RL78/G1H

Example of average current and battery life in intermittent operation

Introduction

This document shows examples of average current and battery life when intermittent operation (TX, RX and CCA) is continued with RF transceiver (RL78/G1H).

Note: The contents of this document are provided as an example for reference and do not guarantee the battery life in systems. When implementing this example into an existing system, thoroughly evaluate the product in the overall system and apply the contents of this document at your own responsibility.

Adaptive Device

RL78/G1H

Contents

1. Overview

This Application Note shows battery life examples when the intermittent operation (TX, RX and CCA) in RL78/G1H (Hereafter described as G1H) is continued.

For G1H operating conditions, functions, and test command, please refer to user's manuals.

Examples of battery life for signal conditions such as data length and intermittent operation interval are introduced. These will be helpful when calculating the battery life according to customer system.

2. Description of intermittent operation

The transition of current consumption of G1H during intermittent operation is shown in Figure 1.

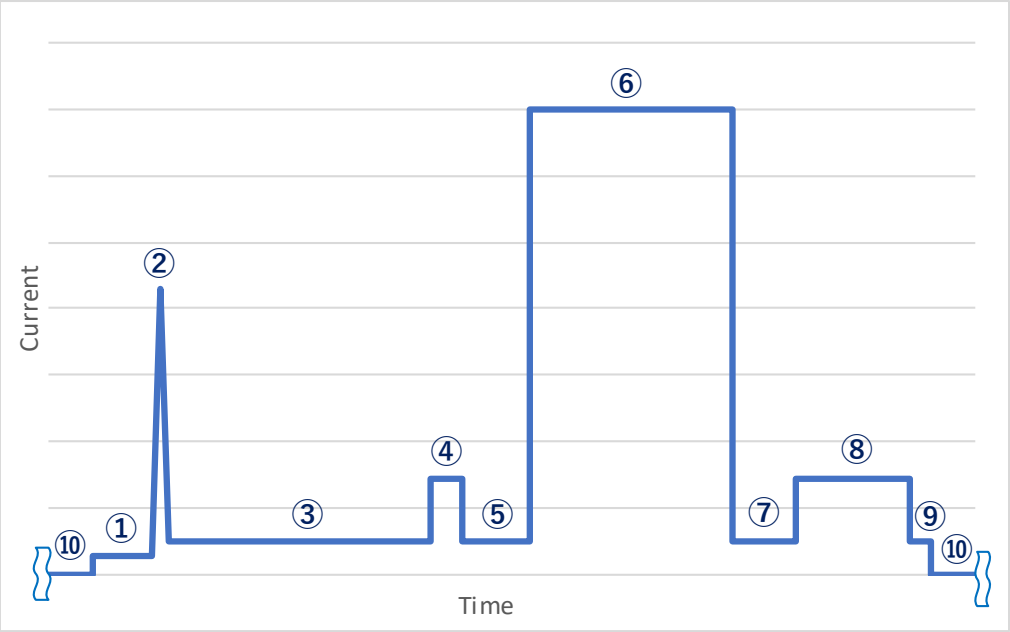

Figure 1. The transition of current consumption during intermittent operation

1) Idle (Only MCU)
This is the term when the MCU and the 48MHz crystal oscillation circuit are ON.

2) Rush Current
This is the term when DCDC converter and LDO are further turned on.

3) Setup
This is the waiting term for the circuit to stabilize, and the term for setting CCA and TX.

4) CCA
This is the receiving term for checking whether the used channel (CH) frequency is not being used by another terminal.

5) Idle
This is the term to end CCA and wait for signal transmission.

6) TX
This is the term for transmitting the packet signal.

7) Idle
This is the term when MCU is setting for receiving.

8) RX
This is the receiving term for receiving ACK.

9) Idle
This is mode that the external crystal oscillation circuit and power supply circuit are operating.

10) Sleep
This is the term when MCU is setting for Sleep.

Table1 shows examples of the timing of each mode under signal conditions shown below.

Signal conditions: Data Rate=100kbps, modulation index=1, CH Frequency=926.1MHz,
Preamble=4byte, Data length=18byte, SFD=2byte, PHR=2byte, FCS Length=2byte
Intermittent operation interval=5sec

Table 1. Timing example of each mode

No	Mode	Term [ms]	
		MCU CLK=8MHz	MCU CLK=32MHz
1	Idle (MCU Only)	0.678	0.678
2	Rush Current	0.198	0.198
3	Setup	2.974	1.628
4	CCA	0.362	0.362
5	Idle	0.758	0.758
6	TX	2.308	2.308
7	Idle	0.711	0.432
8	RX	1.324	1.324
9	Idle	0.240	0.136
10	Sleep	4990.447	4992.176

3. Average current in intermittent operation interval

3.1 Example of average current for intermittent operation interval

This section shows examples of average current for intermittent operation interval. Overall, as the intermittent operation interval gets longer, the average current gets smaller.
Regarding supply voltage, since the built-in DC-DC converter is used during transmission / receiving mode, the current decreases as the supply voltage increases, whereas during Sleep, the current decreases as the supply voltage decreases.
If the intermittent operation interval is short (long), since the former (latter) becomes dominant, the average current becomes smaller as the supply voltage becomes higher (lower).

3.1.1 Example of average current when transmission conditions are changed (MCU CLK=8MHz)

Figure 2 to 19 show examples of average current for the intermittent operation interval when TX power (+10/+13/+15dBm) and TX data length (20/200/2000Byte) are changed. Each figure is enlarged to show the current change according to the voltage.

Signal condition: TX Power=+10dBm, Data Rate=100kbps, modulation index=1, CH Frequency= 926.1MHz, Preamble=4byte, SFD=2byte, PHR=2byte, FCS Length=2byte

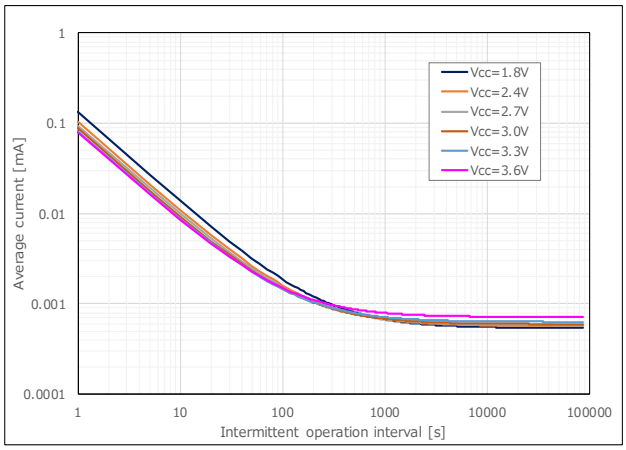

Figure 2. Data Length=20byte

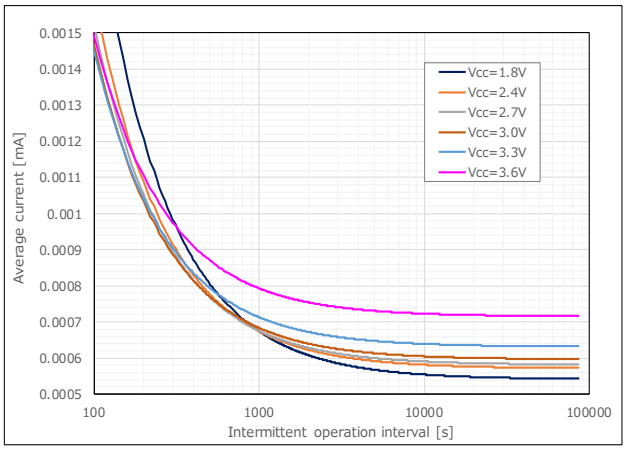

Figure 3. Data Length=20byte (Zoom)

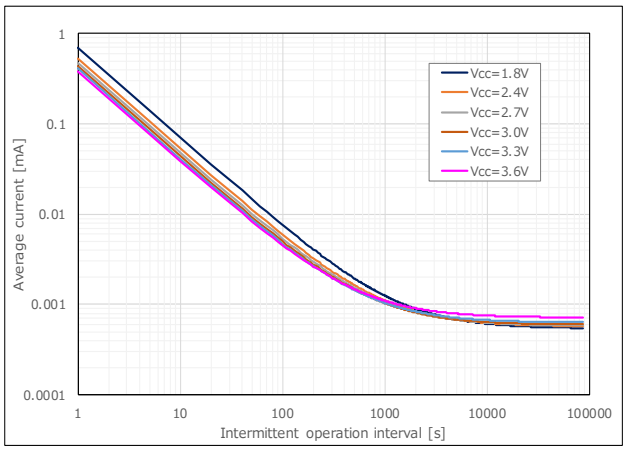

Figure 4. Data Length=200byte

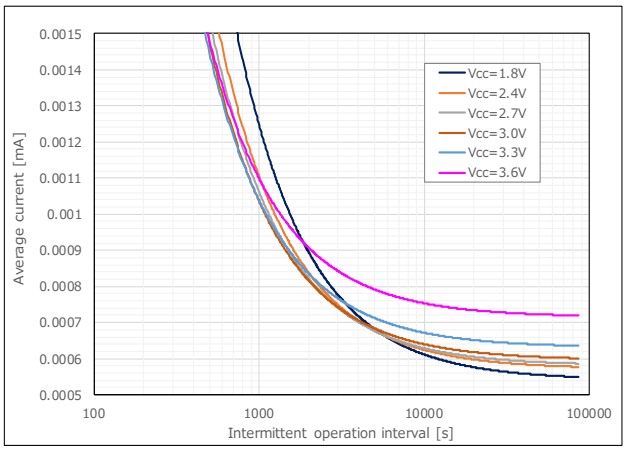

Figure 5. Data Length=200byte (Zoom)

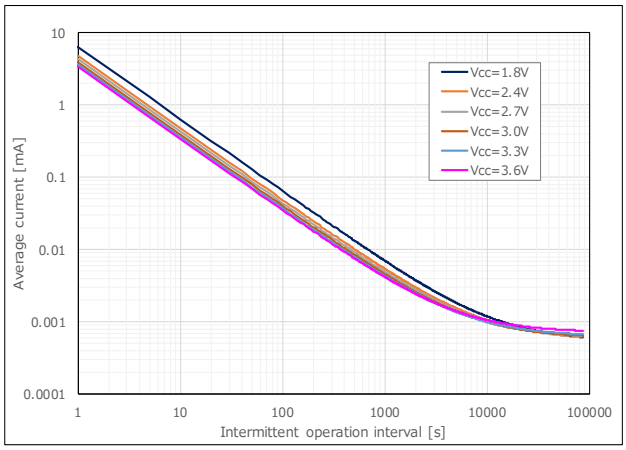

Figure 6. Data Length=2000byte

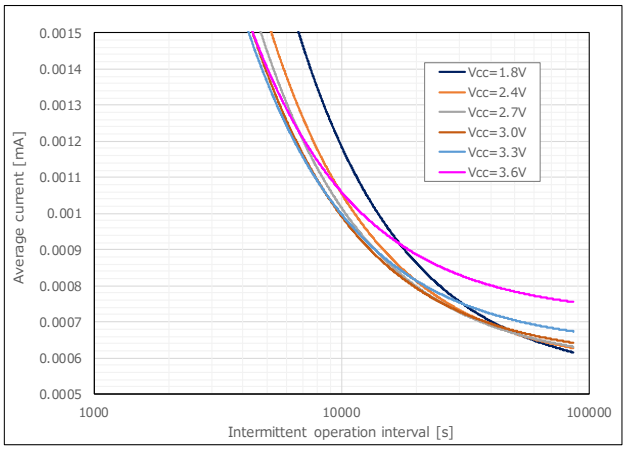

Figure 7. Data Length=2000byte (Zoom)

Signal condition: TX Power=+13dBm, Data Rate=100kbps, modulation index=1, CH Frequency=926.1MHz, Preamble=4byte, SFD=2byte, PHR=2byte, FCS Length=2byte

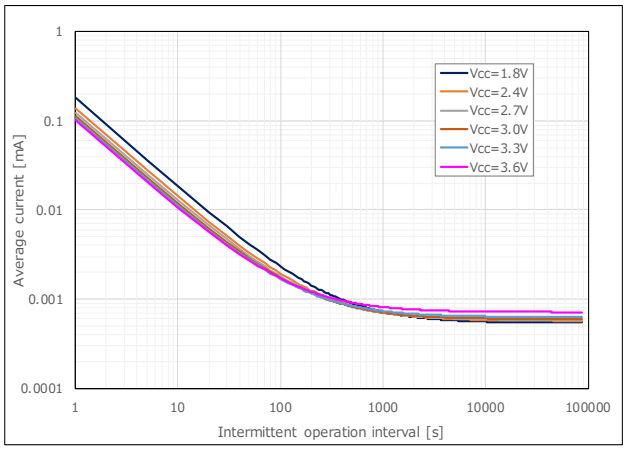

Figure 8. Data Length=20byte

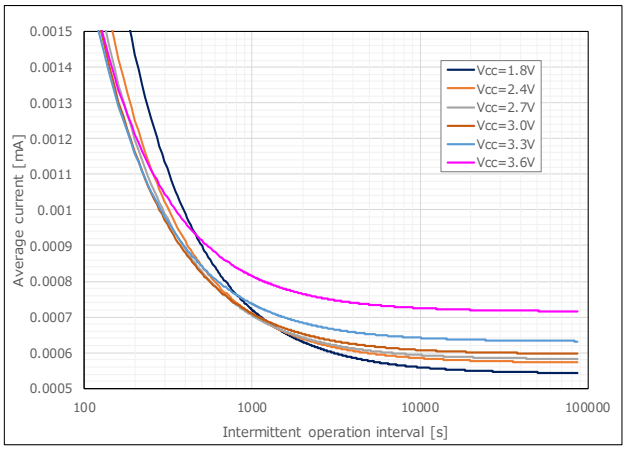

Figure 9. Data Length=20byte (Zoom)

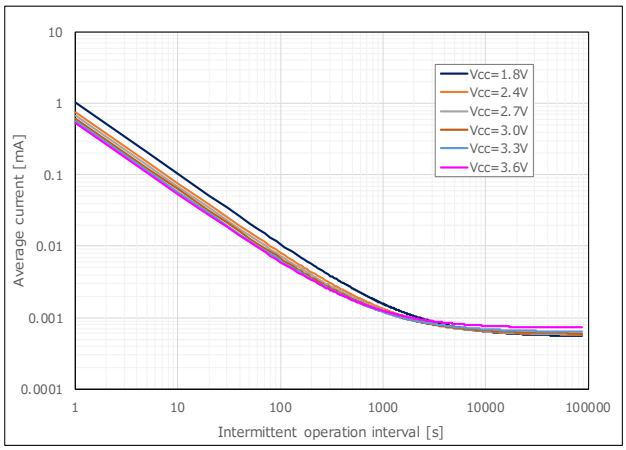

Figure 10. Data Length=200byte

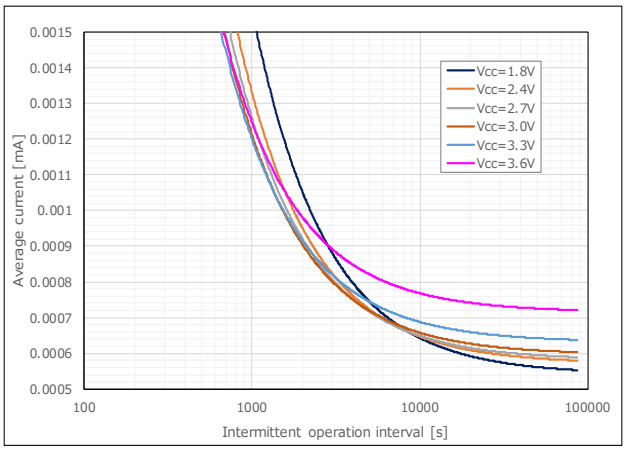

Figure 11. Data Length=200byte (Zoom)

