

Using the S2-LP transceiver under the ARIB STD-T67 standard

Introduction

The S2-LP very low power RF transceiver for RF wireless applications in the sub-1 GHz band is designed to operate both in the license-free ISM and SRD frequency bands at 433, 868, 915 and 920 MHz.

The Japanese association of radio industries and businesses (ARIB) was established in response to the growing internationalization of telecommunications, the convergence of telecommunications and broadcasting, and the need to promote radio-related industries. The scope ARIB is the basic technical requirements for standard specifications of radio equipment.

The performance obtained with the S2-LP under the ARIB STD-T67 2^a standard in the 449 and 469 MHz bands is detailed herein.

^a ARIB STD-T67: "Telemeter, Telecontrol and data transmission radio equipment for specified low-power radio station". Available at www.arib.or.jp/english/index.html.

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1 ARIB STD-T67 overview

This standard is for:

- telemetry radio equipment designed to automatically indicate and/or record the results obtained by remote measuring instruments via radio waves
- telecontrol radio equipment for the transmission of signals to activate, change, or deactivate the functions of devices located remotely by means of radio waves
- data transmission radio equipment for the transmission of information to be processed primarily by machines, or of previously processed information.

Table 1: "Communication method, operating frequencies and antenna power" defines the communication methods along with the operating frequency bands, the antenna powers and the transmission time restrictions.

1.1 ARIB STD-T67 transmitter parameters

Antenna power: specified or rated power supplied from the transmitter to an antenna system feeder in normal operation and averaged over a sufficiently long period of time with respect to the cycle of the lowest frequency).

- 0.01 W (+10 dBm) or less

Frequency tolerance: the maximum allowable deviation of the center frequency of the band occupied by emission from the allocated frequency.

- $\pm 4 \times 10^{-6}$ (± 4 ppm)



A TCXO is necessary to meet this very stringent frequency tolerance requirement.

Modulation method, frequency deviation and modulation rate.

- No specific requirements

Emission class supported by the S2-LP is F1D:

- F - frequency modulation
- 1 - one channel containing digital information, no subcarrier,
- D - data transmission, telemetry or telecontrol

Data rate and frequency deviation are selected to meet the bandwidth requirements in *Table 1: "Communication method, operating frequencies and antenna power"*.

Adjacent channel leakage power requirement: the power radiated in a certain band of the adjacent channel separated from the carrier frequency at the specified frequency interval.

- The power radiated into the ± 4.25 kHz band of the frequency 12.5 kHz distant from the carrier frequency, is lower than by 40 dB or more.

Permissible value for an occupied bandwidth: the bandwidth in which the mean powers radiated below its lower frequency limit and above its upper frequency limit are each equal to 0.5% of the total mean power radiated by a given emission.

- 8.5 kHz.

Spurious emission refers to the emissions on a frequency or frequencies outside the permitted bandwidth and the level of which may be reduced without affecting the corresponding transmission of information, including a high harmonic emission, a low harmonic emission, a parasitic emission and an intermodulation product but excluding an out-of-band emission.

Out-of-band emission refers to the emission which results from the modulation process on a frequency or frequencies outside the permitted bandwidth.

Permissible value of the unwanted (spurious plus out-of-band) emission intensity: the permissible value with respect to the mean power of unwanted emissions of each modulated frequency supplied to the feeder.

- 2.5 μW (-26 dBm) or less in the average power

Table 1: Communication method, operating frequencies and antenna power

Communication method	Operating frequency band [MHz]	Antenna power [W]	Transmission time restriction ⁽¹⁾⁽²⁾
One-way communication, simplex operation, broadcast communication, semi-duplex operation or duplex operation	449.7125 – 449.8125 (12.5 kHz interval)	0.01 or less	TCT: 40 s, TQT: 2 s
	449.8250 (12.5 kHz interval)		TCT: 0.2 s, TQT: 2 s
	449.8375 – 449.8750 (12.5 kHz interval)		TCT: 40 s, TQT: 2 s
	449.8875 (12.5 kHz interval)		TCT: 0.2 s, TQT: 2 s
	469.4375 – 469.4750 (12.5 kHz interval)		TCT: 40 s, TQT: 2 s
	469.4875 (12.5 kHz interval)		TCT: 0.2 s, TQT: 2 s

Notes:

⁽¹⁾TCT: transmission continuous time.

