Products: R&S CMU 200 (base unit), CMUgo

Power Measurements on WLAN Modules with the R&S CMU 200 and with CMUgo

Application Note

This application note describes how to measure the power of WLAN modules both using the remote-control program CMUgo and the R&S CMU 200 in manual mode.

ROHDE & SCHWARZ

Contents

1 Overview

The Radio Communication Tester R&S CMU 200 can be used to perform fast and accurate measurements of different mobile radio standards such as GSM, TDMA IS-136, CDMA IS-95A, CDMA2000, Bluetooth, WCDMA and AMPS. Even the basic functionality of the R&S CMU200, without any network dependent option, provides a couple of interesting possibilities for analyzing RF signals. Also in the so called RF function group the R&S 200 provides the same high accuracy as already known.

With the use of data services spreading to mobile radio networks, functions you are familiar with from PDAs are being increasingly incorporated into mobile software. A typical application would be the capability to read e-mails on your mobile phone as well. It therefore makes sense to use a mobile to connect it via WLAN to the company network. But this is not the only area where WLAN hotspots can be found; they are also being offered more and more at heavily frequented places such as train stations, airports and cafes.

2 WLAN Standards

Within the family of IEEE 802.11 standards on wireless data communications, the three following physical standards deserve to be emphasized:

IEEE 802.11b

This standard uses *direct sequence spread spectrum* (DSSS) within ISM band II (2.4 GHz to 2.4835 GHz), providing four data rates from 1 Mbps to 11 Mbps.

IEEE 802.11g

This standard uses *orthogonal frequency division multiplexing* (OFDM), also within ISM band II (2.4 GHz to 2.4835 GHz). It is downward compatible with IEEE 802.11b. Besides the four data rates from 1 Mbps to 11 Mbps, it also provides eight other data rates from 6 Mbps to 54 Mbps.

IEEE 802.11a

This standard also uses OFDM and provides eight data rates from 6 Mbps to 54 Mbps. However, it uses the U-NII band (5.15 GHz to 5.825 GHz). This frequency range lies outside the operating range of the R&S CMU 200 and therefore cannot be measured using the technique described here.

Frequencies and channels

The following channels are used with IEEE 802.11b/g:

Channel	Frequency
1	2412 MHz
2	2417 MHz
3	2422 MHz
4	2427 MHz
5	2432 MHz
6	2437 MHz
7	2442 MHz
8	2447 MHz
9	2452 MHz
10	2457 MHz
11	2462 MHz
12	2467 MHz
13	2472 MHz
14 (Japan only)	2484 MHz

The following channels are used with IEEE 802.11a:

Channel	Frequency
34	5170 MHz
36	5180 MHz
38	5190 MHz
40	5200 MHz
42	5210 MHz
44	5220 MHz
46	5230 MHz
48	5240MHz
52	5260 MHz
56	5280 MHz
60	5300 MHz
64	5320 MHz
100	5500 MHz
104	5520 MHz
108	5540 MHz
112	5560 MHz
116	5580 MHz
120	5600 MHz
124	5620 MHz
128	5640 MHz
132	5660 MHz
136	5680 MHz
140	5700 MHz
149	5745 MHz
153	5765 MHz
157	5785 MHz
161	5805 MHz

Output power with WLAN

With IEEE 802.11b and IEEE 802.11g, the output power is defined as follows depending on the region:

Region	Maximum output power
USA (FCC 15.247)	1000 mW = 30 dBm
Europe (ETS 300-328)	100 mW = 20 dBm (EIRP)
Japan FH-SS modulation, 2.4 GHz to 2.4835 GHz (MPT Ordinance for Regulating Radio Equipment, Article 49-20)	3 mW/MHz
Japan All other modulation modes and frequencies (MPT Ordinance for Regulating Radio Equipment, Article 49-20)	10 mW/MHz

With IEEE 802.11a, the output power depends on the frequency band as follows:

Frequency band	Output power
5.15 GHz to 5.25 GHz	40 mW (2.5 mW/MHz) = 16 dBm
5.25 GHz to 5.35 GHz	200 mW (12.5 mW/MHz) = 23 dBm
5.35 GHz to 5.825 GHz	800 mW (50 mW/MHz) = 29 dBm

3 Measuring by Integrating Samples Across Single Frequency Bands

WLAN yields a signal bandwidth of approximately 20 MHz. The bandwidth of the intermediate frequency stage of the R&S CMU 200 is not large enough for this. It is therefore not possible to measure the power of a WLAN module in one step. However, if you take into account the signal processing used in the instrument, considerably larger bandwidths can be attained.