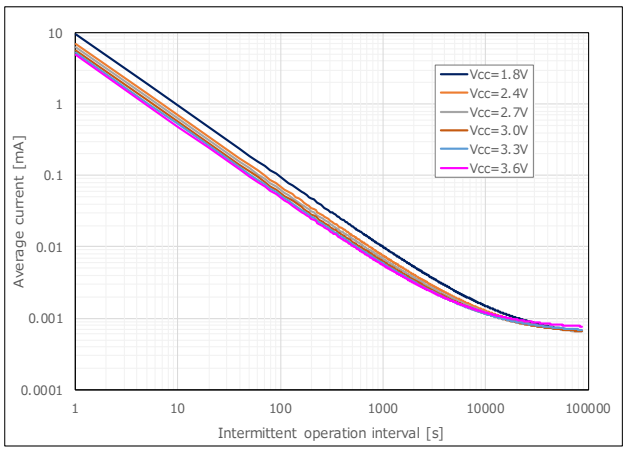

Figure 12. Data Length=2000byte

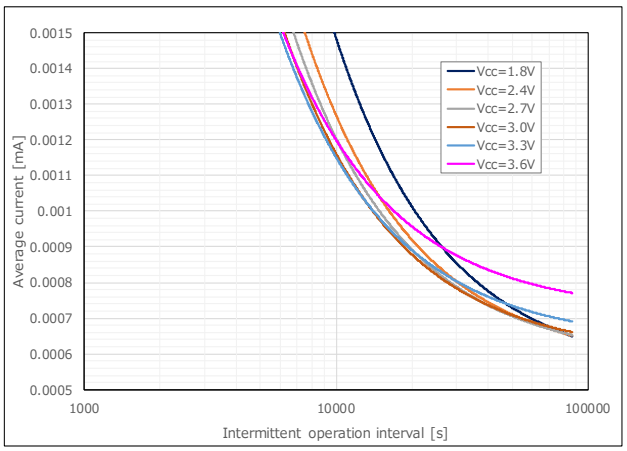

Figure 13. Data Length=2000byte (Zoom)

Signal condition: TX Power=+15dBm, Data Rate=100kbps, modulation index=1, CH Frequency=926.1MHz, Preamble=4byte, SFD=2byte, PHR=2byte, FCS Length=2byte

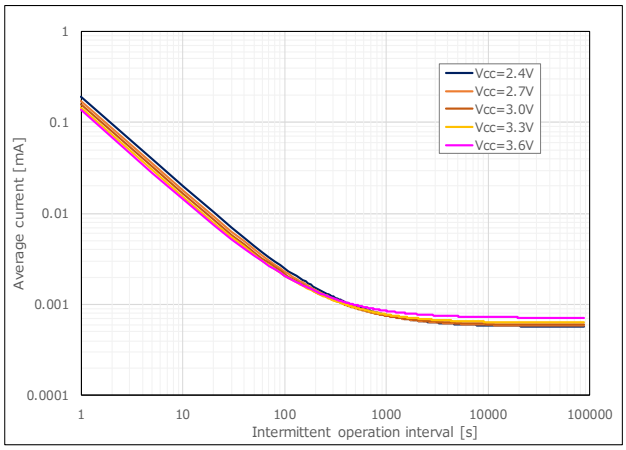

Figure 14. Data Length=20byte

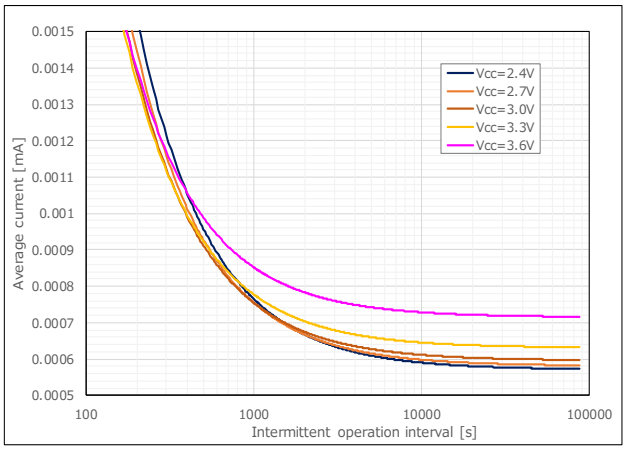

Figure 15. Data Length=20byte (Zoom)

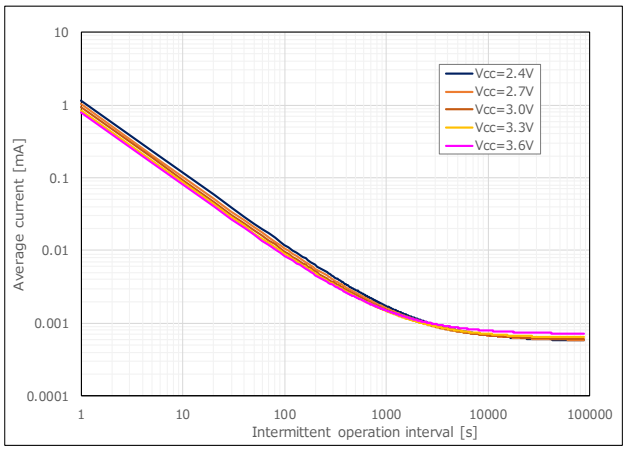

Figure 16. Data Length=200byte

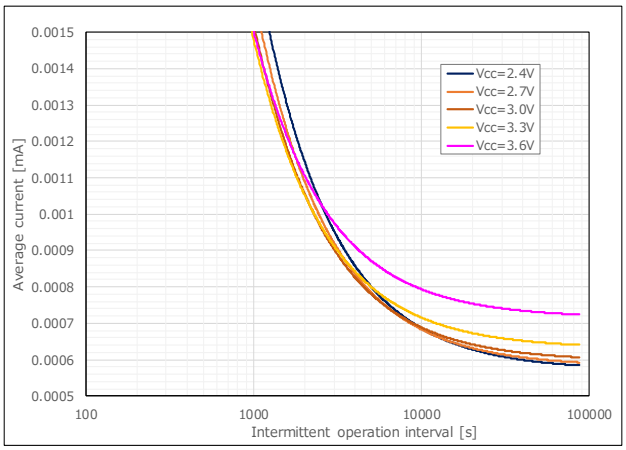

Figure 17. Data Length=200byte (Zoom)

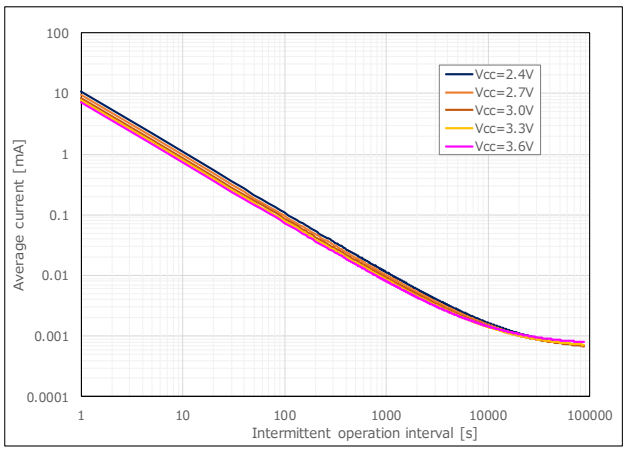

Figure 18. Data Length=2000byte

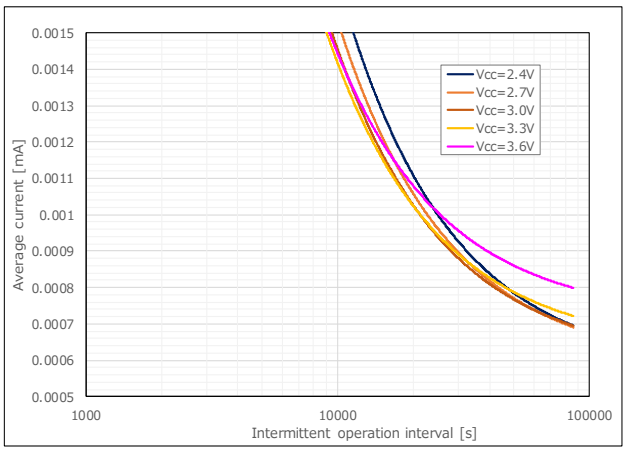

Figure 19. Data Length=2000byte (Zoom)

3.1.2 Example of average current when transmission conditions are changed (MCU CLK=32MHz)

Figure 20 to 37 show examples of average current for the intermittent operation interval when TX power (+10/+13/+15dBm) and TX data length (20/200/2000Byte) are changed. Each figure is enlarged to show the current change according to the voltage.

Signal condition: TX Power=+10dBm, Data Rate=100kbps, modulation index=1, CH Frequency=926.1MHz, Preamble=4byte, SFD=2byte, PHR=2byte, FCS Length=2byte

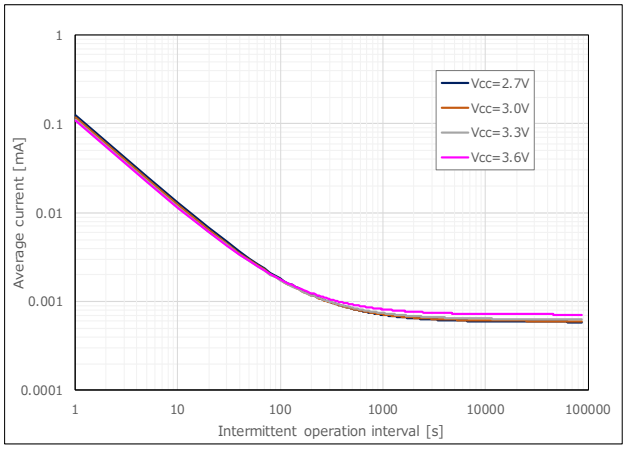

Figure 20. Data Length=20byte

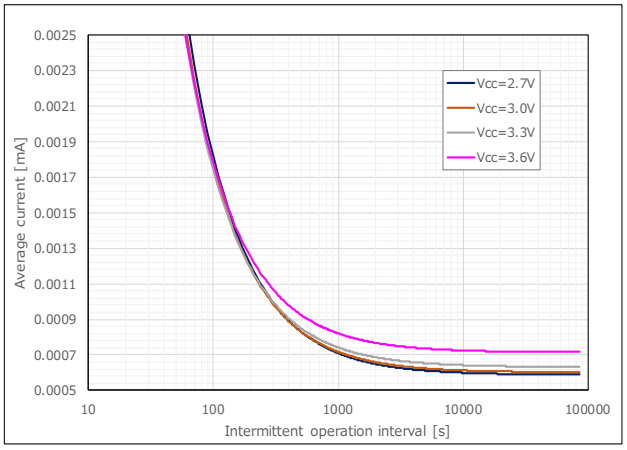

Figure 21. Data Length=20byte (Zoom)

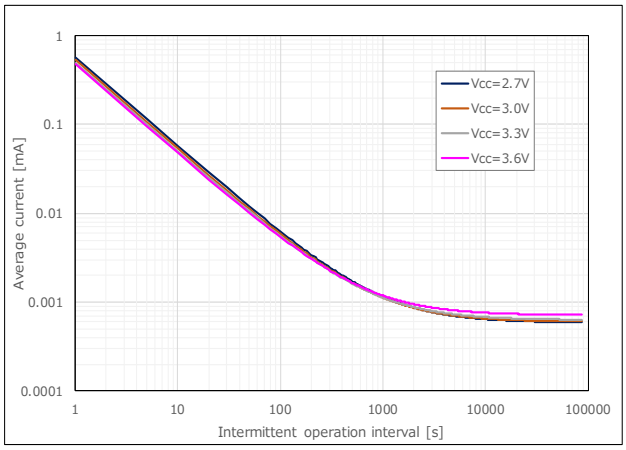

Figure 22. Data Length=200byte

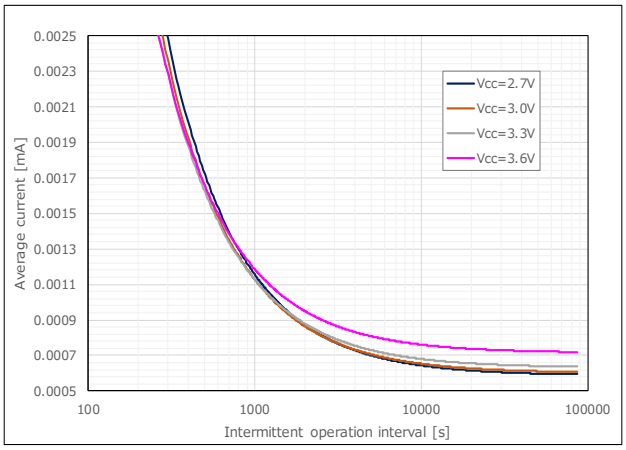

Figure 23. Data Length=200byte (Zoom)

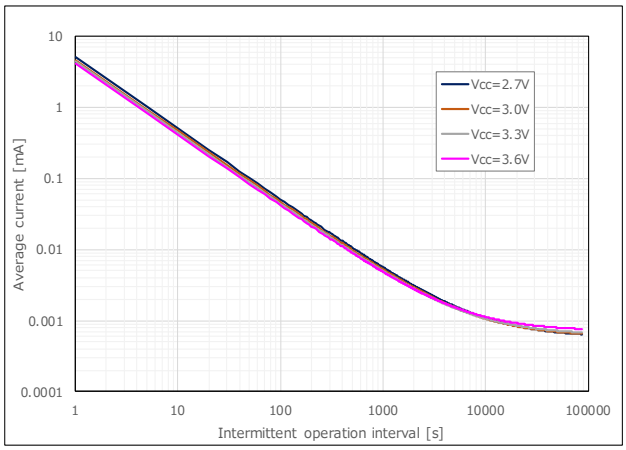

Figure 24. Data Length=2000byte

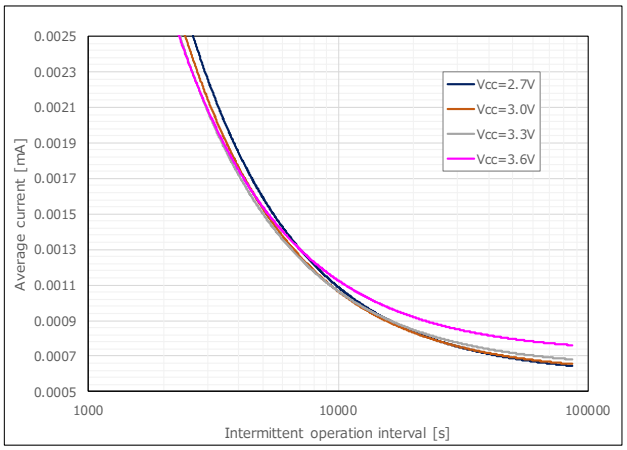

Figure 25. Data Length=2000byte (Zoom)

Signal condition: TX Power=+13dBm, Data Rate=100kbps, modulation index=1, CH Frequency=926.1MHz, Preamble=4byte, SFD=2byte, PHR=2byte, FCS Length=2byte

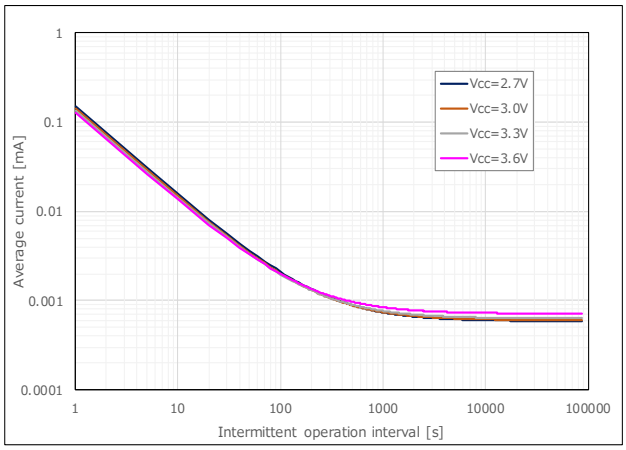

Figure 26. Data Length=20byte

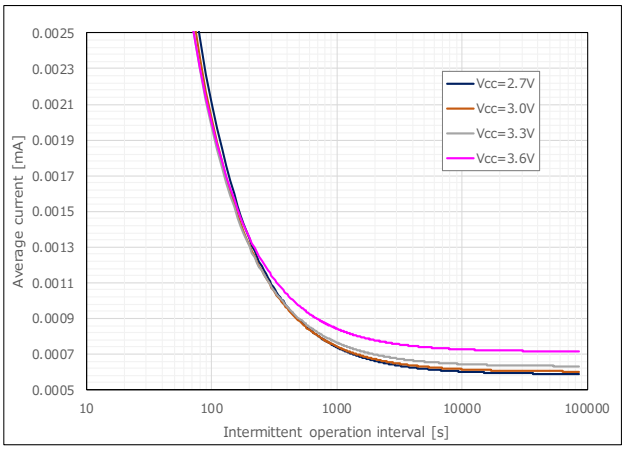

Figure 27. Data Length=20byte (Zoom)

