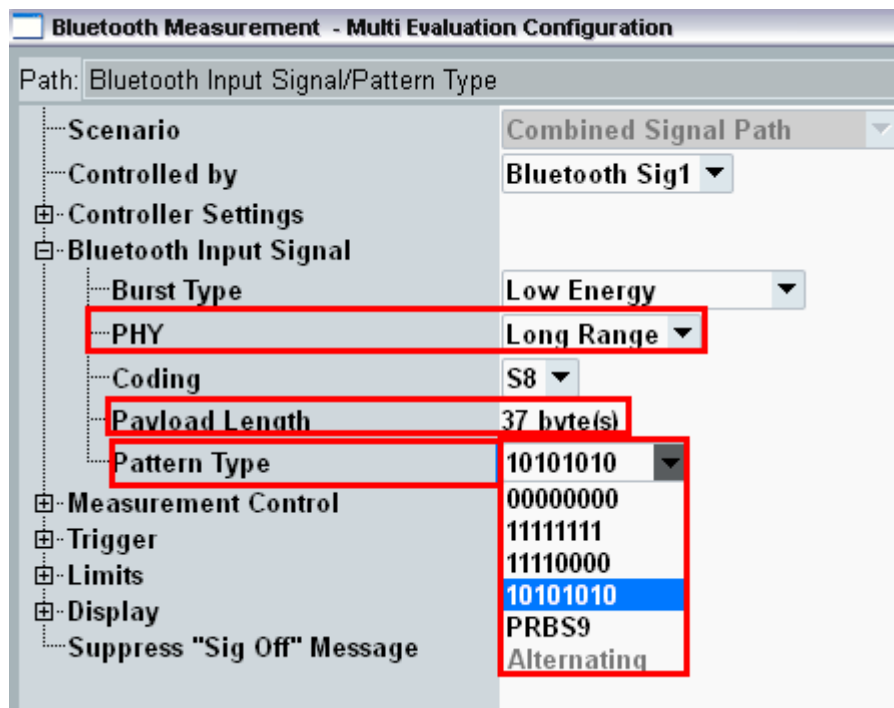
Fig. 5-8: Settings for the Multi Evaluation TX measurement, e.g. PHY, pattern type and payload length
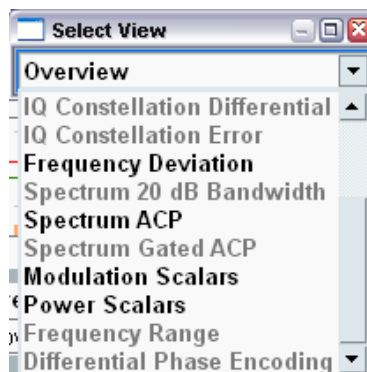
Fig. 5-9: Various Multi Evaluation mode views. The grayed out measurements are not relevant for LE.

5.1.2.1 Output Power

This measurement is specified only for LE1M (test: 01).

The output power is measured with **PRBS9** and the maximum packet length supported by the DUT. Set these two parameters under **Payload Length** and **Pattern Type**.

In **Multi Evaluation**, the **Power Scalars** view is recommended.
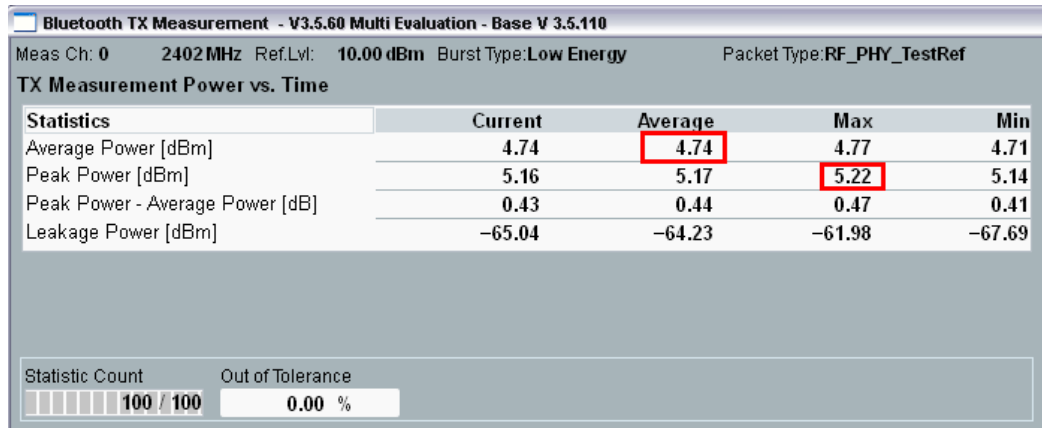
Fig. 5-10: CMW output power: P_{AVG} is the average of the average power and P_{PK} is the maximum peak power

The following conditions must be fulfilled:

∎ –20 dBm ≤ P_{AVG} ≤ +10 dBm (up to core 4.2 without addendum 5)

or

∎ –20 dBm ≤ P_{AVG} ≤ +20 dBm

and

∎ P_{PK} ≤ (P_{AVG} + 3 dB)

P_{AVG}: average power; P_{PK}: peak power

5.1.2.2 In-Band Emissions

This measurement is specified for LE1M and LE2M (tests: 03 and 08).

In-band emissions (also known as adjacent channel power (ACP)) are measured with **PRBS9** and the maximum packet length supported by the DUT. Set these two parameters under **Payload Length** and **Pattern Type**.

In **Multi Evaluation**, the **Spectrum ACP** view is recommended. Under **Measurement Mode**, select *LE All Channels*.
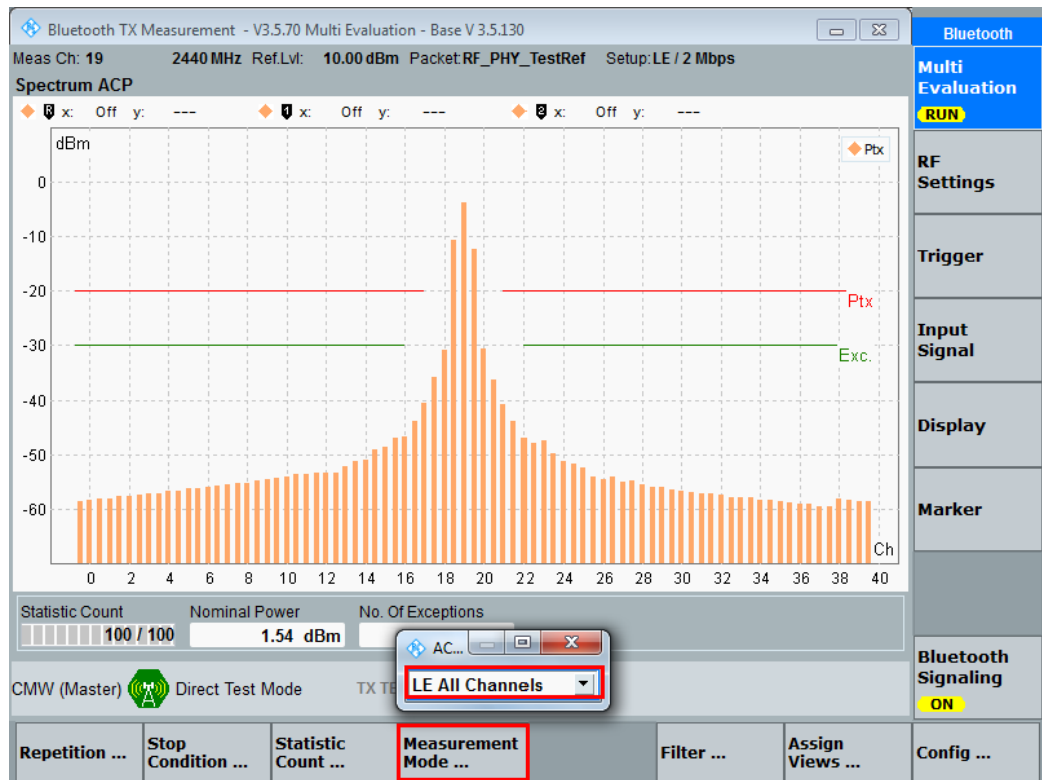
Fig. 5-11: CMW in-band emissions (spectrum ACP). The measurement is performed for 1 MHz channels in the 2401 MHz to 2481 MHz range. The labels on the x axis show the LE channel numbering

The following conditions must be fulfilled:

▪ All measured values in the region of the red line (≤ –20 dBm) must be under the line

▪ Up to three (3) measured values in the region of the green line may lie between the green and red lines

The CMW can display the measured values in graphs and tables. For the table view, see **Display -> Table View**.

5.1.2.3 Modulation Characteristics

This measurement is specified for the following PHYs:

Modulation characteristics and PHYs	
PHY	Test number
LE1M	05
LE2M	10
LE1M, SMI	09
LE2M, SMI	11
LE coded, S=8	13

Table 5-3: Various tests for modulation characteristics

For this test, two measurements must be recorded with two different patterns:

▪ $\Delta f1_{AVG}$ with pattern 11110000

▪ $\Delta f2_{AVG}$ with pattern 10101010 and $\Delta f2$ 99.9 %

Note: for other patterns different results are obtained as shown in Fig. 5-12 and Fig. 5-13 .

In **Multi Evaluation** the **Modulation Scalars** view is recommended.
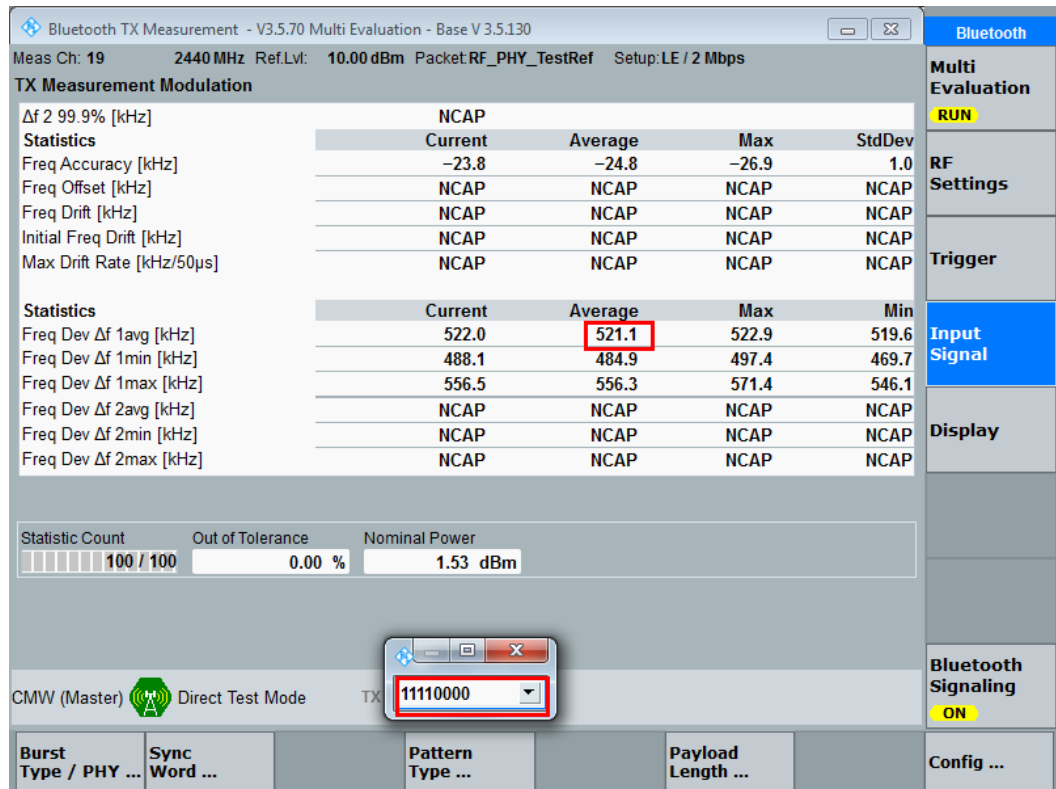
Fig. 5-12: $\Delta f1_{AVG}$ measurement with pattern 00001111 in the LE2M PHY at 2 Mbit/s
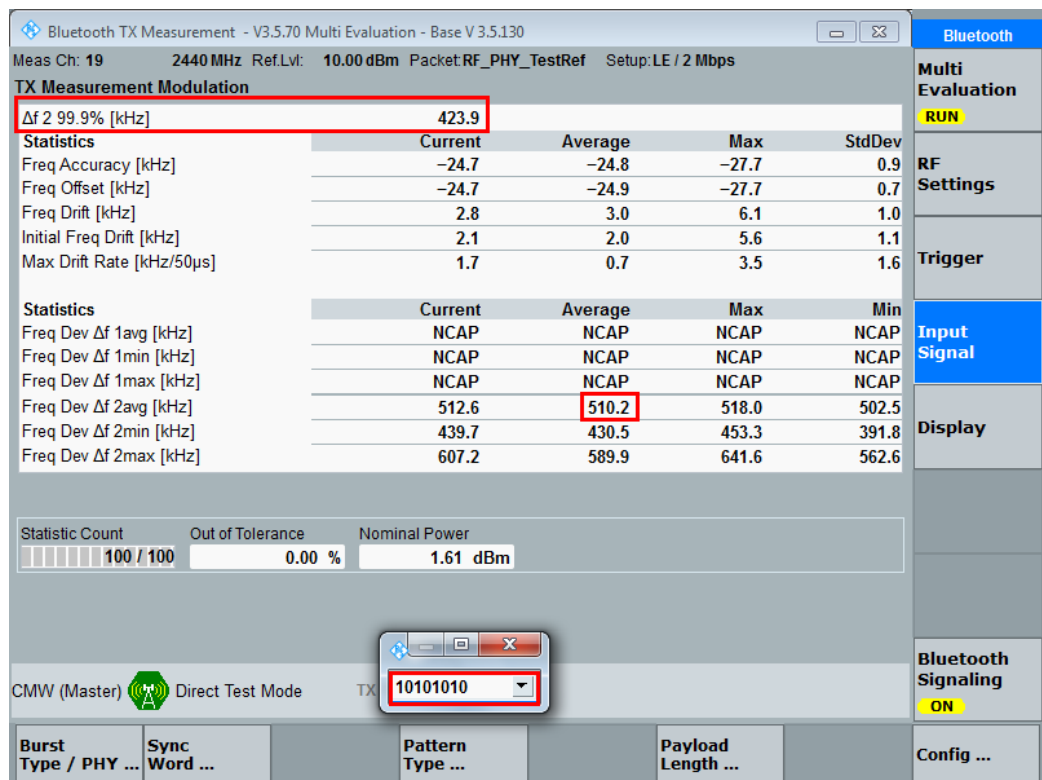
Fig. 5-13: Δf2~AVG~ measurement with pattern 01010101 and Δf2 99.9 % measurement in the LE2M PHY at 2 Mbit/s

The following conditions must be fulfilled:

Modulation characteristics					
Measured value	LE1M Test 05	LE2M Test 10	LE1M with SMI Test 09	LE2M with SMI Test 11	LE coded S=8 Test 13
Δf1$_{AVG}$	225 kHz ≤ x ≤ 275 kHz	450 kHz ≤ x ≤ 550 kHz	247.5 kHz ≤ x ≤ 252.5 kHz	495 kHz ≤ x ≤ 505 kHz	225 kHz ≤ x ≤ 275 kHz
Δf2 99.9 %	> 185 kHz	> 370 kHz	> 185 kHz	> 370 kHz	> 185 kHz
$\dfrac{\Delta f2AVG}{\Delta f1AVG}$	≥ 0.8	≥ 0.8	≥ 0.8	≥ 0.8	?

Table 5-4: Limits for modulation characteristics

5.1.2.4 Carrier Frequency Offset and Drift

This measurement is specified for the following PHYs:

Frequency offset and drift and PHYs	
PHY	**Test number**
LE1M	06
LE2M	12
LE coded, S=8	14

Table 5-5: Various tests for frequency offset and drift

The output power is measured with **10101010** and the maximum packet length supported by the DUT. Set these two parameters under **Payload Length** and **Pattern Type**.

In **Multi Evaluation** the **Modulation Scalars** view is recommended.
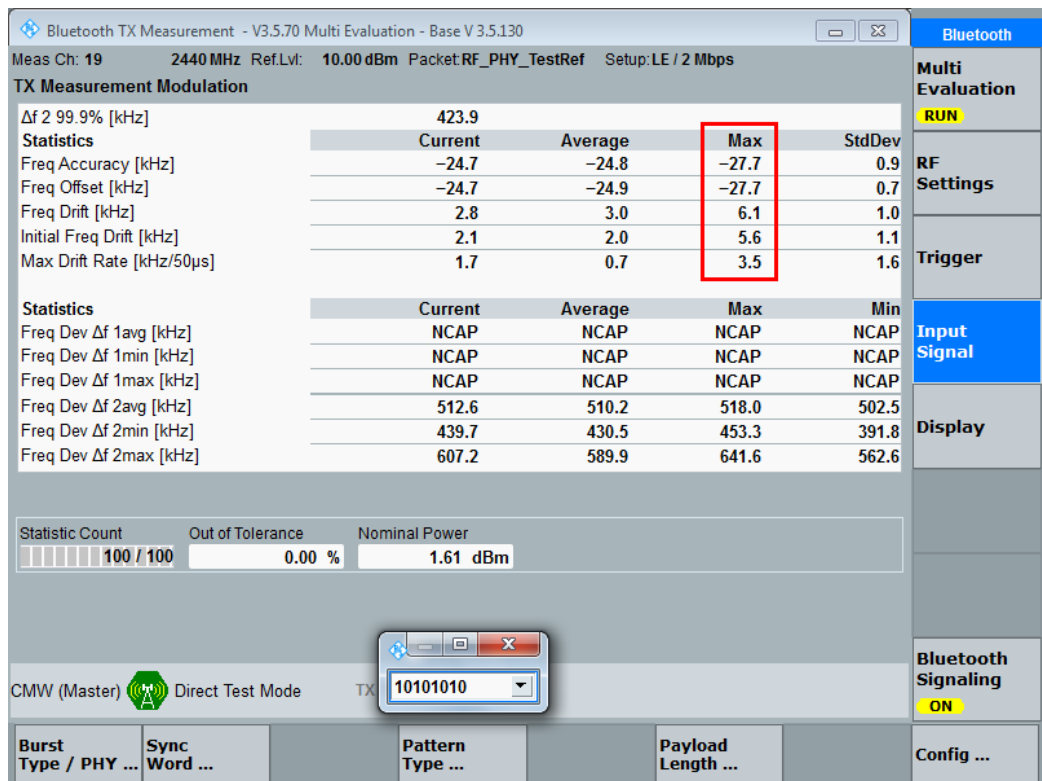
Fig. 5-14: Measured values for carrier frequency offset and drift. The measured values according to the specification are always the maximum values

The following conditions must be fulfilled:

Frequency offset and drift			
Measured value	LE1M Test 06	LE2M Test 12	LE coded with S=8 Test 14
Freq. offset	≤ 150 kHz	≤ 150 kHz	≤ 150 kHz
Freq. drift	≤ 50 kHz	≤ 50 kHz	≤ 50 kHz
Initial freq. drift	≤ 23 kHz	≤ 23 kHz	≤ 19.2 kHz
Max. drift rate	≤ 20 kHz	≤ 20 kHz	≤ 19.2 kHz

Table 5-6: Frequency offset and drift limits

5.1.3 RX Tests

Bluetooth RX Meas performs all RX tests in order to determine the packet error rate (PER). The PER is calculated in the DUT. The DUT reports the PER to the CMW via direct test mode. The parameters can be set in various places, e.g. in **Bluetooth Signaling** or directly in **RX Quality**. Here, the parameters are always set in Rx Quality.

All tests are performed with **Rx Quality**. Only individual parameters such as

▪ Level

▪ Number of packets (typically 1500)

▪ Payload (usually PRBS9)

and e.g. additional interferers are varied. These are explained under the individual tests.

Note

If the DUT supports the "Extended Packet Length" feature (from core specification 4.2), the maximum packet length supported by the DUT needs to be set under the **Payload Length**. This changes the limit for the PER (standard: 30.8 % for 37 bytes) as specified in Table 6.4 in the specification [3].
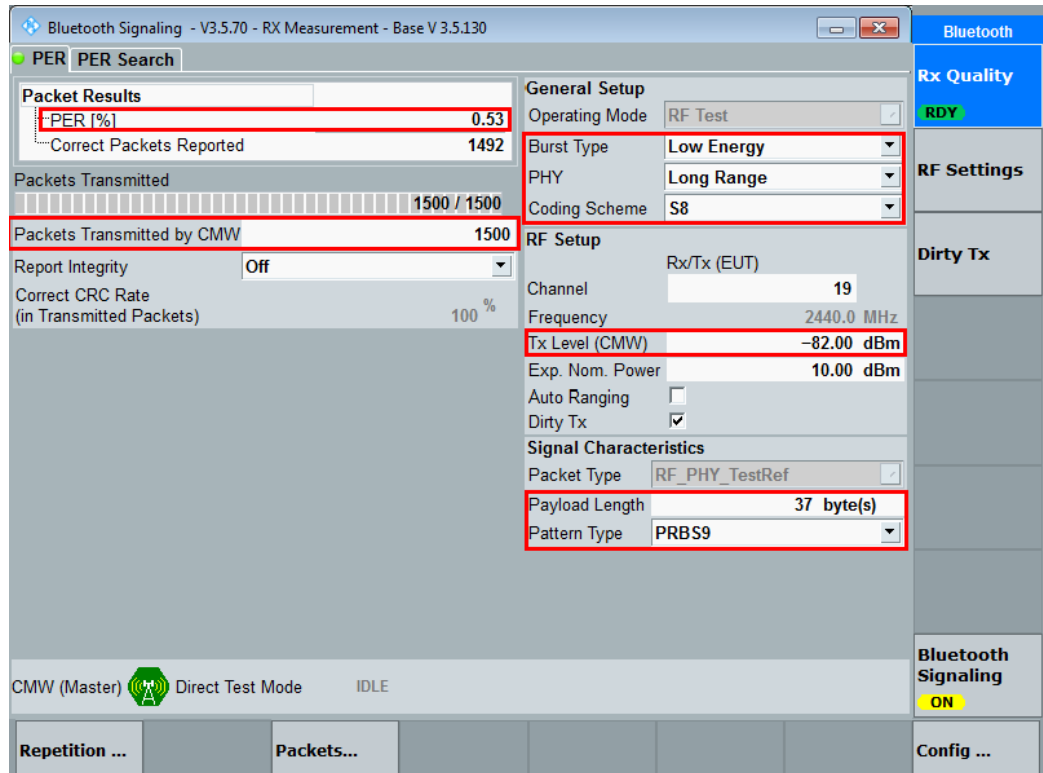
Fig. 5-15: CMW RX quality measurement

Note: the PER measurement is performed under the PER (marked with a green dot) tab.

5.1.3.1 Receiver Sensitivity

This test is specified for all PHYs:

Receiver sensitivity and PHYs		
PHY	**Test number**	**Reference level**
LE1M	01	–70 dBm
LE2M	08	
LE1M, SMI	14	
LE2M, SMI	20	
LE coded, S=2	26	–75 dBm
LE coded, S=8	27	–82 dBm
LE coded, S=2, SMI	32	–75 dBm
LE coded, S=8, SMI	33	–82 dBm

Table 5-7: Various tests for receiver sensitivity

First select the wanted PHY. For this test, set PRBS9, 1500 packets and a level as specified in Table 5-7. In addition, a non-optimal transmitter ("Dirty Tx") is simulated. At the top right, click **Dirty Tx** and make sure that **Dirty Tx Mode** is set to *Spec Table* (bottom). Set **Dirty Tx** to **On** (bottom) and restart the measurement (**Rx Quality**: Restart). All parameters are now set in compliance with the specification. If necessary, set the SMI under CONFIG|DIRTY TX:
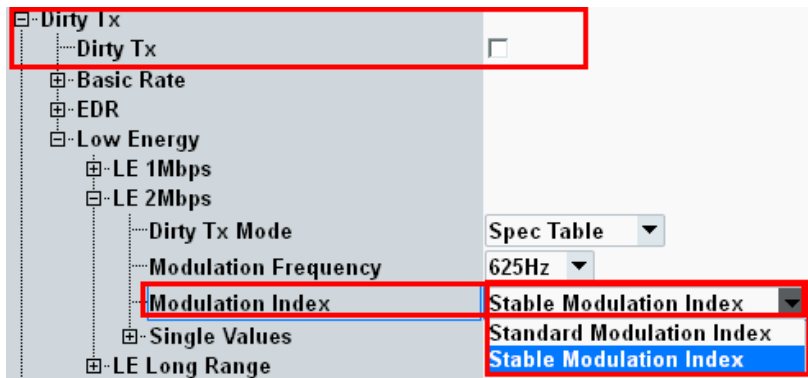
Fig. 5-16: SMI is located under Rx Qual CONFIG
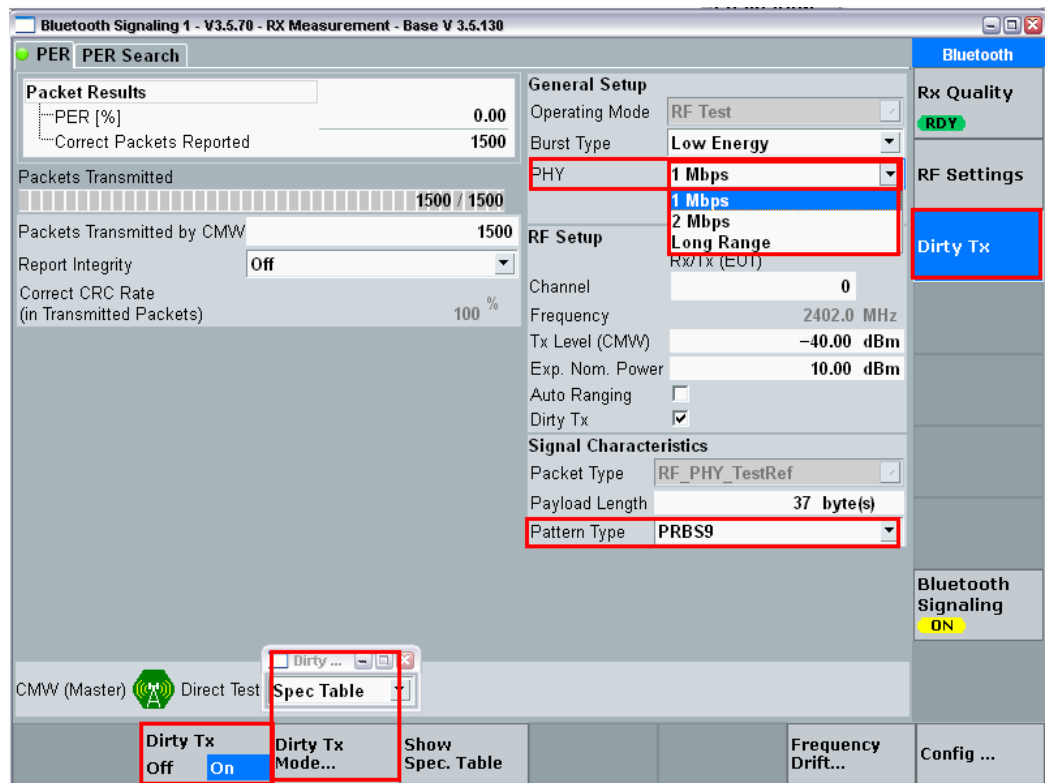
Fig. 5-17: CMW Dirty Tx

The following conditions must be fulfilled:

▪ PER < 30.8 %

5.1.3.2 C/I and Receiver Selectivity Performance

This test is specified for all PHYs:

C/I and receiver selectivity and PHYs	
PHY	**Test number**
LE1M	03
LE2M	09
LE1M, SMI	15
LE2M, SMI	21
LE coded, S=2	28
LE coded, S=8	29
LE coded, S=2, SMI	34
LE coded, S=8, SMI	35

Table 5-8: Various tests for C/I and receiver selectivity

This test tests the behavior of the receiver under the influence of a second Bluetooth signal. A Bluetooth interferer is set with certain levels and frequency spacing from the

wanted Bluetooth signal and the PER measurement is then performed in each case on the wanted signal.
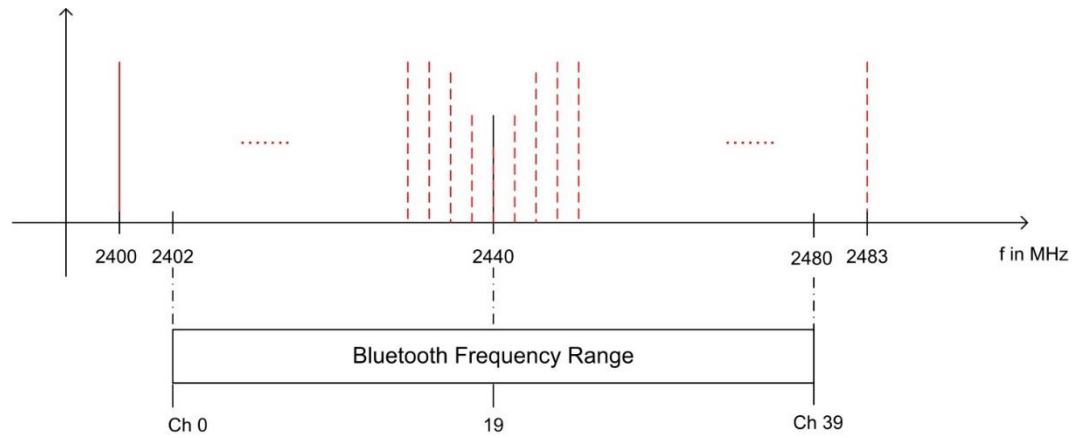
Fig. 5-18: C/I performance: The packet error rate is measured in the presence of a Bluetooth interferer inside the Bluetooth band. The measurement is repeated after shifting the interferer by 1 MHz

C/I LE level settings for tests 03, 09, 15, 21			
Interference signal frequency	**Interferer level (abs)**	**C/I level**	**Wanted signal (abs)**
Co-channel ($f_{RX} = f_{Interference}$)	–88 dBm	21 dB	–67 dBm
Adjacent channel ($f_{Interference} = f_{RX} \pm 1$ MHz)	–82 dBm	15 dB	–67 dBm
Adjacent channel ($f_{Interference} = f_{RX} \pm 2$ MHz)	–50 dBm	–17 dB	–67 dBm
Adjacent channel ($f_{Interference} = f_{RX} \pm (3 + n)$ MHz)	–40 dBm	–27 dB	–67 dBm
Image frequency ($f_{Interference} = f_{Image}$)	–58 dBm	–9 dB	–67 dBm
Adjacent channel to image frequency ($f_{Interference} = f_{Image} \pm 1$ MHz)	–52 dBm	–15 dB	–67 dBm

Table 5-9: C/I and receiver selectivity test parameter settings

C/I LE level settings for tests 28, 34			
Interference signal frequency	**Interferer level (abs)**	**C/I level**	**Wanted signal (abs)**
Co-channel ($f_{RX} = f\,I_{Interference}$)	–89 dBm	17 dB	–72 dBm
Adjacent channel ($f_{Interference} = f_{RX} \pm 1$ MHz)	–83 dBm	11 dB	–72 dBm
Adjacent channel ($f_{Interference} = f_{RX} \pm 2$ MHz)	–51 dBm	–21 dB	–72 dBm
Adjacent channel ($f_{Interference} = f_{RX} \pm (3 + n)$ MHz)	–41 dBm	–31 dB	–72 dBm
Image frequency ($f_{Interference} = f_{Image}$)	–59 dBm	–13 dB	–72 dBm
Adjacent channel to image frequency ($f_{Interference} = f_{Image} \pm 1$ MHz)	–53 dBm	–19 dB	–72 dBm

Table 5-10: C/I and receiver selectivity test parameter settings for LE coded with S=2

C/I LE level settings for tests 29, 35			
Interference signal frequency	**Interferer level (abs)**	**C/I level**	**Wanted signal (abs)**
Co-channel ($f_{RX} = f\,I_{Interference}$)	–91 dBm	12 dB	–79 dBm
Adjacent channel ($f_{Interference} = f_{RX} \pm 1$ MHz)	–85 dBm	6 dB	–79 dBm
Adjacent channel ($f_{Interference} = f_{RX} \pm 2$ MHz)	–53 dBm	–26 dB	–79 dBm
Adjacent channel ($f_{Interference} = f_{RX} \pm (3 + n)$ MHz)	–43 dBm	–36 dB	–79 dBm
Image frequency ($f_{Interference} = f_{Image}$)	–61 dBm	–18 dB	–79 dBm
Adjacent channel to image frequency ($f_{Interference} = f_{Image} \pm 1$ MHz)	–55 dBm	–24 dB	–79 dBm

Table 5-11: C/I and receiver selectivity test parameter settings for LE coded with S=8

Settings:

▪ Signal with PRBS9 and level depending on PHY: –67 dBm, –72 dBm or –79 dBm

▪ 1500 packets

Continuous interferer with GFSK with PRBS15 depending on PHY, level depending on frequency spacing (Table 5-9, Table 5-10 or Table 5-11). 2400 MHz start frequency, up to 2483 MHz in 1 MHz steps.

The Bluetooth interferer can be produced with an additional generator such as the SMBV or SMW. Here, we describe a solution with the general purpose RF generator (GPRF) in the CMW. Select ARB as the baseband mode in the GPRF and load the provided PHY-specific file.

▪ `BTLE1MSPS_Interferer_PRBS15.wv` for LE1M

▪ `BTLE2MSPS_Interferer_PRBS15.wv` for LE2M

▪ `BTLELR_INTEFERENCE_FEC2_PRBS15.wv` for LE coded with S=2

∎   `BTLELR_INTEFERENCE_FEC8_PRBS15.wv` for LE coded with S=8

This solution is also implemented in the automatic solution with CMWrun (see 5.2).
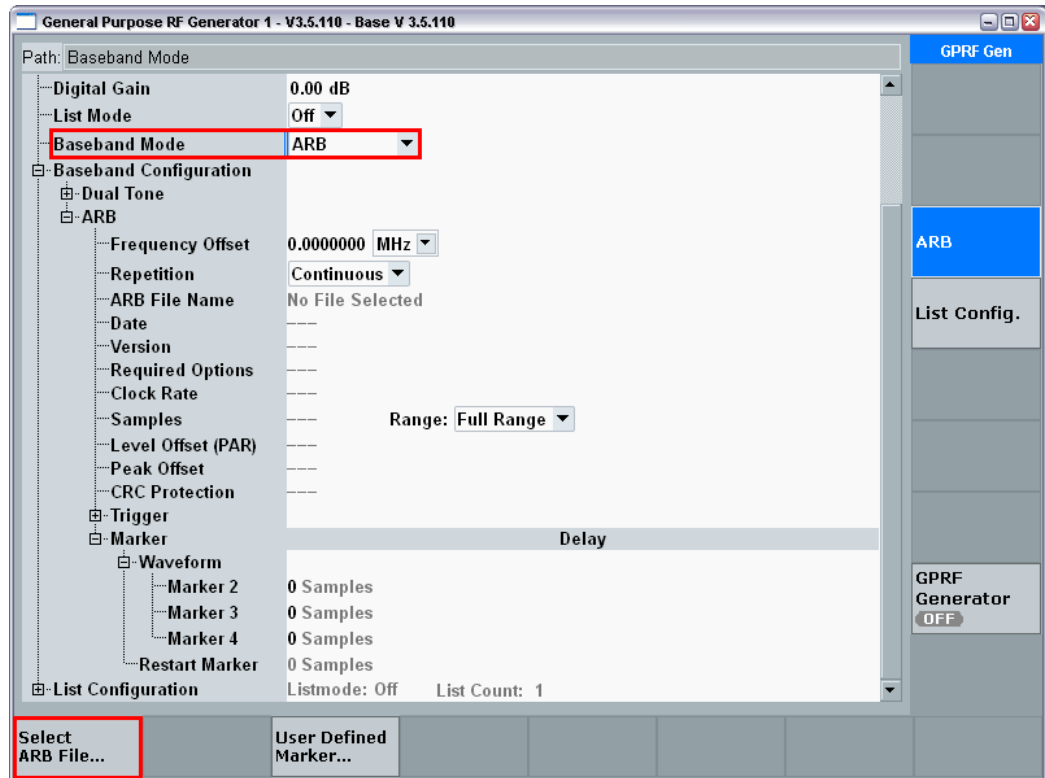
Fig. 5-19: CMW: ARB mode in the GPRF
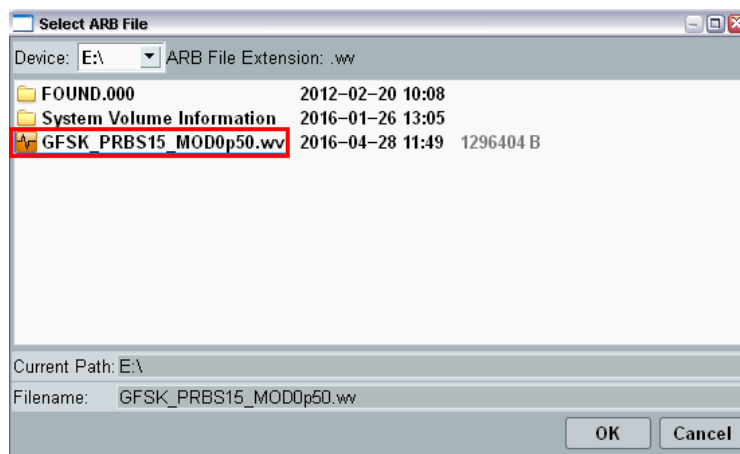
Fig. 5-20: CMW: selection of the ARB file (for LE1M in this example)

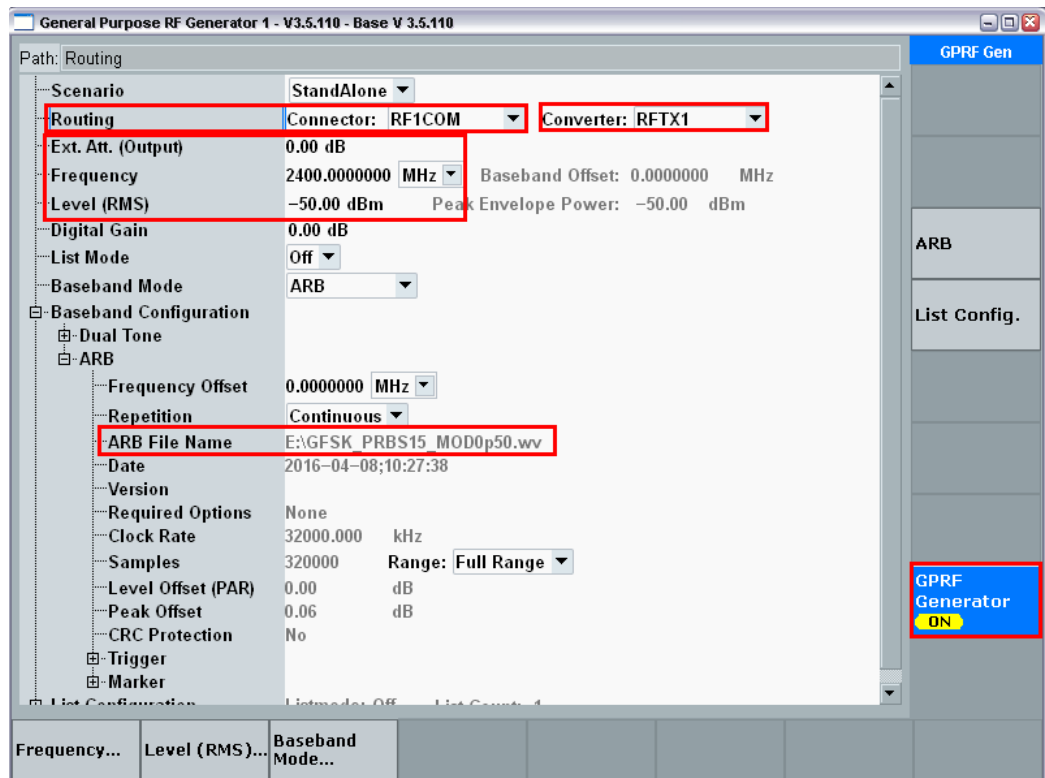Set the parameters such as the level and frequency and turn on the generator (ON).

