Zircon Reference Manual V2.3

An RF tester for the *Bluetooth*® 5 BR/EDR standard, compatible with TLF3000.

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2 Overview.

TLF3000 is a wideband, ultra-high dynamic range 2.4 GHz software-defined receiver, signal analyser and signal generator. It captures and analyses the entire 2402-2480 MHz band simultaneously. It can also generate arbitrary waveforms occupying the band 2395-2485 MHz with a maximum peak level of 0 dBm. Additionally, it includes a CW signal generator covering 25MHz to 6GHz with a typical output level of -50 dBm to -28 dBm

Zircon is a *Bluetooth®* 5 BR/EDR configuration for the *TLF3000* software-defined receiver, signal analyser and signal generator. The *Zircon* configuration can:

1. Act as either a signalling or non-signalling tester.
2. Perform the majority of phy level tests as specified in Bluetooth Radio Frequency Test Specification without the need for additional test equipment. Testing beyond the limits of the specification is also supported.
3. Act as a signal generator, creating all necessary signals for receiver testing including signals outside the specification. Additional test equipment is required to perform high level out-of-band blocking tests.
4. Act as a signal analyser, performing transmitter and receiver tests which are manually configured.
5. Act as a packet sniffer with live output to Wireshark or data archive in pcap-ng format.

The configuration has been honed for speed. The *TLF3000* possesses a unique parallel architecture to maximise throughput.

A key feature of the unit is its ability to perform C/I receiver selectivity and intermodulation tests without the need for additional test equipment. This is possible due to *TLF3000*'s ultra-linear wideband signal generator. This permits both wanted and interfering signals to be generated through the same signal path. The high linearity and low noise floor ensure that there is ample dynamic range to encompass both the wanted and interfering signals. Furthermore, high fidelity filtering of the interfering signals ensures that they are correctly bandlimited and that unwanted sidebands are not responsible for test failures; this is frequently overlooked when external test equipment is used to provide these signals. The single signal path also removes the need for time consuming and laborious calibration of signal combiners as well as eliminating the need to ensure that the injected interfering and wanted signals do not generate intermodulation products before arriving at the DUT.

Unique to *TLF3000* is a 25 MHz to 6 GHz signal generator. The source is not capable of providing the strong blocking signals required by the RF test specification, but it is sufficient to enable receiver blocking performance to be explored in the 2 to 3GHz region.

The *Zircon* configuration is highly parameterised, permitting it to be configured for different scenarios. For example:

1. The unit may be controlled directly from a host machine via USB or Ethernet.
2. The unit can be operated in either signalling or non-signalling mode.

3 Control.

3.1 Overview

Zircon can be controlled in three ways:

Control method	Interface	
	USB	Ethernet
Python	✓	✓
C dll	✓	✓
Zircon GUI	✓	✓

Table 1: Methods of Controlling Zircon

3.2 Python or C dll

Python and C dlls can be provided for driving the *Zircon* application. These can connect to the *Moreph30* unit over either USB or Ethernet.

3.3 Zircon GUI

A GUI is shipped with the *Zircon* application. This permits the application to be controlled via a host running Windows, Linux or OS X. The GUI connects to the *Moreph30* either over USB or Ethernet. The GUI exposes the majority of the *Zircon* functionality.

The GUI may also be used to generate test script files in a format which can be used by the Python and C dlls.

4 Operating Modes.

4.1 Overview

Zircon has three main operating modes:

Mode	DUT control	Test control	Tx Test	Rx Test
Loopback tester	Over-the-air	Script	✓	✓
Signal generator	None	User		✓
Signal analyser	Over-the-air	User	✓	✓

Table 2: Zircon operating modes overview.

In addition to the three main operating modes, *Zircon* also supports packet sniffing and LMP message monitoring to aid debugging of DUT connection issues.

4.2 Loopback tester

The loopback tester mode executes tests in accordance with the Bluetooth Radio Frequency Test Specification. The tests to be performed are entered into a script which is then executed by *Zircon*. The DUT is automatically controlled by *Zircon* over-the-air.

All tests are fully parameterised, permitting exploration of margin against the Bluetooth 5 specification or datasheet figures.

4.3 Signal Generator

The signal generator mode permits manual control of all the signal sources used in the Bluetooth Radio Frequency Test Specification. Any combination of the following signals can be generated simultaneously:

1. Packetised BR/EDR test signal
2. Continuously modulated or packetised BR interferer signal
3. Up to three independent in-band CW signals, which may be pulsed
4. In-band AWGN, which may be pulsed
5. Out-of-band CW signal.

All signal sources are fully parameterised.

4.4 Signal Analyser

The signal analyser mode monitors all 79 BR/EDR channels simultaneously. The signal analyser will process unwhitened packets in accordance with the transmitter tests contained within the Bluetooth Radio Test Specification.

When in signal analyser mode, the DUT may either be controlled over-the-air or independently using the chip vendor’s tools, ie the signal analyser can be operated in either a signalling or non-signalling mode. If the DUT is controlled over-the-air, then it is possible to perform receiver tests as well as transmitter tests.

The signal analyser mode also permits the capture of raw IQ data.

5 Launching the Zircon GUI.

In order to communicate with the *TLF3000* unit, it is necessary to attach it to a host computer via USB or Ethernet (or both). An Ethernet connection is only possible if the host computer and *TLF3000* unit reside on the same subnet. The *TLF3000* IP address can be changed by connecting it to a host computer via USB and using the *Teledyne LeCroy Wireless PHY Tester*.

To launch the *Zircon* GUI it is first necessary to run *Teledyne LeCroy Wireless PHY Tester*. This should result in the following screen being displayed:

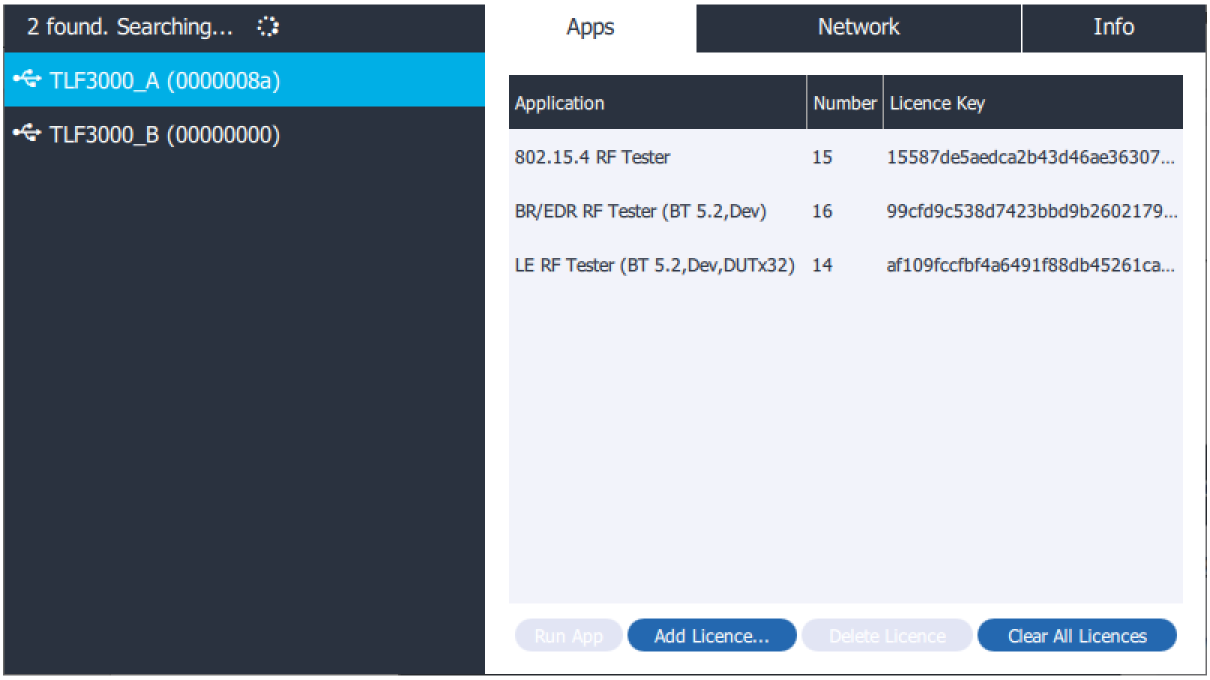


Figure 1: Teledyne LeCroy Wireless PHY Tester main screen.

This screen indicates that the following *TLF3000* devices have been discovered:

1. Serial number 0000008A connected via USB (highlighted)
2. Serial number 00000000 connected via USB

The right-hand side of the window has three tabs:

1. *Configuration*. Shows which configurations are licensed to run on this unit. It also permits the loading of new licence keys.
2. *Network*. Shows the current network settings and permits these to be modified.
3. *Info*. Provides more information about the unit and permits the unit's friendly name to be modified. It also provides a means of updating the firmware on the unit.

To launch the *Zircon* configuration open the ‘Configuration’ tab and then either:

1. Double click on the *BT 5BR/EDR RF Tester* configuration
2. Highlight the *BT 5 BR/EDR RF Tester* configuration and then click the “*Run App*” button.

On launching the configuration, the searching cursor should stall, the fan on the *TLF3000* unit will start to spin and after a few seconds the *Zircon* GUI will load.

6 Anatomy of the Zircon GUI.

6.1 Overview

The Zircon GUI is composed of the following elements:

1. A tool bar along the top of the window
2. A monitor panel to the right of the window
3. A status bar at the bottom of the window
4. Mode tabs located immediately underneath the tool bar
5. A mode control panel to the left of the window
6. A graphics area
7. A scripting/tabular results area below the graphics area
8. An expandable device status area above the graphics area

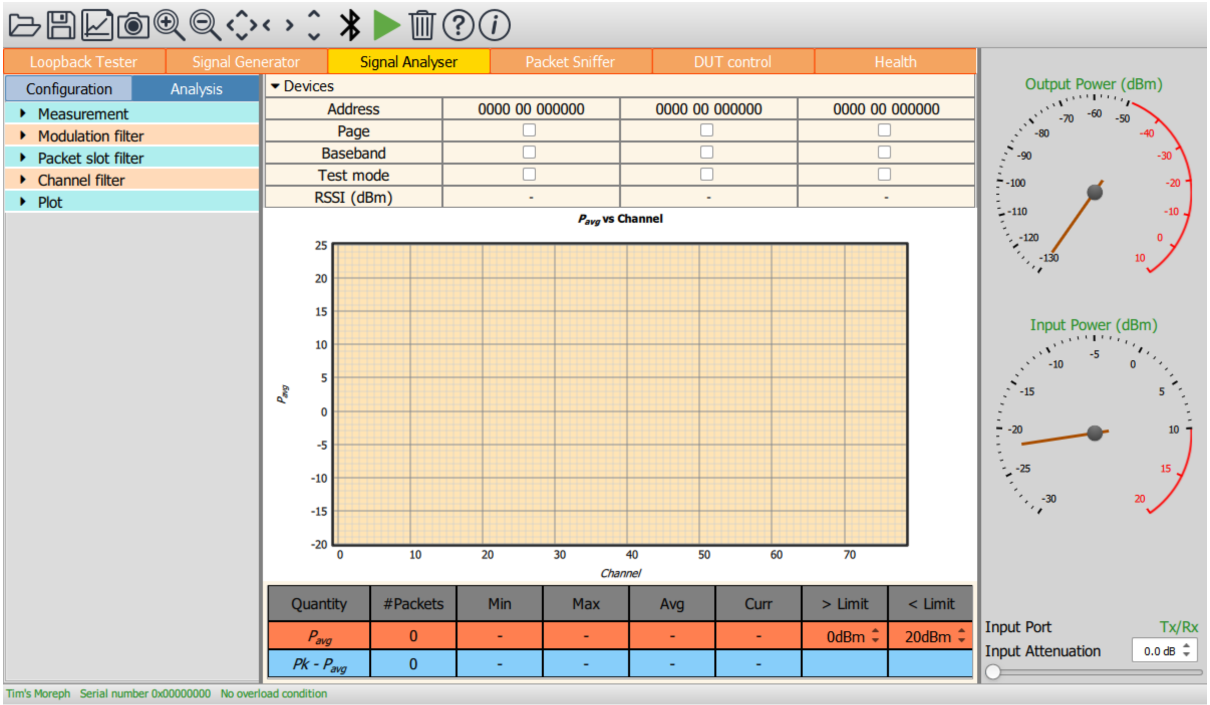


Figure 2: Zircon GUI

6.2 Toolbar

The toolbar contains the following elements:

6.2.1 Open and save

Opens and loads a settings file. Settings are saved individually for each mode of operation. The appropriate settings file is automatically selected on the basis of the current mode tab.

Saves the settings, results or log files. Settings are saved individually for each mode of operation. The choice as to whether settings, results or log files are saved is determined by the file extension which is selected. This tool can also be used to save test scripts in the format required by the native programming language.

6.2.2 Screen capture

Saves the current graphics area as an image file. A variety of image file formats are supported.

Takes a screen shot of the GUI and saves as an image file. A variety of image file formats are supported.

6.2.3 Zooming

Activates the cross-hair cursor which permits zooming within in the graphics area. Depress the left mouse button whilst dragging the cursor to select the area to be displayed. Clicking the right mouse button within the graphics area will give a list of additional zoom options.

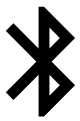
Zooms out within the graphics area. Clicking the right mouse button within the graphics area will give a list of additional zoom options.

Pans within the graphics area. Hold down the left mouse button and drag to pan anywhere within the graphics display.

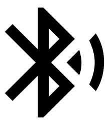
Pans along the x-axis within the graphics area. Hold down the left mouse button and drag horizontally. This is particularly useful for examining long waveforms.

Pans along the y-axis within the graphics area. Hold down the left mouse button and drag vertically.

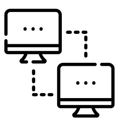
6.2.4 Device control



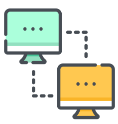
Inquiry button. Clicking this icon will result in a device inquiry being performed. The device status area will be expanded to show the devices which are discovered. Whilst the inquiry is in progress the icon will change to:



Device inquiry in progress. The device inquiry can be stopped by clicking the icon.



Device page and connect icon. When clicked the configuration will attempt to page and connect to the device selected in the device status window. Once connected the icon will change to:



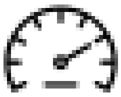
Device connected icon. This shows that a device is currently connected. If this icon is clicked then the device will be disconnected.

6.2.5 Run and clear

Causes the currently selected mode to run. *NOTE: the signal generator will not output energy until this is clicked.*

Stops the currently selected mode running. A running operation will automatically be aborted if a different mode of operation is selected.

Clears the current results history (not applicable in signal generator mode or packet sniffer mode). Any error messages will also be cleared.



Measure the frequency and amplitude of a CW signal. Only applicable in loopback test mode.

6.2.6 Help

Displays the online documentation in a web browser.

Displays version information.

6.3 Monitor panel

6.3.1 Overview

The purpose of the monitor panel is to permit the user to quickly ascertain whether:

1. There is RF energy being emitted from the unit
2. There is RF energy being received by the unit

Whenever the unit or DUT appears to be unable to receive, the monitor panel should always be the first item to examine. Many problems can be quickly resolved with the information that it displays.

The monitor panel also determines which RF port is being used and provides manual control of the receiver front-end attenuation.

6.3.2 Output power

The output power gauge shows the energy being emitted by the *TLF3000*. The gauge is only approximate and should not be used for accurate measurements.

The red arc indicates the overload region. If an overload does occur, this will be evident by the ‘Output Power (dBm)’ label turning red and a warning message being displayed in the status bar.

The output power gauge only shows the energy being emitted within the 2.4 GHz ISM band. Energy from the out-of-band CW blocker is not included, even if its frequency lies within the 2.4 GHz ISM band.

6.3.3 Input power

The input power gauge shows the energy incident on the selected *TLF3000* input port. The gauge is only approximate and should not be used for accurate measurements.

The red arc indicates the overload region. If an overload does occur, this will be evident by the ‘Input Power (dBm)’ label turning red and a warning message being displayed in the status bar. It may be possible to remove a receiver overload condition by:

1. Adding additional receiver front-end attenuation using the control at the bottom of the monitor panel.
2. Swapping to the ‘Tx/Rx’ RF port if the ‘Monitor In’ RF port is being used.

The input power gauge only shows energy within the 2.4 GHz ISM band. F-bar filters at the front of the receiver chain ensure other energy is eliminated and cannot block the receiver.

6.3.4 Input port

The input port switch selects which of the two RF input ports will be used:

1. The 'Monitor In' port is suitable for off-air monitoring and has a noise figure of 6 dB. In benign environments no additional receiver front-end attenuation should be required. However, in environments with strong Wi-Fi activity, it may be necessary to add receiver front-end attenuation to prevent overload conditions.
2. The 'Tx/Rx' port is suitable for conducted measurements. If the DUT is capable of outputting more than +10 dBm, it may be necessary to add receiver front-end attenuation to prevent overloading the receiver.

6.3.5 Input attenuation

These controls are used to select the receiver front-end attenuation. The attenuation may be adjusted by:

1. Moving the slider
2. Using the up/down arrows on the spin box
3. Typing a numeric value into the spin box text area

The available attenuation range is 0 to 31.5 dB in steps of 0.5 dB.

6.4 Status bar

6.4.1 Overview

The status bar at the bottom of the window is divided into four areas:

1. Friendly name of the *TLF3000* unit
2. Serial number of the *TLF3000* unit
3. Overload indicator
4. Error message text
5. Current data and time

6.4.2 Friendly name

Displays the *TLF3000* friendly name. This may be modified using the *Info* tab on the *ApplicatonLoader*.

6.4.3 Unit serial number

Displays the *TLF3000* serial number as an 8 digit hexadecimal value.

6.4.4 Overload indicator

The overload indicator will turn red when an overload condition occurs on either the transmitter output or the selected receiver input port. The text of the message will indicate where the overload condition is occurring.

6.4.5 Error message text

The error message text reflects the last error detected by the *Zircon* configuration running on the *TLF3000* unit. This message is cleared when either the ‘Run’ or ‘Clear’ buttons are pressed, or when a different operating mode is selected.

6.4.6 Data and time

The current data and time are displayed at the bottom right of the status bar.

6.5 Mode tabs

The operating mode is selected by the tabs immediately underneath the tool bar. The following operating modes can be selected:

1. Loopback tester
2. Signal generator
3. Signal analyser
4. Packet sniffer
5. DUT control

In addition, it is possible to display a page showing the health of the *TLF3000* unit.

Whenever a new mode of operation is selected, any currently running tests are aborted.

6.6 Mode control panel

For each operating mode, a mode control panel is displayed to the left of the window. This panel allows the user to define the parameters for the current operating mode. The contents of the mode control panel are mode-specific.

In the case of the loopback tester and signal analyser, the mode control panel is divided into two tabs:

1. *Configuration*. This tab contains parameters which control the over-the-air signalling to the DUT and govern how data will be collected.
2. *Analysis*. This tab contains parameters which determine how results from the collected data will be displayed.

6.7 Graphics area

In the loopback tester and signal analyser modes of operation, a graphical representation of the results is displayed in the graphics area. Which results are displayed and how they are displayed are determined by the settings in the ‘Analysis’ tab on the mode control panel.

In the signal generator mode, the graphics area provides a visual indication of which signals have been programmed. Note that the graphics area only shows what has been programmed; to make the programmed signals appear at the transmitter port, the ‘Play’ button within the tool bar must be activated.

In the packet sniffer mode, the graphics area shows a spectral display of the prevailing RF environment.

In the DUT control mode, the graphics area displays the LMP messages which have been exchanged between the tester and the DUT. The most recent messages are displayed at the top of the screen.

6.8 Scripting/tabular results area

In the loopback tester mode, the region below the graphics area is used for constructing and displaying test scripts. This area also indicates whether the tests have been run, and if so, whether they passed or failed.

In the signal analyser mode, the region below the graphics area is used to display tabular results. Which results are displayed is determined by settings on the ‘Analysis’ tab in the mode control panel. The results tables also contain test limits which can be adjusted by the user. Tests that fail the limits are highlighted. The contents of the graphics display area can also be controlled by highlighting rows within the results table.

The scripting/tabular results area is not used in signal generator mode, packet sniffer mode or DUT control mode.

6.9 Device Status Area

The device status area is available in loopback test mode, signal analyser mode and DUT control mode. It can be expanded or collapsed by clicking on the arrow head at the top left of the window. It will automatically be expanded when an inquiry is performed and automatically collapsed when a test is started.

The device status area is able to display the addresses of up to 3 devices which were discovered during an inquiry. An individual device may be selected to participate in the test by checking the ‘Page’ box directly underneath the address. At the current time only one device may be selected. Future versions of the *Zircon* configuration may permit more than one device to be selected in loopback test mode.

When a test is running, the indicator boxes below the device address should be greyed. The ‘Baseband’ box indicates that the TLF3000 has successfully made a baseband connection with the device. The ‘Test mode’ box indicates that the DUT has successfully entered test mode. This box may flicker each time a change to the DUT test mode parameters is initiated.

7 Signal Generator Mode.

7.1 Overview

The signal generator is able to produce any combination of the following signals:

1. Packetized BR/EDR test signal
2. Continuously modulated or packetised BR interferer signal
3. Three independent in-band CW signals which may be pulsed
4. In-band AWGN which may be pulsed
5. Out-of-band CW signal.

The mode control panel on the left-hand side of the screen lists the signals which can be generated. The switch to the left of the signal name programs the signal on or off. Although a signal may be programmed on, *no output is generated from the unit until the 'Play' button in the tool bar is activated.*

The top graph in the graphics window shows a symbolic representation of signals generated within the 2.4 GHz ISM band. The graphics assume a resolution bandwidth of 100 kHz, hence the displayed levels for modulated signals will be slightly lower than their programmed levels.

The bottom graph in the graphics window shows a symbolic representation of the signals generated between DC and 6 GHz. The graphics assume a resolution bandwidth greater than modulation bandwidth, hence all signals appear at their programmed levels.

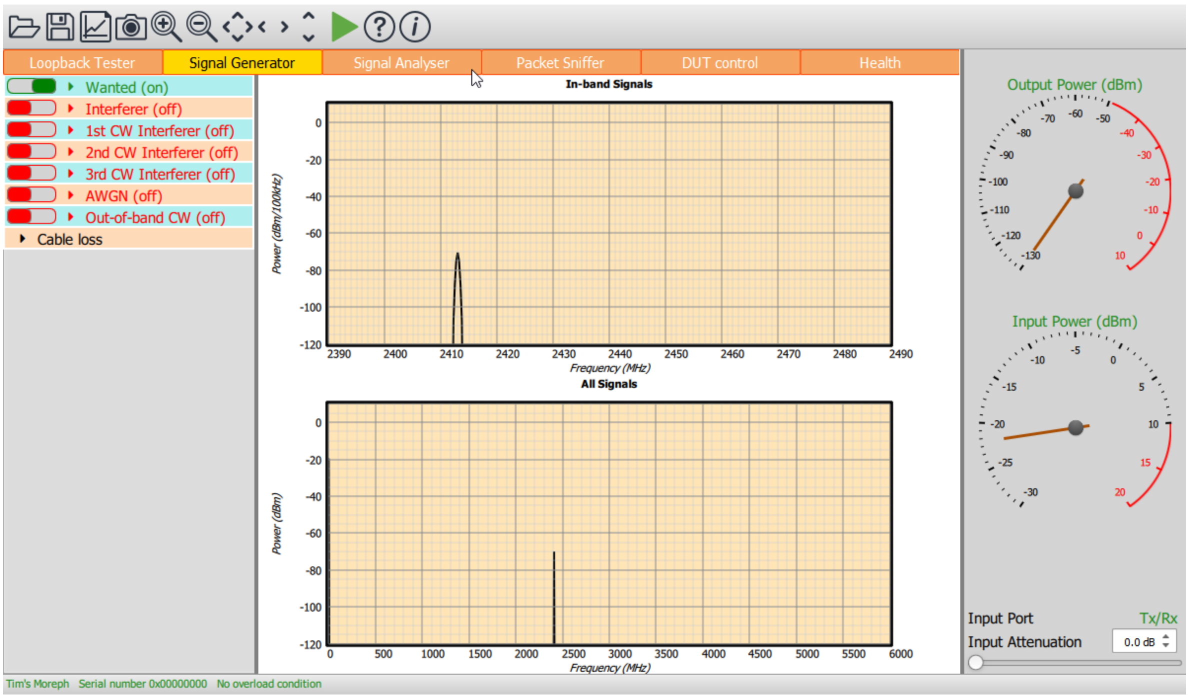


Figure 3: Zircon GUI in signal generator mode.

7.2 RF connections

The signal generator output is on the Tx/Rx port.

7.3 Programming the packetised BR/EDR signal

7.3.1 Overview

To turn the packetised BR/EDR signal on or off, toggle the switch to the left of the 'Wanted' text.

To program the packetised BR/EDR signal, expand the 'Wanted' signal menu by clicking on it:

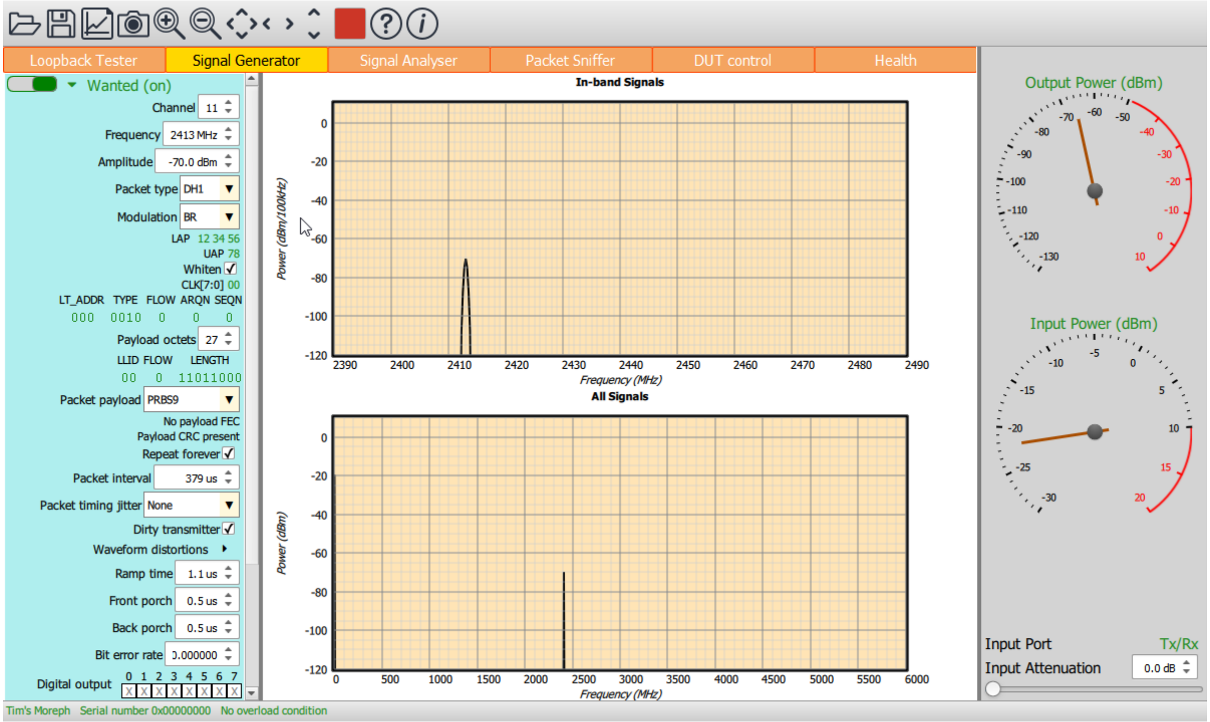


Figure 4: Programming the packetised BR/EDR signal.

7.3.2 Carrier frequency

The frequency of the carrier can be set anywhere between 2395MHz and 2485MHz inclusive in 1MHz steps by:

1. using the channel number spin box
2. using the frequency spin box

As with all spin boxes, adjustment can be performed either by using the up/down arrows or by entering a numeric value into the text field.

7.3.3 Amplitude

The amplitude of the wanted signal can be adjusted from -120 dBm to 0 dBm for basic rate packets and -120dBm to -3.1dBm for EDR packets. For EDR packets, the amplitude denotes the average power in the EDR portion of the packet. The total combined peak output power of the unit within the 2.4 GHz ISM band is limited to 0 dBm. Therefore, if other signals are active, the maximum output power for the wanted signal will be reduced to maintain the peak output power within the 0dBm limit.

7.3.4 EDR Amplitude

When an EDR packet type is selected, a spin box is visible which permits the relative level of the GFSK portion of the packet to be set relative to the EDR portion of the packet. The average energy in the GFSK portion of the packet may be set between +3dB and -1dB relative to the power in the EDR portion of the packet.

7.3.5 Packet type selection

A combo box permits any one of the possible Bluetooth packet types to be generated. Support of DV packets is incomplete. Changing the packet type may impact on which other options are displayed.

7.3.6 Modulation

A combination box is used to display the modulation which will be used, ie BR, 2-EDR or 3-EDR. The modulation cannot be changed directly but is deduced from the packet type which has been selected.

7.3.7 LAP

The LAP used to generate the packet synch word is displayed as a 6 digit hex number. It can be changed by typing over the displayed digits.

If the selected packet type is ID packets, then a checkbox is provided to force the LAP to the general inquiry LAP.

7.3.8 UAP

The UAP used to generate the header error checksum (HEC) is displayed as a 2 digit hex number. It can be changed by typing over the displayed digits.

7.3.9 Whitening

A checkbox indicates whether the contents of the packet will be whitened. If whitening is selected, then the lowest 8 bits of the Bluetooth central clock, CLK[7:0], are displayed as a 2 digit hex number. Bits 1 through 6 are used to determine the whitening seed. Bits 0 and 7 are ignored. The value of CLK[7:0] can be changed by typing over the displayed digits.

7.3.10 Packet header

The contents of the packet header are displayed as five separate fields. Each field has the LSB on the left-hand side:

1. LT_ADDR. This is displayed as a 3 bit binary number. Each bit can be toggled by clicking on it. If the signal generator is to be fed into the signal analyser of a second TLF3000 unit, then set the LR_ADDR to 1.
2. TYPE. The packet type field is displayed as a 4 bit binary number. This is deduced from the packet type selection combo box and cannot be edited directly.
3. FLOW. The FLOW field is a single bit binary number which can be toggled by clicking on it.
4. ARQN. The ARQN field is a single bit binary number which can be toggled by clicking on it.
5. SEQN. The SEQN field is a single bit binary number which can be toggled by clicking on it.

7.3.11 Payload octets

If the selected packet type contains a payload, then a spin box showing the number of payload octets is displayed. The number of octets does not include any payload header or CRC, if present.

7.3.12 Payload header

If the selected packet type requires a payload header, then this is displayed as three binary fields. Each field has the LSB on the left-hand side:

1. LLID. This is a 2 bit binary number which can be modified. Individual bits can be changed by clicking on them.
2. FLOW. This is a 1 bit binary number which can be modified by clicking on the displayed digit.
3. LENGTH. This is either a 5 or 10 bit field, depending on packet type. It displays a binary representation of the payload length. This field is not editable directly but is set based on the payload length spin box.

7.3.13 Payload

The packet payload can be set to any one of the following (least significant bit first):

1. PRBS9 sequence
2. PRBS11 sequence
3. PRBS15 sequence
4. PRBS20 sequence
5. PRBS23 sequence
6. PRBS29 sequence
7. PRBS31 sequence
8. 11110000 repeated
9. 10101010 repeated
10. 11111111 repeated
11. 00000000 repeated
12. 00001111 repeated
13. 01010101 repeated
14. User defined

If the “User defined” option is selected, then a hex representation of the packet payload is displayed below the packet payload combination box. The payload may be edited by directly typing over the displayed hex digits.

7.3.14 FEC

The FEC to be applied to the packet is shown on a single status line. This is deduced from the packet type selected and cannot be edited directly.

7.3.15 CRC

A single status line shows whether a CRC will be added to the packet payload. This is deduced from the packet type selection and cannot be edited directly.

7.3.16 Number of packets to generate

If the ‘Repeat forever’ box is checked, then the signal generator will continue to send BR/EDR packets until the ‘RUN/STOP’ button in the toolbar is reset.

If the ‘Repeat forever’ box is unchecked, then a spin box is displayed which determines the number of packets which will be generated. These packets will commence as soon as the ‘RUN”/STOP’ button in the toolbar is pressed. If any packet parameters are changed during transmission, then the previous transmission will be cancelled, the number of packets transmitted reset to zero and a new sequence of packets with the modified parameters sent.

The minimum number of packets which can be generated is 1 and the maximum number is 65535.

7.3.17 Packet interval

The packet interval is defined as the time between the start of the preamble of one packet and the start of the preamble of the subsequent packet. This interval can be adjusted using the packet interval spin box. The minimum packet interval is dependent on both the payload length and the modulation scheme. The maximum packet interval is 5s.

The packet interval may change automatically if either the payload length or packet type is changed.

7.3.18 Packet timing jitter

It is possible to impose timing jitter on the start of each packet. The timing jitter is relative to the expected packet start time, not relative to the previous packet. Hence the mean symbol timing is correct even if packet timing jitter is enabled.

The packet timing jitter combo box permits 3 different types of jitter distribution:

1. No jitter
2. Uniformly distributed jitter
3. Gaussian distributed jitter (approximate)

If one of the options other than ‘No jitter’ is selected, then a spin box appears which permits the peak jitter to be entered. The peak jitter can be set between 0µs and 1s. If the jitter extends into the period where a subsequent packet is expected to be transmitted, then that packet will be dropped.

7.3.19 Dirty transmitter

7.3.19.1 Overview

By selecting dirty transmitter mode, it is possible to control:

1. Modulation index
2. Carrier offset
3. Carrier drift magnitude
4. Carrier drift rate
5. Symbol timing error

The carrier drift is applied in accordance with the Bluetooth Radio Frequency Test Specification. For basic rate packets the carrier drift is specified as:

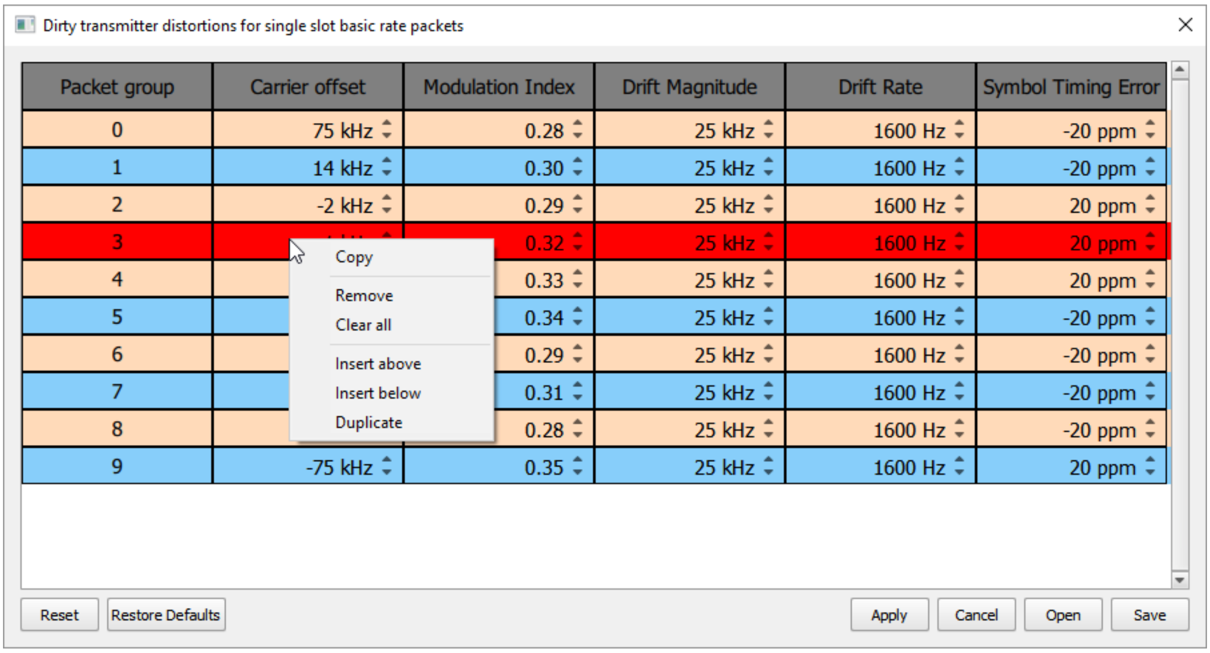
1. The carrier drift at the start of each packet is zero.
2. The carrier drift follows a sinusoidal variation whose frequency is determined by the drift rate parameter.
3. The magnitude of the sinusoidal variation is determined by the drift magnitude parameter.
4. Successive packets have the sign of the carrier drift reversed.

The carrier drift for EDR packets is identical except that no carrier offset is applied during the GFSK portion of the packet and the carrier drift commences at the start of the EDR synchronisation word.

The GUI holds 4 different sets of waveform distortions which are applied to different packet types:

1. Basic rate single slot packets
2. Basic rate 3 slot packets
3. Basic rate 5 slot packets
4. EDR packets

Clicking on the ‘Waveform distortions’ button will pop-up the dirty transmitter dialog which displays the waveform distortion table which is currently in use:



Packet group	Carrier offset	Modulation Index	Drift Magnitude	Drift Rate	Symbol Timing Error
0	75 kHz	0.28	25 kHz	1600 Hz	-20 ppm
1	14 kHz	0.30	25 kHz	1600 Hz	-20 ppm
2	-2 kHz	0.29	25 kHz	1600 Hz	20 ppm
3		0.32	25 kHz	1600 Hz	20 ppm
4		0.33	25 kHz	1600 Hz	20 ppm
5		0.34	25 kHz	1600 Hz	-20 ppm
6		0.29	25 kHz	1600 Hz	-20 ppm
7		0.31	25 kHz	1600 Hz	-20 ppm
8		0.28	25 kHz	1600 Hz	-20 ppm
9	-75 kHz	0.35	25 kHz	1600 Hz	20 ppm

Figure 5: Dirty transmitter dialogue box displaying the waveform distortion table currently in use.

For basic rate packets the transmitted signal is divided into segments 20ms long. Packets residing in the first segment are transmitted using the distortions defined in the first row of the waveform distortion table, packets in the second segment are transmitted using the distortions defined in the second row of the waveform distortion table, etc. Once all the rows in the waveform distortion table have been exhausted, the first row is reused.

For EDR packets, the same scheme is used except that the packets are divided into segments which are each 20 packets long.

Each individual distortion specified in the waveform distortion table can be adjusted using the associated spin box, either by using the up/down arrows or by entering a numeric value into the text field. The parameters can be varied over the following ranges:

Parameter	Minimum value	Maximum value
Carrier offset	-250 kHz	+250kHz
Modulation index	0.23	0.40
Drift magnitude	-78 kHz	+78 kHz
Drift rate	0 Hz	20000 Hz
Symbol timing error	-100 ppm	+100 ppm

Table 3. Ranges over which the transmit distortions may be varied.

7.3.19.2 Editing the waveform distortion table

A row in the table can be selected by left or right clicking on the packet group number in the first column. Once a row in the packet group table has been selected, an edit menu can be popped-up by right clicking anywhere in the selected row.

The edit row permits the following operation to be performed:

1. *Copy*. The contents of the selected row are copied into the waveform distortion clipboard
2. *Paste*. The contents of the waveform distortion clipboard are copied into the selected row (this option is only available if the waveform distortion clipboard is not empty)
3. *Remove*. The selected row is deleted from the waveform distortion table.
4. *Clear All*. The entire waveform distortion table is deleted. Once the table has been cleared, a new entry can be inserted by clicking immediately underneath the table header.
5. *Insert above*. A new entry is inserted above the selected row. The new entry has no distortions and a modulation index of 0.32.
6. *Insert below*. A new entry is inserted below the selected row. The new entry has no distortions and a modulation index of 0.32.
7. *Duplicate*. The selected row is duplicated.

