SIGFOX RADIATED PERFORMANCE TEST SPECIFICATIONS

Version 2.0.4

PUBLIC

Changes description

Version	Description	Author	Date
0.1	Initial spec	B.Ray	August 15th, 2017
0.2	Antenna gain in dB	B.Ray	October 5th, 2017
0.3	RC3, RC5	B.Ray	November 16th, 2017
0.4	RC6	B.Ray	May 23rd, 2018
0.5	Adapt wording to fit new approach	B.Ray	September 14th, 2018
1.0	Combination of specification and test plan in a single new document. All § modified.	V.GAMONAL	July 26th, 2019
2.0.0	Improvement of the document	H. Ardiller	February 20th, 2020
2.0.2	RC3 updated	L.Bordes	October 15th, 2020
2.0.3	RC1 & RC7 update	A. Trombetta	Feb 2nd, 2021
2.0.4	Add note on Singapore regulation	L.Bordes	October 14th,2021

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SUMMARY

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1. Scope

This document is applicable to Sigfox partners planning the radiated tests of the Sigfox Ready ™ certification.

This document specifies technical characteristics and test methods for each radiated test being performed in the conformance assessment of Sigfox devices.

Important:

The Sigfox Ready™ certification for device does not substitute local regulatory requirements (CE marking, FCC, ETSI or other type approval) where the device is to be deployed.

It is the partner's responsibility to comply with local country regulations.

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2. Definitions and Acronyms

2.1. Acronyms

Acronyms	Meaning
CW	Continuous wave
DUT	Device Under Test
EIRP	Effective Isotropic Radiated Power
EIRS	Effective Isotropic Radiated Sensitivity
ERP	Effective Radiated Power
ETSI	European Telecommunications Standards Institute
FAR	Fully Anechoic Room
GFSK	Gaussian Frequency Shift Keying
LNA	Low-Noise Amplifier
OATS	Open Area Test Site
OTA	Over-The-Air
SAR	Semi Anechoic Room
SCA	Sigfox Certification Authority
RC	Radio Configuration
RF	Radio Frequency
RX	Receive
TX	Transmit
VSWR	Voltage Standing Wave Ratio

Table 1: Acronyms

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2.2. DEFINITIONS

DEVICE:

A manufactured end-product that is intended for use by end-user customers on the Sigfox network.

DEVICE UNDER TEST:

Candidate device for certification and used as reference product during the test.

EFFECTIVE RADIATED POWER (ERP):

The power radiated in the direction of maximum field strength under specified conditions of measurements.

$ERP_{dBm} = Conducted\_RF\_Power_{dBm} + Antenna\_Gain_{dB}$

EFFECTIVE ISOTROPIC RADIATED POWER (EIRP):

EIRP refers to an isotropic antenna whereas ERP refers to a perfect dipole antenna. The relation between ERP and EIRP is:

$\mathbf{EIRP}_{dBm} = \mathbf{ERP}_{dBm} + \mathbf{2.15}_{dB}$

PARTNER:

The person/company developing a Sigfox product which can be either a Modular Design, Device intended to go through the Sigfox certification process.

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Radiation pattern:

The variation of the power radiated by an antenna as a function of the direction away from the antenna. This power variation, as a function of the arrival angle, is observed in the antenna's far field.

Radiated receiver sensitivity:

The minimum level of signal at the receiver input, produced by a carrier at the nominal frequency of the receiver, modulated with the normal test signal modulation.

Sigfox Accredited test house:

is a test house accredited by Sigfox to execute Sigfox RF & protocol tests and/or Sigfox radiated performance tests.

Sigfox Ready™ certification:

is the certification required for each Device that is intended to operate on the Sigfox Network.

Sigfox Certification Specifications:

term used in this document and build.sigfox.com covering Sigfox RF & protocol specifications and Sigfox Radiated performance specifications.

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3. Statements

It is the partner responsibility to implement during device integration the hardware achieving a balanced uplink/downlink budget and providing equivalent service map in both communication ways. (Applicable for Uplink/Downlink devices)

Device field radio environment can largely vary depending on the targeted application. An object located on a telecommunication tower needs higher protection from radio interference than an object set in a confined environment. Thus, the partner must pay attention to receive radio parameters (sensitivity, selectivity, blocking ...).

Sigfox Verified™ modular design includes intrinsic radio characteristics that can be improved or altered during final product integration by adding components such as filters, LNA, switches...Sigfox recommends to partners to measure device global performance and radio parameters.

