

RTK0EE0017D11004BJ

Electrical Characteristics of 915-MHz-Band RF Transceiver (FCC Part 15.247)

Introduction

This document shows the electrical characteristics measurement results in the 915 MHz band with the RF transceiver (R9A06G062GNP+Front-end module+RX65N).

The front-end module (FEM) consists of Switch (SW), Power amplifier (PA) and Low noise amplifier (LNA).

The target regulation is “FCC Part 15.247” and the frequency band is 902MHz to 928MHz.

The evaluation board (RTK0EE0017D11004BJ) used in this document is mounted with circuit constants that comply with FCC standards. For details, please refer to the Example of Peripheral Circuit and BOM List at the end of this document.

Note: The contents of this document are provided as an example for reference and do not guarantee the signal quality 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.

Target Device

R9A06G062GNP

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1. Evaluation condition

1.1 System configuration

Figure 1 shows the system configuration using a Sub-GHz RF LSI (R9A06G062GNP) and a front-end module. Table 1 shows the common evaluation conditions. The evaluation described in this document will be performed using a front-end module.

SAW filters are compliant with FCC standards (902-928MHz band) and are used in both transmit and receive lines.

The firmware installed on the MCU is 'rdrv_eva_R9A06G062_RX65N_FCC_V104_02976.mot'.

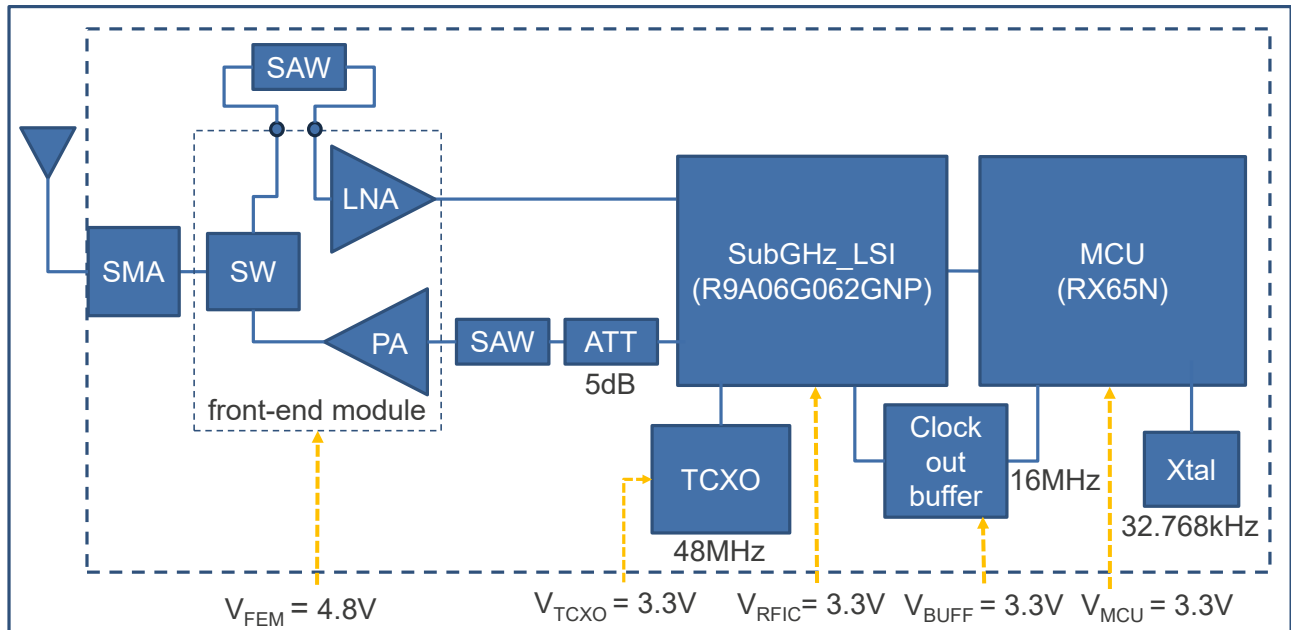


Figure 1 System configuration

1.2 Temperature and supply voltage conditions

Table 1 shows the temperature and voltage settings for each part during evaluation.

Table 1 Temperature and supply voltage conditions

Item	Conditions
Temperature	25deg C
MCU Main clock	96MHz
V_{FEM}	Voltage supplied to FEM
V_{TCXO}	Voltage supplied to TCXO
V_{RFIC}	Voltage supplied to R9A06G062GNP
V_{BUFF}	Voltage supplied to Clock out buffer IC
V_{MCU}	Voltage supplied to MCU

2. Electrical Characteristics

2.1 Current Characteristics

2.1.1 FSK (50kbps, modulation index = 1)

Table 2 shows the current value in each mode for each power supply.

Table 2 Current Characteristics

Item		RF Frequency [MHz]	TX Power [dBm]	Unit	Evaluation results
TX Mode	V _{RFIC}	915.0	+30	mA	28.2
	V _{FEM}			mA	660.4
	V _{MCU}			mA	20.2
RX Mode	V _{RFIC}	915.0	-	mA	16.6
	V _{FEM}			mA	6.6
	V _{MCU}			mA	20.5
Idle Mode	V _{RFIC}	915.0	-	mA	5.6
	V _{FEM}			uA	6.6
	V _{MCU}			mA	19.9

2.1.2 OFDM (Option1, MCS6)

Table 3 shows the current value in each mode for each power supply.

Table 3 Current Characteristics

Item		RF Frequency [MHz]	TX Power [dBm]	Unit	Evaluation results
TX Mode	V _{RFIC}	915.2	+23	mA	40.8
	V _{FEM}			mA	272.5
	V _{MCU}			mA	20.3
RX Mode	V _{RFIC}	915.2	-	mA	22.7
	V _{FEM}			mA	6.6
	V _{MCU}			mA	20.5
Idle Mode	V _{RFIC}	915.2	-	mA	5.6
	V _{FEM}			uA	6.6
	V _{MCU}			mA	19.9

2.2 TX Electrical Characteristics

2.2.1 FSK (50kbps, modulation index = 1)

(1) TX Power sweep characteristics

Signal condition: Frequency = 915MHz

Table 4 TX Power sweep characteristics

Items		Unit	Evaluation results
TX Power Range	Max	dBm	31.7
	Min		10.2
	Variable power range	dB	21.5
Current Range	V _{FEM}	Max	814.7
		Min	90.0
	V _{RFIC}	Max	73.8
		Min	13.8

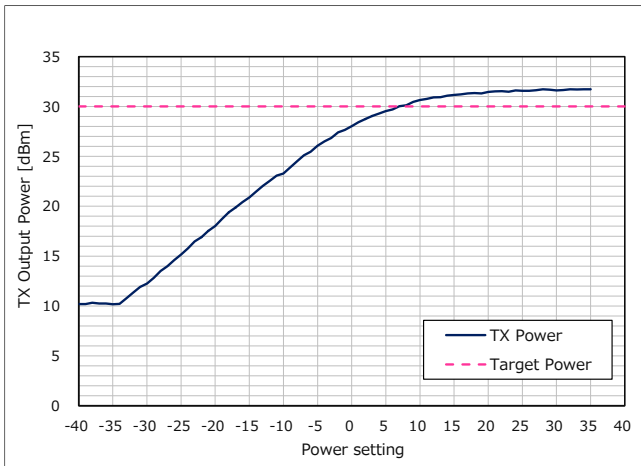


Figure 2 Power Setting vs. TX Power (Frequency = 915MHz)

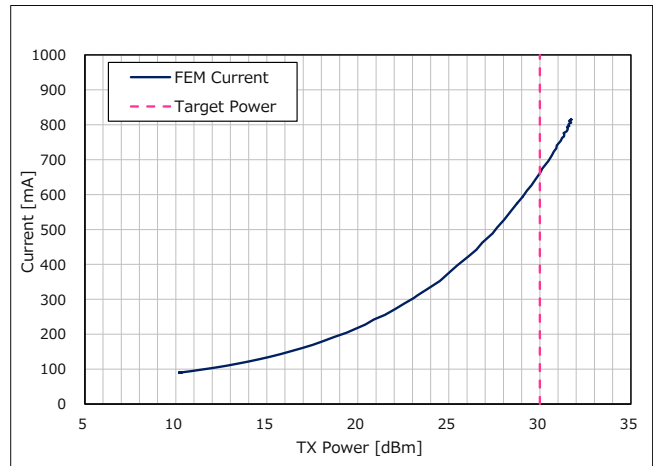


Figure 3 TX Power vs. Current of V_{FEM} for TX mode (Frequency = 915MHz)

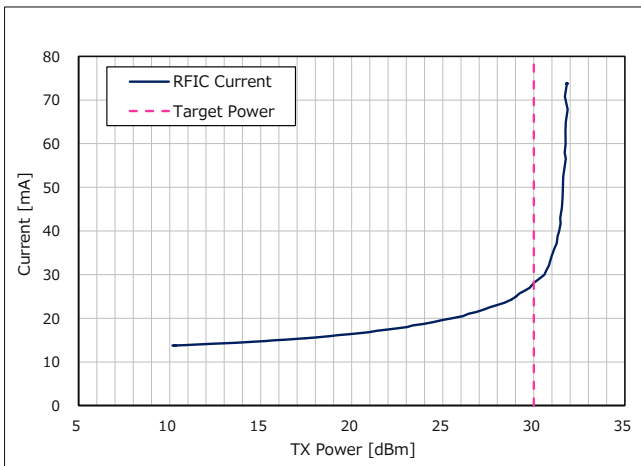


Figure 4 TX Power vs. Current of V_{RFIC} for TX mode (Frequency = 915MHz)

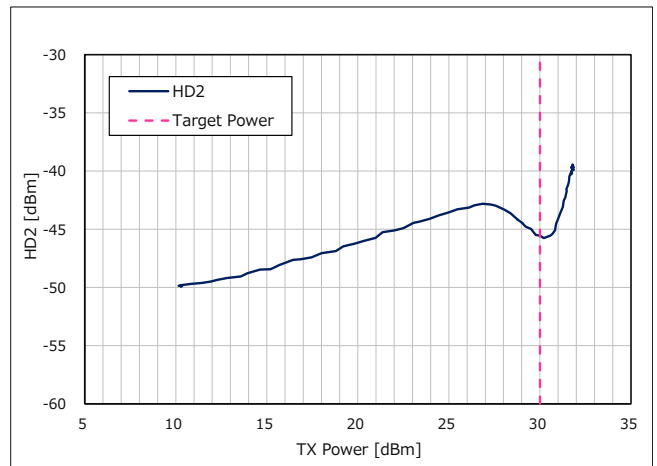


Figure 5 TX Power vs. 2nd Harmonics (Frequency = 915MHz)

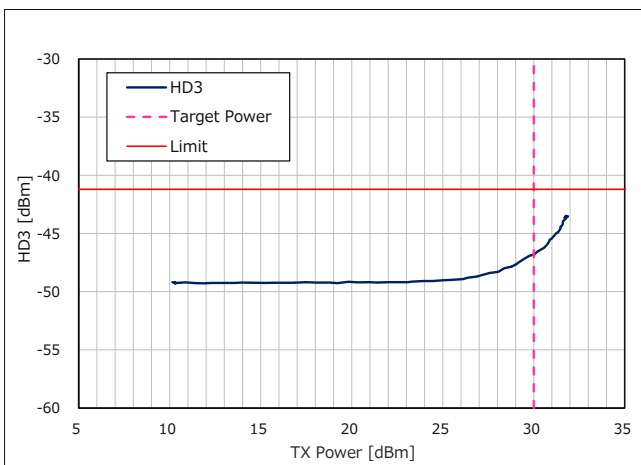


Figure 6 TX Power vs. 3rd Harmonics (Frequency = 915MHz)

(2) TX Radio Regulations characteristics

Signal condition: Target TX Power = +30dBm

Table 5 TX Radio Regulations characteristics (1/2)

Items		RF Frequency [MHz]	Unit	Evaluation results	Spec
TX Power		902.2	dBm	29.8	+30.0 (*1)
		915.0		30.0	
		927.8		29.5	
Harmonics	2nd	902.2	dBm /MHz	-48.0	-
		915.0		-45.7	
		927.8		-44.5	
	3rd	902.2		-46.3	-41.2 (*1)
		915.0		-46.7	
		927.8		-47.0	
Occupied Bandwidth		902.2	kHz	85.7	-
		915.0		86.1	
		927.8		85.4	
6dB Bandwidth (*2)		902.2	kHz	53.5	< 500
		915.0		53.7	
		927.8		53.7	
20dB Bandwidth (*2)		902.2	kHz	93.2	< 250
		915.0		94.8	
		927.8		90.6	
Adjacent Channel Power Ratio (M1_Lower, 150 kHz offset) (*3)		902.2	dBc	-57.3	-25 (*5)
		915.0		-57.3	
		927.8		-56.7	
Adjacent Channel Power Ratio (M1_Upper, 150 kHz offset) (*3)		902.2	dBc	-57.1	-25 (*5)
		915.0		-57.0	
		927.8		-56.6	
Adjacent Channel Power Ratio (M2_Lower, 300 kHz offset) (*3)		902.2	dBc	-64.0	-35 (*5)
		915.0		-63.6	
		927.8		-62.8	
Adjacent Channel Power Ratio (M2_Upper, 300 kHz offset) (*3)		902.2	dBc	-63.7	-35 (*5)
		915.0		-63.6	
		927.8		-63.2	
Deviation Offset		902.2	% rms	3.8	30 (*4)
		915.0		3.8	
		927.8		3.8	
Zero Crossing Error		902.2	% pk	-1.2	±12.5 (*4)
		915.0		1.0	
		927.8		-1.1	
Frequency tolerance (*6)		915.0	ppm	0.9	±20 (*4)

(*1) FCC 47 CFR Part15, Subpart C, Section 15.247

(*2) Since 6dB Bandwidth is less than 500kHz, Digital modulation system is not applied.

Since 20dB Bandwidth is less than 250kHz, Frequency hopping system is applied.

(*3) IEEE.802.15.4-2020

M1: $1.5 \cdot R \cdot (h+1)$, M2: $3 \cdot R \cdot (h+1)$, R (symbol rate): 50kbps, h (modulation index): 1

(*4) Wi-SUN PHY Technical Specification - Amendment 1VA9 (11 Nov 2022). (*5) IEEE.802.15.4-2020

(*6) This characteristic depends on TCXO.

Table 6 TX Radio Regulations characteristics (2/2)

Items		RF Frequency [MHz]	Unit	Evaluation results	Spec
Unwanted emissions	30 - 88MHz	902.2	dBm /100kHz	-62.7	-55.2 (*1)
		915.0		-63.5	
		927.8		-64.1	
	88 - 216MHz	902.2	dBm /100kHz	-59.1	-51.7 (*1)
		915.0		-60.5	
		927.8		-59.7	
	216 - 614MHz	902.2	dBm /100kHz	-57.7	-49.2 (*1)
		915.0		-58.8	
		927.8		-59.2	
	960 - 1722.2MHz	902.2	dBm /MHz	-48.2	-41.2 (*1)
		915.0		-48.6	
		927.8		-47.8	
	2200 - 5460MHz	902.2	dBm /MHz	-46.3	-41.2 (*1)
		915.0		-46.7	
		927.8		-47.0	
	7250 - 9200MHz	902.2	dBm /MHz	-52.0	-41.2 (*1)
		915.0		-52.1	
		927.8		-51.6	
Tx out of band emission (Band edge)	Lower 870 - 902MHz	902.2	dBc	-47.5	-20 (*2)
		915.0		-79.0	
		927.8		-78.0	
	Upper 928 - 960MHz	902.2	dBc	-78.5	-20 (*2)
		915.0		-77.3	
		927.8		-47.6	

(*1) In the FCC standard, spurious emissions are specified by electric field intensity (V / m). Since this document is the result of the wired condition, the value converted to the power value (dBm) is used.

Power (dBm)@3m = $10 \cdot \log(300E^2)$, E = electric field intensity (V / m)

(*2) FCC 47 CFR Part15, Subpart C, Section 15.247

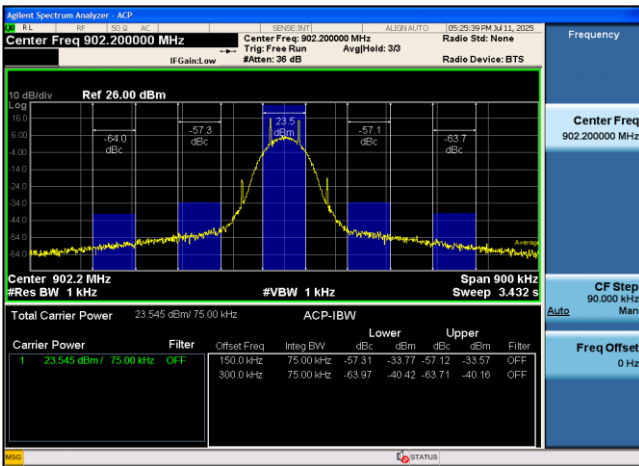


Figure 7 Transmit Spectrum (Frequency = 902.2MHz)

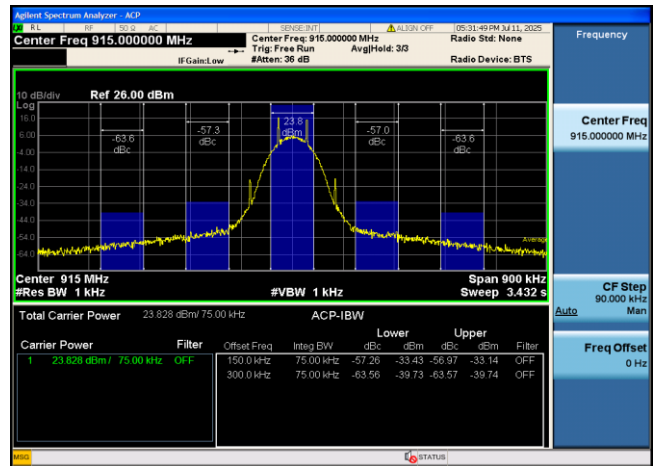


Figure 8 Transmit Spectrum (Frequency = 915.0MHz)

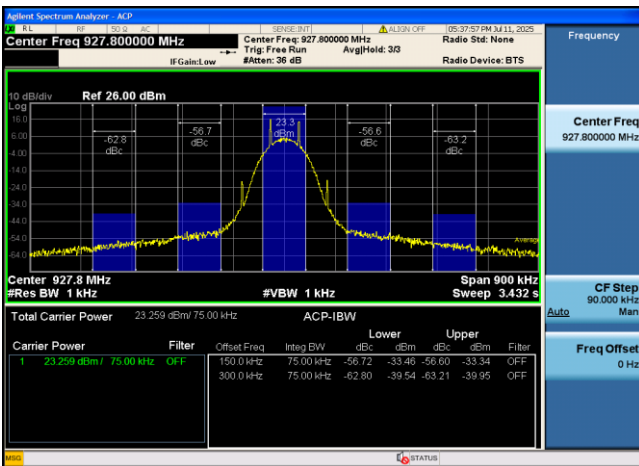


Figure 9 Transmit Spectrum (Frequency = 927.8MHz)

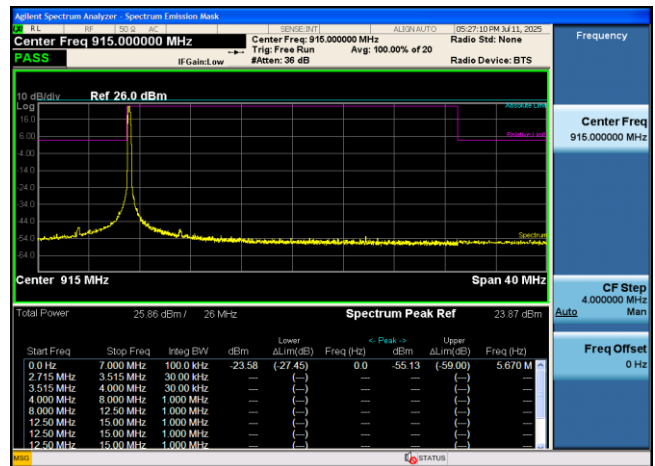


Figure 10 TX Out of Band Emissions for Operational Frequency Band (Frequency = 902.2MHz)

