



Products: FSE, FSIQ

Transmitter Measurements on Bluetooth™ Modules

Application Note

This application note describes how to perform measurements on transmitter modules – largely in conformance with the Bluetooth test specifications – by remote control using FSE or FSIQ Analyzer.

A demo program enclosed with this application note facilitates integration of the analyzers 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. Moreover, the demo program serves as a model for creating user-specific analysis routines.

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1 Overview

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

A demo program enclosed with this application note facilitates integration of the analyzers 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. Moreover, the demo program serves as a model for creating your own analysis routines.

Note: *This application note is intended for use in development and production. There are, therefore, certain limitations with respect to the requirements of the Bluetooth test specifications. In particular, FSE and FSIQ Analyzers do not have signalling capability to switch the Equipment Under Test (EUT) to the test mode.*

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

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 out the optimal parameters for your application 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 the PSM or PSP Industrial Controller if ordered together with the controller (subsequent delivery of the software is not possible).

All measurements described here can be performed both with FSIQ Signal Analyzer and FSE Spectrum Analyzer (with option FSE-B7); operation is the same for both analyzers.

The descriptions given in the following are based on transmitter tests in the Version 0.9 Bluetooth test specifications. The test setup shown in section 3, however, allows only one-slot packets to be measured.

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 FSIQ or FSE Analyzer and the demo program.

The tests vary considerably in complexity. For power measurements, the analyzer itself is sufficient to obtain a result, whereas modulation and drift measurements in particular require a large amount of subsequent computation to verify whether or not the test was passed.

The sequence for each test is as follows:

1. Configure the equipment under test (EUT).
2. Configure the test system.
3. Run the measurements to obtain data.
4. Analyse the data obtained.

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.

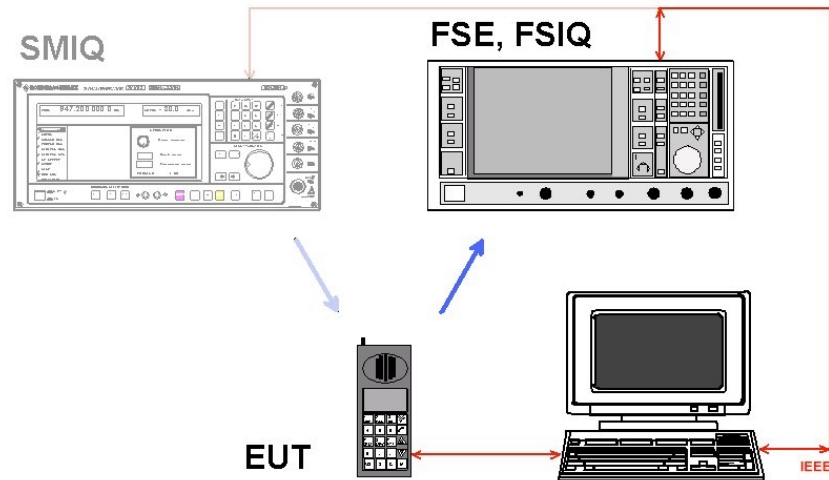


Fig. 1 Test setup for transmitter measurements

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

The analyzer is configured by a test program (for example the demo program, which runs on a PC 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 SMIQ Signal Generator.

You can carry out all transmitter signal measurements using only FSE Spectrum Analyzer with option FSE-B7, or FSIQ Signal Analyzer, and a controller.

FSE and FSIQ Analyzers themselves can be used as controllers, see section 'Hardware and Software Requirements'.

In section 7 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. This can be effected by the test equipment setting up a call with the EUT. In development and production, however, it is certainly more advantageous to activate suitable, manufacturer-specific test modes which directly trigger the EUT to transmit.

If a simple Bluetooth stimulus signal is needed, it can be generated with SMIQ Signal Generator or a combination of SMIQ and AMIQ I/Q Modulation Generator.

On SMIQ, all parameters for the Bluetooth standard (modulation mode, deviation, filtering) can be loaded at a keystroke. Use the Rohde & Schwarz WinIQSIM software package to generate standard-conforming packet data. For detailed instructions see Application Note 1GP38.

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

Hopping

For tests in development and production, hopping can be reduced to two frequencies without affecting the results. 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 EUT synthesizer has to handle the maximum frequency range.

Coupling the EUT

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

This insertion loss has to be exactly determined for quantitative 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 controller, for example Rohde & Schwarz PSM or PSP Industrial Controller with PS-B4 16-bit GPIB bus card or an equivalent GPIB bus card from National Instruments. The appropriate driver software must be installed on your computer.

FSE and FSIQ themselves can be used as controllers. FSE requires option FSE-B15 (Controller for FSE operating under WIN NT, Order No. 1073.5696.06). This option cannot be retrofitted, so the application program cannot run on an older FSE-B15, which operates under DOS/WIN3.1.

The demo program runs 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 PSP Industrial Controller if ordered together with the controller (subsequent delivery of the software is not possible).

Installing the Demo Program

The demo program is enclosed with this application note as a self-expanding file (1ma26_xx.exe; 'xx' = version number). Install the program as follows:

1. Copy 1ma26_xx.exe to a directory of your choice.
2. Call 1ma26_xx.exe.

Among the files expanded, you will find the setup.exe installation program.

3. 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 1ma26_xx.exe, bt_tx.001...003 and setup.exe can be deleted.

Files of Demo Program

The structure of the 1ma26 demo program is very straightforward. The most important module is the 'tests.c' file. This file contains a configuration (Config_) and a measurement (Run_) 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

up 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 the Demo Program

1. Install the 1ma26 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 1ma26 demo program.

On program start, the demo program checks whether FSE or FSIQ Analyzer is connected to the bus and stores the corresponding IEC/IEEE-bus address. If neither of the two analyzers is detected, an error message is output and the program is terminated after the message is acknowledged.