In the case of the WLAN power measurement, the spectrum analyzer used in the "RF Non-Signalling" function group is utilized. The measurement is based on the following settings:

- Center frequency suited to the WLAN channel to be measured

- Span 56 MHz. The R&S CMU 200 measures 560 single points, which results in a frequency difference of 100 kHz between two adjacent points

- Resolution bandwidth 1MHz

- RMS detector

The principle of the measurement is to integrate the partial powers into the individual frequency bands.

It would be ideal to use rectangular filters, which have no attenuation within their bandwidths but an extremely high attenuation outside their bandwidths. Filters of this type, however, exhibit a very unfavorable transient response. Gaussian filters are widely used in signal processing of digital modulation modes. The R&S CMU 200 uses a sophisticated version of this type of filter within the spectrum analyzer function. Comparing the noise bandwidth of a Gaussian filter with that of a rectangular filter of the same bandwidth yields a measurement result that is 6.5% higher. In other words, the area over which samples are integrated is 6.5% larger than the area of the rectangular filter.

The resolution bandwidth itself is 10 times greater than the step width between the individual points, which means that samples are integrated a number of times over each partial area.

The total correction factor is thus 10.65.

The values of the individual points are returned in "dBm". To make addition possible, the first step is to delogarithmize the result.

The second step is to add the results and divide the sum by the above-mentioned factor of 10.65.

Finally, in the third step, the total power is converted from mW back to dBm.

Step 1:

$$P_{n \, (mW)} = 10^{\frac{P_{n(dBm)}}{10}}$$

Step 2:

$$P_{\text{total (mW)}} = \sum_{n=1\,to\,560} \frac{P_n}{10.65}$$

Step 3:

$$P_{\text{total (dBm)}} = 10 \bullet \log(P_{total(mW)})$$

The measurement is made more complicated because WLAN uses TDD (time division duplex). This means the output signal is ramped, unless this characteristic can be switched off. In the transmission-free gaps, the module's receiver is active. The ramping can also be clearly seen in the spectrum display for an averaging factor of 1.
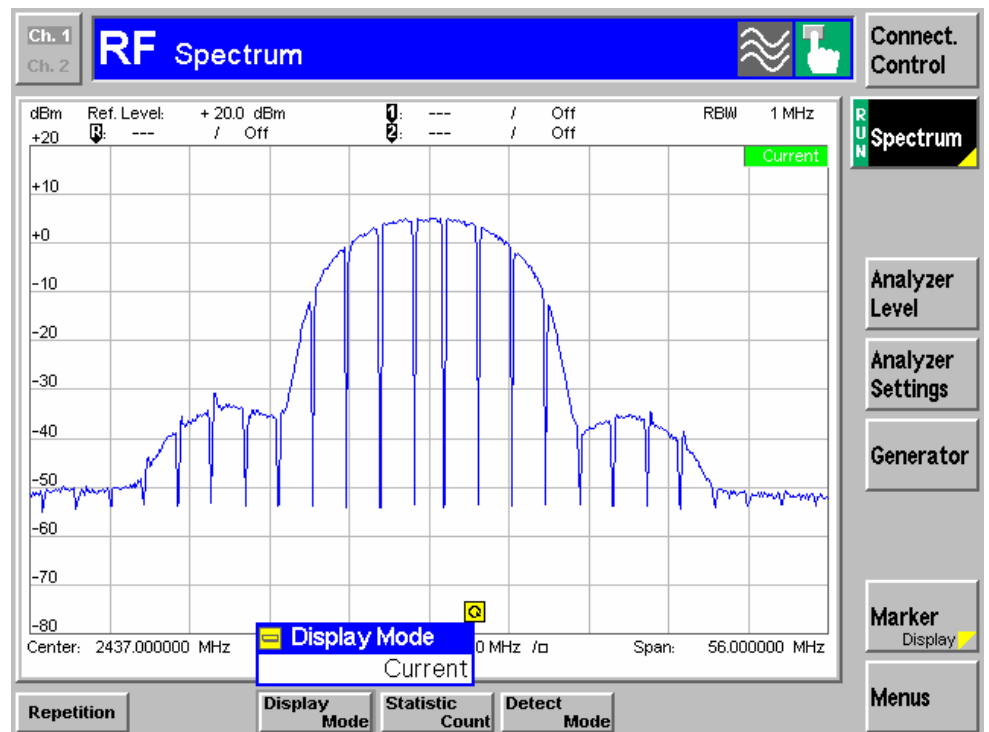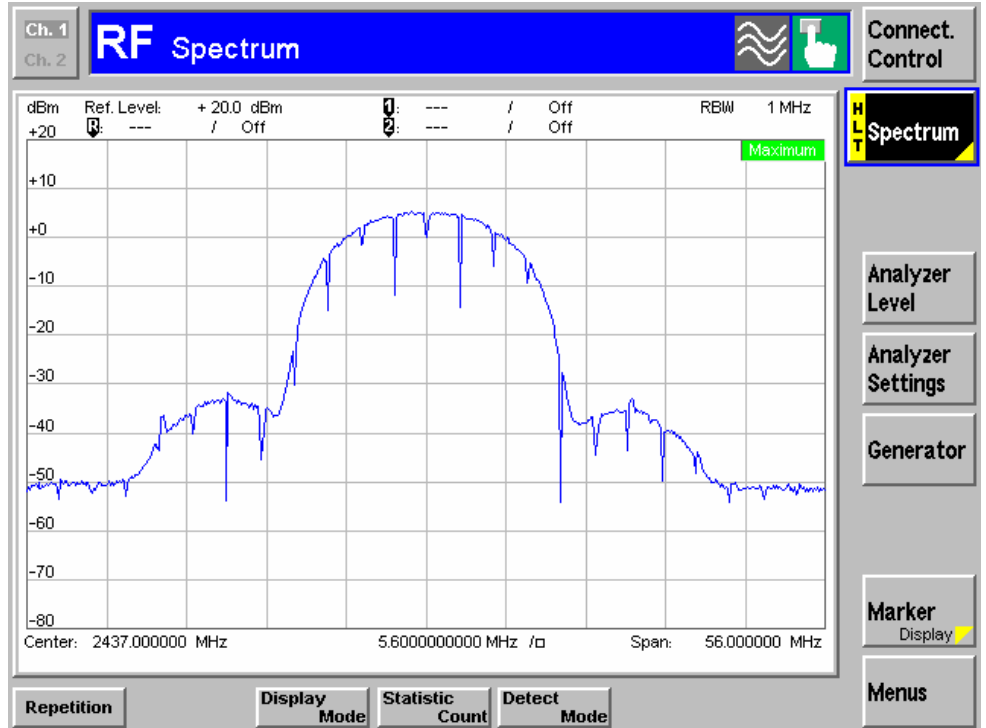
However, the R&S CMU 200 can also output the maximum trace if the averaging factor is appropriate, as can be seen in the following screenshot:
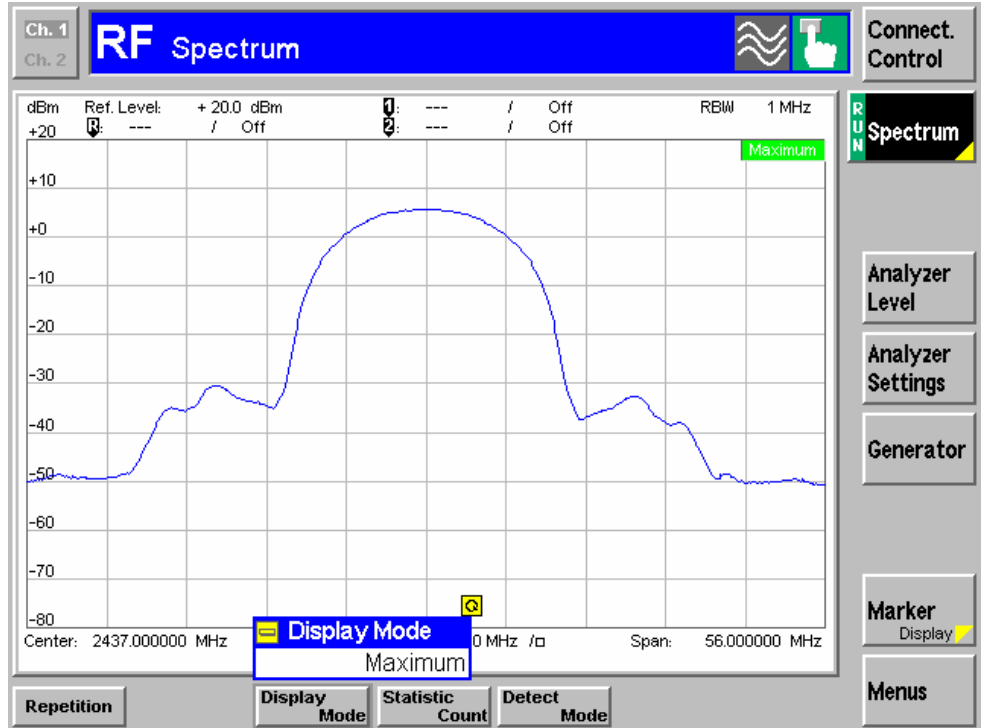
Good results are obtained with an averaging factor of 5, as is shown above. An averaging factor of 2, in contrast, still produces an undesirable number of dips, as shown in the following screenshot:

Do not misinterpret the displayed maximum trace with a peak measurement, since an RMS detector was used for determining the single points. The spectral components of the switching spikes cause a measurement uncertainty, however. For the maxium trace, they have a slight effect on the measurement result. For making adjustments, it would therefore be preferable to set the WLAN module to a continuous transmission mode. In this case, the averaged "Average" trace should be considered, not the maximum trace. When the R&S CMU 200 is operated in manual mode, the individual traces can be selected via the "Display Mode" softkey.

4 Remote Control of the R&S CMU 200 with CMUgo

Software features

CMUgo offers a simple user interface for remote control of the R&S CMU 200 for all standards available on the R&S CMU 200 both via a GPIB bus (IEEE 488.2) and via the RS-232-C interface. CMUgo can be used to output test reports. Moreover, a report of remote-control commands with the times of the individual items can be created and the remote-control commands can be copied directly to the Windows clipboard.

Hardware and software requirements

Hardware requirements

- CPU: 300 MHz or better

- RAM: 64 Mbyte or more

- Monitor: SVGA with 800 x 600 pixels or better

- Hard disk: 50 Mbyte free space

- Periphery: National Instruments GPIB bus or RS-232-C interface
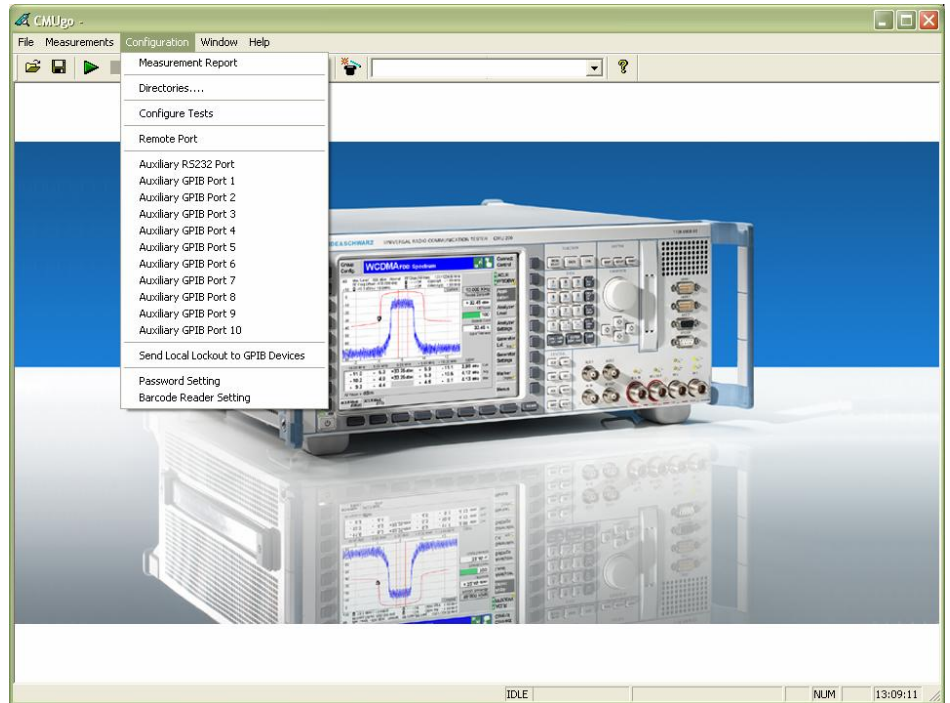
- Mouse

Software requirements

- Windows 98/ME/2000/XP

- CMUgo V1.51

- WLAN module V1.52

Using CMUgo

Read the CMUgo manual [2]. It explains how to connect your computer to the R&S CMU 200, how to install the program and how to start CMUgo. It also describes the basic operation of CMUgo. The "Configure Tests" command is accessible in the "Configuration" menu.

