Products: R&S®SMJ100A, R&S®SMU200A, R&S®SMATE200A, R&S®FSQ6, R&S®FSL6

Transmitter Tests in Accordance with the CTIA Plan for Wi-Fi Mobile Converged Devices

Application Note 1MA107

In response to the growing number of WLAN modules that also support a cellular network (converged devices), CTIA published a plan with new tests in August 2006 that certifies Wi-Fi conformance. This Application Note first addresses the transmitter tests of the CTIA plan. For these tests Rohde&Schwarz offers preprogrammed instrument setups. They enable you to perform the measurements on the WLAN test set easily and quickly. Moreover, this Application Note shows how you can check the spectrum transmit mask defined for OFDM by means of only one keystroke on the Rohde&Schwarz spectrum analyzers.

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Contents

The following abbreviations are used in this Application Note for Rohde & Schwarz test equipment:

- The R&S®SMJ100A vector signal generator is referred to as the SMJ.
- The R&S®SMU200A vector signal generator is referred to as the SMU.
- The R&S®SMATE200A vector signal generator is referred to as the SMATE.
- The R&S®FSQ3/6 signal analyzers are referred to as the FSQ.
- The R&S®FSL3/6 spectrum analyzers are referred to as the FSL.

1 Overview

In response to the growing number of wireless local area network (WLAN) modules that also support a cellular network (converged devices), the Cellular Telecommunications and Internet Association CTIA published a plan with new tests in August 2006 that certifies Wi-Fi conformance [1], [2]. This test plan covers WLAN access points as well as cellular phones (mobiles) with WLAN functionality.

The tests are designed for modules that meet the 802.11a, b and g standards. Before the measurements covered here are performed, the Wi-Fi conformance of these modules with the individual standards must first be verified [3], [4], [5].

Rohde&Schwarz Application Note 1MA69 [6] tells you how you can perform the measurements in accordance with the 802.11a, b or g standards.

The current Application Note first covers the *transmitter performance* tests in the CTIA plan for converged devices. It provides you with preprogrammed instrument setups for the SMJ and SMU generators from Rohde&Schwarz that enable you to easily and quickly validate the measurements on the CTIA-specified tester, the WLAN test set.

Then the Application Note shows you how you can check the spectrum transmit mask for OFDM by means of one keystroke.

Transmitter Performance tests in the CTIA Test Plan

Table 1 shows the transmitter performance tests in the new CTIA test plan. The purpose is to determine the transmitter output power.

Section	Test	Type	Standard
5.	**Mobile Station Testing**		
5.1.1	Conducted Power Output	Conducted	802.11 a, b, g
5.1.2	Total Radiated Power (TRP)	Radiated	802.11 a, b, g
6.	**Access Point Testing**		
6.1.1	Conducted Power Output	Conducted	802.11 a, b, g
6.1.2	Total Radiated Power (TRP)	Radiated	802.11 a, b, g

Table 1: Transmitter performance tests for Wi-Fi converged devices

The CTIA test plan divides testing into mobile station testing and access point testing. The primary difference is the connection setup between the device under test (DUT) and the WLAN test set.

The test plan likewise distinguishes between conducted and radiated RF tests. In the first case, the RF port of the DUT is directly connected with the test setup via cables. In the second case, it is coupled via antennas.

Conducted and radiated tests differ in test setup as well as with regard to the frequencies and data rates used.

In the three WLAN standards, measurements are performed using different frequencies, modulation types and data rates.

However, the measurement procedure is the same in all cases. A detailed description of the transmitter performance tests is provided in Section 2 of this Application Note.

Section 3 provides step-by-step instructions on how to perform the transmitter performance tests, particularly the validation of the measurements on the WLAN test set.

To perform these tests, you need the SMJ (or SMU) vector signal generator from Rohde&Schwarz plus the options SMJ/SMU - B9 (or - B10 or - B11), SMJ/SMU - B13, SMJ/SMU - B106, and the 802.11 personality SMJ/SMU - K48.

If you are working exclusively by remote control the SMATE generator (without display and keys) will also do.

Spectrum Transmit Mask

In addition to the tests specified in Table 1, the CTIA test plan (Section 5.1.1.4) stipulates a check of the spectrum transmit mask for OFDM signals (802.11a, g standards). Section 4 of this Application Note shows how you can do this easily and quickly. You will need one of the spectrum analyzers FSQ or FSL, equipped with the FSQ/FSL - K91 option for 802.11a, b and g.

The spectrum transmit mask is already programmed in the WLAN option of the FSQ and FSL. Thus, you no longer need to enter the individual limit values. In addition, the WLAN option automatically adapts the mask to the peak power of the input signal. You can thus perform the measurement simply by pressing a key.

Ordering Information

Page 18 in the attachment contains the *ordering information*.

2 Principle of Operation for Transmitter Performance Tests

Transmitter performance tests are listed in Sections 5.1.1, 5.1.2, 6.1.1 and 6.1.2 of the CTIA test plan. Fig. 2_1 shows the test setup for the conducted power measurement (5.1.1, 6.1.1). For the radiated power (5.1.2, 6.1.2), the DUT and WLAN test set transmit and receive via antennas that are positioned to be reproducible. The power levels are different; the measurement procedure is the same.