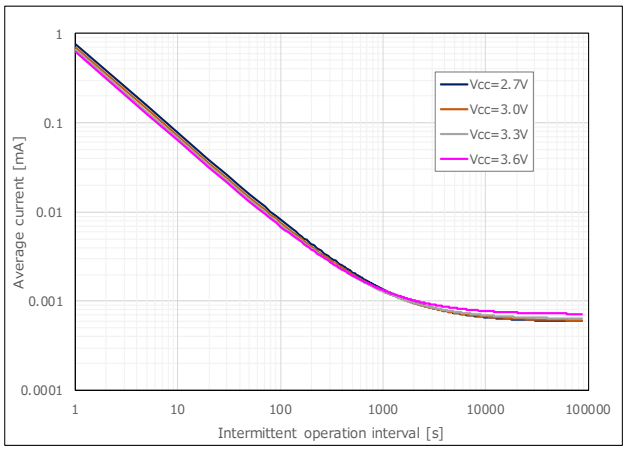

Figure 28. Data Length=200byte

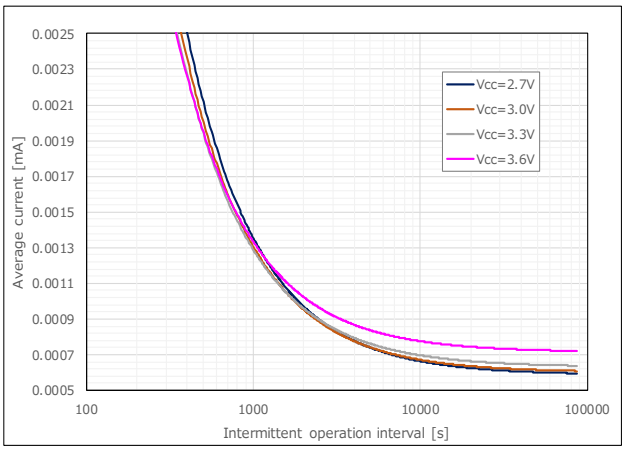

Figure 29. Data Length=200byte (Zoom)

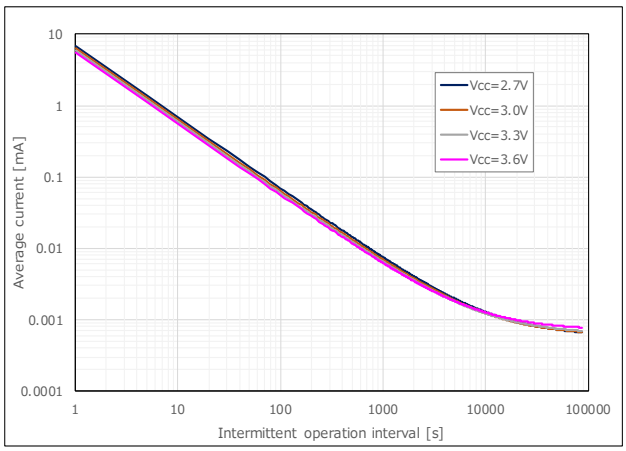

Figure 30. Data Length=2000byte

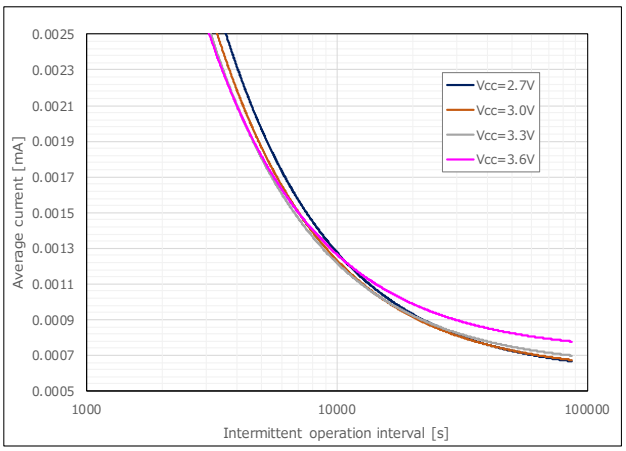

Figure 31. Data Length=2000byte (Zoom)

Signal condition: TX Power=+15dBm, Data Rate=100kbps, modulation index=1, CH Frequency=926.1MHz, Preamble=4byte, SFD=2byte, PHR=2byte, FCS Length=2byte

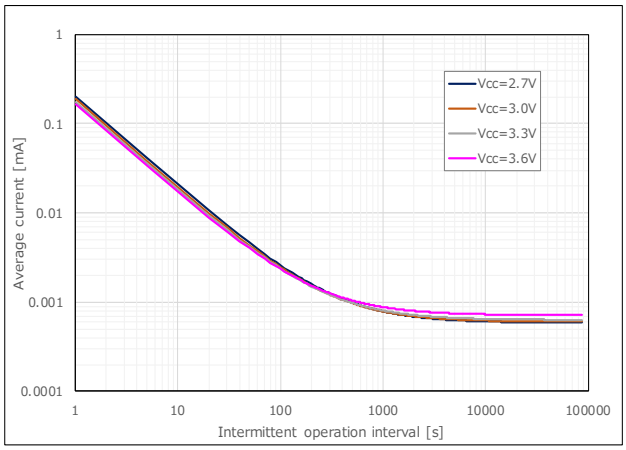

Figure 32. Data Length=20byte

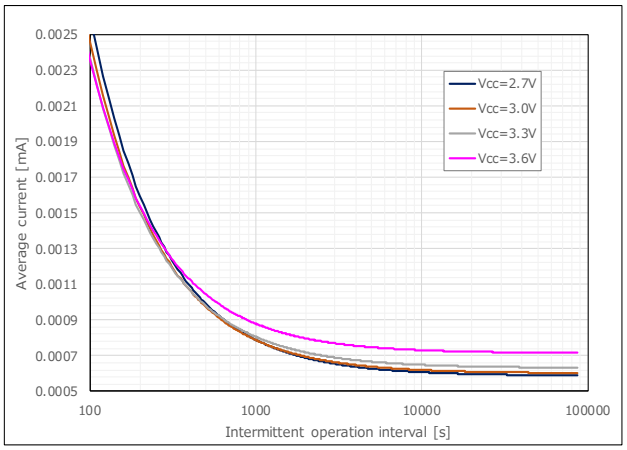

Figure 33. Data Length=20byte (Zoom)

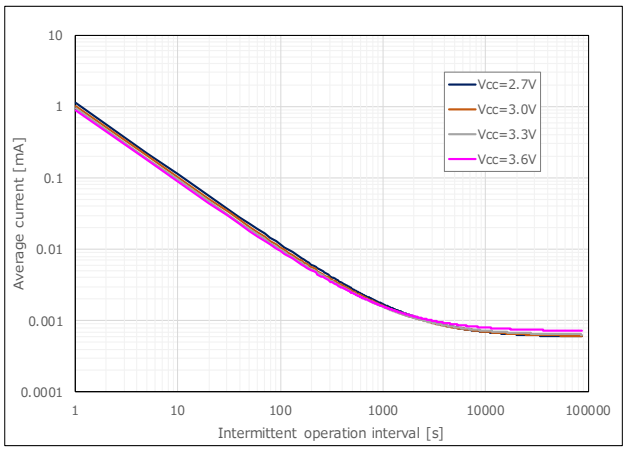

Figure 34. Data Length=200byte

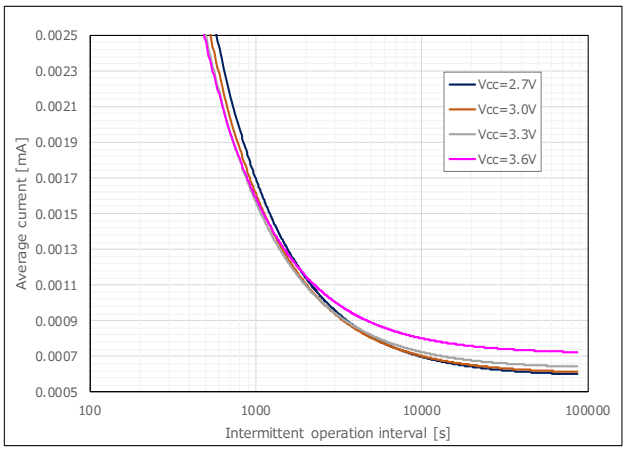

Figure 35. Data Length=200byte (Zoom)

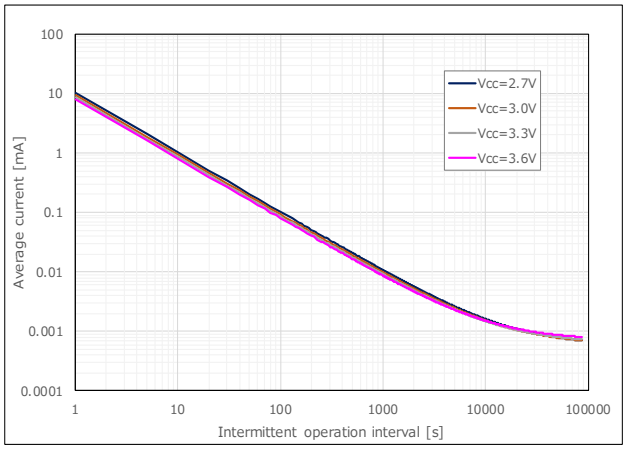

Figure 36. Data Length=2000byte

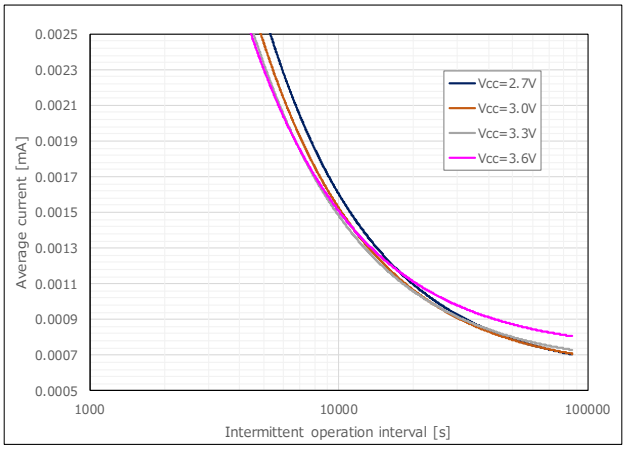

Figure 37. Data Length=2000byte (Zoom)

3.1.3 Example of average current when receiving conditions are changed (MCU CLK=8MHz)

Figure 38 to 41 show examples of average current for intermittent operation interval when receiving term in Figure 8 and 9 (MCU CLK=8MHz, TX Power=+13dBm, Data Length=20byte, receiving term=1.289ms) is changed to 10times (12.89ms) and 100times (128.9ms). Each figure is enlarged to show the current change according to the voltage.

Signal condition: TX Power=+13dBm, Data Rate=100kbps, modulation index=1, CH Frequency=926.1MHz, Preamble=4byte, SFD=2byte, PHR=2byte, FCS Length=2byte, Data Length=20byte

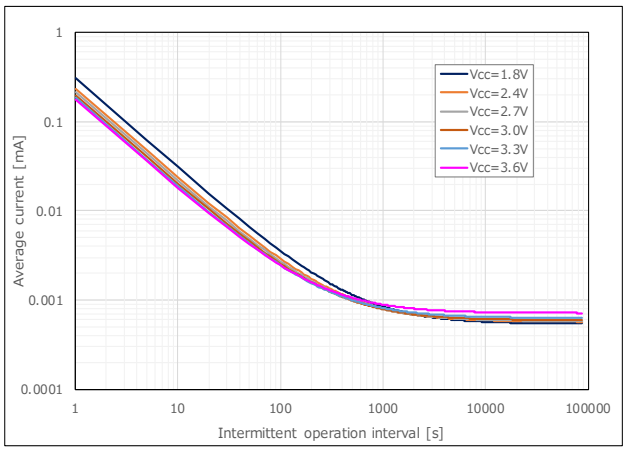

Figure 38. RX-term:10times

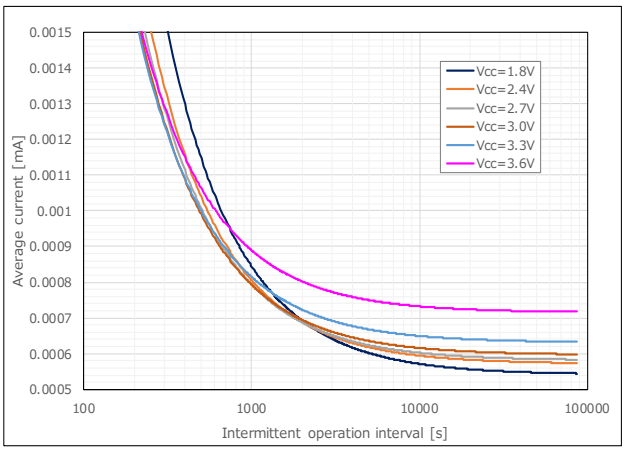

Figure 39. RX-term:10times (Zoom)

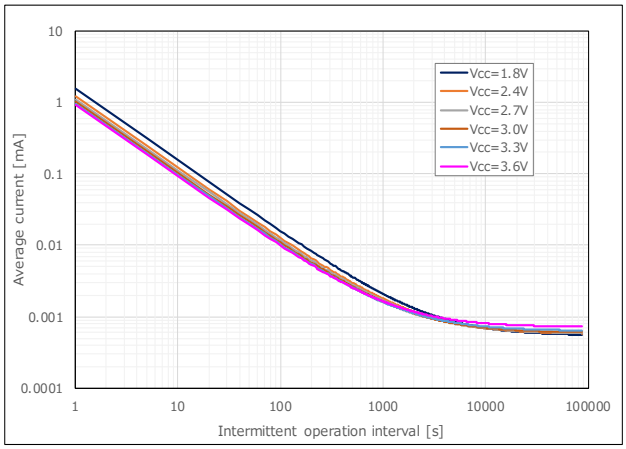

Figure 40. RX-term:100times

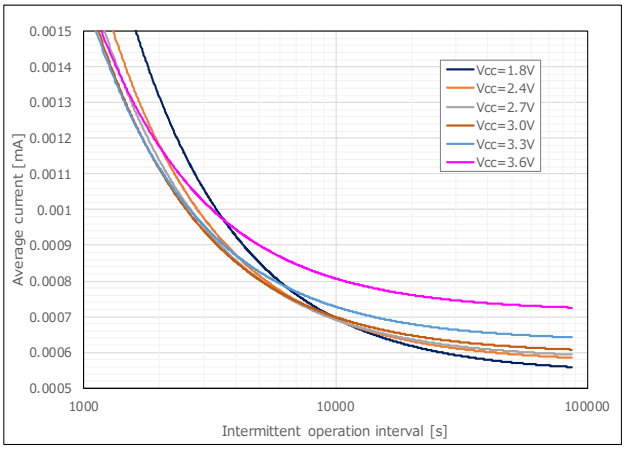

Figure 41. RX-term:100times (Zoom)

3.2 Example of Average current for battery voltage

This section shows examples of average current for battery voltage. Overall, as the intermittent operation interval gets longer, the average current gets smaller. If the intermittent operation interval is long, the average current becomes smaller as the supply voltage becomes lower.

3.2.1 Example of average current when transmission conditions are changed (MCU CLK=8MHz)

Figure 42 to 50 show examples of the average current for battery voltage when TX power (+10/+13/+15dBm) and TX data length (20/200/2000Byte) are changed. The average currents when the intermittent operation interval (5/300/3600/86400sec) is changed are shown in each graph.

