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Sigfox RF & Protocol Specifications for RC5-UDL-ENC-MONARCH

Public Use

Contents

1 Introduction

This document is intended to specify technical operational requirements for a Sigfox RF & PROTOCOL Test :

- RF requirements,
- Sigfox Protocol Requirements.

1.1 Scope

The present document focuses on Sigfox system.

A commercial product might also integrate other systems (multi-system device) which are not covered by this document.

All following test requirements are mandatory, if supported by the product, and the product shall be compliant with all those requirements to be Sigfox certified.

1.2 Requirements coding rules

In order to enable requirement traceability, each requirement is referenced as following:

[<Document Code>-<product mnemonic>-<chrono number>]

[PRS_RFP-RC5-UDL-ENC-MONARCH-xxx]
requirement body

1.3 Acronyms and abbreviations

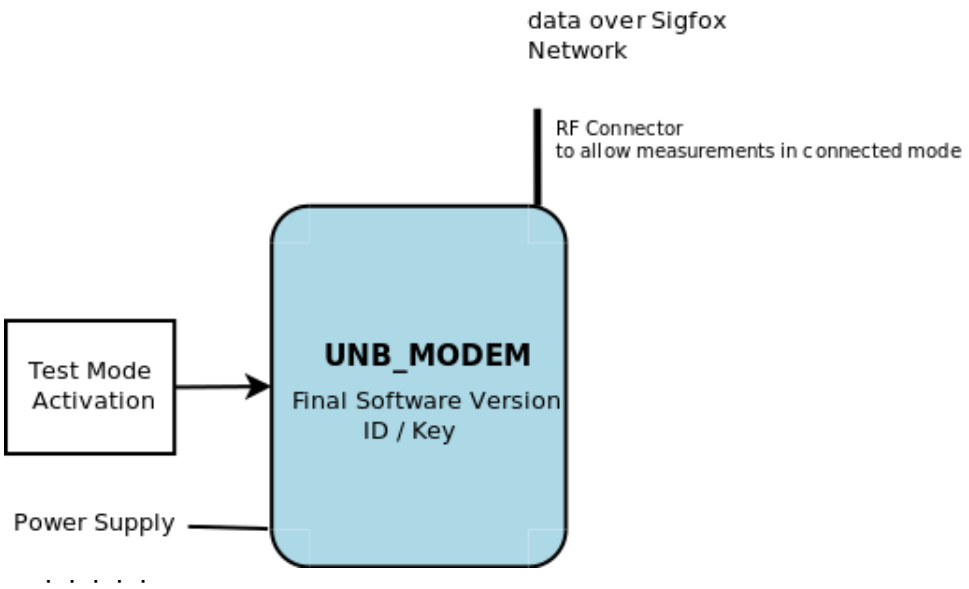
- **2GFSK**: 2-Level Gaussian Frequency Shift Keying
- **ACK**: Acknowledgement
- **AES**: Advanced Encryption Standard
- **Att**: Attenuator
- **CAB**: Client Application Board
- **CBC**: Cipher Block Chaining
- **CS**: Carrier Sense
- **Cold Test**: Test executed in initial condition (wait till the DUT come back to the initial system between two tests)
- **DBPSK**: Differential Binary Phase-Shift Keying
- **DUT**: Device Under Test
- **Duty Cycle**: part of a period in which a signal is active (high state/Period)
- **ENC**: Encrypted
- **Fd**: DUT Frequency
- **Fe**: Equipment Frequency
- **Legacy Uplink**: initial payload format of Sigfox Uplink without encryption
- **LBT**: Listen Before Talk
- **NVM**: Non Volatile Memory
- **OOB**: Out Of Band
- **PAC**: Porting Authorization Code

- **PER**: Packet Error Rate
- **PMR**: Private Mobile Radio
- **RC**: Radio Configuration
- **RF**: Radio Frequency
- **RSA**: Radio_Signal_Analyzer
- **RSSI_dut**: DUT RSSI
- **RSSI_eq**: Equipment RSSI
- **SMIQ**: Vector Signal Generator
- **SOC**: System On Chip
- **Sigfox Message**: Three frames with payload 303132333435363738393A3B
- **UNBT**: Ultra Narrow Band Transceiver

1.4 Frequencies

Radio Configuration	Uplink Frequency (Hz)	Downlink Frequency (Hz)	Baudrate (bps)
RC5	923300000	922300000	100

2 Sigfox RF & PROTOCOL Candidate



3 Operational Requirements

The following operational requirements have to be followed on all range of the **input power supply**.RF tests will be executed on nom, min and max value of the range. All others tests will be executed on nominal value of the range

3.1 Operational Frequencies

[PRS-RF-PROTOCOL-10] Frequency Steps

Specification Description: *Device* or *Modular Design* synthetized frequency error between two expected frequencies (spaced with a specific delta D) has to be, in absolute value, less than D + 300 Hz.