⁽²⁾TQT: transmission quiescence time.

1.2 ARIB STD-T67 receiver parameters

Reference sensitivity: the necessary receiver input voltage in which the output bit error rate of the device is 1×10^{-2} when the desired wave modulated is applied.

- 2 μV (-101 dBm on 50 Ω) or less for receivers with channel intervals of 12.5 kHz

Spurious response at effective selectivity: the ratio of the jamming wave input voltage to the encoding reference sensitivity as the output bit error rate of the device becomes 1×10^{-2} when an un-modulated jamming wave is applied in a state in which a desired wave input voltage 3 dB higher than the encoding reference sensitivity is applied.

- 40 dB or more.

Adjacent channel selectivity at effective selectivity: the ratio of the jamming wave input voltage to the encoding reference sensitivity as the output bit error rate of the device becomes 1×10^{-2} when a jamming wave that is modulated by a signal of repetitive binary pseudo noise with a code length of 32767 bits and is 12.5 kHz in distance from the desired wave is applied to a device with channel interval of 12.5 kHz, respectively, in a state in which the desired wave input voltage 3 dB higher than the encoding reference sensitivity is applied.

- 30 dB or more

Frequency tolerance: same as for transmitter.

- $\pm 4 \times 10^{-6}$ (± 4 ppm)



A TCXO is necessary to meet this very stringent frequency tolerance requirement.

Secondary radiated emission from the receiving equipment limit: in terms of the power of a dummy antenna circuit that has the same electrical constant as the receiving antenna

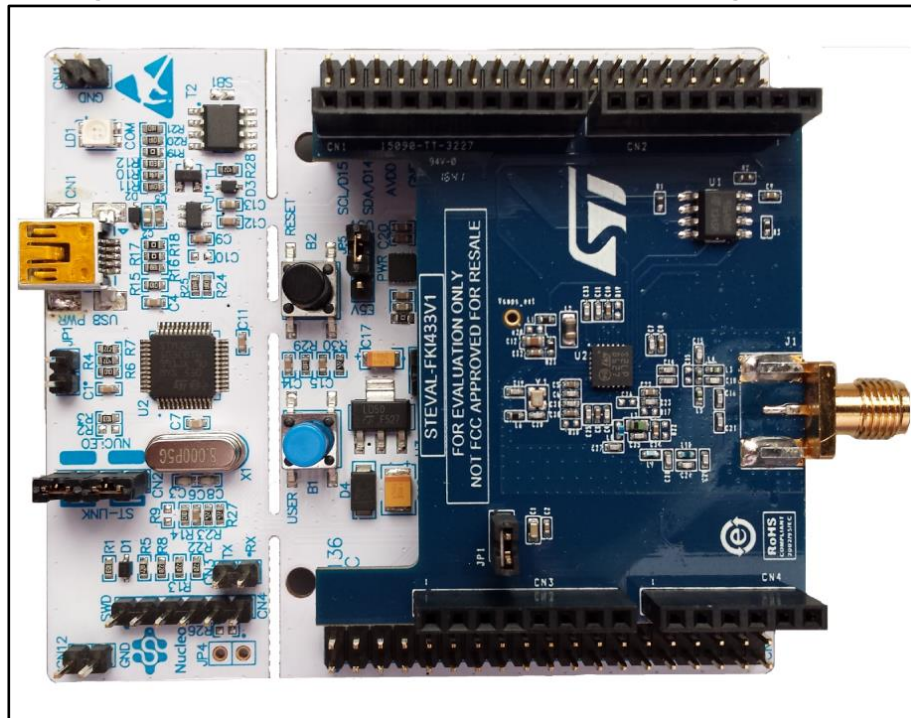
- 4 nW (-54 dBm) or lower

2 Sub-1 GHz transceiver development kit based on S2-LP

The STEVAL-FKI433V1 evaluation board is based on the S2-LP sub-1 GHz ultra-low power, low data-rate transceiver suitable for ISM bands and Wireless M-Bus.