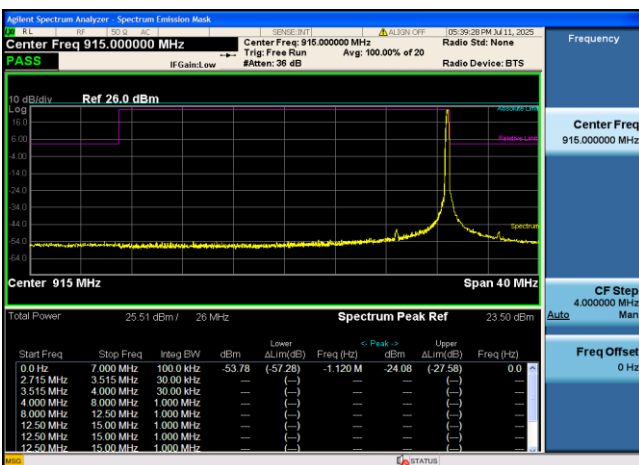


Figure 11 TX Out of Band Emissions for Operational Frequency Band (Frequency = 927.8MHz)

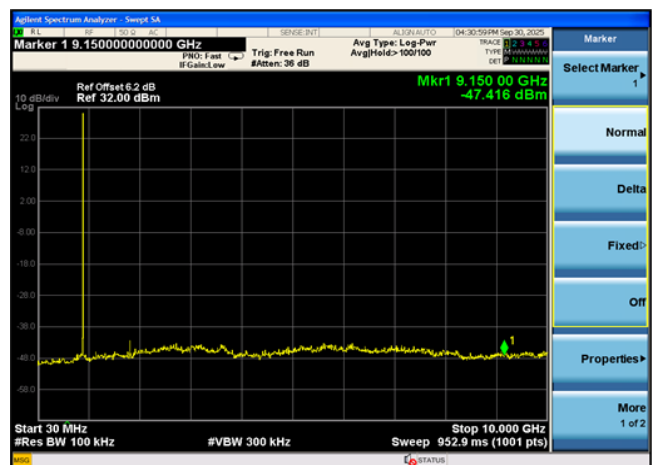


Figure 12 TX Spurious emission (Frequency = 915.0MHz)

2.2.2 FSK (150kbps, modulation index = 0.5)

(1) TX Power sweep characteristics

Signal condition: Frequency = 915.2MHz

Table 7 TX Power sweep characteristics

Items		Unit	Evaluation results
TX Power Range	Max	dBm	31.7
	Min		10.2
	Variable power range	dB	21.5
Current Range	V _{FEM}	Max	813.88
		Min	89.9
	V _{RFIC}	Max	74.0
		Min	13.9

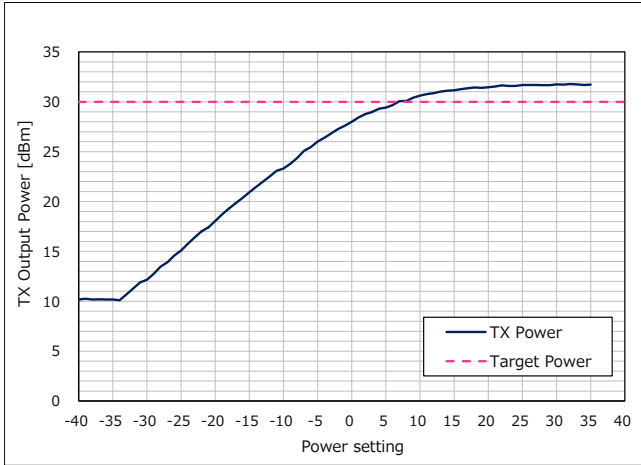


Figure 13 Power Setting vs. TX Power (Frequency = 915.2MHz)

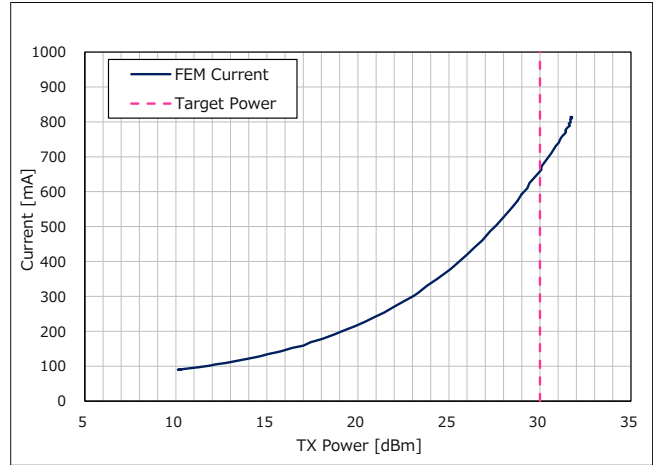


Figure 14 TX Power vs. Current of V_{FEM} for TX mode (Frequency = 915.2MHz)

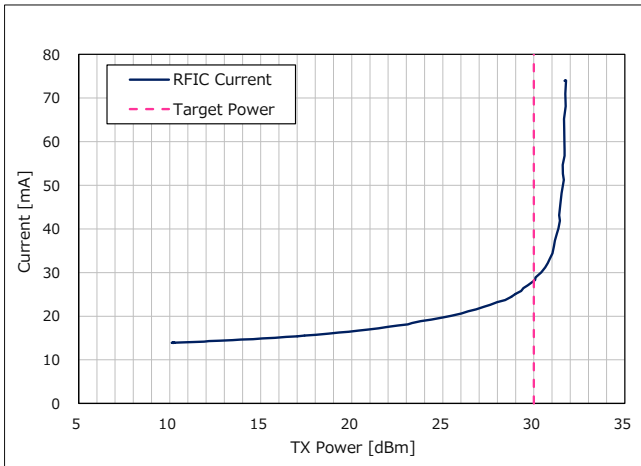


Figure 15 TX Power vs. Current of V_{RFIC} for TX mode (Frequency = 915.2MHz)

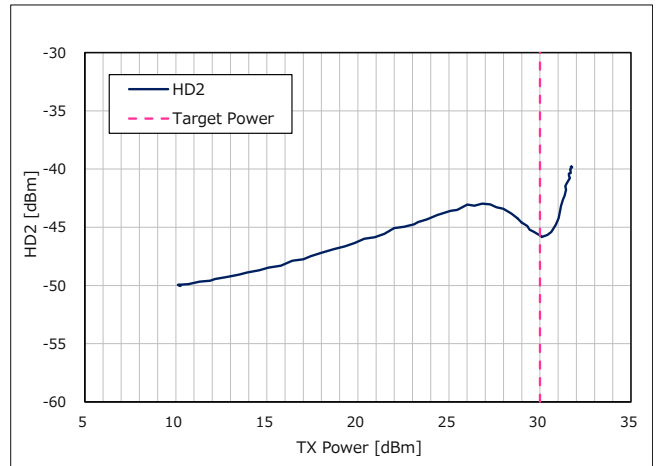


Figure 16 TX Power vs. 2nd Harmonics (Frequency = 915.2MHz)

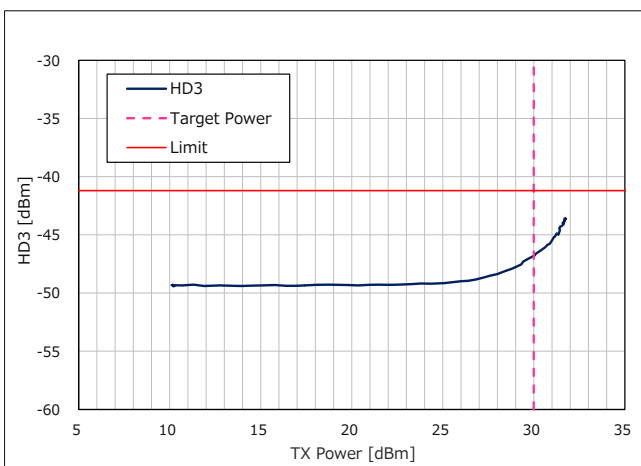


Figure 17 TX Power vs. 3rd Harmonics (Frequency = 915.2MHz)

(2) TX Radio Regulations characteristics

Signal condition: Target TX Power = +30dBm

Table 8 TX Radio Regulations characteristics (1/2)

Items		RF Frequency [MHz]	Unit	Evaluation results	Spec
TX Power		902.2	dBm	29.9	+30.0 (*1)
		915.2		30.1	
		927.8		29.6	
Harmonics	2nd	902.2	dBm /MHz	-48.0	-
		915.2		-45.6	
		927.8		-44.5	
	3rd	902.2		-46.1	-41.2 (*1)
		915.2		-46.7	
		927.8		-47.0	
Occupied Bandwidth		902.4	kHz	162.7	-
		915.2		159.9	
		927.6		161.9	
6dB Bandwidth (*2)		902.4	kHz	94.8	< 500
		915.2		95.5	
		927.6		94.8	
20dB Bandwidth (*2)		902.4	kHz	187.2	< 250
		915.2		182.7	
		927.6		185.8	
Adjacent Channel Power Ratio (M1_Lower, 337.5 kHz offset) (*3)		902.4	dBc	-55.2	-25 (*5)
		915.2		-55.1	
		927.6		-54.9	
Adjacent Channel Power Ratio (M1_Upper, 337.5 kHz offset) (*3)		902.4	dBc	-55.2	-25 (*5)
		915.2		-55.0	
		927.6		-54.9	
Adjacent Channel Power Ratio (M2_Lower, 675 kHz offset) (*3)		902.4	dBc	-64.0	-35 (*5)
		915.2		-63.6	
		927.6		-63.3	
Adjacent Channel Power Ratio (M2_Upper, 675 kHz offset) (*3)		902.4	dBc	-64.1	-35 (*5)
		915.2		-63.6	
		927.6		-63.5	
Deviation Offset		902.4	% rms	5.0	30 (*4)
		915.2		4.8	
		927.6		4.8	
Zero Crossing Error		902.4	% pk	-2.3	±12.5 (*4)
		915.2		2.5	
		927.6		-2.3	
Frequency tolerance (*6)		915.2	ppm	0.9	±20 (*4)

(*1) FCC 47 CFR Part15, Subpart C, Section 15.247

(*2) Since 6dB Bandwidth is less than 500kHz, Digital modulation system is not applied.

Since 20dB Bandwidth is less than 250kHz, Frequency hopping system is applied.

(*3) IEEE.802.15.4-2020

M1: $1.5 \cdot R \cdot (h+1)$, M2: $3 \cdot R \cdot (h+1)$, R (symbol rate): 150kbps, h (modulation index): 0.5

(*4) Wi-SUN PHY Technical Specification - Amendment 1VA9 (11 Nov 2022). (*5) IEEE.802.15.4-2020

(*6) This characteristic depends on TCXO.

Table 9 TX Radio Regulations characteristics (2/2)

Items		RF Frequency [MHz]	Unit	Evaluation results	Spec
Unwanted emissions	30 - 88MHz	902.4	dBm /100kHz	-63.4	-55.2 (*1)
		915.2		-63.1	
		927.6		-62.5	
	88 - 216MHz	902.4	dBm /100kHz	-60.1	-51.7 (*1)
		915.2		-60.4	
		927.6		-60.4	
	216 - 614MHz	902.4	dBm /100kHz	-59.2	-49.2 (*1)
		915.2		-59.3	
		927.6		-59.3	
	960 - 1722.2MHz	902.4	dBm /MHz	-48.6	-41.2 (*1)
		915.2		-49.4	
		927.6		-48.9	
	2200 - 5460MHz	902.4	dBm /MHz	-46.1	-41.2 (*1)
		915.2		-46.7	
		927.6		-47.0	
7250 - 9200MHz	902.4	dBm /MHz	-52.3	-41.2 (*1)	
	915.2		-52.5		
	927.6		-51.6		
Tx out of band emission (Band edge)	Lower 870 - 902MHz	902.4	dBc	-51.8	-20 (*2)
		915.2		-76.6	
		927.6		-77.4	
	Upper 928 - 960MHz	902.4	dBc	-78.9	-20 (*2)
		915.2		-77.9	
		927.6		-50.0	

(*1) In the FCC standard, spurious emissions are specified by electric field intensity (V / m). Since this document is the result of the wired condition, the value converted to the power value (dBm) is used.

Power (dBm)@3m = $10 \cdot \log(300E^2)$, E = electric field intensity (V / m)

(*2) FCC 47 CFR Part15, Subpart C, Section 15.247

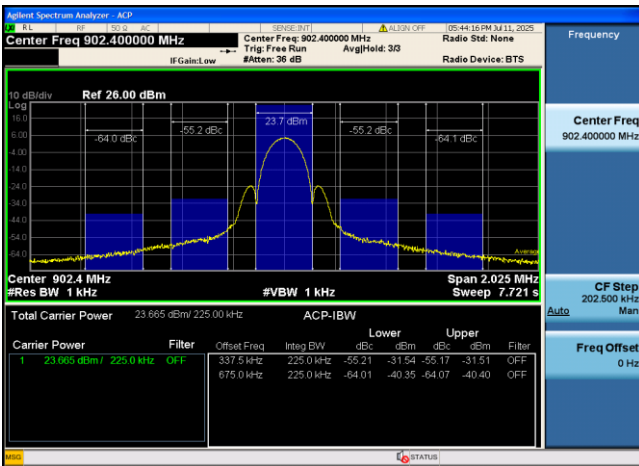


Figure 18 Transmit Spectrum (Frequency = 902.4MHz)

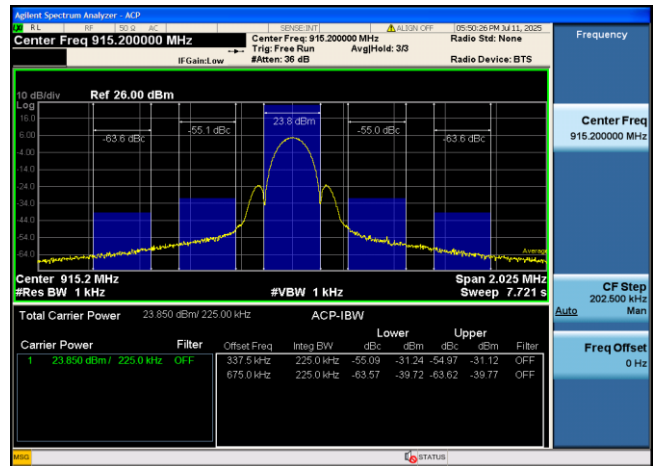


Figure 19 Transmit Spectrum (Frequency = 915.2MHz)

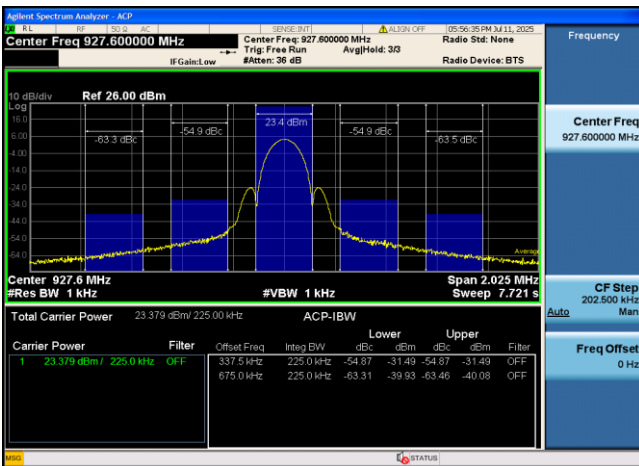


Figure 20 Transmit Spectrum (Frequency = 927.6MHz)

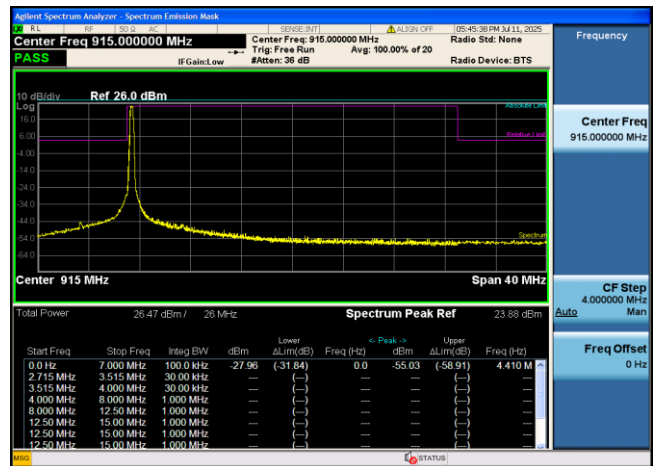


Figure 21 TX Out of Band Emissions for Operational Frequency Band (Frequency = 902.4MHz)

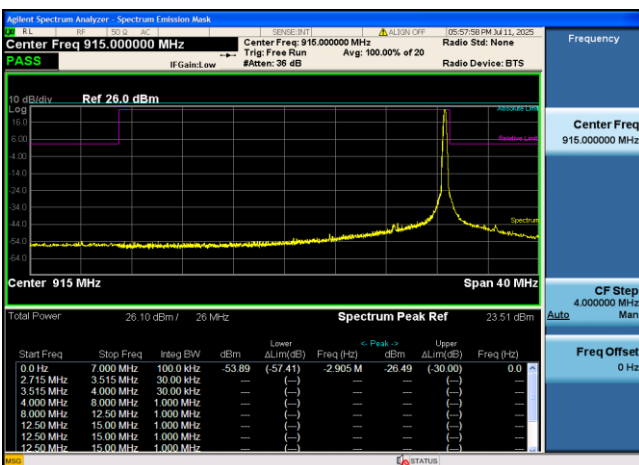


Figure 22 TX Out of Band Emissions for Operational Frequency Band (Frequency = 927.6MHz)

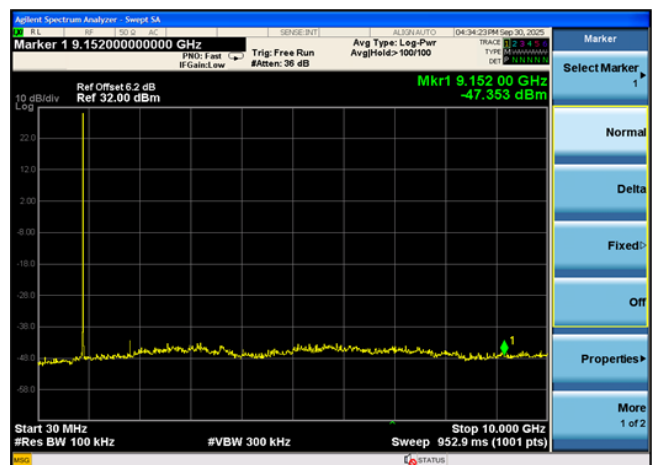


Figure 23 TX Spurious emission (Frequency = 915.2MHz)

2.2.3 OFDM (Option1, MCS6)

(1) TX Power sweep characteristics

Signal condition: Frequency = 915.2MHz

Table 10 TX Power sweep characteristics

Items		Unit	Evaluation results
TX Power Range	Max	dBm	31.2
	Min		6.5
	Variable power range	dB	24.7
Current Range	V _{FEM}	Max	791.7
		Min	71.3
	V _{RFIC}	Max	93.8
		Min	29.8

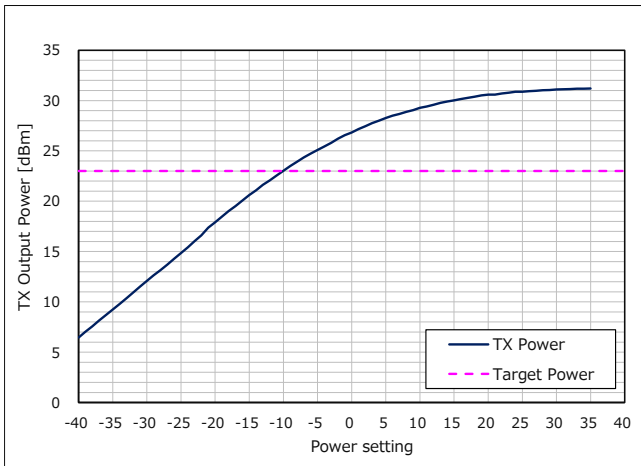


Figure 24 Power Setting vs. TX Power (Frequency = 915.2MHz)

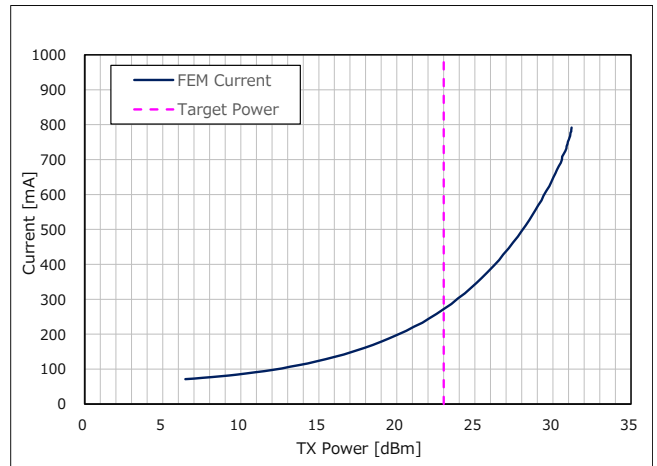


Figure 25 TX Power vs. Current of V_{FEM} for TX mode (Frequency = 915.2MHz)

