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JUNE 24, 2020

Sigfox RF & PROTOCOL Test Report

SEONGJI INDUSTRIAL CO. LTD

Product Type : MODULAR DESIGN

Commercial Name : SFM11R3/ SFM11R3000

Model Name : SFM11R3/ SFM11R3000

Configuration : RC5-UDL

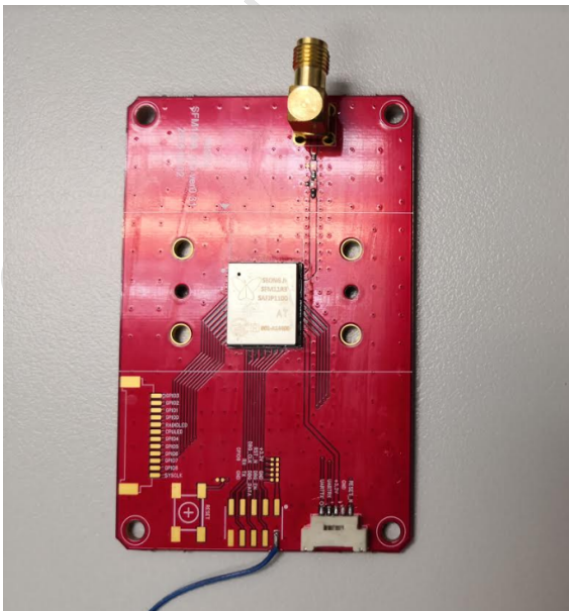
Hardware : V0.2

Firmware : AX-SIGFOX 1.1.0-RCZ3

Sigfox lib/Addon: V1.8.9

Modulated Output Power measured: 10.8dBm

Link Budget: **BALANCED**



Test performed : 2020-06-17

Test report authorized :

Jorge Cabezas Torres	Noemi Perez Dans Noemi Perez Dans Firmado digitalmente por Noemi Perez Dans Fecha: 2020.06.24 15:58:22 +02'00'

Test report generated with Sigfox's tools

Contents

1 Introduction

This document shows the results of the RF product qualification for Sigfox RF & PROTOCOL Specification Compliance.

2 Test Setup Equipment

The qualification is performed using following Laboratory instrumentation :

Test Setup	Equipment
TX Test Setup - DBPSK Modulation Quality	A
TX Test Setup - Demodulated Information	A
RX Test Setup	A
TX/RX Test Setup	A
TX Test Setup - LBT	A,B,C

3 Equipments

3.1 Laboratory Instrumentation

No.	Equipment	Manufacturer	Serial Number	Last Calibration	Next Calibration
A	IQXEL-IOT	Litepoint	IQ112FA2520		
B	Vector Signal Generator E4438C	Agilent	MY49073010	2019-07-09	2020-07-09
C	Power Splitter	Mini-Circuits			

3.2 Firmware

No.	Firmware	Manufacturer	Version
1	Radio Signal Analyzer	Sigfox	2.0.1

4 Test Environment

Sensitivity Uncertainty	+/- 0.75 dB
Temperature Uncertainty	+/- 1 °C
Power Measurement Uncertainty	+/- 0.075 dB
Temperature	23 °C

5 Sigfox RF & Protocol

All tests are sanctioned by following information:

NOT TESTED	The test has not been executed
PASS	The test has been properly executed and match with the Sigfox specification
FAIL	The test has not been properly executed and/or does not match with the Sigfox specification
INFO	Measurement has been done but it's not a verdict

6 Operational Requirements Results

Some of the following requirements have been tested in Nominal, Minimum and Maximum Voltage indicated in the Pre-requisites part.

6.1 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.

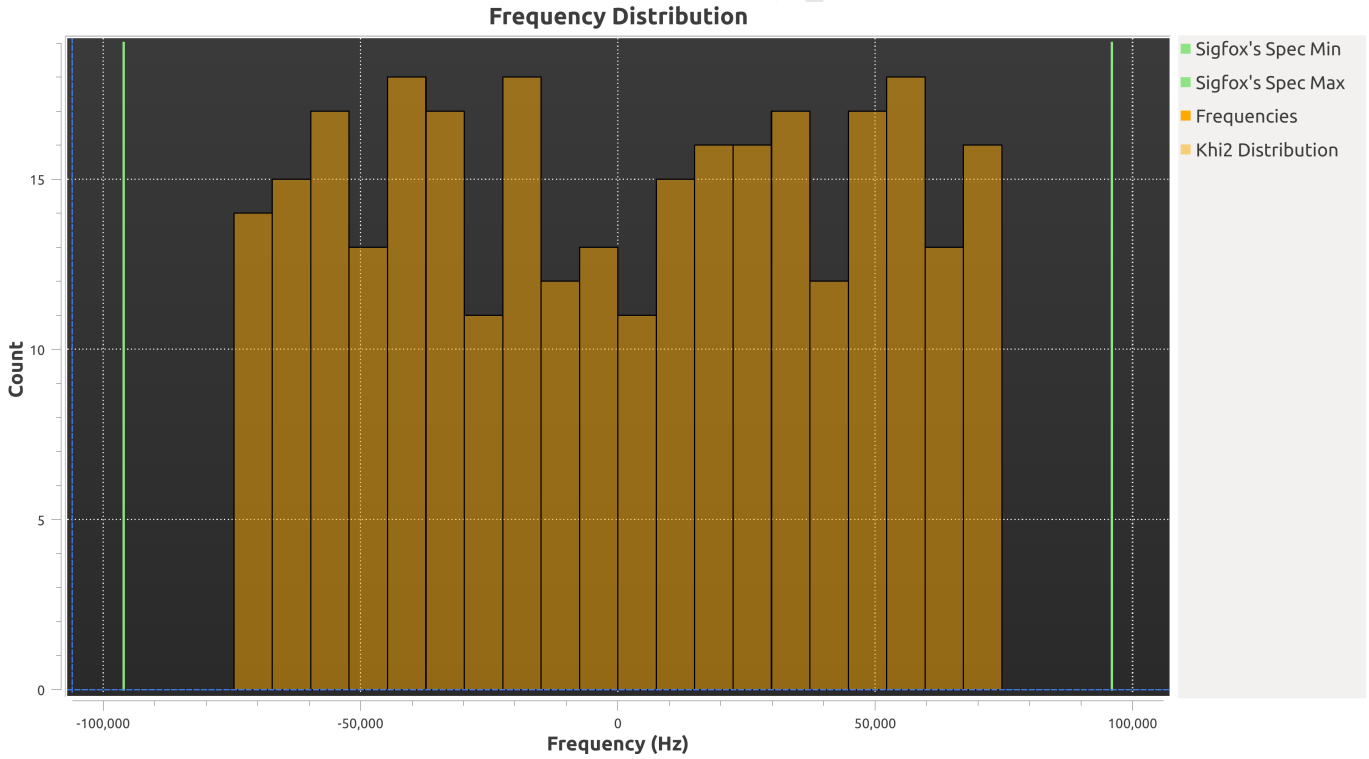
Test Result Nominal Voltage: **PASS**

Number of received frames : 9
Maximum step frequency error : 10 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.

Test Result Nominal Voltage: **PASS**



Number of received frames : 300
Frequency range : 149212 Hz

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

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

Test Result Nominal Voltage: **PASS**

Number of received frames : 300

[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.

Test Result Nominal Voltage: **PASS**

Measured frequency : -217 Hz
Measured ppm (with aging and temperature) : 7.73503 ppm
Declared Aging : 5.00 ppm
Declared Temperature Accuracy: 2.50 ppm

Test Result Minimum Voltage: **PASS**

Measured frequency : -286 Hz
Measured ppm (with aging and temperature) : 7.80976 ppm
Declared Aging : 5.00 ppm
Declared Temperature Accuracy: 2.50 ppm

Test Result Maximum Voltage: **PASS**

Measured frequency : -193 Hz
Measured ppm (with aging and temperature) : 7.70903 ppm
Declared Aging : 5.00 ppm
Declared Temperature Accuracy: 2.50 ppm

6.2 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)

Test Result Nominal Voltage: **PASS**

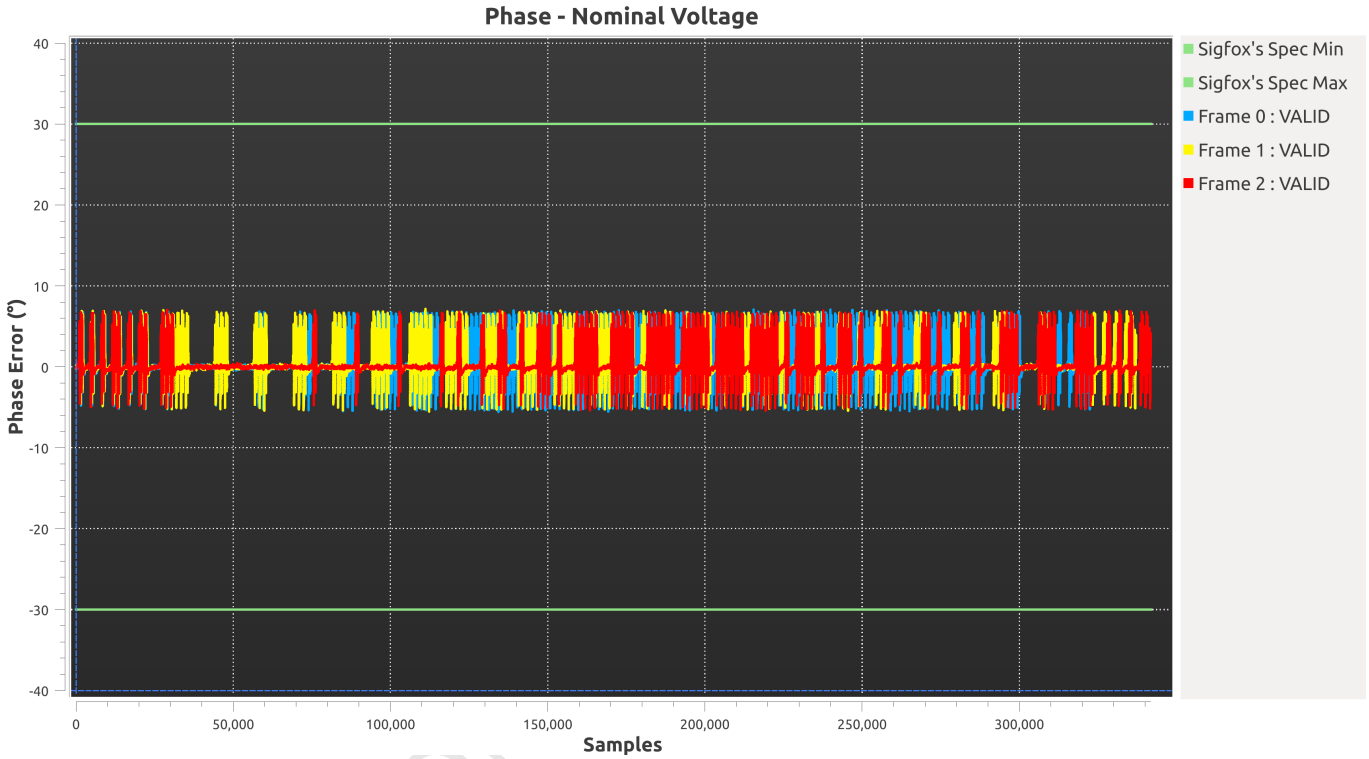
Test Result Minimum Voltage: **PASS**

Test Result Maximum Voltage: **PASS**

[PRS-RF-PROTOCOL-21] Phase Measurement

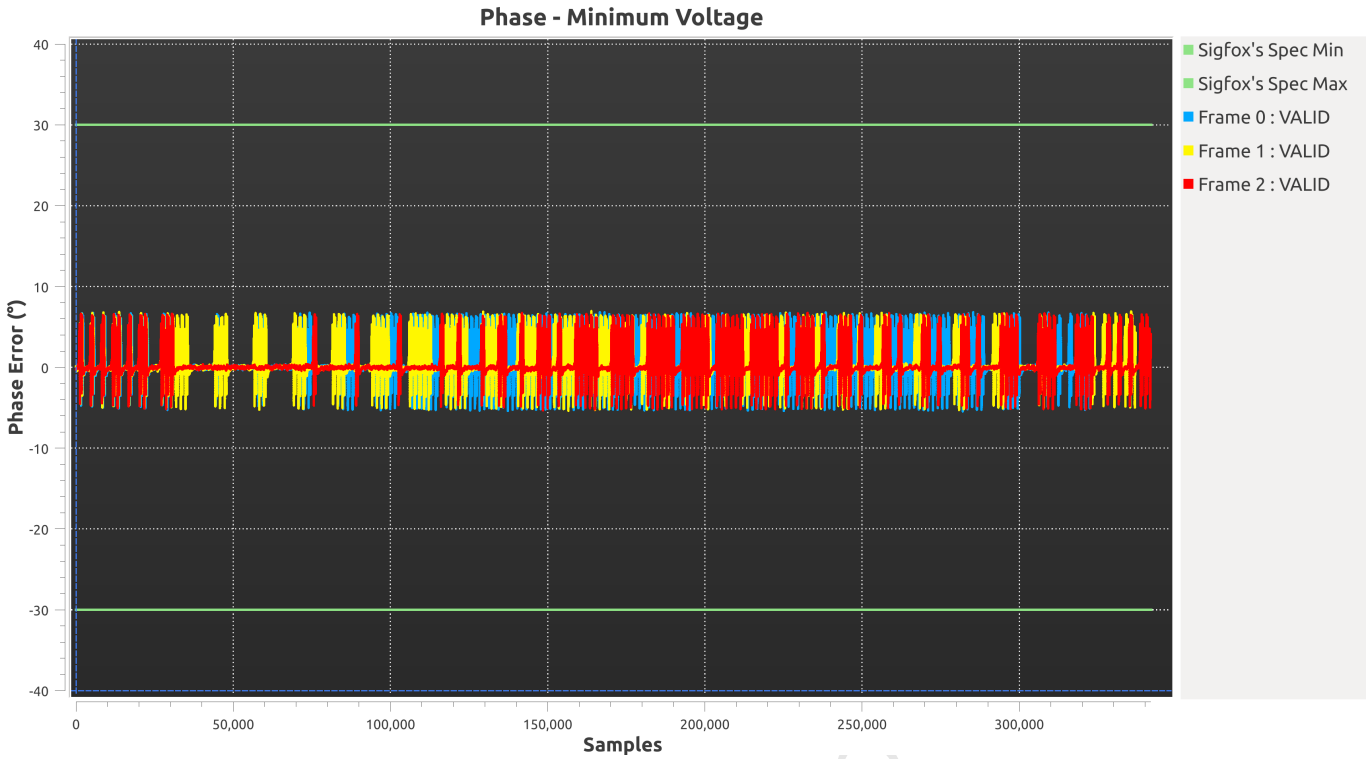
Specification Description: *Device* or *Modular Design* DBPSK modulation must be compliant with following performances :
Maximum modulation RMS phase error : 10 degree from one symbol to another.
Maximum modulation peak phase error : 30 degree from one symbol to another.

Test Result Nominal Voltage: **PASS**



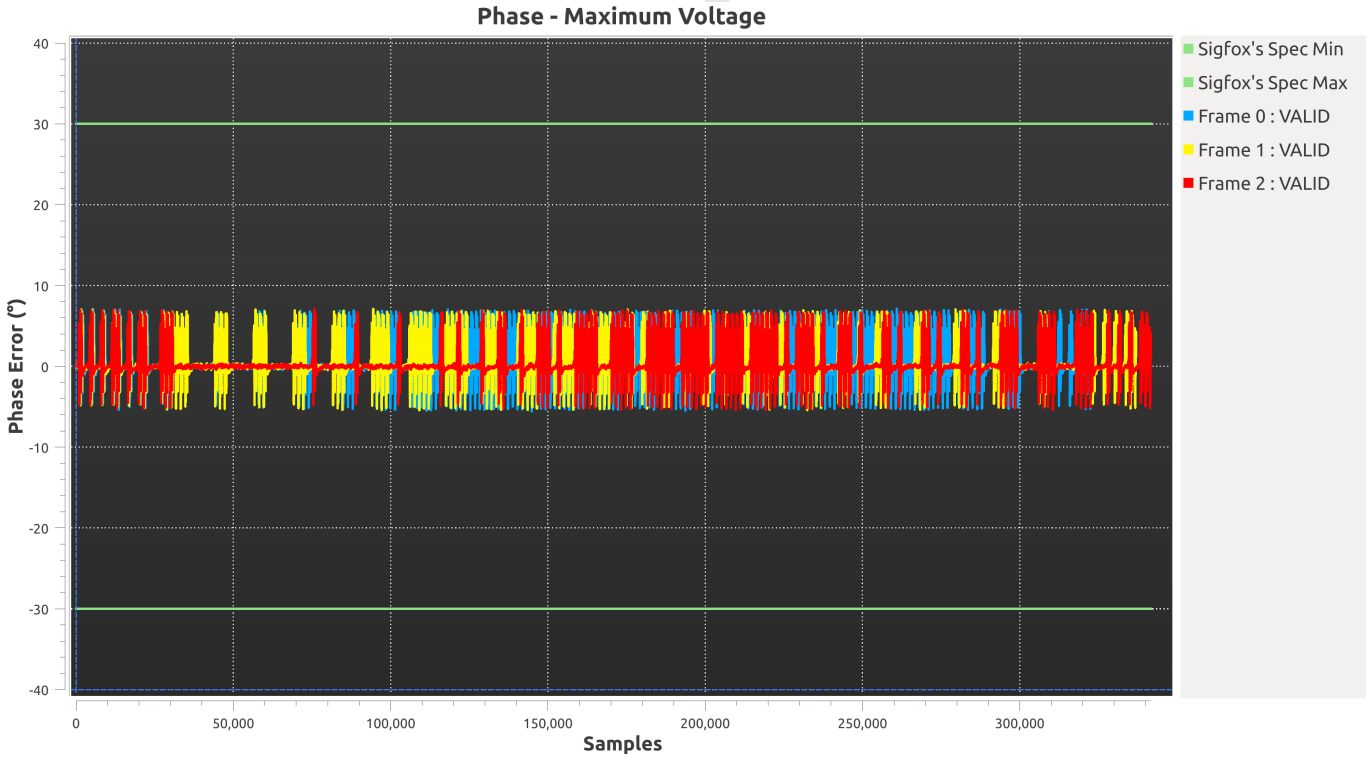
RMS : 2.38093 °
Peak : 7.15124 °

Test Result Minimum Voltage: **PASS**



RMS : 2.35256 °
Peak : 6.95213 °

Test Result Maximum Voltage: **PASS**

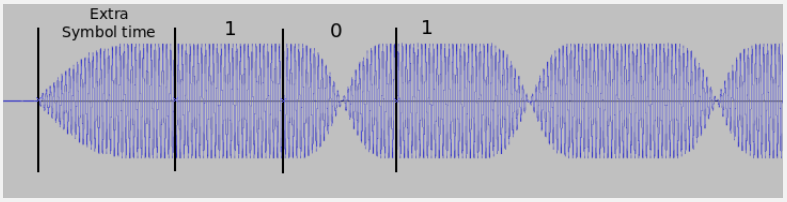


RMS : 2.39039 °
Peak : 7.11282 °

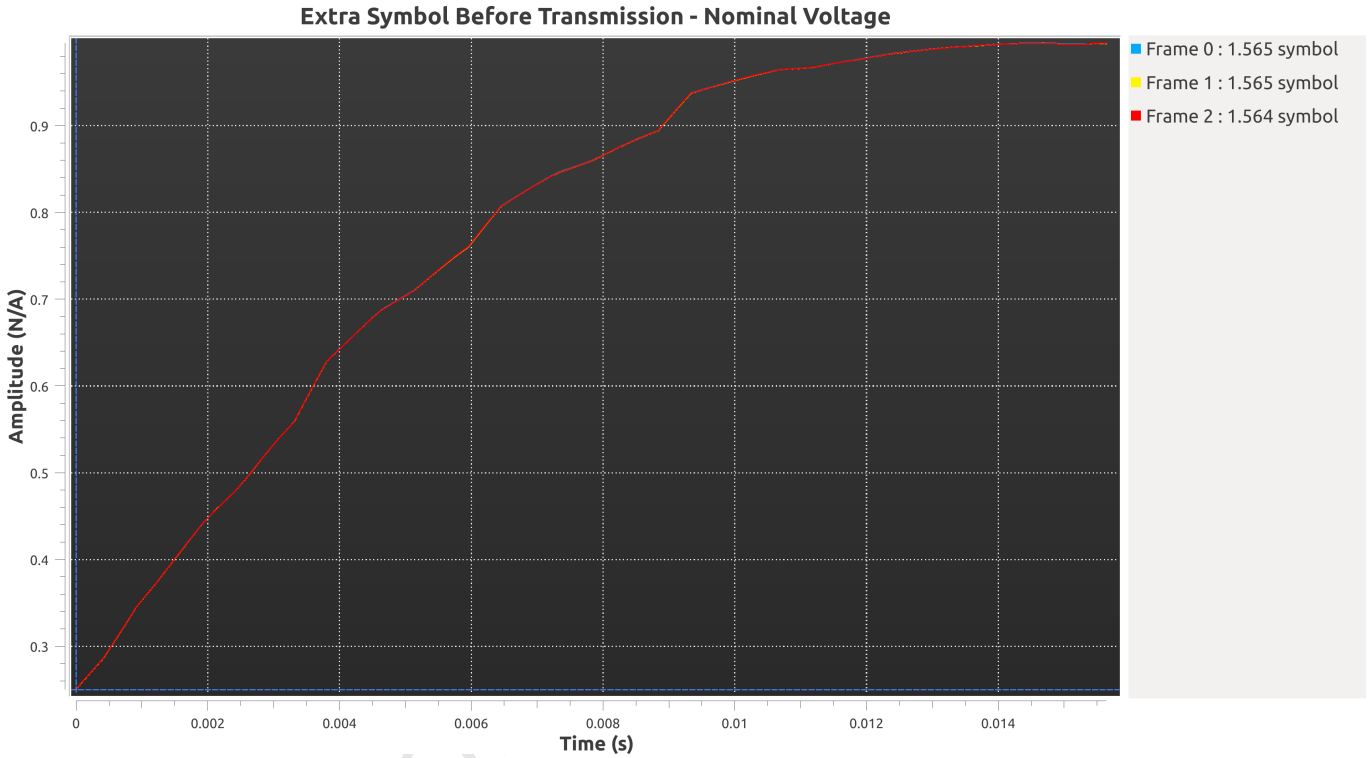
[PRS-RF-PROTOCOL-22] Extra symbols before the first Sigfox bit of the frame