Fig. 5-21: CMW: setting the level and frequency for the Bluetooth interferer

Now perform the **Rx Quality** measurement.

Results:

◻ For all measurements, the PER needs to be better than 30.8 % for a minimum of 1500 packets

◻ For each of the three wanted channels, the PER may exceed 30.8 % for five interferer frequencies. These five exceptions are allowed at certain spacing from the carrier:

C/I exception spacing	
Test	Spacing from the carrier
03, 15, 28, 29, 34 and 35	≥ ±2 MHz
09, 21	±4 MHz, ±6 MHz, ±8 MHz, ….

Table 5-12: C/I spacing from carrier

◻ For the interferer frequencies (max. five) at which the PER limit is exceeded, the PER is measured in a second test run with a relaxed C/I of −17 dB. The PER limit is again 30.8 %.

5.1.3.3 Blocking Performance

This test tests the behavior of the receiver under the influence of a non-Bluetooth signal. The interferer is an unmodulated signal (CW). An interferer is set with certain levels and frequency spacing from the wanted Bluetooth signal and the PER measurement is then performed in each case on the wanted signal.

This test is specified for the following PHYs:

Blocking and PHYs	
PHY	**Test number**
LE1M	04
LE2M	10
LE1M, SMI	16
LE2M, SMI	22

Table 5-13: Various blocking tests
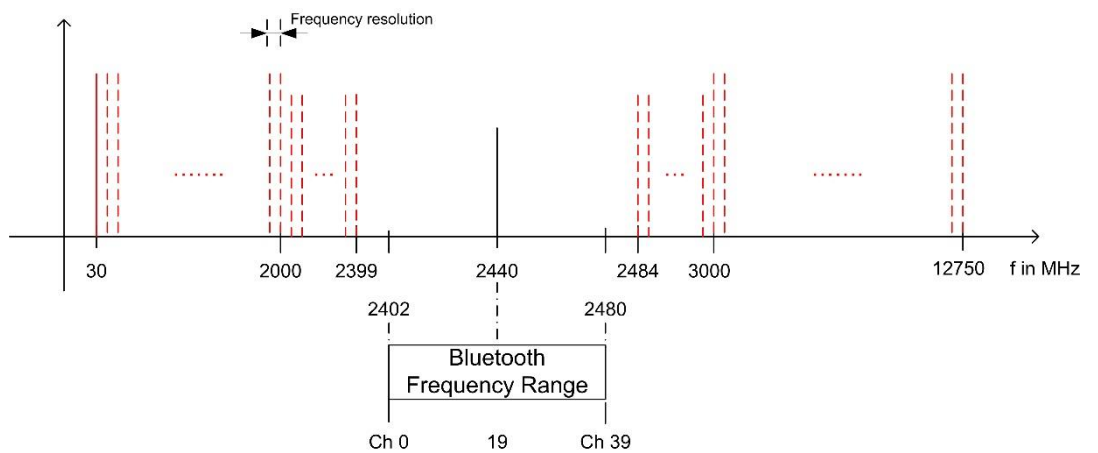
Fig. 5-22: Blocking performance: For one channel, the packet error rate is measured in the presence of a CW interferer outside the Bluetooth band. The measurement is repeated after shifting the interferer by the frequency resolution

Blocking level settings			
Interference signal frequency	Wanted signal level	Blocking signal level	Frequency resolution
30 MHz to 2000 MHz	–67 dBm	–30 dBm	10 MHz
2003 MHz to 2399 MHz	–67 dBm	–35 dBm	3 MHz
2484 MHz to 2997 MHz	–67 dBm	–35 dBm	3 MHz
3000 MHz to 12.75 GHz	–67 dBm	–30 dBm	25 MHz

Table 5-14: Blocking performance parameters, first test run

This test requires the extended test setup as shown in Fig. 5-2 .

Settings:

▪ Signal with PRBS9 and –67 dBm

▪ 1500 packets

- Interferer unmodulated, level depends on frequency spacing (Table 5-9). 30 MHz start frequency, up to 12.75 GHz in steps as specified in Table 5-14 . The Bluetooth range (2400 MHz to 2483 MHz) is skipped

The CW interferer can be produced with an additional generator such as the SGS, SMC or SMF. Here, we describe a solution with the SGS. You can operate the SGS using the free SGMA GUI software.
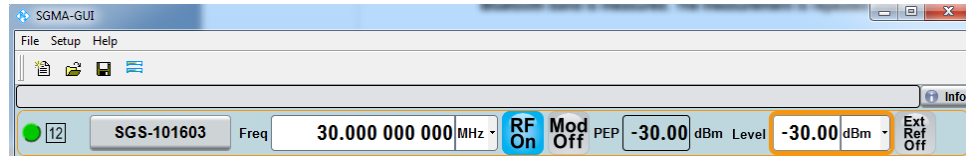
Fig. 5-23: Operating the SGS with the SGMA GUI software

Perform the **Rx Quality** measurement.

Results:

- 1st test run: At each interferer frequency, 1500 packets are measured. The frequencies at which a PER > 30.8 % is obtained are recorded. The number of frequencies recorded here must not exceed ten.

- 2nd test run: At each frequency recorded during the 1st test run, 1500 packets are measured at reduced interferer levels of –50 dBm. The frequencies at which a PER > 30.8 % is obtained are again recorded. The PER limit may be exceeded for a maximum of three frequencies.

5.1.3.4 Intermodulation Performance

This test is specified for the following PHYs:

Intermodulation and PHYs	
PHY	**Test number**
LE1M	05
LE2M	11
LE1M, SMI	17
LE2M, SMI	23

Table 5-15: Various tests for intermodulation

This test tests the behavior of the receiver under the influence of two signals. The first interferer is an unmodulated signal (CW). The second interferer is a continuously modulated Bluetooth signal. The interferers are set with certain levels and frequency spacing from the wanted Bluetooth signal and the PER measurement is then performed in each case on the wanted signal.
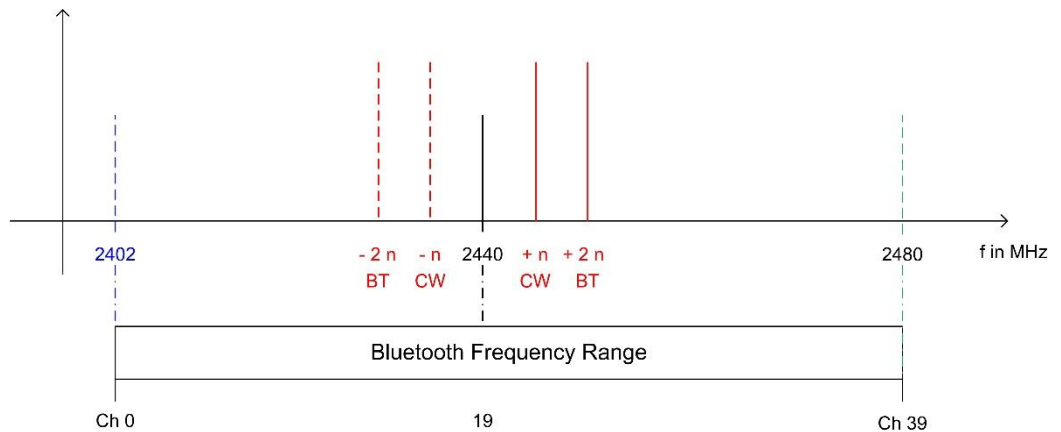
Fig. 5-24: Intermodulation performance: for each of three channels, the packet error rate is measured in the presence of a CW interferer at a distance n and a Bluetooth interferer at a distance 2n

This test requires the extended test setup as shown in Fig. **5-2** .

Settings:

▪ Signal with PRBS9 and –64 dBm

▪ 1500 packets

▪ n = 3, 4 or 5 (specified by manufacturer)

▪ Bluetooth interferer: low energy GFSK with PRBS15 spaced ±2n MHz from wanted signal, level –50 dBm

▪ CW interferer: spaced ±n MHz from wanted signal, level –50 dBm

The CW interferer can be produced with an additional generator such as the SMB, SGS100A, SMC100A or SMF100A. Here, we describe a solution with the SGS. You can use the free SGMA GUI software to operate the SGS. See 5.1.3.3.

The Bluetooth interferer can be produced with an additional generator such as the SMBV or SMW. Here, we describe a solution with the general purpose RF generator (GPRF) in the CMW. Select ARB as the baseband mode in the GPRF and load the provided file.

▪ `GFSK_PRBS15_MOD0p50.wv` for LE1M

▪ `LE2M_INTERFERER_PRBS15.wv` for LE2M

This solution is also implemented in the automatic solution with CMWrun (see 5.2). For details, see 5.1.3.2.

Perform the **Rx Quality** measurement.

Result:

▪ A PER of 30.8 % must be obtained for each of the three channels

5.1.3.5 Maximum Input Signal Level

This test is specified for the following PHYs:

Maximum input signal level and PHYs	
PHY	Test number
LE1M	06
LE2M	12
LE1M, SMI	18
LE2M, SMI	24

Table 5-16: Various tests for maximum input signal level

For this test, set **PRBS9**, 1500 packets and a level of –10 dBm. Perform the **Rx Quality** measurement.

The following conditions must be fulfilled:

▪ PER < 30.8 %

5.1.3.6 PER Report Integrity

This test is specified for all PHYs:

PER report integrity and PHYs	
PHY	Test number
LE1M	07
LE2M	13
LE1M, SMI	19
LE2M, SMI	25
LE coded, S=2	30
LE coded, S=8	31
LE coded, S=2, SMI	36
LE coded, S=8, SMI	37

Table 5-17: Various tests for PER report integrity

In this test, the CMW transmits an incorrect CRC in every second packet. Switch **Report Integrity** to *ON* and set the level to **–30 dBm**. Perform the **Rx Quality** measurement.
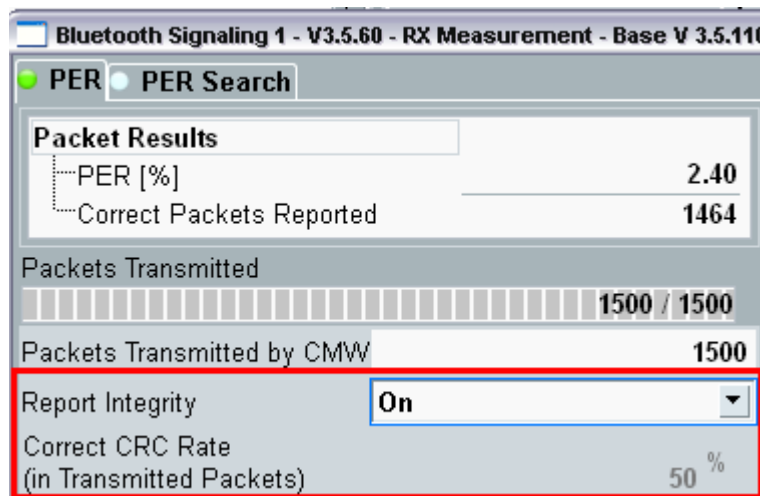
Fig. 5-25: The CMW transmits an incorrect CRC in every second packet

The test needs to be repeated three times with a different random number of packets in the range from 100 to 1500 packets.

The following conditions must be fulfilled:

◾ PER ≥ 50 %

5.2 CMWrun

The CMWrun sequencer software tool is a ready-to-use solution for configuring test sequences by remote control. It can be enhanced with options and used for all standards supported by the CMW family – for general RF testing, preconformance and superior user experience test scenarios.

The software engine is based on the execution of test DLLs (plug-in assemblies). This architecture not only allows easy and straightforward configuration of test sequences without knowledge of specific remote programming of the instrument, it also provides full flexibility in configuring parameters and limits of the test items provided in the CMWrun package options for the different standards. At the end of the test, an easy-to-read test report with limits, test results and verdict is generated and made available in several formats, including csv, txt, xml and pdf.

The CMW KT-057 option (wireless connectivity standards: WiMAX, WLAN, Bluetooth) provides all of the tests, e.g. as preconformance tests as specified in Table 4-1 and Table 4-2 as prepackaged modules. The option therefore also covers all of the tests described in 5.1. The following test plans are supplied:

◾ **BLE_PHY_5_0_0**

- All tests that can be performed with the CMW alone (Not included are the 3 tests: C / I and Receiver sensitivity, Blocking performance tests and Intermodulation performance tests, which can be found in the Advanced Test Plans (see below)).

◾ **BLE_PHY_5_0_0_Advanced_FE-Advanced**

- Additional tests with signal generator, advanced frontend

▪ **BLE_PHY_5_0_0_Advanced_2_FE-Basic**

- Additional tests with signal generator, two basic frontends

Fig. 5-26: Overview of the predefined Bluetooth Low Energy test plans

Double-click a plan to open it:

Fig. 5-27: CMWrun: example of a test plan (predefined plan BLE_PHY_4_2_3)

Double-click the step *BTLE_RF_PHY_TS_5_0_0* to see the supported test cases:
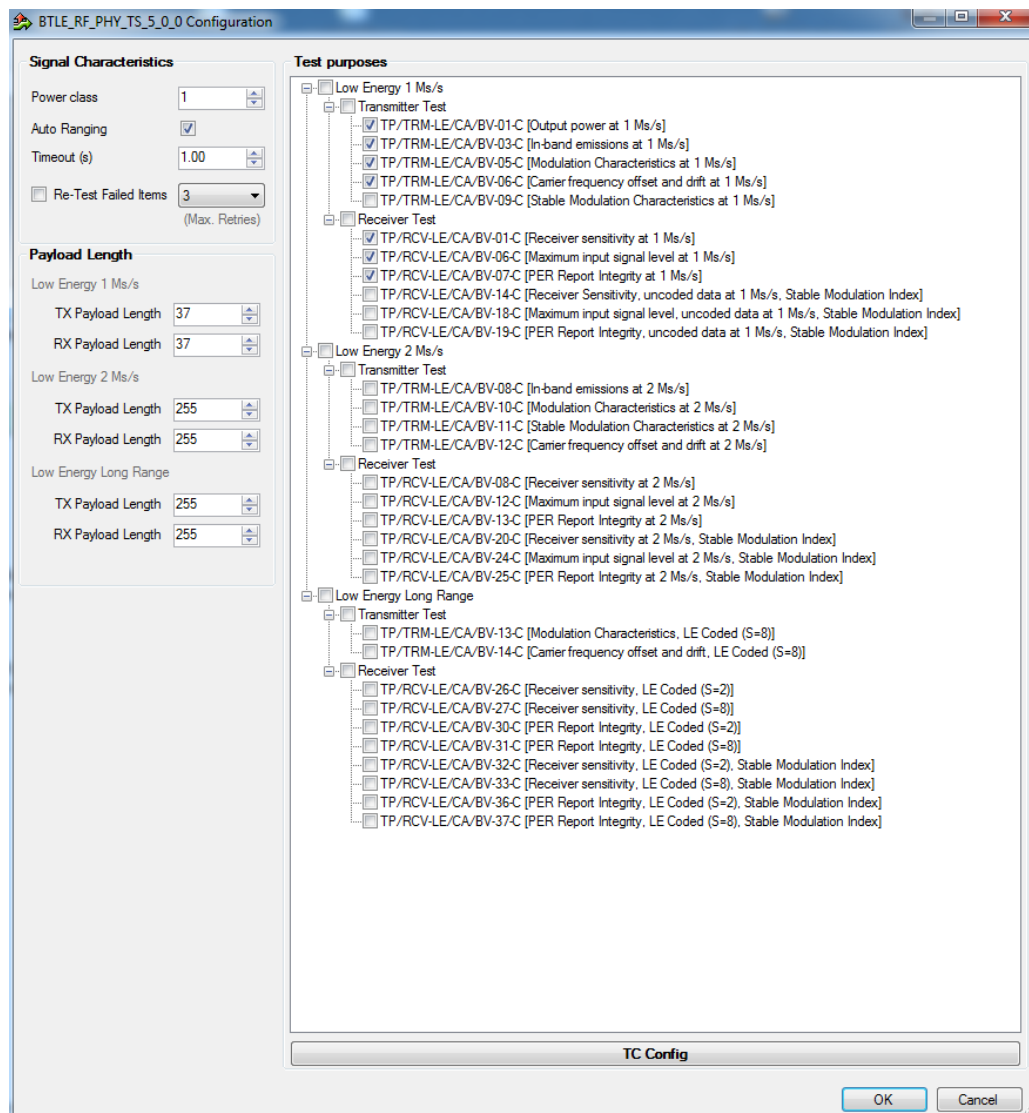
Fig. 5-28: CMWrun: standard test cases

Click **TC Config** to set additional details:
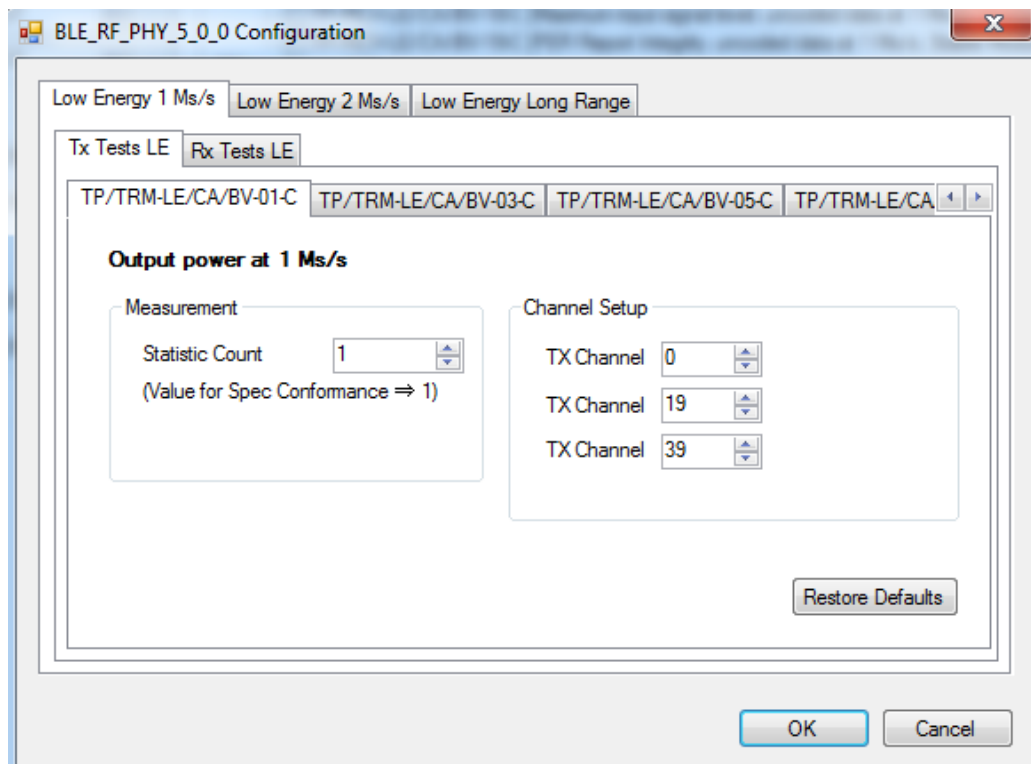
Fig. 5-29: CMWrun: configuration of standard test cases
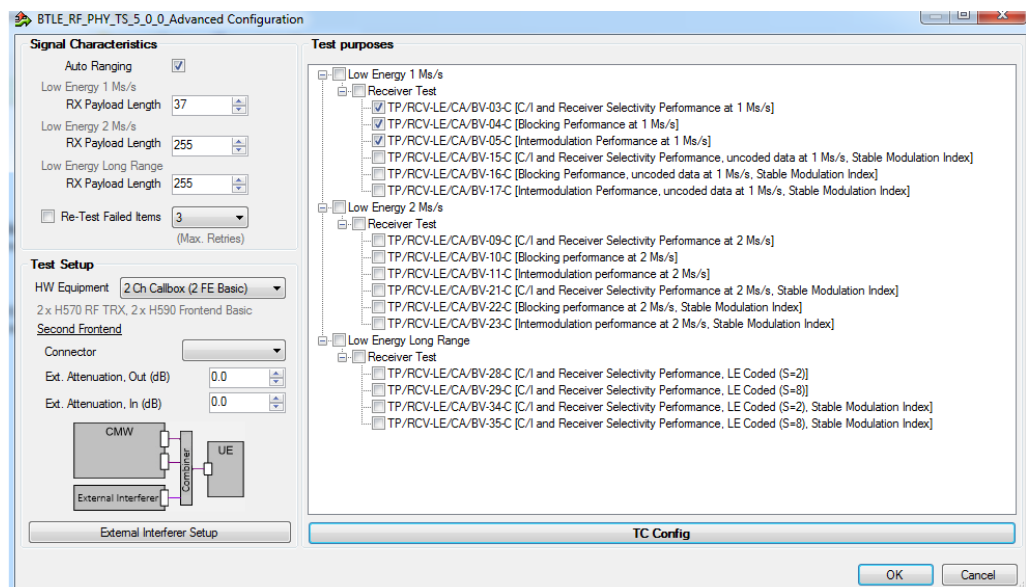
Fig. 5-30: CMWrun: advanced test cases

6 Measurements with Spectrum Analyzer and Signal Generator

Some of the measurements described in 5 can also be performed using a spectrum analyzer and a signal generator. Since these instruments do not allow the DUT to be controlled using the Direct Test mode, the settings specified in the test specification are configured on the DUT using a PC on which the DUT manufacturer's software has been installed (Figure 6-1).

6.1 Measurements on Bluetooth LE Transmitter

Test setup:
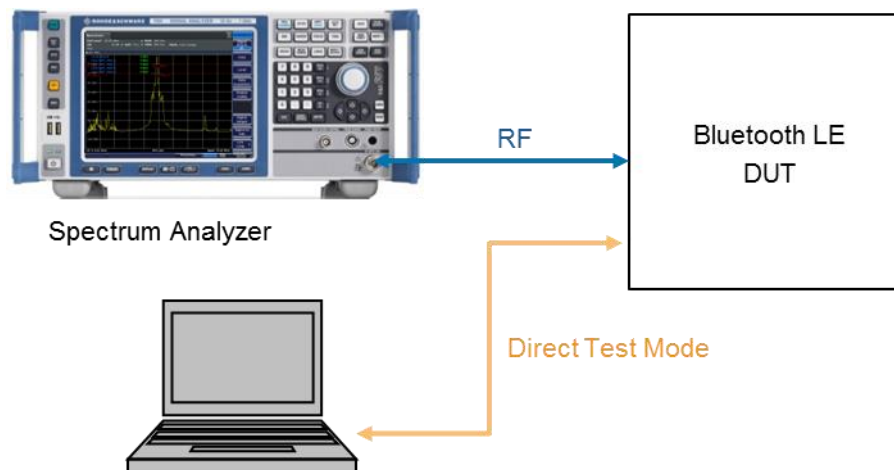
Figure 6-1: Test setup with spectrum analyzer and PC for signaling

6.1.1 Output Power

This measurement is specified only for LE 1M (test: 01).

Measurement of the output power must be performed as specified in the specification: with payload pattern PRBS9, the maximum possible packet length supported by the DUT, maximum power without whitening and without frequency hopping. Use the manufacturer software to configure the DUT as specified. The output power must be measured at three different transmit frequencies. Tables 6.1 and 6.2 in the Bluetooth test specification specify the transmit frequencies to be set on the DUT.

For peripheral and central devices for LE 1M, for example, Table 6.1 specifies the following three transmit frequencies: f_{tx} = 2402 MHz (low), f_{tx} = 2440 MHz (middle) and f_{tx} = 2480 MHz (highest). Table 6.2 is for broadcast and observer devices.

Settings on FSV spectrum analyzer:

1. Press the *PRESET* key.

2. Press the *FREQ* key and enter the transmitter frequency value as the center frequency.

3. Set the resolution bandwidth: press the *BW* key and enter *3 MHz*.

4. Set the video bandwidth: select the *Video BW manual* menu key and enter *3 MHz*.

5. Press the *TRACE* key and select *Trace 1*. Press the *Detector* menu key and select *Positive Peak*.

6. In accordance with the test specification, the output power is measured in the time domain: press the *SPAN* key and enter *0 Hz* or select the *Zero Span* menu key.

7. Press the *TRIG* key and select *Trg/Gate Source*. Press the *IF Power* menu key and enter a suitable value for the trigger level so that a stationary trace is displayed on the screen.

8. Press the *AMP* key and enter a reference level suitable for the maximum displayed signal level.

9. Press the *SWEEP* key and, under *Sweeptime Manual*, set the sweep time so that a complete packet or a burst is displayed.

10. Press the *TRIG* key and use Trigger Offset to move the burst to the center of the screen (Figure 6-2).

11. Press the *PEAK SEARCH* key and record the maximum value of the transmit power level L_{Pk} (Figure 6-2).
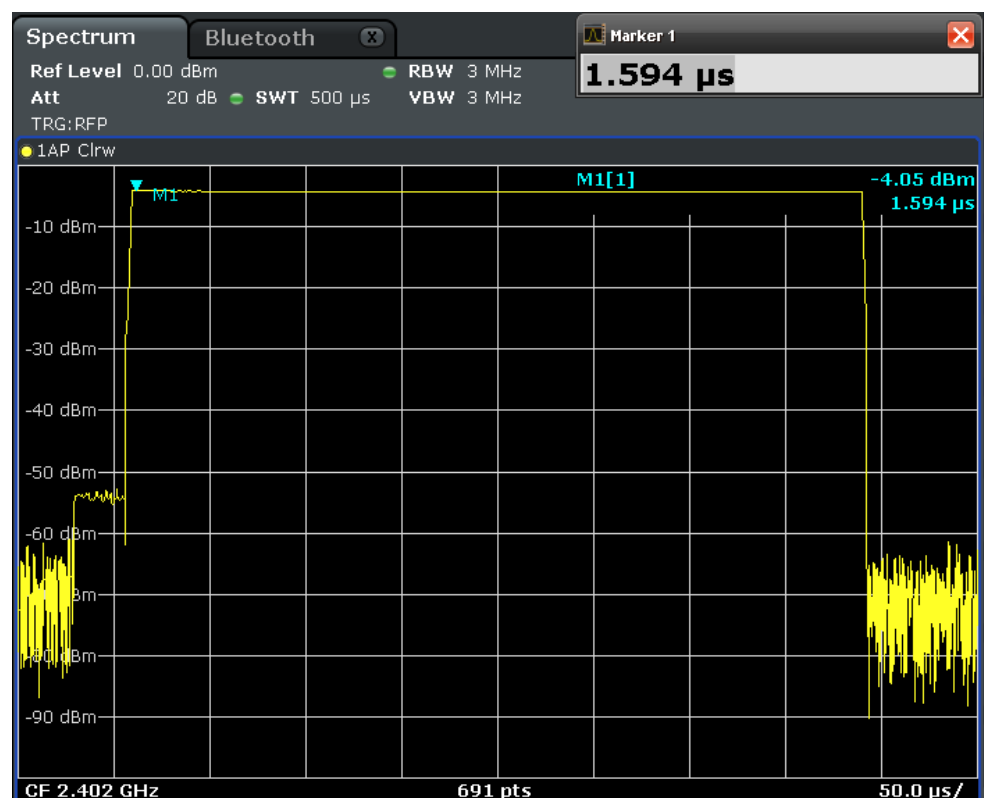
Figure 6-2: Measurement of maximum burst power

12. Press the *AMPT* key and use the *Unit* menu key to select *Watt*.

In the range of at least 20 % to 80 % of the burst duration, use the marker to read out as many values as possible and use these values to calculate the average power P_{avg}. (Note: Vertical time lines can be used to mark the measurement range. Press the *LINES* key, select the *Display Line* menu key and position the two time lines at a distance of max. 20 % of the burst length away from the two burst edges. Use the marker between the two lines to record the measurement data.)
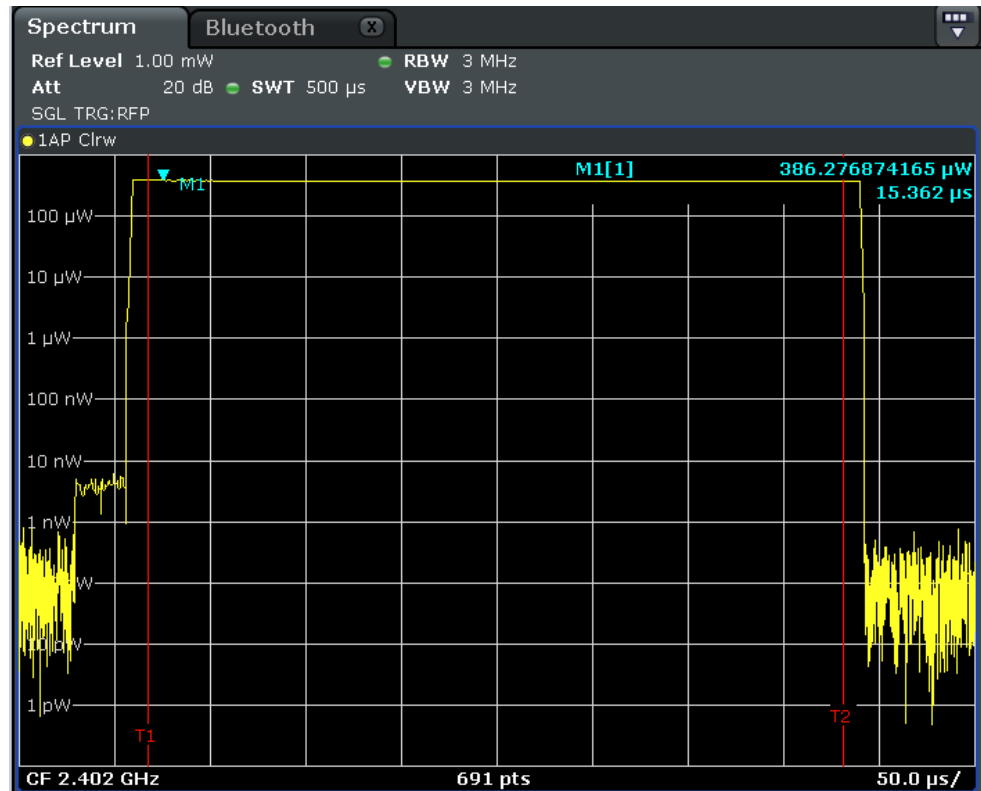
Figure 6-3: Measurement of output power

Calculate the power level with $L_{AVG} = 10 \ dBm \ lg(\frac{P_{AVG}}{1 \ mW})$.

The following conditions must be fulfilled:

▪ –20 dBm ≤ L_{AVG} ≤ +10 dBm (up to Core 4.2 without addendum 5)

or

▪ –20 dBm ≤ L_{AVG} ≤ +20 dBm

and

▪ L_{PK} ≤ (L_{AVG} + 3 dB)

Repeat the measurement for the transmit frequencies f_{TX} (middle) and f_{TX} (highest) specified in the test specification.

6.1.1.1 Output power test with an R&S Forum script

To automatically execute the measurements described under 6.1.1, a R&S Forum script (1MA282_Output_PowerVx.x.py) is included with this application note. This script considerably reduces the amount of work.

Proceed as follows:

1. Open the link 1MA196: Using R&S Forum Application for Instrument Remote Control and download the R&S Forum setup file.

2. Double-click the .exe file and follow the installation routine.

3. Under *Settings -> Instruments…-> Add..*, configure the remote control connection to the spectrum analyzer. For more information, see Application Note 1MA196. Example:
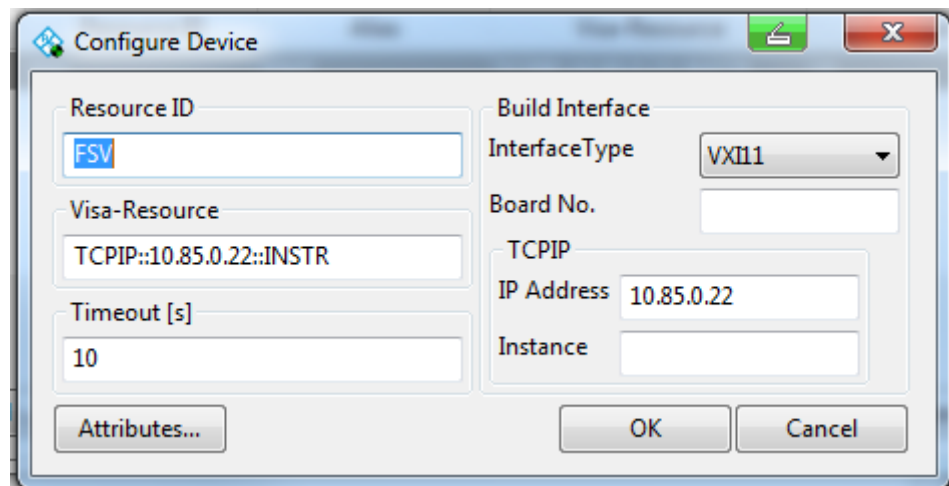
Figure 6-4: Configuration of remote control connection

9. Download the script file (1MA282_Output_PowerVx.x.py) to a directory previously created on the PC.

10. Start R&S Forum and load the script with *File -> Open….*

11. Set the value of the variable "devc" based on the DUT type (devc = 0 for peripheral and central devices, decv = 1 for broadcaster and observer devices) (Figure 6-9).

12. Use the "att" (Attenuation) and "rlev" (Reference Level) parameters to adjust the FSV reference level to the test signal. The trigger level is set with "tlvl". The parameter "coun" defines the number of measured values from which the average power value is calculated (Figure 6-9).

Figure 6-5: Configuration of measurement parameters

13. Use the green arrow key to start the script. On the DUT set the frequencies shown on the screen and follow the displayed hints:
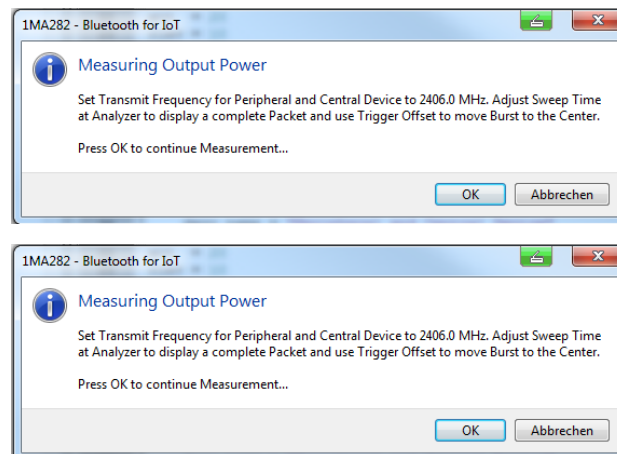
Note: in order to be able to perform the settings on the device, it is necessary to switch the analyzer into the manual operating mode with the menu key *Local*.

After the measurements for three different frequencies have been finished, the result will be displayed (Figure 6-6).

```
┌─ 1MA282_Bluetooth_for_IoT_Output_Power_V1.1[1].ptc ──────────────────── ▼ ┐
│ --------------------------------------------------------------------------- │
│ Evaluation for Peripheral and Central Device.                               │
│ Measured Results.                                                           │
│ --------------------------------------------------------------------------- │
│ Transmit Frequency @ 2406.0 MHz.                                            │
│                                 Min.Limit:  Max.Limit:   Margin:    Check:   │
│                                                                             │
│  Average Power [P_AVG]:   -0.73 dBm   -20.00 dBm   20.00 dBm   19.27 dB  PASSED │
│  Peak Power Value [P_PK]: -0.68 dBm   ------ dBm    2.27 dBm   -2.95 dB  PASSED │
│                                                                             │
│                                                Test Result:         PASS    │
│                                                                             │
│ --------------------------------------------------------------------------- │
│ Transmit Frequency @ 2440.0 MHz.                                            │
│                                 Min.Limit:  Max.Limit:   Margin:    Check:   │
│                                                                             │
│  Average Power [P_AVG]:   -1.01 dBm   -20.00 dBm   20.00 dBm   18.99 dB  PASSED │
│  Peak Power Value [P_PK]: -0.96 dBm   ------ dBm    1.99 dBm   -2.95 dB  PASSED │
│                                                                             │
│                                                Test Result:         PASS    │
│                                                                             │
│ --------------------------------------------------------------------------- │
│ Transmit Frequency @ 2476.0 MHz.                                            │
│                                 Min.Limit:  Max.Limit:   Margin:    Check:   │
│                                                                             │
│  Average Power [P_AVG]:   -1.03 dBm   -20.00 dBm   20.00 dBm   18.97 dB  PASSED │
│  Peak Power Value [P_PK]: -0.99 dBm   ------ dBm    1.97 dBm   -2.96 dB  PASSED │
│                                                                             │
│                                                Test Result:         PASS    │
│                                                                             │
│ --------------------------------------------------------------------------- │
│ Additional Information:                                                      │
│                                                                             │
│  Maximum Limit for Average Power is set to 10 dBm if IUT is compliant to Core │
│  Specification V4.2 or earlier and not compliant to Core Specification Addendum 5. │
│                                                                             │
│ --------------------------------------------------------------------------- │
└─────────────────────────────────────────────────────────────────────────── ┘
```

Figure 6-6: Result of the output power measurement

6.1.2 In-band emissions

This measurement is specified for LE 1M and LE 2M (tests: 03 and 08). In-band emission measurement (also known as adjacent channel power (ACP)) is performed under normal operating conditions.

6.1.2.1 In-band emission test 03 (LE 1M, uncoded data at 1 Ms/s)

This test measures whether the spectral in-band RF leakage exceeds the limits defined in the test specification when the transmitter emits uncoded data at a symbol rate of 1 Ms/s.

Settings on BLE DUT:

1. Switch on Direct Test mode.

2. Set the output power to maximum power.

3. Switch off frequency hopping.

4. Switching off whitening.

5. Symbol rate = 1 Ms/s

6. Set the payload PRBS9 and the maximum packet length supported by the DUT.

14. Tables 6.1 and 6.2 in the Bluetooth test specification specify the transmit frequencies to be set on the DUT. For peripheral and central devices for LE 1M (test number 03), for example, Table 6.1 specifies the following three transmit frequencies: f_{TX} = 2406 MHz (low), f_{TX} = 2440 MHz (middle) and f_{TX} = 2476 MHz (highest). Table 6.2 is used for broadcast and observer devices.

Settings on FSV spectrum analyzer:

1. Press the *PRESET* key.

2. Press the *FREQ* key and enter a center frequency of f_c = *2401 MHz + N MHz*. N = 0 for the first measurement run.

3. Press the *SPAN* key and enter *1 MHz*.

4. Press the *BW* key, select the *RES BW* menu key and set the resolution bandwidth to *100 kHz*.

5. Select the *Video BW Manual* menu key and set the video bandwidth to 300 kHz.

6. Press the *TRACE* key and select *Trace 1*. Press the *Max Hold* menu key.

7. Press the *Detector* menu key and select *Average*.

8. Press the *SWEEP* key and use the *Sweeptime Manual* menu key to enter a sweep time of *100 ms.*

9. Press the *AMP* key and enter a reference level suitable for the maximum displayed signal level.

10. Press the *SWEEP* key, press the *Sweep Count* menu key and enter *10.*

11. Press the *AMPT* key and use the *Unit* menu key to select *Watt*

12. Press the *MKR* key and set *Marker 1* at a distance of –450 kHz from the center frequency (f_{MK1} = 2401 MHz + N MHz – 0.450 MHz = 2400.55 MHz).

13. Select the *Marker 2* menu key, enter *100 kHz* and use the *Marker Norm Delta* menu key to set the marker to *Norm*.

14. Activate eight further markers with the following values: f_{MK3} = 200 kHz, f_{MK4} = 300 kHz, f_{MK5} = 400 kHz, f_{MK6} = 500 kHz, f_{MK7} = 600 kHz, f_{MK8} = 700 kHz, f_{MK9} = 800 kHz, f_{MK10} = 900 kHz. After entering each frequency, set the marker type to *Norm*.