The motherboard is the NUCLEO-L152RE board with STM32L low power microcontroller to control the S2-LP device and integrated ST-LINK/V2-1 debugger and programmer for firmware updating.

Figure 1: STM32 Nucleo board plus S2-LP application daughterboard



The kit features:

- S2-LP narrow band ultra-low power sub-1 GHz transceiver in a standalone RF Module tuned for 430 - 470 MHz frequency bands
- STM32 Nucleo development board with STM32L152RE MCU
- Suitable for Wireless M-Bus systems
- Associated S2-LP development kit including documentation, firmware for STM32L and GUI
- Programmable RF output power up to +16 dBm
- Modulation schemes: 2-FSK, 2-GFSK, 4-FSK, 4-GFSK, OOK, and ASK
- Air data rate from 0.3 to 500 kbps
- Ultra-low power consumption:
 - 6.7 mA RX
 - 10 mA TX @ +10 dBm
- Excellent performance of receiver sensitivity (up to -130 dBm)
- Low duty cycle RX / TX operation mode
- Automatic acknowledgement, retransmission and timeout protocol engine
- SPI interface for microcontroller

- USB interface
- RoHS compliant

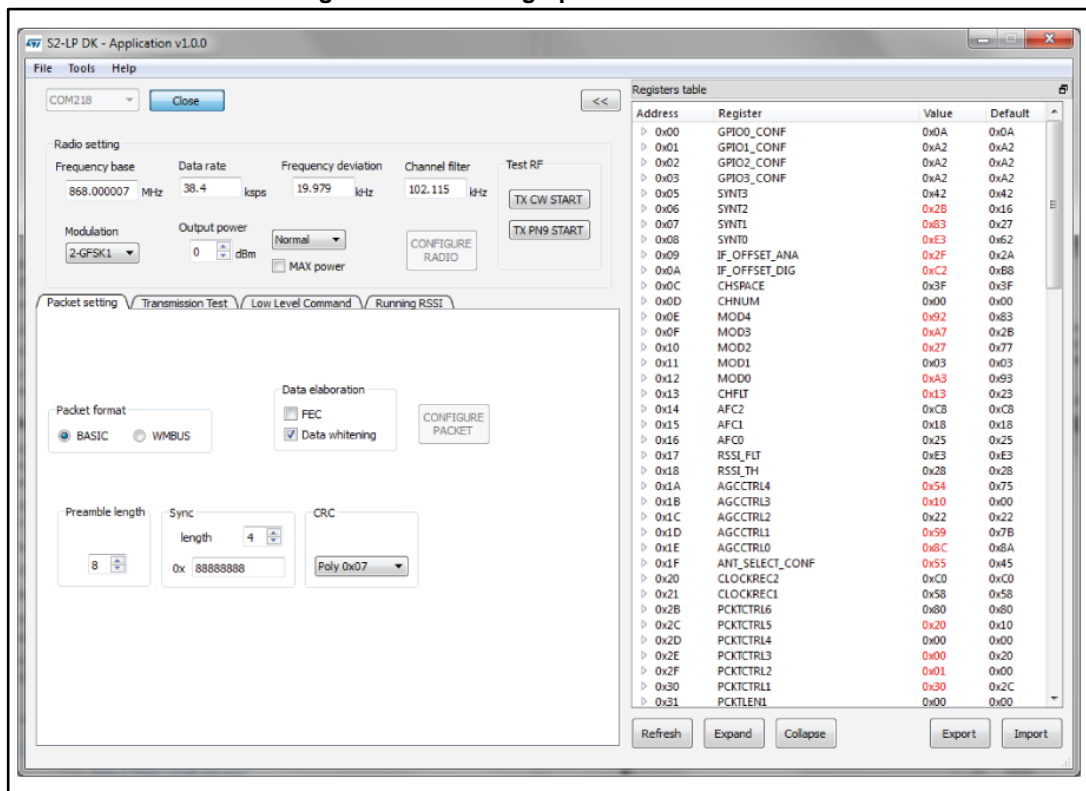
2.1 Evaluation SW package based on S2-LP

The STSW-S2LP-DK is an evaluation SW package based on the S2-LP high performance ultra-low power RF transceiver for RF wireless applications in the sub-1 GHz band. It is designed to operate in both the license-free ISM and SRD frequency bands at 433, 868 and 920 MHz, but can also be programmed to operate at additional frequencies in the 430-470 MHz, 860-940 MHz bands.