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

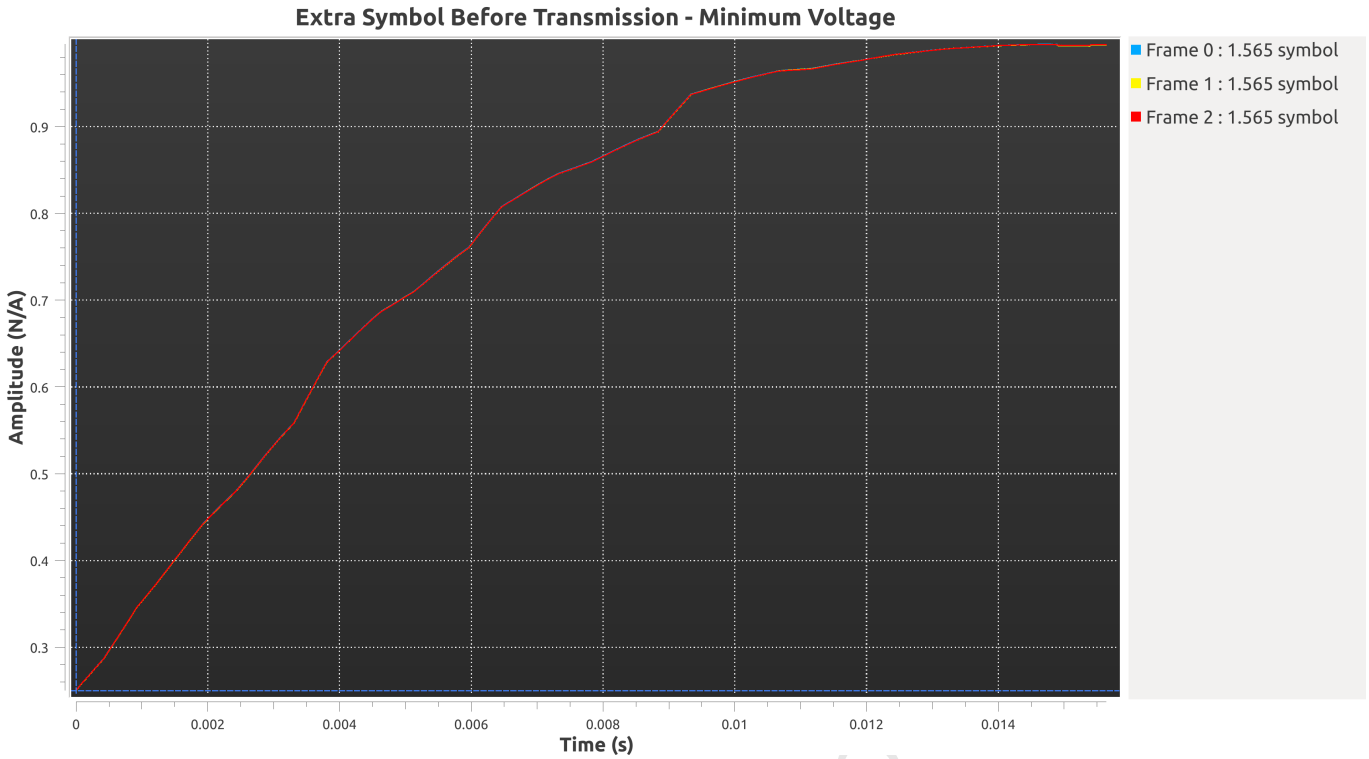


Test Result Nominal Voltage: **PASS**



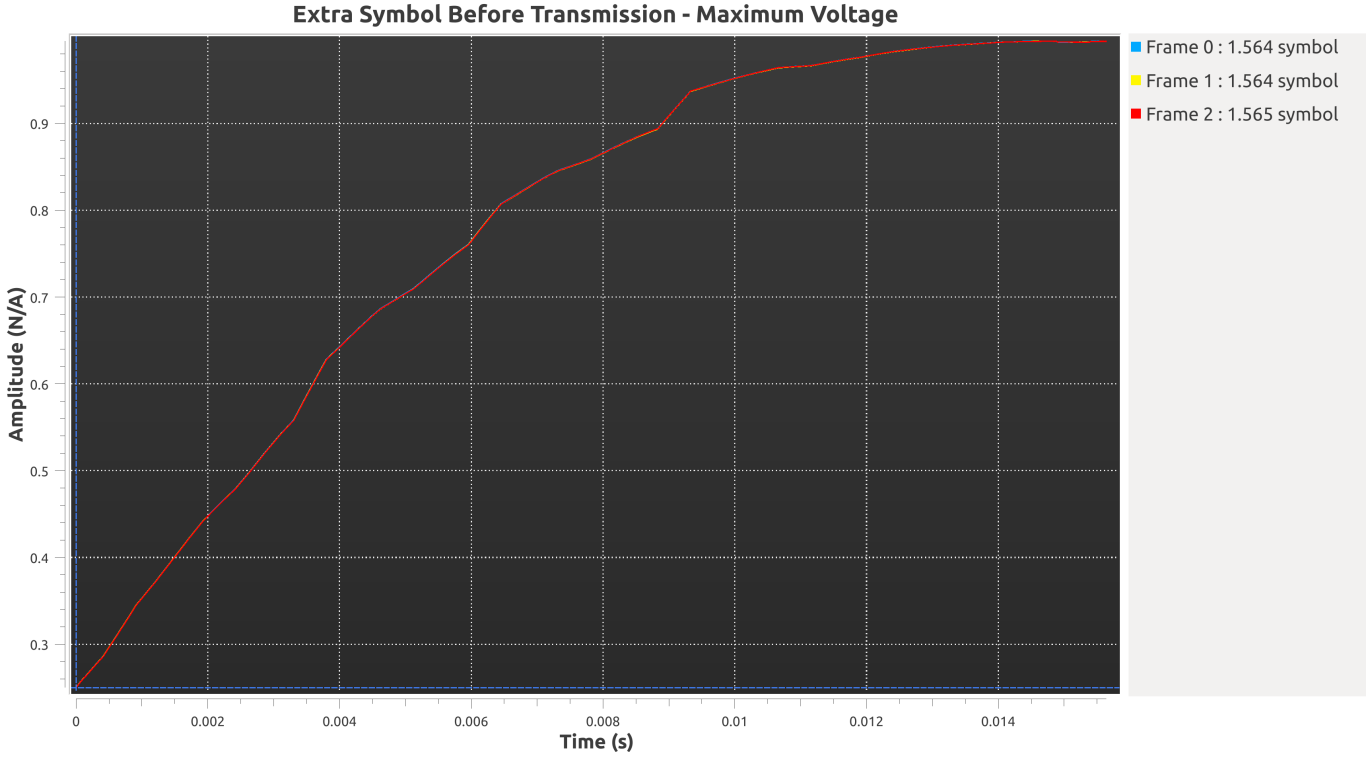
Measured extra symbol before frame : 1.5645 symbols

Test Result Minimum Voltage: **PASS**



Measured extra symbol before frame : 1.5645 symbols

Test Result Maximum Voltage: **PASS**

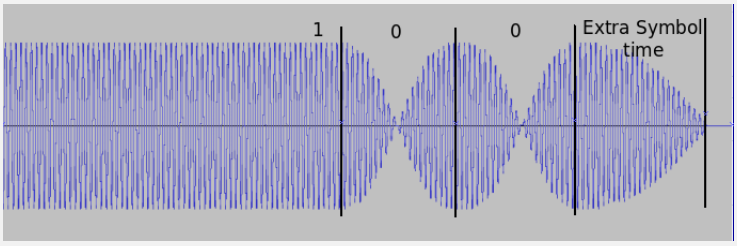


Measured extra symbol before frame : 1.5645 symbols

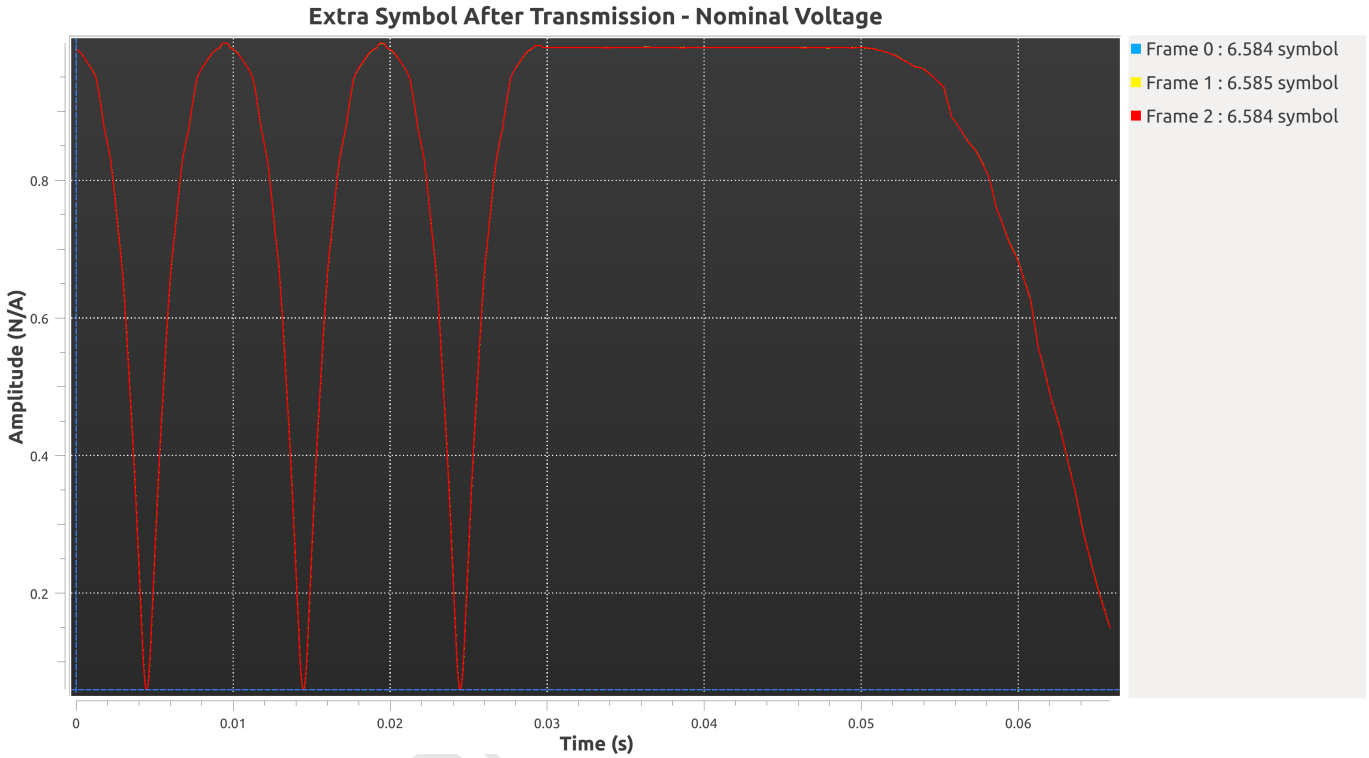
[PRS-RF-PROTOCOL-23] Extra symbols after the last Sigfox bit of the frame

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

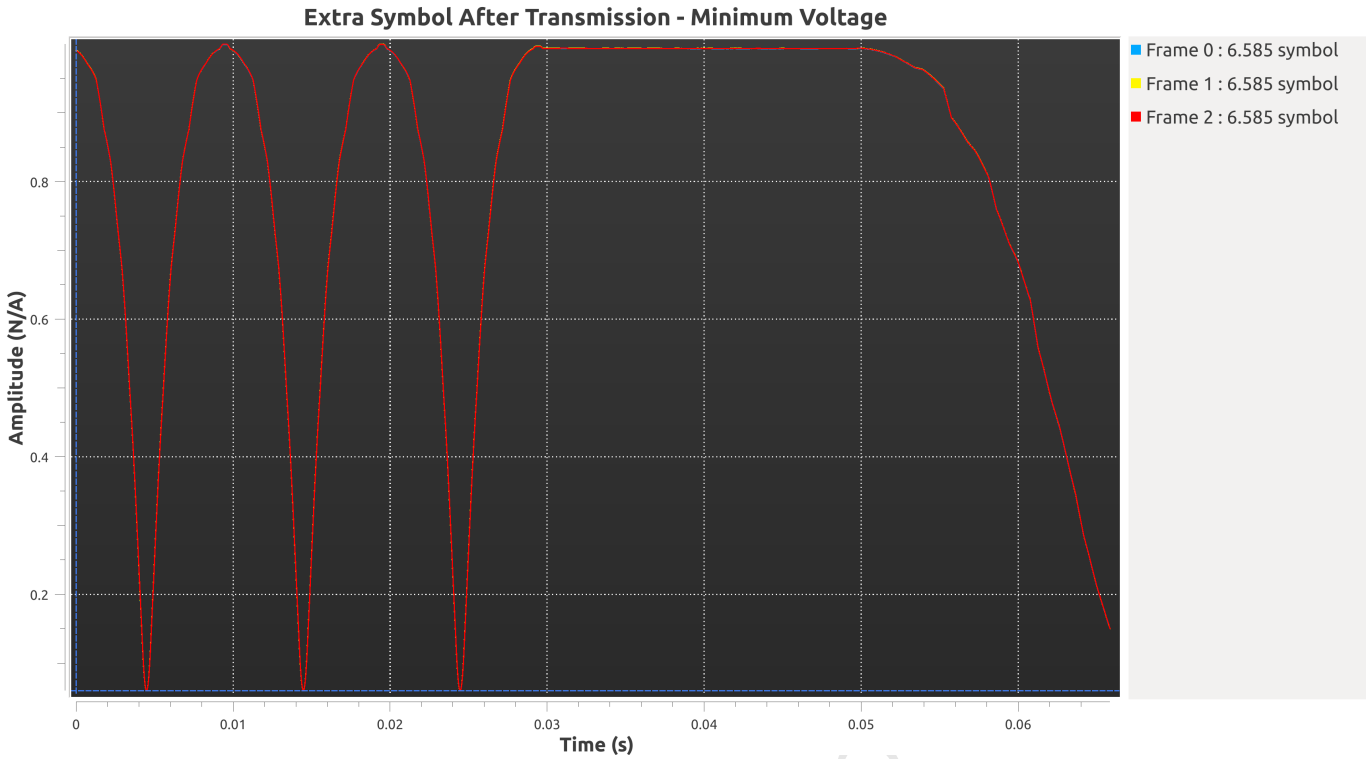


Test Result Nominal Voltage: **FAIL**



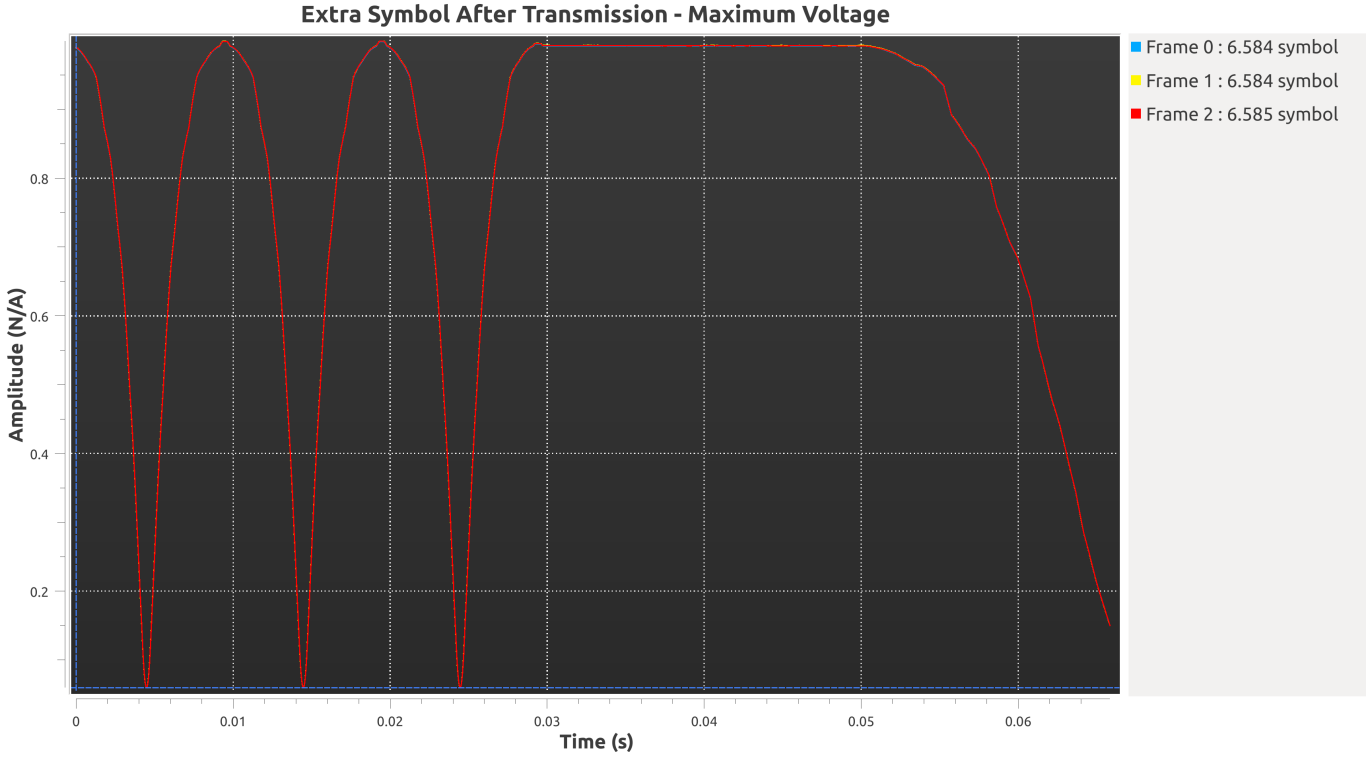
Measured extra symbol after frame : 6.5845 symbols