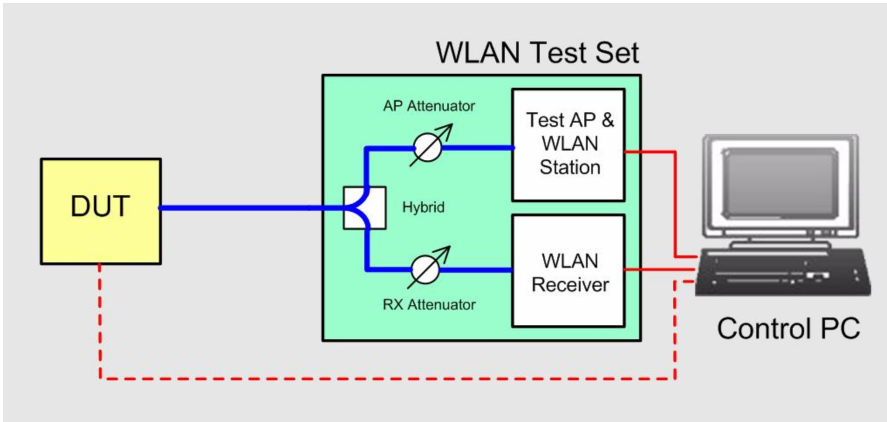

Fig. 2_1: Test setup for conducted RF tests

The WLAN test set contains (Fig. 2_1, top) a test access point (AP) and a WLAN station; both have higher transmit power than customary modules. For testing WLAN mobile stations, set operation is similar to that for an access point. For testing access points, operation is similar to that for a WLAN station. A WLAN receiver is shown at the bottom of the test set. This receiver functions like a WLAN sniffer, but has better RSSI characteristics.

The RF ports of both modules are connected with the DUT via programmable attenuators and a hybrid combiner.

A control PC controls the overall measurement. If the DUT is an access point, it will also be controlled by the control PC.

Measurement Procedure

The WLAN test set first establishes a connection to the DUT. It then continuously transmits *unicast packets* with uniform data content. The measurement is performed at different frequencies and data rates, which are stipulated in the CTIA test plan. Retransmission and rate fallback functionality must be deactivated in the DUT.

The DUT acknowledges the unicast packets with ***ACK control frames***.

The WLAN receiver in the test set can count the number of acknowledgments per second. However, it primarily assesses the received output power in accordance with the ***RSSI*** scale. The power is averaged over 10 seconds, and the measurement result is then logged on the PC.

This procedure is repeated for all frequencies and data rates specified in the test plan.

The **validation** of the RSSI values is carried out in accordance with the substitution method:

The DUT is removed and replaced by a WLAN generator (e.g. the SMU generator from Rohde&Schwarz). The generator now likewise continuously generates ACK control frames at the individual measurement frequencies. You will then need to change the output power of the generator and, if applicable, the settings of the RX attenuator until the receiver in the test set reports the same RSSI value as in the measurement with the DUT. The original output power of the DUT is calculated from the generator level and the variation of the RX attenuator.

CTIA selected this measurement procedure because it works with all types of WLAN devices and does not require any test modes whatsoever in the DUT. In addition, the substitution method eliminates the need to calibrate the test set and to determine the losses in the RF path between the test set and DUT at the individual test frequencies. This is highly beneficially primarily when using coupling via antennas (radiated power).

To validate the RSSI values, you must therefore generate ACK control frames. Section 3 explains how to do this.

Note: For each substandard, one and the same ACK frame applies regardless of the modulation type and data rate of the frame forwarded by the WLAN test set.

Which Generator to Choose

The SMJ and SMU vector signal generators are equally suited for the transmitter performance tests discussed here. If you are working exclusively by remote control an SMATE (without display and keys) will also do.

The generator you choose will depend on your remaining measurement requirements.

Fig. 1_1: SMJ versus SMU

The SMJ and SMU both provide nearly the same features and the same excellent signal quality:

- Very low SSB phase noise of typ. -135 dBc (1GHz, 20 kHz offset, SMU)
- Wideband noise of typ. −153 dBc (CW, f = 1 GHz, >10 MHz carrier offset, 1 Hz BW, SMU)
- Excellent ACLR

- Very high level repeatability
- Baseband generator with universal coder for realtime signal generation
- Arbitrary waveform generator with up to 128 Msamples

Primary differences:

The SMJ is single-channel instrument with **one** path for baseband and **one** RF path up to 6 GHz.

The SMU (and the SMATE) can generate **two** complete baseband paths, an RF path up to 6 GHz plus a second one up to 3 GHz (or two RF paths up to 3 GHz). Together with two each of the -B13 and -B10 baseband and the -K48 options, it can simultaneously supply two independent 802.11a, b or g signals. You will need these independent signals, for example, in several receiver tests from the WLAN standard.

Plus, when equipped with the SMU-B14 and -B15 **fading** options, the SMU simulates two independent multipath signals, which you will need for the performance tests of most mobile radio standards.

➢ The SMU is the ideal choice if you require several generator signals simultaneously; for fading applications, it is a must.

➢ The SMJ is an economical alternative for measurements where only one signal is required, e.g. in the tests presented here.

For more information, see

http://www.rohde-schwarz.com/product/smu200A or

http://www.rohde-schwarz.com/product/smate200A or

http://www.rohde-schwarz.com/product/smj100A

The following instructions apply to both the SMJ and the SMU (or SMATE), even though only the SMU is mentioned for the sake of brevity.

