Sigfox Device

FH mode

White Paper

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CHANGES DESCRIPTION

Version	Description	Author	Date
1.0	Creation	S.Hamard, S.Barreiro,	28/02/2016
2.0	Addition of clarification for power type (sections 2.5 & 4)	S.Barreiro	30/03/2016
3.0	Addition of explanation on pseudorandom system	S.Barreiro	04/05/2016
4.0	Addition of frequency hopping list for 920-922MHz	S.Barreiro	13/07/2016
5.0	New template	S.Barreiro	10/01/2017
6.0	Minor corrections	S.Barreiro	10/05/2017
7.0	Minor corrections	S.Barreiro	26/06/2017
8.0	Updates for publication	T. Schmidt, S. Hamard, S. Barreiro	11/09/2017
9.0	Updates in ITU emission class	T. Schmidt, S. Barreiro	13/11/2017
10.0	Update according last Sigfox library behavior for short message and long message config	Hamard, S.	28/02/2018

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1. Introduction

The IoT presents a different set of communications challenges than those related to conventional internet or cellular networks. Unlike cellphones and computers, IoT devices do not need to transfer large amounts of data. However, requirements for battery life and hardware costs are much more stringent and difficult to meet. For example, a soil moisture sensor might send a single moisture reading – one number – every hour, but for the farmer the batteries in the sensor need to last for at least one growing season, and ideally several years.

The Sigfox network provides a simplified way to connect low energy isolated devices to customer's applications across diverse territories, through a high efficiency radio technology with extreme budget links despite low radiations, and at very low costs.
Customers can then build their applications without having to consider heavy radio network issues and management, and, almost, without having to consider the radio-communication aspects.

Sigfox is building an IoT network that operates in the 902MHz to 928MHz band. Connected devices will behave as narrowband frequency hopping radios, in line with section 15.247(a)(1) of the Code of Federal Regulations on radio frequency devices operated without an individual license.

Sigfox imposes rules on "customer's devices" that are in fact much more stringent on resource usage than the rules given in FCC 15.247.

This whitepaper aims to explain Sigfox device technology and operation in 902-928 MHz band and how to show its compliance to FCC 15.247 and other FH SRD standards.

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2. SIGFOX technology

The Sigfox network system is designed to handle very low bandwidth, long battery life applications. Connected devices can send and receive messages with a payload of 1 to 12 bytes. They are limited by a network policy to a maximum of 140 of these messages per day. This is a tiny amount of data for a person surfing the web, but is more than enough for most IoT applications.

2.1 Spectrum Access method

Sigfox has chosen the Ultra Narrow Band (UNB) frequency hopping method instead of "direct" spreading techniques like DSSS, CSS, CDMA or their derivates. This choice is valid for FCC operations, as per FCC 15.247 and most SRD standards.

The main reasons for this choice were not dictated by budget link gains (ie: range), similar performance being achievable with the other mentioned techniques, but by a better resilience to unexpected or largely unpredictable interferences under "shared spectrums" (typically license exempt bands), and by higher capacity of short messages per MHz, with low if not inexistent synchronization protocols.

2.2 Signal characteristic

The modulation used by the devices is then a 600 bps D-BPSK modulation.
The two figures below show a typical "customer device" spectral occupation. Access Station subcarriers are cleaner after +/- 300 Hz beside carrier as signal synthesis is much more sophisticated. Go to section 4 for more details on the Base Station FDM multiplex transmission.

