ITS-G5 RF Minimum Performance Evaluation Measurements

Document History

Author	Change Notes	Date/Release
R&S	Initial Release	2013-07-29/1.0
R&S	Version 2 API and operator instructions added	2013-08-29/2.0
R&S	Version 3 • Numbering introduced • Power measurements completed • Modulation quality measurements completed • Fading Models added • Receiver sensitivity measurements completed	2013-09-23/3.0
R&S	Version 4 • Test setup updated to support 2 RX antenna inputs at DUT (Figure 1), explanations in subclause 5 • DUT requirements updated Support of FAKRA connectors • Fading profiles updated Doppler shift values corrected	2013-10-07/4.0
R&S	Version 5 • Measurement results modified • DUT Ethernet requirements added	2013-11-07/5.0
R&S	Version 6 • Update fading profiles • CBR test signal description added	2013-11-21/6.0

Contents

References

- [1] Draft ETSI EN 302 571 V1.2.0 (2013-05)
- [2] IEEE Std. 802.11-2012
- [3] ITS G5 RF Channel Models, Paul Alexander (Cohda Wireless), Fredrik Tufvesson (Lund University), Mikael Nilsson (Volvo Cars), Version 4 Sept 2013

1. Scope of measurements

ITS-G5 RF specifications allow single and multi-channel devices within the ITS-G5A, ITS-G5B and ITS-G5C band, with possible extension towards the ITS-G5D band in the future. However, for the first generation of ITS-G5 devices (day 1 implementations), it is expected that there are single channel devices only, supporting the 10 MHz bandwidth Control Channel G5CC at 5900 MHz in the ITS-G5A band. Thus, the design of the 3rd ETSI plugtest RF minimum performance measurement setup assumes ITS-G5A single channel devices only.

R&S provides this RF minimum performance measurement setup according to Figure 1 in order to perform a sample of regulatory RF measurements according to EN 302 571 and additional minimum performance measurements. The regulatory measurements include:

- Unwanted emissions within the ITS-G5 band according to EN 302 571 subclause 6.4.2.
- Unwanted emissions outside the ITS-G5 band according to EN 302 571 subclause 6.4.1.

The out of band unwanted emission measurements will be restricted to the range 30 MHz – 6 GHz. However, this includes the critical ranges next to the ITS-G5A/B/D bands.

The additional minimum performance measurements include:

- Modulation quality, incl. constellation error, spectral flatness, carrier frequency and clock error
- Minimum receiver sensitivity measurements under static conditions
- Receiver performance measurements under AWGN and fading conditions
- optional DCC channel probing measurements (no results recorded)

For the modulation quality and minimum receiver sensitivity measurements the requirements provided by IEEE Std. 802.11-2012 apply. For the receiver performance measurements under non-static conditions are no standardized performance requirements available, yet. Thus, those measurements will be conducted without final measurement verdicts, unless there will be a common agreement on dedicated performance limits for the plugtest.

1.1. Test report

For each test run a test report will be generated, incl. screen shots of the R&S®FSV signal and spectrum analyzer. The test reports are anonymous and will be handed out to the vendors. Numerical results listed in this document will be handed to authorized ETSI representatives for statistical analysis only.

2. Hardware Setup

The setup includes the following devices/instruments:

- Control PC
  - Windows 7 Enterprise™ 64 Bit
  - Matlab™ R2012B 32 Bit
  - Ethernet (192.168.52.XXX) and USB support
- R&S®FSV30 signal and spectrum analyzer
  Data sheet: http://www.rohde-schwarz.com/en/product/fsv-productstartpage_63493-10098.html
- R&S®SMW200A Vector signal generator
  Data sheet: http://www.rohde-schwarz.com/en/product/smw200a-productstartpage_63493-38656.html
- ITS-G5A band reject filter as specified in Figure 2
- RF coupling device to de-couple stimulus and DUT signals

Note:

- DUT power supply to be provided by vendor or plugtest host, if required.
- DUT software drivers for control PC to provided by vendor, if required.
- DUT control PC to be provided by vendor or plugtest host, if required.