The antenna must be designed or selected to comply with transmit but also with receive nominal operation bandwidth.

Depending on the DUT final use-case, device uplink class and environment, Sigfox reserves the right to perform a field test in order to certify the DUT in its dedicated environment.

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4. Test Setup

Below, the test's conditions to be observed:

- Measurements shall be carried out under ambient conditions of temperature, humidity, pressure.
- The DUT must be tested in a full anechoic room (OTA for example), Semi-anechoic room (SAR) or Open Area Test Site (OATS).
- In case the measurement is carried out in a semi-anechoic room, it is required to install some absorbers on the floor to avoid main reflections.
- The test equipment must be adapted to the working frequencies (sub Giga).
- The test equipment must be calibrated periodically:
- External calibration for spectrum analyzer and RF generator
- Normalized Site Attenuation and VSWR for FAR
- The measurement uncertainty must be less than ±3dB with an expansion factor k=2 offering a confidence level of 95.45%.

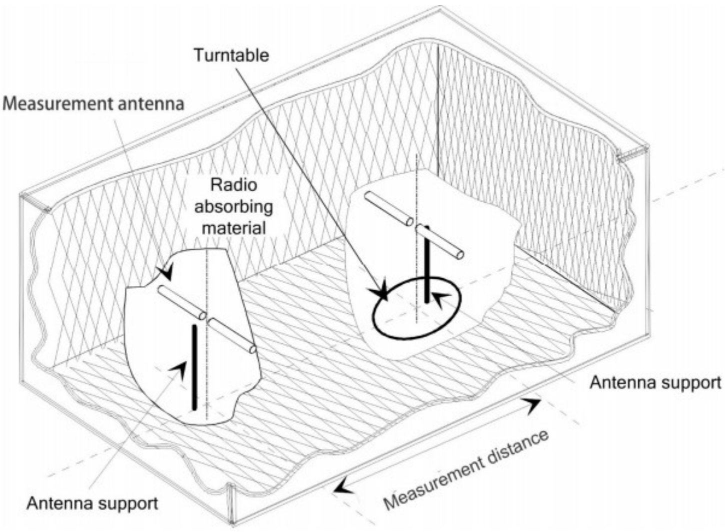

Figure 1: Fully Anechoic room (FAR)

Coordinate system anechoic chamber (OTA) can also be used for testing.

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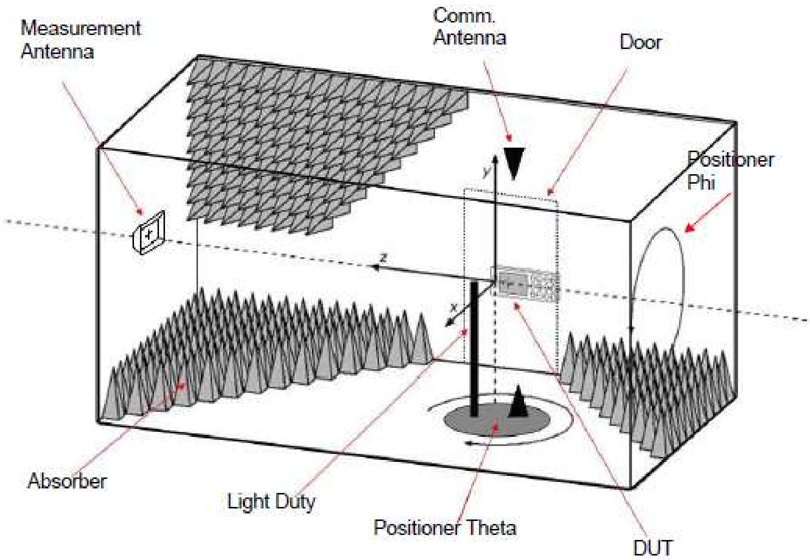

Figure 2: Coordinate system anechoic chamber (OTA)

Measurement antenna is connected to a spectrum analyser.

The chamber and the cable loss must be calibrated at least up to 1 GHz.

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4.1. BUDGET LINK TEST SETUP (OPTIONAL)

- The DUT must use the RX-GFSK test mode (available in Sigfox library).
- The DUT must be oriented in position offering the strongest radiated power (max EIRP) as determined during the TX measurement.
- The receiver sensitivity test is optional but highly recommended. It only applies to DUT operating in bidirectional communication way.

Two test setups are described depending on the test house available equipment.