3 How to Generate the ACK Control Frames

To generate the ACK control frames, you must know three parameters:

- The standard for your DUT (802.11 a/g, b)
- Your test frequency or the channel number
- The MAC address of the WLAN test set

All other parameters are already defined in the two SMU configuration files, which are appended to this Application Note:

ACK_ag.wlan for the 802.11a/g standards and

ACK_b. wlan for the 802.11b standard

Copy the configuration you need to a USB memory stick.

Then proceed as follows on the SMU:

- ➢ Press *PRESET* (blue key) to reset the generator.
- ➢ Enter your test frequency.

If you know only the channel number, you can obtain the appropriate frequency from Table 3.

802a U-NIII Band 5000 MHz to 6000 MHz				802.11b, g ISM Band 2400 MHz to 2497 MHz	
Chan.	Freq. [MHz]	Chan.	Freq. [MHz]	Chan.	Freq. [MHz]
34	5170	108	5540	1	2412
36	5180	112	5560	2	2417
38	5190	116	5580	3	2422
40	5200	120	5600	4	2427
42	5210	124	5620	5	2432
44	5220	128	5640	6	2437
46	5230	132	5660	7	2442
48	5240	136	5680	8	2447
52	5260	140	5700	9	2452
56	5280	149	5745	10	2457
60	5300	153	5765	11	2462
64	5320	157	5785	12	2467
100	5500	161	5805	13	2472
104	5520			14	2484

Table 3: Channels and frequencies for the 802.11a, b, g standards

➢ Insert your memory stick in the SMU.

➢ Using the rotary knob (or the cursor keys), select baseband block A and push the rotary knob (or press *ENTER*).

The selection list of standard modulations will appear; see Fig. 3_1.

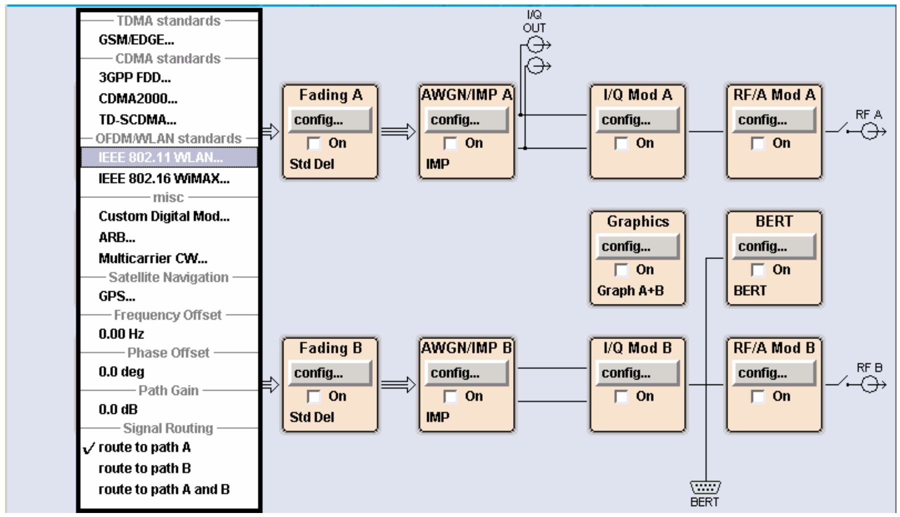

Fig. 3_1: Selection of standards and modulations (excerpt)

➢ Select *IEEE 802.11 WLAN*.

The basic WLAN menu will appear:

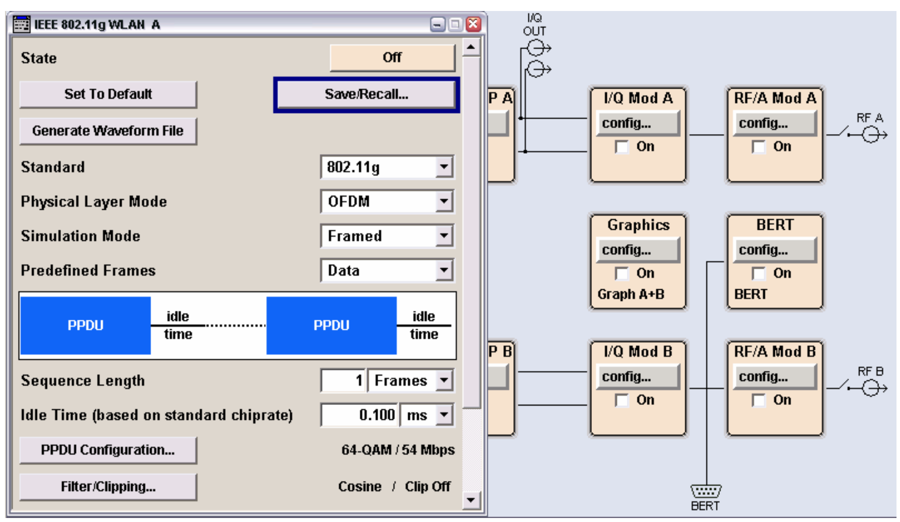

Fig. 3_2: Basic WLAN menu

➢ Select *Save/Recall* and load the configuration that matches the standard for the DUT from the e: drive.