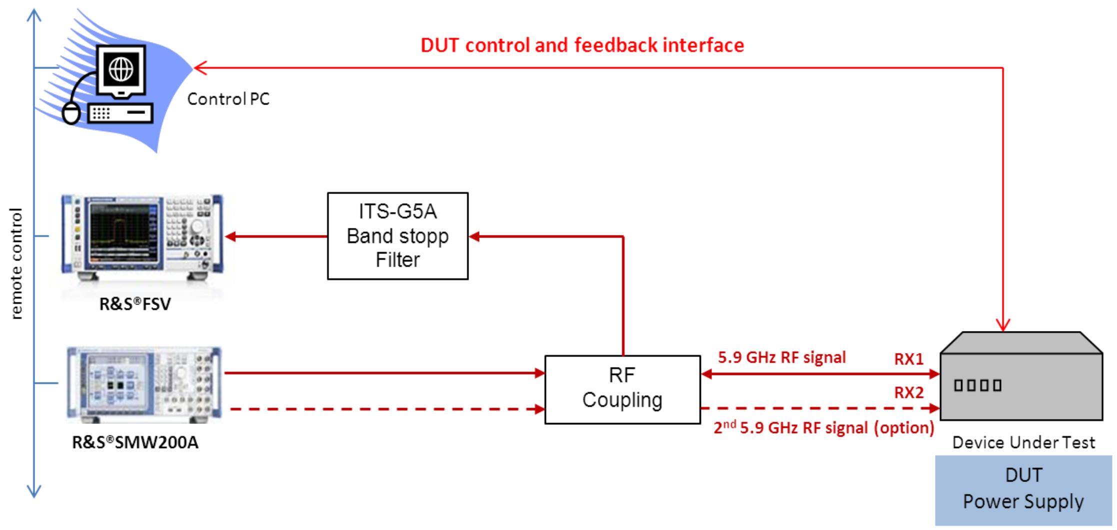

Figure 1: ITS-G5 Measurement Setup Hardware

Band Reject Filter	Cavity Design
Reject Band	5875 MHz to 5905 (ITS-G5A Band)
Reject Attenuation	35 dB

Figure 2: ITS-G5A Band Reject Filter Specification

3. DUT requirements

In order to perform the provided RF measurements it will be necessary to set the device under test (DUT) into known operation state. The RF measurements provided are divided into DUT transmitter and DUT receiver measurements. All measurements are performed conducted, i.e. it is assumed that the DUT provides a standard RF connector for its transmitter output(s) and receiver input(s). Thus, if no standard RF connectors are available, an appropriate adapter should be provided. Supported standard RF connectors are of type N, SMA and FAKRA.

If the DUT has to be connected to the Control PC using Ethernet make sure the IP address is 192.168.52.XXX (XXX should be none of {1, 2, 10, 11}).

The DUT vendor should provide the following for the RF test sessions:

- RF standard connector or appropriate adapter to type N, SMA or FAKRA
- DUT power supply
- DUT control interface (as specified below)

DUT control interface for transmitter measurements

For the DUT transmitter measurements the following parameters need to be set by an appropriate control interface. If a dedicated control software/driver/PC is required, this shall be provided by the DUT vendor. The following transmit signal parameters shall be set prior to the measurements and shall refer to the DUT RF output connector:

- Transmission On/Off
- Transmit burst power level (default: maximum output power)
- Transmit carrier frequency (default: 5900 MHz)
- Transmit channel bandwidth (default: 10 MHz)
- Transmit data rate / or modulation and coding rate (default: 6 Mbps)
- Automatic (DCC) transmit power control enable/disable (default: disabled)
- Automatic (DCC) transmit data rate control enable/disable (default: disabled)
- Transmit packet rate (e.g. PPDUs per second or on air time and idle time)
  Note: Continuous transmission mode for transmitter testing is also a valid option (i.e. zero idle time)
- PSDU length in bytes (informative)
- PSDU or MAC data source (default: pseudo random)

Note: Default values are required values. On request, measurements can be done with other values.

Interface requirements for Rx-measurements

DUT receiver measurements are based on packet error (PER) measurements on MAC level. Thus, access to DUT inbuilt MAC frame counter is required. The inbuilt counter should provide the following services:

- Counter provides number of correct received MAC-Frames (i.e. frames with correct FCS)
- Counter Reset to set counter value to 0 via remote interface on request or manual (e.g. keyboard), or sufficiently large counter range for start/stop operation.
- Counter Start / Stop / Read via remote interface on request or manual (e.g. keyboard)
- Counter access via remote interface on request or manual (e.g. display)
- Counter range at least 32 bit unsigned integer recommended, if no counter reset possible.

