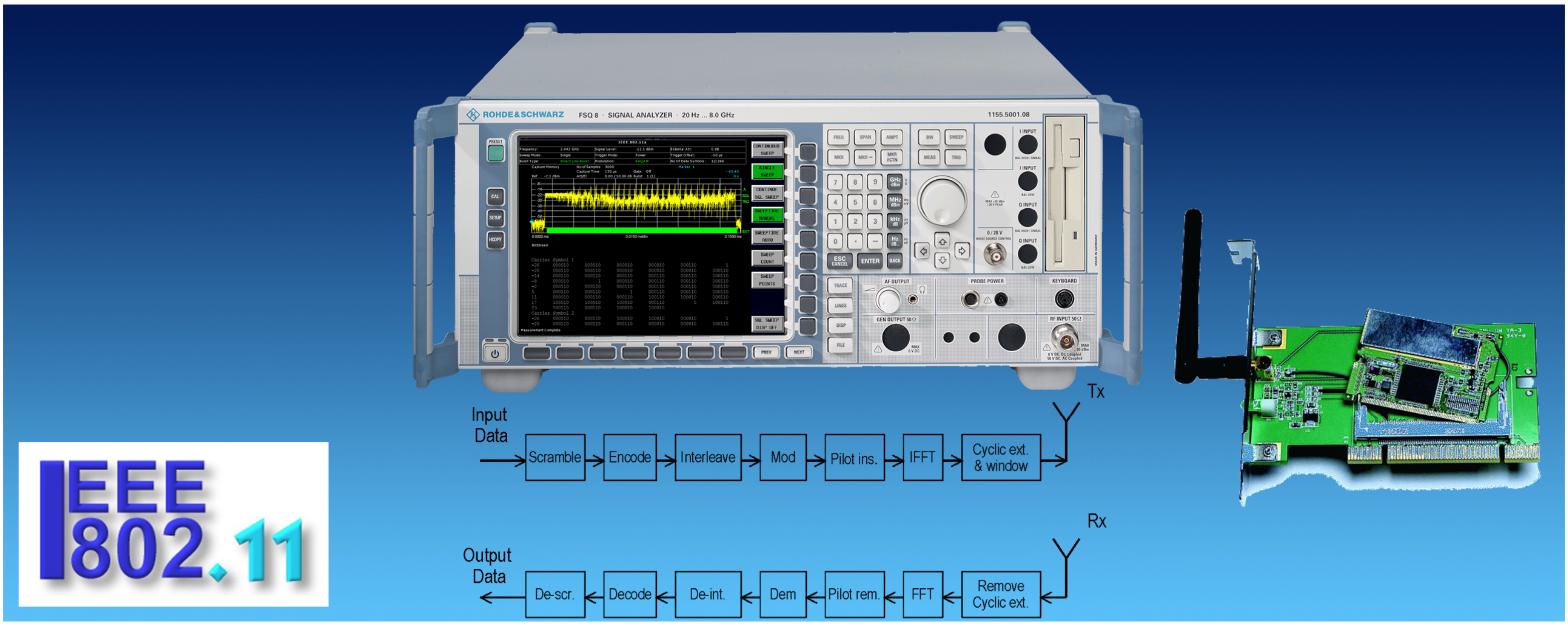

Rohde & Schwarz® Products: AMIQ, AMIQ-K19, SMIQ, SMU, SM300, FSP, FSU, FSQ, FSH3, FS300
SMIQ-B60, FSP-K90, FSQ-K91, SMIQ-K19, SMU-K19, NRP, NRP-Z

WLAN Tests
According to Standard 802.11a/b/g

Application Note 1MA69

The Application Note summarises all measurements for WLAN test, according to the IEEE Standards 802.11a, b and g.
For each measurement, an instrument list, test setups, test method, comments, typical results and implementation hints are included.
The enclosed free of charge software provides all IEEE 488 bus sequences ready to run or copy into your own test environment.

ROHDE&SCHWARZ

Subject to change – M. Weiss 10.2014 – 1MA69_2e

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The following abbreviations are used in this application note for R&S test equipment:

- The Vector Signal Generator R&S® SMU is referred to as the SMU.
- The Vector Signal Generator R&S® SMIQ is referred to as the SMIQ.
- The Vector Signal Generator R&S® SMV is referred to as the SMV.
- The Arbitrary Waveform Generator R&S® SMIQ-B60 option is referred to as the SMIQ-B60.
- The I/Q Modulation Generator R&S® AMIQ is referred to as the AMIQ.
- The Spectrum Analyzer R&S® FSP and FSU are referred to as FSP and FSU.
- The Signal Analyzer R&S® FSQ is referred to as the FSQ.
- FSP, FSU and FSQ in general is referred to as the FSx.
- The Power Meter R&S® NRP is referred to as the NRP.

1 Overview

The test of WLAN devices needs a high-performance solution for R&D purpose on the one hand and also a cost efficient solution for production purpose on the other hand.

This application notes give an overview over all measurements needed in the context of 802.11a/b/g. A free software provides all IEEE bus sequences ready to run or test and copy into your production environment. These sequences can be modified very easily without any special knowledge on programming issues by just editing a text file.

The performance of the test is a trade-off between “operation under all conditions” (including all possible test signal types) and “test execution speed” leading to the fastest measurement speed.

Chapter 2 will give a short introduction to the WLAN Standard 802.11 to understand all terms and test methods used in the application note.

Chapter 3 will provide information on the DUT setup and connection and also on the used test signals for demonstration and evaluation purpose of the Tx tests and for the Rx tests.

Chapter 4 gives a short overview over the available R&S WLAN measurement instruments and the software provided with this application note to demonstrate the WLAN capabilities of our test and measurement instruments.

Chapter 5 provides general information like setting up the correct frequency and levels or instruments needed for Rx testing and Tx demonstration.

Chapter 6 to 16 are intentionally left free in order to match the numbers of the following chapters to the test numbers of the 802.11 standard

Chapter 17 and 18 cover each individual test for 802.11a/b tests. Each test is divided into required instruments showing a list of instruments for doing the test according to the standard, test purpose to show what the test is for, a graphical test setup, a detailed description to perform the test manually (including a step-by-step test procedure), the measurement parameters and limits for the test, hints for the test implementation, and a typical test result. Each of the test has a corresponding test item in the test software to run the test automatically including test report generation and detailed inspection on execution time and instrument status.

Chapter 19 shows all 802.11g test and the corresponding 802.11a/b test including annotations on differences to the standard a/b test scenario.

Chapter 20 to 24 give additional information on e.g. enabling the WLAN options for the signal generation instruments, a Frequently Asked Questions (FAQ) section, and a detailed Literature list referring to all corresponding standard documents.

2 Standard 802: Important Details

The Position of 802.11 as an IEEE Standard

The 802 group within IEEE specify the Standards for Local Area Network (LAN) and Metropolitan Area Network (MAN). There are several groups within the 802 working group which define different parts and aspects of the Standard:

Standard	Name
802.1	Management of 802.x
802.2	standards for LLC (Logical Link Control)
802.3	CSMA/CD (carrier sense multiple access / collision detection) based LAN ("Ethernet")
802.4	Token Passing / Token Bus
802.5	Token Ring / FDDI (Fiber Distributed Data Interface)
802.6	DQDB WAN (Distributed Queue Dual Bus WAN)
802.7	recommended practices for Broadband LAN's (BBTAG)
802.8	recommended practices for fiber optics (FOTAG)
802.9	IsoEnet (Isochronous Ethernet) (ISLAN)
802.10	protocol for security LAN
802.11	protocol for wireless LAN
802.12	100VG AnyLAN (demand priority access method)
802.13	unused
802.14	protocol for cable TV and cable modem
802.15	WPAN (Wireless Personal Area Network)
802.16	WirelessMAN (Wireless Metropolitan Area Networks)
802.17	RPRWG (Resilient Packet Ring Working Group)

Table 1 – List of working groups within the 802 group

Standard	Context
802.11	1 and 2 Mbps on 2.4GHz, FHSS, DSSS and IR
802.11a	6 – 54 Mbps on 5GHz, OFDM
802.11b	5.5 and 11Mbps extension to DSSS
802.11b+	22 MBit/s on 2.4GHz, PBCC, based on TI-ACX100 Chipset
802.11c	Wireless Bridging between Access Points according to ISO/IEC 10038 (IEEE 802.1D)
802.11d	Definitions and requirements to allow the 802.11 Standard in different countries
802.11e	Quality of Service (QoS) for IEEE 802.11
802.11f	Inter-Access Point Protocol - IAPP. Roaming across access points
802.11g	Improvement of the 802.11b using CCK and OFDM, data rates up to 54 Mbps on 2.4GHz. Backwards compatible with 802.11b.
802.11h	Dynamic Frequency Selection (DFS) and Transmit Power Control (TPC) in 5GHz.
802.11i	Enhanced security and authentication mechanisms on 802.11 MAC (AES, WEP+, WPA)
802.11j	Channel selection for 4.9GHz and 5GHz in Japan
802.11k	Definition of Radio Resource Measurement enhancements (e.g. Location-based Services)
802.11m	Maintenance of the IEEE 802.11 Standard
802.11n	Improvements on 802.11, data rates of 108 Mbps and more

Table 2 – 802.11 sub-groups – PHY layer definitions are marked yellow

The Standard 802.11, which the focus of this application note, covers protocols and operation of wireless networks. It only deals with the 2 lowest layers of the OSI reference model:

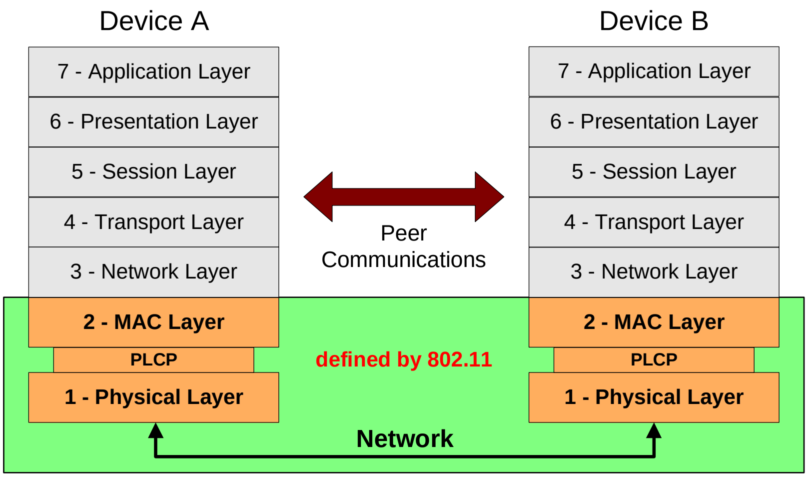


Figure 1 – The Layers of the OSI reference model applying to 802.11

As we can see from Figure 2, 802.11 describe the physical layer and the Media Access Control (MAC) layer. A layer is inserted in between to define the layer interface which is called Physical Layer Convergence Protocol (PLCP).

The influence of other 802 Standard parts on 802.11 can be seen in the figure below:

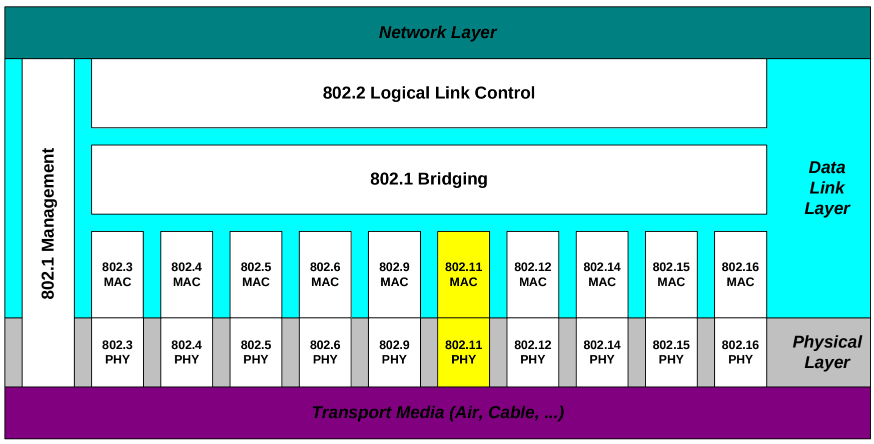


Figure 2 – 802 Standards in the OSI context

For 802.11, some physical layer implementations besides 802.11a/b/g exists which will not be covered in this application note. The figure below gives a brief overview.

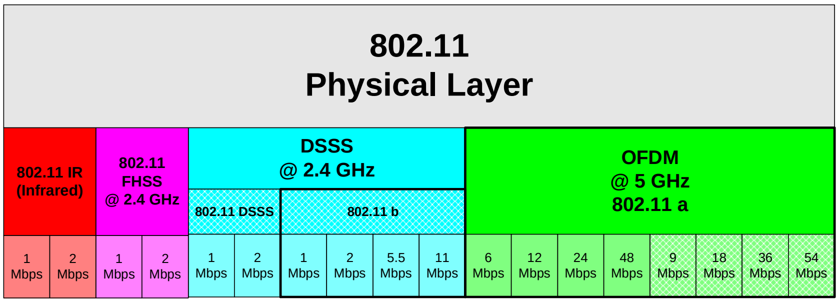


Figure 3 – Overview over standardized 802.11 physical layer systems

Frequency Allocation

Frequencies for WLAN are allocated in

- 16 channels for 802.11a
- 14 channels for 802.11b/g

Channels are assigned in different countries according to national regulations. Table 2 gives an overview over the national regulations.

Standard	Channel Number	Frequency [MHz]	Assigned in / by										
			USA (FCC)	Canada (IC)	EMEA (ETSI)	Spain	France	Japan (MKK)	Japan (TELEC)	Singapore	Taiwan	China (MII)	Israel (MC)
802.11 a	34	5 170							✓				
	36	5 180	✓		✓					✓			
	38	5 190							✓				
	40	5 200	✓		✓					✓			
	42	5 210							✓				
	44	5 220	✓		✓					✓			
	46	5 230							✓				
	48	5 240	✓		✓					✓			
	52	5 260	✓		✓						✓		
	56	5 280	✓		✓						✓		
	60	5 300	✓		✓						✓		
	64	5 320	✓		✓						✓		
	100	5 500			✓								
	104	5 520			✓								
	108	5 540			✓								
	112	5 560			✓								
	116	5 580			✓								
	120	5 600			✓								
	124	5 620			✓								
	128	5 640			✓								
	132	5 660			✓								
	136	5 680			✓								
	140	5 700			✓								
	149	5 745	✓										
	153	5 765	✓										
	157	5 785	✓										
	161	5 805	✓										
802.11 b / g	1	2 412	✓	✓	✓				✓			✓	
	2	2 417	✓	✓	✓				✓			✓	
	3	2 422	✓	✓	✓				✓			✓	
	4	2 427	✓	✓	✓				✓			✓	
	5	2 432	✓	✓	✓				✓			✓	
	6	2 437	✓	✓	✓				✓			✓	
	7	2 442	✓	✓	✓				✓			✓	
	8	2 447	✓	✓	✓				✓			✓	
	9	2 452	✓	✓	✓				✓			✓	
	10	2 457	✓	✓	✓	✓	✓		✓			✓	
	11	2 462	✓	✓	✓	✓	✓		✓			✓	
	12	2 467			✓		✓		✓				
	13	2 472			✓		✓		✓				
	14	2 848						✓					

Table 3 – 802.11 regional regulations in channel allocation

Relation between channel and frequency:

- 802.11a: Frequency = 5000 MHz + (Channel-Nr. * 5 MHz)
- 802.11b/g: Frequency = 2407 MHz + (Channel-Nr. * 5 MHz)

Modulation

Overview

The following table gives an overview of the available 802.11a/b/g modulation schemes including mapping and coder rates:

Standard	Data Rate [Mbit/s]	Modulation per Charrier	Data Charriers	Pilot Charriers	Coding Rate	Mapping from	Mapping to	Mapping Using
802.11 a / g	6	BPSK	48	4	1/2	48 Bits	1 OFDM symbol	48 BPSK charriers
	9	BPSK	48	4	3/4	48 Bits	1 OFDM symbol	48 BPSK charriers
	12	QPSK	48	4	1/2	96 Bits	1 OFDM symbol	48 QPSK charriers
	18	QPSK	48	4	3/4	96 Bits	1 OFDM symbol	48 QPSK charriers
	24	16QAM	48	4	1/2	192 Bits	1 OFDM symbol	48 16QAM charriers
	36	16QAM	48	4	3/4	192 Bits	1 OFDM symbol	48 16QAM charriers
	48	64QAM	48	4	1/2	288 Bits	1 OFDM symbol	48 64QAM charriers
	54	64QAM	48	4	3/4	288 Bits	1 OFDM symbol	48 64QAM charriers
802.11 b	1	DBPSK	1	0	1/11	1 Bit	11 Bit	Barker Sequences
	2	DQPSK	1	0	2/11	2 Bits	11 Complex IQ Values	Barker Sequences
	5.5	DQPSK	1	0	1/2	4 Bits	8 Complex IQ Values	CCK
		BPSK	1	0	1/2	1 Bit	1/2 Complex IQ Value	PBCC
	11	DQPSK	1	0	1	8 Bits	8 Complex IQ Values	CCK
		QPSK	1	0	1/2	1 Bit	1 Complex IQ Value	PBCC
	22	8PSK	1	0	1	2 Bit	1 Complex IQ Value	PBCC
	33	8PSK 1)	1	0	1	2 Bit	1 Complex IQ Value	PBCC
	44							

1) Clock switch from 11 Mchips/s to 16.5 Mchips/s after the preamble phase

Table 4 – Overview over the 802.11 modulation schemes and mappings

802.11a

The Standard 802.11a uses an Orthogonal Frequency Division Multiplex (OFDM) transmission technique including 8 different data rates.

To design an easy-to-implement transmission system, 64 carriers are defined, but only the inner 52 carriers (-26 ... -1, 1 ... 26) are utilized. 4 pilot carriers (± 21 and ± 7) are transmitting a fixed pattern, while the others carrier contain the data. The carrier spacing of 312.5 kHz leads to a nominal signal bandwidth of 16.6 MHz.

The data content of the carriers change every 4 µs (the slot time), except for the preamble period, where the slot time is 8 µs.

- The preamble contains training sequence information used by the receiver for frequency correction and channel estimation.
- The following signal field (4 µs length) contains information on the modulation, the length of the transmission, and other additional information.
- The PLCP Service Data Unit (PSDU) which contains the information follows.

The picture below shows a spectrogram representation of the 802.11a signal as described above.

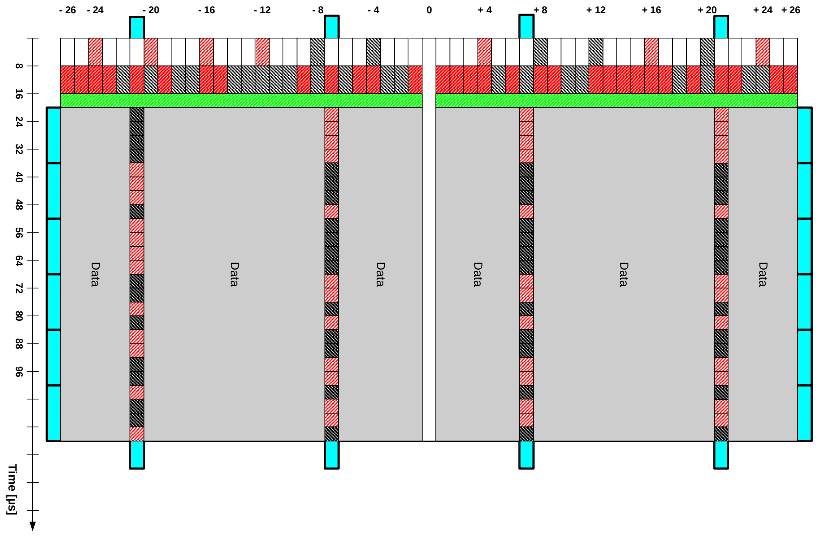


Figure 4 – 802.11a spectrogram representation (carriers vs time)

Each of the 48 data carriers can be modulated with BPSK, QPSK, 16QAM or 64 QAM. This leads - in combination with different coding rates - to a nominal data rate of 6 to 54 Mbit/s. The different constellations are shown in the figure below. The index of b represents the distribution of the bit stream on the constellation points.
(Green and red points are also occupied by blue ones, green points also by red ones)

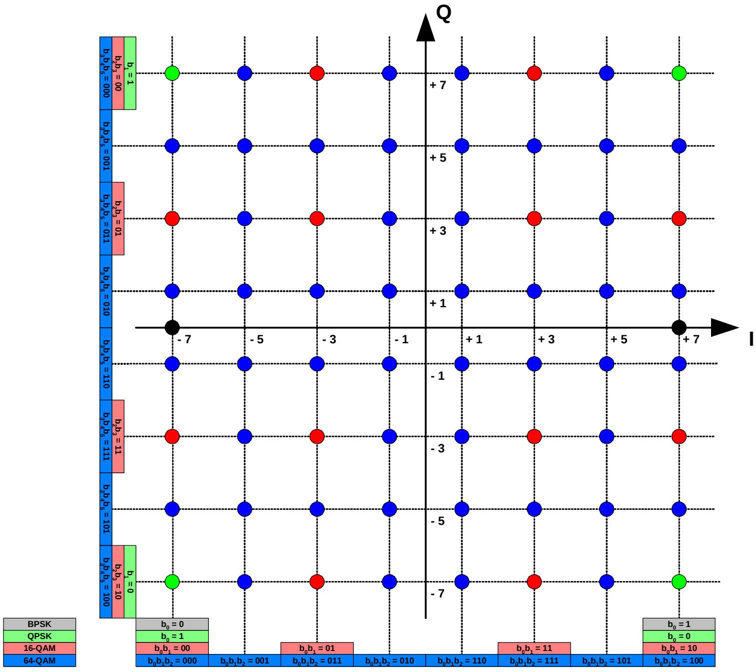


Figure 5 – 802.11a carrier constellations

802.11b

802.11b uses an BPSK / QPKS transmission technique including 4 different data rates.

For 1 and 2 Mbps – the 2 lowest modulation data rates – a Barker sequence in combination with DBPSK or DQPSK is defined.
The Barker sequence used in 802.11b is defined as an 11 bit sequence (101101110000) which has good auto-correlation properties.

The figures below show the modulation signal generation for 1 and 2 Mbit/s operation:

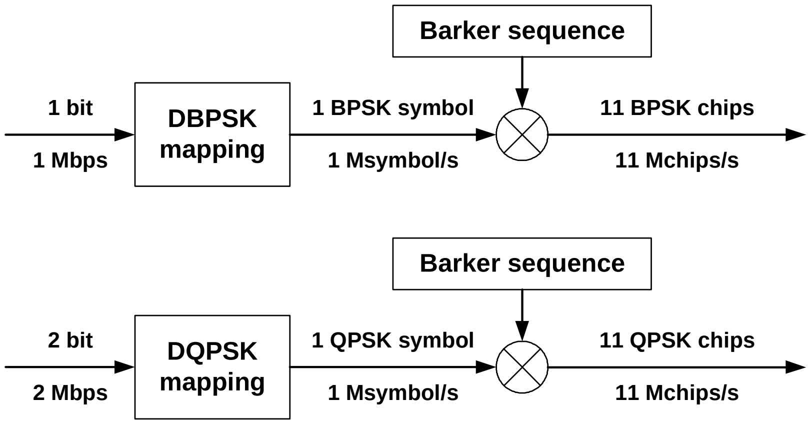


Figure 6 – 802.11b 1/2 Mbit/s operation

For 5.5 and 11 Mbps, 2 different types of modulation are defined:

CCK (Complementary Code Keying) uses a combination of bit-sequence selection and DQPSK modulation:

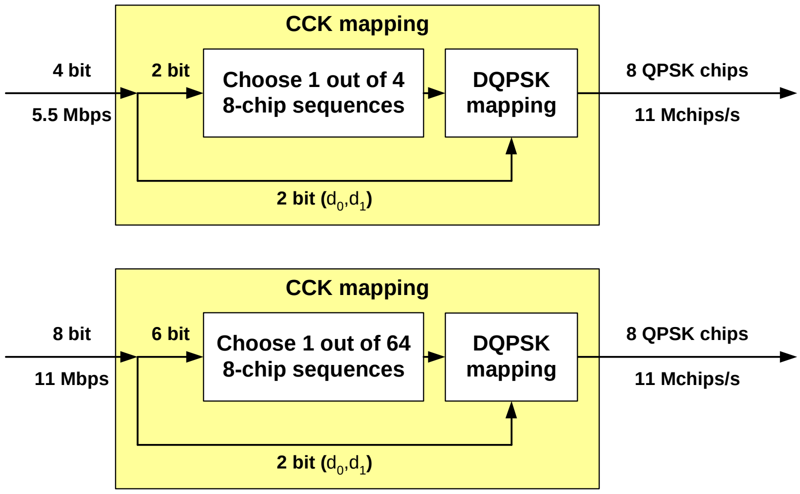


Figure 7 – 802.11b 5.5/11 Mbit/s operation

802.11g

802.11g combines the 2 802.11a and b Standards, using both at the frequency of the 2.4 GHz band (=802.11b channels), and adding 2 optional data rates of 22 and 33 MBit/s with a 802.11b-like modulation.