Signal condition: TX Power=+10dBm, Data Rate=100kbps, modulation index=1, CH Frequency=926.1MHz, Preamble=4byte, SFD=2byte, PHR=2byte, FCS Length=2byte

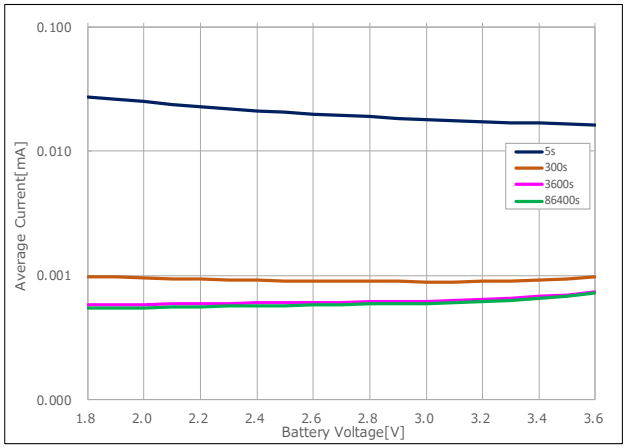

Figure 42. Data Length=20byte

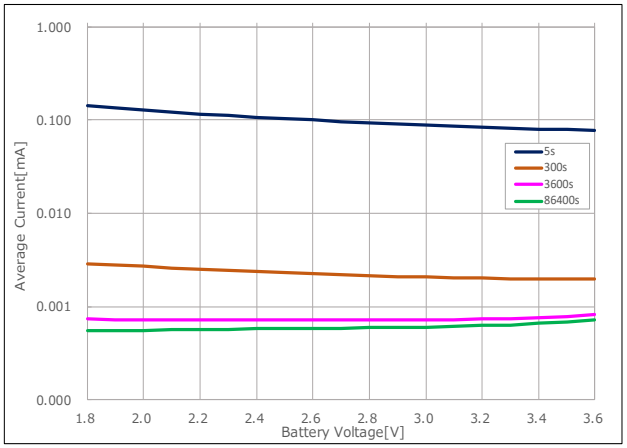

Figure 43. Data Length=200byte

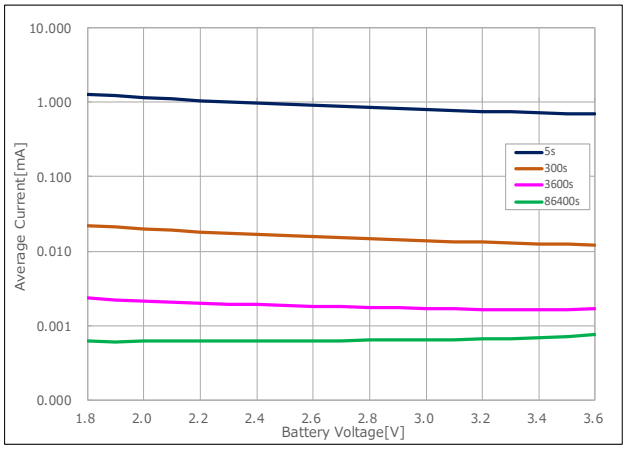

Figure 44. Data Length=2000byte

Signal condition: TX Power=+13dBm, Data Rate=100kbps, modulation index=1, CH Frequency=926.1MHz, Preamble=4byte, SFD=2byte, PHR=2byte, FCS Length=2byte

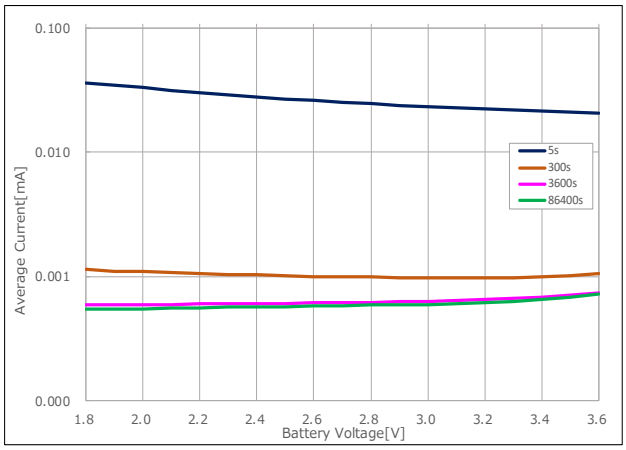

Figure 45. Data Length=20byte

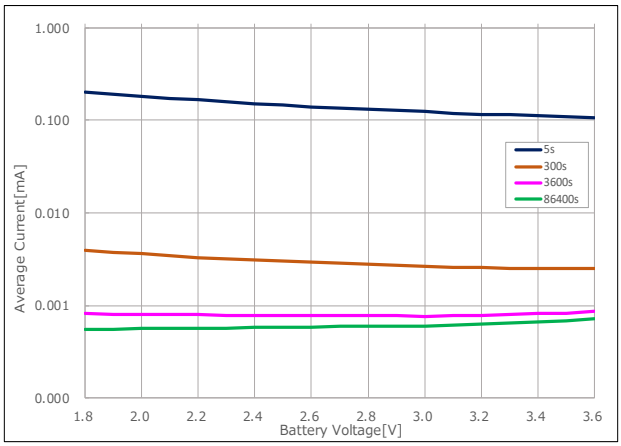

Figure 46. Data Length=200byte

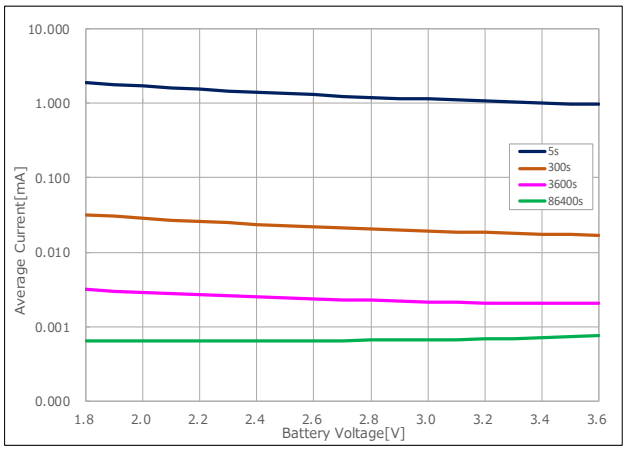

Figure 47. Data Length=2000byte

Signal condition: TX Power=+15dBm, Data Rate=100kbps, modulation index=1, CH Frequency=926.1MHz, Preamble=4byte, SFD=2byte, PHR=2byte, FCS Length=2byte

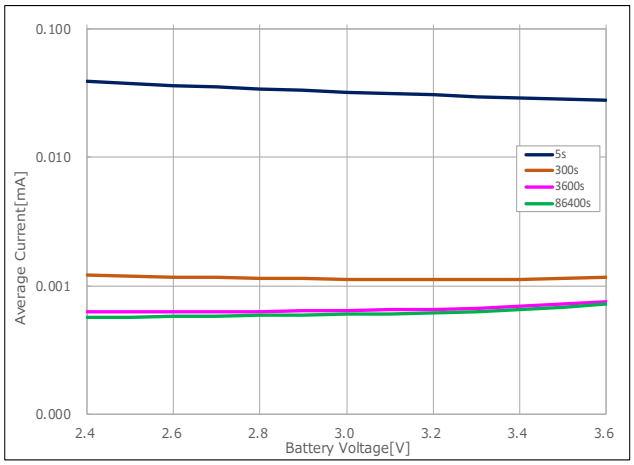

Figure 48. Data Length=20byte

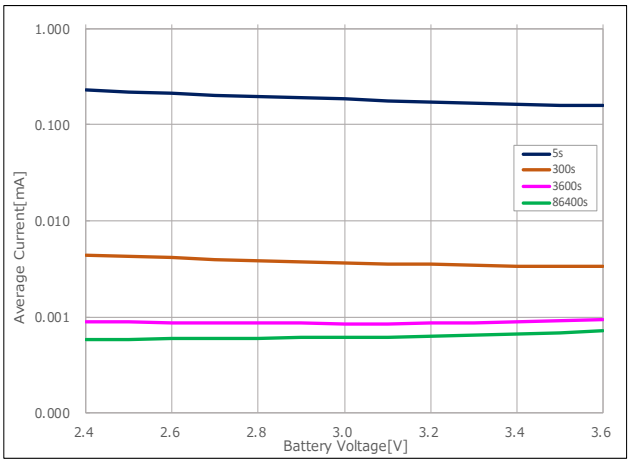

Figure 49. Data Length=200byte

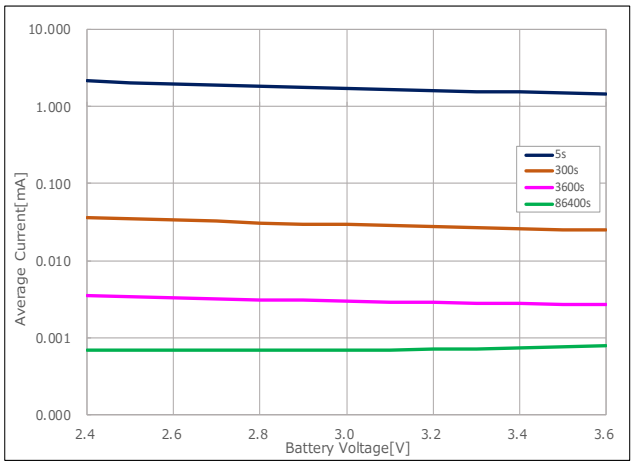

Figure 50. Data Length=2000byte

3.2.2 Example of average current when transmission conditions are changed (MCU CLK=32MHz)

Figure 51 to 59 show examples of the average current for battery voltage when TX power (+10/+13/+15dBm) and TX data length (20/200/2000Byte) are changed. The average currents when the intermittent operation interval (5/300/3600/86400sec) is changed are shown in each graph.

Signal condition: TX Power=+10dBm, Data Rate=100kbps, modulation index=1, CH Frequency=926.1MHz, Preamble=4byte, SFD=2byte, PHR=2byte, FCS Length=2byte

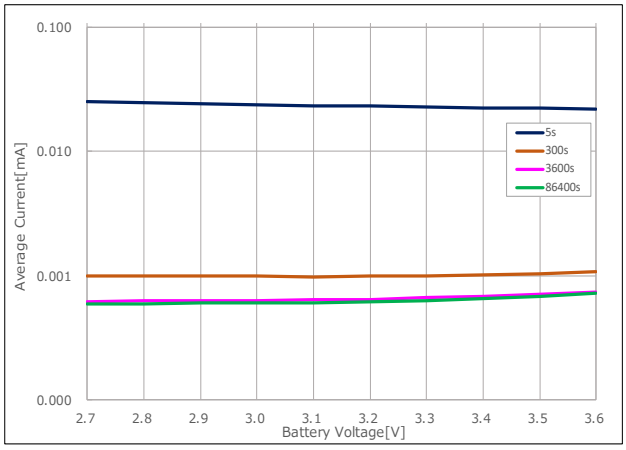

Figure 51. Data Length=20byte

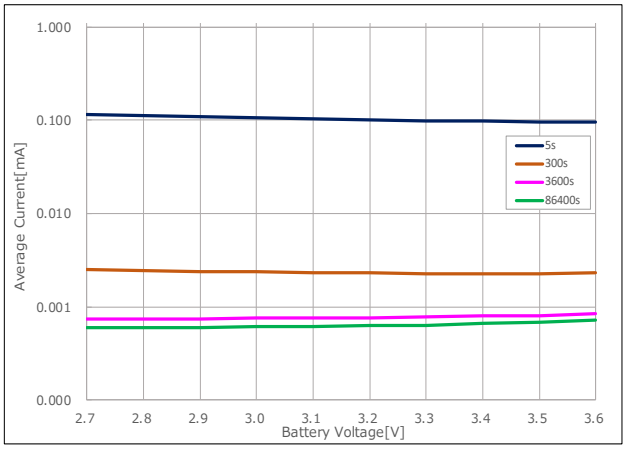

Figure 52. Data Length=200byte

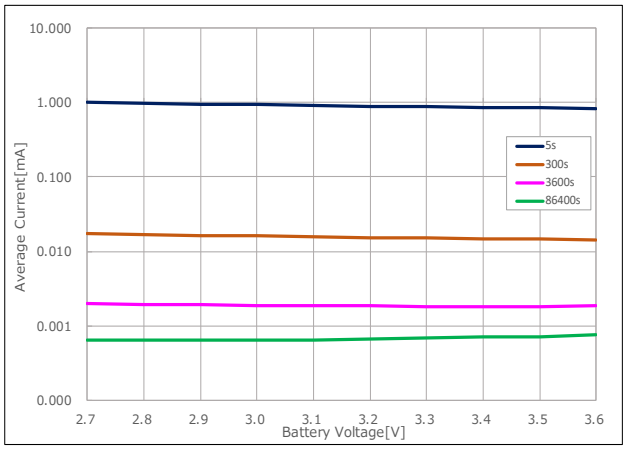

Figure 53. Data Length=2000byte

Signal condition: TX Power=+13dBm, Data Rate=100kbps, modulation index=1, CH Frequency=926.1MHz, Preamble=4byte, SFD=2byte, PHR=2byte, FCS Length=2byte

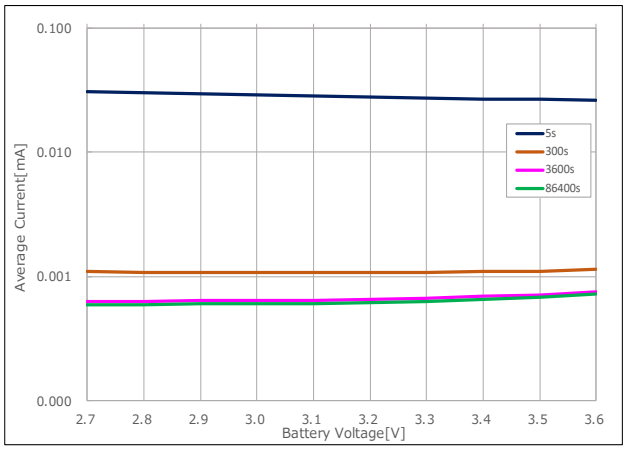

Figure 54. Data Length=20byte

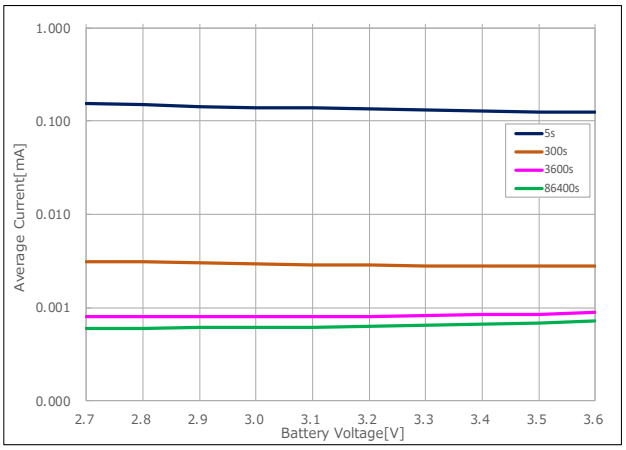

Figure 55. Data Length=200byte

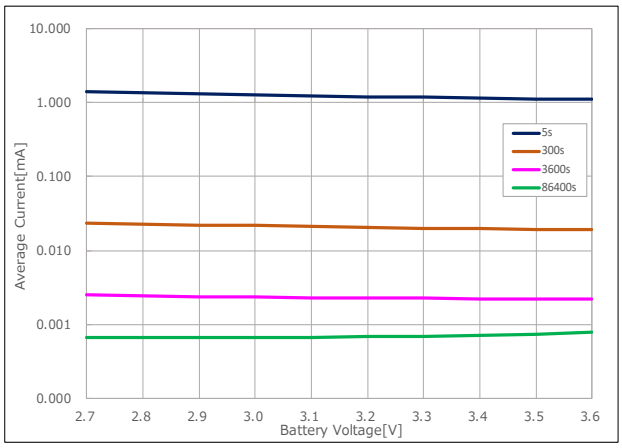

Figure 56. Data Length=2000byte

Signal condition: TX Power=+15dBm, Data Rate=100kbps, modulation index=1, CH Frequency=926.1MHz, Preamble=4byte, SFD=2byte, PHR=2byte, FCS Length=2byte

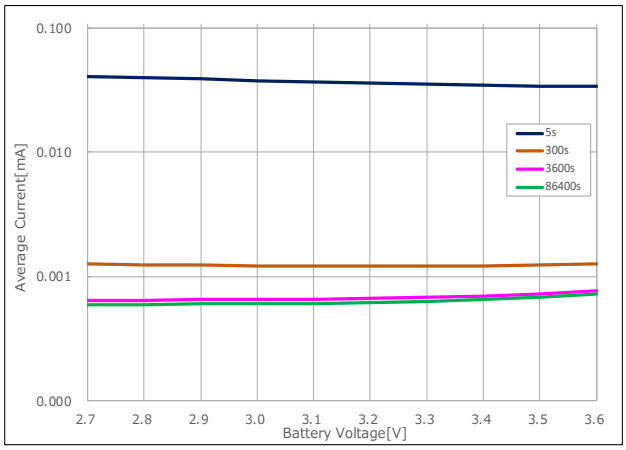

Figure 57. Data Length=20byte

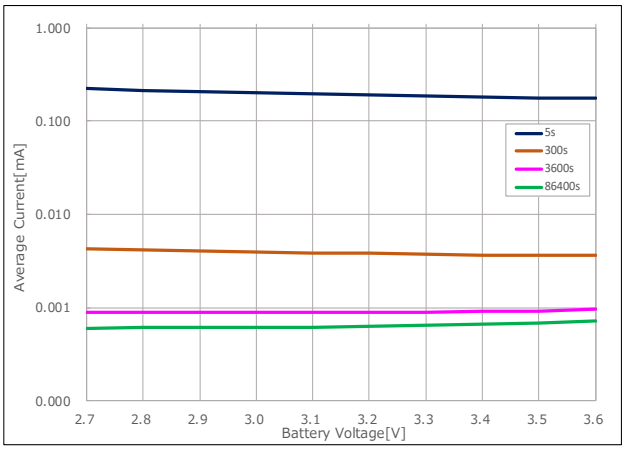

Figure 58. Data Length=200byte

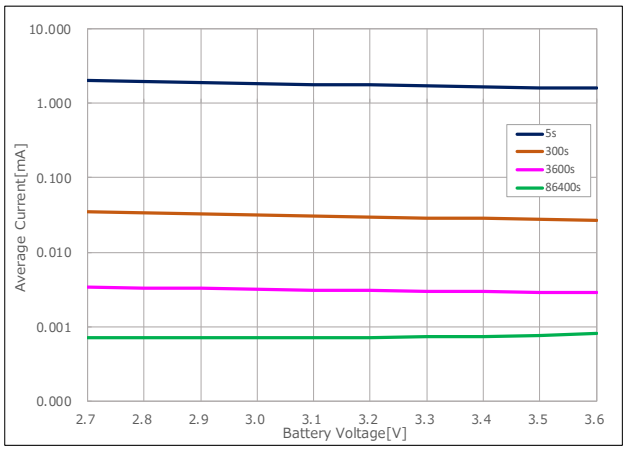

Figure 59. Data Length=2000byte

3.2.3 Example of average current when receiving conditions are changed (MCU CLK=8MHz)

Figure 60 to 61 show examples of average current for intermittent operation interval when receiving term in Figure 45 (MCU CLK=8MHz, TX Power=+13dBm, Data Length=20byte, receiving term=1.289ms) is changed to 10times (12.89ms) and 100times (128.9ms).