Test Result Minimum Voltage: **FAIL**



Measured extra symbol after frame : 6.585 symbols

Test Result Maximum Voltage: **FAIL**



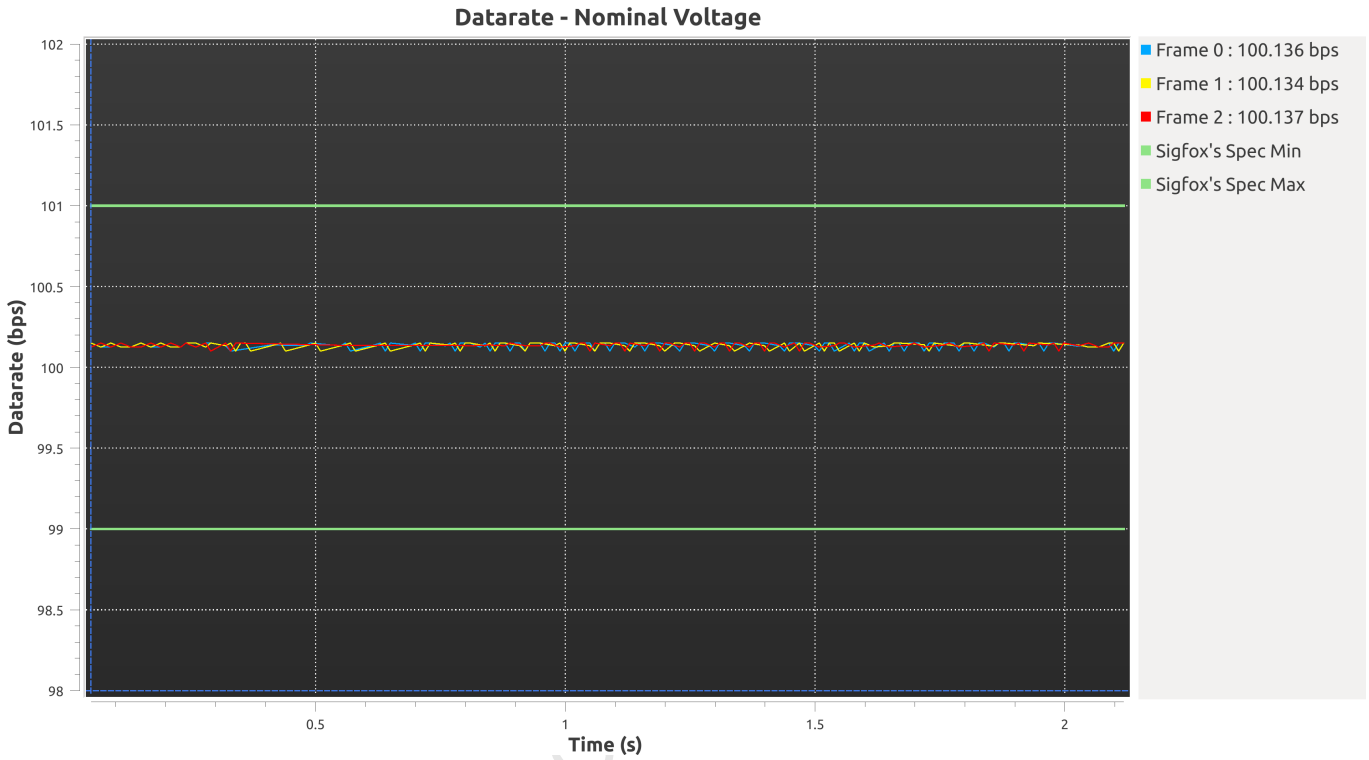
Measured extra symbol after frame : 6.5845 symbols

6.3 TX Baudrate

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

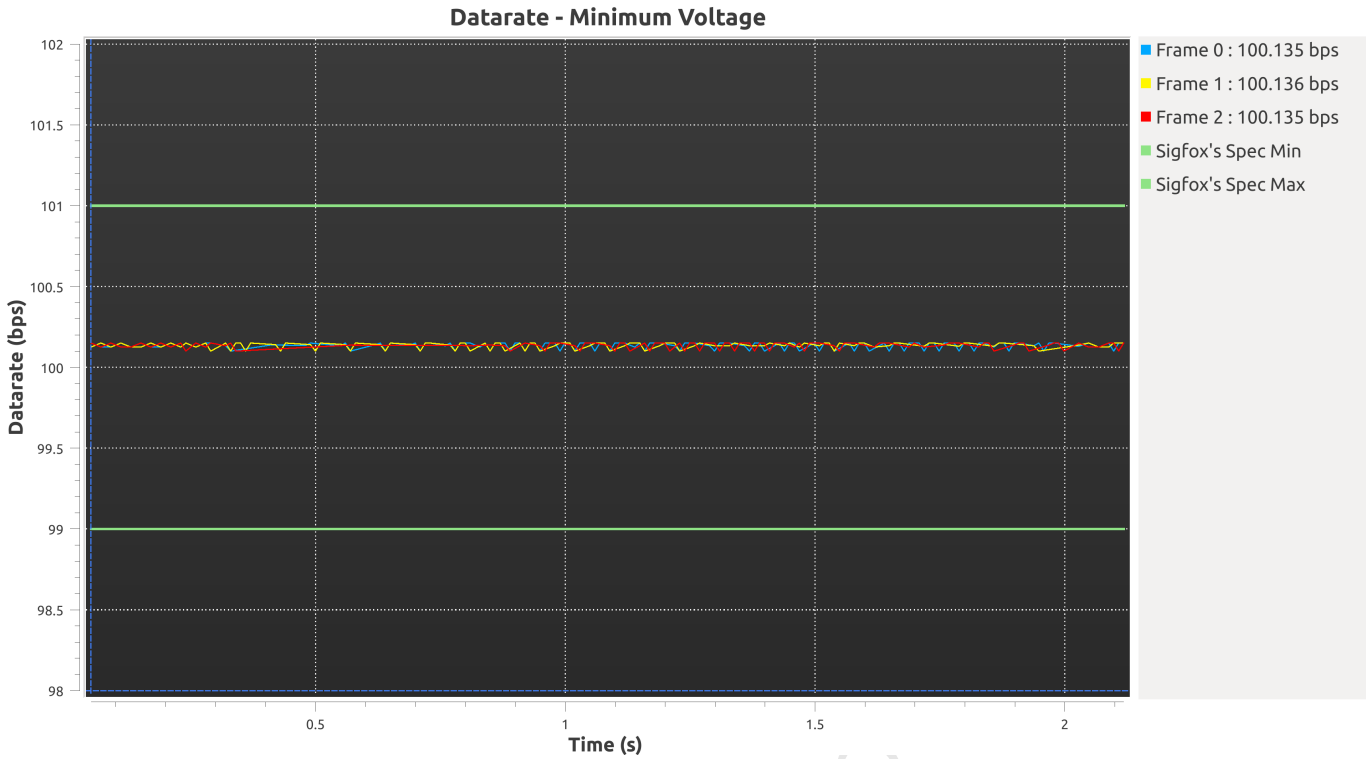
Specification Description: *Device* or *Modular Design* must be able to transmit at a baudrate of 100 bps with DBPSK modulation with following tolerances on the symbol duration of +/- 1 %

Test Result Nominal Voltage: **PASS**



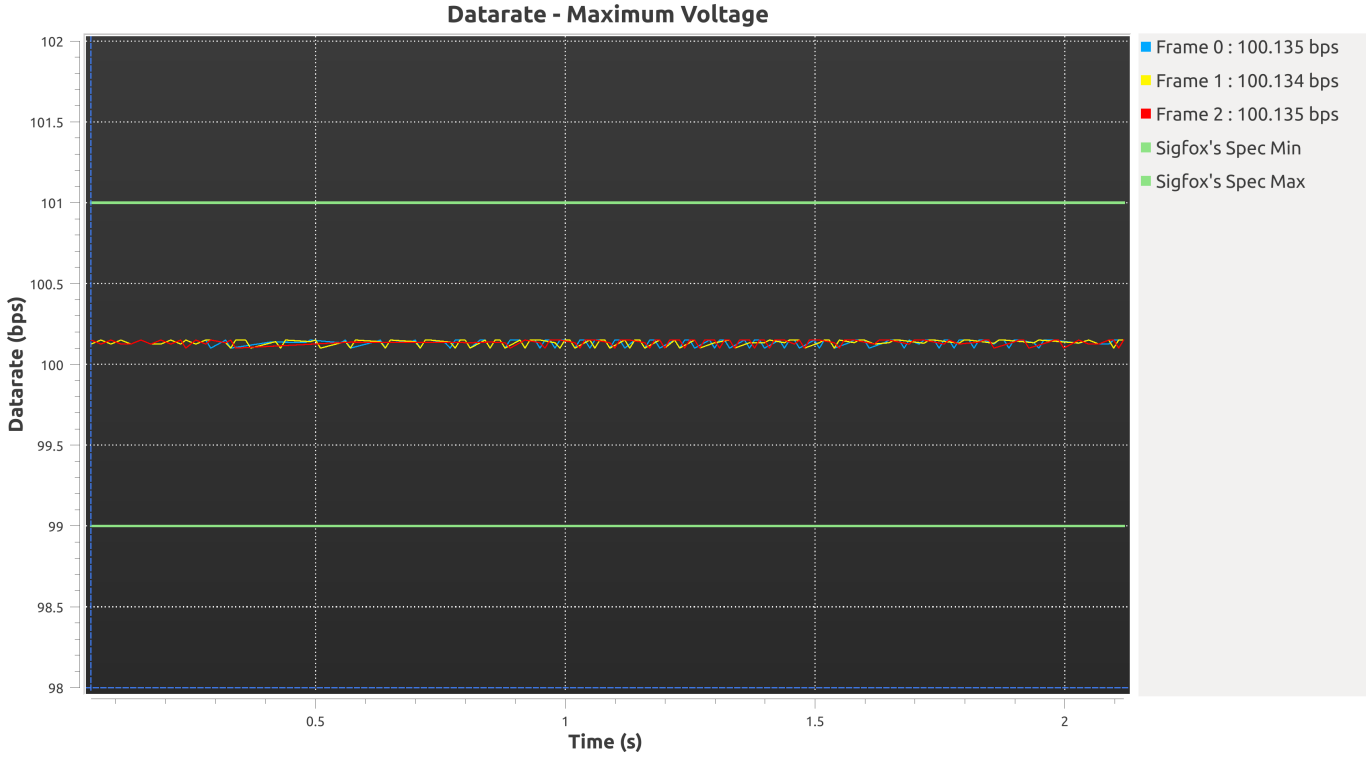
Maximum baudrate : 0.150225 %

Test Result Minimum Voltage: **PASS**



Maximum baudrate : 0.150225 %

Test Result Maximum Voltage: **PASS**

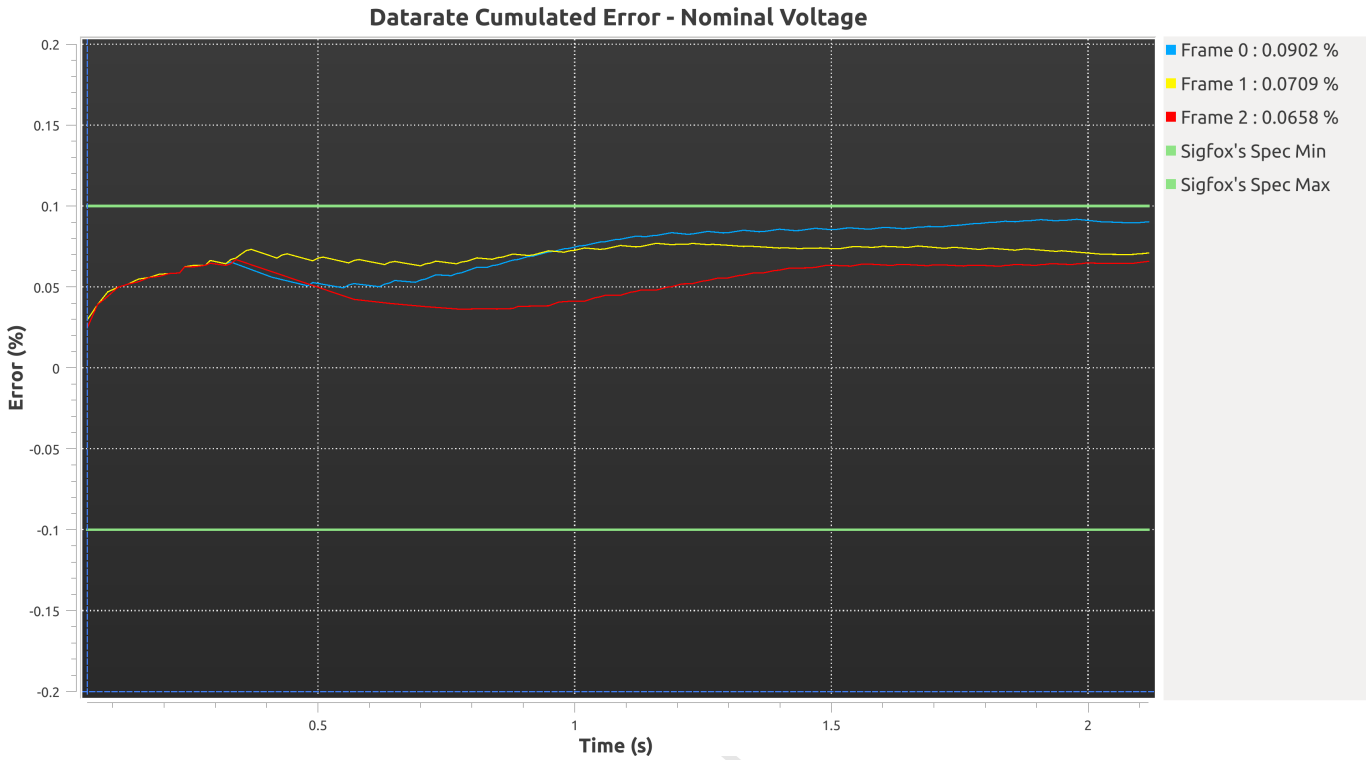


Maximum baudrate : 0.150225 %

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

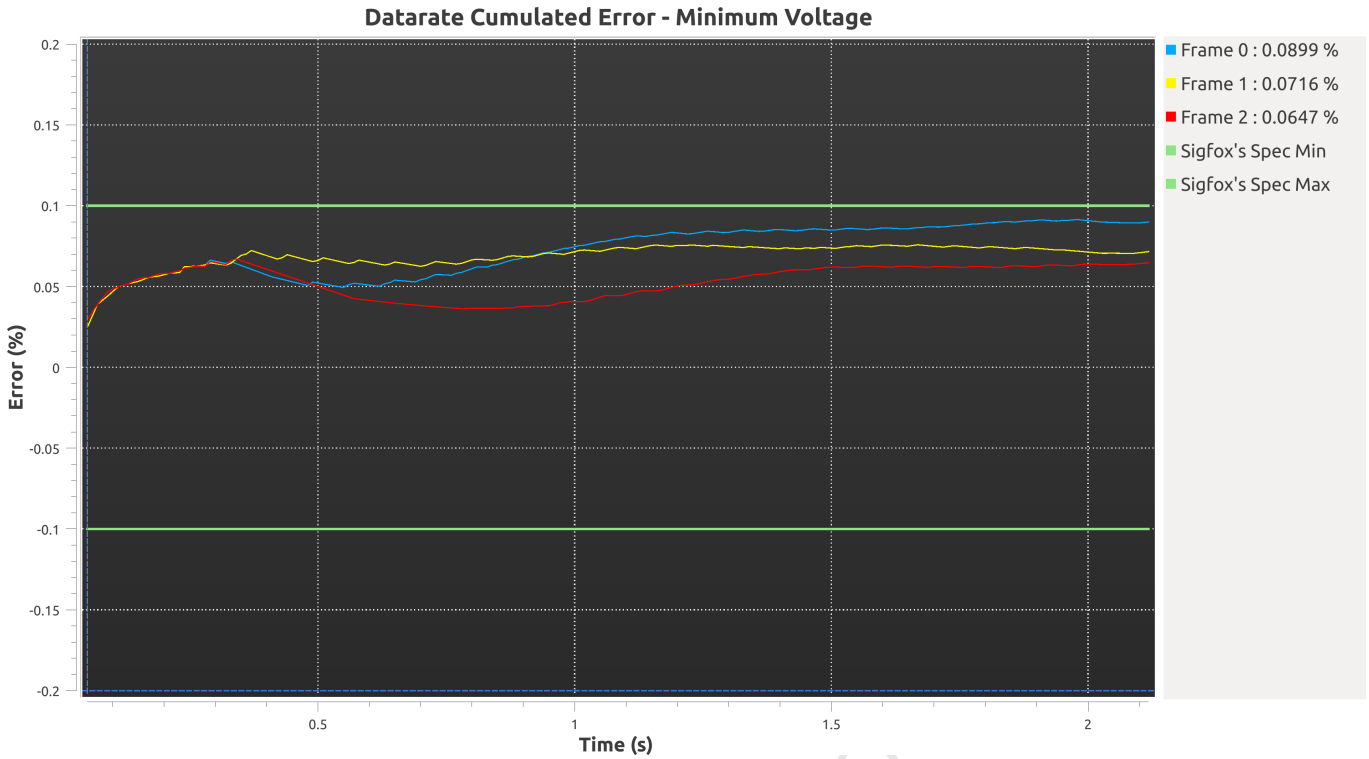
Specification Description: *Device* or *Modular Design* must have a maximum baudrate cumulated error of 0.1 % of the whole ideal transmission time. (i.e : for a 26 bytes frame (2.08 s duration), tolerance of 2.08 ms)