A new row can be inserted at the end of the waveform distortion table by clicking immediately below the last row. The new entry has no distortions and a modulation index of 0.32.

7.3.19.3 Dirty transmitter dialog buttons

The buttons along the bottom of the dirty transmitter dialog perform the following functions:

1. *Reset*. The contents of the waveform distortion table are reset to the values they held when the dirty transmitter dialog was popped up and all edits are discarded.
2. *Restore defaults*. The contents of the waveform distortion table are reset to the values specified in the Bluetooth Radio Frequency Test Specification.
3. *Apply*. The current contents of the waveform distortion table will be used for all future transmissions of the relevant packet type and the dirty transmitter dialog is closed.
4. *Cancel*. Any edits to the waveform distortion table are discarded and the dirty transmission dialog is closed. All future transmissions will use the waveform distortions which were present prior to the dirty transmitter dialog being popped-up.
5. *Open*. The waveform distortion table will be loaded from an XML file.
6. *Save*. The currently displayed waveform distortion table will be saved to an XML file.

7.3.20 Ramp time

The time taken for the power to ramp up and down at the start and end of the packet can be controlled using the 'Ramp time' spin box. The power ramp profile follows a Chebyshev window. The minimum ramp time is 1.1µs and the maximum ramp time is 10µs.

7.3.21 Front and back porch

After the power ramp, there is a period of unmodulated carrier prior to the commencement of the modulated packet preamble. This period is referred to as the front porch. After the last symbol of the payload has been sent, there is a period of unmodulated carrier prior to the down ramp. This period is referred to as the back porch. The length of both the front and back porch may be set independently using the 'Front porch' and 'Back porch' spin boxes. The minimum lengths are 0µs and the maximum lengths are 25µs.

7.3.22 Bit error rate

By default, the wanted signal modulator faithfully outputs the bits as defined by the packet payload. However, it is possible to impose random bit errors on the stream entering the modulator. These errors are uncorrelated. The bit error rate can be specified using the 'Bit error rate' spin box. The maximum bit error rate is 0.0625. The resolution of the bit error rate is 0.000001.

7.3.23 Digital output

To enable other test equipment to be synchronised with Zircon transmissions, it is possible to toggle digital output lines when a packet is being transmitted. The selected lines will be low between transmissions and go high during the transmission.

The *TLF3000* unit has 8 digital output lines. All 8 lines are available for signalling packet transmission. Lines are selected by toggling 'X' to '1' in the appropriate box.

If a digital output line is specified as monitoring both wanted signal transmissions and modulated interferer transmissions, then the state of the line is the logical OR of the two signals.

The IO voltage for the lines may be either:

1. An internal 3.3 V generated supply
2. An external supply in the range 1.2 V to 5.0 V

7.4 Programming the modulated interferer signal

7.4.1 Overview

Zircon can generate either a packetised or continuously modulated interferer signal. This signal is required to perform receiver C/I and intermodulation tests.

To turn the modulated interferer signal on or off, toggle the switch to the left of the 'Interferer' text.

To program the modulated interferer signal, expand the 'Interferer' signal menu by clicking on it:

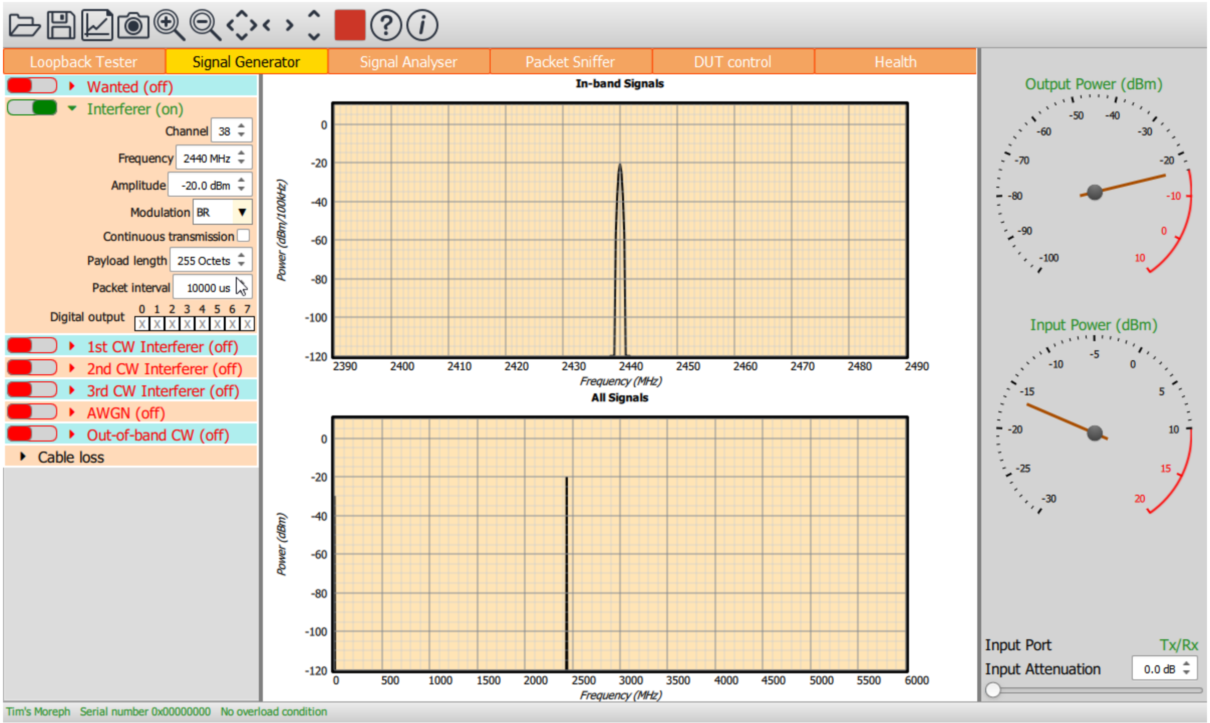


Figure 6: Programming the modulated interferer signal.

7.4.2 Carrier frequency

The frequency of the carrier can be set anywhere between 2395MHz and 2485MHz inclusive in 1MHz steps by:

1. using the channel number spin box
2. using the frequency spin box

As with all spin boxes, adjustment can be performed either by using the up/down arrows or by entering a numeric value into the text field.

If the receiver intermodulation tests are being performed on channels near the band edges, then the required frequency for the modulated interferer signal may fall outside the 2395-2485 MHz band.

Under these circumstances it will not be possible to perform the intermodulation test with the interferers on one side of the wanted signal. It will always be possible to perform the intermodulation test with the interferers placed closer to the band centre than the wanted signal.

7.4.3 Amplitude

The amplitude of the modulated interferer signal can be adjusted from -120 dBm to 0 dBm. The total combined output power of the unit within the 2.4 GHz ISM band is 0 dBm. Therefore, if other signals are active, the maximum output power for the modulated interferer signal will be reduced to maintain the peak output power within the 0 dBm limit.

7.4.4 Modulation

In the current implementation, only basic rate is supported for the interferer signal.

No transmitter distortions are applied to the modulated interfering signal. To apply transmitter distortions to the interfering signal, use *Tanzanite*, the *TLF3000* Bluetooth traffic generator configuration.

The modulation index is fixed at 0.32.

7.4.5 Continuous or packetised transmission

The modulated interferer can be set to be either a packetised transmission or a continuous transmission (as required by the C/I and intermodulation tests). A simple checkbox is provided to switch between these two modes.

When a continuous transmission is selected, the transmission commences with the normal preamble, synchronisation word and header. However, the payload is never terminated, leading to a continuously modulated GFSK signal.

The payload of the transmission is always a PRBS15 sequence.

7.4.6 Payload length

When in packetised mode, it is possible to specify the packet payload length. This is set using the ‘Payload length’ spin box. The minimum payload length is 0 octets and the maximum payload length is 339 octets.

7.4.7 Packet interval

When in packetised mode, it is possible to specify the interval between packets. The packet interval is defined as the time between the start of the preamble of one packet and the start of the preamble of the subsequent packet. This interval can be adjusted using the ‘Packet interval’ spin box. The minimum packet interval is dependent on both the payload length. The maximum packet interval is 5s.

The packet interval may change automatically if the payload length is changed.

7.4.8 Digital output

To enable other test equipment to be synchronised with Zircon's transmissions, it is possible to toggle digital output lines when the modulated interferer signal is being transmitted. The selected lines will be low prior to transmission and go high during the transmission.

The *TLF3000* unit has 8 digital output lines. All 8 lines are available for signalling modulated interferer transmission. Lines are selected by toggling 'X' to '1' in the appropriate box.

If a digital output line is specified as monitoring both wanted signal transmissions and modulated interferer transmissions, then the state of the line is the logical OR of the two signals.

The IO voltage for the lines may be either:

1. An internal 3.3 V generated supply
2. An external supply in the range 1.2 V to 5.0 V

7.5 Programming the in-band CW signal

7.5.1 Overview

Zircon can generate up to 3 in-band (i.e. 2395MHz to 2485MHz) CW interferer signals. These signals are required to perform receiver intermodulation tests. The CW signals may also be used to help characterise AFH classification algorithms.

To turn an in-band CW interferer signal on or off, toggle the switch to the left of the 'nth CW interferer' text.

To program an in-band CW interferer signal, expand the 'nth CW interferer' signal menu by clicking on it:

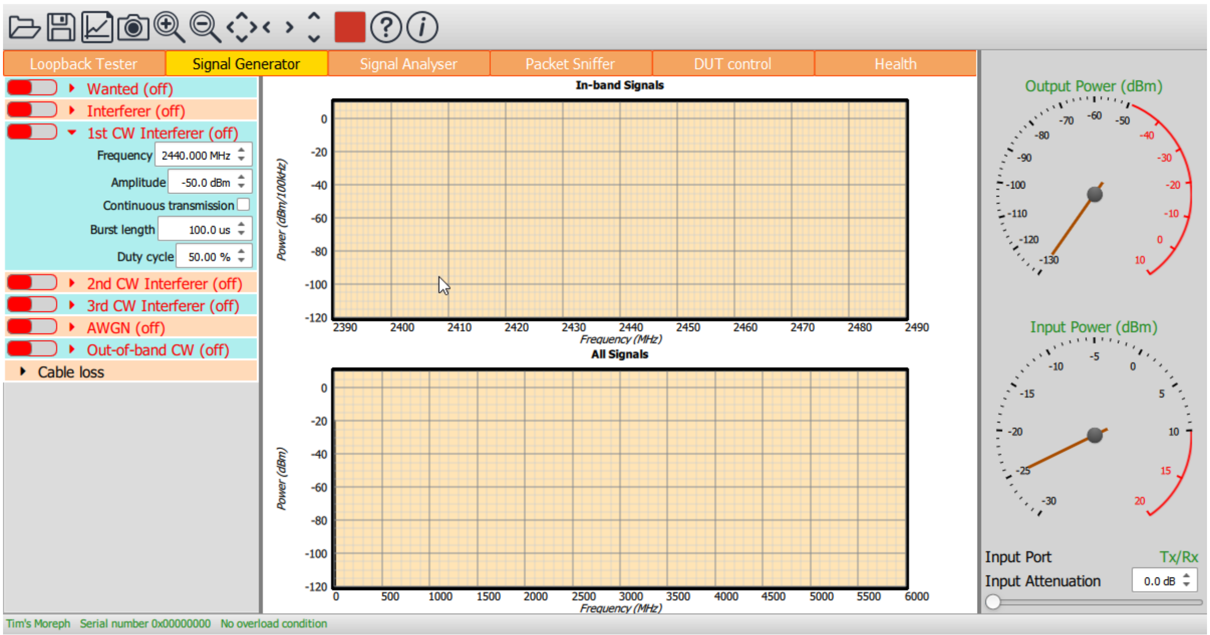


Figure 7: Programming an in-band CW interferer signal.

7.5.2 Frequency

The frequency of the in-band CW interferer signal can be set by:

1. Using the channel number spin box
2. Using the frequency spin box

As with all spin boxes, adjustment can be performed either by using the up/down arrows or by entering a numeric value into the text field.

The frequency can be set anywhere between 2395 MHz and 2485 MHz inclusive with a resolution of 1kHz.

7.5.3 Amplitude

The amplitude of the in-band CW interferer signal can be adjusted from -120 dBm to 0 dBm. The total combined output power of the unit within the 2.4 GHz ISM band is 0 dBm. Therefore, if other signals are active, the maximum output power for the in-band CW interferer signal will be reduced to maintain the peak output power within the 0dBm limit.

7.5.4 Pulsed operation

Each CW signal can be independently set to either continuous or pulsed. If pulsed operation is selected, then the length of each pulse is set using the ‘Burst length’ spin box. The minimum burst length is 0.1µs and the maximum burst length is 1.6s. The duty cycle of the signal is set using the ‘Duty cycle’ spin box.

The commencement and cessation of each pulse is abrupt; there is no power ramp up or down. As a consequence, power may be splattered across the band at the start and end of each burst.

7.6 Programming the AWGN source

7.6.1 Overview

The AWGN source provides uniform output power from 2395MHz to 2485MHz. This source can be used to artificially reduce the signal-to-noise of a signal. The AWGN source can be continuous or pulsed.

To turn the AWGN source on or off, toggle the switch to the left of the ‘AWGN’ text.

To program the AWGN source, expand the ‘AWGN’ signal menu by clicking on it:

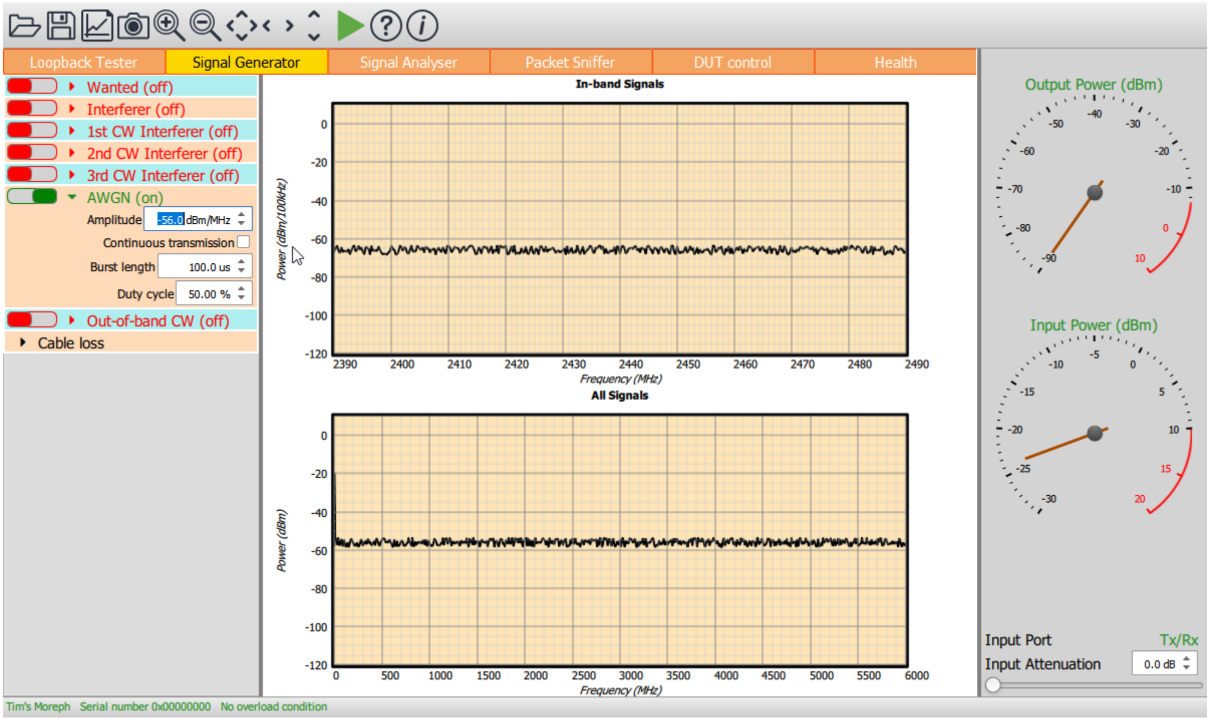


Figure 8: Programming the in-band AWGN source.

7.6.2 Amplitude

The amplitude of the AWGN source can be set in the range -162dBm/MHz to -42dBm/MHz. The total combined output power of the unit within the 2.4GHz ISM band is 0dBm. Therefore, if other signals are active, the maximum output power for the AWGN source will be reduced to maintain the peak output power within the 0dBm limit.

7.6.3 Pulsed operation

The AWGN source may be set to either continuous or pulsed. If pulsed operation is selected, then the length of each pulse is set using the 'Burst length' spin box. The minimum burst length is 0.1µs and the maximum burst length is 1.6s. The duty cycle of the signal is set using the 'Duty cycle' spin box.

7.7 Programming the out-of-band CW signal

Zircon can generate an out-of-band CW interferer signal. This signal can be used to perform receiver blocking tests. However, the available output power is not sufficient to perform out-of-band blocking as specified in the Bluetooth Radio Test Specification. Furthermore, the frequency range of the out-of-band blocker does not extend beyond 6GHz, whereas the Bluetooth Radio Frequency Test Specification requires testing up to 12.75GHz.

To turn the out-of-band CW interferer signal on or off, toggle the switch to the left of the 'Out-of-band CW' text.

To program the out-of-band CW interferer signal, expand the 'Out-of-band CW' signal menu by clicking on it:

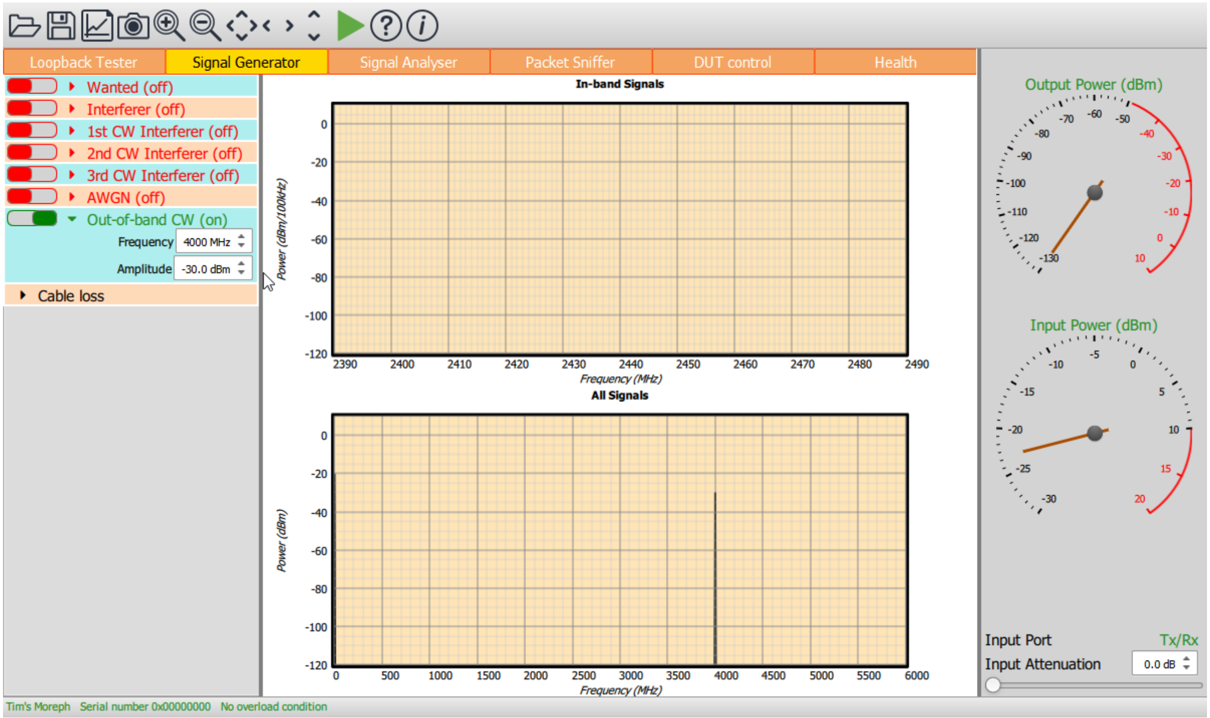


Figure 9: Programming the out-of-band CW interferer signal.

7.7.1 Frequency

The frequency of the out-of-band CW interferer signal can be set by using the frequency spin box. The frequency can be set to any integer MHz between 24 MHz and 6 GHz.

The Bluetooth Radio Frequency Test Specification requires testing of the blocking performance up to 12.75GHz. This is beyond the capabilities of the TLF3000 unit. See also the comments on blocking amplitude below.

7.7.2 Amplitude

The amplitude of the out-of-band CW interferer signal can be adjusted from -50 dBm to -28 dBm.

The Bluetooth Radio Frequency Test Specification requires blocker levels of -10dBm below 2GHz and above 3GHz, and levels of -27dBm between 2GHz and 3GHz. Hence approximate blocking performance between 2 and 3GHz can be measured,

7.8 Programming the cable loss

The signal generator is able to adjust its output power to compensate for cable loss between the *Moreph30* and the DUT. The compensation is only for in-band signals, and hence may be inaccurate for the out-of-band CW signal.

The cable loss is set by expanding the 'Cable loss' menu.

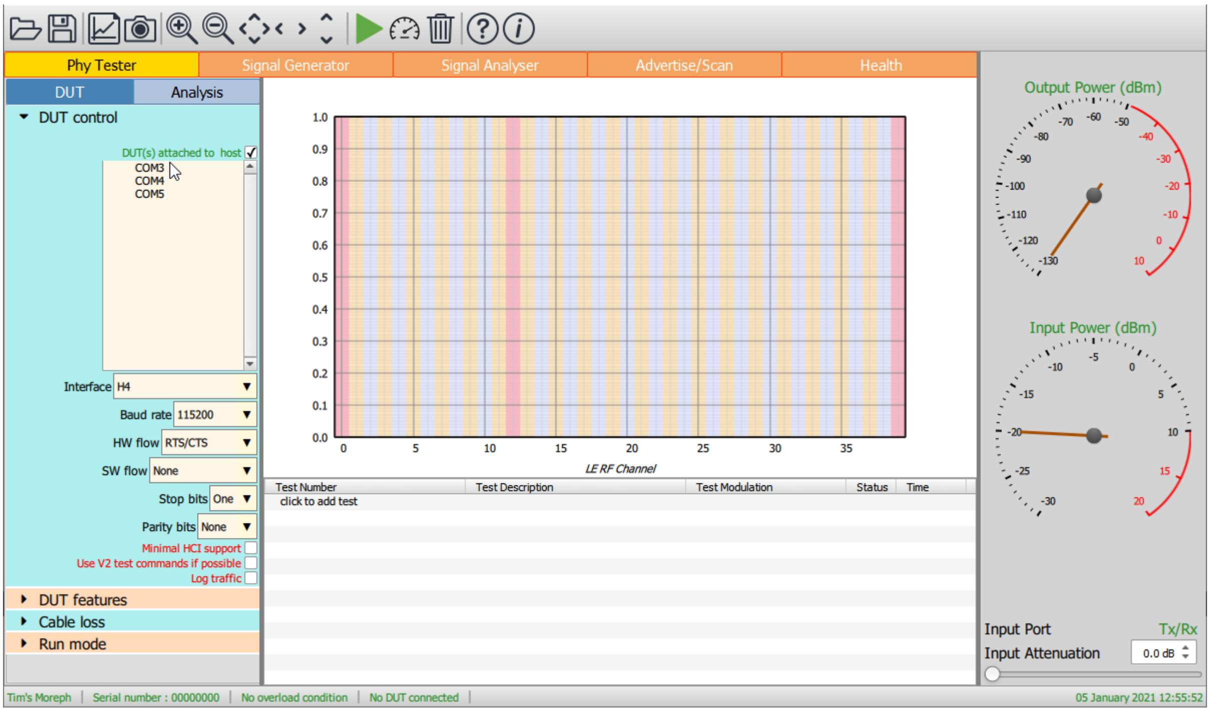


Figure 10: Programming the signal generator cable loss.

The cable loss can be specified at a number of frequencies throughout the ISM band. The frequencies to be used are selected by ticking the checkbox to the left of the frequency label. The cable loss at the frequency can then be entered using the spin box to the right of the label.

A graph at the bottom of the *'Cable loss'* menu shows the cable loss which will be applied.

If the cable loss is specified at a single frequency, then this value will be used throughout the band.

If the cable loss is specified at two or more frequencies, then linear interpolation will be used between the specified frequencies and linear extrapolation applied outside the range of the specified frequencies.

All interpolated/extrapolated cable loss values will be limited to the range 0dB to 25dB.

7.9 Saving and restoring settings

The current signal generator settings can be saved by clicking the 'Save' button on the toolbar. Select the 'Signal generator settings (*.sgs)' file type to save the current settings.

An existing signal generator settings file (*.sgs) can be opened using the 'Open' button on the toolbar.

The signal generator settings file (*.sgs) is an XML file. It is not recommended that this file be edited manually. If it needs to be modified, open it from the signal generator, modify the required parameters and re-save.

8 Signal Analyser Mode.

8.1 Overview

In signal analyser mode, the *Zircon* configuration can analyse incoming signals against the transmitter tests contained within the Bluetooth Radio Frequency Test Specification. The signals may originate from a DUT controlled by the signal analyser or be unwhitened signals from a DUT controlled by other means, ie the signal analyser can operate in both signalling and non-signalling modes. The configuration can analyse both conducted and off-air signals.

If the DUT is controlled over-the-air, then receiver tests can also be performed. The signal analyser mode permits sensitivity, maximum input signal, C/I and intermodulation tests to be carried out.

When performing transmitter tests, all 79 Bluetooth channels are monitored simultaneously, hence there is no requirement to program the signal analyser to look on a specified channel or to look for a specific packet type. The signal analyser accumulates results separately for each channel, number of packet slots and modulation method. This permits the results to be filtered and displayed in a number of different ways.

The left-hand mode control panel is divided into two separate tabs:

1. *Configuration*. This tab primarily provides a mechanism for controlling a DUT over-the-air. It also permits the cable loss and stop condition to be specified.
2. *Analysis*. This tab contains the parameters which define how the captured results will be displayed.

The central graphics area is used to plot the results in a manner defined by the parameters under the analysis tab.

Below the graphics area is a results table which displays statistics of the test quantities defined in the Bluetooth Radio Frequency Test Specification. These results are filtered by the parameters set under the ‘Analysis’ tab in the mode control panel. *If no results are displayed this may be because the analysis filter settings are inconsistent with the packets being received.*

The receiver port and front-end attenuation are set using the controls in the monitor panel on the right-hand side of the window.

Data collection is started/stopped by toggling the ‘Run/Stop’ button in the toolbar.

The ‘Clear’ button in the toolbar will discard all results which have been collected.

See Section 12 if it is wished to control the DUT over-the-air from the *Zircon* configuration.

Figure 11: Zircon GUI signal analyser mode.

8.2 RF connections

The signal analyser can monitor signals on either the 'Tx/Rx' port or the 'Monitor In' port. See Section 8.3.4 on setting the RF input port.

8.3 Configuring data collection

8.3.1 Overview

The 'Configuration' tab provides a means to:

1. Control a DUT over-the-air
2. Specify the cable loss between the DUT and the *TLF3000*
3. Specify a termination criterion for data collection

The control of the DUT is common with the loopback tester and DUT control modes. A description of how the DUT is controlled can be found in Section 12.

It is not necessary for the DUT to be controlled by the signal analyser. The signal analyser will process any unwhitened packets which it receives. Hence it is possible to use the signal analyser in both signalling and non-signalling modes.

8.3.2 Programming the cable loss

In order for the *TLF3000* to be able to make accurate power and spectral measurements, it needs knowledge of the loss between the DUT and the *TLF3000* unit. This can be entered using the cable loss menu.

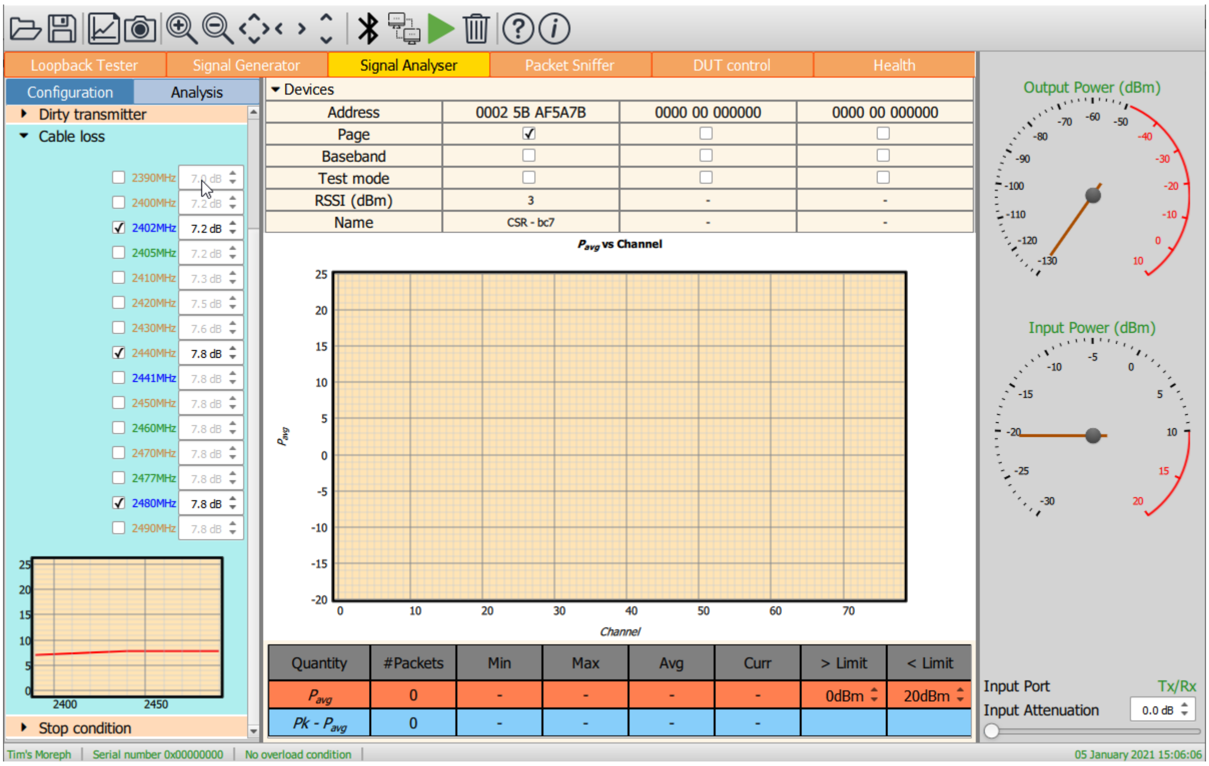


Figure 12: Programming the cable loss.

The cable loss can be specified at a number of frequencies throughout the ISM band. The frequencies to be used are selected by ticking the checkbox to the left of the frequency label. The cable loss at the frequency can then be entered using the spin box to the right of the label.

A graph at the bottom of the *'Cable loss'* menu shows the cable loss which will be applied.

If the cable loss is specified at a single frequency, then this value will be used throughout the band.

If the cable loss is specified at two or more frequencies, then linear interpolation will be used between the specified frequencies and linear extrapolation applied outside the range of the specified frequencies.

All interpolated/extrapolated cable loss values will be limited to the range 0dB to 25dB.

Programming the cable loss will alter both the power and spectral measurements made by the *Zircon* application accordingly, ie these will be representative of what is emitted by the DUT not what is received by the *TLF3000*. The power meters in the monitor panel are unaffected by the cable loss. These always illustrate the power at the *TLF3000* RF connectors.

8.3.3 Programming the termination criterion

Once the signal analyser has been started by toggling the 'Play' button in the toolbar, it will continue to collect, process and display data until either:

1. The 'Stop' button in the toolbar is toggled
2. The stop condition has been set to 'Stop on test fail' and a test limit is failed

The ‘Stop on test fail’ condition is set by the single checkbox under the ‘Stop condition’ menu.

Figure 13: Programming the termination criterion.

The test limits are shown in the results table. The penultimate column of the results table displays the lower limit and the final column the upper limit. They can be altered by changing the values in the spin boxes, either by using the up/down arrows or by entering numeric text directly.

When a limit fail is detected, and the stop condition has been set to ‘Stop on test fail’, then the GUI will automatically alter its graphics and tabular display to reflect the quantity that failed. It is possible that a rogue packet will fail more than one test limit, so the data displayed may only partially reflect the reason why the packet failed. Once stopped, it will be possible to examine the FM demodulated data, etc to determine why the fail occurred.

The stop on fail criterion does not apply to spectral calculations. These calculations are generally performed over a number of packets and hence it is not possible to determine a particular time at which the failure occurred.

8.3.4 Selecting the RF input port

The signal analyser can monitor signals on either the ‘Monitor In’ RF port or the ‘Tx/Rx’ RF port. The selection of which port is used is made clicking the port displayed towards the bottom of the monitor panel.

The Monitor In port is designed for monitoring signals off-air. The Tx/Rx port is designed for conducted measurements.

If the monitor panel shows a lack of RF input energy, check that the DUT is connected to the same RF port as selected by the label at the bottom of the monitor panel.

8.3.5 Adjusting the RF frontend attenuation

The RF frontend attenuation is set via either:

1. The slider at the bottom of the monitor panel
2. The spin box at the bottom of the monitor panel

The RF frontend attenuation can be set between 0 and 31.5 dB in steps of 0.5 dB.

To set the RF attenuation, the 'Input Power' gauge on the monitor panel must be examined. This shows both the current input signal level (the position of the needle) and the point at which saturation of the *TLF3000* receiver will occur (the red arc). The RF attenuation should be adjusted such that the input signal level is just below the saturation level.

If too little attenuation is applied, then there is a danger that the *TLF3000* receiver will be overloaded. An overload condition on the receiver is indicated by:

1. The needle on the 'Input Power' gauge on the monitor panel entering the region of the red arc (the input power measurement is only approximate, so this is only a rough guide)
2. The title of the 'Input Power' gauge on the monitor panel turning red
3. The text 'Rx overload' appearing in red within the status bar at the bottom of the window

If too much attenuation is applied, then the test results may become unreliable. In order to calculate the frequency deviation within a packet, an FM demodulation process is employed. The quality of the output of the FM demodulation process is critically dependent on the signal-to-noise ratio of the signal at the input to the demodulator. If too much attenuation is applied, then the signal to be analysed will be pushed down towards the *TLF3000* receiver noise floor and the accuracy of the test results will be compromised.

8.4 Controlling data analysis and presentation

8.4.1 Overview

The *Zircon* configuration accumulates results independently for each:

1. Modulation scheme, ie BR, 2-EDR and 3-EDR
2. Number of packet slots, ie 1, 3 and 5
3. RF channel, ie 0 to 79

The 'Analysis' tab in the mode control panel determines how these results are filtered and displayed. *If no results are displayed, then it is possible that the current analysis filter settings do not correspond to any of the packets which have been collected.*

The 'Measurement' menu under the 'Analysis' tab determines which group of measurements will be displayed.

The displayed results are filtered according to the settings of the 'Modulation filter', 'Packet slot filter' and 'Channel filter' menus.

The graphics area shows a plot of one of the test quantities. This may be selected either through the 'Plot' menu or by highlighting a row in the results table. The 'Plot' menu also defines the format of the plot.

The results table shows the filtered results for the selected measurement group. It also contains the test limits.

8.4.2 Selecting the measurement group to display

Zircon divides the Bluetooth RF transmitter test measurements into five groups:

8.4.2.1 Power measurements

Quantity	BR	EDR	Test number	Description
P_{avg}	✓		RF/TRM/CA/BV-01	Average power
$Pk - P_{avg}$	✓		N/A	Peak power – average power
EDR re GFSK		✓	RF/TRM/CA/BV-10	EDR relative transmit power
Guard- 99%		✓	RF/TRM/CA/BV-15	Period above which 99% of guard interval measurements lie
Guard+ 99%		✓	RF/TRM/CA/BV-15	Period below which 99% of guard interval measurements lie
Guard > 4.6		✓	RF/TRM/CA/BV-15	Percentage of guard interval measurements which lie above 4.6µs
Guard < 5.4		✓	RF/TRM/CA/BV-15	Percentage of guard interval measurements which lie below 5.4µs

Table 4: Power measurements

8.4.2.2 Modulation characteristics

Quantity	BR	EDR	Test number	Description
$\Delta F1_{max}$	✓		RF/TRM/CA/BV-07	Deviation for 11110000 sequence
$\Delta F1_{avg}$	✓		RF/TRM/CA/BV-07	Average deviation for 1111000 sequence
$\Delta F2_{max}$	✓		RF/TRM/CA/BV-07	Deviation for 10101010 sequence
$\Delta F2_{avg}$	✓		RF/TRM/CA/BV-07	Average deviation for 10101010 sequence
$\Delta F2_{avg}/\Delta F1_{avg}$	✓		RF/TRM/CA/BV-07	Ratio of deviations for 10101010 sequence and 11110000 sequence
$\Delta F2_{max}$ *99.9%*	✓		RF/TRM/CA/BV-07	Deviation above which 99.9% of measurements of $\Delta F2_{max}$ lie
$\Delta F2_{max} > 115$	✓		RF/TRM/CA/BV-07	Percentage of measurements of $\Delta F2_{max}$ which lie above 115kHz
RMS DEVM		✓	RF/TRM/CA/BV-11	RMS value of DEVM
Pk DEVM		✓	RF/TRM/CA/BV-11	Peak value of DEVM
DEVM ≤ 30%		✓	RF/TRM/CA/BV-11	Percentage of measurements with DEVM ≤ 30% (2-EDR only)
DEVM ≤ 20%		✓	RF/TRM/CA/BV-11	Percentage of measurements with DEVM ≤ 20% (3-EDR only)
DEVM 99%		✓	RF/TRM/CA/BV-11	DEVM below which 99% of measured values lie

Table 5: Modulation characteristics measurements

8.4.2.3 Drift and carrier offset measurements

Quantity	BR	EDR	Test number	Description
F_0	✓		RF/TRM/CA/BV-08	Initial carrier frequency
$F_{k+5} - F_k$	✓		RF/TRM/CA/BV-09	Drift rate
1 slot F_0 - F_k	✓		RF/TRM/CA/BV-09	Maximum drift within 1 slot packets
3 slot F_0 - F_k	✓		RF/TRM/CA/BV-09	Maximum drift within 3 slot packets
5 slot F_0 - F_k	✓		RF/TRM/CA/BV-09	Maximum drift within 5 slot packets
ω_i		✓	RF/TRM/CA/BV-11	Carrier frequency estimated from header
ω_0		✓	RF/TRM/CA/BV-11	Carrier frequency relative to header estimated from payload
$\omega_{i} + \omega_0$		✓	RF/TRM/CA/BV-11	Carrier frequency estimated from combination of header and payload measurements

Table6 6: Drift and carrier offset measurements

8.4.2.4 Spectral measurements

Quantity	BR	EDR	Test number	Description
F_L	✓	✓	RF/TRM/CA/BV-04	Frequency range lower limit
F_H	✓	✓	RF/TRM/CA/BV-04	Frequency range upper limit
Δf	✓	✓	RF/TRM/CA/BV-05	20dB bandwidth
$Ptx_{-26} - Ptx_{ref}$		✓	RF/TRM/CA/BV-13	Adjacent channel power, EDR only
$\lvert M\text{-}N \rvert = 2$	✓	✓	RF/TRM/CA/BV-06 RF/TRM/CA/BV-13	Co-adjacent channel power
$\lvert M\text{-}N \rvert = 3$	✓	✓	RF/TRM/CA/BV-06 RF/TRM/CA/BV-13	Adjacent channel power
Exceptions	✓	✓	RF/TRM/CA/BV-06 RF/TRM/CA/BV-13	Number of adjacent channel power exceptions
Max exception	✓	✓	RF/TRM/CA/BV-06 RF/TRM/CA/BV-13	Maximum adjacent channel power exception
$P_{density}$	✓	✓	RF/TRM/CA/BV-02	Peak power density in 100kHz bandwidth

Table 7: Spectral measurements

8.4.2.5 BER measurements

Quantity	BR	EDR	Test number	Description
$Log_{10}(BER)$	✓	✓	RF/RCV/CA/BV-01 RF/RCV/CA/BV-02 RF/RCV/CA/BV-03 RF/RCV/CA/BV-05 RF/RCV/CA/BV-06 RF/RCV/CA/BV-07 RF/RCV/CA/BV-08 RF/RCV/CA/BV-09 RF/RCV/CA/BV-10	Bit error rate
Pkt Loss	✓	✓		Lost packet rate

Table 8: BER measurements

The *Zircon* GUI displays the results from just one of these measurement groups at any one time. The selection of which measurement group to display is accomplished through the ‘Measurement’ menu under the ‘Analysis’ tab.