Signal condition: TX Power=+13dBm, Data Rate=100kbps, modulation index=1, CH Frequency=926.1MHz, Preamble=4byte, SFD=2byte, PHR=2byte, FCS Length=2byte, Data Length=20byte

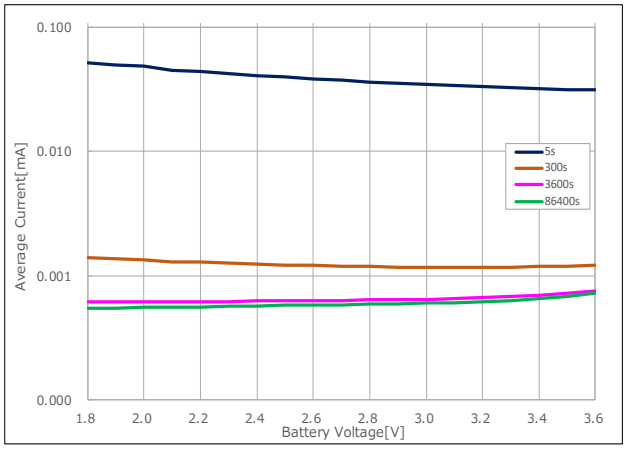

Figure 60. RX-term:10times

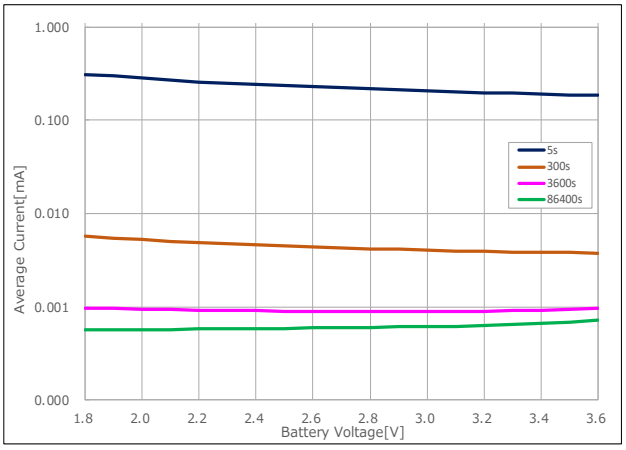

Figure 61. RX-term:100times

3.3 Percentage of current in each mode

This section shows percentage of the current in each mode within the average current.

3.3.1 Percentage of current when transmission conditions are changed

Figure 62 to 73 show percentage of current in each mode when the TX power, TX data length and intermittent operation interval are changed.

In Figures 62 and 63, when the intermittent operation interval is 5seconds (when the communication frequency increases), TX current accounts for more than 60%.

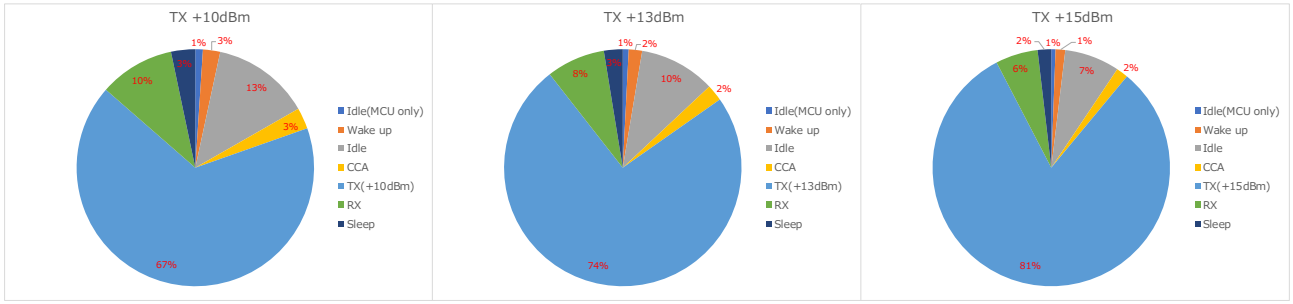

Figure 62. CLK=8MHz, Data Length=20byte, Intermittent operation interval=5sec

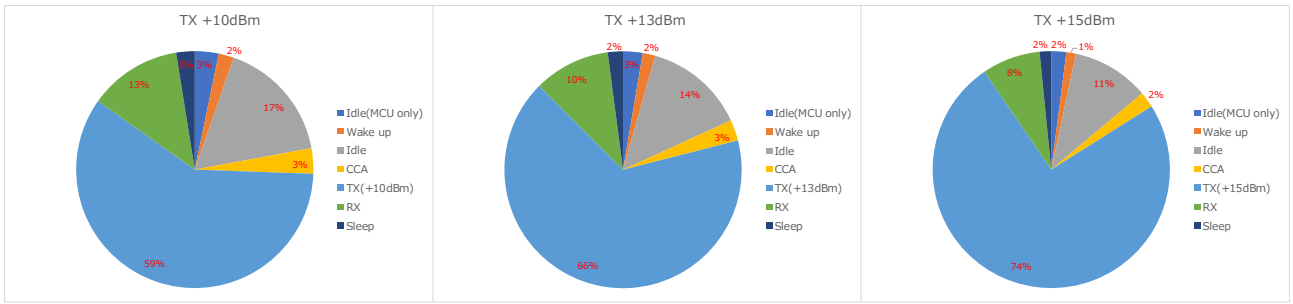

Figure 63. CLK=32MHz, Data Length=20byte, Intermittent operation interval=5sec

In Figure 64 to 65, when the intermittent operation interval is increased to 300seconds (when the communication frequency is reduced), Sleep current accounts for more than 40% in addition to the TX current.

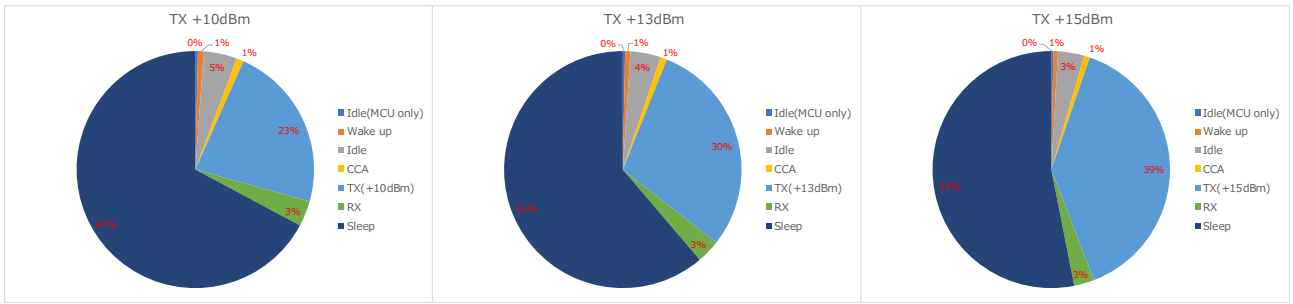

Figure 64. CLK=8MHz, Data Length=20byte, Intermittent operation interval=300sec

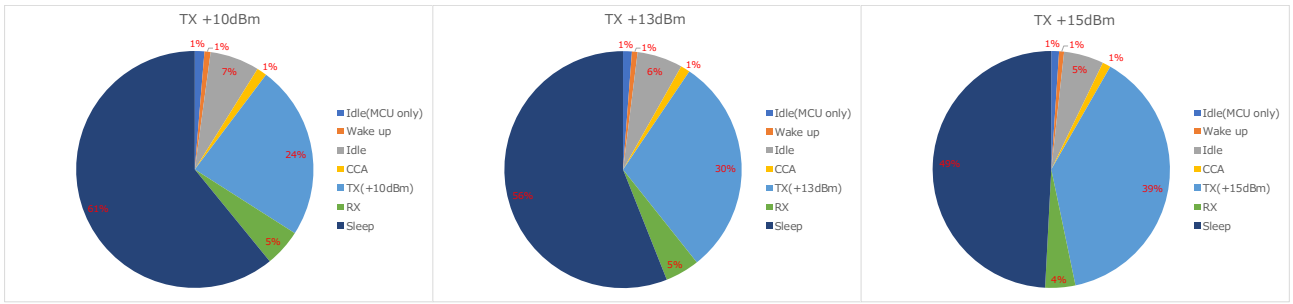

Figure 65. CLK=32MHz, Data Length=20byte, Intermittent operation interval=300sec

In Figure 66 to 67, when the intermittent operation interval is extended to 3600seconds (when the communication frequency is further reduced), Sleep current accounts for more than 90%.

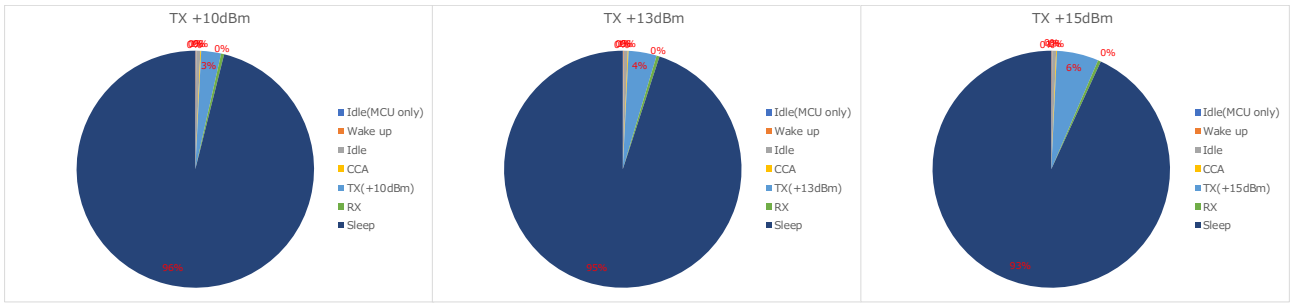

Figure 66. CLK=8MHz, Data Length=20byte, Intermittent operation interval=3600sec

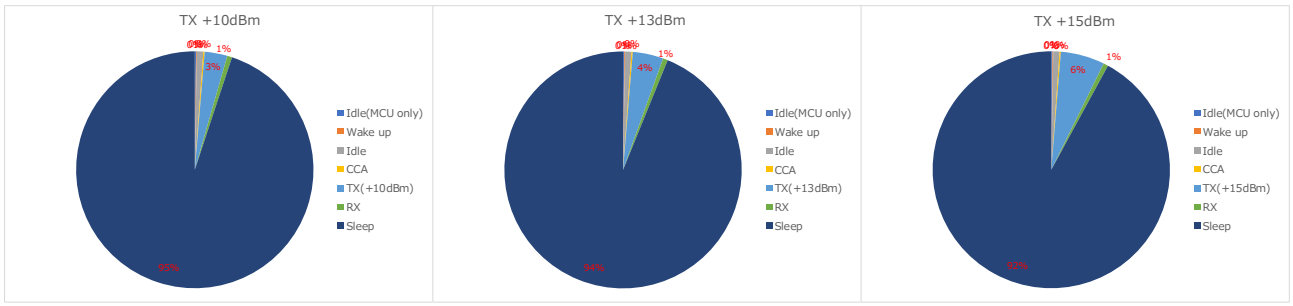

Figure 67. CLK=32MHz, Data Length=20byte, Intermittent operation interval=3600sec

In Figure 68 to 69, when the intermittent operation interval is 300seconds and the TX data length is increased to 200bytes, TX current accounts for more than 60%.

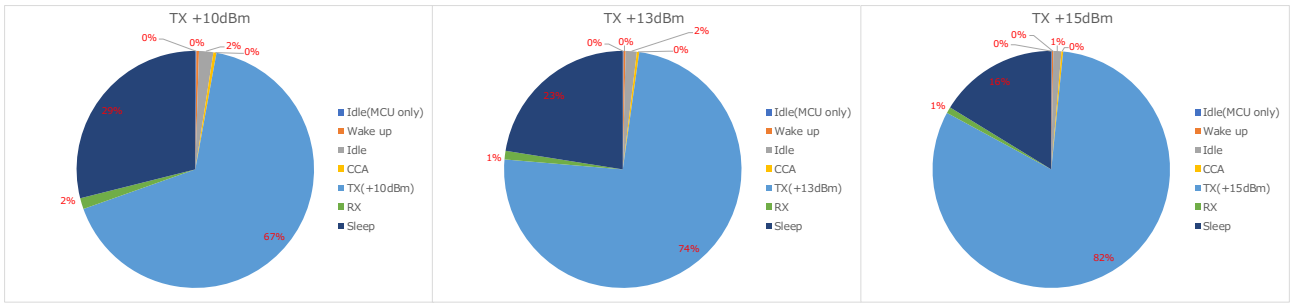

Figure 68. CLK=8MHz, Data Length=200byte, Intermittent operation interval=300sec

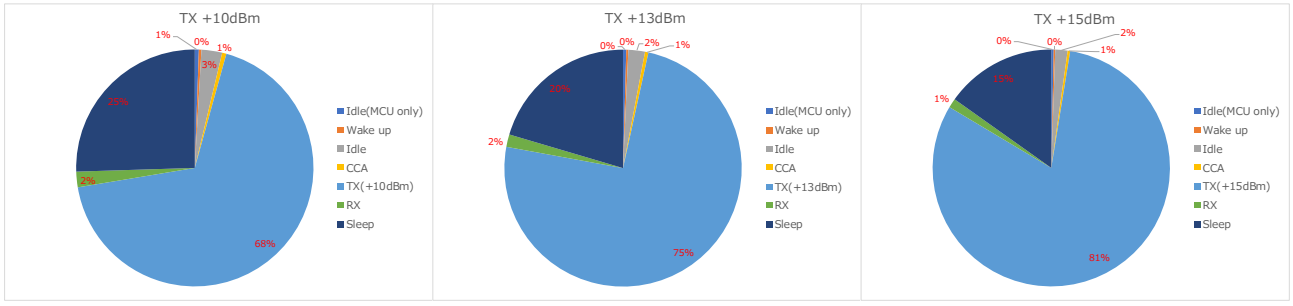

Figure 69. CLK=32MHz, Data Length=200byte, Intermittent operation interval=300sec

In Figure 70 to 71, when the intermittent operation interval is extended to 3600seconds, Sleep current accounts for more than 60% and the TX current also accounts for 10 to 30%.