Test setup 1: Anechoic chamber without spy antenna

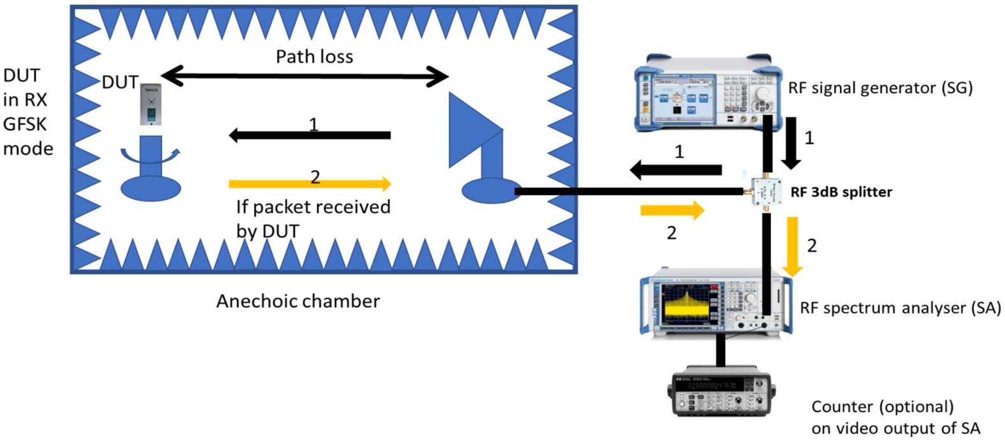

Figure 3: Test setup 1 – Anechoic chamber without spy antenna

Test setup 2: Anechoic chamber with spy antenna

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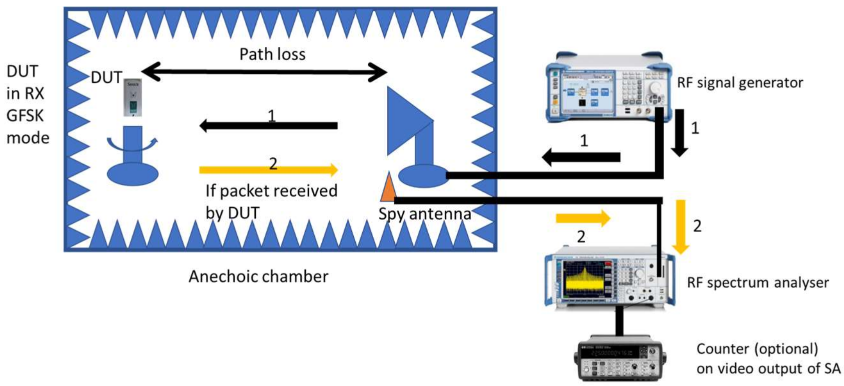

Figure 4: Test setup 2 - Anechoic chamber with spy antenna

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5. MAXIMUM EFFECTIVE ISOTROPIC RADIATED POWER

5.1. DESCRIPTION

The DUT EIRP is measured to assess device transmitter's radiated performances. Sigfox requires a radiated performance test for each targeted RC.

Note: if applying for RC1 and RC7, as the two RCs have very close operational frequencies, only one radiated performance test of either RC1 or RC7 is required.

The Sigfox Ready™ devices (DUT) will be classified in each RC, based on the EIRP measurement value, as 3u, 2u, 1u, 0u accordingly to the table below:

RC	Class 3u	Class 2u	Class 1u	Class 0u	Maximum
	EIRP	EIRP	EIRP	EIRP	recommended
RC1	P < 2 dBm	2 ≤ P < 7 dBm	7 ≤ P< 12 dBm	≥ 12 dBm	16 dBm
RC2	P < 10 dBm	10 ≤ P < 15 dBm	15 ≤ P < 20 dBm	≥ 20 dBm	24 dBm
RC3	P < 2 dBm	2 ≤ P < 7 dBm	7 ≤ P < 12 dBm	≥ 12 dBm	16 dBm
RC4*	P < 10 dBm	10 ≤ P < 15 dBm	15 ≤ P < 20 dBm	≥ 20 dBm	24 dBm
RC5	P < 0 dBm	0 ≤ P < 5 dBm	5 ≤ P < 10 dBm	≥ 10 dBm	14 dBm
RC6	P < 2 dBm	2 ≤ P < 7 dBm	7 ≤ P < 12 dBm	≥ 12 dBm	16 dBm
RC7	P ≤ 2 dBm	2 ≤ P < 7 dBm	7 ≤ P < 12 dBm	≥ 12 dBm	16 dBm

Table 2: Uplink Sigfox classification

The classification must be granted by Sigfox Certification Authority (SCA) only. The class to consider is indicated in the Sigfox Certificate.