If no results are displayed, then it is possible that no packets have been received or that the analysis measurement group selected is incompatible with the packets being transmitted by the DUT. For example, in order to perform all the basic rate modulation measurements, packets with payloads containing both 11110000 and 10101010 must have been seen.

For receiver tests, the DUT must be controlled over-the-air, the test mode must be set to loopback, the packet payload must be set to PRBS9 and the number of octets within the packet payload must be non-zero. If these conditions are not met, then no BER results will be displayed.

Figure 14: Selecting the measurement group to display.

8.4.3 Filtering the displayed results by modulation scheme

The displayed results are filtered by the modulation scheme, ie BR, 2-EDR or 3-EDR. Only the results from one modulation scheme can be displayed at any one time. This restriction is due to the fact that different test limits are applicable to the different modulation schemes.

The modulation scheme filter is accessible from the 'Modulation filter' menu under the 'Analysis' tab. There is a separate checkbox for each modulation scheme.

It is not possible to filter the power density measurement (RF/TRM/CA/BV-02) by modulation scheme. A single power density measurement is performed covering all modulation schemes, packet slot lengths and RF channels.

It is only possible to filter the frequency range (RF/TRM/CA/BV-04), 20dB bandwidth (RF/TRM/CA/BV-05), basic rate adjacent channel power (RF/TRM/CA/BV-06) and EDR spurious emissions (RF/TRM/CA/BV-13) measurements by modulation when in signalling mode, ie the *Zircon* configuration controls the DUT over-the-air. It is not possible to filter these measurements by modulation when the DUT is controlled by a third-party application.

Figure 15: Filtering displayed results by modulation.

8.4.4 Filtering the displayed results by packet slots

The displayed results can be filtered by the number of slots in the packet type. This provides a simple facility for displaying results from specific packet types or for monitoring transmitter quality as a function of packet length. Packet slot lengths of 1, 3 and 5 are available. The filtering is on the basis of the number of slots the packet could occupy given the packet type, not on the basis of the number of slots it actually occupied.

The packet slot filtering is specified via the 'Packet slot filter' menu under the 'Analysis' tab. The required packet slot lengths are selected by ticking the corresponding boxes.

It is not possible to filter the power density measurement (RF/TRM/CA/BV-02) by packet slot. A single power density measurement is performed covering all modulation schemes, packet slot lengths and RF channels.

It is only possible to filter the frequency range (RF/TRM/CA/BV-04), 20dB bandwidth (RF/TRM/CA/BV-05), basic rate adjacent channel power (RF/TRM/CA/BV-06) and EDR spurious emissions (RF/TRM/CA/BV-13) measurements by packet slot when in signalling mode, ie the *Zircon* configuration controls the DUT over-the-air. It is not possible to filter these measurements by packet slot when the DUT is controlled by a third-party application.

Figure 16: Filtering displayed result by packet slots.

8.4.5 Filtering the displayed results by RF channel

The displayed results can be filtered by RF channel number. It provides a simple means of comparing test results on different RF channels.

The RF channels used to filter the results are selected via the 'Channel filter' menu under the 'Analysis' tab.

The required RF channels can be selected by either:

1. Ticking the individual channel boxes
2. Using the quick channel group selection buttons:
    a. Clear all
    b. Select all
    c. Specification channels
    d. Single channel mode
3. Entering a textual description

The textual description must be of the form:

$a_{start}:a_{step}: a_{stop}, b_{start}: b_{step}: b_{stop}, \ldots$

This implies that all channels from a_{start} to a_{stop} in steps of a_{step} will be selected, plus all channels from b_{start} to b_{stop} in steps of b_{step}, etc.

If a_{step} is unity, then $a_{start}:a_{step}: a_{stop}$ can be abbreviated to $a_{start}: a_{stop}$.

If a_{step} is equal to a_{stop} then $a_{start}:a_{step}: a_{stop}$ can be abbreviated to a_{start}.

If the ‘Specification channels’ box is checked, then channels 0, 39 and 78 will be selected. This are the channels which are used in the majority of the transmitter test cases.

If ‘Single channel mode’ is selected, then only one RF channel can be selected at a time. This provides an easy way of stepping the filtering between channels.

It is not possible to filter the power density measurement (RF/TRM/CA/BV-02) by RF channel. A single power density measurement is performed covering all modulation schemes, packet slot lengths and RF channels.

It is only possible to filter the frequency range (RF/TRM/CA/BV-04), 20dB bandwidth (RF/TRM/CA/BV-05), basic rate adjacent channel power (RF/TRM/CA/BV-06) and EDR spurious emissions (RF/TRM/CA/BV-13) measurements by RF channel when in signalling mode, ie the *Zircon* configuration controls the DUT over-the-air. It is not possible to filter these measurements by RF channel when the DUT is controlled by a third-party application.

Figure 17: Filtering displayed results by RF channel.

8.4.6 Understanding the results table

The results table contains a summary of the results obtained from the selected measurement group when filtered by the selected modulation scheme, packet slot lengths and RF channels.

The first column in the table contains the quantities defined in the Bluetooth Radio Frequency Test Specification which are members of the currently selected measurement group.

The second column in the table contains the number of packets which have contributed to the results for each measured quantity. This column is not populated for spectral measurements since these scan multiple packets.

The third and fourth columns contain the minimum and maximum values which have been observed for each measured quantity.

The fifth column contains the average value of the measured quantity overall packets. If the units of the measured quantity are dBm or dB, then the average is the average of the dB values, not an average of the powers or linear ratios.

If the measured quantity is a scalar quantity, i.e. it has a single value per packet, then the last measured value is displayed in the sixth column.

For scalar quantities with test limits, the lower limit is contained in column seven and the upper limit in column eight.

Quantity	#Packets	Min	Max	Avg	Curr	> Limit	< Limit
ΔF_{1max}	10444	149.7 kHz	168.2 kHz	158.7 kHz	-		
ΔF_{1avg}	10444	153.9 kHz	162.3 kHz	158.1 kHz	157.1 kHz	140kHz	175kHz
ΔF_{2max}	30171	138.4 kHz	162.4 kHz	141.7 kHz	-		
ΔF_{2avg}	30171	143.3 kHz	152.0 kHz	147.9 kHz	145.7 kHz		
$\Delta F_{2avg}/\Delta F_{1avg}$	10444	0.987	0.883	0.922	0.928	0.80	
ΔF_{2max} 99.9%	30170	151.0 kHz	160.0 kHz	153.8 kHz	152.0 kHz	115kHz	
$\Delta F_{2max} \geq 115$	30170	100.0 %	100.0 %	100.0 %	100.0 %	99.9%	

Figure 18: The results table.

When the selected filters include more than one RF channel or packet slot length, then the displayed values of minimum, maximum and average are the minimum, maximum and average overall packets which satisfy the selected filtering parameters. Note that frequency range (RF/TRM/CA/BV-04), 20dB bandwidth (RF/TRM/CA/BV-05), basic ratio adjacent channel power (RF/TRM/CA/BV-06) and EDR spurious emissions (RF/TRM/CA/BV-13) measurements will only be filtered in this manner if the signal analyser is in signalling mode, ie the DUT is controlled by the *Zircon* configuration. The power density measurement (RF/TRM/CA/BV-02) is never filtered in this manner.

If no measurement is available, then the symbol '-' is used to fill the corresponding table cell.

If a cell exceeds one of its test limits, then that cell is highlighted in red.

It is possible to select a row in the table by clicking on it. Once a row has been selected, the corresponding quantity will be plotted in the graphics areas. The format of the plot is controlled by the 'Plot' menu under the 'Analysis' tab.

8.4.7 Controlling the graphical data

8.4.7.1 Overview

The graphical data being displayed is controlled by the 'Plot' menu under the 'Analysis' tab. The left-hand combo box lists all the quantities which are measured for the current measurement group (which is selected under the 'Measurement' menu of the 'Analysis' tab). These are the same quantities as displayed in the first column of the results table. The quantity to be plotted can be selected either through the combo box or by highlighting the appropriate row in the results table.

The right had combo box under the 'Plot' menu determines how the measured quantity is to be plotted. Options may include:

1. vs channel
2. vs packet slots
3. as a histogram
4. vs time (not available for spectral measurements)
5. vs frequency (only available for spectral measurements)

The screen update period can also be altered via the 'Plot' menu.

8.4.7.2 vs channel

The quantity to be plotted is shown as a function of the RF channel. For each RF channel the following quantities are displayed:

1. minimum observed value (bottom of pink bar)
2. average value (red line at junction of pink and green bars)
3. maximum observed value (top of green bar)

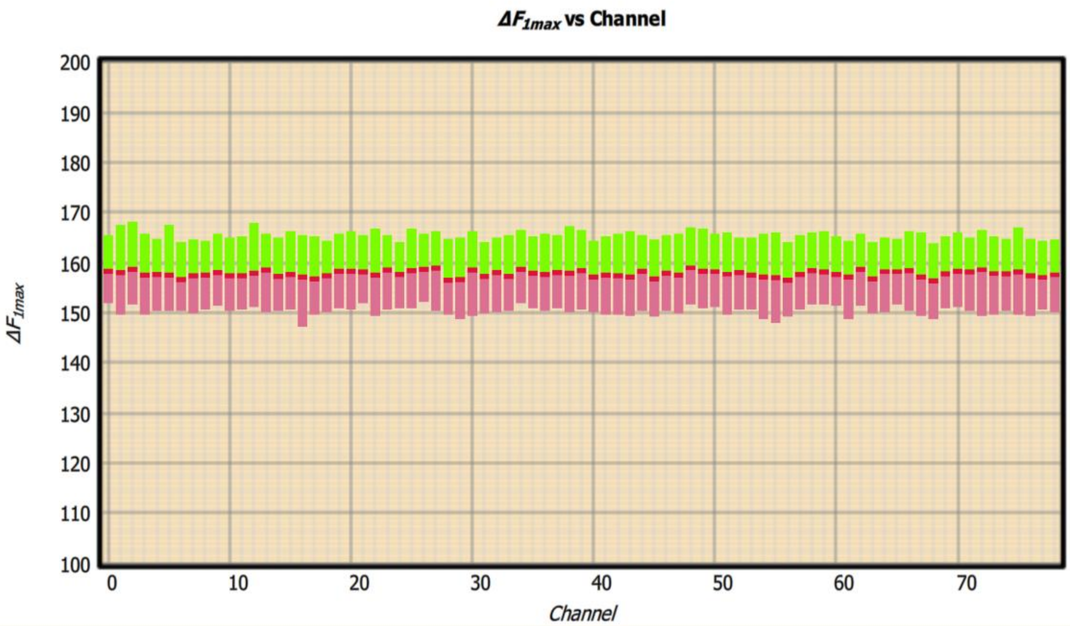


Figure 19: Results vs channel

8.4.7.3 vs packet slot

The quantity to be plotted is shown as a function of the number of slots. For each number of slots the following quantities are displayed:

1. minimum observed value (bottom of pink bar)
2. average value (red line at junction of pink and green bars)
3. maximum observed value (top of green bar)

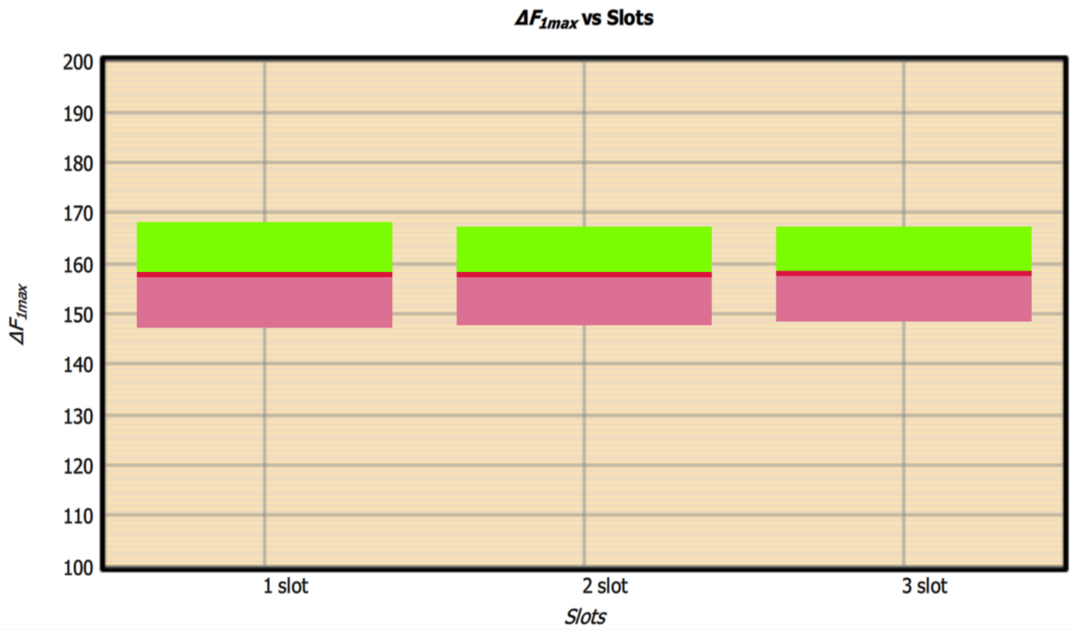


Figure 20: Results vs packet slot.

8.4.7.4 Histogram

A histogram of the plotted quantity is displayed.

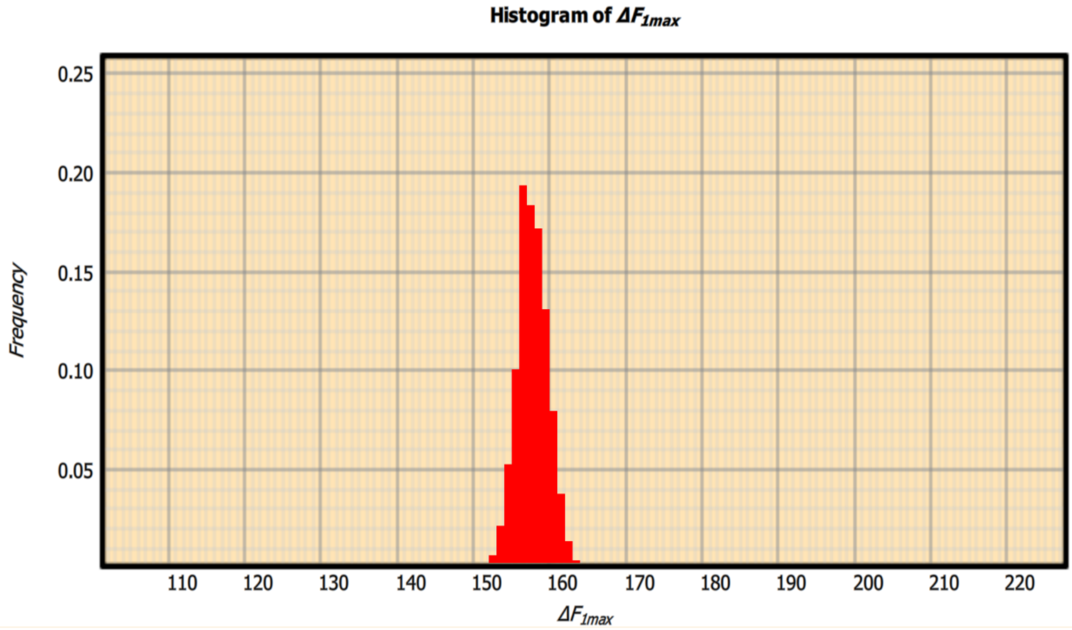


Figure 21: Results plotted as a histogram.

8.4.7.5 vs time

This option is not available for spectral measurements.

The measured quantity is shown by the blue lines on the plot. The plot corresponds to the value(s) obtained from the last packet on which the selected quantity was measurable. In addition, one of the following quantities will be displayed as a red line:

1. power profile
2. frequency deviation
3. DEVM per symbol

The data will only be fully displayed if the quantity to be plotted was measurable on the last received packet.

If the ‘Measurement’ menu has been set to ‘Power’ then a power profile will be displayed.

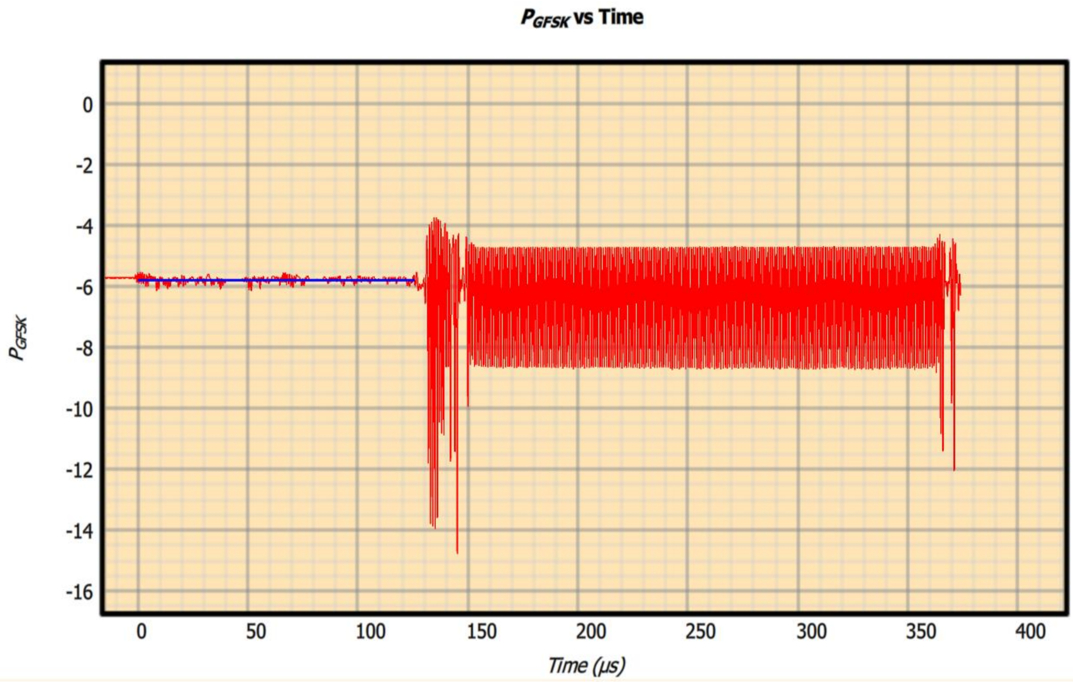


Figure 22: EDR power profile vs time.

If the ‘Measurement’ menu has been set to ‘Drift and carrier offset’ or it has been set to ‘Modulation characteristics’ and the ‘Modulation filter’ has been set to ‘Basic rate’, then an FM demodulated waveform will be displayed.

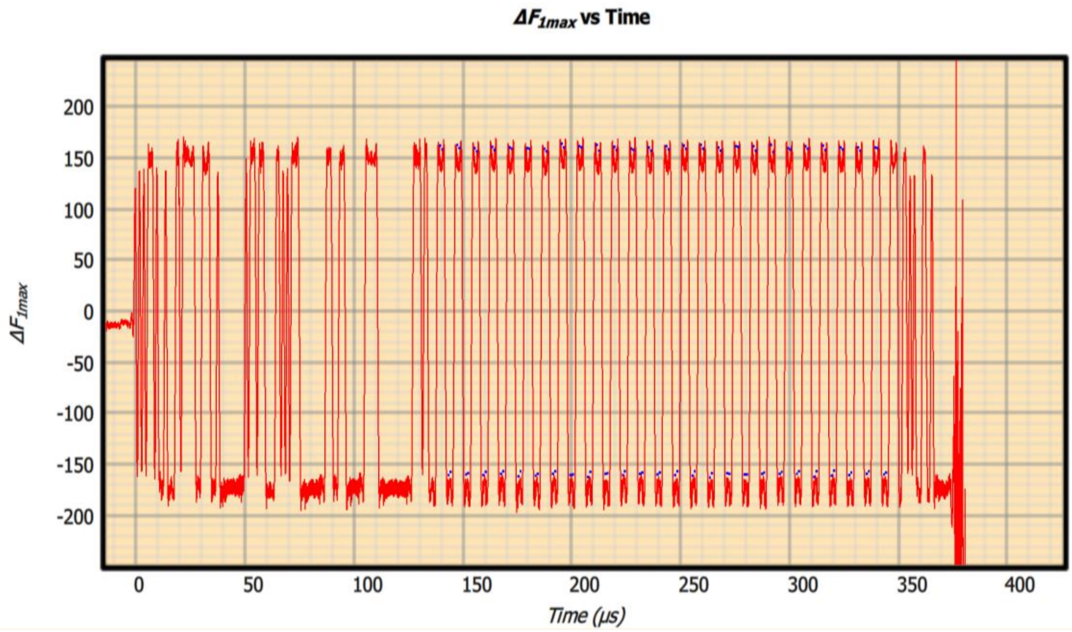


Figure 23: FM demodulated waveform vs time.

If the ‘Measurement’ menu has been set to ‘Modulation characteristics’ and the ‘Modulation filter’ menu has been set to ‘2-EDR’ or ‘3-EDR’ then the DEVM for each symbol will be displayed.

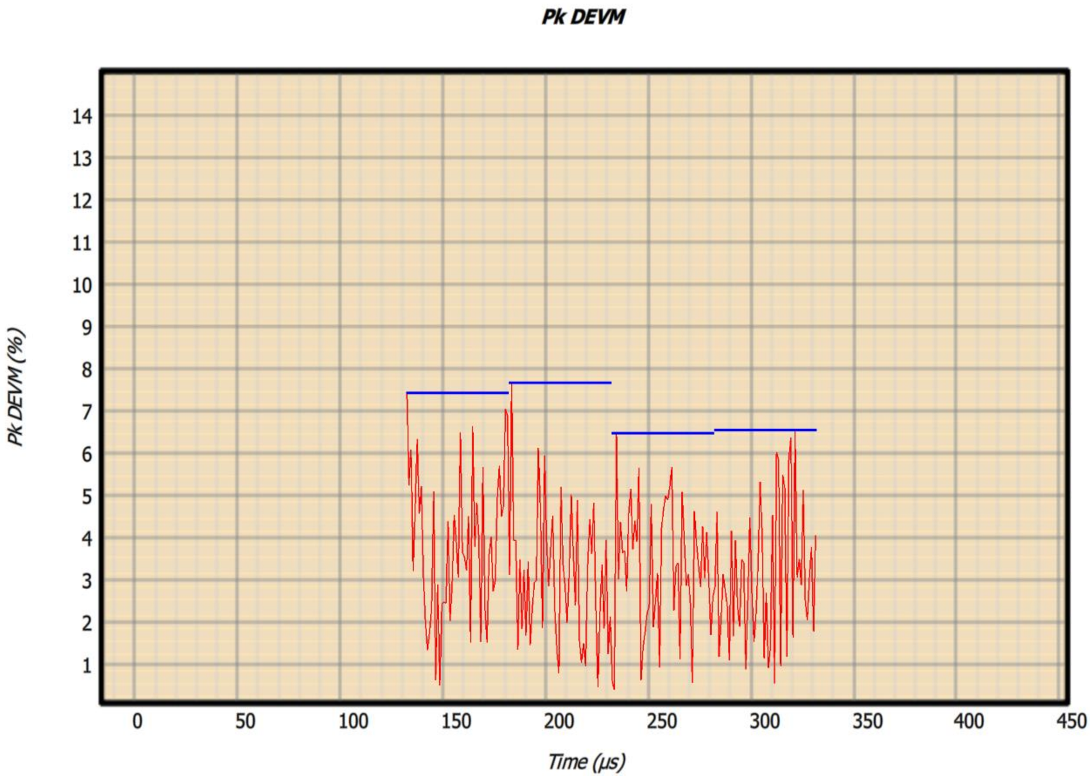


Figure 24: EDR DEVM profile vs time.

8.4.7.6 vs frequency

This option is only available for spectral measurements. Four different spectra can be displayed.

If the frequency range measurements are selected, then the spectrum displayed has 100kHz RBW, peak detector with trace averaging.

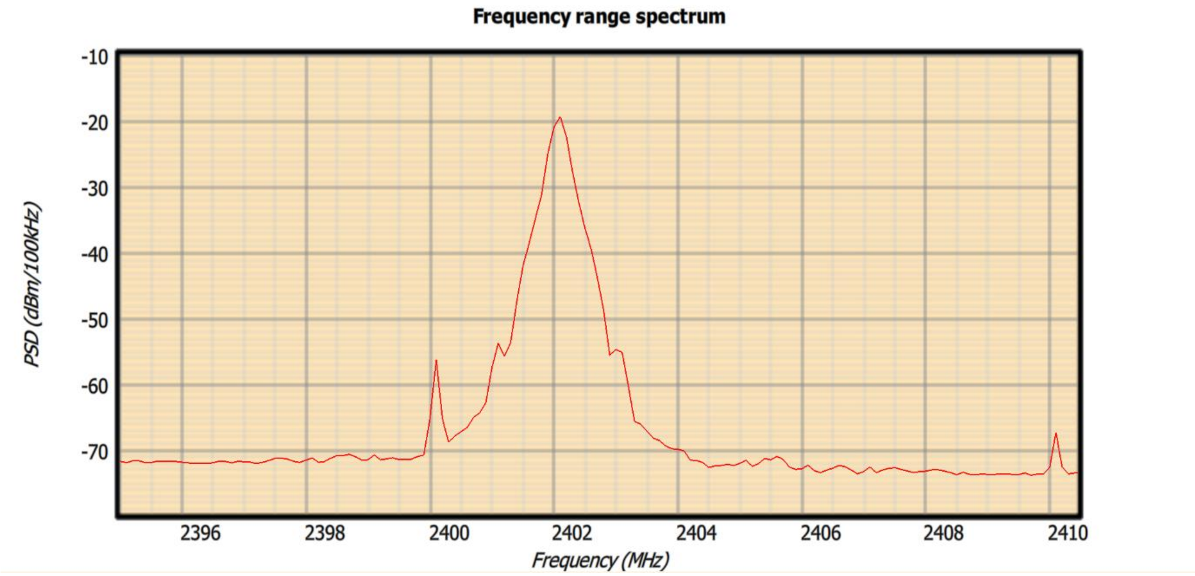


Figure 25: Frequency range spectrum.

If the 20dB bandwidth measurement is selected, then spectrum displayed has 10kHz RBW, peak detector and trace max hold. If the DUT is under control of the signal analyser (signalling mode), then the spectrum extends ±1.5MHz from the centre of the DUT transmission. If the DUT is not under control of the signal analyser (non-signalling mode), then the spectrum extends from 2400.5MHz to 2481.5MHz. In non-signalling mode the spectrum is gradually built up in segments and make take a few seconds to complete.

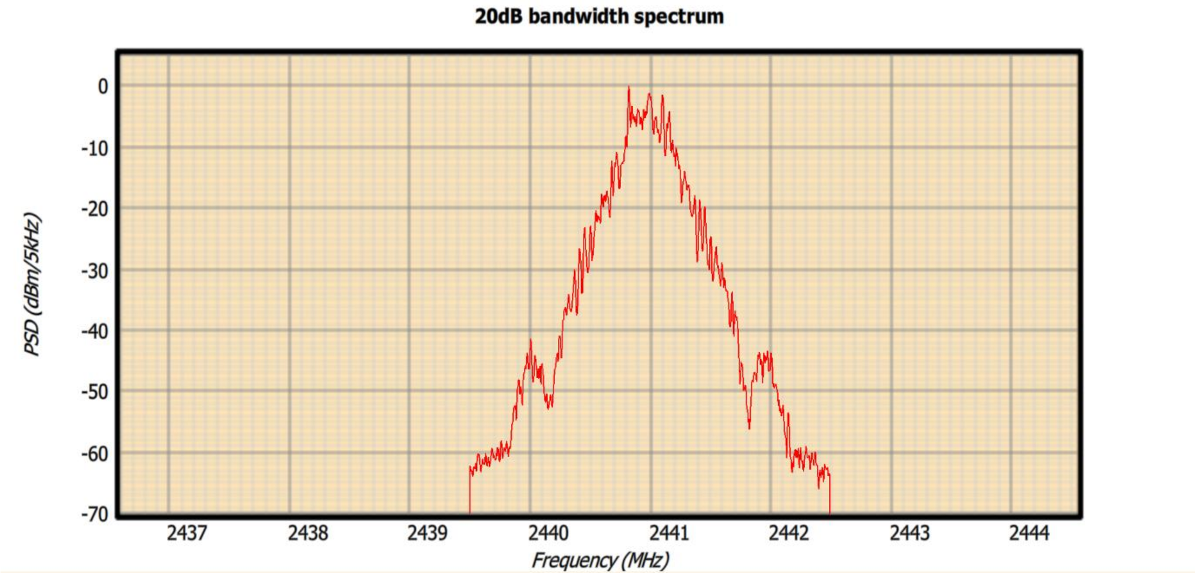


Figure 26: 20dB bandwidth spectrum.

If the basic rate adjacent channel power or EDR in-band spurious emissions measurements are selected, then the two spectra are displayed.

The spectrum drawn with the red line has 100kHz RBW, average detector and trace max hold. This is the raw spectrum from which the ACP and spurious emissions spectra are derived.

The spectrum drawn with the blue line represents the ACP or spurious emissions spectra. Each blue line spans 1MHz and is the sum of the energy from the corresponding points in the 100kH RBW spectrum.

In the case of EDR in-band spurious emissions measurements, the values of the blue spectrum for adjacent and co-channel are calculated differently:

1. For adjacent channels, the displayed value is the mean power over the five 100kHz RBW spectrum points which are furthest from the DUT carrier frequency.
2. For the co-channel, the displayed value is the peak power of the ten 100kHz RBW spectrum points.

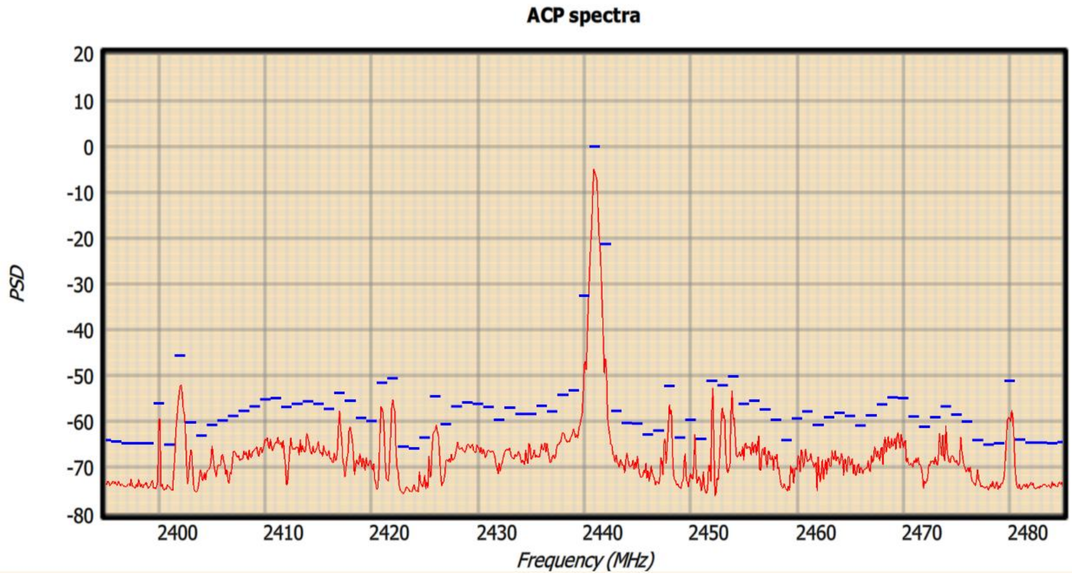


Figure 27: Adjacent power spectrum.

If the power density measurement is selected, then the spectrum has 100KHz RBW, peak detector and trace max hold. The spectrum covers 2395MHz to 2485MHz, a span of 90MHz. This is less than the 240MHz span required by the Bluetooth Radio Frequency Test Specification. However, it is highly likely that the peak power density will reside within this 90MHz and hence a correct reading will be obtained.

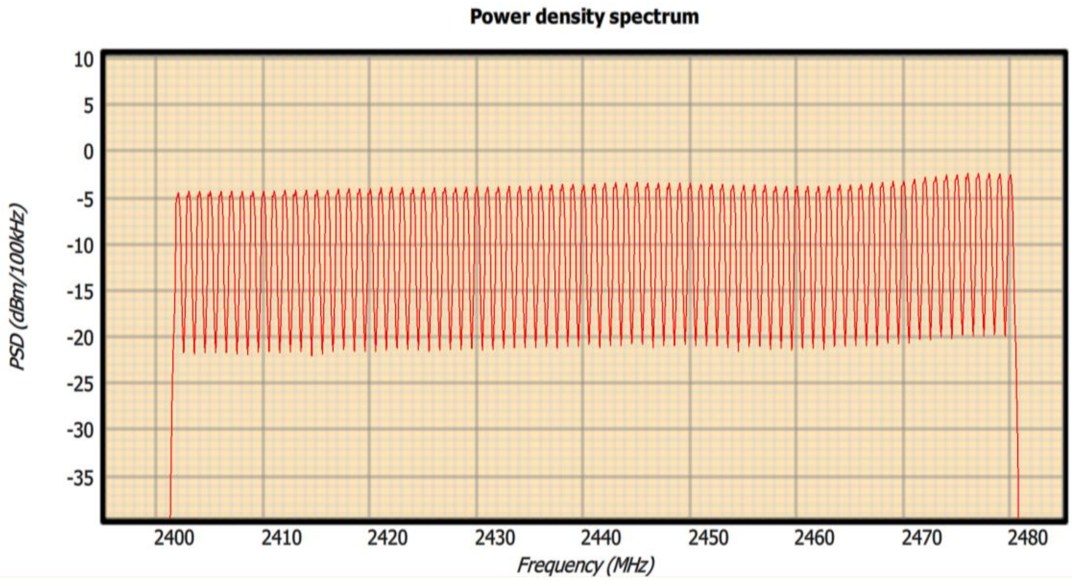


Figure 28: Power density spectrum.

8.4.8 Screen update period

The 'Plot' menu contains a slider which can be used to alter the rate at which the results table and graphics are updated.

The fastest update period possible is around 50 ms, typically limited by the host screen refresh rate. However, if substantial processing is required then the specified update rate may not be achievable.

The slowest update rate is 2 seconds. This gives the user time to assimilate the displayed results and waveform data before the next update.

8.5 Adjusting test limits

The test limits are shown in the results table. The penultimate column of the results table displays the lower limit and the final column the upper limit. They can be altered by changing the values in the spin boxes, either by using the up/down arrows or by entering numeric text directly.

8.6 Performing receiver tests

8.6.1 Prerequisites

In order to perform receiver tests in signal analyser mode, the following conditions must be satisfied:

1. The DUT must be controlled over-the-air, ie signalling mode.
2. The test mode must be set to loopback.
3. The packet payload must be set to PRBS9.
4. The number of octets in the packet payload must be non-zero.

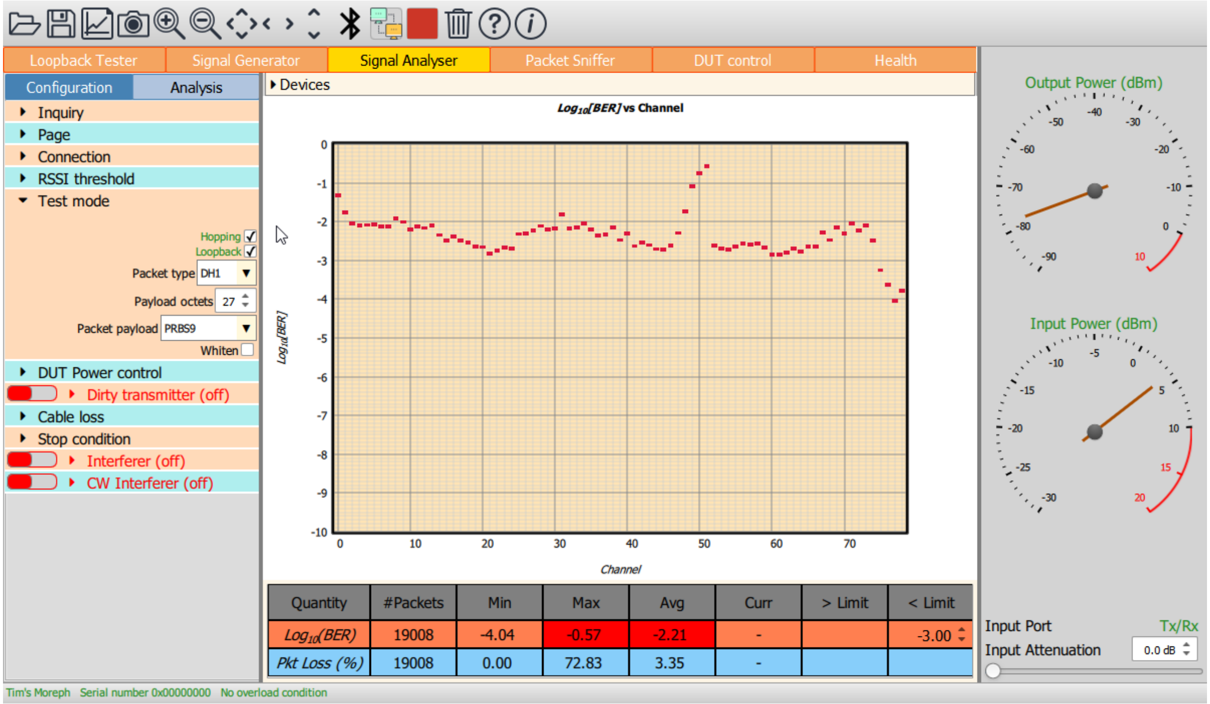


Figure 29: Example test mode suitable for performing receiver testing

8.6.2 Loss of connection

If the *TLF3000* loses connection to the DUT, then the test mode is reset in order to ensure that the connection can automatically be re-established:

1. The test mode is reset to transmitter test.
2. The DUT transmit and receive channels are reset to channel 39.
3. The packet type is reset to DH1.
4. The packet payload is reset to PRBS9.
5. The dirty transmitter is turned off.
6. Any interferers which were present are turned off.

A side effect of these parameter changes is that the receiver testing is aborted.

8.6.3 Additional menus

When the test mode has been set to *Loopback* and a device has been connected, then three additional switched menus appear under the *Configuration* tab:

1. *Dirty transmitter.* This option is always visible, but it can only be enabled once the test mode has been set to *Loopback* and a device has been attached.
2. *Interferer.* This option permits a continuous modulated interferer to be added to the *TLF3000* transmission.
3. *CW interferer.* This option permits a CW interferer to be added to the *TLF3000* transmission.

These menus will only be visible once a device has been connected in loopback test mode.

8.6.4 Controlling the signal level

When performing receiver testing, the level of the signal used for packets whose BER is to measured is determined by the *Loopback power,* which is under the *Connection* menu of the *Configuration* tab. The power level can be varied between -120dBm and -4dBm.