The following table shows the available 802.11g modes and their origin:

Name	Data Rates [Mbit/s]	Derived from
ERP-DSSS	1, 2	802.11b
ERP-CCK	5.5, 11	802.11b
ERP-OFDM	6, 9, 12, 18, 24, 36, 48, 54	802.11a
ERP-PBCC	5.5, 11, 22, 33	802.11b
DSSS-OFDM	6, 9, 12, 18, 24, 36, 48, 54	802.11a+b

Table 5 – Overview over the 802.11 modulation schemes and mappings

Packet format

The images below are a short overview of the packet format of 802.11 a/b/g. For detailed information, please refer to the Standard [3] - [4].

802.11a

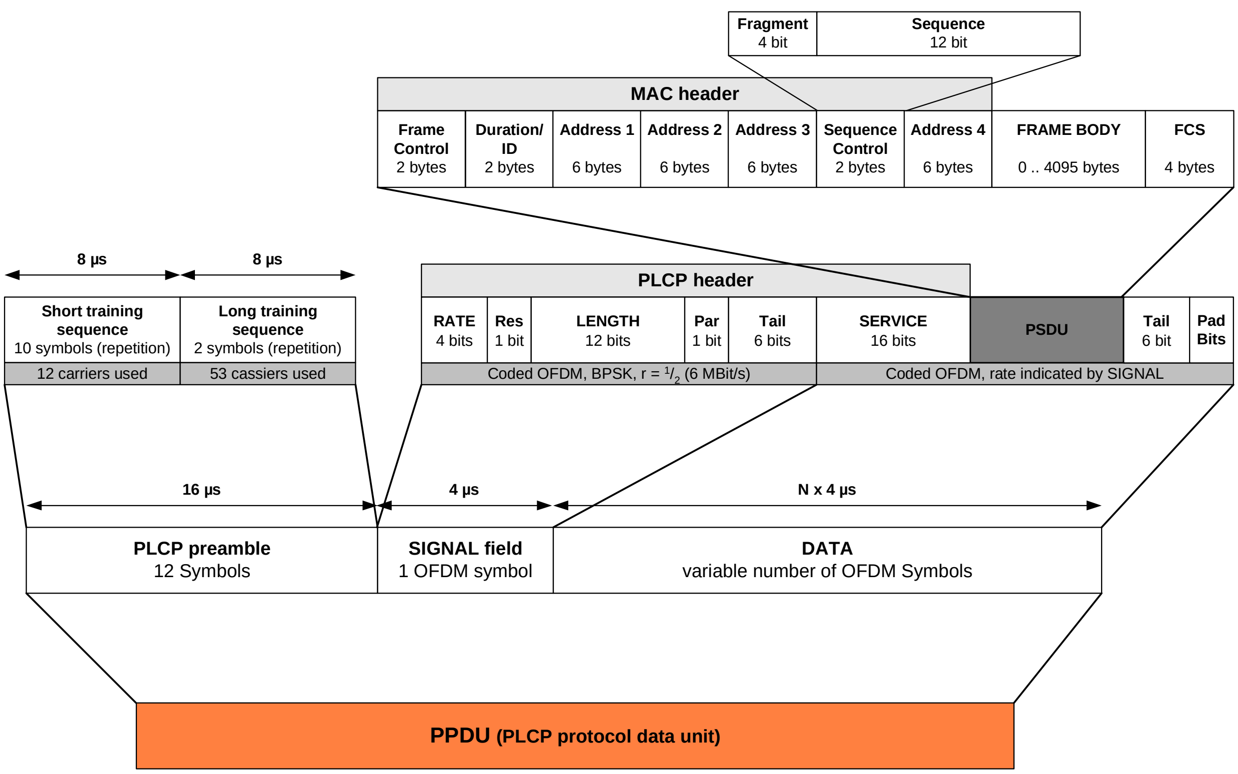


Figure 8 – 802.11a packet format

802.11b

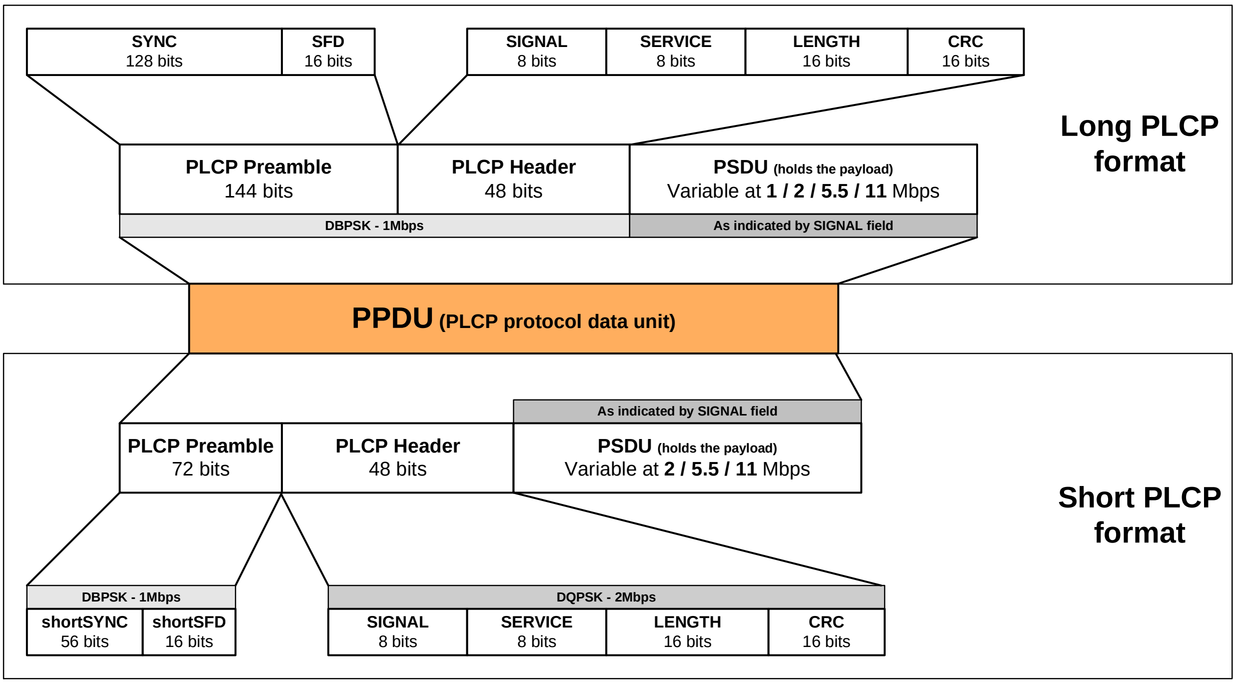


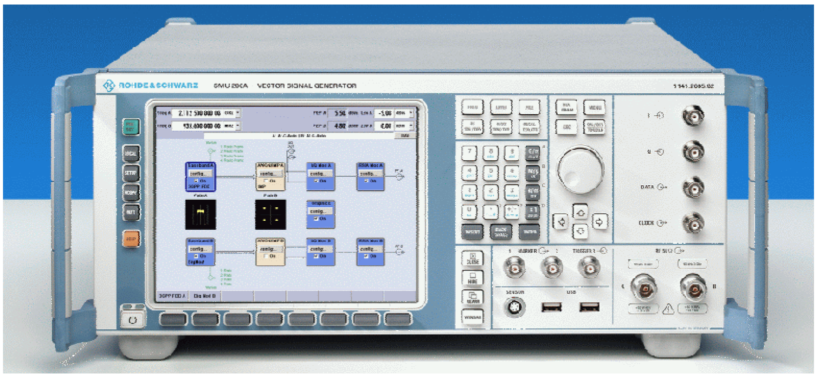
Figure 9 – 802.11b packet format

3 Rohde & Schwarz Test Equipment and Software

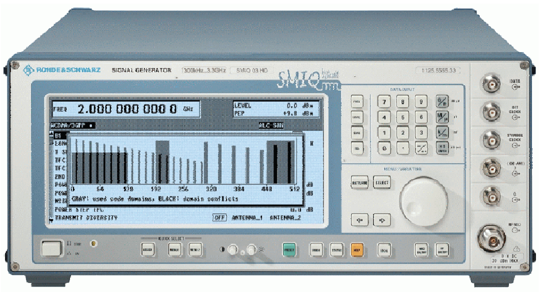
Signal Generators and Modulation Sources

Rohde & Schwarz provides a wide range of signal generators capable for generating 802.11a/b/g signals for R&D and production testing of WLAN modules or WLAN receivers:

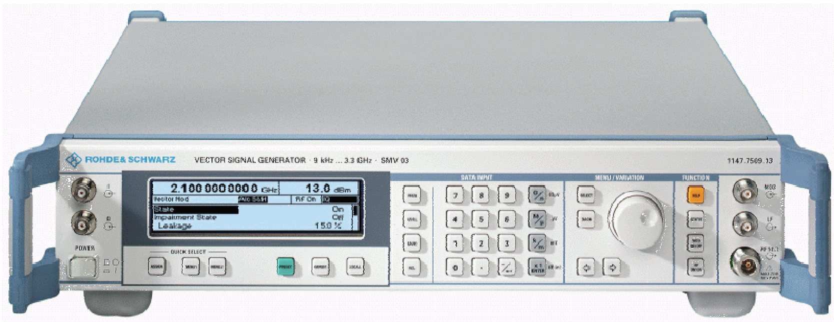
- As top-class, the **R&S SMU200** *Vector Signal Generator* can combine 2 complete RF and baseband paths at a frequency up to 3 GHz or provide 1 RF and 1 baseband path up to 6 GHz. Together with the available built-in *baseband options* **SMU-B13** and **SMU-B10** and the *WLAN option* **SMU-K19**, it is the ideal instrument to generate two independent 802.11a, b or g signals to do all necessary receiver tests including alternate channel tests - with only 1 single instrument.
Due to its flexibility, it can also be used for tests outside the standard, including higher data rates or a combination of the desired signal and any kind of interfering signals. An IQ modulator with 200 MHz RF bandwidth and up to 56 Msamples IQ memory depths provides all the features required in current and tomorrow's development tasks.
Outstanding signal performance and very intuitive GUI, based on a block diagram signal flow user interface, are key features.



- The **R&S SMIQ** *Vector Signal Generator* combines flexibility and high performance within an instrument that perfectly fits the needs of production and also development.
In combination with the available build-in *ARB option* **SMIQ-B60** and the *WLAN option* **SMIQ-K19**, WLAN signals according to 802.11a/b/g can be generated with high performance in any frequency range up to 6 GHz (using the R&S SMIQ06B).



- The **R&S SMV** *Vector Signal Generator* is the ideal instrument - in combination with the R&S AMIQ described below – for doing tests on WLAN modules and cards in a range up to 3.3 GHz frequency. An IQ modulator with 100 MHz RF bandwidth, an electronic attenuator for interruption-free level setting, fast settling time and compact size (2HU) makes it the ideal instrument for production lines and small R&D departments for a very attractive price.



- The **R&S AMIQ** *I/Q Modulation Generator* with 100 MHz sampling rate and up to 16 MSamples IQ memory can generate in combination with the *WLAN option* **AMIQ-K19** any kind of WLAN signal. Together with the option with differential analog I/Q outputs (AMIQ-B2) and digital outputs (AMIQ-B3), it makes this instrument ideal for any kind of R&D tests including module and component test.
  In combination with the SMV Vector Signal Generator, all kinds of WLAN receiver tests on 802.11b/g can be performed.

- The **R&S SM300** *Vector Signal Generator* offers a frequency range up to 3 GHz - the optimum range for 802.11b and g tests. In combination with the **R&S AM300** *Arbitrary / Function Generator*, any signal for WLAN receiver tests can be generated - and this at a very modest price.

- For SMU-B10/13, SMIQ-B60 and AMIQ, **R&S WinIQSIM** can be used to generate WLAN signals according to standard 802.11 with any parameters you need for R&D or production purpose.
  WinIQSIM can be downloaded free-of-charge [13].

Signal Analyzers, Spectrum Analyzers

Rohde & Schwarz offers 3 main signal and spectrum analyzers and 2 flexible versatile instruments for WLAN testing.

- The **R&S FSQ** *Signal Analyzer* is the highest-performance instrument available for WLAN testing. It combines highest RF performance, fast operation, and a flexible usage due to the **FSQ-K70** *Vector Signal Analyzer* included, which can analyze a wide variety of digital modulated signals.
  In combination with the software option **FSQ-K91** *WLAN 802.11 Application Firmware*, it is possible to analyze all current WLAN standard signals (802.11a,b,g and j) to the highest accuracy.
  Together with the hardware option **FSQ-B71** *Baseband Inputs*, analog IQ signals can be analyzed with high performance.
  This is all offered as a single box solution with IEEE and LAN bus interface, ready for production or R&D usage.

- The **R&S FSU** *Spectrum Analyzer* is the ideal choice for measurement purposes where a vector analysis of the WLAN signal is not needed. It gives – except for WLAN modulation analysis – high performance in RF and measurement speed.

- The **R&S FSP** *Spectrum Analyzer* is an instrument ideal for production use due to the fast IEEE and LAN operation, high RF performance, very high measurement speed - vital for production line use - plus many more features.
  Together with the software option **FSP-K90** *WLAN 802.11a Application Firmware* it is possible to measure WLAN 802.11a signals, also in the 5 GHz band using for example the FSP8.

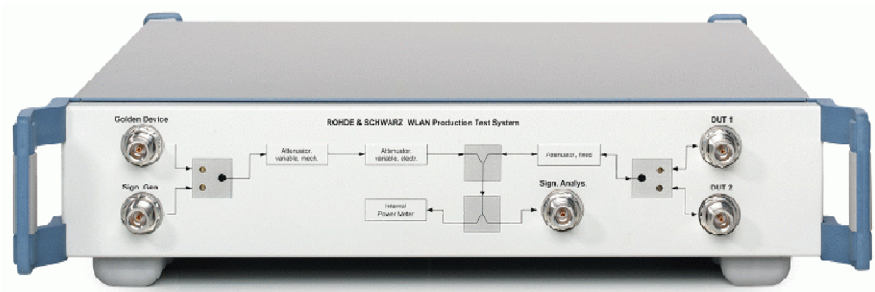
- The **R&S FSH3/6** *Handheld Spectrum Analyzer* is a handy, robust and portable spectrum analyzer for rapid and cost-effective signal investigations. It is ideal for fast tests in field use, providing features like channel power measurement or direct connection to an R&S FSH-Zx power measurement sensor. Is can also be operated via the RS232 interface with the Option **FSH-K1** *Remote Control*, e.g. for monitoring applications [11].

- The **R&S FS300** is a spectrum analyzer with a frequency range up to 3 GHz. Owing to its modern, digital frequency processing technique, it provides high measurement quality at a favourable price, making it an ideal instrument for small R&D labs, education or service.

Power Meters, Additional Equipment

- The versatility of the novel **R&S NRP** *Power Meter Series* is due to the newly developed sensors. These sensors are intelligent standalone instruments that communicate with the basic unit or a PC via a digital interface. The SMART SENSOR TECHNOLOGY^{TM} sets new standards in terms of universality and accuracy.

- The **R&S WLAN Application Test System** is a flexible small system which combines all the necessary equipment for a WLAN test system (including spectrum analyzer, signal generator or Golden Device in combination with a power meter) together to a complete test setup. It includes a step attenuator for Rx signal level setting, couplers for signal level and quality measurement with a power meter and/or a spectrum or signal analyzer and switches for selecting multiple test signal sources and DUT ports. The R&S NRP-Zx power sensor is built in directly in the box, and is controlled – as well as all other switch and attenuation units – via a USB connection.



Test and Demo Software

This application note comes with a small demo program called "GDE" (=Generic Demonstration Engine) which is free of charge.

Each test described in this application note can be executed fast and easyly using the demo program. Results and test times can be evaluated with a single mouse click.

The program offers an easy-to-use User Interface, benchmarking and IEEE command sequence export functions to integrate the programming code in any user-specific test environment.

NOTE - Demonstration:

To demonstrate or evaluate the functions of the instruments, please connect the RF output of SMx Vector Signal Generator directly to the RF input of FSx Signal Analyzer.

PC Hardware Requirements

	Minimum	Recommended
CPU	Pentium 133 MHz	Pentium II 450 MHz or higher
RAM	32 MByte	128 MByte
Harddisc	10 MByte free space	50 MByte free harddisc space (to store WV files and test cases)
Monitor	VGA monitor (640x480)	XGA monitor (1024x768)
IEEE Bus	Rohde & Schwarz IEEE-488.2 bus interface PS-B4, 1006.6207.04, or National Instruments GPIB card	National Instruments GPIB card

PC Software Requirements

	Minimum	Recommended
OS	Windows 95 / 98 / NT 4.0 / 2000 / Me / XP	Windows 98 / 2000 / Me / XP
OS add-ons	---	Microsoft Internet Explorer 5.0 or above
IEEE Bus Driver	Version 1.70 (or above)	---
VISA	National Instrument VISA Version 3.0	---

Installation

The setup file “WLAN_<Version Number>.EXE” is required to install the demo program GDE and the WLAN test cases on the controlling PC.

Execute the installation program and select the installation directory. During installation, program files are copied to a directory of your choice. A new menu item “R&S 802.11 Test Software” is created in the START menu of your Windows system.

Getting started

When you start GDE for the first time, you are requested to register.

We kindly ask you to register GDE. Registration is free of charge and does not obligate you or your company. The unregistered version has full functionality and no expiration date, but will prompt for registration any time you start it.

Please follow the instructions on the screen to register GDE. After clicking "Continue" or entering Name and Key, the user interface will come up:

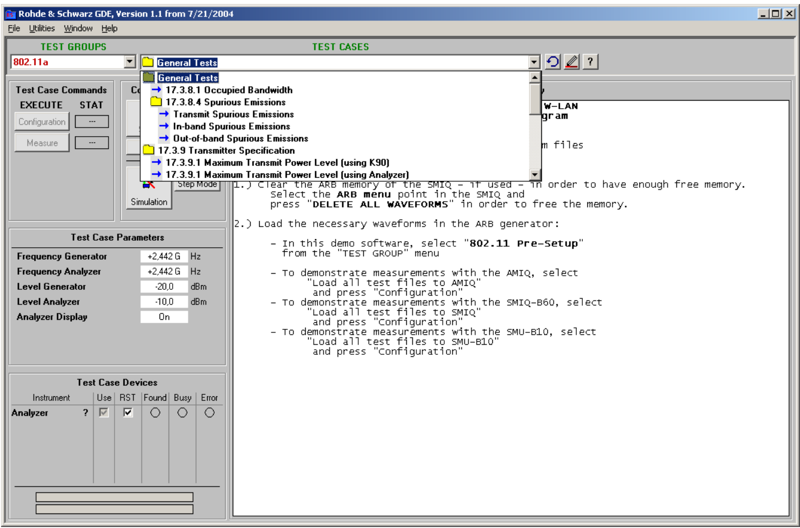


Figure 10 – GDE User Interface for 802.11 Tests

- You can select between Standard 802.11a/b or load all required WV files for transmitter or receiver tests to the SMIQ-B60 / SMU-B10/13 / AMIQ Arbitrary Waveform Generator.
  Select the feature you want to use with the "TEST GROUP" list box.
- Each test described in this application note is listed in the list box "TEST CASE".
- Once selected, you can set up all required parameters ("TEST CASE PARAMETERS") for a test case.
- Tests are always divided into Configuration and Measurement. Use the buttons in the TEST CASE COMMANDS frame to start the individual test steps.
- Results and messages are displayed in the RESULT SUMMARY frame.

4 Test Environment and Signal Description

As this application note covers a general description of WLAN module testing, special aspects of module adaptation, … can not be covered here.

The following chapter provides some hints on adapting WLAN modules for testing in a lab environment.

Card setup for Tx tests

Several conditions must be considered when setting up a WLAN module for testing with R&S measurement equipment:

- Set up the correct RF frequency / channel you want to test
- Select the correct antenna port if more then 1 port is available
- Make the card transmitting the signal
- Set the correct transmission mode / data rate
- Set the module to a mode where it transmits without performing a handshake.

A dedicated test software to adjust these settings must be provided by the manufacturer of the WLAN chipset / card.
Please contact the manufacturer for specific information.

Test Cables

- Many modules for Notebooks use GSC-F connectors to connect the module to the antenna system of the notebook.
  To connect the module to standard test equipment, use an adapter cable for example from MC:
  MC 1213, Adapter 099
  GSC-F-MALE to SMA-MALE, 20 cm
- To measure the cable loss to adjust the power level at the DUT, you have to build a calibration piece, consisting of 2 connectors.
  For GSC-F, the following surface-mounted connectors can be used:
  MuRata, part MM9329-2700

Test Signals

For the receiver tests and for demonstrating the transmitter tests, WinIQSIM files are provided with this application note.

For each signal, WinIQSIM file (*.iqs) and WV files for SMIQ (*_SMIQ.wv), AMIQ (*_AMIQ.wv) and SMU (*_SMU.wv) are provided.

Test Signal 1 (A_54_K19)

This test signal is used as the default 802.11a test signal.

- 802.11a, 54 MBit/s (64QAM)
- 1000 byte / 39 data symbols
- 100 µs idle time, 1 frame
- useable with option AMIQ-K19 / SMIQ-K19 / SMU-K19

Test Signal 2 (B_CCK_11_K19)

This test signal is used as the default 802.11b test signal.

- 802.11b, 11 MBit/s (CCK)
- PSDU length 1024 byte
- 100 µs idle time, 1 frame
- useable with option AMIQ-K19 / SMIQ-K19 / SMU-K19

Test Signal 3 (B_QPSK_2_0101_K19)

This test signal is used for test 18.4.7.7 from Standard 802.11b.

- 802.11b, 2 MBit/s (D-QPSK), no barker spreading
- repetitive 01 data sequence (to measure RF carrier suppression)
- useable with option AMIQ-K19 / SMIQ-K19 / SMU-K19

5 General Test Information

General Information

- **Waveform files**
  Since the waveform files which must be loaded into AMIQ / SMIQ-B60 / SMU-B10/B13 are large and need about 5 seconds to transfer, it is recommended to run the loading routine in the GDE first and start the required test afterwards.

- **Frequencies**
  The supplied IEEE example sequences are independent from the channel used. Select any frequency for the signal generator that is supported by the DUT and select the proper DUT frequencies for the test.
  A frequency in the middle of the band (2442 MHz) is used by default for all automated test examples.

- **Levels**
  You can enter a cable loss for the connection between the signal generator and the DUT to set up the level at the input port of the DUT correctly.

- **Special instrument settings**
  For some measurements, the settings of the instrument depend on the type of signal.
  These settings and their purpose are described in the application note and in the comment of the demo software.
  The given examples are set for measuring signals as provided as ***equivalent WV files***.

- **Demonstration / Evaluation**
  To evaluate the capabilities of the instruments without a DUT, please connect an R&S test signal generator combination (RF Generator + Baseband Generator) to generate the transmitter test signals.

- **Software options K16/K18/K19**
  There are 3 different software options for WLAN test signal generation by AMIQ / SMIQ / SMU:
  The option K16 support 802.11b, the option K18 support 802.11a, and the option K19 support 802.11a,b and g.
  To give the maximum flexibility, the software option K19 is recommended for all WLAN tests and also used for any example within this application note.

Instrument combinations for Rx test / Tx test demonstration

Use any of the following instrument / option combinations can be used for Rx testing and to generate a demo signal for Tx test verification. WinIQSIM is used to generate the test signals.

RF Generator			Baseband Generator	
SMU	**or**	**AND**	SMU-B10 [1)]	**or**
SMIQ	**or**		SMIQ-B60 [2)]	**or**
SMV	**or**		AMIQ	**or**
SM300			AM300	
[1)] built-in SMU option [2)] build-in SMIQ option				

Table 6 – Signal generator instrument combinations

Annotation to SMIQ-B60

Due to the internal memory organization, SMIQ-B60 always uses the internal memory in blocks of 65.527 samples and can hold 22 blocks in its non-volatile memory.
So, it is possible to store a maximum of 22 WV files, even if the only use 1 IQ sample pair.

Using the power meter sensors NRP-Zxx for the Rx tests

Because of the high accuracy of the R&S signal generators and the built-in attenuator, it is not necessary to use a power meter for adjustment of the output power of the receiver test signal generator.

If another WLAN card (the so-called "Golden Device") is used instead of a signal generator to generate the signals required for Rx tests, the level of the signal must be measured with, for example an NRP-Z11 power sensor.

The use of the power meter is the same for all Rx test (measure the power and adjust the receiver test signal generator level). The example sequences do not utilize the NRP power sensor.

The NRP power sensor can be connected to the PC using a USB adapter cable (NRP-Z3 or NRP-Z4) or the NRP base instrument which can be connected to the PC via IEEE, USB or LAN bus.
In this application note, the connection is always shown as IEEE bus connection via the NRP basic instrument. Other connections are possible.

