

Products: FSP

## Transmitter Measurements on Bluetooth™ Modules with FSP

This application note shows how to perform measurements on transmitter modules – largely in conformance with the Bluetooth test specifications – by remote control using an FSP Spectrum Analyzer.

A demo program enclosed with this application note facilitates integrating FSP into existing test systems. The program contains all remote control commands for each test for configuring the analyzer, starting the measurements and reading out the data. The demo program also serves as a model for creating user-specific analysis routines.

BLUETOOTH is a registered trademark of Telefonaktiebolaget L M Ericsson, Sweden.



## Contents

<b>1</b>	<b>Overview</b> .....	<b>3</b>
<b>2</b>	<b>Bluetooth Transmitter Tests</b> .....	<b>4</b>
<b>3</b>	<b>Instrument Setup for Transmitter Tests</b> .....	<b>5</b>
	Required Instruments .....	5
	Test Modes and Stimulus Signals .....	6
	Hopping .....	6
	Coupling the EUT .....	6
<b>4</b>	<b>Working with the Demo Program</b> .....	<b>7</b>
	Hardware and Software Requirements .....	7
	Installing the Demo Program .....	7
	Files of Demo Program .....	8
<b>5</b>	<b>Carrying Out the Transmitter Tests</b> .....	<b>9</b>
	Initial Steps with Demo Program .....	9
	Selecting a Test .....	10
	Setting the Test Parameters .....	10
	Test Sequence .....	11
	Error Handling .....	11
<b>6</b>	<b>The Measurements in Detail</b> .....	<b>12</b>
	Output Power (5.1.3) .....	12
	Test Method .....	12
	Test Results .....	13
	Notes .....	14
	Power Density (5.1.4) .....	15
	Test Method .....	15
	Test Results .....	16
	Notes .....	17
	Power Control (5.1.5) .....	18
	Test Method .....	18
	TX Output Spectrum - Frequency Range (5.1.6) .....	18
	Test Method .....	18
	Test Results .....	20
	Notes .....	21
	TX Output Spectrum - 20 dB Bandwidth (5.1.7) .....	22
	Test Method .....	22
	Test Results .....	23
	Notes .....	23
	TX Output Spectrum - Adjacent Channel Power (5.1.8) .....	24
	Test Method .....	24
	Test Results .....	25
	Notes .....	26
	Modulation Characteristics (5.1.9) .....	26
	Test Method .....	26
	Test Results .....	27
	Notes .....	30
	Initial Carrier Frequency Tolerance (5.1.10) .....	31
	Test Method .....	31
	Test Results .....	32
	Notes .....	33
	Carrier Frequency Drift (5.1.11) .....	34
	Test Method .....	34
	Test Results .....	35
	Notes .....	36
<b>7</b>	<b>Further Test Possibilities</b> .....	<b>37</b>
<b>8</b>	<b>References</b> .....	<b>37</b>
<b>9</b>	<b>Ordering Information</b> .....	<b>38</b>

# 1 Overview

This application note shows how to perform measurements on transmitter modules – largely in conformance with the Bluetooth test specifications – by remote control via the IEC/IEEE bus using an FSP Spectrum Analyzer and the optional FM/AM Demodulator (FS-K7). The application note comes with a demo program to help integrate the FSP into existing test systems. The program contains all remote control commands for each test for configuring the analyzer, starting the measurements and reading out the data. The command strings can be transferred unmodified into user-specific test programs. You can use the demo program as a model for creating your own analysis routines.

**Note:** *This application note is intended for use in development and production, with corresponding limitations with respect to the Bluetooth test specification requirements. In particular, the spectrum analyzer does not have signalling capability to switch the Equipment Under Test (EUT) to the test mode.*

*For qualification and type approval, Rohde & Schwarz offers Test System TS8960, which fully complies with the standard. For protocol tests, Tester PTW60 is available, for measurements at the air interface the Universal Radio Communication Tester, CMU (see section 'Ordering Information').*

*For measurements on Bluetooth transmitter modules with FSE or FS1Q Analyzer please refer to Application Note 1MA26 [3].*

For high speed testing, measurements in development and production are normally made using parameters different from those in type approval testing. The demo program can be modified quickly and easily, so you can find the optimal parameters for your application very conveniently.

To modify the source code and generate a version of your own, you need the LabWindows CVI software from National Instruments (Rev. 5.0 or higher). This software is supplied free of charge as option PSM-K10 or PSP-K10 for Rohde & Schwarz Industrial Controller PSM or PSP7 if ordered together with the controller (subsequent delivery of the software is not possible).

The descriptions given in the following are based on the description of transmitter tests in the Version 0.91 Bluetooth test specifications.

### **2 Bluetooth Transmitter Tests**

The test specifications include the following transmitter tests:

- Output power
- Power density
- Power control
- TX output spectrum - frequency range
- TX output spectrum - 20 dB bandwidth
- TX output spectrum - adjacent channel power
- Modulation characteristics
- Initial carrier frequency tolerance
- Carrier frequency drift

All these tests can be performed with FSP Spectrum Analyzer and the demo program.

The tests vary considerably in complexity. For power measurements, the analyzer itself can obtain a result. Spectrum measurements require subsequent computation to verify whether the test was passed. And for tests 7 to 9, the computational effort is even greater: a special synchronization procedure is needed to clearly identify the position of the data bits in the burst.

The basic sequence of operations with the demo program is the same for each test:

1. configure the EUT.
2. Configure the test system.
3. Start one or more measurements.
4. Read the results.

This sequence is always followed by the demo program.

### 3 Instrument Setup for Transmitter Tests

#### Required Instruments

Fig. 1 shows the basic test setup and the signal paths for the Bluetooth transmitter measurements described here:

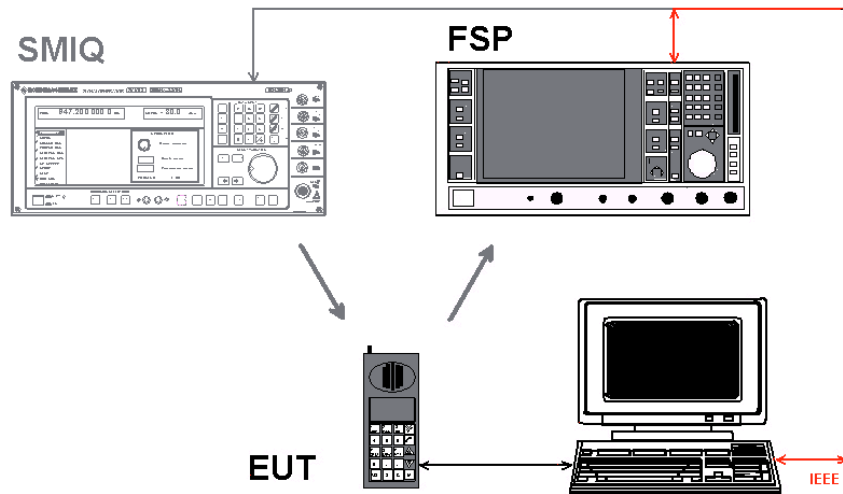


Fig. 1 Test setup for transmitter measurements

The equipment under test (EUT) is switched to a test mode in which it generates the transmitter signal required in each case (see next chapter).

The analyzer is configured by a test program (for example the demo program, which runs on a laptop in Fig. 1), which then starts a measurement. The program fetches the results and evaluates them. If necessary, a Bluetooth stimulus signal can be supplied by Signal Generator SMIQ. So, you can carry out all transmitter signal measurements using only Spectrum Analyzer FSP with option FS-K7 fitted and a controller.

In section 9 you will find order designations of the above units and options and further units useful in Bluetooth measurements.

### **Test Modes and Stimulus Signals**

According to the test specifications, the EUT must be switched to loopback mode by signalling. For that, a call has to be set up before. In development and production, however, it is certainly more advantageous to activate suitable, manufacturer-specific test modes which directly trigger the EUT to transmit, without signalling and call setup.

Bluetooth stimulus signals can be generated with a single SMIQ Signal Generator. More complicated signals require a combination of SMIQ Signal Generator and AMIQ I/Q Modulation Generator.

Application Note 1MA31 [4] describes how to generate simple, repeating Bluetooth stimulus signals very quickly with just an SMIQ. The application note comes with files containing the payload data which are also used here, as well as instructions for loading the files into SMIQ. On SMIQ, all parameters for the Bluetooth standard (modulation mode, deviation, filtering) can be loaded at a keystroke.

To generate continuous data streams, use a combination of SMIQ and AMIQ generators and the Rohde & Schwarz WinIQSIM software package. See Application Note 1GP38 [5] for detailed instructions.

**Note:**        *Signalling is not possible with Signal Generator SMIQ.*

### **Hopping**

For tests in development and production, hopping can be reduced to two frequencies without affecting the results. To do this, set the RX and TX frequencies to the opposite ends of the Bluetooth frequency band. For the analyzer, this simulates non-hopping mode, whereas the synthesizer of the EUT has to handle the maximum frequency range.

### **Coupling the EUT**

Depending on the connection or coupling facilities of the EUT, an insertion loss specific for a given test setup is obtained in the RF path from the EUT to the analyzer.

This insertion loss has to be exactly determined for power measurements prior to carrying out the test. The value obtained can be entered as a level offset on the analyzer and will then be compensated automatically.

## 4 Working with the Demo Program

### Hardware and Software Requirements

To run the demo program, you need a PC with a GPIB card, for example Rohde & Schwarz PSM or PSP7 Industrial Controller with GPIB bus card PS-B4 or an equivalent GPIB bus card from National Instruments. The appropriate driver software must be installed on your computer.

The demo program can be run under Windows 95, Windows 98 or Windows NT.

To modify the source code and generate a version of your own, you need the LabWindows CVI software from National Instruments (Rev. 5.0 or higher). This software is supplied free of charge as option PSM-K10 or PSP-K10 with Rohde & Schwarz PSM or PSP7 Industrial Controller if ordered together with the controller (subsequent delivery of the software is not possible).

### Installing the Demo Program

1. Copy BT\_FSP.001, BT\_FSP.002, BT\_FSP.003, and setup.exe to a directory of your choice.
2. Start **setup.exe** and proceed as prompted by the dialog.

After installation, the LabWindows CVI project file and the source files will be stored in the selected directory in addition to the executable demo program.

