Fraunhofer IIS

Test Operation Procedures

for

Software Defined Radio Platforms

PROPOSAL

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V1.0

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Version	Date	Changes	Author
1.0		initial version	C. Laske

1 Scope

1.1 Purpose

Software Defined Radio (SDR) communication transmitters and receivers can be configured for different waveforms by running different software (waveform applications) in their integrated processors. Thus, the performance of such a Software Defined Radio platform can be tested for a particular communication system, e.g. STANAG 5066, when the according waveform application for this system is running on the platform (operational testing). For this purpose, the test procedures described in ITOP 6.2.242 ([1]) and ITOP 6.2.246 ([2]) are appropriate. However, the SDR platform might provide performance exceeding the specifications for a particular waveform, which cannot be evaluated by operational testing for specific waveforms.

This document defines and describes a proposal for test procedures to be conducted for evaluating the performance of Software Defined Radio Platforms independent of a particular Waveform Application (platform testing).

The test procedures are meant to supplement those in ITOP 6.2.242 ([1]) and ITOP 6.2.246 ([2]) in cases where the procedures from the ITOP cannot be applied or need to be adapted or extended. Structure and format of this document correspond closely to the ITOP.

1.2 Limitations

These Test Operation Procedures do not consider the following:

a) evaluation of human and operational factors (man-machine interface and deployment)
b) reliability, availability, and maintainability
c) equipment control functions and built-in test equipment
d) evaluation of a defined waveform or waveform application or verification of complying with the according specification

The procedures are intended for equipment with standard line impedance (e.g. 50 or 75 ohms) inputs/outputs for connection to external antenna systems. In all cases where standard line impedance cannot be matched (e.g. equipment with an integrated antenna or with a built-in antenna tuner), a test setup for radiation measurement as suggested in 2.7.2 must be used.

The procedures apply primarily to equipment operating within the range of 1 MHz to 4 GHz (and may be applicable to frequencies outside of the stated range) with an interface providing access to the received digital baseband signals and accepting digital baseband signals for transmitting. Alternatively, the digital data interface might be using digital signals at an intermediate frequency, which can be converted to/from digital baseband using offline digital signal processing.

2 General Information and Test Conditions

2.1 Terminology and Definitions

ADC	Analog-to-Digital Converter
AGC	Automatic Gain Control
AWG	Arbitrary Waveform Generator
CW	Continuous Wave
DC	Direct Current
EVM	Error Vector Magnitude
IIP3	3^{rd} order Input Intercept Point
IM	Intermodulation
LNA	Low Noise Amplifier
LO	Local Oscillator
QAM	Quadrature Amplitude Modulation
PEP	Peak Envelope Power
ppm	parts per million
PSD	Power Spectrum Density
RF	Radio frequency
RX	Receiver or Reception
SDR	Software Defined Radio
SINAD	Signal to Noise and Distortion
SNR	Signal-to-Noise Ratio
TX	Transmitter or Transmitting
VSWR	Voltage Standing Wave Ratio

Table 2.1-1: acronyms

2.2 Instrumentation

2.2.1 Calibration

All instrumentation used for accurate measurements shall have a current calibration certificate.

2.2.2 Accuracy

The accuracy and stability of the measuring instrumentation shall exceed the accuracy and stability of the test item by at least one order of magnitude.

2.2.3 Impedance Matching

All instrumentation and terminating loads used during testing shall have input and/or output impedances equal to the nominal RF line impedance of the test item (e.g. 50 ohms). If receiver RF input voltages are related to the line impedance, conversions may be made between power levels (dBm or milliwatts) to input voltage (dB~V or ~volts at 50 ohms) even if the receiver input impedance differs from 50 ohms.

As the receiver input is not necessarily matched, it is recommended to insert a matched device (e.g., an attenuator or amplifier) when the source is sensitive to an unmatched load.

2.3 Test Conditions

a) normal ambient conditions
All test procedures must be performed under normal conditions of temperature and humidity (Temperature 25 ± 10° C, Relative Humidity 50 ± 30 %) in accordance with the test item specification or other applicable standard.

b) electromagnetic environment for the test setup
These tests shall be conducted, as far as practicable, in areas that are sufficiently free from electromagnetic interference fields to allow the measurements to be made without significant adverse effect on the results. Power supply sources shall be sufficiently filtered to accomplish the same end. Test instrumentation shall be properly shielded, filtered, and grounded so as to minimize erroneous results caused by extraneous signal sources. For these reasons and for procedures requiring a wide dynamic range, the test item shall be placed in an electromagnetically shielded room.

c) power supply
Power supply parameters shall be in accordance with the test item specification or other applicable standard.

d) operational environment
The type, resolution, and quantity of data collected should be consistent with the operational environment in which the equipment is intended to operate (e.g., if an HF transmitter will be co-sited with VHF equipment, measurement of spurious emissions in the VHF range should be made).

e) environmental and EMI/EMC tests
Some tests or subtests must be performed in extreme climatic, mechanical and electromagnetic environments to examine the influence of these conditions on equipment performance. These procedures must be performed in accordance with the test item specification or other applicable standards. Paragraph 2.6 lists the procedures of this document that are applicable.

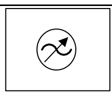
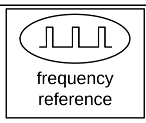
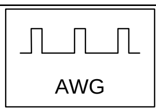
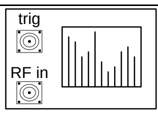
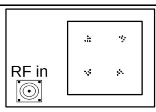
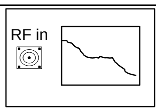
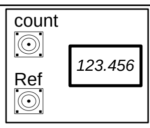
2.4 Common Data Required

a) record test item nomenclature, serial number, technical characteristics, and performance parameters, as applicable
b) photograph the test item in order to provide a visual identification and description
c) record the instrumentation identification, model numbers, serial numbers, and calibration dates
d) record start and completion dates of major test groups (ambient, climatics, mechanics, etc.)
e) record description, dates, corrective actions, and analyses for test item failures
f) collect and save all recorded data sets during tests and reference it to the test item and the test procedure
g) document all data formats used in the collected data sets
h) document and save all off-line processing software and scripts used for the tests

2.5 Symbols Used

2.5.1 Hardware and Equipment

Blocks and signals in the analog domain are depicted in black.

	RF signal generator
	reference frequency generator
	arbitrary waveform generator
	spectrum analyzer
	vector signal analyzer
	phase noise analyzer
	frequency counter
	power meter

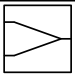
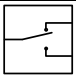
	voltage and current meter
	fixed attenuator
	voltage controlled variable attenuator
	splitter / combiner
	switch
	circulator
	bandpass filter
	notch filter

Table 2.5-1: symbols used for hardware and equipment

2.5.2 Digital Signal Generation and Processing

Blocks and signals in the digital domain are depicted in green.

description	Digital configuration or data item
description	Digital processing item in software

Table 2.5-2: symbols used for digital signal generation and processing

2.6 Application Guide for Environmental Testing

This application guide is intended to suggest the applicability of the test procedures in this document to environmental tests. It is expected that the tester will limit the number of parameters and data points, as appropriate, consistent with the time constraints imposed by the individual environmental tests. In most cases, the tests which are conducted are selected to show changes in performance due to operation in extreme environments.

The tables below show which tests or subtests are to be applied under the following environmental conditions:

A: climatic environments (extreme temperatures and humidity)

B: mechanical environments such as shocks for which the electrical test is conducted before and after the mechanical stress

C: mechanical environments such as vibrations, and electromagnetic environments, for which the test is conducted during the stress

The designators mean:

R: the test is recommended

O: the test is optional

- : the test is not useful

2.6.1 Transmitter Tests

Procedure		Environment		
		A	**B**	**C**
3.1.1	Output Power and Primary Power Consumption	R	R	R
3.1.2	Usable Bandwidth	-	O	R
3.1.3	Influence of Mismatched Loads	O	-	-
3.1.4	Frequency Resolution	R	-	-
3.1.5	Continuous Transmission Time	R	-	O
3.2.1	Frequency Accuracy and Stability	R	-	R
3.2.2	Wideband Carrier Noise	R	-	O
3.2.3	Spurious Signals, Carrier and Sideband Suppression	R	-	O
3.3.1	Compression	R	-	-
3.3.2	Harmonics	R	-	O
3.3.3	Intermodulation	O	-	-
3.3.4	Error Vector Magnitude	R	O	R
3.4.1	Intermodulation with Other Transmitters	-	-	-
3.4.2	Output Power Control	-	-	-
3.5.1	Transmitter Hop Time	O	-	R
3.5.2	Receive-to-Transmit Delay	-	-	-
3.5.3	Retransmission Delay	-	-	-

Table 2.6-1: environmental testing for transmitter tests

2.6.2 Receiver Tests

Procedure		Environment A	Environment B	Environment C
4.1.1	Gain Factor	R	R	R
4.1.2	Usable Bandwidth	-	O	R
4.1.3	Sensitivity	R	R	R
4.1.4	Maximum SINAD	R	R	R
4.1.5	Dynamic Range	-	-	-
4.1.6	Input Impedance	R	R	R
4.2.1	LO and Clock Emissions	O	-	-
4.2.2	Residual Spurious and Noise Response	-	-	R
4.3.1	In-Band Intermodulation	-	-	-
4.4.1	Out of Band Intermodulation	-	-	-
4.4.2	Dynamic Selectivity	R	-	-
4.4.3	Blocking	O	-	-
4.4.4	Input Protection	R	O	R
4.4.5	Spurious Response	O	-	-
4.5.1	Receiver Hop Time	O	-	R
4.5.2	Transmit-to-Receive Delay	-	-	-

Table 2.6-2: environmental testing for receiver tests

2.7 Line Measurements versus RF Radiation Measurements

2.7.1 Line Measurements

The procedures in this document are based on line measurements using artificial antenna loads. They are applicable to all equipment with a standard RF input or output impedance.

2.7.2 RF Radiation Measurements

For equipment with integrated antenna systems where line measurements can not be made, the test setups in this document may be adapted to radiation measurements. In this case, field transmission between the integrated equipment antenna and a calibrated test antenna should be performed in a proper interference-free environment.

A fixed distance between the two antennas should be used (at least 2λ). In order to determine the field attenuation (transmission loss) as a function of the frequency, the test item is replaced with a second calibrated (antenna factor representing the antenna gain) antenna and a signal generator or a test receiver.

Controlling the overall attenuation by an attenuator in the line of the test antenna, the test procedures can basically be performed as described in this document.

Referencing to the measurements with the substitution antenna, the effective radiated power is measured and, knowing the antenna gain, effective signal powers may be referred to an imaginary input or output of the test item with a standard impedance.

2.8 Data Conditioning

The procedures in this document are applicable to test items which provide access to the un-demodulated received signals via a digital interface, and accept signals for transmitting from a digital interface, respectively. The test item should not apply digital signal processing to the signals except amplification, frequency conversion and filtering, e.g. no modulation/demodulation or coding/decoding should occur. Interface and data format have to be suitable for connecting the test item to external equipment for file-based sourcing and sinking of time-domain signals.

If the test item does not provide and accept signals in the complex baseband, all used data sequences should be converted to digital baseband in a commonly usable format. The data sequences should be saved in the digital baseband format as well as the raw format used by the test item for later reference, together with all software used for conversion.

In case the test item receiver suffers from DC offset, the test procedures using CW signals at the nominal receive frequency might have to be adjusted by applying a slight frequency offset to shift the test signal away from DC.

3 Transmitter Tests

3.1 Basic Parameters

3.1.1 Output Power and Primary Power Consumption

3.1.1.1 Scope

The objective of this test is to measure the transmitter RF Output Power over frequency and the Primary Power Consumption as a function of input voltage.

3.1.1.2 Facilities and Instrumentation

a) power supply with variable voltage
b) RF power meter
c) voltage and current meter

3.1.1.3 Test Conditions

a) normal ambient conditions
b) variable power supply voltage

3.1.1.4 Test Procedure

3.1.1.4.1 Measurement Configuration

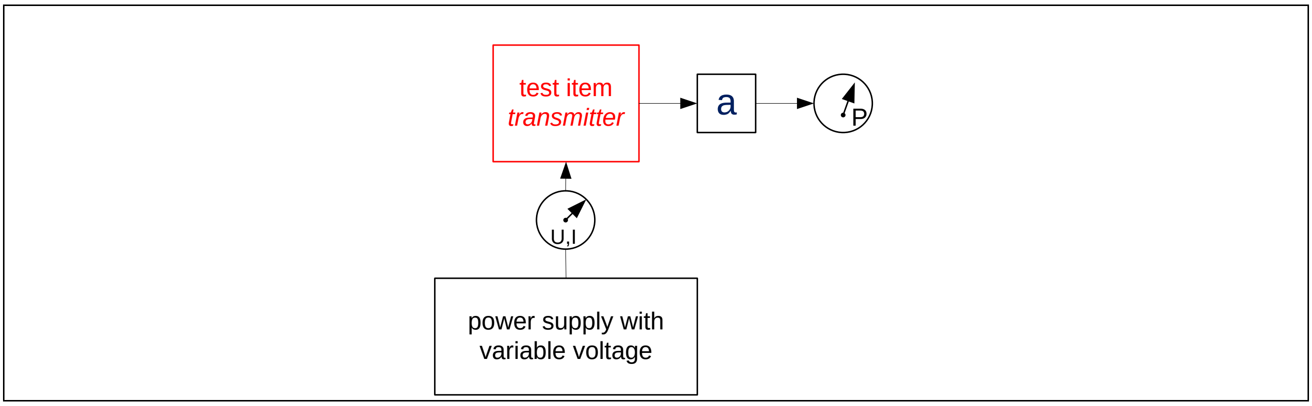


Figure 3.1.1-1: configuration for Output Power and Primary Power Consumption measurement

3.1.1.4.2 Measurement Procedure

a) apply the nominal power supply voltage to the test item
b) configure the test item to transmit a CW signal at the maximum output power
c) measure the RF output power of the transmitter for at least ten different frequencies covering the complete operational frequency range of the test item

d) measure voltage and current of the primary power supply during transmission for at least three different frequencies covering the complete operational frequency range of the test item;
Primary Power Consumption P_0 is calculated as:

$$P_0 = I_o \cdot U_0$$

with I_0: power supply current into the test item
U_0: power supply voltage at the test item

e) perform the measurement for various primary power supply voltages within the specified limits, at least for nominal, minimum and maximum values

3.1.1.4.3 Data Reduction and Presentation

a) plot the RF Output Power and Primary Power Consumption versus frequency for all measured primary power supply voltages
b) plot the RF Output Power and Primary Power Consumption versus primary power supply voltage for the measured RF frequencies
c) optionally, plot the Efficiency of the transmitter versus RF frequency for all measured primary power supply voltages;
the Efficiency η is calculated as:

$$\eta = P_{RF} / P_0$$

with P_{RF}: RF Output Power
P_0: Primary Power Consumption

3.1.2 Usable Bandwidth

3.1.2.1 Scope

The objective of this test is to determine the Usable Bandwidth of the test item transmitter and the according frequency response for all possible configurations of the transmit bandwidth.

3.1.2.2 Facilities and Instrumentation

a) RF spectrum analyzer
b) test item transmit baseband data interface

3.1.2.3 Test Conditions

a) normal ambient conditions
b) nominal power supply voltage
c) low output power setting

3.1.2.4 Test Procedure

3.1.2.4.1 Measurement Configuration

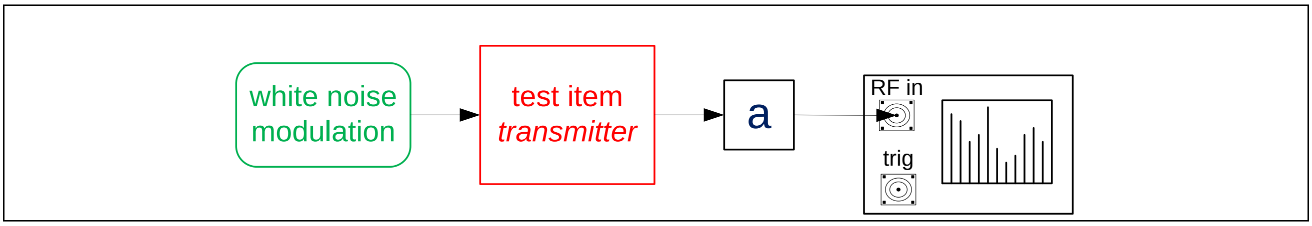


Figure 3.1.2-1: configuration for transmitter Usable Bandwidth measurement

3.1.2.4.2 Measurement Procedure

a) apply an equivalent white noise modulated transmit data signal to the test item transmit interface with a bandwidth at least 10% wider than the expected 3 dB bandwidth of the test item or, if that condition cannot be met by the test item, with the maximum possible bandwidth of the transmit interface
b) evaluate the power spectrum of the transmitted RF signal regarding amplitude ripple and bandwidth
c) perform the measurement for all configurable transmit bandwidths of the test item
d) perform the test for a frequency in the low, mid and high operating range; in case the test item transmitter has several sub-bands with different hardware configurations, e.g. different bandpass filters, perform the test for the min and max frequency of each sub-band

3.1.2.4.3 Data Reduction and Presentation

a) plot the power spectrum for each configurable transmit bandwidth versus frequency offset
b) mark the frequency values for the 3dB- and the 1dB-bandwidth on the plot where the power spectrum magnitude at the filter flanks is down 3 dB and 1 dB respectively, referred to the value at zero frequency offset
c) note the amplitude ripple within the 1dB-bandwidth calculated as the difference between the maximum and the minimum value in the power spectrum, not including the filter flanks with the 1-dB bandwidth points

3.1.3 Influence of Mismatched Loads

3.1.3.1 Scope

The objective of this test is to measure the behavior of the test item transmitter related to Output Power and Primary Power Consumption when a mismatched load is present at the transmit output.

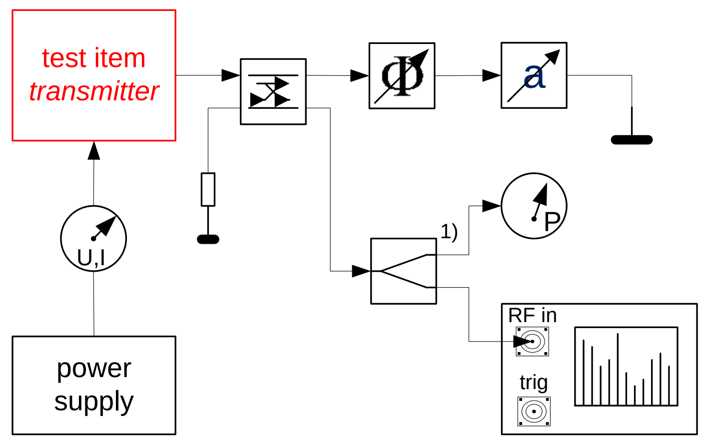
3.1.3.2 Facilities and Instrumentation

a) variable load
a variable load consists of a variable phase shifter connected to a variable resistance to ground, as provided e.g. by a laboratory grade tuner; in case such a tuner is not available, cables of different lengths can be used as phase shifters together with resistors connected directly to ground or, alternatively, together with parallel 50 ohm loads, resulting in a VSWR of N with N being the number of parallel loads
b) directional coupler
c) RF power meter
d) voltage and current meter
e) spectrum analyzer

3.1.3.3 Test Conditions

a) normal ambient conditions
b) nominal power supply voltage
c) maximum output power setting

3.1.3.3.1 Measurement Configuration



[1)] instead of a splitter, also a switch can be used

Figure 3.1.3-1: configuration for Mismatched Load measurement

3.1.3.3.2 Measurement Procedure

a) configure the test item to transmit a CW signal into the mismatched load at maximum power setting
b) set the variable load to different phase angles and VSWR-values in the permitted range of the test item and measure the test item Output Power and Primary Power Consumption (see also 3.1.1.4.2); use at least 10 different phase angles for each VSWR-value spanning 360° and a VSWR of 2, 3, and ∞ (open or short circuit)

c) verify that the transmitter does not produce spurious oscillations for any setting of the variable load
d) perform the test at least for a frequency in the low, mid and high operating range

3.1.3.3.3 Data Reduction and Presentation

a) present the maximum and minimum Output Power and the Primary Power Consumption versus operating frequency for each VSWR-setting
b) in case spurious oscillations occurred, note frequency and level of the oscillations and the according test conditions (VSWR, phase angle, RF frequency, power supply voltage)

3.1.4 Frequency Resolution

3.1.4.1 Scope

The objective of this test is to measure the Frequency Resolution of the test item transmit frequency.