DUT EIRP must conform with the high limit of the local regulation in each RC.

**Warning, if the EIRP measurement value is higher than 22 dBm, the product may not be compliant with Singapore regulations.*

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Nevertheless, Sigfox will give a high limit recommendation to comply with its technology approach of:

- Low consumption
- Balanced budget link between uplink and downlink

It is highly recommended to achieve the Sigfox recommended limits.

Important:

Integration of the antenna into the device is a critical part of the device design. Severe degradation of performance may occur if antenna integration is not properly analysed.

The partner is responsible for adjusting device radio parameters (radiated power, harmonics…) in order to meet performances in the final application environment.

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5.2. TEST PROCEDURE

The specification to be observed during the measurement are following:

- Depending on the applicable RC, the measurement method shall be:
  - RC1, RC3, RC5, RC6, RC7: ETSI EN 300.220-1
  - RC2, RC4: FCC Part15 and ANSI C63 series
- The DUT shall be operated in unmodulated continuous wave test mode.
- The DUT shall transmit at center frequency of the RC. Frequencies by RC are indicated in the next table.

RC	Frequency (MHz)
RC1	868.130
RC2	902.200
RC3	923.200
RC4	920.800
RC5	923.300
RC6	865.200
RC7	868.800

Table 3: Center frequencies by RC

- In the case of adjustable power, the transmission must be done at maximum level. If several power supplies are possible, the measurement must be performed for each power source.
- If the DUT is declared by the manufacturer with a single orientation for the application, the EIRP peak can be searched accordingly to this orientation only.
- If the DUT is declared by the manufacturer as a multi-position, the EIRP peak must be searched for all three possible orientations.

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5.3. RESULTS

The results shall respect the following specifications:

- The maximum EIRP must be expressed in dBm in the report
    - EIRP = ERP + 2.15 dB
- The maximum EIRP must be reported considering only one polarization and **not the combination of both polarizations**.
- The DUT orientation providing the maximum EIRP must be indicated, angular orientation from the start position for example.
- The polarization offering the maximum EIRP must indicated.

All information previously listed must appeared in a table.

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6. Radiation pattern

6.1. Description

The radiation pattern is the variation of the power radiated by an antenna depending on the orientation considered.

An antenna radiates energy in most cases with some directional dependence.

Radiation pattern measurement gives information of the radiation pattern shape and antenna polarization.

DUT shall show an omni-directional pattern to comply with the star Sigfox network topology.

Directional antenna is allowed in case of dedicated end-user application (ex: device mounted on a wall can radiate in the main direction opposite to the wall).

6.2. Test Procedure

The specification to be observed during the measurement are following:

- The DUT shall be set in unmodulated carrier test mode.
- In case of adjustable power, the transmission must be done at maximum level.
- The DUT shall transmit at center frequency of the RC (see the table 3).
- Depending on the device maker's declaration, single or multi-positions device, the radiation pattern can be measured while the DUT turns on only one axis or three axes to provide a full 3D graphical representation.
- The radiation pattern in vertical and horizontal polarization shall be derived from the DUT where maximum EIRP occurs. It shall be normalized to maximum EIRP value and represented in polar coordinates. The measurement unit is dBm
- Both polarizations must be considered during radiation pattern measurement but separately; the final representation shall not show only the combination of both polarizations.

- Radiated power is recorded for every 5° step of the turn table in vertical and horizontal polarization.
- For multi-position DUT, the angular position step (azimuth) shall be equal or less than 5° and the tilt position step (elevation) shall be equal or less than 10°.

The radiation pattern must be performed as quickly as possible to prevent a drop of battery voltage along the measurement.

6.3. Results

The radiation pattern can be represented by 2D or 3D graphs following the software tools available in the laboratory.