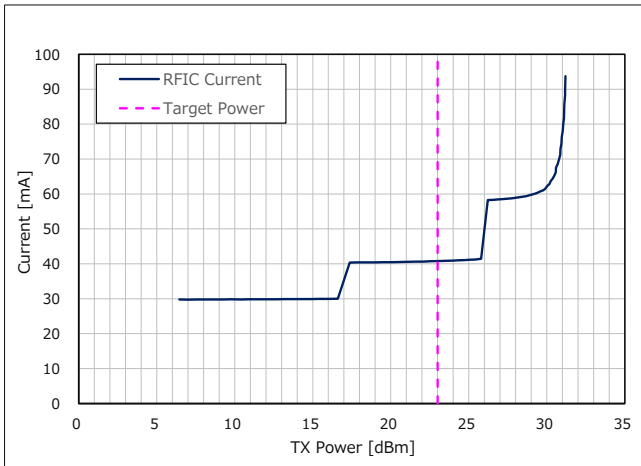


Figure 26 TX Power vs. Current of V_{RFIC} for TX mode (Frequency = 915.2MHz)

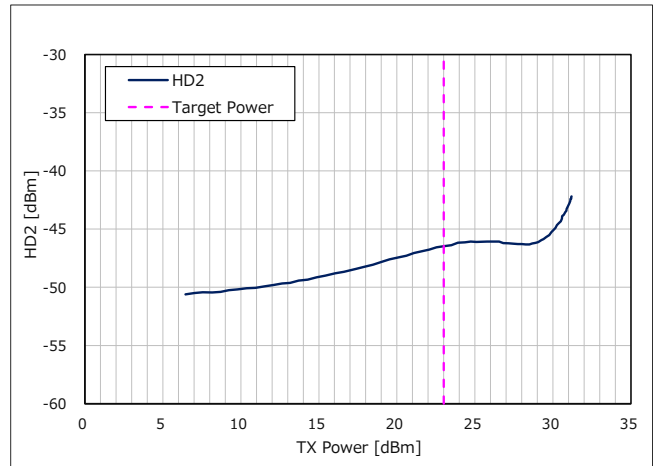


Figure 27 TX Power vs. 2nd Harmonics (Frequency = 915.2MHz)

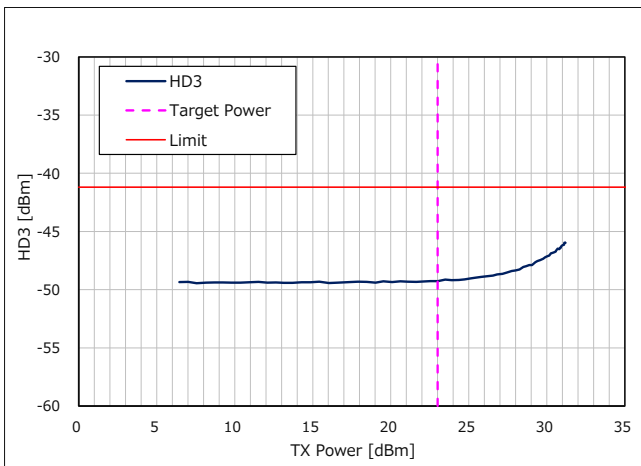


Figure 28 TX Power vs. 3rd Harmonics (Frequency = 915.2MHz)

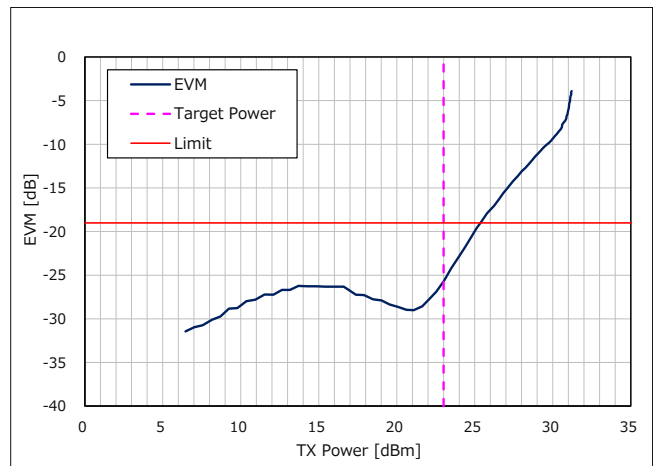


Figure 29 TX Power vs. EVM (Frequency = 915.2MHz)

(2) TX Radio Regulations characteristics

Signal condition: Target TX Power = +23dBm

Table 11 TX Radio Regulations characteristics (1/2)

Items		RF Frequency [MHz]	Unit	Evaluation results	Spec	
TX Power		903.2	dBm	22.6	+30.0 (*1)	
		915.2		23.1		
		926.0		23.1		
Harmonics	2nd	903.2	dBm /MHz	-46.7	-	
		915.2		-46.5		
		926.0		-46.7		
	3rd	903.2		-48.8		-41.2 (*1)
		915.2		-49.2		
		926.0		-49.1		
Occupied Bandwidth		903.2	kHz	1090.6	-	
		915.2		1090.1		
		926.0		1092.3		
6dB Bandwidth (*2)		903.2	kHz	1091.9	≥ 500	
		915.2		1095.6		
		926.0		1092.7		
20dB Bandwidth (*2)		903.2	kHz	1147.6	-	
		915.2		1149.2		
		926.0		1146.1		
Adjacent Channel Power Ratio	Lower	903.2	dBc	-34.0	-20 (*3)	
		915.2		-33.0		
		926.0		-32.6		
	Upper	903.2		-34.4		
		915.2		-33.2		
		926.0		-33.1		
Alternate Channel Power Ratio	Lower	903.2	dBc	-50.5	-40 (*3)	
		915.2		-49.0		
		926.0		-49.0		
	Upper	903.2		-51.0		
		915.2		-49.5		
		926.0		-49.0		
Modulation quality	EVM	903.2	dB	-28.0	-19 (*4)	
		915.2		-25.5		
		926.0		-25.3		

(*1) FCC 47 CFR Part15, Subpart C, Section 15.247

(*2) Since 6dB Bandwidth is more than 500kHz, Digital modulation system is applied.

Since 20dB Bandwidth is more than 500kHz, Frequency hopping system is not applied.

(*3) Wi-SUN PHY Technical Specification - Amendment 1VA9 (11 Nov 2022)

(*4) IEEE.802.15.4-2020

Table 12 TX Radio Regulations characteristics (2/2)

Items		RF Frequency [MHz]	Unit	Evaluation results	Spec
Unwanted emissions	30 - 88MHz	903.2	dBm /100kHz	-65.4	-55.2 (*1)
		915.2		-63.7	
		927.2		-65.7	
	88 - 216MHz	903.2	dBm /100kHz	-61.3	-51.7 (*1)
		915.2		-60.7	
		927.2		-61.1	
	216 - 614MHz	903.2	dBm /100kHz	-62.8	-49.2 (*1)
		915.2		-63.1	
		927.2		-63.2	
	960 - 1722.2MHz	903.2	dBm /MHz	-51.4	-41.2 (*1)
		915.2		-52.5	
		927.2		-51.6	
	2200 - 5460MHz	903.2	dBm /MHz	-48.8	-41.2 (*1)
		915.2		-49.2	
		927.2		-49.1	
	7250 - 9200MHz	903.2	dBm /MHz	-52.0	-41.2 (*1)
		915.2		-51.4	
		927.2		-51.9	
Tx out of band emission (Band edge)	Lower 870 - 902MHz	903.2	dBc	-31.6	-20 (*2)
		915.2		-65.5	
		927.2		-65.0	
	Upper 928 - 960MHz	903.2	dBc	-67.2	-20 (*2)
		915.2		-66.1	
		927.2		-41.5	

(*1) In the FCC standard, spurious emissions are specified by electric field intensity (V / m). Since this document is the result of the wired condition, the value converted to the power value (dBm) is used.

Power (dBm)@3m = $10 \cdot \log(300E^2)$, E = electric field intensity (V / m)

(*2) FCC 47 CFR Part15, Subpart C, Section 15.247

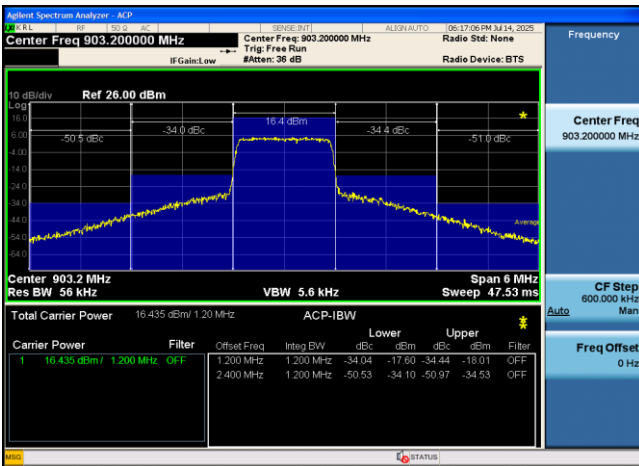


Figure 30 Transmit Spectrum (Frequency = 903.2MHz)

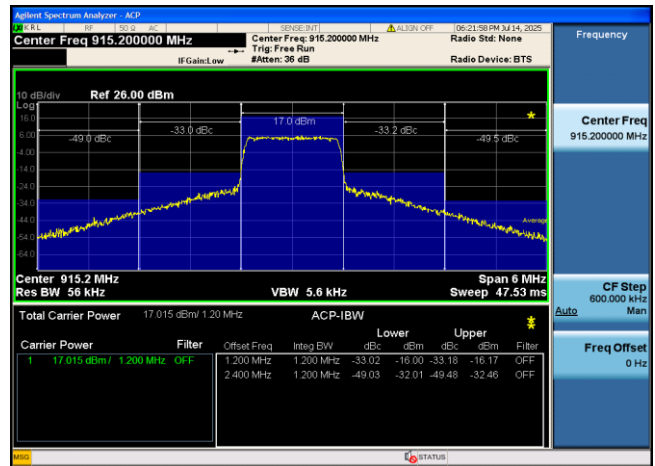


Figure 31 Transmit Spectrum (Frequency = 915.2MHz)

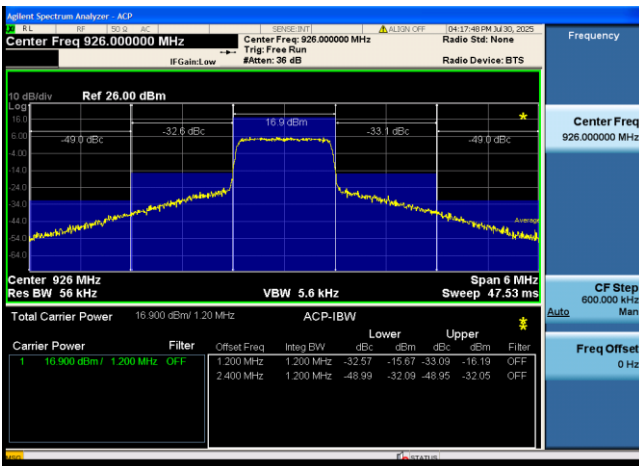


Figure 32 Transmit Spectrum (Frequency = 926.0MHz)

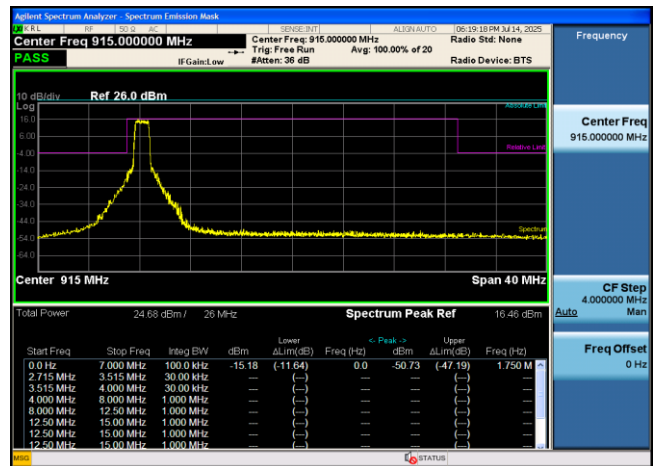


Figure 33 TX Out of Band Emissions for Operational Frequency Band (Frequency = 903.2MHz)



Figure 34 TX Out of Band Emissions for Operational Frequency Band (Frequency = 926.0MHz)

2.2.4 OFDM (Option2, MCS6)

(1) TX Power sweep characteristics

Signal condition: Frequency = 914.8MHz

Table 13 TX Power sweep characteristics

Items		Unit	Evaluation results
TX Power Range	Max	dBm	31.3
	Min		6.4
	Variable power range	dB	24.9
Current Range	V _{FEM}	Max	786.2
		Min	71.0
	V _{RFIC}	Max	94.1
		Min	29.3

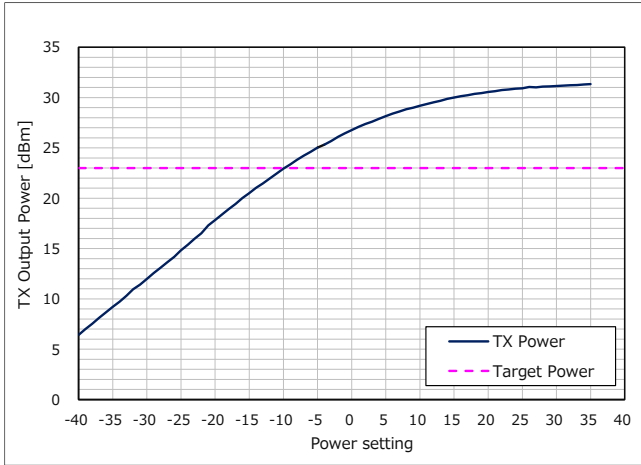


Figure 35 Power Setting vs. TX Power (Frequency = 914.8MHz)

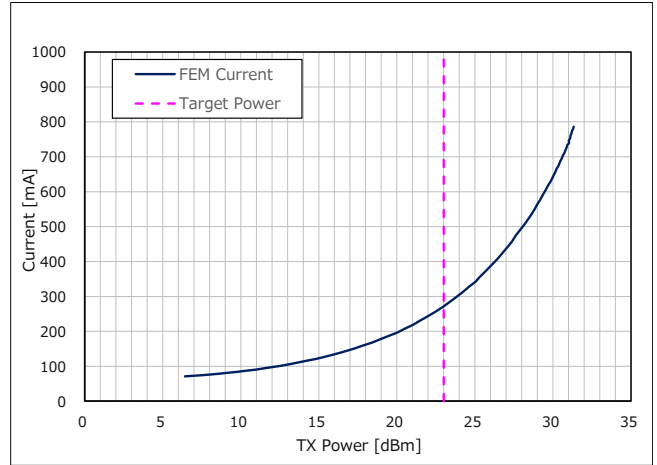


Figure 36 TX Power vs. Current of V_{FEM} for TX mode (Frequency = 914.8MHz)

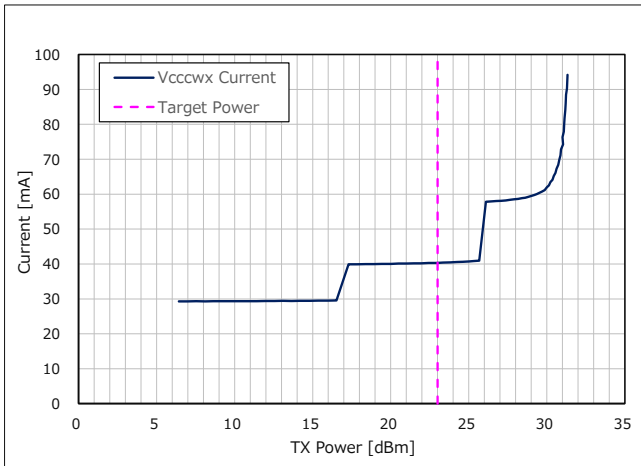


Figure 37 TX Power vs. Current of V_{RFIC} for TX mode (Frequency = 914.8MHz)

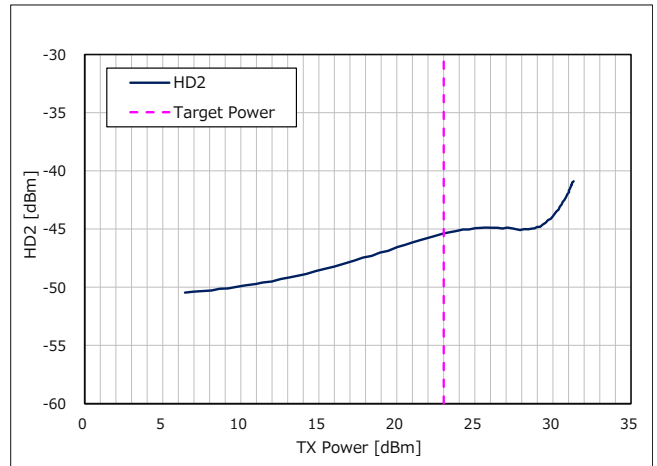


Figure 38 TX Power vs. 2nd Harmonics (Frequency = 914.8MHz)

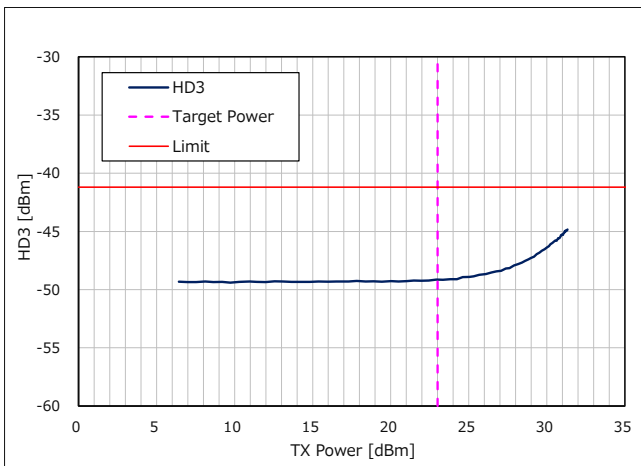


Figure 39 TX Power vs. 3rd Harmonics (Frequency = 914.8MHz)

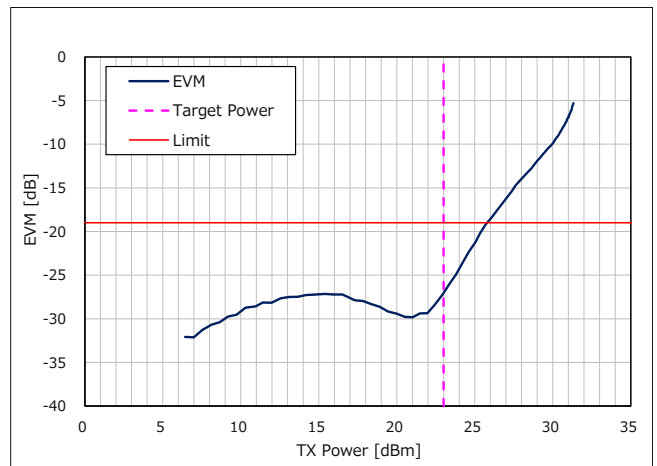


Figure 40 TX Power vs. EVM (Frequency = 914.8MHz)

(2) TX Radio Regulations characteristics

Signal condition: Target TX Power = +23dBm

Table 14 TX Radio Regulations characteristics (1/2)

Items		RF Frequency [MHz]	Unit	Evaluation results	Spec
TX Power		902.8	dBm	22.6	+30.0 (*1)
		914.8		23.2	
		926.8		22.9	
Harmonics	2nd	902.8	dBm /MHz	-45.6	-
		914.8		-45.3	
		926.8		-45.8	
	3rd	902.8		-48.8	-41.2 (*1)
		914.8		-49.0	
		926.8		-49.0	
Occupied Bandwidth		902.8	kHz	556.3	-
		914.8		556.6	
		926.8		557.3	
6dB Bandwidth (*2)		902.8	kHz	552.5	≥ 500
		914.8		551.5	
		926.8		552.1	
20dB Bandwidth (*2)		902.8	kHz	598.6	-
		914.8		598.1	
		926.8		599.7	
Adjacent Channel Power Ratio	Lower	902.8	dBc	-37.2	-20 (*3)
		914.8		-35.6	
		926.8		-35.6	
	Upper	902.8		-37.1	
		914.8		-35.6	
		926.8		-35.6	
Alternate Channel Power Ratio	Lower	902.8	dBc	-55.7	-40 (*3)
		914.8		-54.8	
		926.8		-54.4	
	Upper	902.8		-56.4	
		914.8		-55.4	
		926.8		-54.8	
Modulation quality	EVM	902.8	dB	-29.2	-19 (*4)
		914.8		-27.4	
		926.8		-26.6	

(*1) FCC 47 CFR Part15, Subpart C, Section 15.247

(*2) Since 6dB Bandwidth is more than 500kHz, Digital modulation system is applied.