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

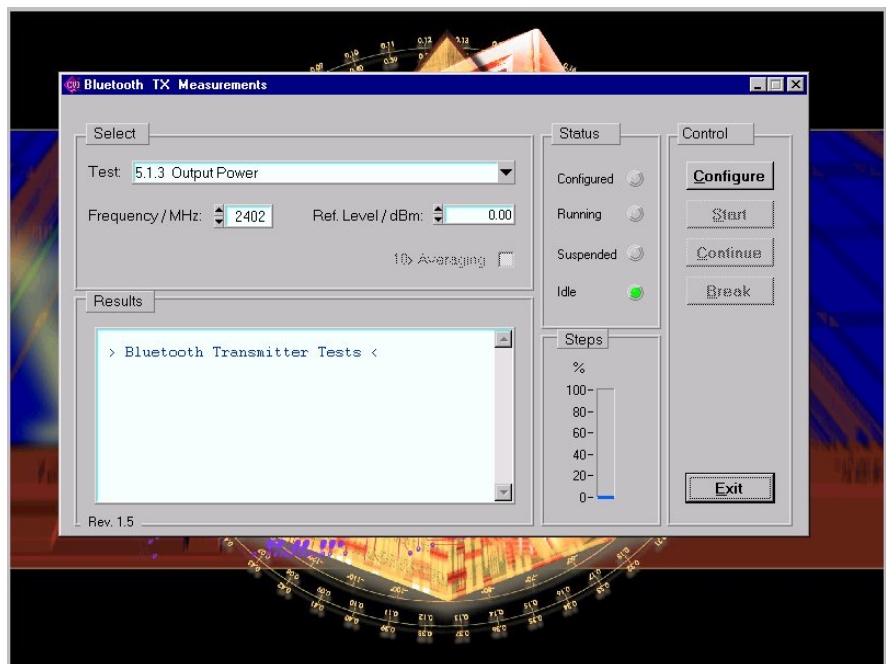


Fig. 2 User interface of demo program

Selecting a Test

1. Double-click the arrow pointing downwards in the *Tests* line. The test list appears:

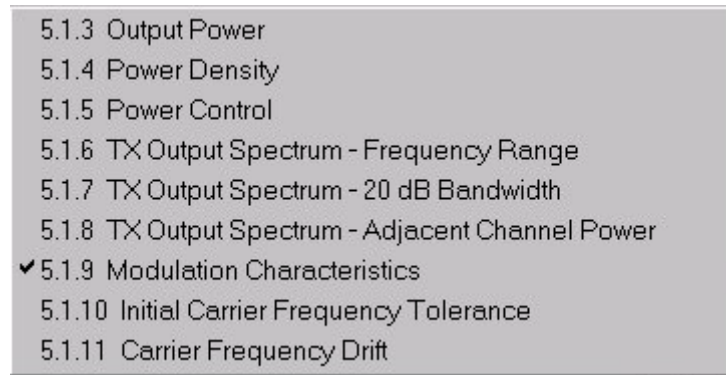


Fig. 3 List of supported tests

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 MHz (low)
2.441 MHz (mid)
2.480 MHz (high)
- Reference level: max. output level of EUT
- Averaging: on / off

Some parameters are not applicable for all tests. The corresponding field is then grey and inactive.

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

Other test parameters are assigned fixed settings. This concerns, 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.

2. 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.

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 necessary, for example if 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

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 at least 20% to 80% of the burst is evaluated. The analyzer is in zero span mode. Both results are obtained in a single measurement.

1. Connect the EUT to 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: 650 μ s
- Trigger: internal video

7. Start the test by clicking the *Start* button in the demo program.
8. Check results in the *Results* window.

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 by the analyzer.

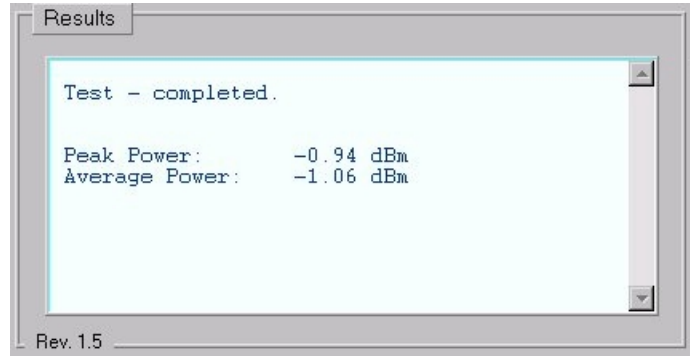


Fig. 4 Output power: results displayed by demo program

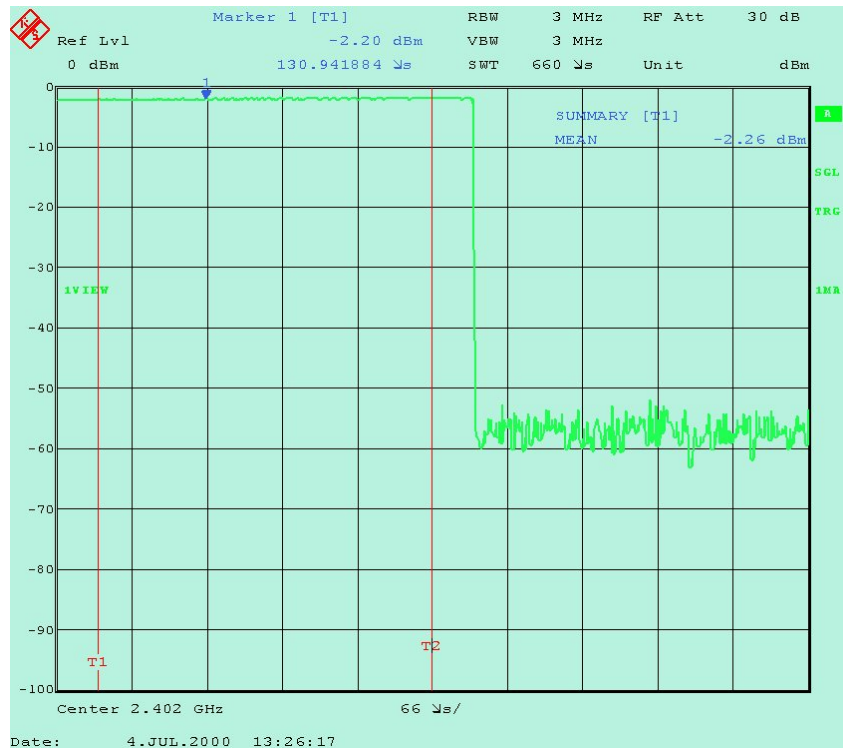


Fig. 5 Output power: results displayed by analyzer

The peak value and the rms value are shown as the results of a summary marker covering the range between time lines TS1 and TS2. TS1 is positioned at 10%, TS2 at 90% of the active part of the burst.

The time lines are not visible in remote control. To display the lines, switch the analyzer to LOCAL.

