Sigfox Device

ARIB Mode

White Paper

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CHANGES DESCRIPTION

Version	Description	Author	Date
1.0	Creation	T. Schmidt, C. Jeloyan	27/07/2017
2.0	Update for publication	S. Barreiro	22/05/2017
3.0	Updates for publication	T. Schmidt, S. Hamard, S. Barreiro	11/09/2017
4.0	Updates in ITU emission class	T. Schmidt, S. Barreiro	13/11/2017
5.0	Max output power modification (ARIB)	S. Barreiro	24/07/2018

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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 920,5-923.5 MHz band in Japan. Connected devices will behave as specified low power radio stations for telemeter, telecontrol and data transmissions, following Article 49, Clause 14-7 and Clause 14-8 of the Ordinance Regulating Radio Equipment Regulations.

Sigfox imposes rules on "customer devices" that are in fact much more stringent on resource usage than the rules given in the regulation and the related ARIB standard STD-T108.

This whitepaper aims to explain Sigfox device technology and operation in the 920 MHz band and to demonstrate how it complies with ARIB STD-T108 and its specific requirements such as frequency tolerance, carrier sense …

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2. Sigfox technology

The Sigfox network system is designed to provide low throughput connectivity and long battery life application. Connected devices can send and receive messages with a payload of 1 to 12 bytes. Devices are limited by a network policy to a maximum of 140 of these messages per day.
Sigfox's system is composed of terminals (end-devices) and base-stations (collecting nodes). Both uplink (from terminals to base-stations) and downlink (from base-station to devices) communications are possible.
For both uplink and downlink, a fixed center frequency is defined for communication.

2.1 Spectrum Access method

Sigfox uses Ultra Narrow Band (UNB) signals coupled with a carrier sense mechanism. This choice is valid for operation in Japan, as per ARIB standard STD-T108.

The main reasons for the choice of UNB signals 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 a low if not inexistent synchronization protocol and the reception of more than 300 simultaneous messages.

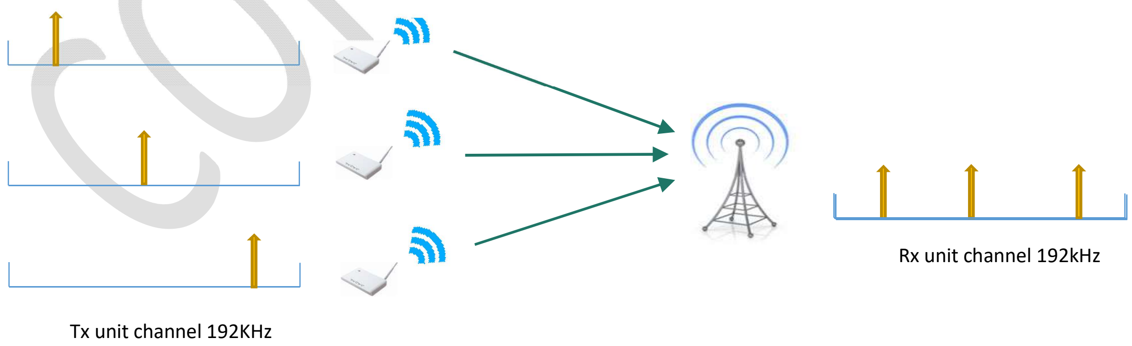

Figure 1- Multi-points to point reception

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2.2 Signal characteristics and channelization

The modulation used by devices is a composite modulation mixing an SSB-SC modulation with a 100 bps D-BPSK modulation of the sub-carriers. The figure below shows a typical "customer's device" spectral occupation.

Each equipment uses one preset unit channel of 200kHz as per ARIB STD-108, Part 2. Table 3-11. The instantaneous occupied bandwidth of each transmission is 100Hz. The use of the whole channel of 200kHz over time is nevertheless mandatory to ensure the appropriate rate and quality of data transmissions at the reception point.

Sigfox specifies the exact channel of operation during network deployment. Equipment can be set within the 920,5 to 923,5MHz band, channel numbers 24 to 38.