The STSW-S2LP-DK SW package supports the S2-LP kits platforms available on associated web pages. It provides an S2-LP library with a complete set of APIs to interface with the S2-LP features, as well as a set of applications demonstrating the use of features of the same device. Each demonstration application comes with a complete set of source files.

The S2-LP DK GUI application provides an interactive PC interface for the registers on the S2-LP. Its main function is to configure the analog radio section and the packet handler in a user friendly manner for the most common applications.

Figure 2: S2-LP DK graphical user interface



- S2-LP DK GUI PC application supporting S2-LP device
- S2-LP library and examples
- SDK Eval NUCLEO-L1 low level API to manage the motherboard (NUCLEO-STM32L1) interfacing with the S2-LP daughterboard
- STM32L1 HAL driver (STM32Cube)
- Drivers for PC (USB Virtual COM + mass storage)

3 Transmitter parameters

The measurements for the transmitter were taken with the following parameters, unless otherwise specified:

- $T_c = 25^\circ\text{C}$
- $V_{dd} = 3.3\text{ V}$
- $f = 449.8\text{ MHz}$ (middle frequency of the useful bandwidth).

The maximum output power requested by the standard is +10 dBm so the S2-LP will be set to this output power.

There are no specific requirements in the standard regarding setting the detector, resolution bandwidth (RBW) or video bandwidth (VBW) of the spectrum analyzer. The detector is set to peak, the resolution and video bandwidths are set sufficiently large to ensure correct measurements.

3.1 Adjacent channel leakage power

The adjacent channel leakage power requirement is the power radiated in a certain band of the adjacent channel separated from the carrier frequency at the specified frequency interval. The power radiated into the $\pm 4.25\text{ kHz}$ band of the frequency 12.5 kHz in distance from the carrier frequency is lower than the carrier power by 40 dB or more.

- Test configuration 1 is:
 - Data rate = 2.4 kbps
 - Frequency deviation = 2.4 kHz
 - Modulation = 2-GFSK with BT = 1
- Test configuration 2 is:
 - Data rate = 4.8 kbps
 - Frequency deviation = 2.4 kHz
 - Modulation = 2-GFSK with BT = 0.5
- The spectrum analyzer settings are:
 - Resolution bandwidth (RBW) = 300 Hz
 - Video bandwidth (VBW) = 300 Hz
 - Detector = peak
 - Trace = max hold

The following images show the adjacent channel power measurements for the different test configurations:

1. Test configuration 1: the measured ACP is 50 dB ([Figure 3: "Adjacent channel power 2.4 Kbps data rate"](#))
2. Test configuration 2: the measured ACP is 60 dB ([Figure 4: "Adjacent channel power 4.8 Kbps data rate"](#))

Hence the ARIB STD-T67 requirement is easily satisfied for the above cases.