6 – 16 intentionally left free

(to match the numbering of 802.11 standard

7 WLAN 802.11a Test

Instruments and Signal list

The table below show all the measurements for transmitter and receiver tests and the required instruments and signals.

Standard				Test parameter	Signal Analysis: FSP	FSP + K90	FSU	FSQ	FSQ + K91	Signal Generation: SMIQ + SMIQ-K19	SMU + SMU-K19
802.11 a	17.3.8 General	1		Occupied bandwidth	✓	👍	✓	✓	👍		
		4		Transmit and receive in-band and out-of-band spurious emissions	👍	👍	👍	👍	👍		
		7		Transmit and receive antenna port impedance							
	17.3.9 Transmitter Specification	1		Maximum transmit power level @ 5.15 - 5.25 GHz	✓	👍	✓	✓	👍		
				@ 5.25 - 5.35 GHz	✓	👍	✓	✓	👍		
				@ 5.725 - 5.825 GHz	✓	👍	✓	✓	👍		
		2		Transmit spectrum mask	✓	👍	✓	✓	👍		
		3		Transmit spurious	👍	👍	👍	👍	👍		
		4		Transmit center frequency tolerance	✓ 2)	✓	✓ 2)	✓ 2)	👍		
		5		Symbol clock frequency tolerance	✗	✓	✗	✗	👍		
		6	1	Transmitter center frequency leakage	✓ 3)	✓	✓ 3)	✓ 3)	👍		
			2	Transmitter spectral flatness	✗	✓ 1)	✗	✗	👍		
			3	Transmitter constellation error	✗	✓ 1)	✗	✗	👍		
		7		Transmit modulation accuracy test	✗	✓ 1)	✗	✗	👍		
	17.3.10 Receiver Specifications	1		Receiver minimum input level						✓	✓
		2		Adjacent channel rejection						✓	✓
		3		Non-adjacent channel rejection						✓	✓
		4		Receiver maximum input level						✓	✓
		5		CCA sensitivity						✓	✓

✗ not possible
✓ possible
👍 best choice
(grey) not available / not used

1) measurement on reduced number of charriers
2) requires special DUT test mode - see test implementation hints
3) measurement possible, but not recommended - see test implementation hints

Table 7 – Required Instruments for WLAN 802.11a tests

17.3.8.1 Occupied Bandwidth

Purpose	Basic instrument	Options	Used to
Measurement	FSP / FSU / FSQ	---	Measure occupied bandwidth
+ demonstration	please refer to page 23		Generate a valid 802.11a signal

Test purpose

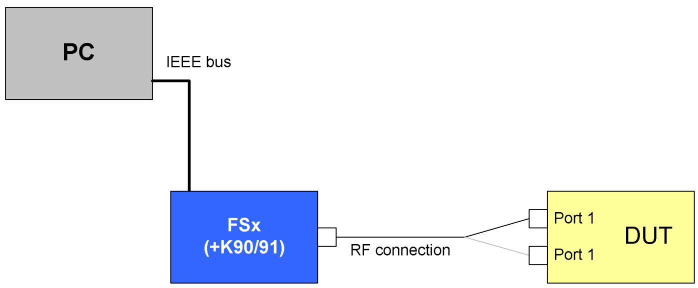
The test ensures that the transmitter filter is well designed and the clock of the DUT is working properly.

If the clock rate is too high, this may result in a wide occupied bandwidth (OBW) and malfunction of the DUT.

DUT setup, equivalent WV file

DUT Status	Tx Active
Signal Type	Standard Tx signal OFDM, 54 Mbit/s
Power Level	Maximum
Antenna	1 or 2
Annotations	---
Equiv. WV file	A_54_K19

Test setup



Drawing 1 – Occupied Bandwidth test setup

17.3.8.1 Occupied Bandwidth

Test method

1. Configure the WLAN module according to the DUT setup (use for example test software provided with the module).
2. Set up the analyzer step-by-step as described below:

PRESET	set instrument to default stats
FREQ CENTER <value>	set signal frequency
SPAN 40 MHz	set span to display complete signal
AMPT REF LEVEL <value>	set level to maximum expected RF level
BW RES BW MANUAL : 100 kHz	set resolution bandwidth to get signal shape correct
TRACE MAX HOLD	switch max hold on to see no “burst gaps”
MEAS OCCUPIED BANDWIDTH	switch to occupied bandwidth measurement

Measurement Parameter, Limits

The Occupied Bandwidth shall be 16.6 MHz.

Test implementation hints

- **Measurement**
  Since the 802.11a signal is a pulsed signal, you have to get some sort of continuous reading for the spectrum in order to measure the output power correctly.
  This can be realized using
  - a continuous transmission mode of the DUT (if available)
  - gated sweeping (as used in the WLAN personality)
  - RMS trace mode and long sweep time in spectrum mode.
  The sweeptime must be set to get 1 complete signal period within 1 pixel on the analyzer screen during the sweep in the frequency domain, which means for example for an FSQ (625 pixel default value) and a signal period of 272 µs (like the used test signal) a minimum sweep time of 272 µs x 625 = 170 ms.

- **Measurement of OBW**
  As this is not a specified limit (it only occures in the table of major parameters of the OFDM PHY in [3], Table 86), the measurement is not evaluated with pass / failed. It also is not included in the WLAN personalities K90/K91. For evaluation of the spectrum “consumption” of the signal, test 17.3.9.2 (Transmit spectrum mask) shall be used.

17.3.8.1 Occupied Bandwidth

Measurement Results

The picture below shows the display of a typical measurement result:

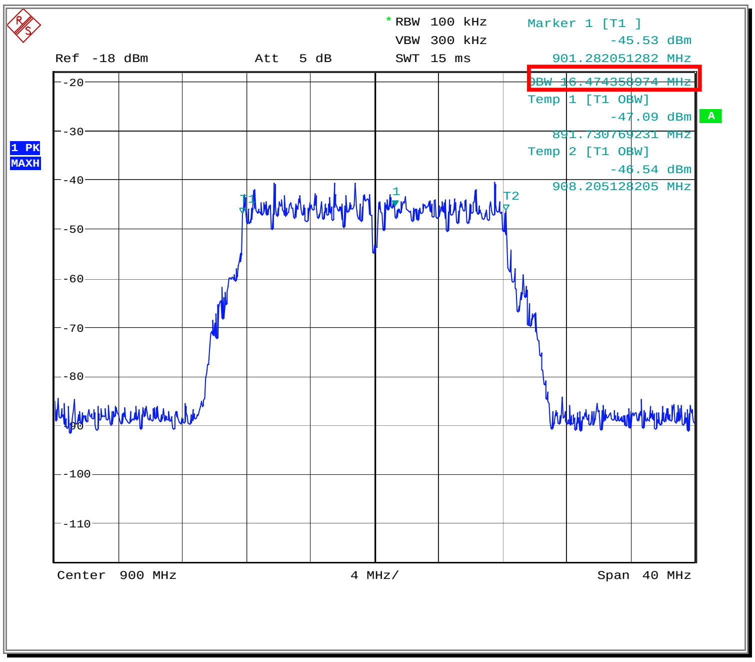


Figure 11 – Occupied bandwidth typical measurement result

17.3.8.4 Transmitter and receiver in-band and out-of-band spurious emissions

Purpose	Basic instrument	Options	Used to
Measurement	FSP / FSU / FSQ	---	Measure spectrum emissions
+ demonstration	please refer to page 23		Generate a valid 802.11a signal

Test purpose

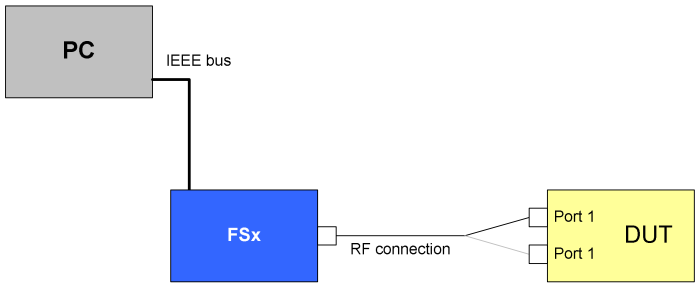
The test is done to check if any spurious emissions are produced from the DUT. This may be for example due to poor design of the oscillator, the shielding of the DUT or the cabling to the antenna.

Spurious emissions can cause problems in other bands like mobile phone or radio and television bands.

DUT setup, equivalent WV file

DUT Status	Tx Active
Signal Type	Standard Tx signal OFDM, 54 Mbit/s
Power Level	Maximum
Antenna	1 or 2
Annotations	---
Equiv. WV file	A_54_K19

Test setup



Drawing 2 – Spurious emissions test setup [1)]

1) additional equipment such as filters may be necessary for this test

17.3.8.4 Transmitter and receiver in-band and out-of-band spurious emissions

Test method

1. Configure the WLAN module according to the DUT setup (use for example test software provided with the module).
2. Set up the analyzer step-by-step as described below:

PRESET	set instrument to default stats
FREQ START <value>	set left frequency range limit 1)
STOP <value>	set right frequency range limit 1)
AMPT REF LEVEL <value>	set level to a sensitive value for the required emission limit
BW RES BW MANUAL <value>	set resolution bandwidth 1)
TRACE MAX HOLD	switch on max hold mode and peak detector
SWEEP SINGLE SWEEP	sweep once to measure the spurious emission

1) these settings depend on regulatory requirements

Measurement Parameters, Limits

The limits for the measurement are subject to the regulatory bodies and therefore not stated here.

Please refer for example to

- FCC 15.407 for regulations valid for the United States [8].
- ETSI EN 301 893 4.4.1.2 for regulation valid in Europe [12].

Test implementation hints

Measurement Results

17.3.9.1 Maximum transmit power level

Purpose	Basic instrument	Options	Used to
Measurement	FSP / (FSU) / FSQ	FSx-K90/91 [1)]	Measure output power
---	please refer to page 23		Generate a valid 802.11a signal

[1)] the base instrument can be used as well

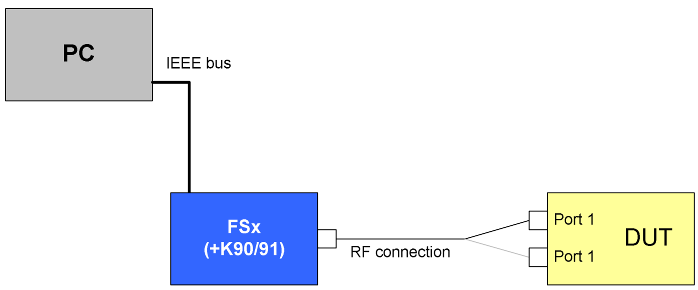
Test purpose

This test ensures that the maximum output power is not exceeded. Excessive output power may result in blocking other WLAN cards from transmission or non-conformance with national regulations for the assigned frequency bands.

DUT setup, equivalent WV file

DUT Status	Tx Active
Signal Type	Standard Tx signal OFDM, 54 Mbit/s
Power Level	Maximum
Antenna	1 or 2
Annotations	---
Equiv. WV file	A_54_K19

Test setup



Drawing 3 – Maximum transmit power level test setup

17.3.9.1 Maximum transmit power level

Test method – without WLAN personality

1. Configure the WLAN module according to the DUT setup (use for example test software provided with the module).
2. Set up the analyzer step-by-step as described below:

PRESET	set instrument to default stats
FREQ CENTER <value>	set signal frequency
SPAN 40 MHz	set span to display complete signal
AMPT REF LEVEL <value>	set level to maximum expected RF level
BW RES BW MANUAL 100 kHz	set resolution bandwidth to get signal shape correct
TRACE DETECTOR RMS	switch on to get correct power measurement
SWEEP SWEEPTIME MANUAL 200 ms	set time to get 1 signal period for each display pixel
MEAS CHAN PWR ACP	switch to channel power meas.
CP / ACP CONFIG : CHANNEL BANDWIDTH : 22 MHz	measure power over complete channel

Test method – with WLAN personality

1. Configure the WLAN module according to the DUT setup (use for example test software provided with the module).
2. Set up the analyzer step-by-step as described below:

PRESET	set instrument to default stats
(MORE) WLAN	switch on WLAN personality
FREQ CENTER <value>	set signal frequency
SPECTRUM SPECTRUM ACP	switch to TX power measurement
RUN SGL	execute one measurement

Measurement Parameter, Limits

The maximum output power must be measured. The limits for the United States are quoted below (according to Table 89 in 802.11a standard and FCC standard 15.407 for UNII band operation):

Frequency band [GHz]	**Maximum output power with up to 6 dBi antenna gain**
5.15 – 5.25	40 mW (2.5 mW/MHz) = 16 dBm
5.25 – 5.35	200 mW (12.5 mW/MHz) = 23 dBm
5.725 – 5.825	800 mW (50 mW/MHz) = 29 dBm

Table 8 – 802.11a Maximum transmit power levels

Test implementation hints

- **Measurement**
  Since the 802.11a signal is a pulsed signal, you have to get some sort of continuous reading for the spectrum to measure the output power correctly.
  This can be realized using
  - a continuous transmission mode of the DUT (if available)
  - gated sweeping (as used in the WLAN personality)
  - RMS trace mode and long sweep time in spectrum mode.
  The sweeptime must be set to get 1 complete signal period within 1 pixel on the analyzer screen during the sweep in the frequency domain, which means for example for an FSQ (625 pixel default value) and a signal period of 272 µs (like the used test signal) a minimum sweep time of 272 µs x 625 = 170 ms.

- **FSP**
  The measurement bandwidth of FSP is not sufficient to use the time domain mode (FS-K90). So, the instrument will automatically switch to the standard spectrum analyzer mode when doing this measurement.
  Gated sweep or maximum trace hold functions can be used in spectrum analyzer mode.

Measurement Results

The picture below shows the display of a typical measurement result:

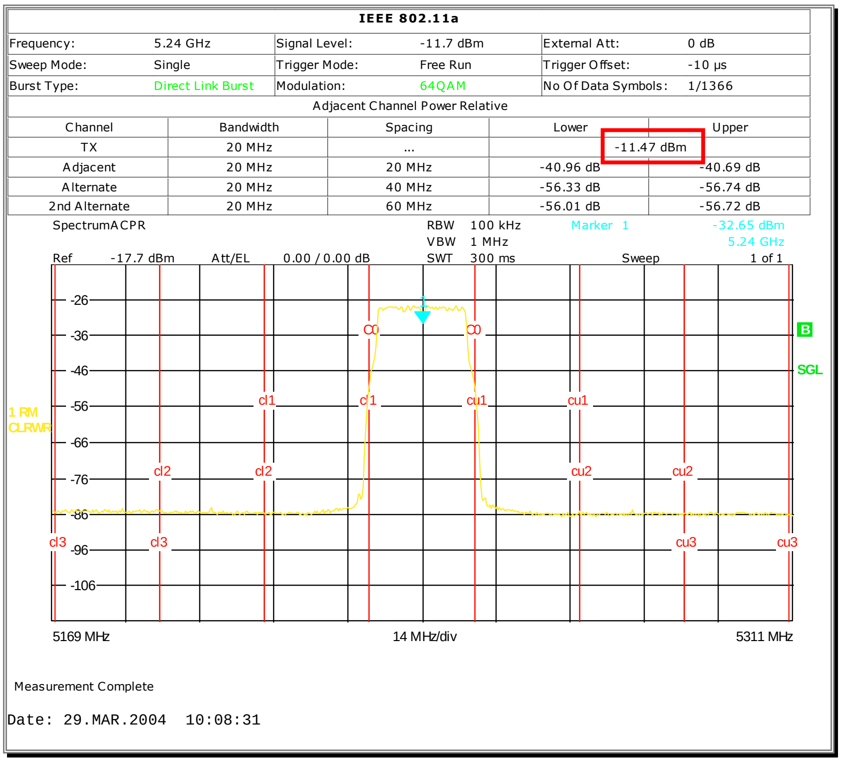


Figure 12 – Maximum transmit power level typical measurement result (using WLAN personality)

17.3.9.2 Transmit spectrum mask

Purpose	Basic instrument	Options	Used to
Measurement	FSP / (FSU) / FSQ	FSx-K90/91 [1)]	Check spectrum mask
---	please refer to page 23		Generate a valid 802.11a signal

[1)] the base instrument can be used as well

Test purpose

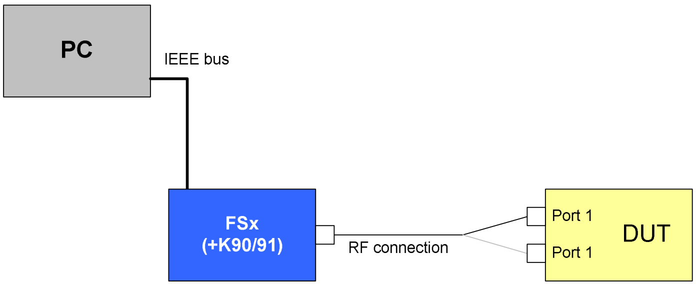
This test ensures that the DUT does not influence other WLAN devices transmitting in adjacent channels. Interference may result in bad or even no connection.

The 802.11a standard does not define a transmitter filter, but only a transmit spectrum mask to be passed. Therefore, the design of the individual output filter is up to the manufacturer of the DUT. The design must be appropriate to ensure a pass of the spectrum mask and good performance in transmission.

DUT setup, equivalent WV file

DUT Status	Tx Active
Signal Type	Standard Tx signal OFDM, 54 Mbit/s
Power Level	Maximum
Antenna	1 or 2
Annotations	---
Equiv. WV file	A_54_K19

Test setup



Drawing 4 – Transmit spectrum mask test setup

17.3.9.2 Transmit spectrum mask

Test method

1. Configure the WLAN module according to the DUT setup (use for example test software provided with the module).
2. Set up the analyzer step-by-step as described below:

PRESET	set instrument to default stats
(MORE) WLAN	switch on WLAN personality
FREQ CENTER <value>	set signal frequency
SPECTRUM SPECTRUM IEEE	switch to power mask measurement
RUN SGL	execute one measurement

Measurement Parameter, Limits

The transmitter spectrum mask is defined as following. The mask is aligned to the maximum spectral density of the signal (according to Figure 120 in 802.11a standard):

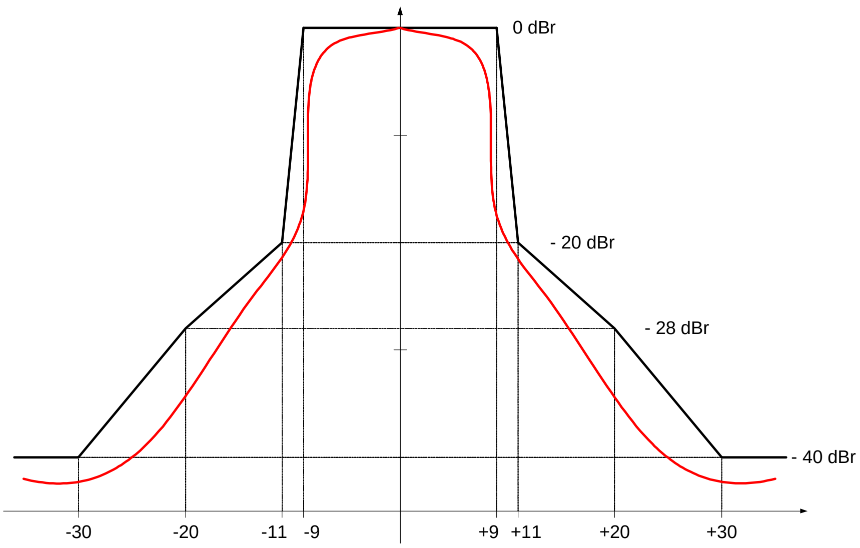


Figure 13 – 802.11a Transmit spectrum mask specification

Test implementation hints

- **Measurement**
  Since the 802.11a signal is a pulsed signal, but the spectrum mask is defined for a continuous signal, you have to get some sort of continuous reading for the spectrum.
  This can be realized using
  - a continuous transmission mode of the DUT (if available)
  - gated sweeping (as used in the WLAN personality)
  - max hold trace mode in spectrum mode
- **Spectrum mask**
  The spectrum mask is automatically aligned to the maximum transmit power level from the WLAN measurement personality

K90/91 when a measurement sweep is finished.
If the measurement is conducted without the WLAN personality, the limit line has to be programmed manually and aligned with the trace maximum. This maximum is the one detected with a maximum peak marker function.

Measurement Results

The picture below shows the display of a typical measurement result:

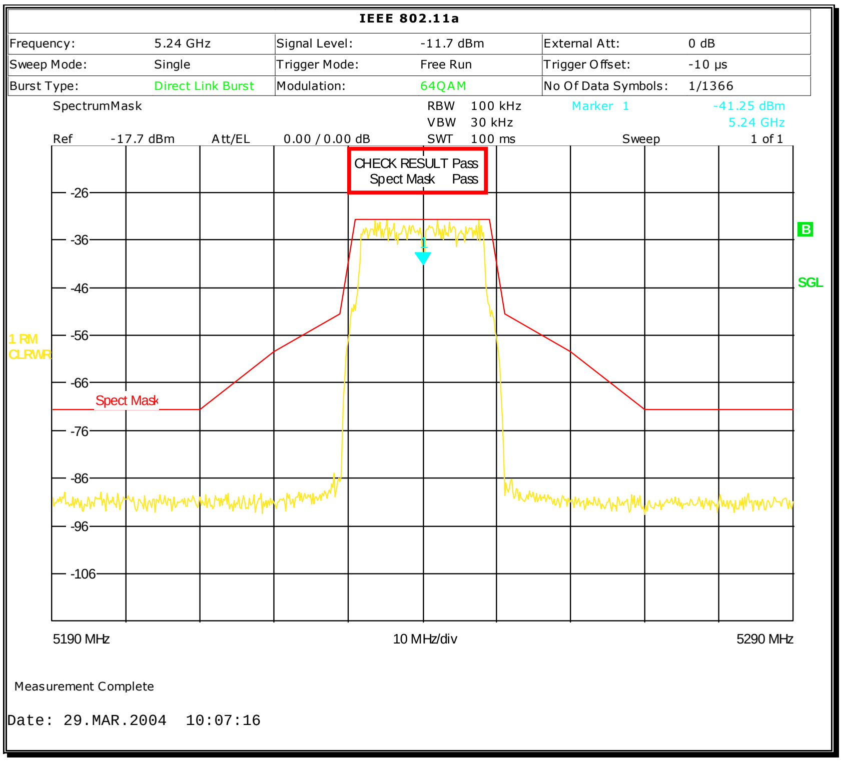


Figure 14 – Transmit spectrum mask measurement result

17.3.9.3 Transmit spurious

Purpose	Basic instrument	Options	Used to
Measurement	FSP / FSU / FSQ	---	Measure spectrum emissions
+ *demonstration*	please refer to page 23		Generate a valid 802.11a signal

Test purpose

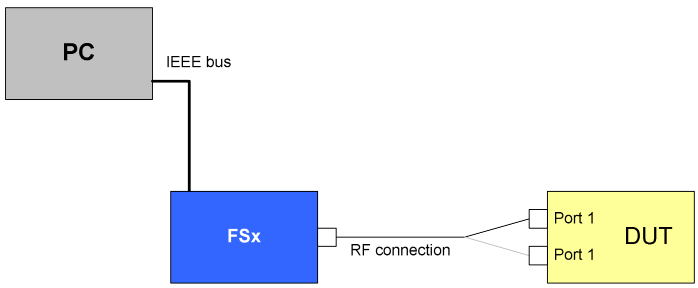
This test checks for spurious emissions from the DUT. This may be due to for example bad design of the oscillator, the shielding of the DUT or the cabling to the antenna.

Spurious emissions can cause problems in equipment using other bands like mobile phones or radio and television.

DUT setup, equivalent WV file

DUT Status	Tx Active
Signal Type	Standard Tx signal OFDM, 54 Mbit/s
Power Level	Maximum
Antenna	1 or 2
Annotations	---
Equiv. WV file	A_54_K19

Test setup



Drawing 5 – Transmit spurious test setup [1)]

1) additional equipment like filters may be necessary for this test

17.3.9.3 Transmit spurious

Test method

1. Configure the WLAN module according to the DUT setup (use for example test software provided with the module).
2. Set up the analyzer step-by-step as described below:

PRESET	set instrument to default stats
FREQ START <value>	set left frequency range limit [1)]
STOP <value>	set right frequency range limit [1)]
AMPT REF LEVEL <value>	set level to a sensitive value for the required emission limit
BW RES BW MANUAL <value>	set resolution bandwidth [1)]
TRACE MAX HOLD	switch on max hold mode and peak detector
SWEEP SINGLE SWEEP	sweep once to measure the spurious emission

1) these settings depend on regulatory requirements

Measurement Parameter, Limits

The limits for the measurement are subject to regulatory bodies and therefore not stated here.

Please refer for example to

- FCC 15.407 for regulations valid for the United States [8].
- ETSI EN 301 893 4.4.1.2 for regulation valid in Europe [12].