Notes

- **Trigger:**

The demo program uses an internal trigger (trigger on power ramp). This trigger setting 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:

```
"trig:seq:sour ext"
```
- **Burst width:**

The Bluetooth test specifications stipulate that either p0 (the first bit of the packet) be taken as the start of the burst or the -3 dB power limit. The definition used in each case will for real bursts lead to different widths since, depending on the manufacturer, the output stage is activated well 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 time lines as required for your application. The IEC/IEEE-bus command for positioning time line 1 to 10% (for example) of a 400 µs burst is as follows (see Config_513 routine):

```
"calc:tlin1 0.040ms"
```
- **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 as 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 for 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. It can be seen immediately whether the burst is within all the limits defined.

Further parameters can be calculated with the summary marker, for example +peak and -peak, \pm peak / 2 and MEAN.
- **Measurable packets:**

One-slot packets can be measured.
- **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 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
- 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 inaccuracy 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 ≤ 50 MHz (FSE and FSIQ Analyzers have a display resolution of 500 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, which is too long for a demo program. The value can be changed 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.

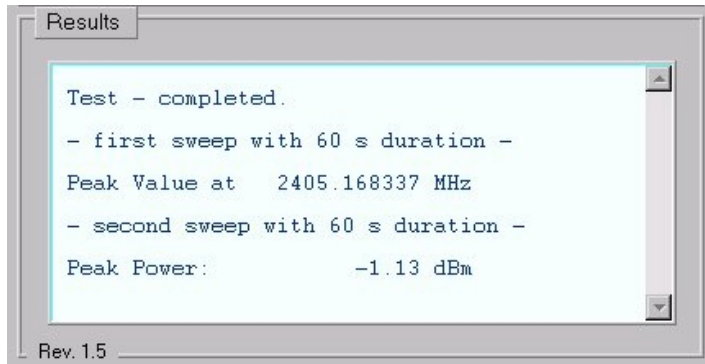


Fig. 6 Power density: results displayed by demo program

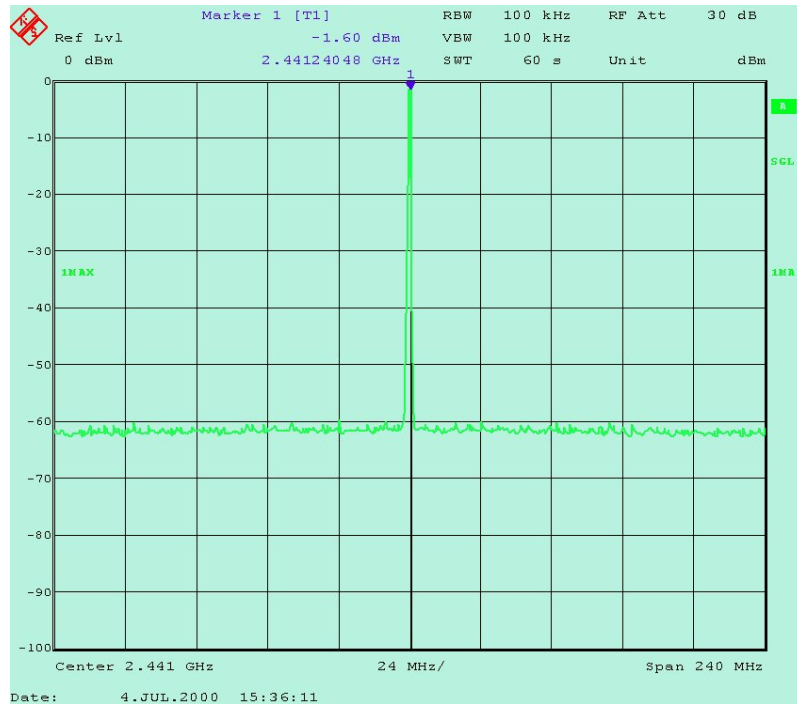


Fig. 7 Power density: results displayed by analyzer, part 1

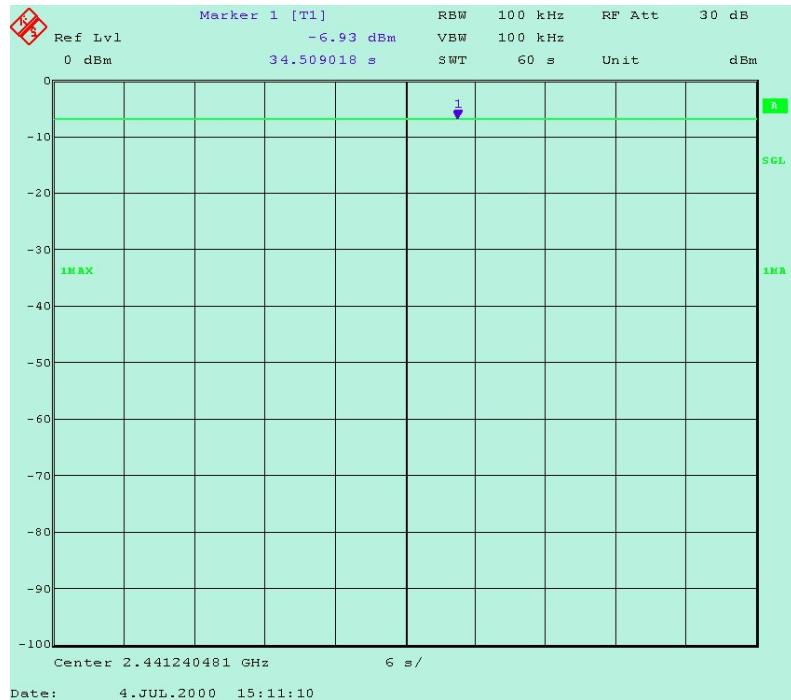


Fig. 8 Power density: results displayed by analyzer, part 2

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 for 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 *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

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 by reading 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 and the test is aborted.

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.

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.