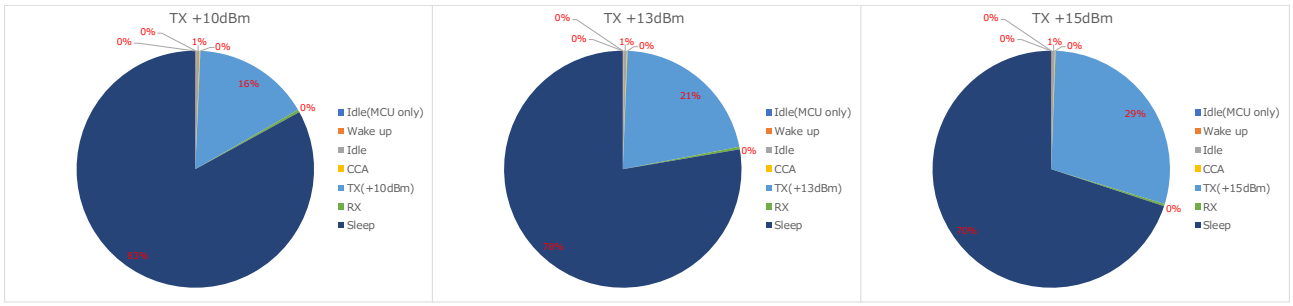

Figure 70. CLK=8MHz, Data Length=200byte, Intermittent operation interval=3600sec

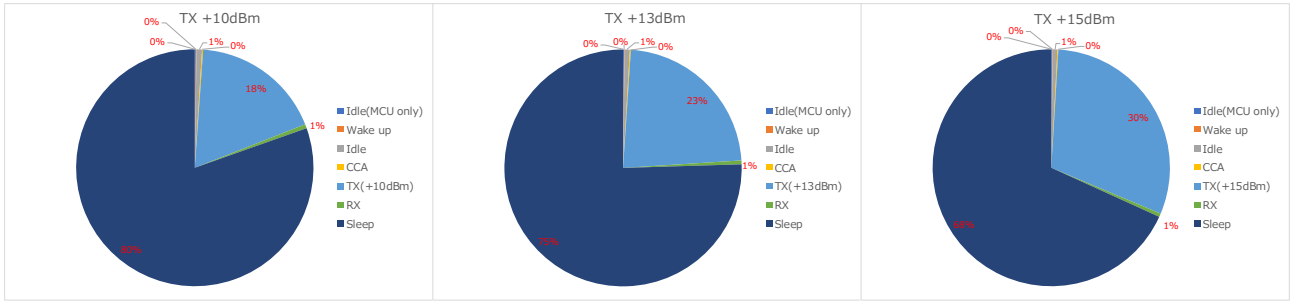

Figure 71. CLK=32MHz, Data Length=200byte, Intermittent operation interval=3600sec

In Figure 72 to 73, when the intermittent operation interval is 3600seconds TX data length is increased to 2000bytes, TX current accounts for more than 60% and Sleep current also accounts for 10 to 35%.

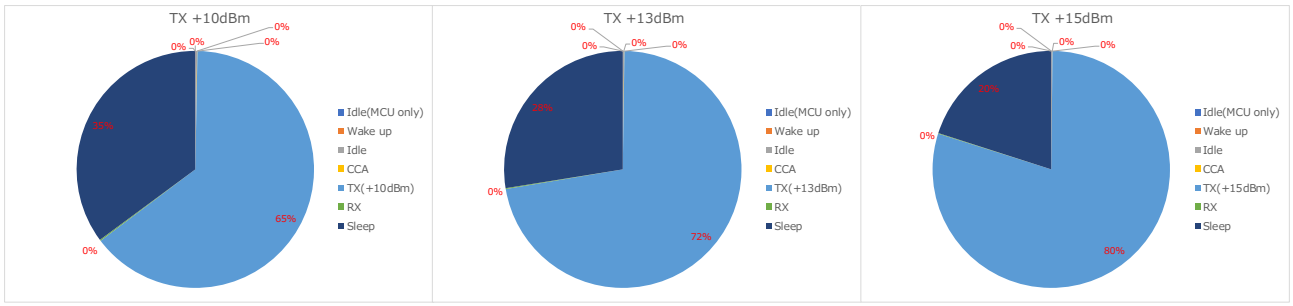

Figure 72. CLK=8MHz, Data Length=2000byte, Intermittent operation interval=3600sec

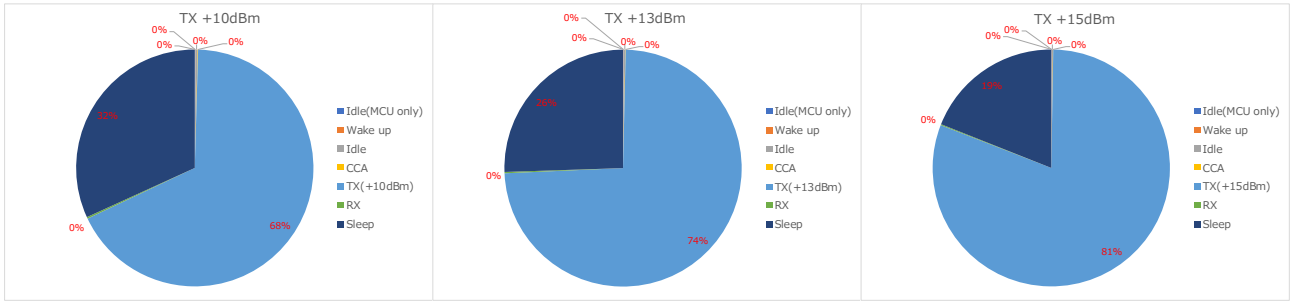

Figure 73. CLK=32MHz, Data Length=2000byte, Intermittent operation interval=3600sec

3.3.2 Percentage of current when receiving conditions are changed

Figures 74 to 75 show percentage of the current in each mode when receiving time and intermittent operation interval are changed from the operating condition in the middle of Figure 62 (MCU CLK=8MHz, TX Power=+13dBm, Data Length=20byte, receiving term=1.289ms).

In Figure 74, when the receiving time is increased by 10times, RX current accounts for almost the same percentage as TX current. When the intermittent operation interval is short (5seconds, etc.), both the RX current and the TX current accounts for more than 40%, when the intermittent operation interval is long (3600seconds, etc.), Sleep current accounts becomes dominant.

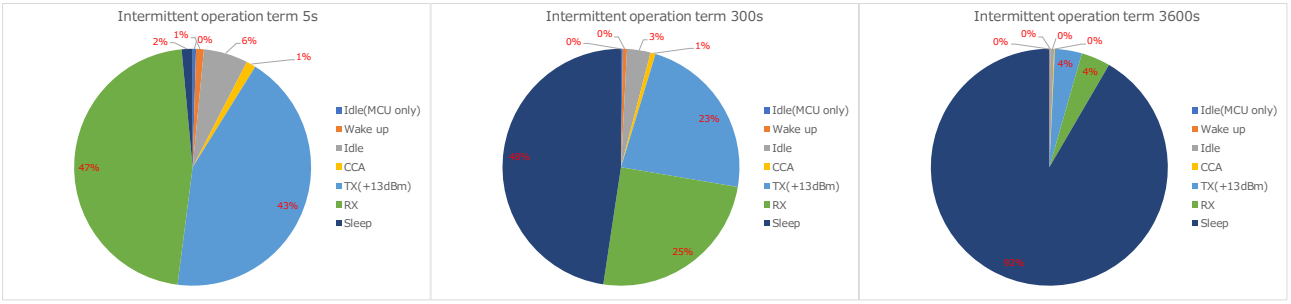

Figure 74. CLK=8MHz, TX Power=+13dBm, Data Length=20byte, RX term:10times (12.89msec)

In Figure 75, when the receiving time is increased by 100times, RX current accounts for a large percentage. When the intermittent operation interval is long, Sleep current accounts for a large percentage.

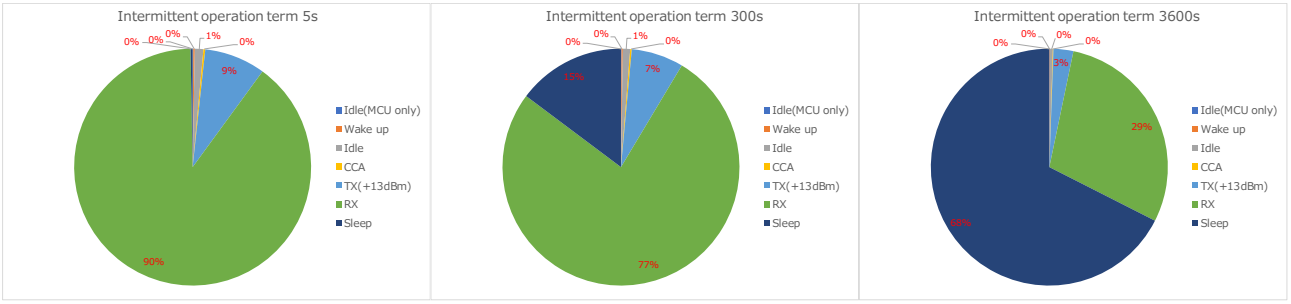

Figure 75. CLK=8MHz, TX Power=+13dBm, Data Length=20byte, RX term:100times (128.9msec)

4. Examples of battery life calculation

This chapter shows examples of battery life for each battery capacity when communication conditions (TX data length, intermittent operation interval, receiving time, etc.) are changed. Selection of battery capacity from communication conditions, or selection of communication conditions from battery capacity can also be used as a guide when customers build systems.

The calculation results shown in this chapter are reference examples for selecting communication conditions does not take into account the aging of the battery itself and does not guarantee the life of G1H over 10 years.

4.1 Battery conditions for ideal batteries

Figure 76 to 79 show ideal battery models. The supply voltage is constant at 3.0V until the total discharge reaches the battery capacity.
The 5000mAh battery is based on the use of two 2500mAh batteries, the 1000mAh battery is based on the use of two 500mAh batteries.

Battery life calculation includes battery self-discharge, which is assumed that 1% of the maximum battery capacity is discharged every year at a fixed value. Table 2 shows battery capacity and self-discharge.

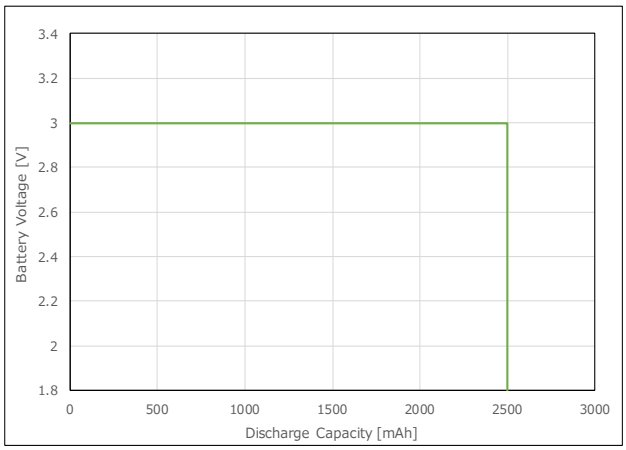

Figure 76. Ideal battery with 2500mAh capacity

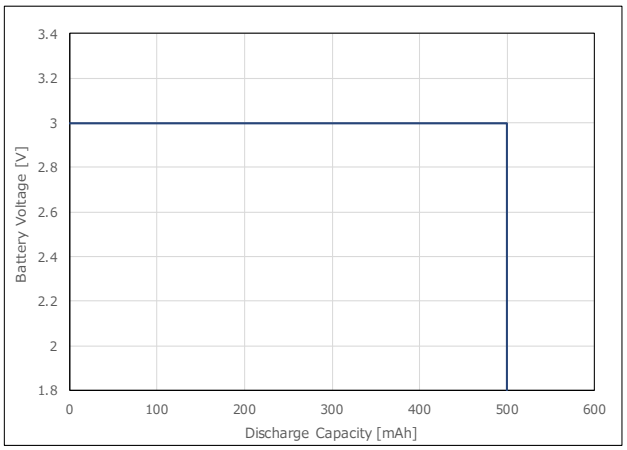

Figure 77. Ideal battery with 500mAh capacity

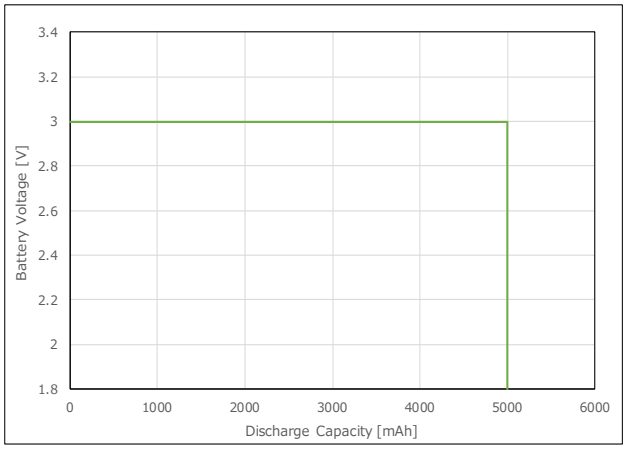

Figure 78. Ideal battery with 5000mAh capacity

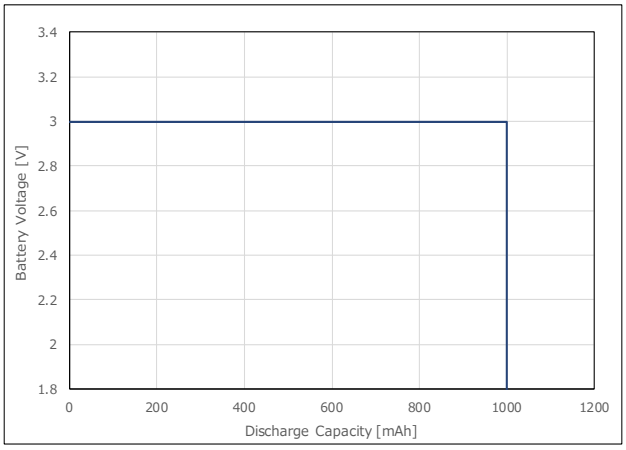

Figure 79. Ideal battery with 1000mAh capacity

Table 2. Battery capacity and self-discharge

	Coin battery		Dry cell	
Quantity	1	2	1	2
Battery capacity [mAh]	500	1000	2500	5000
Self-discharge [mAh]	0.000571	0.001142	0.002854	0.005708

4.2 Example of battery life with ideal battery

4.2.1 Example of battery life when transmission conditions are changed

Table 3 shows examples of battery life with ideal batteries (500/1000/2500/5000mAh) when intermittent operation interval (5/300/3600sec), TX data length, TX power and MCU clock are changed.

Table 3. Example of battery life with ideal batteries when transmission conditions are changed

Battery capacity [mAh]	Operation interval [s]	Data length [Byte]	MCU CLK=8MHz			MCU CLK=32MHz		
			TX Power [dBm]			TX Power [dBm]		
			+10	+13	+15	+10	+13	+15
500	5	20	3y / 0m	2y / 4m	1y / 8m	2y / 3m	1y / 10m	1y / 5m
		200	0y / 6m	0y / 4m	0y / 2m	0y / 5m	0y / 3m	0y / 2m
		2000	0y / 0m	0y / 0m	0y / 0m	0y / 0m	0y / 0m	0y / 0m
	300	20	Over 15y	Over 15y	Over 15y	Over 15y	Over 15y	Over 15y
		200	Over 15y	Over 15y	13y / 4m	Over 15y	Over 15y	12y / 6m
		2000	3y / 11m	2y / 9m	1y / 10m	3y / 4m	2y / 6m	1y / 8m
	3600	20	Over 15y	Over 15y	Over 15y	Over 15y	Over 15y	Over 15y
		200	Over 15y	Over 15y	Over 15y	Over 15y	Over 15y	Over 15y
		2000	Over 15y	Over 15y	Over 15y	Over 15y	Over 15y	Over 15y
1000	5	20	6y / 0m	4y / 7m	3y / 4m	4y / 6m	3y / 9m	2y / 10m
		200	1y / 2m	0y / 10m	0y / 6m	0y / 11m	0y / 8m	0y / 5m
		2000	0y / 0m	0y / 0m	0y / 0m	0y / 0m	0y / 0m	0y / 0m
	300	20	Over 15y	Over 15y	Over 15y	Over 15y	Over 15y	Over 15y
		200	Over 15y	Over 15y	Over 15y	Over 15y	Over 15y	Over 15y
		2000	7y / 10m	5y / 6m	3y / 8m	6y / 6m	4y / 11m	3y / 5m
	3600	20	Over 15y	Over 15y	Over 15y	Over 15y	Over 15y	Over 15y
		200	Over 15y	Over 15y	Over 15y	Over 15y	Over 15y	Over 15y
		2000	Over 15y	Over 15y	Over 15y	Over 15y	Over 15y	Over 15y
2500	5	20	13y / 6m	10y / 10m	8y / 1m	10y / 8m	8y / 11m	6y / 11m
		200	3y / 0m	2y / 2m	1y / 5m	2y / 6m	1y / 11m	1y / 3m
		2000	0y / 3m	0y / 2m	0y / 1m	0y / 2m	0y / 1m	0y / 0m
	300	20	Over 15y	Over 15y	Over 15y	Over 15y	Over 15y	Over 15y
		200	Over 15y	Over 15y	Over 15y	Over 15y	Over 15y	Over 15y
		2000	Over 15y	12y / 8m	8y / 10m	Over 15y	11y / 7m	8y / 3m
	3600	20	Over 15y	Over 15y	Over 15y	Over 15y	Over 15y	Over 15y
		200	Over 15y	Over 15y	Over 15y	Over 15y	Over 15y	Over 15y
		2000	Over 15y	Over 15y	Over 15y	Over 15y	Over 15y	Over 15y
5000	5	20	Over 15y	Over 15y	Over 15y	Over 15y	Over 15y	13y / 0m
		200	6y / 0m	4y / 4m	2y / 11m	5y / 1m	3y / 10m	2y / 8m
		2000	0y / 7m	0y / 5m	0y / 3m	0y / 6m	0y / 4m	0y / 2m
	300	20	Over 15y	Over 15y	Over 15y	Over 15y	Over 15y	Over 15y
		200	Over 15y	Over 15y	Over 15y	Over 15y	Over 15y	Over 15y
		2000	Over 15y	Over 15y	Over 15y	Over 15y	Over 15y	Over 15y
	3600	20	Over 15y	Over 15y	Over 15y	Over 15y	Over 15y	Over 15y
		200	Over 15y	Over 15y	Over 15y	Over 15y	Over 15y	Over 15y
		2000	Over 15y	Over 15y	Over 15y	Over 15y	Over 15y	Over 15y

*1 UNIT y / m: years / month, *2 Over 15y: more than 15 years

Figure 80 to 91 show examples of battery life for intermittent operation interval when the TX power, TX data length and battery capacity are changed.