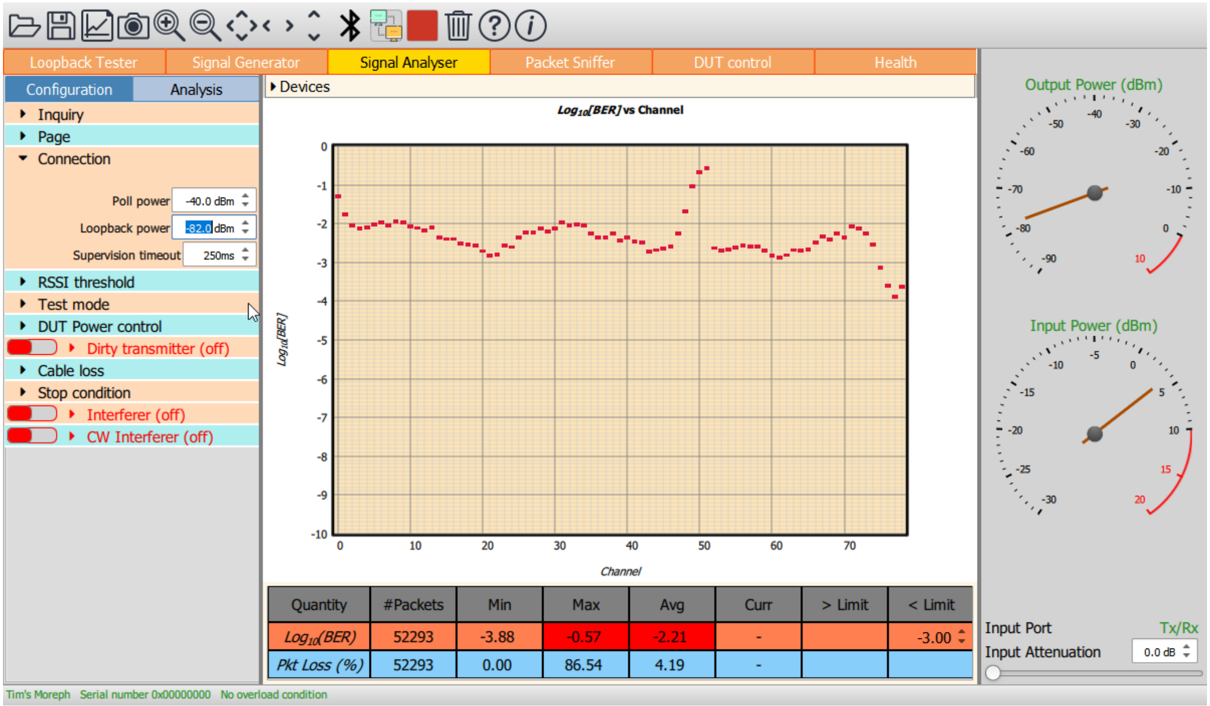


Figure 30: Adjusting the signal level during receiver testing

8.6.5 Controlling the dirty transmitter during receiver testing

The *Dirty transmitter* menu permits the parameters of the dirty transmitter to be adjusted. See Section 7.3.19 for more details. This menu is always visible, however, the switch to turn on the dirty transmitter is only visible if the DUT is connected in loopback test mode.

The dirty transmitter will automatically be disabled if *Zircon* loses connections with the DUT.

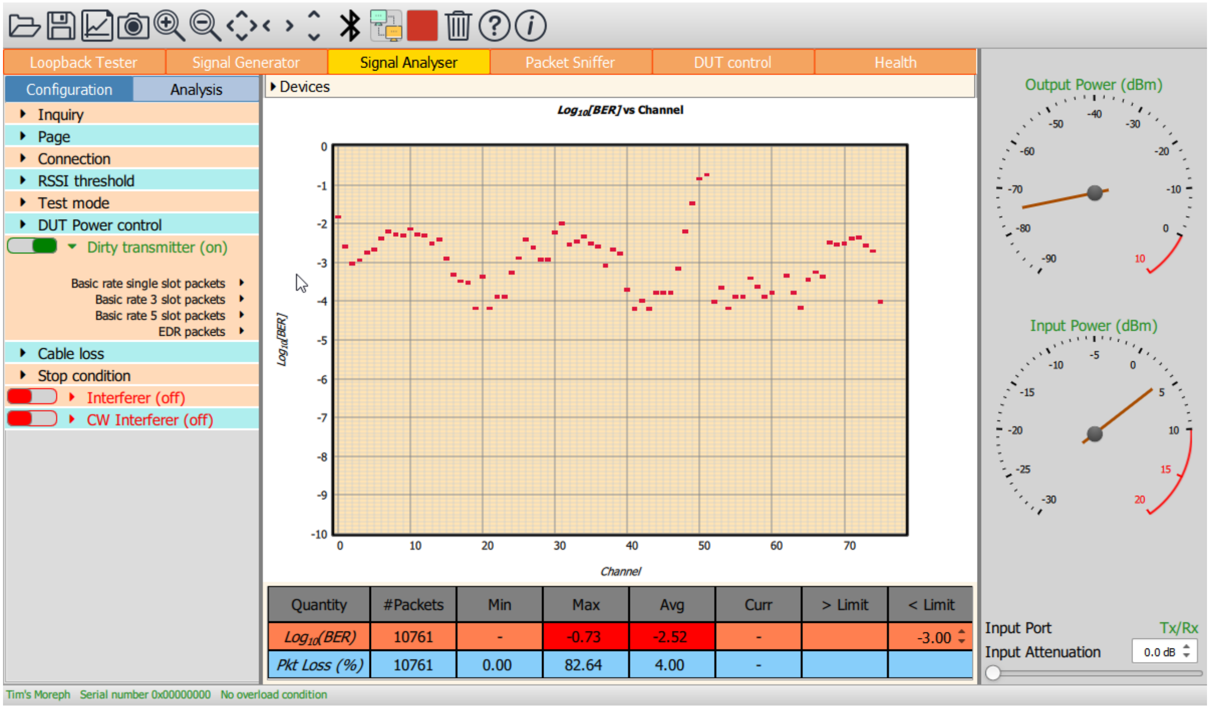


Figure 31: Turning on the dirty transmitter during receiver testing

8.6.6 Adding a modulated interferer during receiver testing

If a DUT is connected in loopback mode, then the *Interferer* menu will be visible. This permits a modulated interferer to be turned on or off. The interferer is GFSK modulated with BT = 0.5 and a modulation index of 0.32. The payload is a PRBS15 sequence.

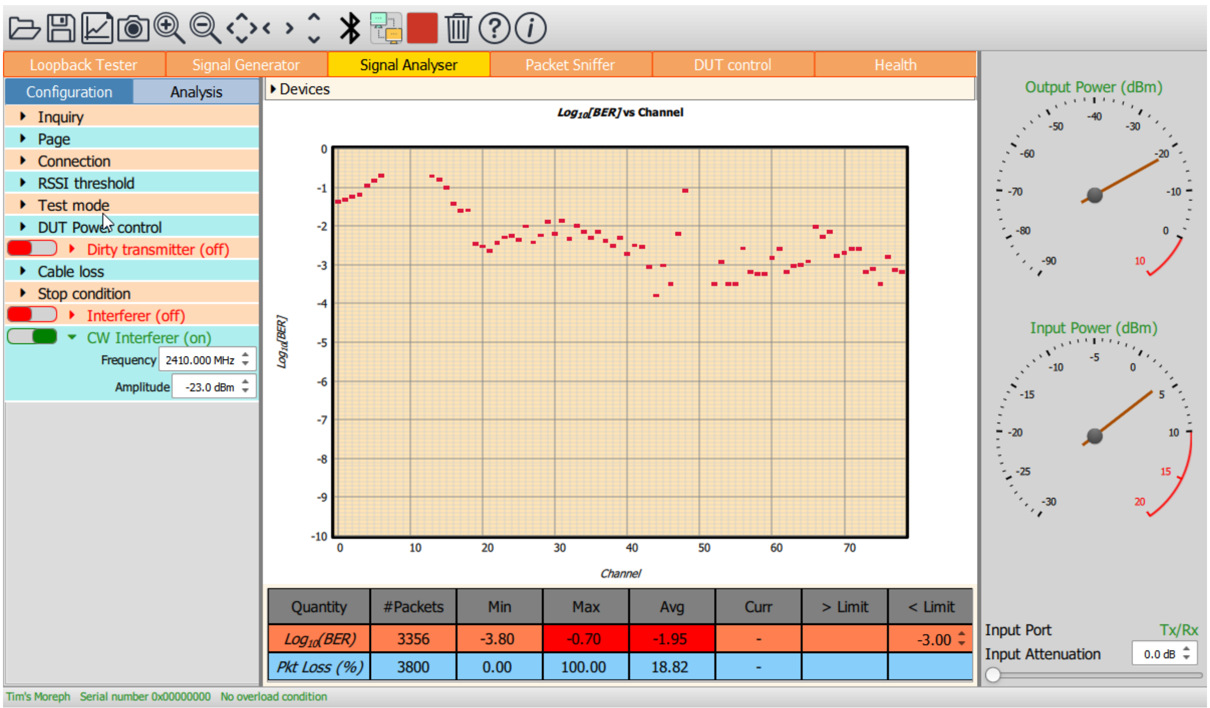


Figure 32: Adding a modulated interferer during receiver testing

The amplitude of the modulated interferer can be varied from -120dBm to 0dBm, however, the total peak output power from the *TLF3000* is limited to 0dBm, so the availability of the higher power levels is dependent on the programming of other transmitted signals.

The modulated interferer can be placed on any 1MHz channel from 2395MHz to 2485MHz, inclusive.

If *Zircon* loses connection with the DUT, then the modulated interferer will automatically be turned off to permit the connection to be re-established.

8.6.7 Adding a CW interferer during receiver testing

If a DUT is connected in loopback mode, then the *CW Interferer* menu will be visible. This permits a CW interferer to be turned on or off.

The amplitude of the CW interferer can be varied from -120dBm to 0dBm, however, the total peak output power from the *TLF3000* is limited to 0dBm, so the availability of the higher power levels is dependent on the programming of other transmitted signals.

The CW interferer can be placed on any 1MHz channel from 2395MHz to 2485MHz, inclusive.

If *Zircon* loses connection with the DUT, then the CW interferer will automatically be turned off to permit the connection to be re-established.

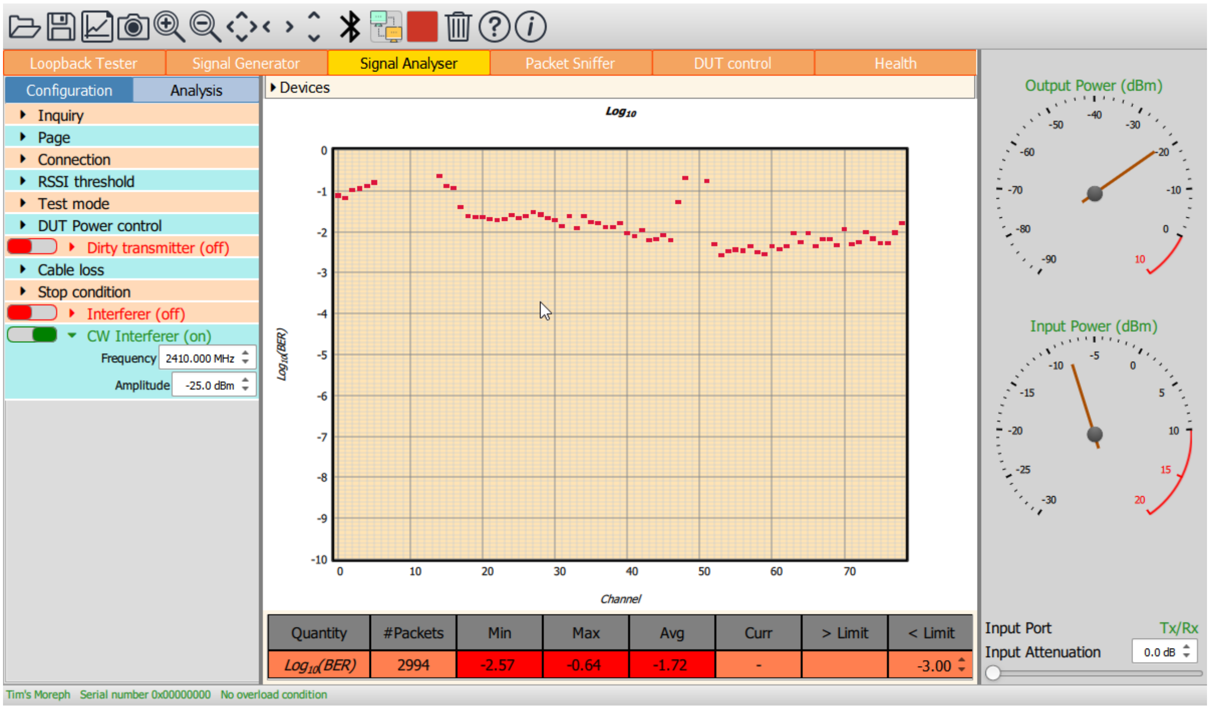


Figure 33: Adding a CW interferer during receiver testing

8.7 Saving and restoring settings

The current configuration and limit settings can be saved by clicking the ‘Save’ button on the toolbar. Select the ‘Signal analysis settings (*.sas)’ file type to save the current settings.

An existing signal analysis settings file (*.sas) can be opened using the ‘Open’ button on the toolbar.

The signal analysis settings file (*.sas) is an XML file. It is not recommended that this file be edited manually. If it needs to be modified, open it from the signal analyser, modify the required parameters and re-save.

8.8 Saving current results table and graphics

The current graph and results table can be saved as an image by clicking the ‘Graph’ button on the toolbar. The range of possible graphics formats includes:

1. Windows bitmap files (*.bmp)
2. Joint photographic expert group files (*.jpg)
3. Portable network graphics files (*.png)
4. Portable bitmap files (*.pbm)
5. Portable graymap files (*.pgm)
6. Portable pixmap files (*.ppm)
7. X11 bitmap files (*.xbm)
8. X11 pixmap files (*.xpm)

9 Loopback Tester Mode.

9.1 Overview

In loopback tester mode, the *Zircon* configuration directly controls the DUT over-the-air and executes an editable test script which defines which of the Bluetooth Radio Frequency Test Specification tests are to be performed.

The configuration is capable of running all of the Bluetooth Radio Frequency Test Specification tests, with the following caveats:

1. Blocking tests cannot be performed above 6 GHz. The Bluetooth Radio Frequency Test Specification states that blocking frequencies up to 12.75 GHz should be used. Since this limit includes the second harmonic of the 2.4 GHz ISM band, it is unlikely that a DUT which passes at frequencies below 6 GHz will fail at frequencies above 6 GHz.
2. Blocking tests cannot be performed with blocking powers above -28dBm (below 3GHz higher powers may be achievable). Below 2GHz and above 3GHz the Bluetooth Radio Frequency Test specification specifies blocking levels of -10dBm, which is substantially higher than the levels which can be generated by the *TLF3000* out-of-band CW generator. Between 2GHz and 3GHz the Bluetooth Radio Frequency Test Specification specifies a level of -27dBm with an uncertainty of ±3dB. It is therefore possible to perform blocking tests between 2GHz and 3GHz using the *TLF3000* hardware.
3. The CW blocker has a relatively high harmonic content. A notch filter is used to reduce the harmonic content falling within the 2.4 GHz ISM band. However, care should be exercised to ensure that blocking failures are not due to harmonics of the blocker landing on the wanted signal. Such care should always be exercised with blocking tests, irrespective of the test equipment being used.
4. The Bluetooth Radio Frequency Test Specification does not specify whether the interferers should be placed above or below the wanted signal during intermodulation testing. If the value of *N* is large and the wanted signal is at the band edge, then the *Zircon* configuration is only capable of performing these tests with the interferers placed towards the centre of the band. If the interferers are placed away from the centre of the band, then they may lie at frequencies beyond those which can be generate by the *TLF3000* hardware. This restriction can be alleviated by additional calibration of the hardware.
5. The power density test (RF/TRM/CA/BV-02-C) requires a spectrum analyser setup with centre frequency 2441MHz and span of 240MHz, ie coverage of 2321MH to 2561MHz. This span exceeds that available from the *TLF3000*. The *Zircon* configuration performs the power density test using a reduced span of 2395MHz to 2485MHz. This will always yield the same results as the full span unless the DUT contains spurious emissions outside the 2.4GHz ISM band which are greater in magnitude that its intended emissions inside the ISM band. A DUT behaving in such a manner is extremely unlikely to pass other test cases, hence the reduced span used by the *Zircon* configuration is of little consequence.

The *Zircon* configuration allows the Bluetooth Radio Frequency Test Specification tests to be expanded to include:

1. Testing with hopping on or off
2. Testing in transmitter test mode or loopback test mode (receiver measurements are always performed in loopback test mode)
3. Testing with whitening on or off
4. Testing on different channels
5. Testing with different packet types
6. Testing over a different number of packets
7. Testing with a different integration time (power density measurements)
8. Testing with a different number of 50 symbol blocks (EDR carrier frequency and modulation accuracy measurements)
9. Testing with a different reference sensitivity level (receiver measurements)
10. Testing with a different wanted signal level or over a sweep of wanted signal levels relative to the reference sensitivity (receiver measurements)
11. Testing with different interferer signal levels or over a sweep of interferer signal levels (C/I, blocking and intermodulation measurements)
12. Testing with different blocker frequencies (receiver blocking measurements)
13. Testing with different BER termination criteria (receiver measurements)

9.2 Communicating with the DUT

Communication with the DUT is performed over-the-air. This is described in detail in Section 12.

If the DUT fails to connect with the *Zircon* configuration, then a second *TLF3000* may be used to sniff the link using the *Zircon* packet sniffer mode. The resulting capture can be used to diagnose why the link was not established.

If the *Zircon* configuration connects to the DUT but there are issues with subsequent LMP commands, then the *Zircon* DUT control mode can be used to investigate further.

9.3 RF connections

For loopback mode testing the DUT is connected to the Tx/Rx RF port.

Zircon needs an estimate of the cable loss between the Tx/Rx port and the DUT at 2.4 GHz. This is necessary to compensate for receiver power levels and to adjust transmitter output levels. The cable loss is entered under the ‘Cable loss’ menu of the ‘Configuration’ tab.

The cable loss can be specified at a number of frequencies throughout the ISM band. The frequencies to be used are selected by ticking the checkbox to the left of the frequency label. The cable loss at the frequency can then be entered using the spin box to the right of the label.

A graph at the bottom of the *‘Cable loss’* menu shows the cable loss which will be applied.

If the cable loss is specified at a single frequency, then this value will be used throughout the band.

If the cable loss is specified at two or more frequencies, then linear interpolation will be used between the specified frequencies and linear extrapolation applied outside the range of the specified frequencies.

All interpolated/extrapolated cable loss values will be limited to the range 0dB to 25dB.

Note that the maximum power output of the *TLF3000* unit is 0dBm. Hence high cable loss values will restrict the maximum power available at the DUT which may in turn limit the applicability of some tests, for example, receiver maximum input signal level.

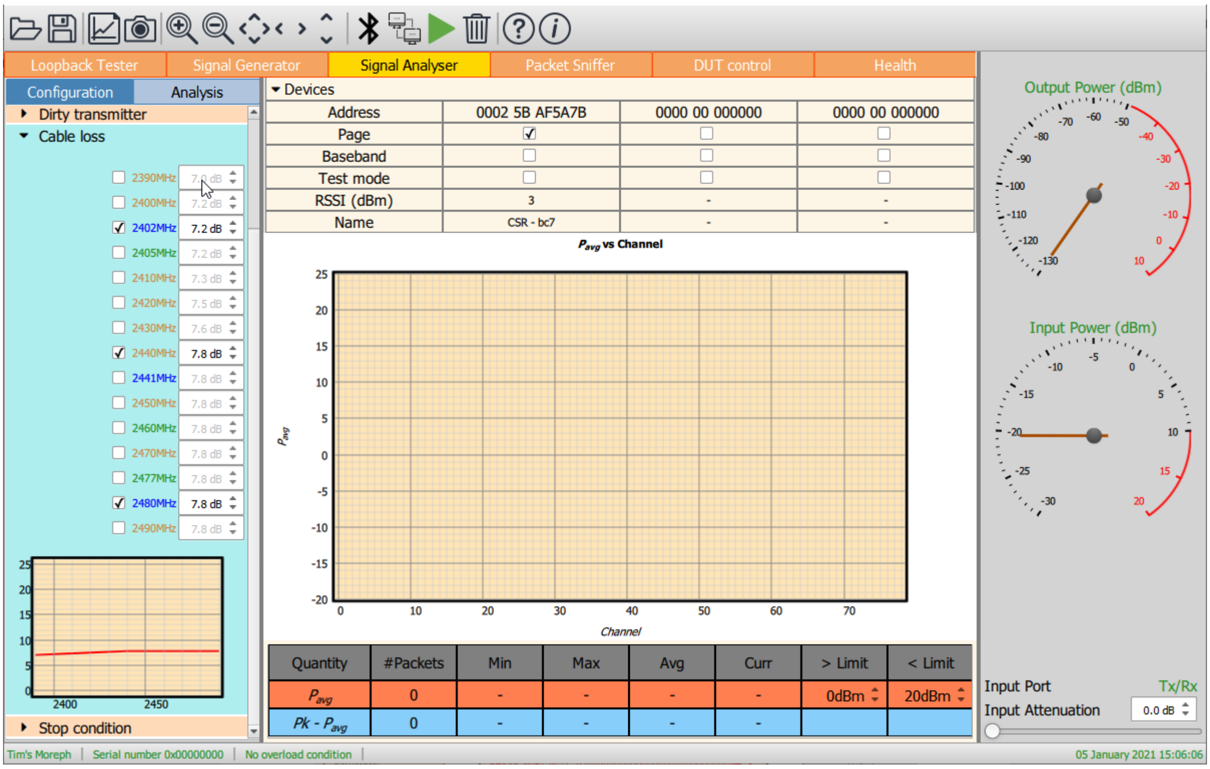


Figure 34: Entering the cable loss value.

The cable loss value is also used to compensate the blocker level. Since the cable loss value is only applicable at 2.4 GHz and the blocker frequency can be anywhere from 24 MHz to 6 GHz, the compensation is extremely rough. However, given the accuracy of the blocker signal level and the relatively low levels of cable attenuation, this is not normally an issue.

9.4 Run modes and termination criteria

The operation of the loopback tester can be modified by using the options available in the 'Run mode' menu under the 'Collection' tab. Available options are:

1. *Only test against limits*. When performing receiver tests, the *Zircon* application continuously monitors the BER which has been achieved. The application is able to determine when the BER has attained a value which guarantees the test will pass or fail, irrespective of the contents of the remaining bits to be tested. By doing so the application is able to terminate the test early and hence save test time. If the test is terminated early then the measured BER will only be approximate, since the specified number of bits will not have been tested. Early termination of the test will only occur if 'Only test against limits' is checked. If an accurate BER value is required, then this box should be left unchecked.
2. *Run to completion*. If the 'Run to completion option' is checked, then *Zircon* will always perform all the tests which have been specified. If this option is not checked, then *Zircon* will terminate execution of the test script as soon as a test failure is detected. An exception to this rule is when BER searches are being performed, either by sweeping the level of the wanted signal or the interfering signals. In these instances, as soon as the test fails *Zircon* will move to the next test item.
3. *Only perform specified tests*. *Zircon* is capable of performing multiple tests in parallel (see Section 9.6). For example, when measuring the output power, it is also possible to measure the initial carrier frequency error. Hence if the *Output power* test is specified, the *Initial carrier frequency tolerance* test can also be performed. This is the default action of the loopback tester. If the 'Only perform specified tests' box is checked, then only the selected test will be performed and the results from tests which could be performed in parallel are discarded.
4. *Show table*. If 'Show table' is checked, then on termination of the test script the test results will be shown in HTML format in a separate browser window.
5. *Include graphs in table.* If 'Include graphs in table' is checked, then graphs will be appended at the end of the HTML results report for each of the transmit spectral tests which were selected.
6. *Force loopback mode*. By default, transmitter tests are done in TxTest mode since this reduces the test time required. However, some DUTs may not support TxTest mode. If *Force looback mode* is checked, then all transmitter tests will be performed Tx Loopback mode.
7. *Loop tests forever*. If 'Loop tests forever' is checked, then once the test script is exhausted it will be re-run indefinitely. This facility is useful for tracking down errors which occur infrequently. If 'Loop tests forever' is not checked, then the test script will be repeated the time number of times indicated by the 'Number of repeats' spinbox.

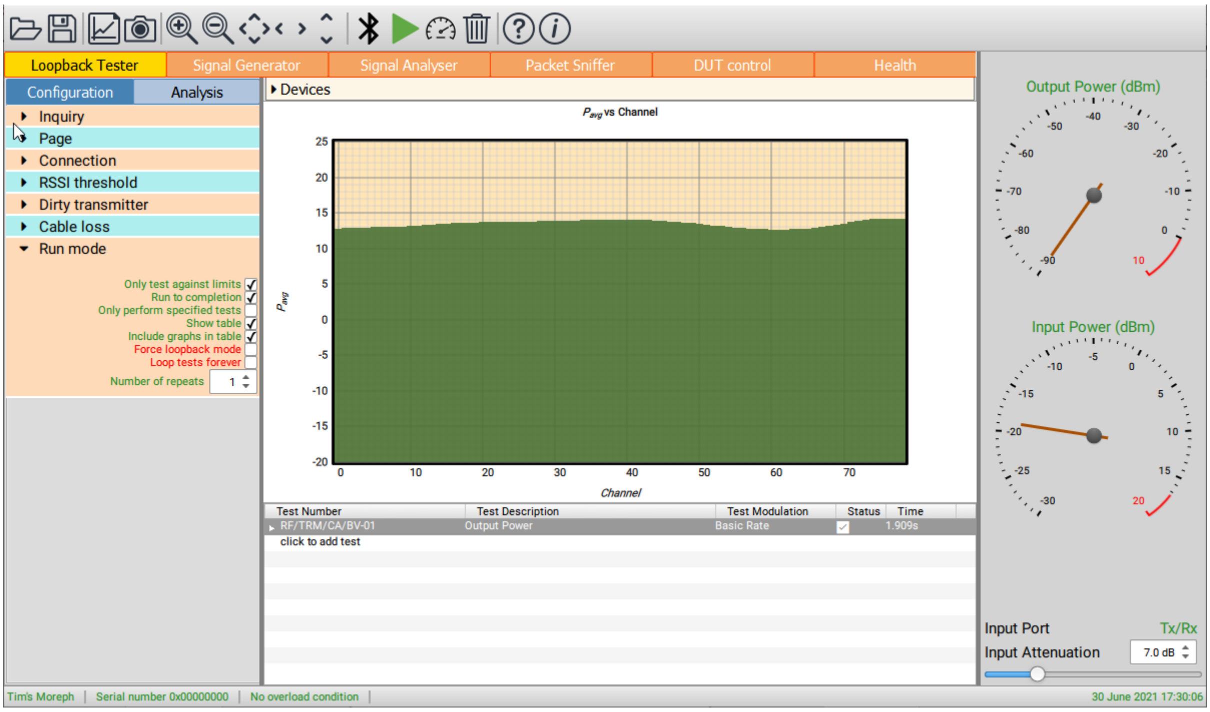


Figure 35. Run modes and termination criteria.

9.5 Entering DUT properties

In order to output power and power density measurements the *Zircon* application requires knowledge of:

1. The DUT antenna gain
2. The power class of the DUT

These parameters are entered using the “DUT properties” menu under the “Configuration” tab.

The antenna gain of the DUT can be set from -10 dBi to +10 dBi in steps of 0.1 dBi. This value is used to in both the output power and power density measurements.

The power class of the DUT can be set to Class 1, Class 2 or Class 3.

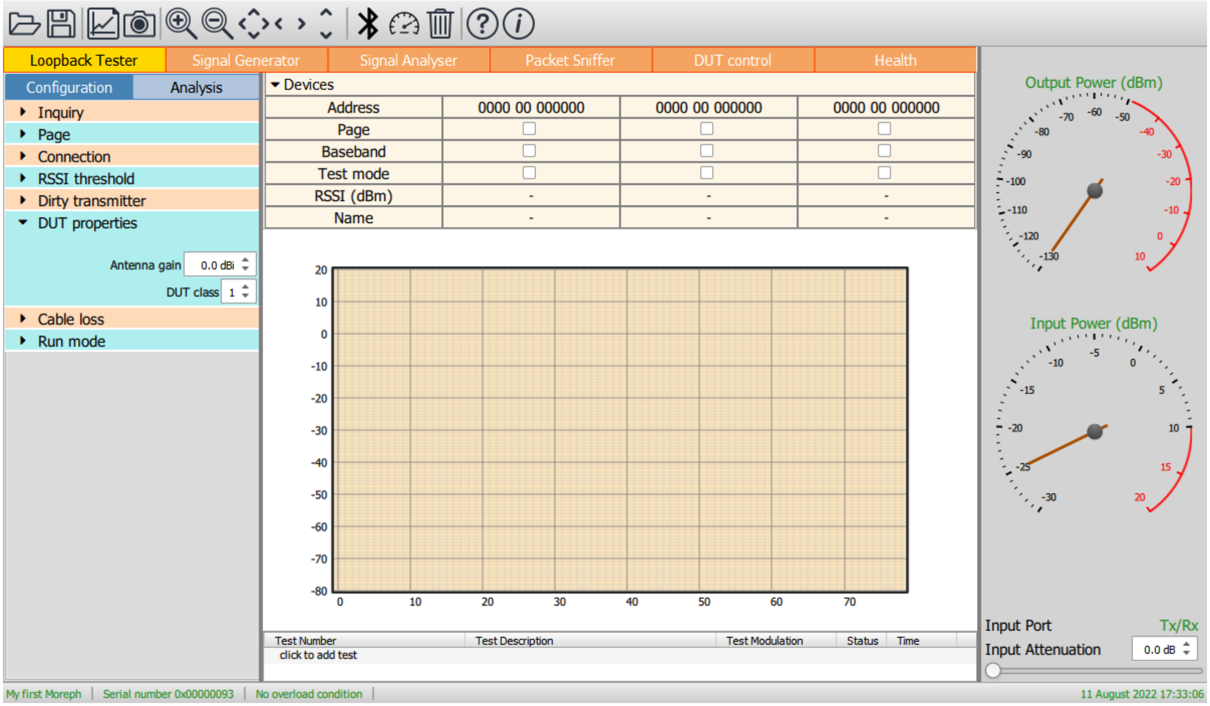


Figure 36. DUT antenna gain and power class

9.6 Building a test script

9.6.1 Overview

The test script will be displayed at the bottom of the window below the graphics area. On entering the loopback tester mode the script will be empty. To commence building a test script, click on 'click to add test'. This will open up a pop-up window where the test contents can be defined.

9.6.2 Test definition window

The pop-up test definition window permits any one of the Bluetooth Radio Frequency Test Specification tests to be selected. Various parameters for each test can also be modified.

The test definition window consists of:

1. A yellow bar containing drop down menus which can be used to select the test to be performed.
2. A list of expandable menus which can be used to alter parameters defining the test.
3. A 'Restore Defaults' button which can be used to reset the test parameters to the values defined in the Bluetooth Radio Frequency Test Specification.
4. An 'Apply' button which will add a new test to the end of the test script or save the edits to an existing test.
5. A 'Cancel' button which will discard all information which has been entered into the test definition window. If a new test was being created, then it will be discarded. If an existing test was being edited, then the edits will be discarded.

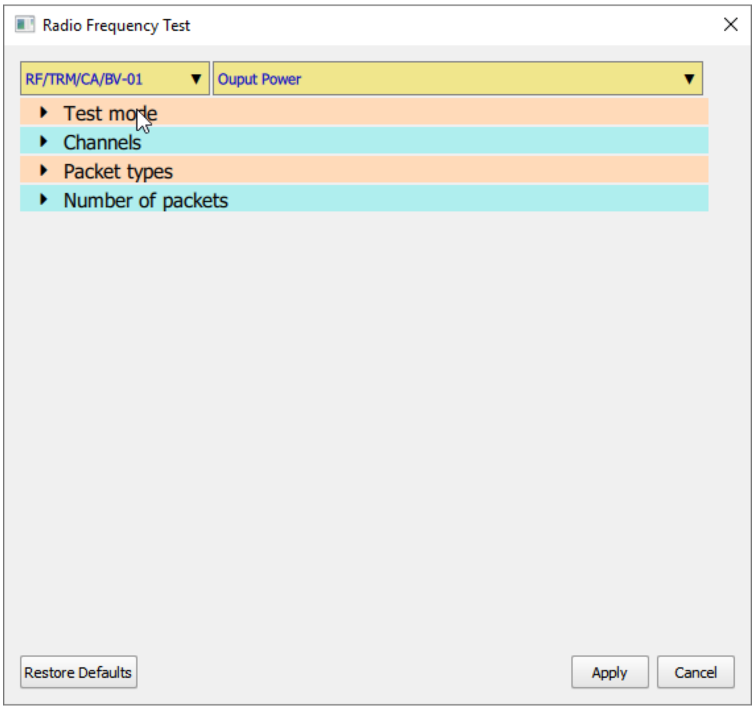


Figure 37: Test definition window.

9.6.3 Selecting the test type

The test type is selected by using the drop-down menus in the yellow bar at the top of the test definition pop-up window.

If the test number if known, then it may be selected directly by using the left-hand drop-down menu.

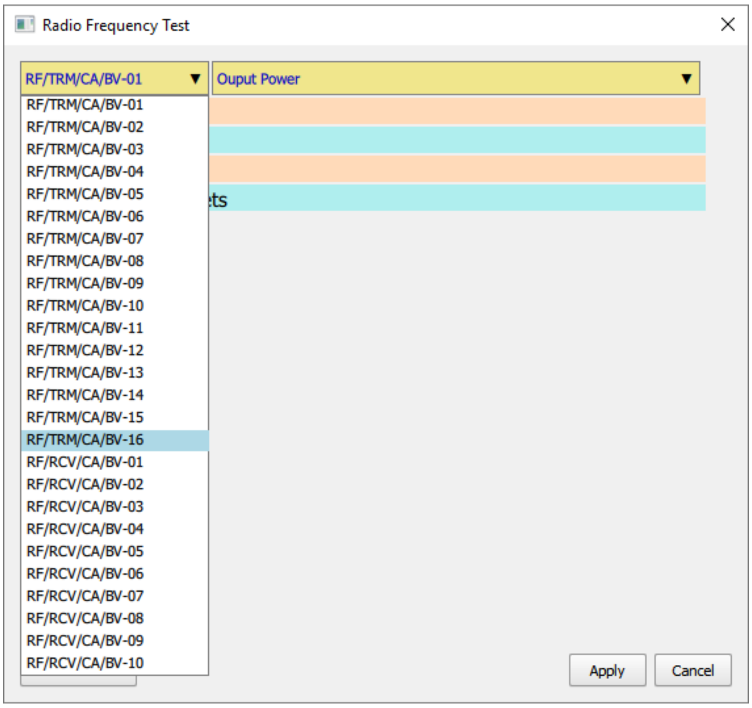


Figure 38: Selecting the test type if the test number is known.

If the test number is not known, then the second drop down menu may be used to select the test by its name.

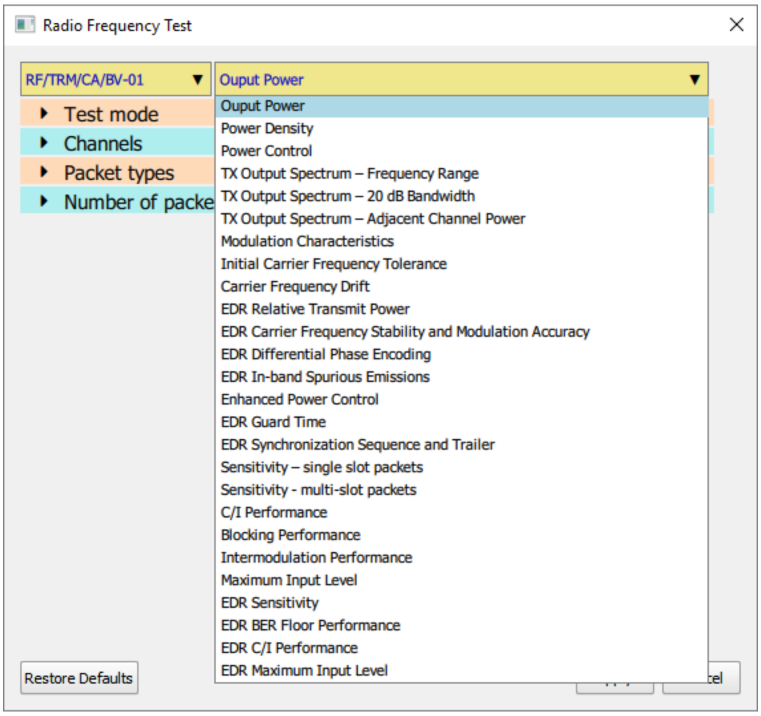


Figure 39: Selecting the test type if the test number is not known.

At the time of test selection, no connection has been established with the DUT. It is therefore impossible to verify at this time whether the selected tests are compatible with the DUT supported features. It is the responsibility of the user to ensure that the test script is appropriate for the DUT.

9.6.4 Selecting the test mode

To select the test mode to be used, expand the ‘Test mode’ menu.

The test mode can be selected by clicking on the checkboxes.

Three checkboxes are displayed:

1. *Hopping*. Determines whether the test should be performed with both *Zircon* and DUT hopping or whether they should be placed on fixed frequencies. Use of hopping is not supported for some transmit output spectral tests.
2. *Loopback*. Determines whether the test should be performed in loopback test mode or transmitter test mode. In loopback test mode the DUT loops back the packets transmitted by *Zircon*. In transmitter test mode, *Zircon* polls the DUT to provoke it into sending a predefined packet. Receiver tests can only be performed in the loopback mode.
3. *Whiten*. Determines whether whitening of the packets should be enabled. This option is only available if ‘Loopback’ has been selected; the transmitter test mode does not support whitening.

Not all options are available for all tests. For example, whitening is not available for the modulation characteristics test (RF/TRM/CA/BV-07-C) since these measurements are reliant on an unwhitened packet payload.

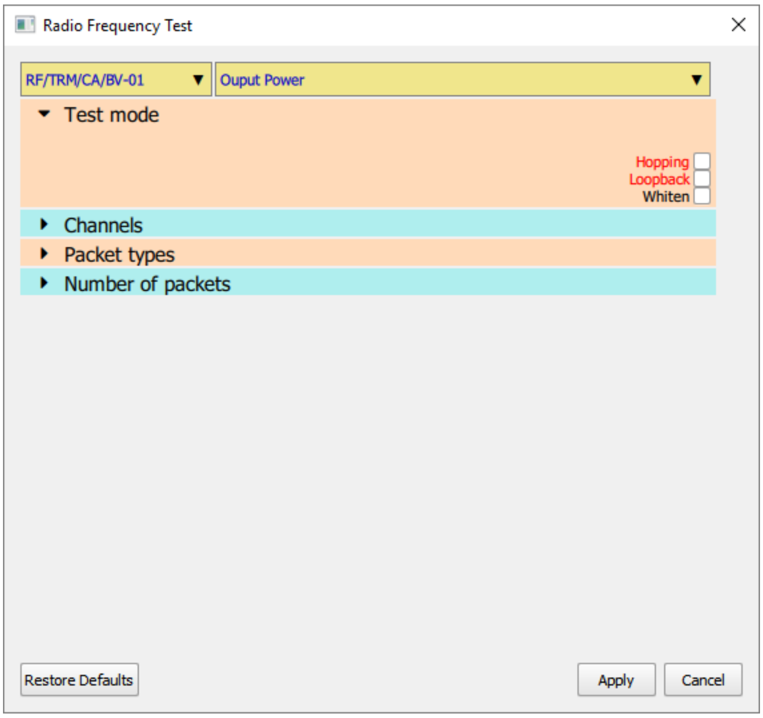


Figure 40: Selecting the test mode.