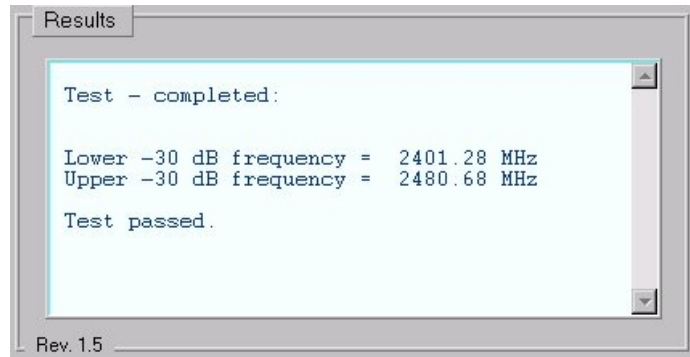


Fig. 9 TX spectrum – frequency range: results displayed by demo program

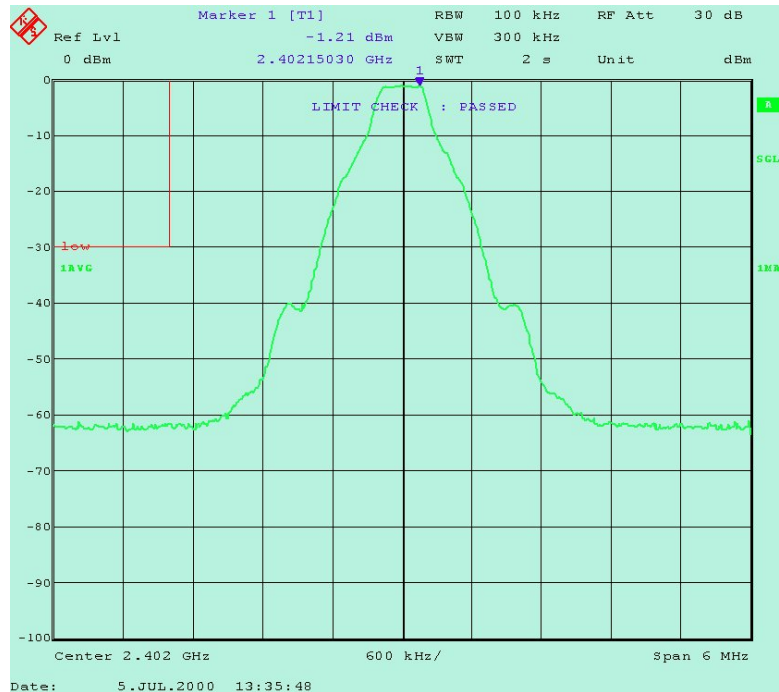


Fig. 10 TX Spectrum - frequency range, lower end of band

There are red limit lines inserted in the analyzer display shown. They mark the range which the test curve must not intersect in accordance with the test specifications. (The time lines are not visible in remote control. To display the lines, switch the analyzer to LOCAL).

Whereas the Bluetooth test specifications stipulate the lower and the upper -30 dB frequency to be determined (which is implemented 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.

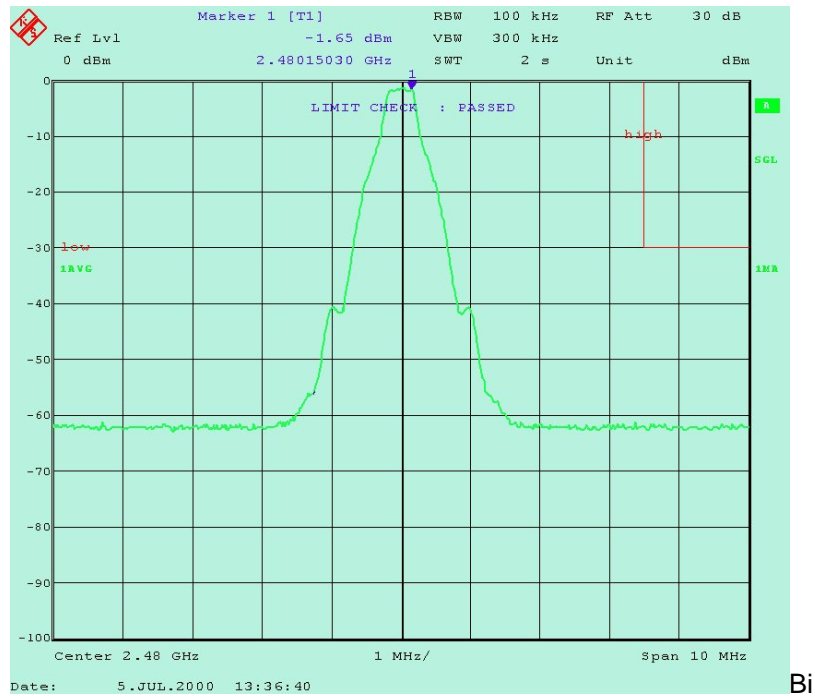


Fig. 11 TX spectrum - frequency range, upper end of band

Notes

- Compensating external losses:

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

To compensate for 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

This test checks 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 μ 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.

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 by the analyzer.

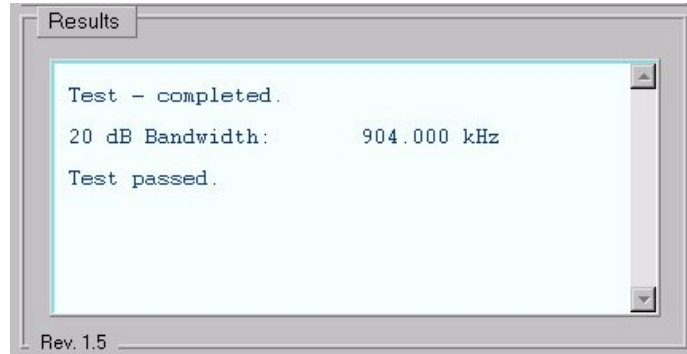


Fig. 12 TX output spectrum – 20 dB bandwidth: results displayed by demo program



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

Note:

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.