15. Press the *RUN SINGLE* key. In line with the test specification, the power is now measured in a 1 MHz wide channel at 10 frequency points with 100 kHz spacing (Figure 6-7).
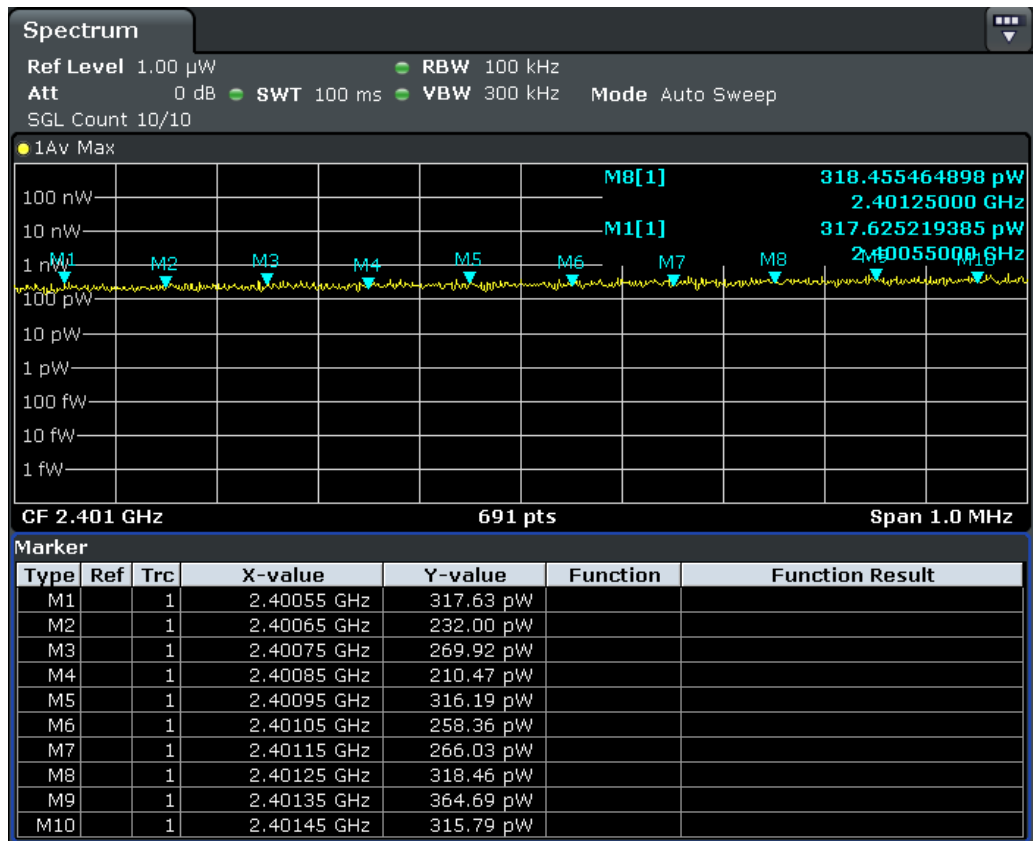
Figure 6-7: Measurement of the in-band emissions at ten frequency points for 2401 GHz. The transmit frequency of the DUT is f_{TX} = 2406 MHz.

16. The individual power values in the marker table in Figure 6-7 are used to calculate the channel power:

$P_{TX} = \sum_{i=0}^{9} P_{TX,i}$ where i = 0, 1, 2, ... 9

and then the power level:

$L_{TX} = 10\ dBm\ \cdot lg(\frac{P_{TX}}{1\ mW})$

17. Except for the center frequency, do not change any of the settings on the DUT or the spectrum analyzer and perform the measurement for all other channels (N = 1, 2, 3, 4 to 79). Channels that fulfill the following condition do not have to be measured: $f_c = f_{tx}$ and $f_c = \pm 1$ MHz

The following conditions must be fulfilled:

I. $L_{TX} \le -20$ dBm for ($f_{TX} \pm 2$ MHz)

II. $L_{TX} \le -30$ dBm for ($f_{TX} \pm [3 + n]$ MHz) where n = 0, 1, 2, …)

For each of the above transmit frequencies f_{TX}, the power level L_{TX} may exceed the second condition three times. The first condition must always be fulfilled.

Perform the above measurement at two other transmit frequencies f_{TX} (middle) and f_{TX} (highest) (configure on the DUT).

6.1.2.2 In-band emission test 08 (LE 2M, uncoded data at 2 Ms/s)

This test measures whether the spectral in-band RF leakage exceeds the limits defined in the test specification when the transmitter emits uncoded data at a symbol rate of 2 Ms/s.

Settings on BLE DUT:

1. As described under 6.1.2.1, but with a symbol rate of 2 Ms/s.

Settings on FSV spectrum analyzer:

1. As described under 6.1.2.1.

2. The individual power values in the marker table in Figure 6-7, are used to calculate the channel power:

$$P_{TX} = \sum_{i=0}^{9} P_{TX,i} \text{ where i = 0, 1, 2, ...9}$$

and then the power level:

$$L_{TX} = 10\ dBm \cdot lg(\frac{P_{TX}}{1\ mW})$$

3. Except for the center frequency, do not change any of the settings on the DUT and spectrum analyzer and perform the measurement for all other channels (N = 1, 2, 3, 4 to 79). . Channels that fulfill the following condition do not have to be measured: $f_c = f_{tx}$, $f_c = \pm 1$ MHz, $f_c = \pm 2$ MHz and $f_c = \pm 3$ MHz

The following conditions must be fulfilled:

I. $L_{TX} \leq$ –20 dBm for (f_{TX} ±4 MHz)

II. $L_{TX} \leq$ –20 dBm for (f_{TX} ±5 MHz)

III. $L_{TX} \leq$ –30 dBm for (f_{TX} ±[6 + n] MHz) where n = 0, 1, 2, …)

For each of the above transmit frequencies f_{TX}, the power level L_{TX} may exceed the third condition three times. The first condition must always be fulfilled.

15. Perform the above measurement at two other transmit frequencies f_{TX} (middle) and f_{TX} (highest) (set on the DUT).

6.1.2.3 In-band emissions test with an R&S Forum script

To automatically execute the measurements described under 6.1.2.1 and 6.1.2.2, a R&S Forum script (1MA282_In-Band_EmissionV1.1.py) is included with this application note. This script considerably reduces the amount of work.

Proceed as follows:

4. Open the link 1MA196: Using R&S Forum Application for Instrument Remote Control and download the R&S Forum setup file.

5. Double-click the .exe file and follow the installation routine.

6. Under *Settings -> Instruments…-> Add..*, configure the remote control connection to the spectrum analyzer. For more information, see Application Note 1MA196. Example:
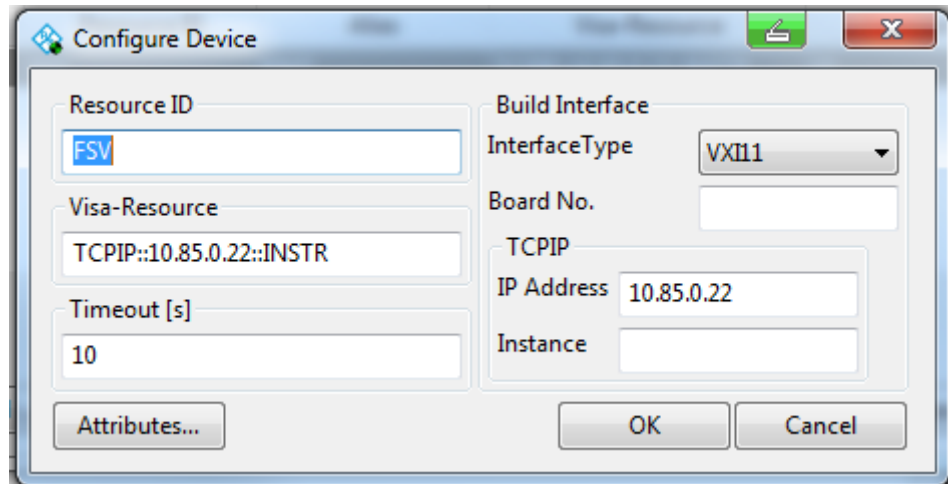
Figure 6-8: Configuration of remote control connection

16. Download the script file (1MA282_In-Band_EmissionV1.1.py) to a directory previously created on the PC.

17. Start R&S Forum and load the script with *File -> Open….*

18. In the Forum editor, set the value of the variable "test" (test = 0 for LE M1 as described in 6.1.2.1, test = 1 for LE M2 as described in 6.1.2.2) (Figure 6-9).

19. Set the value of the variable "devc" based on the DUT type (devc = 0 for peripheral and central devices, decv = 1 for broadcaster and observer devices) (Figure 6-9).
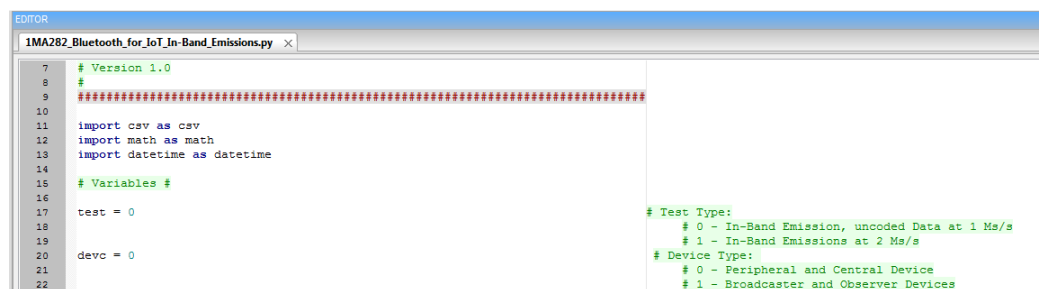
Figure 6-9: Configuration of measurement parameters

20. Use the green arrow key to start the script, and on the DUT set the frequencies shown on the screen:
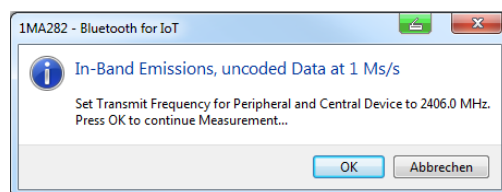
The power in the adjacent channels is output in a table in the *Output* window. As specified in the test specification, there are no limits at certain spacing intervals from the transmit frequency. These values are designated as N.D. (Not Defined). All other frequency values have either the "Passed" or "Failed" status.

Figure 6-10: Result of in-band emissions measurement

The measured values shown in Figure 6-10 are saved as a file in CSV format in an automatically created subdirectory. This file can be imported into a spreadsheet program, for example, where it can be processed further. In addition, the measured values are shown graphically together with the limit lines (Figure 6-11).
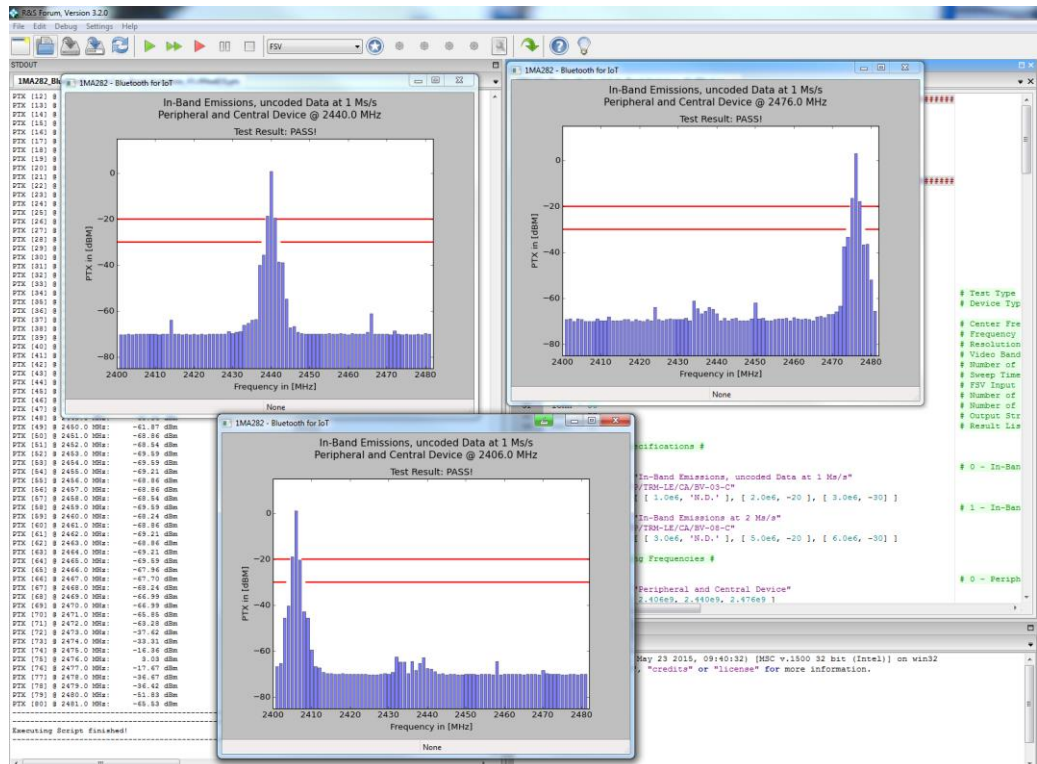
Figure 6-11: Graphical representation of the in-band emissions measurement

6.1.3   Modulation Characteristics / Carrier Frequency Offset and Drift

In order to test Modulation Characteristics of a Bluetooth device, the signal must demodulated in the spectrum analyzer. The R&S® FSx-K70 Vector Signal Analyzer option can be used to demodulate a FSK signal and perform measurements according to the Bluetooth PHY test specification. The option R&S® FSx-K70 contains presets that set the instrument in a state for BT LE analysis.

Loading the Bluetooth preset in R&S® FSx-K70:

1.   Download the zipped preset files FSV-K70_PresetsVx.zip or FSW-K70_PresetsVx.zip and unzip the file.

2.   Copy the preset files *Bluetooth_5_LEx.xml* to *C:\R_S\Instr\vsa\Standards\BLUETOOTH*

3.   Copy the pattern file *BT-LE-Sync.XML* and *BT-LE-coded-Sync.XML* to *C:\R_S\Instr\vsa\Pattern*

4.   Press the *MEAS* hardkey.

5.   Press the *Digital Standards* softkey.

6.   Load *Bluetooth\Bluetooth_5_LEx.xml for the relevant PHY*
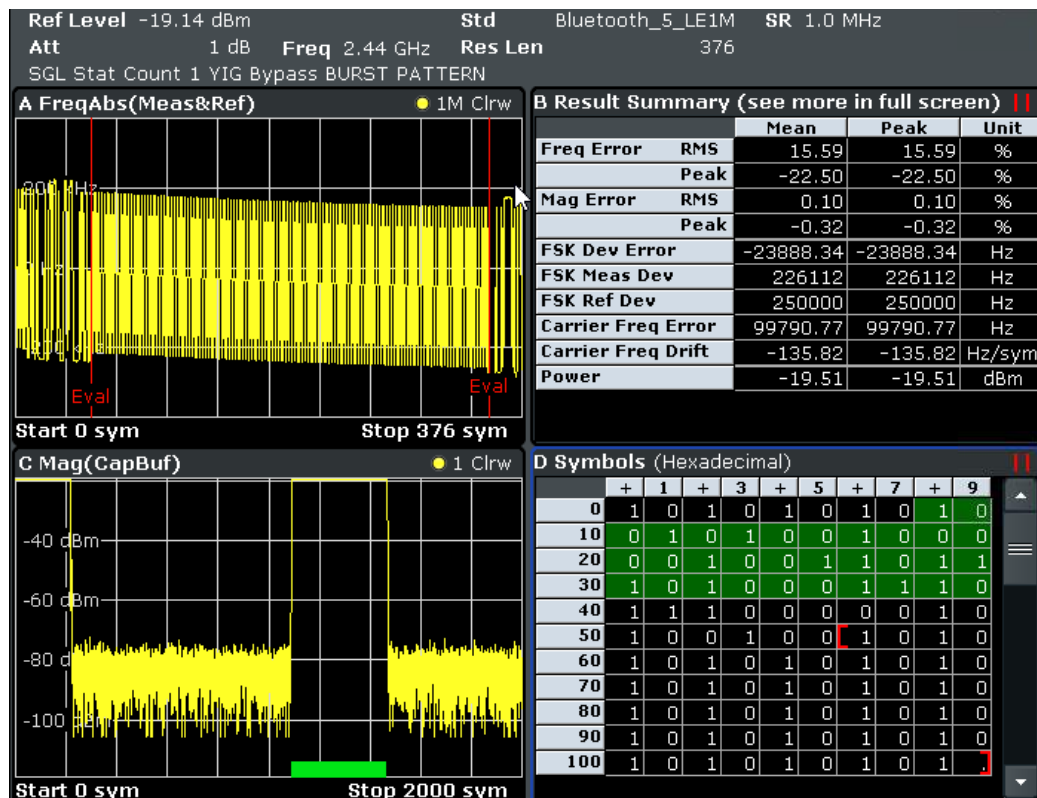
Figure 6-12: R&S® FSV-K70 configured for BT 5.0 LE

7.   Download and install the R&S Forum Application for Instrument Remote Control (1MA196) Software.

To fully comply with the test cases from the RF PHY spec [3] post processing of the results is necessary. A Forum script (1MA282_Modulation_Characteristics.py) is

provided with this application note that configures the instrument for BT LE analysis and performs the necessary processing steps. The results are printed to the STDOUT window (Figure 6-13).

Modulation characteristics	
PHY	**Test number**
LE1M	05
LE2M	10
LE1M, SMI	09
LE2M, SMI	11
LE coded (S=8)	13

Table 6-1: Supported test cases

Carrier Frequency offset and drift	
PHY	**Test number**
LE1M	06
LE2M	12
LE coded (S=8)	14

Table 6-2: Supported test cases
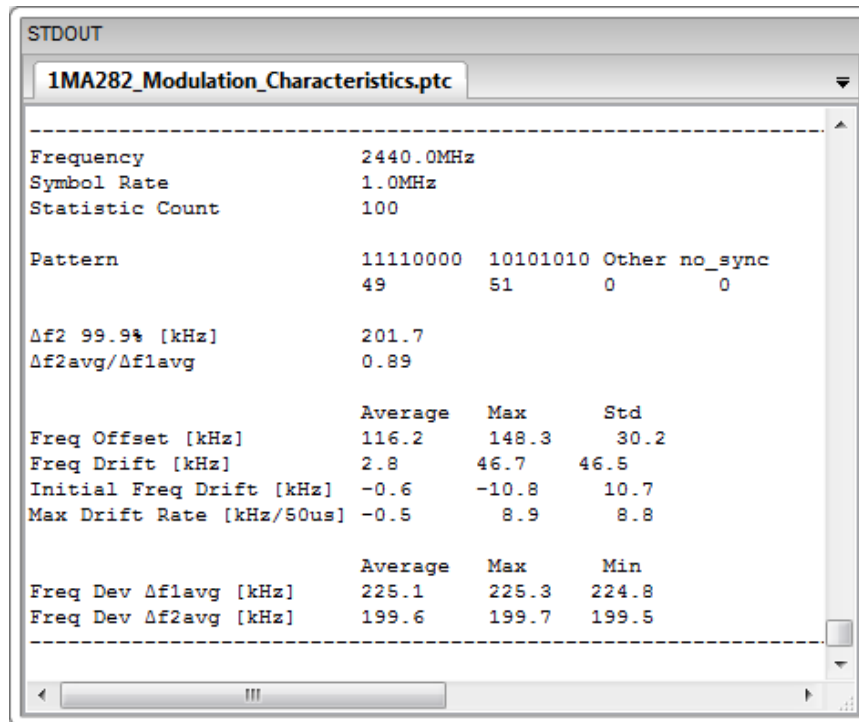
Figure 6-13: Modulation characteristics result display

6.2 Measurements on Bluetooth LE receiver

The packet error rate (PER) is measured in order to assess the receive quality of a Bluetooth LE receiver. The packet error rate is calculated in the DUT itself. The DUT reports the PER via Direct Test mode to the software provided by the manufacturer of the receiver. This software is also used to configure the necessary settings on the DUT.

Important: For all receiver measurements described below, the signal generator must transmit to the receiver a BLE wanted signal consisting of at least 1500 packets. It suffices to transmit the packet length only once for a PER measurement. The signal generator must be in the *Single* trigger mode when the PER is measured. This is configured on the SMBV100A as follows:

1. In the Bluetooth window scroll down with the ⇩ arrow key and select *Trigger/Marker…*:
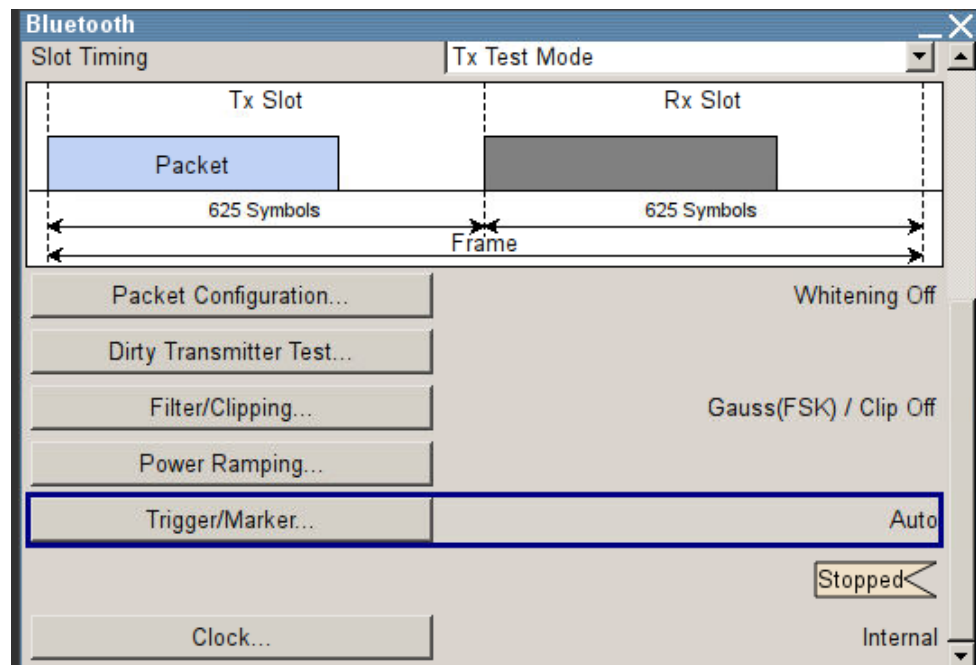
2. Under *Mode*, select *Single*:
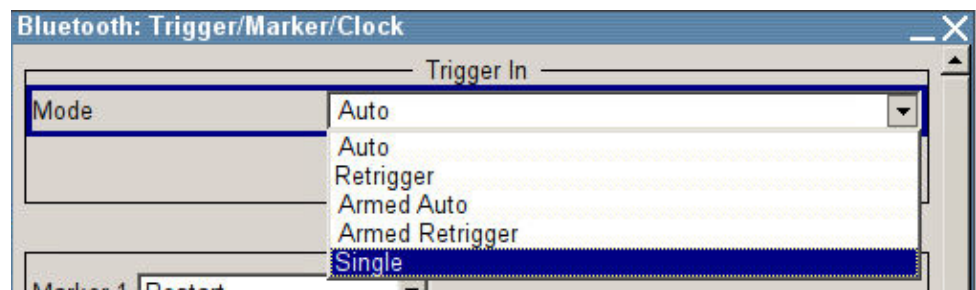
3. Transmit the signal to the receiver by clicking *Execute Trigger*:
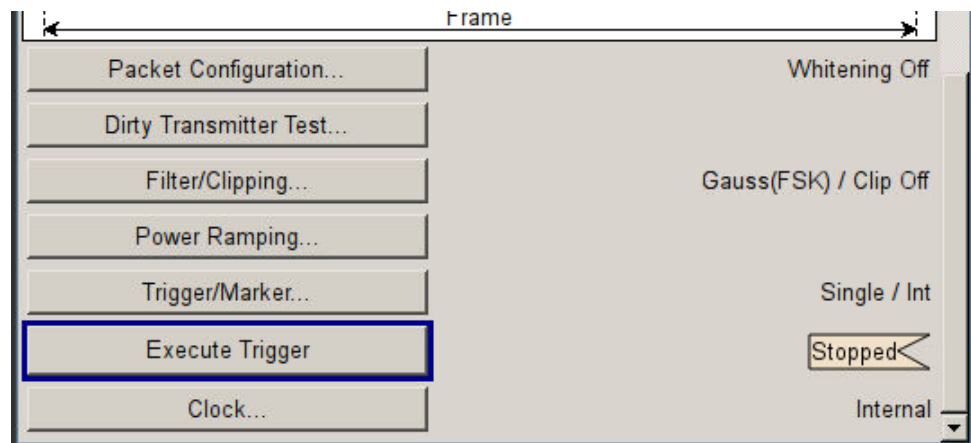
In this application note, the SMBV100A vector signal generator is used to generate the BLE signals. However, the SGT100A vector RF source can be used as a cost-effective alternative. Since up to three signal generators are needed for the receiver tests, the SGT100A with its displayless design offers an extremely compact solution that takes up little space on the workbench. The R&S SGMA GUI software is used to configure the settings. The software can control up to 12 devices simultaneously. Connection to the PC is via USB or LAN. The R&S WINIQSIM simulation software generates the standard-compliant BLE baseband signals. The generated digital waveforms are imported into the SGT100A and processed further.

Figure 6-14: SGS100A vector RF source with R&S SGMA GUI operating software

6.2.1   Receiver sensitivity

This test verifies whether the receiver sensitivity is within the limits defined by the test specification when a non-ideal transmit signal is fed to the receiver. The generated transmit signal varies within the limits defined by the specification and is therefore not ideal. The signal is generated by a vector signal generator, e.g. the SMBV100A.

Test setup:
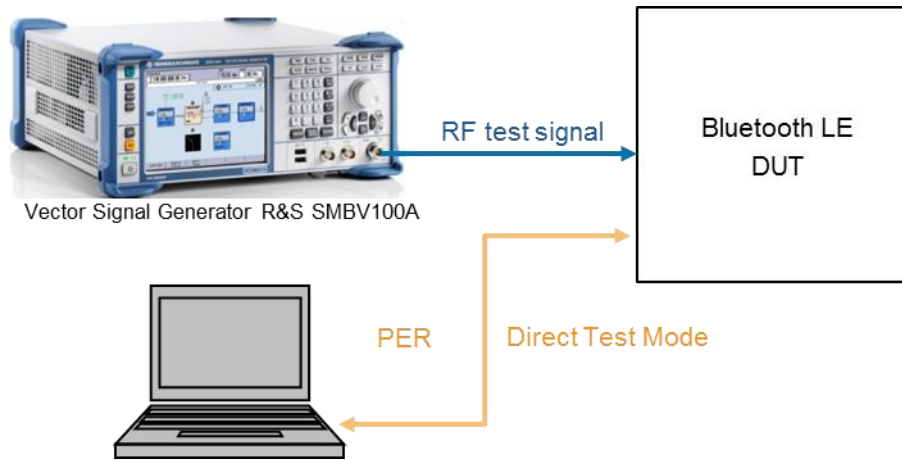
Figure 6-15: Test setup with a signal generator and PC for signaling and reading out the PER

The receiver sensitivity test is specified for all PHYs:

Receiver sensitivity and PHYs		
PHY	Test number	Reference level
LE 1M	01	–70 dBm
LE 2M	08	
LE 1M, SMI	14	
LE 2M, SMI	20	
LE Coded, S=2	26	–75 dBm
LE Coded, S=8	27	–82 dBm
LE Coded, S=2, SMI	32	–75 dBm
LE Coded, S=8, SMI	33	–82 dBm

Table 6-3: Overview of receiver sensitivity tests

6.2.1.1 Receiver Sensitivity Performance Test 01, Uncoded Data at 1 Ms/s

This test measures whether the receiver sensitivity is within the defined limits when a non-ideal uncoded signal with a symbol rate of 1 Ms/s is received.

Settings on DUT:

1. Switch on Direct RX mode. Switch off dewhitening.

2. Switch off frequency hopping.

3. Configure the receiver so that a transmitter with a standard modulation index is expected.

   Tables 6.1 and 6.2 in 6.2 *Frequencies for Testing* of the Bluetooth test specification specify the DUT's transmit and receive frequencies for the different test cases and device types. The receiver sensitivity performance test is only performed for the RX frequency f_{RX} (lowest).

Settings on SMBV100A:

4. Press the *PRESET* key.

5. Press the *MENU* key and select *Bluetooth* from the list:

6. Configure the settings as shown in Figure 6-16. The test specification requires that the test signal consist of at least 1500 data packets (frames).
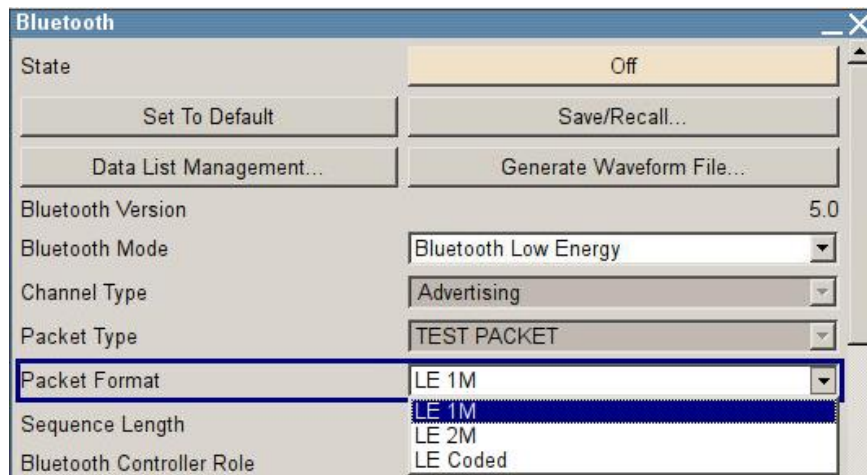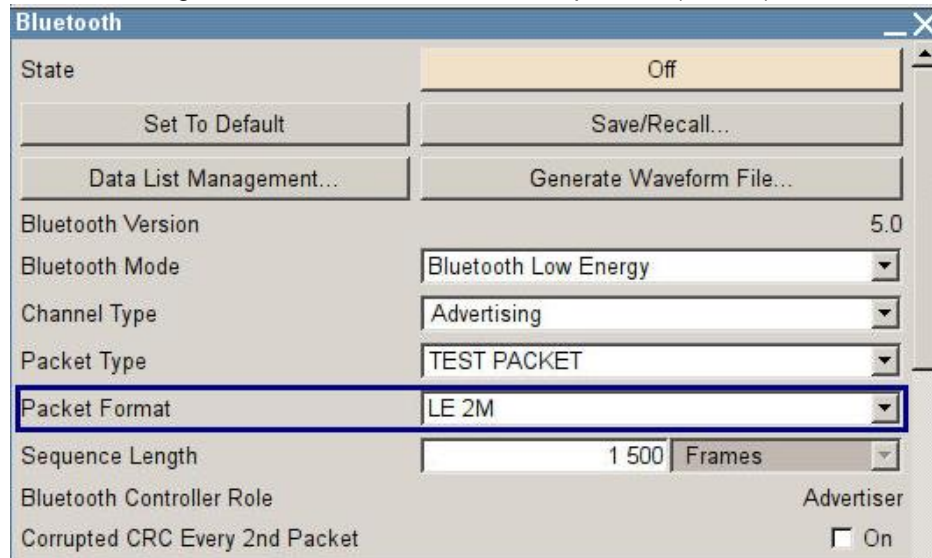

Figure 6-16: Generator settings

7. In the Bluetooth window (Figure 6-16), scroll down with the ⇩ arrow key and select *Dirty Transmitter Test…*:
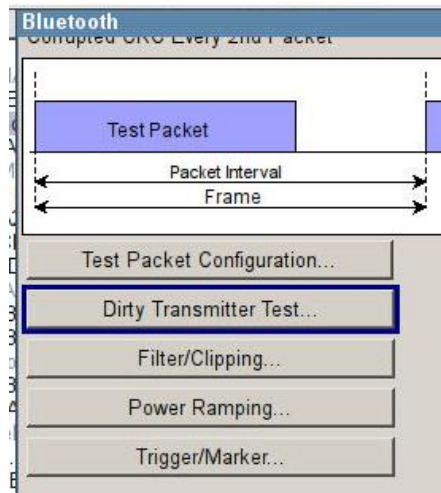
8. In the Dirty Transmitter Test window, select *Test Packet Configuration…*:
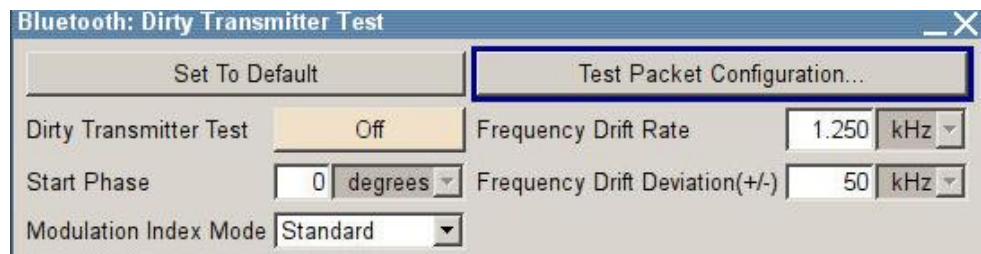
Figure 6-17: Configuration for dirty transmitter test

9. Make sure that **PRBS9** is selected as the payload type. If the DUT supports the "Extended Packet Length" feature (in line with core specification 4.2), then **Payload Length** must be set to the maximum possible packet length supported by the DUT. If "Extended Packet Length" is not supported, *Payload Length* must be set to 37 bytes:
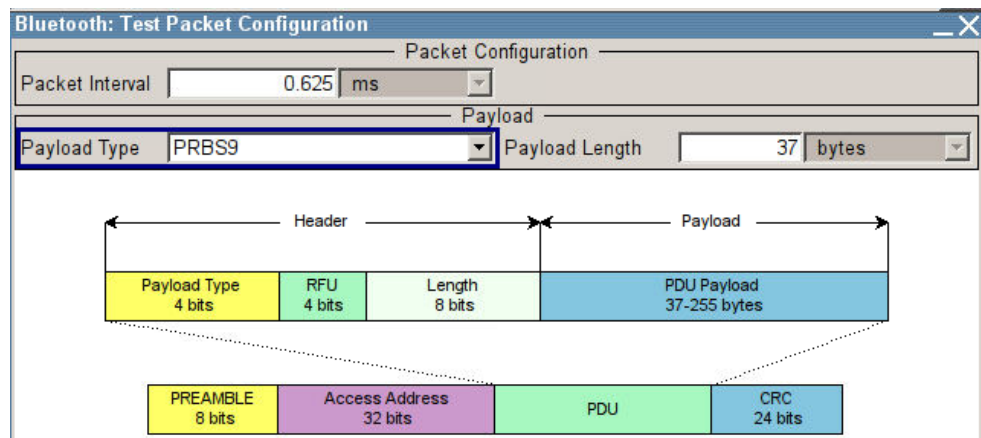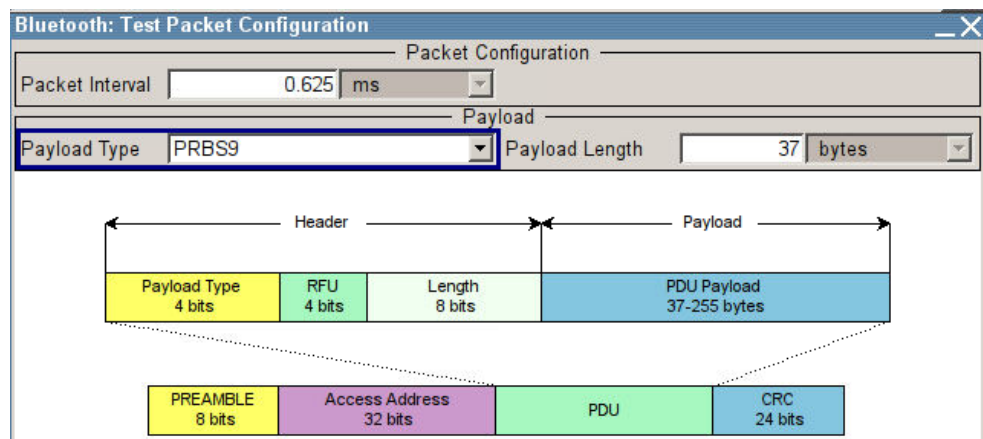

Figure 6-18: Test packet configuration

10. Close the "Test Packet Configuration" window and switch on all test run "Sets" (1 to 10) (State = On). Then set Dirty Transmitter Test to On.
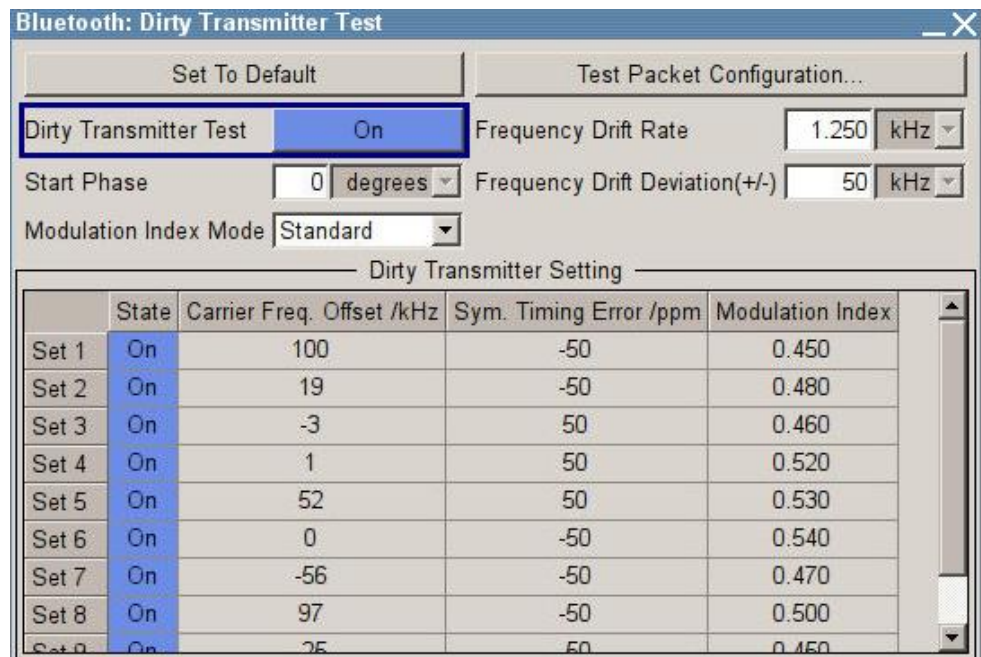
Figure 6-19: Dirty transmitter test settings in line the with test specification

11. Press the *FREQ* key and enter the value of f_{RX} (lowest).

12. Press the *LEVEL* key and enter –70 dBm (see Table 6-3). *Note:* Since the test specification defines the level at the input of the Bluetooth receiver, the additional cable loss must be taken into account when entering the reference level.

13. Start the calculation of the Bluetooth test signal with *State* = On. After the calculation, press the *RF ON/OFF* key to switch on the Bluetooth RF signal.

    With the described settings, the vector signal generator generates a test signal compliant with the test specification. The test signal consists of a series of packets (Figure 6-18). The characteristics of this signal changes after every 50 packets. This change is described by 10 different test run "Sets". As can be seen in Figure 6-19, the carrier frequency offset, the modulation index and the symbol timing error all change based on a fixed pattern. When all 10 test runs have been completed, testing begins again with test run "Set 1" until the number of packets entered under Sequence Length is reached (for trigger mode Single). In addition to the specified parameters, frequency modulation is used to add a time frequency drift to the test signal. The signal to be modulated is sinusoidal with a frequency deviation of 50 kHz and a modulation frequency of 1250 Hz (Figure 6-19).

The following condition must be fulfilled:

▪ PER < 30.8 % (for Payload Length = 37 bytes and at least 1500 packets). For other payload lengths, the PER limit is given in Table 6.4: *PER level by maximum payload length in receiver* of the test specification.