9.6.5 Selecting which channels are tested

To select which RF channels the test is to be performed on, expand the ‘Channels’ menu.

The RF channels can be selected by clicking on the checkboxes.

Groups of RF channels can be selected using the toggle buttons at the bottom left:

1. *Clear all*. All RF channels will be deselected.
2. *Select all*. All RF channels will be selected.
3. *Specification channels*. The RF channels defined for the test in Bluetooth Radio Frequency Test Specification will be selected.
4. *Single channel mode*. When this box is checked, only one channel can be selected. Selecting a new channel will automatically deselect the previous channel.

It is also possible to select the RF channels by entering text into the text field at the bottom of the menu. The required format for the text is described in Section 9.5.15.

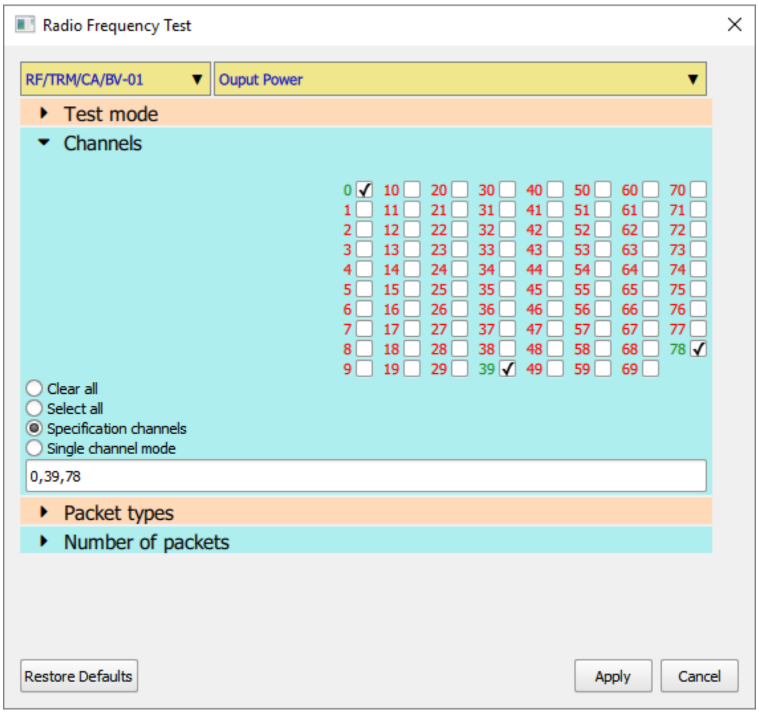


Figure 41: Selecting which channels are tested.

9.6.6 Selecting which packet types are tested

To select which packet types the test is to be performed on, expand the 'Packet types' menu.

The wanted packet types can be selected by clicking on the checkboxes.Not all packet types will be available for every test, for example, EDR packet types will not be available for BR specific tests.

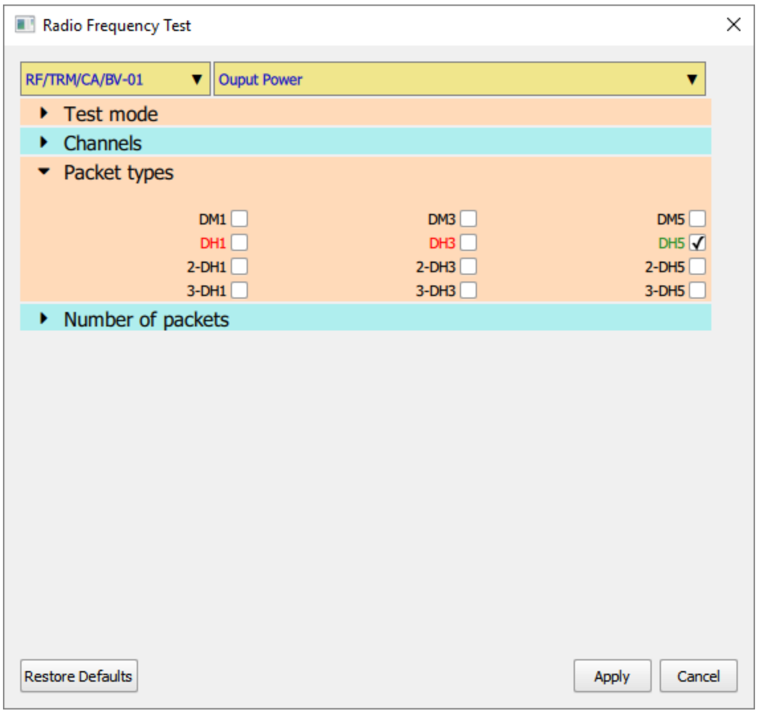


Figure 42: Selecting which packet types are tested.

If the selected packet types encompass more than one modulation scheme, then separate tests entries will be generated for each scheme. For example, the enhanced power control test (RF/TRM/CA/BV-14-C) requires DH1, 2-DH1 and 3-DH1 packets to be tested. The resulting test script shows three separate tests for BR, 2-EDR and 3-EDR.

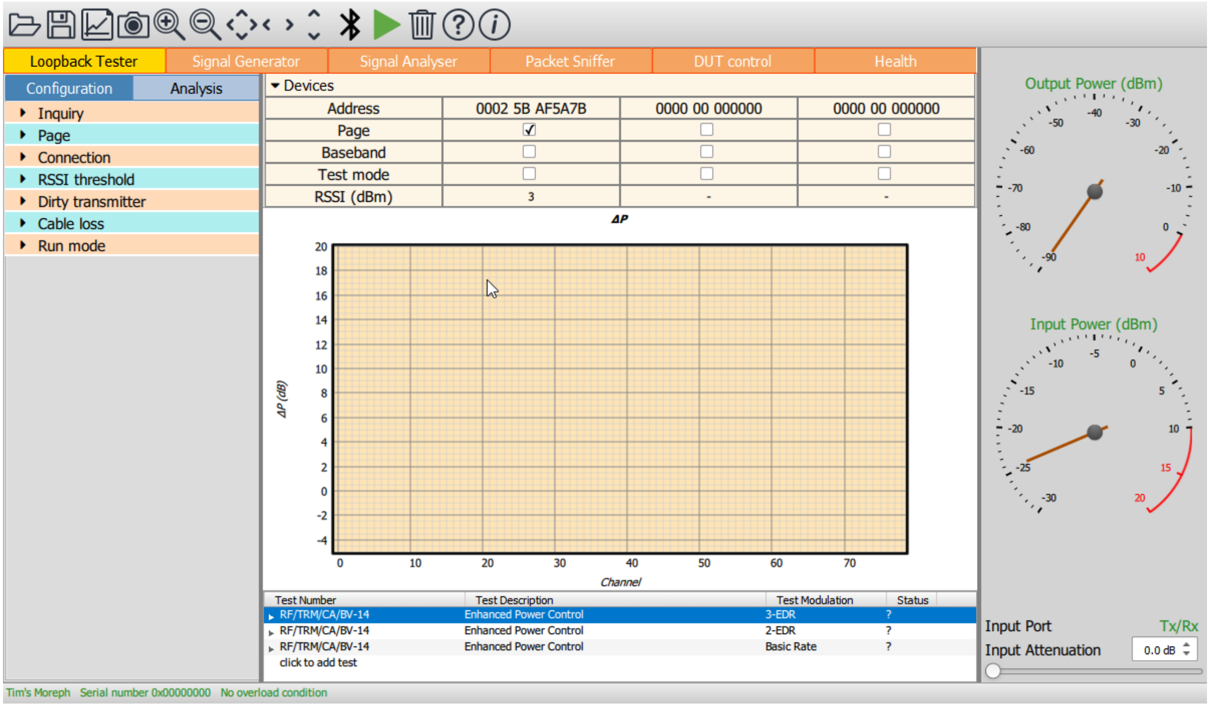


Figure 43: Test script resulting from adding enhanced power control test (RF/TRM/CA/BV-14-C).

9.6.7 Selecting how many packets are used in the test

To select how many packets are used in the test, expand the 'Number of packets' menu.

If the 'Specification' checkbox is ticked, then the number of packets as defined in the Bluetooth Radio Frequency Test Specification will be used. This value will be shown in the spin box. The spin box will not be editable whilst the 'Specification' checkbox is ticked.

If the 'Specification' checkbox is cleared, then the number of packets can be entered into the spin box, either by using the up/down arrows or by entering a numeric value directly into the text field.

The number of packets selection is only available for the following tests:

1. Output power (RF/TRM/CA/BV-01-C)
2. Power control (RF/TRM/CA/BV-03-C)
3. Modulation characteristics (RF/TRM/CA/BV-07-C)
4. Initial carrier frequency tolerance (RF/TRM/CA/BV-08-C)
5. Carrier frequency drift (RF/TRM/CA/BV-09-C)
6. EDR relative transmit power (RF/TRM/CA/BV-10-C)
7. EDR differential phase encoding (RF/TRM/CA/BV-12-C)
8. EDR in-band spurious emissions (RF/TRM/CA/BV-13-C)

9. Enhanced power control (RF/TRM/CA/BV-14-C)
10. EDR guard time (RF/TRM/CA/BV-15-C)
11. EDR synchronisation sequence and trailer (RF/TRM/CA/BV-16-C)

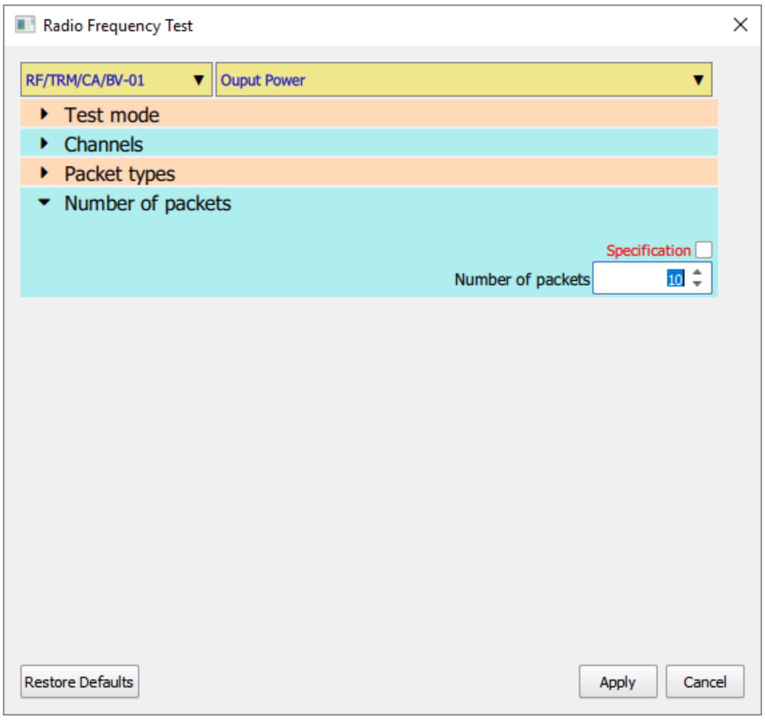


Figure 44: Selecting how many packets are used in the test.

9.6.8 Selecting the integration time (power density test only)

To select the integration time used in the power density test (RF/TRM/CA/BV-02-C), expand the 'Integration time' menu.

If the 'Specification' checkbox is ticked, then the integration time as defined in the Bluetooth Radio Frequency Test Specification will be used. This value will be shown in the spin box. The spin box will not be editable whilst the 'Specification' checkbox is ticked.

If the 'Specification' checkbox is cleared, then the integration time can be entered into the spin box, either by using the up/down arrows or by entering a numeric value directly into the text field.

The power density test is performed in two phases. In the first phase the span is 90MHz and the integration time used is always 1s. In the second phase zero span is used with a default integration time of 60s. It is the integration of the second phase which can be adjusted using the 'Integration time' menu.

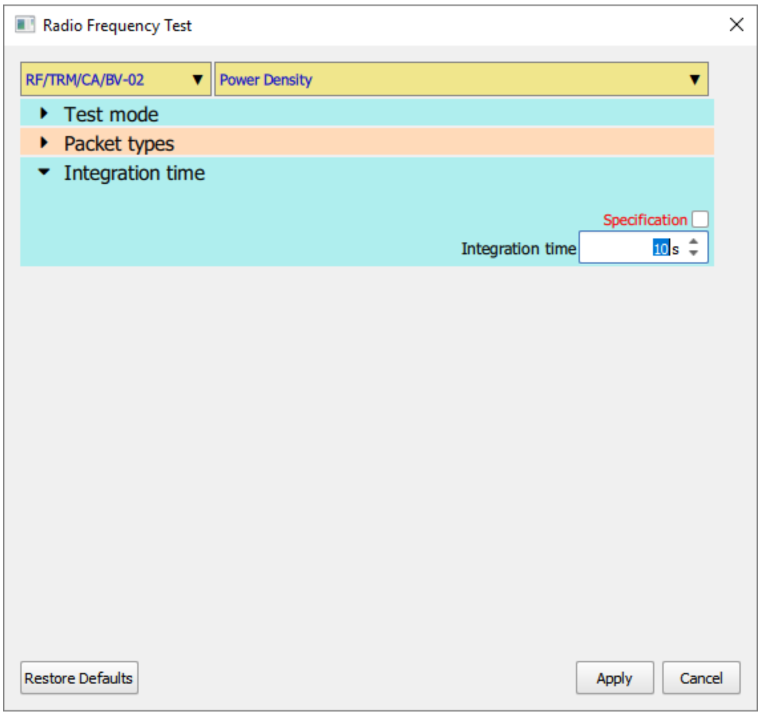


Figure 45: Selecting integration time for the power density test (RF/TRM/CA/BV-02-C).

9.6.9 Selecting the number of 50 symbol blocks (EDR carrier frequency stability and modulation accuracy test only)

To select the number of 50 symbol blocks used in the EDR carrier frequency stability and modulation accuracy test (RF/TRM/CA/BV-11-C), expand the 'Number of blocks' menu.

If the 'Specification' checkbox is ticked, then the number of 50 symbol blocks as defined in the Bluetooth Radio Frequency Test Specification will be used. This value will be shown in the spin box. The spin box will not be editable whilst the 'Specification' checkbox is ticked.

If the 'Specification' checkbox is cleared, then the number of 50 symbol blocks can be entered into the spin box, either by using the up/down arrows or by entering a numeric value directly into the text field.

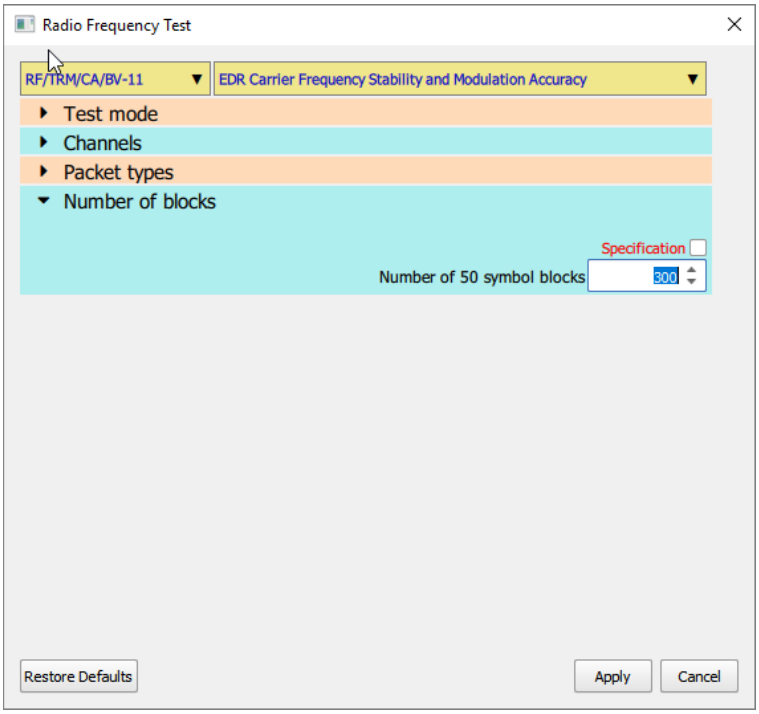


Figure 46: Selecting the number of 50 symbol blocks for the EDR carrier frequency stability and modulation accuracy test (RF/TRM/CA/BV-11-C).

9.6.10 Selecting the number of bits tested for receiver tests

To select the number of bits tested for the receiver test cases, expand the 'Number of bits' menu.

The 'Number of bits' menu shows both the number of bits to be tested and the BER which must be achieved.

If the 'Early exit' box is checked, then two copies of the number of bits to be tested and the BER threshold are shown. The first copy defines the early exit condition, the second copy the final exit condition which is applied if the early exit condition was not satisfied. Early exit permits the testing of a smaller number of bits but with a more stringent BER threshold. By using an early exit condition, test times can be substantially reduced. By default, the testing of BR packets does not include an early exit condition, but the testing of EDR packets does.

If the 'Specification' checkbox is ticked, then the number of bits tested, the BER threshold and the applicability of an early exit condition will be as defined in the Bluetooth Radio Frequency Test Specification. The values defined in the Bluetooth Radio Frequency Test Specification will be shown in the appropriate spin boxes. The use of an early exit condition will be indicated by the state of the early exit checkbox. Neither the spin boxes nor the early exit checkbox will be editable whilst the 'Specification' checkbox is ticked.

If the 'Specification' checkbox is cleared, then the number of bits to be tested and the BER threshold to be applied can be entered into the appropriate spin boxes, either by using the up/down arrows or by entering numeric values directly into the text fields. In addition, the early exit checkbox is enabled.

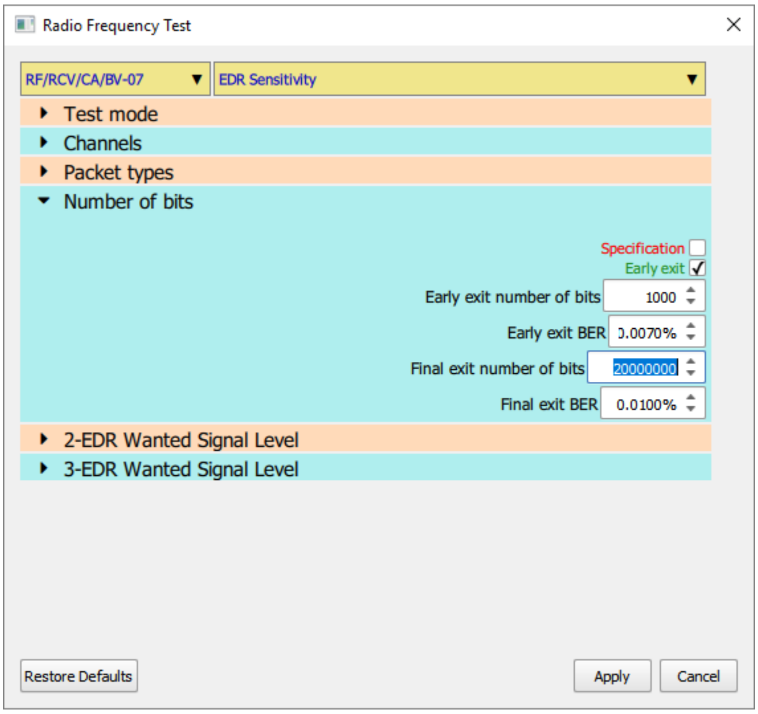


Figure 47: Selecting the number of bits tested for receiver tests.

9.6.11 Selecting the wanted signal level for receiver tests

To select the wanted signal level to be used for receiver tests expand the ‘Basic Rate Wanted Signal Level’, the ‘2-EDR Wanted Signal Level’ or ‘3-EDR Wanted Signal Level’ menu as appropriate.

For tests which have no interferer present, the wanted signal level is entered directly. For tests which have one or more interferers present, a reference sensitivity is defined and the wanted signal is specified as an offset from this value.

9.6.11.1 Tests which have no interferer present

For tests which have no interferer present, the wanted signal level is entered directly.

If the ‘Specification’ checkbox is ticked, then the wanted signal level as defined in the Bluetooth Radio Frequency Test Specification will be used. This value will be shown in the spin box. The spin box will not be editable whilst the ‘Specification’ checkbox is ticked. The wanted signal level will also be shown on the signal level gauge at the bottom of the menu.

Figure 48: Wanted signal level menu using specification value.

If the 'Specification' checkbox is cleared, then the wanted signal level can be entered into the spin box, either by using the up/down arrows or by entering a numeric value directly into the text field. If the cursor is placed directly over the red bar in the signal level gauge, then a '+' will appear adjacent to the cursor. By holding down the left mouse button it is then possible to drag the red bar to set the wanted signal level. Wanted signal levels must be in the range -110 dBm to 0 dBm. The resolution of the wanted signal level is 0.1 dBm.

Figure 49: Setting the wanted signal level.

If it is desired to sweep the wanted signal level over a range of values, for example, to perform a BER search, then tick the ‘Swept’ checkbox. *If interfering signals have been programmed to have swept levels, then it is not possible to sweep the wanted signal level.*

The wanted signal level power sweep is defined by the numbers displayed in the three spin boxes:

1. *Maximum Power*. This indicates the power level at which the sweep will start. The sweep will be from the maximum wanted signal power towards the minimum wanted signal power. The maximum power cannot be above 0 dBm and must be greater than or equal to the minimum power. The resolution of the maximum power is 0.1 dBm.
2. *Power Step*. This is the step size that the sweep will take from the maximum power towards the minimum power. The step size cannot be less than 0.5 dB. The resolution of the step size is 0.1dB.
3. *Minimum Power*. This indicates where the power sweep should terminate. The last wanted signal power to be test will be greater than or equal to the minimum power. The minimum power cannot be below -110 dBm and must be less than or equal to the maximum power. The resolution of the minimum power is 0.1 dBm.

If maximum input signal level tests are being performed, the direction of the sweep is reversed, and the roles of maximum power and minimum power are swapped.

The red bar in the signal level gauge indicates the range selected by the maximum and minimum powers. This entire range may not be explored during the sweep since the actual values tested are dependent on the selection of the step size.

If the cursor is placed over one of the limits of the red bar, then it will change to a double headed cursor. It is then possible to hold down the left mouse button and drag the edge of the red bar to adjust either the minimum or maximum power.

If the cursor is placed over the body of the red bar, then a ‘+’ will appear adjacent to the cursor. It is then possible to hold down the left mouse button and drag the entire sweep range up or down the gauge.

Figure 50: Setting a wanted signal level range.

9.6.11.2 C/I performance tests

For C/I performance tests a reference sensitivity must be defined. The entry of the reference sensitivity is identical to that of wanted signal level as described in Section 9.5.11.1. The reference sensitivity can either be a fixed value or swept. Sweeping of the reference level is only possible if the interfering signals have been programmed with fixed values, ie they are not swept.

In addition to specifying a reference sensitivity, the wanted signal level relative to the reference sensitivity must be defined. Two values for the wanted signal level relative to the reference sensitivity can be entered which correspond to different regions of frequency separation between the interferer and the wanted signal. The first offset applies when the interferer signal is greater than 2MHz from the wanted signal. The second offset applies when the interferer is less than or equal to 2MHz from the wanted signal. Each offset is entered using a spin box. The values entered are positive numbers between 0 and 40dB, indicating that the wanted signal is greater than the reference sensitivity. The values in the spin boxes can only be modified when the 'Specification' checkbox is cleared.

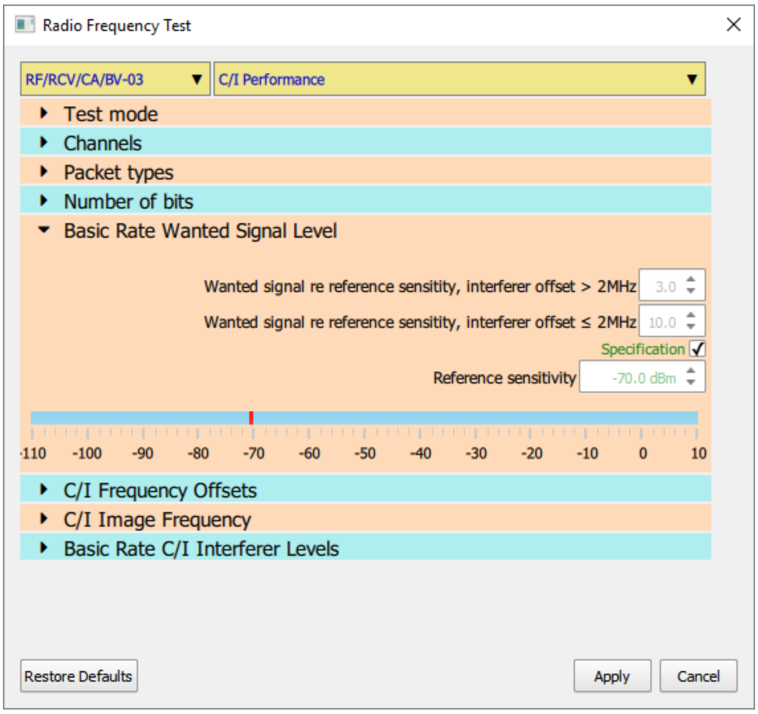


Figure 51: Entering the wanted signal level for C/I performance tests.

9.6.11.3 Blocking and intermodulation tests

For blocking and intermodulation tests a reference sensitivity must be defined. The entry of the reference sensitivity is identical to that of wanted signal level as described in Section 9.5.11.1. The reference sensitivity can either be a fixed value or swept. Sweeping of the reference level is only possible if the interfering signals have been programmed with fixed values, ie they are not swept.

In addition to specifying a reference sensitivity, the wanted signal level relative to the reference sensitivity must be defined. This is done using the ‘Wanted signal re reference sensitivity’ spin box. The value entered is a positive number between 0 and 40dB, indicating that the wanted signal is greater than the reference sensitivity. The values in the spin box can only be modified when the ‘Specification’ checkbox is cleared.

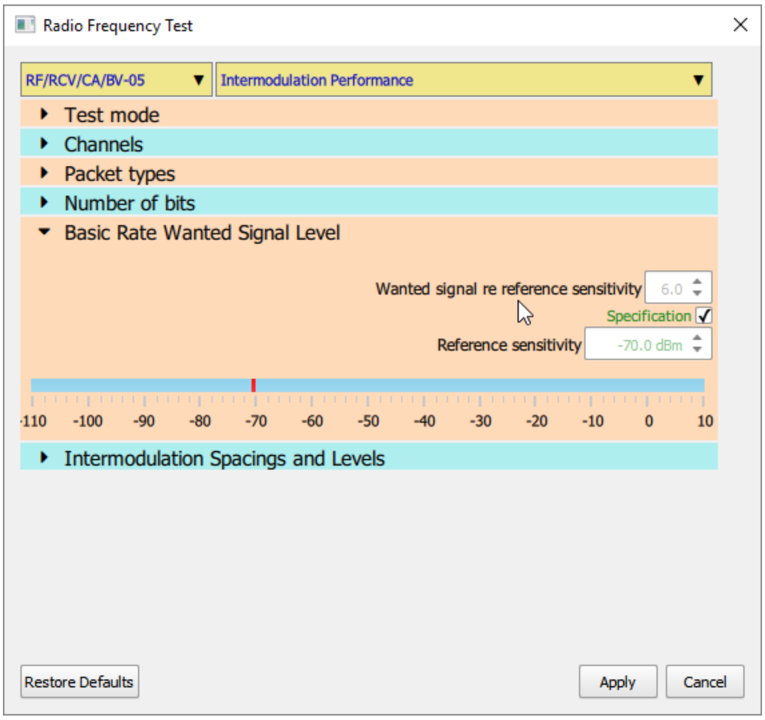


Figure 52: Entering the wanted signal level for blocking and intermodulation tests.

9.6.12 Configuring C/I receiver tests

9.6.12.1 Overview

In order to perform C/I receiver tests, it is necessary for *Zircon* to know where the image frequencies of the DUT receiver lie. The location of the image frequencies alters the level of the interfering signal which must be generated.

The C/I receiver tests can take a long time to perform. Frequently it is only a few offsets of the interferer signal from the wanted signal which are of interest. It is possible to individually select which interferer offset frequencies are used.

Most DUTs will greatly exceed the Bluetooth Radio Frequency Test Specification C/I test. *Zircon* therefore contains the ability to adjust the interferer signal level as well as the ability to sweep it over a range of values.

9.6.12.2 Specifying the DUT image frequencies

To set the DUT image frequency, expand the 'C/I Image Frequency' menu.

The spin box labelled 'Image frequency' determines the offset of the DUT's image frequency. The image frequency can be set to any value from 0 MHz to 100 MHz in steps of 1 MHz. The step size is limited to a resolution of 1 MHz to be compatible with the resolution of the interfering signal offset. *Zircon* implicitly assumes that the image frequency offset is the same for all channels.

For each of the channels it is possible to specify whether high-side or low-side mixing is employed by the DUT. With high-side mixing the image will appear above the wanted signal, whilst with low-side mixing the image will appear below the wanted signal. The choice between high- and low-side mixing can be made by:

1. Toggling the individual checkboxes for each channel
2. Using the toggle buttons at the bottom left of the window:
    a. 'All channels low-side mix' will set low-side mix for all channels
    b. 'All channels high-side mix' will set high-side mix for all channels
3. By entering a text string into the text field at the bottom of the window denoting which channels will employ high-side mix. The format of this text string is defined in Section 9.5.15.

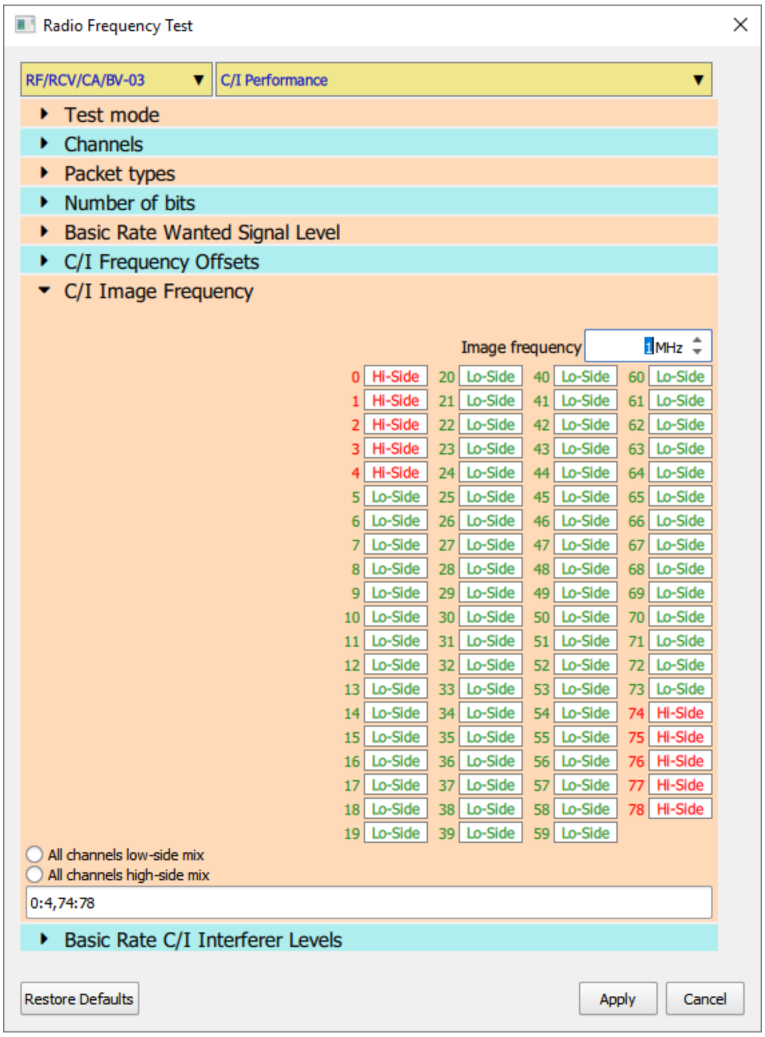


Figure 53: Specifying DUT image frequencies.

9.6.12.3 Selecting the C/I receiver test offset frequencies

To select which offsets of the interferer from the wanted signal are to be explored, expand the 'C/I Frequency Offsets' menu.

The interfering signal can be placed up to 79 MHz from the wanted signal with a resolution of 1 MHz. If the interferer signal is placed outside the range 2402 MHz to 2480 MHz then the test will be silently ignored.

The C/I interferer signal frequency offsets can be set by:

1. Individually ticking the checkboxes for each frequency offset
2. Using the toggle buttons located at the bottom left of the window:
    a. *Clear All*. Removes all C/I interferer offset frequencies
    b. *Select All*. Ticks all C/I interferer offset frequencies
    c. *Force symmetry*. Ensures that the interferer frequency offsets that lie below the wanted signal are an image of the interferer frequency offsets that lie above the wanted signal.
3. Entering a text string directly into the text field at the bottom of the window. The format for this text string is described in Section 9.5.15.

Positive C/I frequency offsets correspond to the interferer being at a higher frequency than the wanted signal. Negative C/I frequency offsets correspond to the interferer being at a lower frequency that the wanted signal.

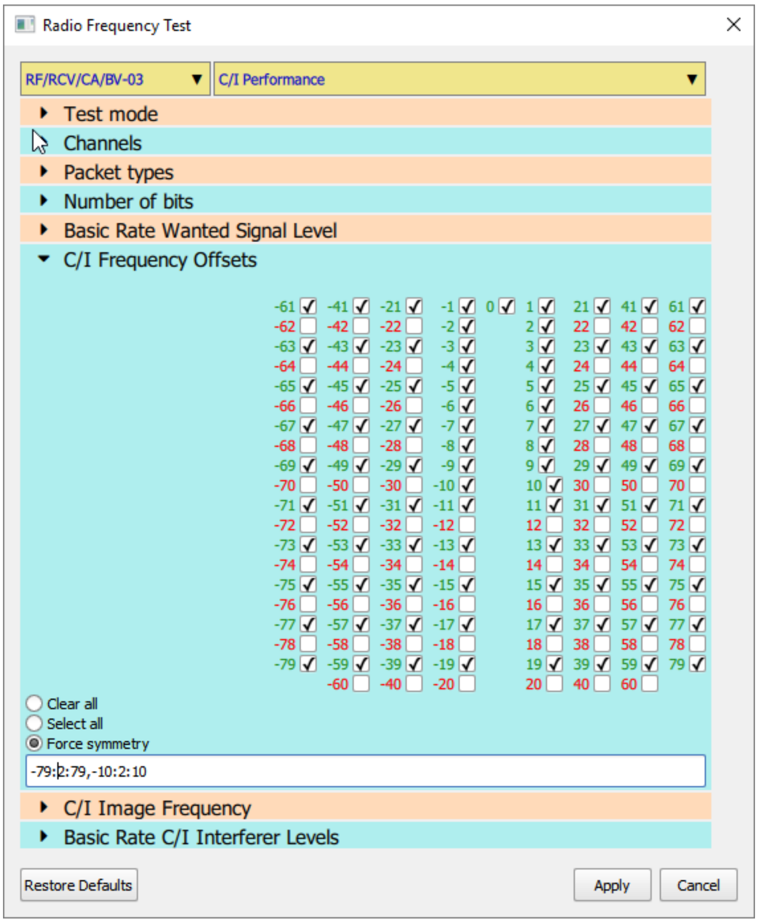


Figure 54: Selecting the C/I receiver test offset frequencies.

9.6.12.4 Selecting the interferer signal level for C/I receiver tests

To select the interferer signal levels to be used in the C/I receiver tests, expand the 'Basic Rate C/I Interferer Levels', the '2-EDR C/I Interferer Levels' or the '3-EDR C/I Interferer Levels' menu as appropriate.

At the top of the window is a graphical display of the C/I levels which have been selected. This has been provided so that the plausibility of the selected parameters can be seen at a glance.

Below the graphical display, the C/I levels are shown in a tabular form, similar to that of the Bluetooth Radio Frequency Test Specification.

Below the table is a 'Specification' checkbox. If this check box is ticked, then the C/I values in the table and displayed on the graph are those defined in the Bluetooth Radio Frequency Test Specification. The spin boxes within the table are disabled when the 'Specification' checkbox is ticked.

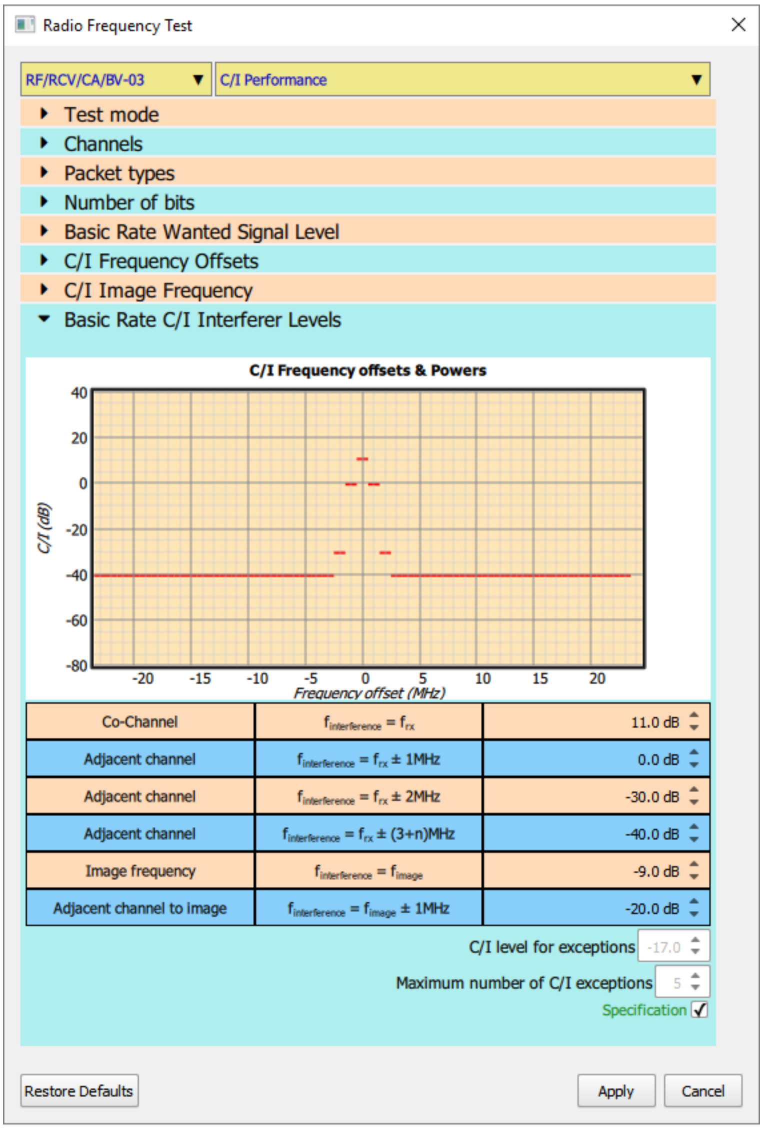


Figure 55: Interferer signal level for C/I receiver tests.

To enable the C/I levels to be adjusted, the 'Specification' checkbox must be cleared. Once the checkbox has been cleared, the following controls are accessible:

1. The individual spin boxes in the last column of the table can be used to adjust the C/I values. Each value can be adjusted from -80 dB to +40 dB with a resolution of 0.1 dB.
2. An offset can be applied to all the C/I levels in the table by using the ‘Offset’ spin box below the table. The offset can be varied from -80 dB to +20 dB. However, many offsets may result in signals levels which cannot be generated by the *TLF3000* unit. When *Zircon* encounters signal levels which cannot be generated the test is ignored and execution moves to the next test.
3. The offset to be applied to all the C/I levels in the table is also shown by the red bar in the gauge at the bottom of the window. It is possible to adjust the offset by clicking on the gauge. Alternatively, if the cursor is placed over the red bar, then a ‘+’ symbol will appear adjacent to the cursor. It is then possible to hold down the left mouse button and drag the red bar.