3.1.4.2 Facilities and Instrumentation

a) frequency counter, alternatively spectrum analyzer

3.1.4.3 Test Conditions

a) normal ambient conditions
b) nominal power supply voltage
c) test item stabilized at the test temperature in a non-operating condition
d) low output power setting

3.1.4.3.1 Measurement Configuration

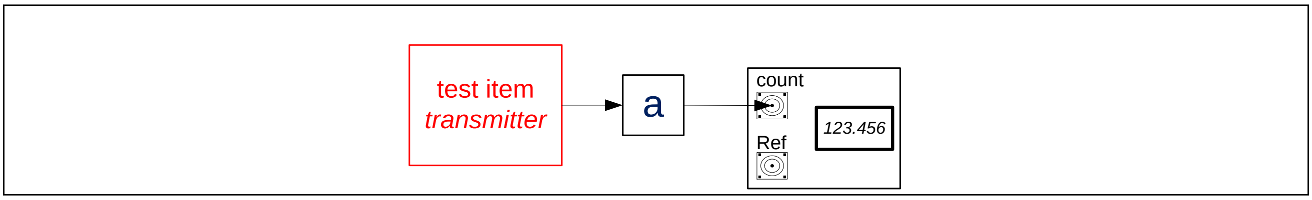


Figure 3.1.4-1: configuration for Frequency Resolution measurement

3.1.4.3.2 Measurement Procedure

a) configure the test item to transmit a CW signal and measure the transmit frequency
b) set the transmitter to the next closest frequency setting and measure the frequency difference

c) perform the test for frequencies close to the lower and the upper limit of the operating range; in case the test item transmitter has several sub-bands with different hardware configurations, e.g. different local oscillators, perform the test at the lower and upper limit of each sub-band

3.1.4.3.3 Data Reduction and Presentation

a) note the maximum observed frequency difference in a sub-band as Frequency Resolution

3.1.5 Continuous Transmission Time

3.1.5.1 Scope

The objective of this test is to verify the specified Continuous Transmission Time of the test item transmitter.

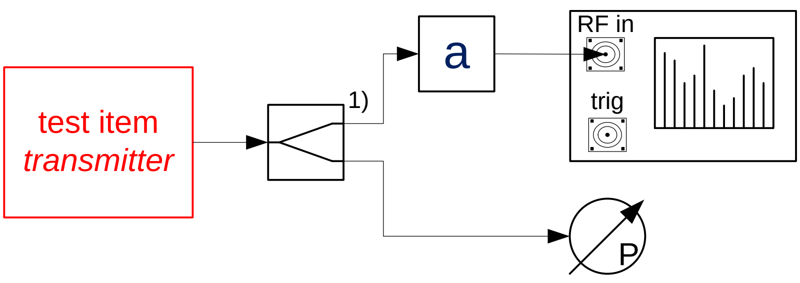
3.1.5.2 Facilities and Instrumentation

a) spectrum analyzer
b) power meter

3.1.5.3 Test Conditions

a) normal ambient conditions
b) nominal power supply voltage
c) maximum output power setting

3.1.5.3.1 Measurement Configuration



[1)] instead of a splitter, also a switch can be used

Figure 3.1.5-1: configuration for Continuous Transmission Time measurement

3.1.5.3.2 Measurement Procedure

a) configure the test item to transmit a CW signal at the maximum output power setting for a time span according to the specified maximum Continuous Transmission Time; if a transmit duty cycle is specified, switch between transmit and receive accordingly, using the maximum possible transmission time
b) after transmitting for the specified time, switch to receive or idle for 10% of the specified Continuous Transmission Time or, if applicable, for the specified minimum cessation time, and repeat the cycle at least 3 times; if a duty cycle is specified operate the test item with this duty cycle for at least 10 cycles or 10 minutes, whichever is longer
c) verify the correct function of the test item transmitter by checking the nominal Output Power and the absence of unwanted signals during and after the test cycles; optionally, the quality of the transmitted signal can be verified before and after the test cycles, e.g. by measuring EVM (see 3.3.4)
d) if possible read out internal temperature information from the test item before and after the test cycles
e) perform the test for a frequency in the low, mid and high operating range

3.1.5.3.3 Data Reduction and Presentation

a) note the RF frequencies and test conditions under which the Continuous Transmission Time was verified and if anomalies were observed during or after the test cycles
b) if applicable, note internal temperature values before and after the test cycles

3.2 Spectral Purity

3.2.1 Frequency Accuracy and Stability

3.2.1.1 Scope

The objective of this test is to measure the Frequency Accuracy and Stability of the test item transmitter.

3.2.1.2 Facilities and Instrumentation

a) frequency counter
b) reference frequency generator with accuracy and stability better than the expected performance of the test item, preferably one order of magnitude

3.2.1.3 Test Conditions

a) normal ambient conditions
b) nominal, lowest and highest specified power supply voltage
c) low output power setting

3.2.1.3.1 Measurement Configuration

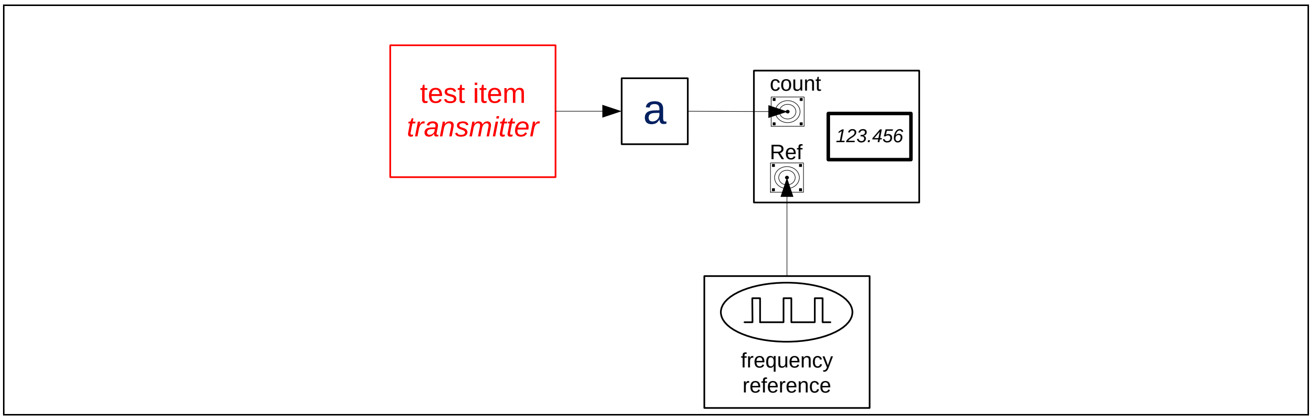


Figure 3.2.1-1: configuration for Frequency Accuracy and Stability measurement

3.2.1.3.2 Measurement Procedure

a) stabilize the test item at the test temperature in a non-operating condition
b) configure the test item to transmit a CW signal at a mid frequency in the operating range and at nominal power supply voltage
c) as soon as the transmitter goes operational, after applying primary power and booting up, measure the transmit frequency, and note the difference to the nominal value and the time span between applying primary power and the measurement
d) switch the test item to idle or receive for some time, then switch to transmit and repeat the measurement; time interval between measurements should be less than 1 minute, transmit duration should be sufficiently long to measure the frequency;

the test duration should be at least 3 times the warm-up time, if specified, or 30 minutes, whichever is greater

e) operate the test item for maximum transmit duration or maximum duty cycle, respectively, as described in 3.1.5, and measure the transmit frequency at the beginning and at the end of the transmission
f) based on the results of the measurements, choose a defined time span between applying primary power and transmit, stabilize the test item again at the test temperature, apply primary power, wait the defined time, and perform a frequency measurement with the test item transmitting
g) perform measurement f) for the lowest and the highest operating frequency
h) perform measurement f) for the lowest and the highest specified power supply voltage

3.2.1.3.3 Data Reduction and Presentation

a) plot the relative frequency error E_f as function of the operating time:

$$E_f = (f_{meas.} - f_{nom}) / f_{nom}$$

with

f_{meas}: measured transmit frequency
f_{nom}: nominal transmit frequency

b) present in a table all relative frequency errors measured after the time span defined in f) above with the according measurement conditions (nominal frequency and power supply voltage)
c) note the maximum error from all performed measurements as the observed Frequency Accuracy; if applicable distinguish between Frequency Accuracy before and after the specified warm-up time
d) optionally, note the maximum observed value for the frequency stability S_f, which can be derived as the maximum frequency change df_{max} per time period dt relative to the nominal transmit frequency f_{nom} if the time period between measurements is short enough to approximate continuous measurements:

$$S_f = df_{max} / (dt \cdot f_{nom})$$

if applicable distinguish between Frequency Stability during and after the specified warm-up time

3.2.2 Wideband Carrier Noise

3.2.2.1 Scope

The objective of this test is to measure the Wideband Carrier Noise of the test item as sideband phase noise of its unmodulated carrier.

3.2.2.2 Facilities and Instrumentation

a) phase noise analyzer, alternatively spectrum analyzer with phase noise measurement option (usually less sensitivity for phase noise measurements)

3.2.2.3 Test Conditions

a) normal ambient conditions
b) nominal power supply voltage
c) maximum output power setting

3.2.2.3.1 Measurement Configuration

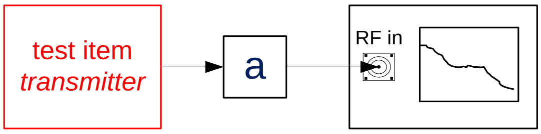


Figure 3.2.2-1: configuration for Wideband Carrier Noise measurement

3.2.2.3.2 Measurement Procedure

a) configure the test item to transmit a CW signal with the maximum output power setting
b) measure the transmitter phase noise for frequency offsets up to at least 10 MHz
c) in case the test item provides different speed modes for changing the LO frequency, e.g. a mode for fast hopping, perform the measurement for all selectable modes
d) perform the test for a frequency in the low, mid and high operating range; in case the test item transmitter has several sub-bands with different hardware configurations, e.g. different local oscillators, perform the test at the lower and upper limit of each sub-band

3.2.2.3.3 Data Reduction and Presentation

a) plot the single sideband phase noise curves in dBm/Hz versus offset frequency from carrier: preferably, use one graphic for each LO speed mode and combine the curves for different carrier frequencies

3.2.3 Spurious Signals, Carrier and Sideband Suppression

3.2.3.1 Scope

The objective of this test is to measure the magnitude of the transmitter Spurious Signals, which are discrete unwanted signals produced by the test item, and the Residual Carrier and Unwanted Sideband Suppression.

Measurement configuration and procedures are the same as for measuring transmitter Harmonics (see 3.3.2).

3.2.3.2 Facilities and Instrumentation

a) spectrum analyzer
b) if needed, notch filter or other filtering means to improve the dynamic range of the spectrum analyzer so that the measuring dynamic range is at least 10 dB better than the specified Spurious Signal ratio

3.2.3.3 Test Conditions

a) normal ambient conditions
b) nominal power supply voltage
c) maximum output power setting

3.2.3.3.1 Measurement Configuration

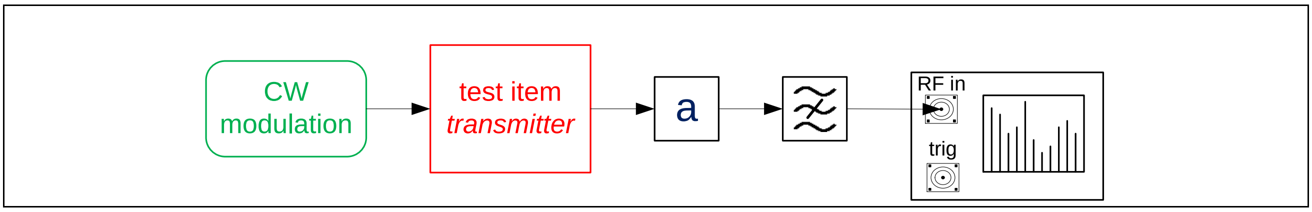


Figure 3.2.3-1: configuration for Spurious Signals measurement

3.2.3.3.2 Measurement Procedure

a) configure the test item to transmit a single-sideband CW signal with a slight offset f_{off} to the center frequency f_{set} well within the transmit bandwidth; set the output power setting to maximum
b) measure the power level of the Residual Carrier at the center frequency f_{set} and the Unwanted Sideband at f_{set} - f_{off}
c) measure the power level of each detectable Spurious Signal in the frequency range of interest
d) perform the test for a transmit frequency in the low, mid and high operating range; in case the test item transmitter has several sub-bands with different hardware configurations, e.g. different transmit filters, perform the test for a low and a high frequency in each sub-band

3.2.3.3.3 Data Reduction and Presentation

a) present in a table for all measured transmit frequencies the measured Residual Carrier Suppression and Unwanted Sideband Suppression in dBc relative to the transmitter output power
b) present in a table for all measured transmit frequencies the detected Spurious Signals with the parameters transmit center frequency, transmit offset frequency, spurious frequency, and Spurious Signal level in dBc relative to the transmitter output power

3.3 Linearity

3.3.1 Compression

3.3.1.1 Scope

The objective of this test is to measure the Compression of the transmitter versus the transmit baseband signal level.

3.3.1.2 Facilities and Instrumentation

a) RF power meter
b) test item transmit baseband data interface
c) CW baseband signal generation with variable level and frequency offset

3.3.1.3 Test Conditions

a) normal ambient conditions
b) nominal power supply voltage
c) maximum output power setting

3.3.1.3.1 Measurement Configuration

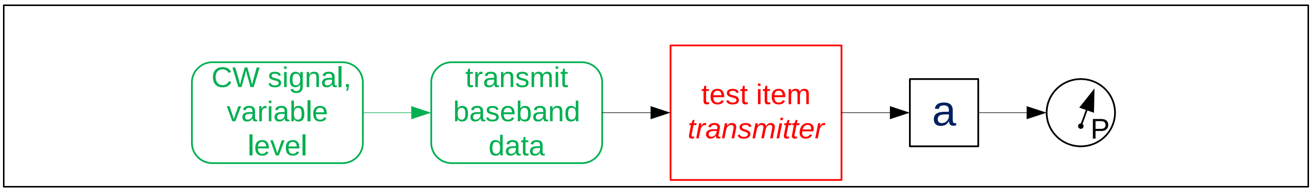


Figure 3.3.1-1: configuration for Compression measurement

3.3.1.3.2 Measurement Procedure

a) configure the test item to transmit a signal sourced from the transmit baseband data interface with the maximum output power setting
b) increase the peak power of the baseband signal in steps of 1 dB from -20 dB to 0 dB in respect to the full-scale of the transmit interface format and measure the according transmit power level; for this, set the test item to transmit only for the time span required for measuring and immediately switch to receive or idle between the measurements to avoid the influence of thermal effects; the resulting duty cycle for this test should be max 10% transmitting
c) perform the test for a frequency in the low, mid and high operating range; in case the test item transmitter has several sub-bands with different hardware configurations, e.g. different power amplifiers, perform the test at the lowest and highest frequency of each sub-band

3.3.1.3.3 Data Reduction and Presentation

a) plot the measured Compression curves as the ratio of output power to nominal power in dB versus the ratio of the baseband signal peak power to the transmit interface full-scale level in dB
b) mark the 1 dB Compression point where the gain (ratio of output power to input power) is 1dB down from the gain in the linear region of the curve (for low baseband signal levels)

3.3.2 Harmonics

3.3.2.1 Scope

The objective of this test is to measure the magnitude of the transmitter Harmonics. Measurement configuration and procedures are the same as for measuring transmitter Spurious Signals (see 3.2.3).

3.3.2.2 Facilities and Instrumentation

a) spectrum analyzer
b) if needed, notch filter or other filtering means to improve the dynamic range of the spectrum analyzer so that the measuring dynamic range is at least 10 dB better than the specified Harmonics ratio

3.3.2.3 Test Conditions

a) normal ambient conditions
b) nominal power supply voltage
c) maximum output power setting

3.3.2.3.1 Measurement Configuration

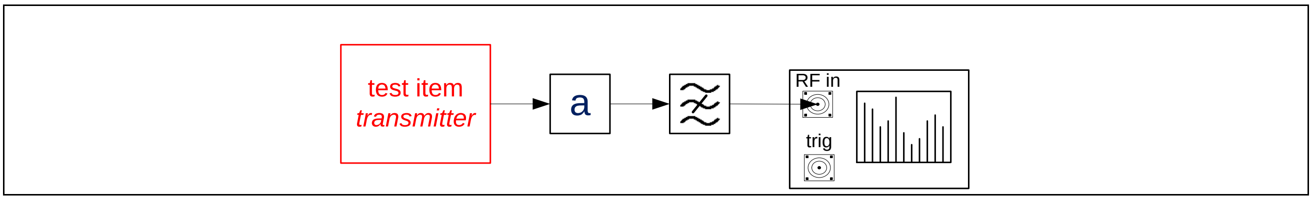


Figure 3.3.2-1: configuration for Harmonics measurement

3.3.2.3.2 Measurement Procedure

a) configure the test item to transmit a CW signal with the maximum output power setting
b) measure the power level of each detectable Harmonic falling in the frequency range of interest
c) perform the test for a frequency in the low, mid and high operating range; in case the test item transmitter has several sub-bands with different hardware configurations, e.g. different harmonic filters, perform the test at the lowest frequency of each sub-band

3.3.2.3.3 Data Reduction and Presentation

a) present in a table for all measured transmit frequencies the level of the detected Harmonics relative to the nominal output power in dBc and the order of the harmonic

3.3.3 Intermodulation

3.3.3.1 Scope

The objective of this test is to measure the odd-order two-tone intermodulation (IM) products of the test item transmitter.