6.2.1.2 Receiver Sensitivity Performance Test 08, Uncoded Data at 2 Ms/s
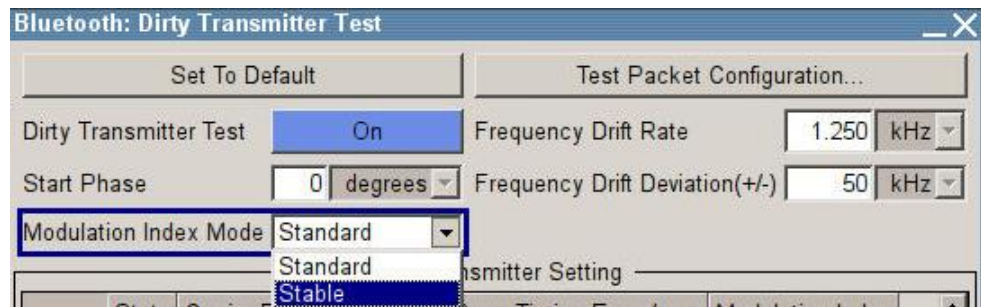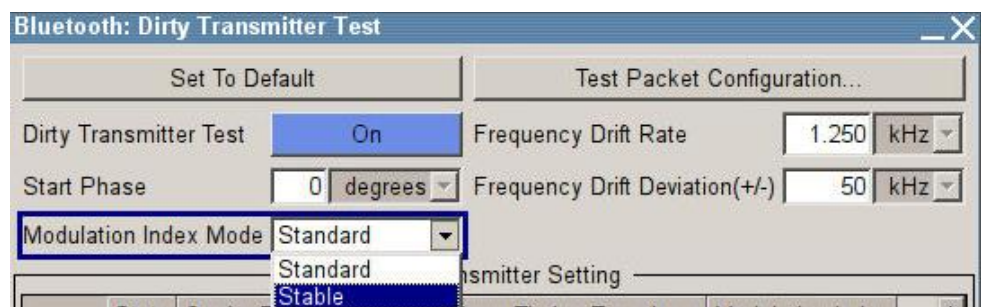
This test measures whether the receiver sensitivity is within the defined limits when a non-ideal uncoded signal with a symbol rate of 2 Ms/s is received.
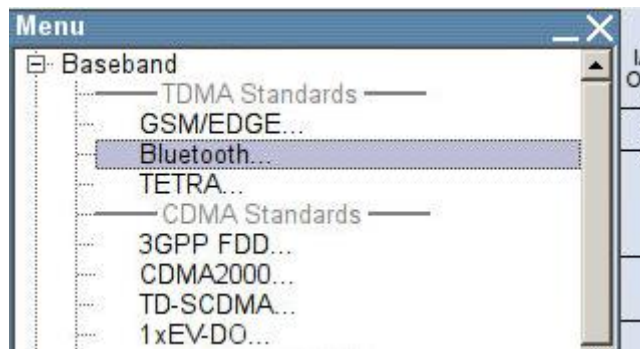
Settings on DUT:

1. Switch on Direct RX mode. Switch off dewhitening.

2. Switch off frequency hopping.

3. Configure the receiver so that a transmitter with a standard modulation index is expected.

   Tables 6.1 and 6.2 in 6.2 *Frequencies for Testing* of the Bluetooth test specification specify the DUT's transmit and receive frequencies for the different test cases and device types. The receiver sensitivity performance test is only performed for the RX frequency f_{RX} (lowest).

Settings on SMBV100A:

4. Press the *PRESET* key.

5. Press the *MENU* key and select *Bluetooth* from the list:

6. Configure the settings as shown in Figure 6-20. The test specification requires that the test signal consist of at least 1500 data packets (frames).
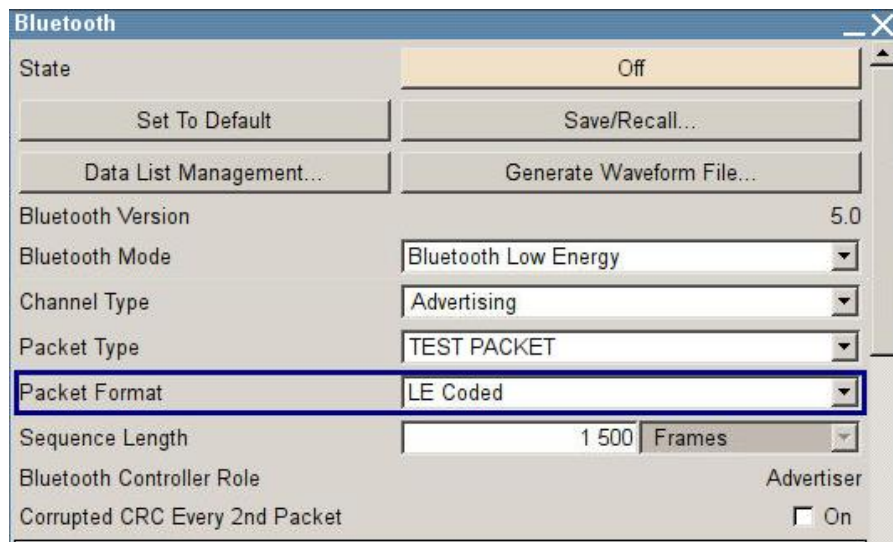

Figure 6-20: Generator settings

7. In the Bluetooth window, scroll down with the ⇩ arrow key and select *Dirty Transmitter Test…*:
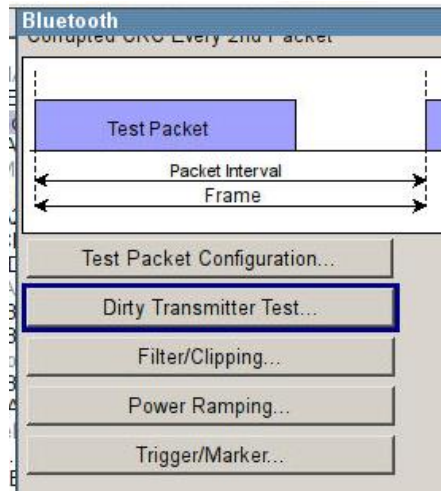
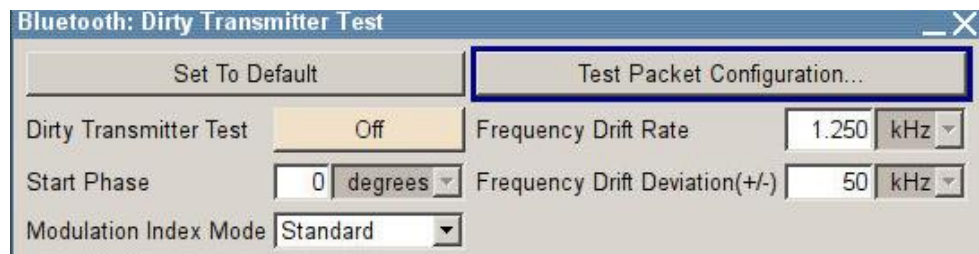8. In the Dirty Transmitter Test window, select *Test Packet Configuration…*:
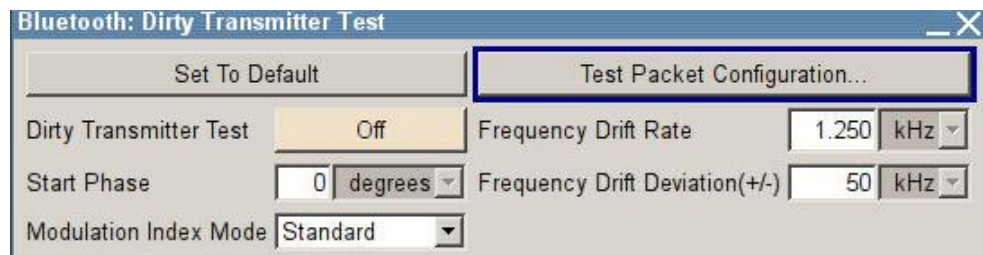
Figure 6-21: Configuration for dirty transmitter test

9. Make sure that **PRBS9** is selected as the payload type. If the DUT supports the "Extended Packet Length" feature (in line with core specification 4.2), then **Payload Length** must be set to the maximum possible packet length supported by the DUT. If "Extended Packet Length" is not supported, *Payload Length* must be set to 37 bytes:
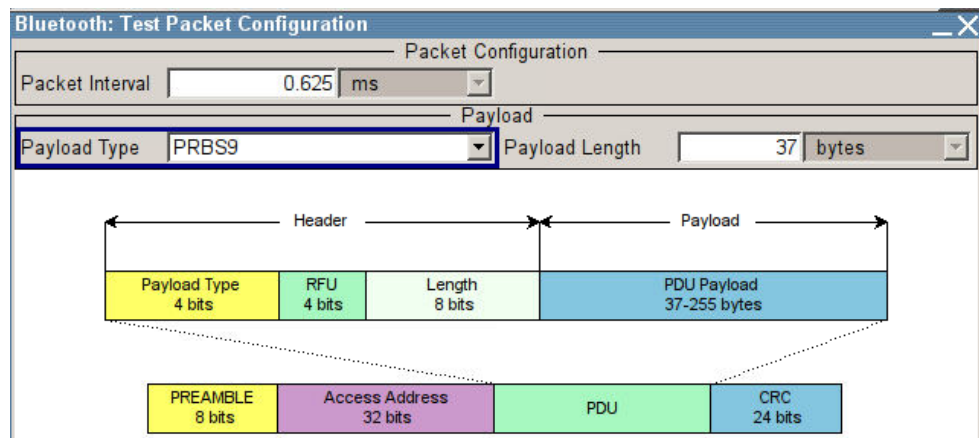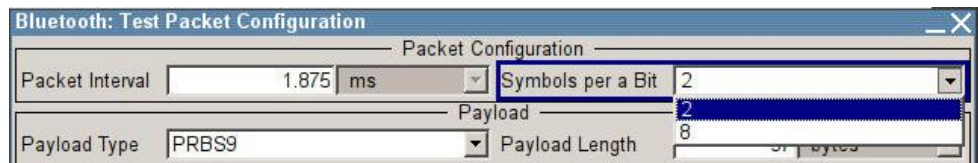

Figure 6-22: Test packet configuration

10. Close the "Test Packet Configuration" window and switch on all test run "Sets" (1 to 10) (State = On). Then set Dirty Transmitter Test to On.
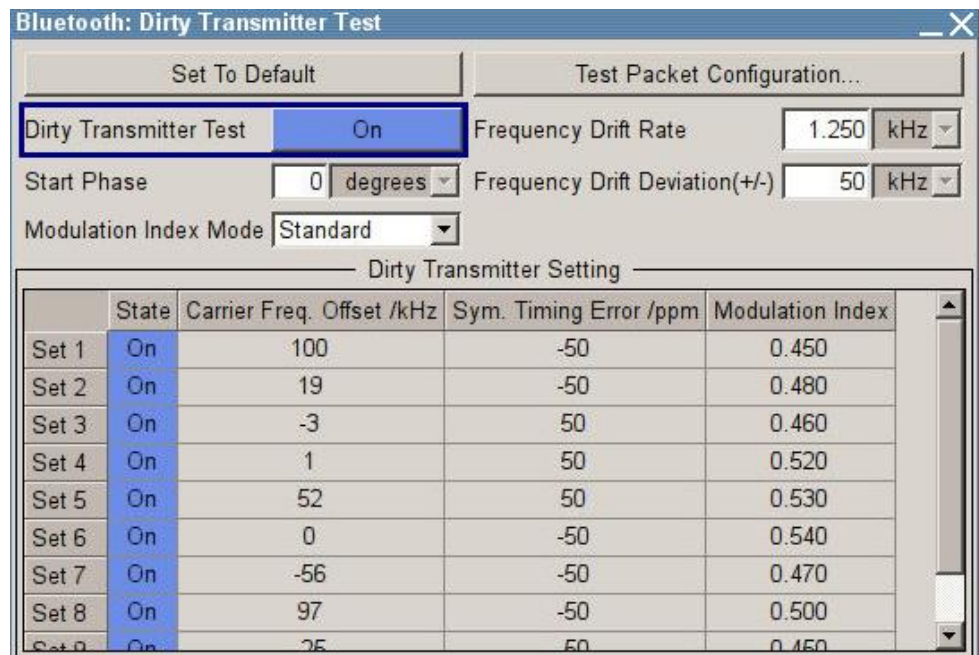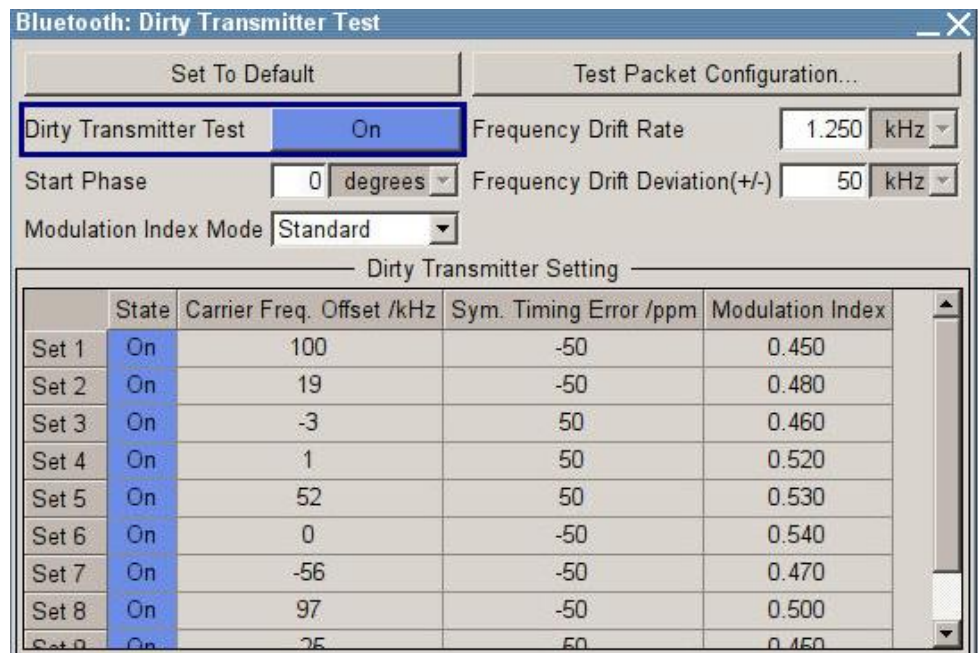
Figure 6-23: Dirty transmitter test settings in line with the test specification

11. Press the *FREQ* key and enter the value of f_{RX} (lowest).

12. Press the *LEVEL* key and enter –70 dBm (see Table 6-3). *Note:* Since the test specification defines the level at the input of the Bluetooth receiver, the additional cable loss must be taken into account when entering the reference level.

13. Start the calculation of the Bluetooth test signal with *State* = On. After the calculation, press the *RF ON/OFF* key to switch on the Bluetooth RF signal.

    With the described settings, the vector signal generator generates a test signal compliant with the test specification.

The following condition must be fulfilled:

▪ PER < 30.8 % (for Payload Length = 37 bytes and at least 1500 packets). For other payload lengths, the PER limit is given in Table 6.4: *PER level by maximum payload length in receiver* of the test specification.

6.2.1.3 Receiver Sensitivity Performance Test 14, Uncoded Data at 1 Ms/s, Stable Modulation Index

This test measures whether the receiver sensitivity is within the defined limits when a non-ideal uncoded signal with a symbol rate of 1 Ms/s is received. Here, the receiver expects a transmitter with a stable modulation index.

Settings on DUT:

▪ As described under 6.2.1.1, but configure the receiver so that a transmitter with a stable modulation index is expected.

Settings on SMBV100A:

▪ As described under 6.2.1.1, but select *Stable* under *Modulation Index Mode* in the dirty transmitter settings:

The following conditions must be fulfilled:

▪ As described under 6.2.1.1.

6.2.1.4 Receiver Sensitivity Performance Test 20, Uncoded Data at 2 Ms/s, Stable Modulation Index
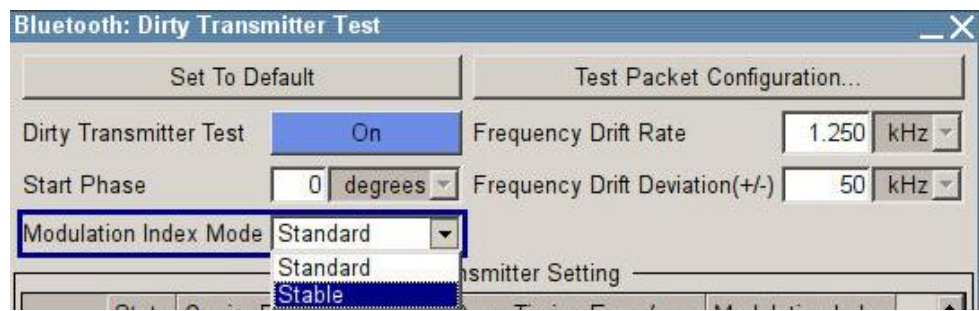
This test measures whether the receiver sensitivity is within the defined limits when a non-ideal uncoded signal with a symbol rate of 2 Ms/s is received. Here, the receiver expects a transmitter with a stable modulation index.

Settings on DUT:

▪ As described under 6.2.1.2, but configure the receiver so that a transmitter with a stable modulation index is expected.

Settings on SMBV100A:

▪ As described under 6.2.1.2, but select *Stable* under *Modulation Index Mode* in the dirty transmitter settings:

The following condition must be fulfilled:

▪ As described under 6.2.1.2.

6.2.1.5 Receiver Sensitivity Performance Test 26, LE Coded (S=2)

This test measures whether the receiver sensitivity is within the defined limits when a non-ideal LE Coded (S=2) signal is received.
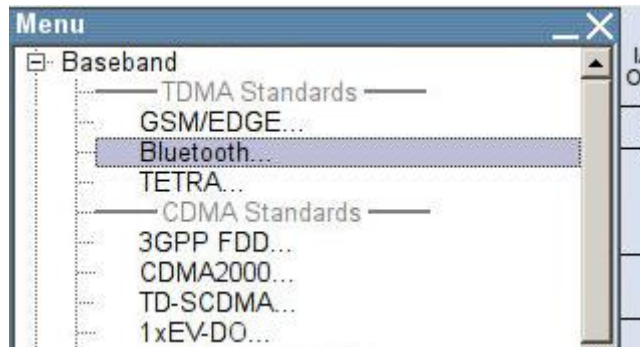
Settings on DUT:

1.   Switch on Direct RX mode. Switch off dewhitening.

2.   Switch off frequency hopping.

3.   Configure the receiver so that a transmitter with a standard modulation index is expected.

       Tables 6.1 and 6.2 in 6.2 *Frequencies for Testing* of the Bluetooth test specification specify the DUT's transmit and receive frequencies for the different test cases and device types. The receiver sensitivity performance test is only performed for the RX frequency f_{RX} (lowest).

Settings on SMBV100A:

4.   Press the *PRESET* key.

5.   Press the *MENU* key and select *Bluetooth* from the list:

6.   Configure the settings as shown in Figure 6-24. The test specification requires that the test signal consist of at least 1500 data packets (frames).
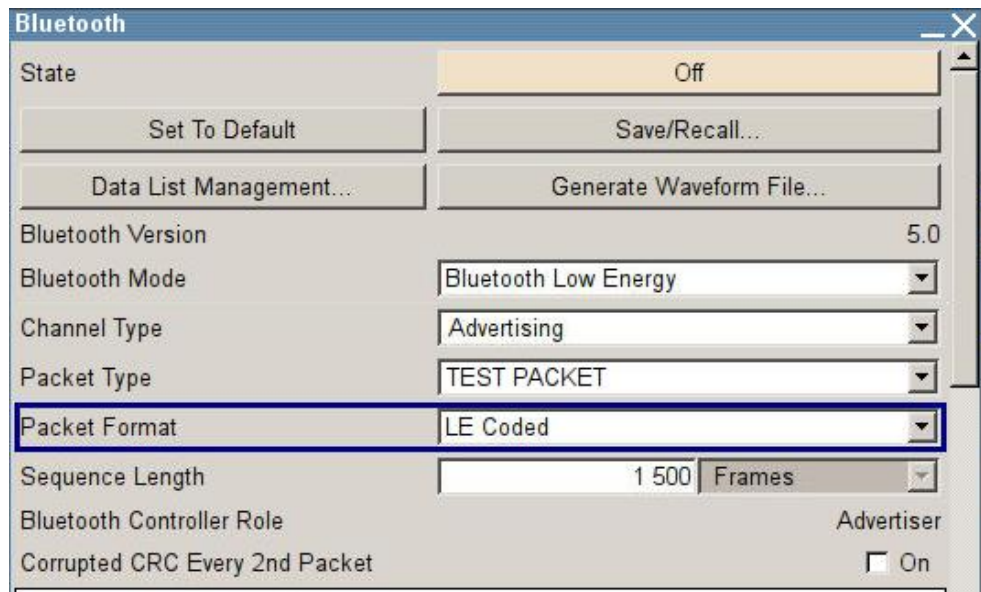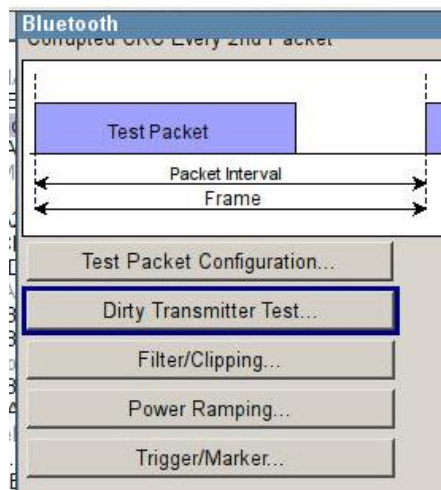

Figure 6-24: Generator settings

7.   In the Bluetooth window (Figure 6-24), scroll down with the ⇩ arrow key and select *Dirty Transmitter Test…*:
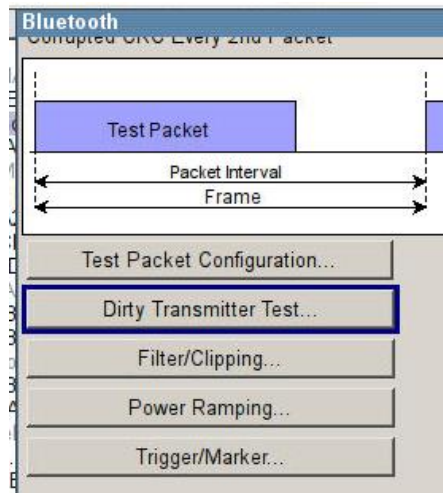
8. In the Dirty Transmitter Test window, select *Test Packet Configuration…*:
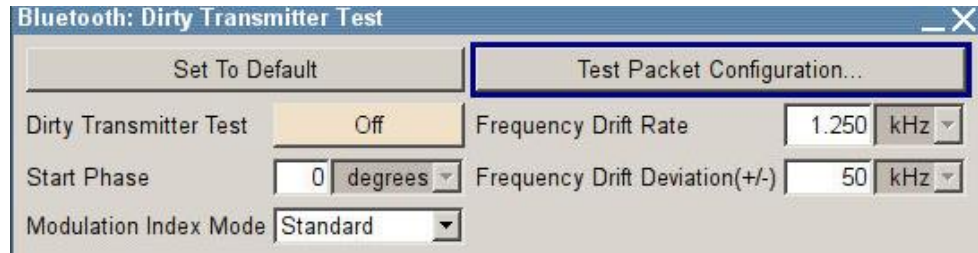

Figure 6-25: Configuration for dirty transmitter test

9. Make sure that **PRBS9** is selected as the payload type. If the DUT supports the "Extended Packet Length" feature (in line with core specification 4.2), then **Payload Length** must be set to the maximum possible packet length supported by the DUT. If "Extended Packet Length" is not supported, *Payload Length* must be set to 37 bytes:
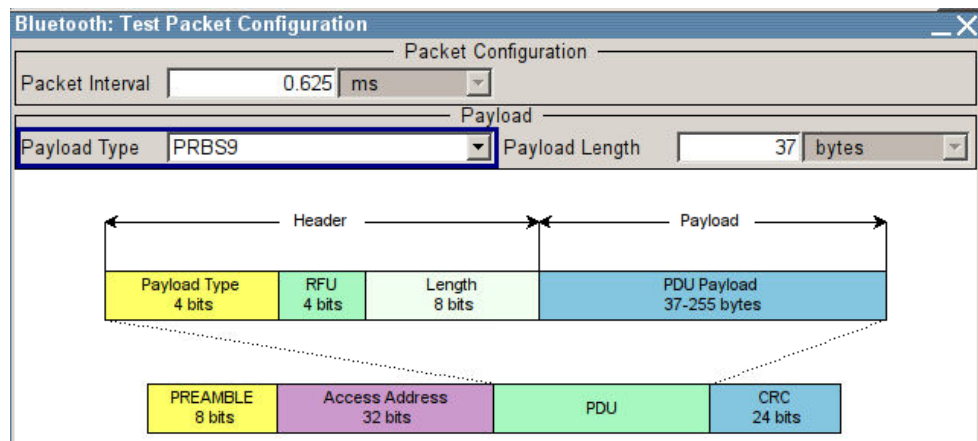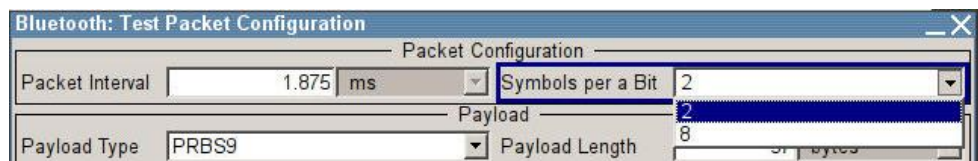

Figure 6-26: Test packet configuration

10. Under *Symbols per a Bit*, select 2:

11. Close the "Test Packet Configuration" window and switch on all test run "Sets" (1 to 10) (State = On). Then set Dirty Transmitter Test to On.
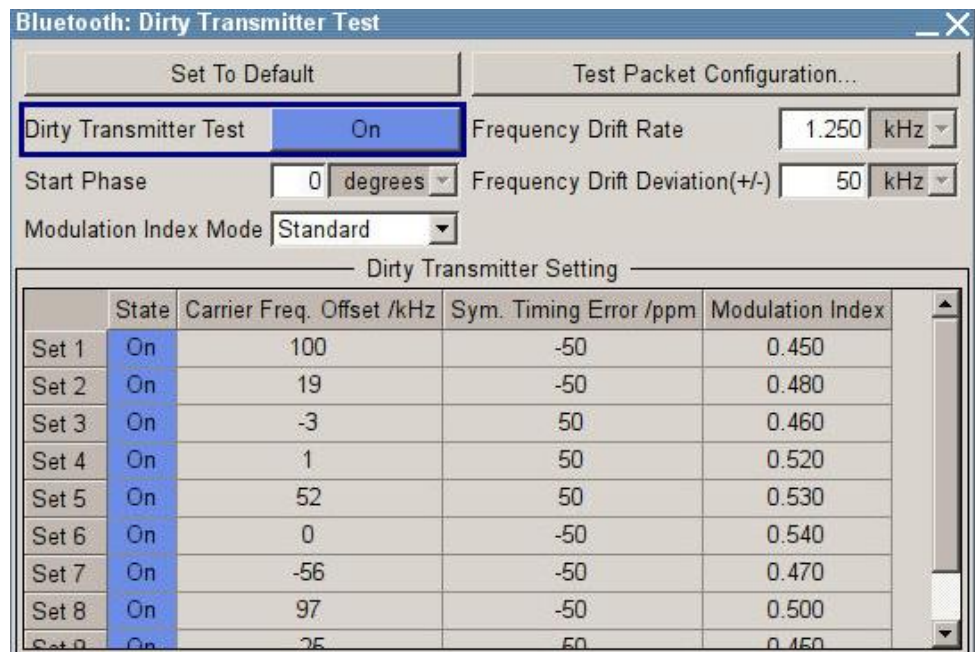

Figure 6-27: Dirty transmitter test settings in line with the test specification

12. Press the *FREQ* key and enter the value of f$_{RX}$ (lowest).

13. Press the *LEVEL* key and enter –75 dBm (see Table 6-3). *Note:* Since the test specification defines the level at the input of the Bluetooth receiver, the additional cable loss must be taken into account when entering the reference level.

14. Start the calculation of the Bluetooth test signal with *State* = On. After the calculation, press the *RF ON/OFF* key to switch on the Bluetooth RF signal.

    With the described settings, the vector signal generator generates a test signal compliant with the test specification.

The following condition must be fulfilled:

▪ PER < 30.8 % (for Payload Length = 37 bytes and at least 1500 packets). For other payload lengths, the PER limit is given in Table 6.4: *PER level by maximum payload length in receiver* of the test specification.

6.2.1.6 Receiver Sensitivity Performance Test 20, Uncoded Data at 2 Ms/s, Stable Modulation Index

This test measures whether the receiver sensitivity is within the defined limits when a non-ideal uncoded signal with a symbol rate of 2 Ms/s is received. Here, the receiver expects a transmitter with a stable modulation index.

Settings on DUT:

▪   As described under 6.2.1.2, but configure the receiver so that a transmitter with a stable modulation index is expected.

Settings on SMBV100A:

▪   As described under 6.2.1.2, but select *Stable* under *Modulation Index Mode* in the dirty transmitter settings:

The following condition must be fulfilled:

▪   As described under 6.2.1.2.

6.2.1.7 Receiver Sensitivity Performance Test 26, LE Coded (S=2)

This test measures whether the receiver sensitivity is within the defined limits when a non-ideal LE Coded (S=2) signal is received.
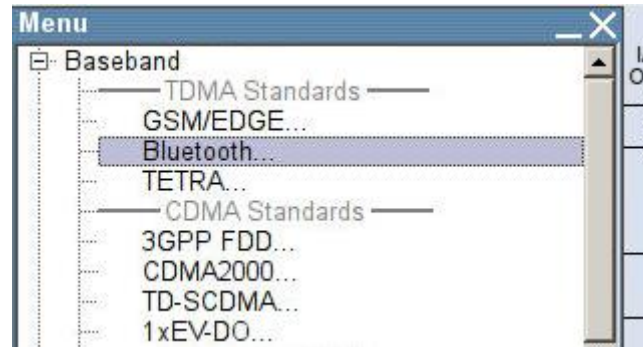
Settings on DUT:

1.   Switch on Direct RX mode. Switch off dewhitening.

2.   Switch off frequency hopping.

3.   Configure the receiver so that a transmitter with a standard modulation index is expected.

Tables 6.1 and 6.2 in 6.2 *Frequencies for Testing* of the Bluetooth test specification specify the DUT's transmit and receive frequencies for the different test cases and device types. The receiver sensitivity performance test is only performed for the RX frequency f_{RX} (lowest).

Settings on SMBV100A:

4.   Press the *PRESET* key.

5.   Press the *MENU* key and select *Bluetooth* from the list:

6. Configure the settings as shown in Figure 6-24. The test specification requires that the test signal consist of at least 1500 data packets (frames).
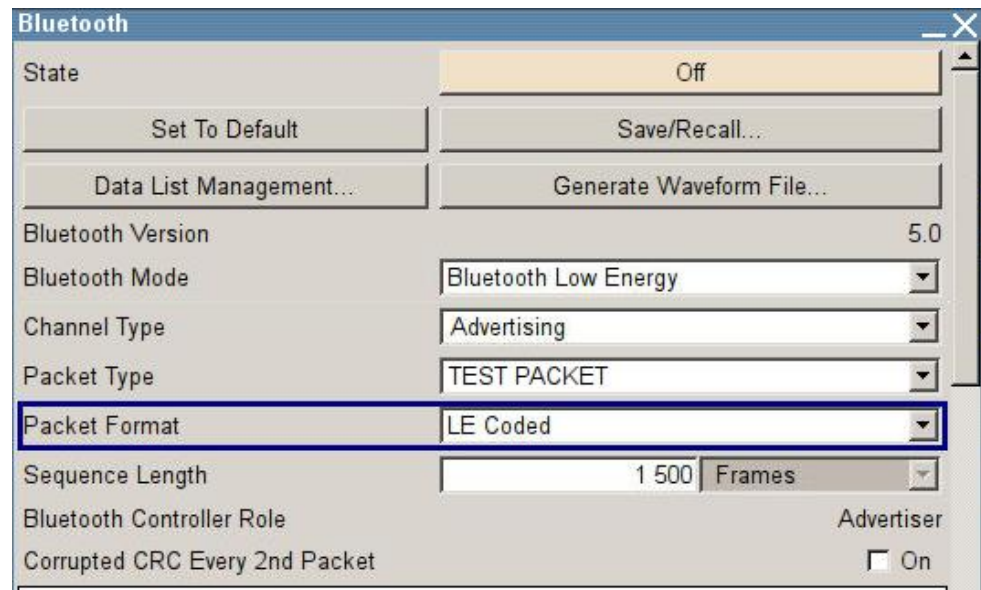

Figure 6-28: Generator settings

7. In the Bluetooth window (Figure 6-24), scroll down with the ⇩ arrow key and select *Dirty Transmitter Test…*:

8. In the Dirty Transmitter Test window, select *Test Packet Configuration…*:
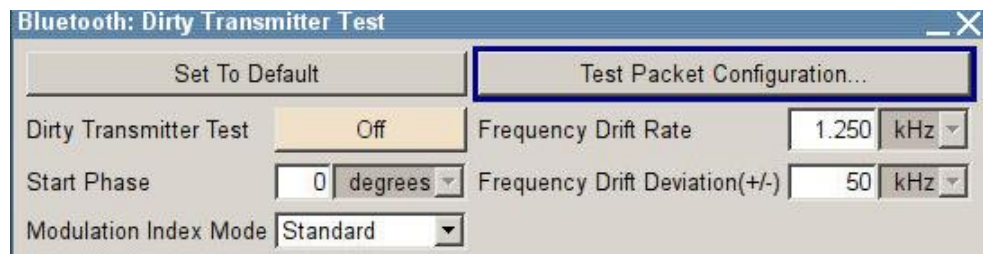

Figure 6-29: Configuration for dirty transmitter test

9. Make sure that **PRBS9** is selected as the payload type. If the DUT supports the "Extended Packet Length" feature (in line with core specification 4.2), then **Payload Length** must be set to the maximum possible packet length supported by the DUT. If "Extended Packet Length" is not supported, *Payload Length* must be set to 37 bytes:
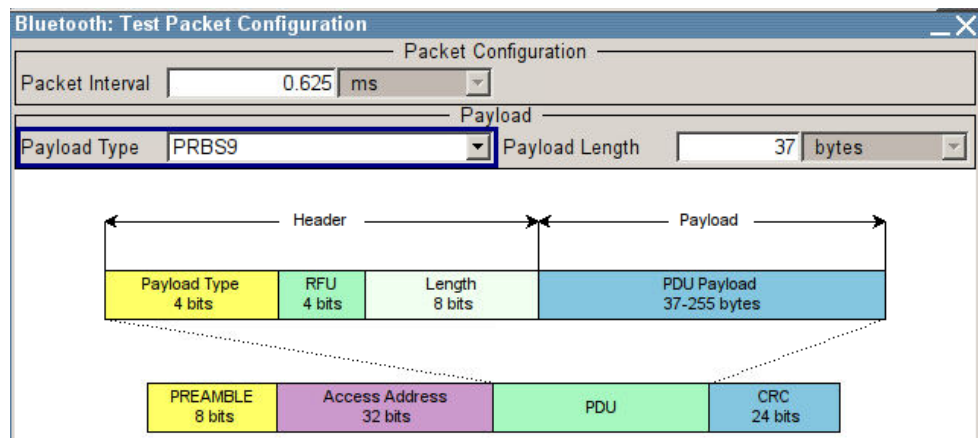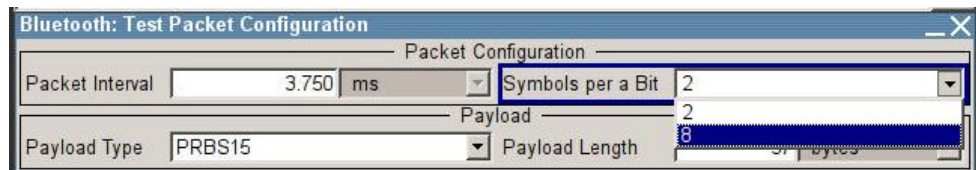

Figure 6-30: Test packet configuration

10. Under *Symbols per a Bit*, select 2:

11. Close the "Test Packet Configuration" window and switch on all test run "Sets" (1 to 10) (State = On). Then set Dirty Transmitter Test to On.
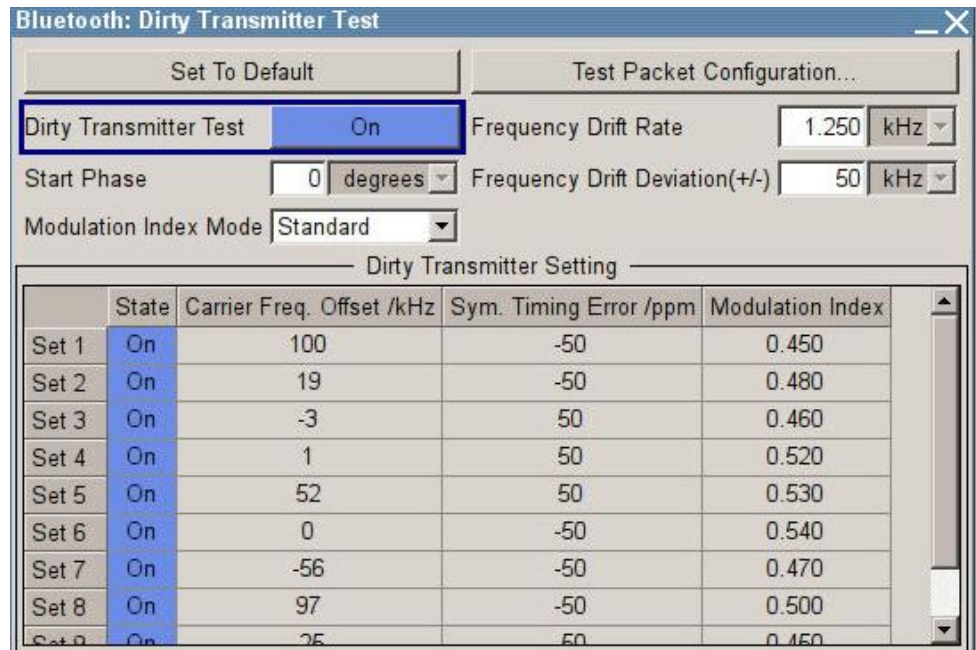
Figure 6-31: Dirty transmitter test settings in line with the test specification

12. Press the *FREQ* key and enter the value of f_{RX} (lowest).

13. Press the *LEVEL* key and enter –75 dBm (see Table 6-3). *Note:* Since the test specification defines the level at the input of the Bluetooth receiver, the additional cable loss must be taken into account when entering the reference level.

14. Start the calculation of the Bluetooth test signal with *State* = On. After the calculation, press the *RF ON/OFF* key to switch on the Bluetooth RF signal.

    With the described settings, the vector signal generator generates a test signal compliant with the test specification.

The following condition must be fulfilled:

▌ PER < 30.8 % (for Payload Length = 37 bytes and at least 1500 packets). For other payload lengths, the PER limit is given in Table 6.4: *PER level by maximum payload length in receiver* of the test specification.

6.2.1.8 Receiver Sensitivity Performance Test 27, LE Coded (S=8)

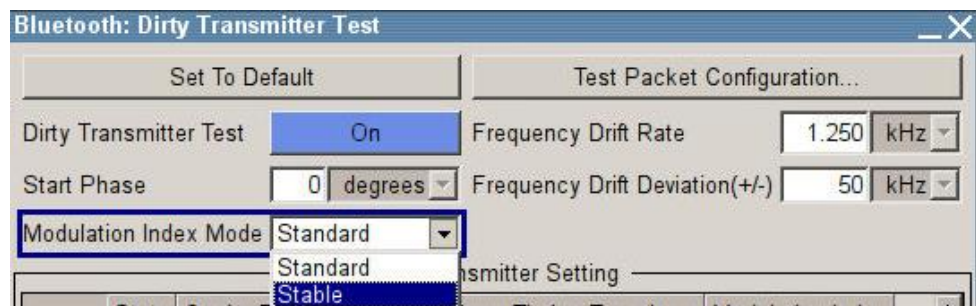This test measures whether the receiver sensitivity is within the defined limits when a non-ideal LE Coded (S=8) signal is received.