In order to allow fully automated PER vs. Receive Level or PER vs. SNR (Signal to Noise Ratio), it is required to provide a tool for the measurement setup control PC, e.g. an executable or a script file with the following command line interface:

For automated PER measurements an executable which can be evaluated with the Matlab command

[*counter_value, optional_param*] = *system('get_mac_counter.exe <input_arg> ')*

is required. *Input_arg* for example could be the DUT IP address.

Similar solutions to provide the counter value to Matlab may also be possible.

Example:

To access the MAC counter of a DUT with the IP address 192.168.52.20 the function call could look like

[counter_value, optional_param] = system('get_mac_counter.exe 192.168.52.20').

The function body could look like this

```
int main(int argc, char *argv[])
{
  printf("%s",optional_param);
  return counter_value;
}
```

4. Transmitter Measurements

4.1. Output Power Measurement

4.1.1. Test Purpose

To verify the RF transmit power prior to test session.

4.1.2. Test Procedure

1. Connect DUT RF transmitter output to R&S®FSV.
2. Activate DUT with specified transmit power @ 5.9 GHz and 10 MHz signal bandwidth.
3. R&S®FSV measurement of DUT RF output power.
4. Repeat steps 2 to 3 for various power settings.

4.1.3. Test Result

Measured output power will be recorded.

Power setting	MCS	Output power
Maximum (23 dBm)	QPSK½	[dBm]
20	QPSK½	[dBm]
10	QPSK½	[dBm]

4.2. Transmitter unwanted emissions within the 5 GHz ITS frequency bands

4.2.1. Test Purpose

To verify DUT transmitter output spectrum emission mask (SEM) according to EN 302 571, subclause 6.4.2.

Notes:

- Measurement bandwidth (i.e. resolution bandwidth of R&S®FSV) set to 100 kHz, as specified in IEEE Std. 802.11-12 annex D.2.3. and the limits in [dBm/MHz] are re-calculated accordingly to [dBm/100 kHz].

  With respect to the measurement bandwidth, there is an inconsistency in the EN 302 571, which specifies a measurement bandwidth of 1 MHz for this test. However, the measured frequency range is divided partly into 500 kHz portions. There, the measurement bandwidth of 1 MHz would exceed the total spectral measurement range. This needs to be rectified in EN 302 571.

- The characteristics of the transmit mask according to EN 302 571 is interpreted as specified in IEEE Std. 802.11-12 Figure D-1.

4.2.2. Test Procedure

1. Connect DUT RF transmitter output to R&S®FSV.
2. Activate DUT with maximum transmit power @ 5.9 GHz and 10 MHz signal bandwidth.
3. R&S®FSV measurement of DUT spectrum emission mask

4.2.3. Test Result

DUT meets requirements according to modified EN 302 571 table 7:

Data rate	**Modulation and Coding rate**	**verdict**
6 Mbit/s	QPSK½	PASS / FAIL

4.3. Transmitter unwanted emissions outside the 5 GHz ITS frequency bands

4.3.1. Test Purpose

To verify DUT transmitter output unwanted out of band emissions according to ETSI EN 302 571, subclause 6.4.1.

Note:

- Spectral measurement range limited to 30 MHz – 6 GHz
- Positive peak detector measurements for the entire spectral range
- Reference bandwidth 100 kHz below 1GHz
- Reference bandwidth 1 MHz above 1 GHz
- Maximum hold trace
- Optional RMS detector measurements on request

4.3.2. Test Procedure

1. Connect DUT RF transmitter output to R&S®FSV via the ITS-G5A band reject filter.
2. Activate DUT with maximum transmit power @ 5.9 GHz, 10 MHz signal bandwidth and 6 Mbit/s.
3. R&S®FSV measurement of DUT unwanted out of band emissions.

4.3.3. Test Result

Freq start / MHz	Freq stop / MHz	Maximum power
30	1000	[dBm / 100kHz]
1000	5795	[dBm / MHz]
5795	5815	[dBm / MHz]
5815	5850	[dBm / MHz]
5850	5855	[dBm / MHz]
5925	5965	[dBm / MHz]
5965	6000	[dBm / MHz]

4.4. Transmit modulation quality measurements

4.4.1. Test Purpose

To verify DUT transmitter modulation quality parameters according to IEEE Std. 802.11-2012, including

- Transmit center frequency tolerance according to IEEE Std. 802.11-2012 subclause 18.3.9.5.
- Symbol clock frequency tolerance according to IEEE Std. 802.11-2012 subclause 18.3.9.6.
- Transmitter relative constellation error according to IEEE Std. 802.11-2012 subclause 18.3.9.7.4.
- Transmitter spectral flatness according to IEEE Std. 802.11-2012 subclause 18.3.9.7.3.