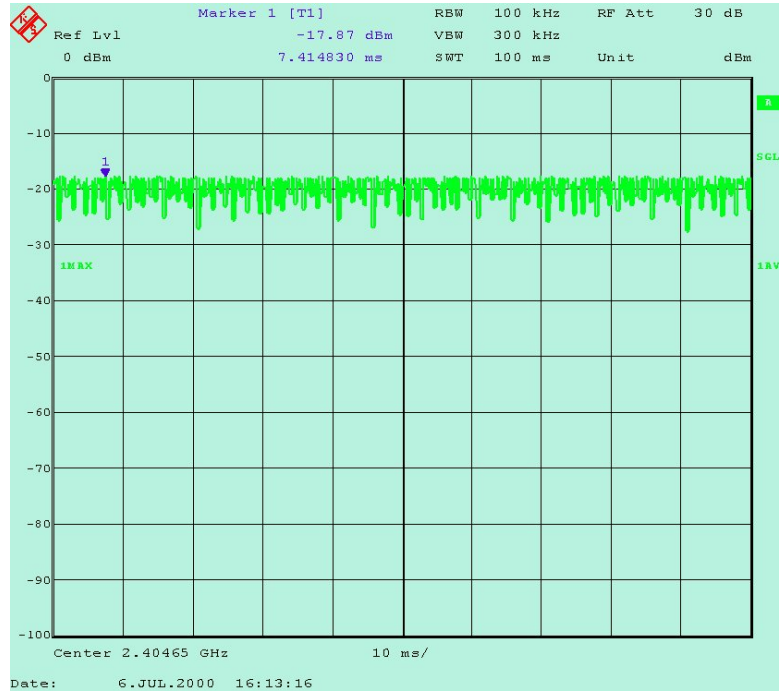


Fig. 14 Determining the adjacent channel power

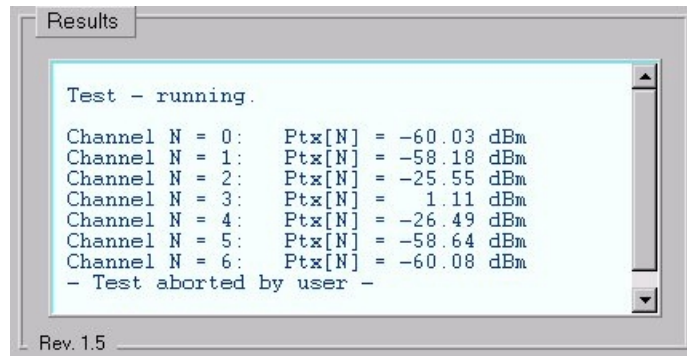


Fig. 15 Adjacent channel power: results displayed by demo program

Notes

- Test specifications:
The Bluetooth test specifications (Rev. 0.9) stipulate that adjacent channel power at a spacing of two channels from the transmitting channel be lower than -20 dBm. 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 for 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...) from the average frequency is determined.

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

In either case, single results are obtained each for 8-bit sections of the payload. The overall result is obtained by forming the average of the single results.

Calculating the overall result from such a large number of single results, which also have to be determined first, is not possible on the analyzer but a task for the controller software. The analysis program has to perform the following tasks:

- Determining the start position (ie the first sample of the first bit) of the payload.
- Computing the single results (average frequency, deviation of each section).
- Computing the overall result.

The demo program carries out all the above steps and calculates the overall result.

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. Set the transmitter frequency 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 and reference level as entered
 - Analyzer mode: vector analyzer
 - Bluetooth settings
 - Points per symbol: 4 (oversampling: fourfold)
 - Display of frequency versus time
 - Result length: 500 symbols
 - Trigger: video 80%
7. Start the test by clicking the *Start* button in the demo program.

Test Results

Figs 16 to 18 show the results of measurements on a real Bluetooth DH1 packet.

Fig. 16 displays the amplitude versus time. Figs 17 and 18 show the frequency deviation versus time. In Fig. 17, data pattern 1111 0000 is used, in Fig. 18 data pattern 1010 1010.

The time resolution is 50 μ s/div in each case. When comparing Fig. 16 with Fig. 17 or 18, it can be seen that an RF signal is present approximately 100 μ s ahead of the preamble, this signal is without valid modulation however.

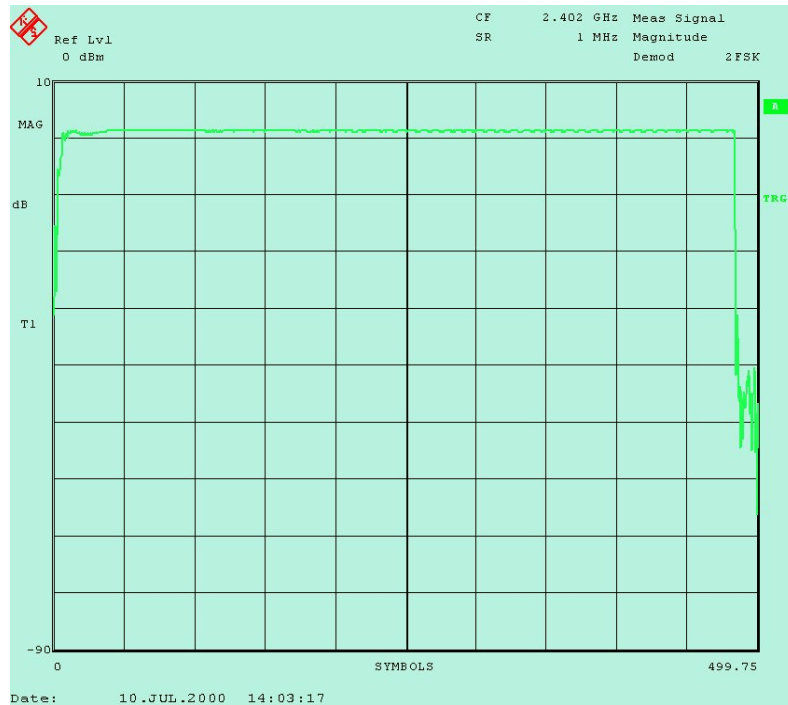


Fig. 16 Modulation characteristics: magnitude

Because of this invalid part, the analyzer cannot find the optimal symbol times for the relevant data in the measurement window or determine the exact start time of the data. These tasks, therefore, have to be software-implemented as mentioned above.

The demo program first reads the complete memory contents and searches for the nominal pattern. 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. As a result, the start index of the first sample of the first payload bit of the array containing the measured data is determined.

8. If necessary, edit the search routine to match your transmit signal. For example, a more complex correlation routine may be required.