The required sequence comprises only two entries. Every test sequence in CMUgo must begin with the "Basic Initializing" test item.
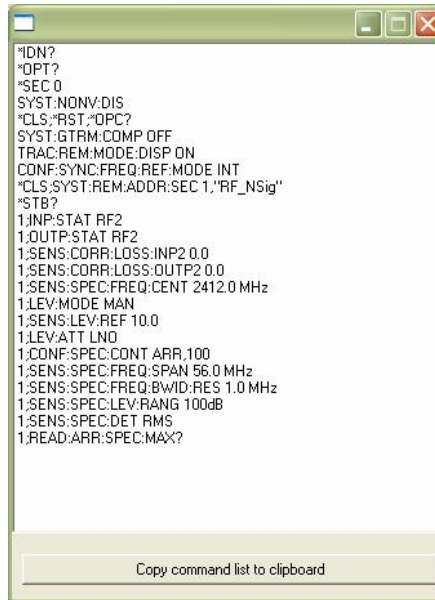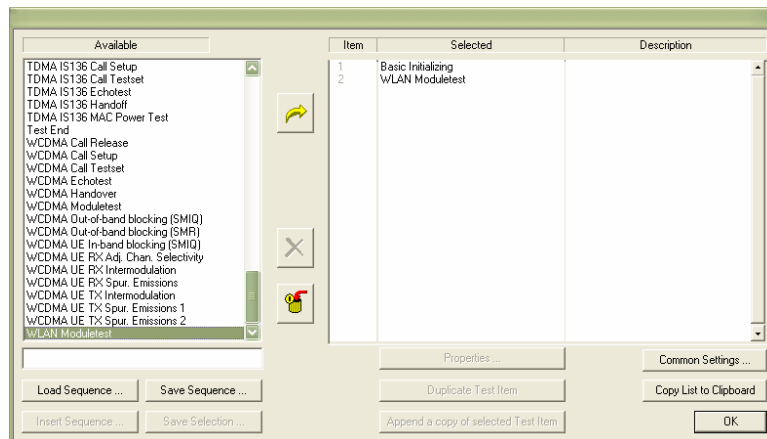

"Basic Initializing" is followed by the "WLAN module test" module.

The remote-control sequence can be output using the **Demo** function of CMUgo. You can select this function in the CMUgo toolbar.

The sequence is started in the usual way. However, the test report is generated without any R&S CMU 200 control. Furthermore, the necessary command sequence is displayed in a popup window and can then be copied to the Windows clipboard.
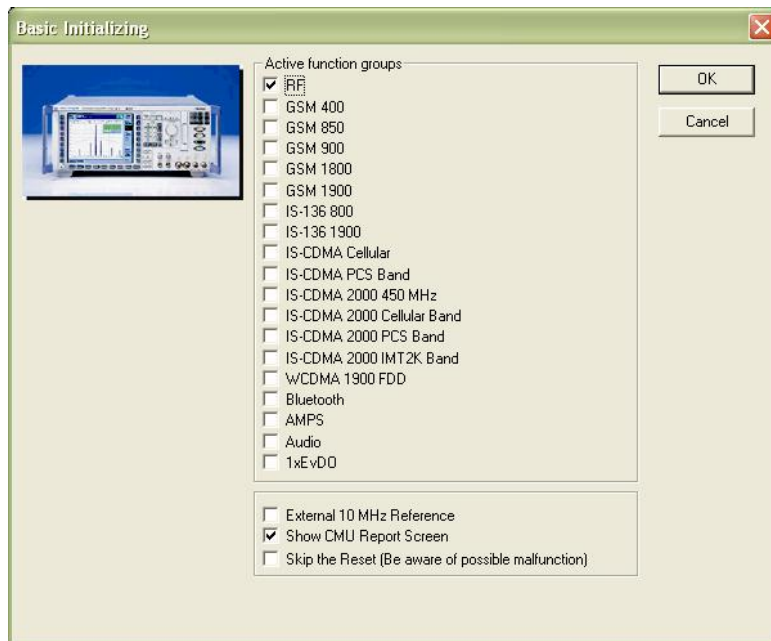
You can then create your own sequences on the basis of this sequence.