2.3 Emission class and modulation description

As indicated above, the device uses a single side band modulation (SSB) with fully suppressed carrier, where a subcarrier is modulated by 100 bps D-BPSK data modulation.

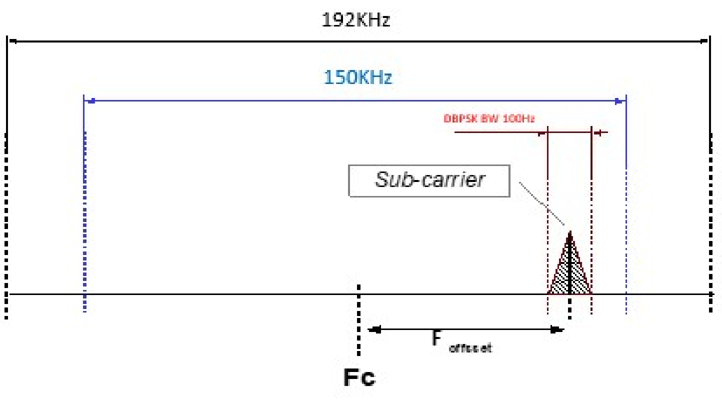

Figure 2- Single side-band modulation illustration

SSB modulation is centered on a fixed central frequency (Fc) and sub-carrier frequency (Fsc) are pseudo-randomly selected within a range of +/- 75 kHz (150kHz), where Fsc= Fc+ Foffest. Frequency offsets are fixed and predetermined values.

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This random distribution is necessary to ensure the required quality of service at the reception point, where up to 300 different sub-carriers are aggregated.

Japanese regulation for specified low power radio stations within the band 920,5-923,5MHz and the related ARIB standard T-108 do not require specific modulation or emission classes.

SSB modulation takes into account natural terminal frequency error in order to ensure an absolute maximum frequency offset of +/- 96 kHz. This spectral occupation is a validating item within SIGFOX Ready certification program applicable to all SIGFOX terminals.

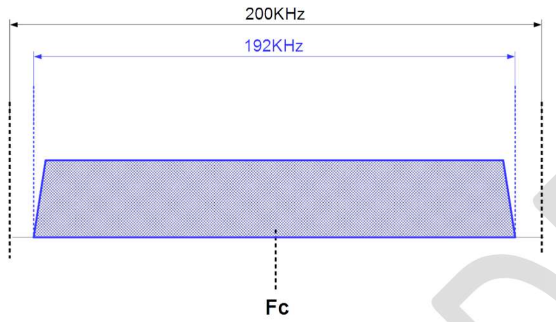

Figure 3- Maximum absolute modulation range (including terminal frequency error)

The related ITU emission class for SIGFOX modulation is: 150KD2D

- 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 150kHz necessary bandwidth (150K)

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

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

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2.4 Necessary bandwidth

For a given class of emission, the width of the frequency band which is just sufficient to ensure the transmission of information at the rate and with the quality required under specified conditions.

The necessary bandwidth (Bn) of the Sigfox signal is calculated as twice the maximum frequency offset (separation) between the furthest sub-carrier frequency and the suppressed carrier at center frequency (Cmax), plus the D-BPSK modulation bandwidth (M).

Bn = 2Cmax + M = 2 x 74.950 + 100 = 150.000Hz

2.5 Frequency tolerance

The maximum frequency error or frequency tolerance prescribed by Sigfox is +/-20ppm as per ARIB STD-108, Part 2 §3.2.4.

The frequency tolerance is defined as the maximum departure of the center of the SSB modulation from the center frequency of the channel or the departure of the sub-carrier frequency from the related reference frequency.

Maximum subcarrier's frequency (Fsc_max) is specified as a fixed value with respect to the center frequency of the channel (Fc) by considering the frequency error (frequency tolerance) to be accommodated within a frequency band of 192kHz per channel unit of 200kHz.

This maximum modulation range of 192kHz equals the necessary bandwidth plus twice the frequency tolerance (18kHz).

Frequency error is normally measured with an unmodulated carrier.