Files BT\_FSP.001, BT\_FSP.002, BT\_FSP.003, and setup.exe can be deleted.

### **Files of Demo Program**

The 1ma33 demo program comes up with all source files. The most important module is the 'tests.c' file. This file contains a configuration and a measurement routine for each test.

The configuration and measurement routines are numbered in accordance with the Bluetooth test specifications as follows:

Config\_513() and Run\_513() for output power measurements to

Config\_5111() and Run\_5111() for carrier frequency drift measurements

Any modifications to the configuration, test sequence or analysis have to be made in the 'tests.c' module.

The other c modules are organized as follows:

main.c main program

ui.c user interface

remote.c IEC/IEEE-bus control

error.c error signalling

The files with the extension 'uir' define the user interface.

These files will not be discussed here.



## 5 Carrying Out the Transmitter Tests

### Initial Steps with Demo Program

1. Install the 1ma33 demo program on your controller.
2. Connect the analyzer with the controller via the IEC/IEEE bus.
3. Switch the analyzer on and wait until initialization is completed.
4. Start the 1ma33 demo program.

On program start, the demo program checks whether Analyzer FSP is connected to the GPIB and stores the GPIB address of FSP. If no FSP is detected, an error message is output and, on acknowledgment of the message, the program goes to the simulation mode. In this mode, you cannot perform any measurements but navigate on the user interface. To exit the simulation mode you have to terminate the program.

After a successful program start, the following panel comes up:

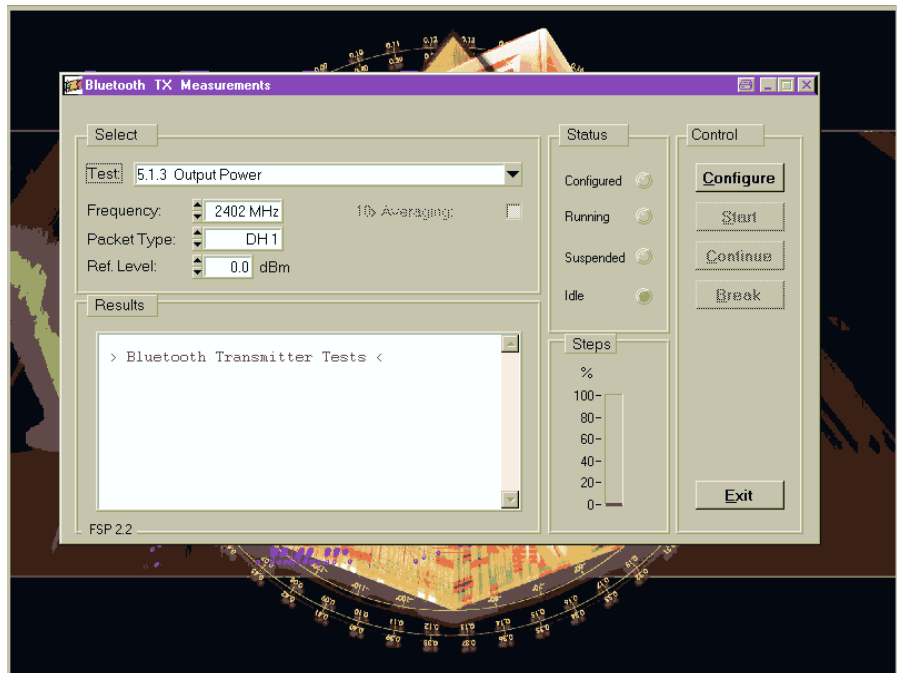


Fig. 2 User interface of demo program

### Selecting a Test

1. Open the test list by double-clicking the downward arrow in the *Test* line.

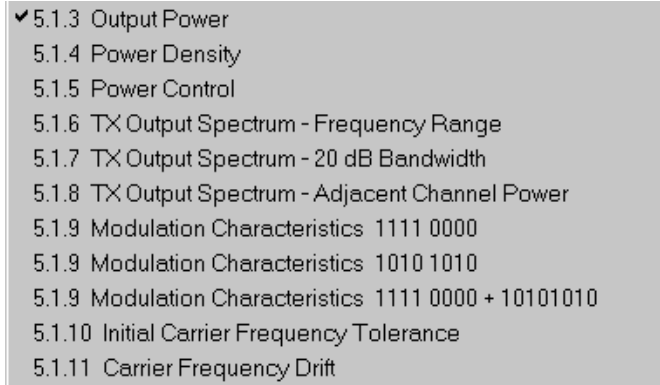


Fig. 3 List of supported tests

2. Select a test by double-clicking the respective line.

### Setting the Test Parameters

The demo program is confined to a small number of settable test parameters:

- Test (see above)
- Transmitter frequency: 2.402 GHz (low)  
2.441 GHz (mid)  
2.480 GHz (high)
- Packet type: DH1, DH3 or DH5
- Reference level: max. output level of EUT
- Averaging: on / off

Not all of these parameters are applicable for all tests. Any fields not needed are shaded and cannot be selected.

The parameter settings last made are stored automatically in the 'setup.btx' file on exiting the program and loaded when the program is next started.

Other test parameters are assigned fixed settings. For example, the actual burst length (or the 20 % and the 80 % point), the bandwidths, the sweep times and the number of measurements to be averaged.

The fixed parameter settings can be changed only in the source code of the 'tests.c' module. After such a change, a new .exe file has to be generated using the LabWindows CVI software.

### Test Sequence

The complete test sequence is controlled via the user interface of the controller (Fig. 2).

The status of the demo program is indicated by LEDs in the *Status* field. During the time no operations are performed, the *Idle* LED lights.

1. Start the configuration by clicking the *Configure* button.

While configuration is running, the *Configured* LED lights yellow, and an hourglass is displayed instead of the mouse pointer. When configuration is completed, the *Configured* LED lights green, and the mouse pointer is displayed again.

Start the selected test by clicking the *Start* button.

While the test is running, the *Running* LED lights yellow. When the test is completed, the *Running* LED goes out and the *Idle* LED lights.

2. Test results are displayed in the *Results* window.

The tests *TX output spectrum – Frequency Range* and *Modulation Characteristics* each comprise two parts, for which different signals have to be set. The demo program for this reason stops after the first part, and the *Suspended* LED lights.

3. Continue the program by clicking the *Continue* button.

Interrupting a running test may be expedient, for example in the event a test has got stuck because there is no trigger signal present. To solve IEC/IEEE-bus problems, click the *Break* button. The program in return sends the IFC command.

4. To interrupt a test, click the *Break* button.
5. To exit the program, click the *Exit* button.

On exiting, the program automatically stores the parameter settings last selected in the 'setup.btx' file and loads these settings when it is restarted.

**Note:** *When the 'Exit' button is clicked, the demo program stops a running measurement by switching trace 1 to VIEW. If you want to continue the measurement manually, set trace 1 to CLEAR / WRITE.*

### Error Handling

Any errors detected by the program are displayed in a pop-up menu and have to be acknowledged. Minor errors lead to an abort of the test in question, grave errors to an abort of the program.

The most important errors that may occur in the tests are discussed below in the relevant sections.

## 6 The Measurements in Detail

**Note:** The numbers given in brackets refer to the relevant sections of the Bluetooth test specifications.

### Output Power (5.1.3)

#### Test Method

In the output power test, the peak and the average power of a single burst are determined. A time window of min. 20 % to 80 % of the burst is evaluated. The analyzer is in the zero span mode. Both results are obtained in a single measurement.

1. Connect the EUT with the analyzer.
2. Configure the EUT.
3. Configure the stimulus generator if necessary.
4. In the demo program, select the *Output Power* test by double-clicking the corresponding line.
5. Set the transmitter frequency and the reference level in the demo program.
6. Start the analyzer configuration by clicking the *Configure* button in the demo program.

When configuration is completed, the following settings are active:

- Transmitter frequency and reference level as entered
  - Zero span
  - Resolution bandwidth: 3 MHz
  - Video bandwidth: 3 MHz
  - Detector: peak
  - Mode: max hold
  - Sweep time: 625  $\mu$ s for DH1, 1.875 ms for DH3, 3.125 ms for DH5
  - Trigger: internal video
7. Start the test by clicking the *Start* button in the demo program.
  8. Check results in the *Results* window.
  9. Repeat the test for different frequencies and in different modes.

## Test Results

Fig. 4 shows the results output by the demo program, Fig. 5 the results displayed on the analyzer.

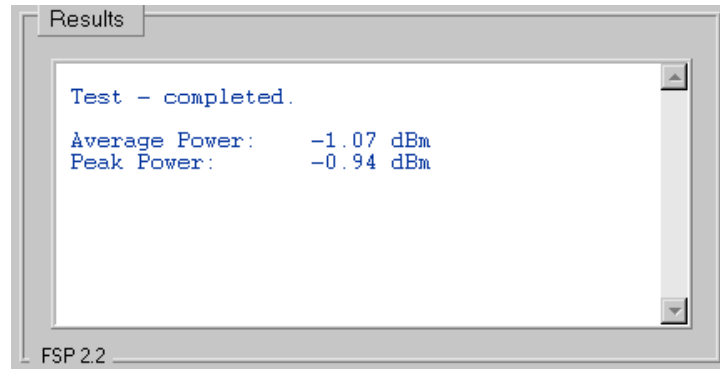


Fig. 4 Output power level: results output by demo program

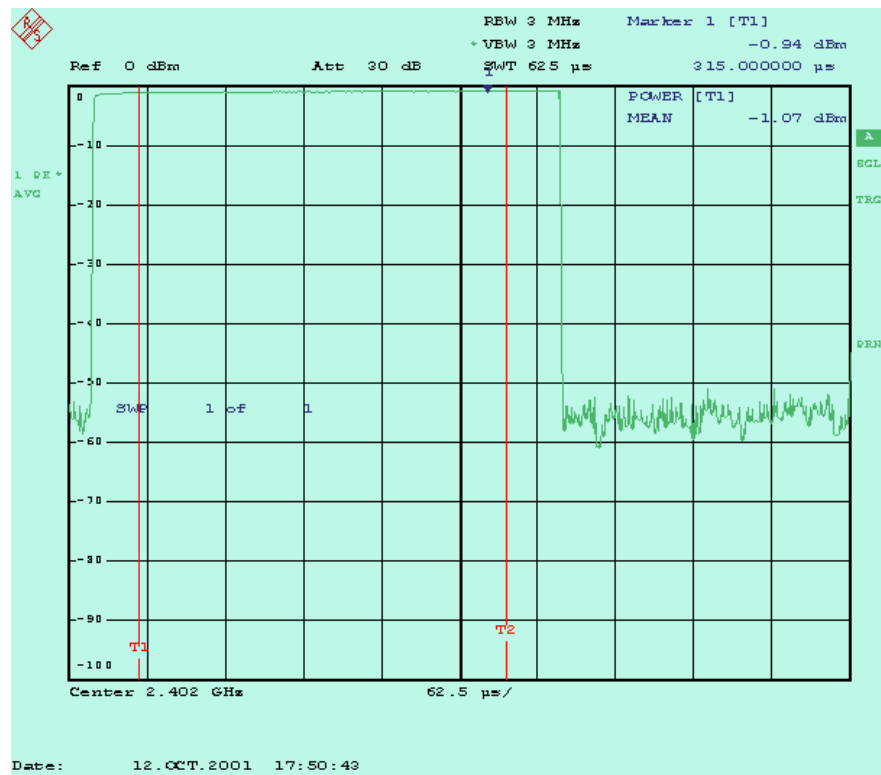


Fig. 5 Output power level: results displayed on analyzer

For rms value calculation, only the range between limit lines T1 and T2 is considered. T1 is positioned at 10 %, T2 at 90 % of the active part of the burst.