➢ Switch ***State ON***

If you have loaded the configuration file for the 802.11a,g standard, the basic WLAN menu will look as Fig. 3_3a:

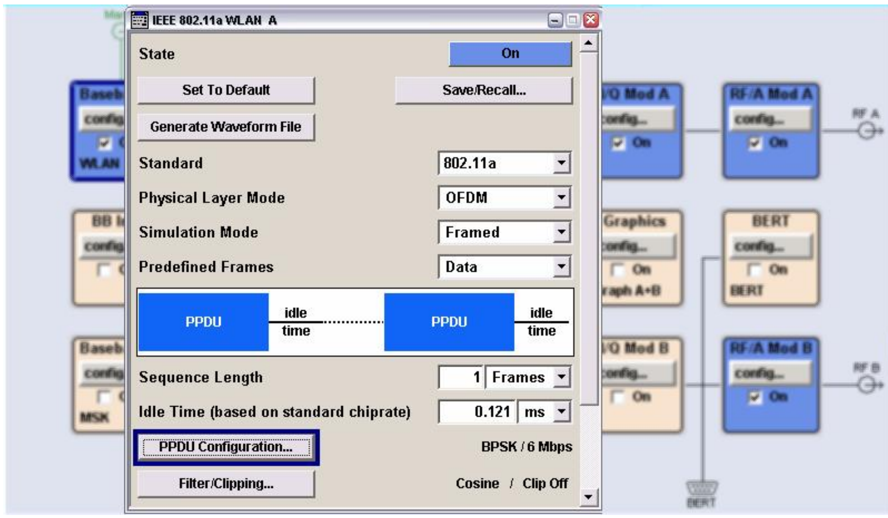

Fig. 3_3a: Basic WLAN menu for the 802.11a, g standard

If you have selected the configuration file for the 802.11b standard, the basic WLAN menu will look as Fig. 3_3b:

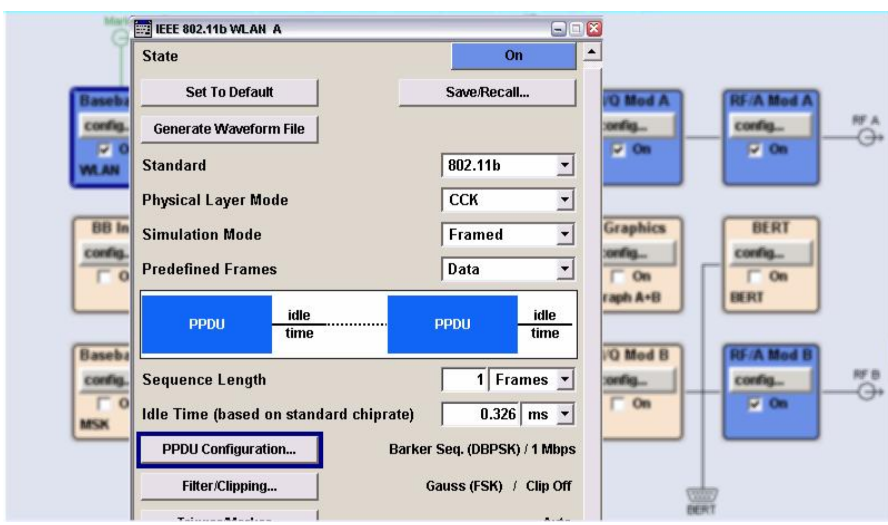

Fig. 3_3b: Basic WLAN menu for the 802.11b standard

In both cases, the SMU immediately starts to generate ACK frames using the preprogrammed configuration. The ACKs are periodically repeated after the idle time.

(There is no signal at the output connector if the RF is still switched off!)

At this point, you have selected the right standard and have set the test frequency.

Now, you merely need to change the preprogrammed MAC address of the ready-made configuration into the MAC address of the WLAN test set.

How to Edit the MAC Address in the ACK Frame?

The ACK frame is a special case of a general WLAN frame. In particular, it does not contain any user data. The general frame, which is transmitted over the air interface, is also called the PLCP Protocol Data Unit (PPDU). PLCP stands for Physical Layer Convergent Protocol; see below.

An 802.11 frame consists of specific elements in the different OSI layers, see Fig. 3_4:

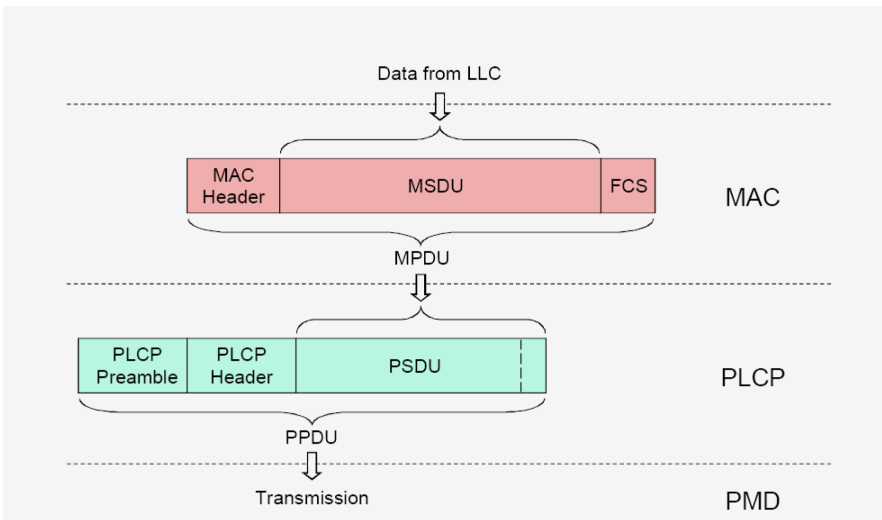

Fig. 3_4: Data encapsulation procedure in MAC and PLCP

Transmission takes place in the Physical Medium Dependent (PMD) layer. This is layer 1. The standard selected determines what is transmitted or received here.