3.3.3.2 Facilities and Instrumentation

a) spectrum analyzer
b) test item transmit baseband data interface
c) two-tone baseband signal generation (centered around DC, same amplitude for each tone) with variable frequency distance and a full-scale peak power level in respect to the baseband interface

3.3.3.3 Test Conditions

a) normal ambient conditions
b) nominal power supply voltage
c) maximum output power setting

3.3.3.3.1 Measurement Configuration

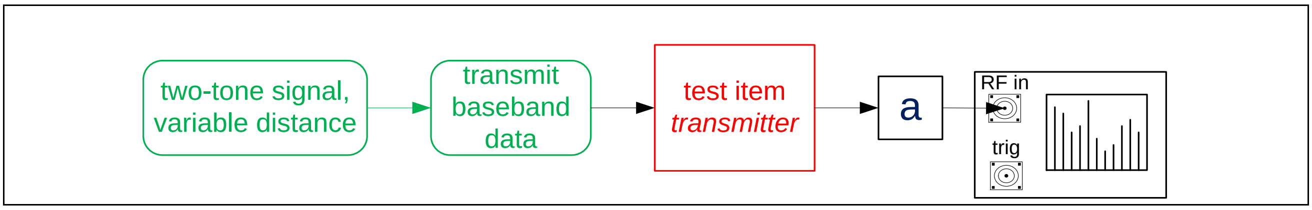


Figure 3.3.3-1: configuration for transmitter Intermodulation measurement

3.3.3.3.2 Measurement Procedure

a) configure the test item to transmit a signal sourced from the transmit baseband data interface with the maximum output power setting

b) measure the power level of the detectable odd-order IM products, located at the frequency offsets f_{off} above the upper signal of the two-tone and f_{off} below the lower signal of the two-tone, according to the following:

$$f_{off}(n) = \Delta f \cdot (n - 1) / 2$$

with

$f_{off}(n)$: frequency offset for the n-th order IM product, n = 3, 5,…
Δf: two-tone frequency distance

c) note the ratio of the higher power level of the two IM products of the same order to the level of one tone of the two-tone as intermodulation distance
d) perform the measurement for different two-tone distances up to the Usable Bandwidth of the actual transmit bandwidth setting;
recommended values are:
   i. ¼ of the smallest planned channel bandwidth
   ii. the planned channel spacings
   iii. ¼ of the Usable Bandwidth
   iv. the Usable Bandwidth
e) perform the measurements for all configurable transmit bandwidth settings
f) perform the test for a frequency in the low, mid and high operating range; in case the test item transmitter has several sub bands with different hardware configurations, e.g. different bandpass filters, perform the test for the min and max frequency in each sub-band

3.3.3.3.3 Data Reduction and Presentation

a) for each tested transmit frequency and transmit bandwidth setting, plot the intermodulation distance of the n-th order IM products in dB versus the two-tone frequency distance; preferably, combine in one plot all measured IM products for one bandwidth setting
b) optionally, also the 3rd order Output Intercept Point OIP3 can be calculated from the 3rd order IM products according to:

$$OIP3 = P_{tone} + 0.5 \cdot IM_D$$

with

P_{tone}: power level of one of the two tones
IM_D: intermoldulation distance for the 3rd order IM products according to c) above

3.3.4 Error Vector Magnitude

3.3.4.1 Scope

The objective of this test is to measure the Error Vector Magnitude (EVM) of the transmit signal with a 64-QAM modulation for all available power settings of the test item. Optionally, a different type of vector modulation might be used, e.g. 16-QAM.

3.3.4.2 Facilities and Instrumentation

a) vector signal analyzer with EVM-measurement capability for 64-QAM
b) test item transmit baseband data interface
c) 64-QAM modulated test signal generation

3.3.4.3 Test Conditions

a) normal ambient conditions
b) nominal power supply voltage
c) bandwith of the test item set to maximum
d) maximum output power setting

3.3.4.4 Test Procedure

3.3.4.4.1 Measurement Configuration

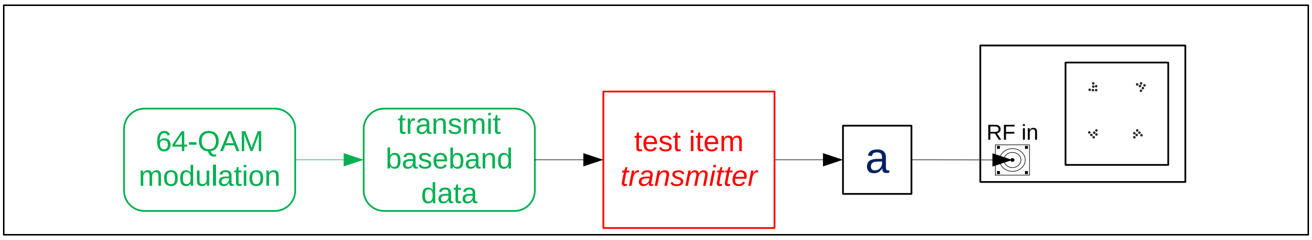


Figure 3.3.4-1: configuration for EVM measurement

3.3.4.4.2 Measurement Procedure

a) choose the value of the attenuator such that the noise of the vector signal analyzer is negligible
b) configure the test item to transmit a 64-QAM modulated test signal with nominal peak envelope power and a bandwidth according to the Usable Bandwidth
c) measure the Error Vector Magnitude of the transmitted RF output signal
d) perform the measurement for all transmit power settings of the test item
e) perform the test for a frequency in the low, mid and high operating range

In case the test item is not capable of transmitting a 64-QAM modulated signal with sufficient linearity for demodulation by a standard laboratory vector signal analyzer, a modulation with lower order might be used, e.g. 16-QAM.

3.3.4.4.3 Data Reduction and Presentation

a) present in a table for all measured gain settings and RF frequencies the according EVM values as percentage or in dB

3.4 Immunity to Interference

3.4.1 Intermodulation with Other Transmitters

3.4.1.1 Scope

The objective of this test is to measure the 3rd order intermodulation (IM) products generated in the test item transmitter when another co-located transmitter is operating simultaneously.

3.4.1.2 Facilities and Instrumentation

a) RF signal generator to provide the co-located transmitter signal
b) spectrum analyzer
c) circulator to de-couple the signal generator from the test item transmit signal; in case a circulator is not available, e.g. for lower operating frequencies, a directional coupler can be used

3.4.1.3 Test Conditions

a) normal ambient conditions
b) nominal power supply voltage
c) maximum output power setting

3.4.1.3.1 Measurement Configuration

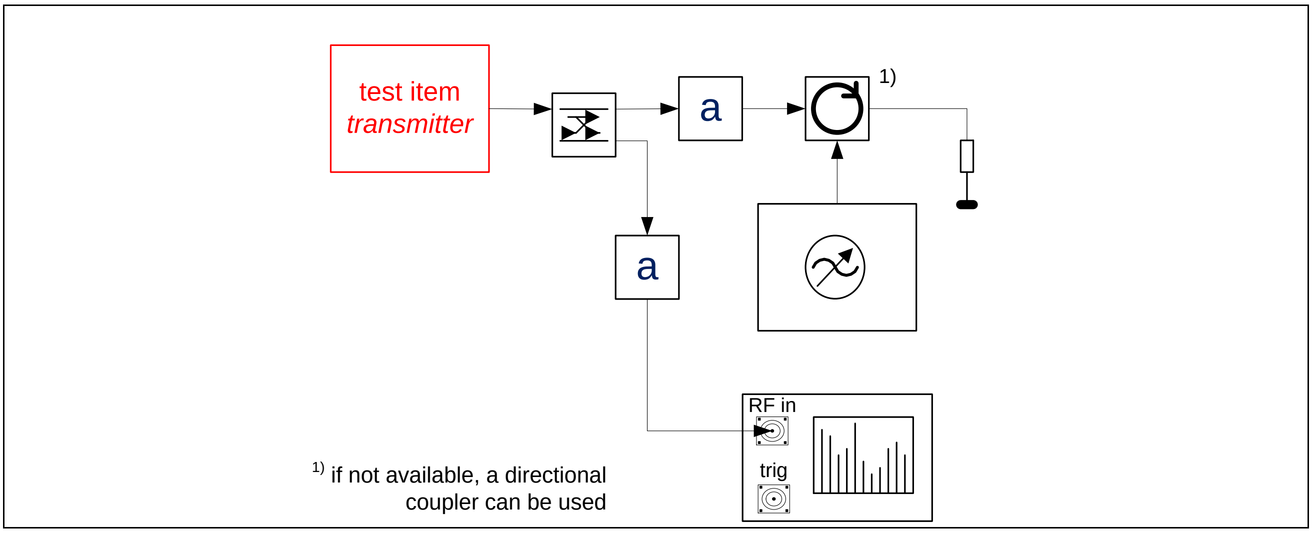


Figure 3.4.1-1: configuration for Intermodulation with Other Transmitters measurement

3.4.1.3.2 Measurement Procedure

a) configure the test item to transmit a CW signal at a frequency f_1 with the maximum output power level P_1

b) feed a CW signal at a frequency f_2 from the RF generator to the test item output resulting in a signal level P_2 at the test item output according to:

$$P_2(f_2) = P_{co,max}(f_2) - L_{min}(f_2)$$

with

$P_{co,max}(f_2)$:	the max expected co-located transmitter power
$L_{min}(f_2)$:	the min expected decoupling between the co-located transmitters

c) increase the frequency distance between f_1 and f_2 from min to max of the expected frequency separation between co-located transmitters and measure the power level of the 3rd order IM product located at 2 $f_1 - f_2$; the increment for f_2 should be the minimum channel bandwidth when f_2 is close to f_1; it can be increased for higher frequency separation

d) perform the test for a frequency f_1 in the low, mid and high operating range; in case the test item transmitter has several sub-bands with different hardware configurations, e.g. different harmonic filters, perform the test at the lowest and the highest frequency of each sub-band

3.4.1.3.3 Data Reduction and Presentation

a) present in a table the frequency ranges for f_2 where the co-located transmitter power P_2 is constant and note the corresponding values of P_2 and the minimum de-coupling L

b) note in the table for each range the according maximum measured value of the IM product power relative to the test item transmit power P_1 in dBc

3.4.2 Output Power Control

3.4.2.1 Scope

The objective of this test is to measure the behavior of the test item output power control in the presence of a co-located transmitter operating simultaneously.

3.4.2.2 Facilities and Instrumentation

a) RF signal generator to provide the co-located transmitter signal

b) spectrum analyzer

c) circulator to de-couple the signal generator from the test item transmit signal; in case a circulator is not available, e.g. for lower operating frequencies, a directional coupler can be used

3.4.2.3 Test Conditions

a) normal ambient conditions

b) nominal power supply voltage

3.4.2.3.1 Measurement Configuration

The measurement configuration is the same as for measuring Intermodulation with Other Transmitters (3.4.1).

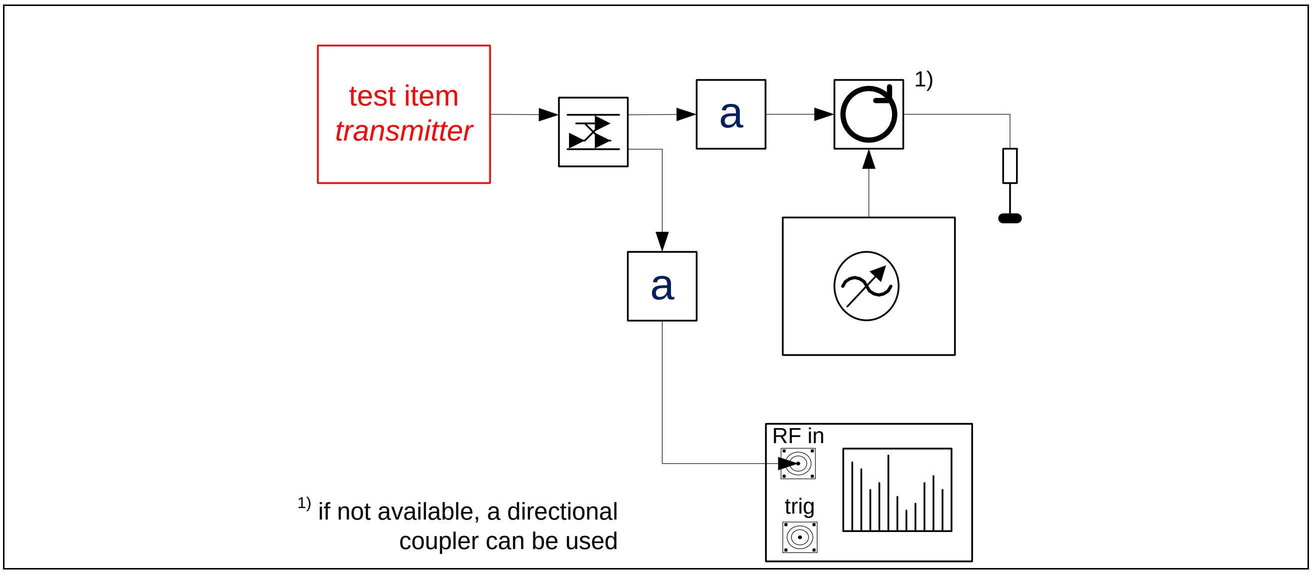


Figure 3.4.2-1: configuration for Output Power Control measurement

3.4.2.3.2 Measurement Procedure

a) configure the test item to transmit a CW signal at a frequency f_1 with the output power level P_1
b) feed a CW signal at a frequency f_2 from the RF generator to the test item output resulting in a signal level P_2 at the test item output with its maximum value $P_{2,max}$ according to:

   $P_{2,max}(f_2) = P_{co,max}(f_2) - L_{min}(f_2)$

   with

   $P_{co,max}(f_2)$: the max expected co-located transmitter power at f_2
   $L_{min}(f_2)$: the min expected decoupling between the co-located transmitters at f_2
c) set f_2 to the minimum of the expected frequency separation between co-located transmitters for a given $P_{co,max}$
d) vary the co-located transmitter power P_2 from its maximum value $P_{2,max}$ to $P_{2,max}$ – 20 dB and measure the variation of the test item output power
e) perform the measurement for all selectable output power settings of the test item
f) perform the test for a frequency f_1 in the low, mid and high operating range

3.4.2.3.3 Data Reduction and Presentation

a) present in a table the values of f_1 and f_2, note the corresponding values of P_1, P_2 and minimum de-coupling L, and note the maximum measured variation of the test item output power in dB

3.5 Timing

3.5.1 Transmitter Hop Time

3.5.1.1 Scope

The objective of this test is to measure the minimum required timespan for the test item to switch between two transmit frequencies. Also, the delay between the command to switch the frequency and the actual effect of the command can be measured.

Definitions:

The Transmitter Hop Time is the time between the moment when the level of the transmitted signal at the original frequency has dropped to 90% of its steady state value, and the moment when the level of the transmitted signal at the new frequency has reached 90% of its steady state value.

The Transmit Hop Command Delay is the time between the moment when the transmit hop command is transferred completely to the test item command interface, and the moment when the level of the transmitted signal at the original frequency has dropped to 90% of its steady state value.

3.5.1.2 Facilities and Instrumentation

a) change frequency command sequence
b) spectrum analyzer with time domain evaluation

3.5.1.3 Test Conditions

a) normal ambient conditions
b) nominal power supply voltage
c) maximum output power setting

3.5.1.4 Test Procedure

3.5.1.4.1 Measurement Configuration

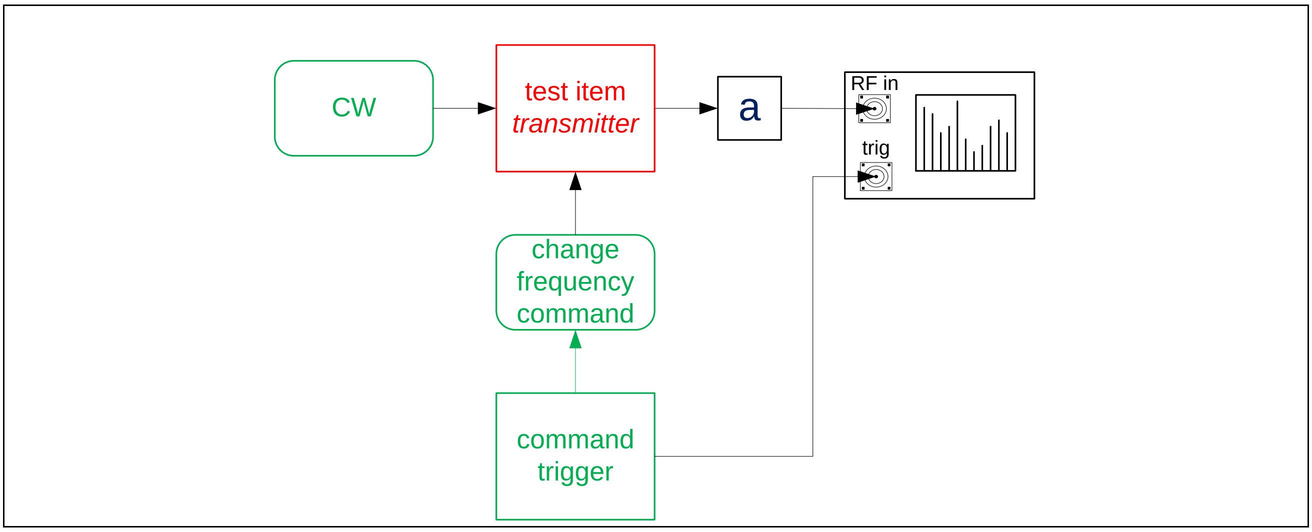


Figure 3.5.1-1: configuration for Transmitter Hop Time measurement

3.5.1.4.2 Measurement Procedure

a) configure the test item to transmit a CW signal at frequency f1
b) set the spectrum analyzer to f2 in time-domain mode
c) trigger a change frequency command to the test item to switch immediately to transmit frequency f2
d) derive the hop delay from the time-domain data according to the following:

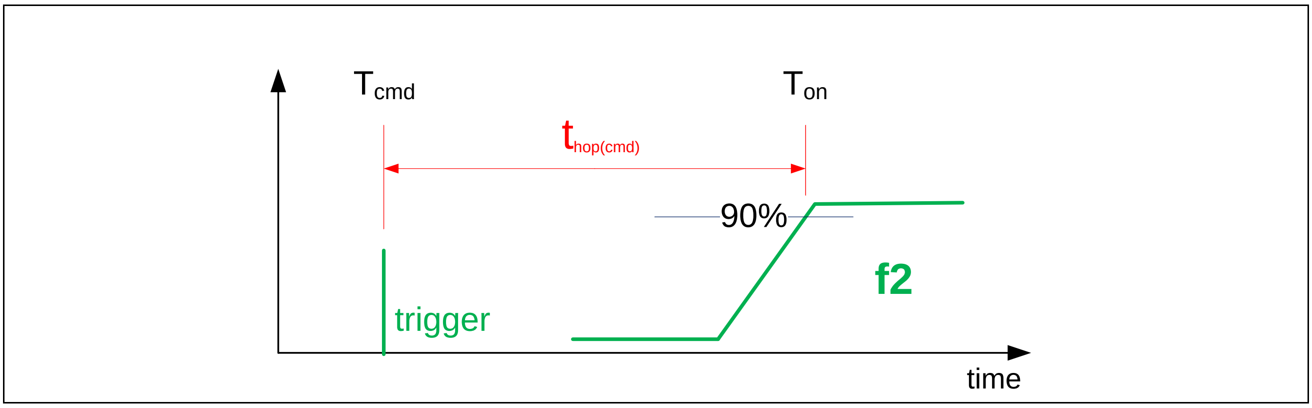


Figure 3.5.1-2: Transmitter Hop Time

i. T_{cmd} is the time of the command trigger, corrected for the delay between the trigger signal and the command being completely transferred to the test item command interface (not shown in diagram)
ii. T_{on} is the time where the signal magnitude at frequency f2 has increased to 90% of its steady state value and – if applicable - the frequency deviation is equal or smaller than the required value
iii. the Transmitter Hop Time $t_{hop(cmd)}$ - *including the command delay* - is the time between T_{cmd} and T_{on}

e) repeat the measurement at least three times for the same frequency hop and observe variations of the hop time; note the maximum occurring hop time $(max)t_{hop(cmd)}$
f) perform the test for all hop distances and ranges for f1 which are of interest