Test Result Nominal Voltage: **PASS**



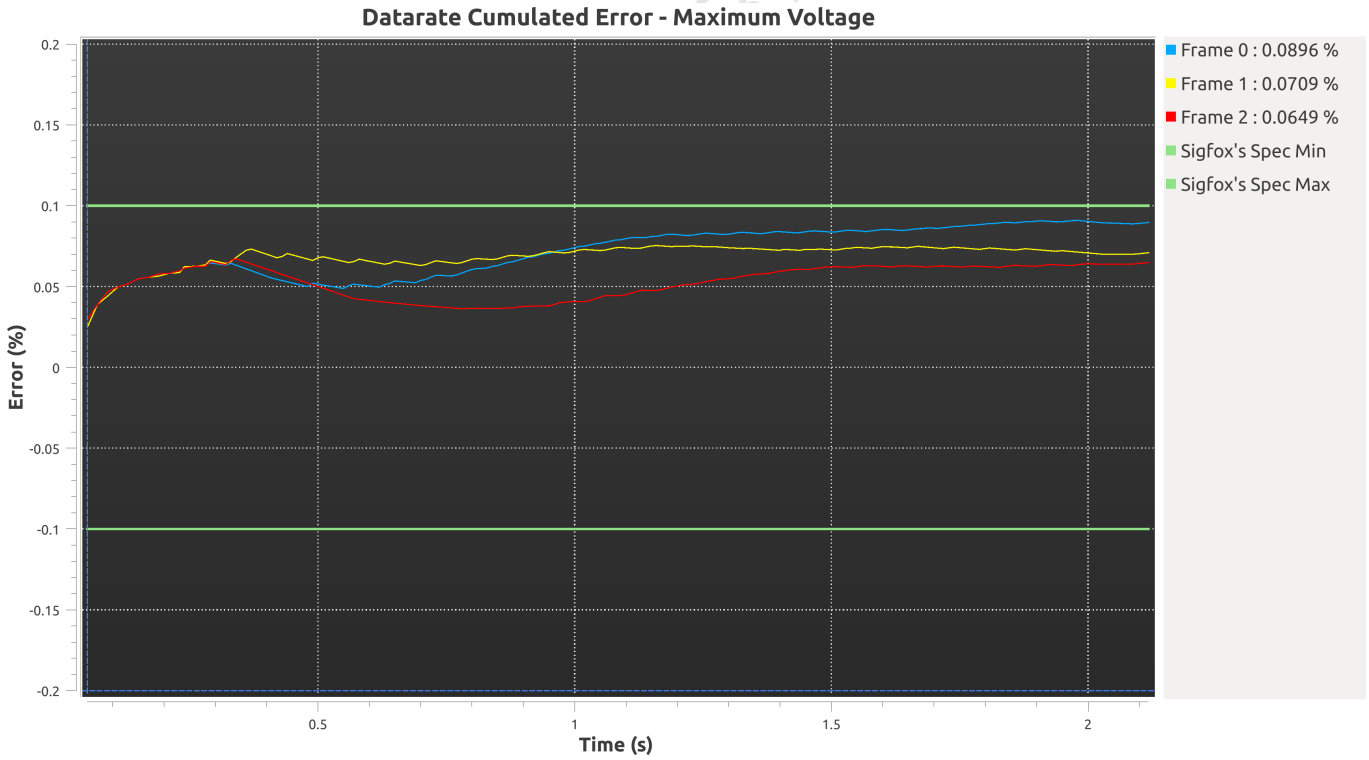
Total cumulated error : 0.0902145 %

Test Result Minimum Voltage: **PASS**



Total cumulated error : 0.0898997 %

Test Result Maximum Voltage: **PASS**

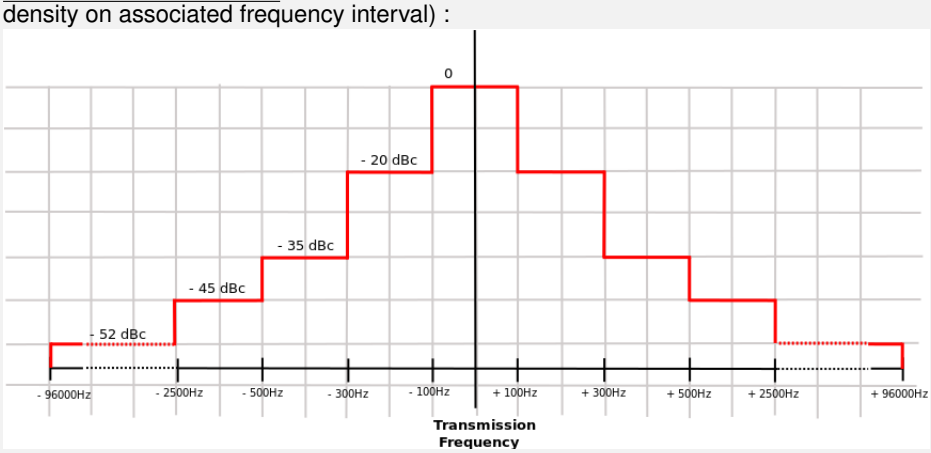


Total cumulated error : 0.0895851 %

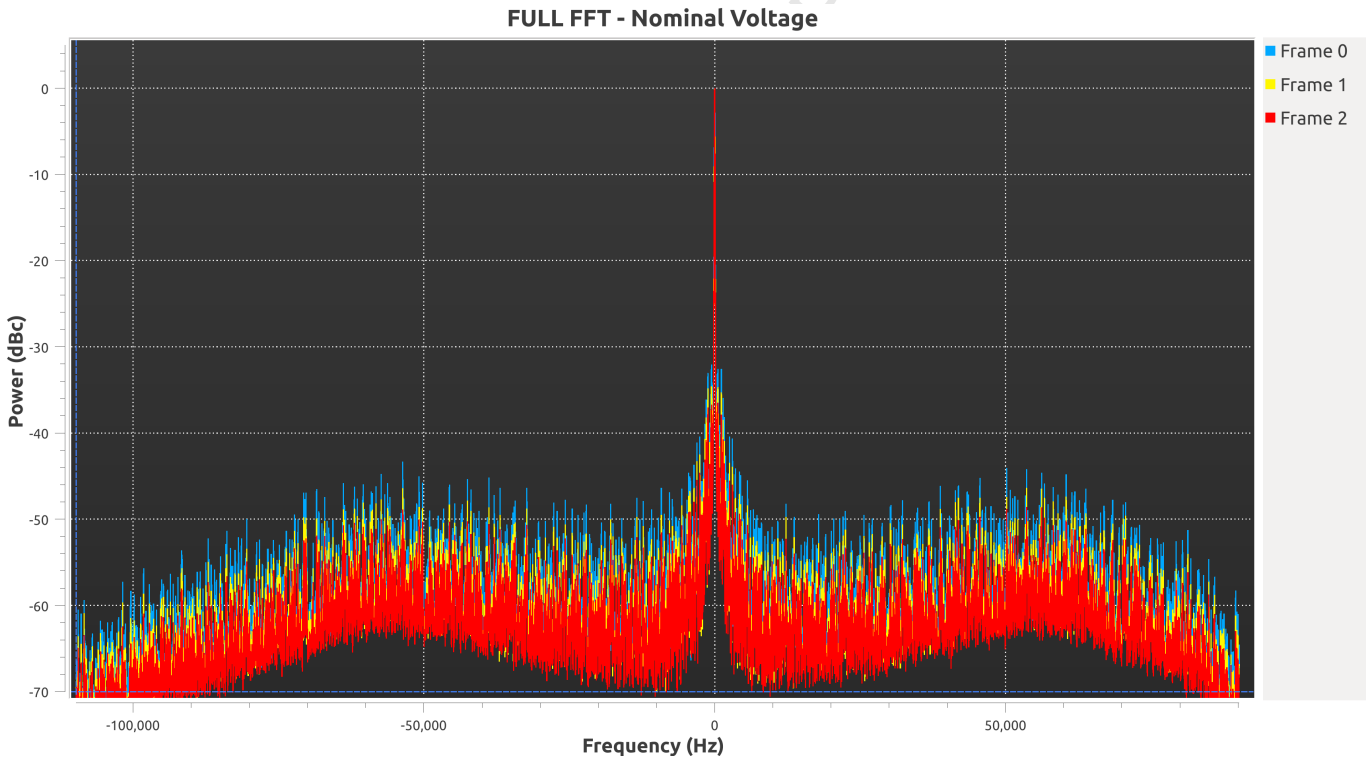
6.4 Output Spectrum

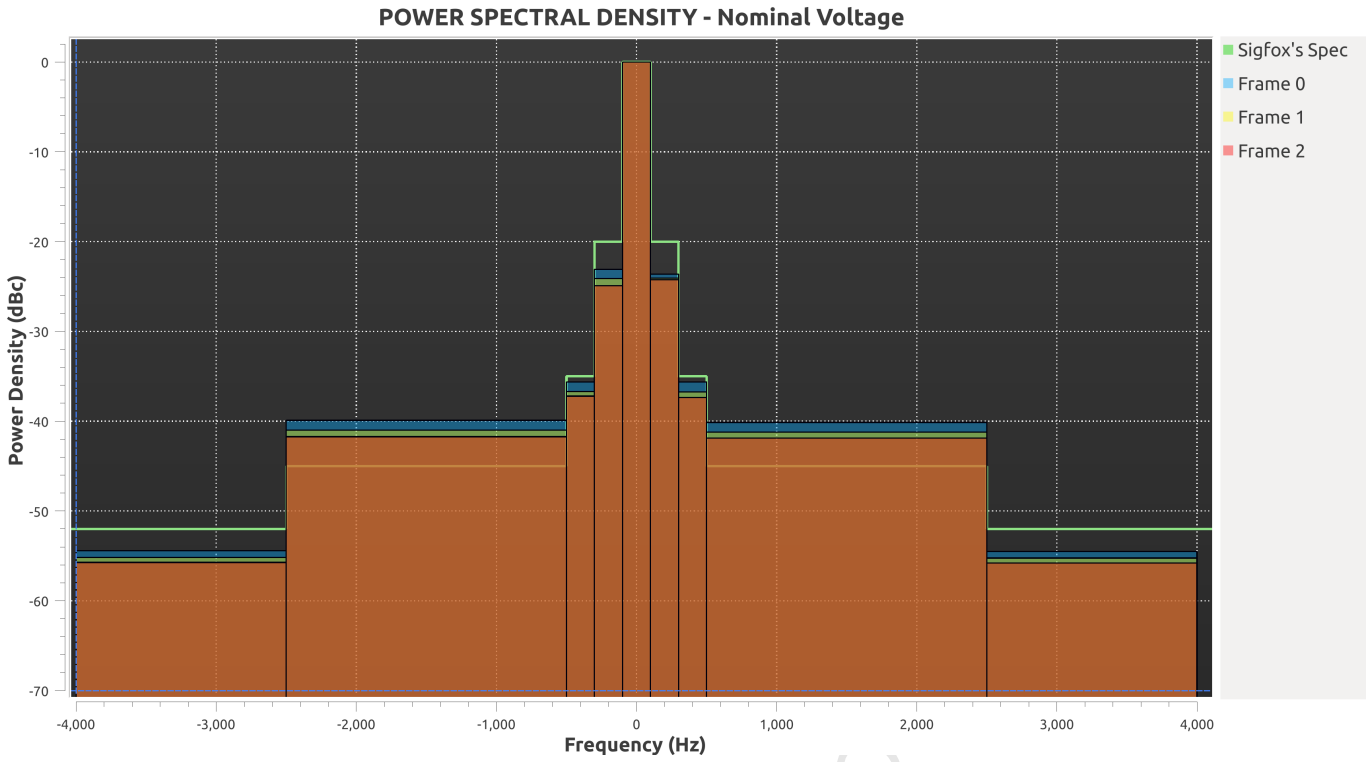
[PRS-RF-PROTOCOL-40] Power Spectral Density