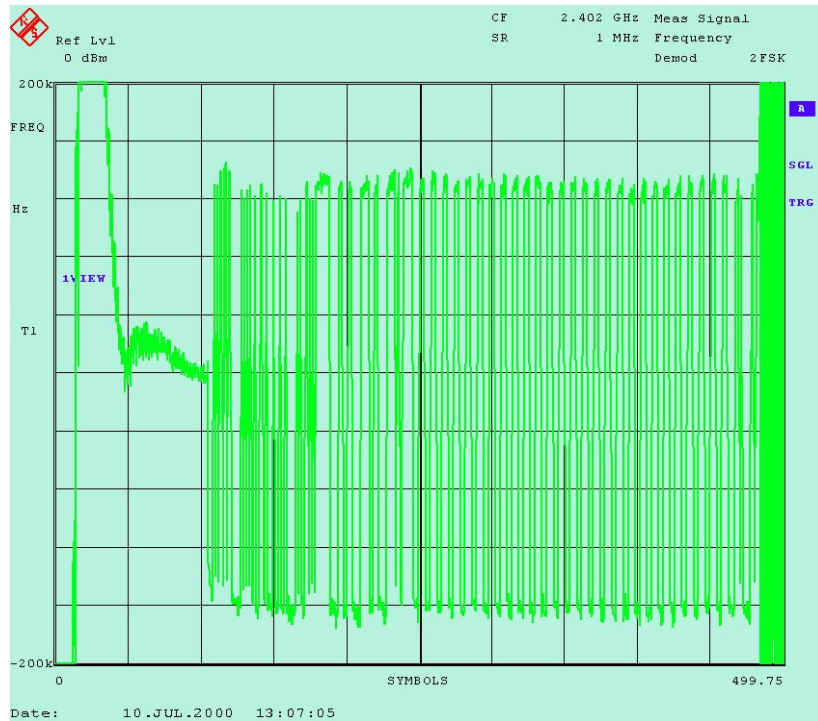


Fig. 17 Modulation characteristics: frequency deviation with pattern 1111 0000

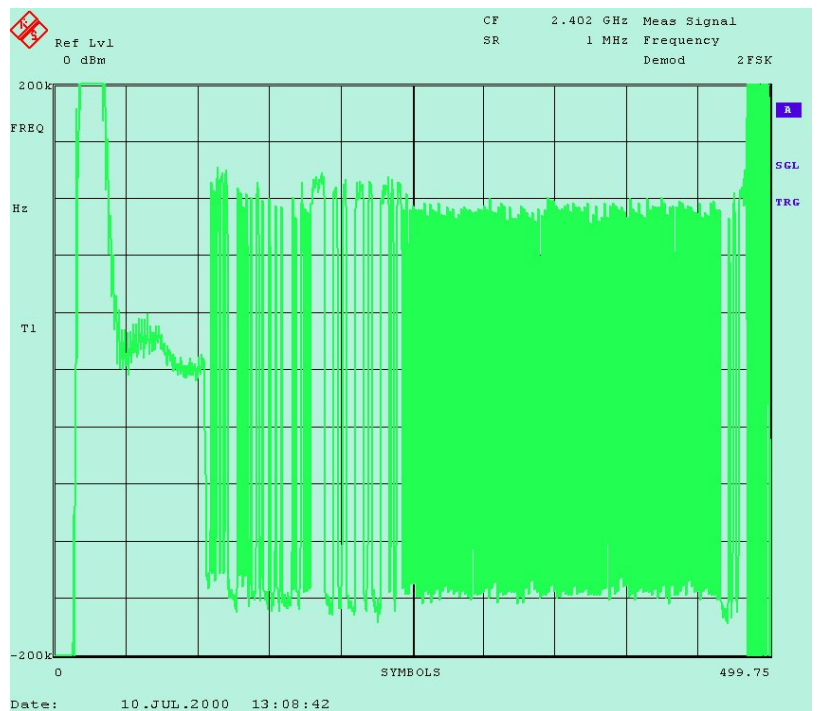
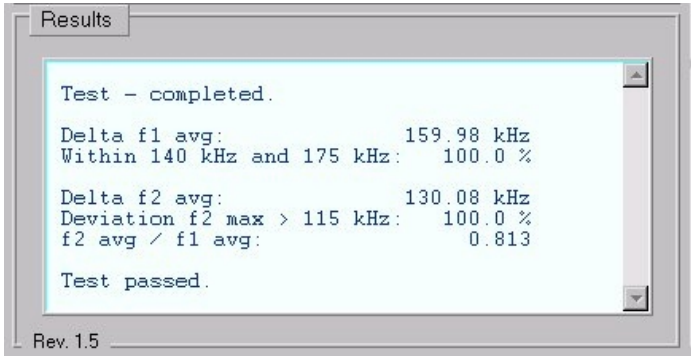


Fig. 18 Modulation characteristics: frequency deviation with pattern 1010 1010

The described synchronization procedure carried out by the program is the same for both parts of the test (ie for the 1111 0000 and the 1010 1010 pattern). This is possible since the payload header differs from the payload pattern in either case.

After synchronization, the steps differ for the two parts. To calculate the average frequency for each 8-bit section, the demo program uses all the available samples.

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



```
Results
-----
Test - completed.

Delta f1 avg:           159.98 kHz
Within 140 kHz and 175 kHz: 100.0 %

Delta f2 avg:           130.08 kHz
Deviation f2 max > 115 kHz: 100.0 %
f2 avg / f1 avg:       0.813

Test passed.

Rev. 1.5
```

Fig. 19 Modulation characteristics: results displayed by demo program

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

Notes

- With only fourfold oversampling, the actual maximum frequency deviation *Delta f2 avg* cannot be optimally determined by means of a single measurement. Results will, therefore, be spread to some extent.
- 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* program module.

Initial Carrier Frequency Tolerance (5.1.10)

Test Method

This test is to determine the frequency accuracy of the preamble of a packet. This is done by integration over the frequencies of the four bits of the preamble. According to the Bluetooth test specifications, a DH1 packet with PRBS9 payload should be used as a transmitter signal.

For integration over the four bits of the preamble, the precise start position p_0 must first be determined. The preamble itself is too short to serve as an unambiguous search word. (The preamble pattern in part also occurs in the invalid part of the burst ahead of the preamble.)

The demo program therefore synchronizes to the payload. This requires the 1010 data pattern to be used instead of PRBS9.

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. Set the transmitter frequency 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 and reference level as entered
 - Analyzer mode: vector analyzer
 - Bluetooth settings
 - Points per symbol: 4 (oversampling: fourfold)
 - Display of frequency versus time
 - Result length: 500 symbols
 - Trigger: video 80%
7. Start the test by clicking the *Start* button in the demo program.

Test Results

Fig. 20 shows a typical frequency-versus-time characteristic for a DH1 packet. The demo program reads the analyzer memory and searches for the start of the payload. The preamble is positioned further ahead in the result field, separated from the payload by the number of bits of the header and access code. The program is thus independent of whether a 0101 or a 1010 pattern is used for the preamble.