Test implementation hints

- **Sweeptime selection**
  The sweeptime must be set to get 1 complete signal period within 1 pixel on the analyzer screen during the sweep in the frequency domain, which means for example for an FSQ (625 pixel default value) and a signal period of 272 µs (like the used test signal) a minimum sweep time of 272 µs x 625 = 170 ms.

Measurement Results

17.3.9.4 Transmit center frequency tolerance

Purpose	Basic instrument	Options	Used to
Measurement	FSP / (FSU) / FSQ	FS-K90/91 [1)]	Measure frequency tolerance
+ demonstration	please refer to page 23		Generate a valid 802.11a signal

[1)] basic instrument can be used as well if a special test mode in the DUT is available

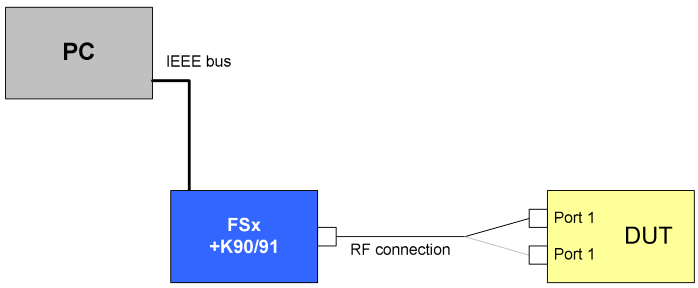
Test purpose

If the transmitter frequency is not accurate enough, this may result in a failed spectrum mask (Test 17.3.9.2) or in high readings of Error Vector Magnitude (EVM) (Test 17.3.9.6.3). It may also cause the DUT not to be able to connect to another WLAN module / access point.

DUT setup, equivalent WV file

DUT Status	Tx Active
Signal Type	Standard Tx signal OFDM, 54 Mbit/s
Power Level	Maximum
Antenna	1 or 2
Annotations	---
Equiv. WV file	A_54_K19

Test setup



Drawing 6 – Center frequency tolerance test setup

17.3.9.4 Transmit center frequency tolerance

Test method

1. Configure the WLAN module according to the DUT setup (use for example test software provided with the module).
2. Set up the analyzer step-by-step as described below:

PRESET	set instrument to default stats
(MORE) WLAN	switch on WLAN personality
FREQ <value>	set signal frequency
DISPLAY LIST	show result summary
RUN SGL	execute one measurement

Measurement Parameter, Limits

The transmit clock frequency tolerance shall be ± 20 ppm maximum relative to the center frequency. This is equivalent to a maximum error of 116.1 kHz for the highest assigned 802.11a transmission frequency (5.805 GHz).

Test implementation hints

- **Test mode**
  The center frequency error can also be measured if modulation is switched off and only the unmodulated carrier is transmitted.
  This measurement can then be done without the WLAN personality by using a simple frequency counter measurement.
  The DUT must provide a special test mode for switching the modulation off, and side effects in the DUT (current consumption, thermal drifts, ...) can result in a slightly different measurement value.
  So, it is recommended to do the measurement in normal operation mode with modulation switched on using the K90/K91 functionality.

17.3.9.4 *Transmit center frequency tolerance*

Measurement Results

The picture below shows the display of a typical measurement result:

IEEE 802.11a

Frequency:	1 GHz	Signal Level:	-30 dBm	External Att:	0 dB
Sweep Mode:	Single	Trigger Mode:	Free Run	Trigger Offset:	-10 µs
Burst Type:	Direct Link Burst	Modulation:	64QAM	No Of Data Symbols:	1/1366

Result Summary

No. of Bursts	4					
	Min	Mean	Limit	Max	Limit	Unit
EVM All Carriers	0.71	0.74	5.62	0.75	5.62	%
	- 42.93	- 42.63	- 25.00	- 42.48	- 25.00	dB
EVM Data Carriers	0.72	0.75	5.62	0.76	5.62	%
	- 42.88	- 42.53	- 25.00	- 42.40	- 25.00	dB
EVM Pilot Carriers	0.58	0.63	39.81	0.68	39.81	%
	- 44.74	- 44.02	- 8.00	- 43.34	- 8.00	dB
IQ Offset	- 64.46	- 63.17	- 15.00	- 61.67	- 15.00	dB
Gain Imbalance	0.06	0.07		0.08		%
	0.01	0.01		0.01		dB
Quadrature Offset	- 0.01	0.01		0.02		°
Center Frequency Error	154.96	158.06	± 20000	160.83	± 20000	Hz
Symbol Clock Error	- 0.03	- 0.16	± 20	- 0.34	± 20	ppm
Burst Power	- 40.84	- 40.84		- 40.84		dBm
Crest Factor	9.02	9.03		9.04		dB

Measurement Complete

Date: 9.FEB.2004 10:43:16

Figure 15 – Transmit center frequency measurement result

17.3.9.5 Symbol clock frequency tolerance

Purpose	Basic instrument	Options	Used to
Measurement	FSP / FSQ	FS-K90/91	Measure symbol clock tolerance
+ demonstration	please refer to page 23		Generate a valid 802.11a signal

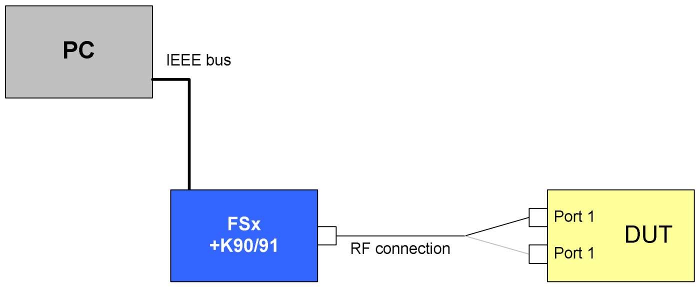
Test purpose

If the symbol clock frequency is not accurate enough, this may result in high EVM readings (Test 17.3.9.6.3). It may also cause the DUT to fail to connect to another WLAN module / access point.

DUT setup, equivalent WV file

DUT Status	Tx Active
Signal Type	Standard Tx signal OFDM, 54 Mbit/s
Power Level	Maximum
Antenna	1 or 2
Annotations	---
Equiv. WV file	A_54_K19

Test setup



Drawing 7 – Symbol clock tolerance test setup

17.3.9.5 Symbol clock frequency tolerance

Test method

1. Configure the WLAN module according to the DUT setup (use for example test software provided with the module).
2. Set up the analyzer step-by-step as described below:

PRESET	set instrument to default stats
(MORE) WLAN	switch on WLAN personality
FREQ <value>	set signal frequency
DISPLAY LIST	show result summary
RUN SGL	execute one measurement

Measurement Parameter, Limits

The symbol clock frequency tolerance shall be ± 20 ppm maximum relative to the symbol clock frequency.
This is equivalent to a maximum error of 5 Hz for the 802.11a symbol clock frequency of 4 µs = 250 kHz.

Test implementation hints

17.3.9.5 Symbol clock frequency tolerance

Measurement Results

The picture below shows the display of a typical measurement result:

IEEE 802.11a					
Frequency:	5.24 GHz	Signal Level:	-8.52 dBm	External Att:	0 dB
Sweep Mode:	Single	Trigger Mode:	Free Run	Trigger Offset:	-10 µs
Burst Type:	Direct Link Burst	Modulation:	64QAM	No Of Data Symbols:	1/1366

Result Summary						
No. of Bursts	4					
	Min	Mean	Limit	Max	Limit	Unit
EVM All Carriers	0.62	0.65	5.62	0.69	5.62	%
	- 44.16	- 43.79	- 25.00	- 43.20	- 25.00	dB
EVM Data Carriers	0.62	0.64	5.62	0.69	5.62	%
	- 44.19	- 43.82	- 25.00	- 43.19	- 25.00	dB
EVM Pilot Carriers	0.61	0.67	39.81	0.77	39.81	%
	- 44.34	- 43.42	- 8.00	- 42.23	- 8.00	dB
IQ Offset	- 40.14	- 40.08	- 15.00	- 40.01	- 15.00	dB
Gain Imbalance	- 0.01	- 0.00		0.01		%
	- 0.00	- 0.00		0.00		dB
Quadrature Error	- 0.05	- 0.04		- 0.04		°
Center Frequency Error	0.21	- 0.80	± 104800	- 2.83	± 104800	Hz
Symbol Clock Error	0.02	- 0.12	± 20	- 0.34	± 20	ppm
Burst Power	- 11.10	- 11.10		- 11.10		dBm
Crest Factor	9.05	9.05		9.05		dB

Measurement Complete

Date: 29.MAR.2004 11:47:42

Figure 16 – Symbol clock frequency measurement result

17.3.9.6.1 Transmitter center frequency leakage

Purpose	Basic instrument	Options	Used to
Measurement	FSP / (FSU) / FSQ	FS-K90/91 [1)]	Measure center frequency leakage
+ demonstration	please refer to page 23		Generate a valid 802.11a signal

[1)] possible also with basic instrument, but not recommended

Test purpose

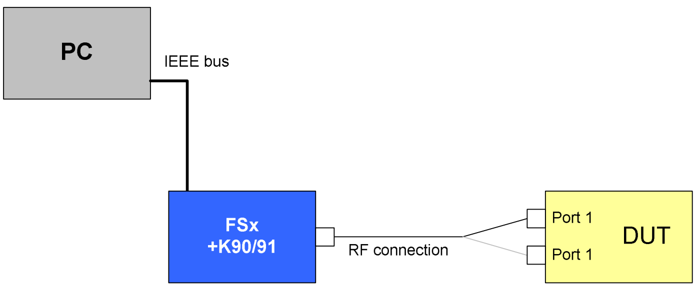
Center frequency leakage results in a DC voltage in receivers using a zero-mixing concept. This can lead – depending on the demodulator concept like zero-mixing – to bad demodulation performance.

The measurement is done within the short training sequence of the transmission where only every 4th carrier is used for transmission of a fixed pattern.

DUT setup, equivalent WV file

DUT Status	Tx Active
Signal Type	Standard Tx signal OFDM, 54 Mbit/s
Power Level	Maximum
Antenna	1 or 2
Annotations	---
Equiv. WV file	A_54_K19

Test setup



Drawing 8 – Center frequency leakage test setup

17.3.9.6.1 Transmitter center frequency leakage

Test method – Using IQ offset reading

1. Configure the WLAN module according to the DUT setup (use for example test software provided with the module).
2. Set up the analyzer step-by-step as described below:

PRESET	set instrument to default stats
(MORE) WLAN	switch on WLAN personality
FREQ <transmit frequency>	set signal frequency
DISPLAY LIST	show result summary
RUN SGL	execute one measurement

Test method – Using FFT spectrum display with WLAN personality

1. Configure the WLAN module according to the DUT setup (use for example test software provided with the module).
2. Set up the analyzer step-by-step as described below:

PRESET	set instrument to default stats
(MORE) WLAN	switch on WLAN personality
FREQ <value>	set signal frequency
TRIG Power	select power trigger to find burst begin
SWEEP Capture Time <value>	set capture length to capture 1 burst (e.g. 200 µs)
SPECTRUM SPECTRUM FFT	switch on FFT spectrum display
GATING ON	switch on gating to measure training sequence
GATE SETTINGS Delay: 10 µs, Length: 8 µs	select training sequence to be measured
RUN SGL	execute one measurement
SCREEN B	activate FFT spectrum display
MKR <center frequency>	set marker to center frequency and read marker level

Measurement Parameter, Limits

The carrier leakage shall not exceed -15 dB relative to the total signal power, or +2 dB relative to the average energy of all subcarriers except the center carrier.

17.3.9.6.1 Transmitter center frequency leakage

Test implementation hints

- **Measurement methods**
  There are 2 different methods within the K90/91 WLAN measurement personality to measure the center frequency leakage:
  The ***IQ offset method*** is good for fast evaluation of the center frequency leakage *value*.
  The ***FFT method*** can be used to have a detailed look at the *spectrum over all carriers* itself.

- **Readings**
  The measurement value from the WLAN personality is evaluated according to the requirement for the total signal power and checked against the limit value of -15 dB.

Measurement Results

The first picture shows the result of a measurement according to the IQ offset method:

IEEE 802.11a					
Frequency:	5.24 GHz	Signal Level:	-8.37 dBm	External Att:	0 dB
Sweep Mode:	Single	Trigger Mode:	Free Run	Trigger Offset:	-10 µs
Burst Type:	Direct Link Burst	Modulation:	64QAM	No Of Data Symbols:	1/1366

Result Summary						
No. of Bursts	4					
	Min	Mean	Limit	Max	Limit	Unit
EVM All Carriers	0.58	0.63	5.62	0.69	5.62	%
	- 44.69	- 44.04	- 25.00	- 43.19	- 25.00	dB
EVM Data Carriers	0.58	0.63	5.62	0.71	5.62	%
	- 44.73	- 44.04	- 25.00	- 43.03	- 25.00	dB
EVM Pilot Carriers	0.51	0.62	39.81	0.68	39.81	%
	- 45.89	- 44.14	- 8.00	- 43.33	- 8.00	dB
IQ Offset	- 39.90	- 39.85	- 15.00	- 39.82	- 15.00	dB
Gain Imbalance	- 0.00	0.00		0.00		%
	- 0.00	0.00		0.00		dB
Quadrature Error	- 0.05	- 0.04		- 0.03		°
Center Frequency Error	0.10	- 0.76	± 104800	- 1.92	± 104800	Hz
Symbol Clock Error	0.05	- 0.02	± 20	- 0.26	± 20	ppm
Burst Power	- 11.20	- 11.20		- 11.19		dBm
Crest Factor	9.11	9.11		9.12		dB

Measurement Complete

Date: 29.MAR.2004 11:04:31

Figure 17 – Transmit center frequency leakage measurement result

17.3.9.6.1 Transmitter center frequency leakage

The next picture shows the result of a measurement according to the FFT spectrum method:

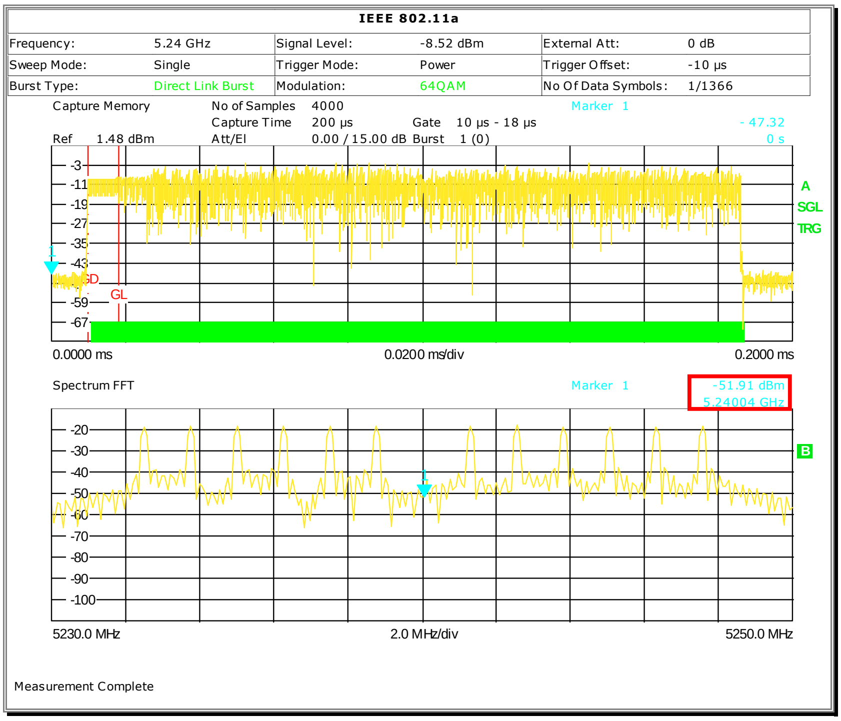


Figure 18 – Transmit center frequency leakage measurement result (using WLAN personality)

17.3.9.6.2 Transmitter spectral flatness

Purpose	Basic instrument	Options	Used to
Measurement	FSP / FSQ	FS-K90/91 [1)]	Measure spectrum flatness
+ demonstration	please refer to page 23		Generate a valid 802.11a signal

[1)] measurement with FSP possible, but only on a limited number of carriers

Test purpose

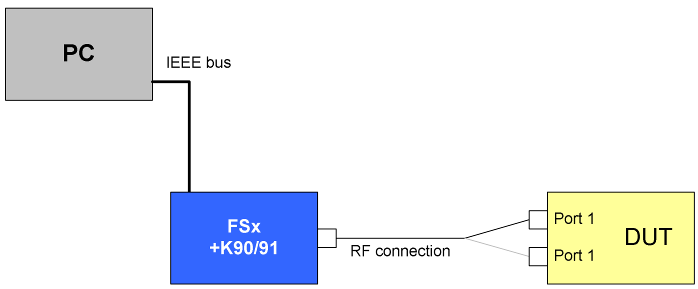
Filters within the RF frontend of the DUT can cause a frequency response leading to degradation of the total EVM of the signal and a bad link performance. So, effects like this must be kept low.

The measurement is done within the long training sequence of the transmission where all carriers are used for transmission of a fixed pattern.

DUT setup, equivalent WV file

DUT Status	Tx Active
Signal Type	Standard Tx signal OFDM, 54 Mbit/s
Power Level	Maximum
Antenna	1 or 2
Annotations	---
Equiv. WV file	A_54_K19

Test setup



Drawing 9 – Transmit spectrum flatness test setup

17.3.9.6.2 Transmitter spectral flatness

Test method

1. Configure the WLAN module according to the DUT setup (use for example test software provided with the module).
2. Set up the analyzer step-by-step as described below:

PRESET	set instrument to default stats
(MORE) WLAN	switch on WLAN personality
FREQ <transmit frequency>	set signal frequency
SPECTRUM	switch on spectrum display (flatness is selected by default)
RUN SGL	execute one measurement

Measurement Parameter, Limits

The energy of each spectral line shall not excide the following limits relative to the average energy of the spectral lines -16 .. -1 and +1 .. +16:

Line number range	Upper limit	Lower limit
-26 … -17	+ 2 dB	- 4 dB
-16 … -1	+ 2 dB	- 2 dB
+1 … +16	+ 2 dB	- 2 dB
+17 … +26	+ 2 dB	- 4 dB

Table 9 – 802.11a Transmitter spectral flatness limits

Test implementation hints

- **Measurement with FSP / FSQ**
  Due to the bandwidth of the FSP in IQ mode of only 8 MHz, not all carriers can be captured and analyzed.
  Only carrier number {-14 .. +14} can be analyzed.
  This is in most cases enough to verify the result for EVM and modulation accuracy.
  If filter effects disturb the modulation, this can be seen in the spectrum flatness display.
  If some problems with the modulator occur, this can also be seen (in most cases) clearly from the lower order carriers captured from the FSP.
  If any non-linear amplifier effects disturbs the transmission, this carrier is influenced in the same way, and can so also be seen clearly as effects on the lower-order carriers.
  If a detailed view on all carriers is required, you must use an FSQ to demodulate all carriers of the 802.11a signal.

17.3.9.6.2 Transmitter spectral flatness

Measurement Results

The picture below shows the display of a typical measurement result:

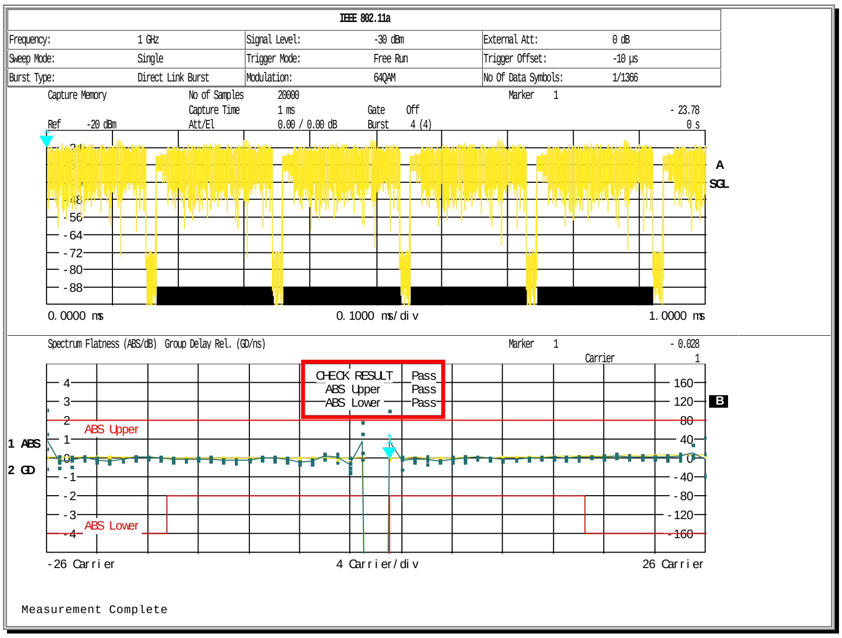


Figure 19 – Transmit spectral flatness measurement result

17.3.9.6.3 Transmitter constellation error

Purpose	Basic instrument	Options	Used to
Measurement	FSP / FSQ	FS-K90/91	Measure constellation error
+ demonstration	please refer to page 23		Generate a valid 802.11a signal

Test purpose

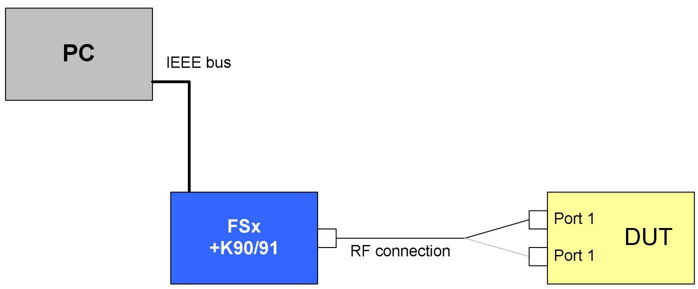
Testing only the spectrum mask (Test 17.3.9.2) and the spectrum flatness (Test 17.3.9.6.2) may not be enough for state-of-the art WLAN transmitters because effects in for example the power amplifiers may result in errors in the modulation domain only.

So, additional measurements of the constellation error are essential for testing a WLAN DUT.

DUT setup, equivalent WV file

DUT Status	Tx Active
Signal Type	Standard Tx signal OFDM, 54 Mbit/s
Power Level	Maximum
Antenna	1 or 2
Annotations	---
Equiv. WV file	A_54_K19

Test setup



Drawing 10 – Constellation error test setup

17.3.9.6.3 Transmitter constellation error

Test method

1. Configure the WLAN module according to the DUT setup (use for example test software provided with the module).
2. Set up the analyzer step-by-step as described below:

PRESET	set instrument to default stats
(MORE) WLAN	switch on WLAN personality
FREQ <transmit frequency>	set signal frequency
DISPLAY LIST	show result summary
RUN SGL	execute one measurement

Measurement Parameters, Limits

The relative constellation RMS error, averaged over all subcarriers, OFDM frames, and packets, shall not exceed the values listed below (according to Table 90 in 802.11a):

Data rate [Mbit/s]	Const. Error [dB]	Const. Error [%]
6	-5	56.2
9	-8	39.8
12	-10	31.6
18	-13	22.4
24	-16	15.8
36	-19	11.2
48	-22	7.94
54	-25	5.62

Table 10 – 802.11a Maximum transmitter constellation error

Test implementation hints

- **Measurement with FSP / FSQ**
  Due to the bandwidth of the FSP in IQ mode of only 8 MHz, not all carriers can be captured and analyzed.
  Only carrier number {-14 .. +14} can be analyzed.
  This is in most cases enough to verify the result for EVM and modulation accuracy.
  If filter effects disturb the modulation, this can be seen in the spectrum flatness display.
  If some problems with the modulator occur, this can also be seen (in most cases) clearly from the lower order carriers captured from the FSP.
  If any non-linear amplifier effects disturbs the transmission, this carrier is influenced in the same way, and can so also be seen clearly as effects on the lower-order carriers.
  If a detailed view on all carriers is required, you must use an FSQ to demodulate all carriers of the 802.11a signal.