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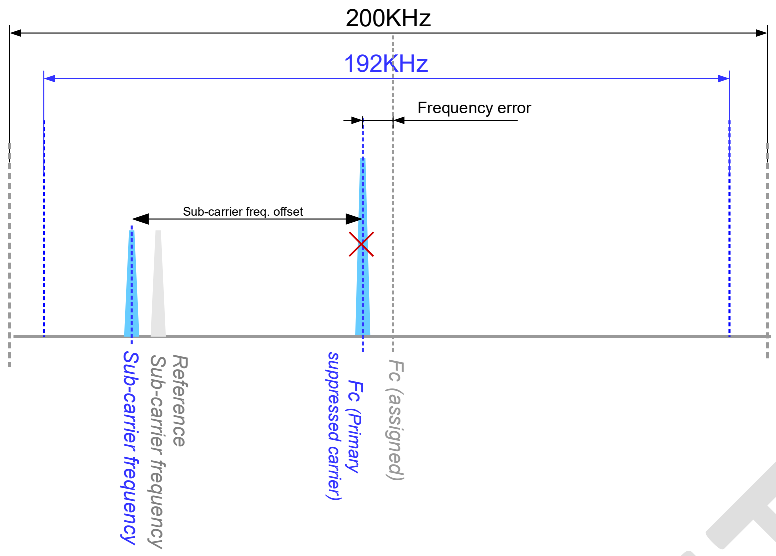

Figure 4- Frequency tolerance measurement

If the equipment is not capable of producing an unmodulated carrier, then power modulation bandwidth can be measured by sweeping all sub-carriers and measuring the departure of its center frequency from the center of the channel.

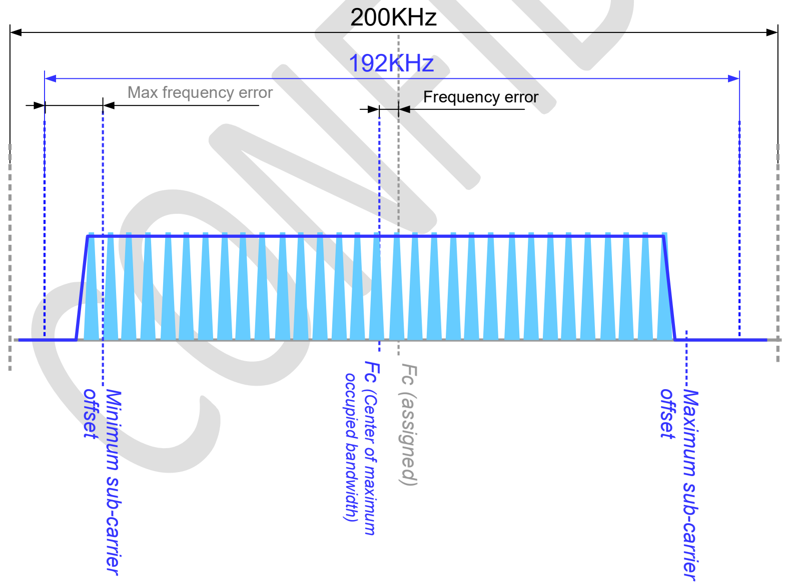

Figure 5- Frequency tolerance measurement based on modulated carriers

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2.6 Medium access control and transmission sequence

When continuously transmitting, devices will randomly distribute sub-carriers within the channel with frame time of 2s. They will select the transmit frequency from a **pseudorandom sequence (PN11 generator)** to ensure the equal usage of the necessary bandwidth over time.

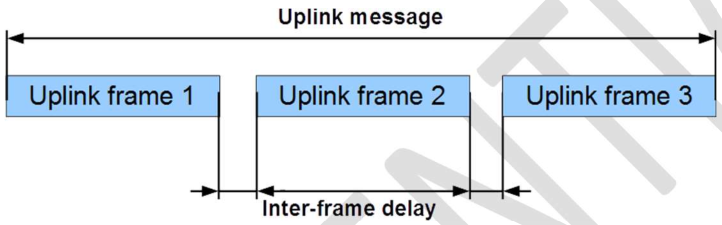

Figure 6- Up-link sequence

ARIB STD-T108 standards defines a carrier sense mechanism ('Listen-Before-Talk' - LBT) to rule the RF medium access. Below the definition of the parameters for the 'listen-before-talk' function.