To measure the command delay, do the following:

g) configure the test item to transmit a CW signal at frequency f1
h) set the spectrum analyzer to f1 in time-domain mode
i) trigger a change frequency command to the test item to switch immediately to transmit frequency f2
j) derive the command delay from the time-domain data according to the following:

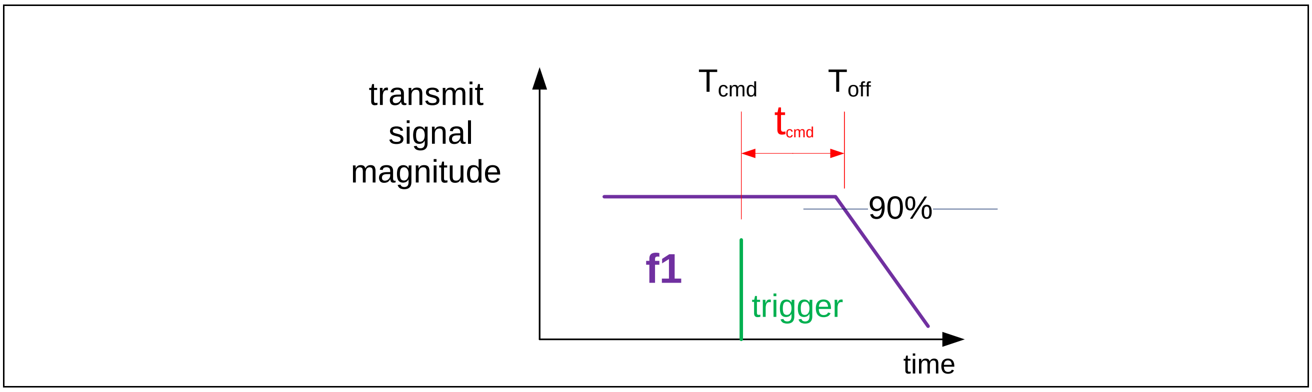


Figure 3.5.1-3: Transmitter Hop Command Delay

v. T_{off} is the time where the signal magnitude (from the RF signal at frequency f1) has decreased to 90% of its steady state value

ii. T_{cmd} is the time of the command trigger, triggering also the spectrum analyzer, corrected for the delay between the trigger signal and the command being completely transferred to the test item command interface (not shown in diagram)

vi. the Command Delay t_{cmd} is the time between T_{cmd} and T_{off}

k) repeat the measurement at least three times for the same frequency hop command and note the minimum and maximum command delay, (min)T_{cmd} and (max)T_{cmd}

l) the maximum hop time without command delay can be estimated as:

$$(max)t_{hop} = (max)t_{hop(cmd)} - (min)T_{cmd}$$

3.5.1.4.3 Data Reduction and Presentation

a) present in a table the maximum measured hop time (including the command delay) for each hop distance and note the observed variations

b) if measured, state the maximum and minimum command delay and note its observed variation

c) give an estimate of the maximum hop time without command delay according to l)

3.5.2 Receive-to-Transmit Delay

3.5.2.1 Scope

The objective of this test is to measure the required timespan for the test item to switch from receiving to transmitting at the same frequency. Also, the delay between the command to switch to transmit and the actual effect of the command is measured.

The test is applicable only for half-duplex transceivers.

Definitions:

The Receive-to-Transmit Delay is the time between the moment when the level of the signal at the test item receive output has dropped to 90% of its steady state value, and the moment when the level of the transmitted signal at the test item transmit output has reached 90% of its steady state value.

The Receive-to-Transmit Command Delay is the time between the moment when the Receive-to-Transmit command is transferred completely to the test item command interface, and the moment when the level of the signal at the test item receive output has dropped to 90% of its steady state value.

3.5.2.2 Facilities and Instrumentation

a) RF signal generator
b) continuously variable attenuator
c) transmit command sequence
d) spectrum analyzer with time domain evaluation
e) test item received baseband data interface
f) baseband data time / frequency evaluation

3.5.2.3 Test Conditions

a) normal ambient conditions
b) nominal power supply voltage
c) maximum output power setting
d) fixed receiver gain setting (no AGC active)

3.5.2.4 Test Procedure

3.5.2.4.1 Measurement Configuration

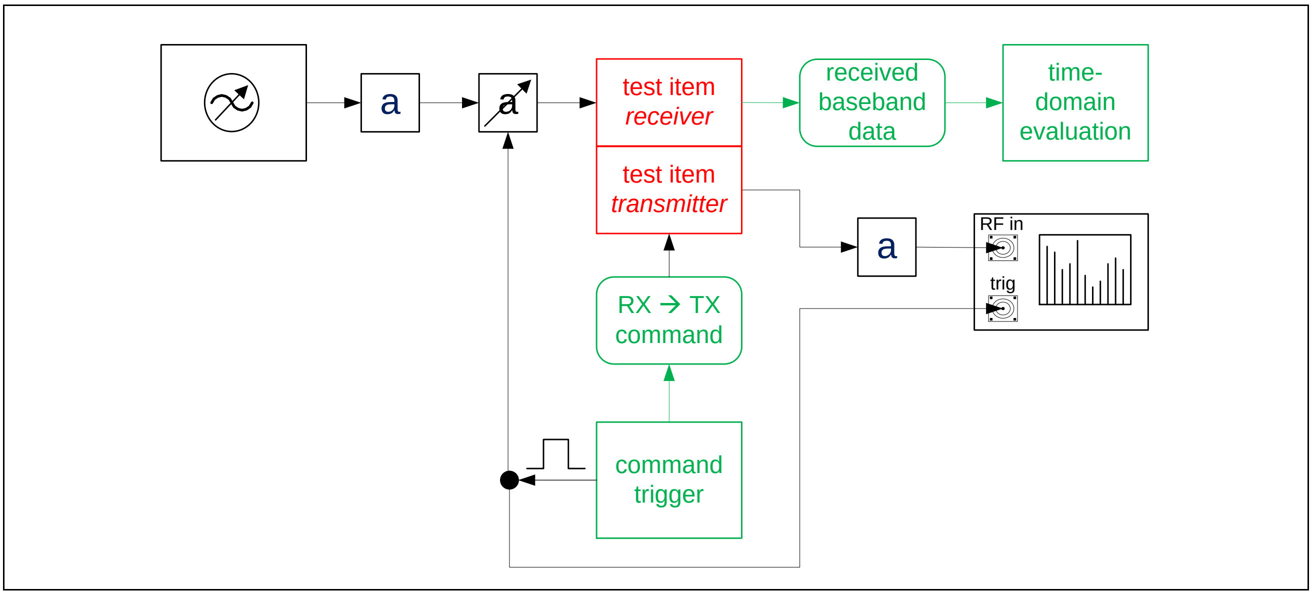


Figure 3.5.2-1: configuration for Receive-to-Transmit Delay measurement

3.5.2.4.2 Measurement Procedure

a) tune the RF signal generator to transmit a CW signal at the test item receive frequency
b) set the spectrum analyzer to the test item transmit frequency in time-domain mode
c) trigger a transmit command to the test item to switch immediately from receive to transmit at the same frequency
d) derive the receive-to-transmit delay from the test item transmitter time-domain data according to the following:

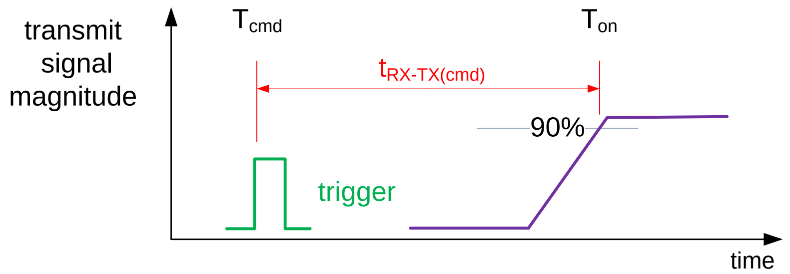


Figure 3.5.2-2: Receive-to-Transmit Delay

i. T_{cmd} is the time of the command trigger, triggering also the spectrum analyzer, corrected for the delay between the trigger signal and the command being completely transferred to the test item command interface (not shown in diagram)
ii. T_{on} is the time where the magnitude of the transmitted signal has increased to 90% of its steady state value and – if applicable - the frequency deviation is equal or smaller than the required value
iii. the Receive-to-Transmit Delay $t_{RX-TX(cmd)}$ - *including the command delay* - is the time between T_{cmd} and T_{on}

e) derive the command delay from the test item received baseband data according to the following:

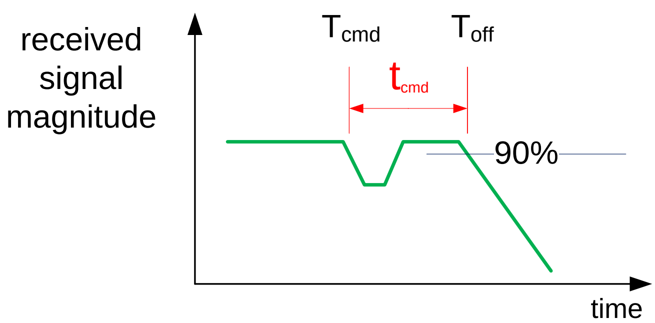


Figure 3.5.2-3: Receive-to-Transmit Command Delay

iv. T_{cmd} is the time where the command trigger is occurring in the receive baseband signal magnitude, corrected for the delay between the trigger signal and the command being completely transferred to the test item command interface (not shown in diagram)

v. T_{off} is the time where the magnitude of the receive baseband signal has decreased to 90% of its steady state value

vi. the command delay t_{cmd} is the time between T_{cmd} and T_{off}

f) the Receive-to-Transmit Delay $t_{RX\text{-}TX}$ - *without command delay* - can be calculated as:

$$t_{RX\text{-}TX} = t_{RX\text{-}TX(cmd)} - t_{cmd}$$

g) perform the test for a frequency in the low, mid and high operating range

Note:

In case of excessive ringing or overshoot, a criterion different from the 90% level can be chosen, e.g. the level where the first overshoot reaches 110% of the steady state value.

3.5.2.4.3 Data Reduction and Presentation

a) Note the maximum measured Receive-to-Transmit Delay with and without command delay, and the according command delay

3.5.3 Retransmission Delay

3.5.3.1 Scope

The objective of this test is to measure the minimum time delay between the reception of a signal and its retransmission without any demodulation. It is applicable only for transceivers.

For full-duplex transceivers with continuous retransmission, the Retransmission Delay is the delay between the reception and retransmission of a defined point in the received signal stream. For half-duplex transceivers with block-wise retransmission, this delay is dependent of the retransmission block length. A more general parameter for half-duplex transceivers is therefore the Additional Retransmission Delay, which is the Retransmission Delay less the retransmission block length (see also Figure 3.5.3-3).

Another parameter relevant for block-wise retransmission is the Retransmission Gap, which is the time the test item is busy transmitting or changing its state, so that a signal potentially received within this time span is lost for retransmission (see also Figure 3.5.3-3).

3.5.3.2 Facilities and Instrumentation

a) RF signal generator
b) trigger generator (for testing full-duplex transceivers) or arbitrary waveform generator (for testing half-duplex transceivers)
c) continuously variable attenuator, alternatively AM modulation for the RF signal generator
d) spectrum analyzer with time domain evaluation

3.5.3.3 Test Conditions

a) normal ambient conditions
b) nominal power supply voltage
c) maximum output power setting
d) fixed receiver gain setting (no AGC active)

3.5.3.4 Test Procedure

3.5.3.4.1 Measurement Configuration

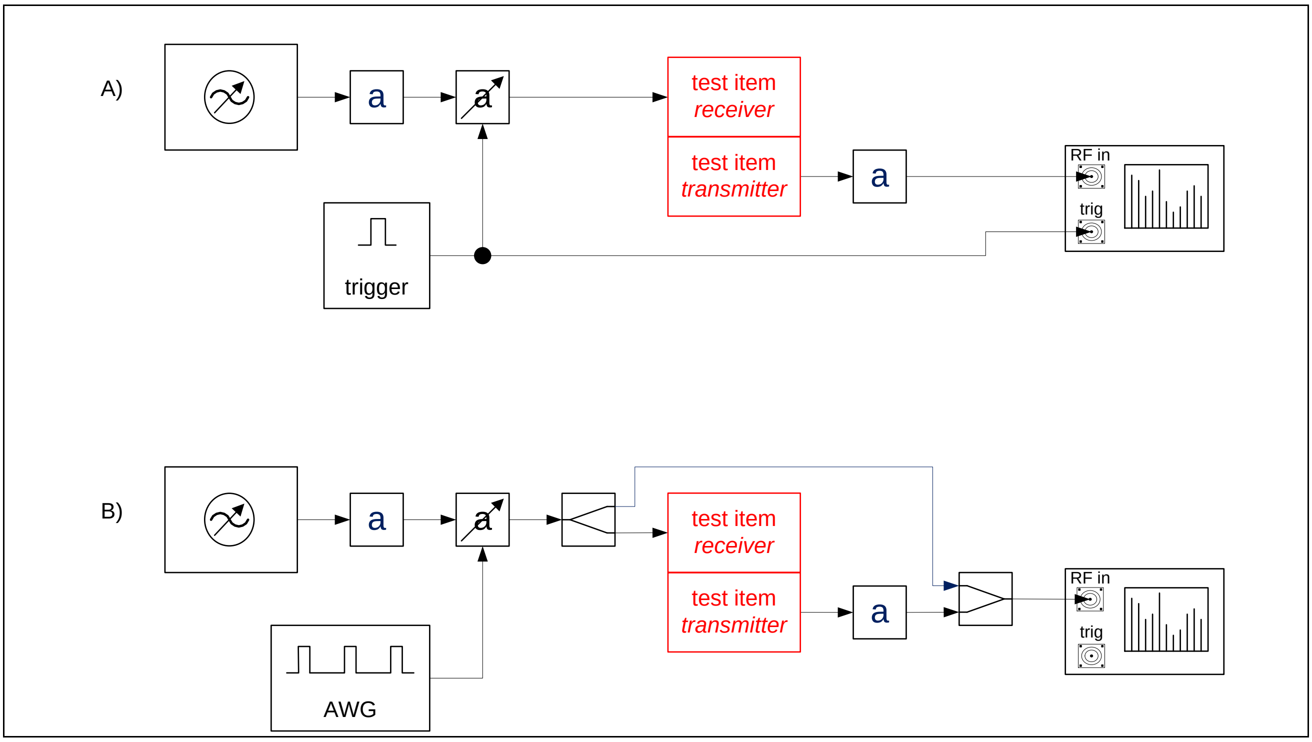


Figure 3.5.3-1: configuration for Retransmission Delay measurement

A) configuration for measuring a full-duplex transceiver
B) configuration for measuring a half-duplex transceiver

In case B), the fixed attenuators shall be configured in such a way that the signal from the RF generator can be observed at the spectrum analyzer in time domain together with the signal from the test item transmitter, with the power level from the RF generator at least 10 dB lower than the signal from the transmitter.

3.5.3.4.2 Measurement Procedure

a) configure the test item transceiver for retransmission of received data
b) tune the RF signal generator to the test item receive frequency
c) set the spectrum analyzer to the test item transmit frequency in time-domain mode

For full-duplex transceivers with continuous retransmission:

d) create a trigger pulse for the variable attenuator and the spectrum analyzer
e) derive the Retransmission Delay in the time-domain data according to the following:

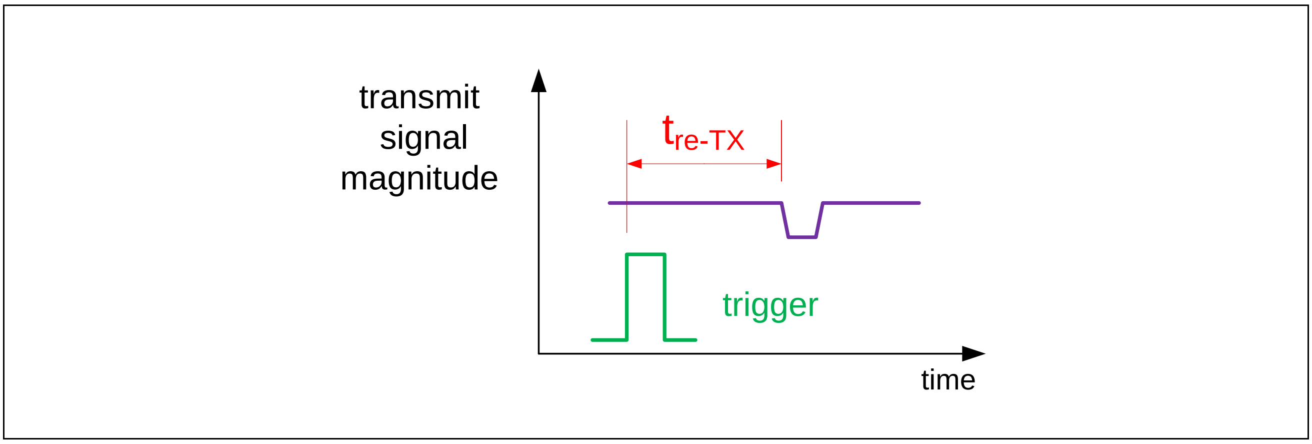


Figure 3.5.3-2: Retransmission Delay for continuous retransmission

i. the Retransmission Delay $t_{re\text{-}TX}$ is the time between the trigger and the according dip in magnitude in the re-transmitted signal

e) repeat the measurement at least three times and observe if variations in the Retransmission Delay occur

For half-duplex transceivers with block-wise retransmission:

f) create a time synchronization pulse train for the variable attenuator in such a way that only one synchronization pulse occurs between two retransmitted blocks
g) derive the Retransmission Block Length in the time-domain data according to the following (items in blue are for illustration only, they cannot be measured directly) and verify that it is at least as large as the nominal retransmission block length:

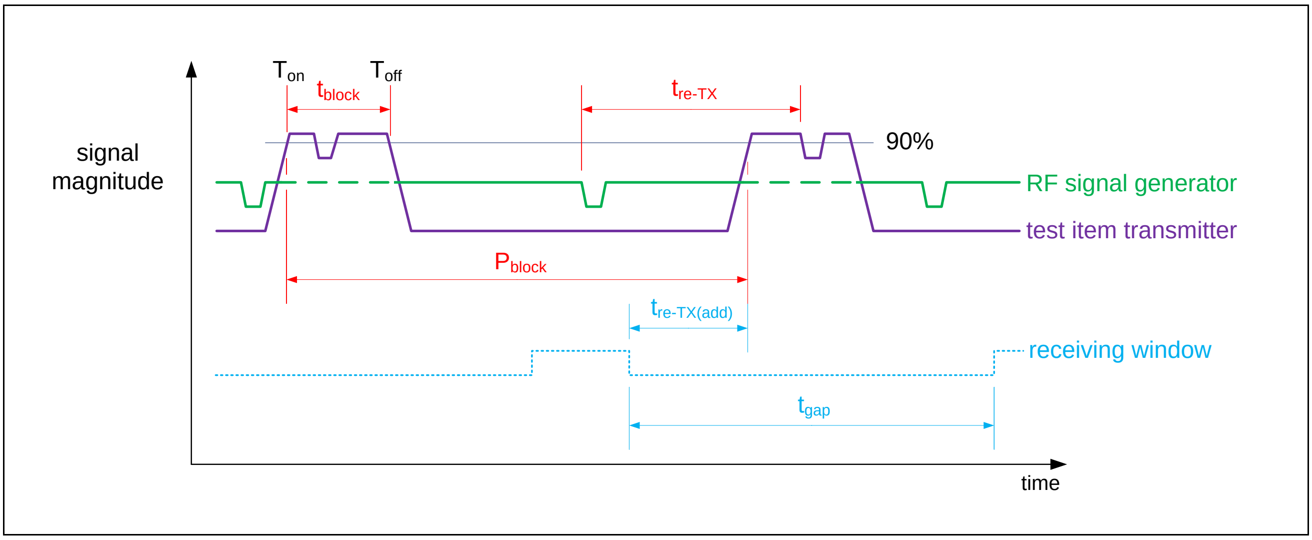


Figure 3.5.3-3: Retransmission Delay for block-wise retransmission

i. T_{on} is the time where the magnitude of the retransmitted signal has increased to 90% of its steady state value and – if applicable - the frequency deviation is equal or smaller than the required value

ii. T_{off} is the time where the magnitude of the retransmitted signal has decreased to 90% of its steady state value

iii. the retransmitted block length t_{block} is the time between T_{on} and T_{off}

h) derive the Retransmission Delay in the time-domain data according to the following:

iv. the Retransmission Delay $t_{re\text{-}TX}$ is the time between the trigger pulse occurring in the time-domain signal from the RF generator and its occurrence in the signal retransmitted by the test item

v. the Additional Retransmission Delay $t_{re\text{-}TX(add)}$ is calculated as: $t_{re\text{-}TX(add)} = t_{re\text{-}TX} - t_{block}$

vi. the retransmission period P_{block} is the time between two retransmitted blocks

vii. the Retransmission Gap t_{gap} is calculated as: $t_{gap} = P_{block} - t_{block}$

i) repeat the measurement at least three times and observe if variations in the Retransmission Delay occur

j) perform the measurement for zero offset between receiving and retransmitting frequency and other frequency offsets of interest

k) perform the test for a frequency in the low, mid and high operating range

Note:

In case of excessive ringing or overshoot, a criterion different from the 90% level can be chosen, e.g. the level where the first overshoot reaches 110% of the steady state value.