17.3.9.6.3 Transmitter constellation error

Measurement Results

The figure below shows a typical measurement result display:

IEEE 802.11a					
Frequency:	5.24 GHz	Signal Level:	-8.52 dBm	External Att:	0 dB
Sweep Mode:	Single	Trigger Mode:	Free Run	Trigger Offset:	-10 µs
Burst Type:	Direct Link Burst	Modulation:	64QAM	No Of Data Symbols:	1/1366

Result Summary						
No. of Bursts	4					
	Min	Mean	Limit	Max	Limit	Unit
EVM All Carriers	**0.62**	**0.65**	5.62	**0.69**	5.62	%
	- 44.16	**- 43.79**	- 25.00	**- 43.20**	- 25.00	dB
EVM Data Carriers	**0.62**	**0.64**	5.62	**0.69**	5.62	%
	- 44.19	**- 43.82**	- 25.00	**- 43.19**	- 25.00	dB
EVM Pilot Carriers	**0.61**	**0.67**	39.81	**0.77**	39.81	%
	- 44.34	**- 43.42**	- 8.00	**- 42.23**	- 8.00	dB
IQ Offset	**- 40.14**	**- 40.08**	- 15.00	**- 40.01**	- 15.00	dB
Gain Imbalance	**- 0.01**	**- 0.00**		**0.01**		%
	- 0.00	**- 0.00**		**0.00**		dB
Quadrature Error	**- 0.05**	**- 0.04**		**- 0.04**		°
Center Frequency Error	**0.21**	**- 0.80**	± 104800	**- 2.83**	± 104800	Hz
Symbol Clock Error	**0.02**	**- 0.12**	± 20	**- 0.34**	± 20	ppm
Burst Power	**- 11.10**	**- 11.10**		**- 11.10**		dBm
Crest Factor	**9.05**	**9.05**		**9.05**		dB

Measurement Complete

Figure 20 – Transmit constellation error measurement result

17.3.9.7 Transmit modulation accuracy error

Purpose	Basic instrument	Options	Used to
Measurement	FSP / FSQ	FS-K90/91	Measure modulation accuracy
+ demonstration	please refer to page 23		Generate a valid 802.11a signal

Test purpose

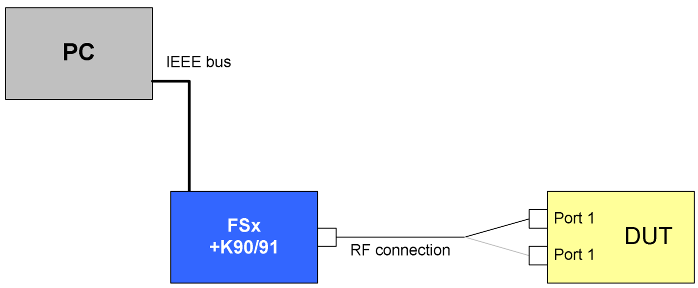
This test is some sort of EVM test as described in test 17.3.9.6.3, but specially described for DUT's converting the RF signal to an IF signal and then doing a sampling of this signal.

So, the test can also be done the same way as test 17.3.9.6.3, using the lower IF frequency as test frequency.

DUT setup, equivalent WV file

DUT Status	Tx Active
Signal Type	Standard Tx signal OFDM, 54 Mbit/s
Power Level	Maximum
Antenna	1 or 2
Annotations	---
Equiv. WV file	A_54_K19

Test setup



Drawing 11 – Modulation accuracy test setup

17.3.9.7 Transmit modulation accuracy error

Test method

1. Configure the WLAN module according to the DUT setup (use for example test software provided with the module).
2. Set up the analyzer step-by-step as described below:

PRESET	set instrument to default stats
(MORE) WLAN	switch on WLAN personality
FREQ <transmit frequency>	set signal frequency
DISPLAY LIST	show result summary
RUN SGL	execute one measurement

Measurement Parameters, Limits

There are no limits specified for this test.

Test implementation hints

- **Measurement with FSP / FSQ**
  Due to the bandwidth of the FSP in IQ mode of only 8 MHz, not all carriers can be captured and analyzed.
  Only carrier number {-14 .. +14} can be analyzed.
  This is in most cases enough to verify the result for EVM and modulation accuracy.
  If filter effects disturb the modulation, this can be seen in the spectrum flatness display.
  If some problems with the modulator occur, this can also be seen (in most cases) clearly from the lower order carriers captured from the FSP.
  If any non-linear amplifier effects disturbs the transmission, this carrier is influenced in the same way, and can so also be seen clearly as effects on the lower-order carriers.
  If a detailed view on all carriers is required, you must use an FSQ to demodulate all carriers of the 802.11a signal.
- **Capture length**
  The Standard requires a capture length of at least 20 frames, each with at least 16 random OFDM symbols as packet load.

17.3.10.1 Receiver minimum input level

Purpose	Basic instrument	Options	Used to
Measurement	please refer to page 23		Generate a valid 802.11a signal
+ demonstration	---	---	---

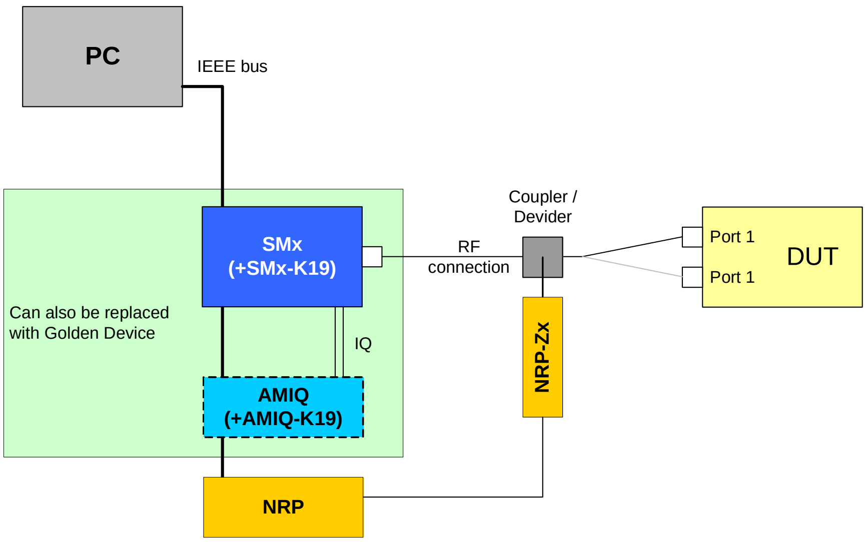
Test purpose

The WLAN DUT must be able to setup a connection and transmit data for low input levels. This test makes sure that the DUT is able to receive data with a defined maximum Packet Error Rate (PER) at a defined minimum level, measured at the antenna port.

DUT setup, equivalent WV file

DUT Status	Rx Active
Signal Type	Standard Tx signal OFDM, variable data rate
Power Level	as described in table below
Antenna	1 or 2
Annotations	---
Equiv. WV file	e.g. A_54_K19 for 54 MBit/s

Test setup



Drawing 12 – Receiver minimum input level test setup

17.3.10.1 Receiver minimum input level

Test method

1. Set up the test signal generator (R&S instrument or Golden Device combined with a programmable step attenuator) to transmit a signal.
2. Set up the DUT in receiver mode and for PER calculation (this feature is available in a special DUT test mode) or use the PER software [9].
3. Reduce the input level at the DUT Rx port until a PER of 10 % is reached and check if the level is lower then the specified minimum sensitivity level (test PASSED) or higher (test FAILED)
   OR
   Setup the minimum sensitivity level as specified and check if the PER is below 10 % (test PASSED) or above 10 % (test FAILED).

Measurement Parameters, Limits

A PER of 10 % or lower, measured over a PSDU length of 1000 byte, shall be reached for levels less or equal to the values listed below (according to Table 91 in 802.11a):

Data rate [Mbit/s]	Minimum sensitivity [dBm]
6	-82
9	-81
12	-79
18	-77
24	-74
36	-70
48	-66
54	-65

Table 11 – 802.11a Minimum sensitivity levels

Test implementation hints

Measurement Results

17.3.10.2 Adjacent channel rejection

Purpose	Basic instrument	Options	Used to
Measurement	please refer to page 23		Generate a valid 802.11a signal
+ demonstration	---	---	---

Test purpose

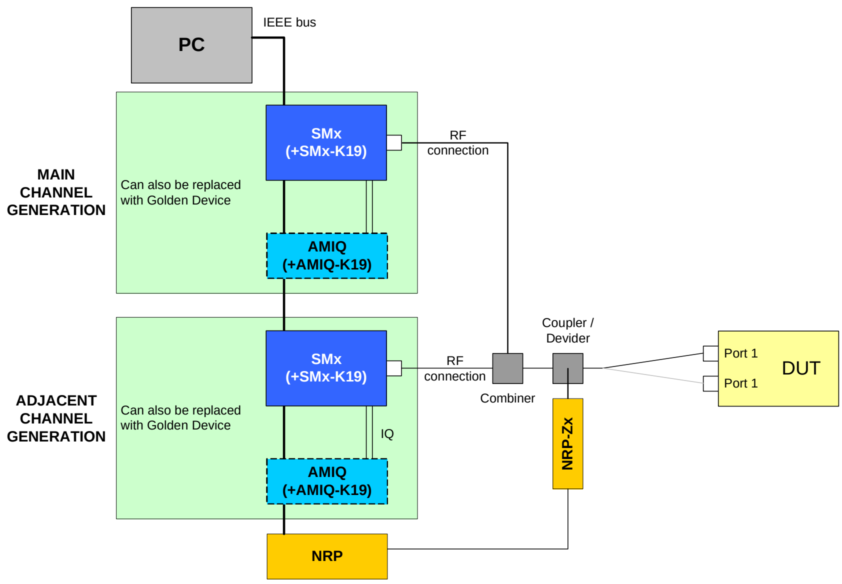
For stable operation, it is important that a WLAN card can establish and hold a connection if other channels, especially the adjacent channel, are occupied by other users.

This test ensures that the DUT can operate while the adjacent channels is occupied, and the signal strength of the adjacent channel is significantly higher then the desired channel.

DUT setup, equivalent WV file

DUT Status	Rx Active
Signal Type	Standard Tx signal OFDM, variable data rate
Power Level	as described in table below
Antenna	1 or 2
Annotations	---
Equiv. WV file	e.g. A_54_K19 for 54 MBit/s

Test setup



Drawing 13 – Adjacent channel rejection test setup

17.3.10.2 Adjacent channel rejection

Test method

1. Set up the ***first*** test signal generator (R&S instrument or Golden Device combined with a programmable step attenuator) to transmit the ***desired*** signal at a level 3 dB above the minimum sensitivity level (rate-specific specified for test 17.3.10.1).
2. Set up the ***second*** test signal generator (R&S instrument or Golden Device combined with a programmable step attenuator) to transmit the ***interfering*** signal at the same level as the first test signal generator, using an adjacent channel of the desired signal.
3. Set up the DUT to receiver mode and PER calculation (this feature is available in a special DUT test mode) or use the PER software [9].
4. Increase the output level of the second test signal generator until a PER of 10 % is reached and check if the level is lower then the specified adjacent channel rejection level = -63 dBm (test PASSED) or higher (test FAILED)
   OR
   Setup the level of the second test signal generator to -63 dBm and check if the PER is below 10 % (test PASSED) or above 10 % (test FAILED).

Measurement Parameters, Limits

A PER of 10 % or lower, measured over a PSDU length of 1000 bytes, shall be reached for adjacent channel levels equal higher or equal to the values listed below (according to Table 91 in 802.11a standard):

Data rate [Mbit/s]	Adjacent channel rejection [dB]	Resulting minimum Adjacent channel power [dBm]
6	16	**-63**
9	15	
12	13	
18	11	
24	8	
36	4	
48	0	
54	-1	

Table 12 – 802.11a Minimum adjacent channel powers

Test implementation hints

Measurement Results

17.3.10.3 Non-adjacent channel rejection

Purpose	Basic instrument	Options	Used to
Measurement	please refer to page 23		Generate a valid 802.11a signal
+ demonstration	---	---	---

Test purpose

For a stable operation, it is important that a WLAN card can establish and hold a connection then other channels are occupied by other users.

This test ensures that the DUT can operate while the alternate channels are occupied, and the signal strength of the alternate channel is significantly higher then the desired channel.

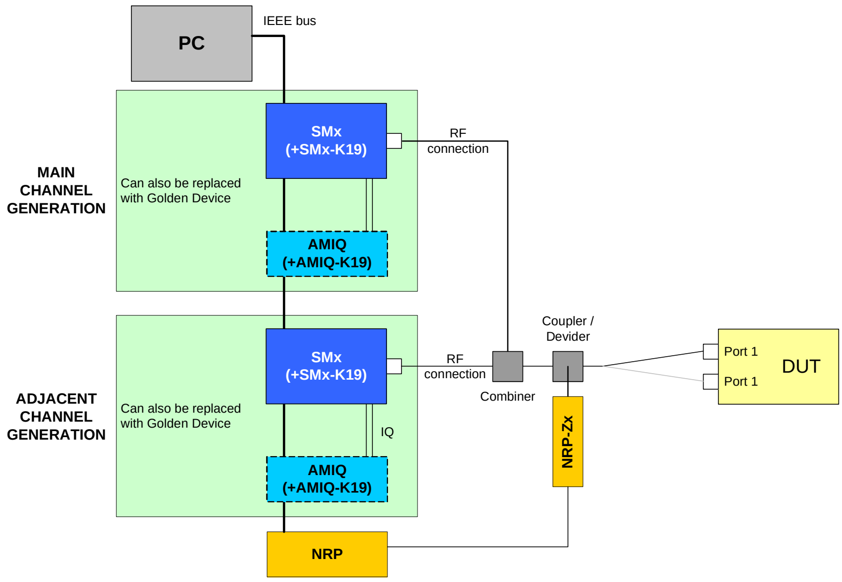
The difference to test 17.3.10.2 (Adjacent channel rejection) is that channels above and below the adjacent channels are tested with a higher interference level.

DUT setup, equivalent WV file

DUT Status	Rx Active
Signal Type	Standard Tx signal OFDM, variable data rate
Power Level	as described in Table 12
Antenna	1 or 2
Annotations	---
Equiv. WV file	e.g. A_54_K19 for 54 MBit/s

17.3.10.3 Non-adjacent channel rejection

Test setup



Drawing 14 – Non-adjacent channel rejection test setup

Test method

1. Set up the ***first*** test signal generator (R&S instrument or Golden Device combined with a programmable step attenuator) to transmit the ***desired*** signal at a level 3 dB above the minimum sensitivity level (rate-specific specified for test 17.3.10.1).
2. Set up the ***second*** test signal generator (R&S instrument or Golden Device combined with a programmable step attenuator) to transmit the ***interfering*** signal at the same level as the first test signal generator, using an non-adjacent channel to the desired signal.
3. Set up the DUT to receiver mode and PER calculation (this feature is available in a special DUT test mode) or use the PER software [9].
4. Increase the output level of the second test signal generator until a PER of 10 % is reached and check if the level is lower then the specified adjacent channel rejection level = -63 dBm (test PASSED) or higher (test FAILED)
   OR
   Setup the level of the second test signal generator to -63 dBm and check if the PER is below 10 % (test PASSED) or above 10 % (test FAILED).

17.3.10.3 Non-adjacent channel rejection

Measurement Parameters, Limits

A PER of 10 % or lower, measured over a PSDU length of 1000 bytes, shall be reached for adjacent channel levels higher or equal to the values listed below (according to Table 91 in 802.11a standard):

Data rate [Mbit/s]	Alternate adjacent channel rejection [dB]	Resulting minimum Alternate adjacent channel power [dBm]
6	16	**-47**
9	15	
12	13	
18	11	
24	8	
36	4	
48	0	
54	-1	

Table 13 – 802.11a Minimum alternate adjacent channel powers

Test implementation hints

Measurement Results

17.3.10.4 Receiver maximum input level

Purpose	Basic instrument	Options	Used to
Measurement	please refer to page 23		Generate a valid 802.11a signal
+ demonstration	---	---	---

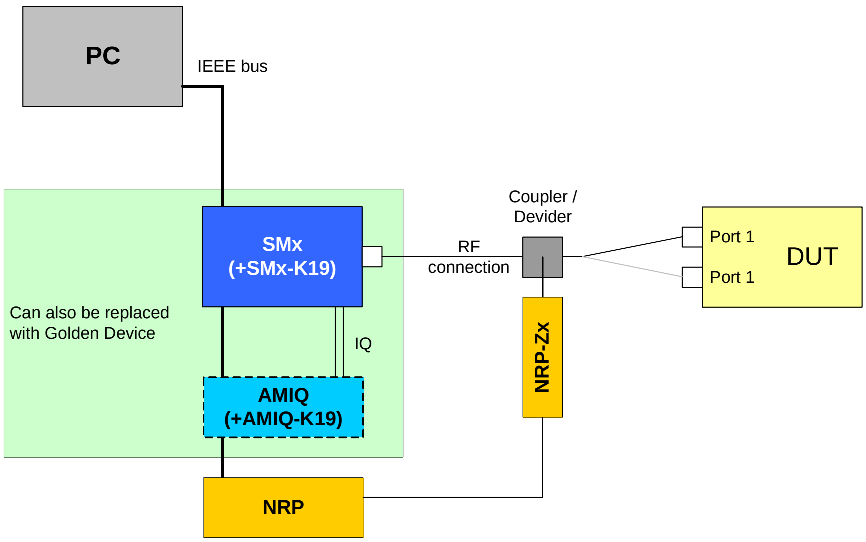
Test purpose

A WLAN card must be able to set up a connection and transmit if the distance between transmitter and receiver is very low. The test makes sure that the DUT can receive data with a defined maximum packet error rate (PER) at a defined maximum level, measured at the antenna port.

DUT setup, equivalent WV file

DUT Status	Rx Active
Signal Type	Standard Tx signal OFDM
Power Level	-30 dBm at antenna port
Antenna	1 or 2
Annotations	---
Equiv. WV file	e.g. A_54_K19 for 54 MBit/s

Test setup



Drawing 15 – Receiver maximum input level test setup

17.3.10.4 Receiver maximum input level

Test method

1. Set up the test signal generator (R&S instrument or Golden Device combined with a programmable step attenuator) to transmit a signal.
2. Set up the DUT to receiver mode and PER calculation (this feature is available in a special DUT test mode) or use the PER software [9].
3. Increase the input level at the DUT Rx port until a PER of 10 % is reached and check if the level is above -30 dBm (test PASSED) or below (test FAILED)
   OR
   Setup the input level to -30 dBm and check if the PER is below 10 % (test PASSED) or above 10 % (test FAILED).

Measurement Parameters, Limits

A PER of 10 % or lower, measured over a PSDU length of 1000 byte, shall be reached for levels higher or equal to -30 dBm.

Test implementation hints

Measurement Results

17.3.10.5 CCA sensitivity

Purpose	Basic instrument	Options	Used to
Measurement	please refer to page 23		Generate a valid 802.11b signal
	Oscilloscope		Shiw timing between burst and CA
+ demonstration	---	---	---

Test purpose

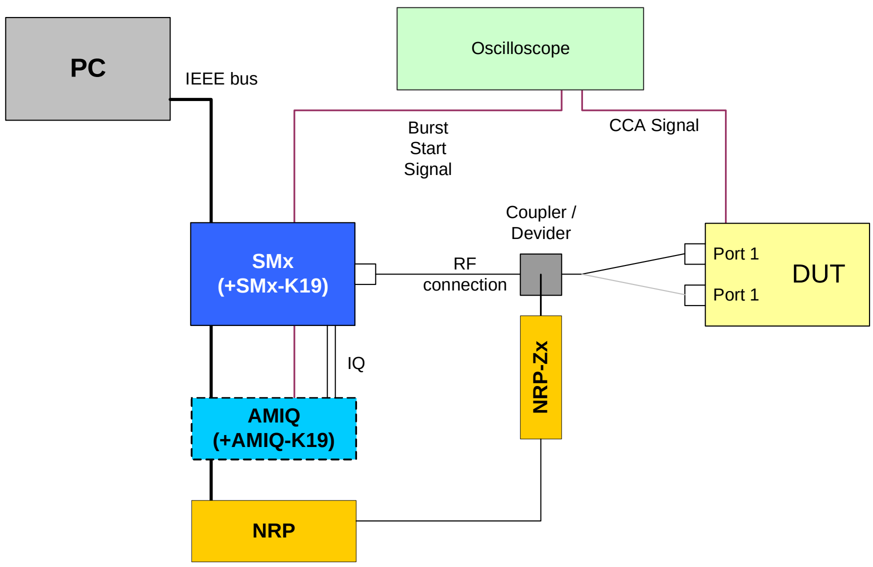
Clear Channel Assessment (CCA) is used to detect if the planned channel for transmission is free or used by another WLAN connection.

Mis-detection will lead to interference with an existing connection, and WLAN 802.11 has no dedicated access method like for example GSM via a separate connection control channels.

DUT setup, equivalent WV file

DUT Status	Rx Active
Signal Type	Standard Tx signal OFDM
Power Level	-82 dBm at antenna port
Antenna	1 or 2
Annotations	---
Equiv. WV file	e.g. A_54_K19 for 54 MBit/s

Test setup



Drawing 16 – CCA sensitivity test setup

Test method

Measurement Parameters, Limits

The CCA signal shall change to "BUSY":

- a maximum of 4 µs after the start of a valid OFDM transmission with a level equal or above -82 dBm has been detected (detection probability: 90 %)
- after any signal with a level equal or above -62 dBm (timing and probability not explicitly defined)

The figure below gives a graphic interpretation of the behaviour:

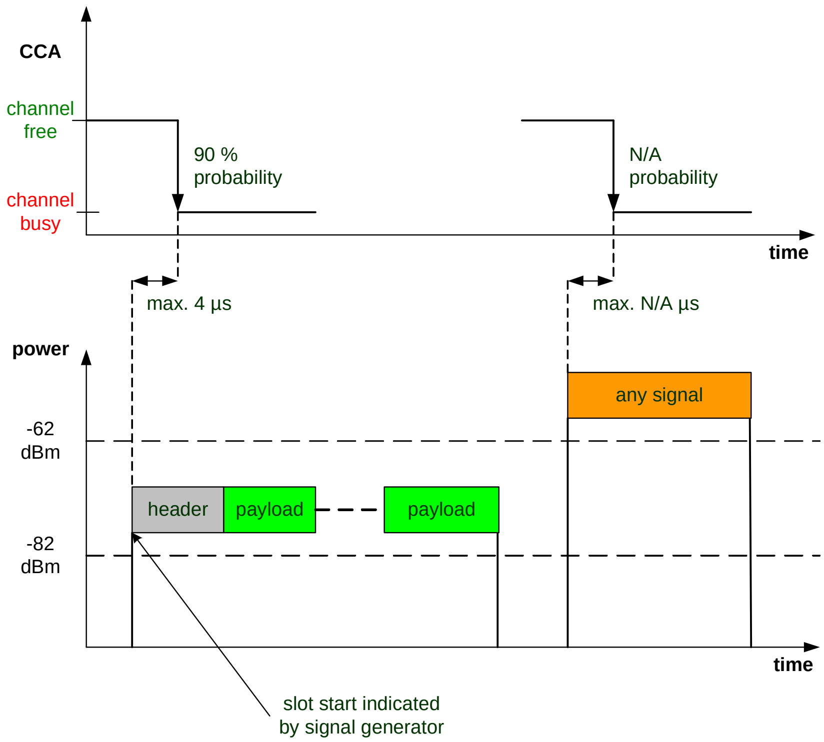


Figure 21 – CCA sensitivity timing overview

Test implementation hints

- **CCA signal measurement**
  This measurement can only be executed if the CCA signal is available over an exposed test point.
  Contact the chipset manufacturer if you plan to test CCA with your WLAN module to get information on the access to the CCA signal.

Measurement Results

---

8 WLAN 802.11b Tests

Instruments and signal list

The table below shows all the measurements for transmitter and receiver tests and the required instruments and signals:

Standard			Test parameter	Signal Analysis FSP	FSP + K90	FSU	FSQ	FSQ + K91	Signal Generation SMIQ + SMIQ-K19	SMU + SMU-K19
802.11 b	18.4.7 Transmitter Specifications	1	Transmit power levels (maximum power)	👍		👍	👍	👍		
		2	Transmit power level control	👍		👍	👍	👍		
		3	Transmit spectrum mask	✓		✓	✓	👍		
		4	Transmit center frequency tolerance	✗		✗	✗	👍		
		5	Chip clock frequency tolerance	✗		✗	✗	👍		
		6	Transmit power-on and power-down ramp	✗		✗	✓ 1)	👍		
		7	RF carrier suppression	✓		✓	✓	👍		
		8	Transmit modulation accuracy	✗		✗	✗	👍		
	18.4.8 Receiver Specifications	1	Receiver minimum input level sensitivity						✓	✓
		2	Receiver maximum input level						✓	✓
		3	Receiver adjacent channel rejection						✓	✓
		4	CCA						✓	✓

✗ not possible

✓ possible

👍 best choice

(grey) not available / not used

1) measurement possible, but not recommended - see test implementation hints

Table 14 – Required instruments for WLAN 802.11b tests

18.4.7.1 Transmit power levels (maximum power)

Purpose	Basic instrument	Options	Used to
Measurement	FSP / (FSU) / FSQ	FSQ-K91 [1)]	Measure output power
+ demonstration	please refer to page 23		Generate a valid 802.11b signal

[1)] the base instrument can be used as well

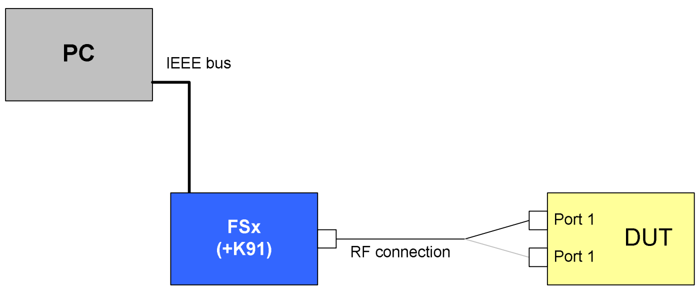
Test purpose

This test ensures that the maximum output power is not exceeded. Excessive transmission power may result in blocking other WLAN cards from transmission and non-conformance with national regulations for the assigned frequency bands.