### Notes

- Trigger:

The demo program uses an internal trigger (trigger on power ramp). Use of this trigger requires that only the transmitter signal – and not, for example, a stimulus signal – be present at the analyzer input. If an external trigger signal is available, this signal should be used. The IEC/IEEE-bus command for setting an external trigger in the Config\_513 routine is as follows:

```
"trig:seq:sour ext"
```

- Burst width:

The Bluetooth test specifications stipulate that either p0 (i.e. the first bit of the packet) be taken as the start of the burst or the -3 dB power limits (to measure over at least 20 % to 80 % of the burst width thus defined). The definition used in each case will for real bursts lead to different widths since, depending on the manufacturer, the output stage is activated ahead of p0. Due to this unmodulated header, a DH1 packet with a 366 µs modulation section is usually more than 400 µs long.

Set the limit lines as required for your application. The IEC/IEEE-bus command for positioning the lefthand limit line 1 to 10 % (for example) of a 400 µs burst is as follows (see Config\_513 routine):

```
"calc:mark:x:slim:left 0.04ms"
```

- Averaging:

To form an average over several measurements, set the sweep counter to the desired number of measurements. The average power is the mean value of the single results. The peak power is the highest value found in all sweeps.

For an average over 5 measurements, for example, change the IEC/IEEE-bus command in Config\_513 to

```
"swe:coun 5"
```

- Compensating external losses:

Enter the insertion loss between the EUT and the analyzer in the form of a reference level offset on the analyzer. The analyzer will then display exactly the level values present at the RF port of the EUT.

To compensate 0.8 dB cable loss, for example, change the IEC/IEEE-bus command in Config\_513 to

```
"disp:tracel:y:rlevel:offset 0.8db"
```

- Other possible measurements:

If the burst is to match a defined tolerance window, templates can be generated by means of limit lines. As a result, a summary message is output indicating whether the burst is within all the limits defined.

- Modify the program as required for your application.

(After such modification, a new .exe file has to be generated using the LabWindows CVI software.)

### **Power Density (5.1.4)**

#### **Test Method**

In this test, the maximum power density is determined. This requires two measurements. First, the frequency band is swept very slowly with a narrow analyzer bandwidth, and the frequency is found at which the maximum level occurs. Then the analyzer determines the maximum level at this frequency in the zero span mode.

The two measurements are performed by the demo program one after the other.

1. Connect the EUT with the analyzer.
2. Configure the EUT.
3. Configure the stimulus generator if necessary.
4. In the demo program, select the *Power Density* test by double-clicking the corresponding line.
5. Set the reference level (*Ref. Level*) in the demo program.
6. Start the analyzer configuration by clicking the *Configure* button in the demo program.

When configuration is completed, the following settings are active:

- Reference level as entered
- Span: 240 MHz
- This value does not comply with the frequency resolution of 1 sample per 100 kHz stipulated by the Bluetooth test specifications. (This has been deliberately taken into account for the demo program.) Strictly speaking, the measurement would therefore have to be split into single measurements with span  $\leq 50$  MHz (Analyzer FSP has a display resolution of 501 pixels).
- This makes no difference however for the basic test run.
- Resolution bandwidth: 100 kHz
- Video bandwidth: 100 kHz
- Detector: peak
- Mode: max hold
- Trigger: free run
- Sweep time: 60 s

This value is below the sweep time stipulated by the Bluetooth test specifications. The value of 1 s / 100 kHz specified for type approval tests results in a measurement time of 40 minutes. (This is too long for a demo program, but the value can be set in the source code.)

7. Start the test by clicking the *Start* button in the demo program.

When the first measurement is completed, the demo program sets the analyzer to the frequency at which the maximum was found, switches to zero span and starts the second measurement. The sweep time is 1 minute. The maximum is determined again.

8. Check the results in the *Results* window.
9. Repeat the test in different modes.

## Test Results

Fig. 6 shows the results output by the demo program, Figs 7 and 8 the results of the two partial measurements on the analyzer.

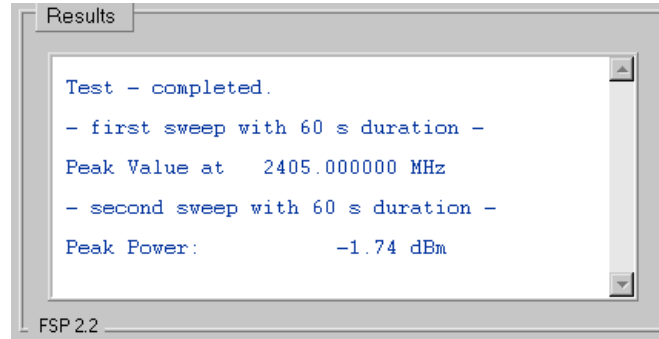


Fig. 6 Power density: results output by demo program

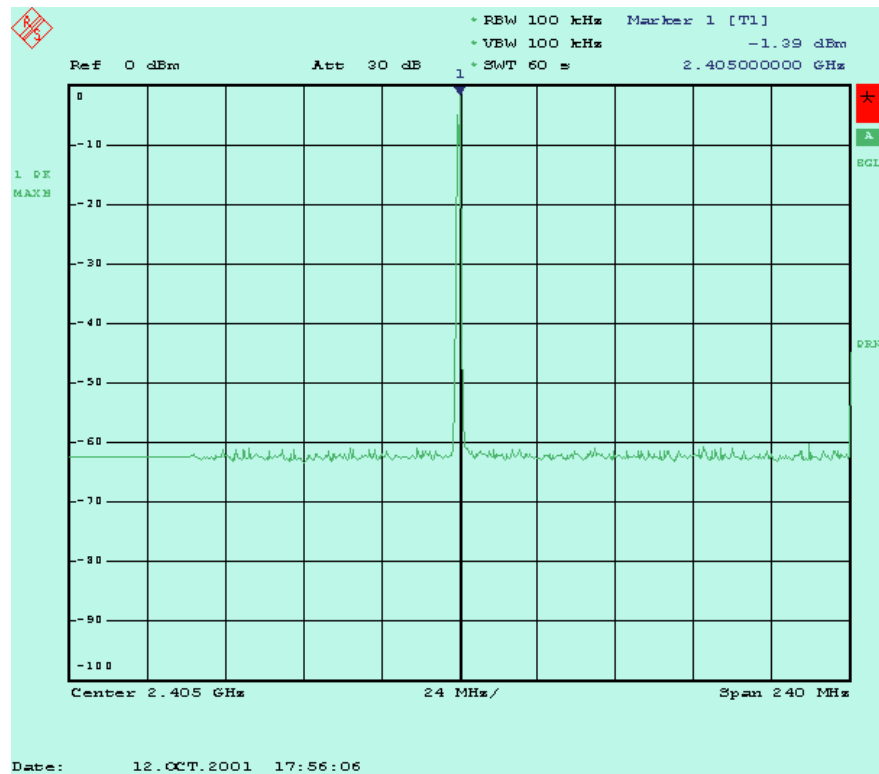


Fig. 7 Power density: results displayed on analyzer, part 1



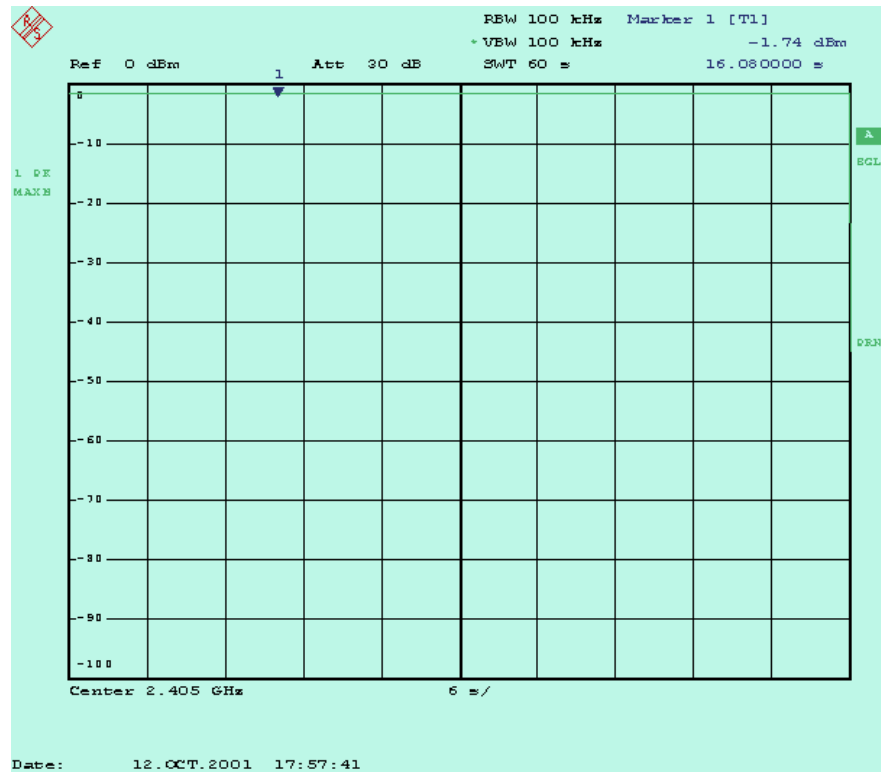


Fig. 8 Power density: results displayed on analyzer, part 2

## Notes

- Compensating external losses:  
Enter the insertion loss between the EUT and the analyzer as a reference level offset on the analyzer. The analyzer will then display exactly the level values at the RF port of the EUT.  
To compensate 0.8 dB cable loss, for example, change the IEC/IEEE-bus command in Config\_514 to  
`"disp:tracel:y:rlevel:offset 0.8db"`

### **Power Control (5.1.5)**

#### **Test Method**

This test corresponds, in terms of operation and test parameters, to the average measurement of the *Output Power* test.