Settings on DUT:

1. Switch on Direct RX mode. Switch off dewhitening.

2. Switch off frequency hopping.

3. Configure the receiver so that a transmitter with a standard modulation index is expected.

Tables 6.1 and 6.2 in 6.2 *Frequencies for Testing* of the Bluetooth test specification specify the DUT's transmit and receive frequencies for the different test cases and device types. The receiver sensitivity performance test is only performed for the RX frequency f_{RX} (lowest).

Settings on SMBV100A:

4. Press the *PRESET* key.

5. Press the *MENU* key and select *Bluetooth* from the list:

6. Configure the settings as shown in Figure 6-24. The test specification requires that the test signal consist of at least 1500 data packets (frames).

Figure 6-32: Generator settings

7. In the Bluetooth window (Figure 6-24), scroll down with the ⇩ arrow key and select *Dirty Transmitter Test…*:
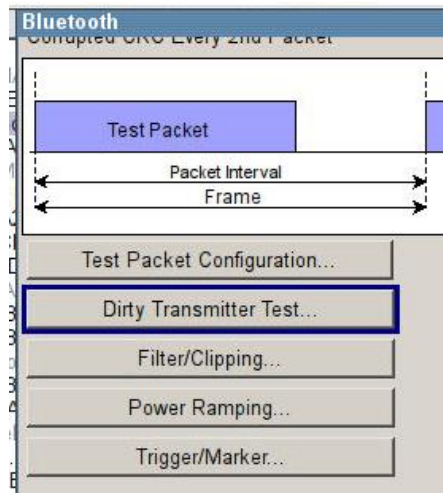
8. In the Dirty Transmitter Test window, select *Test Packet Configuration…*:

Figure 6-33: Configuration for dirty transmitter test

9. Make sure that **PRBS9** is selected as the payload type. If the DUT supports the "Extended Packet Length" feature (in line with core specification 4.2), then **Payload Length** must be set to the maximum possible packet length supported by the DUT. If "Extended Packet Length" is not supported, *Payload Length* must be set to 37 bytes:

Figure 6-34: Test packet configuration

10. Under *Symbols per a Bit*, select 8:

11. Close the "Test Packet Configuration" window and switch on all test run "Sets" (1 to 10) (State = On). Then set Dirty Transmitter Test to On.

Figure 6-35: Dirty transmitter test settings in line with the test specification

12. Press the *FREQ* key and enter the value of f$_{RX}$ (lowest).

13. Press the *LEVEL* key and enter –82 dBm (see Table 6-3). *Note:* Since the test specification defines the level at the input of the Bluetooth receiver, the additional cable loss must be taken into account when entering the reference level.

14. Start the calculation of the Bluetooth test signal with *State* = On. After the calculation, press the *RF ON/OFF* key to switch on the Bluetooth RF signal.

   With the described settings, the vector signal generator generates a test signal compliant with the test specification.

The following condition must be fulfilled:

▮ PER < 30.8 % (for Payload Length = 37 bytes and at least 1500 packets). For other payload lengths, the PER limit is given in Table 6.4: *PER level by maximum payload length in receiver* of the test specification.

6.2.1.9 Receiver Sensitivity Performance Test 32, LE Coded (S=2), Stable Modulation Index

This test measures whether the receiver sensitivity is within the defined limits when a non-ideal LE Coded (S=2) signal is received. Here, the receiver expects a transmitter with a stable modulation index.

Settings on DUT:

ι   As described under 6.2.1.7, but configure the receiver so that a transmitter with a stable modulation index is expected.

Settings on SMBV100A:

ι   As described under 6.2.1.7, but select *Stable* under *Modulation Index Mode* in the dirty transmitter settings:

The following condition must be fulfilled:

ι   As described under 6.2.1.7.

6.2.1.10 Receiver Sensitivity Performance Test 33, LE Coded (S=8), Stable Modulation Index

This test measures whether the receiver sensitivity is within the defined limits when a non-ideal LE Coded (S=8) signal is received. Here, the receiver expects a transmitter with a stable modulation index.

Settings on DUT:

ι   As described under 6.2.1.8, but configure the receiver so that a transmitter with a stable modulation index is expected.

Settings on SMBV100A:

ι   As described under 6.2.1.7, but select *Stable* under *Modulation Index Mode* in the dirty transmitter settings:
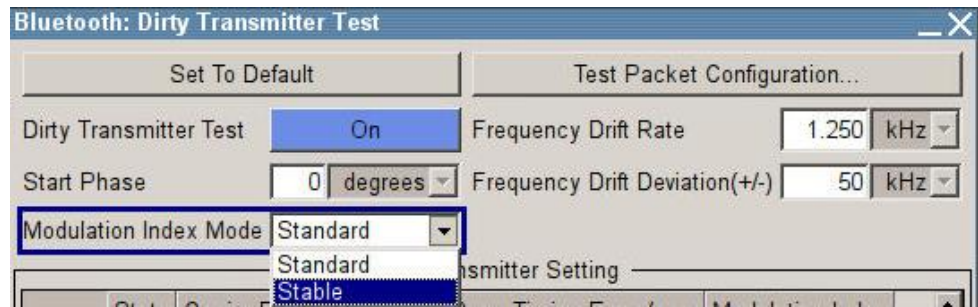
The following condition must be fulfilled:

▪ As described under 6.2.1.7.

6.2.2 C/I and Receiver Selectivity Performance

This test checks the behavior of the receiver under the influence of a second Bluetooth signal. A Bluetooth interferer is set with specific levels and frequency spacing from the wanted Bluetooth signal. The PER is measured on the wanted signal.
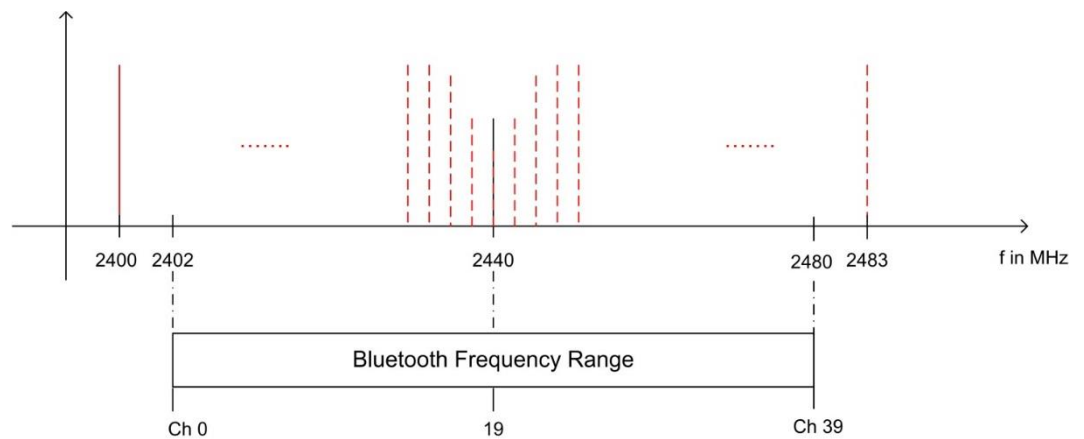
Figure 6-36: C/I performance: The packet error rate is measured in the presence of a Bluetooth interferer inside the Bluetooth band. The measurement is repeated after shifting the interferer by 1 MHz.

This test is specified for all PHYs:

C/I and receiver selectivity and PHYs	
PHY	**Test number**
LE 1M	03
LE 2M	09
LE 1M, SMI	15
LE 2M, SMI	21
LE Coded, S=2	28
LE Coded, S=8	29
LE Coded, S=2, SMI	34
LE Coded, S=8, SMI	35

Table 6-4: Various tests for C/I and receiver selectivity

Test setup:

The test setup in Figure 6-37 consists of two signal generators, the signals from which are fed to the DUT as a sum signal via a power combiner. Generator #1 generates a continuously modulated (not pulsed) BLE interferer with PRBS15. Generator #2 delivers the BLE wanted signal with PRBS9. Two isolators are used to ensure that the two signals do not influence each other. The level values L_i (interferer) and L_{ws} (wanted signal) are set according to Table 6-5, Table 6-6 and Table 6-7 depending on the tests performed. The additional attenuation value L_a caused by the cable, isolator and power combiner must be taken into account when setting the level.
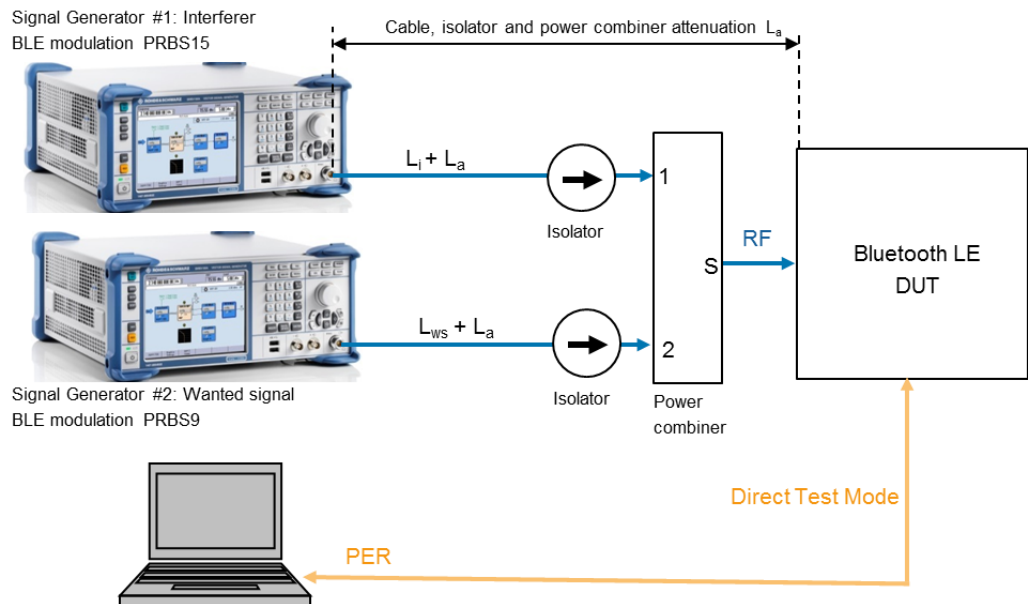
Figure 6-37: Test setup measuring C/I and receiver selectivity performance

C/I LE level settings for tests 03, 09, 15, 21			
Interference signal frequency	**Interferer (abs), L_i**	**C/I**	**Wanted signal (abs), L_{ws}**
Co-channel ($f_{RX} = f_{Interference}$)	–88 dBm	21 dB	–67 dBm
Adjacent channel ($f_{Interference} = f_{RX} \pm 1$ MHz)	–82 dBm	15 dB	–67 dBm
Adjacent channel ($f_{Interference} = f_{RX} \pm 2$ MHz)	–50 dBm	–17 dB	–67 dBm
Adjacent channel ($f_{Interference} = f_{RX} \pm (3 + n)$ MHz) n = 0, 1, 2, 3… (2400 MHz ≤ $f_{Interference}$ ≤ 2483 MHz)	–40 dBm	–27 dB	–67 dBm
Image frequency ($f_{Interference} = f_{Image}$)	–58 dBm	–9 dB	–67 dBm
Adjacent channel to image frequency ($f_{Interference} = f_{Image} \pm 1$ MHz)	–52 dBm	–15 dB	–67 dBm

Table 6-5: C/I and receiver selectivity test parameter settings

C/I LE level settings for tests 28, 34			
Interference signal frequency	**Interferer (abs), L_i**	**C/I**	**Wanted signal (abs), L_{ws}**
Co-channel ($f_{RX} = f_{Interference}$)	–89 dBm	17 dB	–72 dBm
Adjacent channel ($f_{Interference} = f_{RX} \pm 1$ MHz)	–83 dBm	11 dB	–72 dBm
Adjacent channel ($f_{Interference} = f_{RX} \pm 2$ MHz)	–51 dBm	–21 dB	–72 dBm
Adjacent channel ($f_{Interference} = f_{RX} \pm (3 + n)$ MHz) n = 0, 1, 2, 3… (2400 MHz ≤ $f_{Interference}$ ≤ 2483 MHz)	–41 dBm	–31 dB	–72 dBm
Image frequency ($f_{Interference} = f_{Image}$)	–59 dBm	–13 dB	–72 dBm
Adjacent channel to image frequency ($f_{Interference} = f_{Image} \pm 1$ MHz)	–53 dBm	–19 dB	–72 dBm

Table 6-6: C/I and receiver selectivity test parameter settings for LE Coded S=2

C/I LE level settings for tests 29, 35			
Interference signal frequency	Interferer (abs), L_i	C/I	Wanted signal (abs), L_{ws}
Co-channel ($f_{RX} = f_{Interference}$)	–91 dBm	12 dB	–79 dBm
Adjacent channel ($f_{Interference} = f_{RX} \pm 1$ MHz)	–85 dBm	6 dB	–79 dBm
Adjacent channel ($f_{Interference} = f_{RX} \pm 2$ MHz)	–53 dBm	–26 dB	–79 dBm
Adjacent channel ($f_{Interference} = f_{RX} \pm (3 + n)$ MHz) n = 0, 1, 2, 3… (2400 MHz ≤ $f_{Interference}$ ≤ 2483 MHz)	–43 dBm	–36 dB	–79 dBm
Image frequency ($f_{Interference} = f_{Image}$)	–61 dBm	–18 dB	–79 dBm
Adjacent channel to image frequency ($f_{Interference} = f_{Image} \pm 1$ MHz)	–55 dBm	–24 dB	–79 dBm

Table 6-7: C/I and receiver selectivity test parameter settings for LE Coded S=8

6.2.2.1 C/I and Receiver Selectivity Performance Test 03, Uncoded Data at 1 Ms/s

This test checks the behavior of a BLE receiver in the presence of a Bluetooth interferer with uncoded data and a 1 Ms/s data rate. The interferer is transmitted on the receive frequency or in the adjacent channel. The image frequency suppression of the receiver is also tested.

Settings on DUT:

1. Switch on Direct RX mode. Switch off dewhitening.

2. Switch off frequency hopping.

3. Set the symbol rate to 1 Ms/s.

4. Configure the receiver so that a transmitter with a standard modulation index is expected.

5. Set the receive frequency.

    Tables 6.1 and 6.2 in 6.2 *Frequencies for Testing* of the Bluetooth test specification specify the DUT's transmit and receive frequencies for the different test cases and device types. The C/I and receiver selectivity performance test is performed for all three RX frequencies: f_{RX} (low), f_{RX} (middle) and f_{RX} (highest).

Settings on signal generator #2 (SMBV100A): wanted signal

6. Press the *PRESET* key.

7. Press the *MENU* key and select *Bluetooth* from the list:
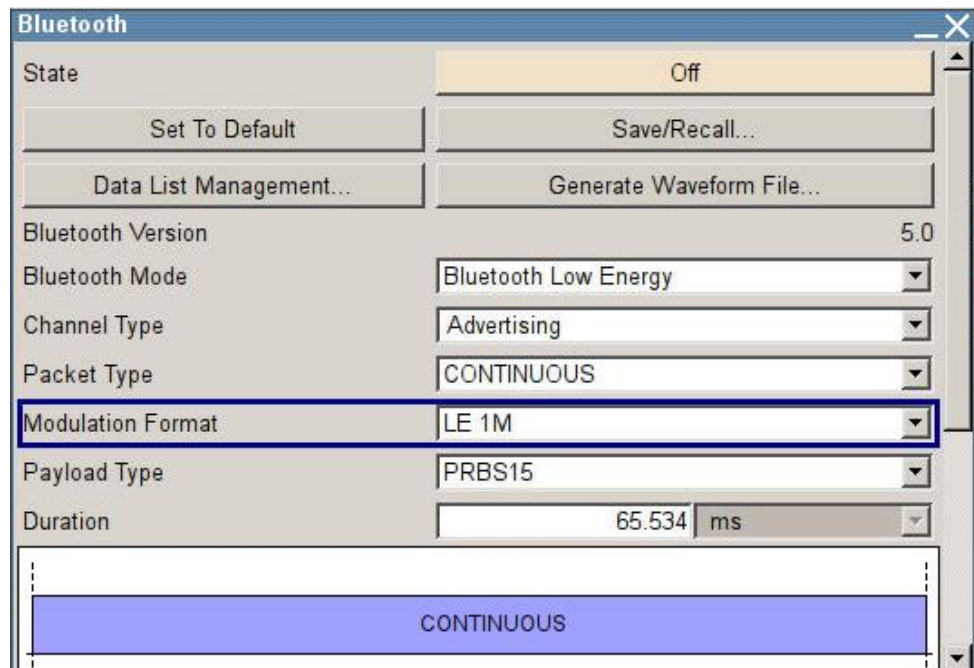
8. Configure the settings as shown in Figure 6-38. The *Sequence Length* must be at least 1500.
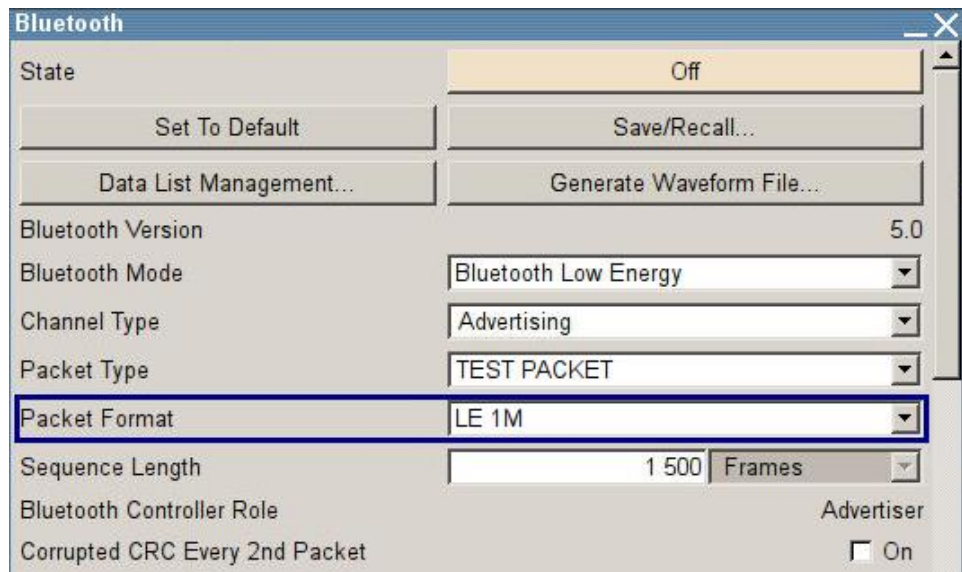
Figure 6-38: Generator settings for the wanted signal

9. In the Bluetooth window (Figure 6-38), scroll down with the ⇩ arrow key and select *Test Packet Configuration…*:
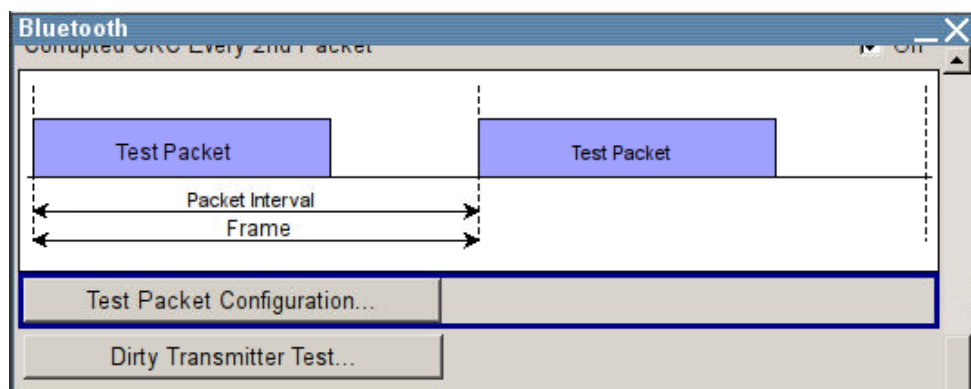
10. Make sure that **PRBS9** is selected as the payload type. If the DUT supports the "Extended Packet Length" feature (in line with core specification 4.2), then **Payload Length** must be set to the maximum possible packet length supported by the DUT. If "Extended Packet Length" is not supported, *Payload Length* must be set to 37 bytes:
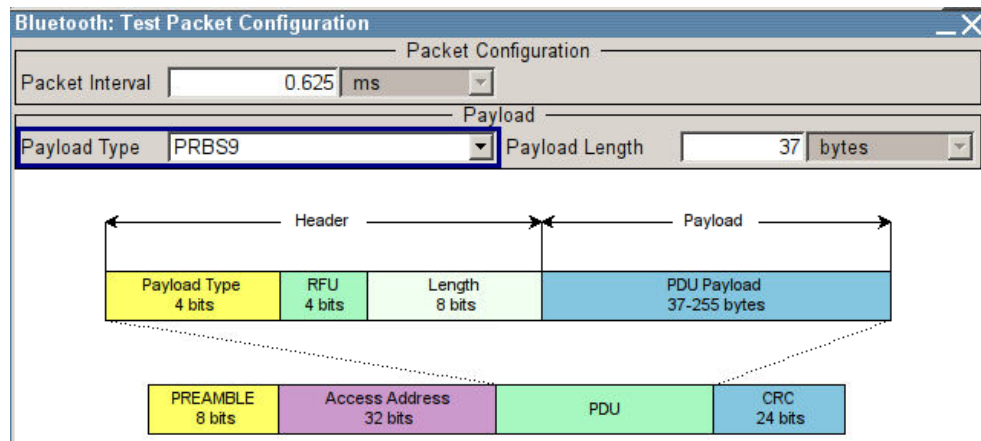
Figure 6-39: Test packet configuration

11. Close the "Test Packet Configuration" window.

12. Press the *FREQ* key and, for the first test run, enter the frequency value for f_{RX} (low) as described under 6.2 *Frequencies for Testing* in the test specification. For the second and third test runs, enter f_{RX} (middle) and f_{RX} (highest).

13. Press the *LEVEL* key and enter the value –67 dBm + L_a (see also Table 6-5 and Figure 6-37).

14. Start the calculation of the Bluetooth test signal with *State* = On. After the calculation, press the *RF ON/OFF* key to switch on the Bluetooth RF signal.

Settings on signal generator #1 (SMBV100A): interferer

15. Press the *PRESET* key.

16. Press the *MENU* key and select *Bluetooth* from the list:

17. Configure the settings as shown in Figure 6-40.

Figure 6-40: Generator settings for the interferer

18. Start the calculation of the Bluetooth test signal with *State* = On. After the calculation, press the *RF ON/OFF* key to switch on the Bluetooth RF signal.

19. $f_{interfer}$ = 2400 MHz.

20. Use the FREQ key and LEVEL key to enter the frequency and level values specified in Table 6-5 one after the other and determine the associated PER. (See also TIP below.)

    Note: The manufacturer of the BLE receiver specifies f_{Image} in Table 6-5 for the currently used symbol rate.

The following conditions apply:

∎ PER < 30.8 % (for Payload Length = 37 bytes and at least 1500 packets). For other payload lengths, the PER limit is given in Table 6.4: *PER level by maximum payload length in receiver* of the test specification.

   In the case of signal-to-interference ratios ≥ ±2 MHz in the 2400 MHz to 2483 MHz frequency band, the specified PER limit is allowed to be exceeded five times. Record the frequencies for these values. If more than five frequencies fail to fulfill this condition, the DUT has not passed the test and the test can be terminated immediately. For all recorded frequencies (≤ 5), repeat the test as follows:

21. On signal generator #1, set the level of the interferer to –50 dBm + L_a (corresponds to C/I = –17 dB).

The following condition must be fulfilled:
PER < 30.8 % (for Payload Length = 37 bytes and at least 1500 packets). For other payload lengths, the PER limit is given in Table 6.4: *PER level by maximum payload length in receiver* of the test specification.

22. Repeat the measurement procedure from step 20 onward with $f_{interfer}$ = 2400 MHz + N MHz, where N = 1, 2, 3 to 83.

23. Repeat the entire measurement procedure (starting with step 1) for f_{RX} (middle) and f_{RX} (highest).

☞ TIP: For the frequency change, it is possible to define the required step size on the SMBV100A. This makes manual setting of the frequencies much easier. To do so, proceed as follows:

1. Press the *MENU* key and select *RF/A Mod* from the list.

2. Select *Frequency / Phase…* from the list.

3. Under *Variation Step,* enter the step size and activate. In this case, a step size of 1 MHz is recommended:

4. The frequency can now be changed easily in 1 MHz steps using the ⇧⇩ arrow keys or the rotary knob.

6.2.2.2 C/I and Receiver Selectivity Performance Test 09, Uncoded Data at 2 Ms/s

This test checks the behavior of a BLE receiver in the presence of a Bluetooth interferer with uncoded data and a 2 Ms/s data rate. The interferer is transmitted at the receive frequency or in the adjacent channel. The image frequency suppression of the receiver is also tested.

Settings on DUT:

1. Switch on Direct RX mode. Switch off dewhitening.

2. Switch off frequency hopping.

3. Set the symbol rate to 1 Ms/s.

4. Configure the receiver so that a transmitter with a standard modulation index is expected.

5. Set the receive frequency.

    Tables 6.1 and 6.2 in 6.2 *Frequencies for Testing* of the Bluetooth test specification specify the DUT's transmit and receive frequencies for the different test cases and device types. The C/I and receiver selectivity performance test is performed for all three RX frequencies: f_{RX} (low), f_{RX} (middle) and f_{RX} (highest).

Settings on signal generator #2 (SMBV100A): wanted signal

6. Press the *PRESET* key.

7. Press the *MENU* key and select *Bluetooth* from the list:
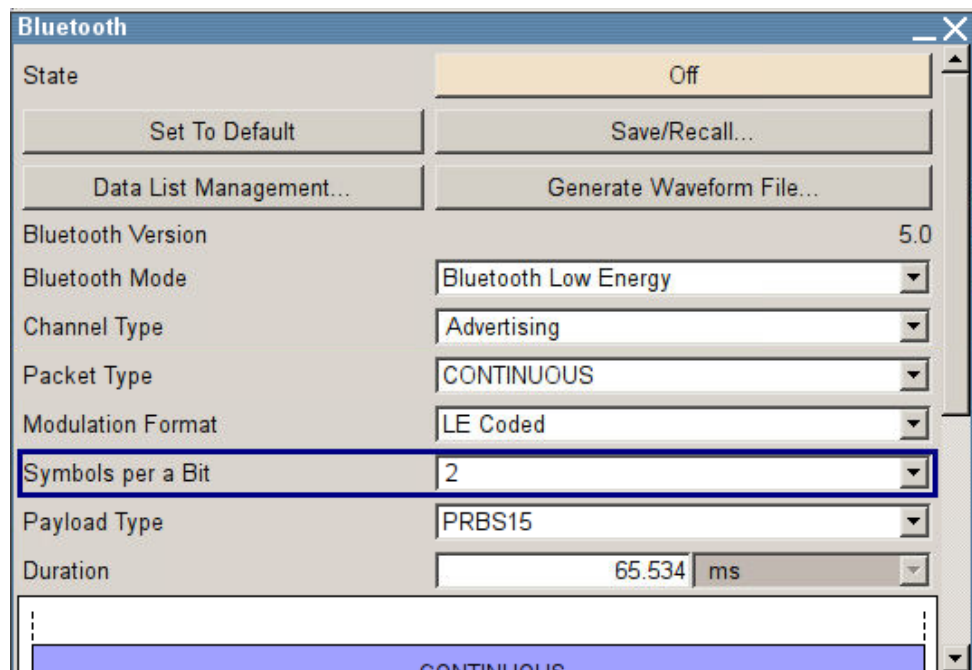

8. Configure the settings as shown in Figure 6-41. The *Sequence Length* must be at least 1500.
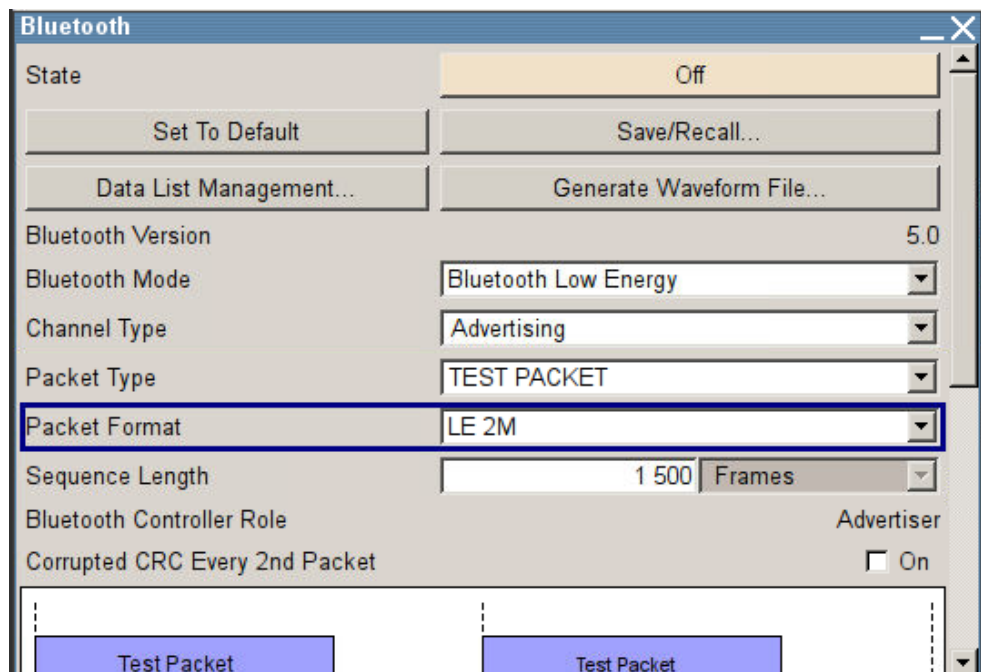
Figure 6-41: Generator settings for the wanted signal

9. In the Bluetooth window (Figure 6-41), scroll down with the ⇩ arrow key and select *Test Packet Configuration…*:
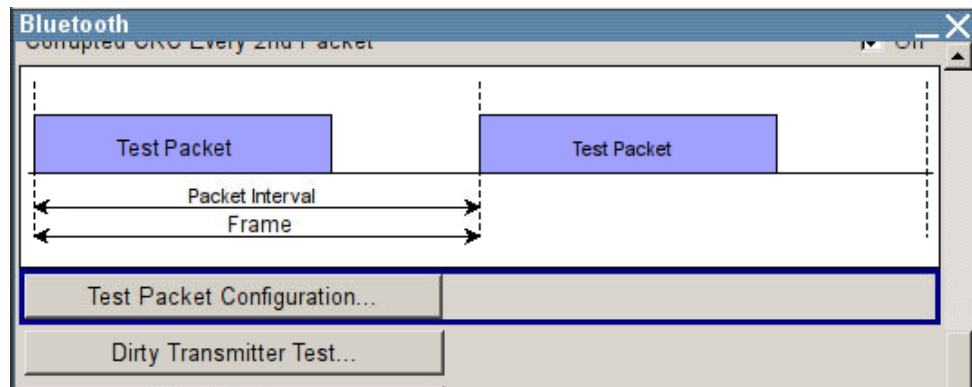
10. Make sure that **PRBS9** is selected as the payload type. If the DUT supports the "Extended Packet Length" feature (in line with core specification 4.2), then **Payload Length** must be set to the maximum possible packet length supported by the DUT. If "Extended Packet Length" is not supported, *Payload Length* must be set to 37 bytes:
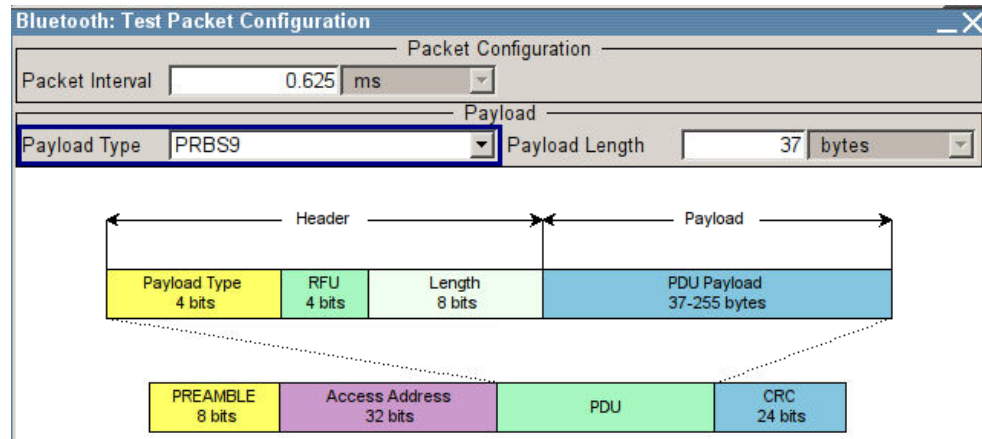
Figure 6-42: Test packet configuration

11. Close the "Test Packet Configuration" window.

12. Press the *FREQ* key and, for the first test run, enter the frequency value for f_{RX} (low) as describes desd under 6.2 *Frequencies for Testing* in the test specification. For the second and third test runs, enter f_{RX} (middle) and f_{RX} (highest).

13. Press the *LEVEL* key and enter the value –67 dBm + L_a (see also Table 6-5 and Figure 6-37).

14. Start the calculation of the Bluetooth test signal with *State* = On. After the calculation, press the *RF ON/OFF* key to switch on the Bluetooth RF signal.

Settings on signal generator #1 (SMBV100A): interferer

15. Press the *PRESET* key.

16. Press the *MENU* key and select *Bluetooth* from the list:
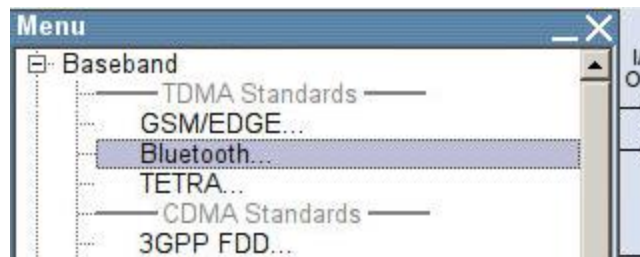
17. Configure the settings as shown in Figure 6-44.

Figure 6-43: Generator settings for the interferer

18. Start the calculation of the Bluetooth test signal with *State* = On. After the calculation, press the *RF ON/OFF* key to switch on the Bluetooth RF signal.

19. $f_{interfer}$ = 2400 MHz.

20. Use the FREQ key and LEVEL key to enter the frequency and level values specified in Table 6-5 one after the other and determine the associated PER. (See also TIP below.)

Note: The manufacturer of the BLE receiver specifies f_{Image} in Table 6-5 for the currently used symbol rate.

The following conditions apply:

ı PER < 30.8 % (for Payload Length = 37 bytes and at least 1500 packets). For other payload lengths, the PER limit is given in Table 6.4: *PER level by maximum payload length in receiver* of the test specification.

ı In the case of the signal-to-interference ratios ±4 MHz, ±6 MHz, ±8 MHz, etc. in the 2400 MHz to 2483 MHz frequency band, the specified PER limit is allowed to be exceeded five times. Record the frequencies for these values. If more than five frequencies fail to fulfill this condition, the DUT has not passed the test and the test can be terminated immediately.

For all recorded frequencies (≤ 5), repeat the test as follows:

21. On signal generator #1, set the level of the interferer to

   –50 dBm + L_a (corresponds to C/I = –17 dB).

The following condition must be fulfilled:

ı PER < 30.8 % (for Payload Length = 37 bytes and at least 1500 packets). For other payload lengths, the PER limit is given in Table 6.4: *PER level by maximum payload length in receiver* of the test specification.

22. Repeat the procedure from step 20 onward with $f_{interfer}$ = 2400 MHz + 2N MHz, where N = 1, 2, 3 to 41.

23. Repeat the entire measurement procedure (starting with step 1) for f_{RX} (middle) and f_{RX} (highest).

☞ TIP: For the frequency change, it is possible to define the required step size on the SMBV100A. This makes manual setting of the frequencies much easier. To do so, proceed as follows:

1. Press the *MENU* key and select *RF/A Mod* from the list.

2. Select *Frequency / Phase…* from the list.

3. Under *Variation Step*, enter the step size and activate. In this case, a step size of 1 MHz is recommended:

4. The frequency can now be changed easily in 1 MHz steps using the ⇧⇩ arrow keys or the rotary knob.

6.2.2.3 C/I and Receiver Sensitivity Performance Test 15, Uncoded Data at 1 Ms/s, Stable Modulation Index

This test checks the behavior of a BLE receiver in the presence of a Bluetooth interferer with uncoded data and a 1 Ms/s data rate. Here, the receiver expects a transmitter with a stable modulation index. The interferer is transmitted at the receive frequency or in the adjacent channel. The image frequency suppression of the receiver is also tested.

Settings on DUT:

▪ As described under 6.2.2.1, but configure the DUT so that a transmitter with a stable modulation index is expected.

Settings on signal generator #2 (SMBV100A): wanted signal

▪ As described under 6.2.2.1.

Settings on signal generator #1 (SMBV100A): interferer

▪ As described under 6.2.2.1.

6.2.2.4 C/I and Receiver Sensitivity Performance Test 21, Uncoded Data at 2 Ms/s, Stable Modulation Index

This test checks the behavior of a BLE receiver in the presence of a Bluetooth interferer with uncoded data and a 2 Ms/s data rate. Here, the receiver expects a transmitter with a stable modulation index. The interferer is transmitted at the receive frequency or in the adjacent channel. The image frequency suppression of the receiver is also tested.

Settings on DUT:

▪ As described under 6.2.2.2, but configure the DUT so that a transmitter with a stable modulation index is expected.

Settings on signal generator #2 (SMBV100A): wanted signal

▪ As described under 6.2.2.2.

Settings on signal generator #1 (SMBV100A): interferer

▪ As described under 6.2.2.2.

6.2.2.5 C/I and Receiver Selectivity Performance Test 28, LE Coded (S=2)

This test checks the behavior of a BLE receiver in the presence of a Bluetooth interferer when an LE Coded signal with S=2 is received. The interferer is transmitted

at the receive frequency or in the adjacent channel. The image frequency suppression of the receiver is also tested.

Settings on DUT:

1. Switch on Direct RX mode. Switch off dewhitening.

2. Switch off frequency hopping.

3. Configure to receive LE Coded PHY with data coding S=2 and a bit rate of 500 kB/s.

4. Configure the receiver so that a transmitter with a standard modulation index is expected.

5. Set the receive frequency.

   Tables 6.1 and 6.2 in 6.2 *Frequencies for Testing* of the Bluetooth test specification specify the DUT's transmit and receive frequencies for the different test cases and device types. The C/I and receiver selectivity performance test is performed for all three RX frequencies: f_{RX} (low), f_{RX} (middle) and f_{RX} (highest).