DUT setup, equivalent WV file

DUT Status	Tx Active
Signal Type	Standard Tx signal CCK, 11 Mbit/s
Power Level	Maximum
Antenna	1 or 2
Annotations	---
Equiv. WV file	B_CCK_11_K19

Test setup



Drawing 17 – Transmit power levels test setup

18.4.7.1 Transmit power levels (maximum power)

Test method – spectrum analyzer mode

1. Configure the WLAN module according to the DUT setup (use for example test software provided with the module).
2. Set up the analyzer step-by-step as described below:

PRESET	set instrument to default stats
FREQ CENTER <value>	set signal frequency
SPAN 40 MHz	set span to display complete signal
AMPT REF LEVEL <value>	set level to maximum expected RF level
BW RES BW MANUAL 100 kHz	set resolution bandwidth to get signal shape correct
TRACE DETECTOR RMS	switch on to get correct power measurement
SWEEP SWEEPTIME MANUAL 800 ms	set time to get 1 signal period for each display pixel
MEAS CHAN PWR ACP	switch to channel power measurement
CP / ACP CONFIG CHANNEL BANDWIDTH 30 MHz	measure power over complete channel
SWEEP SINGLE SWEEP	execute one measurement

Test method – with WLAN personality

1. Configure the WLAN module according to the DUT setup (use for example test software provided with the module).
2. Set up the analyzer step-by-step as described below:

PRESET	set instrument to default stats
(MORE) WLAN	switch on WLAN personality
GENERAL SETTINGS Standard IEEE 802.11b	switch to 802.11b
FREQ CENTER <value>	set signal frequency
SPECTRUM SPECTRUM ACP	switch to TX power measurement
RUN SGL	execute one measurement

18.4.7.1 Transmit power levels (maximum power)

Measurement Parameters, Limits

The maximum output power must be measured. The limits for the different geographic locations are quoted below (according to Table 115 in 802.11b):

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

Table 15 – 802.11b Maximum transmit power levels

Test implementation hints

- **Measurement**
  Since the 802.11b signal is a pulsed signal, you have to get some sort of continuous reading for the spectrum in order to measure the output power correctly.
  This can be realized using
  - a continuous transmission mode of the DUT (if available)
  - gated sweeping (as used in the WLAN personality)
  - RMS trace mode and long sweep time in spectrum mode.
  The sweeptime must be set to get 1 complete signal period within 1 pixel on the analyzer screen during the sweep in the frequency domain, which means for example for an FSQ (625 pixel default value) and a signal period of 1,037 ms (like the used test signal) a minimum sweep time of 1,037 ms x 625 = 648,125 ms.
  Since the measurement bandwidth is not explicitly stated, so the 100 kHz RBW filter is used as in the Transmit spectrum mask (Test 18.4.7.3).

Measurement Results

The pictures below show typical measurement results for both spectrum analyzer and WLAN mode.

18.4.7.1 Transmit power levels (maximum power)

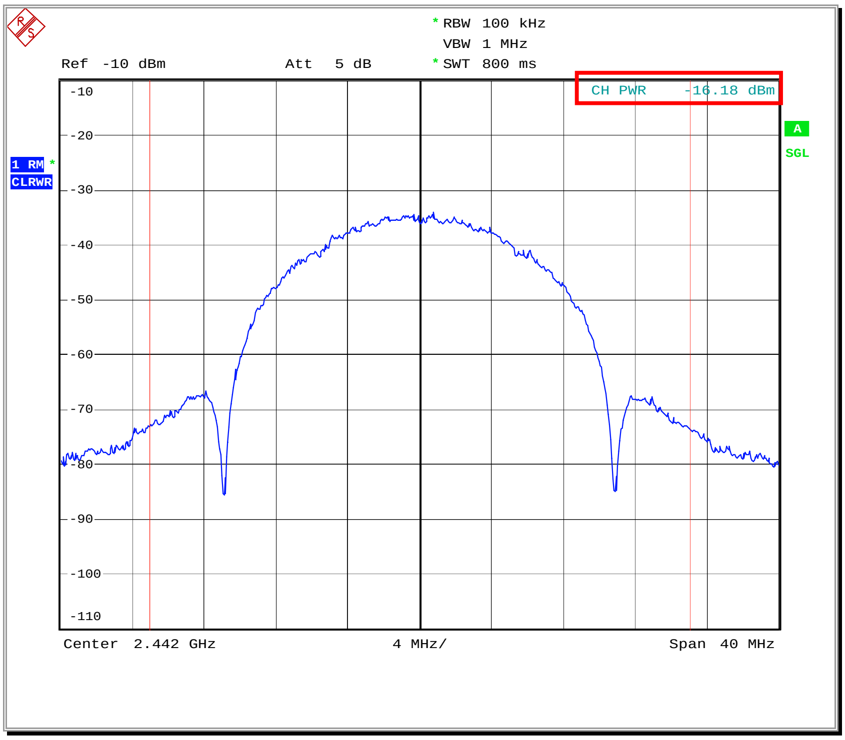
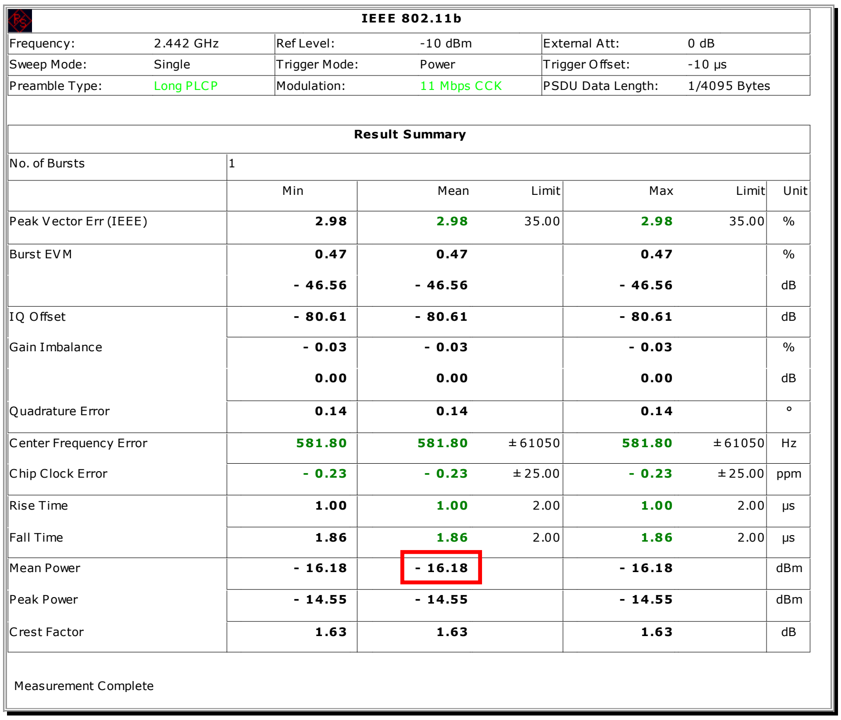


Figure 22 – Transmit power levels typical measurement result (using spectrum analyzer function)



IEEE 802.11b

Frequency:	2.442 GHz	Ref Level:	-10 dBm	External Att:	0 dB
Sweep Mode:	Single	Trigger Mode:	Power	Trigger Offset:	-10 µs
Preamble Type:	Long PLCP	Modulation:	11 Mbps CCK	PSDU Data Length:	1/4095 Bytes

Result Summary

No. of Bursts	1					
	Min	Mean	Limit	Max	Limit	Unit
Peak Vector Err (IEEE)	2.98	2.98	35.00	2.98	35.00	%
Burst EVM	0.47	0.47		0.47		%
	- 46.56	- 46.56		- 46.56		dB
IQ Offset	- 80.61	- 80.61		- 80.61		dB
Gain Imbalance	- 0.03	- 0.03		- 0.03		%
	0.00	0.00		0.00		dB
Quadrature Error	0.14	0.14		0.14		°
Center Frequency Error	581.80	581.80	± 61050	581.80	± 61050	Hz
Chip Clock Error	- 0.23	- 0.23	± 25.00	- 0.23	± 25.00	ppm
Rise Time	1.00	1.00	2.00	1.00	2.00	µs
Fall Time	1.86	1.86	2.00	1.86	2.00	µs
Mean Power	- 16.18	- 16.18		- 16.18		dBm
Peak Power	- 14.55	- 14.55		- 14.55		dBm
Crest Factor	1.63	1.63		1.63		dB

Measurement Complete

Figure 23 – Transmit power levels typical measurement result (using WLAN personality function)

18.4.7.2 Transmit power level control

Purpose	Basic instrument	Options	Used to
Measurement	FSP / (FSU) / FSQ	FSQ-K91 [1)]	Measure output power
+ *demonstration*	please refer to page 23		Generate a valid 802.11b signal

[1)] the base instrument can be used as well

Test purpose

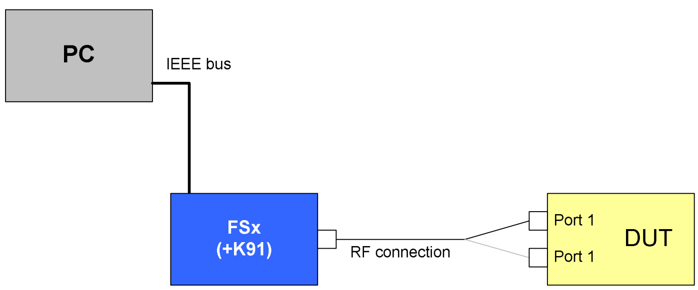
The DUT must be able to control the output power in 2 to 4 steps. For modules providing more then 100 mW, a second output power of 100 mW or less must be available.

This test ensures that the DUT is capable to set the correct output power.

DUT setup, equivalent WV file

DUT Status	Tx Active
Signal Type	Standard Tx signal CCK, 11 Mbit/s
Power Level	all available power levels
Antenna	1 or 2
Annotations	---
Equiv. WV file	B_CCK_11_K19

Test setup



Drawing 18 – Transmit power level control test setup

18.4.7.2 Transmit power level control

Test method – without WLAN personality

1. Configure the WLAN module according to the DUT setup (use for example test software provided with the module).
2. Set up the analyzer step-by-step as described below:

PRESET	set instrument to default stats
FREQ CENTER <value>	set signal frequency
SPAN 40 MHz	set span to display complete signal
AMPT REF LEVEL <value>	set level to maximum expected RF level
BW RES BW MANUAL 100 kHz	set resolution bandwidth to get signal shape correct
TRACE DETECTOR RMS	switch on to get correct power measurement
SWEEP SWEEPTIME MANUAL 800 ms	set time to get 1 signal period for each display pixel
MEAS CHAN PWR ACP	switch to channel power measurement
CP / ACP CONFIG CHANNEL BANDWIDTH 30 MHz	measure power over complete channel
SWEEP SINGLE SWEEP	execute one measurement

Test method – with WLAN personality

1. Configure the WLAN module according to the DUT setup (use for example test software provided with the module).
2. Set up the analyzer step-by-step as described below:

PRESET	set instrument to default stats
(MORE) WLAN	switch on WLAN personality
GENERAL SETTINGS Standard IEEE 802.11b	switch to 802.11b
FREQ CENTER <value>	set signal frequency
SPECTRUM SPECTRUM ACP	switch to TX power measurement
RUN SGL	execute one measurement

18.4.7.2 Transmit power level control

Measurement Parameters, Limits

The output power shall be measured for all available power steps.

Test implementation hints

- **Measurement**
  Since the 802.11b signal is a pulsed signal, you have to get some sort of continuous reading for the spectrum in order to measure the output power correctly.
  This can be realized using
  - a continuous transmission mode of the DUT (if available)
  - gated sweeping (as used in the WLAN personality)
  - RMS trace mode and long sweep time in spectrum mode.
  The sweeptime must be set to get 1 complete signal period within 1 pixel on the analyzer screen during the sweep in the frequency domain, which means for example for an FSQ (625 pixel default value) and a signal period of 1,037 ms (like the used test signal) a minimum sweep time of 1,037 ms x 625 = 648,125 ms.

- **Repetitive measurements**
  If the output power is changed, re-run the measurement.
  Using the WLAN personality, simply press "RUN SGL" again.
  Using the standard analyzer measurement function, press
  TRACE CLR WRT to reset the max detector and after that
  TRACE MAX HOLD to re-run the measurement.
  If you are running in single sweep mode and set a sweep count greater then 1, simply re-run the measurement pressing
  SWEEP SINGL SWEEP.

Measurement Results

See 18.4.7.1 for measurement results.

18.4.7.3 Transmit spectrum mask

Purpose	Basic instrument	Options	Used to
Measurement	FSP / (FSU) / FSQ	FSQ-K91 [1)]	Check spectrum mask
+ *demonstration*	please refer to page 23		Generate a valid 802.11b signal

[1)] the base instrument can be used as well

Test purpose

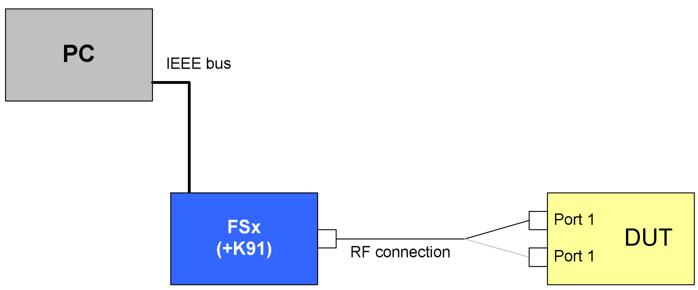
This test ensures that the DUT does not influence other WLAN devices transmitting in adjacent channels. This may result in a bad or even no connection.

The 802.11b standard does not define a transmitter filter, but only a transmit spectrum mask to be passed. So, the design of the output filter is up to the manufacturer of the DUT ensuring to pass the spectrum mask while leading good performance in transmission.

DUT setup, equivalent WV file

DUT Status	Tx Active
Signal Type	Standard Tx signal CCK, 11 Mbit/s
Power Level	Maximum
Antenna	1 or 2
Annotations	---
Equiv. WV file	B_CCK_11_K19

Test setup



Drawing 19 – Transmit spectrum mask test setup

18.4.7.3 Transmit spectrum mask

Test method

1. Configure the WLAN module according to the DUT setup (use for example test software provided with the module).
2. Set up the analyzer step-by-step as described below:

PRESET	set instrument to default stats
(MORE) WLAN	switch on WLAN personality
GENERAL SETTINGS Standard IEEE 802.11b	switch to 802.11b
FREQ CENTER <value>	set signal frequency
SPECTRUM SPECTRUM MASK	switch to TX spectrum mask measurement
RUN SGL	execute one measurement

Measurement Parameters, Limits

The transmitter spectrum mask is defined as following. The mask is aligned to the maximum spectral density of the signal (according to Figure 145 in 802.11b standard):

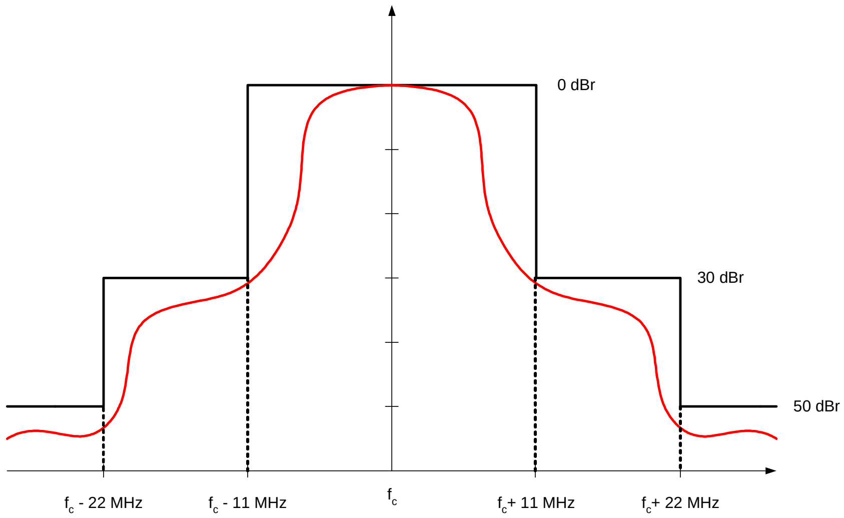


Figure 24 - 802.11b Transmit Spectrum Mask Specification

Test implementation hints

- **Measurement**
  Since the 802.11a signal is a pulsed signal, but the spectrum mask is defined for a continuous signal, you have to get some sort of continuous reading for the spectrum.
  This can be realized using
  - a continuous transmission mode of the DUT (if available)
  - gated sweeping (as used in the WLAN personality)
  - max hold trace mode in spectrum mode

18.4.7.3 Transmit spectrum mask

- **Spectrum mask**
  The spectrum mask is automatically set up aligned from the WLAN measurement personality FSQ-K91 when a measurement sweep is finished.
  If the measurement shall be done with the normal analyzer function, the limit line has to be programmed manually and aligned with the trace maximum detected with a maximum peak marker function.

Measurement Results

The picture below shows the display of a typical measurement result:

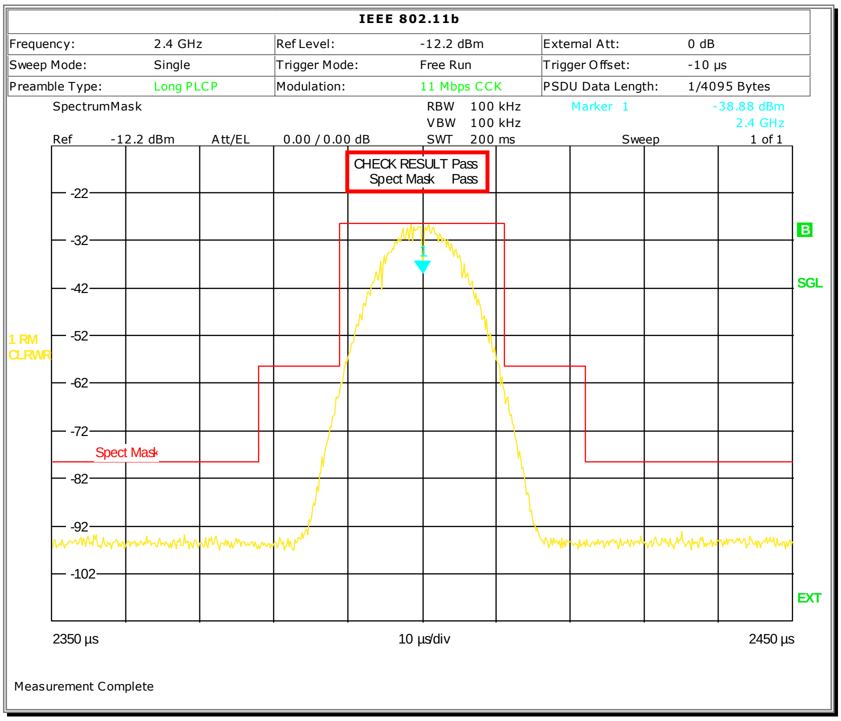


Figure 25 – Transmit spectrum mask typical measurement result

18.4.7.4 Transmit center frequency tolerance

Purpose	Basic instrument	Options	Used to
Measurement	FSQ	FSQ-K91 [1)]	Measure frequency tolerance
+ demonstration	please refer to page 23		Generate a valid 802.11b signal

[1)] the base instrument (including FSP/FSU) can be used as well if special DUT test mode is available

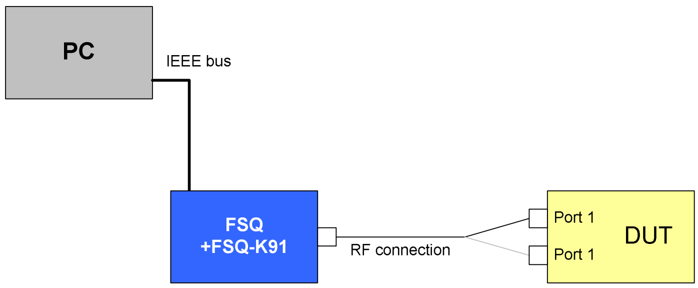
Test purpose

If the transmitter frequency is not accurate enough, this may result in high EVM readings for example (Test 18.4.7.8). It may also cause the DUT to fail to connect to another WLAN module / access point.

DUT setup, equivalent WV file

DUT Status	Tx Active
Signal Type	Standard Tx signal CCK, 11 Mbit/s **OR** unmodulated signal
Power Level	Maximum
Antenna	1 or 2
Annotations	---
Equiv. WV file	B_CCK_11_K19

Test setup



Drawing 20 – Transmit center frequency tolerance test setup

18.4.7.4 Transmit center frequency tolerance

Test method – using spectrum analyzer

1. Configure the WLAN module according to the DUT setup (use for example test software provided with the module) and ***switch off modulation***.
2. Set up the analyzer step-by-step as described below:

PRESET	set instrument to default stats
FREQ CENTER <value>	set signal frequency
SPAN 1MHz	set span to see the signal
AMP REF LEVEL <value>	set to CW signal power
MKR SIGNAL COUNT	switch on marker and activate signal counter
NEXT CNT RESOL <value>	set resolution as decided

Test method – using WLAN personality

1. Configure the WLAN module according to the DUT setup (use for example test software provided with the module) and generate a ***standard Tx test signal***.
2. Set up the analyzer step-by-step as described below:

PRESET	set instrument to default stats
(MORE) WLAN	switch on WLAN personality
GENERAL SETTINGS Standard IEEE 802.11b	switch to 802.11b
FREQ CENTER <value>	set signal frequency
DEMOD SETTINGS Auto Demodulation ON	auto detection of modulation type
TRIGGER Trigger Mode Power	trigger on raising burst edge
SWEEP Capture Time 1ms	capture at least 1 burst
RUN SGL	execute one measurement

Measurement Parameters, Limits

The transmit clock frequency tolerance shall be ± 25 ppm maximum relative to the center frequency.
This is equivalent to a maximum error of 71.2 kHz for the highest assigned 802.11b transmission frequency (2.848 GHz).

Test implementation hints

- **Test mode**
  The center frequency error can also be measured if modulation is switched off and only the unmodulated carrier is transmitted.
  This measurement can then be done with the a spectrum analyzer

without WLAN personality and a simple frequency counter measurement.
To do this, the DUT has to provide a special test mode for switching the modulation off, and special effects in the DUT (current consumption, thermal drifts, ...) can result in a slightly different measurement value. So, it is recommended to do the measurement in normal operation mode with modulation switched on using the FSQ-K91 functionality.