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

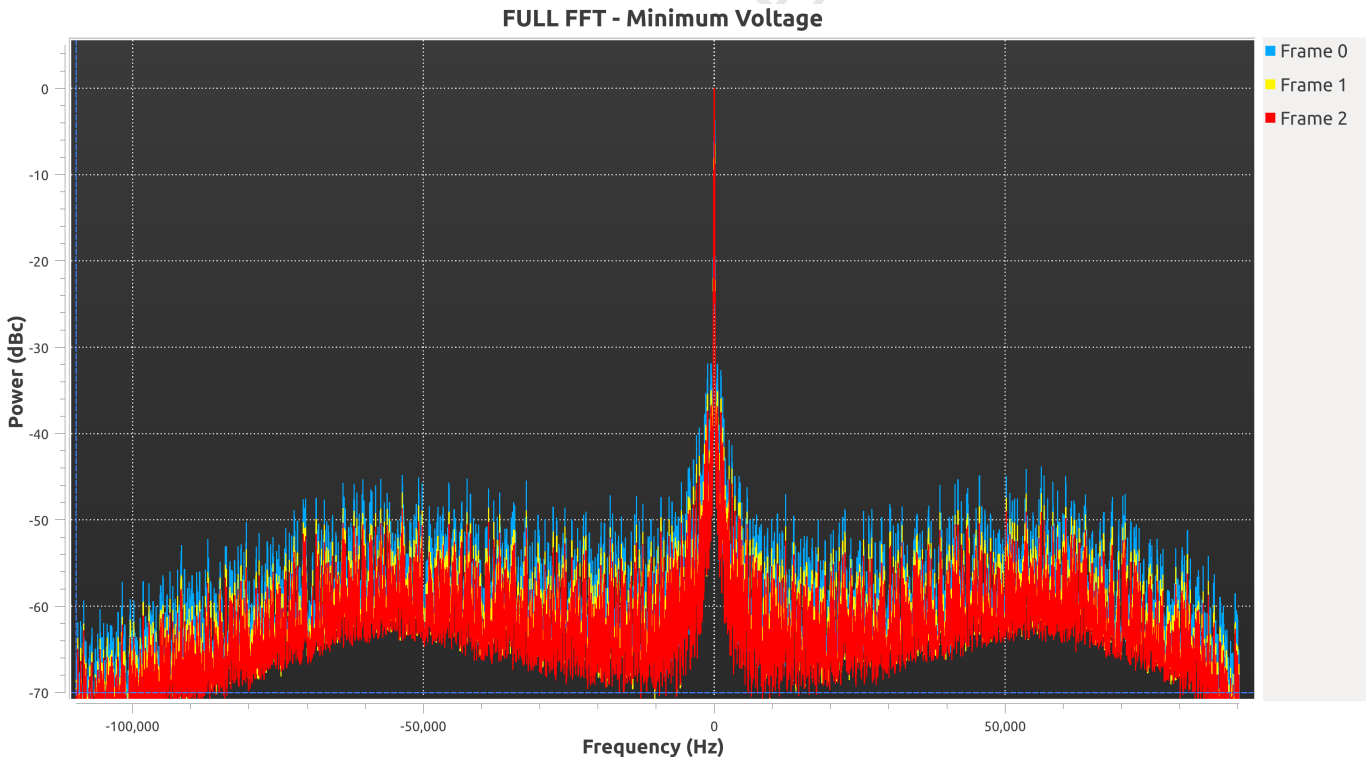


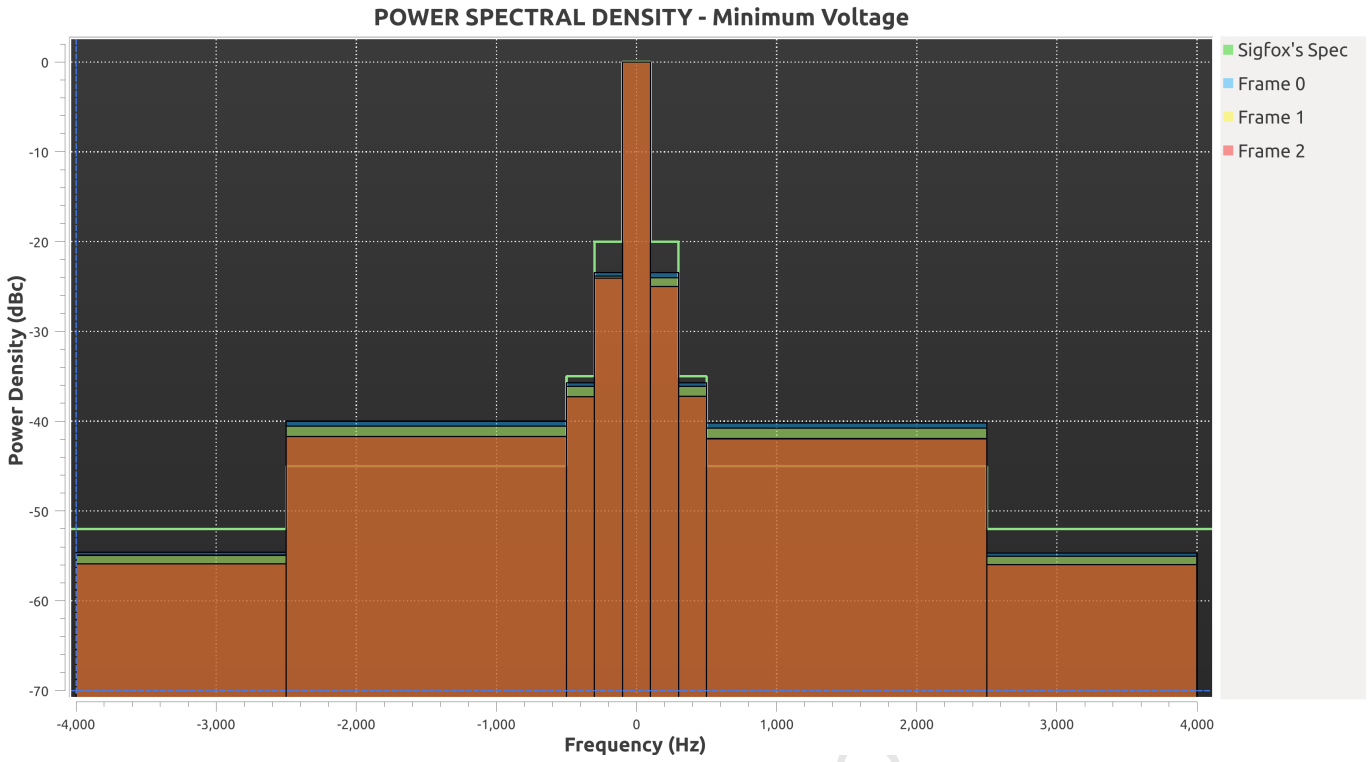
Test Result Nominal Voltage: **FAIL**



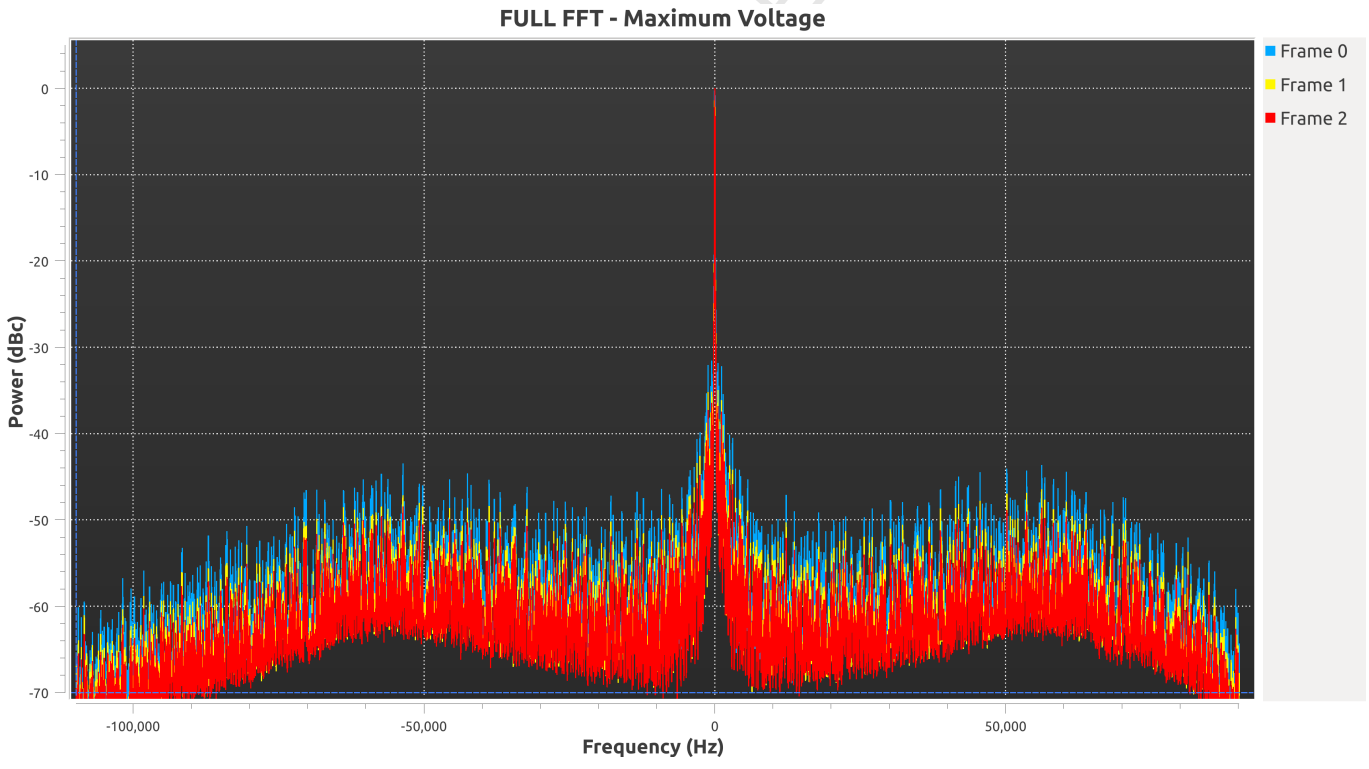


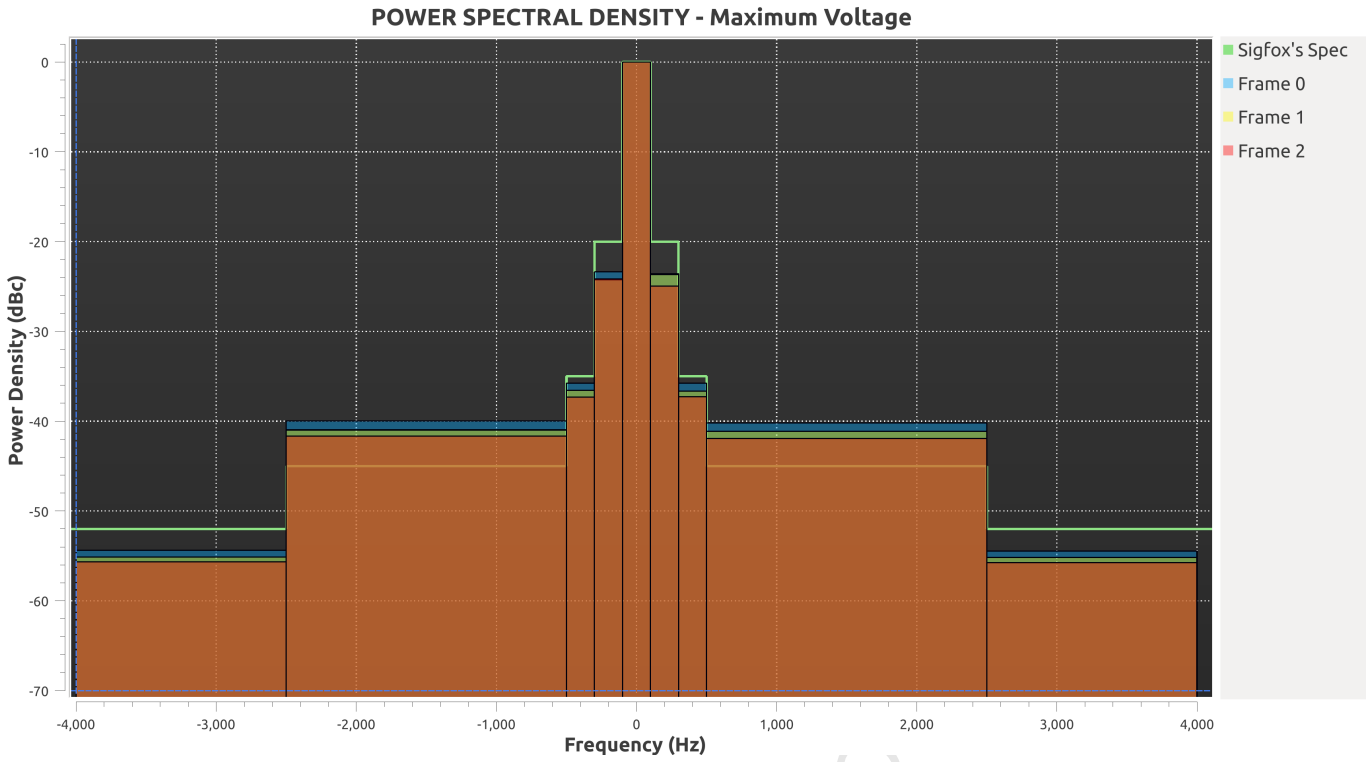
Test Result Minimum Voltage: **FAIL**





Test Result Maximum Voltage: **FAIL**



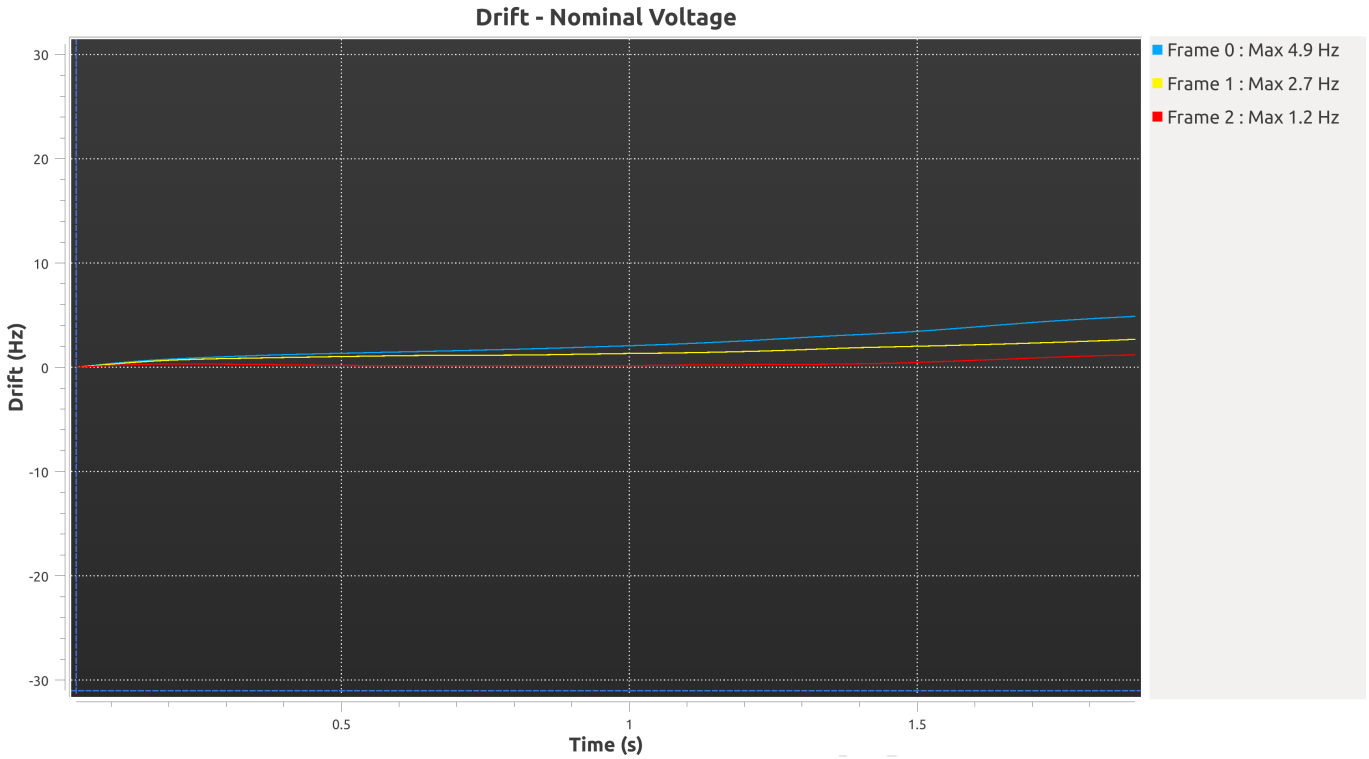


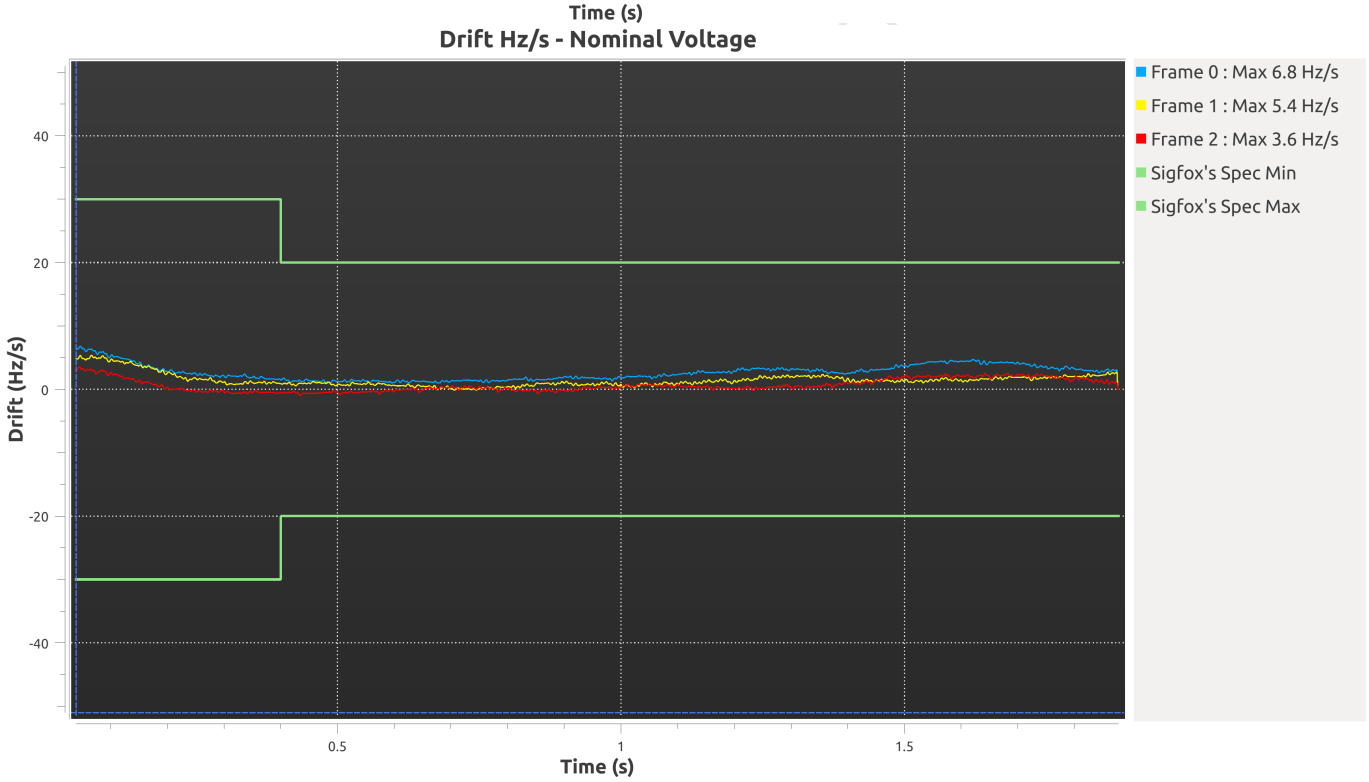
6.5 Carrier frequency stability

[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.