Settings on signal generator #2 (SMBV100A): wanted signal

6. Press the *PRESET* key.

7. Press the *MENU* key and select *Bluetooth* from the list:
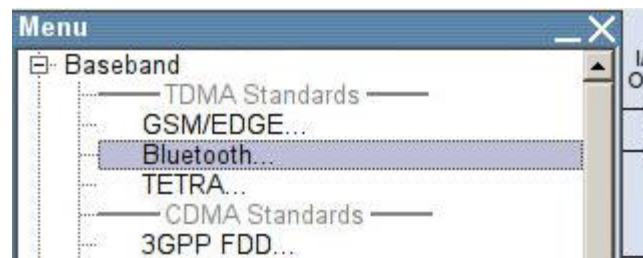

8. Configure the settings as shown in Figure 6-44. The *Sequence Length* must be at least 1500.
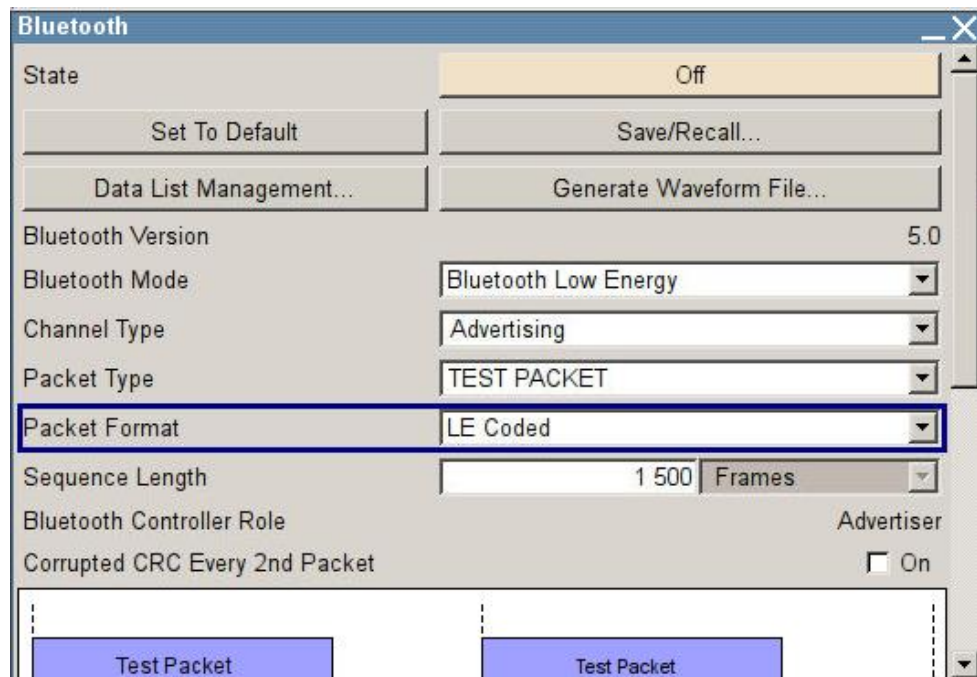
Figure 6-44: Generator settings for the wanted signal

9. In the Bluetooth window (Figure 6-44), scroll down with the ⇩ arrow key and select *Test Packet Configuration…*:
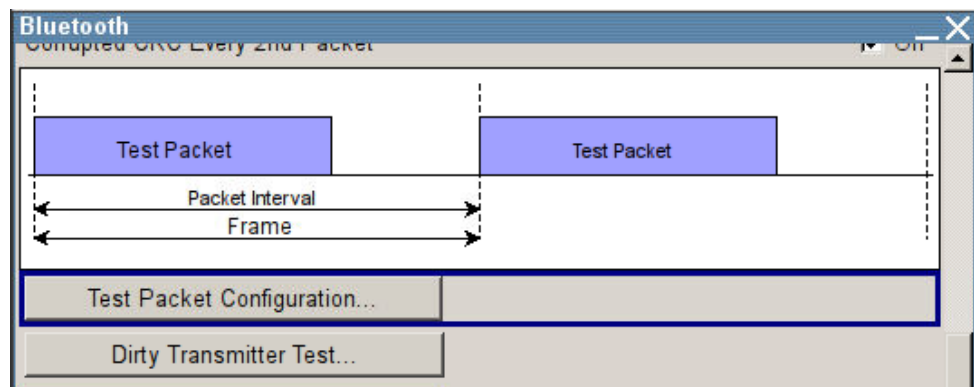
10. Set *Symbols per a Bit* to 2 and make sure that **PRBS9** is selected as the payload type. If the DUT supports the "Extended Packet Length" feature (in line with core specification 4.2), then **Payload Length** must be set to the maximum possible packet length supported by the DUT. If "Extended Packet Length" is not supported, *Payload Length* must be set to 37 bytes:
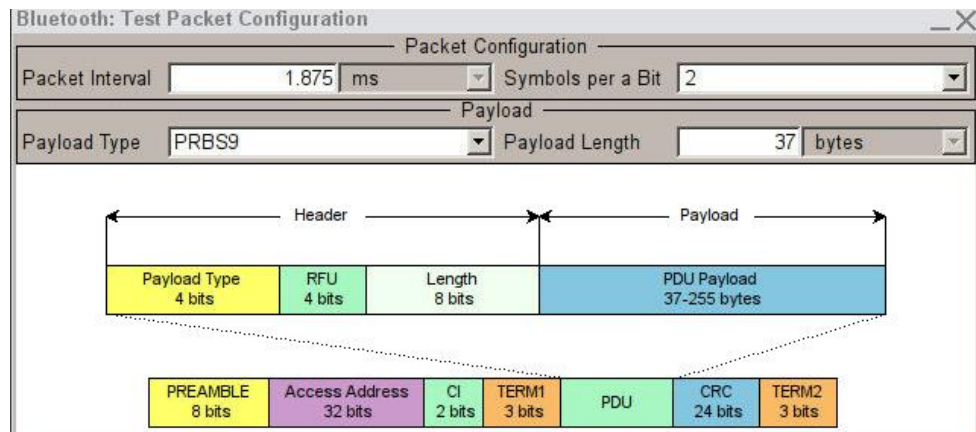
Figure 6-45: Test packet configuration

11. Close the "Test Packet Configuration" window.

12. Press the *FREQ* key and, for the first test run, enter the frequency value for f_{RX} (low) as described under 6.2 *Frequencies for Testing* in the test specification. For the second and third test runs, enter f_{RX} (middle) and f_{RX} (highest).

13. Press the *LEVEL* key and enter the value –72 dBm + L_a (see also Table 6-6 and Figure 6-37).

14. Start the calculation of the Bluetooth test signal with *State* = On. After the calculation, press the *RF ON/OFF* key to switch on the Bluetooth RF signal.

Settings on signal generator #1 (SMBV100A): interferer

15. Press the *PRESET* key.

16. Press the *MENU* key and select *Bluetooth* from the list:
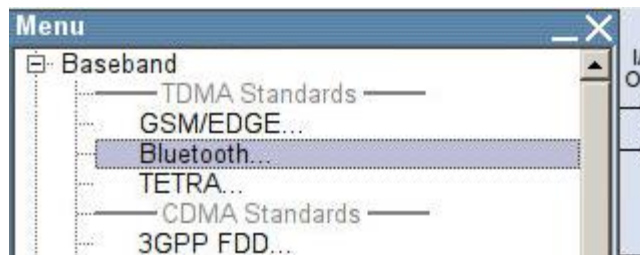
17. Configure the settings as shown in Figure 6-46.
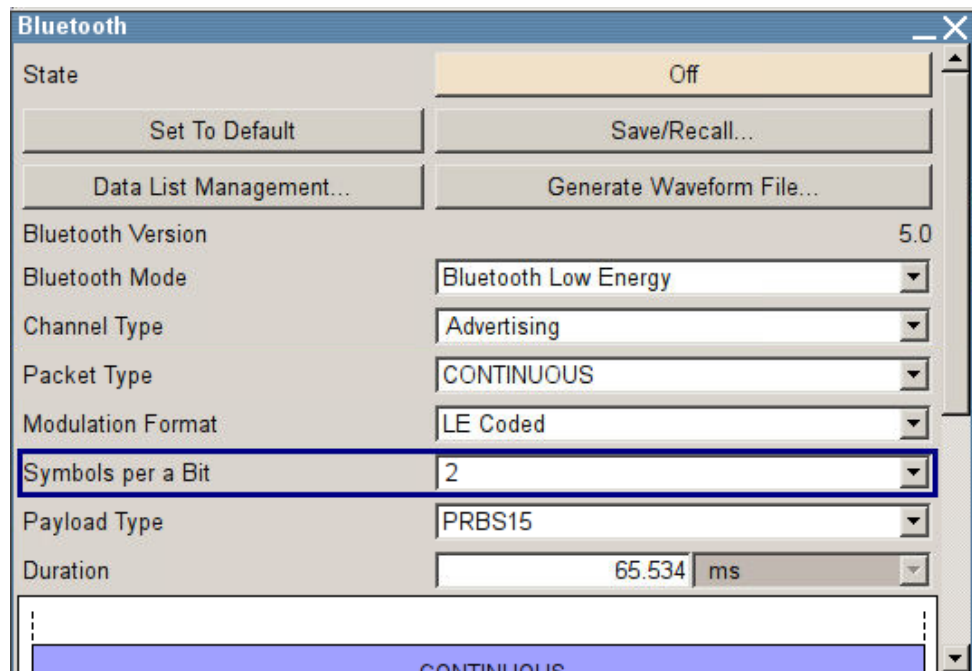
Figure 6-46: Generator settings for the interferer

18. Start the calculation of the Bluetooth test signal with *State* = On. After the calculation, press the *RF ON/OFF* key to switch on the Bluetooth RF signal.

19. $f_{interfer}$ = 2400 MHz.

20. Use the FREQ key and LEVEL key to enter the frequency and level values specified in Table 6-6 and determine the associated PER. (See also TIP below.)

    Note: The manufacturer of the BLE receiver specifies f_{Image} in Table 6-6 for the currently used symbol rate.

The following conditions apply:

ı   PER < 30.8 % (for Payload Length = 37 bytes and at least 1500 packets). For other payload lengths, the PER limit is given in Table 6.4: *PER level by maximum payload length in receiver* of the test specification.

    In the case of signal-to-interference ratios ≥ ±2 MHz in the 2400 MHz to 2483 MHz frequency band, the specified PER limit is allowed to be exceeded five times. For these values, record the associated frequency. If more than five frequencies fail to fulfill this condition, the DUT has not passed the test and the test can be terminated immediately.

For all recorded frequencies (≤ 5), repeat the test as follows:

21. On signal generator #1, set the level of the interferer to –55 dBm + L_a (corresponds to C/I = –17 dB).

The following condition must be fulfilled:

▪ PER < 30.8 % (for Payload Length = 37 bytes and at least 1500 packets). For other payload lengths, the PER limit is given in Table 6.4: *PER level by maximum payload length in receiver* of the test specification.

22. Repeat the procedure from step 20 onward with $f_{interfer}$ = 2400 MHz + N MHz, where N = 1, 2, 3 to 83.

23. Repeat the entire measurement procedure (starting with step 1) for f_{RX} (middle) and f_{RX} (highest).

☞ TIP: For the frequency change, it is possible to define the required step size on the SMBV100A. This makes manual setting of the frequencies much easier. To do so, proceed as follows:

1. Press the *MENU* key and select *RF/A Mod* from the list.

2. Select *Frequency / Phase…* from the list.

3. Under *Variation Step*, enter the step size and activate. In this case, a step size of 1 MHz is recommended:

4. The frequency can now be changed easily in 1 MHz steps using the ⇧⇩ arrow keys or the rotary knob.

6.2.2.6 C/I and Receiver Selectivity Performance Test 29, LE Coded (S=8)

This test checks the behavior of a BLE receiver in the presence of a Bluetooth interferer when an LE Coded signal with S=8 is received. The interferer is transmitted at the receive frequency or in the adjacent channel. The image frequency suppression of the receiver is also tested.

Settings on DUT:

1. Switch on Direct RX mode. Switch off dewhitening.

2. Switch off frequency hopping.

3. Configure to receive LE Coded PHY with data coding S=8 and a bit rate of 125 kB/s.

4. Configure the receiver so that a transmitter with a standard modulation index is expected.

5. Set the receive frequency.

    Tables 6.1 and 6.2 in 6.2 *Frequencies for Testing* of the Bluetooth test specification specify the DUT's transmit and receive frequencies for the different test cases and device types. The C/I and receiver selectivity performance test is performed for all three RX frequencies: f_{RX} (low), f_{RX} (middle) and f_{RX} (highest).

6. Settings on signal generator #2 (SMBV100A): wanted signal

7. Press the *PRESET* key.

8. Press the *MENU* key and select *Bluetooth* from the list:
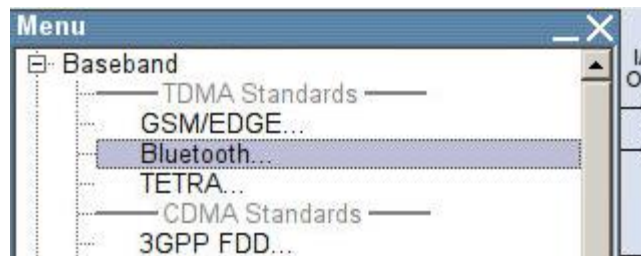
9. Configure the settings as shown in Figure 6-47. The *Sequence Length* must be at least 1500.
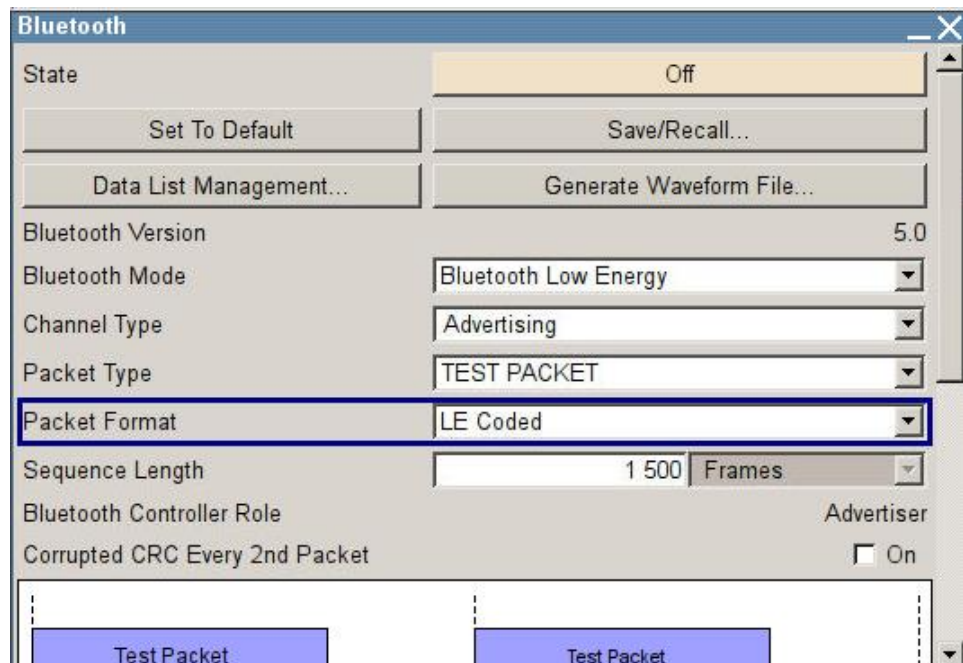
    Figure 6-47: Generator settings for the wanted signal

10. In the Bluetooth window (Figure 6-44), scroll down with the ⇩ arrow key and select *Test Packet Configuration…*:
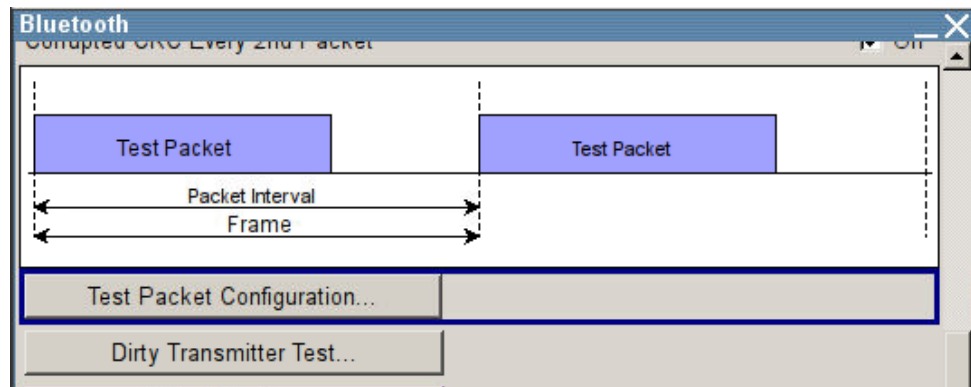
11. Set *Symbols per a Bit* to 8 and make sure that **PRBS9** is selected as the payload type. If the DUT supports the "Extended Packet Length" feature (in line with core specification 4.2), then **Payload Length** must be set to the maximum possible packet length supported by the DUT. If "Extended Packet Length" is not supported, *Payload Length* must be set to 37 bytes:
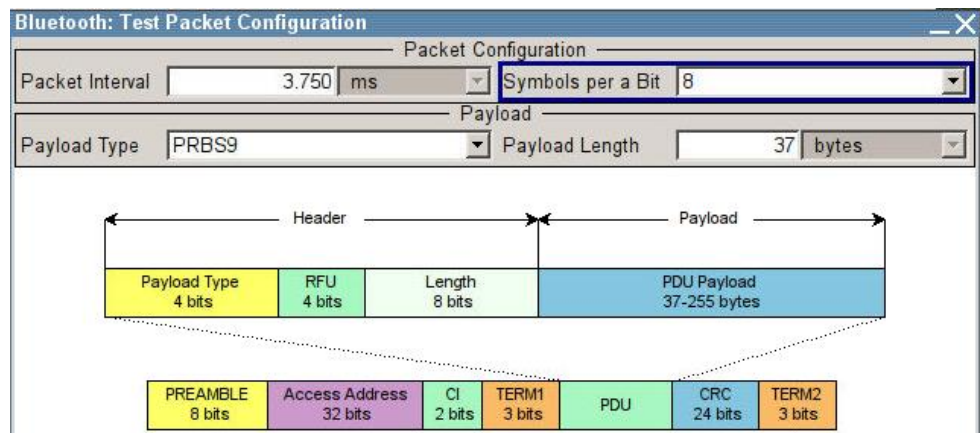

Figure 6-48: Test packet configuration

12. Close the "Test Packet Configuration" window.

13. Press the *FREQ* key and, for the first test run, enter the frequency value for f_{RX} (low) as described under 6.2 *Frequencies for Testing* in the test specification. For the second and third test runs, enter f_{RX} (middle) and f_{RX} (highest).

14. Press the *LEVEL* key and enter the value –79 dBm + L_a (see also Table 6-7 and Figure 6-37).

15. Start the calculation of the Bluetooth test signal with *State* = On. After the calculation, press the *RF ON/OFF* key to switch on the Bluetooth RF signal.

Settings on signal generator #1 (SMBV100A): interferer

16. Press the *PRESET* key.

17. Press the *MENU* key and select *Bluetooth* from the list:
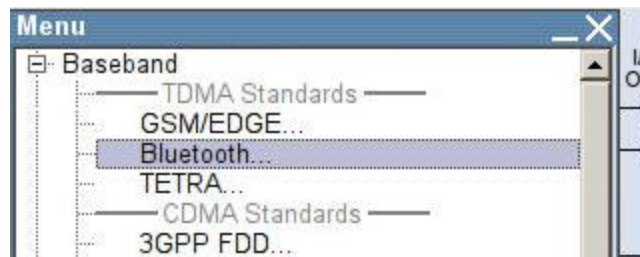
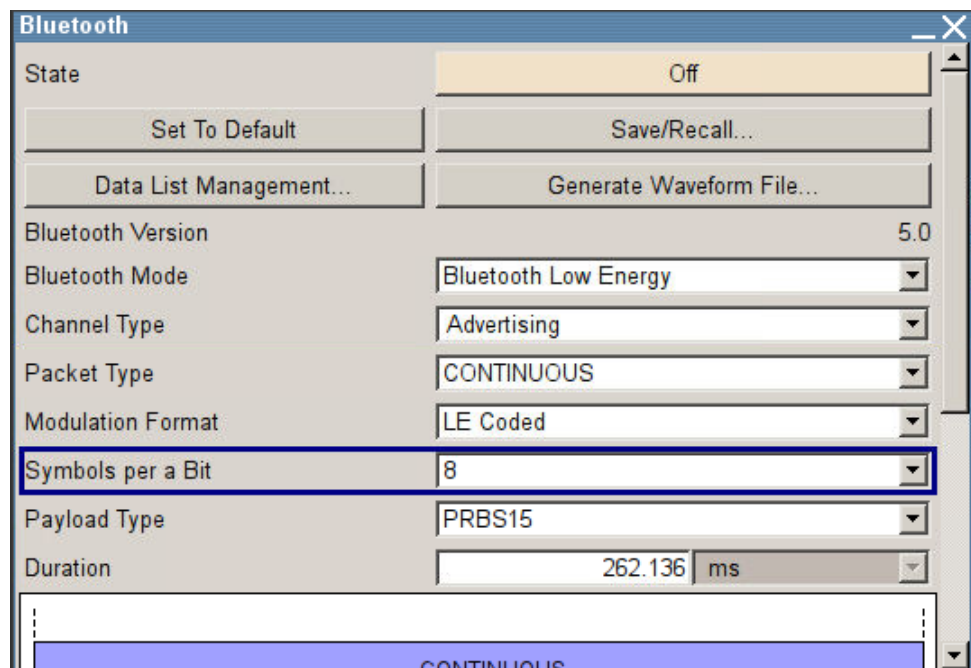18. Configure the settings as shown in Figure 6-49.

Figure 6-49: Generator settings for the interferer

19. Start the calculation of the Bluetooth test signal with *State* = On. After the calculation, press the *RF ON/OFF* key to switch on the Bluetooth RF signal.

20. $f_{interfer}$ = 2400 MHz.

21. Use the FREQ key and LEVEL key to enter the frequency and level values specified in Table 6-7 and LEVEL key, and determine the associated PER. (See also TIP below.)

Note: The manufacturer of the BLE receiver specifies f_{Image} in Table 6-7 for the currently used symbol rate.
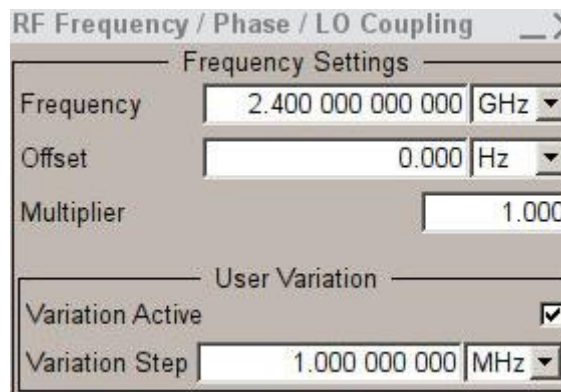
The following conditions apply:

ι PER < 30.8 % (for Payload Length = 37 bytes and at least 1500 packets). For other payload lengths, the PER limit is given in Table 6.4: *PER level by maximum payload length in receiver* of the test specification.

In the case of signal-to-interference ratios ≥ ±2 MHz in the 2400 MHz to 2483 MHz frequency band, the specified PER limit is allowed to be exceeded five times. For these values, record the associated frequency. If more than five frequencies fail to fulfill this condition, the DUT has not passed the test and the test can be terminated immediately.

For all recorded frequencies (≤ 5), repeat the test as follows:

22. On signal generator #1, set the level of the interferer to –62 dBm + L_a (corresponds to C/I = –17 dB).

The following condition must be fulfilled:

ι PER < 30.8 % (for Payload Length = 37 bytes and at least 1500 packets). For other payload lengths, the PER limit is given in Table 6.4: *PER level by maximum payload length in receiver* of the test specification.

23. Repeat the procedure from step 22 onward with $f_{interfer}$ = 2400 MHz + N MHz, where N = 1, 2, 3 to 83.

24. Repeat the entire measurement procedure (starting with step 1) for f_{RX} (middle) and f_{RX} (highest).

☞ TIP: For the frequency change, it is possible to define the required step size on the SMBV100A. This makes manual setting of the frequencies much easier. To do so, proceed as follows:

1. Press the *MENU* key and select *RF/A Mod* from the list.

2. Select *Frequency / Phase…* from the list.

3. Under *Variation Step*, enter the step size and activate. In this case, a step size of 1 MHz is recommended:

4. The frequency can now be changed easily in 1 MHz steps using the ⇧⇩ arrow keys or the rotary knob.

6.2.2.7 C/I and Receiver Selectivity Performance Test 34, LE Coded (S=2), Stable Modulation Index

This test checks the behavior of a BLE receiver in the presence of a Bluetooth interferer when an LE Coded signal with S=2 is received. Here, the receiver expects a transmitter with a stable modulation index. The interferer is transmitted at the receive frequency or in the adjacent channel. The image frequency suppression of the receiver is also tested.

Settings on DUT:

ı   As described in 6.2.2.5, but configure the receiver so that a transmitter with a stable modulation index is expected.

Settings on signal generator #2 (SMBV100A): wanted signal

ı   As described in 6.2.2.5.

Settings on signal generator #1 (SMBV100A): interferer

ı   As described in 6.2.2.5.

6.2.2.8 C/I and Receiver Selectivity Performance Test 34, LE Coded (S=8), Stable Modulation Index

This test checks the behavior of a BLE receiver in the presence of a Bluetooth interferer when an LE Coded signal with S=8 is received. Here, the receiver expects a transmitter with a stable modulation index. The interferer is transmitted at the receive frequency or in the adjacent channel. The image frequency suppression of the receiver is also tested.

Settings on DUT:

ı   As described in 6.2.2.6, but configure the receiver so that a transmitter with a stable modulation index is expected.

Settings on signal generator #2 (SMBV100A): wanted signal

ı   As described in 6.2.2.6.

Settings on signal generator #1 (SMBV100A): interferer

ı   As described in 6.2.2.6.

6.2.3 Blocking Performance

This test checks the behavior of the receiver under the influence of a non-Bluetooth signal. The interferer is an unmodulated signal (CW) and moves outside the Bluetooth frequency band (2400 MHz to 2483 MHz) with different frequency steps (frequency resolution). An interferer is set with specific levels and frequency spacing from the wanted Bluetooth signal. The PER is measured on the wanted signal. (Figure 6-50).
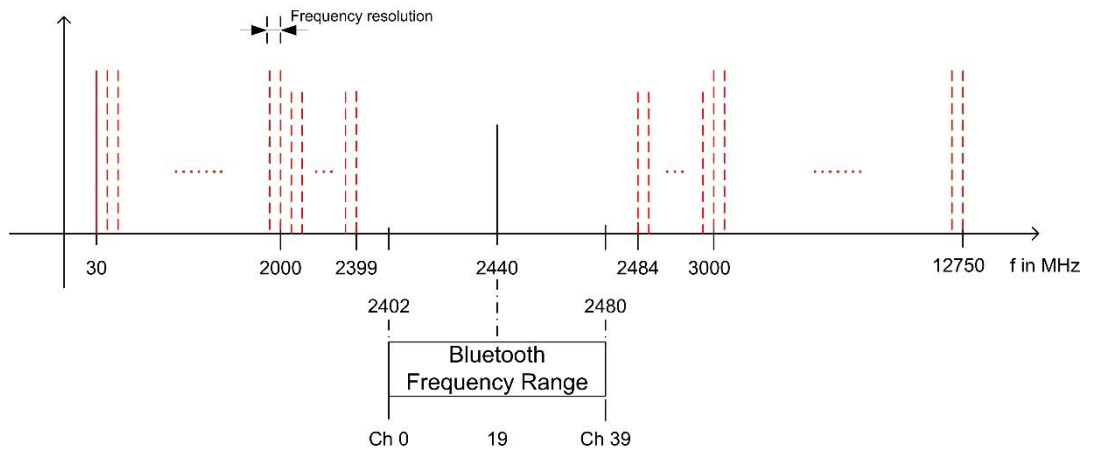
Figure 6-50: Blocking performance: For a wanted channel in the center of the band, the packet error rate is measured in the presence of a CW interference signal outside the Bluetooth frequency band.

This test is specified for the following PHYs:

Blocking and PHYs	
PHY	**Test number**
LE 1M	04
LE 2M	10
LE 1M, SMI	16
LE 2M, SMI	22

Table 6-8: Various tests for blocking

Test setup:

The test setup in Figure 6-51 consists of two signal generators, the signals from which are fed to the DUT as a sum signal via a power combiner. Generator #1 generates an unmodulated, sinewave interference signal outside the Bluetooth frequency band. The SGS100A signal generator used here is configured via a LAN or USB connection using a PC and the R&S SGMA GUI software. Generator #2 delivers the BLE wanted signal with PRBS9; the frequency of this signal is at the center of the Bluetooth frequency band. Two isolators are used to ensure that the two signals do not influence each other. Two runs with different parameters for the interferer are required for the test. The parameters are listed in Table 6-9 and Table 6-10. The additional attenuation value L_a caused by the cable, isolator and power combiner must be taken into account for all level settings.
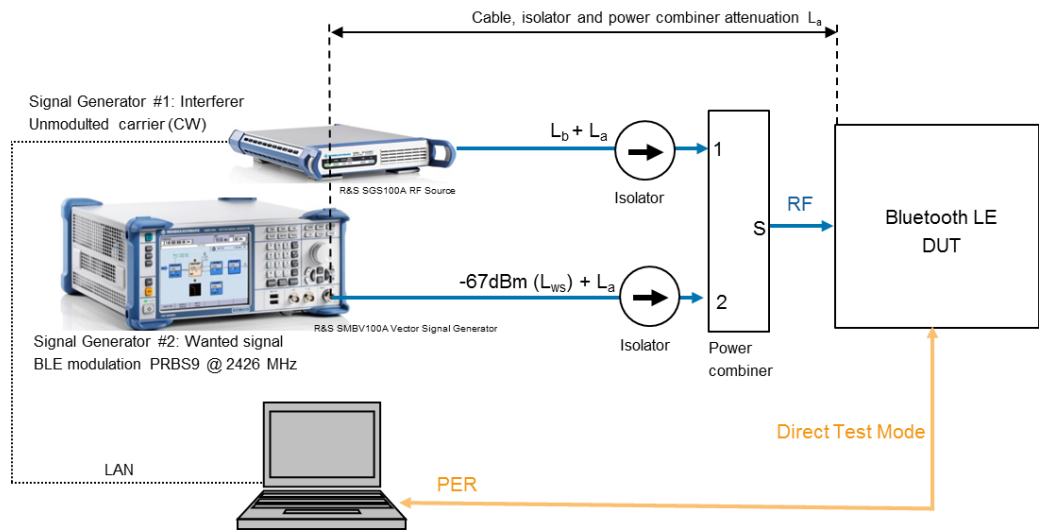
Figure 6-51: Test setup for blocking performance measurement

Blocking settings			
Interference signal frequency, f_i	Wanted signal level, L_{ws}	Blocking signal level, L_b	Frequency resolution, f_{res}
30 MHz to 2000 MHz	–67 dBm	–30 dBm	10 MHz
2003 MHz to 2399 MHz	–67 dBm	–35 dBm	3 MHz
2484 MHz to 2997 MHz	–67 dBm	–35 dBm	3 MHz
3000 MHz to 12.75 GHz	–67 dBm	–30 dBm	25 MHz

Table 6-9: Blocking performance parameters – 1st test run

Blocking settings			
Interference signal frequency, f_i	Wanted signal level, L_{ws}	Blocking signal level, L_b	Frequency resolution, f_{res}
30 MHz to 2000 MHz	–67 dBm	–50 dBm	10 MHz
2003 MHz to 2399 MHz	–67 dBm	–50 dBm	3 MHz
2484 MHz to 2997 MHz	–67 dBm	–50 dBm	3 MHz
3000 MHz to 12.75 GHz	–67 dBm	–50 dBm	25 MHz

Table 6-10: Blocking performance parameters – 2nd test run

6.2.3.1 Blocking Performance Test 04 (LE 1M, Uncoded Data at 1 Ms/s)

This test checks whether a BLE receiver operates satisfactorily in the presence of a CW interferer outside the Bluetooth frequency band when uncoded data with a symbol rate of 1 Ms/s is received.

Settings on DUT:

1.   Switch on Direct RX mode. Switch off dewhitening.

2.   Switch off frequency hopping.

3.   Set the symbol rate to 1 Ms/s.

4. Configure the DUT so that a transmitter with a standard modulation index is expected.

5. Settings on SMBV100A #2 (wanted signal):

6. Press the *PRESET* key.

7. Press the *MENU* key and select *Bluetooth* from the list:
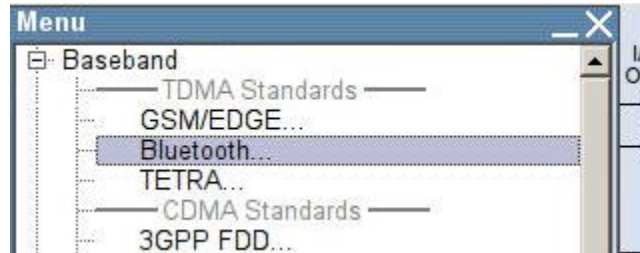
8. Configure the settings as shown in Figure 6-52. The *Sequence Length* must be at least 1500.
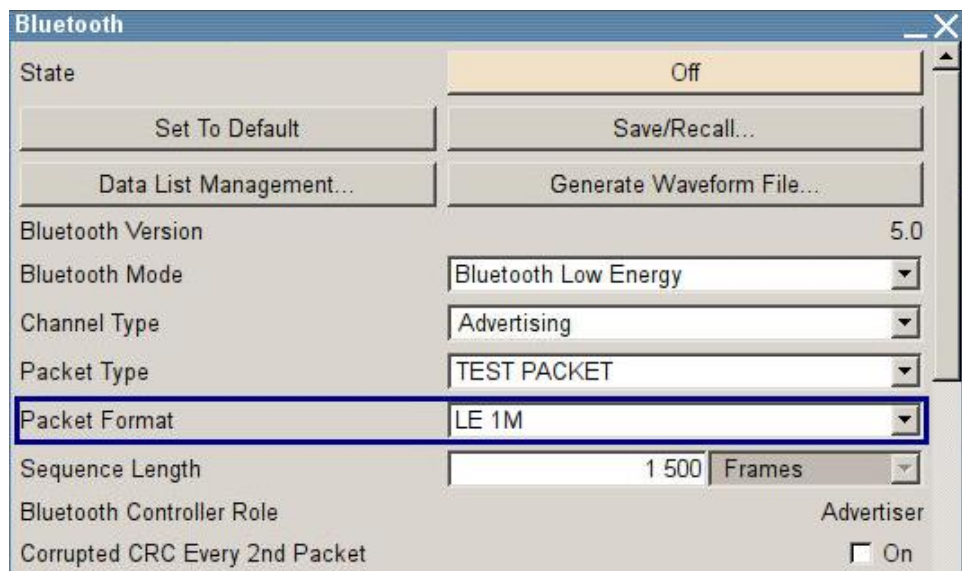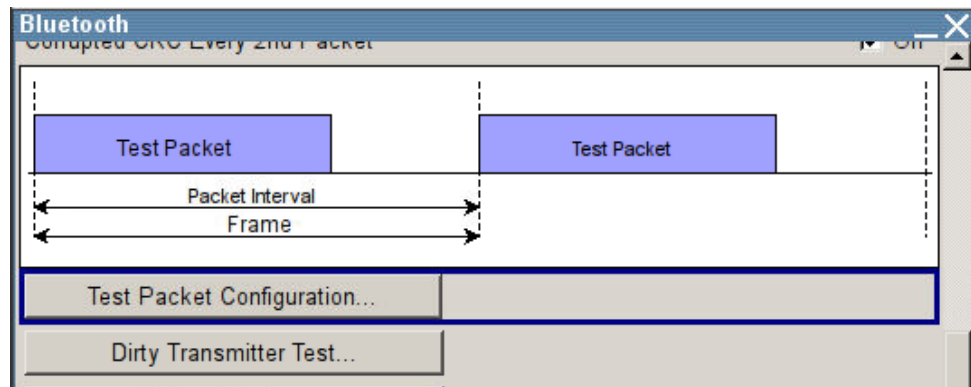

Figure 6-52: Generator settings for Maximum Input Level Test 04

9. In the Bluetooth window (Figure 6-52), scroll down with the ⇩ arrow key and select *Test Packet Configuration…*:

10. Make sure that **PRBS9** is selected as the payload type. If the DUT supports the "Extended Packet Length" feature (in line with core specification 4.2), then **Payload Length** must be set to the maximum possible packet length supported by the DUT. If "Extended Packet Length" is not supported, *Payload Length* must be set to 37 bytes:
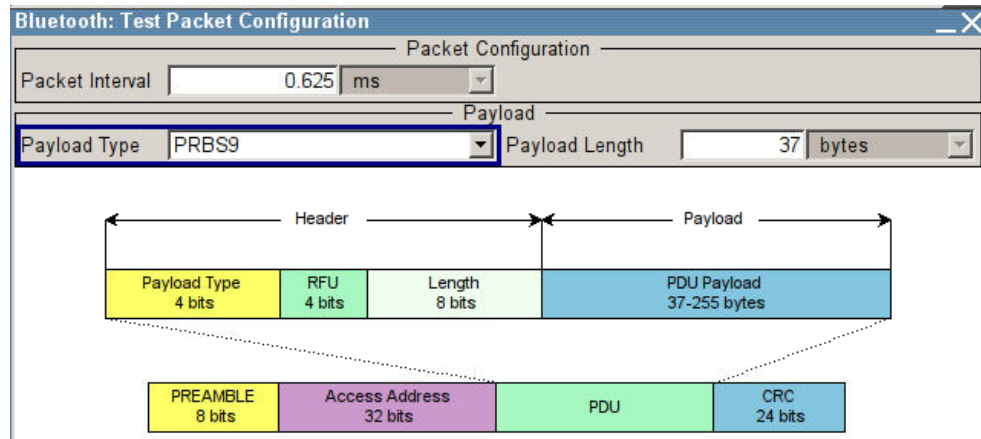
Figure 6-53: Test packet configuration

11. Close the "Test Packet Configuration" window.

12. Press the *FREQ* key and enter the frequency value f_{RX} (middle) as described under 6.2 *Frequencies for Testing* in the test specification.

13. Press the *LEVEL* key and enter L_{ws} = –67 dBm + L_a (see also Table 6-9, Table 6-10 and Figure 6-51).

14. Start the calculation of the Bluetooth test signal with *State* = On. After the calculation, press the *RF ON/OFF* key to switch on the Bluetooth RF signal.

Settings on SGS100A #1 (interferer):

15. In the SGMA GUI software, perform a *preset* (under SGS100A -> Preset).

1st test run:

16. Enter the start frequency of the interferer, f_i = 30 MHz, under *Freq* (Figure 6-54).

17. Under *Level*, enter L_b from Table 6-9 based on the frequency range of the interference signal. Here: –30 dBm. Note: Take the value for L_a (Figure 6-51) into account when setting the level (Figure 6-54).

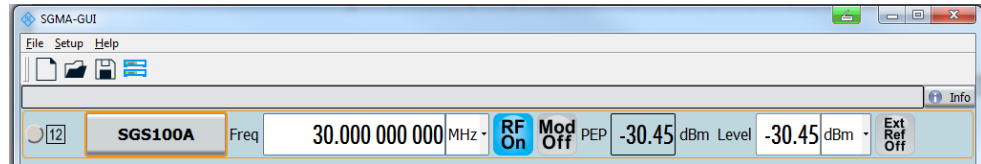18. Press the *RF ON/OFF* key to switch on the RF signal (Figure 6-54).

Figure 6-54: Setting CW interference signal at SGS100A using R&S SGMA GUI software

19. Measure the PER at all frequency points and levels specified in Table 6-9. All frequencies that do not fulfill the 1st test run conditions listed below are recorded as f_{b_1}.

2nd test run:

20. Perform in the same way as the 1st test run, but use the interference signal parameters from Table 6-10. All frequencies that do not fulfill the 2nd test run conditions listed below are recorded as f_{b_2}.

The following conditions must be fulfilled:

ɪ   1st test run: PER < 30.8 % (for Payload Length = 37 bytes and at least 1500 packets). For other payload lengths, the PER limit is given in Table 6.4: *PER level by maximum payload length in receiver* of the test specification. The number of f_{b_1} values recorded must not be greater than 10.

ɪ   2nd test run: PER < 30.8 % (for Payload Length = 37 bytes and at least 1500 packets). For other payload lengths, the PER limit is given in Table 6.4: *PER level by maximum payload length in receiver* of the test specification. The number of f_{b_2} values recorded must not be greater than 3.