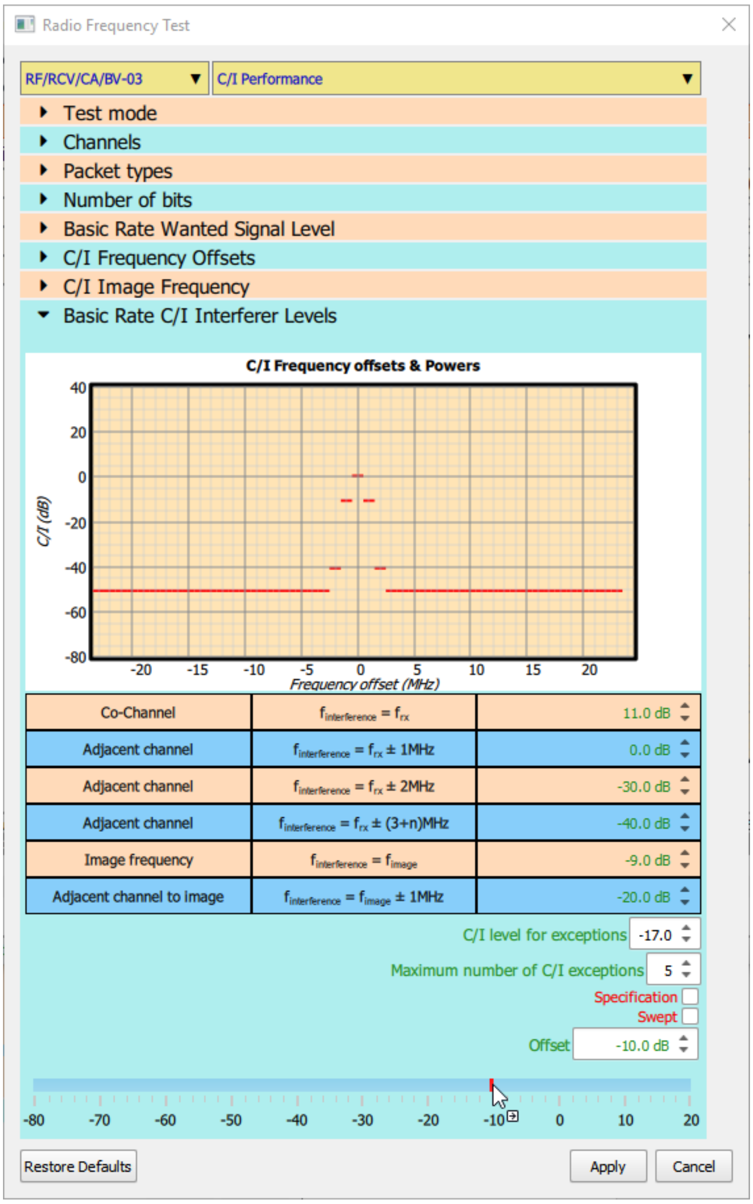


Figure 56: Changing the signal level for C/I receiver tests.

If it is desired to perform the C/I receiver tests over a range of interfering signal levels, then the 'Swept' checkbox must be ticked. *It is only possible to sweep the interferer signal level if the wanted signal is not being swept.*

The sweep of interferer levels is accomplished by applying a swept offset to all the values in the C/I table. It is not possible to specify individual sweeps for each row of the table. If this facility is required, then multiple C/I tests should be placed in the test script, each test configured to execute one row in the C/I table.

The offset level sweep is defined by the numbers displayed in the three spin boxes:

1. *Maximum Offset*. This indicates the offset at which the sweep will start. The sweep will always be from the maximum C/I towards the minimum C/I. The maximum offset cannot be above +20 dB and must be greater than or equal to the minimum offset. The resolution of the offset is 0.1 dB.
2. *Offset Step*. This is the step size that the sweep will take from the maximum C/I towards the minimum C/I. The step size cannot be less than 0.5 dB. The resolution of the step size is 0.1dB.
3. *Minimum Offset*. This indicates where the C/I sweep should terminate. The last interferer signal level to be tested will be greater than or equal to the signal level defined by this offset. The minimum offset cannot be below -80 dB and must be less than or equal to the maximum offset. The resolution of the minimum offset is 0.1 dB.

The red bar in the signal level gauge indicates the range selected by the maximum and minimum offsets. This entire range may not be explored during the sweep since the actual values tested are dependent on the selection of the step size.

If the cursor is placed over one of the limits of the red bar, then it will change to a double headed cursor. It is then possible to hold down the left mouse button and drag the edge of the red bar to adjust either the minimum or maximum offset.

If the cursor is placed over the body of the red bar, then a '+' will appear adjacent to the cursor. It is then possible to hold down the left mouse button and drag the entire sweep range up or down the gauge.

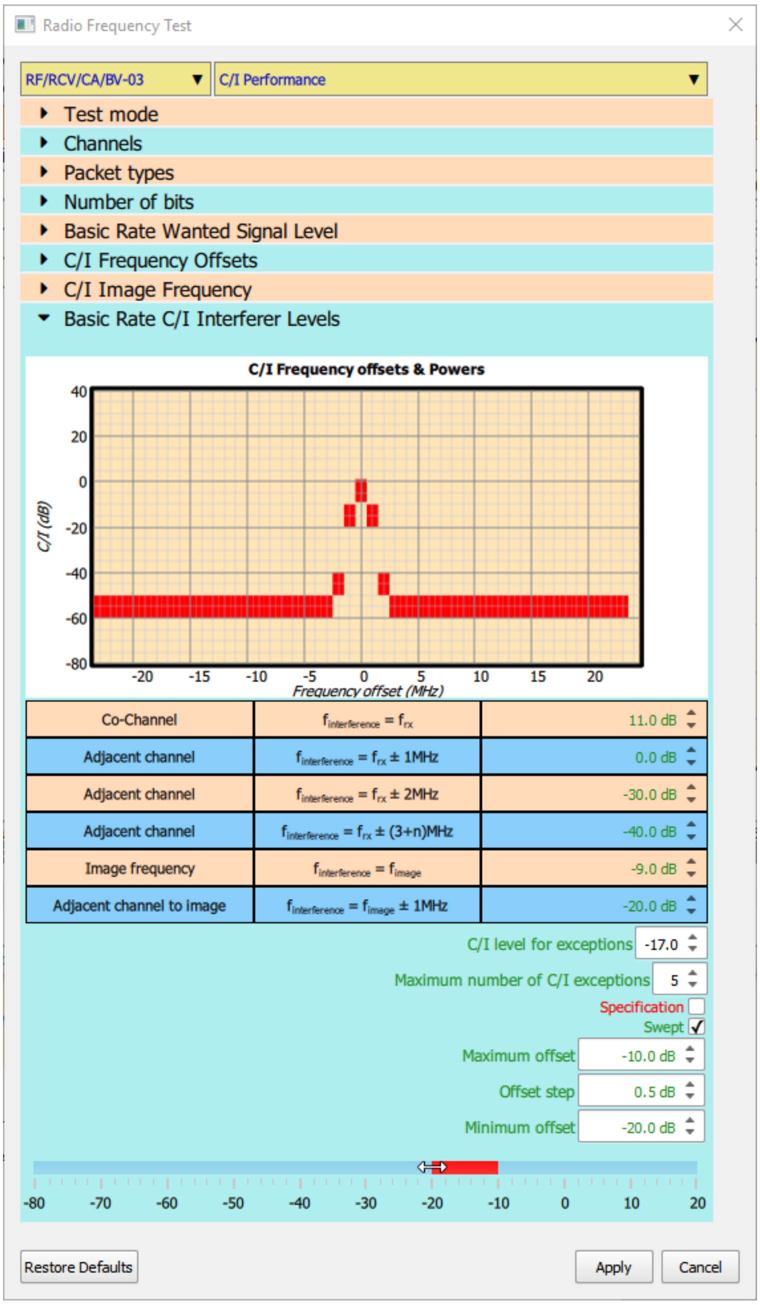


Figure 57: Selecting a range of signal levels for C/I receiver tests.

9.6.13 Configuring blocker receiver tests

To configure the blocker frequencies and levels to be used in the blocker receiver tests, expand the ‘Blocker’ menu.

At the top of the window is a graphical display of the blocker levels which have been selected. This has been provided so that the plausibility of the selected parameters can be seen at a glance.

Below the graphical display, the blocker levels are shown in a tabular form, similar to that of the Bluetooth Radio Frequency Test Specification. The range of blocker frequencies is subdivided into a number of segments, each segment occupies one row of the table. The second column shows the frequency at the start of the segment, the third column the step size that will be used to move the blocker through the segment and the fourth column denotes the end of the segment. The final column specifies the blocker level to be used for the segment.

Below the table is a ‘Specification’ checkbox. If this check box is ticked, then the blocker frequencies and levels in the table and displayed on the graph are those defined in the Bluetooth Radio Frequency Test Specification. Editing of the table is disabled when the ‘Specification’ checkbox is ticked. *Note that the TLF3000 is not capable of generating the higher blocking levels defined in the Bluetooth Radio Frequency Test Specification.*

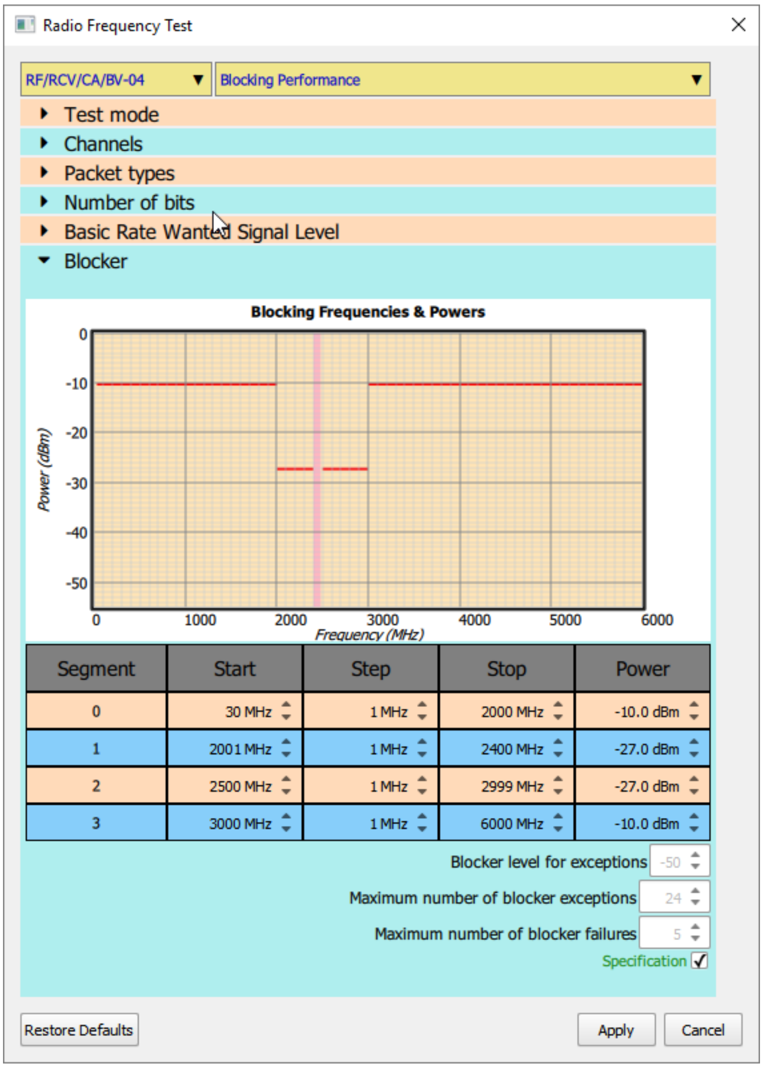


Figure 58: Blocker frequencies and levels.

To enable the blocker levels to be adjusted, the ‘Specification’ checkbox must be cleared. Once the checkbox has been cleared, the following controls are accessible:

1. The individual spin boxes in the last column of the table can be used to adjust the blocker values. Each value can be adjusted from -55 dBm to -25 dBm with a resolution of 0.1 dB.
2. An offset can be applied to all the blocker levels in the table by using the ‘Offset’ spin box below the table. The offset can be varied from -40 dB to +20 dB. However, many offsets may result in blocker levels which cannot be generated by the *TLF3000* unit. When *Zircon* encounters signal levels which cannot be generated the test is ignored and execution moves to the next test.

The offset to be applied to all the blocker levels in the table is also shown by the red bar in the gauge at the bottom of the window. It is possible to adjust the offset by clicking on the gauge. Alternatively, if the cursor is placed over the red bar, then a ‘+’ symbol will appear adjacent to the cursor. It is then possible to hold down the left mouse button and drag the red bar.

Clearing the ‘Specification’ checkbox also permits the blocker frequencies to be adjusted. The start, step and stop frequencies within the table can now be adjusted using the associated spin box. The segments within the table are always held in order of increasing frequency. The minimum start frequency is 24 MHz for the first segment or 1 MHz above the stop frequency of the previous segment. The maximum stop frequency is 6 GHz for the last segment or 1 MHz below the start frequency of the subsequent segment. Step sizes can be varied from 1 MHz to 1 GHz. The resolution of all blocker frequency parameters is 1 MHz.

It is also possible to remove or add blocker frequency segments. To do so, highlight a frequency segment by clicking on the segment number in the first column. If the right mouse button is held down, then a pop-up menu will appear with the following options:

1. *Delete*. The highlighted row will be deleted.
2. *Insert above*. A new frequency segment will be inserted above the highlighted segment. This option will only be displayed if the start frequency of the highlighted segment is at least 2MHz greater than the stop frequency of the previous segment.
3. *Insert below*. A new frequency segment will be inserted below the highlighted segment. This option will only be displayed if the stop frequency of the highlighted segment is at least 2MHz less than the start frequency of the subsequent segment.

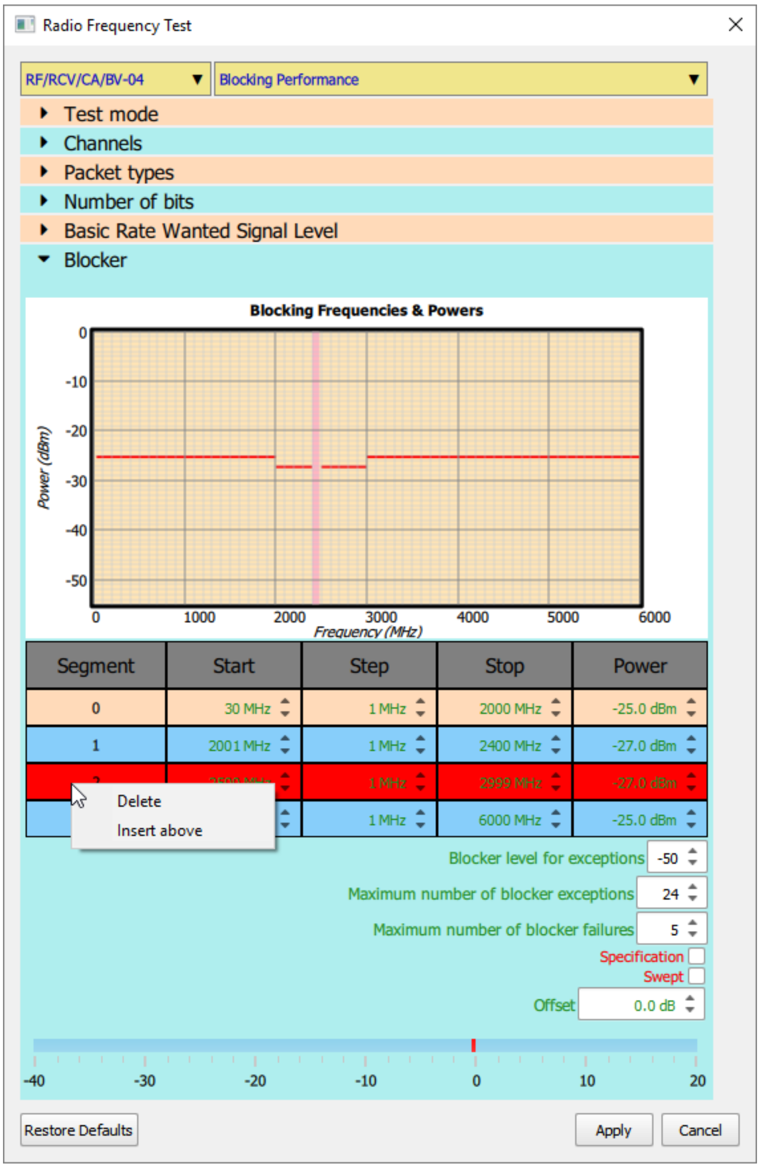


Figure 59: Removing or adding blocker frequencies and levels.

If it is desired to perform the blocker receiver tests over a range of blocker signal levels, then the ‘Swept’ checkbox must be ticked. *It is only possible to sweep the blocker signal level if the wanted signal is not being swept.*

The sweep of blocker levels is accomplished by applying a swept offset to all the values in the blocker table. It is not possible to specify individual sweeps for each frequency segment of the table. If this facility is required, then multiple blocker tests should be placed in the test script, each test configured to execute one frequency segment.

The offset level sweep is defined by the numbers displayed in the three spin boxes:

1. *Minimum Offset*. This indicates the offset at which the sweep will start. The sweep will always be from minimum blocker level to maximum blocker level. The minimum offset cannot be below -40 dB and must be less than or equal to the maximum offset. The resolution of the offset is 0.1 dB.
2. *Offset Step*. This is the step size that the sweep will take from the minimum blocker level to the maximum blocker level. The step size cannot be less than 0.5 dB. The resolution of the step size is 0.1 dB.
3. *Maximum Offset*. This indicates where the blocker sweep should terminate. The last blocker level to be tested will be less than or equal to the signal level defined by this offset. The maximum offset cannot be above +20 dB and must be greater than or equal to the minimum offset. The resolution of the minimum offset is 0.1 dB.

The red bar in the signal level gauge indicates the range selected by the maximum and minimum offsets. This entire range may not be explored during the sweep since the actual values tested are dependent on the selection of the step size.

If the cursor is placed over one of the limits of the red bar, then it will change to a double headed cursor. It is then possible to hold down the left mouse button and drag the edge of the red bar to adjust either the minimum or maximum offset.

If the cursor is placed over the body of the red bar, then a ‘+’ will appear adjacent to the cursor. It is then possible to hold down the left mouse button and drag the entire sweep range up or down the gauge.

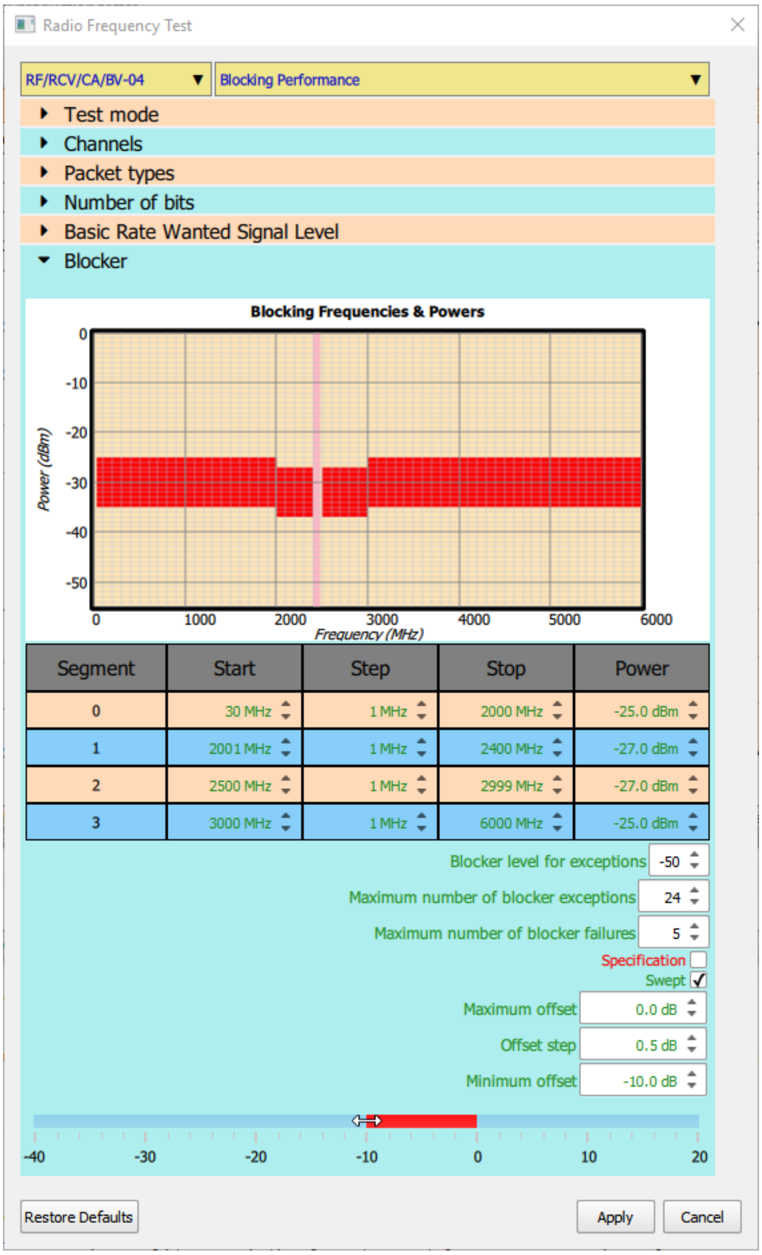


Figure 60: Selecting a range of blocker frequencies and levels.

9.6.14 Configuring receiver intermodulation tests

To configure the parameters to be used in the receiver intermodulation tests, expand the 'Intermodulation Spacings and Levels' menu.

At the top of the window is a graphical display of the interferer levels and frequencies which have been selected. This has been provided so that the plausibility of the selected parameters can be seen at a glance. The graph is constructed as follows:

1. Wide bars are used to indicate continuously modulated interferer signals
2. Narrow bars are used to indicate CW interferers
3. The bars are colour coded as:
    a. Green: interferer spacing $N = 3$
    b. Blue: interferer spacing $N = 4$
    c. Red: interferer spacing $N = 5$
4. The interferer frequencies are shown below the wanted signal. The test will be performed for the interferer frequencies both below and above the wanted signal.

Below the graphical display are a series of checkboxes to select the frequency offsets of the interfering signals. The frequencies of the interfering signals are related by:

$$F_{wanted} = 2\,F_{cw} - F_{modulated}$$

and:

$$|\,F_{modulated} - F_{CW}| = N$$

where: F_{wanted} is the frequency of the wanted signal

$F_{modulated}$ is the frequency of the continuously modulated interfering signal

F_{CW} is the frequency of the CW interfering signal

N is the parameter selected by the checkboxes

The Bluetooth Radio Frequency Test Specification does not provide a default value for the parameter N. *Zircon* adopts the default value of 3.

The interferer signal levels are displayed in a spin box and a signal gauge at the bottom of the window. The CW interferer and the continuously modulated interferer are always constrained to have the same signal level.

Below the checkboxes which select the parameter N is a ‘Specification’ checkbox. If this check box is ticked, then the interferer signal levels are those defined in the Bluetooth Radio Frequency Test Specification.

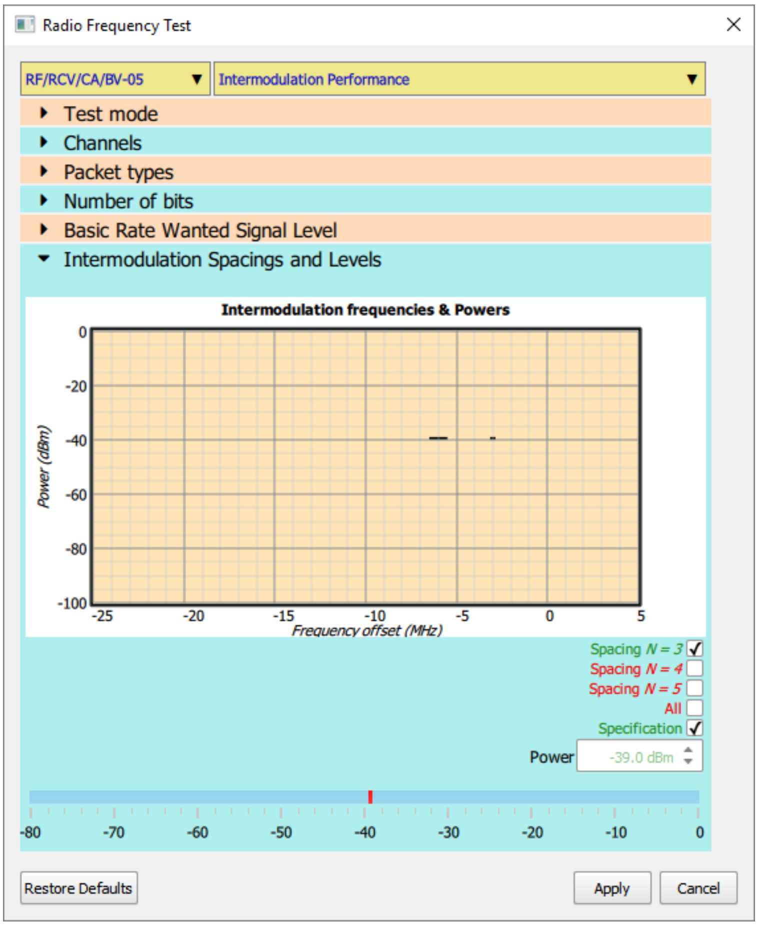


Figure 61: Configuring the intermodulation test.

If the ‘Specification’ checkbox is cleared, then the interferer signal levels can be entered into the spin box, either by using the up/down arrows or by entering a numeric value directly into the text field. If the cursor is placed directly over the red bar in the signal level gauge, then a ‘+’ will appear adjacent to the cursor. By holding down the left mouse button it is then possible to drag the red bar to set the interferer signal levels. Interferer signal levels must be in the range -80 dBm to 0 dBm. The resolution of the interferer signal levels is 0.1 dBm.

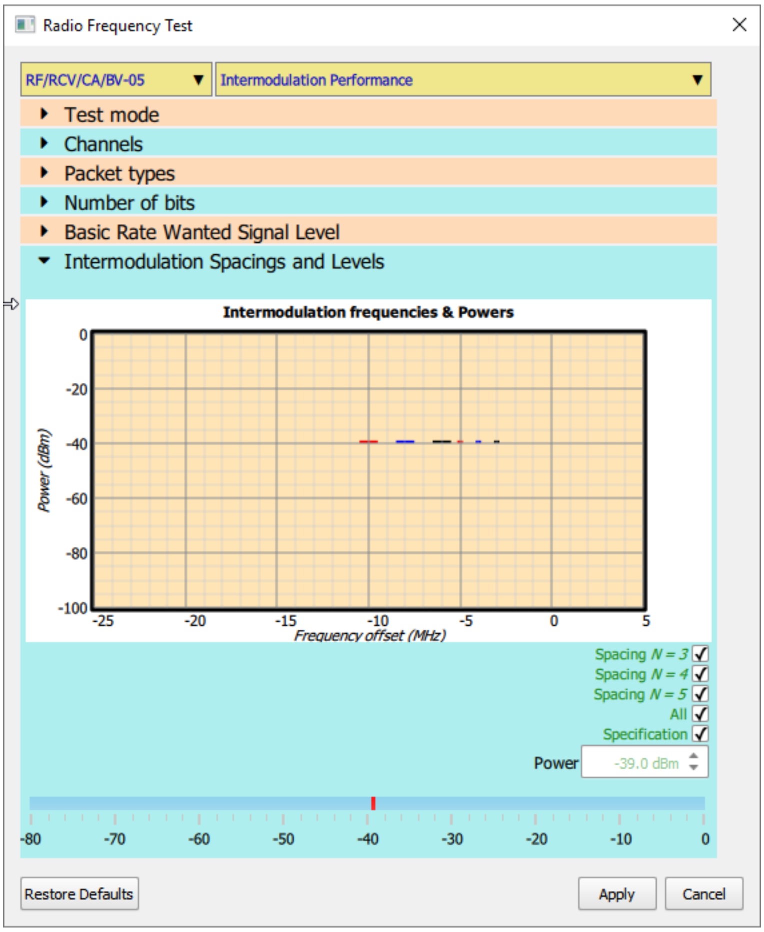


Figure 62: Selecting interferer signal levels.

If it is desired to sweep the interferer signal levels over a range of values then tick the 'Swept' checkbox. *If wanted signal has been programmed to have swept levels, then it is not possible to sweep the interferer signal levels.*

The interferer signal level power sweep is defined by the numbers displayed in the three spin boxes:

1. *Minimum Power*. This indicates the power level at which the sweep will start. The sweep will always be from the minimum interferer signal power towards the maximum interferer signal power. The minimum power cannot be below -80 dBm and must be less than or equal to the maximum power. The resolution of the minimum power is 0.1 dBm.
2. *Power Step*. This is the step size that the sweep will take from the minimum power towards the maximum power. The step size cannot be less than 0.5 dB. The resolution of the step size is 0.1 dB.
3. *Maximum Power*. This indicates where the power sweep should terminate. The last interferer signal power to be test will be less than or equal to the maximum power. The maximum power cannot be above 0dBm and must be greater than or equal to the minimum power. The resolution of the maximum power is 0.1 dBm.

The red bar in the signal level gauge indicates the range selected by the maximum and minimum powers. This entire range may not be explored during the sweep since the actual values tested are dependent on the selection of the step size.

If the cursor is placed over one of the limits of the red bar, then it will change to a double headed cursor. It is then possible to hold down the left mouse button and drag the edge of the red bar to adjust either the minimum or maximum power.

If the cursor is placed over the body of the red bar, then a '+' will appear adjacent to the cursor. It is then possible to hold down the left mouse button and drag the entire sweep range up or down the gauge.

9.6.15 Textual input of test parameters

Many of the menus for configuring the test parameters permit the input of text strings to define ranges of parameter values. These textual descriptions must be of the form:

a_{start}:a_{step}: a_{stop}, b_{start}: b_{step}: b_{stop}, …

This implies that all values from a_{start} to a_{stop} in steps of a_{step} will be selected, plus all values from b_{start} to b_{stop} in steps of b_{step}, etc.

If a_{step} is unity, then a_{start}:a_{step}: a_{stop} can be abbreviated toa_{start}: a_{stop}.

If a_{step} is equal to a_{stop} then a_{start}:a_{step}: a_{stop} can be abbreviated toa_{start}.

9.7 Test duplication

When a transmitter test is run, results for other transmitter tests may also be returned. This is possible because multiple measurements can be made on the same packet simultaneously. For example, if output power is being measured, then initial carrier frequency tolerance can be measured at the same time. However, the additional measurements may not always be performed in exact accordance with the specification. For example, the Bluetooth Radio Frequency Test Specification states that output power can be measured with hopping either on or off, whilst initial carrier frequency tolerance should be measured with hopping on.

By careful selection of the test mode and packet types, results for multiples tests can be accumulated from a smaller number of tests. This can lead to a substantial saving in the overall test time. The table below shows the results which are returned when a single test is executed using the default parameters for test mode and packet type.

If it is desired that the additional tests are not performed, then tick the 'Only perform specified tests' checkbox under the 'Run mode' menu of the 'Configuration' tab. See Section 9.4.

	Test results measured															
Test executed	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16
RF/TRM/CA/BV-01	✓							✓								
RF/TRM/CA/BV-02		✓														
RF/TRM/CA/BV-03			✓													
RF/TRM/CA/BV-04				✓												
RF/TRM/CA/BV-05					✓											
RF/TRM/CA/BV-06						✓										
RF/TRM/CA/BV-07	✓						✓	✓	✓							
RF/TRM/CA/BV-08	✓							✓								
RF/TRM/CA/BV-09	✓							✓	✓							
RF/TRM/CA/BV-10	✓									✓	✓				✓	
RF/TRM/CA/BV-11	✓									✓	✓				✓	
RF/TRM/CA/BV-12												✓				
RF/TRM/CA/BV-13													✓			
RF/TRM/CA/BV-14														✓		
RF/TRM/CA/BV-15	✓									✓	✓				✓	
RF/TRM/CA/BV-16																✓

Table 9: Test duplication with default parameter settings

9.8 Test script window

The test script is displayed at the bottom of the window underneath the graphics area. Each row in the table represents one test in the test script. The columns in the table contain:

1. Column 1 contains the test script number as defined in the Bluetooth Radio Frequency Test Specification
2. Column 2 contains the test script title, providing a textual description of the test
3. Column 3 indicates whether the packets to be used for the test are basic rate, 2-EDR or 3-EDR
4. Column 4 indicates the test status:
   a. '?' indicates that the test has not been run and no results are available
   b. ' ▸ ' indicates that the test is currently being run
   c. '✓' indicates that the test has been run and the test limits have been passed
   d. '✗' indicates that the test has been run and at least one test limit has failed

When a test is running, it is highlighted in the test script window.

By clicking on a test number, the test entry will be expanded to show the parameters defining the test.

Tests can be added to the test script by clicking on the 'click to add test' text at the bottom of the test script. To edit a test, double click the entry in the test script. To delete a test, double click on the entry and then select 'Discard' in the test definition pop-up window.

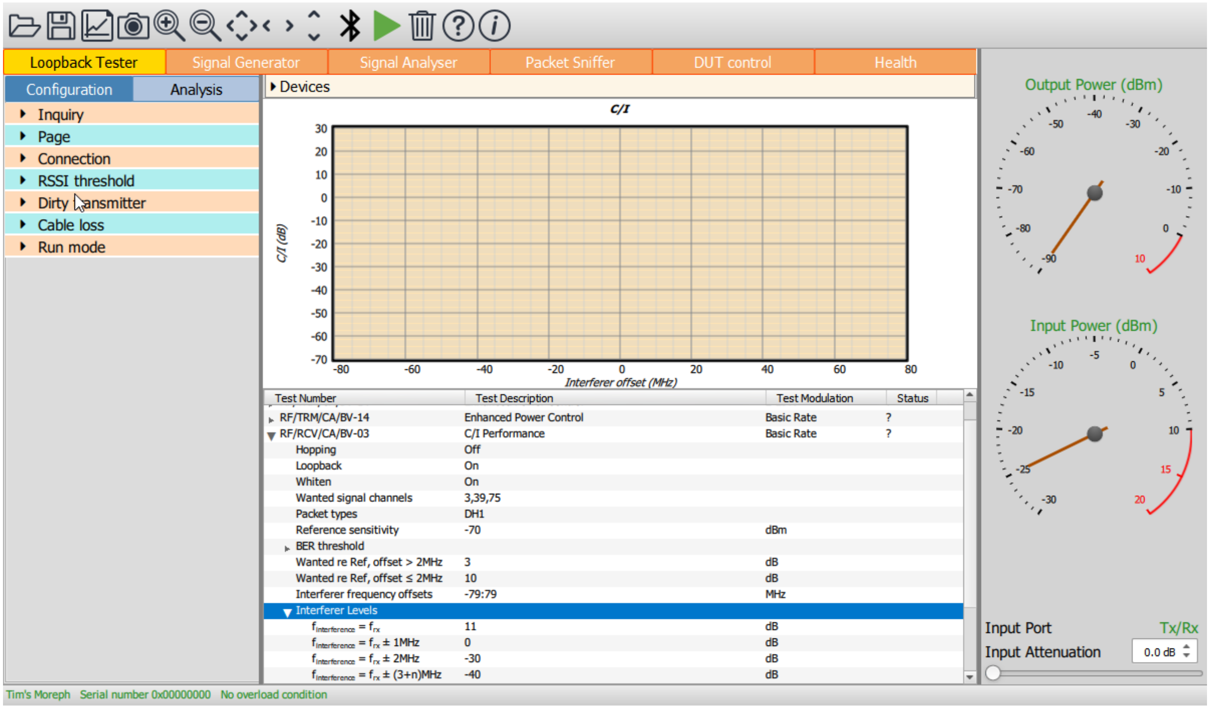


Figure 63: The test script window.

9.9 Saving and recalling test scripts

The current test script can be saved by clicking the 'Save' button in the toolbar. The test script can be saved in two formats:

1. Test script file (*.tsf). This is an XML file containing the test script. These files can be read back into the *Zircon* GUI. Test script files should never be edited manually. To edit a test script file, read it back into the *Zircon* GUI, edit it and then save it again. This format also contains all the settings contained in the 'Configuration' and 'Analysis' tabs.
2. Text file (*.txt). This an ASCII text file representation of the test script. The format of this file is that used by the native programming language.

To recall a test script, click the 'Open' button in the toolbar and *Zircon* filter by test script files (*.tsf).

9.10 Running a test script

In order to run a test script, the following steps must be taken:

1. The DUT must be physically connected to the *TLF3000* unit by an RF cable connected to the Tx/Rx port.
2. *Zircon* must be informed of the DUTs Bluetooth address. This may either be done by issuing an inquiry or by entering the address directly into the device status window. See Section 12. The device must also be selected by checking the 'Page' box in the device status window.
3. The cable loss between the *TLF3000* unit and the DUT must be entered in the 'Cable loss' menu under the 'Configuration' tab. If a test script is loaded from a test script file, then these parameters will be read in from the file.

4. The termination criteria must be set in the ‘Run mode’ menu under the ‘Configuration’ tab. If a test script is loaded from a test script file, then these parameters will be read in from the file.
5. A test script must either be entered manually (see Section 9.5) or loaded from a file using the ‘Open’ button in the toolbar.

Once these steps have been taken, the test script can be executed by pressing the ‘Run’ button in the toolbar.

While the test script is executing the GUI will display the following:

1. The test currently being run will be highlighted in the test script panel
2. The status of the test being run will change from ‘?’ to ‘ ⏵ ’
3. The graphics window will plot one of the quantities being tested

After each test in the test script terminates, its displayed status will change to either:

1. ‘✓’ to indicate that all test limits associated with the test passed
2. ‘×’ to indicate that one or more the test limits associated with the test failed

When the test script terminates execution the ‘Stop’ button in the toolbar will revert to the ‘Run’ button. If appropriate, an error message will be displayed in the status indicating why the test script terminated.

If the test script terminates due to a test limit failure, then the graphics window will plot the quantity which failed.

9.11 Viewing the results

9.11.1 Overview

Once a test script has be run, the results can be viewed using the controls under the ‘Analysis’ tab.

The results which are plotted in the graphics area can be filtered by:

1. Packet type
2. RF channel

9.11.2 Filtering by packet type

To filter the displayed results by packet type, expand the 'Packet type filter' menu under the 'Analysis' tab. The required packet types can be selected by:

1. Ticking the individual packet type checkboxes
2. Using the toggle buttons at the bottom left of the window:
    a. *Clear all*. All packet types will be deselected.
    b. *Select all*. All packet types will be selected.
    c. *Single packet type mode*. When checked, only a single packet type can be selected. Selecting a new packet type will automatically deselect the previously selected packet type.

If the quantity to be displayed is to be plotted against packet type, the packet type filter settings are ignored.