4.4.2. Test Procedure

1. Connect DUT RF transmitter output to R&S®FSV.
2. Activate DUT with maximum transmit power @ 5.9 GHz and 10 MHz signal bandwidth.
3. R&S®FSV measurement of DUT transmit modulation quality parameters.
4. Repeat measurements for different modulation and coding schemes
5. Repeat step 2 to 4 for all rates supported by DUT.

4.4.3. Test Results

1. Frequency error:

Data rate	Modulation and Coding rate	Center frequency error
3 Mbit/s	BPSK½	[Hz]
6 Mbit/s	QPSK½	[Hz]
12 Mbit/s	16-QAM½	[Hz]

2. Symbol clock error:

Data rate	Modulation and Coding rate	Symbol clock error
3 Mbit/s	BPSK½	[ppm]
6 Mbit/s	QPSK½	[ppm]
12 Mbit/s	16-QAM½	[ppm]

3. The relative constellation error (corresponds to EVM, Error Vector Magnitude), averaged over subcarriers, OFDM frames and packets:

Data rate	**Modulation and Coding rate**	**EVM**
3 Mbit/s	BPSK½	[dB]
6 Mbit/s	QPSK½	[dB]
12 Mbit/s	16-QAM½	[dB]

4. The average energy of the constellations in each of the spectral lines -16 ... -1 and +1 ... +16 shall deviate no more than +/- 4dB from their average energy. The average energy of the constellations in each of the spectral lines -26 … -17 and +17 … +26 shall deviate no more than +4/-6 dB from the average energy of spectral lines -16 ... -1 and +1 ... +16.: yes/no?

Data rate	**Modulation and Coding rate**	**verdict**
3 Mbit/s	BPSK½	PASS / FAIL
6 Mbit/s	QPSK½	PASS / FAIL
12 Mbit/s	16-QAM½	PASS / FAIL

5. Receiver sensitivity measurements

According to Figure 1, the RF test setup supports both, single and dual receiver DUT implementations. Thus, the DUT vendor shall declare whether the receiver measurements shall be performed with one or two active receivers. By default, the test setup provides a single base band source (non-faded or faded) within the SMW200A signal generator. This will be sent over one RF output towards a single receiver DUT implementation. To support dual receiver DUT implementations, the single source base band signal will be symmetrically split onto two RF outputs within the SMW200A signal generator. The output power will also be split. Using one antenna with a power level L is equal to two antennas with L-3dB on each antenna.

5.1. Receiver sensitivity under static conditions

5.1.1. Test Purpose

To measure the packet error rate (PER) at the receiver sensitivity level as specified in IEEE Std. 802.11-2012 subclause 18.3.10.2. to verify the minimum receiver sensitivity at 10 MHz bandwidth.

The packet error ratio (PER) shall be 10% or less when the PSDU length is 1000 octets and the rate-dependent input level is as shown in IEEE Std. 802.11-2012 table 18-14.

Note:

- The rate-dependent sensitivity threshold will be measured and evaluated by default
- Performance measurement PER vs. RxLevel or SNR can be measured and recorded on request (DUT support of automated MAC counter read out required)
- (1-PER) corresponds to PSR (Packet Success Rate), i.e. the requirement of PER ≤ 10 % corresponds to the requirement PSR ≥ 90 %.

5.1.2. Test Procedure

1. Connect DUT RF receiver input to R&S®SMW output
2. Reset and activate DUT receive MAC frame counter.
3. Transmit known number of PSDUs (1000 by default) with R&S®SMW at rate-dependent minimum sensitivity level.
4. Check DUT receive MAC frame counter and calculate PER.
5. Repeat step 2 to 4 for all rates supported by DUT.