3.5.3.4.3 Data Reduction and Presentation

a) note the maximum measured Retransmission Delay and observed variations
b) if applicable note the according Additional Retransmission Delay and the Retransmission Gap

4 Receiver Tests

4.1 Basic Parameters

4.1.1 Gain Factor

4.1.1.1 Scope

The objective of this test is to determine the voltage gain factor between the receive antenna port and the digital receive baseband data interface for different receiver gain settings.

For the scaling of the receive baseband data, there are two possibilities:

a) *non-compensating:*
the receive signal is directly derived from the receive ADC, possibly including digital processing like filtering or sample rate conversion, but not compensating for varying receiver gain;
in this case, the Gain Factor is directly related to the receiver gain setting

b) *gain-compensating:*
the signal level of the receive baseband signal is automatically adjusted according to the actual receiver gain setting, thus compensating any Automatic Gain Control and providing a signal directly referenced to the test item antenna input;
in this case, the Gain Factor is constant and this test determines the quality of the gain compensating functionality of the test item

4.1.1.2 Facilities and Instrumentation

a) RF signal generator
b) power meter
c) test item received baseband data interface
d) baseband data time-domain evaluation
e) baseband data PSD evaluation

4.1.1.3 Test Conditions

a) normal ambient conditions
b) nominal power supply voltage
c) fixed receiver gain setting (no AGC active)

4.1.1.4 Test Procedure

4.1.1.4.1 Measurement Configuration

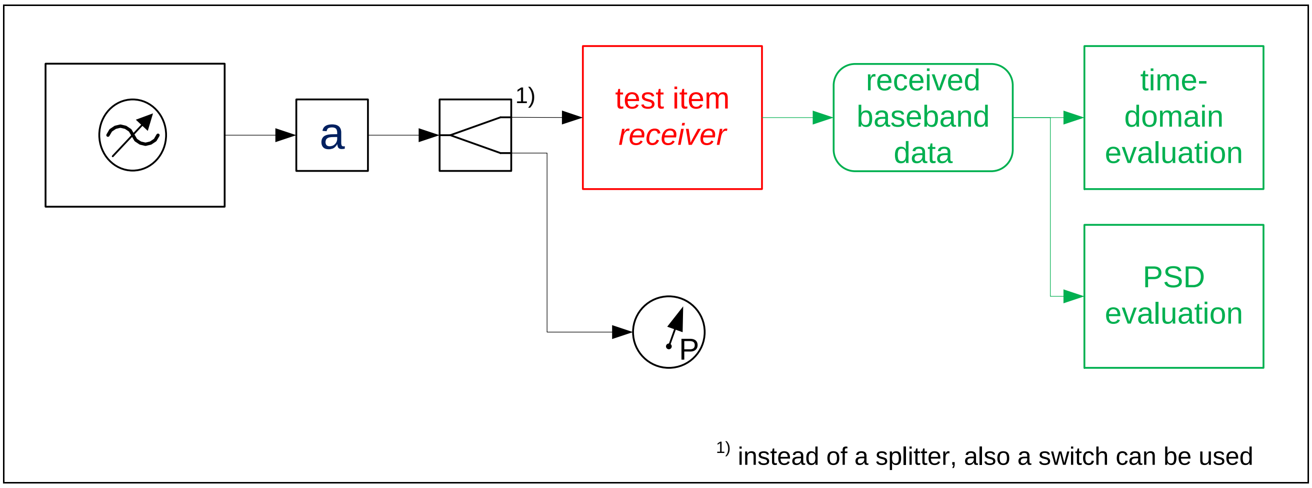


Figure 4.1.1-1: configuration for Gain Factor measurement

4.1.1.4.2 Measurement Procedure

a) apply an unmodulated RF test signal at the test item receive port
b) measure the power of the RF signal with the help of a power meter
c) evaluate the peak and RMS value of the received baseband signal; adjust the RF test signal power level in such a way that the signal-to-noise ratio (SNR) of the received baseband signal is at least 30 dB according to the power spectrum density (PSD) of the received baseband signal
d) verify that the receiver is not in compression by decreasing the RF test signal power by 3 dB and observing the resulting receive signal level
e) the Gain Factor G_U can be calculated according to the following:

$$G_U = \frac{S_{RX,peak}}{U_{RF,peak}} \qquad \left[\frac{1}{V}\right]$$

with

$S_{RX,peak}$: the peak value of the receive signal magnitude [ ]
$U_{RF,peak}$: the peak voltage of the RF input test signal [V]

the peak voltage of the RF input test signal $U_{RF,peak}$ can be calculated from the RF test signal power P_{RF} and the test item input impedance R_{in} as:

$$\mathrm{U_{RF,peak}} = \sqrt{2} \cdot \sqrt{\mathrm{P_{RF}} * \mathrm{R_{in}}}$$

f) perform the measurement for different receiver gain settings in the low, mid and high gain setting range; for non-compensating receivers use at least five different settings, for compensating receivers ten
g) perform the test for a frequency in the low, mid and high operating range; in case the test item transmitter has several sub bands with different hardware configurations, e.g. different bandpass filters, perform the test at the min and max frequency of each sub-band

4.1.1.4.3 Data Reduction and Presentation

a) for non-compensating receivers, plot for all measured frequencies the Gain Factor G_U as a function of the test item gain setting
b) for compensating receivers, list for all measured frequencies the maximum observed variation of the Gain Factor G_U

4.1.2 Usable Bandwidth

4.1.2.1 Scope

The objective of this test is to determine the Usable Bandwidth of the test item receiver and the according frequency response for all possible configurations of the receive bandwidth.

4.1.2.2 Facilities and Instrumentation

a) RF signal generator modulated with a signal shaped like white noise with a bandwidth larger than the expected Usable Bandwidth of the test item
b) test item received baseband data interface
c) baseband data PSD evaluation

4.1.2.3 Test Conditions

a) normal ambient conditions
b) nominal power supply voltage
c) fixed receiver gain setting (no AGC active)

4.1.2.4 Test Procedure

4.1.2.4.1 Measurement Configuration

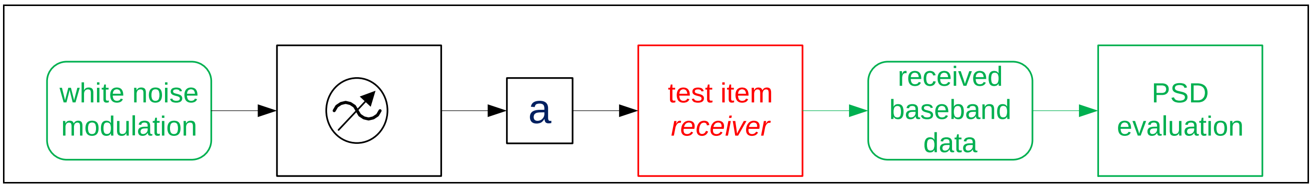


Figure 4.1.2-1: configuration for receiver Usable Bandwidth measurement

4.1.2.4.2 Measurement Procedure

a) apply a RF test signal shaped like white noise at the test item receive port with a bandwidth of at least 10% more than the expected 3 dB bandwidth of the test item
b) evaluate the power spectrum of the receive baseband signal regarding amplitude ripple and bandwidth
c) perform the measurement for all configurable receive bandwidths of the test item
d) perform the test for a frequency in the low, mid and high operating range; in

case the test item has several sub-bands with different hardware configurations, e.g. different preselector filters, perform the test for the min and max frequency of each sub-band

4.1.2.4.3 Data Reduction and Presentation

a) plot the power spectrum for each configurable receive bandwidth versus frequency offset
b) mark the frequency values for the 3dB- and the 1dB-bandwidth on the plot where the power spectrum magnitude at the filter flanks is down 3 dB and 1 dB respectively, referred to the value at zero frequency offset
c) note the amplitude ripple within the 1dB-bandwidth calculated as the difference between the maximum and the minimum value in the power spectrum, not including the filter flanks with the 1-dB bandwidth points

4.1.3 Sensitivity

4.1.3.1 Scope

The objective of this test is to measure the Sensitivity of the test item receiver as the input power level of a CW signal for which the signal-to-noise ratio SNR at the test item receive baseband interface is 10 dB within a defined bandwidth.

4.1.3.2 Facilities and Instrumentation

a) RF signal generator
b) RF power meter
c) variable attenuator
d) test item received baseband data interface
e) baseband data SNR/SINAD evaluation

4.1.3.3 Test Conditions

a) normal ambient conditions
b) nominal power supply voltage
c) activated AGC with nominal settings

4.1.3.4 Test Procedure

4.1.3.4.1 Measurement Configuration

The measurement configuration is the same as for measuring Maximum SINAD (4.1.4).

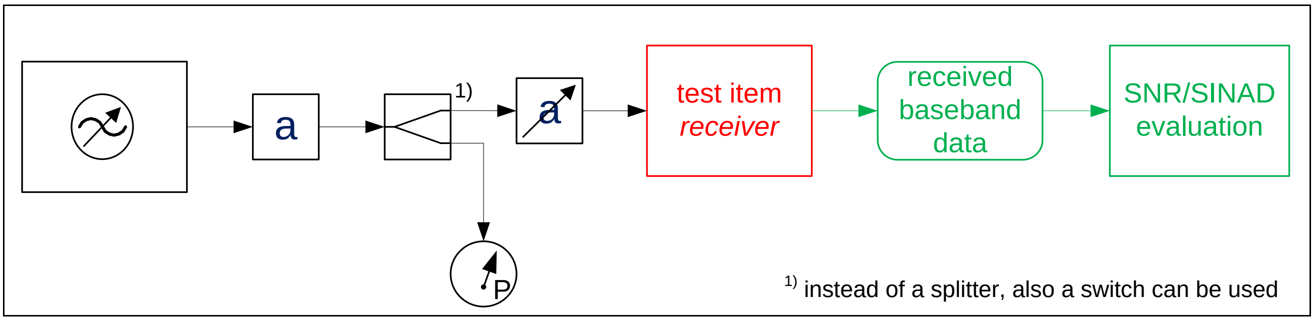


Figure 4.1.3-1: configuration for Sensitivity measurement

4.1.3.4.2 Measurement Procedure

a) apply a RF CW signal at the test item receive input with a defined power level and at the nominal receive frequency; in case there is a DC offset or a notch around DC present at the receive baseband interface, apply an offset to the RF signal frequency smaller than the bandwidth of interest so that the CW signal can be clearly distinguished from the DC offset and the notch has no influence on the CW signal

b) record the received baseband data and evaluate the SNR according to:

$$SNR = P_{cw}\,[dB] - P_{BW/CW}\,[dB]$$

with

P_{CW}: power level of the RF CW signal at the receive baseband interface

$P_{BW/CW}$: power at the receive baseband interface integrated from – ½ BW to + ½ BW, excluding the power from the RF CW signal

BW: bandwidth of interest

the resolution bandwidth of the SNR evaluation should be minimum $^{1}/_{20}$ BW

c) reduce the power level of the RF CW signal until the SNR is 10 dB; the Sensitivity is the according RF power level at the test item receive input

d) perform the measurement for all bandwidths of interest

e) perform the measurements for all test item settings which have influence on the Sensitivity, e.g. activated/de-activated LNA

f) perform the test for a frequency in the low, mid and high operating range; in case the test item receiver has several sub-bands with different hardware configurations, e.g. different preselector filters, do the measurements for a frequency in the low, mid and high range of the sub-band;

g) in case residual spurious signals are present in the receive baseband data within the bandwidth of interest, move the RF CW signal frequency slightly and change the test item receive frequency accordingly; note the receive frequency where the spurious occurred as a Residual Spurious Response (see also 4.2.2) and note the level of the spurious

4.1.3.4.3 Data Reduction and Presentation

a) present in a table the Sensitivity levels in dBm for all tested configurations
b) list all detected Residual Spurious with receive frequency and spurious level and note the test item configuration

4.1.4 Maximum SINAD

4.1.4.1 Scope

The objective of this test is to measure the maximum obtainable Signal to Noise and Distortion ratio (SINAD) of the test item receiver within a defined bandwidth.

4.1.4.2 Facilities and Instrumentation

a) RF signal generator
b) RF power meter
c) variable attenuator
d) test item received baseband data interface
e) baseband data SNR/SINAD evaluation

4.1.4.3 Test Conditions

a) normal ambient conditions
b) nominal power supply voltage
c) activated AGC with nominal settings

4.1.4.4 Test Procedure

4.1.4.4.1 Measurement Configuration

The measurement configuration is the same as for measuring Sensitivity (4.1.3).

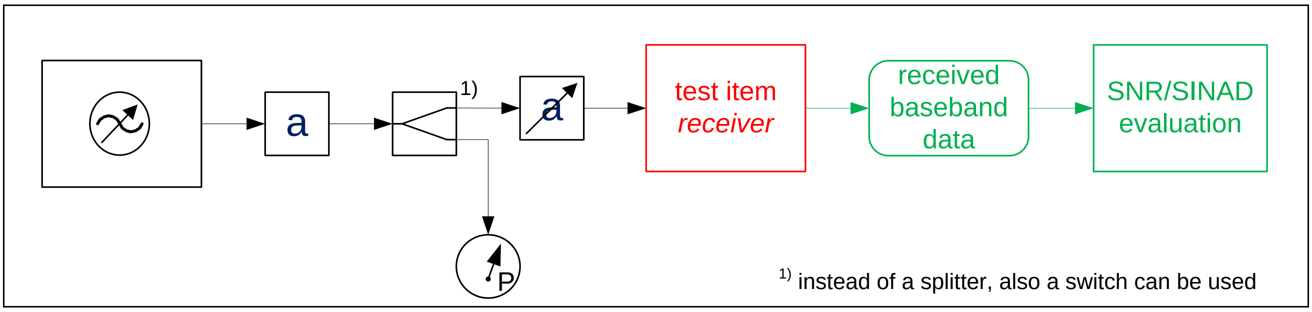


Figure 4.1.4-1: configuration for Maximum SINAD measurement

4.1.4.4.2 Measurement Procedure

a) apply a RF CW signal at the test item receive input and adjust its power level to the Sensitivity of the test item; in case there is a DC offset or a notch around DC present at the receive baseband interface, apply an offset to the RF signal frequency smaller than the bandwidth of interest so that the CW signal can be clearly distinguished from the DC offset and the notch has no influence on the CW signal

b) record the received baseband data and evaluate the SINAD according to:

$$SINAD = P_{cw}\,[dB] - P_{BW/CW} \qquad [dB]$$

with

P_{CW}: power level of the RF CW signal at the receive baseband interface
$P_{BW/CW}$: power at the receive baseband interface integrated from – ½ BW to + ½ BW, excluding the power from the RF CW signal
BW: bandwidth of interest

the resolution bandwidth of the SINAD evaluation should be minimum $^{1}/_{20}$ BW

c) increase the power level of the RF CW signal until the SINAD reaches a maximum or the max input power level of the test item receiver is reached; note the according SINAD value and the RF CW signal power
d) perform the measurement for all bandwidths of interest
e) perform the measurements for all test item settings which have influence on the SINAD, e.g. activated/de-activated LNA
f) perform the test for a frequency in the low, mid and high operating range

4.1.4.4.3 Data Reduction and Presentation

a) present in a table for all tested configurations the Maximum SINAD values in dB and the according RF signal levels in dBm

4.1.5 Dynamic Range

4.1.5.1 Scope

The objective of this test is to determine the Dynamic Range of the test item receiver. Note that the Dynamic Range of a receiver can be limited also by its In-Band Intermodulation properties as measured in 4.3.1, especially when using multi-tone modulation schemes like OFDM, which is not taken into account here.

4.1.5.2 Facilities and Instrumentation

a) RF signal generator
b) RF power meter
c) variable attenuator
d) test item received baseband data interface
e) baseband data SNR/SINAD evaluation

4.1.5.3 Test Conditions

a) normal ambient conditions
b) nominal power supply voltage
c) activated AGC with nominal settings

4.1.5.4 Test Procedure

4.1.5.4.1 Measurement Configuration

The measurement configuration is the same as for measuring Maximum SINAD (4.1.4).