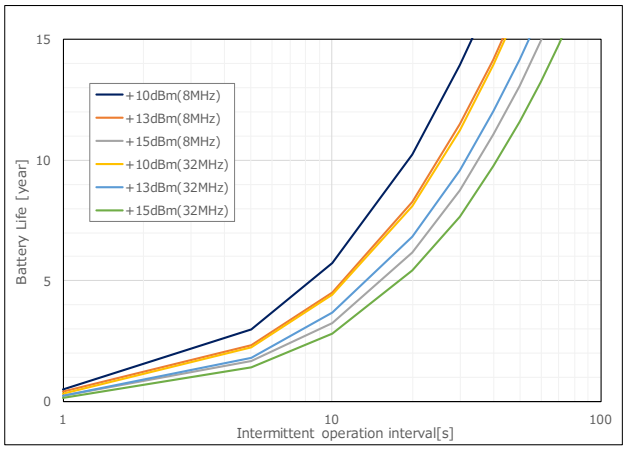

Figure 80. Battery capacity=500mAh
Data length=20byte

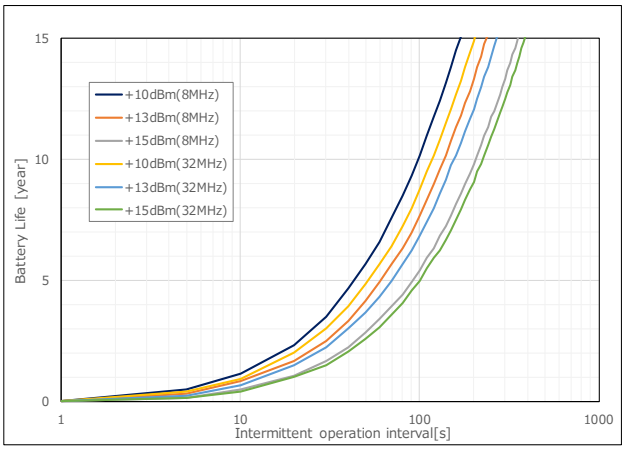

Figure 81. Battery capacity=500mAh
Data length=200byte

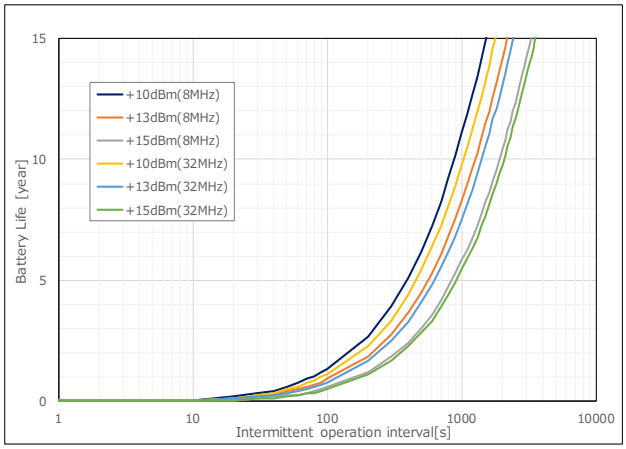

Figure 82. Battery capacity=500mAh
Data length=2000byte

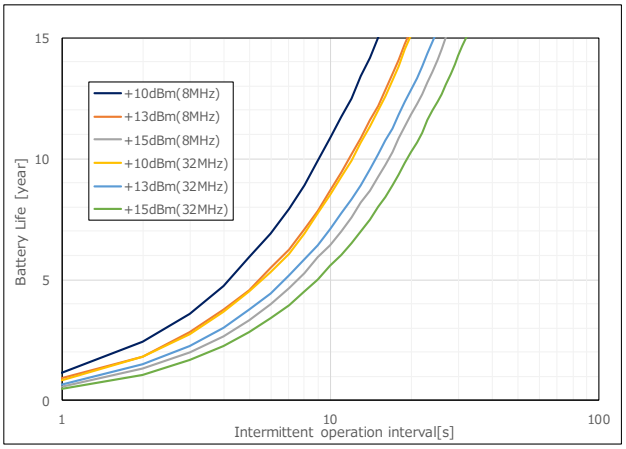

Figure 83. Battery capacity=1000mAh
Data length=20byte

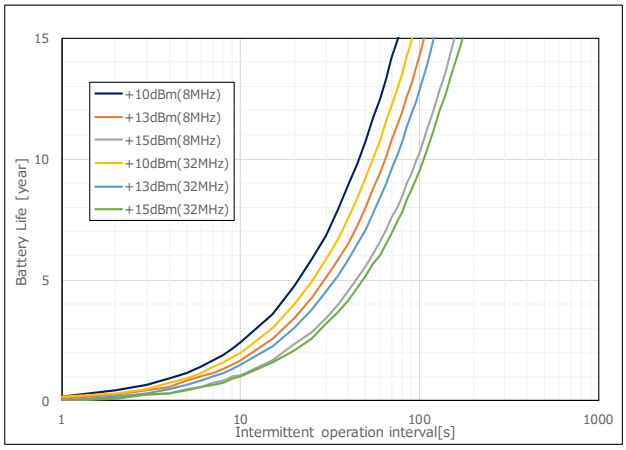

Figure 84. Battery capacity=1000mAh
Data length=200byte

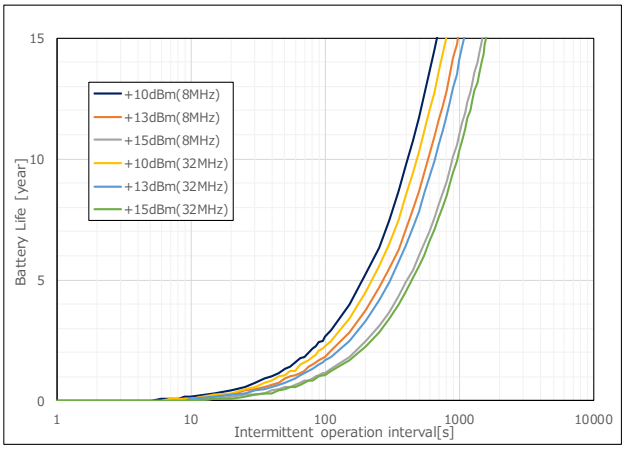

Figure 85. Battery capacity=1000mAh
Data length=2000byte

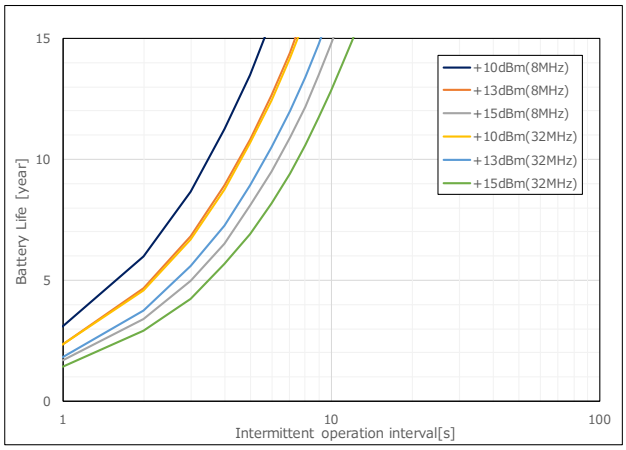

Figure 86. Battery capacity=2500mAh
Data length=20byte

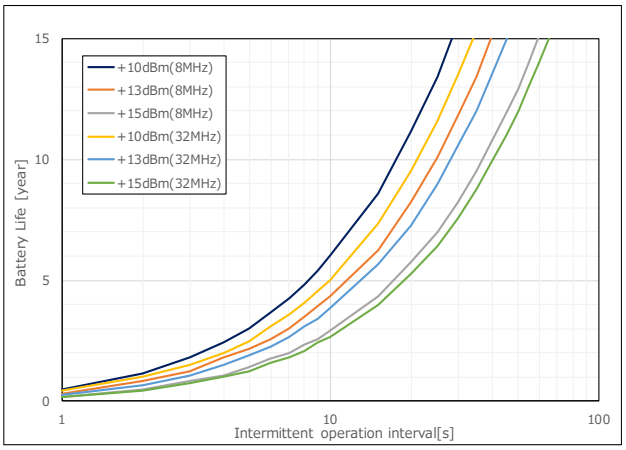

Figure 87. Battery capacity=2500mAh
Data length=200byte

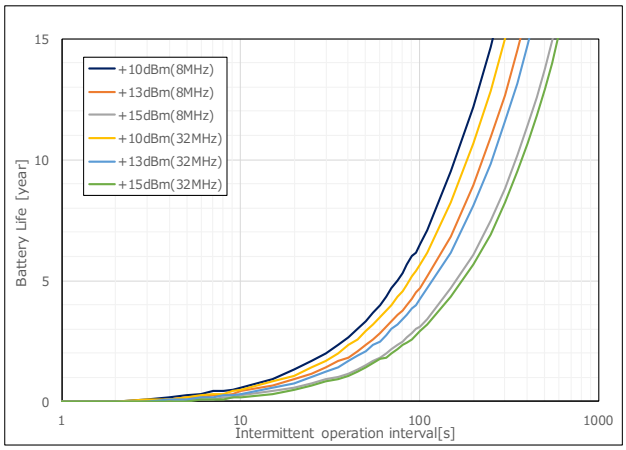

Figure 88. Battery capacity=2500mAh
Data length=2000byte

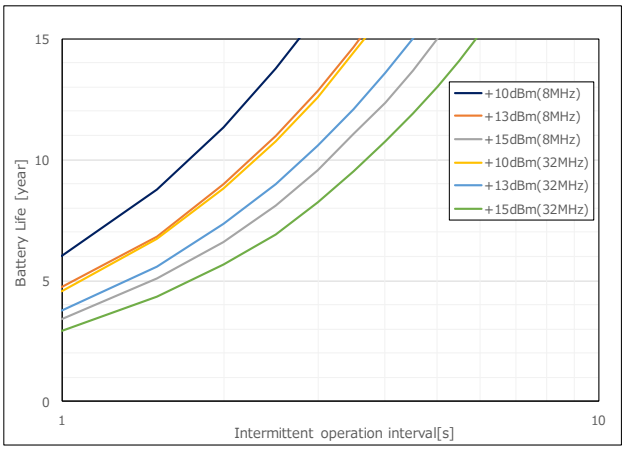

Figure 89. Battery capacity=5000mAh
Data length=20byte

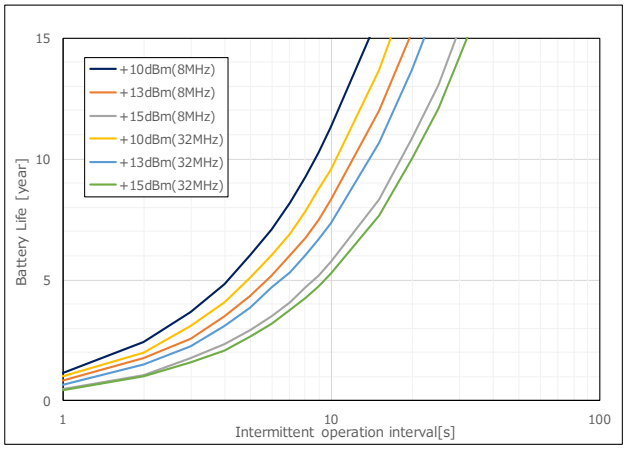

Figure 90. Battery capacity=5000mAh
Data length=200byte

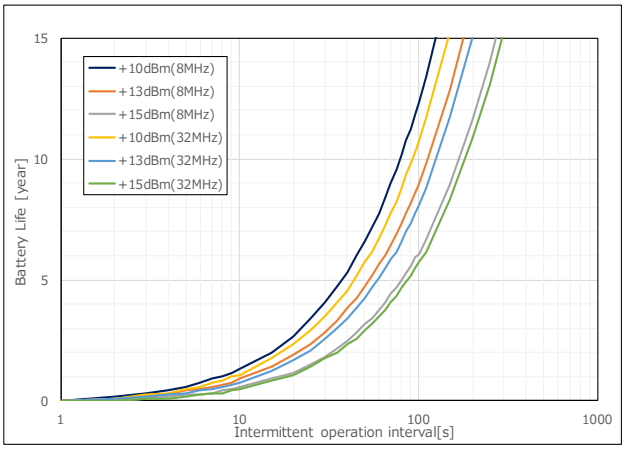

Figure 91. Battery capacity=5000mAh
Data length=2000byte

4.2.2 Example of battery life when receiving conditions are changed (MCU CLK=8MHz)

Table 4 shows examples of battery life with ideal batteries when RX term is changed to 10times (12.89ms) and 100times (128.9ms).

Table 4. Example of battery life with ideal batteries when receiving conditions are changed

Battery capacity [mAh]	Operation interval [s]	MCU CLK=8MHz, TX Power=+13dBm, Data length=20byte		
		RX term:1time	RX term:10times	RX term:100times
500	5	2y / 4m	1y / 4m	0y / 2m
	300	Over 15y	Over 15y	12y / 3m
	3600	Over 15y	Over 15y	Over 15y
1000	5	4y / 7m	2y / 8m	0y / 5m
	300	Over 15y	Over 15y	Over 15y
	3600	Over 15y	Over 15y	Over 15y
2500	5	10y / 10m	6y / 7m	1y / 3m
	300	Over 15y	Over 15y	Over 15y
	3600	Over 15y	Over 15y	Over 15y
5000	5	Over 15y	12y / 4m	2y / 7m
	300	Over 15y	Over 15y	Over 15y
	3600	Over 15y	Over 15y	Over 15y

*1 UNIT y / m: years / month, *2 Over 15y: more than 15 years

Figure 92 to 95 show examples of battery life for intermittent operation interval when RX term and battery capacity are changed.