5.1.3. Test Result

PER is 10 % or less at rate-dependent minimum sensitivity levels according to IEEE Std. 802.11-2012 table 18-14 for 10 MHz:

Data rate	Modulation and Coding rate	sensitivity level	Number of rx antennas
3 Mbit/s	BPSK½	[dBm]	
6 Mbit/s	QPSK½	[dBm]	
12 Mbit/s	16-QAM½	[dBm]	

5.2. Receiver sensitivity under fading conditions

5.2.1. Test Purpose

To measure receiver sensitivity level under fading, i.e. multipath and Doppler channel conditions. The measurement is based on PER measurements, as in the receiver performance measurements under static conditions, i.e. the PSDU length is 1000 bytes and the target PER is 10 %.

Reference [3] specifies 5 typical C2C multipath scenarios:

1. Rural LOS
2. Highway LOS
3.
4. Urban Approaching LOS
5. Crossing NLOS
6. Highway NLOS

The corresponding channel model parameters are given in Figure 3.

	Tap1	Tap2	Tap3		Units
Power	0	-14	-17		dB
Delay	0	83	183		ns
Doppler	0	492	295		Hz
Profile	STATIC	Rayleigh	Rayleigh		
K					dB

Profile 1: Rural LOS Parameters

	Tap1	Tap2	Tap3	Tap4	Units
Power	0	-10	-15	-20	dB
Delay	0	100	167	500	ns
Doppler	0	689	492	886	Hz
Profile	STATIC	Rayleigh	Rayleigh	Rayleigh	
K					dB

Profile 2: Highway LOS Parameters

	Tap1	Tap2	Tap3	Tap4	Units
Power	0	-8	-10	-15	dB
Delay	0	117	183	333	ns
Doppler	0	236	157	492	Hz
Profile	STATIC	Rayleigh	Rayleigh	Rayleigh	
K					dB

Profile 3: Urban Approaching LOS Parameters

	Tap1	Tap2	Tap3	Tap4	Units
Power	0	-2	-5	-7	dB
Delay	0	200	433	700	ns
Doppler	0	689	492	886	Hz
Profile	STATIC	Rayleigh	Rayleigh	Rayleigh	
K					dB

Profile 4: Highway NLOS Parameters

	Tap1	Tap2	Tap3	Tap4	Units
Power	0	-3	-5	-10	dB
Delay	0	267	400	533	ns
Doppler	0	295	98	591	Hz
Profile	STATIC	Rayleigh	Rayleigh	Rayleigh	
K					dB

Profile 5: Crossing NLOS Parameters

Figure 3: Channel model parameters

6.2.2. Test Procedure

1. Connect DUT RF receiver input to R&S®SMW output
2. Reset and activate DUT receive MAC frame counter.
3. Transmit known number of PSDUs with R&S®SMW at rate-dependent minimum sensitivity level at given fading profile.
4. Check DUT receive MAC frame counter and calculate PER.
5. Find receiver minimum sensitivity level, i.e. receiver level where PER reaches threshold of 10 %.
6. Repeat step 2 to 5 for different fading conditions.

6.2.3. Test Result

Record rate-dependent receiver level where PER is 10 % for each Fading profile at 6 Mbits/s (i.e. QPSK½):

Fading Profile	Modulation and Coding rate	sensitivity level	Number of rx antennas
1	QPSK½ (6 Mbit/s)	[dBm]	
2	QPSK½ (6 Mbit/s)	[dBm]	
3	QPSK½ (6 Mbit/s)	[dBm]	
4	QPSK½ (6 Mbit/s)	[dBm]	
5	QPSK½ (6 Mbit/s)	[dBm]	

6. Optional DCC_access channel probing quality measurements

It is the goal to provide DCC_access channel probing quality measurements for the plugtest. However, the test method is still to be drafted. There is still a need to identify the type of channel probing output parameters which would be available for evaluation.

Different test signals with the following parameters will be provided:

- CBR from 5% to 95% (5% step size)
- different lengths (e.g. 200 Byte, 350 Byte or 700 Byte @6Mbit/s)
- varying output power

The channel probing measurements can serve as basis for a more detailed test case at the next plugtest.

6.1. Test Purpose

To measure the quality of the DUT channel probing capability.

6.2. Possible Test Procedure

1. Connect DUT RF receiver input to R&S®SMW output
2. Activate DUT channel probing
3. Setup R&S®SMW to simulate defined channel load
4. Monitor and record DUT channel probing output
5. Repeat steps 3 to 4 for specified channel loads or fading profiles.

6.3. Test Result

No results will be recorded. This test case is only to find out how a channel probing test case could be designed.