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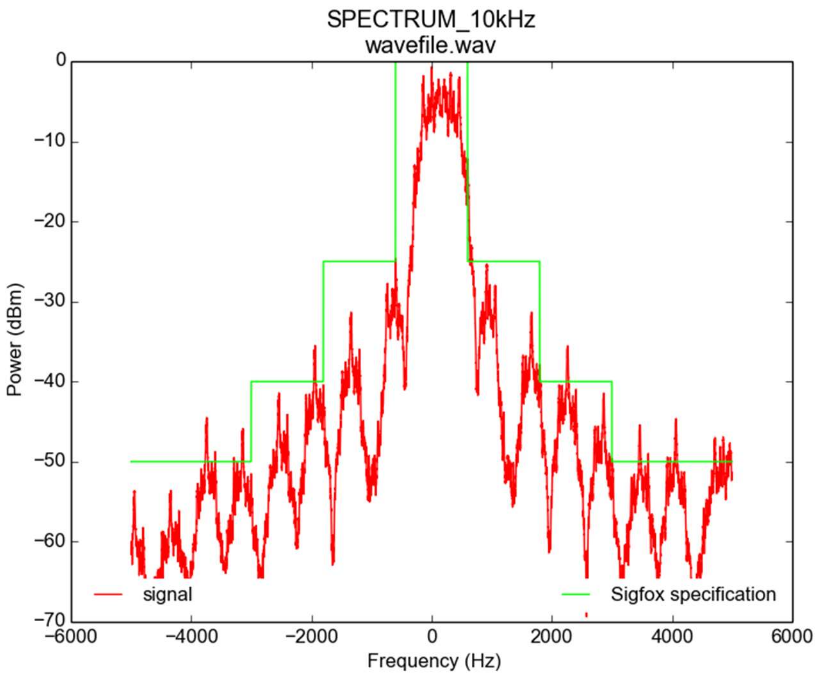
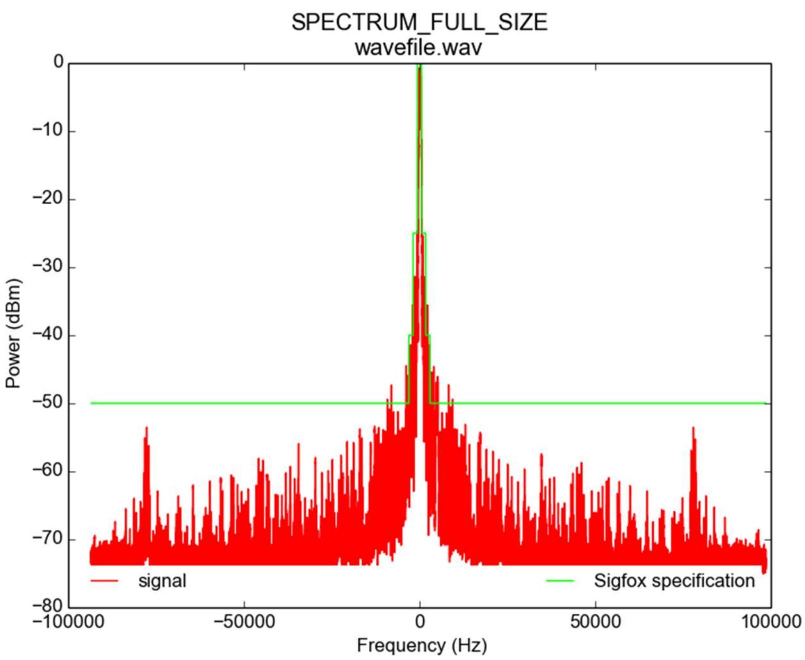
See below the typical spectrum shaping of 600bps D-BPSK modulation:



12 KHz span



200 KHz span

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2.3 Modulation description

The device uses a single side band modulation with a fully suppressed carrier, where a subcarrier is modulated by a 600 bps D-BPSK data modulation. The offset of this SSB subcarrier is related to the central frequency "F0" of each declared 25 KHz channel in which the device is hopping as per 15.247 regulation (54 channels for continuous transmission). The magnitude of the subcarrier's pseudo random offset is calculated to fulfill the 25 KHz mask requirement, taking maximal natural frequency error related to F0 into account.

The related ITU emission class for SIGFOX modulation is: 19K2D2D

- Emission in which the main carrier is amplitude and angle-modulated either simultaneously or in a pre-established sequence (D), with modulating subcarrier (2) modulated by a data content (D) over a 19,2KHz channel (19K2)

The related ITU emission class for sub-carrier modulation is: G1D

- Phase modulation (G), without modulating subcarrier (1) modulated by a data content (D)

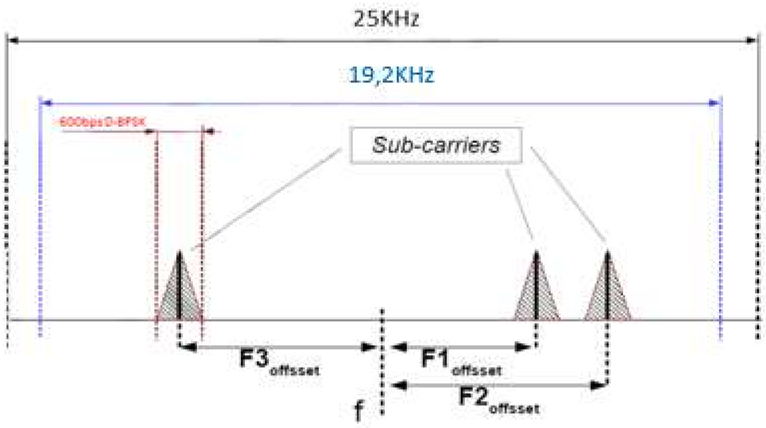

Figure 3- Independent side-band modulation illustration with 3 sub-carriers

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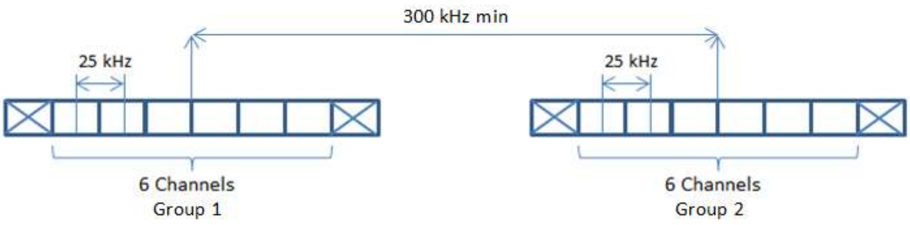
2.4 Modulation scheme