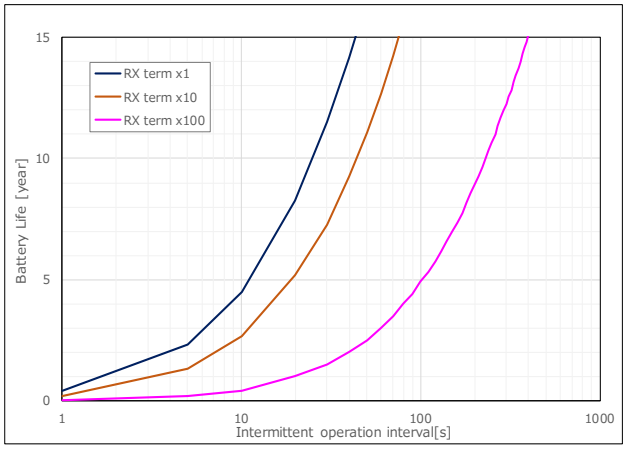

Figure 92. Battery Capacity=500mAh

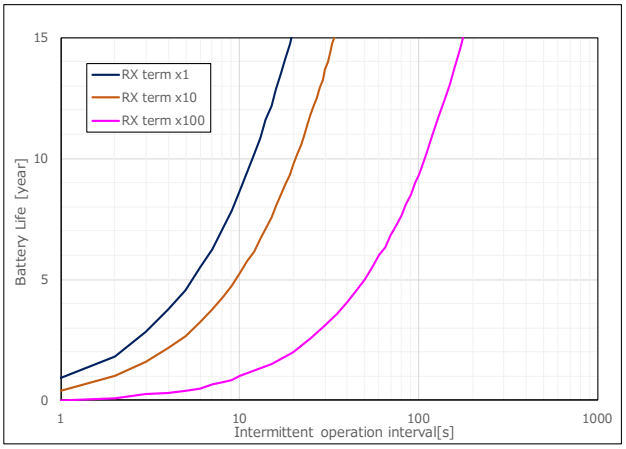

Figure 93. Battery Capacity=1000mAh

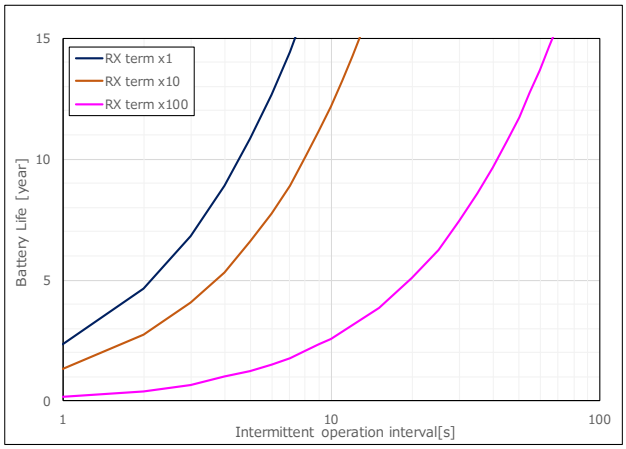

Figure 94. Battery Capacity=2500mAh

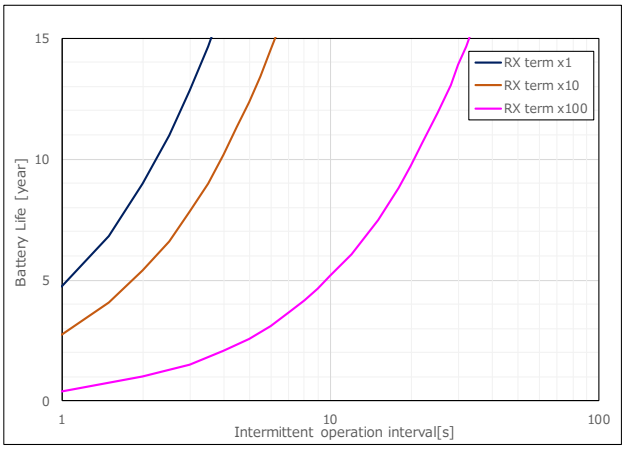

Figure 95. Battery Capacity=5000mAh

4.3 Example of battery life with a battery model considering voltage drop

This section shows examples of calculating the battery life with a battery model considering voltage drop. A battery model shown here is only an example. The actual voltage drop characteristics will vary under various conditions such as battery specifications, temperature, average current, and aging.

4.3.1 Example of battery life considering voltage drop.

Figure 96 shows an example of a battery model with battery capacity of 2500mAh considering voltage drop. It is assumed that the voltage drop starts when the discharge capacity exceeds 1900mAh, and the voltage drops to 1.8V when the discharge amount is 2500mAh. When G1H is operated, the battery life ends when the discharge capacity reaches 2500mAh or when the battery voltage reaches the lower limit of the operating voltage of G1H.

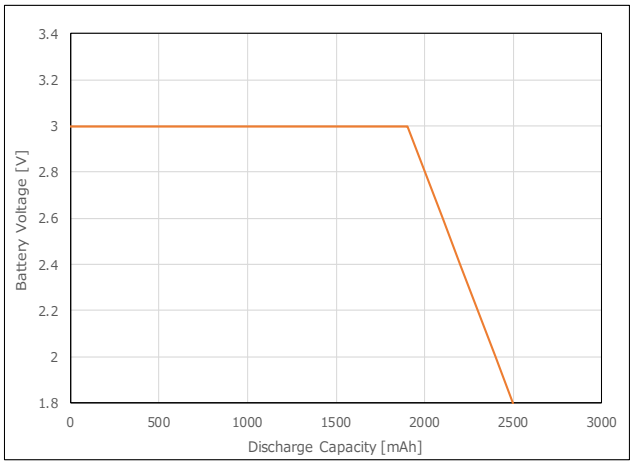

Figure 96. Battery model example with voltage drop

Table 5 and Figure 97 to 98 show the battery life with the battery model considering the voltage drop and the ideal battery. They are examples of the battery life when the intermittent operation interval is 300seconds, the TX data length is 2000bytes, and the battery capacity is 2500mAh. The difference between the two models is about 3-20%, the battery life considering the voltage drop is shorter than that of the ideal battery model.
This is because that the maximum discharge capacity cannot be used up in the battery model considering the voltage drop. For example, when the operating voltage lower limit is 1.8V (MCU CLK=8MHz / TX Power=10dBm and 13dBm), the difference from the ideal battery is small, and when it is 2.4V (MCU CLK=8MHz / TX Power=15dBm) or 2.7V (MCU CLK=32MHz), the difference becomes large.

Table 5. Example of battery life calculation result

	MCU CLK=8MHz			MCU CLK=32MHz		
	TX Power [dBm]			TX Power [dBm]		
	+10	+13	+15	+10	+13	+15
Battery considering voltage drop (Figure 96)	Over 15y	12y / 3m	7y / 8m	12y / 4m	9y / 6m	6y / 9m
Ideal battery	Over 15y	12y / 8m	8y / 10m	Over 15y	11y / 7m	8y / 3m

*1 UNIT y / m: years / month

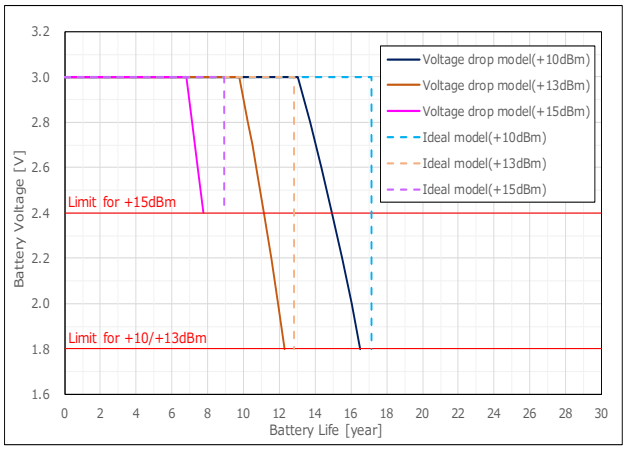

Figure 97. Example of battery life considering voltage drop (8MHz)

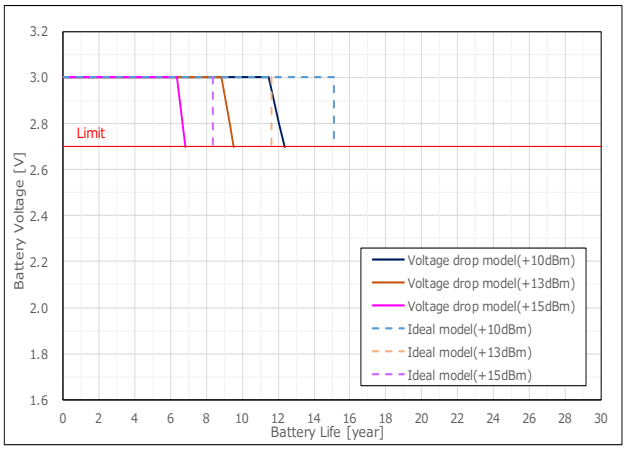

Figure 98. Example of battery life considering voltage drop (32MHz)

4.3.2 Example of battery life using ideal battery with modified capacity

In the preceding paragraph, it was stated that the battery life is shorter with the battery model considering the voltage drop than that with the ideal battery model because the maximum discharge capacity of the battery cannot be used up.
This section shows an example of battery life calculation using an ideal battery model with the maximum discharge capacity modified.
Figure 99 shows an example of the ideal battery model with a modified capacity. Table 6 shows the battery capacity values before and after the correction.
For MCU CLK=8MHz / TX Power=15dBm, the minimum operating voltage is 2.4V. Applying this to the battery model shown in Figure 96, it can be seen that up to 2200mAh of the 2500mAh battery capacity can be used effectively. The “ideal battery with modified capacity” is a simplified version of this and is regarded as battery with constant terminal voltage of 3V and capacity of 2200mAh.
However, they include the self-discharge current of the battery, there is no change to discharge 1% of the 2500mAh capacity at a fixed value every year, which is the same as the battery model considering the voltage drop.

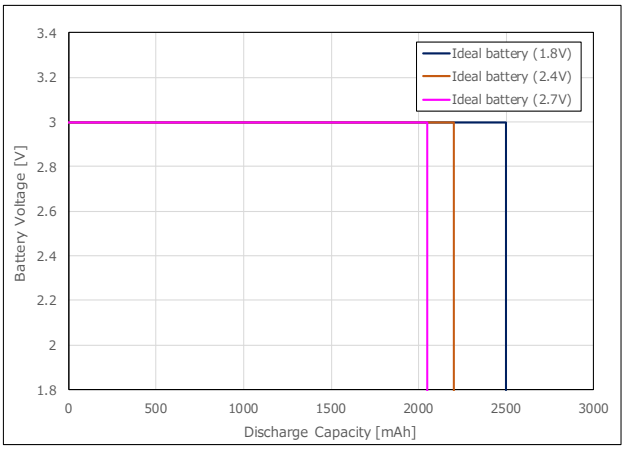

Figure 99. Ideal battery with modified capacity

Table 6. Battery capacity value before and after correction

	G1H Operating voltage lower limit [V]	Ideal model (before correction) [mAh]	Ideal model with modified capacity [mAh]
MCU CLK=8MHz, TX Power=+10/+13dBm	1.8	2500	2500
MCU CLK=8MHz, TX Power=+15dBm	2.4	2500	2200
MCU CLK=32MHz	2.7	2500	2050

Table 7 and Figure 100 to 101 show the results of calculating the battery life using an ideal battery with modified capacity and a battery considering voltage drop. Even with such a simplified battery model, the battery life is close to that of the battery model considering voltage drop.

Table 7. Example of battery life calculation result

	MCU CLK=8MHz			MCU CLK=32MHz		
	TX Power [dBm]			TX Power [dBm]		
	+10	+13	+15	+10	+13	+15
Battery considering voltage drop (Figure 96)	Over 15y	12y / 3m	7y / 8m	12y / 4m	9y / 6m	6y / 9m
Ideal battery with modified capacity (Figure 99)	Over 15y	12y / 8m	7y / 9m	12y / 3m	9y / 6m	6y / 9m

*1 UNIT y / m: years / month, *2 Over 15y: more than 15 years

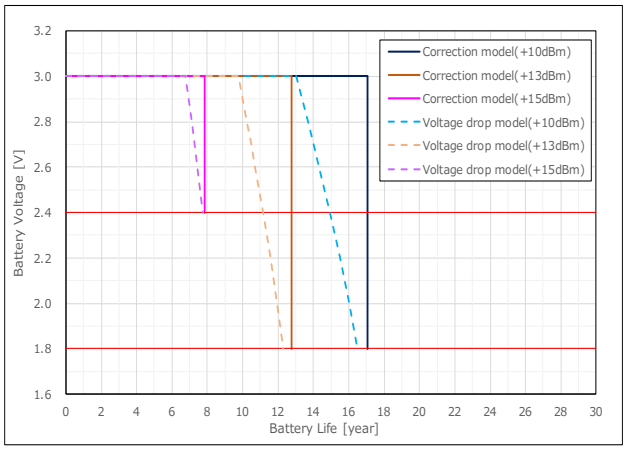

Figure 100. Example of battery life using ideal battery with modified capacity (8MHz)

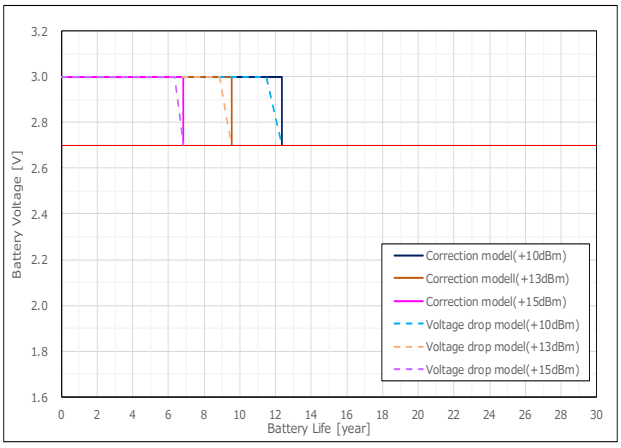

Figure 101. Example of battery life using ideal battery with modified capacity (32MHz)

Revision History

Rev.	Date	Description	
		Page	Summary
1.00	Apr 6, 2020	-	First edition issued

General Precautions in the Handling of Microprocessing Unit and Microcontroller Unit Products

The following usage notes are applicable to all Microprocessing unit and Microcontroller unit products from Renesas. For detailed usage notes on the products covered by this document, refer to the relevant sections of the document as well as any technical updates that have been issued for the products.

1. Precaution against Electrostatic Discharge (ESD)

   A strong electrical field, when exposed to a CMOS device, can cause destruction of the gate oxide and ultimately degrade the device operation. Steps must be taken to stop the generation of static electricity as much as possible, and quickly dissipate it when it occurs. Environmental control must be adequate. When it is dry, a humidifier should be used. This is recommended to avoid using insulators that can easily build up static electricity. Semiconductor devices must be stored and transported in an anti-static container, static shielding bag or conductive material. All test and measurement tools including work benches and floors must be grounded. The operator must also be grounded using a wrist strap. Semiconductor devices must not be touched with bare hands. Similar precautions must be taken for printed circuit boards with mounted semiconductor devices.
2. Processing at power-on

   The state of the product is undefined at the time when power is supplied. The states of internal circuits in the LSI are indeterminate and the states of register settings and pins are undefined at the time when power is supplied. In a finished product where the reset signal is applied to the external reset pin, the states of pins are not guaranteed from the time when power is supplied until the reset process is completed. In a similar way, the states of pins in a product that is reset by an on-chip power-on reset function are not guaranteed from the time when power is supplied until the power reaches the level at which resetting is specified.
3. Input of signal during power-off state

   Do not input signals or an I/O pull-up power supply while the device is powered off. The current injection that results from input of such a signal or I/O pull-up power supply may cause malfunction and the abnormal current that passes in the device at this time may cause degradation of internal elements. Follow the guideline for input signal during power-off state as described in your product documentation.
4. Handling of unused pins

   Handle unused pins in accordance with the directions given under handling of unused pins in the manual. The input pins of CMOS products are generally in the high-impedance state. In operation with an unused pin in the open-circuit state, extra electromagnetic noise is induced in the vicinity of the LSI, an associated shoot-through current flows internally, and malfunctions occur due to the false recognition of the pin state as an input signal become possible.
5. Clock signals

   After applying a reset, only release the reset line after the operating clock signal becomes stable. When switching the clock signal during program execution, wait until the target clock signal is stabilized. When the clock signal is generated with an external resonator or from an external oscillator during a reset, ensure that the reset line is only released after full stabilization of the clock signal. Additionally, when switching to a clock signal produced with an external resonator or by an external oscillator while program execution is in progress, wait until the target clock signal is stable.
6. Voltage application waveform at input pin

   Waveform distortion due to input noise or a reflected wave may cause malfunction. If the input of the CMOS device stays in the area between V_{IL} (Max.) and V_{IH} (Min.) due to noise, for example, the device may malfunction. Take care to prevent chattering noise from entering the device when the input level is fixed, and also in the transition period when the input level passes through the area between V_{IL} (Max.) and V_{IH} (Min.).
7. Prohibition of access to reserved addresses

   Access to reserved addresses is prohibited. The reserved addresses are provided for possible future expansion of functions. Do not access these addresses as the correct operation of the LSI is not guaranteed.
8. Differences between products

   Before changing from one product to another, for example to a product with a different part number, confirm that the change will not lead to problems. The characteristics of a microprocessing unit or microcontroller unit products in the same group but having a different part number might differ in terms of internal memory capacity, layout pattern, and other factors, which can affect the ranges of electrical characteristics, such as characteristic values, operating margins, immunity to noise, and amount of radiated noise. When changing to a product with a different part number, implement a system-evaluation test for the given product.

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