Figure 3: Adjacent channel power 2.4 Kbps data rate

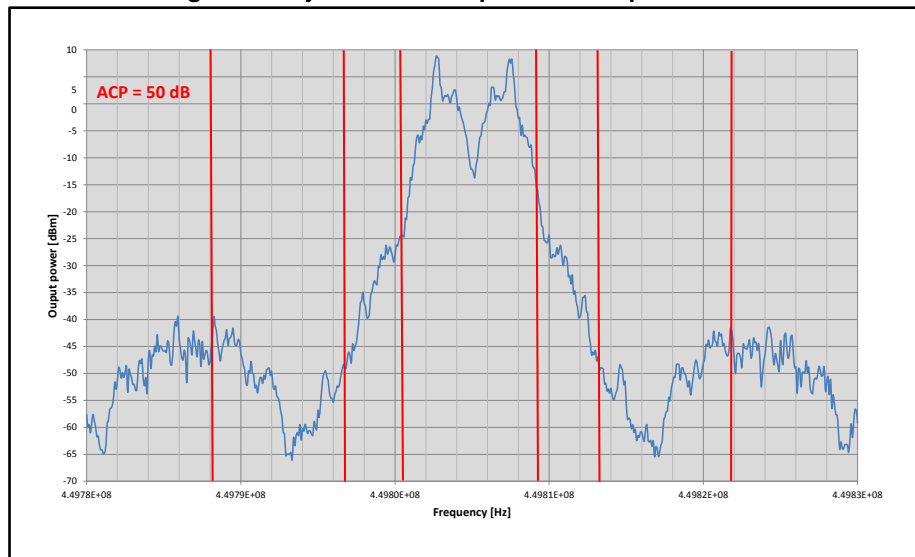
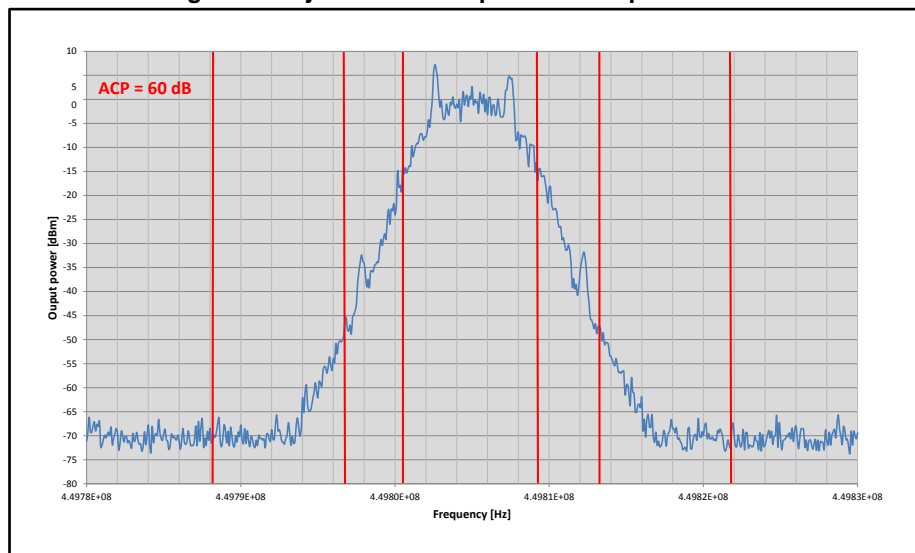


Figure 4: Adjacent channel power 4.8 Kbps data rate



3.2 Permissible value of the occupied bandwidth

The permissible value for an occupied bandwidth (the bandwidth in which the mean powers radiated below its lower frequency limit and above its upper frequency limit are each equal to 0.5% of the total mean power radiated by a given emission, which is 99% of the powers) is 8.5 kHz.

- Test configuration 1 is:
 - Data rate = 2.4 kbps
 - Frequency deviation = 2.4 kHz
 - Modulation = 2-GFSK with BT = 1
- Test configuration 2 is:
 - Data rate = 4.8 kbps
 - Frequency deviation = 2.4 kHz
 - Modulation = 2-GFSK with BT = 0.5

1. Test configuration 1: the occupied bandwidth 7.1 kHz (*Figure 3: "Adjacent channel power 2.4 Kbps data rate"*)
2. Test configuration 2: the occupied bandwidth 8 kHz (*Figure 4: "Adjacent channel power 4.8 Kbps data rate"*)

Hence the ARIB STD-T67 requirement is satisfied for the above cases.

3.3 Permissible values of spurious emission or unwanted emission

Spurious emission refers to the emissions on a frequency or frequencies outside the permitted bandwidth and the level of which may be reduced without affecting the corresponding transmission of information, including a high harmonic emission, a low harmonic emission, a parasitic emission and an intermodulation product but excluding an out-of-band emission.

Out-of-band emission refers to the emission which results from the modulation process on a frequency or frequencies outside the permitted bandwidth.

Permissible value of the unwanted (spurious plus out-of-band) emission intensity: the permissible value with respect to the mean power of unwanted emissions of each modulated frequency supplied to the feeder.

The permissible value of the unwanted emission 2.5 μW (-26 dBm) or less in the average power.