In the *Output Power* average measurement, only the full output power is measured, whereas in the *Power Control* test the EUT power is decreased step by step and increased again.

Here, too, a time window of at least 20 % to 80 % of the active part of the burst is measured with the analyzer in the zero span mode.

- For analyzer configuration, measurements, results and notes please refer to the *Output Power* measurements section.
- In the demo program, adjust the reference level as required for the transmit level.

### **TX Output Spectrum - Frequency Range (5.1.6)**

#### **Test Method**

In this test, it is determined whether emissions of the EUT exceeding -30 dBm are within the permissible frequency band.

The test is divided in two parts: first the EUT sends at the lowest frequency and the spectrum at the lower end of the band is measured, then the EUT sends at the highest frequency and the spectrum at the upper end of the band is measured.

1. Connect the EUT with the analyzer.
2. Configure the EUT (lowest frequency).
3. Configure the stimulus generator if necessary.
4. In the demo program, select the *TX Output Spectrum - Frequency Range* test by double-clicking the corresponding line.
5. Set the reference level in the demo program.
6. Start the analyzer configuration by clicking the *Configure* button in the demo program.

When configuration is completed, the following settings are active:

- Start frequency: 2399 MHz, stop frequency: 2405 MHz
- Resolution bandwidth: 100 kHz
- Video bandwidth: 300 kHz
- Detector: peak
- Mode: averaging
- Sweep time: 2 s
- Number of sweeps: 5

## ***Transmitter Measurements on Bluetooth™ Modules***

---

The number of sweeps is smaller than the value stipulated by the Bluetooth test specifications (50). Because of the long sweep time, however, the spectrum does not change significantly after a few sweeps.

- Trigger: free run

The Bluetooth test specifications call for an external trigger signal. This is not necessary because of the long sweep time. (The sweep time is 4 ms per pixel; this covers more than three DH1 bursts. The exact start time is therefore not important.)

7. Start the test by clicking the *Start* button in the demo program.

In the first part of the test, the spectrum at the lower end of the band is measured.

The demo program first searches for the maximum level in the frequency range to ensure that the EUT is sending and the RF coupling is in order. Then it looks for the -30 dBm point, starting at the lowest frequency. (To this effect, it reads the analyzer memory.)

If the maximum found is lower than -30 dBm, or if -30 dBm is already exceeded at the lowest frequency, an error message is output which leads to an abort of the test.

Successful completion of the first part of the test is indicated in the *Results* window. The demo program stops.

8. Reconfigure the EUT (highest frequency).

9. Continue the program by clicking the *Continue* button.

In the second part of the test, the spectrum at the upper end of the band is measured.

The demo program first searches for the maximum level in the frequency range to ensure that the EUT is sending and the RF coupling is in order. Then it looks for the -30 dBm point, starting at the highest frequency.

If the maximum found is lower than -30 dBm, or if -30 dBm is already exceeded at the highest frequency, an error message is output which leads to an abort of the test.

After successful completion of the test:

10. Check the results in the *Results* window.

11. Repeat the test in different modes if required.

## Test Results

Fig. 9 shows the results output by the demo program, Figs 10 and 11 the results displayed on the analyzer.

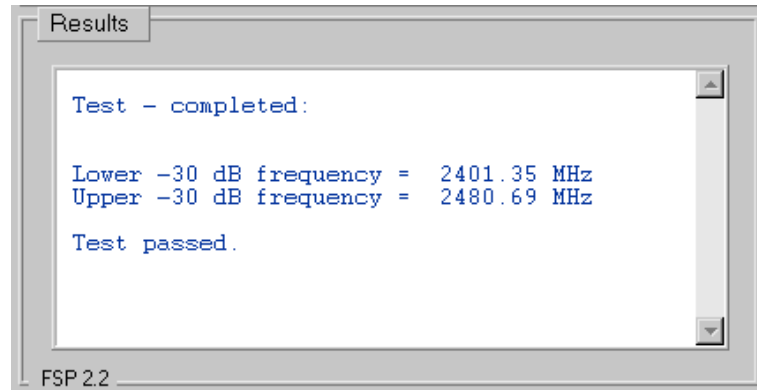


Fig. 9 TX output spectrum - frequency range: results output by demo program

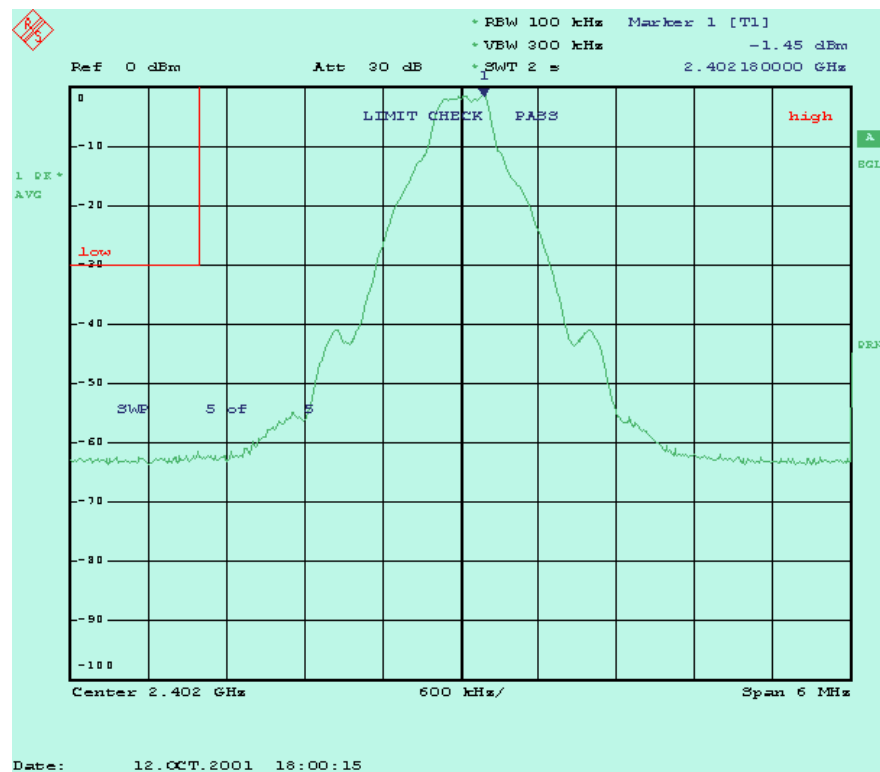


Fig. 10 TX output spectrum - frequency range: lower end of band

There are red limit lines inserted in the analyzer display. They mark the range which the test curve must not intersect in accordance with the test specifications. Whereas the Bluetooth test specifications stipulate the lower and the upper -30 dB frequency to be determined (which is implemented

## Transmitter Measurements on Bluetooth™ Modules

here), it is sufficient in development and production to query the status of the limit lines.

The LIMIT CHECK: PASSED message can be taken as sufficient evidence that the test step in question was passed.

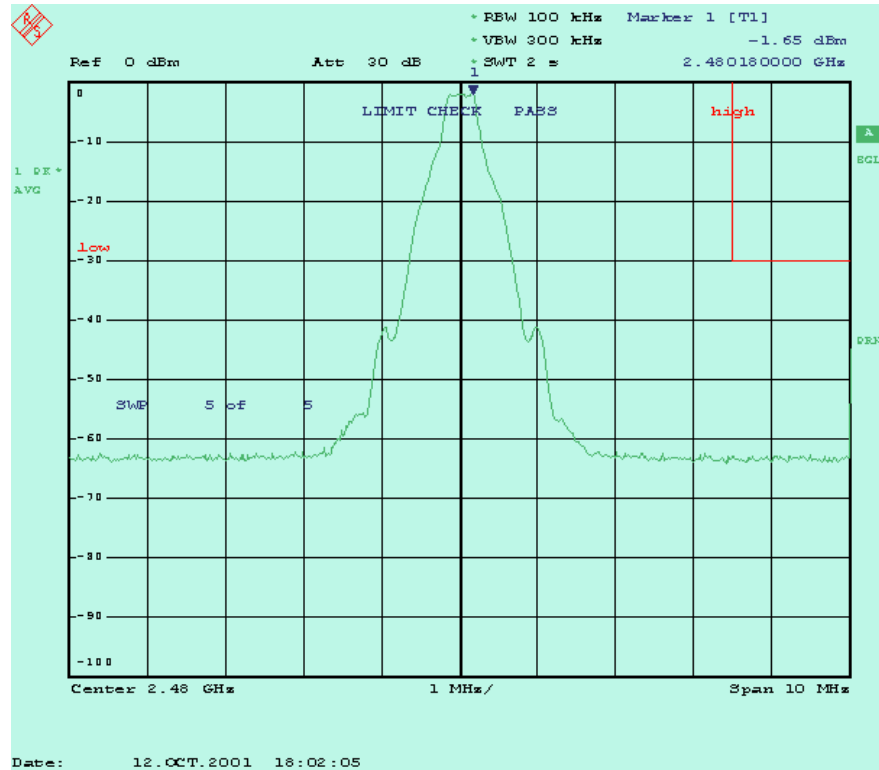


Fig. 11 TX output spectrum - frequency range: upper end of band

### Notes

- Compensating external losses:

Enter the insertion loss between the EUT and the analyzer as a reference level offset on the analyzer. The analyzer will then display exactly the level values at the RF port of the EUT.