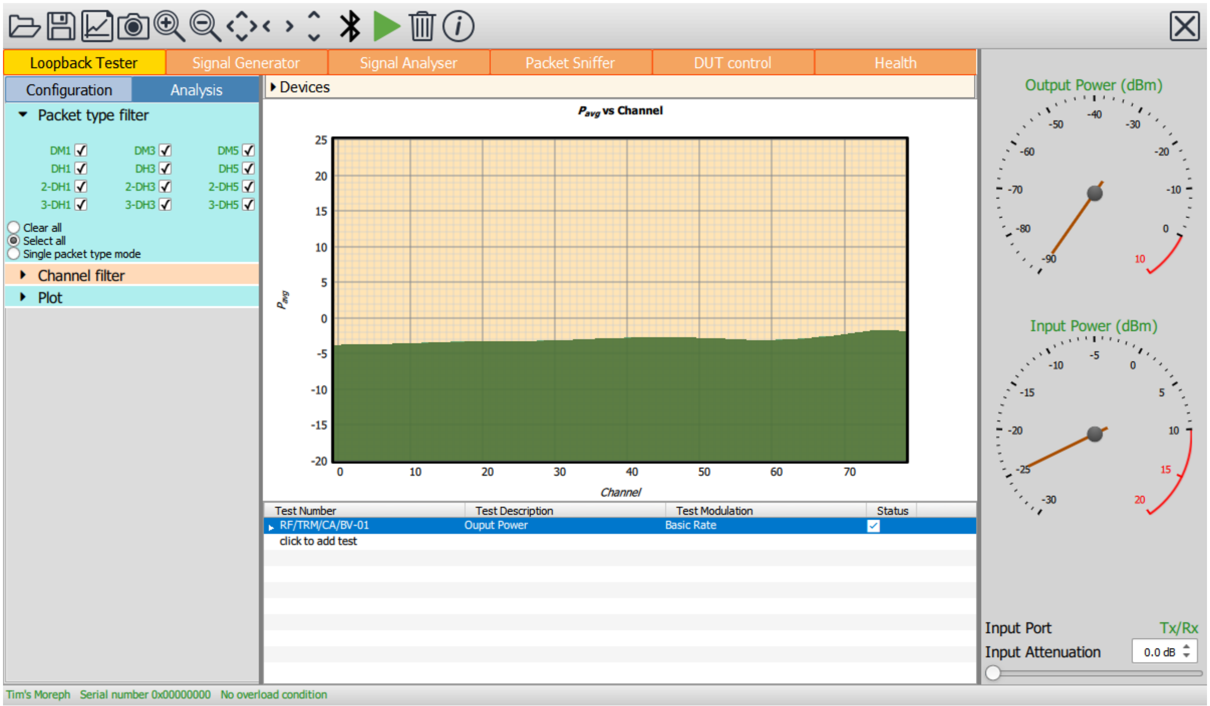


Figure 64: Filtering by packet type.

9.11.3 Filtering by RF channel number

To filter the displayed results by RF channel, expand the 'Channel filter' menu under the 'Analysis' tab. The required RF channels can be selected by:

1. Ticking the individual channel checkboxes
2. Using the toggle buttons at the bottom left of the window:
    a. *Clear all*. All RF channels will be deselected.
    b. *Select all*. All RF channels will be selected.
    c. *Specification channels*. The RF channels defined for the test in Bluetooth Radio Frequency Test Specification will be selected.
    d. *Single channel mode*. When checked, only a single RF channel can be selected. Selecting a new RF channel will automatically deselect the previously selected RF channel.
3. Entering a text string in the text field at the bottom of the window. The required format of the text string is described in Section 9.5.15.

If the quantity to be displayed is to be plotted against RF channel, the RF channel filter settings are ignored.

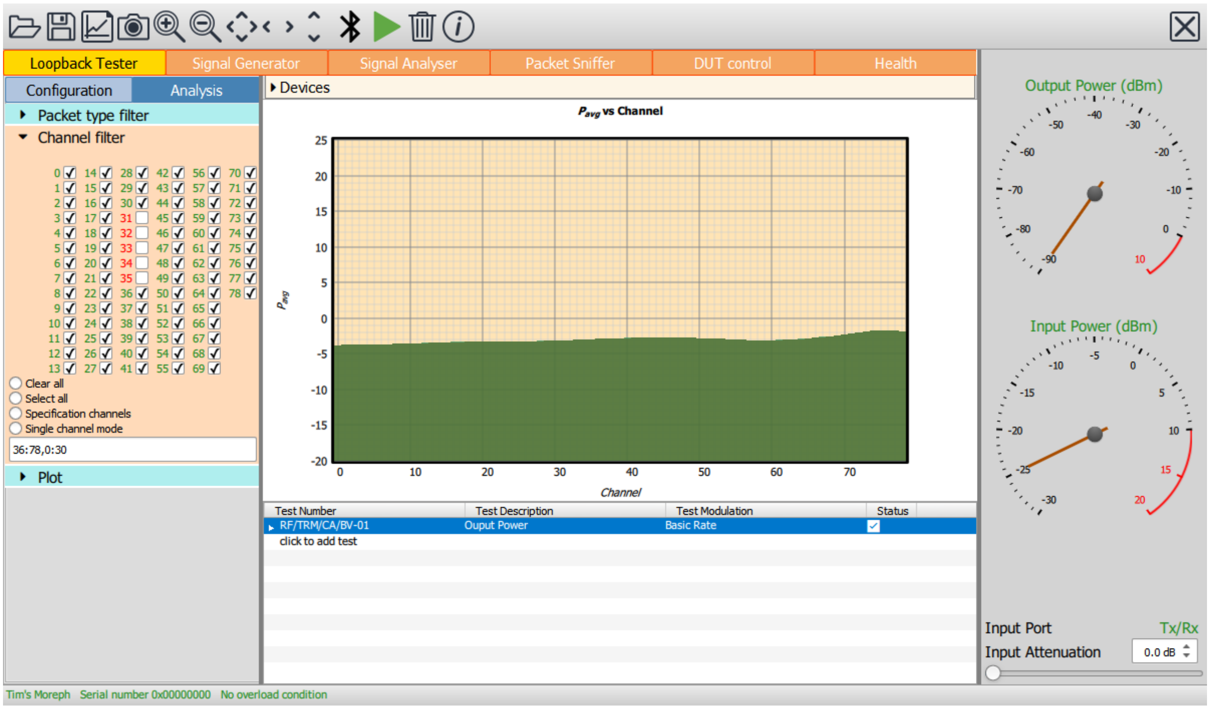


Figure 65: Filtering by RF channel.

9.11.4 Selecting the quantity to be plotted

To select which test results are to be plotted, highlight the associated test in the test script window by clicking it.

To change the contents of the graphics area, expand the ‘Plot’ menu under the ‘Analysis’ tab. The left-hand combo box determines the quantity to be plotted on the y-axis and the right-hand combo box the quantity to be plotted on the x-axis.

9.11.4.1 Transmitter tests

For transmitter tests, the quantity plotted on the y-axis can be anyone of the quantities against which a test limit is applied in the Bluetooth Radio Frequency Test Specification:

Quantity	BR	EDR	Test number	Description
P_{avg}	✓		RF/TRM/CA/BV-01	Average power
$P_{density}$	✓		RF/TRM/CA/BV-02	Power density
ΔP	✓		RF/TRM/CA/BV-03	Power control step
P_{min}	✓		RF/TRM/CA/BV-03	Minimum output power
F_L	✓		RF/TRM/CA/BV-04	Frequency range lower extent
F_H	✓		RF/TRM/CA/BV-04	Frequency range upper extent
ΔF	✓		RF/TRM/CA/BV-05	20dB bandwidth
P_{tx} |M–N|=2	✓		RF/TRM/CA/BV-06	Co-adjacent channel power
P_{tx} |M–N|>2	✓		RF/TRM/CA/BV-06	Spurious emissions
Num excep	✓		RF/TRM/CA/BV-06	Number of ACP exceptions
Max excep	✓		RF/TRM/CA/BV-06	Maximum ACP exception
$\Delta F1_{avg}$	✓		RF/TRM/CA/BV-07	Average of *ΔF1* measurements
$\Delta F2_{avg}/\Delta F1_{avg}$	✓		RF/TRM/CA/BV-07	Ratio of *ΔF2* and *ΔF1*
$\Delta F2_{max}$ *99%*	✓		RF/TRM/CA/BV-07	99 percentile for *ΔF2*
$\Delta F2_{max} \geq 115$	✓		RF/TRM/CA/BV-07	% of *ΔF2* measurements ≥115kHz
F_o	✓		RF/TRM/CA/BV-08	Initial carrier frequency
$F_k - F_0$	✓		RF/TRM/CA/BV-09	Carrier drift rate
$F_{k+5} - F_k$	✓		RF/TRM/CA/BV-09	Carrier drift
EDR re GFSK		✓	RF/TRM/CA/BV-10	EDR relative transmit power
RMS DEVM		✓	RF/TRM/CA/BV-11	RMS value of DEVM
Pk DEVM		✓	RF/TRM/CA/BV-11	Peak value of DEVM
DEVM ≤ 30%		✓	RF/TRM/CA/BV-11	% measurements with DEVM ≤ 30% (2-EDR)
DEVM ≤ 20%		✓	RF/TRM/CA/BV-11	% measurements with DEVM ≤ 20% (3-EDR)
DEVM 99%		✓	RF/TRM/CA/BV-11	99 percentile for DEVM
ω_i		✓	RF/TRM/CA/BV-11	Carrier frequency estimated from header
ω_0		✓	RF/TRM/CA/BV-11	Carrier frequency relative to header
$\omega_i + \omega_0$		✓	RF/TRM/CA/BV-11	Carrier frequency estimation
Good pkts rx		✓	RF/TRM/CA/BV-12	Percentage of good packets received
$P_{tx} - P_{txref}$		✓	RF/TRM/CA/BV-13	Adjacent channel power
P_{tx} |M–N|=2		✓	RF/TRM/CA/BV-13	Co-adjacent channel power
P_{tx} |M–N|>2		✓	RF/TRM/CA/BV-13	Spurious emissions
Num excep		✓	RF/TRM/CA/BV-13	Number of ACP exceptions
Max excep		✓	RF/TRM/CA/BV-13	Maximum ACP exception
ΔP	✓	✓	RF/TRM/CA/BV-14	Power control step
ΔP_{GFSK}	✓	✓	RF/TRM/CA/BV-14	GFSK power step
P_{min}	✓	✓	RF/TRM/CA/BV-14	Minimum output power
ΔP_{repeat}	✓	✓	RF/TRM/CA/BV-14	Difference in repeat measurement
Guard		✓	RF/TRM/CA/BV-15	% of measurements within guard limits
Bad sync seq		✓	RF/TRM/CA/BV-16	% of band sync sequences
Trailer BER		✓	RF/TRM/CA/BV-16	Trailer bit error rate

Table 10: Transmitter measurements

The selected quantity may be plotted against:

1. RF channel
2. Packet type

apart from $P_{density}$ which can only be plotted against packet type.

The selected quantity is plotted in the graphics area as a series of green bars.

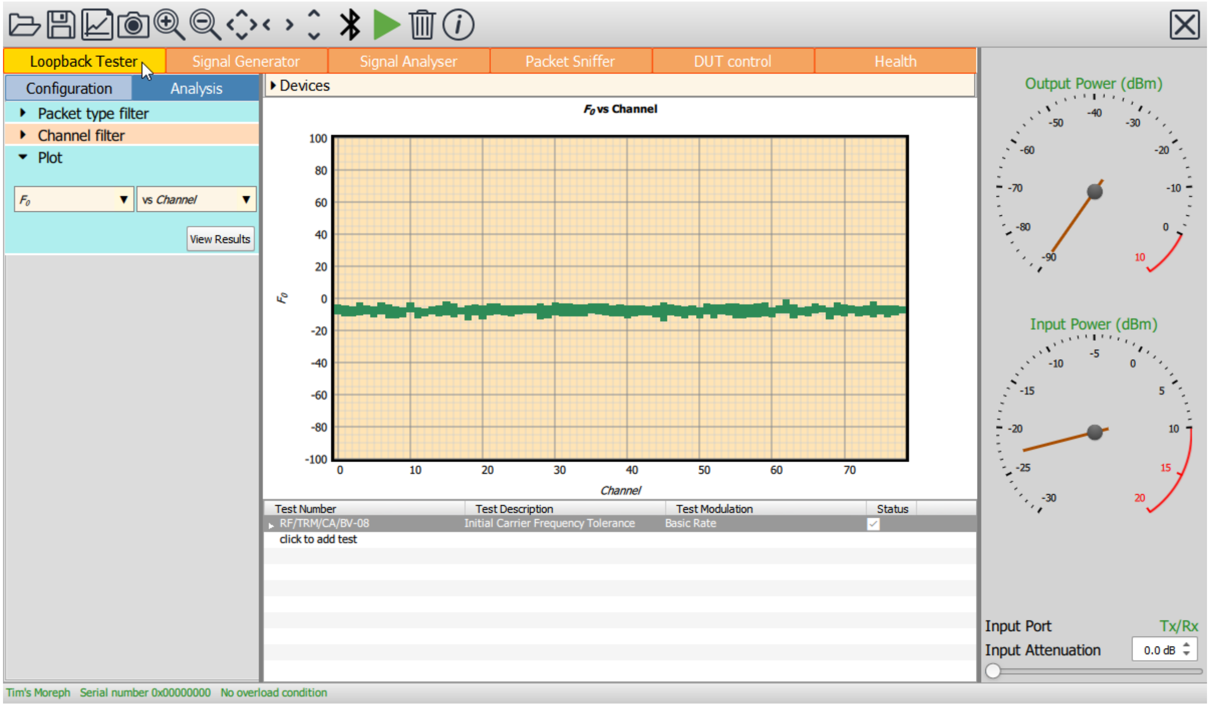


Figure 66: Example display of transmitter test vs channel.

For some tests additional quantities which do not possess test limits may also be plotted. These are provided for diagnostic purposes:

1. Power density:
   a. Power spectral density from 2395MHz to 2485MHz.
2. Tx output spectrum – frequency range
   a. Power spectral density from 2395MHz to 2405MHz
   b. Power spectral density from 2475MHz to 2485MHz
3. Tx output spectrum – 20dB bandwidth
   a. F_L vs channel or packet type
   b. F_H vs channel or packet type
   c. Power spectral density ±1.5MHz from carrier frequency
4. Tx output spectrum – adjacent channel power
   a. 1MHz resolution spectrum used to calculate adjacent channel power

5. Modulation characteristics:
    a. $\Delta F1_{max}$ vs channel or packet type
    b. $\Delta F2_{avg}$ vs channel or packet type
    c. $\Delta F2_{max}$ vs channel or packet type
6. EDR relative transmit power:
    a. P_{GFSK} vs channel or packet type
7. EDR in-band spurious emissions:
    a. 1MHz resolution spectrum used to calculate spurious emission power

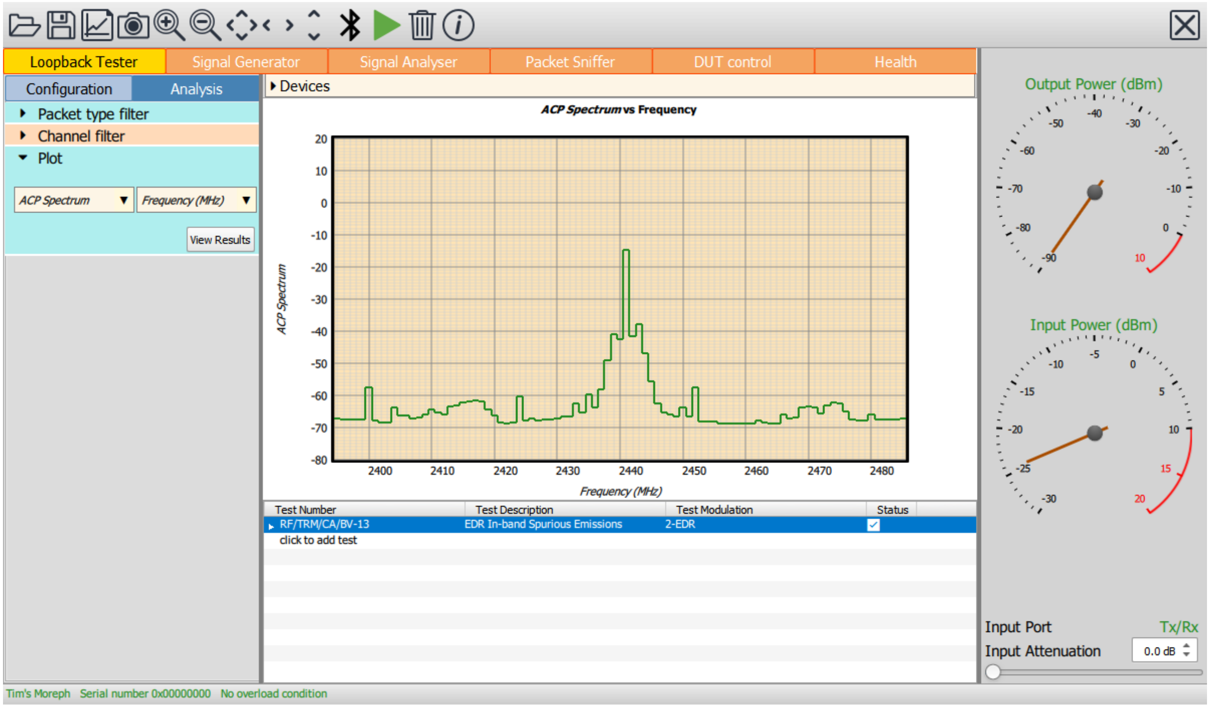


Figure 67: Example of additional data being displayed for EDR in-band spurious emissions test.

9.11.4.2 Receiver sensitivity and maximum input signal tests

The y-axis can be selected to be either:

1. Wanted signal level
2. Log_{10}(BER)

If the y-axis is selected to be wanted signal level, then the x-axis can be either:

1. RF channel
2. Packet type

If the y-axis is selected to be Log_{10}(BER) then the x-axis is the wanted signal level and a classical BER curve is displayed.

The results are plotted as a series of diamonds which are colour coded red for fail and green for pass.

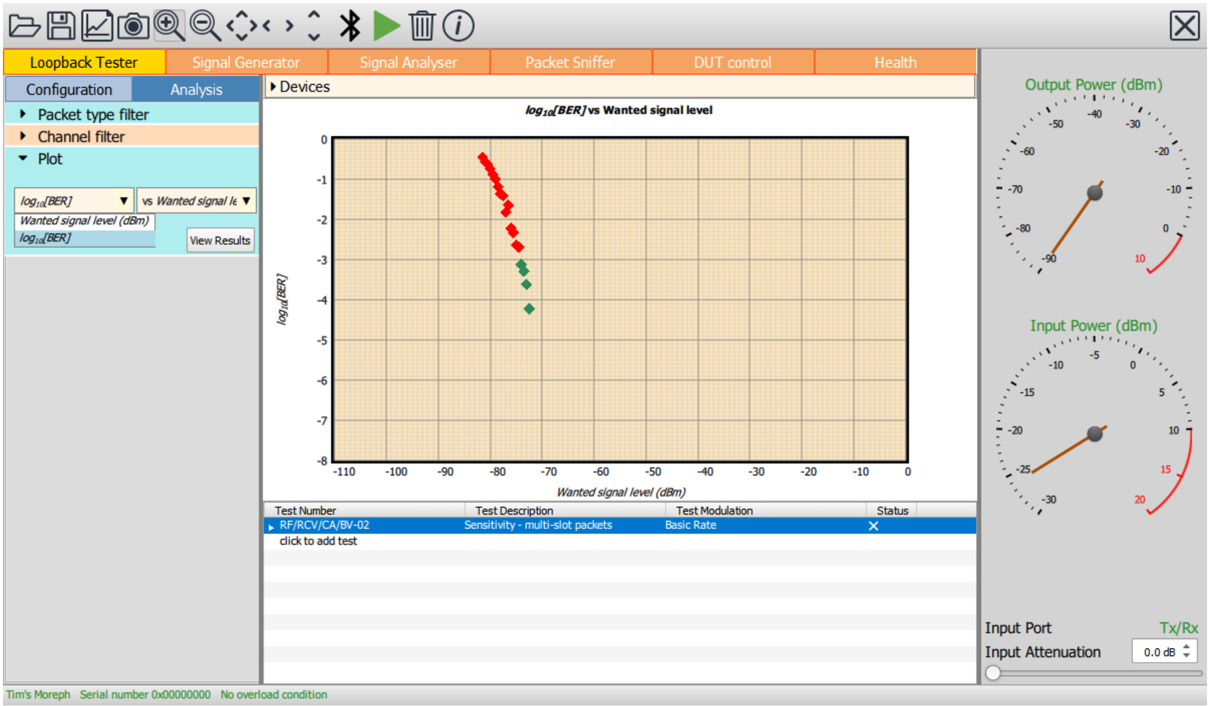


Figure 68: Receiver sensitivity test showing Log_{10}(BER) vs signal level

9.11.4.3 Receiver C/I tests

For receiver C/I tests, the y-axis may be selected to be one of the following:

1. C/I level
2. Wanted signal level
3. Interferer signal level
4. Number of exceptions

When the y-axis is C/I level, wanted signal level or interferer signal level, the x-axis is always the offset of the interferer from the wanted signal.

When the y-axis is number of exceptions, the x-axis may be:

1. RF channel
2. Packet type

Results are plotted as diamonds which are colour coded red for failure and green for pass.

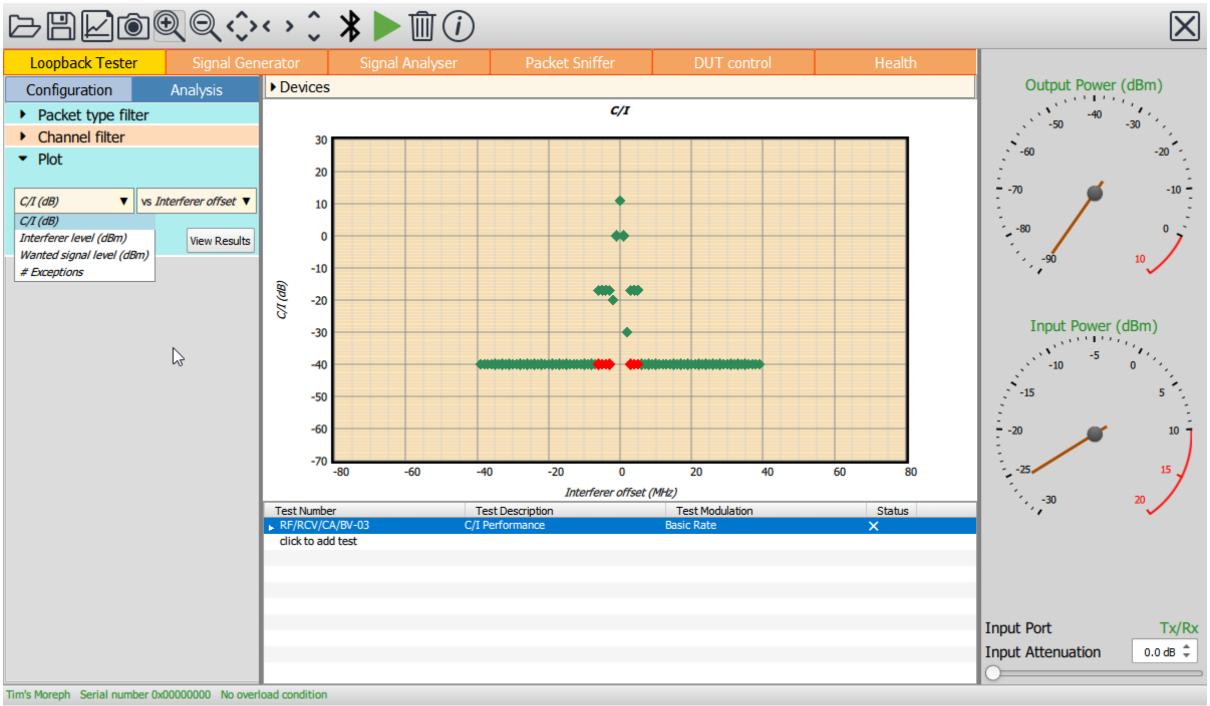


Figure 69: Receiver C/I tests.

9.11.5 Receiver blocking tests

For receiver blocking tests, the x-axis is always the blocker frequency. The y-axis may be selected to be one of the following:

1. Blocker level
2. Wanted signal level

Results are plotted as diamonds which are colour coded red for failure and green for pass.

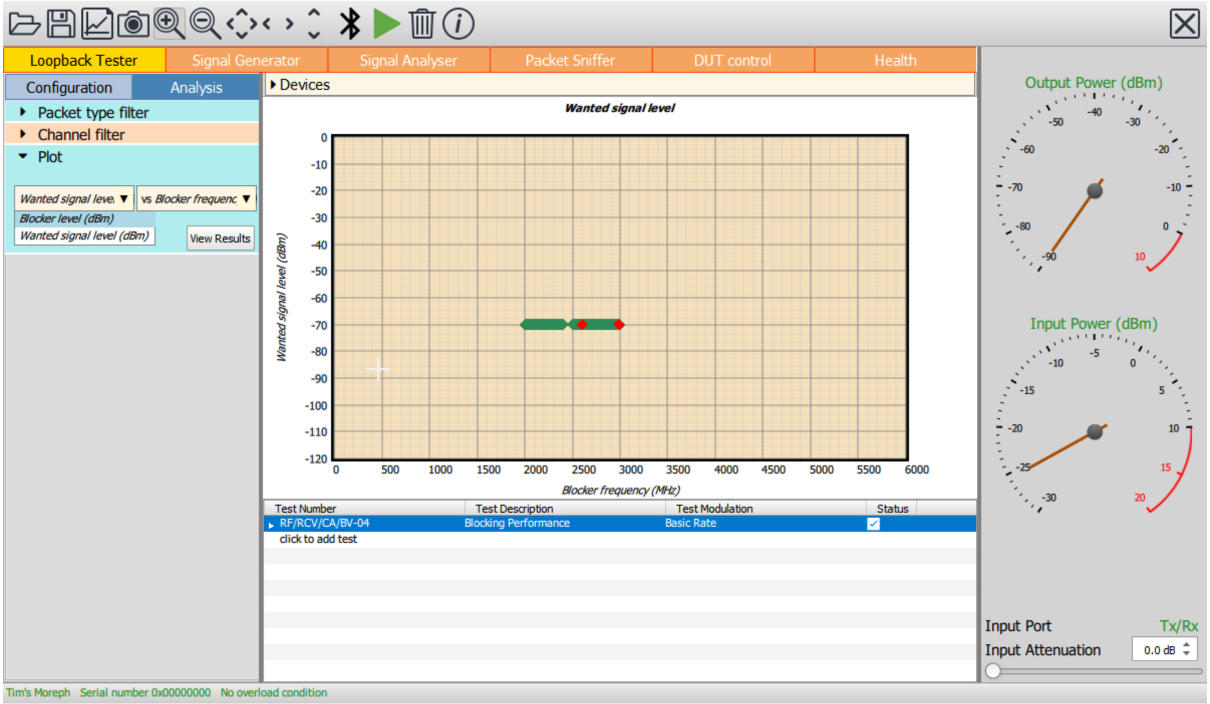


Figure 70: Receiver blocking tests.

9.11.6 Receiver intermodulation tests

The y-axis can be selected to be either:

1. Wanted signal level
2. Interferer signal level
3. $Log_{10}(BER)$

If the y-axis is either wanted signal level or interferer signal level, the x-axis can be either RF channel or packet type.

If the y-axis is selected to be $Log_{10}(BER)$ then a classical BER curve is displayed against either the wanted signal level or the interferer signal level.

Results are plotted as diamonds which are colour coded red for failure and green for pass.

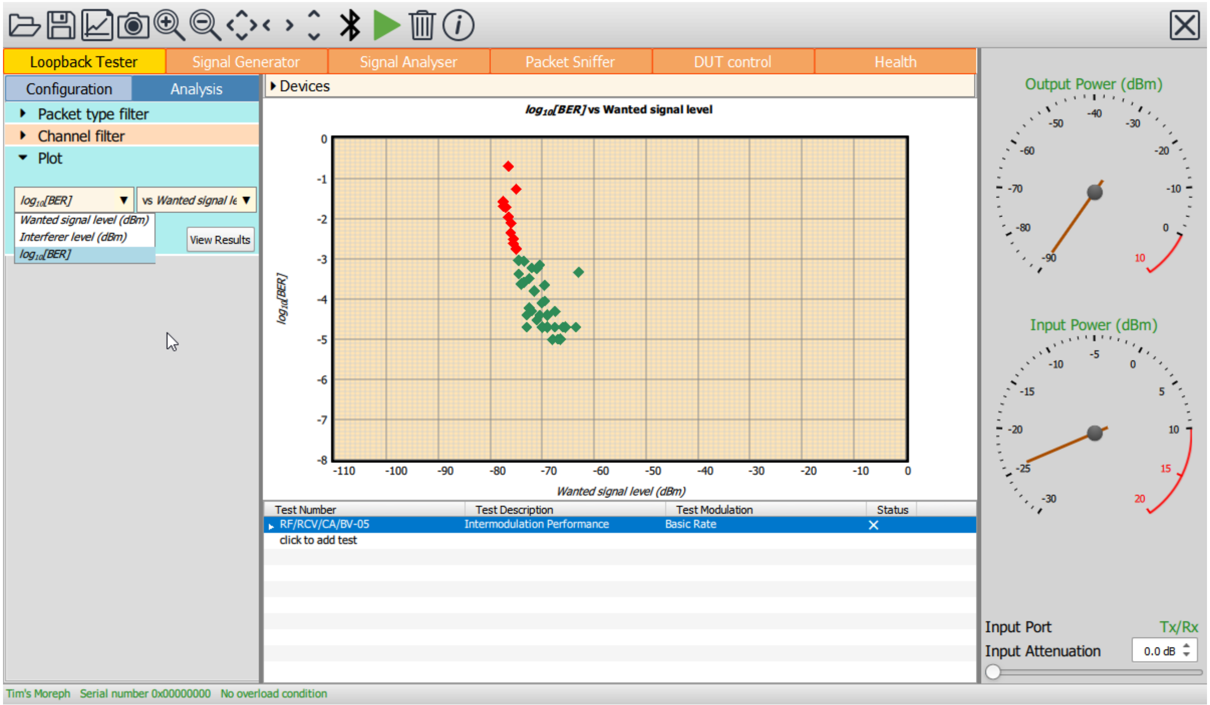


Figure 71: Receiver intermodulation tests.

9.12 Saving results

The test script results can be saved by clicking the 'Save' button on the toolbar. By selecting the appropriate file type, the results can be saved in anyone of the following formats:

1. HTML (*.html)
2. ASCII text file (*.txt)
3. Comma separate variable (*.csv)
4. XML (*.xml)

The current graph can also be saved as an image by clicking the ‘Graph’ button on the toolbar. The range of possible graphics formats includes:

1. Windows bitmap files (*.bmp)
2. Joint photographic expert group files (*.jpg)
3. Portable network graphics files (*.png)
4. Portable bitmap files (*.pbm)
5. Portable graymap files (*.pgm)
6. Portable pixmap files (*.ppm)
7. X11 bitmap files (*.xbm)
8. X11 pixmap files (*.xpm)

9.13 List of supported tests

The Zircon applications supports the following tests defined in the Bluetooth Radio Frequency Test Specification with no additional test equipment:

Test number	Test description	Phy	Limitations
RF/TRM/CA/BV-01-C	Output power	BR	
RF/TRM/CA/BV-02-C	Power density	BR	See (a)
RF/TRM/CA/BV-03-C	Power control	BR	
RF/TRM/CA/BV-04-C	Tx output spectrum – frequency range	BR	
RF/TRM/CA/BV-05-C	Tx output spectrum – 20dB bandwidth	BR	
RF/TRM/CA/BV-06-C	Tx output spectrum – adjacent channel power	BR	
RF/TRM/CA/BV-7-C	Modulation characteristics	BR	
RF/TRM/CA/BV-8-C	Initial carrier frequency tolerance	BR	
RF/TRM/CA/BV-9-C	Carrier frequency drift	BR	
RF/TRM/CA/BV-10-C	EDR relative transmit power	2-EDR/3-EDR	
RF/TRM/CA/BV-11-C	EDR carrier frequency stability & modulation accuracy	2-EDR/3-EDR	
RF/TRM/CA/BV-12-C	EDR differential phase encoding	2-EDR/3-EDR	
RF/TRM/CA/BV-13-C	EDR in0band spurious emissions	2-EDR/3-EDR	
RF/TRM/CA/BV-14-C	Enhanced power control	BR/2-EDR/3-EDR	
RF/TRM/CA/BV-15-C	EDR guard time	2-EDR/3-EDR	
RF/TRM/CA/BV-16-C	EDR synchronization sequence & trailer	2-EDR/3-EDR	
RF/RCV/CA/BV-01-C	Sensitivity – single slot packets	2-EDR/3-EDR	
RF/RCV/CA/BV-02-C	Sensitivity – multi slot packets	BR	
RF/RCV/CA/BV-03-C	C/I performance	BR	
RF/RCV/CA/BV-04-C	*Blocking performance*	*BR*	*See (b)*
RF/RCV/CA/BV-05-C	Intermodulation performance	BR	See (c)
RF/RCV/CA/BV-06-C	Maximum input level	BR	
RF/RCV/CA/BV-07-C	EDR sensitivity	2 Mbps	
RF/RCV/CA/BV-08-C	EDR BER floor performance	2-EDR/3-EDR	
RF/RCV/CA/BV-09-C	EDR C/I performance	2-EDR/3-EDR	
RF/RCV/CA/BV-10-C	EDR maximum input level	2-EDR/3-EDR	

Table 11: Supported tests

Limitations:

a) The initial sweep for the power density is performed over 90MHz and not 240MHz as per the specification. Unless the device under test has severe issues, this should return the correct frequency for the second scan and hence the correct value for the power density.

b) Blocking tests are limited to the range 25 MHz to 6 GHz and to blocking levels of -30dBm or less, although at frequencies below 3GHz output powers of -25dBm should be achievable. This is substantially less coverage than dictated by the specification. Hence additional test equipment will be required to evaluate the blocking performance. The unit contains a high-performance F-BAR filter at its input and possesses an extremely high dynamic range. This ensures that the DUT will always be blocked before the tester. The unit can also provide a gating signal for the blocker.

c) The intermodulation test can be performed provided both the CW and continuous interferers lie within the range 2395MHz to 2485MHz. This can always be arranged by choosing whether they are placed above or below the wanted signal.

9.14 Performing CW measurements

When in phy tester mode, it is possible to measure the frequency and power of a CW signal generated by the DUT. These measurements can be used to trim the crystal frequency of the DUT prior to perform a test run.

To initiate a CW measurement, press the CW measurement icon on the tool bar. The measured CW frequency and power will be displayed in a pop-up window.

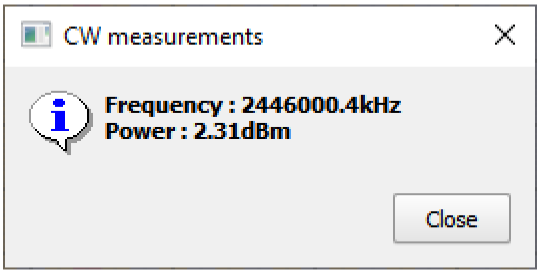


Figure 72: CW measurement window

10 Packet sniffer (Wireshark) mode.

10.1 Overview

The packet sniffer mode monitors all 79 channels simultaneously Any packets which are detected are demodulated and the bit stream either piped directly into Wireshark for live analysis, and/or saved to file in pcap-ng format. An RSSI threshold can be set to help filter out weak packets from distant devices. During capture, a spectrum display is available so that the prevailing RF environment can be monitored.

The packet sniffer is included in the *Zircon* configuration to enable one *TLF3000* to be used to debug connection issues between a second *TLF3000* and a DUT. It is not intended to be used as protocol analysis tool. The recovered packets are neither de-whitened nor decrypted.

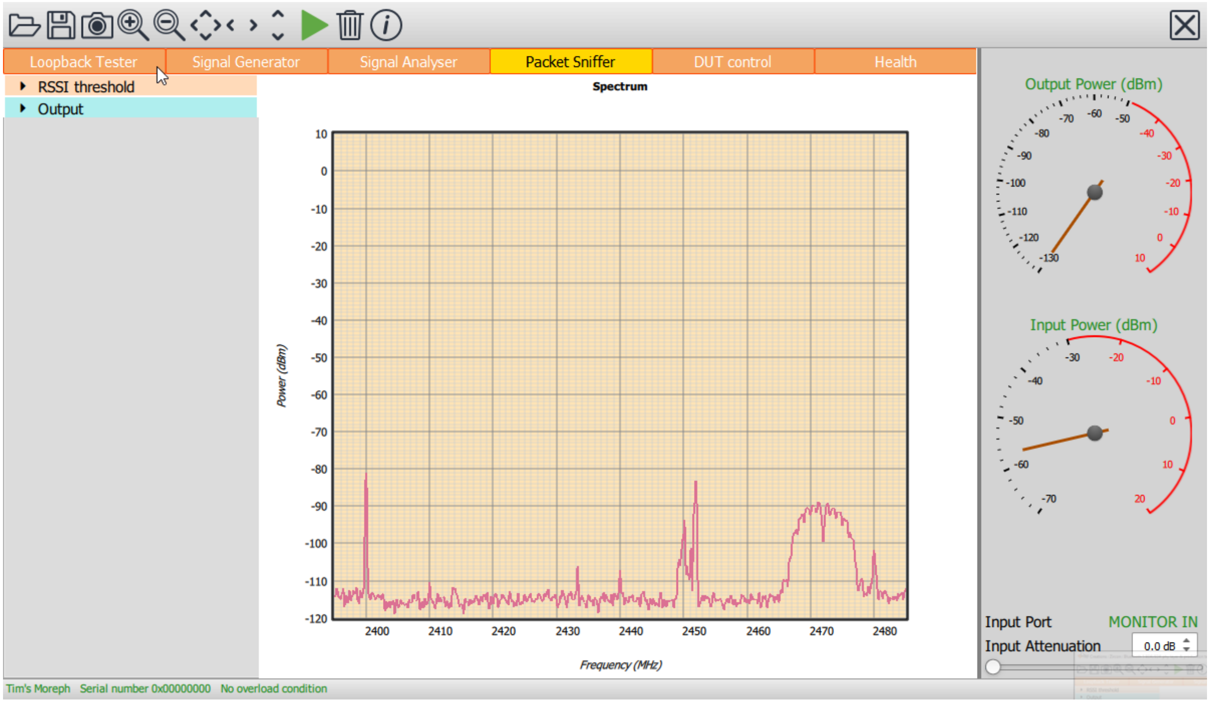


Figure 73: Zircon packet sniffer mode.

10.2 Pre-requisites

Wireshark 2.4.2 or later must be installed on the host computer.

10.3 RF connections

The packet sniffer can monitor signals on either the ‘Tx/Rx’ port or the ‘Monitor In’ port. See Section 8.3.4 on setting the RF input port and Section 8.3.5 on setting the RF frontend attenuator. It is important that the RF frontend attenuator is set correctly to maximize sensitive and prevent RF overload.

10.4 Programming the packet sniffer

10.4.1 Programming the RSSI threshold

The 'RSSI threshold' permits weak signal strength packets to be ignored. This feature is useful when there is prevailing Bluetooth activity in the test area, since it allows the weak packets from distance devices to be ignored and only the strong packets from the nearby devices under test to be collected.

The RSSI threshold for packets to be collected can be set anywhere from -120dBm to +20dBm in steps of 1dBm.