Since 20dB Bandwidth is more than 500kHz, Frequency hopping system is not applied.

(*3) Wi-SUN PHY Technical Specification - Amendment 1VA9 (11 Nov 2022)

(*4) IEEE.802.15.4-2020

Table 15 TX Power sweep characteristics (2/2)

Items		RF Frequency [MHz]	Unit	Evaluation results	Spec
Unwanted emissions	30 - 88MHz	902.8	dBm /100kHz	-64.7	-55.2 (*1)
		914.8		-65.9	
		926.8		-65.2	
	88 - 216MHz	902.8	dBm /100kHz	-61.1	-51.7 (*1)
		914.8		-60.9	
		926.8		-61.5	
	216 - 614MHz	902.8	dBm /100kHz	-62.6	-49.2 (*1)
		914.8		-63.1	
		926.8		-63.3	
	960 - 1722.2MHz	902.8	dBm /MHz	-50.7	-41.2 (*1)
		914.8		-52.2	
		926.8		-50.8	
	2200 - 5460MHz	902.8	dBm /MHz	-48.8	-41.2 (*1)
		914.8		-49.0	
		926.8		-49.0	
7250 - 9200MHz	902.8	dBm /MHz	-51.9	-41.2 (*1)	
	914.8		-51.4		
	926.8		-51.2		
Tx out of band emission (Band edge)	Lower 870 - 902MHz	902.8	dBc	-39.5	-20 (*2)
		914.8		-68.6	
		926.8		-68.1	
	Upper 928 - 960MHz	902.8	dBc	-68.6	-20 (*2)
		914.8		-69.5	
		926.8		-42.7	

(*1) In the FCC standard, spurious emissions are specified by electric field intensity (V / m). Since this document is the result of the wired condition, the value converted to the power value (dBm) is used.

Power (dBm)@3m = $10 \cdot \log(300E^2)$, E = electric field intensity (V / m)

(*2) FCC 47 CFR Part15, Subpart C, Section 15.247

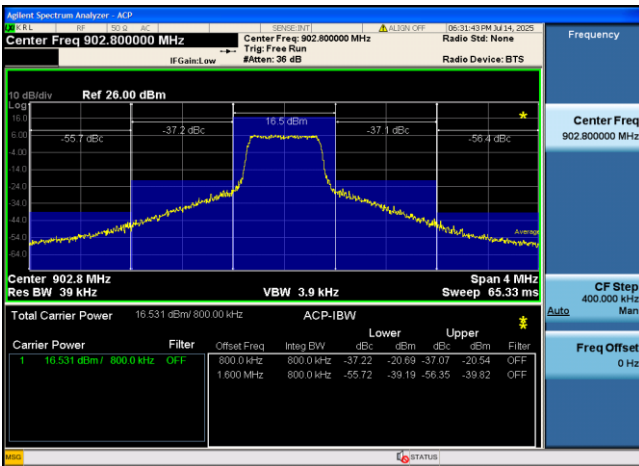


Figure 41 Transmit Spectrum (Frequency = 902.8MHz)

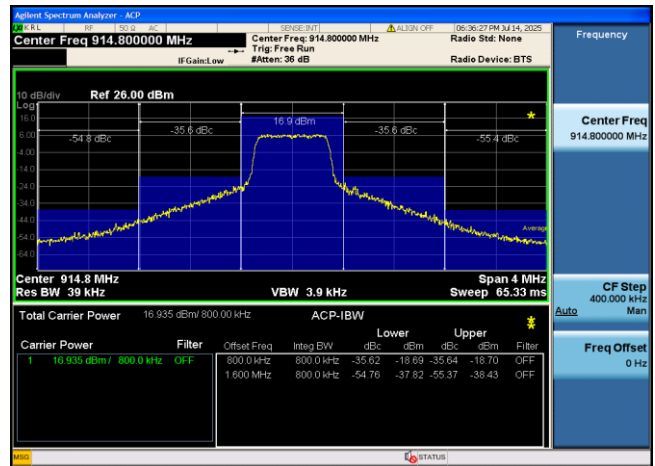


Figure 42 Transmit Spectrum (Frequency = 914.8MHz)

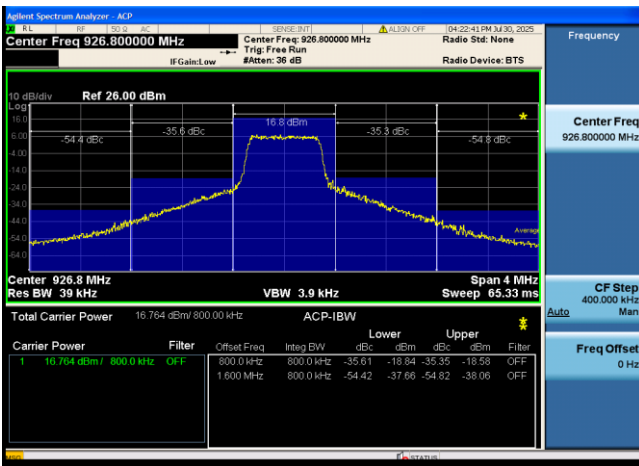


Figure 43 Transmit Spectrum (Frequency = 926.8MHz)

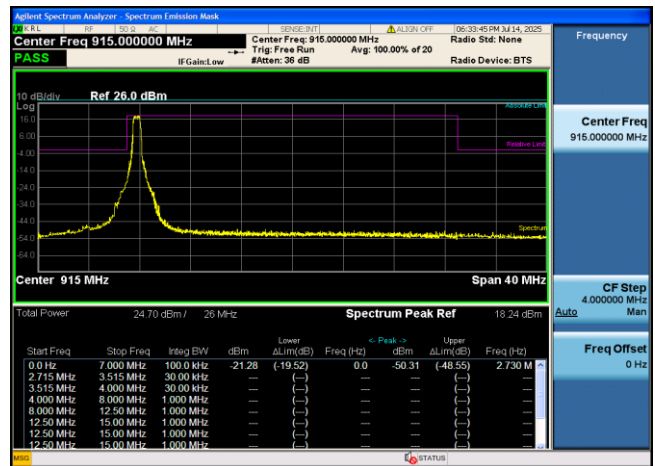


Figure 44 TX Out of Band Emissions for Operational Frequency Band (Frequency = 902.8MHz)

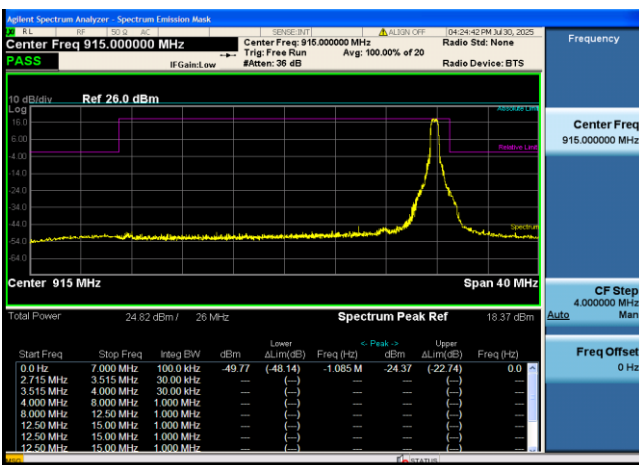


Figure 45 TX Out of Band Emissions for Operational Frequency Band (Frequency = 926.8MHz)

2.2.5 OFDM (Option3, MCS6)

(1) TX Power sweep characteristics

Signal condition: Frequency = 915.2MHz

Table 16 TX Power sweep characteristics

Items		Unit	Evaluation results
TX Power Range	Max	dBm	31.2
	Min		6.4
	Variable power range	dB	24.8
Current Range	V _{FEM}	Max	785.1
		Min	71.1
	V _{RFIC}	Max	93.0
		Min	29.9

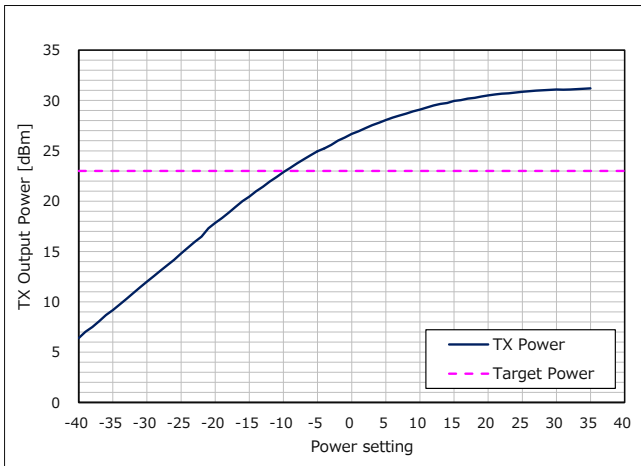


Figure 46 Power Setting vs. TX Power (Frequency = 915.2MHz)

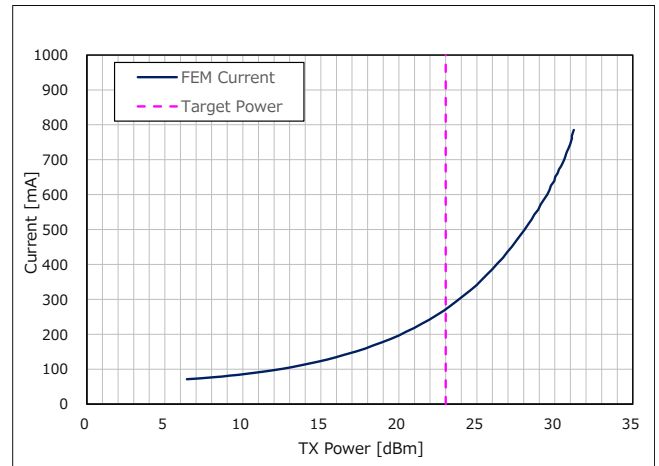


Figure 47 TX Power vs. Current of V_{FEM} for TX mode (Frequency = 915.2MHz)

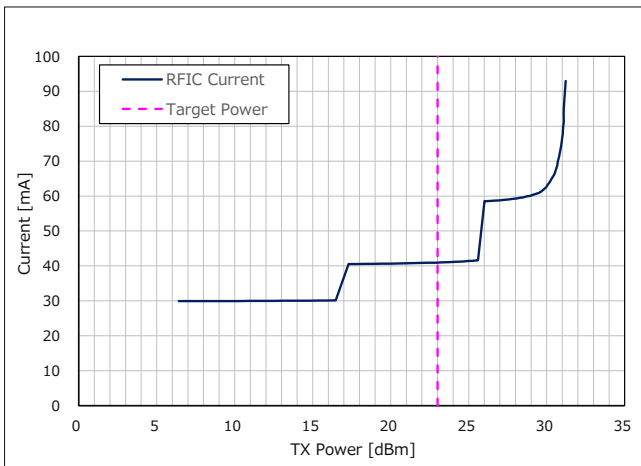


Figure 48 TX Power vs. Current of V_{RFIC} for TX mode (Frequency = 915.2MHz)

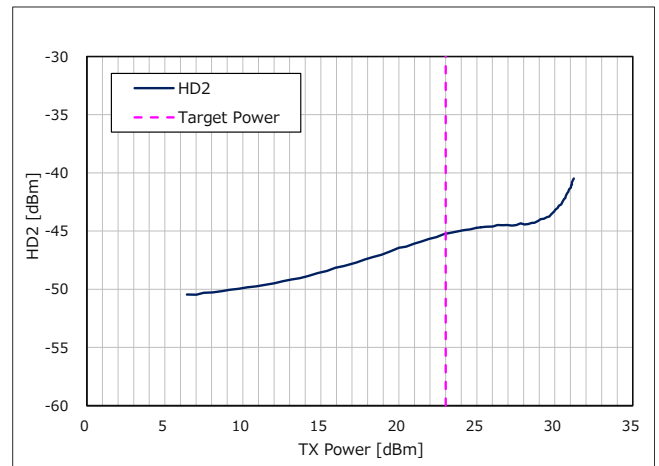


Figure 49 TX Power vs. 2nd Harmonics (Frequency = 915.2MHz)

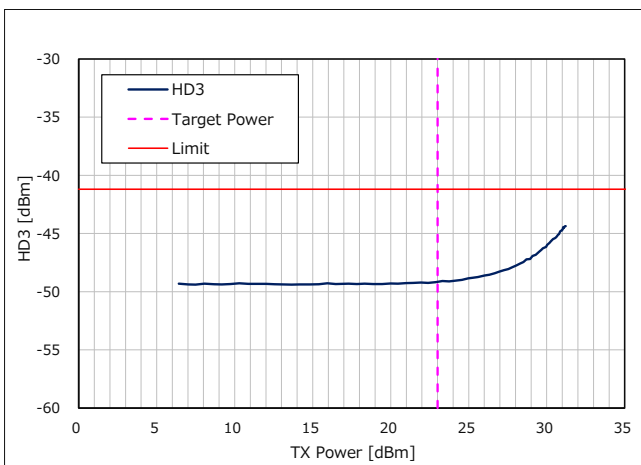


Figure 50 TX Power vs. 3rd Harmonics (Frequency = 915.2MHz)

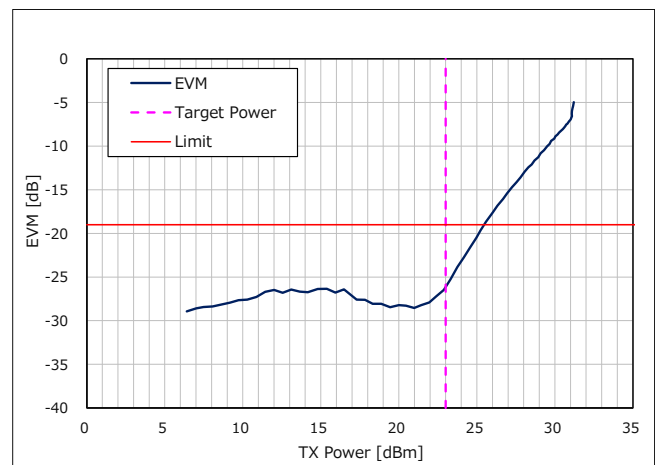


Figure 51 TX Power vs. EVM (Frequency = 915.2MHz)

(2) TX Radio Regulations characteristics

Signal condition: Target TX Power = +23dBm

Table 17 TX Radio Regulations characteristics (1/2)

Items		RF Frequency [MHz]	Unit	Evaluation results	Spec
TX Power		902.4	dBm	22.4	+30.0 (*1)
		915.2		23.0	
		927.6		22.6	
Harmonics	2nd	902.4	dBm /MHz	-45.5	-
		915.2		-45.3	
		927.6		-45.9	
	3rd	902.4		-48.8	-41.2 (*1)
		915.2		-49.2	
		927.6		-49.0	
Occupied Bandwidth		902.4	kHz	283.8	-
		915.2		285.6	
		927.6		284.4	
6dB Bandwidth (*2)		902.4	kHz	281.8	< 500
		915.2		281.8	
		927.6		281.6	
20dB Bandwidth (*2)		902.4	kHz	317.7	< 500
		915.2		317.8	
		927.6		318.7	
Adjacent Channel Power Ratio	Lower	902.4	dBc	-37.1	-20 (*3)
		915.2		-34.5	
		927.6		-34.6	
	Upper	902.4		-36.2	
		915.2		-34.5	
		927.6		-34.6	
Alternate Channel Power Ratio	Lower	902.4	dBc	-55.6	-40 (*3)
		915.2		-54.0	
		927.6		-54.2	
	Upper	902.4		-55.9	
		915.2		-54.2	
		927.6		-54.4	
Modulation quality	EVM	902.4	dB	-27.5	-19 (*4)
		915.2		-26.1	
		927.6		-25.5	

(*1) FCC 47 CFR Part15, Subpart C, Section 15.247

(*2) Since 6dB Bandwidth is less than 500kHz, Digital modulation system is not applied.

Since 20dB Bandwidth is less than 500kHz, Frequency hopping system is applied.

(*3) Wi-SUN PHY Technical Specification - Amendment 1VA9 (11 Nov 2022)

(*4) IEEE.802.15.4-2020

Table 18 TX Radio Regulations characteristics (2/2)

Items		RF Frequency [MHz]	Unit	Evaluation results	Spec
Unwanted emissions	30 - 88MHz	902.4	dBm /100kHz	-65.3	-55.2 (*1)
		915.2		-64.8	
		927.6		-65.4	
	88 - 216MHz	902.4	dBm /100kHz	-60.9	-51.7 (*1)
		915.2		-61.5	
		927.6		-61.0	
	216 - 614MHz	902.4	dBm /100kHz	-61.8	-49.2 (*1)
		915.2		-62.3	
		927.6		-63.1	
	960 - 1722.2MHz	902.4	dBm /MHz	-51.5	-41.2 (*1)
		915.2		-50.8	
		927.6		-50.3	
	2200 - 5460MHz	902.4	dBm /MHz	-48.8	-41.2 (*1)
		915.2		-49.2	
		927.6		-49.0	
7250 - 9200MHz	902.4	dBm /MHz	-52.7	-41.2 (*1)	
	915.2		-52.0		
	927.6		-52.3		
Tx out of band emission (Band edge)	Lower 870 - 902MHz	902.4	dBc	-36.3	-20 (*2)
		915.2		-70.4	
		927.6		-70.1	
	Upper 928 - 960MHz	902.4	dBc	-71.5	-20 (*2)
		915.2		-70.7	
		927.6		-29.9	

(*1) In the FCC standard, spurious emissions are specified by electric field intensity (V / m). Since this document is the result of the wired condition, the value converted to the power value (dBm) is used.