[PRS-RF-PROTOCOL-11] Operational Frequencies Range

Specification Description: Range of frequencies used during transmission has to be between 136800 Hz and 192 kHz.

[PRS-RF-PROTOCOL-12] Operational Frequencies Distribution

Specification Description: The distribution of all frequencies used during transmission has to be uniform.

[PRS-RF-PROTOCOL-13] Static Frequency Tolerance

Specification Description: *Device* or *Modular Design* carrier frequency (absolute value) must be at +/- 20 ppm for operational bands.
These 20 ppm are managed by the Sigfox system (network + Firmware library) .

One solution is to use a crystal or TCXO with these characteristics:

- Static Frequency Tolerance: precision is not so important if this parameter is calibrated at factory in order to cancel this static imprecision.
- Temperature Frequency tolerance added to Aging frequency tolerance must be less or equal to +/- 20 ppm during all the product life.

All other system can be used if the global imprecision is +/- 20 ppm for operational bands all over the product life.

3.2 TX RF modulation

[PRS-RF-PROTOCOL-20] DBPSK Modulation envelope

Specification Description: *Device* or *Modular Design* must use DBPSK modulation. Modulation mapping (0: modulate 1: do not modulate)

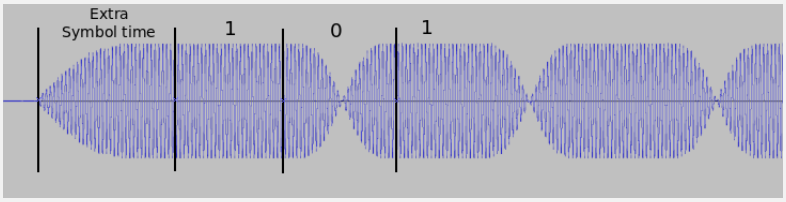
[PRS-RF-PROTOCOL-21] Phase Measurement

Specification Description: *Device* or *Modular Design* DBPSK modulation must be compliant with following performances : Maximum modulation RMS phase error : 10 degree from one symbol to another.
Maximum modulation peak phase error : 30 degree from one symbol to another.

[PRS-RF-PROTOCOL-22] Extra symbols before the first Sigfox bit of the frame

Specification Description: Transmission must include an extra symbol timing from 0 to 2 symbols time before the first Sigfox bit. No phase shifting is allowed during this phase except at the symbol time.

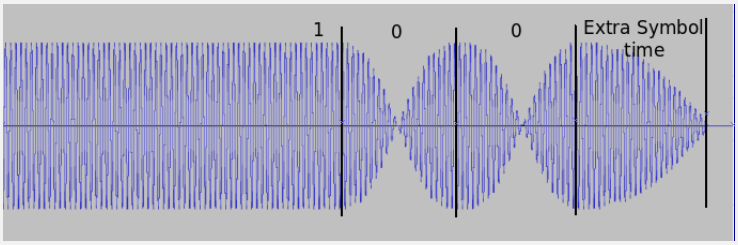
- Extra symbols timing before the first Sigfox bit of the frame



[PRS-RF-PROTOCOL-23] Extra symbols after the last Sigfox bit of the frame

Specification Description: Transmission must include an extra symbol timing from 0 to 2 symbols time after the transmission of the last Sigfox bit. No phase shifting is allowed during this phase except at the symbol time.

- Extra symbols timing after the last Sigfox bit of the frame



3.3 TX Baudrate

[PRS-RF-PROTOCOL-30] TX Max Symbol duration

Specification Description: *Device* or *Modular Design* must be able to transmit at a baudrate of 100 bps with DBPSK modulation with following tolerances on the symbol duration of +/- 1 %