The following plots show the readings for spurious emission below 1 GHz and above 1 GHz, along with the ARIB STD-T67 specification mask.

The S2-LP easily satisfies the spurious emission requirements.

Figure 5: TX spurious emission below 1 GHz

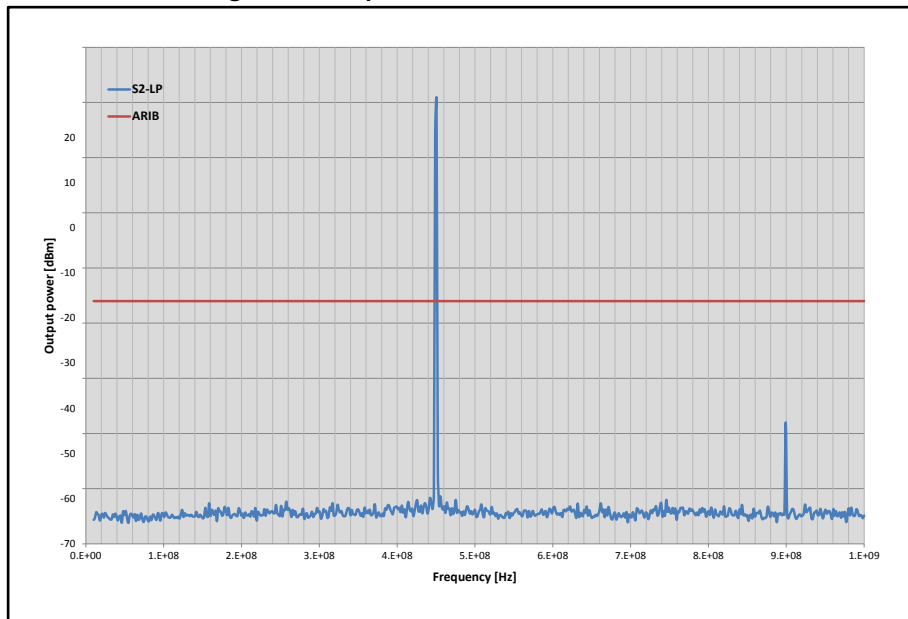
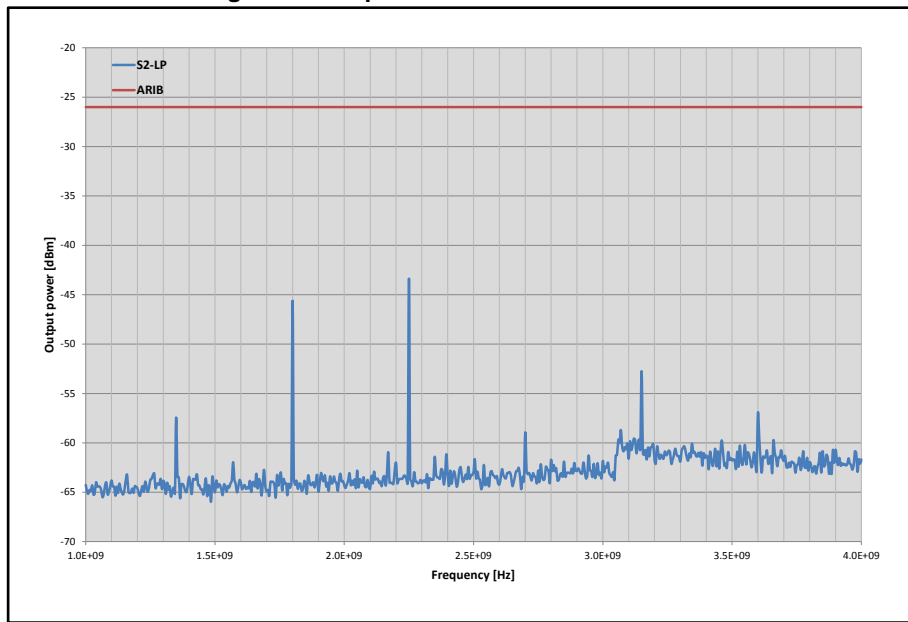


Figure 6: TX spurious emission above 1 GHz



4 Receiver parameters

The measurements for the receiver were taken with the following parameters, unless otherwise specified:

- $T_c = 25\text{ }^\circ\text{C}$
- $V_{dd} = 3.3\text{ V}$
- $f = 449.8\text{ MHz}$.