To compensate 0.8 dB cable loss, for example, change the IEC/IEEE-bus command in Config\_516 to

```
"disp:tracel:y:rlevel:offset 0.8db"
```

### **TX Output Spectrum - 20 dB Bandwidth (5.1.7)**

#### **Test Method**

With this test it is checked whether emissions of the EUT exceeding the peak value of -20 dB are within the 1 MHz channel in each case.

1. Connect the EUT with the analyzer.
2. Configure the EUT.
3. Configure the stimulus generator if necessary.
4. In the demo program, select the *TX Output Spectrum – 20 dB Bandwidth* test by double-clicking the corresponding line.
5. Set the transmitter frequency and the reference level in the demo program.
6. Start the analyzer configuration by clicking the *Configure* button in the demo program.

When configuration is completed, the following settings are active:

- Transmitter frequency and reference level as entered
- Resolution bandwidth: 10 kHz
- Video bandwidth: 30 kHz
- Span: 2 MHz
- Detector: peak
- Mode: max hold
- Number of sweeps: 10
- Trigger: free run
- Sweep time manual: 1 s

The Bluetooth test specifications allow for automatic selection of the sweep time. The results obtained in this way are difficult to reproduce, however, since with 50 ms sweep time, for example, only 100  $\mu$ s per pixel is available. This covers no more than one sixth of a TX burst or one tenth of a TX / RX DH1 communication cycle.

With a sweep time of 1 s, on the other hand, about 2 TX bursts / pixel are reliably covered.

7. Start the test by clicking the *Start* button in the demo program.

After 10 measurements in the max hold mode, the demo program determines the maximum power. Then it searches all points lower than 20 dB, starting from the channel boundaries. (To this effect, it reads the analyzer memory.)

After successful completion of the test:

8. check the results in the *Results* window.
9. Repeat the test in different modes if required.

## Test Results

Fig. 12 shows the results output by the demo program, Fig. 13 the results displayed on the analyzer.

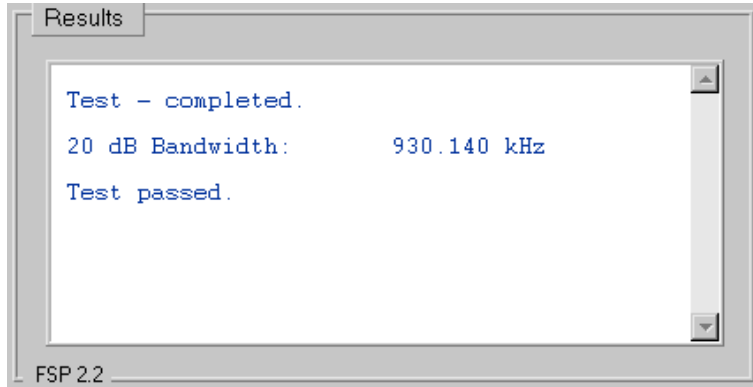


Fig. 12 TX output spectrum – 20 dB bandwidth: results output by demo program

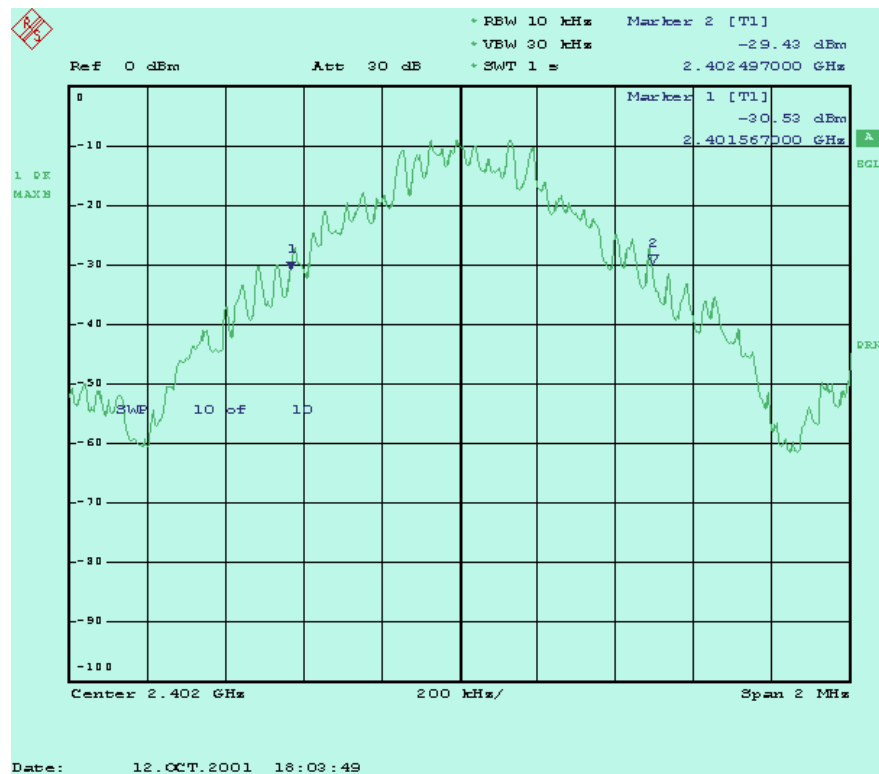


Fig. 13 TX output spectrum – 20 dB bandwidth: results displayed on analyzer

## Notes

With a sweep time of 1 s, the displayed result does not change significantly after a few sweeps. The sweep count can therefore be reduced.

- Optimize the sweep time and sweep count.

### **TX Output Spectrum - Adjacent Channel Power (5.1.8)**

#### **Test Method**

The adjacent channel power for each 1 MHz channel is calculated in accordance with the Bluetooth test specifications by adding up the results of 10 single measurements at a 100 kHz spacing within the channel boundaries. Each measurement is made over 10 sweeps.

The demo program performs the single measurements, adds up the results and displays the adjacent channel power for each channel. There is no comparison of adjacent channel powers in the demo program.

1. Connect the EUT with the analyzer.
2. Configure the EUT.
3. Configure the stimulus generator if necessary.
4. In the demo program, select the *TX Output Spectrum - Adjacent Channel Power* test by double-clicking the corresponding line.
5. Set the reference level in the demo program.
6. Start the analyzer configuration in the demo program by clicking the *Configure* button.

When configuration is completed, the following settings are active:

- Reference level as entered
- Start frequency: 2401.55 MHz
- Frequency step width: 100 kHz
- Resolution bandwidth: 100 kHz
- Video bandwidth: 300 kHz
- Zero span
- Detector: average
- Mode: max hold
- Sweep time manual: 100 ms
- Number of sweeps: 10
- Trigger: free run

7. Start the test by clicking the *Start* button in the demo program.

The demo program starts measuring at the frequency 2.402 GHz - 450 kHz, this is the lowest test frequency for channel  $N = 0$ . The maximum level measured in 10 sweeps is read out by the program. In the next step, the test frequency is increased by 100 kHz, the maximum level of 10 sweeps determined and read out, and so on.

After the 10th measurement, the adjacent channel power  $P_{TX}$  for channel  $N = 0$  is calculated and displayed.

This procedure is repeated until the upper measurement limit of 2.480 GHz + 450 kHz.



## Test Results

Fig. 14 is a screenshot of the analyzer during a running measurement; Fig. 15 shows the results output by the demo program.

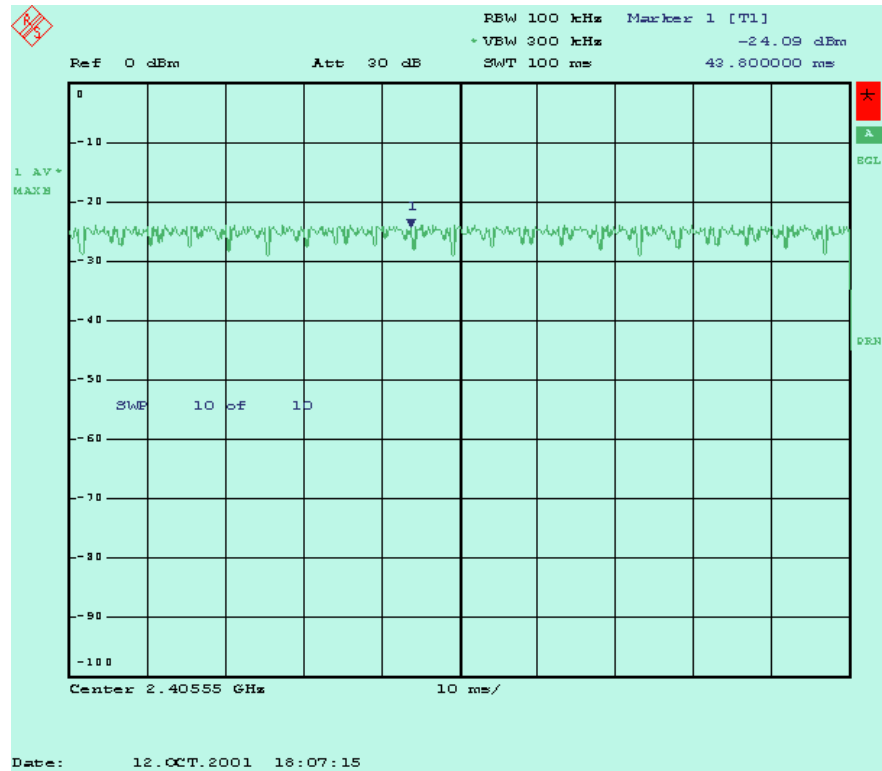


Fig. 14 Determining the adjacent channel power

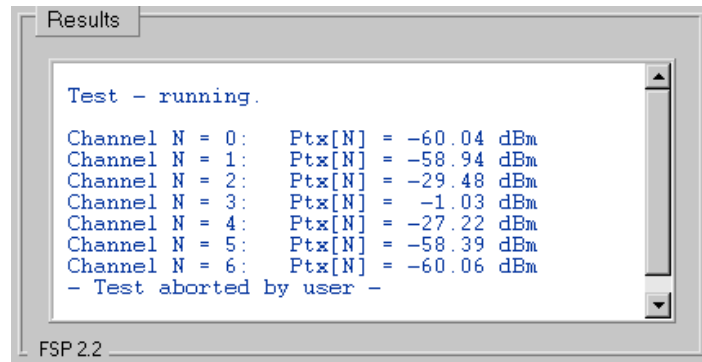


Fig. 15 Adjacent channel power: results output by demo program

### Notes

- Test specifications:

The Bluetooth test specifications (Rev. 0.9) stipulate that adjacent channel power be lower than -20 dBm at a spacing of two channels from the transmitting channel. In the channels spaced at a greater distance, adjacent channel power should be lower than -40 dBm.