6.2.3.2   Blocking Performance Test 10 (LE 2M, Uncoded Data at 2 Ms/s)
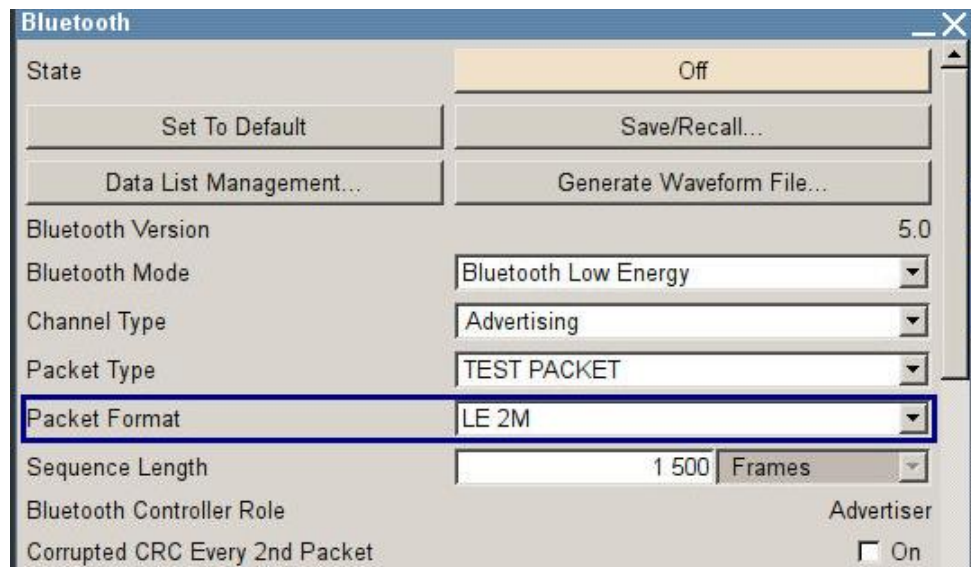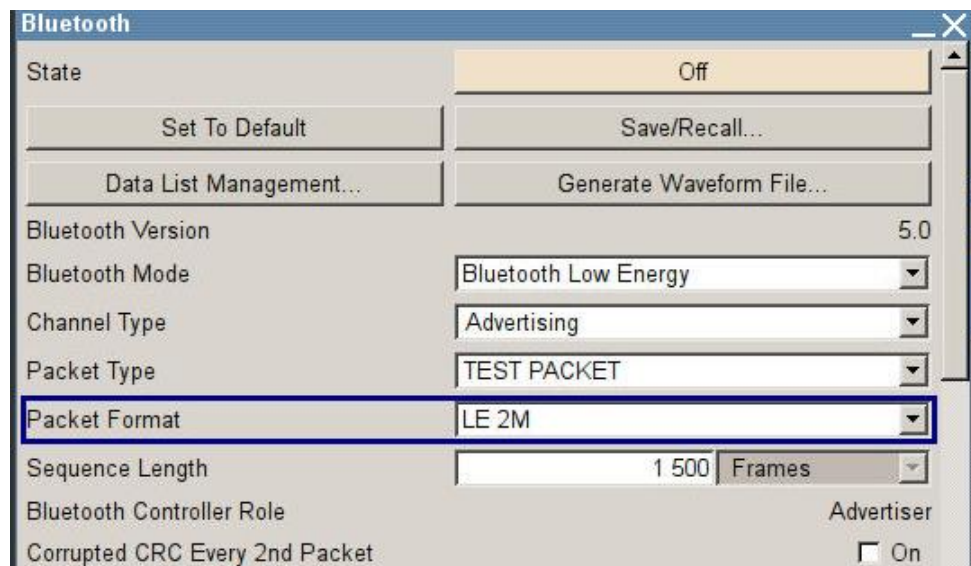
This test checks whether a BLE receiver operates satisfactorily in the presence of a CW interferer outside the Bluetooth frequency band when uncoded data with a symbol rate of 2 Ms/s is received.

Settings on DUT:

ɪ   As described under 6.2.3.1, but set the symbol rate to 2 Ms/s.

Settings on SMBV100A #2 (wanted signal):

ɪ   As described under 6.2.3.1, but set the packet format to LE 2M:

Settings on SGS100A #1 (interferer):

ı   As described under 6.2.3.1.

The following conditions must be fulfilled:

ı   As described under 6.2.3.1.

6.2.3.3 Blocking Performance Test 16 (LE 1M, Uncoded Data at 1 Ms/s, Stable Modulation Index)

This test checks whether a BLE receiver operates satisfactorily in the presence of a CW interferer outside the Bluetooth frequency band when uncoded data with a symbol rate of 2 Ms/s is received. Here, the receiver expects a transmitter with a stable modulation index.

Settings on DUT:

ı   As described under 6.2.3.1, but configure the DUT so that a transmitter with a stable modulation index is expected.

Settings on SMBV100A #2 (wanted signal):

ı   As described under 6.2.3.1.

Settings on SGS100A #1 (interferer):

ı   As described under 6.2.3.1.

The following conditions must be fulfilled:

ı   As described under 6.2.3.1.

6.2.3.4 Blocking Performance Test 22 (LE 2M, Uncoded Data at 2 Ms/s, Stable Modulation Index)

This test checks whether a BLE receiver operates satisfactorily in the presence of a CW interferer outside the Bluetooth frequency band when uncoded data with a symbol rate of 2 Ms/s is received. Here, the receiver expects a transmitter with a stable modulation index.

Settings on DUT:

ı As described under 6.2.3.1, but set the symbol rate to 2 Ms/s and configure the DUT so that a transmitter with a stable modulation index is expected.

Settings on SMBV100A #2 (wanted signal):

ı As described under 6.2.3.1, but set the packet format to LE 2M:

Settings on SGS100A #1 (interferer):

ı As described under 6.2.3.1.

The following conditions must be fulfilled:

ı As described under 6.2.3.1.

6.2.4 Intermodulation Performance

This test checks the behavior of the receiver under the influence of two signals. The first interferer is an unmodulated signal (CW). The second interferer is a continuously modulated Bluetooth signal. The interferers are set with specific levels and frequency spacing from the wanted Bluetooth signal. The PER is measured on the wanted signal.
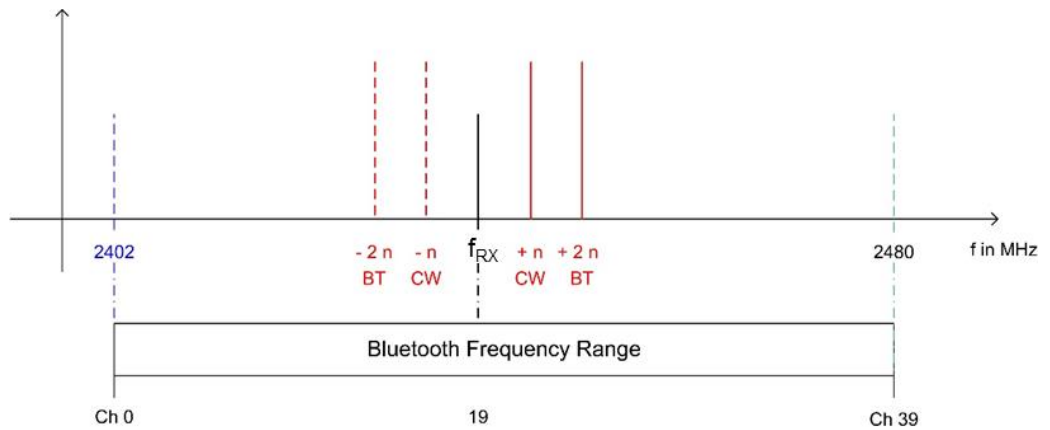
Figure 6-55: Intermodulation performance for LE M1 – On three channels, the PER is measured in the presence of a CW interferer with a spacing of ±n and in the presence of a Bluetooth interferer with a spacing of ±2n.

This test is specified for the following PHYs:

Intermodulation and PHYs	
PHY	Test number
LE 1M	05
LE 2M	11
LE 1M, SMI	17
LE 2M, SMI	23

Table 6-11: Various tests for intermodulation

Test setup:

The test setup in Figure 6-56 consists of three signal generators, the signals from which are fed to the DUT as a sum signal via a power combiner. Generator #1 generates an unmodulated, sinewave interference signal (CW) with a spacing of ± n·1 MHz relative to the receive frequency. (Note: The settings on generator #1 are made using the R&S SGMA GUI software.) Generator #2 delivers a continuously modulated BLE interferer with a spacing of ± 2n·1 MHz relative to the receive frequency. The manufacturer of the receiver specifies the value of n (n = 3, 4 or 5). Generator #3 delivers the BLE wanted signal with PRBS9 for the three receive frequencies f_{RX} (lowest), f_{RX} (middle) and f_{RX} (highest). Suitable isolators are used to ensure that the three signals do not influence each other. The additional attenuation value L_a caused by the cable, isolator and power combiner must be taken into account for all level settings.
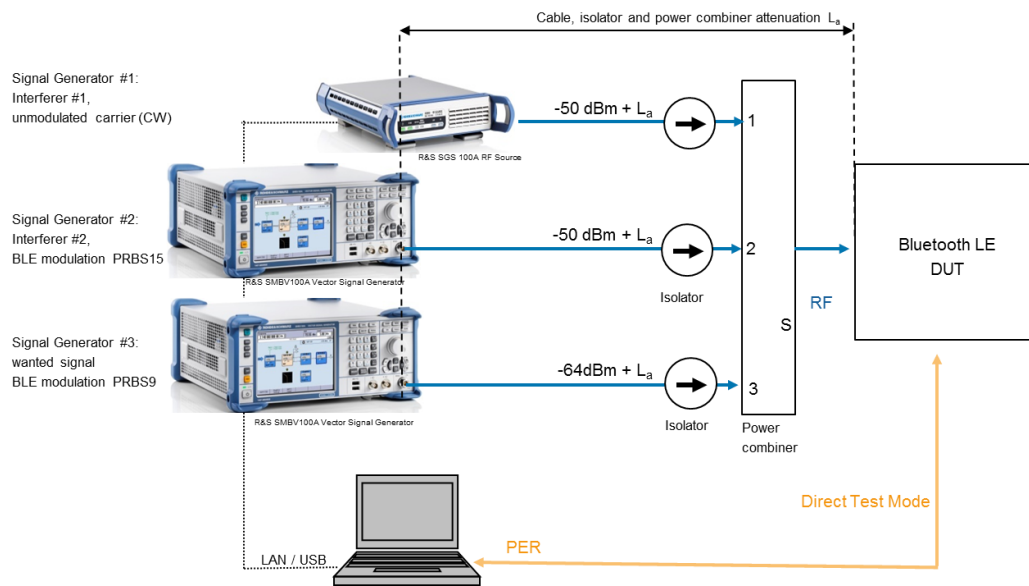
Figure 6-56: Test setup for intermodulation performance test

6.2.4.1 Intermodulation Performance Test 05 (LE 1M, Uncoded Data at 1 Ms/s)

This test checks whether the intermodulation performance of the receiver is satisfactory for an uncoded receive signal with 1 Ms/s.

Settings on DUT:

1. Switch on Direct RX mode. Switch off dewhitening.

2. Switch off frequency hopping.

3. Set the symbol rate to 1 Ms/s.

4. Configure the DUT so that a transmitter with a standard modulation index is expected.

5. Depending on the DUT, set the receive frequency f_{RX} (lowest) in line with the test specification, 6.2 "Frequencies for Testing".

Settings on signal generator #1 (SGS100A): (interferer #1):

6. In the R&S SGMA GUI software, perform a *Preset*.

7. Under *Level*, enter the value $-50dB + L_a$.

8. Under *Freq*, enter the value f_{RX} (lowest) + n·1 MHz.

9. Use the *RF ON/OFF* key to switch on the signal.

Settings on signal generator #2 (SMBV100A) (interferer #2):

10. Press the *PRESET* key.

11. Press the *MENU* key and select *Bluetooth* from the list:
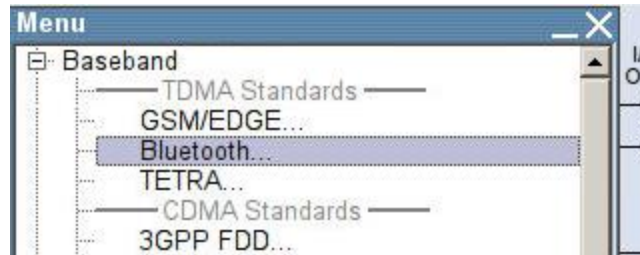
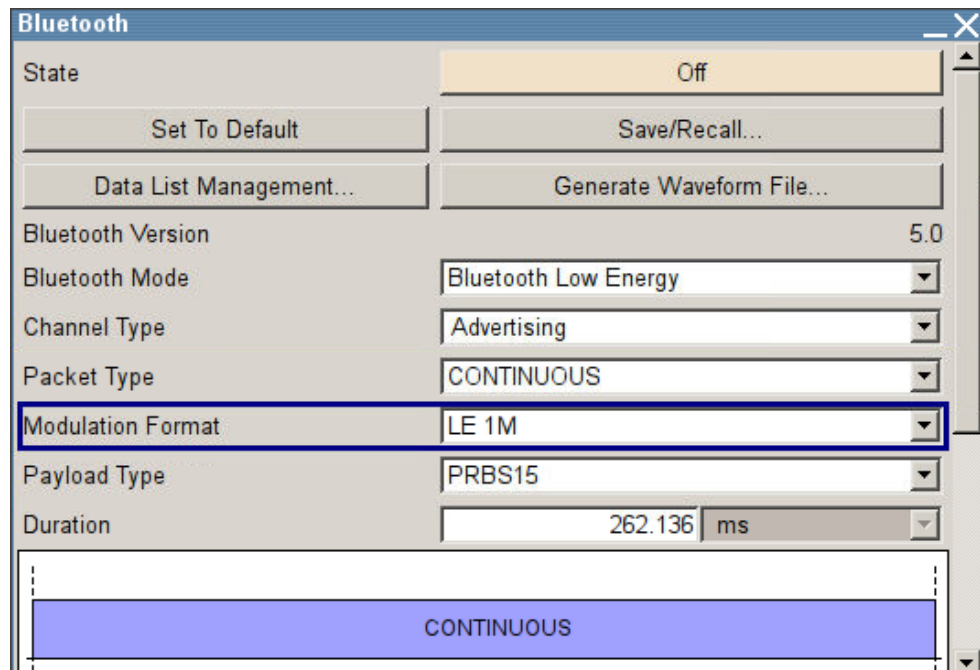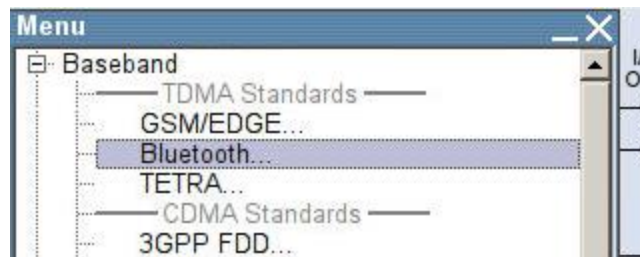12. Configure the settings as shown in Figure 6-57.

Figure 6-57: Generator settings for the interferer

13. Start the calculation of the Bluetooth test signal with *State* = On.

14. Press the *LEVEL* key and enter the value –50 dB + L_a.

15. Press the *FREQ* key and enter the value f_{RX} (lowest) + 2n·1 MHz.

16. Use the RF ON/OFF key to switch on the signal.

Settings on signal generator #3 (SMBV100A) (wanted signal):

17. Press the *PRESET* key.

18. Press the *MENU* key and select *Bluetooth* from the list:

19. Configure the settings as shown in Figure 6-58. The *Sequence Length* must be at least 1500.
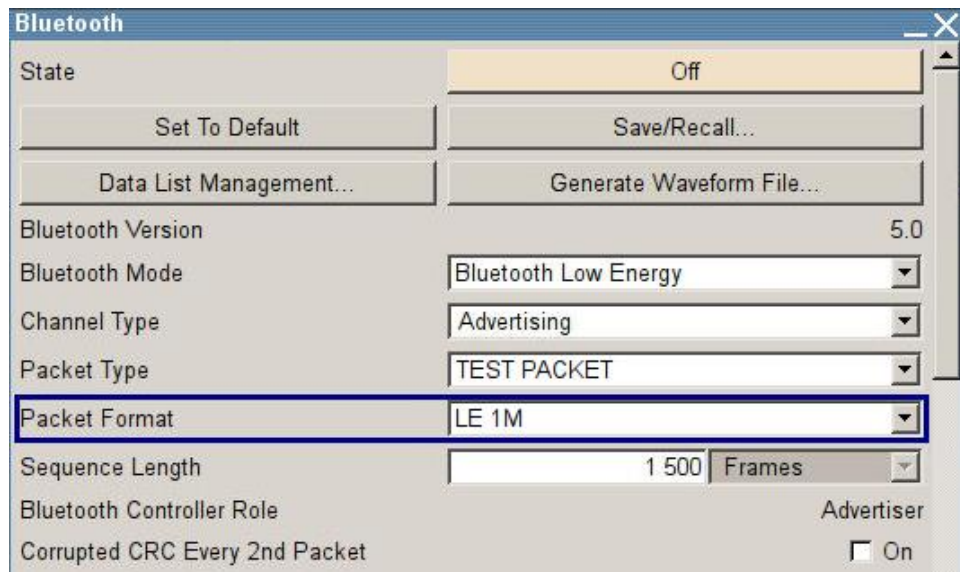
Figure 6-58: Generator settings for the wanted signal

20. In the Bluetooth window (Figure 6-58), scroll down with the ⇩ arrow key and select *Test Packet Configuration…*:
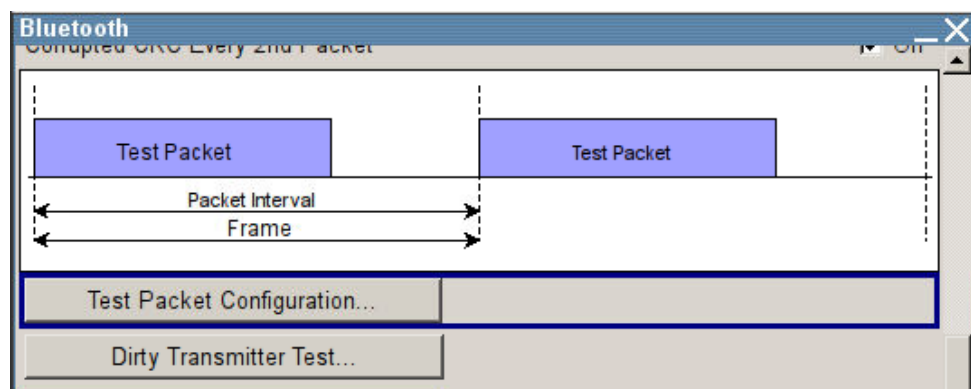
21. Make sure that **PRBS9** is selected as the payload type. If the DUT supports the "Extended Packet Length" feature (in line with core specification 4.2), then **Payload Length** must be set to the maximum possible packet length supported by the DUT. If "Extended Packet Length" is not supported, *Payload Length* must be set to 37 bytes:
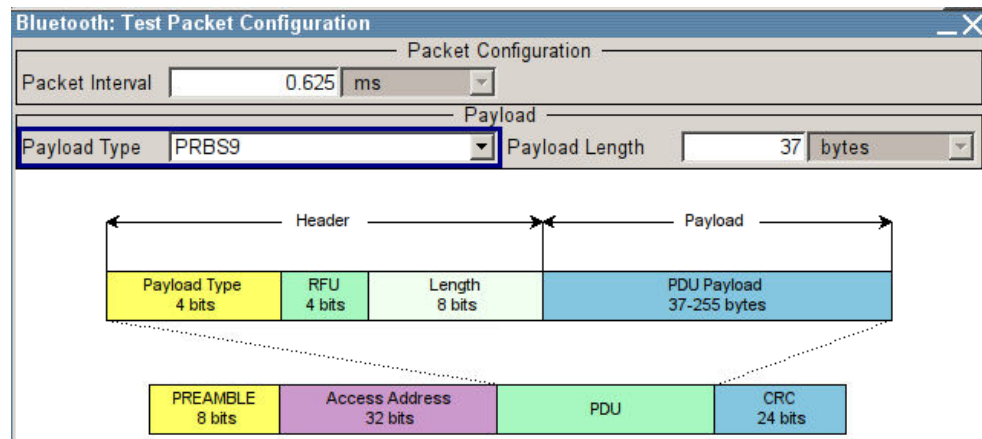
Figure 6-59: Test packet configuration

22. Close the "Test Packet Configuration" window.

23. Press the *FREQ* key and enter the value for f_{RX} (lowest).

24. Press the *LEVEL* key and enter the value –64 dBm + L_a.

25. Start the calculation of the Bluetooth test signal with *State* = On. After the calculation, press the *RF ON/OFF* key to switch on the Bluetooth RF signal.

26. Determine the PER.

27. Set the frequency of signal generator #1 to f_{RX} (lowest) – n·1 MHz.

28. Set the frequency of signal generator #2 to f_{RX} (lowest) – 2n·1 MHz.

29. Determine the PER.

The following condition must be fulfilled for all frequency settings:

▪ PER < 30.8 % (for Payload Length = 37 bytes and at least 1500 packets). For other payload lengths, the PER limit is given in Table 6.4: *PER level by maximum payload length in receiver* of the test specification.

30. Repeat the above-described test for f_{RX} (middle) and f_{RX} (highest).

6.2.4.2 Intermodulation Performance Test 11 (LE 2M, Uncoded Data at 2 Ms/s)

This test checks whether the intermodulation performance of the receiver is satisfactory for an uncoded receive signal with 2 Ms/s.

Settings on DUT:

1. Switch on Direct RX mode. Switch off dewhitening.

2. Switch off frequency hopping.

3. Set the symbol rate to 2 Ms/s.

4. Configure the DUT so that a transmitter with a standard modulation index is expected.

5. Depending on the DUT, set the receive frequency f_{RX} (lowest) in line with the test specification, 6.2 "Frequencies for Testing".

Settings on signal generator #1 (SGS100A) (interferer #1):

6. In the R&S SGMA GUI software, perform a *Preset*.

7. Under *Level*, enter the value –50dB + L_a.

8. Under *Freq*, enter the value f_{RX} (lowest) + n·2 MHz.

9. Use the *RF ON/OFF* key to switch on the signal.

Settings on signal generator #2 (SMBV100A) (interferer #2):

10. Press the *PRESET* key.

11. Press the *MENU* key and select *Bluetooth* from the list:
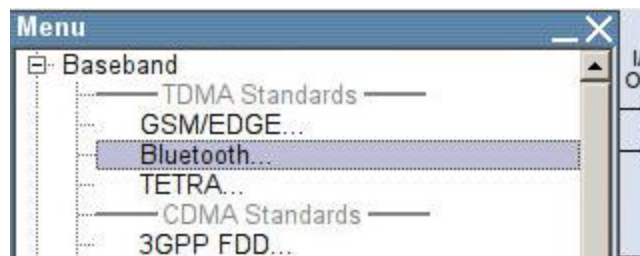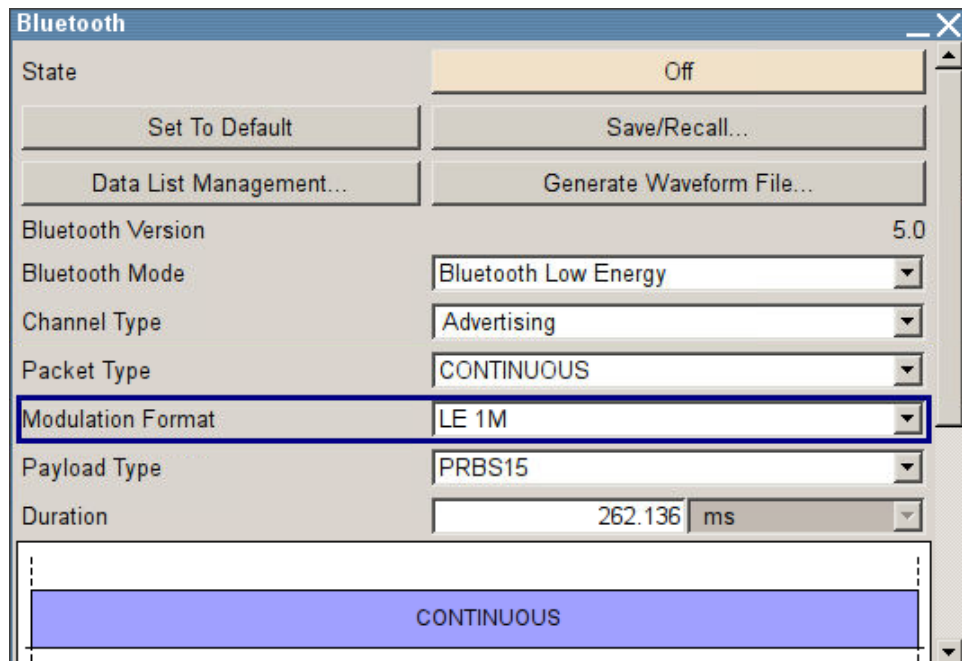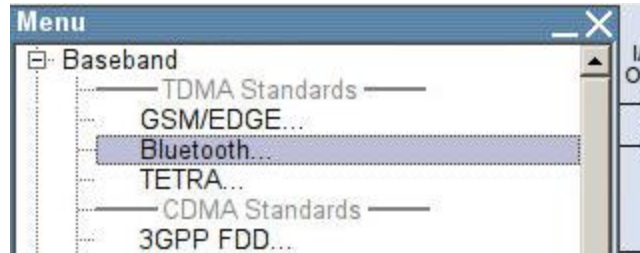

12. Configure the settings as shown in Figure 6-60.

Figure 6-60: Generator settings for interference signal

13. Start the calculation of the Bluetooth test signal with *State* = On.

14. Press the *LEVEL* key and enter the value –50 dB + L_a.

15. Press the *FREQ* key and enter the value f_{RX} (lowest) + 2n·2 MHz.

16. Use the RF ON/OFF key to switch on the signal.

Settings on signal generator #3 (SMBV100A) (wanted signal):
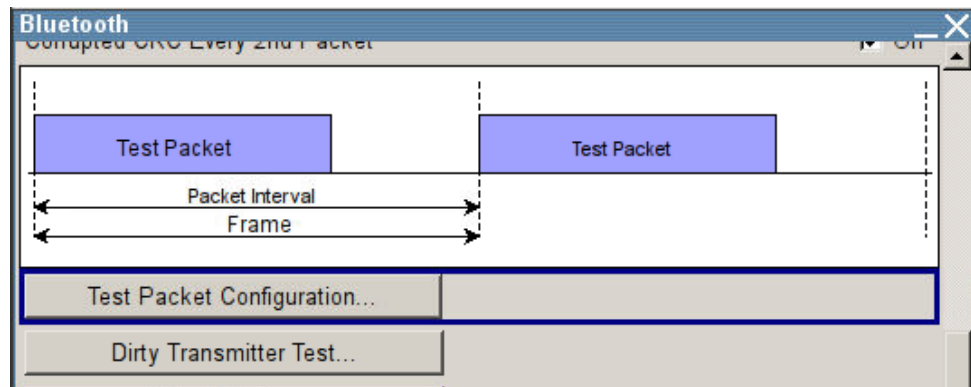
17. Press the *PRESET* key.

18. Press the *MENU* key and select *Bluetooth* from the list:

19. Configure the settings as shown in Figure 6-61. The *Sequence Length* must be at least 1500.
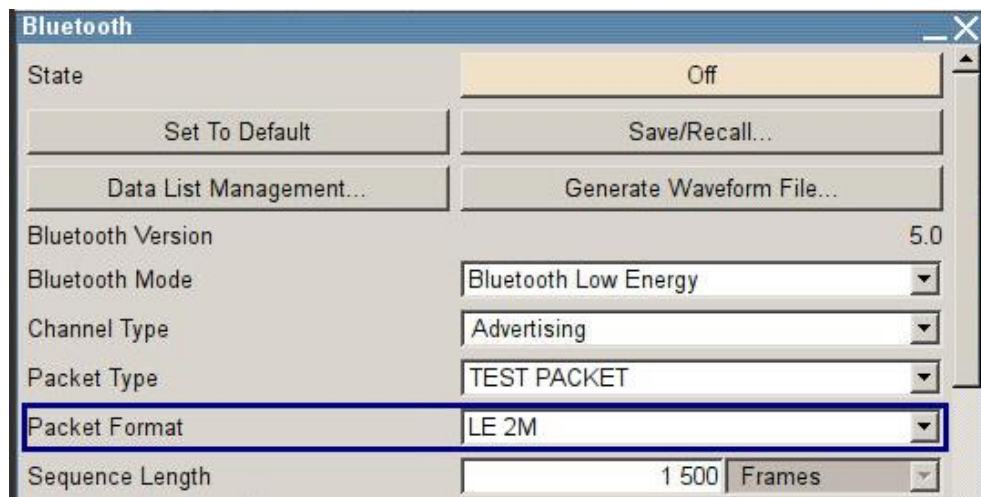
20. Figure 6-61: Generator settings for wanted signal

21. In the Bluetooth window (Figure 6-61), scroll down with the ⇩ arrow key and select *Test Packet Configuration…*:

22. Make sure that **PRBS9** is selected as the payload type. If the DUT supports the "Extended Packet Length" feature (in line with core specification 4.2), then **Payload Length** must be set to the maximum possible packet length supported by the DUT. If "Extended Packet Length" is not supported, *Payload Length* must be set to 37 bytes:
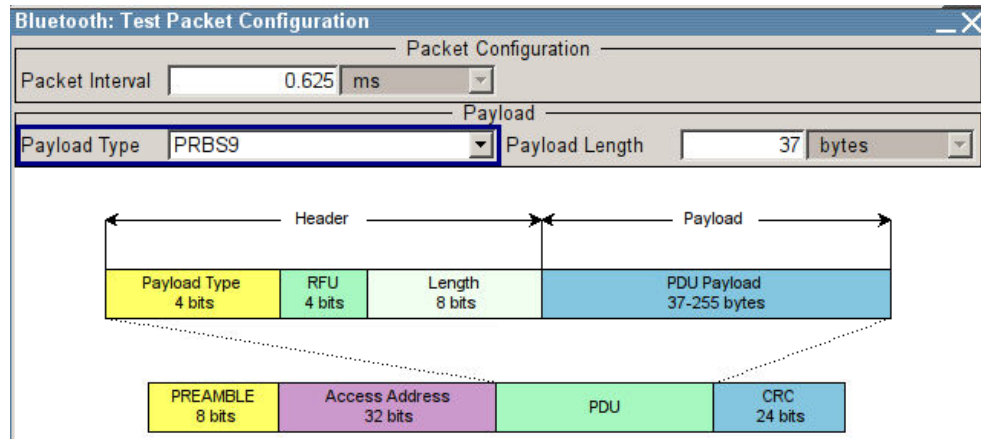

Figure 6-62: Test packet configuration

23. Close the "Test Packet Configuration" window.

24. Press the *FREQ* key and enter the value for f_{RX} (lowest).

25. Press the *LEVEL* key and enter the value –64 dBm + L_a.

26. Start the calculation of the Bluetooth test signal with *State* = On. After the calculation, press the *RF ON/OFF* key to switch on the Bluetooth RF signal.

27. Set the frequency of signal generator #1 to f_{RX} (lowest) – n·1 MHz.

28. Set the frequency of signal generator #2 to f_{RX} (lowest) – 2n·1 MHz.

The following condition must be fulfilled for all frequency settings:

ι   PER < 30.8 % (for Payload Length = 37 bytes and at least 1500 packets). For other payload lengths, the PER limit is given in Table 6.4: *PER level by maximum payload length in receiver* of the test specification.

29. Repeat the above test for f_{RX} (middle) and f_{RX} (highest).

6.2.4.3 Intermodulation Performance Test 17 (LE 1M, Uncoded Data at 1 Ms/s, Stable Modulation Index)

This test checks whether the intermodulation performance of the receiver is satisfactory for an uncoded receive signal with 1 Ms/s. The receiver expects a transmitter with a stable modulation index.

Settings on DUT:

▮ As described under 6.2.4.1, but configure the receiver so that a transmitter with a stable modulation index is expected.

Settings on signal generator #1 (SGS100A) (interferer #1):

▮ As described under 6.2.4.1.

Settings on signal generator #2 (SMBV100A) (interferer #2):

▮ As described under 6.2.4.1.

Settings on signal generator #3 (SMBV100A) (wanted signal):

▮ As described under 6.2.4.1.

The following condition must be fulfilled for all frequency settings:

▮ As described under 6.2.4.1.

6.2.4.4 Intermodulation Performance Test 23 (LE 2M, Uncoded Data at 2 Ms/s, Stable Modulation Index)

This test checks whether the intermodulation performance of the receiver is satisfactory for an uncoded receive signal with 2 Ms/s. The receiver expects a transmitter with a stable modulation index.

Settings on DUT:

As described under 6.2.4.2, but configure the receiver so that a transmitter with a stable modulation index is expected.

Settings on signal generator #1 (SGS100A) (interferer #1):

▮ As described under 6.2.4.2.

Settings on signal generator #2 (SMBV100A) (interferer #2):

▮ As described under 6.2.4.2.

Settings on signal generator #3 (SMBV100A) (wanted signal):

ı   As described under 6.2.4.2.

The following condition must be fulfilled for all frequency settings:

ı   As described under 6.2.4.2.

6.2.5   Maximum Input Signal Level

This test checks whether the receiver can correctly demodulate different signals at a high input level.
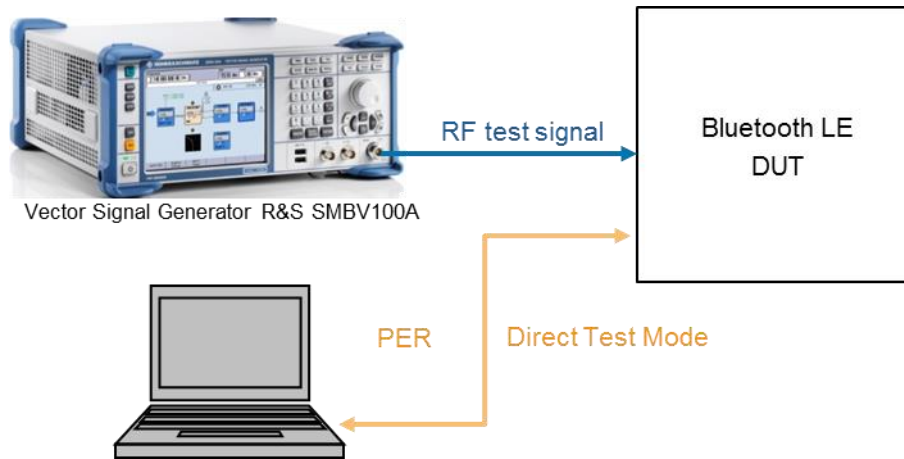
Test setup:

Figure 6-63: Test setup with a signal generator and PC for signaling and readout of PER

This test is specified for the following PHYs:

Maximum input signal level and PHYs	
PHY	Test number
LE 1M	06
LE 2M	12
LE 1M, SMI	18
LE 2M, SMI	24

Table 6-12: Various tests for maximum input signal level

### 6.2.5.1   Maximum Input Level Test 06 (LE 1M, Uncoded Data at 1 Ms/s)

This test checks whether the receiver can correctly demodulate a 1 Ms/s signal at a high input level.

Settings on DUT:

1.   Switch on Direct RX mode. Switch off dewhitening.

2.   Switch off frequency hopping.

3.   Set the symbol rate to 1 Ms/s.

4.   Configure the DUT so that a transmitter with a standard modulation index is expected.

5.   Depending on the DUT, set the receive frequency f_{TX} (lowest) in line with the test specification, 6.2 "Frequencies for Testing".

Settings on SMBV100A:

6.   Press the *PRESET* key.

7.   Press the *MENU* key and select *Bluetooth* from the list:
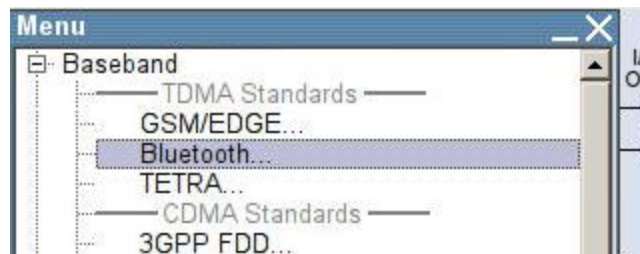
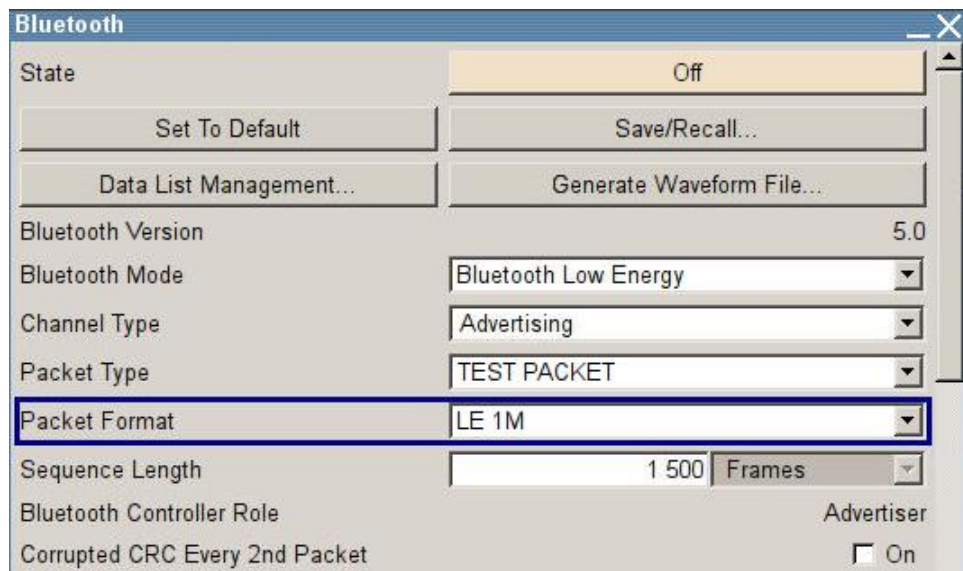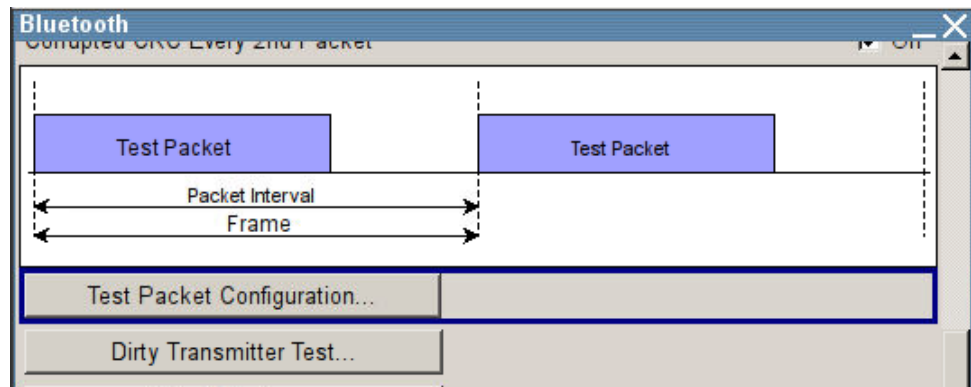8.   Configure the settings as shown in Figure 6-64. The *Sequence Length* must be at least 1500.

Figure 6-64: Generator settings for Maximum Input Level Test 06

9.   In the Bluetooth window (Figure 6-64), scroll down with the ⇩ arrow key and select *Test Packet Configuration…*:

10. Make sure that **PRBS9** is selected as the payload type. If the DUT supports the "Extended Packet Length" feature (in line with core specification 4.2), then **Payload Length** must be set to the maximum possible packet length supported by the DUT. If "Extended Packet Length" is not supported, *Payload Length* must be set to 37 bytes:
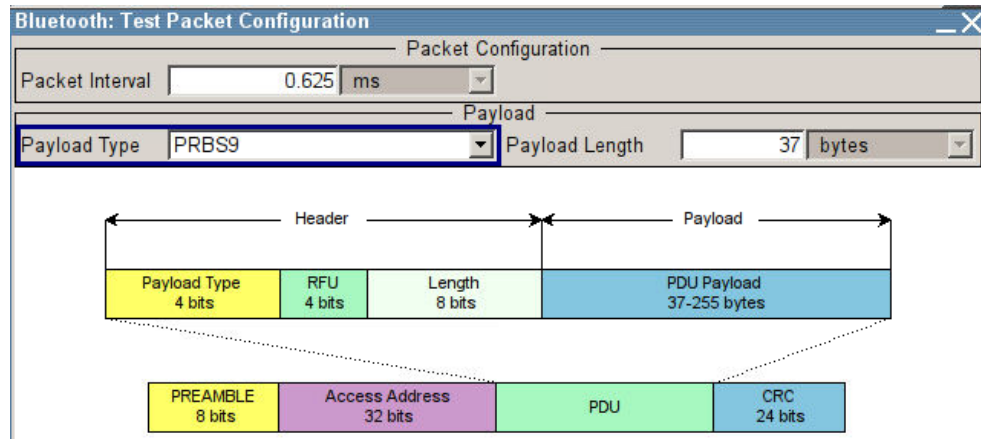

Figure 6-65: Test packet configuration

11. Close the "Test Packet Configuration" window.

12. Press the *FREQ* key and enter the previously configured receive frequency of the DUT.

13. Press the *LEVEL* key and enter –10 dBm.

14. Note: Since the test specification defines the level at the input of the Bluetooth receiver, the additional cable loss must be taken into account when entering the reference level.