The Medium Access Control (MAC) layer forms the lowest level of layer 2. This layer and the data format used here are the same for the WLAN 802.11 a, b and g standards.

The different layer-1 formats are adapted in an interim layer by means of the Physical Layer Convergence Protocol (PLCP).

Definitions:

PPDU: PLCP Protocol Data Unit

PSDU: PLCP Service Data Unit

MPDU: MAC Protocol Data Unit

MSDU: MAC Service Data Unit

FCS: Frame Check Sequence

The **MAC address** that you must input **is part of the of the MAC header**; see Fig. 3_4. You can access the appropriate edit field on the SMU via the configuration of the PPDU; see Figs. 3_3a and 3_3b.

➢ Select *PPDU Configuration*, and press *ENTER*.

If you have loaded the configuration file for the 802.11a, g standard, the following PPDU configuration menu will appear:

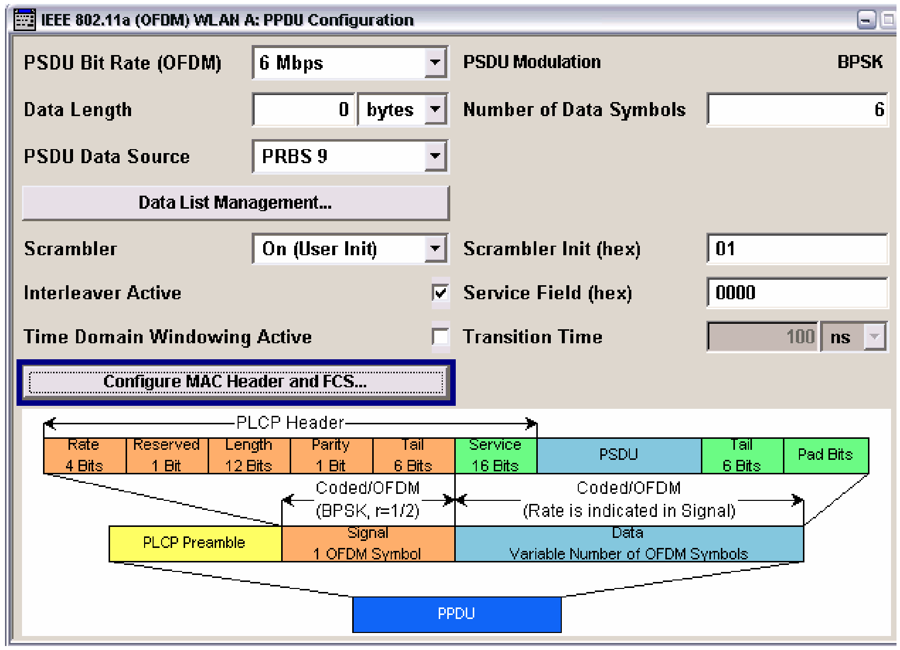

Fig. 3_5a: Configuration of the PPDU for the 802.11a, g standard

If you have loaded the configuration file for the 802.11b standard, the following PPDU configuration menu will appear:

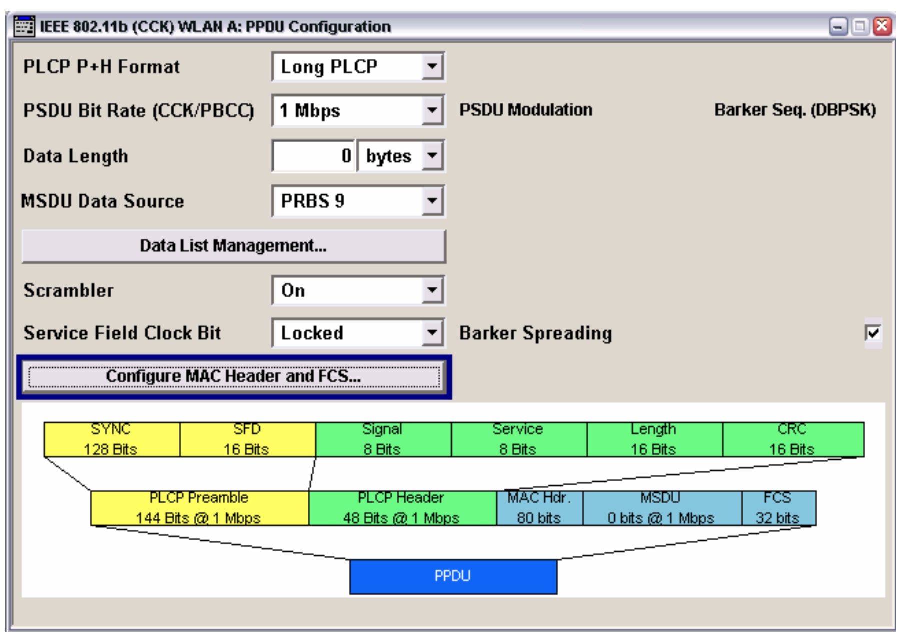

Fig. 3_5b: Configuration of the PPDU for the 802.11b standard

The following default settings are important:

- The data rate of the ACK frame for 802.11a/g is always 6 Mbps – regardless of the bit rate of the user data in the frame forwarded by the WLAN test set; for 802.11b, it is always 1 Mbps.
- Since the ACK control frame does not contain any data (no MSDU), the data length is zero.