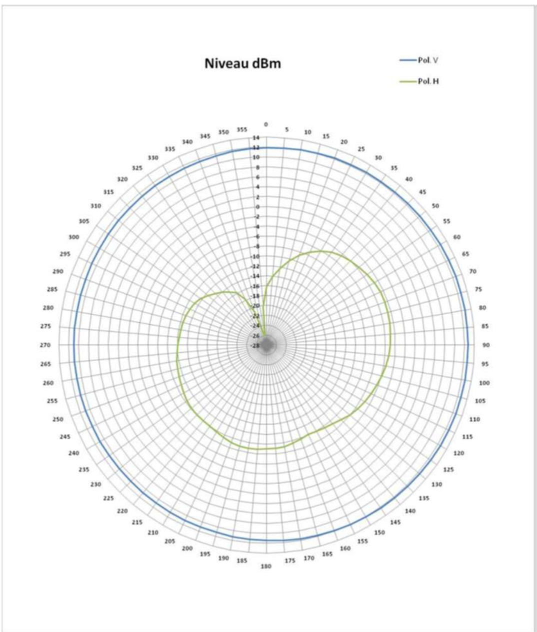

Figure 5: 2D representation

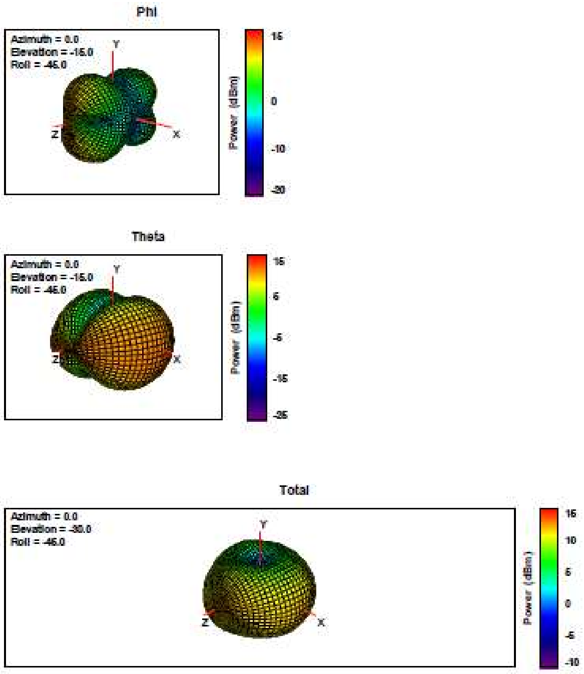

Figure 6: 3D representation

The amplitude of the measured field can be referred to peak EIRP or directly expressed in dBm.

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7. BUDGET LINK (OPTIONAL)

Important:

The Rx Tests are only applicable to DUT with an **uplink and downlink** configuration.

It is not mandatory because already performed in conducted mode during RF & protocol test.

Nevertheless, this test is highly recommended to prevent a major degradation brought by integration in end product.

7.1. DESCRIPTION

For devices offering bi-directional communications on the Sigfox networks, it is important to respect a balanced link budget between uplink and downlink.

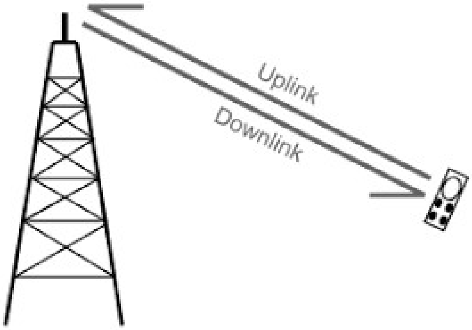

Figure 7: Uplink / Downlink convention

Otherwise a device, with a strong power transmission, could reach a base station even if in far location, but could not receive the downlink frames from this base station because the sensitivity would be poor.

In conclusion, more the device is powerful, more the sensitivity must be valuable; that is why we talk about a balance.

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7.2. LIMITS

During RF & protocol testing, the conducted sensitivity should be at least -126dBm depending on the strength of the output power to achieve a balanced link budget.

For Radiated Performance Tests, an equivalent relationship determines the minimum EIRS to ensure a balanced link budget. The values are given in the table below:

Radio Configuration	Recommended EIRS (dBm)	Test frequencies
RC1	≤ -128 – (EIRP – 16)	869.525 MHz
RC2	≤ -128 – (EIRP – 24)	905.200 MHz
RC3	≤ -128 – (EIRP – 16)	922.200 MHz
RC4	≤ -128 – (EIRP – 24)	922.300 MHz
RC5	≤ -128 – (EIRP – 14)	922.300 MHz
RC6	≤ -128 – (EIRP – 16)	866.300 MHz
RC7	≤ -128 – (EIRP – 16)	868.100 MHz

Table 4: EIRS vs RC

The Rx sensitivity is considered as the minimum value of EIRS at which the DUT is able to decode at least **10% of sent frames over an amount of 30 frames**.