It may be envisaged to change these absolute to relative values.
- Compensating external losses:

Enter the insertion loss between the EUT and the analyzer as a reference level offset on the analyzer. The analyzer will then display exactly the level values at the RF port of the EUT.

To compensate 0.8 dB cable loss, for example, change the IEC/IEEE-bus command in Config\_518 to

```
"disp:tracel:y:rlevel:offset 0.8db"
```

## Modulation Characteristics (5.1.9)

### Test Method

This test consists of two parts for which different patterns are used in the payload.

In the first part with the pattern 1111 0000..., the average deviation of the 'middle' bits (...11110000...) relative to the average frequency is determined.

In the second part with the pattern 1010 1010..., the maximum deviation relative to the average frequency is determined.

From version 1.5, the two partial tests with payload patterns 1111 0000 and 1010 1010 are implemented as separate, independent tests in addition to the combined test, in which the payload pattern has to be switched.

For either part of the test, results are obtained for each 8-bit section of the payload. The partial results are averaged to give the overall result. With Option FS-K7, control and result analysis are remote via GPIB, so the demodulated signal is displayed on the controller's monitor.

The analysis program has to perform the following tasks:

- Determining the start position of the payload (i.e. the first sample of the first bit of the payload)
- Displaying the packet found
- Computing the partial results (average and maximum deviation of each 8-bit section)
- Computing the overall result

The demo program operates without an external trigger signal. Instead, the data stream is recorded over a sufficiently long period of time, then the program searches for the start of the payload in the FSP memory. A 16-bit search word containing the payload data pattern is used. To accommodate for jitter and frequency offset, individual samples are not taken into account

on changing from 0 to 1 and vice versa when comparing measured data with the nominal pattern.

- If necessary, edit the search routine to match your transmit signal. For example, a different search pattern or a more complex correlation routine may be more appropriate for your application.
- If an external trigger signal is available, it should be used. It results in a substantial reduction in measurement time!

To carry out the measurement,

1. connect the EUT with the analyzer.
2. Configure the EUT.
3. Configure the stimulus generator if necessary.
4. In the demo program, select the *Modulation Characteristics* test by double-clicking the corresponding line.
5. Select the transmitter frequency, the packet type and the reference level in the demo program.
6. Start the analyzer configuration in the demo program by clicking the *Configure* button.

When configuration is completed, the following settings are active:

- Transmitter frequency, packet type and reference level as entered
  - Analyzer mode: FM demodulator
  - Points per symbol: 8 (eightfold oversampling)
  - Display of results: frequency versus time
  - Trigger: immediate
7. Start the test by clicking the *Start* button in the demo program.

### **Test Results**

After the start of the measurement and successful synchronization, the demo program displays the recorded packet. The window size corresponds to the maximum possible number of bits. The demodulated signals, frequency deviation versus time, are displayed.

Figures 16 and 17 show a DH1 packet, with payload patterns 1010 1010 and 1111 0000. If DH3 is selected as packet type, 1622 bits are displayed; with DH5, 2780.

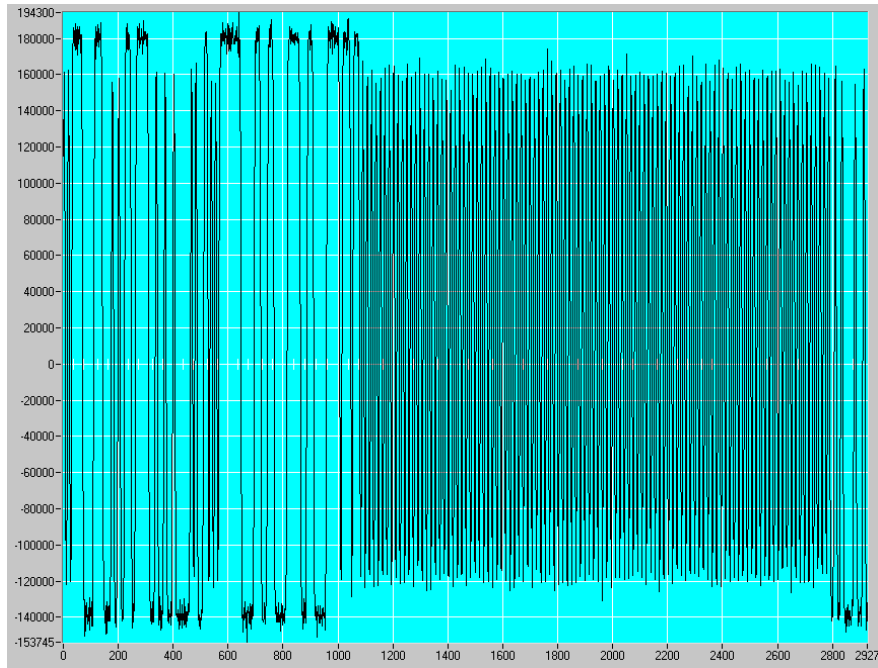


Fig. 16 Modulation characteristics: frequency deviation with pattern 1010 1010 (DH1 packet)

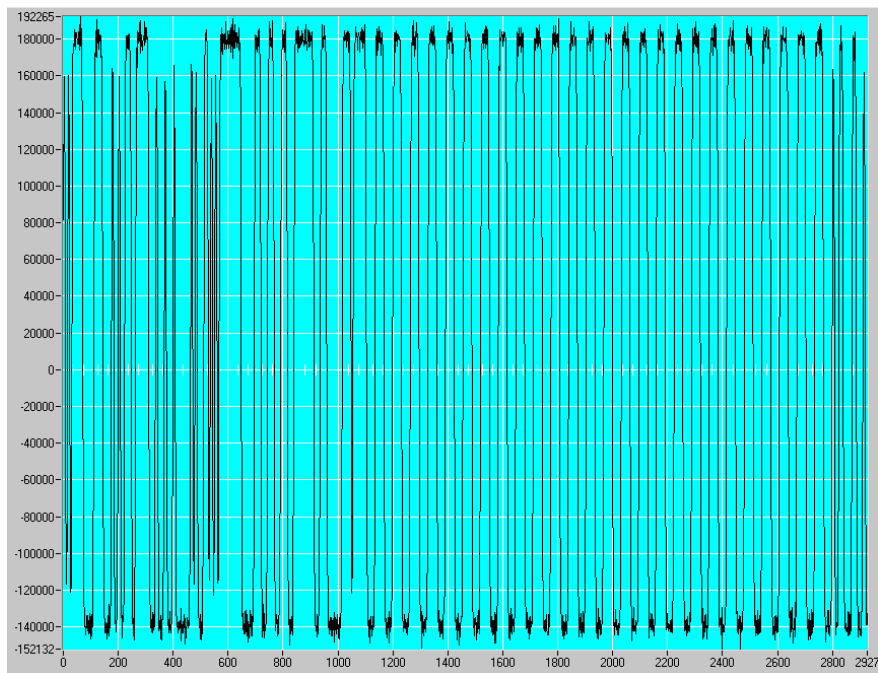


Fig. 17 Modulation characteristics: frequency deviation with pattern 1111 0000 (DH1 packet)

A continuous trace is obtained through linear interpolation between discrete measured values (samples).

The standard calls for a minimum of 4 samples per bit, the demo program for FSP uses 8 samples per bit. The X axis is scaled in samples. In the case of a DH1 packet, the payload data start with bit 134, i.e. at sample 1072.

## Transmitter Measurements on Bluetooth™ Modules

Whereas Figures 16 and 17 show the packet proper - the useful part of the burst - Fig. 18 is a screenshot of the overall burst, the upper trace showing RF power versus time, the lower trace the demodulated signal, i.e. frequency deviation versus time. (The signal was recorded with FSIQ Spectrum Analyzer.)

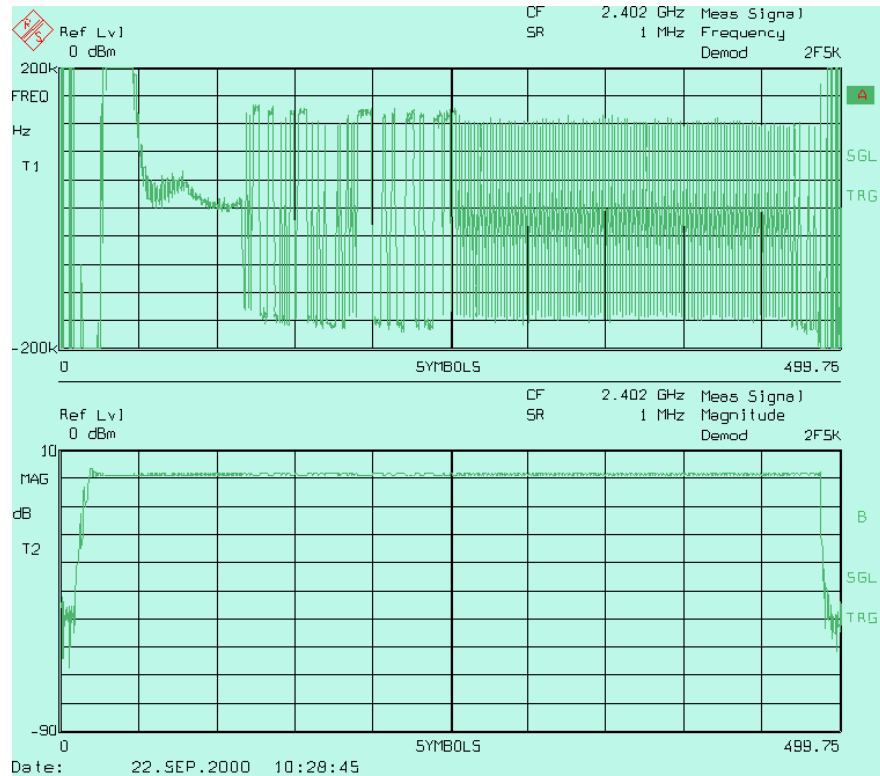


Fig. 18 Complete Bluetooth burst

The time resolution is  $50 \mu\text{s}$  per division. The packet with the valid modulation data does not start until about  $100 \mu\text{s}$  after the start of the burst; the time until the start of the packet is needed for the synthesizer to settle before data is modulated on the signal. In the first section of the burst, the signal is not valid, as its modulation is ambiguous. To determine the exact start of the payload, a search pattern must be selected which does not occur in the undefined section. The payload pattern can be used since it differs from the access code, the header, and the payload header for either part of the test.