Figs. 3_5a and b show that the PPDUs of the various WLAN standards contain different elements and have different structures.

But the MAC frame supplied by layer 2 is the same: In Fig. 3_5a, it is the PSDU; in Fig. 3_5b, it consists of the following blocks: MAC header, MSDU and FCS.

➢ Select *Configure MAC Header and FCS*, and press *ENTER*.

The following menu will appear (uniform for the 802.11a, b and g standards):

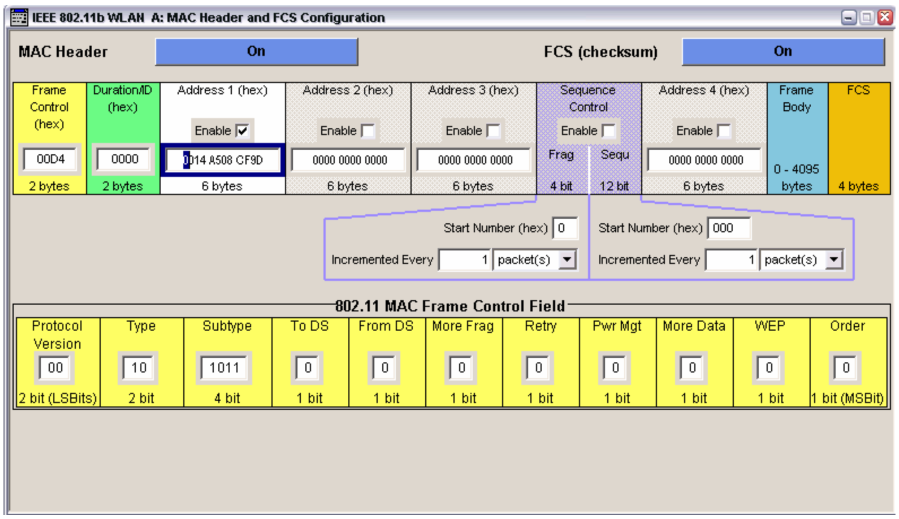

Fig. 3_6: MAC configuration for 802.11

The supplied configuration generates an ACK control frame, which is shorter than the general data frame. Therefore, not all of the possible elements are enabled here.

The *frame control* D4 identifies the frame as ACK. The *duration* is again zero (no *frame body* present).

➢ For *Address 1*, enter the MAC address of the WLAN test set, and acknowledge with *ENTER*.

The SMU will then set your MAC address and recalculate the checksum *FCS*.

➢ Activate the output stage of the generator by using the ***RF ON*** key.

The generator will now output repeating ACK frames with the correct MAC address. Fig. 3_7a/b show recordings of the SMU signal with the spectrum analyzer.

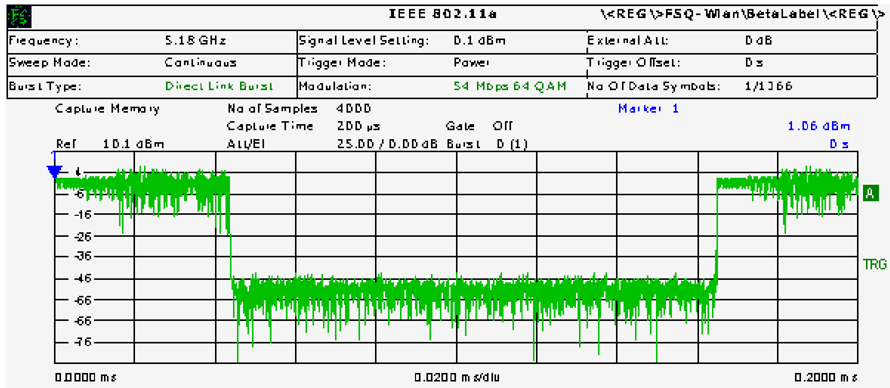

Fig. 3_7a: Power versus time for the ACK frame in accordance with the 802.11a, g standard

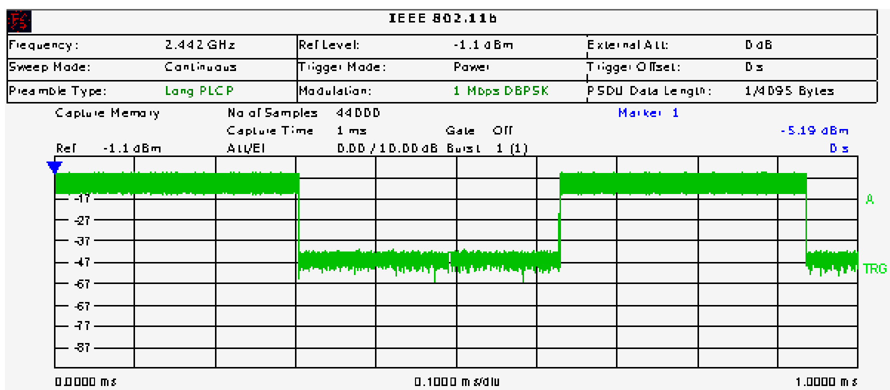

Fig. 3_7b: Power versus time for the ACK frame in accordance with the 802.11b standard

For 802.11a/g, the repetition rate must be 165 µs. This requires an idle time of 121 µs; see Fig. 3_2a. In the case of 802.11b an *idle time* of 326 µs yields a repetition rate of 630 µs; see Fig. 3_2b.