Power (dBm)@3m = $10 \cdot \log(300E^2)$, E = electric field intensity (V / m)

(*2) FCC 47 CFR Part15, Subpart C, Section 15.247

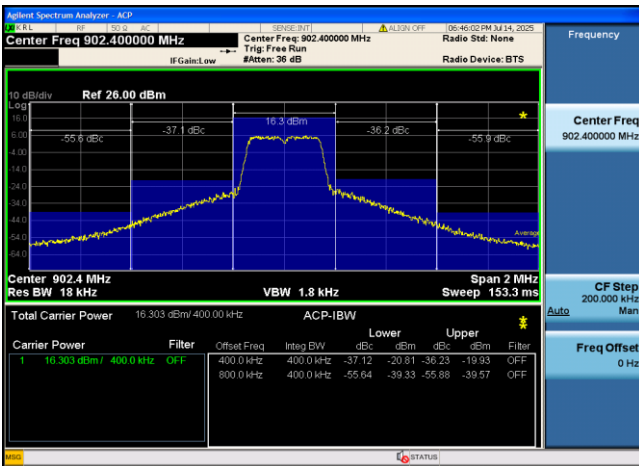


Figure 52 Transmit Spectrum (Frequency = 902.4MHz)

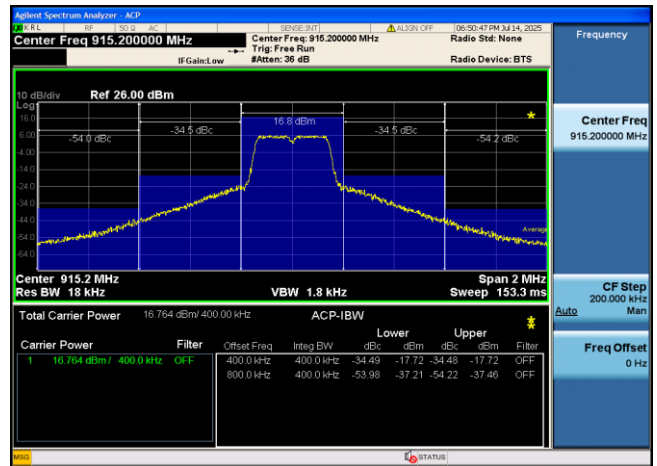


Figure 53 Transmit Spectrum (Frequency = 915.2MHz)

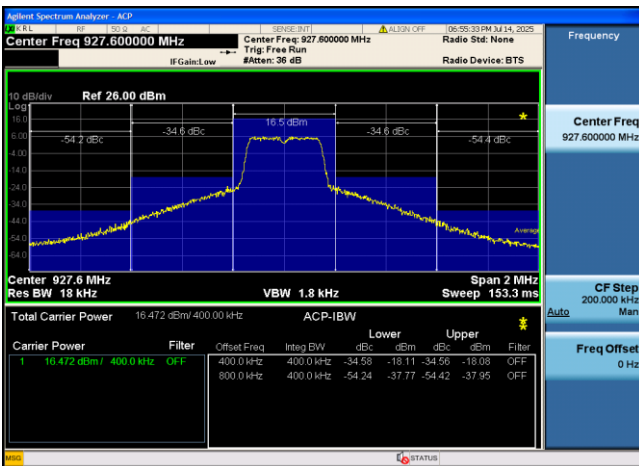


Figure 54 Transmit Spectrum (Frequency = 927.6MHz)

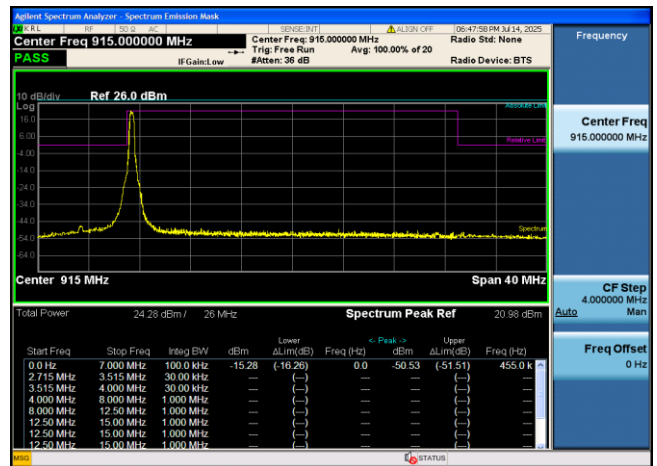


Figure 55 TX Out of Band Emissions for Operational Frequency Band (Frequency = 902.4MHz)

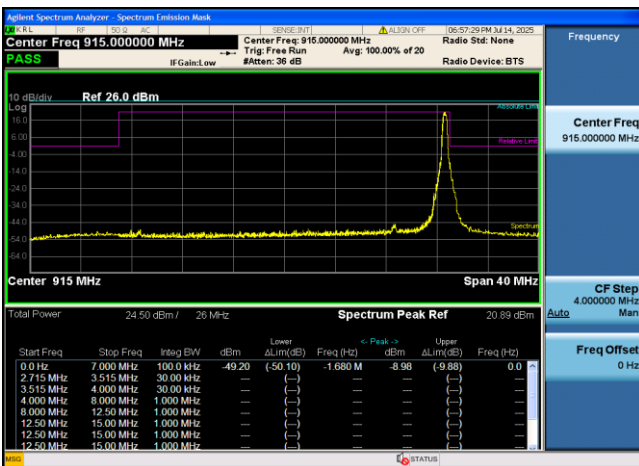


Figure 56 TX Out of Band Emissions for Operational Frequency Band (Frequency = 927.6MHz)

2.2.6 OFDM (Option4, MCS6)

(1) TX Power sweep characteristics

Signal condition: Frequency = 915MHz

Table 19 TX Power sweep characteristics

Items		Unit	Evaluation results
TX Power Range	Max	dBm	31.0
	Min		6.5
	Variable power range	dB	24.5
Current Range	V _{FEM}	Max	785.4
		Min	71.8
	V _{RFIC}	Max	93.0
		Min	29.1

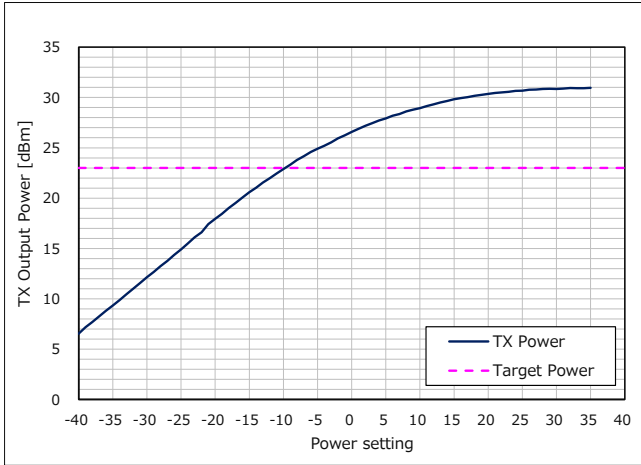


Figure 57 Power Setting vs. TX Power (Frequency = 915MHz)

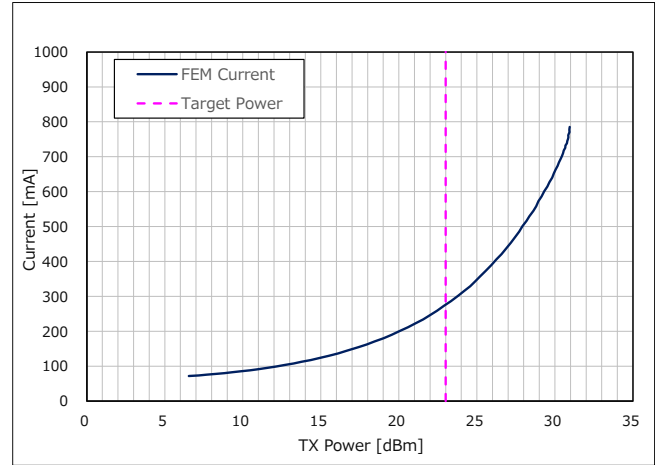


Figure 58 TX Power vs. Current of V_{FEM} for TX mode (Frequency = 915MHz)

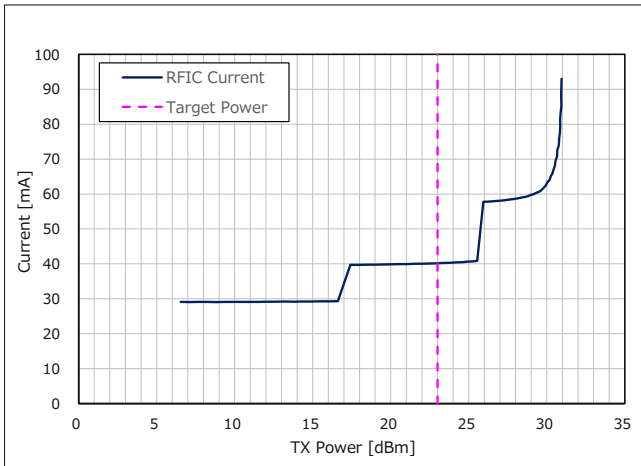


Figure 59 TX Power vs. Current of V_{RFIC} for TX mode (Frequency = 915MHz)

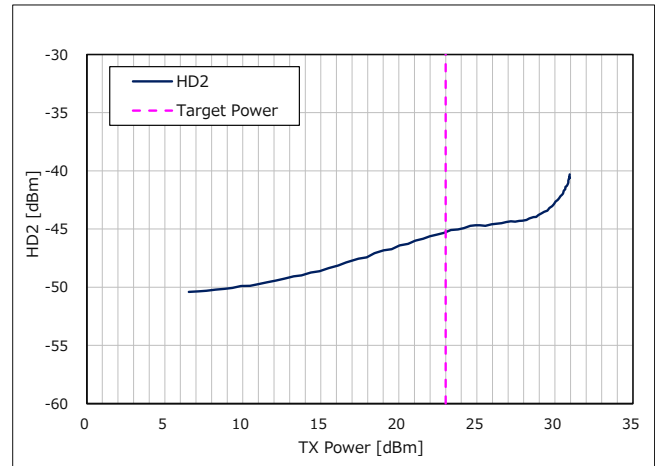


Figure 60 TX Power vs. 2nd Harmonics (Frequency = 915MHz)

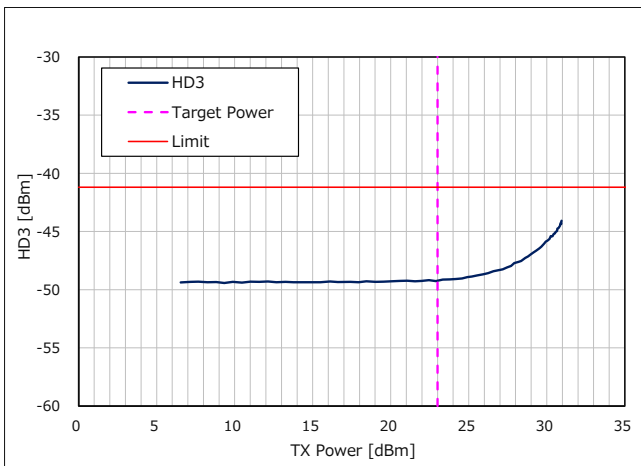


Figure 61 TX Power vs. 3rd Harmonics (Frequency = 915MHz)

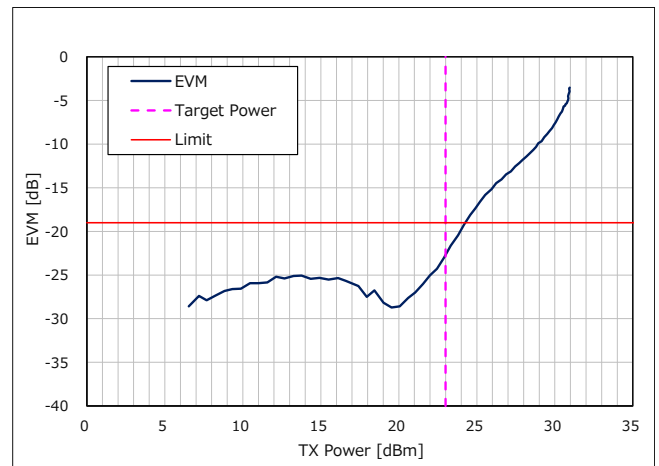


Figure 62 TX Power vs. EVM (Frequency = 915MHz)

(2) TX Radio Regulations characteristics

Signal condition: Target TX Power = +23dBm

Table 20 TX Radio Regulations characteristics (1/2)

Items		RF Frequency [MHz]	Unit	Evaluation results	Spec	
TX Power		902.2	dBm	22.6	+30.0 (*1)	
		915.0		23.2		
		927.8		22.7		
Harmonics	2nd	902.2	dBm /MHz	-45.5	-	
		915.0		-45.2		
		927.8		-45.9		
	3rd	902.2		-48.7		-41.2 (*1)
		915.0		-49.2		
		927.8		-49.0		
Occupied Bandwidth		902.2	kHz	158.2	-	
		915.0		158.8		
		927.8		159.0		
6dB Bandwidth (*2)		902.2	kHz	154.8	< 500	
		915.0		155.5		
		927.8		154.8		
20dB Bandwidth (*2)		902.2	kHz	179.2	< 250	
		915.0		181.2		
		927.8		178.8		
Adjacent Channel Power Ratio	Lower	902.2	dBc	-33.5	-20 (*3)	
		915.0		-31.4		
		927.8		-31.4		
	Upper	902.2		-32.7		
		915.0		-31.2		
		927.8		-31.0		
Alternate Channel Power Ratio	Lower	902.2	dBc	-52.3	-40 (*3)	
		915.0		-50.3		
		927.8		-49.9		
	Upper	902.2		-52.6		
		915.0		-50.7		
		927.8		-50.1		
Modulation quality	EVM	902.2	dB	-25.3	-19 (*4)	
		915.0		-22.9		
		927.8		-23.5		

(*1) FCC 47 CFR Part15, Subpart C, Section 15.247

(*2) Since 6dB Bandwidth is less than 500kHz, Digital modulation system is not applied.

Since 20dB Bandwidth is less than 250kHz, Frequency hopping system is applied.

(*3) Wi-SUN PHY Technical Specification - Amendment 1VA9 (11 Nov 2022)

(*4) IEEE.802.15.4-2020

Table 21 TX Radio Regulations characteristics (2/2)

Items		RF Frequency [MHz]	Unit	Evaluation results	Spec
Unwanted emissions	30 - 88MHz	902.2	dBm /100kHz	-65.4	-55.2 (*1)
		915.0		-65.2	
		927.8		-65.9	
	88 - 216MHz	902.2	dBm /100kHz	-61.2	-51.7 (*1)
		915.0		-61.3	
		927.8		-61.0	
	216 - 614MHz	902.2	dBm /100kHz	-59.8	-49.2 (*1)
		915.0		-62.5	
		927.8		-61.8	
	960 - 1722.2MHz	902.2	dBm /MHz	-51.7	-41.2 (*1)
		915.0		-51.7	
		927.8		-50.7	
	2200 - 5460MHz	902.2	dBm /MHz	-48.7	-41.2 (*1)
		915.0		-49.2	
		927.8		-49.0	
	7250 - 9200MHz	902.2	dBm /MHz	-51.5	-41.2 (*1)
		915.0		-51.6	
		927.8		-51.4	
Tx out of band emission (Band edge)	Lower 870 - 902MHz	902.2	dBc	-27.6	-20 (*2)
		915.0		-71.9	
		927.8		-71.0	
	Upper 928 - 960MHz	902.2	dBc	-72.4	-20 (*2)
		915.0		-72.3	
		927.8		-26.9	

(*1) In the FCC standard, spurious emissions are specified by electric field intensity (V / m). Since this document is the result of the wired condition, the value converted to the power value (dBm) is used.

Power (dBm)@3m = $10 \cdot \log(300E^2)$, E = electric field intensity (V / m)

(*2) FCC 47 CFR Part15, Subpart C, Section 15.247

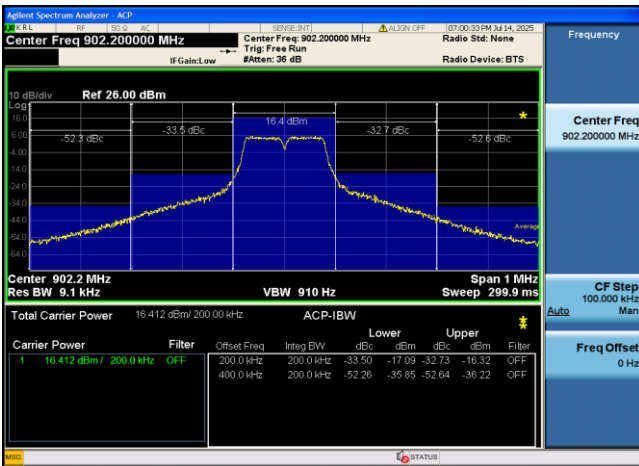


Figure 63 Transmit Spectrum (Frequency = 902.2MHz)

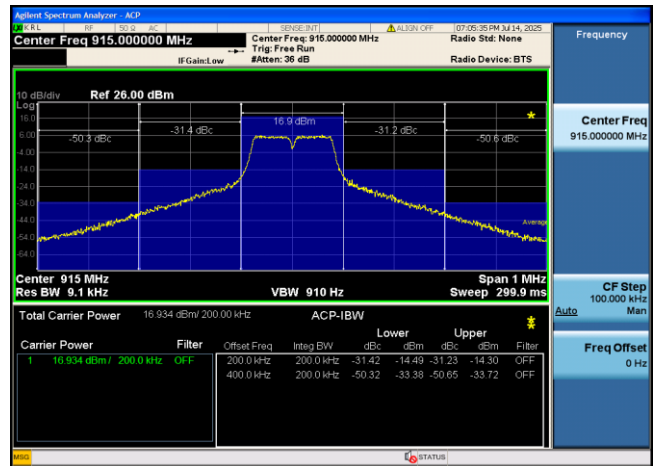


Figure 64 Transmit Spectrum (Frequency = 915MHz)

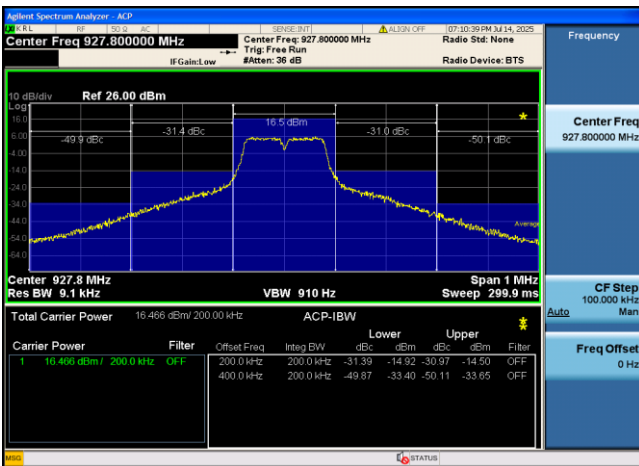


Figure 65 Transmit Spectrum (Frequency = 927.8MHz)

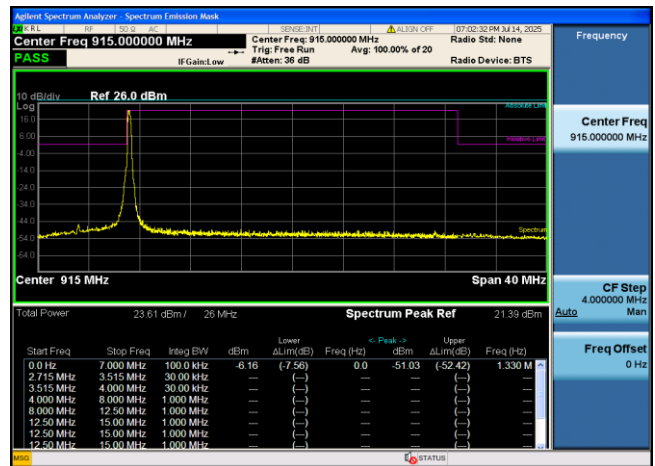


Figure 66 TX Out of Band Emissions for Operational Frequency Band (Frequency = 902.2MHz)

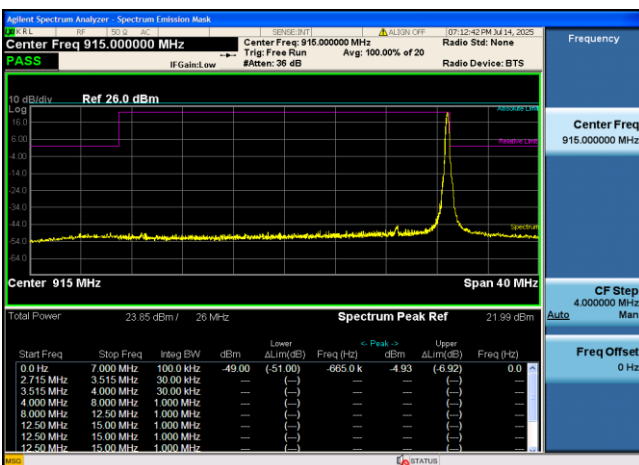


Figure 67 TX Out of Band Emissions for Operational Frequency Band (Frequency = 927.8MHz)

2.3 RX Electrical Characteristics

2.3.1 FSK (50kbps, modulation index = 1)

Table 22 RX Electrical Characteristics 1

Items			RF Frequency [MHz]	Unit	Evaluation result	Spec
Receiver sensitivity	PER < 10% Length 250 octets		902.2	dBm	-109	-91 (*4)
			915.0		-109	
			927.8		-108	
Maximum Input level	PER < 10% Length 250 octets		902.2	dBm	10	-
			915.0		10	
			927.8		10	
RSSI accuracy	Average	RSSI range: -109dBm to -20dBm (*1)	902.2	dB	1.5	-
			915.0		2.0	
			927.8		-1.8	
	MAX		902.2		2.0	
			915.0		2.0	
			927.8		-1.5	
	MIN		902.2		-1.5	
			915.0		1.5	
			927.8		-2	
ED accuracy	Average	ED range: -109dBm to -20dBm (*1)	915.0	dB	1.2	-
	MAX		915.0		2.0	
	MIN		915.0		0.5	
Frequency tolerance	Max	PER < 10% Length 250 octets	915.0	ppm	≥ 85	±20
	Min				≤ -85	
Adjacent channel rejection	-200kHz	PER < 10% (*2) (*3) Length 250 octets	915.0	dB	45	10 (*4)
	+200kHz				45	
Alternate channel rejection	-400kHz	PER < 10% (*2) (*3) Length 250 octets	915.0	dB	52	30 (*4)
	+400kHz				52	
Co channel rejection	±0MHz	PER < 10% (*2) (*3) Length 250 octets	915.0	dB	-5	-
Blocking	+1MHz	PER < 10% (*2) (*3) Length 250 octets	915.0	dB	66	-
	-2MHz				70	
	+2MHz				70	
	-10MHz				73	
	+10MHz				74	
Image rejection	-1.1MHz-	PER < 10% (*2) (*3) Length 250 octets	915.0	dB	36	-
Receiver spurious emission	30 - 1000MHz		902.2	dBm /100kHz	-86.4	-
			915.0		-86.9	
			927.8		-86.7	
	1 - 10GHz		902.2	dBm /MHz	-72.1	-
			915.0		-72.1	
			927.8		-72.4	

(*1) Lower limit: RX sensitivity / Upper limit: Limit described in the user's manual (-5dBm) - FEM LNA gain (16dB) + SAW Filter Loss (1dB).