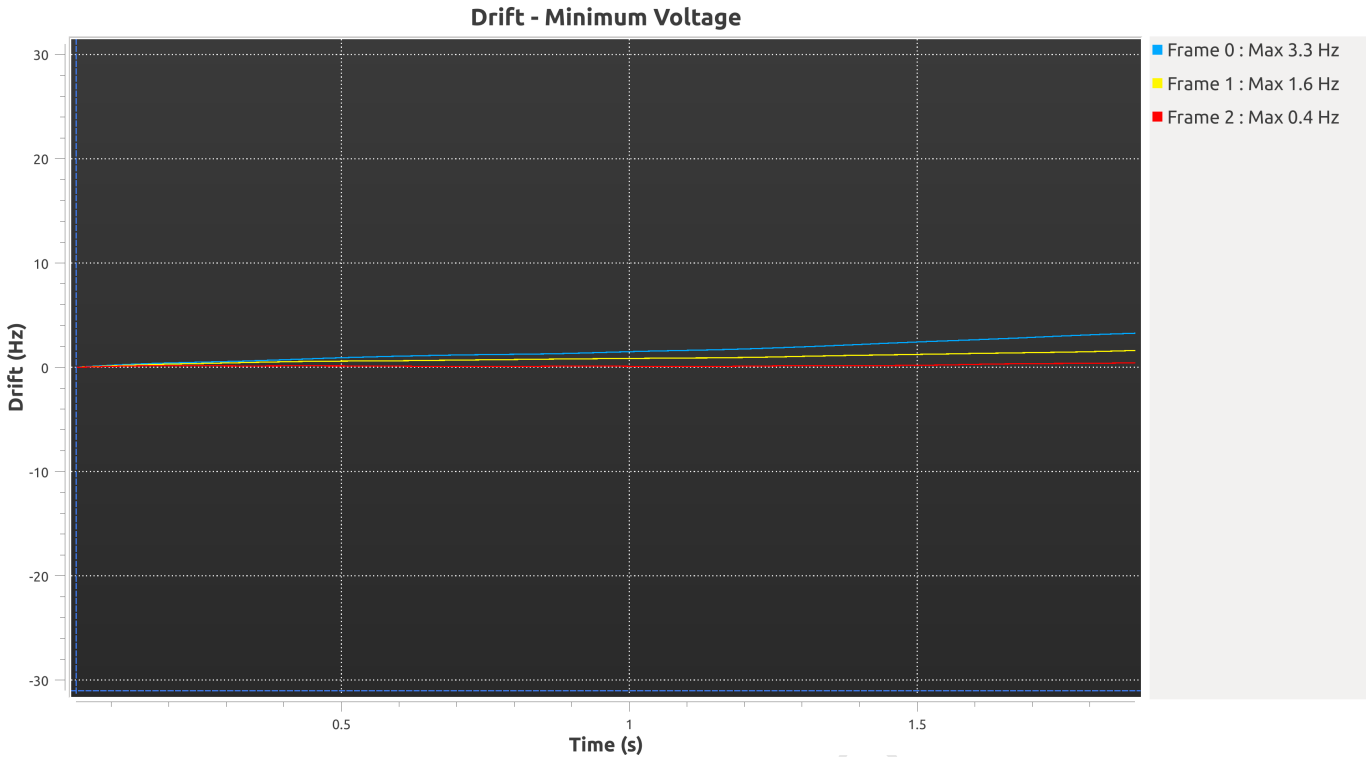
Test Result Nominal Voltage: **PASS**

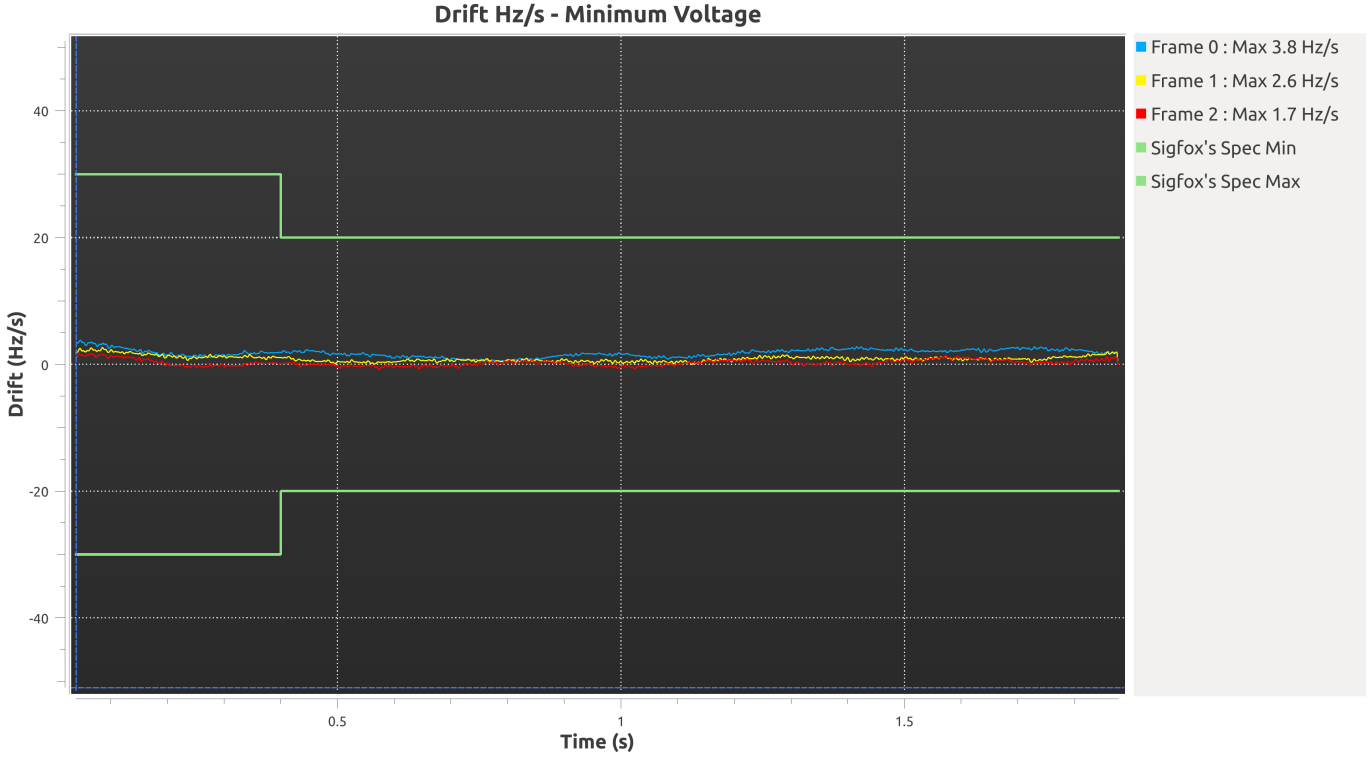




Maximum measured frequency : 6.83857 Hz/s

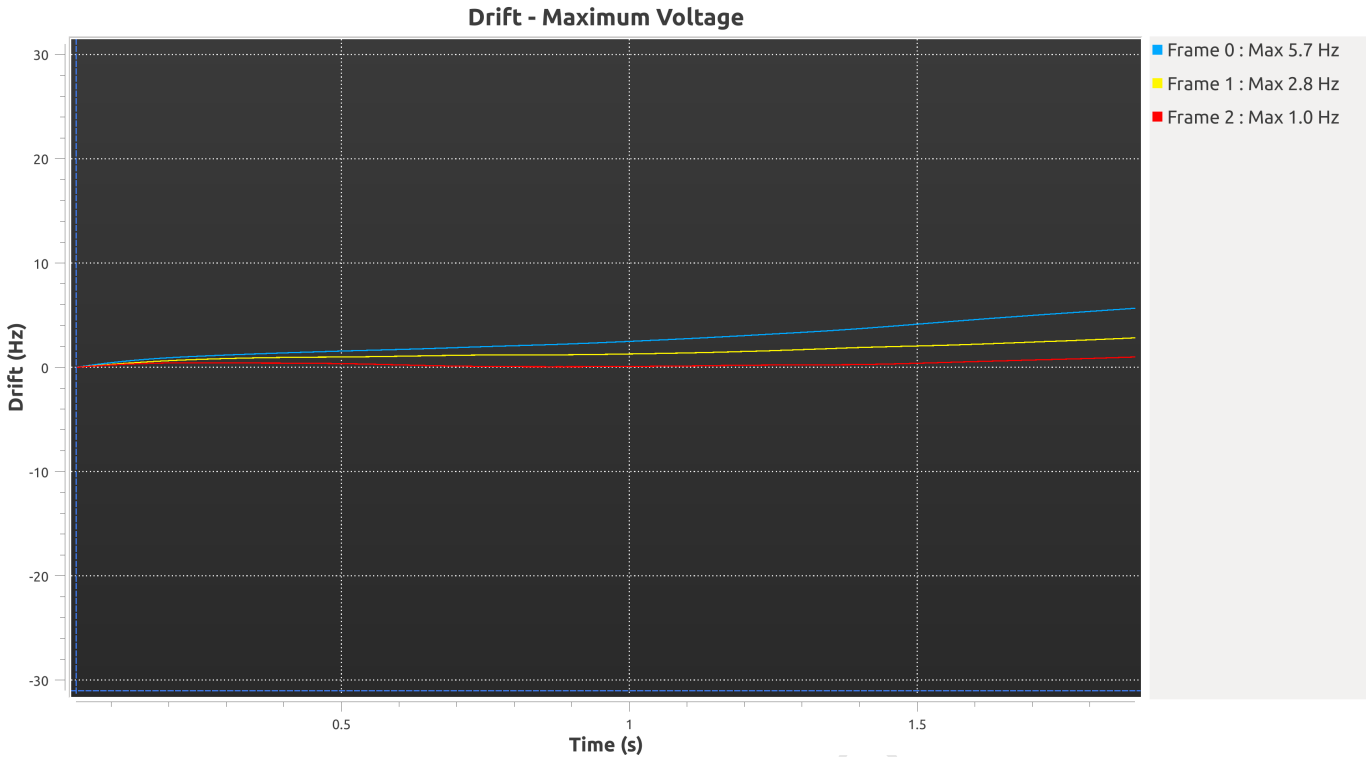
Test Result Minimum Voltage: **PASS**

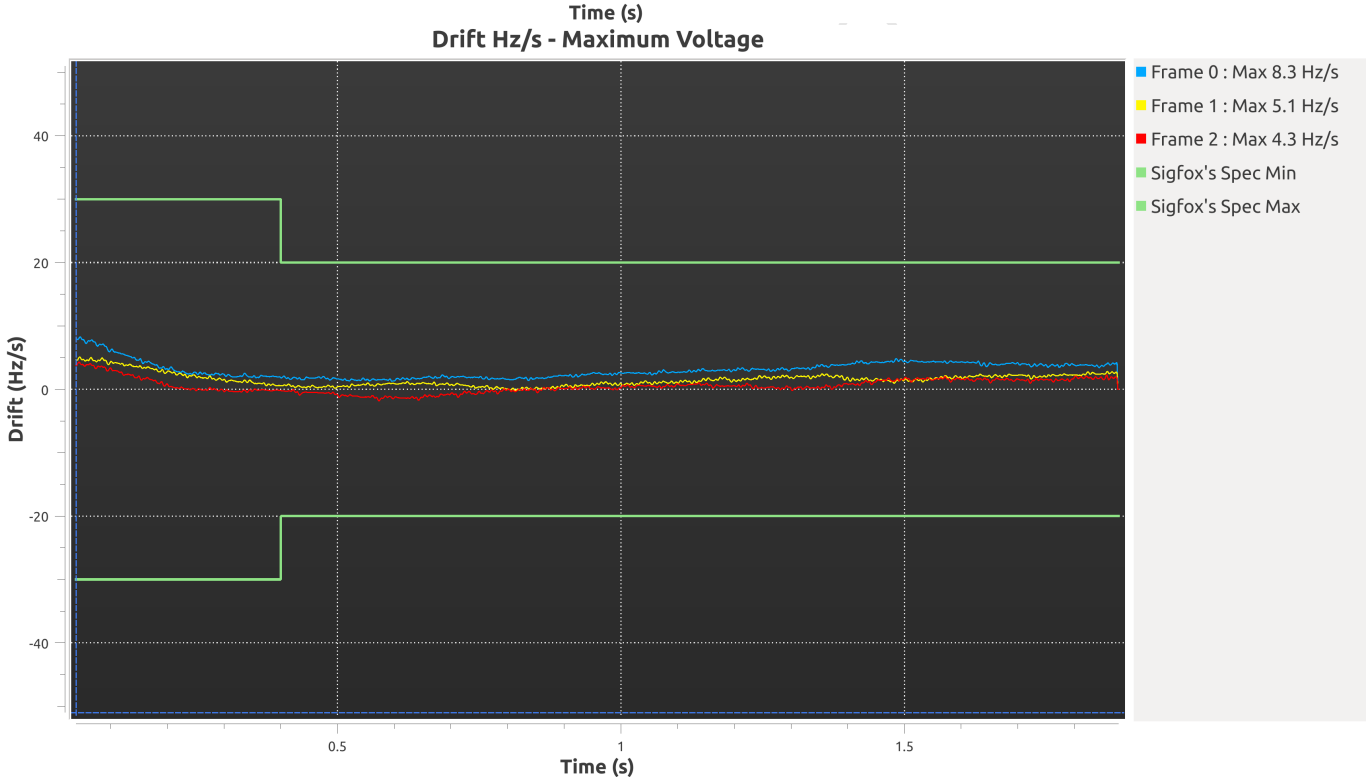




Maximum measured frequency : 3.82953 Hz/s

Test Result Maximum Voltage: **PASS**



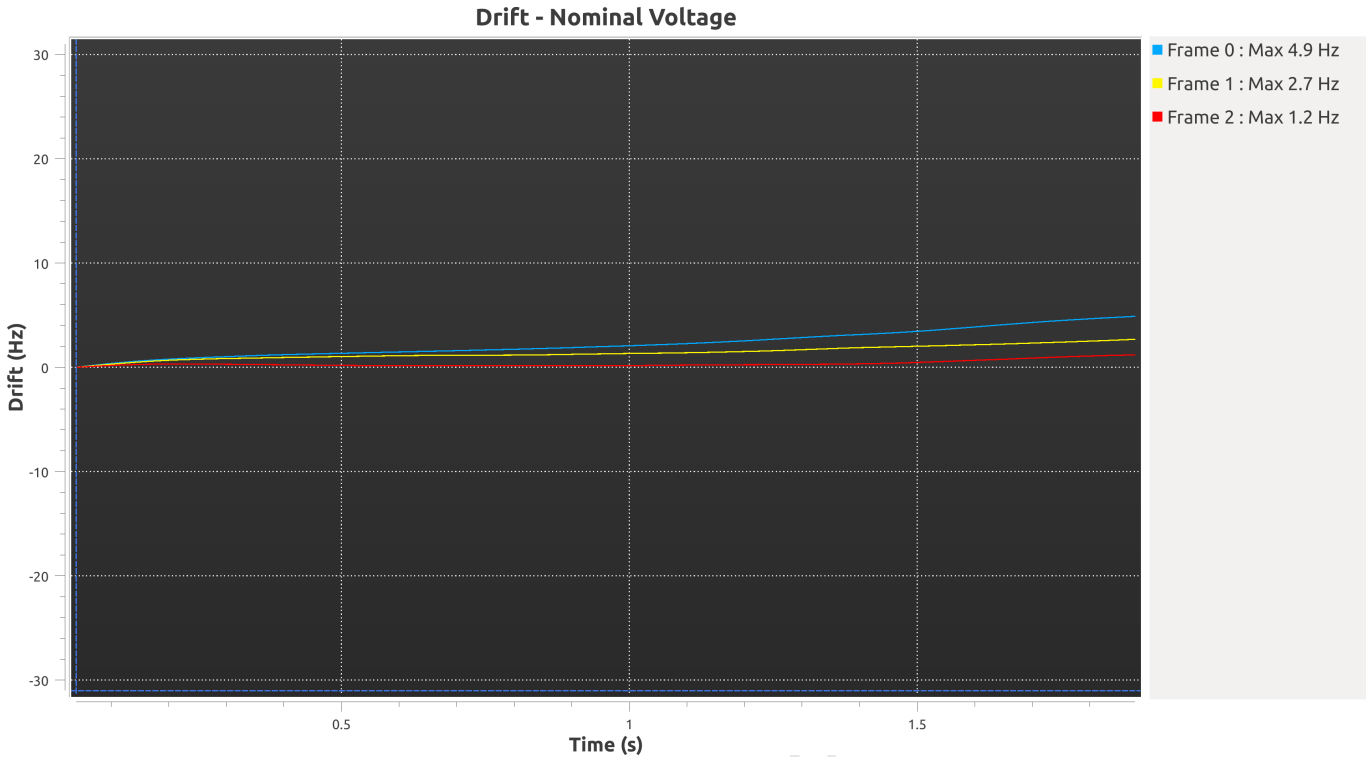


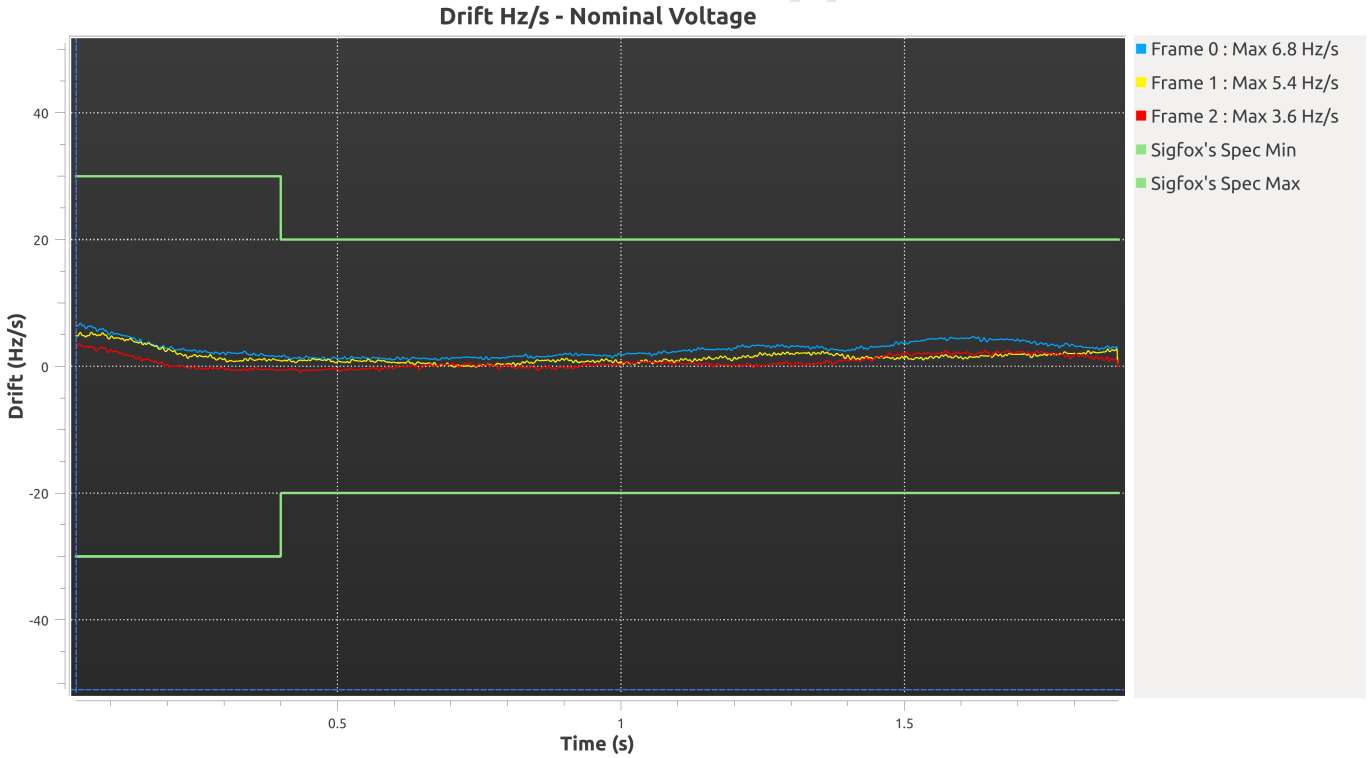
Maximum measured frequency : 8.28444 Hz/s

[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.

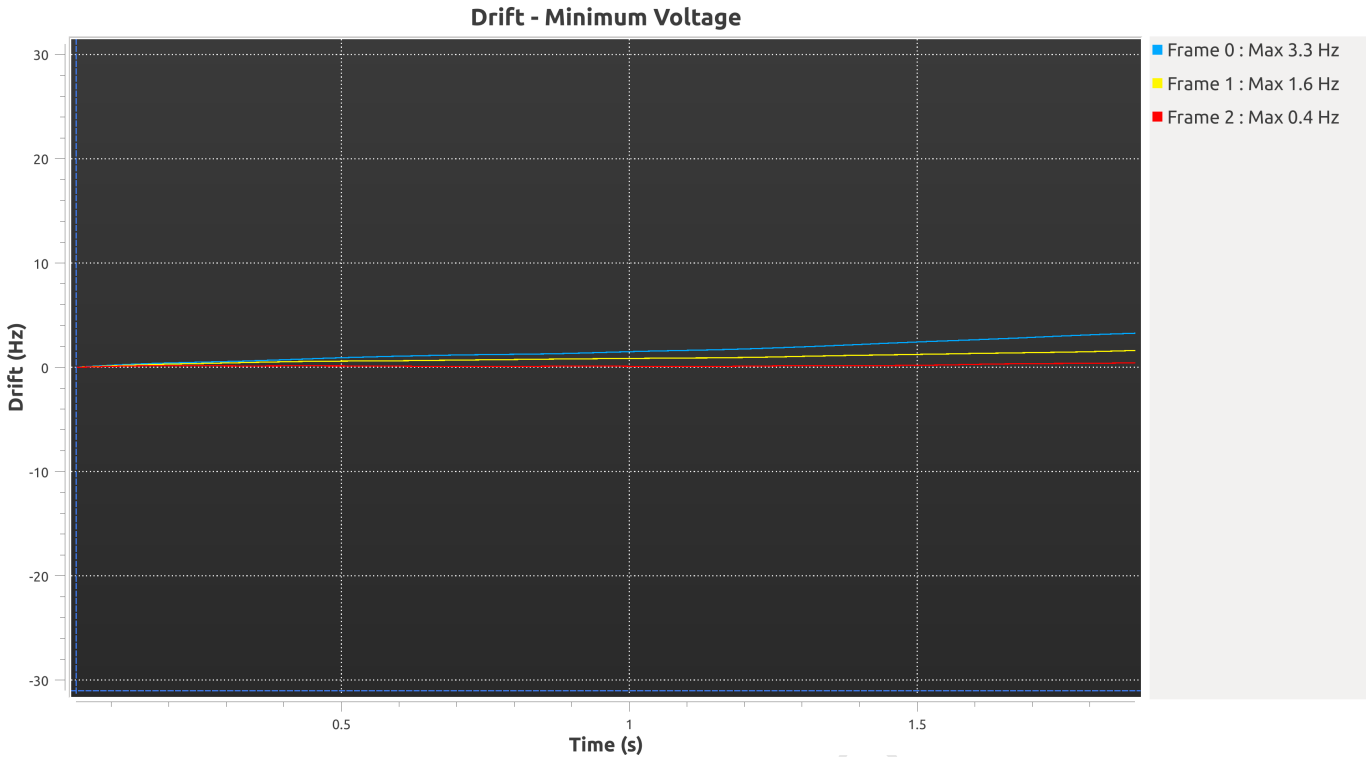
Test Result Nominal Voltage: **PASS**

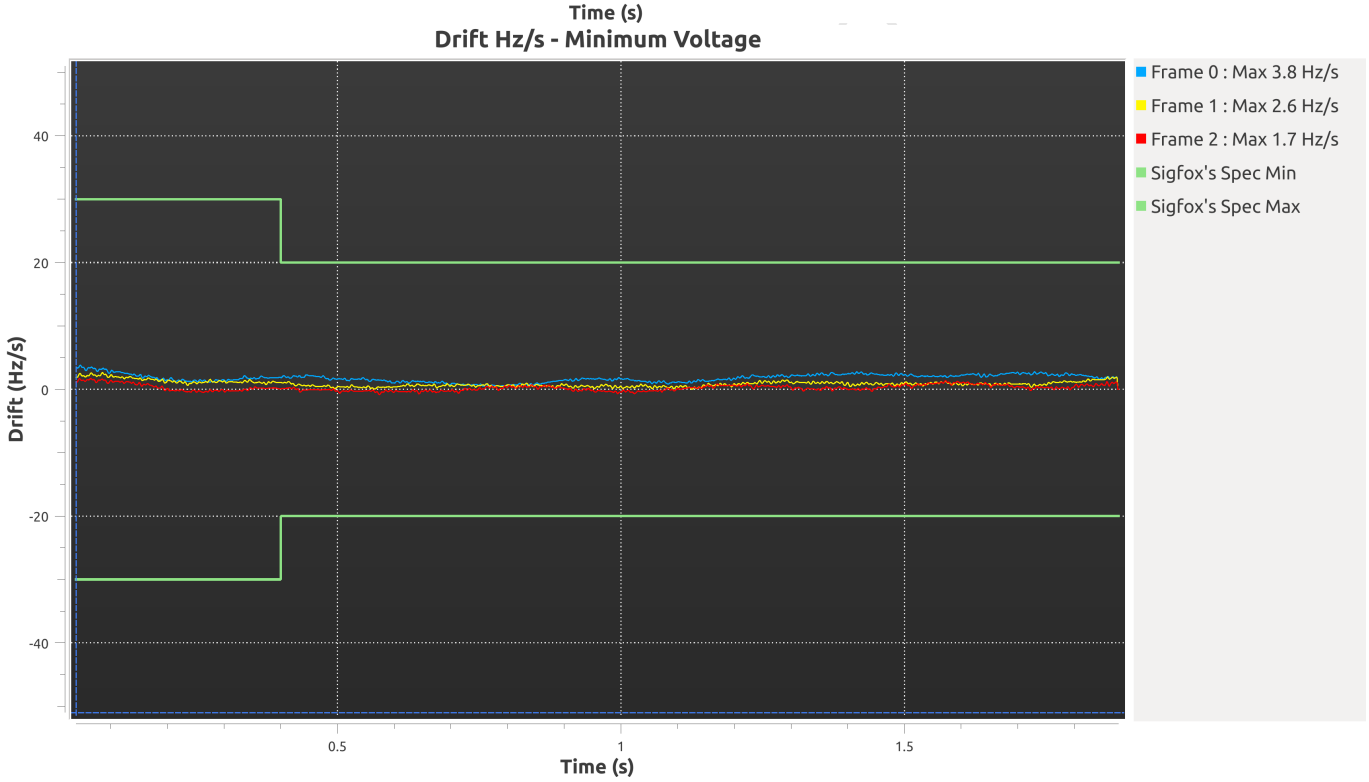




Maximum measured drift : 4.69773 Hz/s

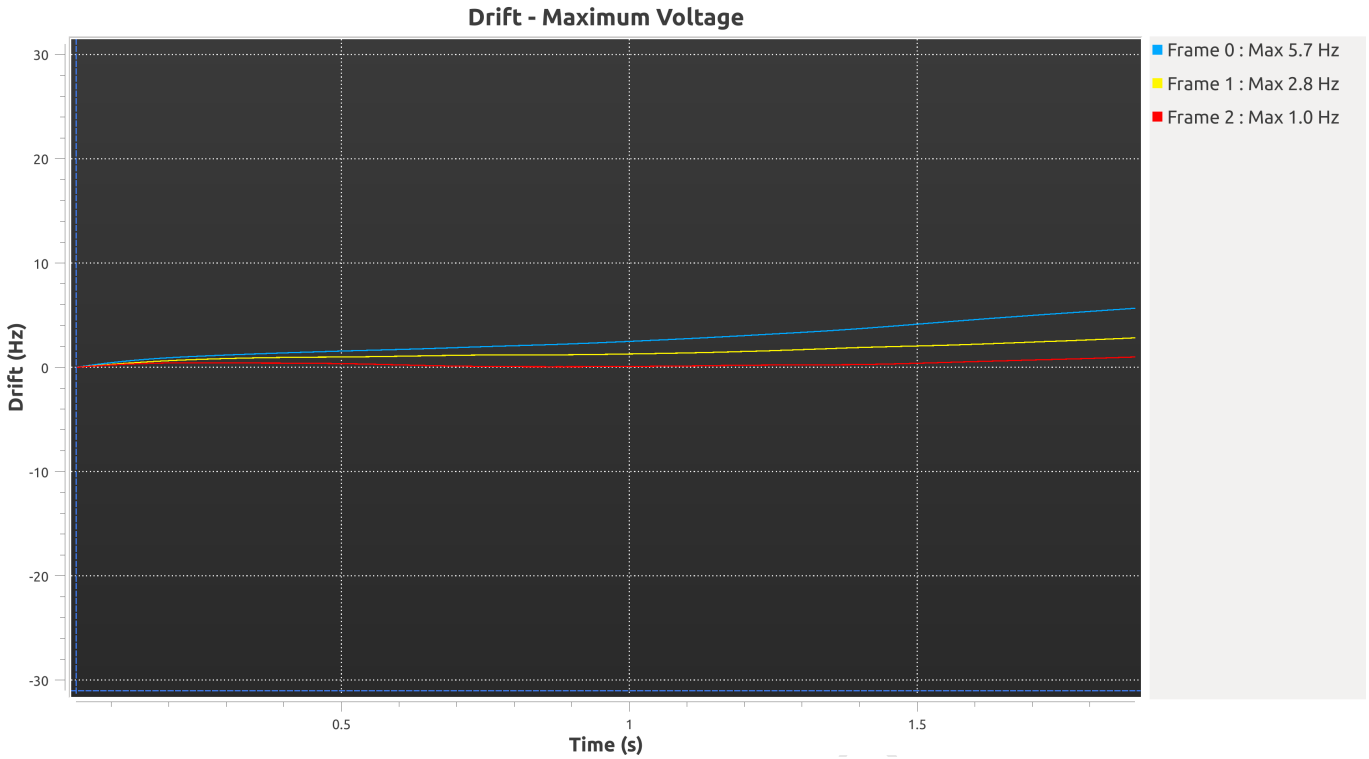
Test Result Minimum Voltage: **PASS**

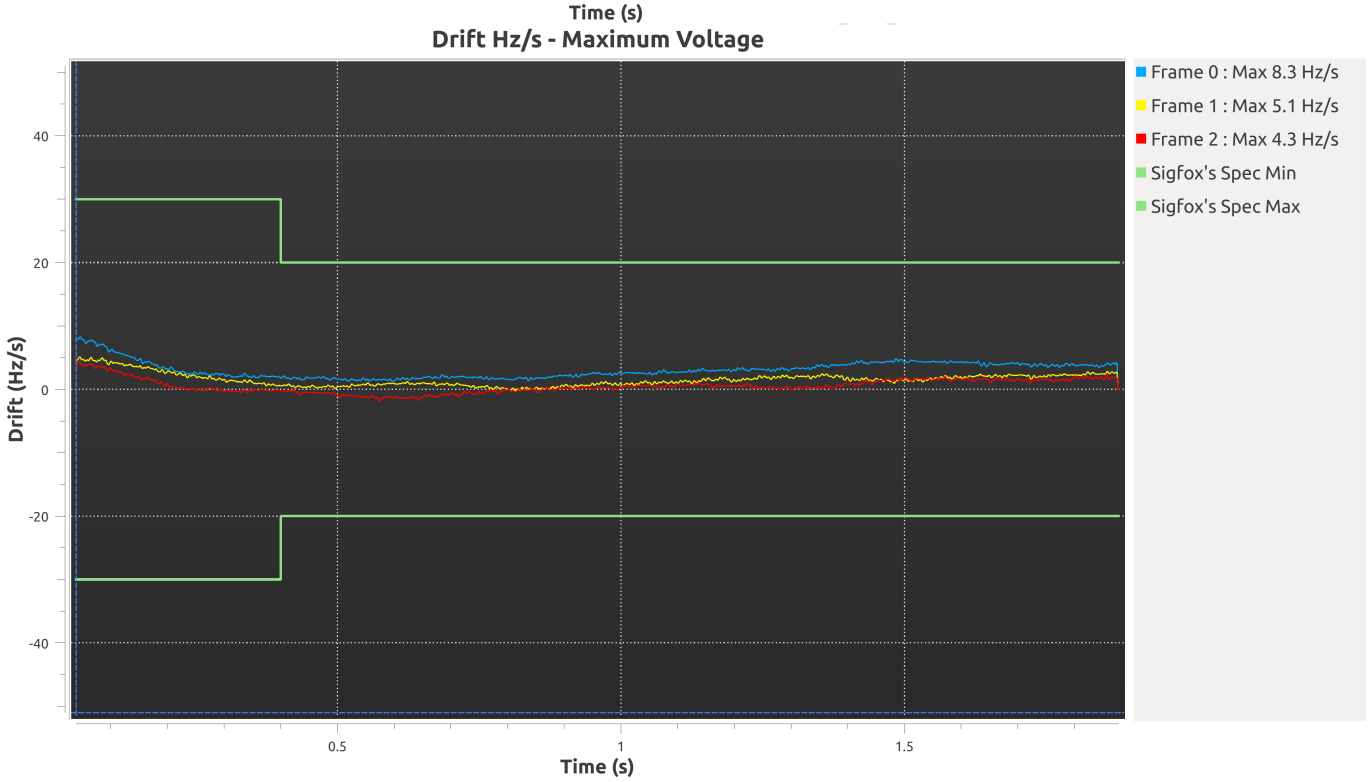




Maximum measured drift : 2.79239 Hz/s

Test Result Maximum Voltage: **PASS**





Maximum measured drift : 4.84258 Hz/s

6.6 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).

Test Result Nominal Voltage: **PASS**

6.7 Sigfox Link Budget

[PRS-RF-PROTOCOL-70] 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

Test Result Nominal Voltage: **PASS**

Number of message : 35
FER : 0 %
Test executed for a balanced link budget at -124.8 dBm

6.8 Protocol

[PRS-RF-PROTOCOL-80] 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.

Test Result Nominal Voltage: **PASS**

[PRS-RF-PROTOCOL-81] NVM Frequency Storage

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

Test Result Nominal Voltage: **PASS**

[PRS-RF-PROTOCOL-82] 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.

Test Result Nominal Voltage: **PASS**

[PRS-RF-PROTOCOL-83] 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)*

Test Result Nominal Voltage: **NOT APPLICABLE**

test is NOT APPLICABLE

[PRS-RF-PROTOCOL-84] 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.

Test Result Nominal Voltage: **PASS**

[PRS-RF-PROTOCOL-85] Legacy Uplink

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

Test Result Nominal Voltage: **PASS**

All frame types received

[PRS-RF-PROTOCOL-86] 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.

Test Result Nominal Voltage: **PASS**

[PRS-RF-PROTOCOL-87] 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).