Now proceed as described in the CTIA test plan:

1. Determine the RSSI values for your DUT signal at the frequencies and data rates specified in the test plan.
2. Remove the DUT and connect the generator at the test point.
3. Change the output power of the generator and, if necessary, the settings of the RX attenuator until the receiver in the test set reports the same value as in the measurement with the DUT.
4. Calculate the original output power of the DUT from the generator power and the variation of the RX attenuator.
5. Repeat steps 2 to 4 for the other frequencies in the test plan.

4 How to Check the Transmit Power Mask

Section 5.1.1.4 in the CTIA test plan requires that the transmitter spectrum be checked with a tolerance mask.

The purpose is to ensure that the DUT does not disturb other WLAN modules that are active in the adjacent channels. The 802.11a standard offers the following drawing:

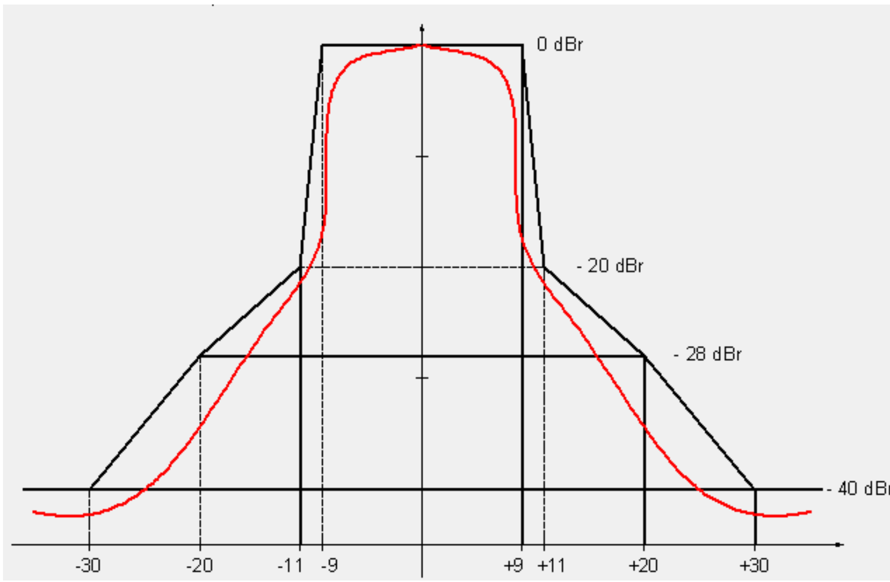

Fig. 4_1: Definition of the transmit spectrum mask for 802.11a

Check the transmitter output signal for OFDM at a data rate of 6 Mbps. The procedure is as follows ():

1. Connect your DUT with the FSQ or FSL spectrum analyzer.
2. Press *PRESET* on the analyzer.
3. Select the personality *WLAN* (*MORE* softkey).
4. Enter the operating frequency *FREQ*.
5. Press the *SPECTRUM* softkey, and select *SPECTRUM IEEE.*
6. Start a measurement with the *RUN SGL* softkey.

Since the 802.11a signal is pulsed, the WLAN personality in the spectrum analyzer uses a gated sweep. If you wish to perform a measurement across several frames, start the measurement with *RUN CONT*. By using *TRACE, MAX HOLD*, you can determine the peak value over a longer period.

The analyzer firmware automatically applies the mask at the peak power.

Fig. 4_2 shows a typical measurement result.

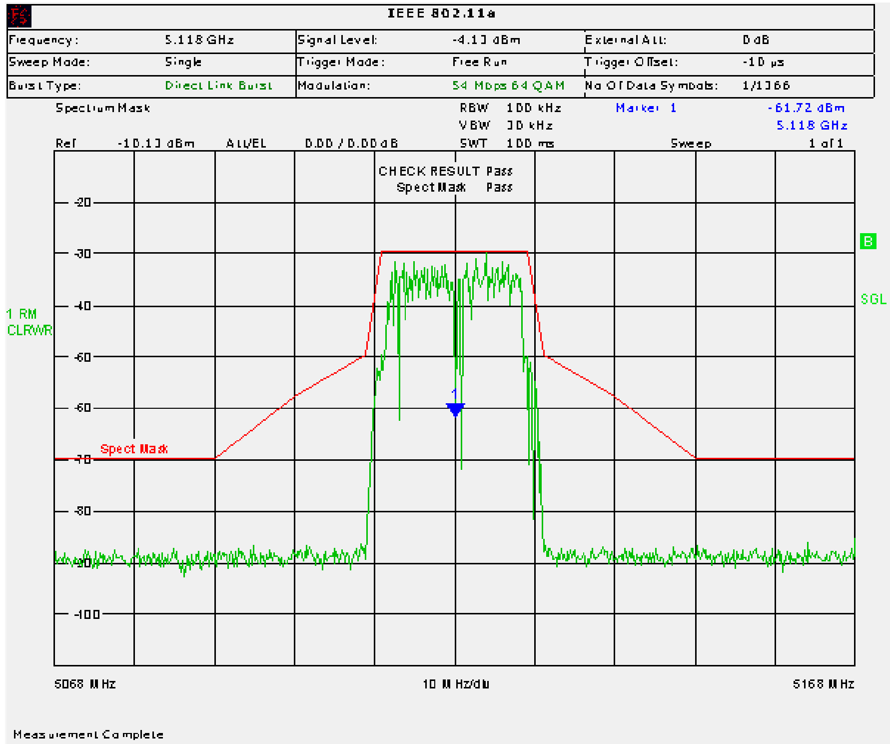

Fig. 4_2: Spectrum and transmission mask

The transmitter spectrum recorded here is definitely below the limit values. The analyzer returns the following as the result:

CHECK RESULT: Pass.