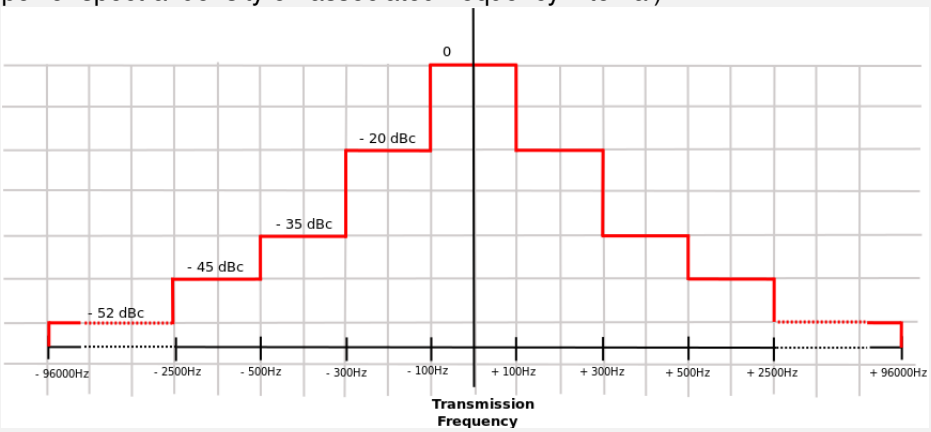
[PRS-RF-PROTOCOL-31] Max TX Baudrate Cumulated Error

Specification Description: *Device* or *Modular Design* must have a maximum baudrate cumulated error of 0.1 % of the whole ideal transmission time. (i.e : for a 26 bytes frame (2.08 s duration), tolerance of 2.08 ms)

3.4 Output Spectrum

[PRS-RF-PROTOCOL-40] Power Spectral Density

Specification Description: *Device* or *Modular Design* shall respect the following spectrum occupation (averaged power spectral density on associated frequency interval) :



3.5 Carrier frequency stability

[PRS-RF-PROTOCOL-50] Transitional Frequency Dynamic Drift

Specification Description: *Device* or *Modular Design* carrier frequency must respect a max absolute frequency shifting peak of 30 Hz/s from the first quarter of the synchro bits to the end of the synchro bits.

[PRS-RF-PROTOCOL-51] Established Frequency Dynamic Drift

Specification Description: *Device* or *Modular Design* carrier frequency must respect a max absolute frequency shifting of 20 Hz/s from end of synchro bits to the end of a transmission of the maximum Sigfox frame. Method of the least squares will be used for the measurement.

3.6 RX Demodulation

[PRS-RF-PROTOCOL-60] 2GFSK 600bps **DOWNLINK**

Specification Description: *Device* or *Modular Design* must be able to demodulate 2GFSK at 600bps (BT = 1.0, delta_f = +/- 800Hz).

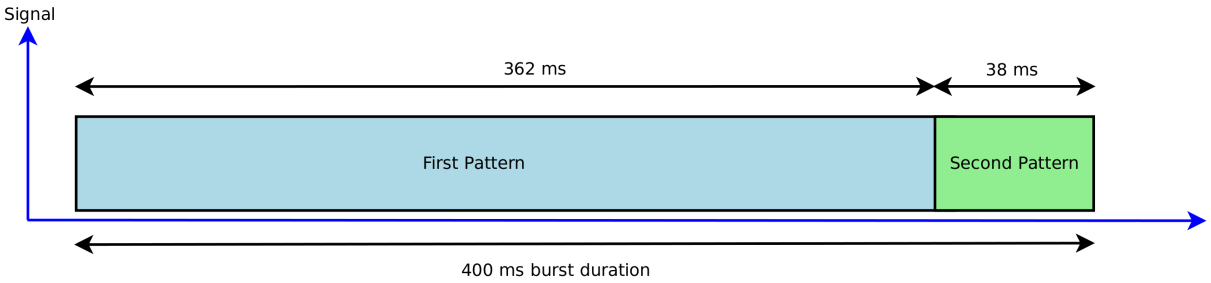
3.7 Monarch RC determination

General Information on RC5 Beacon

The RC5 beacon is sent at 922250000 Hz.

The beacon is transmitted during 400 ms. It is composed of:

- First Pattern during 362ms
- Second Pattern during 38ms



A pattern is composed of 12 tones. A tone is a single Continuous Wave signal, and each tone is separated from the other by exactly "x" Hz.

The maximum bandwidth of the composite signal is less than 20kHz.

[PRS-RF-PROTOCOL-70] Radio Configuration determination from Monarch signal at high power level MONARCH

Specification Description: *Device* or *Modular Design* must be able to identify the RC5 based on Monarch signal when only an RC5 beacon is transmitted at -27dBm (power level of the whole beacon).

[PRS-RF-PROTOCOL-71] Link Budget on Monarch signal MONARCH

Specification Description: *Device* or *Modular Design* Monarch Sensitivity should be <= -126 dBm with a PER at 10 % within a confidence interval greater or equal to 95% when the Modulated Output Power is 12 dBm ERP, to keep the link budget balanced.
If the Modulated Output Power is less than 12 dBm, so all dB lost in Tx will be added at -126 to keep the link budget balanced +/-2 dBm.