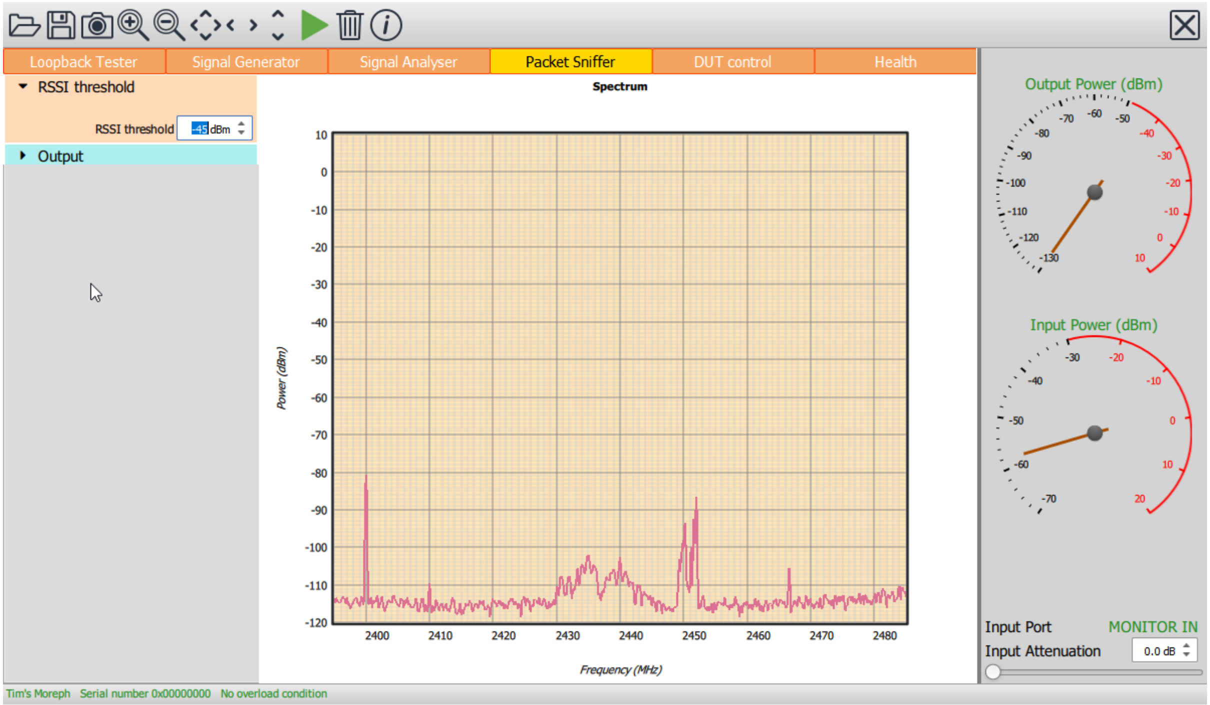


Figure 74: Programming the sniffer RSSI threshold.

10.4.2 Programming the data sink

The 'Output' menu dictates where the demodulated packets are sent.

Two options are available for the packet sink:

1. *Live capture & decode*. The packets will be piped into Wireshark which will perform limited real-time protocol analysis.
2. *Stream packets to file*. The packets will be written to file in pcap-ng format.

One or both of these options may be selected.

If the 'Stream packets to file' option is selected, then the name of the file to receive the data will be displayed. If the user clicks on the output file name, then the file selection box will popup allowing the selection of a different destination.

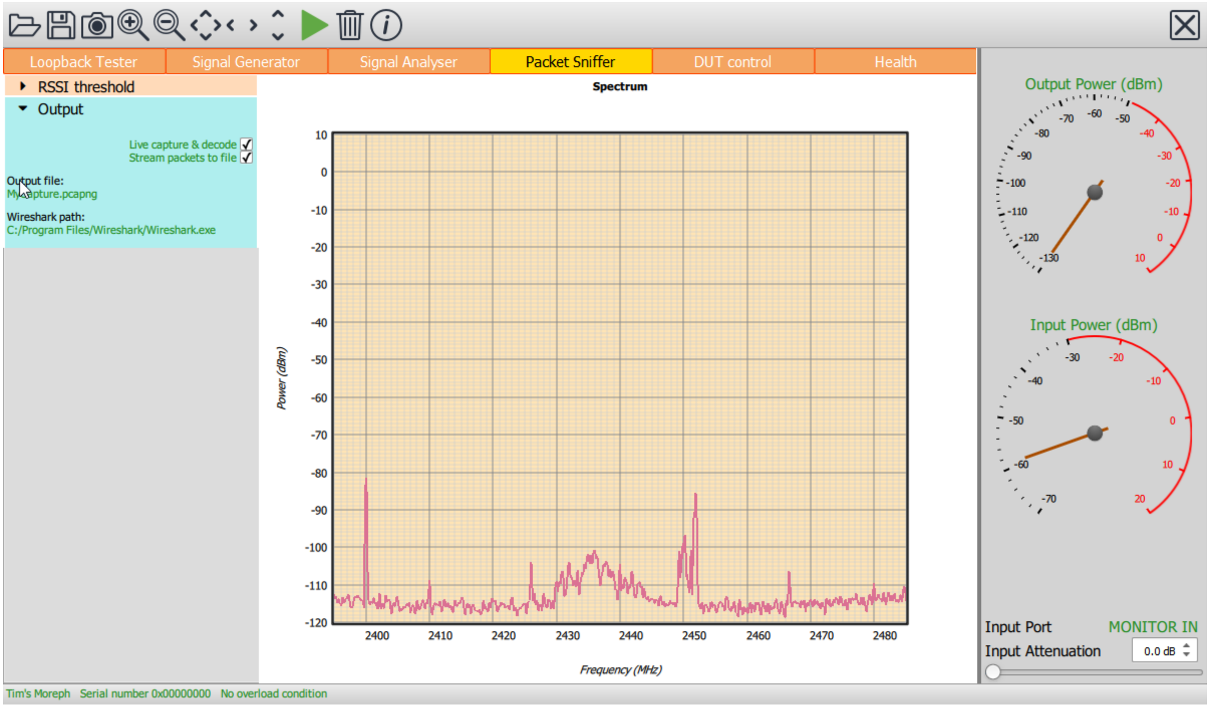


Figure 75: Programming the packet data sink

10.4.3 Programming the Wireshark executable path

By default, the path for the Wireshark executable is C:\Program Files\Wireshark. This is displayed as the last item in the menu. If the user clicks on the displayed path name, then a file selection box will popup allowing the user to select an alternative path.

10.5 Controlling the packet sniffer

10.5.1 Starting the packet sniffer

The packet sniffer is started by clicking the 'Run/Stop' button on the toolbar. If 'Live capture & decode' has been selected in the 'Output' menu, then an attempt will be made to launch Wireshark.

It may take a few seconds to launch Wireshark. If the 'Stream packets to file' option has also been selected in the 'Output' menu, then packets will be streamed to file whilst Wireshark is launching. However, no packets can be streamed to Wireshark until it has successfully launched. As a consequence, the capture file may contain more packets than displayed in Wireshark

10.5.2 Controlling sniffing from the Zircon GUI

Sniffing can be controlled using the 'Run/Stop' button in the *Zircon* GUI toolbar.

If capture is halted from the *Zircon* GUI, then:

1. If packets are being streamed to Wireshark, then this streaming will stop. However, Wireshark will remain active and the pipe between *Zircon* and Wireshark will remain open. Wireshark is unaware that the capture has been paused and continues to wait for further packets.
2. If packets are being written to file, then the file will be closed.

If capture is restarted from the *Zircon* GUI then:

1. If Wireshark is already open, and the 'Live capture & decode' option is currently selected, the packets will be streamed to Wireshark. Provided Wireshark is still in the run state, it will receive and process the packets as if part of the previous capture. If on restarting the capture from the *Zircon* GUI Wireshark is in the stopped state, then a window will popup requesting the user to restart Wireshark capture using the 'Start' option under the Wireshark 'Capture' menu.
2. If the 'Stream packets to file' option is currently selected, then an attempt will be made to open the specified output file. If the file exists, the user will be prompted as to whether the contents of the file should be overridden, or whether a new section should be appended to the existing file. Once the file has been opened, packets will be streamed into it.

10.5.3 Controlling sniffing from Wireshark

Once Wireshark has been launched, packet capture can be controlled directly from Wireshark. Under the Wireshark capture menu, the following options will function:

1. Start
2. Stop
3. Restart

10.6 Output file format

When streaming decoded packets to file, they are saved in pcap-ng format. The data are stored in the LINKTYPE_BLUETOOTH_BREDR_BB format. The timestamp resolution in the interface header blocks is set to 100ns.

If capture is stopped and then restarted, the user is given the option of either overriding the existing file or appending a new section to the end of the file.

10.7 Known issues

The modulation associated with each packet (basic rate, 2-EDR, 3-EDR) may not always be correct. It is difficult for the demodulator to accurately discriminate between 2-EDR and 3-EDR under all circumstances. Furthermore, packets with no payload may be classified as 2-EDR or 3-EDR, even though they have only a GFSK portion.

ID packets may have their timestamp offset by 58µs. This is a known bug which does not impact on the sniffer's ability to debug connection issues between another *TLF3000* and a DUT.

10.8 Graphical display

Whilst packet capture is in progress, the graphics area shows a spectrum of the 2.4GHz ISM band. The spectrum has 100kHz resolution and uses a peak detector. The spectrum display provides the user with a visual indication of the prevailing RF conditions. This can be important in understanding why some packets may not have been captured.

10.9 Saving and restoring settings

The settings can be saved by clicking the 'Save' button on the toolbar. Select the 'Wireshark settings (*.wss)' file type to save the current settings.

An existing packet sniffer settings file (*.wss) can be opened using the 'Open' button on the toolbar.

The packet sniffer settings file (*.aas) is an XML file. It is not recommended that this file be edited manually. If it needs to be modified, open it from the packet sniffer mode, modify the required parameters and re-save.

10.10 Saving current results table and graphics

The current graph can be saved as an image by clicking the '*Graph*' button on the toolbar. The range of possible graphics formats includes:

1. Windows bitmap files (*.bmp)
2. Joint photographic expert group files (*.jpg)
3. Portable network graphics files (*.png)
4. Portable bitmap files (*.pbm)
5. Portable graymap files (*.pgm)
6. Portable pixmap files (*.ppm)
7. X11 bitmap files (*.xbm)
8. X11 pixmap files (*.xpm)

11 DUT Control Mode

11.1 Overview

The DUT control mode permits the user to connect to a DUT over-the-air and the issue the following LMP commands to the DUT:

1. LMP_test_control
2. LMP_incr_power_req (when only legacy power control is supported by the DUT)
3. LMP_decr_power_req (when only legacy power control is supported by the DUT)
4. LMP_power_control_req (when enhanced power control is supported by the DUT)

The LMP messages which are transferred between the *Zircon* configuration and the DUT are displayed as a message chart.

It is also possible to control the power at which the *Zircon* configuration transmits to the DUT, as well as its dirty transmitter parameters.

The purpose of the DUT control mode is to aid in the debugging of connectivity issues between the *Zircon* configuration and the DUT.

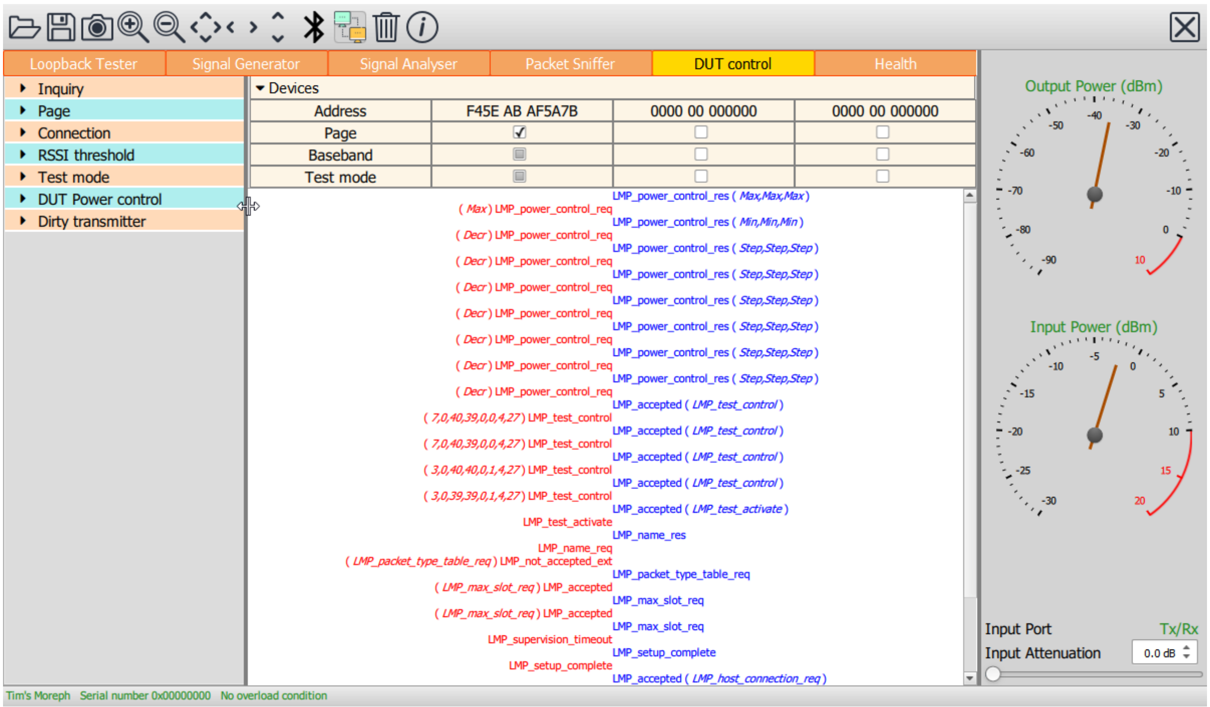


Figure 76: DUT control mode

11.2 RF connections

The DUT control mode transmits on the 'Tx/Rx' port. It can receive signals on either the 'Tx/Rx' port or the 'Monitor In' port. See Section 8.3.4 for settings the RF input port.

11.3 Connecting to and controlling the DUT

Section 12 contains full details of how to connect to a DUT and how to control it.

11.4 LMP message chart

The message chart is divided into two halves. The left-hand half contains LMP messages originating from the *Zircon* configuration in red. The right-hand half contains LMP messages received from the DUT in blue.

When there is no connection between the *Zircon* configuration and the DUT, then **Disconnected** is shown in bold on the left-hand side of the chart.

When a connection is established between the *Zircon* configuration and the DUT, then **Connected** is shown in bold on the left-hand side of the chart.

The majority of LMP messages are only represented by their name and no information on their parameters is displayed. There are a few exceptions to this rule where additional information is contained in parenthesis adjacent to the LMP message name. The exceptions are:

1. LMP_power_control_req messages which may indicate:
    a. Incr: the DUT is instructed to increment its power by one step
    b. Decr: the DUT is instructed to decrement its power by one step
    c. Max: the DIT is instructed to go to maximum output power
2. LMP_power_control_res messages which may include:
    a. Step: to indicate that the DUT changed its power by one step
    b. Max: to indicate that the DUT is at maximum output power
    c. Min: to indicate that the DUT is at minimum output power

    These values will be repeated three times to indicate the state of power control for basic rate packets, 2-EDR packets and 3-EDR packets, respectively.
3. LMP_accepted messages which indicate which LMP command is being accepted.
4. LMP_rejected messages which indicate which LMP command is being rejected.
5. LMP_test_control messages which have seven parameters indicating:
    a. Test scenario
    b. Hopping mode
    c. Tx channel for DUT
    d. Rx channel for DUT
    e. Power control mode
    f. Poll period
    g. Packet type
    h. Length of test sequence

The most recent messages are displayed at the top of the screen.

11.5 Saving a log file

A log file of the LMP messages can be saved by clicking the ‘Save’ button on the toolbar. Select the ‘DUT log (*.log)’ file type to save the log file.

The log file is a simple text file. The first character on each line is either ‘>’, indicating that the message is from the *Zircon* configuration to the DUT, or ‘<’, indicating that the message is from the

DUT to the *Zircon* configuration. The remainder of the line contains the message as displayed in the configuration.

```
> Disconnected
> Connected
> LMP_features_req
< LMP_features_res
> LMP_version_req
< LMP_version_res
> LMP_host_connection_req
< LMP_accepted ( LMP_host_connection_req )
> LMP_setup_complete
< LMP_setup_complete
> LMP_supervision_timeout
< LMP_max_slot_req
>  ( LMP_max_slot_req ) LMP_accepted
< LMP_max_slot_req
>  ( LMP_max_slot_req ) LMP_accepted
< LMP_packet_type_table_req
> ( LMP_packet_type_table_req ) LMP_not_accepted_ext
> LMP_name_req
< LMP_name_res
> LMP_test_activate
< LMP_accepted ( LMP_test_activate )
> ( 3,0,39,39,0,1,4,27 ) LMP_test_control
< LMP_accepted ( LMP_test_control )
> ( 3,0,40,40,0,1,4,27 ) LMP_test_control
< LMP_accepted ( LMP_test_control )
> ( 7,0,40,39,0,0,4,27 ) LMP_test_control
< LMP_accepted ( LMP_test_control )
> ( 7,0,40,39,0,0,4,27 ) LMP_test_control
< LMP_accepted ( LMP_test_control )
> ( Decr ) LMP_power_control_req
< LMP_power_control_res ( Step,Step,Step )
> ( Decr ) LMP_power_control_req
< LMP_power_control_res ( Step,Step,Step )
> ( Decr ) LMP_power_control_req
< LMP power control res ( Step,Step,Step )
```

Figure 77: Example DUT control log file

11.6 Saving and restoring settings

The settings can be saved by clicking the ‘Save’ button on the toolbar. Select the ‘DUT control settings (*.dcs)’ file type to save the current settings.

An existing DUT control settings file (*.dcs) can be opened using the ‘Open’ button on the toolbar.

The DUT control settings file (*.dcs) is an XML file. It is not recommended that this file be edited manually. If it needs to be modified, open it from the DUT control mode, modify the required parameters and re-save.

12 Connecting to and controlling the DUT

12.1 Overview

Control of the DUT over-the-air is possible in the following modes:

1. Loopback tester mode
2. Signal analyser mode
3. DUT control mode

In these modes, the mode control panel has several options for controlling the over-the-air link. These options are described in this section.

12.2 Prerequisites

In order for the DUT to respond to the *TLF3000* it is necessary for it to be in the correct state. Three separate commands should be issued to the DUT over HCI to prepare it for connection with the *TLF3000*:

`HCI_write_scan_enable 0x03` (page & inquiry scan)

`HCI_set_event_filter 0x02 0x00 0x02` (connection setup, all devices, accept with role switch disabled)

`HCI_enable_device_under_test_mode`

12.3 Determining which DUT to connect to

The drop-down device status area provides details of which DUTs are available and their connection status. This area will drop down automatically if an inquiry is initiated and collapse automatically when a connection to a DUT is attempted. The device status area may be expanded or collapsed manually by clicking on the arrow head at the top left of the area.

The device status area shows the status of up to 3 DUTs. The top row shows the full Bluetooth address of each device. Unpopulated devices are given a Bluetooth address of all zeros. The Bluetooth address of a discoverable device can be populated automatically by clicking the ‘Inquiry’ button in the toolbar. Alternatively, Bluetooth addresses can be entered manually by typing directly over the digits in the displayed addresses. Only the UAP and the LAP need be entered since the NAP portion is not required in order to establish a connection.

The page row in the device status area determines which DUTs the *TLF3000* will attempt to connect to. Click on the checkbox in the appropriate column to select a DUT. In the current version of the *Zircon* configuration, only one DUT can be connected to at a time.

The RSSI row in the device status area shows the RSSI of the first inquiry response received from the device. The discovered devices are always listed in order of decreasing RSSI.

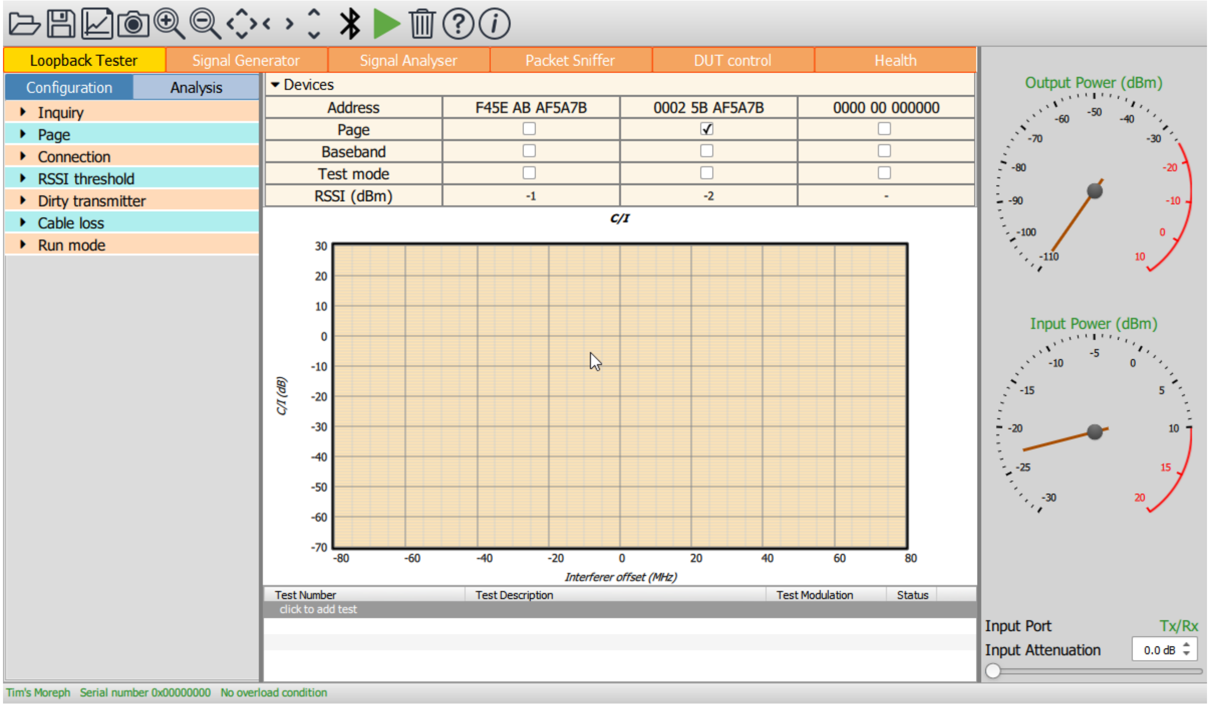


Figure 78: Device status area showing two Bluetooth devices

12.4 Connecting to a DUT

In loopback tester mode, the *Zircon* configuration will automatically connect to the selected DUT when a test is initiated, ie the ‘Run/Stop’ button in the toolbar is clicked. In signal analyser and DUT control modes, connection to the DUT is initiated by clicking the ‘Device page & connect’ icon in the toolbar.

The device status area indicates whether a successful connection to the DUT was made. The row labelled ‘Baseband’ indicates whether a baseband connection to the DUT has successfully been established. The row labelled ‘Test mode’ indicates whether the corresponding DUT has successfully been placed into device under test mode.

12.4.1 Controlling and performing an inquiry

An inquiry is initiated by clicking the ‘Inquiry’ icon in the toolbar. This will automatically expand the device status area and populate the addresses if any devices are found. Once the inquiry is in progress, the ‘Inquiry’ icon will change form to indicate that the *TLF3000* is actively seeking devices. The inquiry can be cancelled at any time by clicking the ‘Inquiry’ icon.

In order to minimise the time required to discover a device, the *TLF3000* transmits on all 64 inquiry channels simultaneously. This eliminates the need to wait for the *TLF3000* and the DUT to be resident on the same channel at the same time.

The parameters controlling the inquiry can be modified by expanding the ‘Inquiry’ menu.

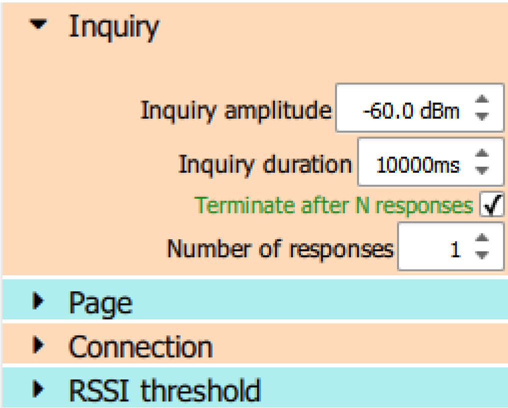


Figure 79: Controlling inquiry

The amplitude of the transmission used during the inquiry can be modified using the 'Inquiry amplitude' spin box. This determines the transmission amplitude per inquiry channel. It can be varied between -120dBm and -30dBm. The upper amplitude is limited due to the need to transmit on all inquiry channels simultaneously.

The length of the inquiry can be modified using the 'Inquiry duration' spin box. This is the maximum length of time that the inquiry is permitted to last.

If 'Terminate after N responses' is checked, the inquiry will terminate as soon as the number of devices specified in the 'Number of responses' spin box have been discovered, or the time specified in the 'Inquiry duration' spin box has been reached.

If 'Terminate after N responses' is unchecked, the inquiry will terminate only when the time specified in the 'Inquiry duration' spin box has been reached.

12.4.2 Controlling the page procedure and connecting to a device

In loopback tester mode, the *Zircon* configuration will automatically connect to the selected DUT when a test is initiated, ie the 'Run/Stop' button in the toolbar is clicked. In signal analyser and DUT control modes, connection to the DUT is initiated by clicking the 'Device page & connect' icon in the toolbar. In signal analyser and DUT control modes, a connected device can be disconnected by clicking the 'Device page & connect' icon.

When *TLF3000* pages a device, it transmits on all 64 paging channels simultaneously. This reduces the time taken to page a device since it is unnecessary to wait for the *TLF3000* and DUT to be resident on the same channel at the same time.

The parameters controlling the paging can be modified by expanding the "Page" menu.

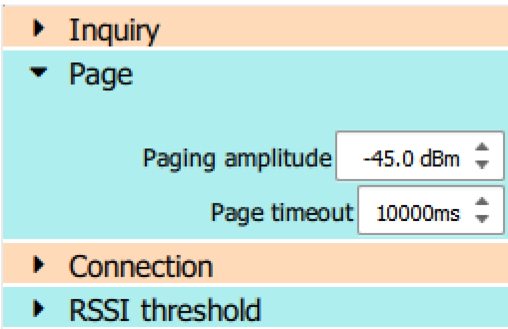


Figure 80: Controlling paging

The amplitude of the transmission used during paging can be modified using the 'Paging amplitude' spin box. This determines the transmission amplitude per paging channel. It can be varied between -120dBm and -30dBm. The upper amplitude is limited due to the need to transmit on all paging channels simultaneously

The 'Page timeout' spin box determines how long the *TLF3000* will page the device before giving up.

12.4.3 Controlling the link

The 'Connection' menu contains parameters which control the link once it has been established:

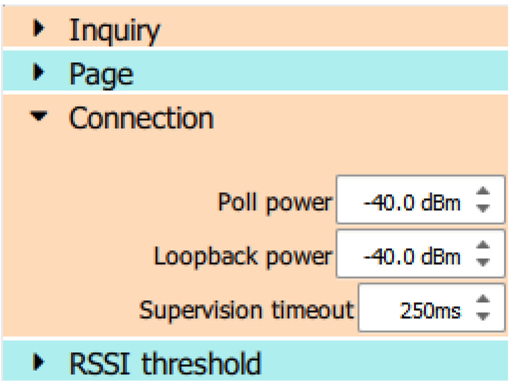


Figure 81: Controlling the link

The 'Poll power' spin box governs the transmit power of the *TLF3000* when sending:

1. LMP messages
2. Poll packets used in transmitter test mode

The poll power may be set between -120dBm and 0dBm.

The 'Loopback power' spin box governs the transmit power of the *TLF3000* when sending packets to be loopback by the DUT. It may be set between -120dBm and -4dBm. This option is not available when in loopback tester mode since the amplitude of the packets to be looped back is automatically determined by the test script.

The 'Supervision timeout' spin box sets the links supervision timeout as defined in the Bluetooth 5 Core Specification.

12.4.4 Restricting which packets are processed

When performing an inquiry, responses from any discoverable device in the vicinity may be received. It is possible to restrict which response are processed by setting an RSSI threshold in the 'RSSI threshold' menu:

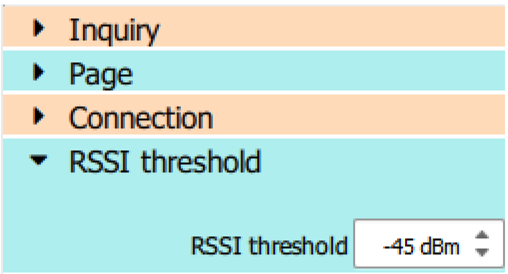


Figure 82: Setting the RSSI threshold

If the DUT is connected via a cable, then an RSSI threshold can be set to accept the wanted responses from the DUT whilst eliminating spurious responses from nearby devices.

The RSSI threshold applies not only to FHS packets received during an inquiry but to all received packets.

Care should be taken in setting the RSSI threshold if the DUT is to be operated at reduced power. The DUT may reduce its power under the following circumstances:

1. The user instructs the DUT to reduce its output power in either signal analyser to DUT control mode.
2. One of the following tests in run in loopback tester mode:
    a. Power control
    b. Enhanced power control
    c. EDR relative transmit power

   Each of these tests require the DUT power to be reduced to its minimum value.

If any of these circumstances are likely to arise, then the RSSI threshold must be set lower than the minimum DUT power.

12.4.5 Controlling the DUT transmissions

12.4.5.1 Overview

When a Bluetooth device is in device under test mode, it can operate in two distinct modes:

1. Transmitter test mode
2. Loopback mode

In transmitter test mode, the *TLF3000* sends a message to the DUT to inform it what packet type it should transmit and what the contents of that packet should be. The *TLF3000* then sends poll packets to the DUT and the DUT responds with the previously described packet type and format. If hopping is disabled, then the *TLF3000* and the DUT use the same RF channel. In transmitter test mode whitening is disabled.

In loopback mode, the *TLF3000* sends a packet to the DUT, the DUT receives the packet and then sends it back to the *TLF3000*, either in the next or subsequent slots. If hopping is disabled, then the RF channels for the *TLF3000* and the DUT can be independently assigned. In loopback test mode whitening may be either enabled or disabled.

Transmitter test mode is primarily used for testing the properties of the DUT transmissions. Loopback mode is primarily used to test the DUT receiver performance.

The DUT transmissions can only be controlled by the user in signal analyser and DUT control modes. In loopback tester mode the DUT transmissions are automatically defined by the test scripts.

12.4.5.2 Transmitter test mode

Transmitter test mode is selected by unchecking ‘Loopback’ in the ‘Test mode’ menu.

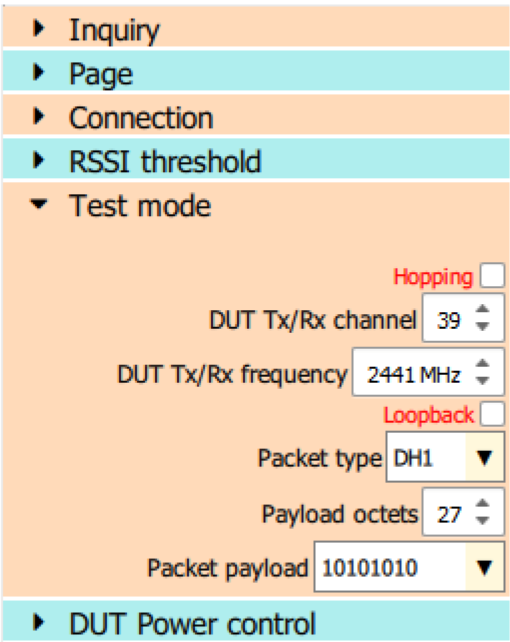


Figure 83: Controlling the DUT transmissions in transmitter test mode

The DUT and *TLF3000* can either be configured to use the same channel or can be configured to follow the *TLF3000* hopping sequence. (See Section 12.5 for the *TLF3000* Bluetooth address which determines the hopping sequence.) The selection is made using the ‘Hopping’ checkbox.

If hopping is not selected, then the RF channel used by the *TLF3000* and DUT can be selected either by:

1. entering the channel number in the ‘DUT Tx/Rx channel’ spin box, or
2. entering the RF frequency in the ‘DUT Tx/Rx frequency’ spin box.

The type of packet to be transmitted by the DUT is selected by the 'Packet type' combo box. In the current version of *Zircon* only DH packets are supported.

The number of user octets in the payload (ie excluding payload header and CRC) of the packets to be transmitted by the DUT is set by the 'Payload octets' spin box.

The contents of the user octets in the payload of the packets to be transmitted by the DUT is determined by the 'Packet payload' combo box. The following selections are supported:

1. PRBS9 sequence
2. Repeated 11110000 pattern
3. Repeated 101010101 pattern
4. All 1's
5. All 0's

12.4.5.3 Loopback test mode

Loopback test mode is selected by checking 'Loopback' in the 'Test mode' menu.

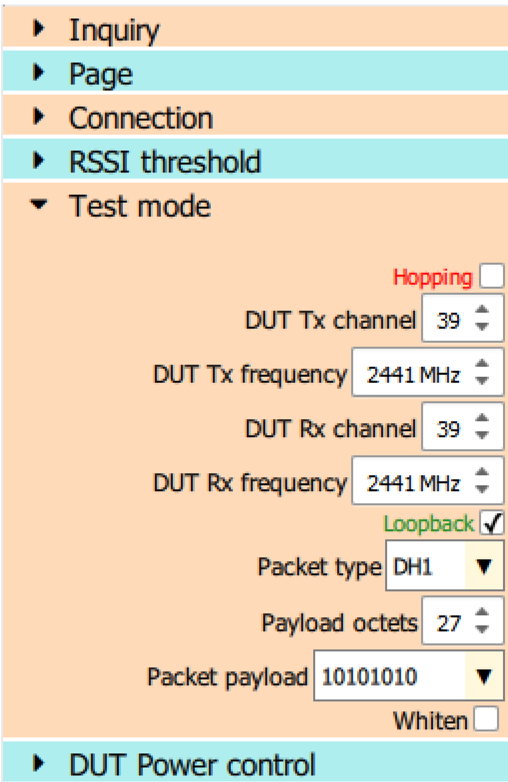


Figure 84: Controlling the DUT transmissions in loopback test mode

If hopping is not selected, then the RF channels used by the *TLF3000* and DUT can independently be selected either by:

1. entering a channel number in the 'DUT Tx channel' and 'DUT Rx channel' spin boxes, or
2. entering an RF frequency in the 'DUT Tx frequency' and 'DUT Rx frequency' spin boxes.

The type of packet to be looped back by the DUT is selected by the ‘Packet type’ combo box. In the current version of *Zircon* only DH packets are supported.

The number of user octets in the payload (ie excluding payload header and CRC) of the packets to be looped back by the DUT is set by the ‘Payload octets’ spin box.

The contents of the user octets in the payload of the packets to be looped back by the DUT is determined by the ‘Packet payload’ combo box. The following selections are supported:

1. PRBS9 sequence
2. Repeated 11110000 pattern
3. Repeated 101010101 pattern
4. All 1’s
5. All 0’s

The packets transferred between *TLF3000* and the DUT will be whitened if the ‘Whiten’ checkbox is checked.

12.4.6 Controlling the DUT output power

In signal analyser and DUT control modes it is possible to instruct the DUT to modify its output power. If the DUT supports enhanced power control, then LMP_power_control_req messages will be used. If the DUT only supports legacy power control, then LMP_incr_power_req and LMP_decr_power_req messages will be used.

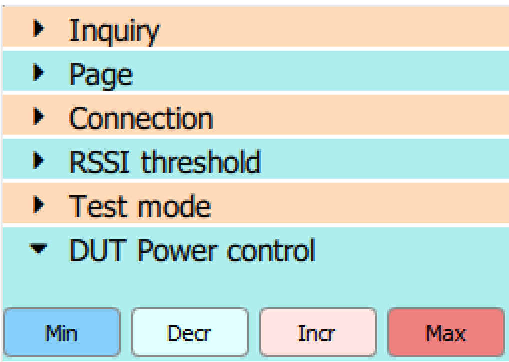


Figure 85: Controlling the DUT output power

The ‘DUT Power control’ menu contains four push buttons:

1. *Min* instructs the DUT to adopt its minimum output power setting for the currently selected packet type
2. *Decr* instructs the DUT to decrement its output power by one step
3. *Incr* instructs the DUT to increment its output power by one step
4. *Max* instructs the DUT to adopt its maximum output power setting for the currently selected packet type

12.5 *TLF3000* Bluetooth address

In the current software version, the Bluetooth address of the TLF3000 unit is fixed at:

0x7083 0xD5 0x1DDnnn

where nnn is the 12 bit RF Creations assigned MAC address for the unit.

12.6 Setting the RF input port

In signal analyser and DUT control modes, signals can be received and analysed on either the 'Monitor In' RF port or the 'Tx/Rx' RF port. The selection of which port is used is made clicking the port displayed towards the bottom of the monitor panel.

The Monitor In port is designed for monitoring signals off-air. The Tx/Rx port is designed for conducted measurements.

If the monitor panel shows a lack of RF input energy, check that the DUT is connected to the same RF port as selected by the label at the bottom of the monitor panel.

12.7 Adjusting the RF frontend attenuation

The RF frontend attenuation is set via either:

1. The slider at the bottom of the monitor panel
2. The spin box at the bottom of the monitor panel

The RF frontend attenuation can be set between 0 and 31.5 dB in steps of 0.5 dB.

To set the RF attenuation, the 'Input Power' gauge on the monitor panel must be examined. This shows both the current input signal level (the position of the needle) and the point at which saturation of the *TLF3000* receiver will occur (the red arc). The RF attenuation should be adjusted such that the input signal level is just below the saturation level.

If too little attenuation is applied, then there is a danger that the *TLF3000* receiver will be overloaded. An overload condition on the receiver is indicated by:

1. The needle on the 'Input Power' gauge on the monitor panel entering the region of the red arc (the input power measurement is only approximate, so this is only a rough guide)
2. The title of the 'Input Power' gauge on the monitor panel turning red
3. The text 'Rx overload' appearing in red within the status bar at the bottom of the window

If too much attenuation is applied, then the test results may become unreliable. In order to calculate the frequency deviation within a packet, an FM demodulation process is employed. The quality of the output of the FM demodulation process is critically dependent on the signal-to-noise ration of the signal at the input to the demodulator. If too much attenuation is applied, then the signal be analysed will be pushed down towards the *TLF3000* receiver noise floor and the accuracy of the test results will be compromised.

12.8 Connecting to devices over-the-air (Radiated measurements)

In order to successfully connect to devices over-the-air, the default values of a number of parameters must be changed.

12.8.1 Inquiry parameters

If possible, avoid performing an inquiry to discover the DUT by entering a device address directly into the ‘Device status’ window. This will prevent *Zicon* connecting to the wrong device.

If an inquiry is to be performed, then the inquiry power should be set to its maximum value of -30dBm per channel using the ‘Inquiry power’ spin box under the ‘Inquiry’ menu. It is recommended that the ‘Terminate after N responses’ is left unchecked and the ‘Inquiry duration’ is set to a few seconds. During the inquiry a number of spurious devices may be discovered. The discovered devices will be listed in order of decreasing RSSI within the ‘Device status’ window. The wanted device will normally be that with the largest RSSI, ie the first device listed.

12.8.2 Paging parameters

The ‘Paging amplitude’ spin box under the ‘Page’ menu should be set to its maximum value of -30dBm per channel.

12.8.3 Poll power

The ‘Poll power’ spin box under the ‘Connection’ menu should be set to 0dBm. This will help establish a reliable link to the DUT.

12.8.4 RSSI threshold

The ‘RSSI threshold’ spin box determines the minimum received signal level which will be processed. The default value is suitable for conducted measurements but is inappropriate for radiated measurements. The RSSI threshold should be reduced to a value at which the transmissions from the DUT can be reliably received. A value of around -90dBm may be appropriate.

12.8.5 RF connections

An antenna should be connected to the ‘Tx/Rx’ port. This will be used for the *Zircon* transmissions.

Zircon can receive signals from the DUT using either the ‘Tx/Rx’ port or the ‘Monitor In’ port. If the signals from the DUT are strong, then use of the ‘Tx/Rx’ port may be possible. However, if the signals from the DUT are weak, then it may be necessary to connect another antenna to the ‘Monitor In’ port for reception. The appropriate input port for reception should be selected in the ‘Monitor panel’, see Section 12.6.

If the ‘Monitor In’ port is used for reception of the DUT transmissions, then it may be necessary to adjust the *TLF3000* receiver frontend attenuation, see Section 12.7.