Fig. 19 shows the numerical results output by the demo program.

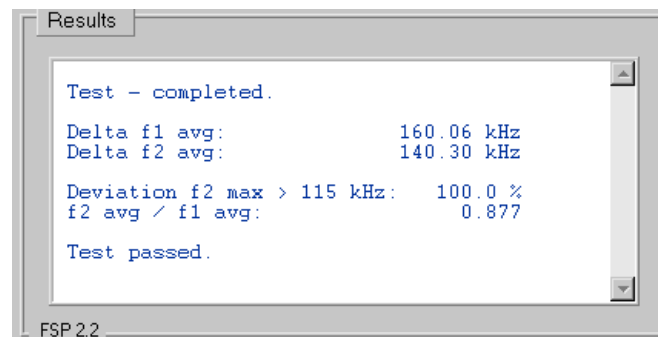


Fig. 19 Modulation characteristics: results output by demo program

## ***Transmitter Measurements on Bluetooth™ Modules***

---

- Repeat the test for the same frequency and for different frequencies.

### **Notes**

- To form an average over several measurements, activate the Averaging checkbox on the user interface of the demo program.
- To change the number of sweeps to be averaged, assign a different value to the `AVERAGING` constant in the `ui.h` module.

### **Initial Carrier Frequency Tolerance (5.1.10)**

#### **Test Method**

This test determines the frequency accuracy of the beginning of a packet by integrating the frequency samples of the preamble bits. According to the Bluetooth test specifications, a DH1 packet with PRBS9 payload should be used as a transmitter signal.

For integration from bit position 0.5 to 3.5, the precise start position p0 must first be determined. The preamble itself is too short to serve as a search word. (The preamble pattern in part also occurs in the invalid part of the burst ahead of the preamble.)

So, in this test too, the demo program synchronizes to the payload.

- Use the 1010 data pattern instead of PRBS9.

With Option FS-K7, control and result analysis are remote via GPIB, so the demodulated signal is displayed on the controller's monitor.

The demo program operates without an external trigger signal. Instead, the data stream is recorded over a sufficiently long period of time, then the program searches the start of the payload in the FSP memory.

- If necessary, edit the search routine to match your transmit signal. For example, a different search pattern or a more complex correlation routine may be more appropriate for your application.
- If an external trigger signal is available, it should be used. It results in a substantial reduction in measurement time!

To carry out the measurement:

1. connect the EUT with the analyzer.
2. Configure the EUT.
3. Configure the stimulus generator if necessary.
4. In the demo program, select the *Initial Carrier Frequency Tolerance* test by double-clicking the corresponding line.
5. Select the transmitter frequency, the packet type and the reference level in the demo program.
6. Start the analyzer configuration in the demo program by clicking the *Configure* button.

When configuration is completed, the following settings are active:

- Transmitter frequency, packet type and reference level as entered
  - Analyzer mode: FM demodulator
  - Bluetooth modulation parameters
  - Points per symbol: 8 (eightfold oversampling)
  - Display of results: frequency versus time
  - Trigger: immediate
8. Start the test by clicking the *Start* button in the demo program.

### Test Results

Once synchronization has taken place, the demo program displays the recorded packet. The window size corresponds to the maximum possible number of bits.

The complete packet is displayed, so it can be ascertained whether the software synchronization procedure has operated properly.

The demodulated signals, i.e. the frequency deviation versus time, are displayed. Fig. 20 shows 366 bits of a DH1 packet. If DH3 is selected as packet type, 1622 bits are displayed, if DH5, 2870 bits.

A continuous trace is obtained through linear interpolation between discrete measured values (samples). The standard calls for a minimum of 4 samples per bit, the demo program for FSP uses 8 samples per bit. The X axis is scaled in samples. In the case of a DH1 packet, the payload data starts with bit 134, at sample 1072.

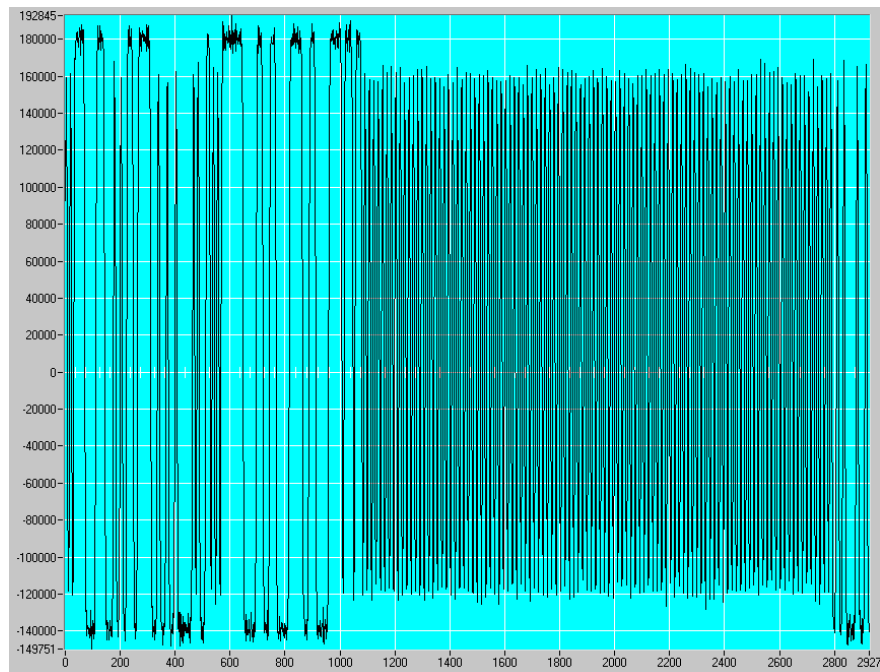


Fig. 20 Initial carrier frequency: packet displayed on analyzer

Confirm the complete packet with *OK*, the preamble section selected by the program is displayed (see Fig. 21). The sample values are joined by straight lines.



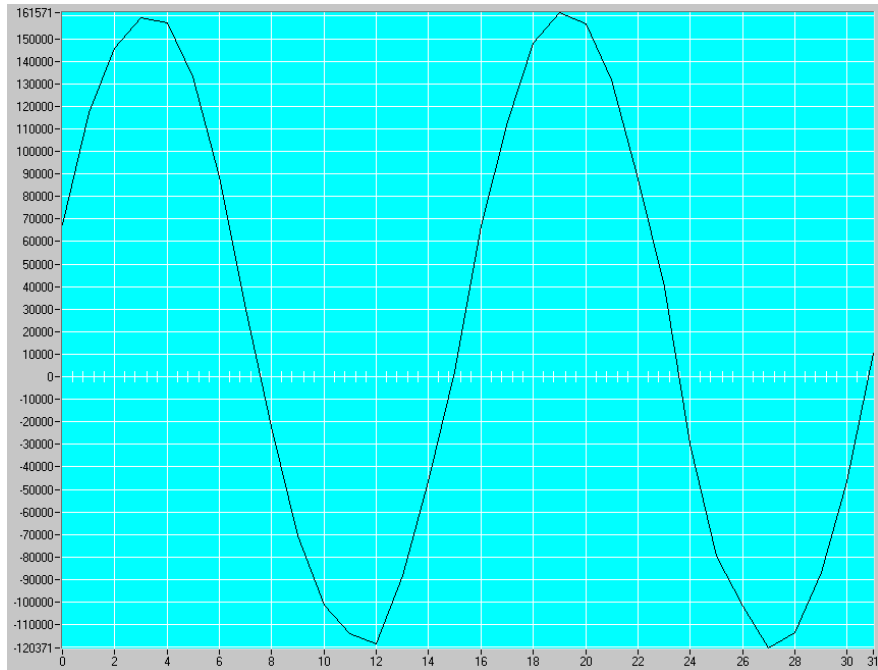


Fig. 21 Initial carrier frequency: samples of the preamble

Fig. 22 shows the results obtained for this measurement:

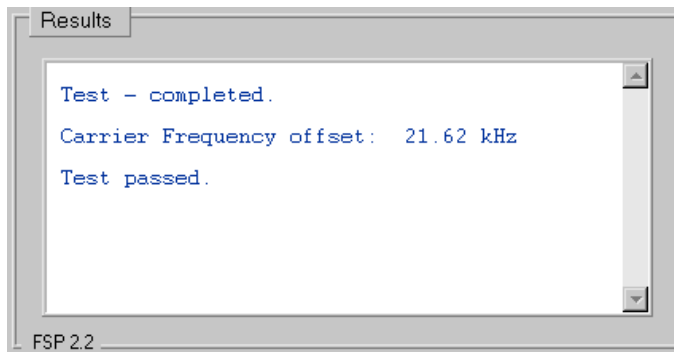


Fig. 22 Initial carrier frequency: results output by demo program

- Repeat the test for the same frequency and for different frequencies.

### Notes

- To form an average over several measurements, activate the Averaging checkbox on the user interface of the demo program.
- To change the number of sweeps to be averaged, assign a different value to the AVERAGING constant in the ui.h module.
- If the access code is known, it is also possible to synchronize to the access code instead of the payload. The payload however offers the advantages of being independent of the tester and the EUT and offering the longest synchronization pattern.

### **Carrier Frequency Drift (5.1.11)**

#### **Test Method**

Similar to the *Modulation Characteristics* measurement, the average frequencies of different packet sections are determined and the results are compared with one another. These sections are the preamble as well as 10-bit groups of the payload.

As in the previous tests, the demo program finds the start point and calculates the results.

With Option FS-K7, control and result analysis are remote via GPIB, so the demodulated signal is displayed on the controller's monitor.

The demo program operates without an external trigger signal. Instead, the data stream is recorded over a sufficiently long period of time, then the program searches for the start of the payload in the FSP memory.

- If necessary, edit the search routine to match your transmit signal. For example, a different search pattern or a more complex correlation routine may be more appropriate for your application.
- If an external trigger signal is available, it should be used. It results in a substantial reduction in measurement time!