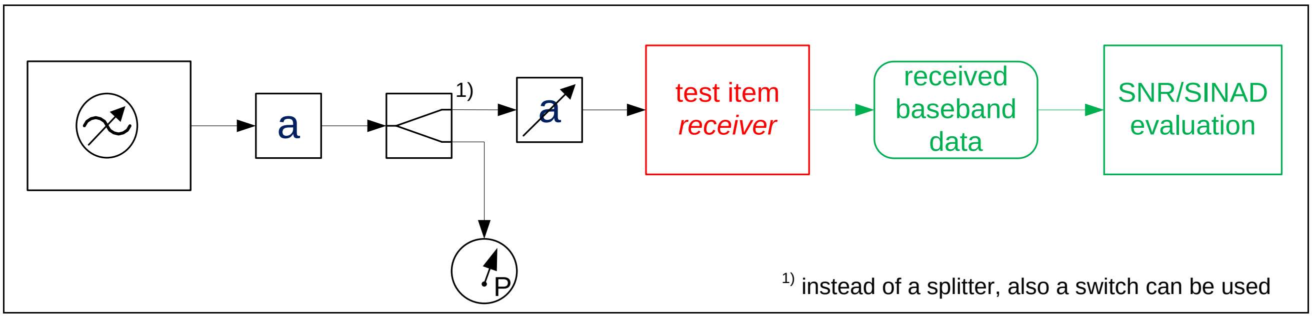


Figure 4.1.5-1: configuration for Dynamic Range measurement

4.1.5.4.2 Measurement Procedure

a) apply a RF CW signal at the test item receive input and adjust its power level to the Sensitivity of the test item (see 4.1.3); in case there is a DC offset or a notch around DC present at the receive baseband interface, apply an offset to the RF signal frequency smaller than the bandwidth of interest so that the CW signal can be clearly distinguished from the DC offset and the notch has no influence on the CW signal

b) record the received baseband data and evaluate the SINAD according to:

$$SINAD = P_{cw}\,[dB] - P_{BW/CW} \qquad [dB]$$

with

- P_{CW}: power level of the RF CW signal at the receive baseband interface
- $P_{BW/CW}$: power at the receive baseband interface integrated from – ½ BW to + ½ BW, excluding the power from the RF CW signal
- BW: bandwidth of interest

the resolution bandwidth of the SINAD evaluation should be minimum $^1/_{20}$ BW

c) set the power level of the RF CW signal to the value for Maximum SINAD (see 4.1.4) and increase the power level further until the SINAD decreases to 10 dB or the max input power level of the test item receiver is reached; note the according RF CW signal power P_{max}

d) the Dynamic Range of the test item is the difference between P_{max} and the test item Sensitivity

e) perform the measurement for all bandwidths of interest

f) perform the measurements for all test item settings which have influence on the SINAD, e.g. activated/de-activated LNA

g) perform the test for a frequency in the low, mid and high operating range

4.1.5.4.3 Data Reduction and Presentation

a) present in a table for all tested configurations the Dynamic Range values in dB

4.1.6 Input Impedance

4.1.6.1 Scope

The objective of this test is to measure the Input Impedance of the test item receiver as VSWR-value.

4.1.6.2 Facilities and Instrumentation

a) network analyzer (1-port)

4.1.6.3 Test Conditions

a) normal ambient conditions
b) nominal power supply voltage
c) fixed receiver gain setting (no AGC active)

4.1.6.4 Test Procedure

4.1.6.4.1 Measurement Configuration

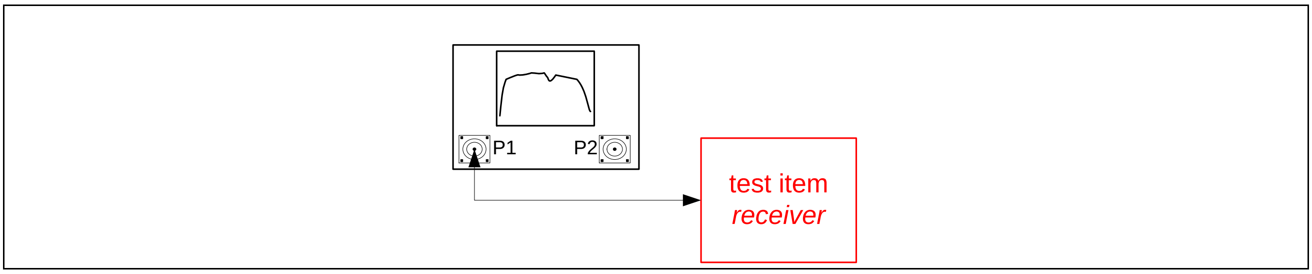


Figure 4.1.6-1: configuration for Input Impedance measurement

4.1.6.4.2 Measurement Procedure

a) set the test item to receive at frequency f
b) measure the Input Impedance of the test item in the Usable Bandwidth around f as VSWR-value referenced to 50 ohm using a network analyzer
c) perform the measurement for all test item settings which have influence on the Input Impedance, e.g. activated/de-activated LNA
d) perform the test for a frequency in the low, mid and high operating range

4.1.6.4.3 Data Reduction and Presentation

a) present in a table for each tested configuration the test item receive frequency and the according maximum VSWR-value in the measured frequency range

4.2 Spectral Purity

4.2.1 LO and Clock Emissions

4.2.1.1 Scope

The objective of this test is to measure the test item receiver residual emissions from the local oscillators and clocks.

4.2.1.2 Facilities and Instrumentation

a) spectrum analyzer
b) if necessary RF amplifier to increase the sensitivity of the spectrum analyzer

4.2.1.3 Test Conditions

a) normal ambient conditions
b) nominal power supply voltage
c) fixed receiver gain setting (no AGC active)
d) if possible test item configured for bypassing all internal input stages, e.g. LNA or preselector filter
e) RF input of the test item terminated with specified input impedance

4.2.1.4 Test Procedure

4.2.1.4.1 Measurement Configuration

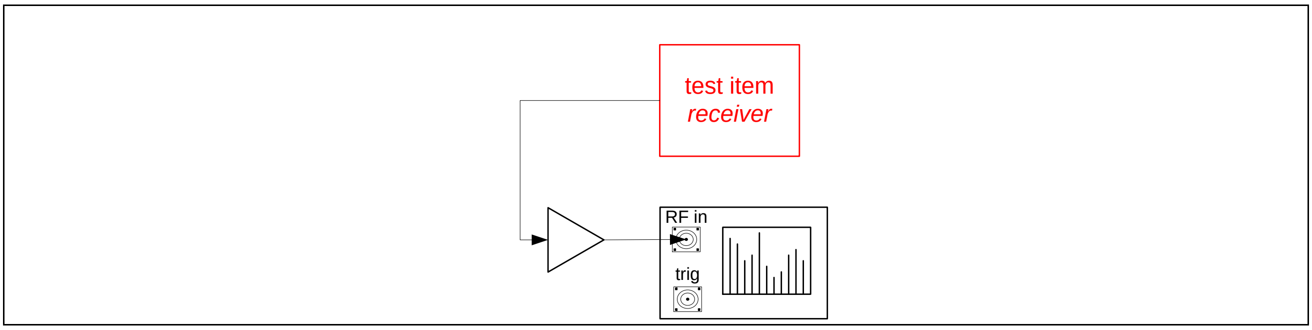


Figure 4.2.1-1: configuration for LO and Clock Emissions measurement

4.2.1.4.2 Measurement Procedure

a) configure the test item to receive and connect a spectrum analyzer to the test item receive input; if necessary , use a Low Noise Amplifier to increase the sensitivity of the spectrum analyzer
b) measure the emissions from all receiver LOs and their harmonics
c) measure the emissions from all test item clocks and their harmonics
d) measure all occurring emissions at the test item receive input from other sources
e) perform the test for a frequency in the low, mid and high operating range

4.2.1.4.3 Data Reduction and Presentation

a) present in a table for all tested receive frequencies the level of the observed emissions and the according emission frequency, and, if known, the emission source

4.2.2 Residual Spurious and Noise Response

4.2.2.1 Scope

The objective of this test is to determine the Residual Spurious and Noise Responses of the test item receiver. Residual Spurious Responses are signals at the receiver output generated inside the receiver itself, e.g. by mixing products of internal LOs or clocks, which are thus also present when no input signal is applied, and reduce the test item sensitivity. The same applies for Residual Noise signals, which might be generated e.g. by internal noise-shaped clocks.

4.2.2.2 Facilities and Instrumentation

a) test item received baseband data interface
b) baseband data PSD evaluation

4.2.2.3 Test Conditions

a) normal ambient conditions
b) nominal power supply voltage
c) maximum fixed receiver gain setting (no AGC active)

4.2.2.4 Test Procedure

4.2.2.4.1 Measurement Configuration

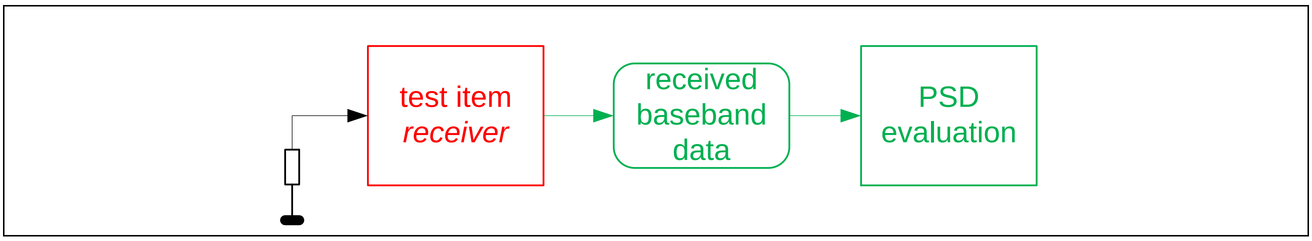


Figure 4.2.2-1: configuration for Residual Spurious Response measurement

4.2.2.4.2 Measurement Procedure

a) terminate the test item receive input with its specified impedance
b) tune the test item receiver over the whole operating range and note all occurrences where, at the test item output, there is a Residual Spurious signal present or the noise level is increased relative to the normal conditions for which the specified Sensitivity is reached (see also 4.1.3)

c) measure the level of the Residual Spurious signal relative to a RF CW test signal resulting in a 10 dB SNR ratio under normal conditions (as measured in 4.1.3) and its offset frequency, or the increase of the noise relative to the normal conditions and its bandwidth, respectively

4.2.2.4.3 Data Reduction and Presentation

a) present in a table all receive frequencies where a Residual Spurious was observed, its level in dB, and its offset frequency
b) present in a table all receive frequencies where Residual Noise was observed, its level in dB, and its bandwidth

4.3 Linearity

4.3.1 In-Band Intermodulation

4.3.1.1 Scope

The objective of this test is to determine the odd-order (mainly 3rd order) Intermodulation Response within the Usable Bandwidth (see chapter 4.1.1) when receiving a two-tone signal. It is expressed as the ratio [dB] between the level of one of the received tones and the stronger of the two corresponding intermodulation (IM) products.

The Intermodulation Response is determined depending on the test item receive gain setting and the frequency distance between the two RF input tones (tone-distance).

4.3.1.2 Facilities and Instrumentation

a) two-tone RF signal generator, consisting either of
   A) one generator capable to generate a two-tone signal with sufficient tone distance and linearity
   B) two RF generators combined with sufficient linearity
b) spectrum analyzer
c) test item received baseband data interface
d) baseband data PSD evaluation

4.3.1.3 Test Conditions

a) normal ambient conditions
b) nominal power supply voltage
c) maximum fixed receiver gain setting (no AGC active)

4.3.1.4 Test Procedure

4.3.1.4.1 Measurement Configuration

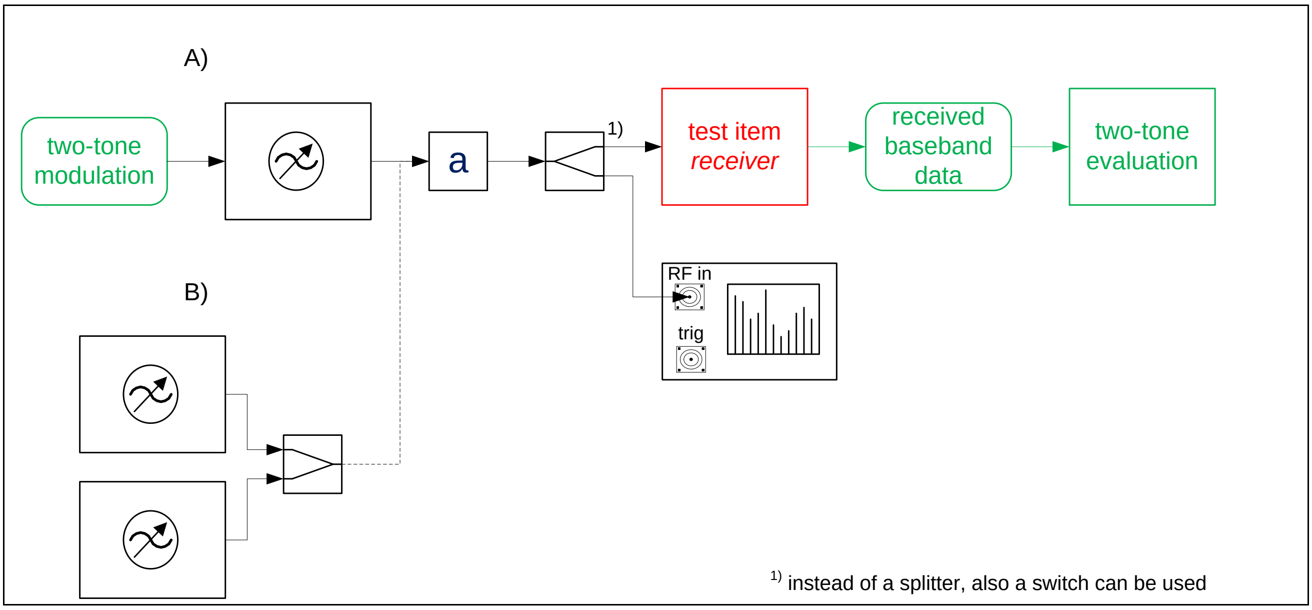


Figure 4.3.1-1: configuration for In-Band Intermodulation measurement

4.3.1.4.2 Measurement Procedure

a) apply a two-tone RF test signal consisting of two sine signals at equal amplitudes and variable tone-distance at the test item receive port

b) ensure that the IM products in the RF test signal are lower than those expected for the test item by measuring them with a spectrum analyzer according to Figure 4.3.1-1;
the relevant IM products for the n^{th} order (n = 3, 5, 7, ..) are located at the frequencies:
   i. (n - 1) / 2 tone-distances above the higher tone
   ii. (n - 1) / 2 tone-distances below the lower tone

c) evaluate the IM product levels in the test item received baseband output signal at the frequencies noted in b) referred to the level of one sine signal of the two-tone in the received baseband signal, using the strongest of the intermodulation products from i. and ii;
the frequency resolution for the measurements in b) and c) should be equal to or less than ¼ of the tone-distance

d) verify the result by comparing it with the results in b) above:
only those IM products can be related to the test item which are at least 6 dB higher in amplitude than those of the test signal measured under b) above

e) perform the measurement for several RF input levels, starting with a level where the resulting received baseband signal peak value is four bits at the test item baseband data interface and up to the limit where either the measured IM distance decreases to 10 dB, or the received baseband signal peak value reaches full-scale of the test item ADC

f) perform the test for different tone-distances;
recommended are:
   i. ¼ of the smallest planned channel bandwidth
   ii. all planned channel spacings
   iii. ¼ of the Usable Bandwidth
   iv. $\lesssim$ ½ of the Usable Bandwidth, with a frequency offset of + ½ tone-distance such that the higher tone is at the upper end of the Usable Bandwidth and one 3rd order IM product is at the lower end of the Usable Bandwidth
   v. $\lesssim$ ½ of the Usable Bandwidth, with a frequency offset of - ½ tone-distance such that the lower tone is at the lower end of the Usable Bandwidth and one 3rd order IM product is at the upper end of the Usable Bandwidth

g) perform the test for at least the max, medium and min receiver gain setting

4.3.1.4.3 Data Reduction and Presentation

a) plot the levels of all measured IM orders (in dB referred to the level of one sine signal of the two-tone) as a function of the peak envelope RF input level

b) if the data can be clearly represented combine the plots for different gain settings in one graphic for each tone-distance

4.4 Immunity to Interference

4.4.1 Out of Band Intermodulation

4.4.1.1 Scope

The objective of this test is to measure the 3rd order intermodulation (IM) products generated in the test item when a strong out of band two-tone signal is present.

4.4.1.2 Facilities and Instrumentation

a) two RF generators
b) bandpassfilter to suppress the noise sidebands of the RF signal at frequency f1 to below the test item receiver noise level at the receive frequency; if necessary also a bandpassfilter to suppress the noise sidebands of the RF signal at frequency f2, which has a higher distance to the receive frequency than f1
c) combiner for the signals from the RF signal generators with sufficient isolation to prevent intermodulation between the generators
d) variable attenuator
e) if necessary an attenuator placed after the RF signal combiner to provide a broadband 50 ohm load to the RF signals at frequencies f1 and f2
f) spectrum analyzer
g) test item received baseband data interface
h) baseband data PSD evaluation

4.4.1.3 Test Conditions

a) normal ambient conditions
b) nominal power supply voltage
c) maximum fixed receiver gain setting (no AGC active)

4.4.1.4 Test Procedure

4.4.1.4.1 Measurement Configuration

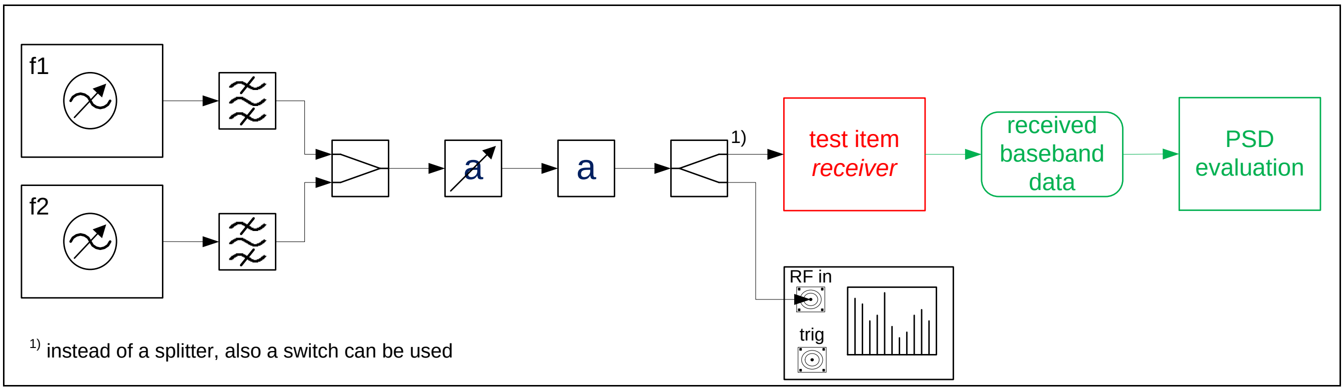


Figure 4.4.1-1: configuration for Out of Band Intermodulation measurement

4.4.1.4.2 Measurement Procedure

a) apply a two-tone RF test signal consisting of two sine signals at equal amplitudes and variable tone-distance at the test item receive port
b) tune the test item and the RF generators according to the following:

$$f_{RX} = 2\,f1 - f2$$

with

f_{RX}:	test item receive frequency
f1:	frequency of RF generator 1
f2:	frequency of RF generator 2

c) set the test item to the maximum receive bandwidth, tune f1 to a value just outside the Usable Bandwidth, and tune f2 according to b)
d) increase the power level of the two-tone until the IM product can be observed in the test item receive output with at least 6 dB SNR or the maximum specified input power is reached;
the 3rd order input intercept point IIP3 can be calculated as:

$$IIP3 = P_{tone} + \tfrac{1}{2}\,(P_{tone} - (S_{IM} - G))$$

with

P_{tone}:	the power level of a single tone of the RF test signal
S_{IM}:	the power level of the intermodulation product at the test item receive interface
G:	the Gain Factor of the test item receiver

e) verify that the level of the IM product at the test item receive output is at least 6 dB higher than the according level from the IM product present in the RF test signal by measuring it using a spectrum analyzer and referring it to the test item receive output with the according test item Gain Factor
f) perform the measurement for frequencies f1 below and above the test item receive frequency f_{RX}, starting with f1 just outside the Usable Bandwidth and increasing the distance to f_{RX} , with f1 covering the operating range of the test item; set f2 according to b);
depending on the used bandpassfilters, the frequency f1 might be held constant while f_{RX} and f2 are varied
g) perform the test for at least a frequency in the low, mid and high operating range; in case the test item has several sub-bands with different hardware configurations, e.g. different preselector filters, perform the test at a mid frequency in each sub-band

4.4.1.4.3 Data Reduction and Presentation

a) present in a table for all measured receive frequencies the derived IIP3 values in dBm versus the frequency distance between f1 and f_{RX}

4.4.2 Dynamic Selectivity

4.4.2.1 Scope

The objective of this test is to determine the Dynamic Selectivity of the test item receiver describing the capability to suppress strong interfering signals as function of the frequency offset to the wanted signal. Insufficient Dynamic Selectivity leads to a decrease of Sensitivity in the presence of strong unwanted signals.