Measurement Results

The picture below shows the display of a typical measurement result for both WLAN and counter measurement:

IEEE 802.11b

Frequency:	2.4 GHz	Ref Level:	-4.3 dBm	External Att:	0 dB
Sweep Mode:	Single	Trigger Mode:	Free Run	Trigger Offset:	-10 µs
Preamble Type:	Long PLCP	Modulation:	11 Mbps CCK	PSDU Data Length:	1/4095 Bytes

Result Summary

No. of Bursts	3					
	Min	Mean	Limit	Max	Limit	Unit
Peak Vector Err (IEEE)	1.10	1.17	35.00	1.21	35.00	%
Burst EVM	0.32	0.32		0.32		%
	- 49.97	- 49.95		- 49.90		dB
IQ Offset	- 59.37	- 59.22		- 59.09		dB
Gain Imbalance	- 0.21	- 0.15		- 0.06		%
	0.00	0.01		0.02		dB
Quadrature Error	- 0.12	- 0.06		0.02		°
Center Frequency Error	49.81	50.18	±60000	50.52	±60000	Hz
Chip Clock Error	- 0.00	- 0.00	±25.00	- 0.00	±25.00	ppm
Rise Time	0.39	0.39	2.00	0.39	2.00	µs
Fall Time	0.30	0.30	2.00	0.30	2.00	µs
Mean Power	- 10.81	- 10.80		- 10.80		dBm
Peak Power	- 9.45	- 9.45		- 9.44		dBm
Crest Factor	1.36	1.36		1.36		dB

Measurement Complete

Figure 26 – Transmit center frequency error typical measurement result – WLAN personality

18.4.7.4 Transmit center frequency tolerance

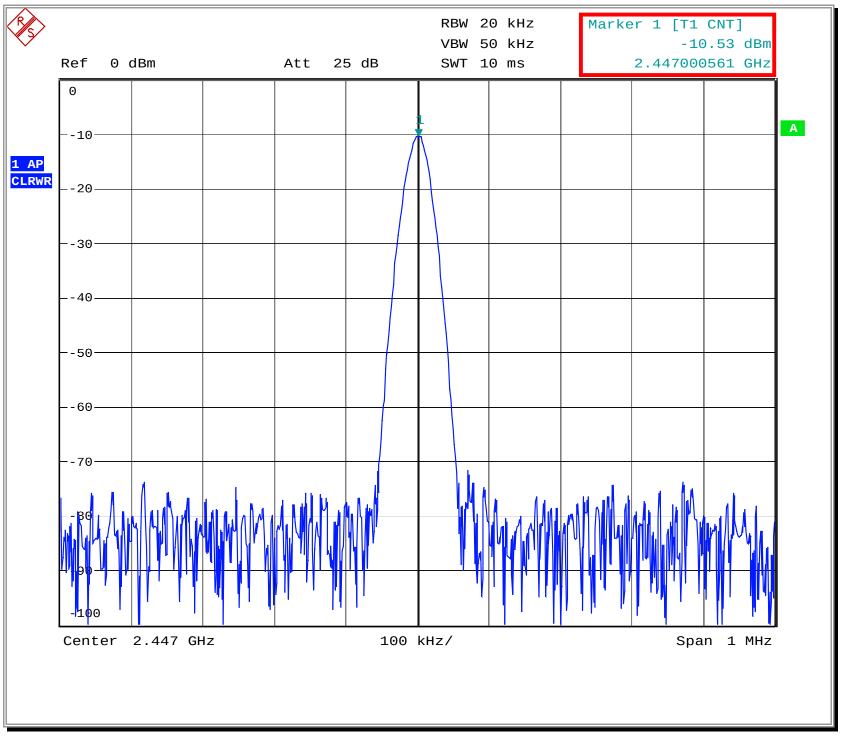


Figure 27 – Transmit center frequency error typical measurement result – counter measurement

18.4.7.5 Chip clock frequency tolerance

Purpose	Basic instrument	Options	Used to
Measurement	FSQ	FSQ-K91	Measure chip clock frequency tol.
+ *demonstration*	please refer to page 23		Generate a valid 802.11b signal

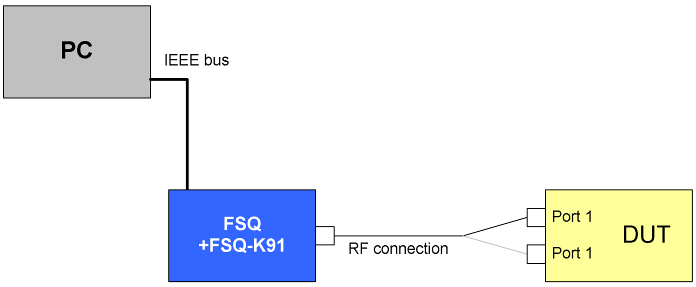
Test purpose

If the symbol clock frequency is not accurate enough, this may result in high EVM readings (Test 18.4.7.8). It may also cause the DUT to fail to connect to another WLAN module / access point.

DUT setup, equivalent WV file

DUT Status	Tx Active
Signal Type	Standard Tx signal CCK, 11 Mbit/s
Power Level	Maximum
Antenna	1 or 2
Annotations	---
Equiv. WV file	B_CCK_11_K19

Test setup



Drawing 21 – Chip clock frequency tolerance test setup

18.4.7.5 Chip clock frequency tolerance

Test method

1. Configure the WLAN module according to the DUT setup (use for example test software provided with the module).
2. Set up the analyzer step-by-step as described below:

PRESET	set instrument to default stats
(MORE) WLAN	switch on WLAN personality
GENERAL SETTINGS Standard IEEE 802.11b	switch to 802.11b
FREQ CENTER <value>	set signal frequency
DEMOD SETTINGS Auto Demodulation ON	auto detection of modulation type
TRIGGER Trigger Mode Power	trigger on raising burst edge
SWEEP Capture Time 1ms	capture at least 1 burst
RUN SGL	execute one measurement

Measurement Parameters, Limits

The symbol clock frequency (=chip rate) tolerance shall be ± 25 ppm maximum relative to the nominal symbol clock frequency.
This is equivalent to a maximum error of 275 Hz for the highest assigned 802.11b symbol clock frequency (11 MHz).

Test implementation hints

18.4.7.5 Chip clock frequency tolerance

Measurement Results

The picture below shows the display of a typical measurement result:

IEEE 802.11b					
Frequency:	2.4 GHz	Ref Level:	-4.3 dBm	External Att:	0 dB
Sweep Mode:	Single	Trigger Mode:	Free Run	Trigger Offset:	-10 µs
Preamble Type:	Long PLCP	Modulation:	11 Mbps CCK	PSDU Data Length:	1/4095 Bytes

Result Summary						
No. of Bursts	4					
	Min	Mean	Limit	Max	Limit	Unit
Peak Vector Err (IEEE)	1.23	1.26	35.00	1.30	35.00	%
Burst EVM	0.31	0.32		0.32		%
	- 50.07	- 50.03		- 49.98		dB
IQ Offset	- 58.74	- 58.71		- 58.69		dB
Gain Imbalance	- 0.15	- 0.15		- 0.14		%
	0.01	0.01		0.01		dB
Quadrature Error	0.09	0.09		0.09		°
Center Frequency Error	0.02	- 0.06	± 60000	- 0.43	± 60000	Hz
Chip Clock Error	- 0.56	- 0.56	± 25.00	- 0.56	± 25.00	ppm
Rise Time	0.39	0.39	2.00	0.39	2.00	µs
Fall Time	0.30	0.30	2.00	0.30	2.00	µs
Mean Power	- 10.83	- 10.83		- 10.83		dBm
Peak Power	- 9.47	- 9.46		- 9.46		dBm
Crest Factor	1.36	1.36		1.37		dB

Measurement Complete

Figure 28 – Chip clock frequency tolerance typical measurement result

18.4.7.6 Transmit power-on and power-down ramp

Purpose	Basic instrument	Options	Used to
Measurement	FSQ	FSQ-K91 [1)]	Measure power ramps
+ demonstration	please refer to page 23		Generate a valid 802.11b signal

[1)] the base instrument can be used as well, but is not recommended

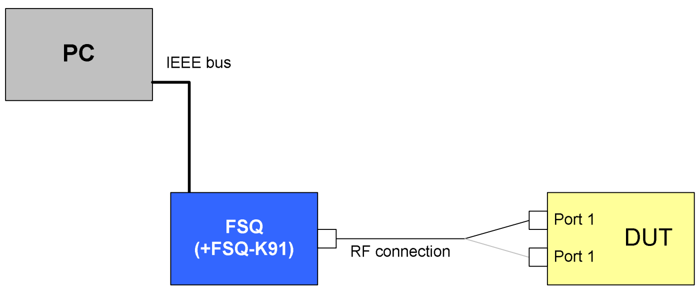
Test purpose

The test ensures that the output signal of the DUT is stable after a certain time.

DUT setup, equivalent WV file

DUT Status	Tx Active
Signal Type	Standard Tx signal CCK, 11 Mbit/s
Power Level	Maximum
Antenna	1 or 2
Annotations	---
Equiv. WV file	B_CCK_11_K19

Test setup



Drawing 22 – Transmit power ramps test setup

18.4.7.6 Transmit power-on and power-down ramp

Test method

1. Configure the WLAN module according to the DUT setup (use for example test software provided with the module).
2. Set up the analyzer step-by-step as described below: PRÜFEN

PRESET	set instrument to default stats
(MORE) WLAN	switch on WLAN personality
GENERAL SETTINGS Standard IEEE 802.11b	switch to 802.11b
FREQ CENTER <value>	set signal frequency
DEMOD SETTINGS Auto Demodulation ON	auto detection of modulation type
TRIGGER Trigger Mode Power	trigger on raising burst edge
SWEEP Capture Time 1ms	capture at least 1 burst
PVT	switch on power vs time
RUN SGL	execute one measurement

Measurement Parameters, Limits

The power-up and power-down ramp between 10% and 90% of the maximum signal power shall not be greater than 2 µs.
The power-down ramp is only specified up to 4 µs starting from the power-down ramp start.
This results in the 2 figures below (according to [4], Figures 146 and 147):

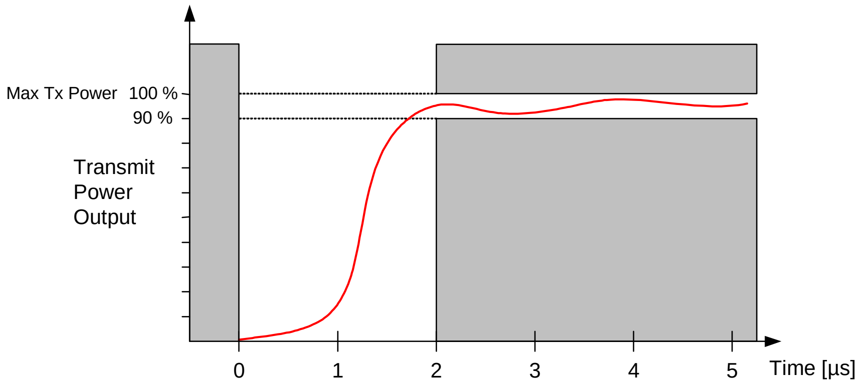


Figure 29 – 802.11b Power-up ramp specification

18.4.7.6 Transmit power-on and power-down ramp

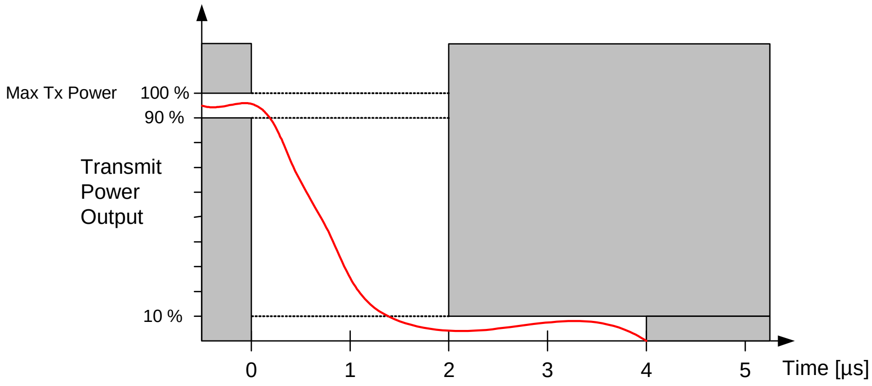


Figure 30 – 802.11b Power-down ramp specification

Test implementation hints

- **Suitable Instruments**
  Only the FSQ can do this measurement because the raise / fall sweep of the signal is too high to be detected with the 10 MHz maximum resolution bandwidth of the FSP/FSU.
  This applies to both standard analyzer mode and FSQ-K91 modulation analysis mode.
- **Measurement**
  The time domain masks are automatically set up from the WLAN measurement personality FSQ-K91 when a measurement is started.
  If the measurement is done with the analyzer without WLAN personality in time-domain mode (zero span), the mask line has to be programmed manually and aligned with the using for example a video trigger.

Measurement Results

The 2 pictures below show the power-up and power-down ramp as shown in the FSQ-K91 WLAN measurement personality:

18.4.7.6 Transmit power-on and power-down ramp

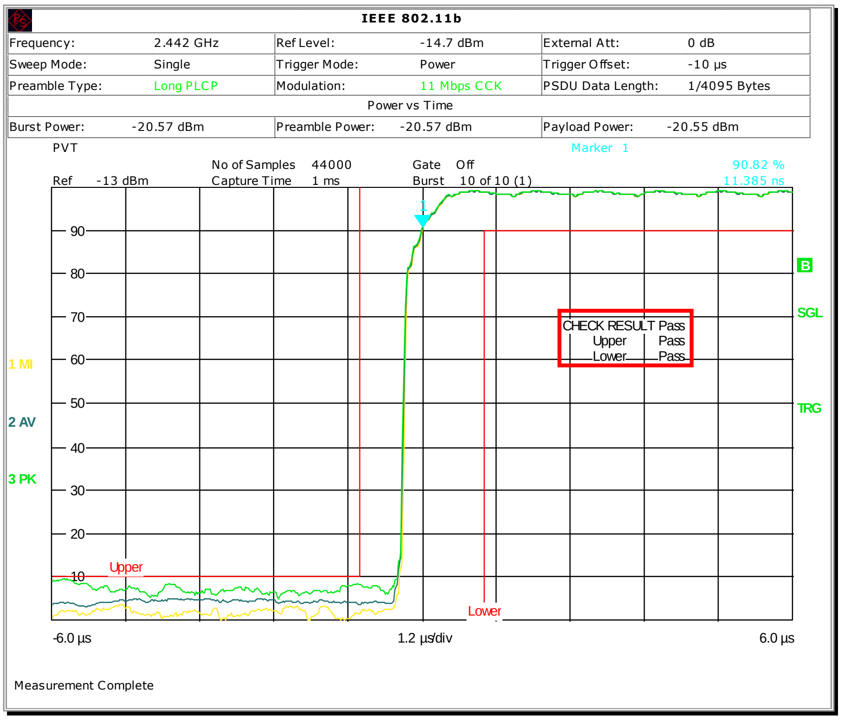


Figure 31 – Transmit power ramp typical measurement result (power-up ramp)

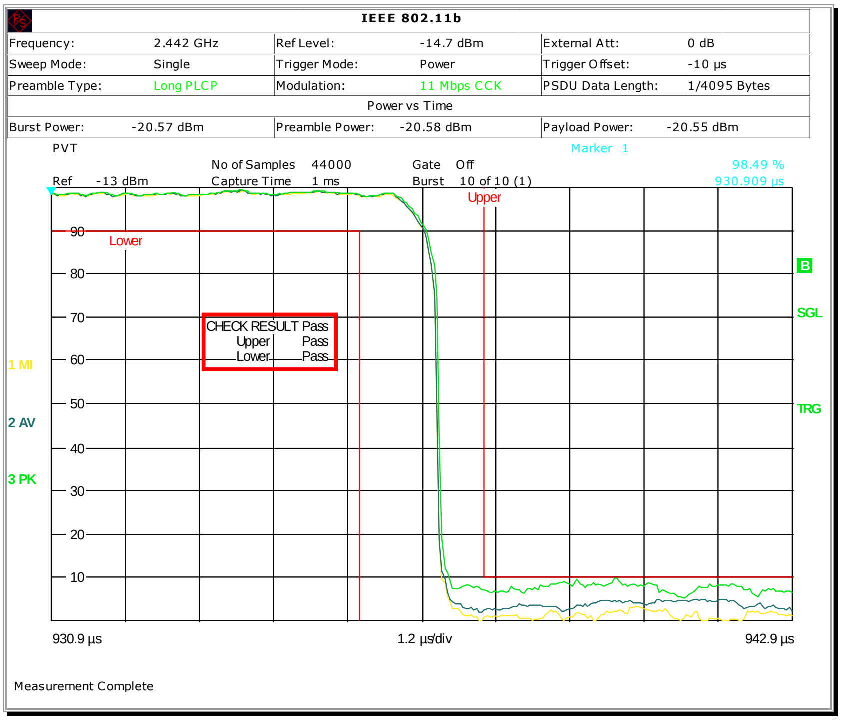


Figure 32 – Transmit power ramp typical measurement result (power-down ramp)

18.4.7.7 RF carrier suppression

Purpose	Basic instrument	Options	Used to
Measurement	FSP / FSU / FSQ	FSQ-K91 [1)]	Measure RF carrier suppression
+ demonstration	please refer to page 23		Generate a valid 802.11b signal

[1)] the base instrument can be used as well if the DUT provides a special test mode

Test purpose

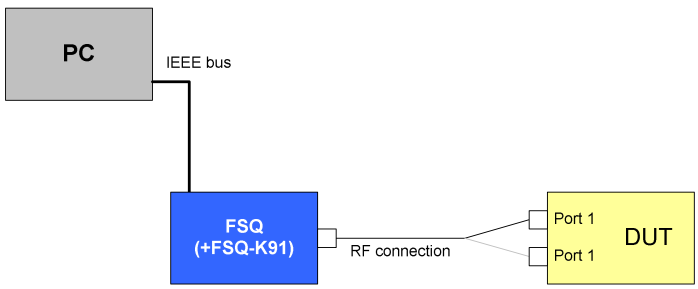
RF carrier frequency leakage results in a DC voltage for receivers using a zero-mixing concept. This can lead to bad demodulation performance.

The test is similar to test 17.3.9.6.1 of Standard 802.11a.

DUT setup, equivalent WV file

DUT Status	Tx Active		
Signal Type	Standard Tx signal CCK, 11 Mbit/s	**OR**	Tx signal, scrambler OFF, data sequence 01 repetitive CCK, 11 Mbit/s
Power Level	Maximum		
Antenna	1 or 2		
Annotations	---		
Equiv. WV file	B_CCK_11_K19		B_QPSK_2_0101_K19

Test setup



Drawing 23 – RF carrier suppression test setup

18.4.7.7 RF carrier suppression

Test method – using standard DUT operation mode and WLAN measurement function

1. Configure the WLAN module according to the DUT setup (use for example test software provided with the module).
2. Set up the analyzer step-by-step as described below:

PRESET	set instrument to default stats
(MORE) WLAN	switch on WLAN personality
FREQ <transmit frequency>	set signal frequency
DISPLAY LIST	show result summary
RUN SGL	execute one measurement and read IQ offset value = carrier suppress.

Test method – using DUT CW mode and spectrum analyzer functions

1. Configure the WLAN module according to the DUT setup (use for example test software provided with the module).
2. Set up the analyzer step-by-step as described below:

PRESET	set instrument to default stats
FREQ <transmit frequency+250 kHz>	set center frequency to signal frequency of D-QPSK signal
SPAN <1 MHz>	set span to see DC carrier
BW RES BW MANUAL <30 kHz>	set bandwidth to have good resolution of RF carrier
TRIG IF POWER	trigger on IF power
GATE SETTINGS	switch to gate configuration
GATE DELAY <500 µs>	set gate start to start of unscrambled PSDU
GATE LENGTH <3.5 ms>	analyze complete PSDU
↑ GATED TRIGGER	switch on gated trigger
SWEEP SINGLE SWEEP	execute one sweep
MKR MARKER 1	switch on first marker (will automatically jump to peak)
MKR MARKER 2	switch on delta marker (will automatically jump to next peak)
MARKER NORM	switch marker 2 to absolute frequency mode
MARKER 2 <transmit frequency>	set marker 2 to carrier frequency
MARKER DELTA	switch marker 2 to delta marker to display carrier suppression

18.4.7.7 RF carrier suppression

Measurement Parameters, Limits

The RF carrier suppression must be at least 15 dB relative to the SIN(x)/x spectrum peak, meaning 15 dB below the highest level found in the spectrum.

Test implementation hints

- **Used Signal**
  To generate a signal with a suppressed carrier for 802.11b as required for measurements with the base instrument, a 2 Mbps signal type is used with an alternating 01 bit sequence and disabled barker spreading. This results in a IQ diagram which will not cross the point (0,0) and so will not generate a DC component resulting in a suppressed RF carrier.
  A special WinIQSIM setting (B_QPSK_2_0101_K19) is used to generate the signal.

Measurement Results

The picture below shows a typical measurement result using the standard 11 Mbps signal with the FSQ-K91 WLAN option:

IEEE 802.11b

Frequency:	2.4 GHz	Ref Level:	-4.3 dBm	External Att:	0 dB
Sweep Mode:	Single	Trigger Mode:	Free Run	Trigger Offset:	-10 µs
Preamble Type:	Long PLCP	Modulation:	11 Mbps CCK	PSDU Data Length:	1/4095 Bytes

Result Summary

No. of Bursts	3					
	Min	Mean	Limit	Max	Limit	Unit
Peak Vector Err (IEEE)	1.38	1.40	35.00	1.41	35.00	%
Burst EVM	0.31	0.31		0.32		%
	- 50.12	- 50.06		- 50.02		dB
IQ Offset	- 58.15	- 58.14		- 58.13		dB
Gain Imbalance	- 0.14	- 0.14		- 0.14		%
	0.01	0.01		0.01		dB
Quadrature Error	0.09	0.09		0.09		°
Center Frequency Error	0.16	0.16	± 60000	0.80	± 60000	Hz
Chip Clock Error	- 0.00	0.00	± 25.00	0.01	± 25.00	ppm
Rise Time	0.39	0.39	2.00	0.39	2.00	µs
Fall Time	0.30	0.30	2.00	0.30	2.00	µs
Mean Power	- 10.84	- 10.84		- 10.84		dBm
Peak Power	- 9.48	- 9.48		- 9.48		dBm
Crest Factor	1.36	1.36		1.36		dB

Measurement Complete

Figure 33 – RF carrier suppression typical measurement result (WLAN analyzer mode)

18.4.7.7 RF carrier suppression

The picture below shows a typical measurement result using the special unscrambled signals at 2 Mbps and gated sweeping:

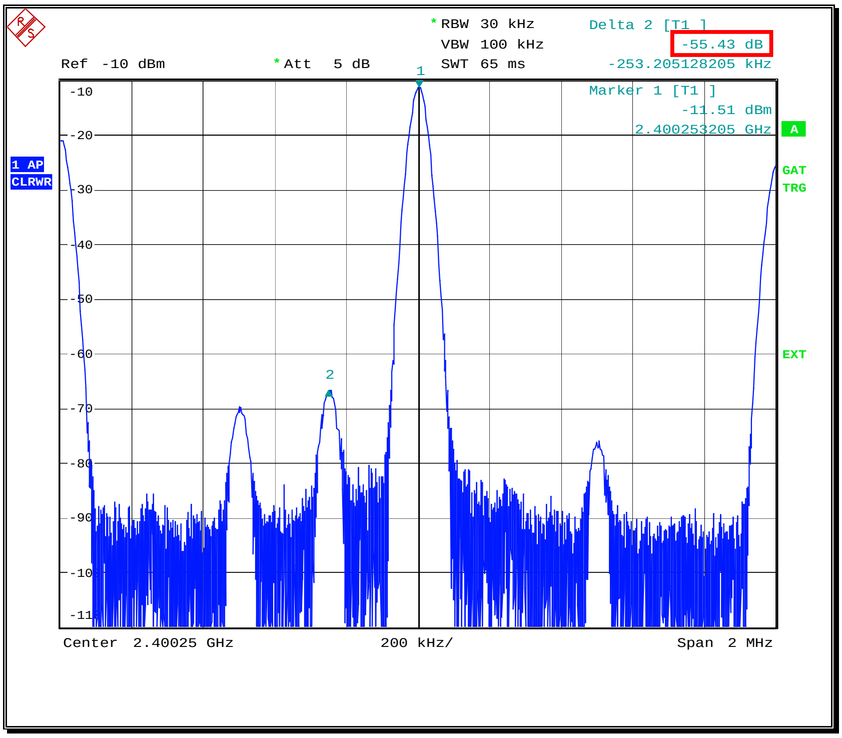


Figure 34 – RF carrier suppression typical measurement result (spectrum analyzer mode)

18.4.7.8 Transmit modulation accuracy

Purpose	Basic instrument	Options	Used to
Measurement	FSQ	FSQ-K91	Measure EVM
+ demonstration	please refer to page 23		Generate a valid 802.11b signal

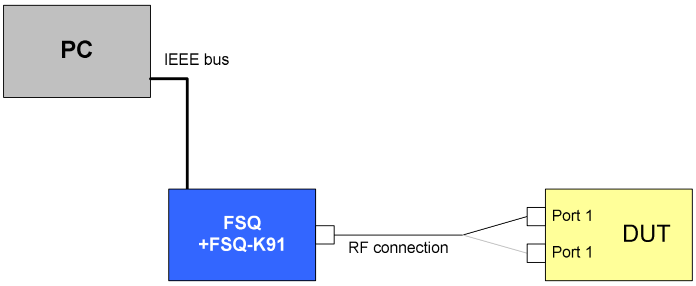
Test purpose

The test ensures that the modulator is working properly, generating a signal with low EVM, low noise, only small nonlinear effects and without other error signal components.

DUT setup, equivalent WV file

DUT Status	Tx Active
Signal Type	Standard Tx signal CCK, 11 Mbit/s
Power Level	Maximum
Antenna	1 or 2
Annotations	---
Equiv. WV file	B_CCK_11_K19

Test setup



Drawing 24 – Transmit modulation accuracy test setup

Test method / Measurement Parameters. Limits

Refer to 18.4.7.7 for details because there are no additional details specified for this test.

Test implementation hints / Measurement Results

Refer to 18.4.7.7 for details because there are no additional details specified for this test.