Example: If we assume that a DUT is measured in RC1 at 9 dBm EIRP, Sigfox recommendation is to have at least a measured EIRS better or equal to:

- 128 – (9 – 16) dBm = **- 121 dBm** in order to achieve a balanced budget link.

EIRS test result is not a pass/fail criteria, it is only informative.

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7.3. TEST PROCEDURE

Definition:

The RX-GFSK mode (See Annex 8.2) allows to sense the center of the frequency band in downlink at dedicated RC. At this frequency, when a signal with a known pattern is decoded, the Sigfox library used in the device initiates a result.

From this, a strategy of acknowledgment can be set following the means of both device makers and test houses (RF transmission, RS-232 data or LED blinking…could be implemented) to perform the test

The strategy described in this paragraph is based on a RF transmission generated by the DUT when a frame is decoded while set in RX-GFSK mode.

1. The DUT must be placed in the anechoic chamber with the best orientation accordingly to the TX measurement.
2. The DUT must be set in RX-GFSK mode
3. The test house sets its RF generator to produce a frame with relevant characteristics:
    - Frequency set to the center of the RC frequency band (see table 4.1)
    - Output level variable following the results
    - Symbol rate: 600 symb/s
    - Modulation: 2-FSK
    - Deviation: 800Hz
    - Filter: Gauss (FSK) and B*T=0,35
    - No Coding
    - Pattern: AA AA B2 27 1F 20 41 84 32 68 C5 BA 53 AE 79 E7 F6 DD 9B

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Important:

The DUT uses a narrow band filter in reception around 1-2kHz max. The center of this filter is quite dependent on the temperature. When the DUT is listening to decode a frame, the current consumption is important bringing a temperature increase. Consider this drift when you generate the frame to ensure a perfect matching with the frequency expected by the DUT.

3. The generated signal is injected to the transmission path into the anechoic chamber.
4. A spectrum analyzer is connected onto the output of the reception path from the anechoic chamber. It can be set in zero span at the expected frequency used by the DUT for acknowledgement.
5. For each frame sent by the RF generator, the acknowledgment by the DUT is scanned on the spectrum analyzer screen.
6. Decrease the power level of RF generator until some frames be lost by the DUT.

See in appendix several examples of settings for RF generator.

7.4. RESULT

The RX sensitivity value (EIRS) is determined as a threshold such as the lost frames rate is 10% of sent frames over an amount of 30 frames.

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8. APPENDIX

8.1. RF GENERATOR SETTINGS

RF signal generator, example of settings:

- For SMIQ Signal Generator from R&S:

```
DIGITAL MOD
        STATE : ON
        SOURCE : DATA_LIST
                PATTERN : 0
                PRBS LENGTH : 15
                SELECT DATA LIST : CURRENT : DLIST00
                CONTROL STATE : OFF
        SELECT STANDARD : USER
                APCO C4FM
        MODULATION : GFSK/800.0Hz
                TYPE : GFSK 1 b/sym
                FSK DEVIATION : 800 Hz
                FSK OFFSET : 0 Hz
                MODULATION DELAY : 15.3 ms
        SYMBOL RATE : 600 sym/s
        FILTER : GAUSS/0.35
        CODING : OFF
        CLOCK : INT/SYMBOL
        POWER RAMP CONTROL : OFF
        EXT INPUTS : Kohm/GND
```

DATA LIST: AA AA B2 27 1F 20 41 84 32 68 C5 BA 53 AE 79 E7 F6 DD 9B

- For SMBV100A Signal Generator from R&S:

In « baseband », go to custom digital modulation and enter following parameters:

  - Adjust freq and power level
  - Create a data_list with following pattern:

AA AA B2 27 1F 20 41 84 32 68 C5 BA 53 AE 79 E7 F6 DD 9B

  - No control list
  - symbol rate = 600 symb/s
  - coding off
  - modulation type = 2FSK
  - deviation = 800 Hz
  - filter = Gauss(FSK) and B*T = 0.35

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8.2. RX-GFSK DESCRIPTION TEST

Loop on 300 repetitions of the following :

- Send one Sigfox frame (repetition 1)** :
  1. If at least 8 bytes supported : with payload (Transmission counter bytes[0] and byte[1], Reception counter byte[2] and byte[3], RSSI byte[4], Timeout counter byte[5] and byte[6], command byte[7]).
- command =0x24 on the first frame and 0x25 on the last
  2. Otherwise bit 0 if no downlink frame received, bit 1 if downlink frame received
- Wait for a downlink message during a listening window of 4s.
- Wait for 6s before starting the next loop item.

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