To carry out the measurement:

1. connect the EUT with the analyzer.
2. Configure the EUT.
3. Configure the stimulus generator if necessary.
4. In the demo program, select the *Carrier Frequency Drift* test by double-clicking the corresponding line.
5. Select the transmitter frequency, the packet type and the reference level in the demo program.
6. Start the analyzer configuration in the demo program by clicking the *Configure* button.

When configuration is completed, the following settings are active:

- Transmitter frequency, packet type and reference level as entered
  - Analyzer mode: FM demodulator
  - Bluetooth modulation parameters
  - Points per symbol: 8 (eightfold oversampling)
  - Display of results: frequency versus time
  - Trigger: immediate
7. Start the test by clicking the *Start* button in the demo program.

### Test Results

Once synchronization has taken place, the demo program displays the recorded packet. The window size corresponds to the maximum possible number of bits.

The complete packet is displayed, to show whether the software synchronization procedure has operated properly.

The demodulated signals, i.e. the frequency deviation versus time, are displayed. Fig. 23 shows 366 bits of a DH1 packet. If DH3 is selected as packet type, 1622 bits are displayed, if DH5, 2870 bits.

A continuous trace is obtained through linear interpolation between discrete measured values (samples). The standard calls for a minimum of 4 samples per bit, the demo program for FSP uses 8 samples per bit. The X axis is scaled in samples. In the case of a DH1 packet, the payload data starts with bit 134, at sample 1072.

Confirming the complete packet with *OK*, the program adds up the results for each section and calculates the absolute and the relative maximum differences. The results are output graphically (Fig. 24) and numerically (Fig. 25).

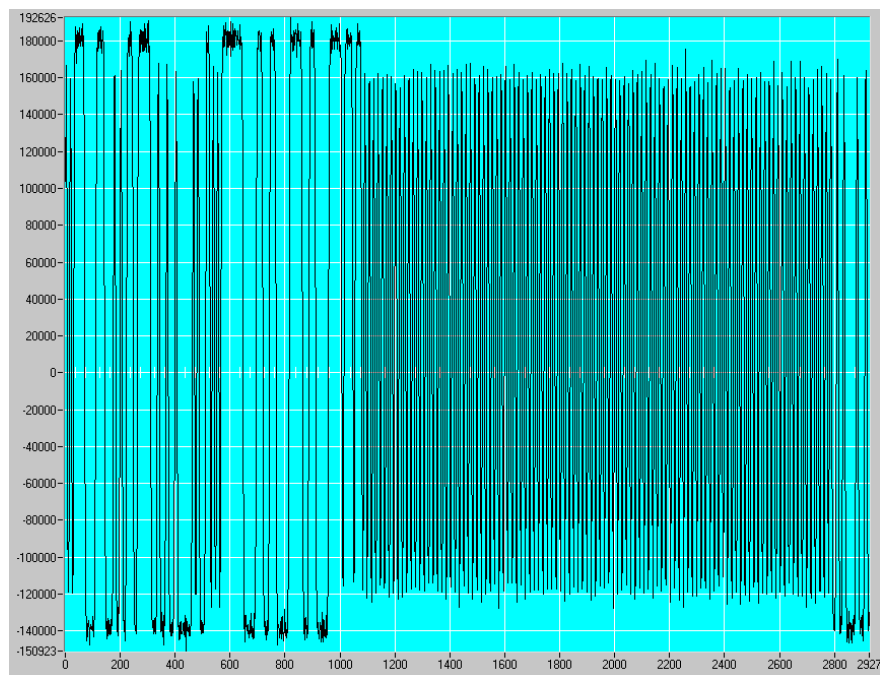


Fig. 23 Carrier frequency drift: packet displayed on analyzer

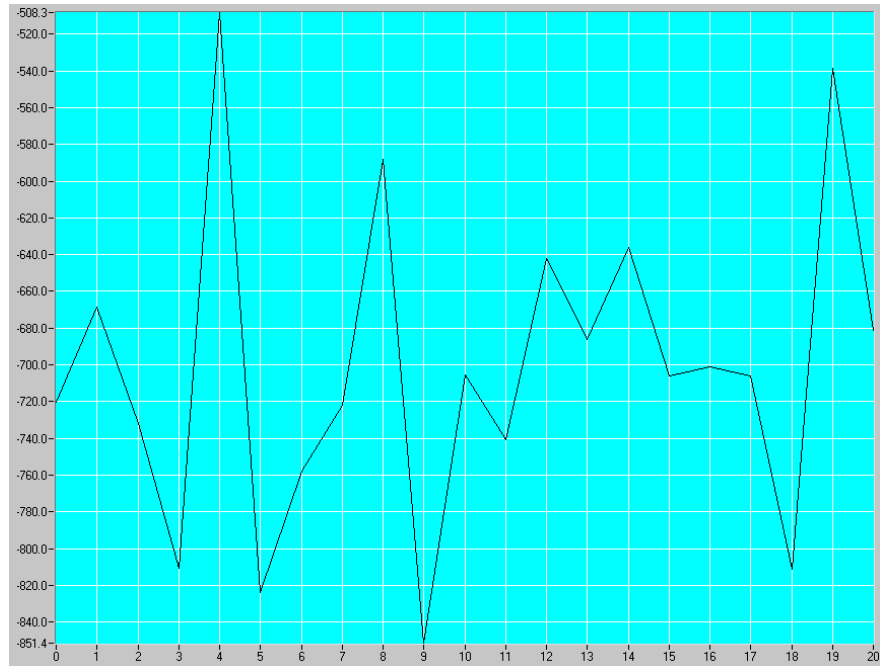


Fig. 24: Carrier frequency drift of the individual 10-bit groups

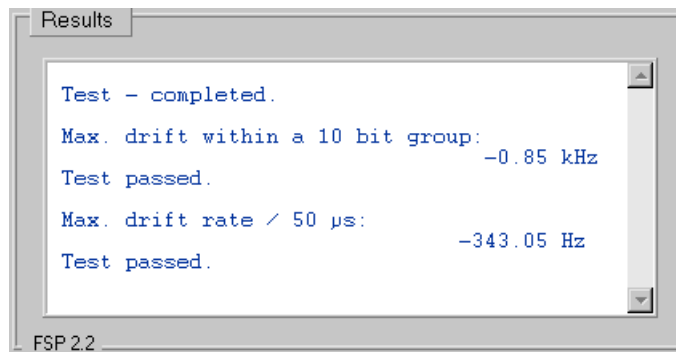


Fig. 25 Carrier frequency drift: results output by demo program

- Repeat the test for the same and for different frequencies.

### Notes

- To form an average over several measurements, activate the Averaging checkbox on the user interface of the demo program.
- To change the number of sweeps to be averaged, assign a different value to the AVERAGING constant in the ui.h module.

### **7 Further Test Possibilities**

This application note describes how to carry out transmitter measurements in accordance with the Bluetooth test specifications using an FSP and a controller.

But this is by far not all FSP Spectrum Analyzer has to offer in terms of Bluetooth measurements.

You may wish to examine the transient behaviour of the synthesizer of your module, for example. Simply configure and start the FSP as for the *Modulation Characteristics* test. After localizing the start of the packet in the memory, you can select any part of the recorded data stream for analysis.

Or, you can measure the emissions of your module with the transmitter switched off, and so on.

Treat the demo program supplied with this application note as a specimen from which you can create test programs of your own. You can modify the program to your own test sequences and requirements in terms of frequencies, spans, sweep times, trigger conditions. You can also use it as a tool for optimizing your test procedures.

### **8 References**

- [1] Bluetooth RF Test Specification, Revision 0.91, 23.7.2001
- [2] Bluetooth Core Specification, Revision 1.0b, 12.6.1999
- [3] Transmitter Measurements on Bluetooth Modules, Application Note 1MA26, Rohde & Schwarz, 2000
- [4] Generation of Bluetooth RF Test Signals with Signal Generator SMIQ, Application Note 1MA31, Rohde & Schwarz, 2000
- [5] Creating Test Signals for Bluetooth with AMIQ/WinIQSIM and SMIQ, Application Note 1GP38, Rohde & Schwarz, 1999

### 9 Ordering Information

To perform the transmitter measurements presented in this application note, Spectrum Analyzer FSP with option FS-K7 is needed.

Option FS-K7 provides an AM / FM measurement demodulator for the FSP. Control and result analysis are remote via the GPIB.

For further information about the equipment and options described, please contact your local R&S representative.

#### Spectrum Analyzer FSP:

FSP	9 kHz up to 3 GHz	1093.4495.03
FSP	9 kHz up to 7 GHz	1093.4495.07
Options:		
FS-K7	FM- / AM-Demodulator	1141.1796.02

Further instruments from the Rohde & Schwarz product line useful for Bluetooth measurements:

#### Vector Signal Generator SMIQ:

SMIQ02B	300 kHz up to 2.2 GHz	1125.5555.02
SMIQ03B	300 kHz up to 3.3 GHz	1125.5555.03
SMIQ04B	300 kHz up to 4.4 GHz	1125.5555.04
SMIQ06B	300 kHz up to 6.4 GHz	1125.5555.06
Options:		
SMIQB11	Data Generator	1085.4502.04
SMIQB12	Memory Extension	1085.2800.04
SMIQB20	Modulation Coder	1125.5190.02
AMIQ	I/Q Modulation Generator	1110.2003.03/04
PSM	Industrial Controller	1116.5004.70/20
PSM-K10	System Software	1116.7507.31/32
PSP7	Industrial Controller	1099.6002.71
PSP-K10	System Software	1091.4500.31/32
PS-B4	IEEE 488.2-Bus Interface	1006.6207.04
TS9860	BLUETOOTH CERTIFICATION / TYPE APPROVAL TEST SYSTEM	1133.1810.02
CMU	Universal Radio Communication Tester	1100.0008.02
PTW60	Bluetooth Protocol Tester	1133.3006.02



ROHDE & SCHWARZ GmbH & Co. KG · Mühldorfstraße 15 · D-81671 München · Postfach 80 14 69 · D-81614 München ·  
Tel (089) 4129 -0 · Fax (089) 4129 - 13777 · Internet: <http://www.rohde-schwarz.com>

*Die Nutzung dieser Application Note und der mitgelieferten Programme darf nur unter Anerkennung der Nutzungsbedingungen erfolgen, die in der Download-Area der Rohde & Schwarz-Web-Site aufgeführt sind.*