At the balanced link budget, the Monarch Rx sensitivity should be : MonarchRxSensiAtBalancedLinkBudget = -126+12 -TxPower

[PRS-RF-PROTOCOL-72] Robustness to High Power Level interferer for Monarch signal MONARCH

Specification Description: *Device* or *Modular Design* must not detect RC5 when only First pattern of RC5 (or Second Pattern of RC5) is sent during 400 ms at -27dBm (power level of the whole beacon).

[PRS-RF-PROTOCOL-73] Robustness to Low Power Level interferer for Monarch signal MONARCH

Specification Description: *Device* or *Modular Design* must not detect RC5 when only First Pattern of RC5 (or Second Pattern of RC5) is sent during 400 ms at -120dBm.

3.8 Sigfox Link Budget

[PRS-RF-PROTOCOL-80] Sigfox Link Budget **DOWNLINK**

Specification Description: *Device* or *Modular Design* link budget should be <= -126 dBm with a PER at 10 % within a confidence interval greater or equal to 95% when the Modulated Output Power is 12 dBm ERP, to keep the link budget balanced.
If the Modulated Output Power is less than 12 dBm, so all dB lost in Tx will be added at -126 to keep the link budget balanced.

At the balanced link budget, the Rx level should be : RxLevelAtBalancedLinkBudget = -126+12 -TxPower

3.9 Protocol

[PRS-RF-PROTOCOL-90] AES

Specification Description: *Device* or *Modular Design* must include an AES module with CBC mode with a 16 bytes key (Hardware or Software) for authentication on network. The Init Vector (IV) is set to 0.

[PRS-RF-PROTOCOL-91] NVM Frequency Storage

Specification Description: *Device* or *Modular Design* must include a non volatile memory for frequency carrier storage (at least 2 bytes).

[PRS-RF-PROTOCOL-92] NVM Sequence Number Storage

Specification Description: *Device* or *Modular Design* must include a non volatile memory for a protocol sequence number storage (at least 2 bytes), not readable by application.

[PRS-RF-PROTOCOL-93] Public Key switch

Specification Description: *Device* or *Modular Design* must allow a way to switch from private to public key. This requirement is not mandatory for Device and DUT containing a Secure Element (SE), but mandatory for Modular Design and development solution.

- KEY = 00112233445566778899AABBCCDDEEFF *(KEY[0]=00, KEY[15]=FF)*

[PRS-RF-PROTOCOL-94] Number of frames per message in Uplink mode

Specification Description: Without blocker, *Device* or *Modular Design* must send 3 Sigfox RF frames per customer message.

[PRS-RF-PROTOCOL-95] Legacy Uplink

Specification Description: *Device* or *Modular Design* has to be able to send Sigfox Frame through the Sigfox Test Mode function.

[PRS-RF-PROTOCOL-96] Uplink Encrypted payload

Specification Description: *Device* or *Modular Design* has to be able to send Sigfox encrypted Frames through the Sigfox Test Mode function.

[PRS-RF-PROTOCOL-97] Downlink Legacy DOWNLINK

Specification Description: *Device* or *Modular Design* has to be able to receive Sigfox Frames through the Sigfox Test Mode function and to report if a frame has been received properly or not.

[PRS-RF-PROTOCOL-98] Downlink Encrypted Payload DOWNLINK

Specification Description: *Device* or *Modular Design* has to be able to receive Sigfox encrypted Frames.

[PRS-RF-PROTOCOL-99] RSSI level DOWNLINK

Specification Description: At a specific Downlink Frame level, the OOB shall return the same level of RSSI of the received GFSK (+/-2dB).

[PRS-RF-PROTOCOL-100] Number of Uplink frame in bi-directional mode DOWNLINK

Specification Description: *Device* or *Modular Design* must send 3 Sigfox RF frames per customer message for a message requesting a downlink response.

3.10 Timings

[PRS-RF-PROTOCOL-110] TX Interframe Timing in Uplink mode

Specification Description: Without blocker, the TX interframe duration in Uplink mode has to be between 50 ms and 2000 ms .

[PRS-RF-PROTOCOL-111] TX repeat timeout

Specification Description: 8 s (+/- 10%) after the end of transmission of the first frame, the *Device* or *Modular Design* shall not start any repetition.
Note : End of transmission of the frame is considered when energy left is at 10% of its maximum.