5 Basic Initializing

"Basic Initializing" is always at the beginning of a remote-control sequence. In this test item, the available R&S CMU 200 options are queried. In addition, addresses are mapped, i.e. the individual secondary addresses are assigned to the appropriate function groups.

To minimize the time required for the initialization routine, all function groups that are not involved should be deactivated.

By means of the three check boxes at the bottom you can select whether an external reference frequency is to be used. You can also choose whether the remote-control sequences are to be displayed on the screeen of the R&S CMU 200.

To save time, it is also possible to disable the "Reset" (i.e. the function used to reset the R&S CMU 200 to its default state). However, you must know the precise state of the instrument prior to resetting, since in test functions CMUgo does not send settings to the instrument unless these settings differ from the instrument default state.

The individual items when executing this test are the following:

- Query the R&S CMU 200 and the installed firmware versions.

- Query the R&S CMU 200 options.

- Set the secondary address 0 if the serial interface is used.

- To optimize speed, switch off the nonvolatile RAM. This memory is usually used to save the device settings so that they are not lost when the R&S CMU 200 is switched off. This is not necessary in remote-control mode.

- Reset the instrument to its initial state.

- Prevent the instrument from losing the connection in the case of "Local/Remote" transitions.

```
*IDN?
*OPT?
*SEC 0
SYST:NONV:DIS
*CLS;*RST;*OPC?
SYST:GTRM:COMP OFF
```

- Display the received remote-control commands and sent measured values on the screen of the R&S CMU 200. The default setting is OFF.

- Use the internal reference frequency.

```
TRAC:REM:MODE:DISP OFF
CONF:SYNC:FREQ:REF:MODE INT
```

- Reset the status byte to "0".

- Assign the secondary address 1 to the function group "RF Non-Signalling".

- Query whether the assignment of the secondary addresses has caused an error.

```
*CLS;SYST:REM:ADDR:SEC 1,"RF_NSig"
*STB?
```

Secondary addressing of the R&S CMU 200

Every function group of the R&S CMU 200 is addressed by independent subaddresses. The first subaddress refers to the base system of the R&S CMU 200 and is permanently 0. All other subaddresses are defined by the user. The R&S CMU 200 can be addressed in two different ways, described in the following two subsections.

Using a dedicated handle for each secondary address

Before you can address an instrument on the GPIB bus, you must obtain a handle for this instrument. The way to do this varies depending on the driver of the GPIB controller card used. With GPIB controller cards from National Instruments, the necessary function is called "ibdev" or "ibfind".

```
int h_BASE;

// GPIB board index

#define BdIndx 0

// Primary address

#define pad 20

// Secondary address for Base Definition (National Instruments specific)

#define sad 96

// Timeout

#define tmo T_30s

// EOT

#define eot (int) 1

// EOS

#define eos (int) 0


h_Base = ibdev (BdIndx, pad, sad, tmo, eot, eos);
```

The example in C generates a handle for accessing the R&S CMU 200 base system. The primary address 20 (pad) and the secondary address 0 (sad) are used together with the appropriate timeout and terminator. With controllers from National Instruments, an integer value of 96 is specified for a secondary address 0, an integer value of 97 for a secondary address 1, and so on. This offset of 96 is not used for GPIB bus controllers from other manufacturers. With controllers from other manufacturers, the primary address and secondary address are frequently combined into one integer value, i.e. 2000 for primary address 20 and secondary address 00, 2001 for primary address 20 and secondary address 01, and so on.

If you now want to address another function group of the R&S CMU 200, you can generate another handle to this function group.

```
int h_RF_Nig;

#define sad_rf  sad+1


h_RF_NSig = ibdev (BdIndx, pad, sad_rf, tmo, eot, eos);
```

The function group "RF Non-Signalling" now has its own handle. If you write a command to the base address of the R&S CMU 200, the associated handle is used, as is the case for the identification query "*IDN?" in this example.

```
ibwrt(h_Base, "*IDN?", 5);
```

However, if you then want to address the function group "RF Non-Signalling", use the RF non-signalling handle, as shown here for setting the autoranging mode.

```
ibwrt(h_RF_NSig, "LEV:MODE AUT", 12);
```

However, before doing this, do not forget to define the address mapping of the R&S CMU 200, e.g. with the following command that is sent to the base address.