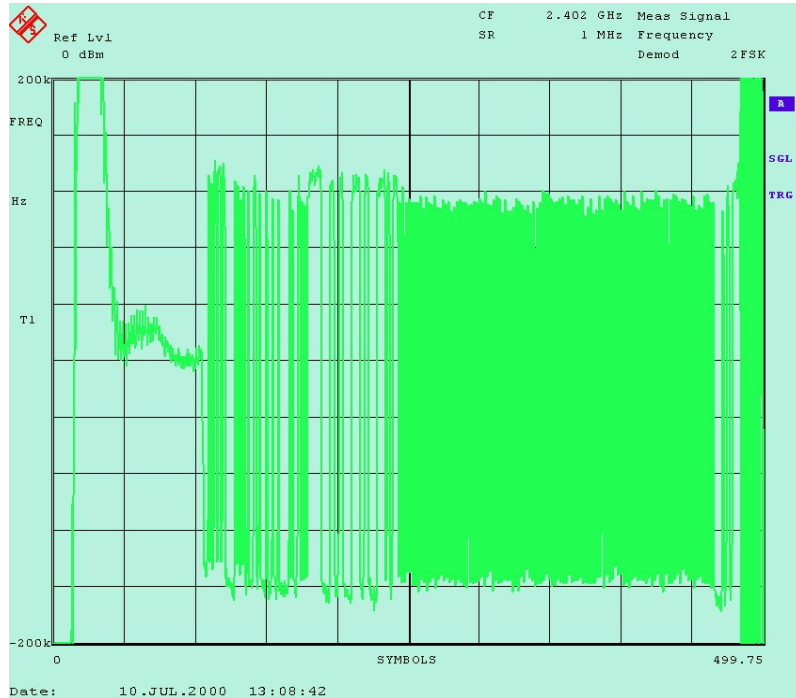


Fig. 20 Initial carrier frequency: results displayed by analyzer

Fig. 21 shows the preamble section selected by the program. The sample values are joined by straight lines.

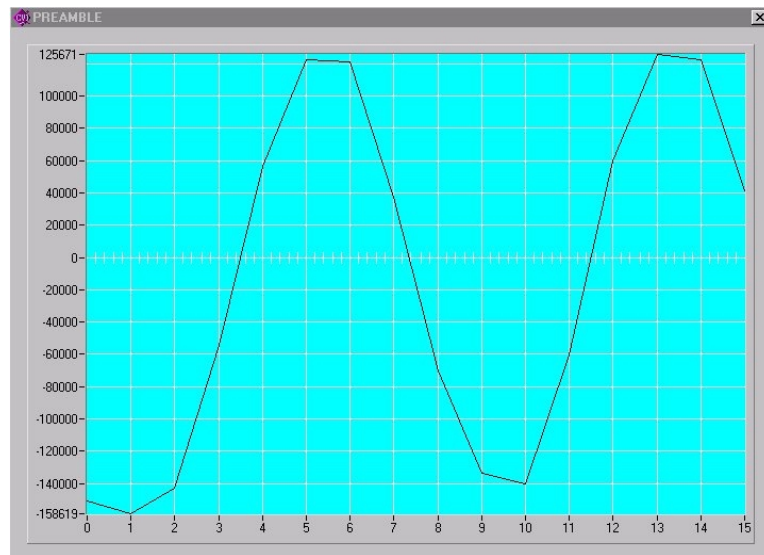


Fig. 21 Initial carrier frequency: sample values of preamble

All frequency values are added up to yield the carrier frequency offset (Fig. 22).

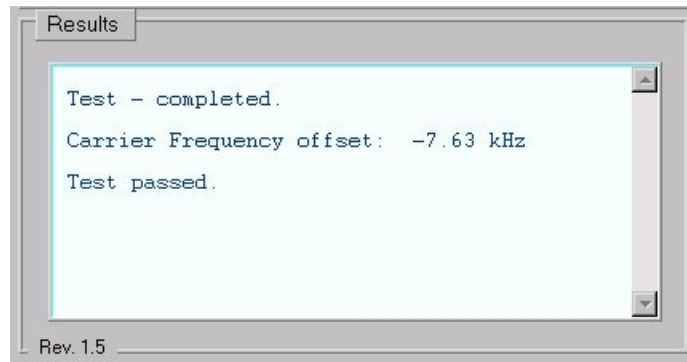


Fig. 22 Initial carrier frequency: results displayed by demo program

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

Notes

- Integration over all samples of the preamble (as described in the test specifications) results in a systematic error which depends on the type of bits present ahead of the first and after the last bit of the preamble. The large negative offset shown in Fig. 21 is due to the fact that low bits were applied by the modulator ahead of the first bit of the preamble (the first valid bit). To avoid this systematic error, use only the samples of the second and the third bit of the preamble for analysis. This will improve absolute accuracy and reproducibility by more than a factor of ten. This procedure is already implemented in the source code but still marked as a comment. Use this part of the code if you want to adjust the initial carrier frequency, for example.
- With only fourfold oversampling, another systematic error will make itself felt clearly if the symbol rate and the sampling rate do not exactly agree. This error can be compensated by averaging. 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' program 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

In this test, the average frequencies of individual packet sections are determined and 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.

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. Set the transmitter frequency 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 and reference level as entered
 - Analyzer mode: vector analyzer
 - Bluetooth settings
 - Points per symbol: 4 (oversampling: fourfold)
 - Display of frequency versus time
 - Result length: 500 symbols
 - Trigger: video 80%
8. Start the test by clicking the *Start* button in the demo program.

Test Results

The analyzer displays the frequency versus time (Fig. 23). The demo program reads the analyzer memory and searches for the start of the payload. The preamble is positioned further ahead in the result field, separated from the payload by the number of bits of the header and access code.

The program adds up the frequencies for each section and calculates the absolute and the relative maximum differences (Fig. 24).