18.4.8.1 Receiver minimum input level sensitivity

Purpose	Basic instrument	Options	Used to
Measurement	please refer to page 23		Generate a valid 802.11b signal
+ demonstration	---	---	---

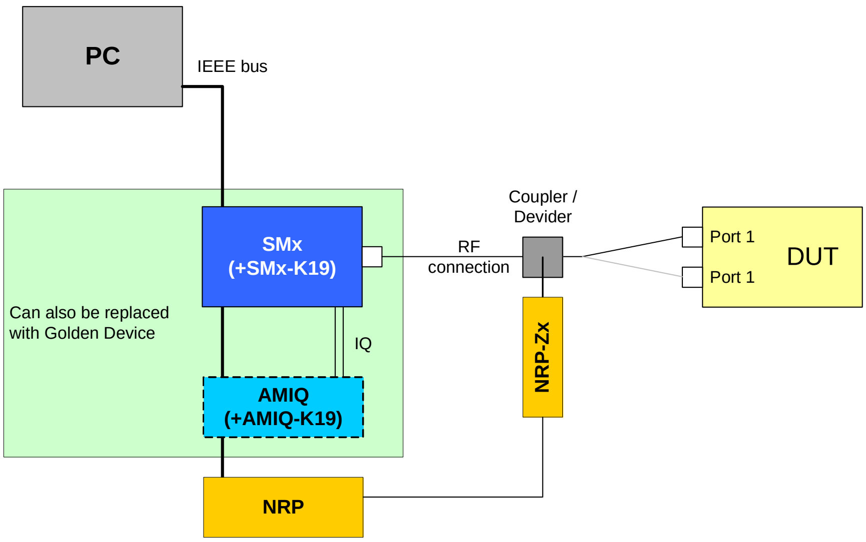
Test purpose

A WLAN card must be able to setup a connection and transmit data for low input levels. This test makes sure that the DUT is able to receive data with a defined maximum packet error rate (PER) at a defined minimum level, measured at the antenna port.

DUT setup, equivalent WV file

DUT Status	Rx Active
Signal Type	Standard Tx signal CCK, 11 Mbit/s
Power Level	-76 dBm at antenna port
Antenna	1 or 2
Annotations	---
Equiv. WV file	B_CCK_11_K19

Test setup



Drawing 25 – Receiver minimum input level sensitivity test setup

18.4.8.1 Receiver minimum input level sensitivity

Test method

1. Set up the test signal generator (R&S instrument or Golden Device combined with a programmable step attenuator) to transmit a signal.
2. Set up the DUT in receiver mode and FER calculation (this feature is provided in a special DUT test mode) or use the PER software [9].
3. Reduce the input level at the DUT Rx port until a PER of 8 % is reached and check if the level if lower -76 dBm (test PASSED) or higher (test FAILED)
   OR
   Setup the a transmitter level of -76 dBm and check if the PER is below 8 % (test PASSED) or above 8 % (test FAILED).

Measurement Parameters, Limits

A FER of 8 % or lower, measured over a PSDU length of 1024 octets, shall be reached for a level equal or less than -76 dBm, measured at the antenna connector.

The test shall be executed using a 11 Mbit/s CCK modulated signal.

Test implementation hints

Measurement Results

18.4.8.2 Receiver maximum input level

Purpose	Basic instrument	Options	Used to
Measurement	please refer to page 23		Generate a valid 802.11b signal
+ demonstration	---	---	---

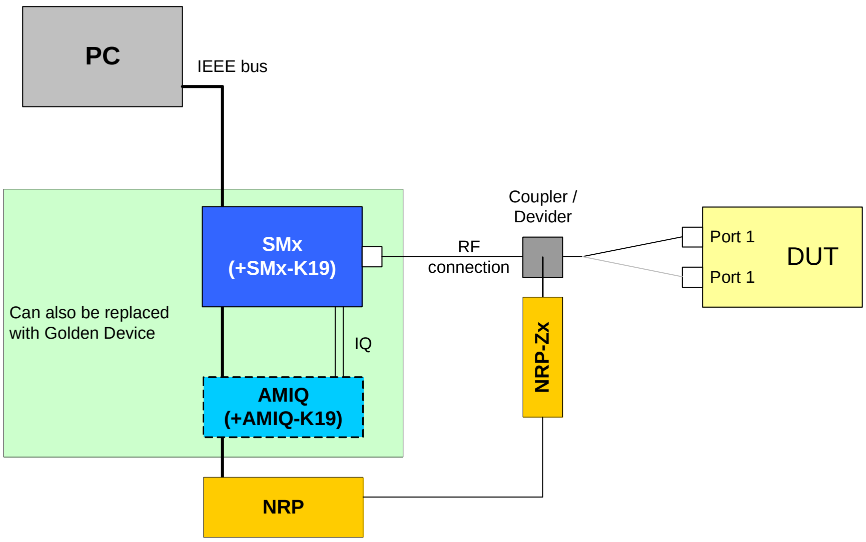
Test purpose

A WLAN card must be able to setup a connection and transmit if the distance between transmitter and receiver is very low. The test makes sure that the DUT is able to receive data with a defined maximum packet error rate (PER) at a defined maximum level, measured at the antenna port.

DUT setup, equivalent WV file

DUT Status	Rx Active
Signal Type	Standard Tx signal CCK, 11 Mbit/s
Power Level	-10 dBm at antenna port
Antenna	1 or 2
Annotations	---
Equiv. WV file	B_CCK_11_K19

Test setup



Drawing 26 – Receiver maximum input level test setup

18.4.8.2 Receiver maximum input level

Test method

1. Set up the test signal generator (R&S instrument or Golden Device combined with a programmable step attenuator) to transmit a signal.
2. Set up the DUT to receiver mode and PER calculation (this feature is provided in a special DUT test mode) or use the PER software [9].
3. Increase the input level at the DUT Rx port until a FER of 8 % is reached and check if the level is above -10 dBm (test PASSED) or below (test FAILED)
   OR
   Setup the input level to -10 dBm and check if the FER is below 8 % (test PASSED) or above 8 % (test FAILED).

Measurement Parameters, Limits

A FER of 8 % or lower, measured over a PSDU length of 1024 octets, shall be reached for levels higher or to -10 dBm.

The test shall be executed using a 11 Mbit/s CCK modulated signal.

Test implementation hints

Measurement Results

18.4.8.3 Receiver adjacent channel rejection

Purpose	Basic instrument	Options	Used to
Measurement	please refer to page 23		Generate a valid 802.11b signal
+ demonstration	---	---	---

Test purpose

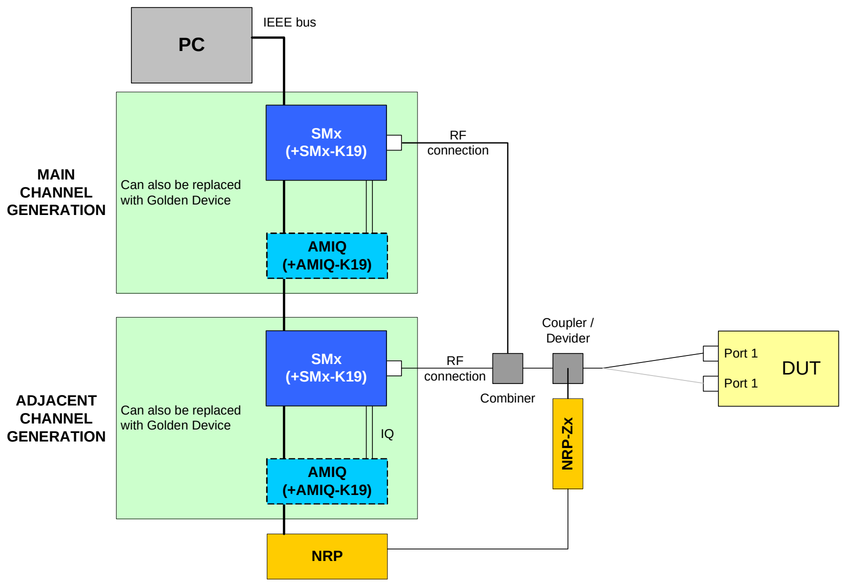
For stable operation, it is important that a WLAN card can establish and hold a connection if also other channels, especially the adjacent channels, are occupied by other users.

This test ensures that the DUT is capable of operating while the adjacent channels are occupied, and the signal strength of the adjacent channels is significantly higher then the own desired channel.

DUT setup, equivalent WV file

DUT Status	Rx Active
Signal Type	Standard Tx signal CCK, 11 Mbit/s
Power Levels	as described below
Antenna	1 or 2
Annotations	---
Equiv. WV file	B_CCK_11_K19

Test setup



Drawing 27 – Receiver adjacent channel rejection test setup

18.4.8.3 Receiver adjacent channel rejection

Test method

1. Setup the ***first*** test signal generator (R&S instrument or Golden Device combined with a programmable step attenuator) to transmit the ***desired*** signal at a level 6 dB above the minimum sensitivity level (-76 dBm) = -70 dBm.
2. Setup the ***second*** test signal generator (R&S instrument or Golden Device combined with a programmable step attenuator) to transmit the ***interfering*** signal at a level 41 dB above the minimum sensitivity level (-76 dBm) = -35 dBm, using one adjacent channel relative to the desired signal channel with a minimum spacing of the center frequencies of 25 MHz.
3. Set up the DUT to receiver mode and PER calculation (this feature is provided in a special DUT test mode) or use the PER software [9].
4. Check if the FER is below 8 % (test PASSED) or above 8 % (test FAILED).

Measurement Parameters, Limits

The FER must be equal or below 8 % for a adjacent channel rejection of 35 dB for a desired channel signal level of -76 dBm and an adjacent channel frequency of a least 25 MHz offset from the desired channel.

The test shall be executed using a 11 Mbit/s CCK modulated signal, PSDU length 1024 octets.

Test implementation hints

- **Definition of adjacent channel**
  In contrast to Standard 802.11a, test 17.3.10.2, the adjacent channel in Standard 802.11b is defined as a channel having a distance of ≥ 25 MHz from the desired operation channel, which is a channel distance of four 802.11b channels in between this 2 channels.
  Proper operation in a multiple cell network in only guaranteed if the channel spacing is at least 25 MHz (according to Standard 802.11b, 18.4.6.2, last paragraph), and therefore only tested under these conditions.

Measurement Results

18.4.8.4 CCA

Purpose	Basic instrument	Options	Used to
Measurement	please refer to page 23		Generate a valid 802.11b signal
	Oscilloscope		Shiw timing between burst and CA
+ demonstration	---	---	---

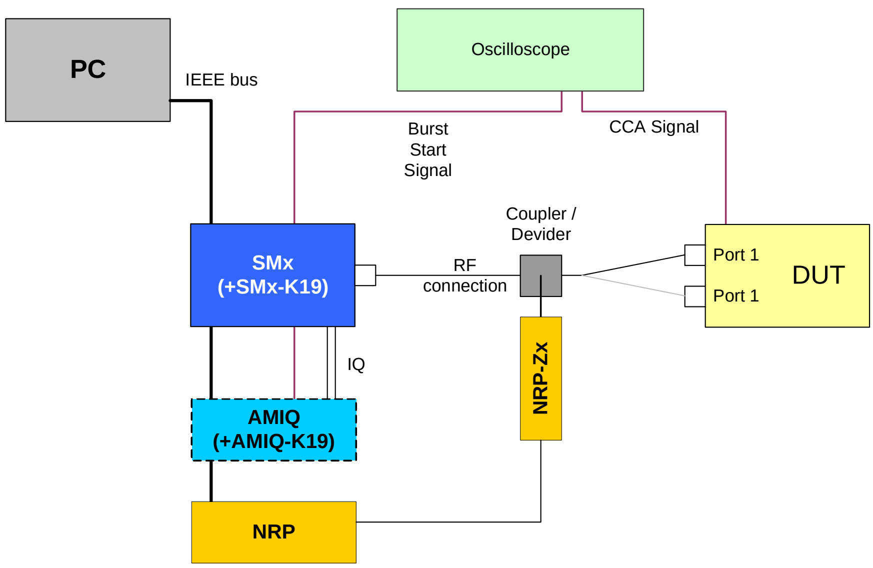
Test purpose

Clear Channel Assessment (CCA) is used to detect if the channel planned for transmission is free or used by another WLAN connection.

Mis-detection will lead to interference with the existing connection, and WLAN 802.11 has no dedicated access method such as GSM via separate connection control channels.

DUT setup, equivalent WV file

Test setup



Drawing 28 – CCA test setup

Test method

Please refer to the standard for details on the test method and implementation.

18.4.8.4 CCA

Measurement Parameters, Limits

Please refer to the standard for details on the test limits.

Test implementation hints

- **CCA signal measurement**
  This measurement can only be executed if the CCA signal is available over an exposed test point.
  Contact the chipset manufacturer if you plan to test CCA with your WLAN module to get information on the access to the CCA signal.

Measurement Results

18.4.8.4 CCA

9 WLAN 802.11g Tests

The test requirements for 802.11g devices are taken from the test requirements for 802.11a and 802.11b, with some numeric modifications in limits and additional requirements for additional test modes.

Please refer to the table below for details and reference to the corresponding test in this document.

Standard				Test parameter		802.11g Paragraph
802.11 a	17.3.8 General	1		Occupied bandwidth		---
		4		Transmit and receive in-band and out-of-band spurious emissions		19.4.3
		7		Transmit and receive antenna port impedance		---
	17.3.9 Transmitter Specification	1		Maximum transmit power level	@ 5.15 - 5.25 GHz	19.4.7.1
					@ 5.25 - 5.35 GHz	19.4.7.1
					@ 5.725 - 5.825 GHz	19.4.7.1
		2		Transmit spectrum mask		19.5.4
		3		Transmit spurious		---
		4		Transmit center frequency tolerance		19.4.7.2 [1]
		5		Symbol clock frequency tolerance		19.4.7.3
		6	1	Transmitter center frequency leakage		---
			2	Transmitter spectral flatness		---
			3	Transmitter constellation error		---
		7		Transmit modulation accuracy test		19.7.2.7 [5]
	17.3.10 Receiver Specifications	1		Receiver minimum input level		19.5.1
		2		Adjacent channel rejection		19.5.2
		3		Non-adjacent channel rejection		---
		4		Receiver maximum input level		19.5.3 [2]
		5		CCA sensitivity		19.4.6 [3]
802.11 b	18.4.7 Transmitter Specifications	1		Transmit power levels (maximum power)		19.4.7.1
		2		Transmit power level control		---
		3		Transmit spectrum mask		19.5.4
		4		Transmit center frequency tolerance		---
		5		Chip clock frequency tolerance		---
		6		Transmit power-on and power-down ramp		---
		7		RF carrier suppression		---
		8		Transmit modulation accuracy		---
	18.4.8 Receiver Specifications	1		Receiver minimum input level sensitivity		19.6.1 [4]
		2		Receiver maximum input level		19.5.3 [2]
		3		Receiver adjacent channel rejection		19.5.2
		4		CCA		19.4.6 [3]

NOTE ***if no annotation is given, test are the same for g and a/b***

ANNOTATIONS

--- not stated in the standard
1) tolerance increased to 25 ppm
2) 10 % PER, 1000 byte PSDU length, -20 dBm at antenna connector, at **any** supported data rate
3) changed values, please refer to standard and text for details
4) sensitivity level changed to -74 dBm for 33 Mbit/s mode, other modes unchanged
5) only for DSSS-OFDM

10 Notes

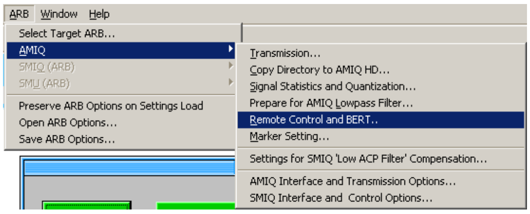
Enabling the WinIQSIM Option for WLAN

The AMIQ-K19, SMIQ-K19 or the SMU-K19 option as applicable must be enabled to generate WLAN signals with the AMIQ / SMIQ-B60 / SMU-B10.

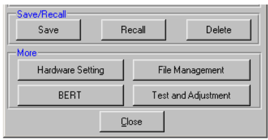
Enabling the AMIQ-K19 Option

Connect AMIQ to the computer using the IEEE bus, start WinIQSIM and proceed as follows:

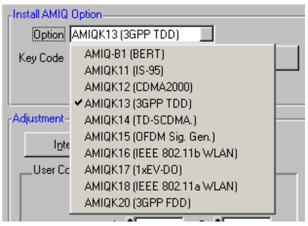
1. Open the dialog box for remote control of the AMIQ:



2. Select “Test and Adjustment”:



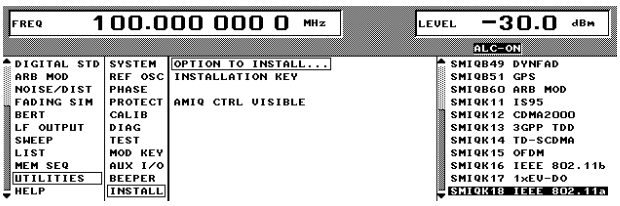
3. Select the WLAN option “AMIQ-K19”:



4. Enter the enabling code and click on “Install”. The option is installed and is immediately usable.

Enabling the SMIQ-K19 Option

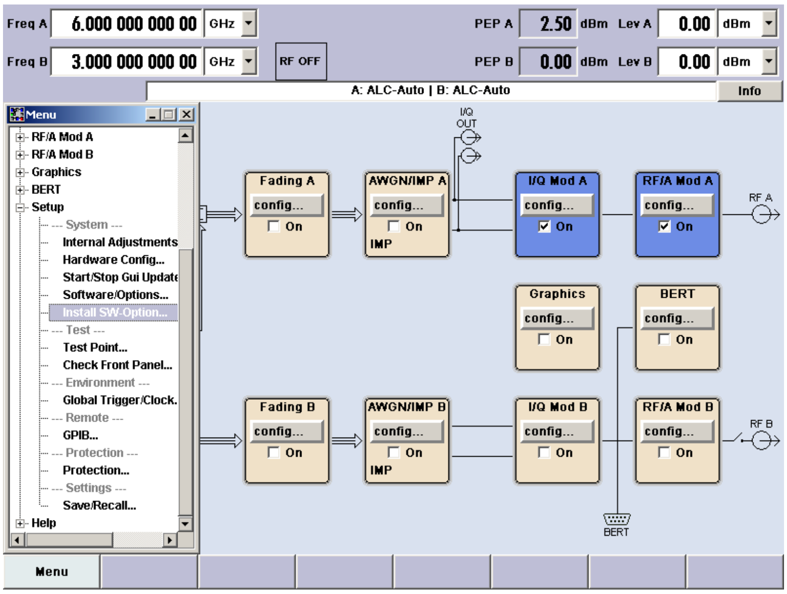
To install the option in SMIQ, select the following submenu:



Enter the installation key.

Enabling the SMU-K19 Option

To install the option in SMU, select the following submenu (after pressing the SETUP hardkey):



Enter the installation key.

11 Frequently Asked Questions

Some frequently asked questions relating to the generation and measurement of WLAN signals are answered below:

Question:
How can I set my DUT into test mode and set the parameters?

Answer:
The manufacturer of the chipset normally can provide a special software to set the WLAN chip into special test modes.
Please contact the manufacturer of the chipset for more information.

Question:
Why is no signal transmitted by the DUT?

Answer:
- Is the WLAN DUT activated?
- Is the correct frequency / level set?
- Is the correct antenna port (1 or 2 if present) set as Tx antenna?
- Is the device in continuously transmitting mode?
- Is the data rate set correct?

Question:
Why are all gated measurements very slow?

Answer:
Switch off all Rx signals to avoid ACK frame activity.

Question:
Why can the FS-K90 not measure the signal provided by the DUT?

Answer:
- Switch off the Rx signal (the card will try to send asynchronous burst if an Rx signal is present).
- Is the auto-level function of the FS-K90 executed once?

Question:
Why is the signal level very low?

Answer:
- Is gain control set correct?
- Is the correct antenna (1 or 2) set as Tx antenna?
- Perhaps the cable is broken.
- Perhaps the GSC connector to the module is broken.

Question:
The Rx packets for PER measurement are all lost.

Answer:
- Is the signal level high enough?

12 Abbreviations

Abbrev.	Meaning
16QAM	*16-Quadratur Amplitude Modulation* Modulation schema for 802.11
64QAM	*64-Quadratur Amplitude Modulation* Modulation schema for 802.11
BPSK	*Binary Phase Shift Keying* Modulation schema for 802.11
CCA	*Clear Channel Assessment* Signal indicating that the channel is clear and can be used
CCK	*Complementary Code Keying* Type of modulation / mapping for 802.11b
Chip	Part of a complete transmission symbol
DSSS	*Direct Sequence Spread Spectrum* Type of modulation / mapping for 802.11b
DUT	*Device Under Test* The part being tested (e.g. a Wireless LAN card)
ERP	*Extended Rate PHY* 802.11b modes added to 802.11a to give 802.11g
EVM	*Error Vector Magnitude* Figure of merit for the quality of a modulator; ”difference between wanted and produced IQ signal”
FCS	*Frame Check Sequence*
FER	*Frame Error Rate* Rate between "wrong" frames and total number of frames
Golden Device	Electronic part which generates the reference signal e.g. for Rx test
ISM	*Industrial, Scientific, Medical* Name of the band 802.11b/g is operating in
MAC	*Media Access Control*
OFDM	*Orthogonal Frequency Division Multiplexing* Type of modulation for 802.11a/g
PBCC	*Packet Binary Convolutional Coding* Type of mapping for 802.11b/g
PER	*Packet Error Rate* Rate between "wrong" packets and total number of packets
PLCP	*Physical Layer Convergence Protocol*
PPDU	*PLCP Protocol Data Unit*
PSDU	*PLCP Service Data Unit*
QPSK	*Quadratur Phase Shift Keying* Modulation schema for 802.11
Rx	*Reception* Identifier to refer to the receiver aspect of a signal
Tx	*Transmission* Identifier to refer to the transmitter aspect of a signal

13 Additional Information

Please contact TM-Applications@rsd.rohde-schwarz.com for comments and further suggestions.

14 Literature

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http://standards.ieee.org/getieee802/download/802.11-1999.pdf

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PDF-ISBN: 0-7381-2929-1
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Available for free download (including software):
http://www.rohde-schwarz.com/appnote/1GP56

[10] Generating Signals for Wireless LANs, Part I: IEEE 802.11b, Application Note 1GP49, Rohde & Schwarz, 2002
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http//www.rohde-schwarz.com/appnote/1GP49

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http://www.rohde-schwarz.com/appnote/1MA70

[12] ETSI EN 301 893: Broadband Radio Access Networks (BRAN); 5 GHz high performance RLAN; Harmonized EN covering essential requirements of article 3.2 of the R&TTE Directive

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Available for free download:
http://www.rohde-schwarz.com/product/WinIQSIM

15 Ordering Information

I/Q Modulation Generator / Modulation Source Options

R&S AMIQ	Max. 16 Msamples I and Q	1110.2003.04
R&S AMIQ-K19	Digital Standard IEEE 802.11	1122.3200.02
R&S SMIQ-B60	Max. 512 Ksamples I and Q	1136.4390.02
R&S SMIQ-K19	Digital Standard IEEE 802.11	1154.8307.02
R&S SMU-B13	Baseband Main Module	1141.8003.02
R&S SMU-B10	Max. 64 Msamples I and Q, Dig. Modulation	1141.7007.02
R&S SMU-K19	Digital Standard IEEE 802.11	1160.8805.02
R&S WinIQSIM	IQ simulation software (Version 4.00 or later)	1110.3600.02

Vector Signal Generator

R&S SMIQ02B	0.3 ... 2.2 GHz	1125.5555.02
R&S SMIQ03B	0.3 ... 3.3 GHz	1125.5555.03
R&S SMIQ04B	0.3 ... 4.4 GHz	1125.5555.04
R&S SMIQ06B	0.3 ... 6.4 GHz	1125.5555.06
R&S SMIQ03HD	0.3 ... 3.3 GHz	1125.5555.33
R&S SMIQ-Z5	BNC Adapter for rear panel	1104.8555.02
R&S SMU200A	Basic Instrument	1141.2005.02
R&S SMU-B106	100 kHz ... 6 GHz for 1st path	1141.8803.02
R&S SMU-B103	100 kHz ... 3 GHz for 1st path	1141.8603.02
R&S SMU-B203	100 kHz ... 3 GHz for 2nd path	1141.9500.02

Signal Analyzer, Spectrum Analyzer and Options

R&S FSP3	9 kHz ... 3 GHz	1093.4495.03
R&S FSP7	9 kHz ... 7 GHz	1093.4495.07
R&S FSP13	9 kHz ... 13 GHz	1093.4495.13
R&S FSP30	9 kHz ... 30 GHz	1093.4495.30
R&S FSP40	9 kHz … 40 GHz	1093.4495.40
R&S FSP-K90	Application Firmware 802.11a	1300.6650.02
R&S FSQ3	20 Hz ... 3.6 GHz	1155.5001.03
R&S FSQ8	20 Hz ... 8 GHz	1155.5001.08
R&S FSQ26	20 Hz ... 26,5 GHz	1155.5001.26
R&S FSQ-K91	Application Firmware 802.11a/b/g/j	1157.3129.02
R&S FSU3	20 Hz ... 3.6 GHz	1166.1660.03
R&S FSU8	20 Hz ... 8 GHz	1166.1660.08
R&S FSU26	20 Hz ... 26.5 GHz	1166.1660.26
R&S FSU46	20 Hz ... 46 GHz	1166.1660.46

Power Meter and Options

R&S NRP	Power Meter	1143.8500.02
R&S NRP-Z11	Power Sensor 10 MHz … 8 GHz	1138.3004.02
R&S NRP-Z3	USB Adapter (active)	1146.7005.02
R&S NRP-Z4	USB Adapter (passive)	1146.8001.02

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