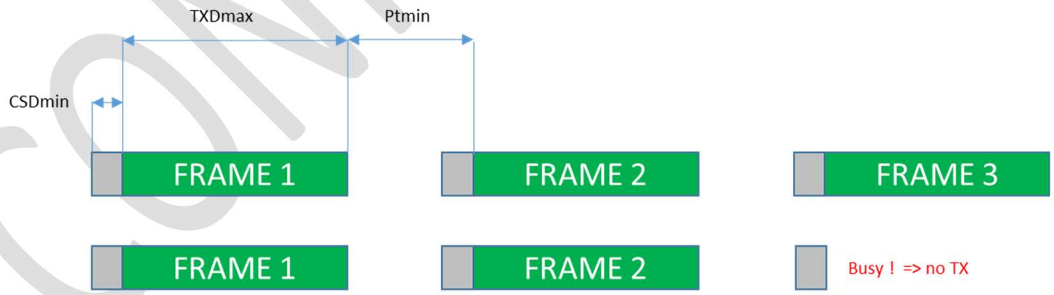

Figure 7- LBT timing specification

SIGFOX radio equipment will implement a 'listen-before-talk' mechanism as follows:

Equipment shall sense channel power for CSDmin or more before transmitting.

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- If channel is busy, equipment shall not transmit.
- If channel is idle, equipment is authorized to transmit.

Channel shall be considered as busy if the integrated RF power in the 200kHz of the unit radio channel to transmit is superior or equal to CDTH (in dBm). Channel is otherwise considered idle.
Equipment transmission duration shall be less than TXDmax maximum (TX max. time)

Equipment shall wait at least PTmin time before transmitting again (Pause time)

	ARIB STD-T108	
LBT parameter	Min	Max
CDTH (in 200Khz BW)	-	-80dBm
CSD_{min}	5ms	-
TXD_{max}	-	4s
PT_{min}	50ms	-

Table 1- LBT parameters limits

2.7 Maximum power

As per Japanese regulation, Sigfox also imposes a maximum device radiated power of 16 dBm e.i.r.p (40mWatts).

Maximum allowed output power in the selected channels are:

Equipment	**Max. conducted output power**	**Max. antenna gain**	**Max. EIRP**
Device (specified low-power radio)	24dBm (250mW)	3dBi	16dBm (40mW)

Table 2- ARIB maximum allowed RF output power (typical values)

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2.8 Channels used

Sigfox devices use now following channels:

- ⇒ TX: channel 37
- ⇒ RX: channel 32

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 100 Bps, a frame lasts between 1 and 2s, and shall not exceed 4s.

In summary, due to Sigfox's "internal specifications", a Sigfox device appears less than 1 % of the time (cumulated, hour or day basis) over the 920 MHz spectrum.

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

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4. ANNEXE 2: Reference documents

1. Ordinance Regulating Radio Equipment Standard: **無線設備規則** - Chapter I – IV, Section 4.17, Article 49.14.7

2. ARIB STD-T108 v1.2 920MHz-BAND, TELEMETER, TELECONTROL AND DATA TRANSMISSION RADIO EQUIPMENT

3. TELEC-T245 - Characteristic test method for Specified low-power radio stations (920Mhz band)

4. TELEC-T258 - Characteristic test method for Convenience radio stations (920Mhz band)

5. Sigfox – PRS-UNBT document – Ultra Narrow Band Transceiver Product Requirements Specifications

6. Sigfox – OTP Field Test Procedure – Contractual Coverage Test Procedure for a Sigfox network

7. Sigfox – Sigfox technology introduction

8. Sigfox – Downlink Modes in Sigfox networks

9. ETSI – EN 300-220

10. Appendix 1 (Rev. WRC-12) of the Radio Regulations (ITU) - “Necessary bandwidths and classification of emissions”

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