Test Result Nominal Voltage: **FAIL**

GFSK response level : -100 dBm
Returned RSSI from device : -95 dBm

[PRS-RF-PROTOCOL-88] 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.

Test Result Nominal Voltage: **PASS**

6.9 Timings

[PRS-RF-PROTOCOL-90] 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 .

Test Result Nominal Voltage: **FAIL**

Minimum measured interframe : 2.54753 s
Maximum measured interframe : 2.55082 s

[PRS-RF-PROTOCOL-91] 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.

Test Result Nominal Voltage: **FAIL**

[PRS-RF-PROTOCOL-92] 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.

Test Result Nominal Voltage: **FAIL**

Minimum measured interframe : 2.54818 s
Maximum measured interframe : 2.5491 s

[PRS-RF-PROTOCOL-93] 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:

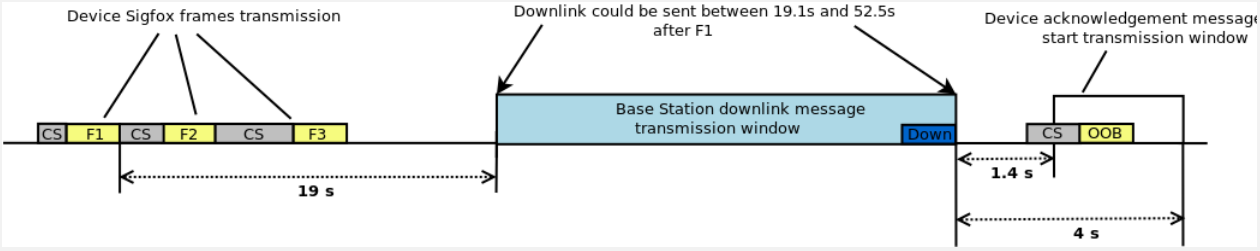


Figure 1: Downlink Timings

Test Result Nominal Voltage: **PASS**

[PRS-RF-PROTOCOL-94] 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:

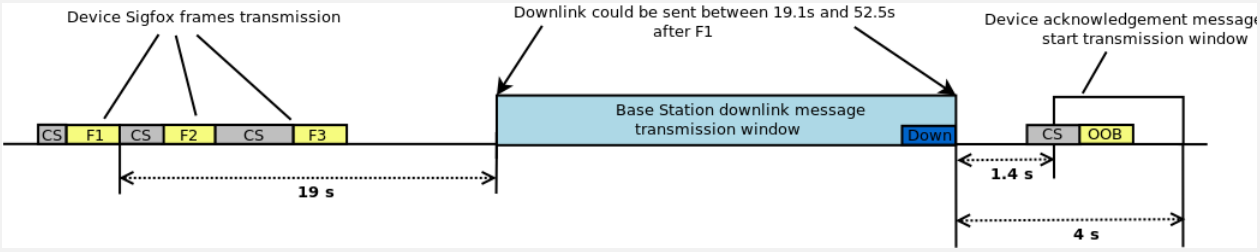


Figure 2: Downlink Timings (last chance to receive downlink frame case)

Test Result Nominal Voltage: **PASS**

[PRS-RF-PROTOCOL-95] 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.

Test Result Nominal Voltage: **PASS**

Measured downlink GFSK response to OOB : 3.4271 s

7 Additonal Measurements Results

7.1 Modulated Conducted TX Output power

[PRS-RF-PROTOCOL-100] 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).

Test Result Nominal Voltage: **INFO**

Minimum Measured output power : 10.3995 dBm
Maximum Measured output power : 10.7547 dBm

Test Result Minimum Voltage: **INFO**

Minimum Measured output power : 10.4195 dBm
Maximum Measured output power : 10.7777 dBm

Test Result Maximum Voltage: **INFO**

Minimum Measured output power : 10.3928 dBm
Maximum Measured output power : 10.748 dBm

7.2 Validation of the information contained in the OOB Frame

[PRS-RF-PROTOCOL-110] 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.

Test Result Nominal Voltage: **INFO**

Returned temperature from device : 26 °C

[PRS-RF-PROTOCOL-111] 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.

Test Result Nominal Voltage: **INFO**

Returned Voltage Idle from device : 3.565 V
Returned Voltage Tx from device : 3.53 V

7.3 I/Q Wave record

[PRS-RF-PROTOCOL-120] I/Q Wave record

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

Test Result Nominal Voltage: **PASS**

8 Tracability Matrix

8.1 Operational Requirements Results

Requirement	Voltage	Test Verdict
[PRS-RF-PROTOCOL-10] Frequency Steps	Vnom	PASS
[PRS-RF-PROTOCOL-11] Operational Frequencies Range	Vnom	PASS
[PRS-RF-PROTOCOL-12] Operational Frequencies Distribution	Vnom	PASS
[PRS-RF-PROTOCOL-13] Static Frequency Tolerance	Vnom	PASS
	Vmin	PASS
	Vmax	PASS
[PRS-RF-PROTOCOL-20] DBPSK Modulation envelope	Vnom	PASS
	Vmin	PASS
	Vmax	PASS
[PRS-RF-PROTOCOL-21] Phase Measurement	Vnom	PASS
	Vmin	PASS
	Vmax	PASS
[PRS-RF-PROTOCOL-22] Extra symbols before the first Sigfox bit of the frame	Vnom	PASS
	Vmin	PASS
	Vmax	PASS
[PRS-RF-PROTOCOL-23] Extra symbols after the last Sigfox bit of the frame	Vnom	FAIL
	Vmin	FAIL
	Vmax	FAIL
[PRS-RF-PROTOCOL-30] TX Max Symbol duration	Vnom	PASS
	Vmin	PASS
	Vmax	PASS
[PRS-RF-PROTOCOL-31] Max TX Baudrate Cumulated Error	Vnom	PASS
	Vmin	PASS
	Vmax	PASS
[PRS-RF-PROTOCOL-40] Power Spectral Density	Vnom	FAIL
	Vmin	FAIL
	Vmax	FAIL
[PRS-RF-PROTOCOL-50] Transitional Frequency Dynamic Drift	Vnom	PASS
	Vmin	PASS
	Vmax	PASS
[PRS-RF-PROTOCOL-51] Established Frequency Dynamic Drift	Vnom	PASS
	Vmin	PASS

continued on next page

continued from previous page		
Requirement	**Voltage**	**Test Verdict**
	Vmax	PASS
[PRS-RF-PROTOCOL-60] 2GFSK 600bps	Vnom	PASS
[PRS-RF-PROTOCOL-70] Sigfox Link Budget	Vnom	PASS
[PRS-RF-PROTOCOL-80] AES	Vnom	PASS
[PRS-RF-PROTOCOL-81] NVM Frequency Storage	Vnom	PASS
[PRS-RF-PROTOCOL-82] NVM Sequence Number Storage	Vnom	PASS
[PRS-RF-PROTOCOL-83] Public Key switch	Vnom	NOT APPLICABLE
[PRS-RF-PROTOCOL-84] Number of frames per message in Uplink mode	Vnom	PASS
[PRS-RF-PROTOCOL-85] Legacy Uplink	Vnom	PASS
[PRS-RF-PROTOCOL-86] Downlink Legacy	Vnom	PASS
[PRS-RF-PROTOCOL-87] RSSI level	Vnom	FAIL
[PRS-RF-PROTOCOL-88] Number of Uplink frame in bi-directional mode	Vnom	PASS
[PRS-RF-PROTOCOL-90] TX Interframe Timing in Uplink mode	Vnom	FAIL
[PRS-RF-PROTOCOL-91] TX repeat timeout	Vnom	FAIL
[PRS-RF-PROTOCOL-92] TX Interframe Timing in Bi-directional mode	Vnom	FAIL
[PRS-RF-PROTOCOL-93] RX Start Of Listening	Vnom	PASS
[PRS-RF-PROTOCOL-94] RX End Of Listening	Vnom	PASS
[PRS-RF-PROTOCOL-95] RX to OOB(ack) Timing	Vnom	PASS

8.2 Measurements Results

Measurement	Voltage	Test Verdict
[PRS-RF-PROTOCOL-100] Modulated Conducted Output Power	Vnom	INFO
	Vmin	INFO
	Vmax	INFO
[PRS-RF-PROTOCOL-110] DUT Temperature level	Vnom	INFO
[PRS-RF-PROTOCOL-111] DUT Voltage level	Vnom	INFO
[PRS-RF-PROTOCOL-120] I/Q Wave record	Vnom	PASS

9 User Manual for testing

SFM11R3 Test Manual

Rev.01

SEONG JI

April. 17, 2020

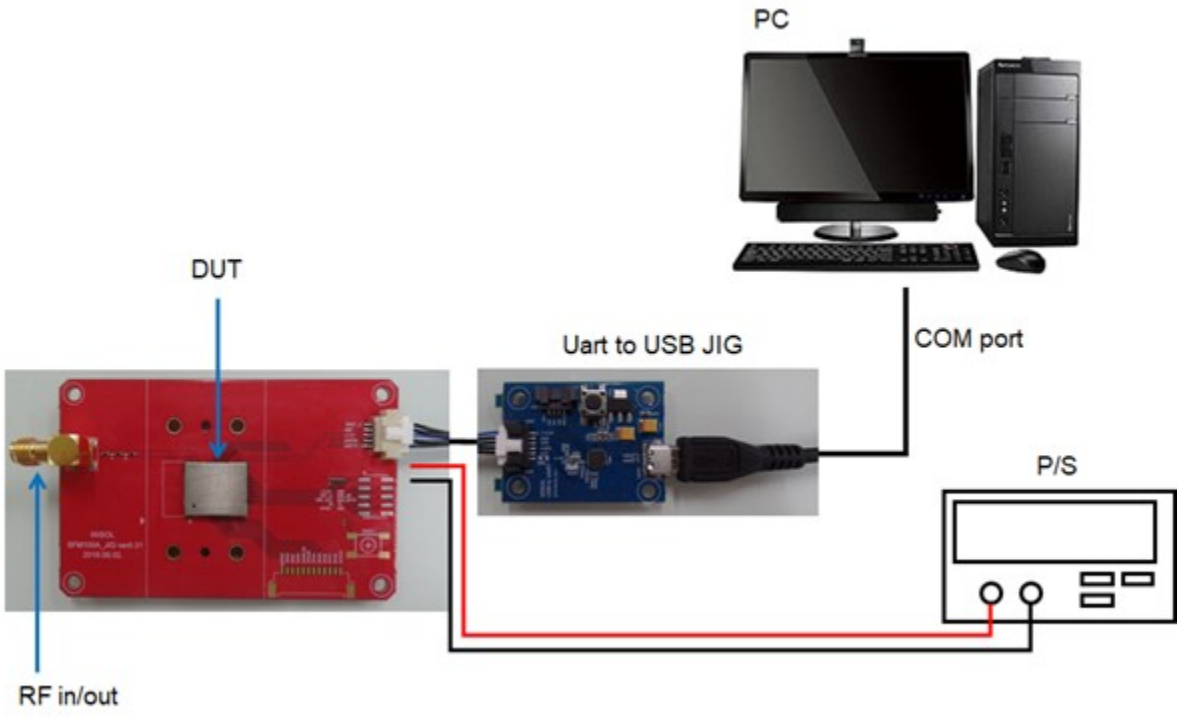
Contents

Model	F/W
SFM11R3	-

Setup & Test

DUT Connection

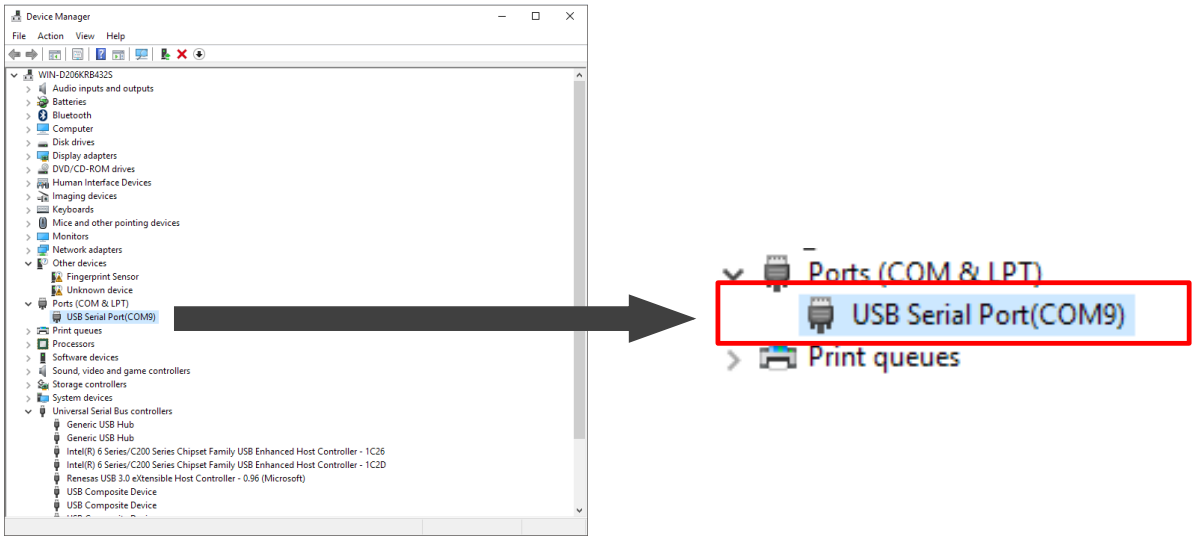
1. DUT connect to Window PC by JIG & USB cable.



Program execution

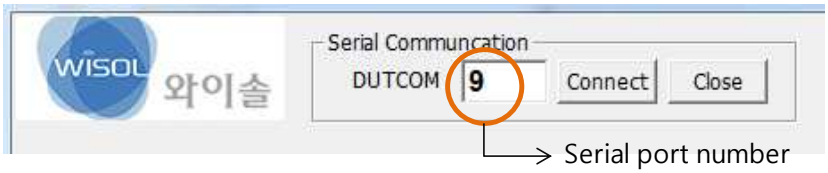
1. DUT connected serial-poet in Windows PC, and then check the COM-port number in device manager.

- USB Serial Port(Com□□)



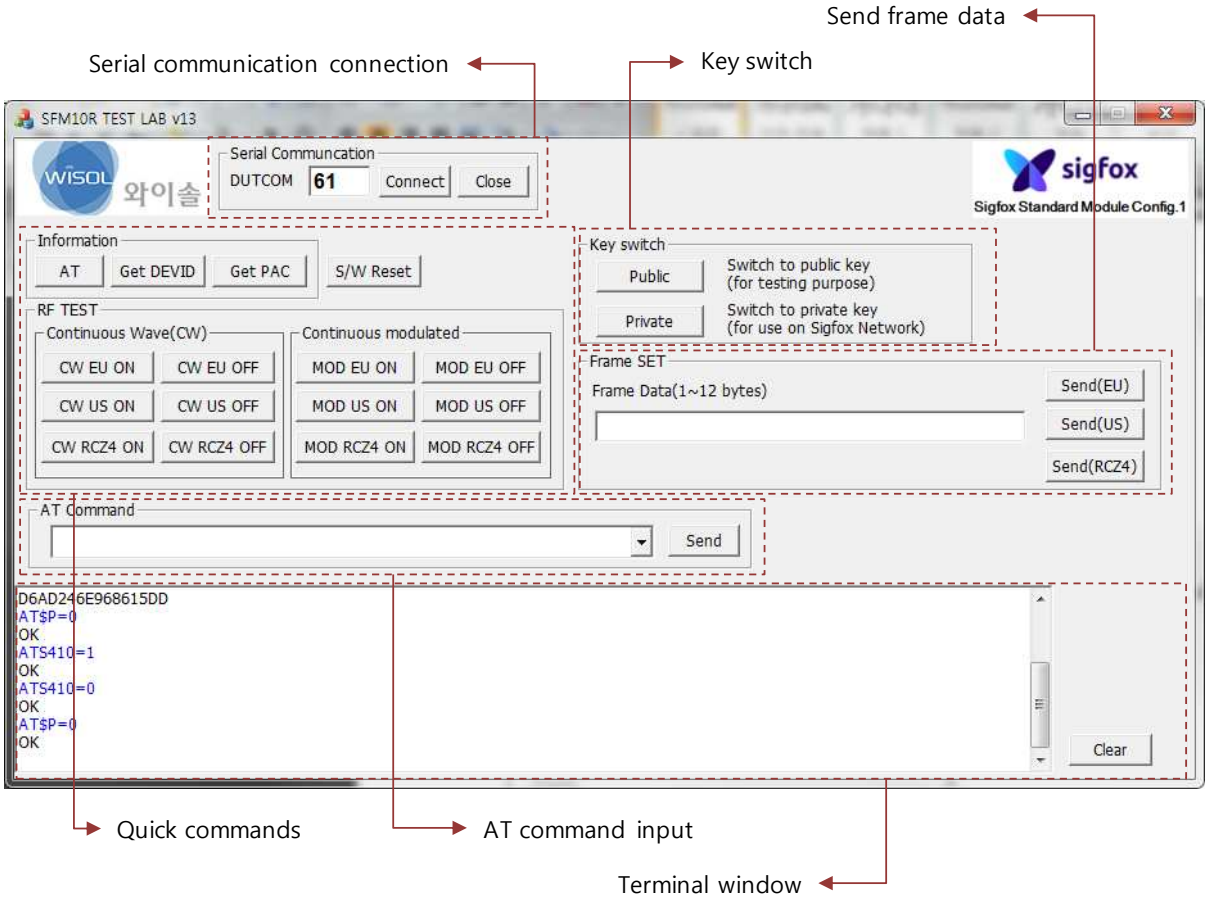
[Fig. serial port]

2. Run serial communication program "SFM10R_AT_TEST.exe"
3. Write serial port Number in 'DUTCOM' BOX, and then 'connect' click.



[Fig. Serial port number]

Test program Description



[Fig. Screen of execute Test program**(v13)**]

- Serial Communication
  - (1) DUTCOM: Input serial port number of USB
  - (2) Connect : Serial port open
  - (3) Close: Serial port close

- Quick commands
  - (1) AT: Just returns 'OK' and does nothing else. Can be used to check communication.
  - (2) Get DEVID: Read Device ID [AT$I=10]
  - (3) Get PAC: Read Device PAC [AT$I=11]
  - (4) S/W Reset : Software reset [AT$P=0]
  - (5) CW_EU_ON: To run Continuous Wave emission tests for RCZ1 module.
    [AT$CW=868130000,1,15]
  - (6) CW_EU_OFF: RCZ1 continuous wave Off [AT$CW=868130000,0,15]
  - (7) CW_US_ON: To run Continuous Wave emission tests for RCZ2 module.
    [AT$CW=902200000,1,24]

(8) CW_US_OFF: RCZ2 continuous wave Off [AT$CW=902200000,0,24]

(9) CW_RCZ4_ON: To run Continuous Wave emission tests for RCZ4 module.
[AT$CW=920800000,1,24]

(10) CW_RCZ4_OFF: RCZ4 continuous wave Off [AT$CW=920800000,0,24]

(11) MOD_EU_ON: Modulation wave ON for EU

AT$IF=868130000

ATS302=15 *// set output power to maximum power level.**

AT$CB=-1,1

(12) MOD_US_ON: Modulation wave ON for US

AT$IF=902200000

AT$CB=-1,1

(13) MOD_RCZ4_ON: Modulation wave ON for RCZ4

AT$IF=920800000

AT$CB=-1,1

(14) MOD_EU(US/RCZ4)_OFF: Modulation wave Off [AT$CB=-1,0]

(15) Frame Data: Send a SIGFOX message for EU

ATS302=15 *// set output power to maximum power level.**

AT$SF= xxxxxxxxxxxx

(16) Frame Data: Send a SIGFOX message for US Tx only

AT$GI? → return X,Y

If X=0 or Y<3

AT$RC

AT$SF= xxxxxxxxxxxx

(17) Frame Data: Send a SIGFOX message for RCZ4 Tx only

AT$GI? → return X,Y

If X=0 or Y<3

AT$RC

AT$SF= xxxxxxxxxxxx

* Execute S/W reset to ensure Tx frequency on payload data sending with Send(XX) button because Tx frequency can be changed when RF TEST buttons executed.