4.1 Encoding reference sensitivity

The reference sensitivity, or the necessary receiver input voltage in which the output bit error rate of the device is 1×10^{-2} when the desired wave modulated is applied is $2\text{ }\mu\text{V}$ (-101 dBm on $50\text{ }\Omega$) or less for receivers with channel intervals of 12.5 kHz

The receiver sensitivity measurements for different cases are reported in the table below.

The S2-LP easily satisfies the reference sensitivity requirements.

Table 2: Encoding reference sensitivity

Modulation	Data rate [Kbps]	Deviation [kHz]	Channel filter [kHz]	Sensitivity [dBm]	
				S2-LP	ARIB
2GFSK 0.5	2.4	2.4	8.5	-122	< -101
2GFSK 0.5	4.8			-122	

4.2 Spurious response at effective selectivity

The spurious response at effective selectivity (the ratio of the jamming wave input voltage to the encoding reference sensitivity as the output bit error rate of the device becomes 1×10^{-2} when a un-modulated jamming wave is applied in a state in which a desired wave input voltage 3 dB higher than the encoding reference sensitivity is applied) is 40 dB or more.

Table 3: "Spurious response at effective selectivity " shows the readings for different data rates when two signal generators are connected by a power combiner, along with the corresponding ARIB STD-T67 requirement.

1. The first generator was set with the modulation data given in the table and with PN9 as data. The level was set at 3 dB higher than sensitivity.
2. The second generator was then powered with an un-modulated carrier set at $\pm 12.5\text{ kHz}$ from the fundamental and its level was raised until 1% of BER was reached.
3. The desired value was taken as the difference between the two levels.

The S2-LP easily satisfies the requirements of the standard.

Table 3: Spurious response at effective selectivity

Modulation	Data rate [Kbps]	Deviation [kHz]	Channel filter [kHz]	Spurious response [dB]		
				-12.5 kHz	+12.5 kHz	ARIB
2GFSK 0.5	2.4	2.4	8.5	88	87	>40
2GFSK 0.5	4.8			74	76	

4.3 Adjacent channel selectivity at effective selectivity

The adjacent channel selectivity at effective selectivity (the ratio of the jamming wave input voltage to the encoding reference sensitivity as the output bit error rate of the device becomes 1×10^{-2} when a jamming wave that is modulated by a signal of repetitive binary pseudo noise with a code length of 32767 bits and is 12.5 kHz distant from the desired wave is applied to a device with channel interval of 12.5 kHz, respectively, in a state in which the desired wave input voltage 3 dB higher than the encoding reference sensitivity is applied) is 30 dB or more.

Table 4: "Adjacent channel selectivity at effective selectivity" shows the results for different data rates when two signal generators are connected by a power combiner, along with the corresponding ARIB STD-T67 requirement.

1. The first generator was set with the modulation data given in the table and with PN9 as data. The level was set at 3 dB higher than sensitivity.
2. The second generator was then powered with a modulated carrier (same modulation, data rate, frequency deviation and data of the fundamental) set at ± 12.5 kHz from the fundamental and its level was raised until 1% of BER was reached.
3. The desired value was taken as the difference between the two levels.

The S2-LP easily satisfies the requirements of the standard.

Table 4: Adjacent channel selectivity at effective selectivity

Modulation	Data rate [Kbps]	Deviation [kHz]	Channel filter [kHz]	Spurious response [dB]		
				- CH	+ CH	ARIB
2GFSK 0.5	2.4	2.4	8.5	87	87	>40
2GFSK 0.5	4.8			86	86	

4.4 Limit on secondary radiated emissions

The limit of the secondary radiated emission from the receiving equipment is, in terms of the power of a dummy antenna circuit that has the same electrical constant as the receiving antenna, 4 nW (-54 dBm on 50 Ω load) or lower.

The following plots show the readings for radiated emissions below 1 GHz and above 1 GHz, along with the ARIB STD-T67 specification mask.