(*2) The level of the desired signal: RX sensitivity + 3dB (-106dBm)

(*3) Interference signal is non-modulated wave. (*4) IEEE.802.15.4-2020.

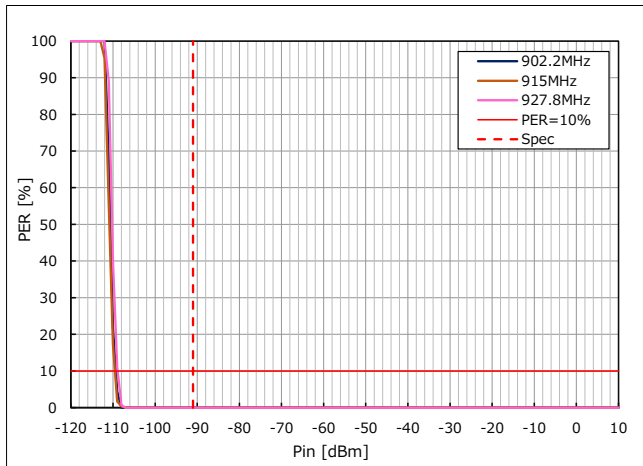


Figure 68 RF Input Level vs. Packet Error Rate (Frequency = 902.2 / 915 / 927.8MHz)

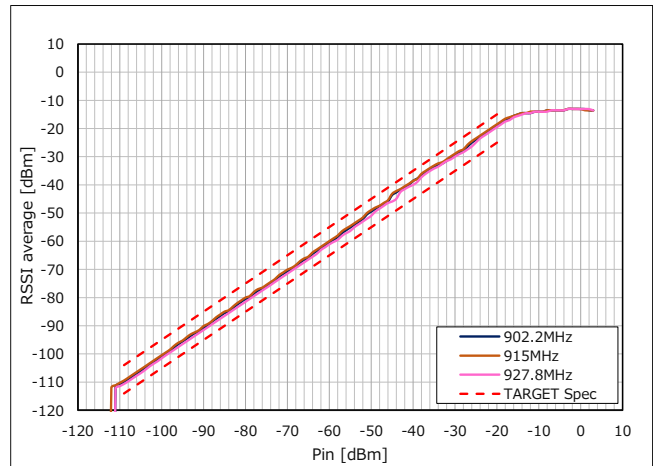


Figure 69 RF Input Level vs. RSSI average (Frequency = 902.2 / 915 / 927.8MHz)

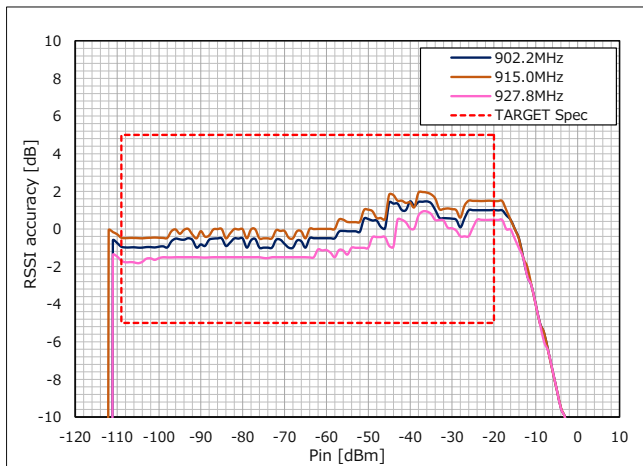


Figure 70 RF Input Level vs. RSSI accuracy (Frequency = 902.2 / 915 / 927.8MHz)

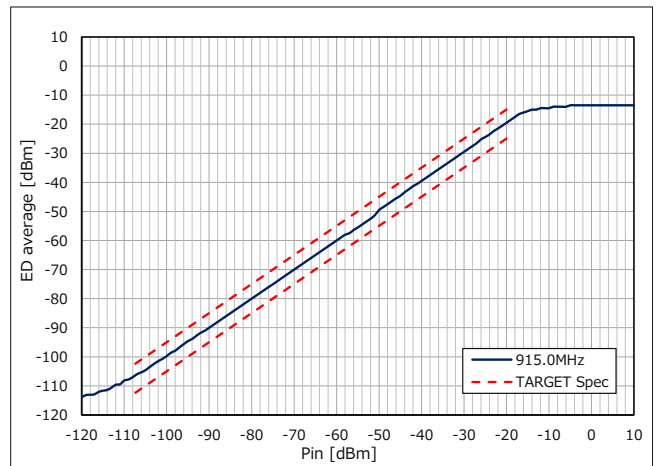


Figure 71 RF Input Level vs. ED average (Frequency = 915MHz)

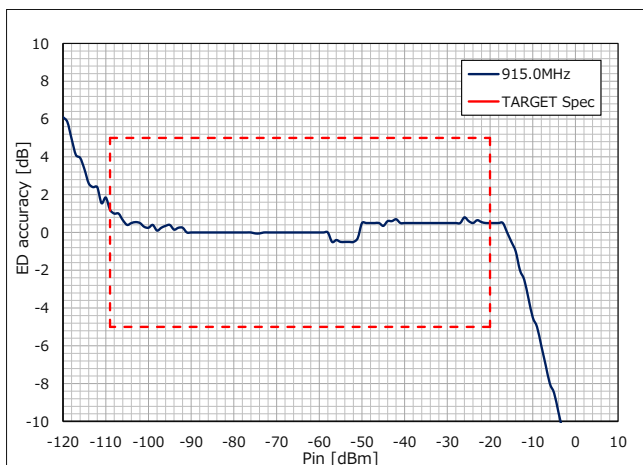


Figure 72 RF Input Level vs. ED accuracy (Frequency = 915MHz)

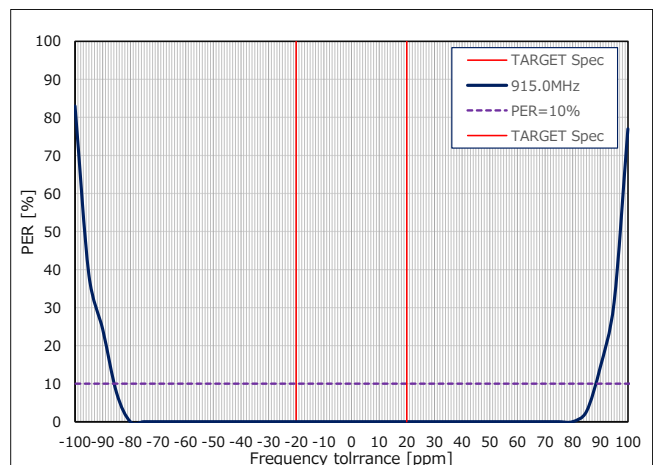


Figure 73 RF Frequency tolerance vs. Packet Error Rate (Frequency = 915MHz)

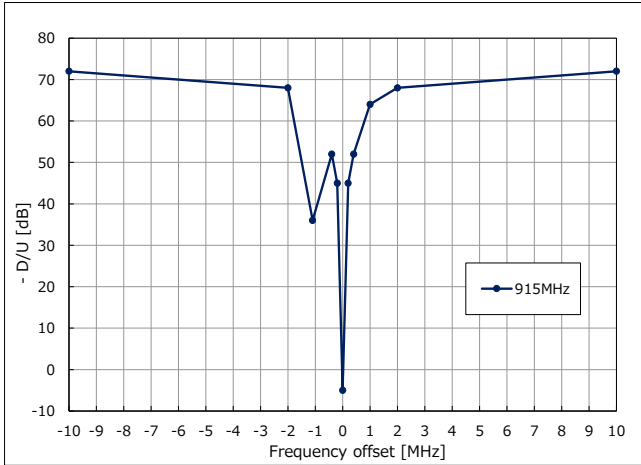


Figure 74 RF Frequency offset vs. Desire/Unwanted Signal Ratio (Frequency = 915MHz)

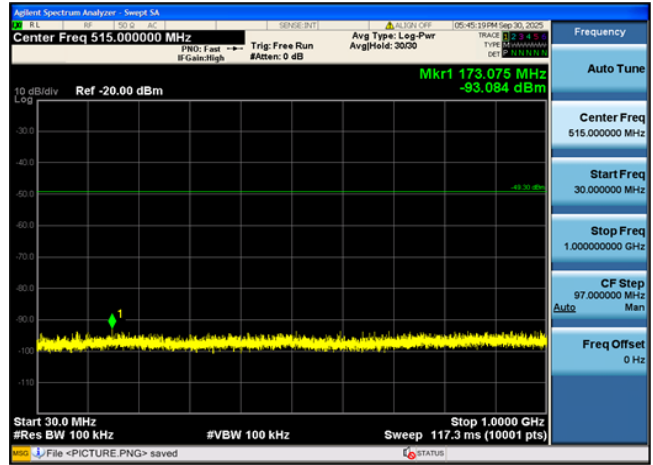


Figure 75 Receiver spurious emission (30MHz -1GHz) (Frequency = 915MHz)

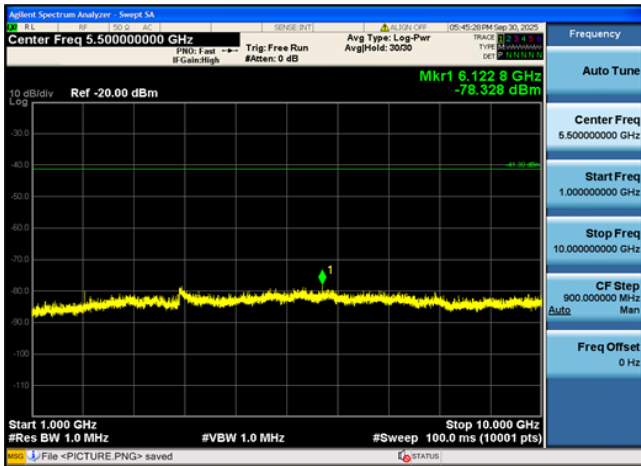


Figure 76 Receiver spurious emission (1GHz -10GHz) (Frequency = 915MHz)

2.3.2 FSK (150kbps, modulation index = 0.5)

Table 23 RX Electrical Characteristics 2

Items			RF Frequency [MHz]	Unit	Evaluation result	Spec
Receiver sensitivity	PER < 10% Length 250 octets		902.4	dBm	-105	-86.2 (*4)
			915.2		-105	
			927.6		-104	
Maximum Input level	PER < 10% Length 250 octets		902.4	dBm	10	-
			915.2		10	
			927.6		10	
RSSI accuracy	Average	RSSI range: -105dBm to -20dBm (*1)	902.4	dB	-1.5	-
			915.2		1.5	
			927.6		-2.0	
	MAX		902.4		-1.5	
			915.2		1.5	
			927.6		-2	
	MIN		902.4		-2	
			915.2		1	
			927.6		-2.5	
ED accuracy	Average	ED range: -105dBm to -20dBm (*1)	915.2	dB	1.1	-
	MAX		915.2		1.5	
	MIN		915.2		0.5	
Frequency tolerance	Max	PER < 10% Length 250 octets	915.2	ppm	≥ 85	±20
	Min				≤ -90	
Adjacent channel rejection	-400kHz	PER < 10% (*2) (*3) Length 250 octets	915.2	dB	47	10 (*4)
	+400kHz				47	
Alternate channel rejection	-800kHz	PER < 10% (*2) (*3) Length 250 octets	915.2	dB	57	30 (*4)
	+800kHz				58	
Co channel rejection	±0MHz	PER < 10% (*2) (*3) Length 250 octets	915.2	dB	-4	-
Blocking	+1MHz	PER < 10% (*2) (*3) Length 250 octets	915.2	dB	62	-
	-2MHz				66	
	+2MHz				66	
	-10MHz				69	
	+10MHz				70	
Image rejection	-1.1MHz-	PER < 10% (*2) (*3) Length 250 octets	915.2	dB	34	-
Receiver spurious emission	30 - 1000MHz		902.4	dBm /100kHz	-86.4	-
			915.2		-86.6	
			927.6		-86.2	
	1 - 10GHz		902.4	dBm /MHz	-71.5	-
			915.2		-72.5	
			927.6		-71.9	

(*1) Lower limit: RX sensitivity / Upper limit: Limit described in the user's manual (-5dBm) - FEM LNA gain (16dB) + SAW Filter Loss (1dB).

(*2) The level of the desired signal: RX sensitivity + 3dB (-102dBm)

(*3) Interference signal is non-modulated wave. (*4) IEEE.802.15.4-2020.

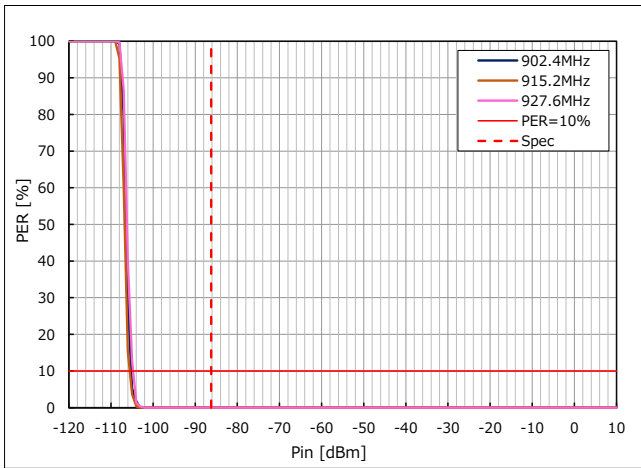


Figure 77 RF Input Level vs. Packet Error Rate
(Frequency = 902.4 / 915.2 / 927.6MHz)

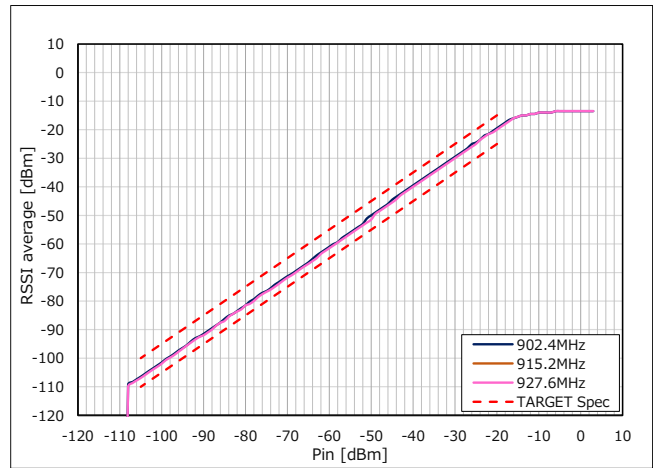


Figure 78 RF Input Level vs. RSSI average
(Frequency = 902.4 / 915.2 / 927.6MHz)

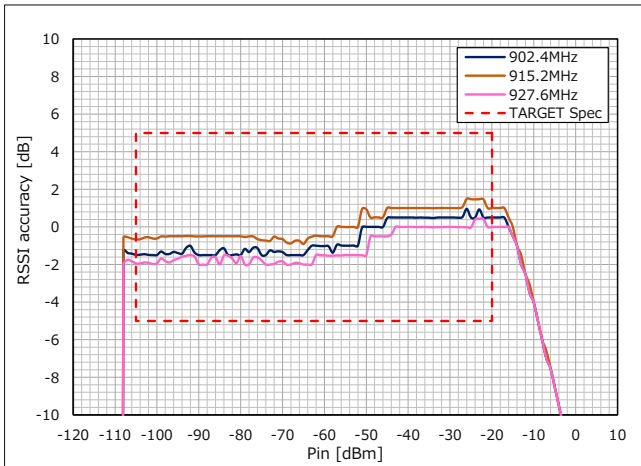


Figure 79 RF Input Level vs. RSSI accuracy
(Frequency = 902.4 / 915.2 / 927.6MHz)

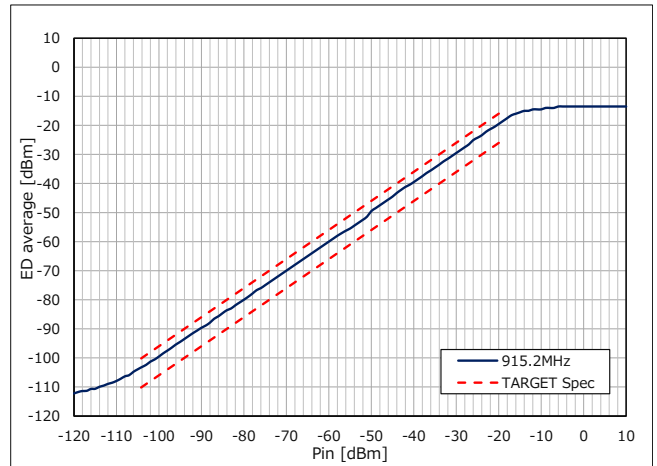


Figure 80 RF Input Level vs. ED average
(Frequency = 915.2MHz)

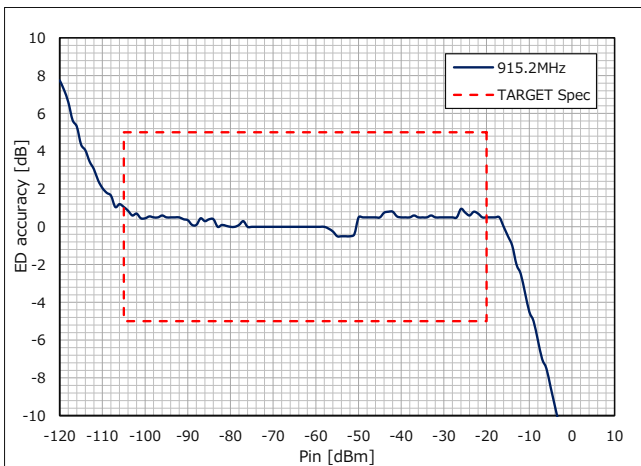


Figure 81 RF Input Level vs. ED accuracy
(Frequency = 915.2MHz)

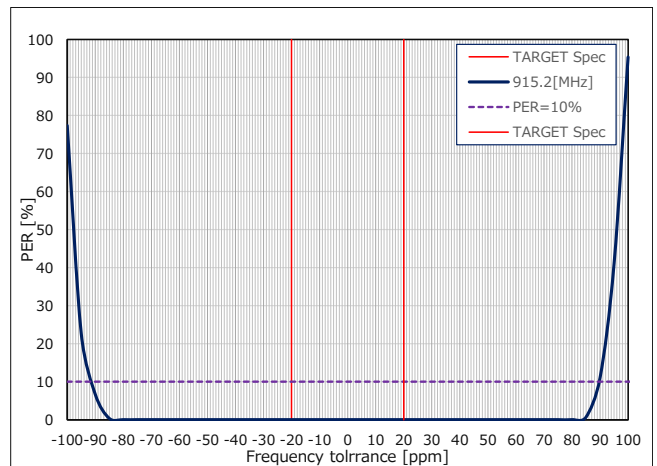


Figure 82 RF Frequency tolerance vs. Packet Error Rate
(Frequency = 915.2MHz)

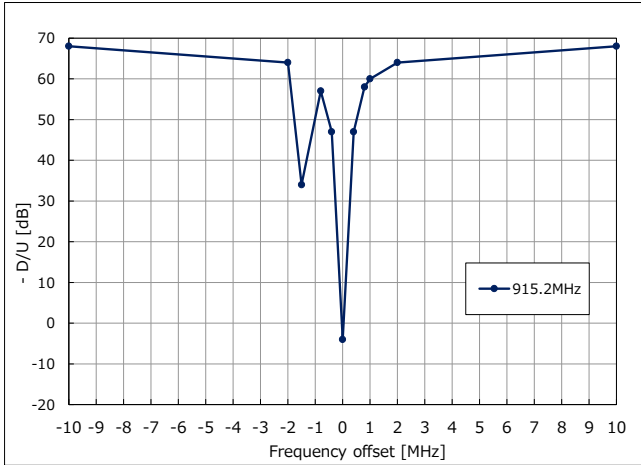


Figure 83 RF Frequency offset vs. Desire/Unwanted Signal Ratio (Frequency = 915.2MHz)