`SYST:REM:ADDR:SEC 1,"RF_NSig"`

Using only one handle

Another possibility is to use only one handle, i.e. the handle of the function group "Base" (the base system). Here a number followed by a semicolon is placed in front of the command. The command for the function group "RF Non-Signalling" described above then looks like this:
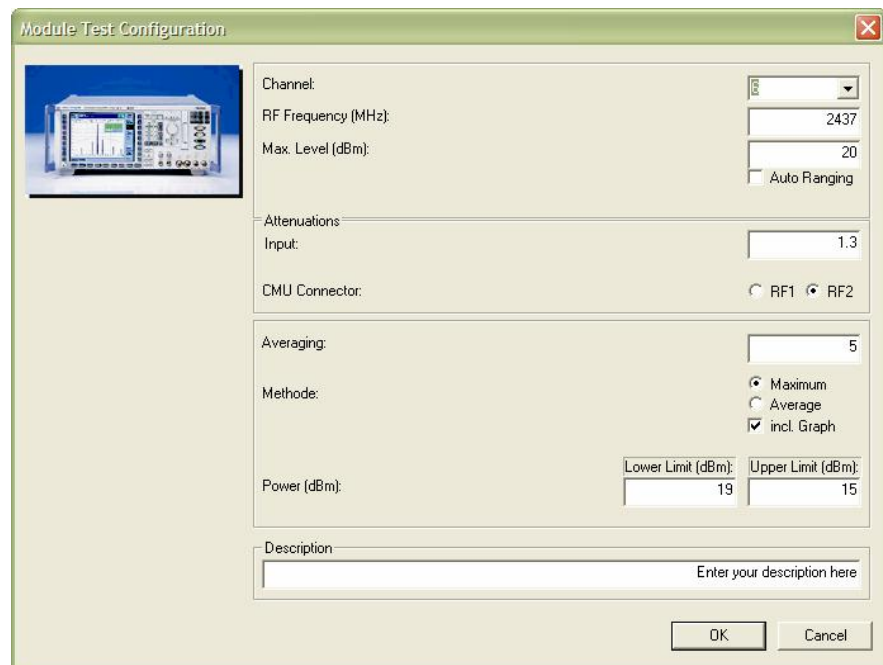
`ibwrt(h_Base, "1;LEV:MODE AUT", 14);`

This remapping mode of the R&S CMU 200 is used with CMUgo. The sequences shown are all based on this mode.

Once again, before doing this, do not forget to define the address mapping of the R&S CMU 200, e.g. with the following command that is sent to the base address.

`SYST:REM:ADDR:SEC 1,"RF_NSig"`

6 WLAN Module Test

The following general settings can be made in the "Module Test Configuration" dialog shown above:

- WLAN channel or RF frequency. The R&S CMU 200 is always controlled using the frequency value.

- Autoranging mode or max. level.

- The WLAN module is connected to RF connector RF1 or RF2.

- The attenuation of the RF connection between the WLAN module and the measuring instrument.

- Averaging used for the measurement. If there is a continuous input signal, an averaging factor of 1 can be set. With a burst input signal, a factor of at least 5 should be used.

- Measurement method. Use "Average" for continuous input signals. Otherwise the "Maximum" measurement method should be used.

- Specification as to whether a spectrum graph is output or not.

- Upper and lower limits within which the test is to be considered passed.

In remote-control mode, this results in the following sequence:

- Specification of the instrument interface, attenuation value and the center frequency.

```
1;INP:STAT RF2
1;SENS:CORR:LOSS:INP2 1.3
1;SENS:SPEC:FREQ:CENT 2437.0 MHz
```

- Specification of the reference level and operation in low noise mode.

```
1;LEV:MODE MAN
1;SENS:LEV:REF 20.0
1;LEV:ATT LNO
```

- Specification of the averaging factor, the span of 56 MHz and the resolution bandwidth of 1 MHz. Use of the RMS detector.

```
1;CONF:SPEC:CONT ARR,5
1;SENS:SPEC:FREQ:SPAN 56.0 MHz
1;SENS:SPEC:FREQ:BWID:RES 1.0 MHz
1;SENS:SPEC:LEV:RANG 100dB
1;SENS:SPEC:DET RMS
```