5 Attachment

References

[1] **"Test Plan for RF Performance Evaluation of Wi-Fi Mobile Converged Devices",** Cellular Telecommunications and Internet Association, August 2006, Revision 1.0

[2] **"Test Plan for Mobile Station Over the Air Performance"** Cellular Telecommunications and Internet Association, Method of Measurement for Radiated RF Power and Receiver Performance, April 2005, Revision 2.1

[3] **IEEE Std 802.11a-1999** Amendment 1: "High-Speed Physical Layer in the 5 GHz Band"

[4] **IEEE Std 802.11b-1999** (Supplement to ANSI/IEEE Std 802.11, 1999 Edition): "Higher-Speed Physical Layer Extension in the 2.4 GHz Band"

[5] **IEEE P802.11g/D8.2, April 2003** (Supplement to IEEE Std 802.11 1999 (Reaff 2003)): "Further Higher Data Rate Extension in the 2.4 GHz Band"

[6] **WLAN Tests According to Standard 802.11a/b/g**, Application Note 1MA69, Rohde & Schwarz, 2004

Additional Information

This Application Note is updated from time to time. Please visit the website http://www.rohde-schwarz.com/appnote/1MA107 to download latest versions.

Please send any comments or suggestions about this Application Note to **TM-Applications@rsd.rohde-schwarz.com**.

Ordering Information

Vector signal generator

R&S SMJ100A	Base unit	1403.4507.02
R&S SMJ-B103	100 kHz to 3 GHz for 1st path	1403.8502.02
R&S SMJ-B106	100 kHz to 6 GHz for 1st path	1403.8702.02
R&S SMJ-B9	Baseband, ARB 128M and Dig. Modulation	1404.1501.02
R&S SMJ-B10	Baseband, ARB 64M and Dig. Modulation	1403.8902.02
R&S SMJ-B11	Baseband, ARB 16M and Dig. Modulation	1403.9009.02
R&S SMJ-B13	Baseband Main Module	1403.9109.02
R&S SMJ-K48	Dig. Std. IEEE 802.11 (a/b/g)	1404.1001.02
R&S SMU200A	Base unit	1141.2005.02
R&S SMU-B103	100 kHz to 3 GHz for 1st path	1141.8603.02
R&S SMU-B106	100 kHz to 6 GHz for 1st path	1141.8803.02
R&S SMU-B203	100 kHz to 3 GHz for 2nd path	1141.9500.02
R&S SMU-B9	Baseband, ARB 128M and Dig. Modulation	1161.0766.02
R&S SMU-B10	Baseband, ARB 64M and Dig. Modulation	1141.7007.02
R&S SMU-B11	Baseband, ARB 16M and Dig. Modulation	1159.8411.02
R&S SMU-B13	Baseband Main Module	1141.8003.02
R&S SMU-K48	Dig. Std. IEEE 802.11 (a/b/g)	1161.0266.02
R&S SMATE200A	Base unit	1400.7005.02
R&S SMATE-B103	100 kHz to 3 GHz for 1st path	1401.1000.02
R&S SMATE-B106	100 kHz to 6 GHz for 1st path	1401.1200.02
R&S SMATE-B203	100 kHz to 3 GHz for 2nd path	1401.1400.02
R&S SMATE-B206	100 kHz to 6 GHz for 2nd path	1401.1600.02
R&S SMATE-B9	Baseband, ARB 128M and Dig. Modulation	1404.7500.02
R&S SMATE-B10	Baseband, ARB 64M and Dig. Modulation	1401.2707.02
R&S SMATE-B11	Baseband, ARB 16M and Dig. Modulation	1401.2807.02
R&S SMATE-B13	Baseband Main Module	1401.2907.02
R&S SMATE-K48	Dig. Std. IEEE 802.11 (a/b/g)	1404.6703.02

Signal analyzer, spectrum analyzer and options

R&S FSQ3	20 Hz to 3.6 GHz	1155.5001.03
R&S FSQ8	20 Hz to 8 GHz	1155.5001.08
R&S FSQ26	20 Hz to 26.5 GHz	1155.5001.26
R&S FSQ-K91	Application Firmware 802.11a/b/g/j	1157.3129.02
R&S FSL3	9 kHz to 3 GHz	1300.2502.03
R&S FSL13	9 kHz to 3 GHz incl. tracking gen.	1300.2502.13
R&S FSL6	9 kHz to 6 GHz	1300.2502.06
R&S FSL16	9 kHz to 6 GHz incl. tracking gen.	1300.2502.16
R&S FSL-K91	Application Firmware 802.11a/b/g/j	1302.0094.02

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