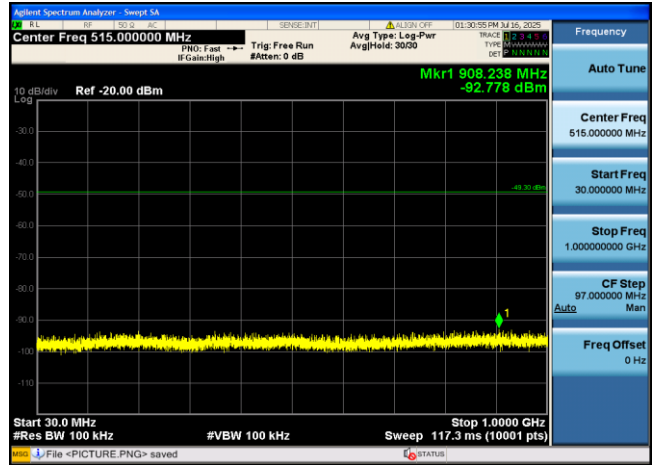


Figure 84 Receiver spurious emission (30MHz -1GHz) (Frequency = 915.2MHz)

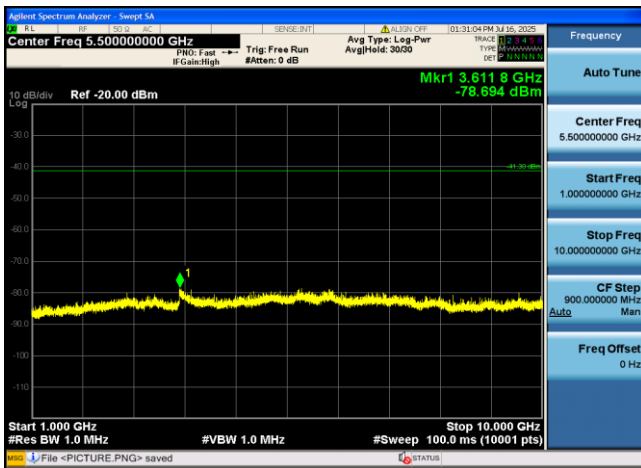


Figure 85 Receiver spurious emission (1GHz -10GHz) (Frequency = 915.2MHz)

2.3.3 OFDM (Option1, MCS6)

Table 24 RX Electrical Characteristics 3

Items			RF Frequency [MHz]	Unit	Evaluation result	Spec
Receiver sensitivity	PER < 10% Length 250 octets		903.2	dBm	-96	-85 (*6)
			915.2		-97	
			926.0		-97	
Maximum Input level	PER < 10% Length 250 octets		903.2	dBm	-10	-
			915.2		-11	
			926.0		-10	
RSSI accuracy	Average	RSSI range: -97dBm to -20dBm (*1)	903.2	dB	-1.5	-
			915.2		0.8	
			926.0		-1.7	
	MAX		903.2		-1.5	
			915.2		1.0	
			926.0		-1.5	
	MIN		903.2		-1.5	
			915.2		-1.0	
			926.0		-2.0	
ED accuracy	Average	ED range: -97dBm to -20dBm (*1)	915.2	dB	-1.0	-
	MAX		915.2		-1.0	
	MIN		915.2		-1.0	
Frequency tolerance	Max	PER < 10% Length 250 octets	915.2	ppm	≥ 80	±20
	Min				≤ -70	
Adjacent channel rejection	-1.2MHz	PER < 10% (*2) (*3) (*5) Length 250 octets	915.2	dB	24	2 (*7)
	+1.2MHz				25	
Alternate channel rejection	-2.4MHz	PER < 10% (*2) (*3) (*5) Length 250 octets	915.2	dB	44	26 (*7)
	+2.4MHz				43	
Co channel rejection	±0MHz	PER < 10% (*2) (*4) (*5) Length 250 octets	915.2	dB	-13	-23 (*7)
Blocking	-2MHz	PER < 10% (*2) (*3) (*5) Length 250 octets	915.2	dB	25	-
	+2MHz				43	
	-10MHz				44	
	+10MHz				45	
Image rejection	-1.3MHz	PER < 10% (*2) (*3) (*5) Length 250 octets	915.2	dB	22	-
Receiver spurious emission	30 - 1000MHz		903.2	dBm /100kHz	-85.5	-
			915.2		-86.3	
			926.0		-86.3	
	1 - 10GHz		903.2	dBm /MHz	-70.4	-
			915.2		-72.3	
			926.0		-71.5	

(*1) Lower limit: RX sensitivity / Upper limit: Limit described in the user's manual (-5dBm) - FEM LNA gain (16dB) + SAW Filter Loss (1dB).

(*2) The level of the desired signal: RX sensitivity + 3dB (-94dBm)

(*3) Interference signal pattern defined by the certification body (*4) Interference signal pattern without LTF and STF defined by Wi-SUN.

(*5) Interference signal is modulated wave. (*6) IEEE.802.15.4-2020.

(*7) Wi-SUN PHY Technical Specification - Amendment 1VA9 (11 Nov 2022)

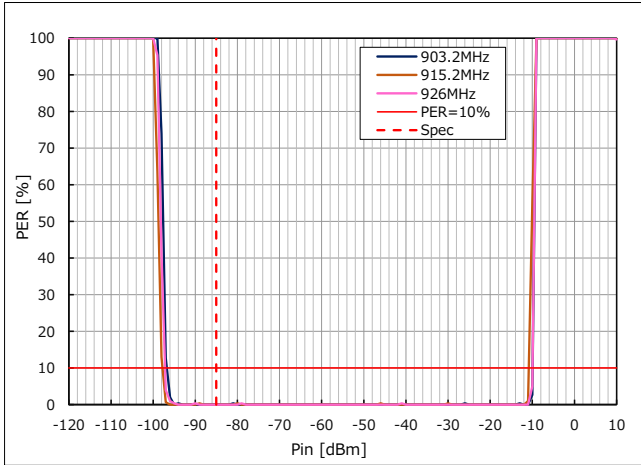


Figure 86 RF Input Level vs. Packet Error Rate
(Frequency = 903.2 / 915.2 / 926.0MHz)

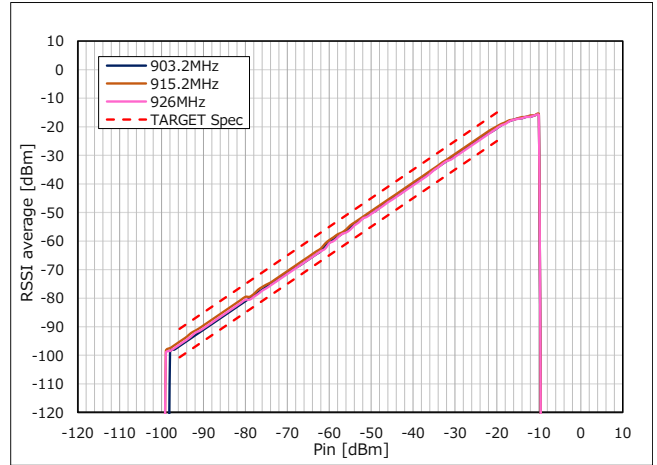


Figure 87 RF Input Level vs. RSSI average
(Frequency = 903.2 / 915.2 / 926.0MHz)

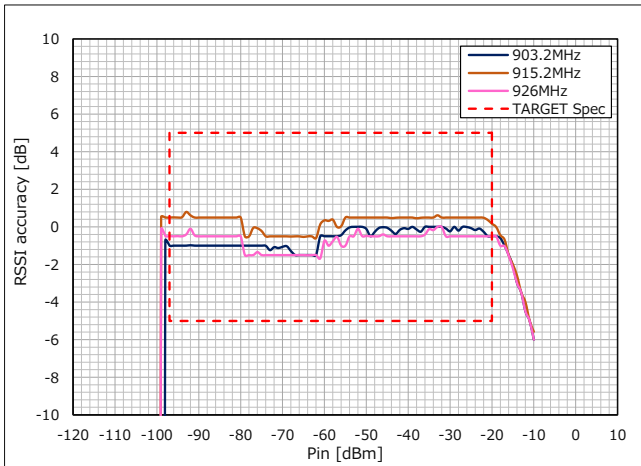


Figure 88 RF Input Level vs. RSSI accuracy
(Frequency = 903.2 / 915.2 / 926.0MHz)

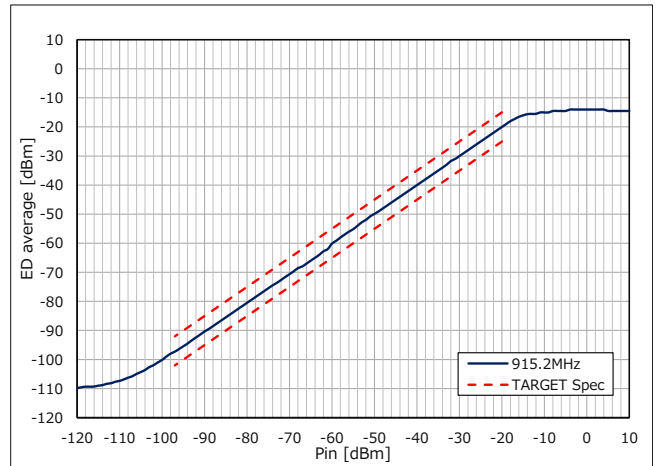


Figure 89 RF Input Level vs. ED average
(Frequency = 915.2MHz)

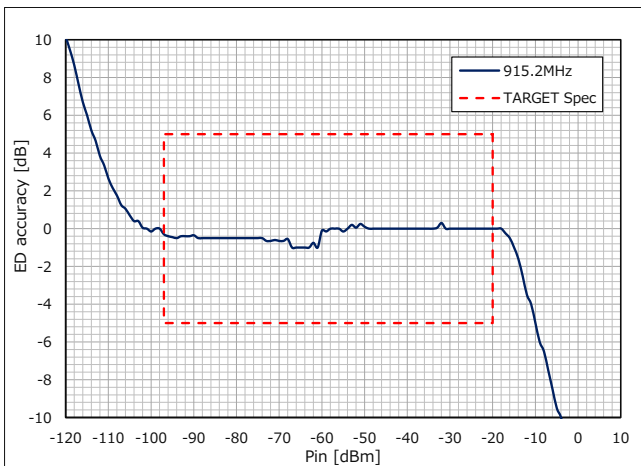


Figure 90 RF Input Level vs. ED accuracy
(Frequency = 915.2MHz)

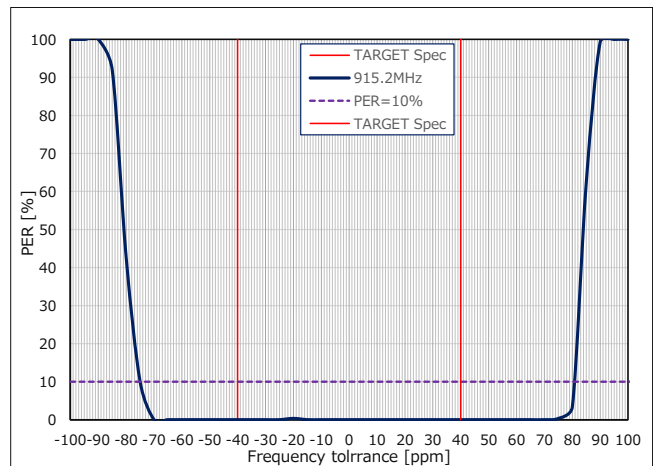


Figure 91 RF Frequency tolerance vs. Packet Error Rate
(Frequency = 915.2MHz)

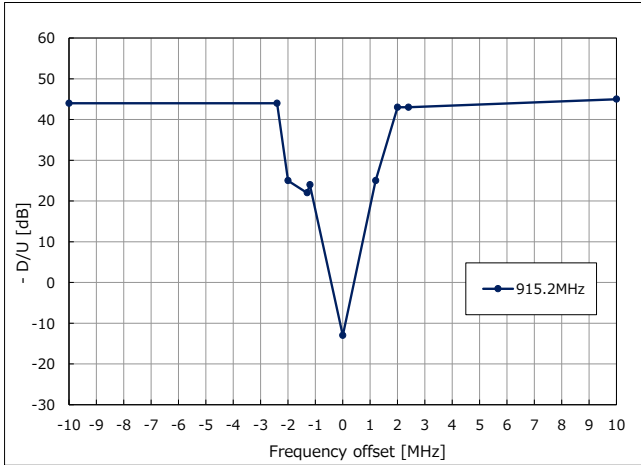


Figure 92 RF Frequency offset vs. Desire/Unwanted Signal Ratio (Frequency = 915.2MHz)

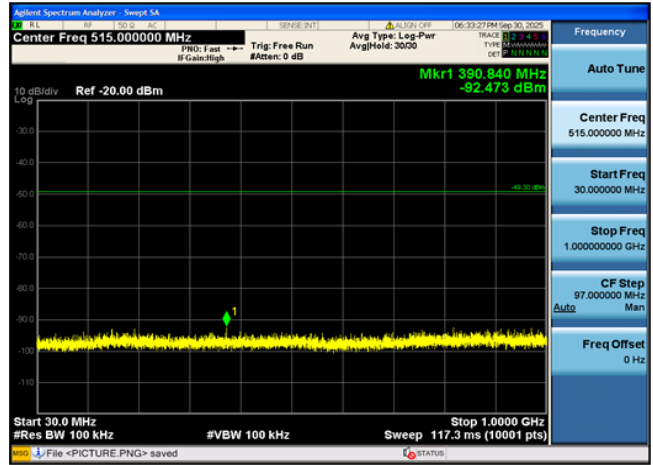


Figure 93 Receiver spurious emission (30MHz -1GHz) (Frequency = 915.2MHz)

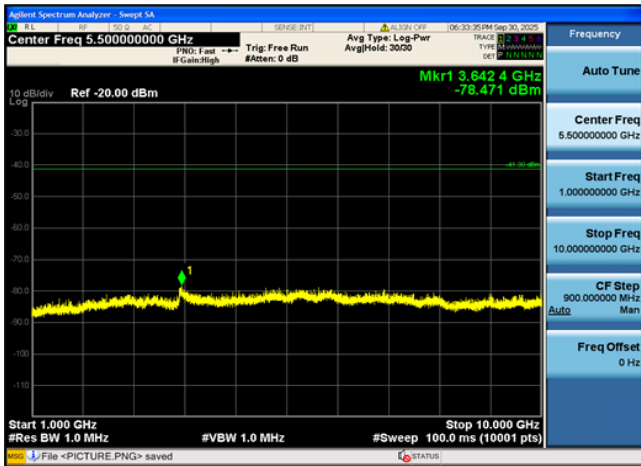


Figure 94 Receiver spurious emission (1GHz -10GHz) (Frequency = 915.2MHz)

2.3.4 OFDM (Option2, MCS6)

Table 25 RX Electrical Characteristics 4

Items		RF Frequency [MHz]	Unit	Evaluation result	Spec		
Receiver sensitivity	PER < 10% Length 250 octets	902.8	dBm	-99	-88 (*6)		
		914.8		-100			
		926.8		-99			
Maximum Input level	PER < 10% Length 250 octets	902.8	dBm	-17	-		
		914.8		-18			
		926.8		-16			
RSSI accuracy	Average	RSSI range: -100dBm to -20dBm (*1)	dB	902.8	-0.8	-	
				914.8	1.5		
				926.8	-1.2		
	MAX			902.8	1.0		
				914.8	1.5		
				926.8	-1.0		
	MIN			902.8	-1.0		
				914.8	1.0		
				926.8	-1.5		
ED accuracy	Average	ED range: -100dBm to -20dBm (*1)	dB	914.8	-0.9	-	
				MAX	914.8		0.5
				MIN	914.8		-1.0
Frequency tolerance	Max	PER < 10% Length 250 octets	914.8	ppm	≥ 65	±20	
	Min				≤ -65		
Adjacent channel rejection	-800kHz	PER < 10% (*2) (*3) (*5) Length 250 octets	914.8	dB	25	2 (*7)	
	+800kHz				40		
Alternate channel rejection	-1.6MHz	PER < 10% (*2) (*3) (*5) Length 250 octets	914.8	dB	45	26 (*7)	
	+1.6MHz				46		
Co channel rejection	±0MHz	PER < 10% (*2) (*4) (*5) Length 250 octets	914.8	dB	-13	-23 (*7)	
Blocking	-2MHz	PER < 10% (*2) (*3) (*5) Length 250 octets	914.8	dB	47	-	
	+2MHz				46		
	-10MHz				47		
	+10MHz				47		
Image rejection	-1.04MHz	PER < 10% (*2) (*3) (*5) Length 250 octets	914.8	dB	10	-	
Receiver spurious emission	30 - 1000MHz		dBm /100kHz	902.8	-86.3	-	
				914.8	-86.7		
				926.8	-86.6		
	1 - 10GHz		902.8	-71.9	-		
			914.8	-72.4			
			926.8	-71.5			

(*1) Lower limit: RX sensitivity / Upper limit: Limit described in the user's manual (-5dBm) - FEM LNA gain (16dB) + SAW Filter Loss (1dB).

(*2) The level of the desired signal: RX sensitivity + 3dB (-97dBm)

(*3) Interference signal pattern defined by the certification body (*4) Interference signal pattern without LTF and STF defined by Wi-SUN.

(*5) Interference signal is modulated wave. (*6) IEEE.802.15.4-2020.

(*7) Wi-SUN PHY Technical Specification - Amendment 1VA9 (11 Nov 2022)

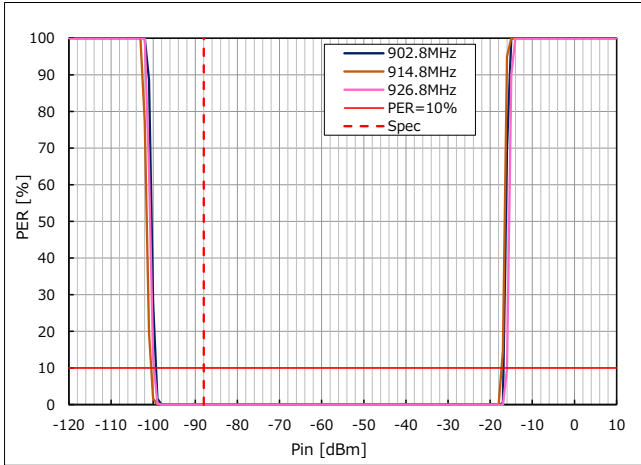


Figure 95 RF Input Level vs. Packet Error Rate
(Frequency = 902.8 / 914.8 / 926.8MHz)

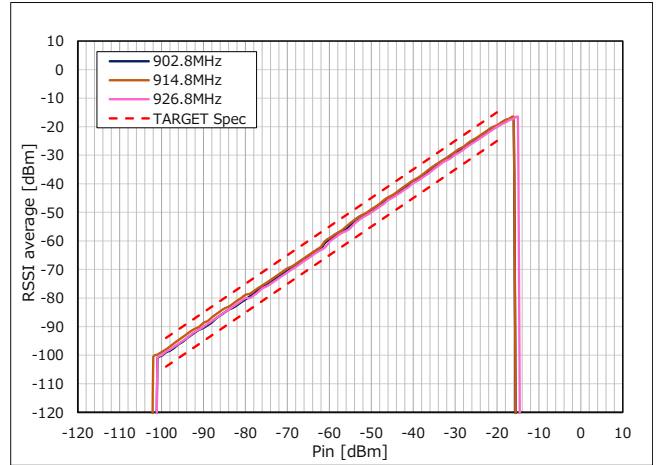


Figure 96 RF Input Level vs. RSSI average
(Frequency = 902.8 / 914.8 / 926.8MHz)

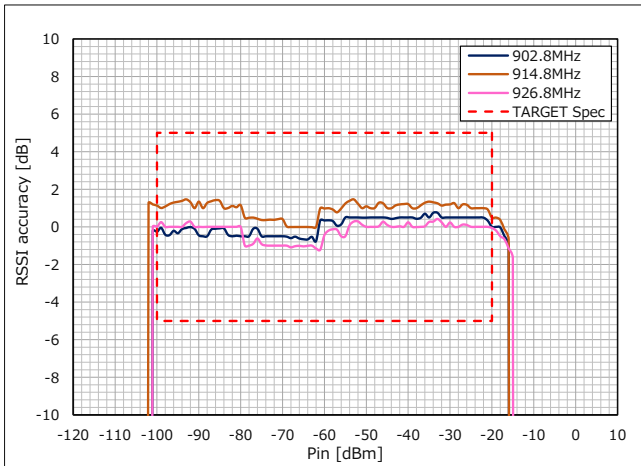


Figure 97 RF Input Level vs. RSSI accuracy
(Frequency = 902.8 / 914.8 / 926.8MHz)