4.4.2.2 Facilities and Instrumentation

a) two RF signal generators
b) bandpassfilter to suppress the noise sidebands of the RF signal at frequency f2 to below the test item receiver noise level at frequency f1
c) if needed, amplifier to increase the power level of the RF signal at frequency f2 and the isolation between the two RF signal generators
d) combiner for the signals from the RF signal generators with sufficient isolation to prevent intermodulation between the generators
e) attenuator placed after the RF signal combiner to provide a broadband 50 ohm load to the RF signal at frequency f2
f) RF power meter
g) variable attenuator
h) test item received baseband data interface
i) baseband data SNR/SINAD evaluation

4.4.2.3 Test Conditions

a) normal ambient conditions
b) nominal power supply voltage
c) activated AGC with nominal settings

4.4.2.4 Test Procedure

4.4.2.4.1 Measurement Configuration

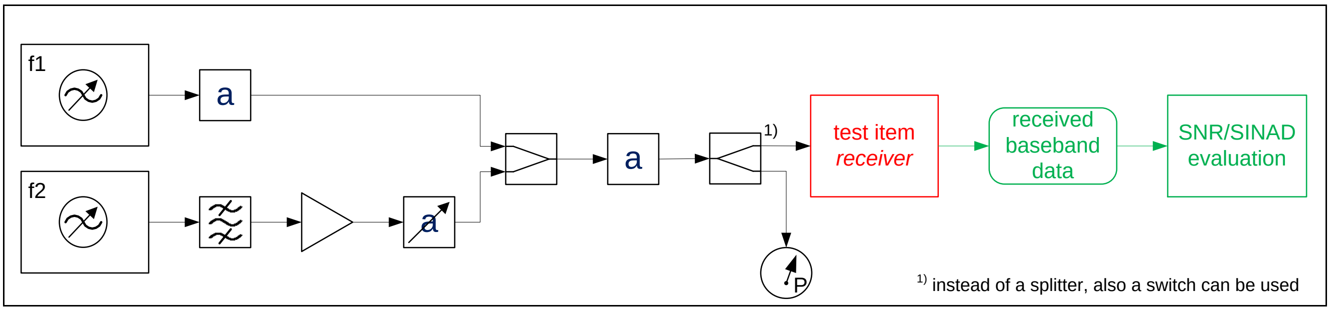


Figure 4.4.2-1: configuration for Dynamic Selectivity measurement

4.4.2.4.2 Measurement Procedure

a) configure the test item to receive at frequency f1

b) for the wanted signal, apply a RF CW signal at the frequency f1 with the specified sensitivity level of the test item at this frequency; even if the actual Sensitivity is higher or lower than specified, use this value as the reference
c) for the unwanted signal, apply a RF CW signal at a frequency f2 with offset $\Delta f = |f1 - f2|$ and increase its power level until the SINAD ratio of the wanted signal is reduced 3 dB in respect to the SINAD for the specified sensitivity (see also 4.1.4)
d) the Selectivity of the test item receiver for the frequency offset Δf is the difference between this level and the reference value of the wanted signal
e) vary the frequency offset Δf in both directions from the minimum planned channel spacing to the frequency range of interest, at least 10% of f1; when using a fixed narrowband bandpassfilter for the signal at f2, the unwanted signal can remain at f2 and the frequency of the wanted signal can be varied, together with the test item receive frequency
f) perform the test for at least a frequency in the low, mid and high operating range; in case the test item has several sub-bands with different hardware configurations, e.g. different preselector filters, perform the test at a mid frequency in each sub-band

4.4.2.4.3 Data Reduction and Presentation

a) for each tested receive frequency, plot the Dynamic Selectivity curve in dB versus the frequency offset Δf
b) note discrete drops in the curve as Spurious Responses

4.4.3 Blocking

4.4.3.1 Scope

The objective of this test is to determine the Blocking level of the test item receiver at which an unwanted signal outside the passband leads to compression of the wanted output signal. The effects of Blocking are similar to those of desensitization as measured by the test for Dynamic Selectivity (see 0) but independent of the power level of the wanted signal: whereas the criterion for desensitization is a reduced SINAD, here the reduction of the wanted signal level is used.

4.4.3.2 Facilities and Instrumentation

a) two RF signal generators
b) bandpassfilter to suppress the noise sidebands of the RF signal at frequency f2 to below the RF signal power level at frequency f1
c) if needed, amplifier to increase the power level of the RF signal at frequency f2 and the isolation between the two RF signal generators
d) combiner for the signals from the RF signal generators with sufficient isolation to prevent intermodulation between the generators

e) attenuator placed after the RF signal combiner to provide a broadband 50 ohm load to the RF signal at frequency f2
f) RF power meter
g) variable attenuator
h) test item received baseband data interface
i) baseband data PSD evaluation

4.4.3.3 Test Conditions

a) normal ambient conditions
b) nominal power supply voltage
c) activated AGC with nominal settings

4.4.3.4 Test Procedure

4.4.3.4.1 Measurement Configuration

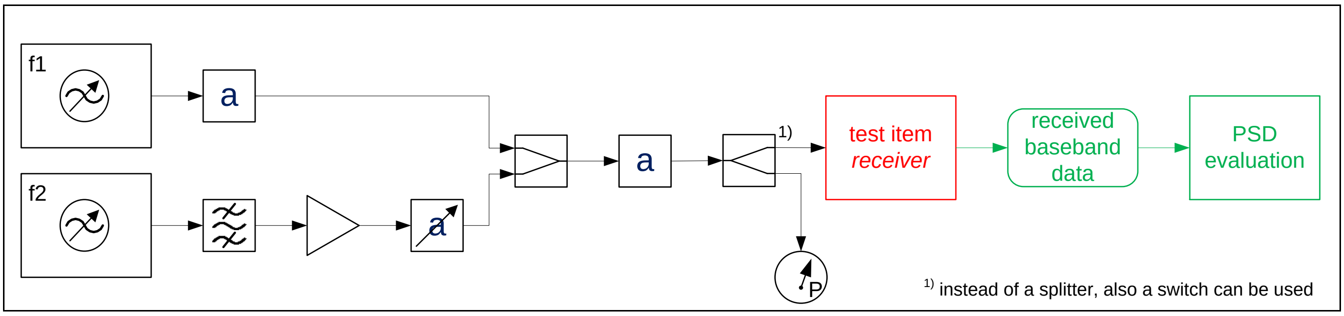


Figure 4.4.3-1: configuration for Blocking measurement

4.4.3.4.2 Measurement Procedure

a) configure the test item to receive at frequency f1
b) for the wanted signal, apply a RF CW signal at the frequency f1 with the specified sensitivity level of the test item at this frequency; even if the actual Sensitivity is higher or lower than specified, use this value as the reference
c) for the unwanted signal, apply a RF CW signal at a frequency f2 with offset $\Delta f = |f1 - f2|$ and increase its power level until the power level of the wanted signal at the test item receive output is reduced by 3 dB
d) the Selectivity of the test item receiver for the frequency offset Δf is the difference between this level and the reference value of the wanted signal
e) vary the frequency offset Δf in both directions from 5% to the frequency range of interest or up to the operating range; when using a fixed narrowband bandpassfilter for the signal at f2, the unwanted signal can remain at f2 and the frequency of the wanted signal can be varied, together with the test item receive frequency
f) perform the test for at least a frequency in the low, mid and high operating range; in case the test item has several sub-bands with different hardware configurations, e.g. different preselector filters, perform the test at a mid frequency in each sub-band

4.4.3.4.3 Data Reduction and Presentation

a) for each tested receive frequency, plot the Blocking curve in dB versus the frequency offset Δf
b) note discrete drops in the curve as Spurious Responses

4.4.4 Input Protection

4.4.4.1 Scope

The objective of this test is to verify the Input Protection of the test item as capability to function properly after a strong input signal was present at its input for a defined duration.

4.4.4.2 Facilities and Instrumentation

a) RF signal generator capable of generating a sufficiently high signal level, if necessary together with a power amplifier
b) RF power meter
c) variable attenuator
d) test item received baseband data interface
e) baseband data SNR/SINAD evaluation

4.4.4.3 Test Conditions

a) normal ambient conditions
b) nominal power supply voltage
c) activated AGC with nominal settings

4.4.4.4 Test Procedure

4.4.4.4.1 Measurement Configuration

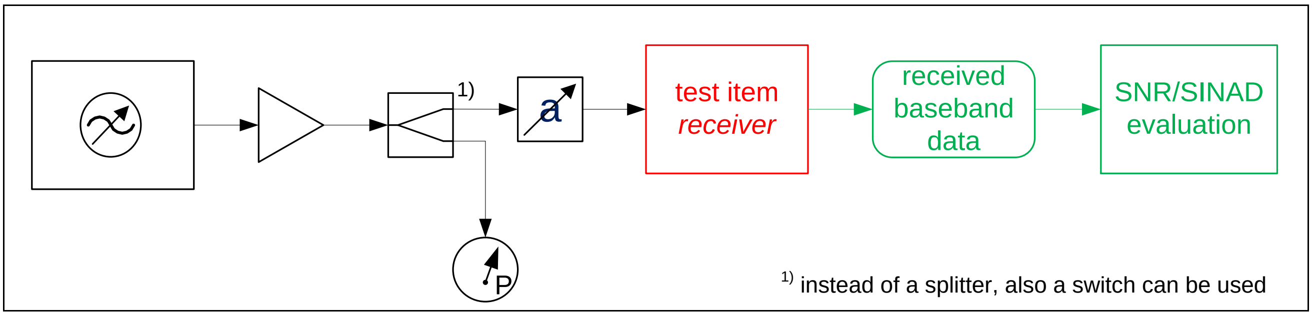


Figure 4.4.4-1: configuration for Input Protection measurement

4.4.4.4.2 Measurement Procedure

a) measure the Sensitivity of the test item according to 4.1.3
b) apply a high power RF CW signal with the same frequency as for a) at the test item receive input with the maximum power level and the maximum duration specified for not damaging the test item
c) measure again the Sensitivity of the test item
d) the test item Input Protection is effective up to the tested signal level and duration when the Sensitivity measurements differ only within the measurement uncertainty of the measurement setup
e) perform the measurement for all test item receive settings which might have an impact on the Input Protection, e.g. activated/de-activated LNA or different AGC settings
f) perform the test for a frequency in the low, mid and high operating range; in case the test item receiver has several sub-bands with different hardware configurations, e.g. different preselector filters, do the measurements for a frequency in the low, mid and high range of the sub-band

4.4.4.4.3 Data Reduction and Presentation

a) state the conditions and frequencies for which the Input Protection was tested and, if the test criterion was not met, note the test item Sensitivity before and after applying the high power test signal

4.4.5 Spurious Response

4.4.5.1 Scope

The objective of this test is to determine the Spurious Responses of the test item receiver. Spurious Responses are caused by RF signals at frequencies different from the tuned frequency which are translated by the test item circuits and induce a measurable signal at test item receiver output. They are caused e.g. by nonlinearities in the receiver input or by insufficient suppression of oscillator harmonics.

Intermediate frequency and image frequency are special cases of Spurious Responses.

4.4.5.2 Facilities and Instrumentation

a) RF signal generator
b) test item received baseband data interface
c) baseband data SNR/SINAD evaluation

4.4.5.3 Test Conditions

a) normal ambient conditions
b) nominal power supply voltage
c) activated AGC with nominal settings

4.4.5.4 Test Procedure

4.4.5.4.1 Measurement Configuration

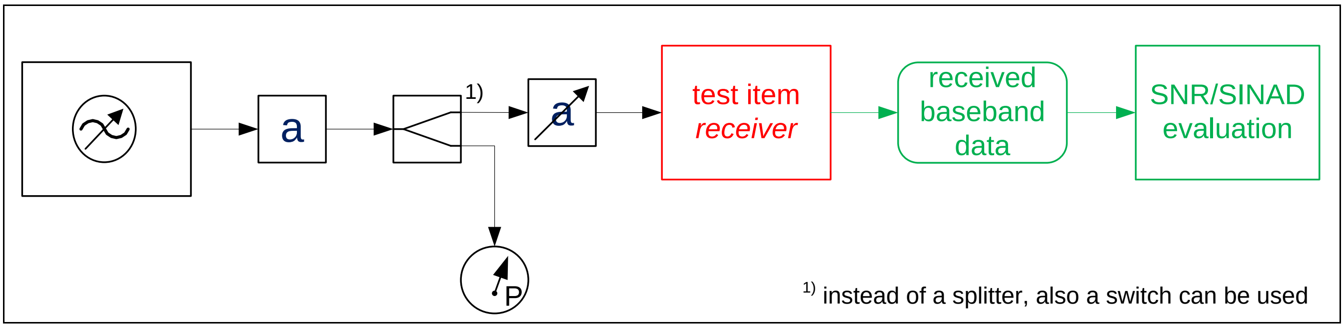


Figure 4.4.5-1: configuration for Residual Spurious Response measurement

4.4.5.4.2 Measurement Procedure

a) apply a RF CW signal at the frequency f1 with a power level P_{ref} resulting in a receiver output signal with the SNR specified for its Sensitivity; use this value as the reference and note the power level $S_{rx,ref}$ of the according signal at the test item receive output

b) keep the test item receiving at f1 and change the RF signal generator to a frequency f2; increase its power level P_{spur} until a signal at the test item receive output is induced with the same resulting level $S_{rx,ref}$ as in a) or the maximum specified input power level is reached

c) the Spurious Response suppression is the difference between this RF signal level P_{spur} and the reference level P_{ref} of the test item receiver

d) perform the test for all frequencies where a Spurious Response might occur; the minimum set are the frequencies complying with the following condition for the main spurious frequencies:

$$\pm q\, f_{spur} \pm p\, f_{LO} = f_{if}$$

with

f_{spur}:	frequency of a Spurious Response
f_{LO}:	frequency of the test item first local oscillator
f_{if}:	intermediate frequency of the test item
q:	positive integer, denoting the harmonic order of the test item input signal
p:	0 or positive integer, denoting the harmonic order of the test item local oscillator

for the intermediate frequency:	q = 1 and p = 0
for the image frequency:	q = 1 and p = 1

e) perform the test for a frequency in the low, mid and high operating range; in case the test item has several sub-bands with different hardware configurations, e.g. different preselector filters, perform the test at a mid frequency in each sub-band

4.4.5.4.3 Data Reduction and Presentation

a) for each receive frequency f1, present in a table all Spurious Response frequencies and the according suppression in dB
b) identify the image and intermediate frequency

4.5 Timing

4.5.1 Receiver Hop Time

4.5.1.1 Scope

The objective of this test is to measure the minimum required timespan for the test item to switch between two receive frequencies. Optionally, also the delay between the command to switch the frequency and the actual effect of the command can be measured.

Definitions:

The Receiver Hop Time is the time between the moment when the level of the signal from the original receive frequency at the test item receive output has dropped to 90% of its steady state value, and the moment when the level of the signal from the new receive frequency at the test item receive output has reached 90% of its steady state value.

The Receiver Hop Command Delay is the time between the moment when the Receiver Hop command is transferred completely to the test item command interface, and the moment when the level of the signal at the test item receive output has dropped to 90% of its steady state value.

There are two possibilities for the receive baseband data interface to handle the frequency switching:

a) *continuously sampled baseband data*:
the interface provides an uninterrupted seamless data stream during the frequency change even when part of the data might not be useful; in this case timing relations can be calculated directly from the baseband data

b) *not continuously sampled baseband data*:
during the frequency change the baseband data stream is shortly stopped, resulting in a gap in the data with unknown duration; in this case, some sort of time synchronization between the data before and after the frequency change has to be provided, proposed here by introducing a periodic amplitude modulation to the test signals

4.5.1.2 Facilities and Instrumentation

a) two RF signal generators, their outputs combined
b) test item received baseband data interface
c) baseband data time / frequency evaluation
d) change frequency command sequence
e) spectrum analyzer
f) continuously variable attenuator

In case the received baseband data is not continuously sampled:

g) arbitrary waveform generator

4.5.1.3 Test Conditions

a) normal ambient conditions

b) nominal power supply voltage
c) fixed receiver gain setting (no AGC active)

4.5.1.4 Test Procedure

4.5.1.4.1 Measurement Configuration

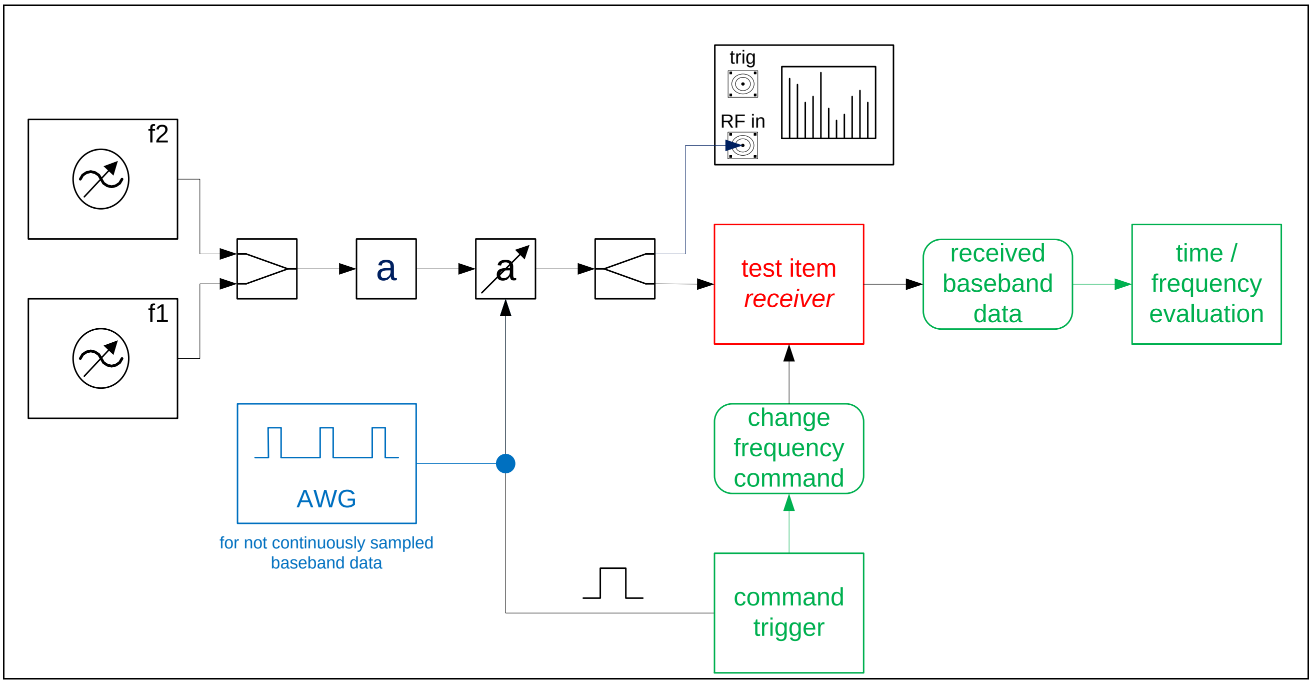


Figure 4.5.1-1: configuration for Receiver Hop Time measurement

4.5.1.4.2 Measurement Procedure (continuously sampled baseband data)

a) tune one signal generator to the frequency f1, the other to the frequency f2, with the level set equal and resulting in a sufficiently high signal-to-noise ratio at the test item receiver
b) configure the test item to receive at frequency f1
c) start recording received baseband data, then trigger a change frequency command to set the receive frequency to f2
d) in case the command delay shall also be measured, modulate the amplitude of the signal at frequency f1 with the command trigger pulse by applying the trigger signal as control voltage to a continuously variable attenuator in the RF signal path, resulting in a short dip in the signal magnitude; use a command which changes the receive frequency immediately

e) derive the time delay from the recorded baseband data according to the following:

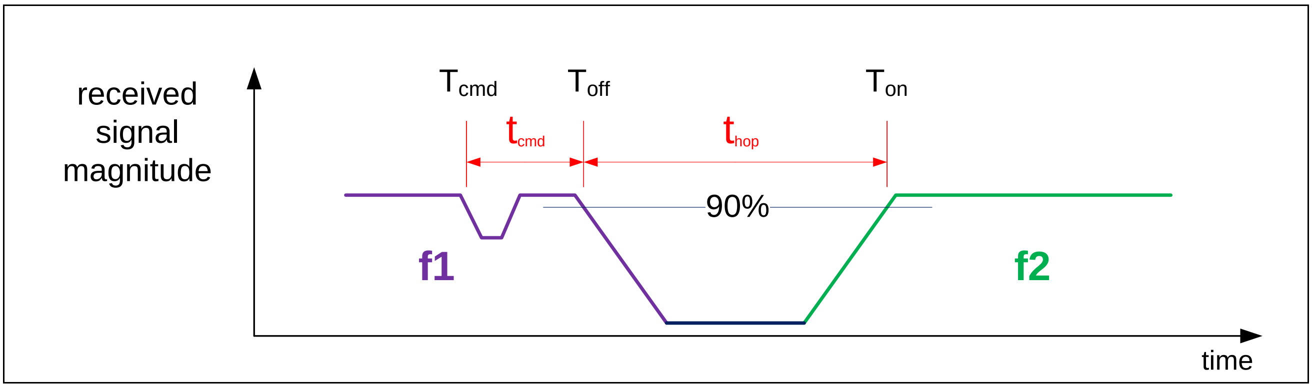


Figure 4.5.1-2: Receiver Hop Time in continuously sampled baseband data

i. T_{off} is the time where the signal magnitude (from the RF signal at frequency f1) has decreased to 90% of its steady state value

ii. T_{on} is the time where the signal magnitude (from the RF signal at frequency f2) has increased to 90% of its steady state value and – if applicable - the frequency deviation is equal or smaller than the required value

iii. the receive frequency hop time t_{hop} is the time between T_{off} and T_{on}

iv. T_{cmd} is the time where the begin of the command trigger pulse can be observed in the signal magnitude (from the RF signal at frequency f1), corrected for the delay between the trigger signal and the command being completely transferred to the test item command interface (not shown in diagram)

v. the command delay t_{cmd} is the time between T_{cmd} and T_{off}

vi. the receive frequency hop time $t_{hop(cmd)}$ - *including the command delay* - is t_{cmd} + t_{hop}

f) repeat the measurement at least three times for the same frequency hop and observe variations of the hop time

g) perform the test for all hop distances of interest

Notes:

In case the time points in the received baseband data cannot be observed clearly, different frequency offsets (within the receive bandwidth of the test item) for the RF test signals at f1 and f2 can be applied, allowing to better distinguish the two signals in the received baseband data by using narrow bandpass filters in digital signal processing, which are tuned to the respective offset frequencies.

In case of excessive ringing or overshoot, a criterion different from the 90% level can be chosen, e.g. the level where the first overshoot reaches 110% of the steady state value.

4.5.1.4.3 Measurement Procedure (not continuously sampled baseband data)

If the received baseband data is not continuously sampled during the frequency hop, there is a gap in the recorded data with unknown duration. In this case, a time synchronization signal has to be applied to the RF test signals by modulating its amplitudes with a pulse train.

This can be done by generating a time synchronization pulse train using an arbitrary waveform generator and applying its output as control voltage to a continuously variable attenuator in the RF signal path, as depicted in Figure 4.5.1-1

The time period of the synchronization pulse train has to be larger than the maximum expected hop time to avoid ambiguity of the results.

Perform the tests according to 4.5.1.4.2 except for e):

e) derive the time delay from the recorded baseband data according to the following:

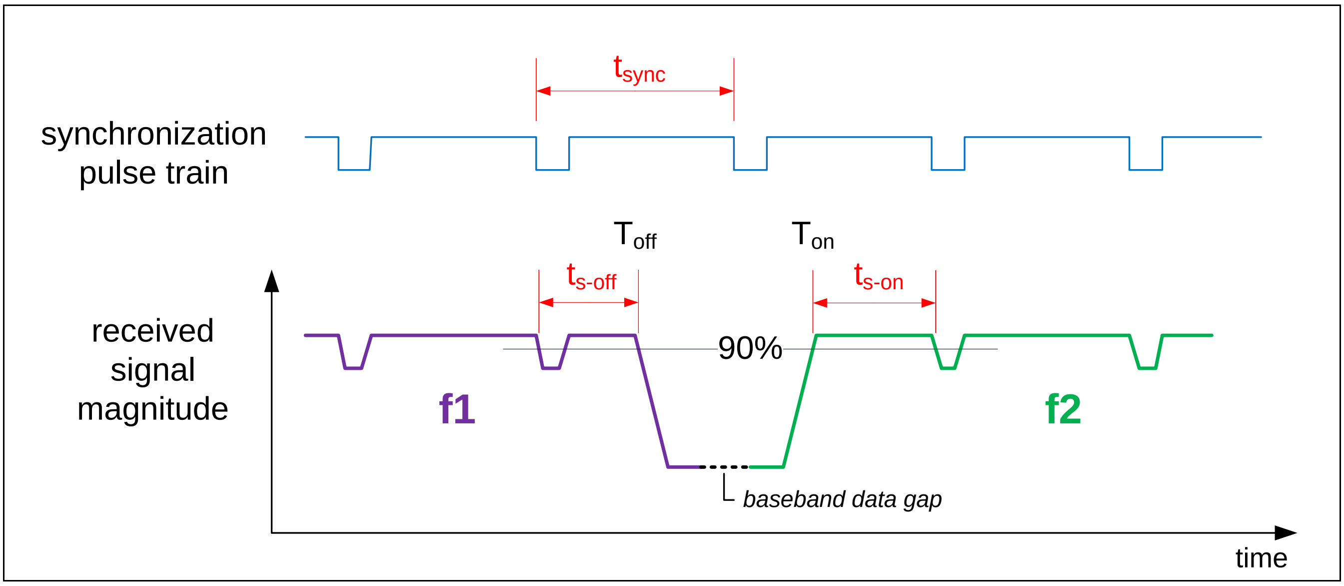


Figure 4.5.1-3: Receiver Hop Time in non-continuously sampled baseband data

i. T_{off} is the time where the signal magnitude (from the RF signal at frequency f1) has decreased to 90% of its steady state value

ii. T_{on} is the time where the signal magnitude (from the RF signal at frequency f2) has increased to 90% of its steady state value and – if applicable - the frequency deviation is equal or smaller than the required value

iii. the sync-to-off time $t_{s\text{-}off}$ is the time between the begin of the last synchronization pulse in the signal magnitude (from the RF signal at frequency f1) and T_{off}

iv. the sync-to-on time $t_{s\text{-}on}$ is the time between T_{on} and the begin of the next synchronization pulse in the signal magnitude (from the RF signal at frequency f2)

v. t_{sync} is the period of the time synchronization pulse train

vi. the receive frequency hop time t_{hop} can be calculated as follows:

$$t_{hop} = \begin{cases} 2 \cdot t_{sync} - t_{s-off} - t_{s-on} & for\ (t_{s-off} + t_{s-on}) > t_{sync} \quad \text{(I)} \\ t_{sync} - t_{s-off} - t_{s-on} & otherwise \quad \text{(II)} \end{cases}$$

with the condition $t_{hop} < t_{sync}$

in case (I), one synchronization pulse falls in the gap of the non-continuously sampled baseband data as depicted in Figure 4.5.1-3;
in case (II), all synchronization pulses are observed in the baseband data

Note:
In case of excessive ringing or overshoot, a criterion different from the 90% level can be chosen, e.g. the level where the first overshoot reaches 110% of the steady state value.

4.5.1.4.4 Data Reduction and Presentation

a) list in a table the maximum measured hop time for each hop distance and note the observed variations
b) if measured, state the maximum command delay and note its observed variation as well as the maximum hop time including command delay

4.5.2 Transmit-to-Receive Delay

4.5.2.1 Scope

The objective of this test is to measure the required timespan for the test item to switch from transmitting to receiving at the same frequency. Also, the delay between the command to switch to receive and the actual effect of the command can be measured.

The test is applicable only for half-duplex transceivers.

Definitions:

The Transmit-to-Receive Delay is the time between the moment when the level of the transmitted signal at the test item transmit output has dropped to 90% of its steady state value, and the moment when the level of the signal at the test item receive output has reached 90% of its steady state value.

The Transmit-to-Receive Command Delay is the time between the moment when the Transmit-to-Receive command is transferred completely to the test item command interface, and the moment when the level of the signal at the test item transmit output has dropped to 90% of its steady state value.

4.5.2.2 Facilities and Instrumentation

a) RF signal generator

b) arbitrary Waveform Generator
c) two continuously variable attenuators
d) spectrum analyzer with time domain evaluation
e) test item received baseband data interface
f) baseband data time / frequency evaluation
g) receive command sequence

4.5.2.3 Test Conditions

a) normal ambient conditions
b) nominal power supply voltage
c) fixed receiver gain setting (no AGC active)

4.5.2.4 Test Procedure

4.5.2.4.1 Measurement Configuration

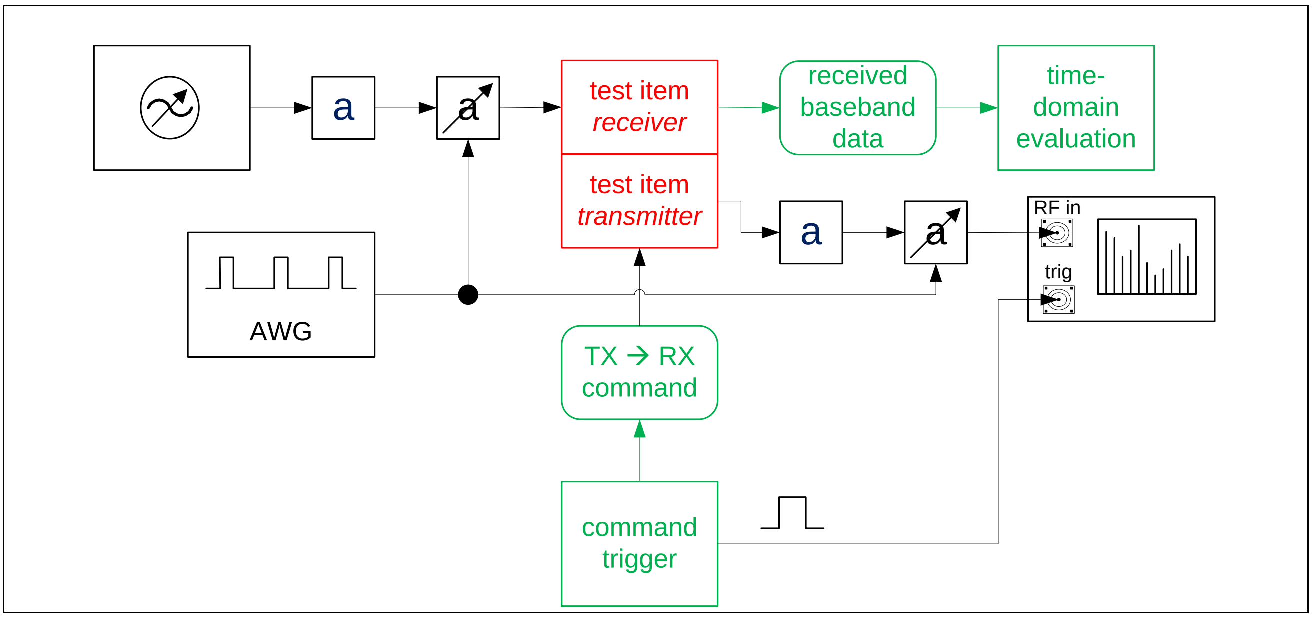


Figure 4.5.2-1: configuration for Transmit-to-Receive Delay measurement

4.5.2.4.2 Measurement Procedure

a) tune the spectrum analyzer to the test item transmit frequency
b) tune the signal generator to the test item receive frequency, which should be the same as the transmit frequency
c) generate a time synchronization pulse train using an arbitrary waveform generator and apply its output as control voltage to the continuously variable attenuators in the RF receive path and the RF transmit path;
the time period of the synchronization pulse train has to be larger than the maximum expected Transmit-to-Receive Delay to avoid ambiguity of the results

d) configure the test item to transmit a CW signal
e) command the test item to switch from transmit to receive
f) derive the time delay from the recorded baseband data according to the following:

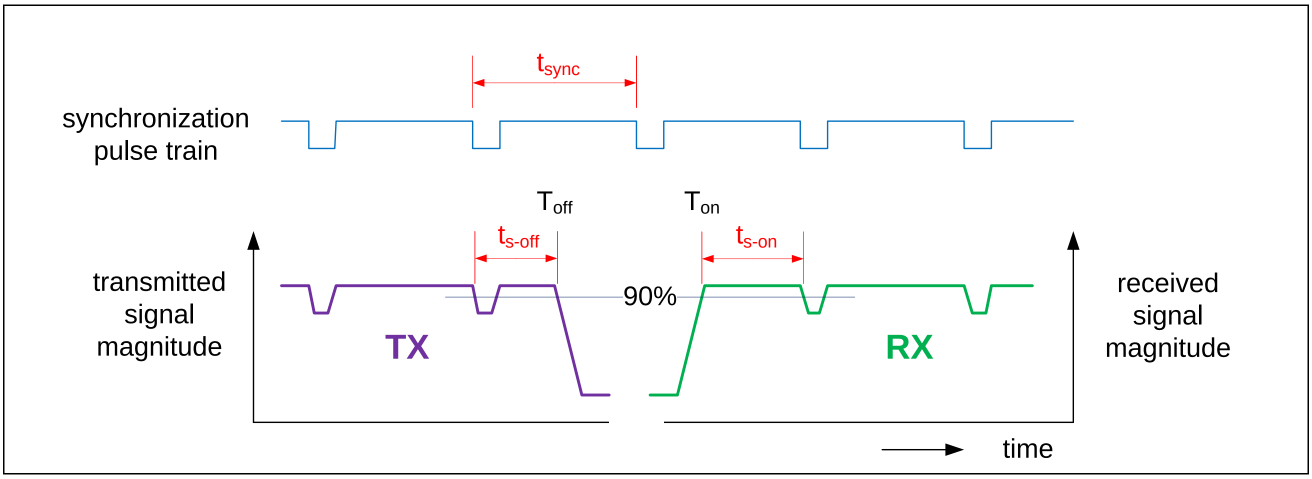


Figure 4.5.2-2: Transmit-to-Receive Delay

i. T_{off} is the time where the magnitude of the transmit signal has decreased to 90% of its steady state value
ii. T_{on} is the time where the signal magnitude of the received baseband data has increased to 90% of its steady state value and – if applicable - the frequency deviation is equal or smaller than the required value
iii. the sync-to-off time $t_{s\text{-}off}$ is the time between the begin of the last synchronization pulse in the magnitude of the transmit signal and T_{off}
iv. the sync-to-on time $t_{s\text{-}on}$ is the time between T_{on} and the begin of the next synchronization pulse in the signal magnitude of the received baseband data
v. t_{sync} is the period of the time synchronization pulse train

the transmit-to-receive delay $t_{TX\text{-}RX}$ can be calculated as follows:

$$t_{TX-RX} = \begin{cases} 2 \cdot t_{sync} - t_{s-off} - t_{s-on} & for\ (t_{s-off} + t_{s-on}) > t_{sync} \quad (\mathrm{I}) \\ t_{sync} - t_{s-off} - t_{s-on} & otherwise \quad (\mathrm{II}) \end{cases}$$

with the condition $t_{TX\text{-}RX} < t_{sync}$

in case (I), one synchronization pulse falls in the gap of the transmit-to-receive transition as depicted in Figure 4.5.2-2;
in case (II), all synchronization pulses are observed in the transmit and receive data

To measure also the command delay, do the following:

g) disable the synchronization pulse

h) send a command to the test item to switch immediately from transmit to receive, triggering the spectrum analyzer at the same time
i) derive the command delay from the transmit signal according to the following:

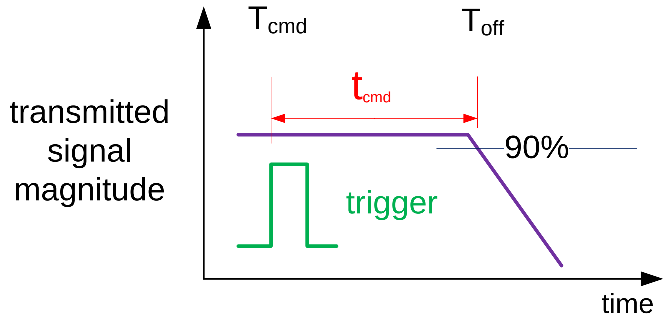


Figure 4.5.2-3: Transmit-to-Receive Command Delay

vii. T_{cmd} is the time of the command trigger, corrected for the delay between the trigger signal and the command being completely transferred to the test item command interface (not shown in diagram)
viii. T_{off} is the time where the magnitude of the transmit signal has decreased to 90% of its steady state value
ix. the command delay t_{cmd} is the time between T_{cmd} and T_{off}

Note:
In case of excessive ringing or overshoot, a criterion different from the 90% level can be chosen, e.g. the level where the first overshoot reaches 110% of the steady state value.

4.5.2.4.3 Data Reduction and Presentation

a) note the measured Transmit-to-Receive Delay and the according command delay

5 Related Documents

[1] International Test Procedures (ITOP) 6-2-242 Analog Communication Transmitter and Receiver Test Procedures, 13.10.1993

[2] International Test Procedures (ITOP) 6-2-246, Digital Communication Transmitter and Receiver Test Procedures, 12.10.1995

6 List of Figures

7 List of Tables