15. Start the calculation of the Bluetooth test signal with *State* = On. After the calculation, press the *RF ON/OFF* key to switch on the Bluetooth RF signal. The DUT now receives a test signal with a level of –10 dBm.

The following conditions must be fulfilled after the test signal has been received by the Bluetooth receiver:

▪ PER < 30.8 % (for Payload Length = 37 bytes and at least 1500 packets)

For other payload lengths, the PER limit is given in Table 6.4: *PER level by maximum payload length in receiver* of the test specification.

16. Perform the test at two other receive frequencies f_{TX} (middle) and f_{TX} (highest) as described in 6.2 *Frequencies for Testing*.

6.2.5.2 Maximum Input Level Test 12 (LE 2M, Uncoded Data at 2 Ms/s)

This test checks whether the receiver can correctly demodulate a 2 Ms/s signal at a high input level.

Settings on DUT:

ı As described under 6.2.5.1, but set the symbol rate to 2 Ms/s.

Settings on SMBV100A:

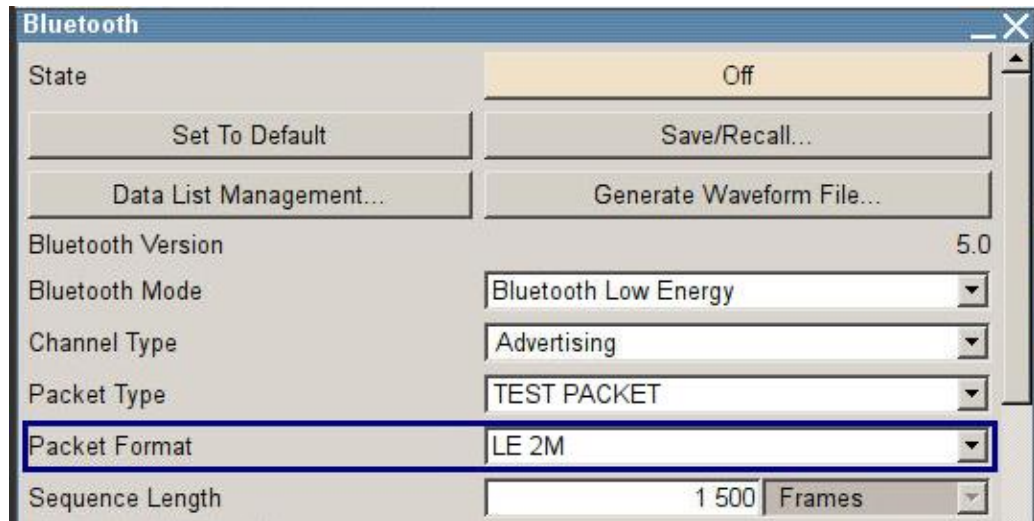ı As described under 6.2.5.1, but set *Packet Format* to:

Figure 6-66: Generator settings for Maximum Input Level Test 12

The following conditions must be fulfilled after the test signal has been received by the Bluetooth receiver:

ı As described under 6.2.5.1.

ı Perform the test at two other receive frequencies f_{TX} (middle) and f_{TX} (highest) as described in 6.2 *Frequencies for Testing*.

6.2.5.3 Maximum Input Level Test 18 (LE 1M, Uncoded Data at 1 Ms/s, Stable Modulation Index)

This test checks whether the DUT, which expects a transmitter with a stable modulation index, can correctly demodulate a 1 Ms/s signal at a high input level.

Settings on DUT:

ı As described under 6.2.5.1, but configure the DUT so that a transmitter with a stable modulation index is expected.

Settings on SMBV100A:

ı   As described under 6.2.5.1.

The following conditions must be fulfilled after the test signal has been received by the Bluetooth receiver:

ı   As described under 6.2.5.1.

ı   Perform the test at two other receive frequencies f_{TX} (middle) and f_{TX} (highest) as described in 6.2 *Frequencies for Testing*.

6.2.5.4   Maximum Input Level Test 24 (LE 2M, Uncoded Data at 2 Ms/s, Stable Modulation Index)

This test checks whether the DUT, which expects a transmitter with a stable modulation index, can correctly demodulate a 2 Ms/s signal at a high input level.

Settings on DUT:

ı   As described under 6.2.5.1, but set the symbol rate to 2 Ms/s and configure the DUT so that a transmitter with a stable modulation index is expected.

Settings on SMBV100A:

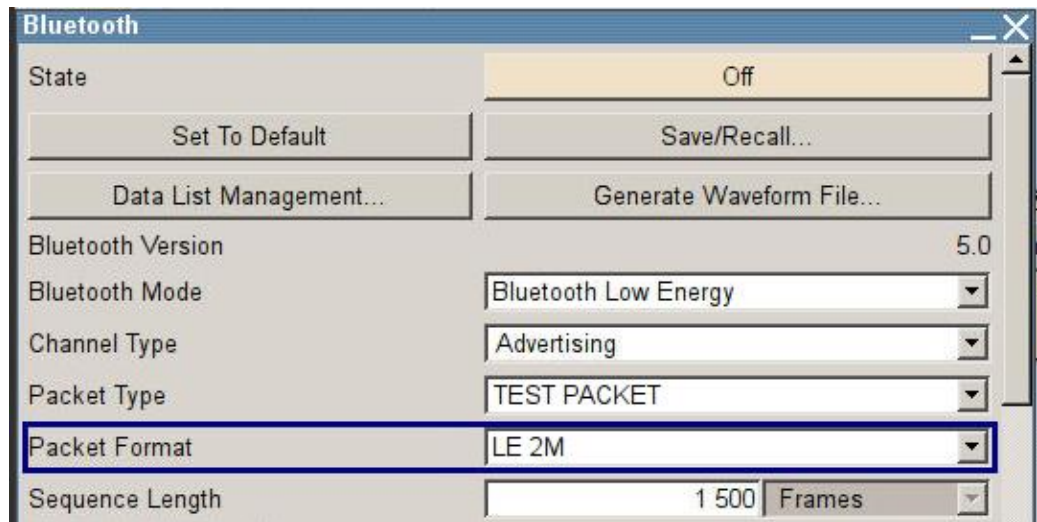ı   As described under 6.2.5.1, but set *Packet Format* to LE 2M:

Figure 6-67: Generator settings for Maximum Input Level Test 18

The following conditions must be fulfilled after the test signal has been received by the Bluetooth receiver:

ı   As described under 6.2.5.1.

▪ Perform the test at two other receive frequencies f_{TX} (middle) and f_{TX} (highest) as described in 6.2 *Frequencies for Testing*.

6.2.6 PER Report Integrity

In this test, the signal generator transmits an incorrect cyclic redundancy check (CRC) in every second packet. The PER is then determined.

This test is specified for all PHYs:

PER report integrity and PHYs	
PHY	**Test number**
LE 1M	07
LE 2M	13
LE 1M, SMI	19
LE 2M, SMI	25
LE Coded, S=2	30
LE Coded, S=8	31
LE Coded, S=2, SMI	36
LE Coded, S=8, SMI	37

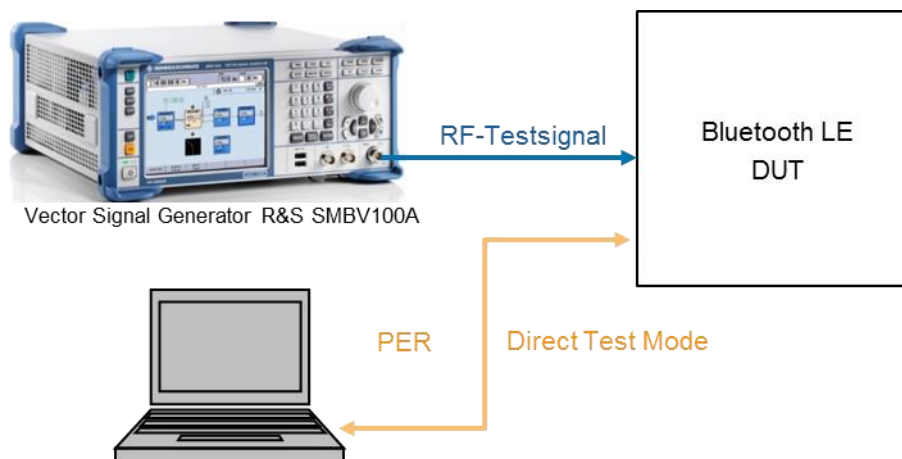**Table 6-13: Various tests for PER report integrity**

Test setup:

Figure 6-68: Test setup with a signal generator and PC for signaling and readout of PER

6.2.6.1 PER Report Integrity Test 07 (LE 1M, Uncoded Data at 1 Ms/s)

This test verifies whether the DUT's PER reporting mechanism reports the correct number of packets received with uncoded data at 1 Ms/s.

Settings on DUT:

1. Switch on Direct RX mode. Switch off dewhitening.

2.   Switch off frequency hopping.

3.   Set the symbol rate to 1 Ms/s.

4.   Configure the receiver so that a transmitter with a standard modulation index is expected.

5.   Depending on the DUT, set the receive frequency f_{TX} (middle) as described in 6.2 "Frequencies for Testing".

Settings on SMBV100A:

6.   Press the *PRESET* key.

7.   Press the *MENU* key and select *Bluetooth* from the list:
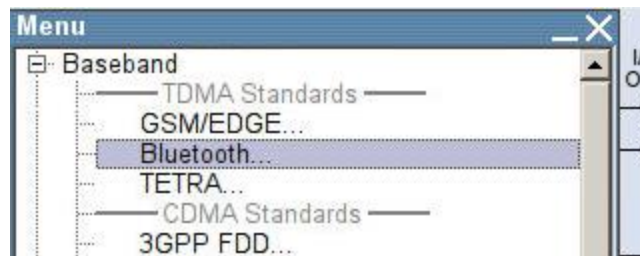
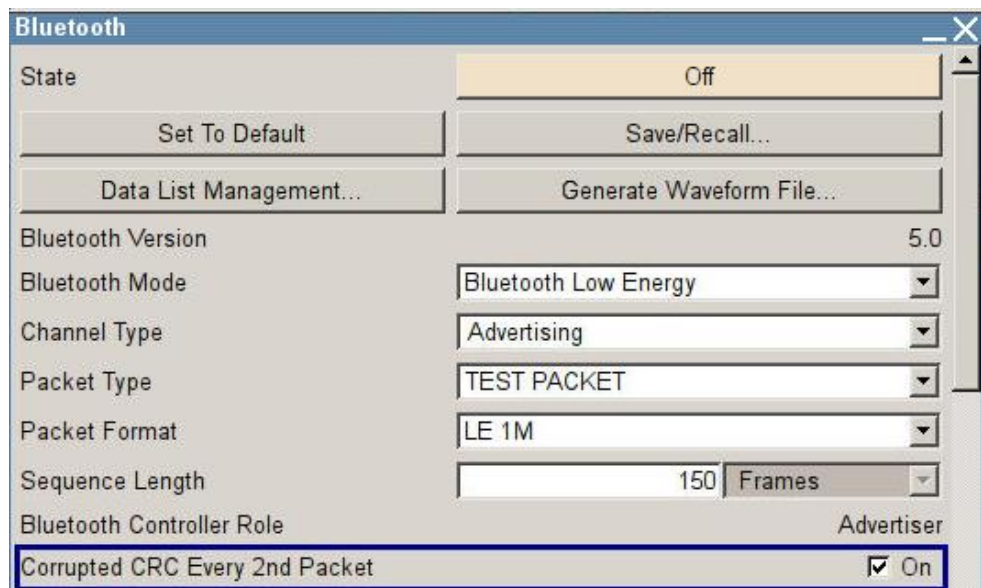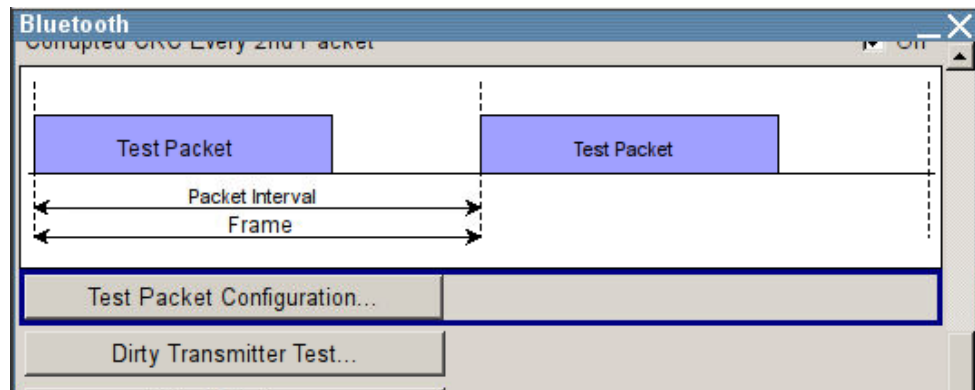8.   Configure the settings as shown in Figure 6-69. For *Sequence Length*, enter any value from 100 to 1500.

Figure 6-69: Generator settings for PER report integrity test number 07

9.   In the Bluetooth window (Figure 6-69), scroll down with the ⇩ arrow key and select *Test Packet Configuration…*:

Make sure that **PRBS9** is selected as the payload type. If the DUT supports the "Extended Packet Length" feature (in line with core specification 4.2), then **Payload Length** must be set to the maximum possible packet length supported by the DUT. If "Extended Packet Length" is not supported, *Payload Length* must be set to 37 bytes:
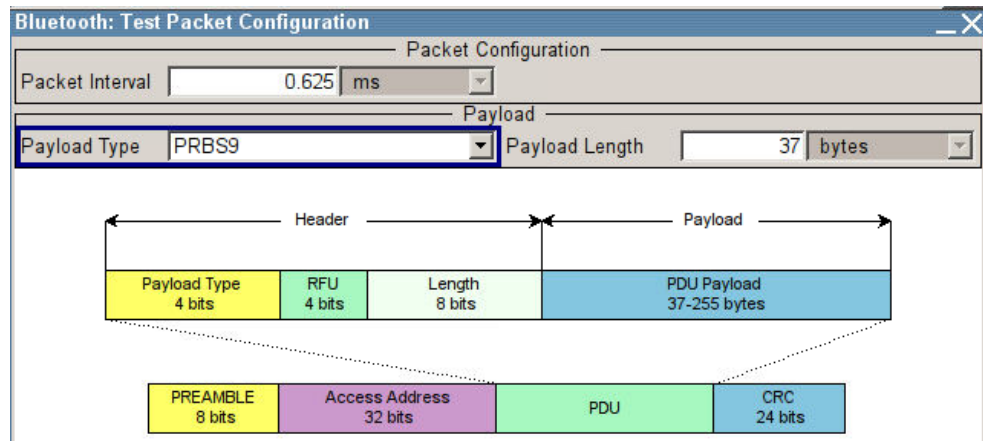

Figure 6-70: Test packet configuration

10. Close the "Test Packet Configuration" window.

11. Press the *FREQ* key and enter the previously configured receive frequency of the DUT.

12. Press the *LEVEL* key and enter –30 dBm.

13. Note: Since the test specification defines the level at the input of the Bluetooth receiver, the additional cable loss must be taken into account when entering the reference level.

14. Start the calculation of the Bluetooth test signal with *State* = On. After the calculation, press the *RF ON/OFF* key to switch on the Bluetooth RF signal. The DUT now receives a test signal in which in every second packet contains a corrupted CRC.

The following conditions must be fulfilled:

▪ 50 % ≤ PER ≤ (50+P/2) %, where P is the corresponding PER value from Table 6.4: *PER level by maximum payload length in receiver* of the test specification. This value depends on the maximum payload length supported by the DUT.

15. Repeat the test two more times with a different, random number of packets ranging from 100 to 1500 packets.

## 6.2.6.2 PER Report Integrity Test 13 (LE 2M, Uncoded Data at 2 Ms/s)

This test verifies whether the PER reporting mechanism in the DUT reports the correct number of packets received with uncoded data at 2 Ms/s.

Settings on DUT:

1. Switch on Direct RX mode. Switch off dewhitening.

2. Switch off frequency hopping.

3. Set the symbol rate to 2 Ms/s.

4. Configure the receiver so that a transmitter with a standard modulation index is expected.

5. Depending on the DUT, set the receive frequency f_{TX} (middle) as described in 6.2 "Frequencies for Testing".

Settings on SMBV100A:

6. Press the *PRESET* key.

7. Press the *MENU* key and select *Bluetooth* from the list:
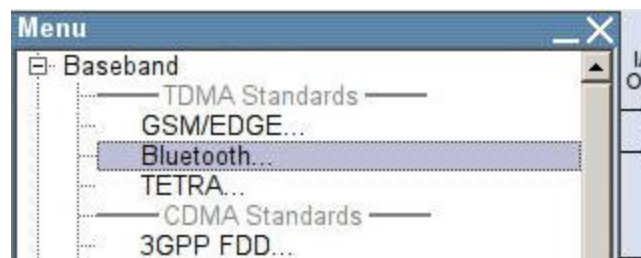
Configure the settings as shown in Figure 6-71. For *Sequence Length*, enter any value from 100 to 1500.
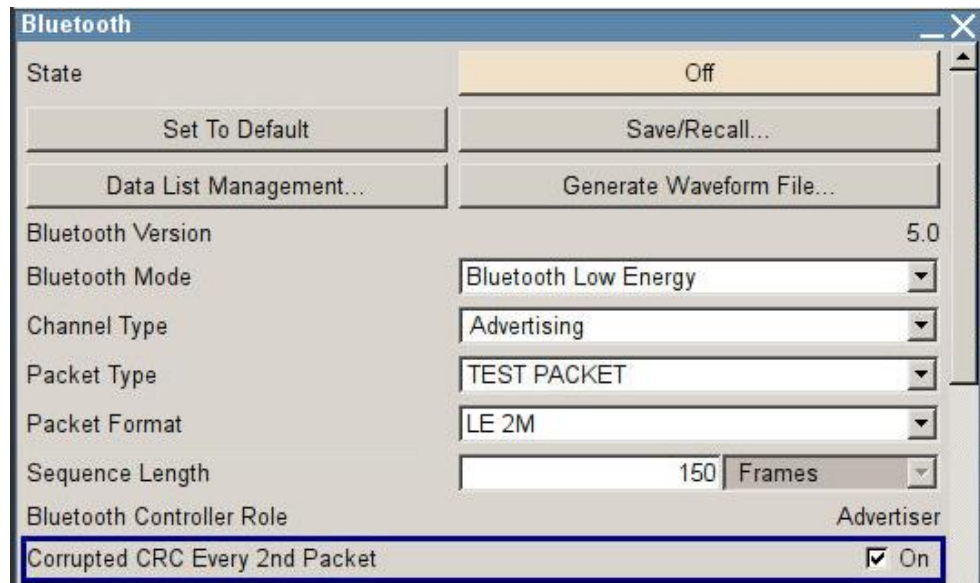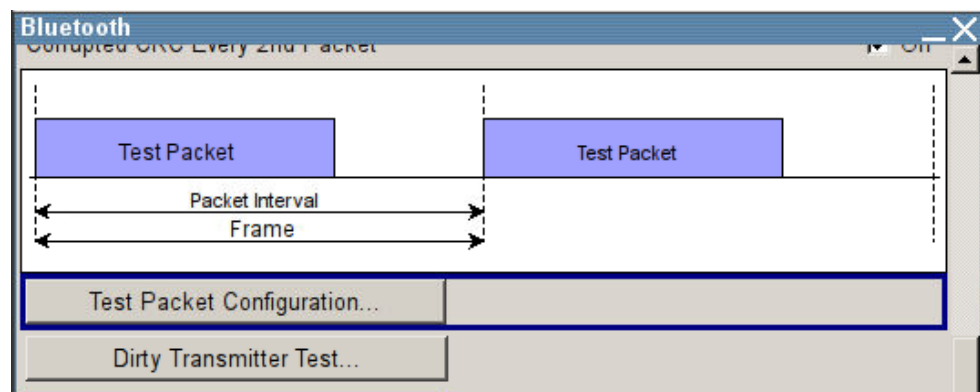
Figure 6-71: Generator settings for PER report integrity test number 13

8. In the Bluetooth window (Figure 6-71), scroll down with the ⇩ arrow key and select *Test Packet Configuration…*:

9. Make sure that **PRBS9** is selected as the payload type. If the DUT supports the "Extended Packet Length" feature (in line with core specification 4.2), then **Payload Length** must be set to the maximum possible packet length supported by the DUT. If "Extended Packet Length" is not supported, *Payload Length* must be set to 37 bytes:
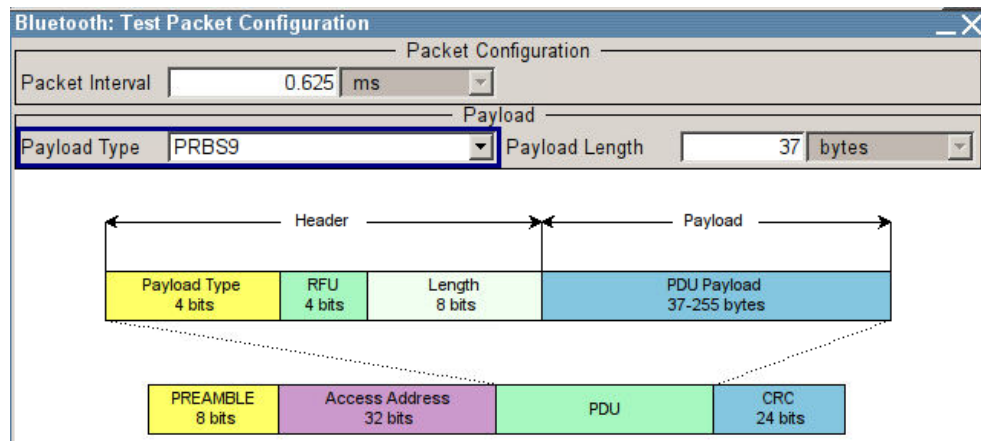
Figure 6-72: Test packet configuration

10. Close the "Test Packet Configuration" window.

11. Press the *FREQ* key and enter the previously configured receive frequency of the DUT.

12. Press the *LEVEL* key and enter –30 dBm.

13. Note: Since the test specification defines the level at the input of the Bluetooth receiver, the additional cable loss must be taken into account when entering the reference level.

14. Start the calculation of the Bluetooth test signal with *State* = On. After the calculation, press the *RF ON/OFF* key to switch on the Bluetooth RF signal. The DUT now receives a test signal in which in every second packet contains a corrupted CRC.

The following conditions must be fulfilled:

▮ 50 % ≤ PER ≤ (50+P/2) %, where P is the corresponding PER value from Table 6.4 of the test specification. This value depends on the maximum payload length supported by the DUT.

15. Repeat the test two more times with a different, random number of packets ranging from 100 to 1500 packets.

6.2.6.3 PER Report Integrity Test 19 (LE 1M, Uncoded Data at 1 Ms/s, Stable Modulation Index)

This test verifies whether the PER reporting mechanism in the DUT reports the correct number of packets received at 1 Ms/s when the DUT expects a transmitter with a stable modulation index.

Settings on DUT:

▮ As described under 6.2.6.1, but configure the receiver so that a transmitter with a stable modulation index is expected.

Settings on SMBV100A:

▪ As described under 6.2.6.1.

The following conditions must be fulfilled:

▪ As described under 6.2.6.1.

6.2.6.4 PER Report Integrity Test 25 (LE 2M, Uncoded Data at 2 Ms/s, Stable Modulation Index)

This test verifies whether the PER reporting mechanism in the DUT reports the correct number of packets received at 2 Ms/s when the DUT expects a transmitter with a stable modulation index.

Settings on DUT:

▪ As described under 6.2.6.2, but configure the receiver so that a transmitter with a stable modulation index is expected.

Settings on SMBV100A:

▪ As described under 6.2.6.2.

The following conditions must be fulfilled:

▪ As described under 6.2.6.2.

6.2.6.5 PER Report Integrity Test 30 (LE Coded, S=2)

This test verifies whether the PER reporting mechanism in the DUT reports the correct number of packets received when the DUT uses LE Coded PHY with data coding $S = 2$.
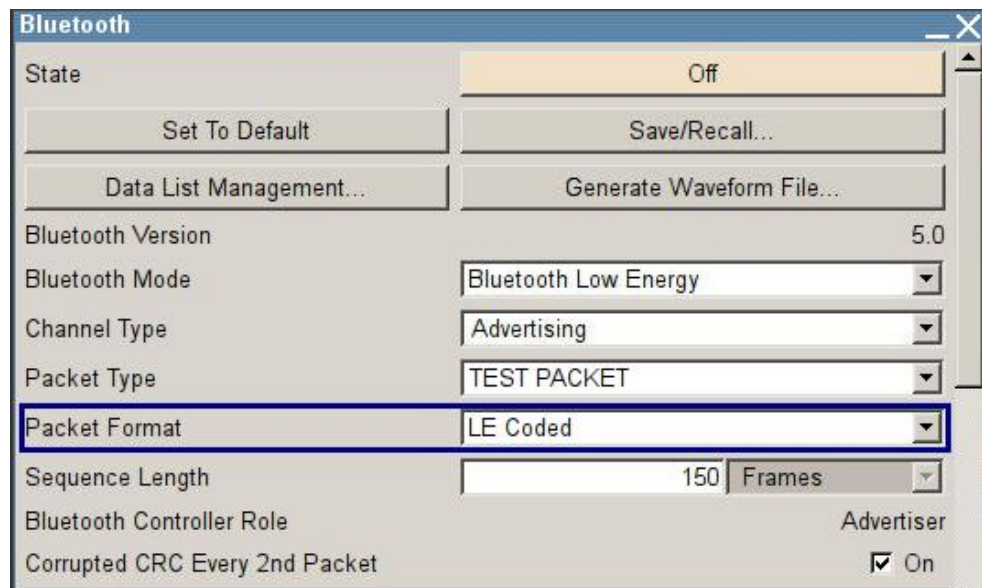
Settings on DUT:

▪ As described under 6.2.6.1, but do not set the receiver symbol rate to 1 Ms/s; instead, set the receiver to LE Coded PHY with data coding $S = 2$.

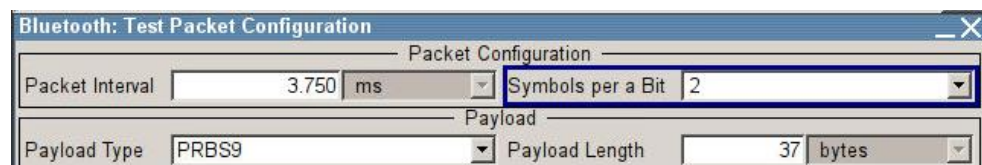**Settings on SMBV100A:**

As described under 6.2.6.1, but:

▪ Under *Packet Format*, set *LE Coded*:

ı In the "Test Packet Configuration" window, set *Symbols per a Bit* to 2:

The following conditions must be fulfilled:

ı As described under 6.2.6.1.

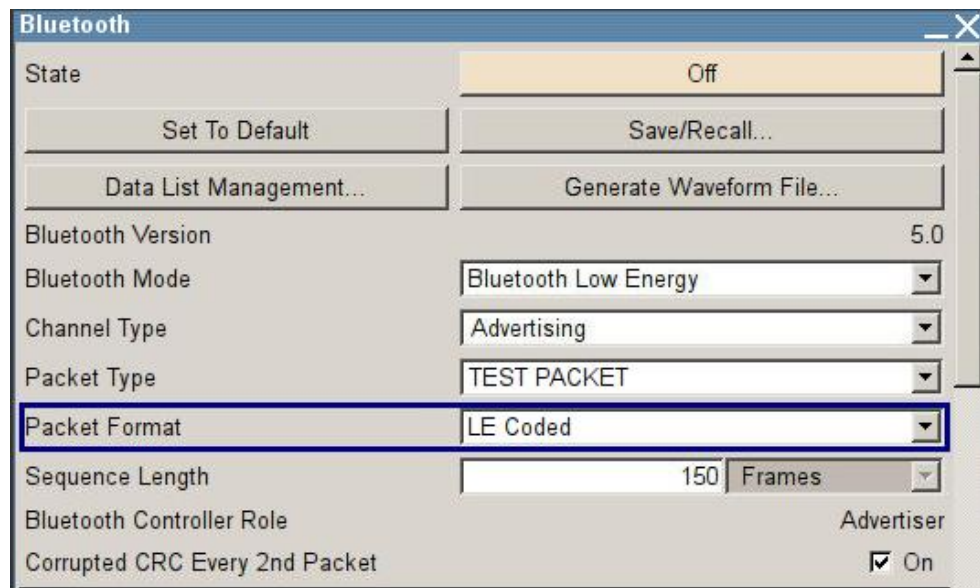### 6.2.6.6 PER Report Integrity Test 31 (LE Coded, S=8)

This test verifies whether the PER reporting mechanism in the DUT reports the correct number of packets received when the DUT uses LE Coded PHY with data coding S = 8.

Settings on DUT:
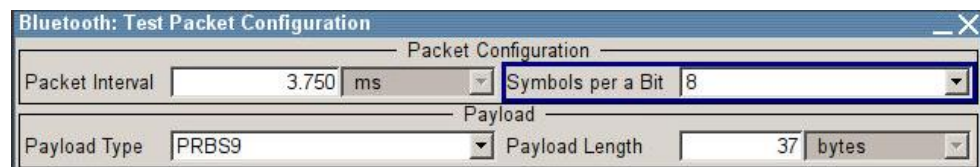
ı As described under 6.2.6.1, but do not set the receiver symbol rate to 1 Ms/s; instead, set the receiver to LE Coded PHY with data coding S = 8.

Settings on SMBV100A:

ı As described under 6.2.6.1, but set *Packet Format* to *LE Coded*:

ı In the "Test Packet Configuration" window, set *Symbols per a Bit* to 8:

The following conditions must be fulfilled:

ı As described under 6.2.6.1.

6.2.6.7 PER Report Integrity Test 36 (LE Coded, S=2, Stable Modulation Index)

This test verifies whether the PER reporting mechanism in the DUT reports the correct number of packets received when the DUT uses LE Coded PHY with data coding S = 2 and expects a transmitter with a stable modulation index.

Settings on DUT:

ı As described under 6.2.6.1, but do not set the receiver symbol rate to 1 Ms/s; instead, set the receiver to LE Coded PHY with data coding S = 8 and configure it so that a transmitter with a stable modulation index is expected.

Settings on SMBV100A:

As described under 6.2.6.1, but:

ı Set *Packet Format* to *LE Coded*:

ı   In the "Test Packet Configuration" window, set *Symbols per a Bit* to 2:

The following conditions must be fulfilled:

ı   As described under 6.2.6.1.

6.2.6.8 PER Report Integrity Test 37 (LE Coded, S=8, Stable Modulation Index)

This test verifies whether the PER reporting mechanism in the DUT reports the correct number of packets received when the DUT uses LE Coded PHY with data coding S = 8 and expects a transmitter with a stable modulation index.
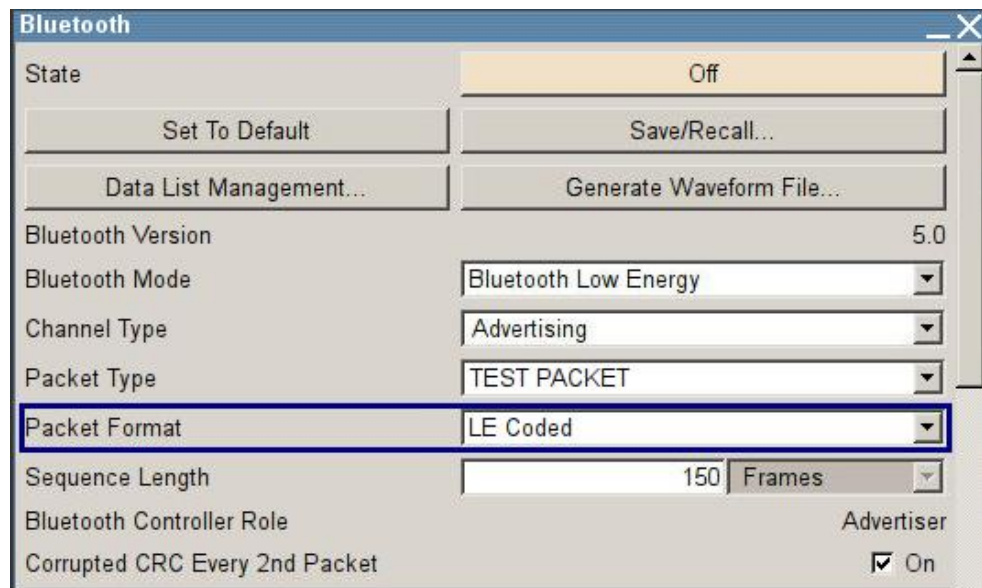
Settings on DUT:

ı   As described under 6.2.6.1, but do not set the receiver symbol rate to 1 Ms/s; instead, set the receiver to LE Coded PHY with data coding S = 2 and configure it so that a transmitter with a stable modulation index is expected.
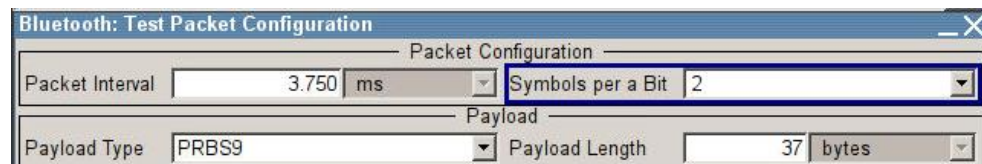
Settings on SMBV100A:

ı   As described under 6.2.6.1, but:

Set *Packet Format* to *LE Coded*:
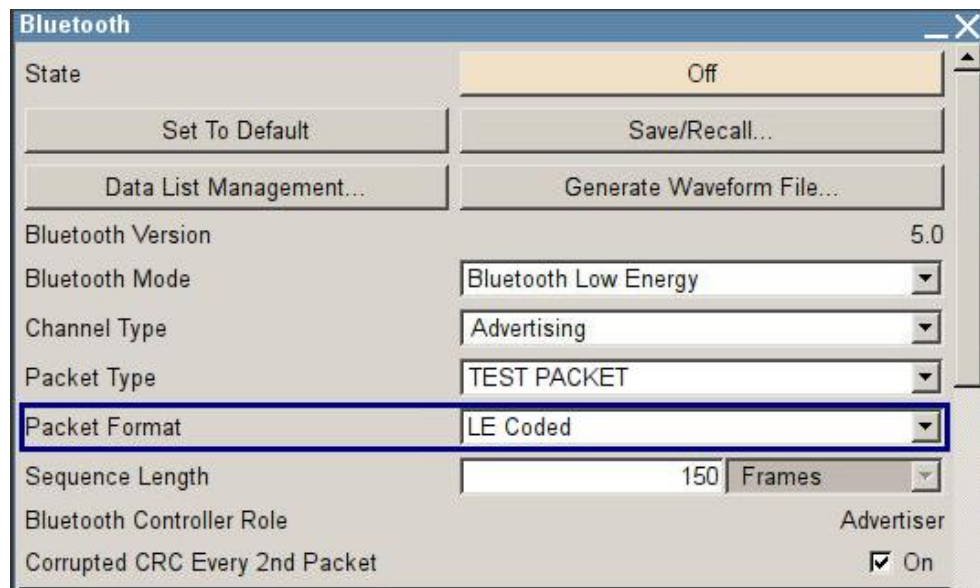
In the "Test Packet Configuration" window, set *Symbols per a Bit* to 8:
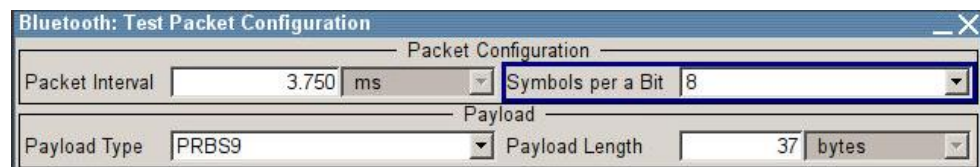
The following conditions must be fulfilled:

ı   As described under 6.2.6.1.

7 References

[1]   1. **Schulz, Bernhard.** 1MA108. *From cable replacement to the IoT: Bluetooth 5.* s.l. : Rohde & Schwarz, 2016. 3e.

[2]   2. **Coupe, Cheryl.** *A Guide to Joining the Internet of Things.* s.l. : Bluetooth SIG, Inc, 2016.

[3]   3. **Bluetooth SIG.** RF PHY. *Bluetooth Test Specification.* December 2016. RF-PHY.TS.5.0.0.

[4]   4. —. Bluetooth Core Specification v5.0. 06 December 2016.

8 Ordering Information

CMW hardware		
Designation	Type	Order No.
Radiocommunication Tester	R&S®CMW500 R&S®CMW290 R&S®CMW270	1201.0002K50 1201.0002K29 1201.0002K75
Basic Assembly	R&S®CMW-PS503 (CMW500) R&S®CMW-PS272 (CMW270)	1202.5408.02 1202.9303.02
Baseband Measurement Unit	R&S®CMW-B100A	1202.8607.02
Baseband Measurement Generator	R&S®CMW-B110A	1202.5508.02
Baseband Interconnection Board	R&S®CMW-S550B	1202.4801.03
Advanced RF Frontend Module or RF Frontend Module Extra RF Frontend Module	R&S®CMW-S590D R&S®CMW-S590A R&S®CMW-B590A	1202.8707.03 1202.5108.02
RF Converter Module Extra RF Converter Module	R&S®CMW-S570B R&S®CMW-B570B	1202.8659.03
Signaling Unit Universal (SUU)	R&S®CMW-B200A	1202.6104.02

CMW software		
Designation	Type	Order No.
Bluetooth Low Energy Signaling	R&S®CMW-KS611	1207.8805.02
Bluetooth, Low Energy, TX Measurement	R&S®CMW-KM611	1203.9307.02
Spectrum Analyzer	R&S®CMW-KM010	1203.5953.02

Spectrum analyzers		
Designation	Type	Order No.
Signal and Spectrum Analyzer	R&S®FSWxx xx: 8,13,26,43,50,67,85	1321.8000Kyy yy: 08,13,26,43,50,67,85
Signal and Spectrum Analyzer	R&S®FSVxx xx: 4,7,13,30,40	1321.3008Kyy yy: 04,07,13,30,39,40
Signal and Spectrum Analyzer	R&S®FSVAxx xx: 4,7,13,30,40	1321.3008Kyy yy: 05,08,14,31,41
Vector Signal Analysis for FSW	R&S®FSW-K70	1313.1416.02
Vector Signal Analysis for FSV/A	R&S®FSV/A-K70	1310.8455.02

xx: indicates the upper frequency limit in GHz.

Signal generators		
Designation	Type	Order No.
Vector Signal Generator Base Unit [1]	R&S®SMW200A	1412.0000.02
Vector Signal Generator Base Unit [1]	R&S®SMBV100A	1407.6004.02
RF and Microwave Signal Generator Base Unit [1]	R&S®SMB100A	1406.6000.02
Signal Generator Base Unit [1]	R&S®SMC100A	1411.4002.02
SGMA Vector RF Source, 1 MHz to 3 GHz RF, baseband hardware included [1]	R&S®SGT100A	1419.4501.02
SGMA RF Source [1]	R&S®SGS100A	1416.0505.02

1) The equipment options for the base unit can be found at www.rohde-schwarz.com or contact your local Rohde & Schwarz representative.

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