The S2-LP easily satisfies the radiated emission requirements.

Figure 7: RX radiated emission below 1 GHz

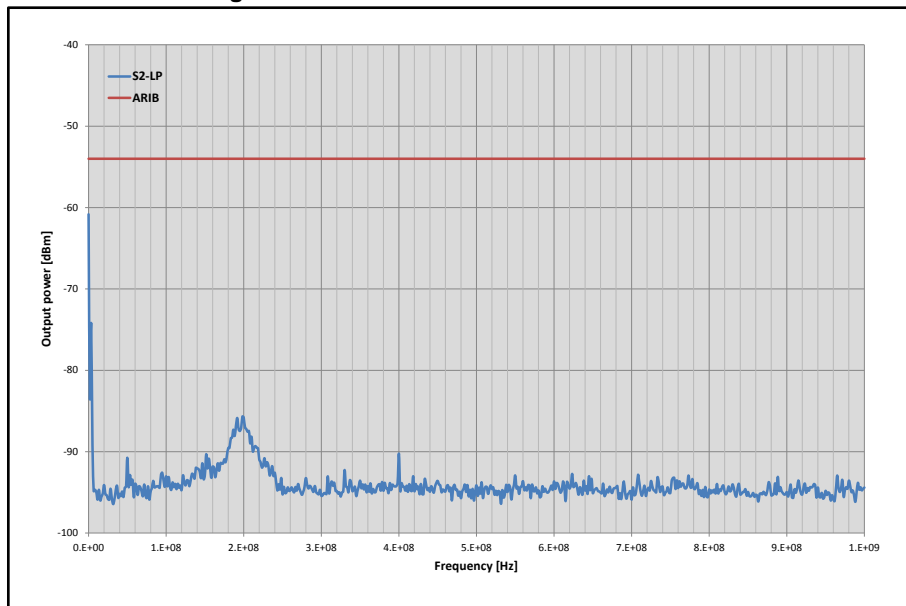
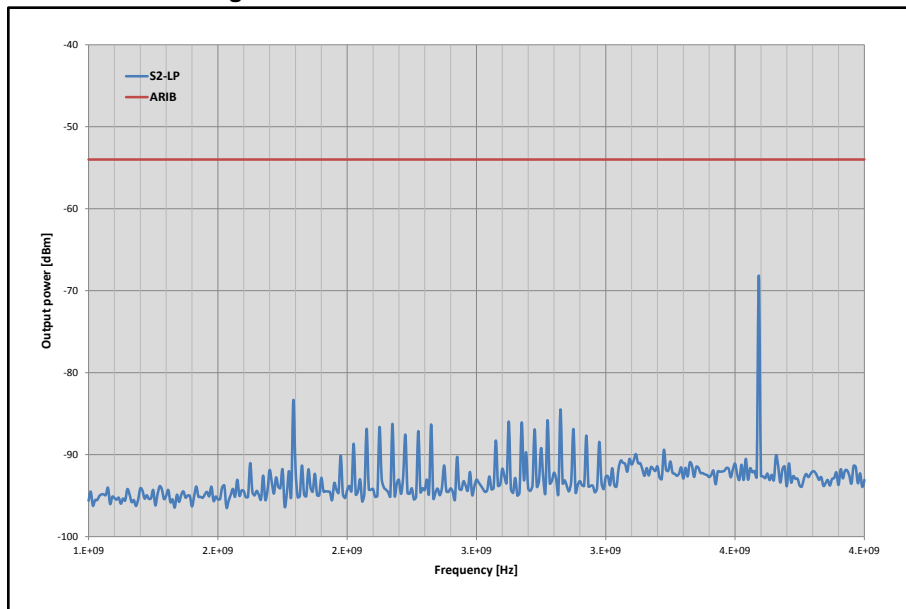


Figure 8: RX radiated emission above 1 GHz



5 References

1. S2-LP datasheet.
2. ARIB STD-T67: "Telemeter, Telecontrol and data transmission radio equipment for specified low-power radio station".

6 Revision history

Table 5: Document revision history

Date	Version	Changes
04-Apr-2017	1	Initial release.

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