In the SIGFOX FCC modulation scheme, channel frequencies are distributed into 9 groups of 6 channels. Each group's center frequency is separated from the other by 300kHz and inside a group, each channel's center frequency is separated from the other by 25kHz, as required by part 15.247.



2.5 Pseudorandom hopping sequence

When transmitting continuously, device radios will hop over 54 frequency channels. They will select the transmit frequency from a **pseudorandom sequence (PRBS-7 generator)** stored in a frequency hopping table. This ensures the equally usage of all channels.
The dwell time is between 200 to 350ms per channel, well within the 400ms limit required by section 15.247(a)(1)(i) of the regulation.

2.6 Maximum power

Sigfox also imposes a maximum device radiated power of 22 dBm e.r.p (158mWatts).

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2.7 FCC Table declaration

Device makers, have to declare FCC channels where they will use the device for Sigfox network in FCC applicable zones.

There are 2 lists of frequency hopping channels.

One for the low part of the band: (902.1375-904.6625MHz)

Micro Channel 1 (MHz)	Micro Channel 2 (MHz)	Micro Channel 3 (MHz)	Micro Channel 4 (MHz)	Micro Channel 5 (MHz)	Micro Channel 6 (MHz)
902.1375	902.1625	902.1875	902.2125	902.2375	902.2625
902.4375	902.4625	902.4875	902.5125	902.5375	902.5625
902.7375	902.7625	902.7875	902.8125	902.8375	902.8625
903.0375	903.0625	903.0875	903.1125	903.1375	903.1625
903.3375	903.3625	903.3875	903.4125	903.4375	903.4625
903.6375	903.6625	903.6875	903.7125	903.7375	903.7625
903.9375	903.9625	903.9875	904.0125	904.0375	904.0625
904.2375	904.2625	904.2875	904.3125	904.3375	904.3625
904.5375	904.5625	904.5875	904.6125	904.6375	904.6625

Another for the high part of the band: (920.1375-922.6625MHz)

Micro Channel 1 (MHz)	Micro Channel 2 (MHz)	Micro Channel 3 (MHz)	Micro Channel 4 (MHz)	Micro Channel 5 (MHz)	Micro Channel 6 (MHz)
920,1375	920,1625	920,1875	920,2125	920,2375	920,2625
920,4375	920,4625	920,4875	920,5125	920,5375	920,5625
920,7375	920,7625	920,7875	920,8125	920,8375	920,8625
921,0375	921,0625	921,0875	921,1125	921,1375	921,1625
921,3375	921,3625	921,3875	921,4125	921,4375	921,4625
921,6375	921,6625	921,6875	921,7125	921,7375	921,7625
921,9375	921,9625	921,9875	922,0125	922,0375	922,0625
922,2375	922,2625	922,2875	922,3125	922,3375	922,3625
922,5375	922,5625	922,5875	922,6125	922,6375	922,6625

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3. Typical resource usage

The nature of IoT communications, and the need to preserve battery life, means that it is very unusual for Sigfox devices to transmit data continuously. The radio is generally only powered up when there is some data to send. When there is no data to send the radio is completely turned off to save power. As a result, the radio is normally active for a few seconds per day or less. This is how Sigfox connected devices are able to achieve a battery life of several years.

A frame is composed, of a signaling/protocol data embedding a "commercial payload" of 1 to 12 Bytes. Consequently,
at 600 Bps, a frame lasts between 200 and 350 ms, and shall not exceed 400ms. Contiguous frames are not transmitted on the same frequency and follow a frequency hopping sequence over fifty-four 25 KHz channels spread over around 2.6 MHz of spectrum. More than 22 seconds are needed to run through the 54 channels so that a return to a given channel cannot occur before 20 seconds as per FCC 15.247 for continuous transmission. Each frame is designed to be transmitted inside a 25KHz channel/350ms or less. A short message contains only one frame.

In summary, due to SIGFOX "internal specifications", **a SIGFOX device appears below 0.175 % of time** (cumulated, hour or day basis) over the 902-928 MHz spectrum.