[PRS-RF-PROTOCOL-112] TX Interframe Timing in Bi-directional mode DOWNLINK

Specification Description: Without blocker, the TX interframe duration in Uplink/Downlink mode has to be between 50 ms and 2000 ms.

[PRS-RF-PROTOCOL-113] RX Start Of Listening DOWNLINK

Specification Description: *Device* or *Modular Design* must be able to receive a Downlink frame sent 19.1 s after the first frame (This timing take into account the extra symbol time and the downlink frame duration), following the implementation described in the graph:

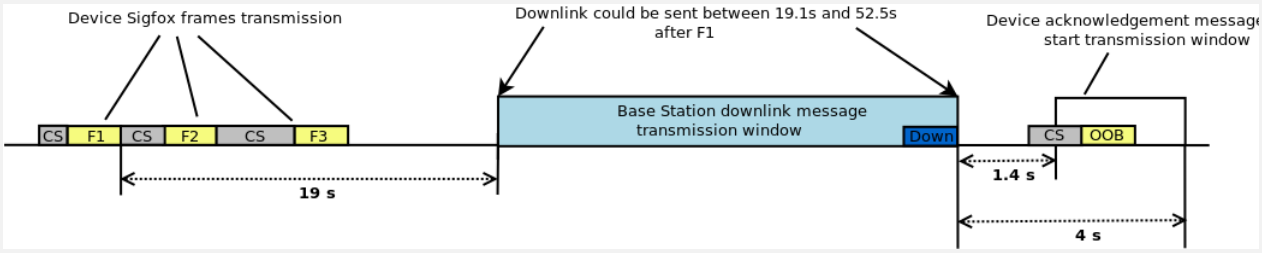


Figure 1: Downlink Timings

[PRS-RF-PROTOCOL-114] RX End Of Listening DOWNLINK

Specification Description: The *Device* or *Modular Design* must be able to receive a Downlink frame sent 52.5 s after the first frame (This timing take into account the extra symbol time and the downlink frame duration), following the implementation described in the graph:

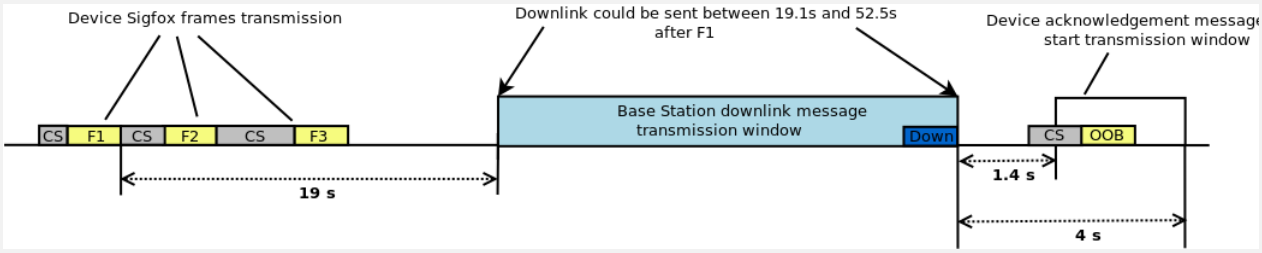


Figure 2: Downlink Timings (last chance to receive downlink frame case)

[PRS-RF-PROTOCOL-115] RX to OOB(ack) Timing DOWNLINK

Specification Description: After receiving the downlink frame, *Device* or *Modular Design* has to wait 1.4 s and no later than 4 s before sending the acknowlegement frame (OOB), following the implementation described in the figure 2. The OOB Frame may not be send if the Carrier Sense does not allow it.

4 Additional Measurements

4.1 Modulated Conducted TX Output power

[PRS-RF-PROTOCOL-120] Modulated Conducted Output Power

Measurement: To be able to benefit from optimal Quality of Service with a balanced link budget, Sigfox recommends to respect the following maximum output radiated power : 12dBm ERP(or 14dBm EIRP).

4.2 Validation of the information contained in the OOB Frame

[PRS-RF-PROTOCOL-130] DUT Temperature level

Measurement: The OOB shall return the level of Temperature at which the test is executed or 0 is the device is not able to return it.

[PRS-RF-PROTOCOL-131] DUT Voltage level

Measurement: The OOB shall return the level of Voltage at which the test is executed or 0 is the device is not able to return it.

4.3 I/Q Wave record

[PRS-RF-PROTOCOL-140] I/Q Wave record

Measurement: Test Mode TX-BPSK shall be recorded with a 20dB minimum SNR in .raw format.