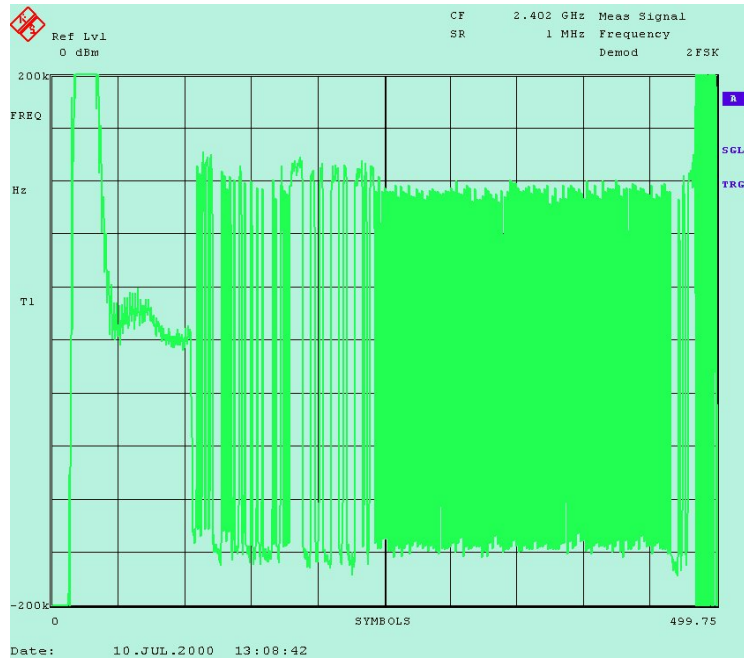


Fig. 23 Carrier frequency drift: results displayed by analyzer

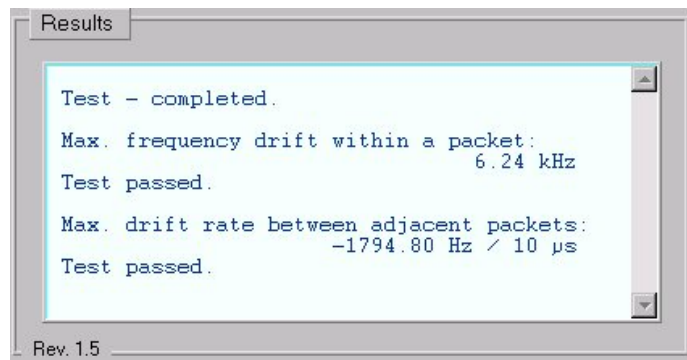


Fig. 24 Carrier frequency drift: results displayed by demo program

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

Notes

- Same as with initial carrier frequency measurement, integration over all samples of the preamble (as described in the test specifications) results in a systematic error which depends on the type of bits present ahead of the first and after the last bit of the preamble. Likewise, a systematic error is introduced by the last bit of the payload header immediately ahead of the useful pattern. Fig. 25 shows the effect of this bit on the result of the drift calculation for the individual 10-bit groups. Since logic ones were present in the header immediately ahead of the useful pattern, a marked frequency drift is found (only) in the first 10-bit group. Here, the maximum frequency drift is detected. The maximum drift rate is, therefore, obtained between the first and the second 10-bit group:

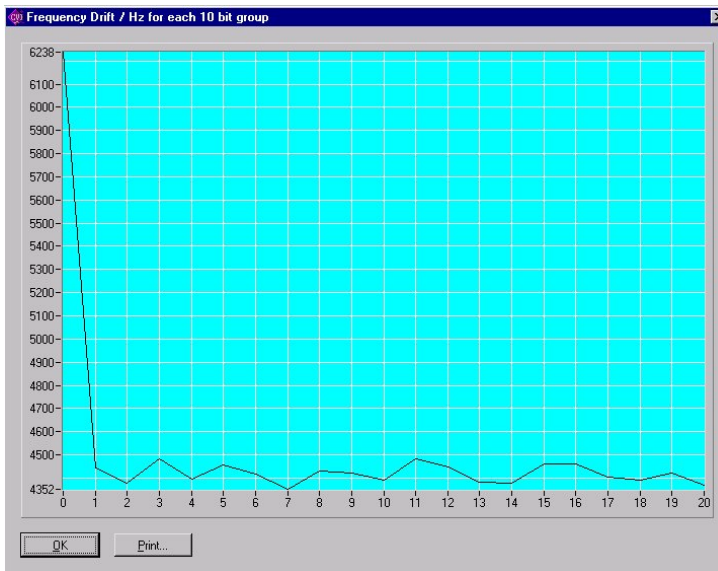


Fig. 25: Carrier frequency drift of the individual 10-bit groups

- To avoid these two systematic errors, use only the samples of the second and the third bit of the preamble for analysis and ignore the first useful bits of the payload. This will, again, improve absolute accuracy and reproducibility by more than a factor of ten. This procedure, too, is already implemented in the source code but still marked as a comment. Use this part of the code if you want to adjust the initial carrier frequency, for example.
- With only fourfold oversampling, another systematic error will make itself felt clearly if the symbol rate and the sampling rate do not exactly agree. This error can be compensated by averaging. 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' program module.

7 Ordering Information

To perform the transmitter measurements presented in this application note, FSE Spectrum Analyzer with option FSE-B7 or FSIQ Signal Analyzer is required.

The instruments must be equipped with the specified or later firmware versions. For a firmware update contact your local Rohde & Schwarz representative.

FSE Spectrum Analyzer:

FSEA30	20 Hz to 3.5 GHz	1065.6000.35	1.93
FSEB30	20 Hz to 7 GHz	1066.3010.35	1.93
FSEM30	20 Hz to 26.5 GHz	1079.8500.35	1.93
FSEK30	20 Hz to 40 GHz	1088.3494.35	1.93

Options:

FSE-B7	Vector Signal Analyzer	1066.4317.02	
FSE-B15	Controller for FSE	1073.5696.06	
FSE-B17	2nd IEC/IEEE-Bus Interface for FSE	1066.4017.02	

Firmware:

FSIQ Signal Analyzer:

FSIQ3	20 Hz to 3.5 GHz	1119.5005.13	2.07
FSIQ7	20 Hz to 7 GHz	1119.5005.17	2.07
FSIQ26	20 Hz to 26 GHz	1119.6001.27	2.07
FSIQ40	20 Hz to 40 GHz	1119.6001.40	2.07

TX and Spectrum Measurements on Bluetooth™ Modules

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

SMIQ Vector Signal Generator:

SMIQ02B	300 kHz to 2.2 GHz	1125.5555.02
SMIQ03B	300 kHz to 3.3 GHz	1125.5555.03
SMIQ03B	300 kHz to 3.3 GHz	1125.5555.03
SMIQ04B	300 kHz to 4.4 GHz	1125.5555.04
SMIQ06B	300 kHz 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	1110.2003.02
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



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