- Values for continuous input signals are measured and returned. If the averaging factor is 5, for example, the average values per single point of all five measurements are output.

```
1;READ:ARR:SPEC:AVER?
```

- In contrast, if a burst signal is used, the "Max." trace is evaluated. If the averaging factor is 5, for example, the maximum values per single point of all five measurements are output.

```
1;READ:ARR:SPEC:MAX?
```

The test report looks like the one shown on the following page:
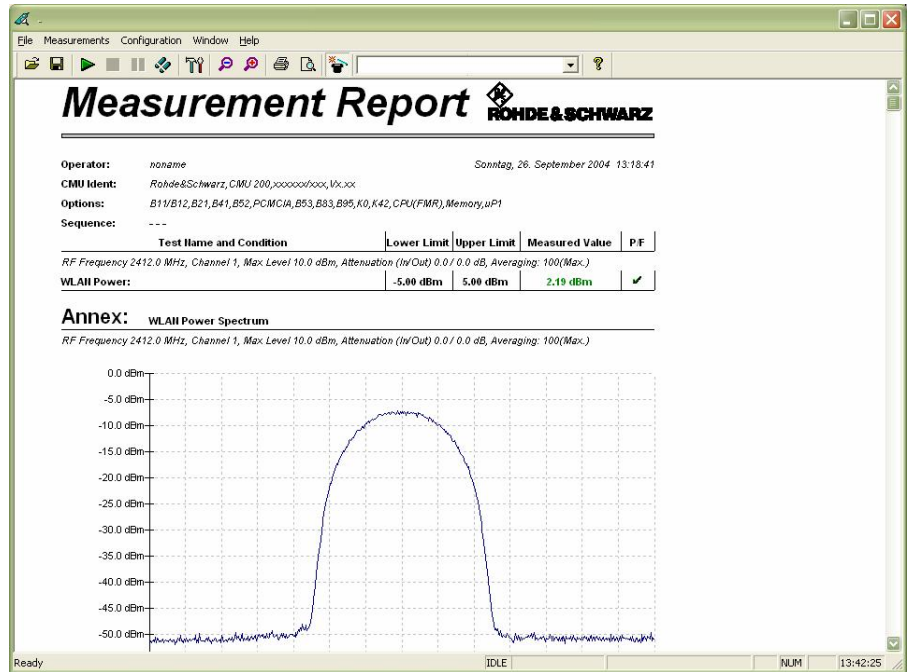
7 Example of Routine for Calculating the Total Power in C++

This example calculates the total power from the 560 single values stored in a CStringArray.

```cpp
double SUMLevel;       // Sum of the 560 compensated values
double Level;          // keeps de-logarithmed value (mW)
double Power           // Total Power (dBm)
CStringArray Results;  // keeps the 560 measurement points
SUMLevel = 0.0;
for(i=0;i<Spectrum_NUM;i++) {
  Level    = pow (10,atof(Results[i])/10.0);
  SUMLevel += (Level / 10.65);
}
Power = 10.0*log10(SUMLevel);
```

8 Example of Routine for Separating Individual Results from Strings

In this example, the R&S CMU 200 result string has been referenced by a *source CString pointer. The individual results are stored in a CStringArray that is referenced by a *dest pointer.

```cpp
SeparateParts(CStringArray *dest, CString *source)
```

```
{
  int PosFromLeft;
  int PosFromRight;
  CString remaining;
  CString part;
  remaining = *source;
  dest->RemoveAll();
  do {
    PosFromLeft  = remaining.FindOneOf( ",;");
    if (PosFromLeft != -1) {
      PosFromRight = remaining.GetLength() - PosFromLeft - 1;
      part = remaining.Left(PosFromLeft);
      dest->Add(part);
      remaining = remaining.Right(PosFromRight);
    }
  } while (PosFromLeft != -1);
  if (remaining.GetLength() != 0) {
    dest->Add(remaining);
  }
}
```

9 Additional Information

Please send any comments or suggestions concerning this application note to **TM-Applications@rsd.rohde-schwarz.com**.

10 Ordering Information

Radio Communication Tester

R&S CMU 200	base unit	1100.0008.02