** By default, register 302 is set to 14 level which leads to an output power of 12.5dBm. Use the command ATS302=15 to set the output power to the maximum power level. This register is only accessible for RCZ1 module.*

- Key switch

(1) Public: switch to public key [ATS410=1]

(2) Private: switch to private key [ATS410=0]

- AT Command input
  (1) Typing and send AT commands

AT command for DUT

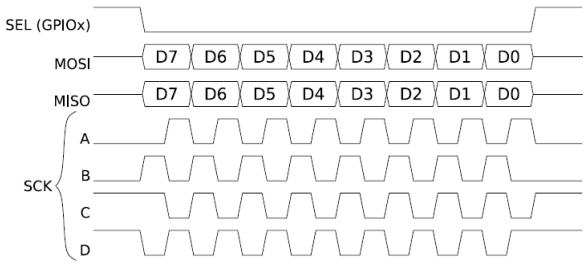
A typical serial terminal emulator can also be used to control the DUT instead of the proposed test SW. In that case the following parameters should be used:

- Speed : 9600 bauds
- Data bits: 8
- Stop bits: 1
- Parity: None

The following table gather all AT command available:

Command	Name	Description
AT	Dummy Command	Just returns 'OK' and does nothing else. Can be used to check communication.
AT$SB=bit[,bit]	Send Bit	Send a bit status (0 or 1). Optional bit flag indicates if AX–SFEU should receive a downlink frame.
AT$SF=frame[,bit]	Send Frame	Send payload data, 1 to 12 bytes. Optional bit flag indicates if AX–SFEU should receive a downlink frame.
AT$SO	Manually send out of band message	Send the out–of–band message.
AT$TR?	Get the transmit repeat	Returns the number of transmit repeats. Default: 2
AT$TR=?	Get transmit range	Returns the allowed range of transmit repeats.
AT$TR=uint	Get transmit repeat	Sets the transmit repeat.
ATSuint?	Get Register	Query a specific configuration register's value. See chapter "Registers" for a list of registers.
ATSuint=uint	Set Register	Change a configuration register.
ATSuint=?	Get Register Range	Returns the allowed range of transmit repeats.
AT$IF=uint	Set TX Frequency	Set the output carrier macro channel for Sigfox frames.
AT$IF?	Get TX Frequency	Get the currently chosen TX frequency.
AT$DR=uint	Set RX Frequency	Set the reception carrier macro channel for Sigfox frames.
AT$DR?	Get RX Frequency	Get the currently chosen RX frequency.
AT$CW=uint,bit[,uint_opt]	Continuous Wave	To run emission tests for Sigfox certification it is necessary to send a continuous wave, i.e. just the base frequency without any modulation. Parameters: **Name** / **Range** / **Description** Frequency / 800000000–999999999, 0 / Continuous wave frequency in Hz. Use 868130000 for Sigfox or 0 to keep previous frequency. Mode / 0, 1 / Enable or disable carrier wave. Power / 0–14 / dBm of signal | Default: 14
AT$CB=uint_opt,bit	Test Mode: TX constant byte	For emission testing it is useful to send a specific bit pattern. The first parameter specifies the byte to send. Use '–1' for a (pseudo–)random pattern. Parameters: **Name** / **Range** / **Decsription** Pattern / 0–255, –1 / Byte to send. Use '–1' for a (pseudo–)random pattern. Mode / 0, 1 / Enable or disable pattern test mode.
AT$T?	Get Temperature	Measure internal temperature and return it in 1/10th of a degree Celsius.
AT$V?	Get Voltages	Return current voltage and voltage measured during the last transmission in mV.

Command	Name	Description
AT$I=uint	Information	Display various product information: 0: Software Name & Version Example Response: AX-SFEU 1.0.6-ETSI 1: Contact Details Example Response: support@axsem.com 2: Silicon revision lower byte Example Response: 8F 3: Silicon revision upper byte Example Response: 00 4: Major Firmware Version Example Response: 1 5: Minor Firmware Version Example Response: 0 7: Firmware Variant (Frequency Band etc. (EU/US)) Example Response: ETSI 8: Firmware VCS Version Example Response: v1.0.2-36 9: SIGFOX Library Version Example Response: DL0-1.4 10: Device ID Example Response: 00012345 11: PAC Example Response: 0123456789ABCDEF
AT$P=uint	Set Power Mode	To conserve power, the AX-SFEU can be put to sleep manually. Depending on power mode, you will be responsible for waking up the AX-SFEU again! 0: software reset (settings will be reset to values in flash) 1: sleep (send a break to wake up) 2: deep sleep (toggle GPIO9 or RESET_N pin to wake up; the AX-SFEU is not running and all settings will be reset!)
AT$WR	Save Config	Write all settings to flash (RX/TX frequencies, registers) so they survive reset/deep sleep or loss of power. Use AT$P=0 to reset the AX-SFEU and load settings from flash.
AT:Pn?	Get GPIO Pin	Return the setting of the GPIO Pin *n*; *n* can range from 0 to 9. A character string is returned describing the mode of the pin, followed by the actual value. If the pin is configured as analog pin, then the voltage (range 0…1 V) is returned. The mode characters have the following meaning: **Mode** **Description** 0 Pin drives low 1 Pin drives high Z Pin is high impedance input U Pin is input with pull-up A Pin is analog input (GPIO pin 0…3 only) T Pin is driven by clock or DAC (GPIO pin 0 and 4 only) The default mode after exiting reset is U on all GPIO pins.
AT:Pn=?	Get GPIO Pin Range	Print a list of possible modes for a pin. The table below lists the response. **Pin** **Modes** P0 0, 1, Z, U, A, T P1 0, 1, Z, U, A P2 0, 1, Z, U, A P3 0, 1, Z, U, A P4 0, 1, Z, U, T P5 0, 1, Z, U P6 0, 1, Z, U P7 0, 1, Z, U P8 0, 1, Z, U P9 0, 1, Z, U
AT:Pn=mode	Set GPIO Pin	Set the GPIO pin mode. For a list of the modes see the command AT:Pn?

Command	Name	Description
AT:ADC Pn[–Pn[(1V|10V)]]?	Get GPIO Pin Analog Voltage	Measure the voltage applied to a GPIO pin. The command also allows measurement of the voltage difference across two GPIO pins. In differential mode, the full scale range may also be specified as 1 V or 10 V. Note however that the pin input voltages must not exceed the range 0..VDD_IO. The command returns the result as fraction of the full scale range (1 V if none is specified). The GPIO pins referenced should be initialized to analog mode before issuing this command.
AT:SPI[(A|B|C|D)]=bytes	SPI Transaction	This command clocks out *bytes* on the SPI port. The clock frequency is 312.5 kHz. The command returns the bytes read on MISO during output. Optionally the clocking mode may be specified (default is A): **Mode** **Clock Inversion** **Clock Phase** A normal normal B normal alternate C inverted normal D inverted alternate  Note that SEL, if needed, is not generated by this command, and must instead be driven using standard GPIO commands (AT:Pn=0|1).
AT:CLK=freq,reffreq	Set Clock Generator	Output a square wave on the pin(s) set to T mode. The frequency of the square wave is (freq / 2^{16}) × reffreq. Possible values for reffreq are 20000000, 10000000, 5000000, 2500000, 1250000, 625000, 312500, 156250. Possible values if freq are 0…65535.
AT:CLK=OFF	Turn off Clock Generator	Switch off the clock generator
AT:CLK?	Get Clock Generator	Return the settings of the clock generator. Two numbers are returned, freq and reffreq.
AT:DAC=value	Set ΣΔ DAC	Output a ΣΔ DAC value on the pin(s) set to T mode. Parameter value may be in the range –32768…32767. The average output voltage is (1/2 + value / 2^{17}) × VDD. An external low pass filter is needed to get smooth output voltages. The modulation frequency is 20 MHz. A possible low pass filter choice is a simple RC low pass filter with R = 10 kΩ and C = 1 µF.
AT:DAC=OFF	Turn off ΣΔ DAC	Switch off the DAC
AT:DAC?	Get ΣΔ DAC	Return the DAC value

Command	Name	Description
AT$TM=mode,config	Activates the Sigfox Testmode	Available test modes: 0. TX BPSK Send only BPSK with Synchro Bit + Synchro frame + PN sequence: No hopping centered on the TX_frequency. Config bits 0 to 6 define the number of repetitions. Bit 7 of config defines if a delay is applied of not in the loop 1. TX Protocol: Tx mode with full protocol with Sigfox key: Send Sigfox protocol frames with initiate downlink flag = True. Config defines the number of repetitions. 2. RX Protocol: This mode tests the complete downlink protocol in Downlink only. Config defines the number of repetitions. 3. RX GFSK: RX mode with known pattern with SB + SF + Pattern on RX_frequency (internal comparison with received frame ⇔ known pattern = AA AA B2 27 1F 20 41 84 32 68 C5 BA AE 79 E7 F6 DD 9B. Config defines the number of repetitions. Config defines the number of repetitions. 4. RX Sensitivity: Does uplink + downlink frame with Sigfox key and specific timings. This test is specific to SIGFOX's test equipments & softwares. 5. TX Synthesis: Does one uplink frame on each Sigfox channel to measure frequency synthesis step
AT$SE	Starts AT$TM=3,255 indefinitely	Convenience command for sensitivity tests
AT$SL[=frame]	Send local loop	Sends a local loop frame with optional payload of 1 to 12 bytes. Default payload: 0x84, 0x32, 0x68, 0xC5, 0xBA, 0x53, 0xAE, 0x79, 0xE7, 0xF6, 0xDD, 0x9B.
AT$RL	Receive local loop	Starts listening for a local loop.

Registers

RC1/6/7

Number	Name	Description	Default	Range	Units
300	Out Of Band Period	AX-SFEU sends periodic static messages to indicate that they are alive. Set to 0 to disable.	24	0–24	hours
302	Power Level	The output power of the radio.	14	0–14	dBm

RC2/4

Number	Name	Description	Default	Range	Units
300	Out Of Band Period	AX-SFUS sends periodic static messages to indicate that they are alive. Set to 0 to disable.	24	0–24	hours
400	Macrochannel Mask	The mask of Macrochannels to use.	<000001FF> <00000000> <00000000>,1		
410	Encryption Key Configuration	Set to zero for normal operation. Set to one for use with the SIGFOX Network Emulator Kit (SNEK)	0	0–1	0: private key 1: public key

RC3/5

Number	Name	Description	Default	Range	Units
300	Out Of Band Period	AX-SFJK sends periodic static messages to indicate that they are alive. Set to 0 to disable.	24	0–24	hours
400	LBT Mask	LBT configurations to be used.	<1> <15000> <0>,0		
410	Encryption Key Configuration	Set to zero for normal operation. Set to one for use with the SIGFOX Network Emulator Kit (SNEK)	0	0–1	0: private key 1: public key
800	LBT RSSI Offset	Shifts the carrier sense threshold. Positive values result in a lower threshold.	0	−128–127	dB

Zone Setting AT-Commands

RC3

1. AT$IF=923200000
2. AT$DR=922200000
3. ATS400=<1><15000><256>,0
4. ATS800=0
5. AT$WR

RC5

1. AT$IF=923300000
2. AT$DR=922300000
3. ATS400=<1><15000><256>,1
4. ATS800=-8
5. AT$WR

1. Device Name TCXO
2. Model Name DSB211SDN
3. Nominal Frequency 48.000 MHz
4. Mass 0.015g max.

5. Absolute Maximum Ratings

	Item	Symbol	Rating	unit
1	Supply Voltage	V_{CC}	-0.3~+4.6	V
2	Storage Temperature Range	$T_{\_STG}$	-40~+85	°C

6. Recommended Operating Conditions

	Item	Symbol	min.	typ.	max.	unit
1	Supply Voltage	V_{CC}	+1.71	+1.8	+3.7	V
2	Load Impedance (resistance part)	L_{OAD}_R	9	10	11	kΩ
	(parallel capacitance)	L_{OAD}_C	9	10	11	pF
3	Operating Temperature Range	$T_{\_OPR}$	-30	-	+85	°C

7. Electrical Characteristics

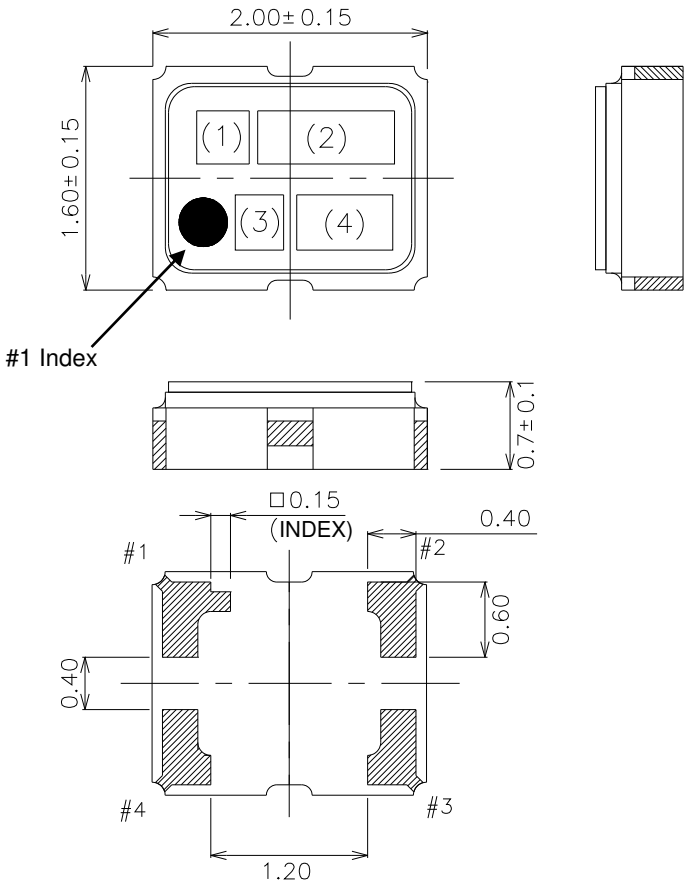
(T_A=-30~+85°C, L_{OAD}_R//C=10kΩ//10pF, V_{CC}=+1.8V, unless otherwise noted)

	Item	Conditions	Limits			unit	Notes
			min.	typ.	max.		
1	Current Consumption		-	-	+2.0	mA	
2	Output Level		0.8	-	-	V_{P-P}	1
3	Symmetry	GND level (DC cut)	40/60	-	60/40	%	
4	Harmonics		-	-	-5	dBc	
5	Frequency Stability 1.Tolerance	After 2 times reflow Ref. to nominal frequency	-	-	±2.0	ppm	2,3
	2.vs Temperature	T_A=-30~+85°C Ref. to frequency (T_A=+25°C)	-	-	±2.5	ppm	
	3.vs Supply Voltage	V_{CC}=+1.8±5%	-	-	±0.2	ppm	
	4.vs Load Variation	L_{OAD}_R//C=(10kΩ//10pF)±10%	-	-	±0.2	ppm	
	5.vs Aging	T_A=Room ambient	-	-	±1.0	ppm/year	
6	Start Up Time	@90% of final Vout level	-	-	2.0	ms	
7	SSB Phase Noise	Relative to F0 level offset 1Hz	-	-55	-	dBc/Hz	2
		Relative to F0 level offset 10Hz	-	-85	-	dBc/Hz	
		Relative to F0 level offset 100Hz	-	-109	-	dBc/Hz	
		Relative to F0 level offset 1kHz	-	-131	-	dBc/Hz	
		Relative to F0 level offset 10kHz	-	-145	-	dBc/Hz	
		Relative to F0 level offset 100kHz	-	-150	-	dBc/Hz	
		Relative to F0 level offset 1MHz	-	-150	-	dBc/Hz	

Notes
1. Clipped sine wave (DC-coupled)
2. T_A=+25°C
3. Please leave after reflow in 2h or more at room ambient.

8. Outline, Pin Connections

Outline



Pin Connections

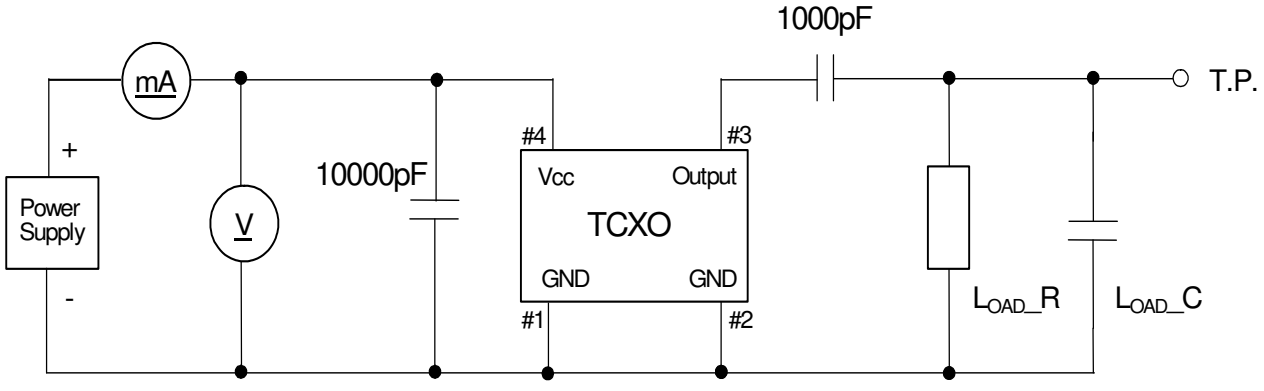
Pin No.	Connection
#1	GND
#2	GND
#3	Output
#4	V_{CC}

Marking

(1) Model code	BN
(2) Frequency	48.0 (MHz, 3digits)
(3) Logo	D
(4) Date code	Year (1digit) +Week (2digits) e.g.2016/1/1 → 601

unit: mm
Dimensional Tolerance: ±0.1
(Unless otherwise noted)

9. Measurement Circuit



L_{OAD}_R=10kΩ

L_{OAD}_C=10pF (Include Jig stray capacitance)

TITLE DSB211SDN TYPE SPECIFICATION	Remark		
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SFM11R3_RC5

No	Item	Pre-Requisite Description	Feature
2.3.0.a DUT Declarative Pre-requisites			
1	[PREREQUISITE-10] Device Configuration	Radio configuration	RC5
		Modem type (i.e. Uplink only or Uplink and Downlink)	Uplink and Downlink
		Encryption capability	Not-support
		Repeater	Not a repeater
		Monarch	Not-support
		Secure Element	no SE
2	[PREREQUISITE-11] Device Identification	Commercial product name	Sigfox Single Module
		Product model name/number	SFM11R3/ SFM11R3000
		Certification type (i.e. Device , Modular Design)	This is a Modular Design
3	[PREREQUISITE-12] RF & Protocol Test Guide	Test Guide	"[Seongji]SFM11R3_Test-Manual_200420.pdf"
4	[PREREQUISITE-13] Input Power Supply	MIN-NOMINAL-MAX, Current	2.1V-3.3V-3.6V, 200mA
5	[PREREQUISITE-14] Adjustable RF Output Power	RC5	12.7dBm(default)
6	[PREREQUISITE-15] Oscillator datasheet	Oscillator datasheet	"DS_48MHz_TCXO.pdf" Aging : ± 1.0ppm(for 1 years) , Temperature : ± 2.5ppm(-30 ~ +85 degree Celsius)
7	[PREREQUISITE-16] DUT representative to mass-production product		No wrapped wires
2.3.0.b DUT Hardware Pre-requisites			
8	[PREREQUISITE-20] RF connector		The EVB has SMA termination connector.
9	[PREREQUISITE-21] Input Power Supply Testability		"[Seongji]SFM11R3_Test-Manual_200420.pdf"
10	[PREREQUISITE-22] Hardware version	Hardware version	V0.2
2.3.0.c DUT Software Pre-requisites			
11	[PREREQUISITE-30] All Firmware versions flashed	All Firmware versions	Sigfox LIb Version : V1.8.9 Firmware version : AX-Sigfox 1.1.0-RCZ3
12	[PREREQUISITE-31] DUT Firmware and Sigfox Lib version check	Version check	Sigfox LIb Version : Command 'AT$I=9' Firmware version : Command 'AT$I=0'
13	[PREREQUISITE-32] LBT Carrier Sense duration		CS : 15s (only for RC3 and RC5)
14	[PREREQUISITE-33] RX RSSI Calibrated	DUT is calibrated in RX RSSI level	Our solution current do not support RX RSSI calibration
15	[PREREQUISITE-34] RX GFSK Reporting		During the Command 'AT$TM=3,30' : the RSSI value will be returned in the terminal with "TEST-PASSED" if the frame has been received properly
16	[PREREQUISITE-35] Test Procedure Commands availability		"[Seongji]SFM11R3_Test-Manual_200420.pdf" Zone setting(RC5): AT$IF=923300000 AT$DR=922300000 ATS400=<1><15000><256>,1 ATS800=-8 AT$WR Public Key : Command 'ATS410=1' Command : AT$TM=x,config TX-BPSK test: AT$TM=0,3 TX-PROTOCOL test: AT$TM=1,1 Frequency Distribution: AT$TM=1,14 RX-PROTOCOL test: AT$TM=2,1 RX-GFSK test: AT$TM=3,30 RX-SENSITIVITY test: AT$TM=4,31 TX-SYNTH test: AT$TM=5,0 Sigfox Message (payload 1 bit only) : command AT$SB=1 and AT$SB=0 Sigfox Message (all payload size) : command AT$SF=4041 (for 2 bytes for example) Sigfox OOB : command AT$SO
17	[PREREQUISITE-36] Specific Credentials	ID,PAC, KEY	ID : Read Command 'AT$I=10' PAC : Read Command 'AT$I=11' KEY : Our solution current do not support