Devices cannot be "remote controlled" upon a network initiative. They can only possibly be reached by the network right after an uplink (20 to 30 seconds later, so that base stations can be organized to "multiplex" more than one device)

4. Compliance to FCC 15.247

Section 15.247(a)(1) of the Code of Federal Regulations on radio frequency devices operated without an individual license, states that every hopping frequency should be used equally on average. When a Sigfox radio is allowed to transmit continuously for long enough (about 20s) it will behave like this, using all 54 channels equally (PRBS-7 generator).

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However, because IoT devices generally transmit very short messages, the Sigfox radio will often be shut down before it has had the opportunity to hop onto all 54 channels.

When the radio switches on, it starts on the first channel of the declared hopping list. Transmission can stop before going over the 54 channels if the message is short. No individual channel will ever be used more often than it is allowed.

The device does not last more than 350 ms on each channel, and a minimum delay is set between each transmission so that whatever the duration of each transmission, the device never comes back on a given channel before 20 s (30 to 40 s in reality).

Transmit power is 22dBm ERP: 25 times less than the power limit.

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5. ANNEXE 1: How to prepare a device for testing

5.1 SIGFOX Usecases

Sigfox is able to propose services in different macro channels of 192KHz. For each service, 6 micro channels of 25KHz are available. In the following usecases, a Sigfox device is using a micro channel of 25KHz, respecting the FCC duty cycle of 20s to send a frame.

5.1.1 Usecase 1: long message transmission

In this usecase, the device will have long messages to send. This mode is used for testing the 54 channels coverage. To run this scenario device, the following pseudo code will have to be used:

Solution 1: Long message send frame API with SFX_LIB (>=V2.2.0)

```
OPEN( RC2)
// activate 54 channels
SET_STANDARD(RC2_LM_CONFIG, timer_enable=1)

Message = long message = frame1 + frame2 + … frame n
n = Message_length / MAX_SIZE_PER_FRAME
Loop for n iterations
        SEND_FRAME(frame n,
                        Frame length_n,
                        customer_response_ptr,
                                2,
                                0);
end loop
CLOSE()
```


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WARNING#1 : 54 * 346ms = 18720 ms + all interframes (at least 500ms between each frame)

WARNING#2 : The TX ramping up and down time (complete energy must have a duration time of less than 400ms.

Solution 2: Long message using send frame simple API *(with SIGFOX library version <=V1.8.7)*

```
OPEN( 902200000,
      905200000,
      id_ptr,
      SFX_STD_FCC)
// activate 54 channels
SET_STANDARD(     0x000001FF,
                  0x00000000,
                  0x00000000,
                  0x01)
RESET()
Message = long message = frame1 + frame2 + … frame n
n = Message_length / MAX_SIZE_PER_FRAME
Loop for n iterations
      SEND_FRAME(frame n,
                  Frame length_n,
                  customer_response_ptr,
                        2,
                        0);
end loop
CLOSE()
```

WARNING#1 : 54 * 346ms = 18720 ms + all_interframes (at least 500ms between each frame)

WARNING#2 : The TX ramping up and down time (complete energy must have a duration time of less than 400ms.

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5.1.2 Usecase 2: short message transmission

To run this usecase, the following pseudo code has to be used:

Solution 1: Send a short message composed of 3 frames (>=V2.2.0)

```
OPEN( RC2)
// activate 54 channels
SET_STANDARD( RC2_SM_CONFIG, timer_enable=1) *
Message  = short message = 3 frames for example
SEND_FRAME( message,
                        Frame n length,
                        customer_response_ptr,
                         2,
                        0);

CLOSE()
```

** to speed up some test as -20dBc adjacent 25KHz channel rejection, you can reset (timer_enable = 0) Warning : this configuration will not match with FCC duty cycle but will allow quickest test.*

Solution 2: Send a short message composed of 3 frames (with SFX_LIB <=1.8.7)

```
OPEN( 902200000,
        905200000,
        id_ptr,
        SFX_STD_FCC)
// activate 54 channels
SET_STANDARD(         0x000001FF,
                        0x00000000,
                        0x00000000,
```


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```
                        0x01)
RESET()

Message  = short message = 3 frames for example
SEND_FRAME(message,
                        Frame n length,
                        customer_response_ptr,
                         2,
                        0);

CLOSE()
```


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6. ANNEXE 2: Reference documents

1. FCC – Title 47 Part 15 and in particular Part 15.247
2. SIGFOX – PRS-UNBT document – Ultra Narrow Band Transceiver Product Requirements Specifications
3. SIGFOX – OTP Field Test Procedure – Contractual Coverage Test Procedure for a SIGFOX network
4. SIGFOX – SIGFOX technology introduction
5. SIGFOX – Downlink Modes in SIGFOX networks
6. ETSI – EN 300-220
7. ETSI – EN 300-113
8. Appendix 1 (Rev. WRC-12) of the Radio Regulations (ITU) - "Necessary bandwidths and classification of emissions"

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