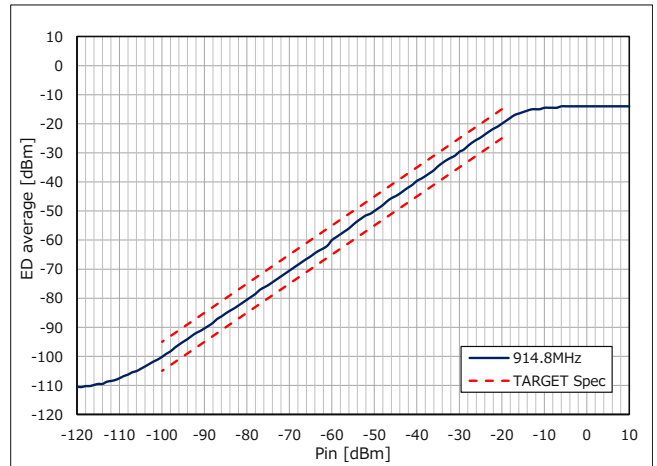


Figure 98 RF Input Level vs. ED average
(Frequency = 914.8MHz)

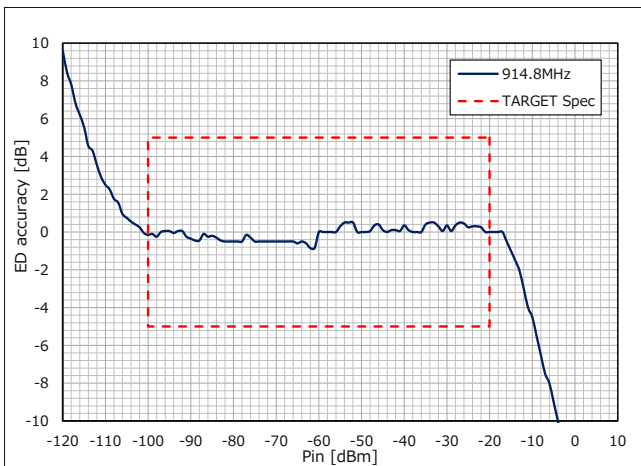


Figure 99 RF Input vs. Level ED accuracy
(Frequency = 914.8MHz)

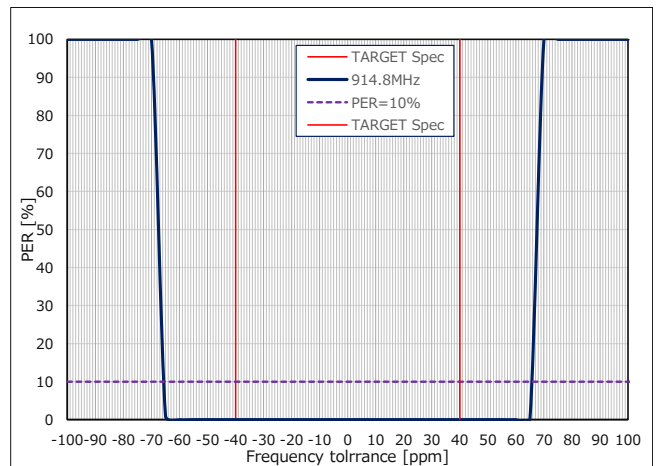


Figure 100 RF Frequency tolerance vs. Packet Error Rate
(Frequency = 914.8MHz)

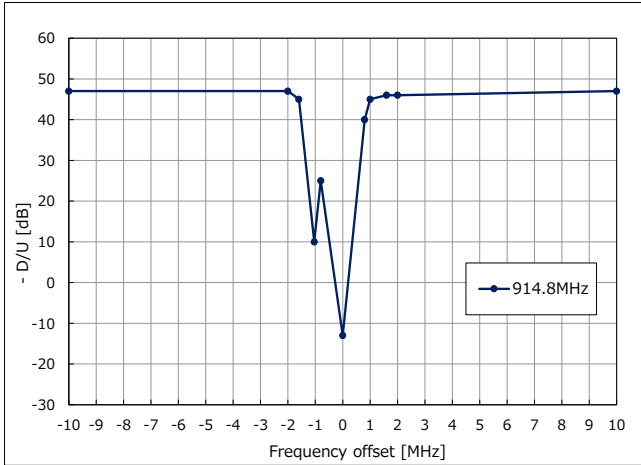


Figure 101 RF Frequency offset vs. Desire/Unwanted Signal Ratio (Frequency = 914.8MHz)

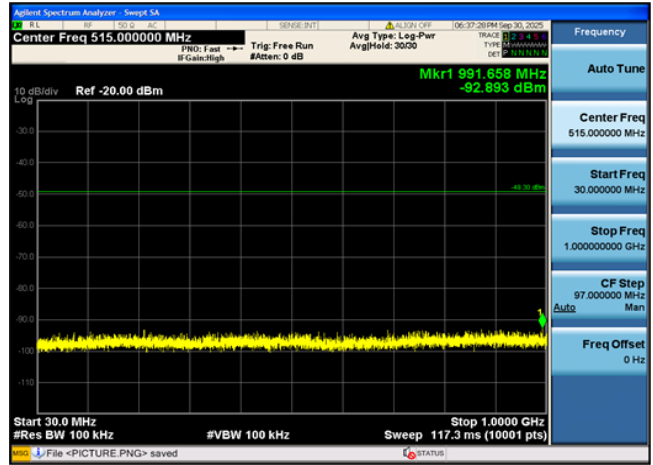


Figure 102 Receiver spurious emission (30MHz -1GHz) (Frequency = 914.8MHz)

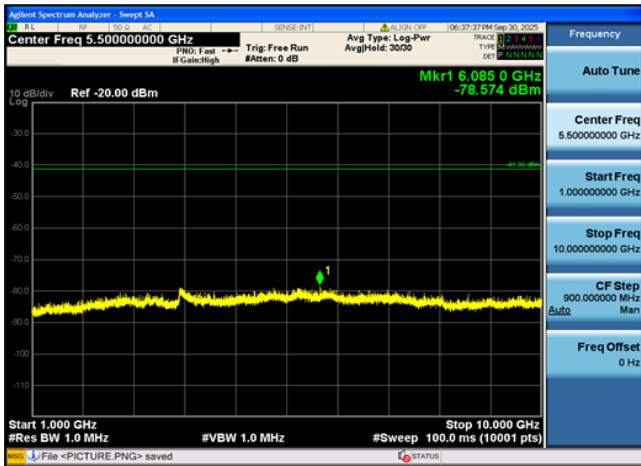


Figure 103 Receiver spurious emission (1GHz -10GHz) (Frequency = 914.8MHz)

2.3.5 OFDM (Option3, MCS6)

Table 26 RX Electrical Characteristics 5

Items		RF Frequency [MHz]	Unit	Evaluation result	Spec		
Receiver sensitivity	PER < 10% Length 250 octets	902.4	dBm	-102	-91 (*6)		
		915.2		-103			
		927.6		-103			
Maximum Input level	PER < 10% Length 250 octets	902.4	dBm	-14	-		
		915.2		-14			
		927.6		-13			
RSSI accuracy	Average	RSSI range: -103dBm to -20dBm (*1)	dB	902.4	1.0	-	
				915.2	1.7		
				927.6	-1.0		
	MAX			902.4	1.5		
				915.2	2.0		
				927.6	1.0		
	MIN			902.4	1.0		
				915.2	1.5		
				927.6	-1.0		
ED accuracy	Average	ED range: -103dBm to -20dBm (*1)	dB	915.2	1.0	-	
				MAX	915.2		1.0
				MIN	915.2		1.0
Frequency tolerance	Max	PER < 10% Length 250 octets	915.2	ppm	≥ 50	±20	
	Min				≤ -50		
Adjacent channel rejection	-400kHz	PER < 10% (*2) (*3) (*5) Length 250 octets	915.2	dB	37	2 (*7)	
	+400kHz				36		
Alternate channel rejection	-800kHz	PER < 10% (*2) (*3) (*5) Length 250 octets	915.2	dB	47	26 (*7)	
	+800kHz				49		
Co channel rejection	±0MHz	PER < 10% (*2) (*4) (*5) Length 250 octets	915.2	dB	-13	-23 (*7)	
Blocking	+1MHz	PER < 10% (*2) (*3) (*5) Length 250 octets	915.2	dB	49	-	
	-2MHz				49		
	+2MHz				49		
	-10MHz				49		
	+10MHz				50		
Image rejection	-1.5MHz	PER < 10% (*2) (*3) (*5) Length 250 octets	915.2	dB	18	-	
Receiver spurious emission	30 - 1000MHz		902.4	dBm /100kHz	-86.4	-	
					915.2		-85.9
					927.6		-86.4
	1 - 10GHz			dBm /MHz	-72.3	-	
					915.2		-72.0
					927.6		-72.2

(*1) Lower limit: RX sensitivity / Upper limit: Limit described in the user's manual (-5dBm) - FEM LNA gain (16dB) + SAW Filter Loss (1dB).

(*2) The level of the desired signal: RX sensitivity + 3dB (-100dBm)

(*3) Interference signal pattern defined by the certification body (*4) Interference signal pattern without LTF and STF defined by Wi-SUN.

(*5) Interference signal is modulated wave. (*6) IEEE.802.15.4-2020.

(*7) Wi-SUN PHY Technical Specification - Amendment 1VA9 (11 Nov 2022)

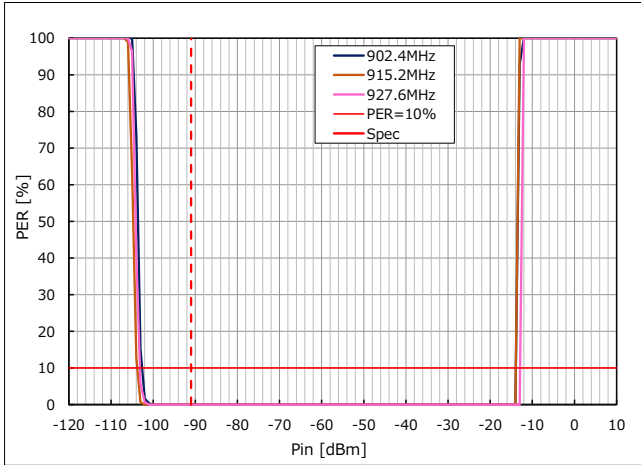


Figure 104 RF Input Level vs. Packet Error Rate
(Frequency = 902.4 / 915.2 / 927.6MHz)

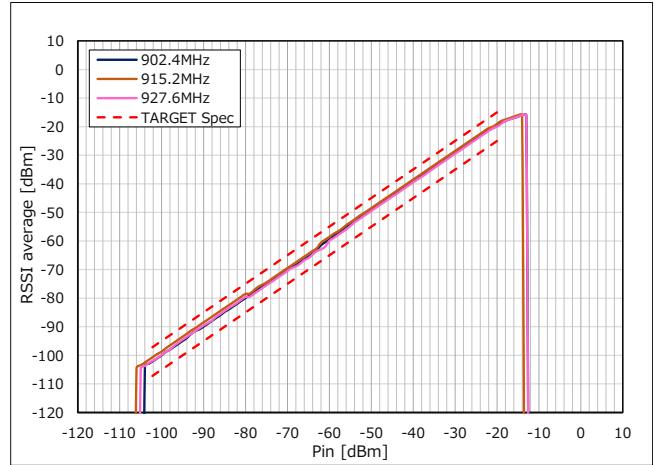


Figure 105 RF Input Level vs. RSSI average
(Frequency = 902.4 / 915.2 / 927.6MHz)

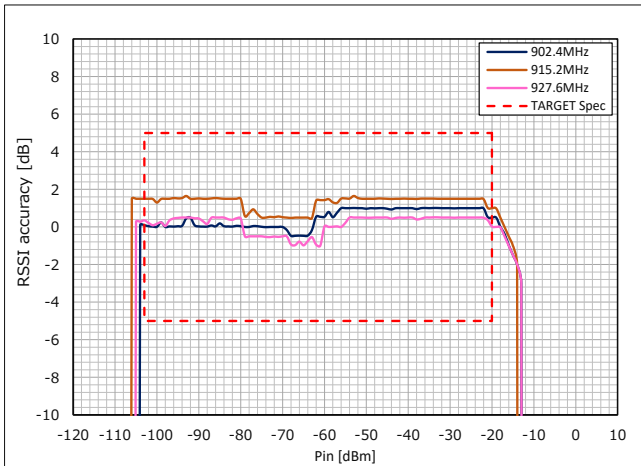


Figure 106 RF Input Level vs. RSSI accuracy
(Frequency = 902.4 / 915.2 / 927.6MHz)

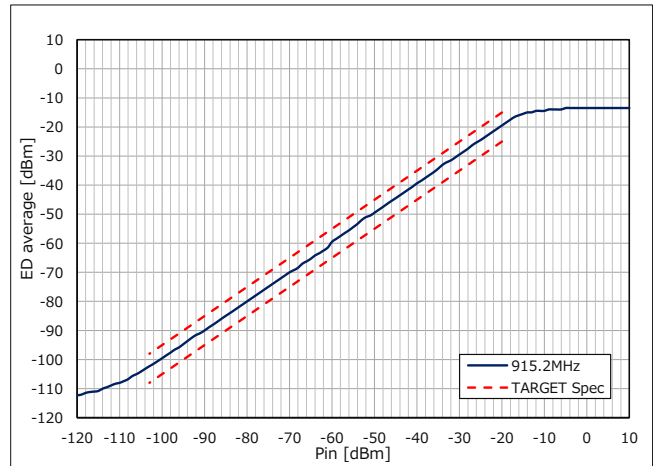


Figure 107 RF Input Level vs. ED average
(Frequency = 915.2MHz)

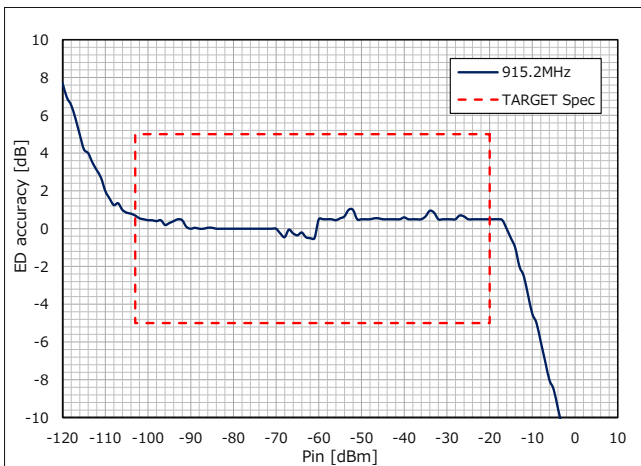


Figure 108 RF Input Level vs. ED accuracy
(Frequency = 915.2MHz)

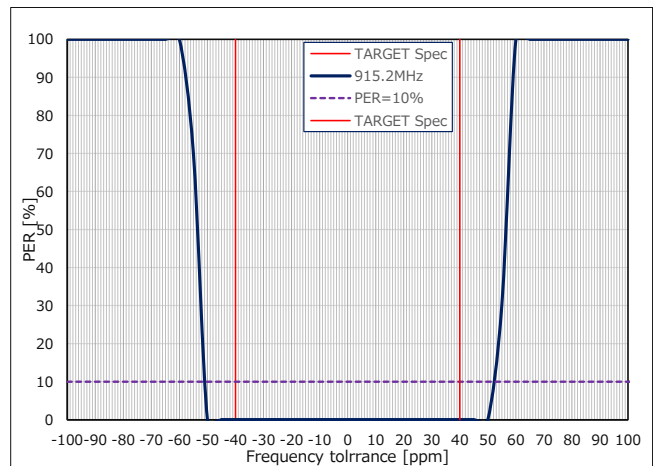


Figure 109 RF Frequency tolerance vs. Packet Error Rate
(Frequency = 915.2MHz)

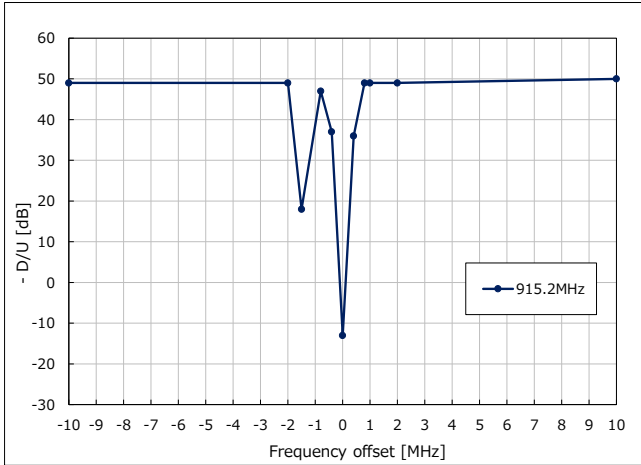


Figure 110 RF Frequency offset vs. Desire/Unwanted Signal Ratio (Frequency = 915.2MHz)

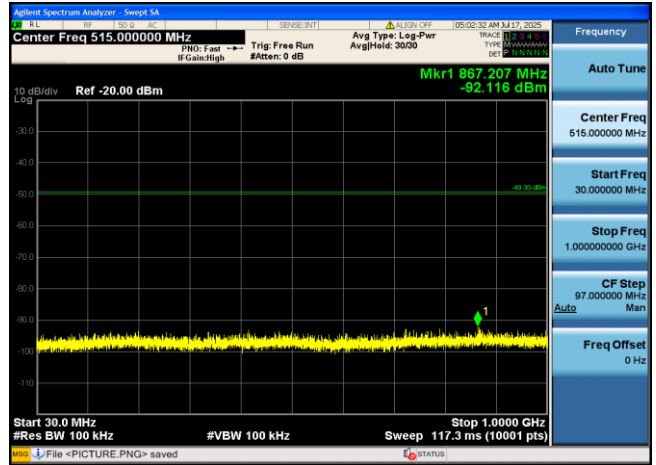


Figure 111 Receiver spurious emission (30MHz -1GHz) (Frequency = 915.2MHz)

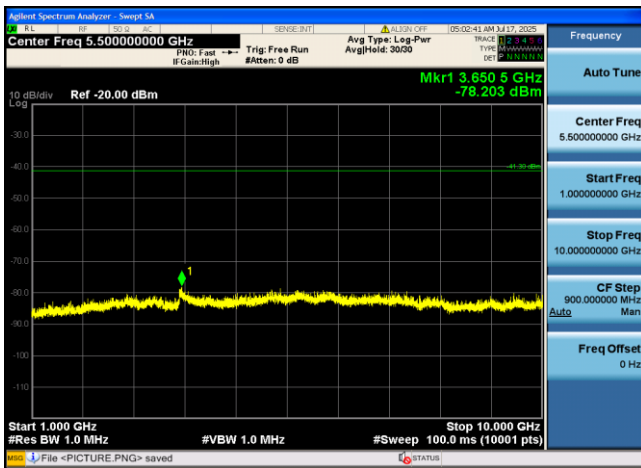


Figure 112 Receiver spurious emission (1GHz -10GHz) (Frequency = 915.2MHz)

2.3.6 OFDM (Option4, MCS6)

Table 27 RX Electrical Characteristics 6

Items		RF Frequency [MHz]	Unit	Evaluation result	Spec
Receiver sensitivity	PER < 10% Length 250 octets	902.2	dBm	-105	-94 (*6)
		915.0		-106	
		927.8		-106	
Maximum Input level	PER < 10% Length 250 octets	902.2	dBm	-14	-
		915.0		-15	
		927.8		-14	
RSSI accuracy	Average	902.2	dB	1.5	-
		915.0		2.0	
		927.8		-1.0	
	MAX	902.2		1.5	
		915.0		2.0	
		927.8		1.0	
	MIN	902.2		1.0	
		915.0		1.5	
		927.8		-1.0	
ED accuracy	Average	915.0	dB	1.0	-
	MAX	915.0		1.0	
	MIN	915.0		0.5	
Frequency tolerance	Max	915.0	ppm	-40	±20
	Min			40	
Adjacent channel rejection	-200kHz	915.0	dB	28	2 (*7)
	+200kHz			27	
Alternate channel rejection	-400kHz	915.0	dB	45	26 (*7)
	+400kHz			47	
Co channel rejection	±0MHz	915.0	dB	-13	-23 (*7)
Blocking	+1MHz	915.0	dB	51	-
	-2MHz			52	
	+2MHz			52	
	-10MHz			52	
	+10MHz			53	
Image rejection	-1.1MHz	915.0	dB	19	-
Receiver spurious emission	30 - 1000MHz	902.2	dBm /100kHz	-86.2	-
		915.0		-86.2	
		927.8		-86.7	
	1 - 10GHz	902.2	dBm /MHz	-71.9	-
		915.0		-72.0	
		927.8		-71.5	

(*1) Lower limit: RX sensitivity / Upper limit: Limit described in the user's manual (-5dBm) - FEM LNA gain (16dB) + SAW Filter Loss (1dB).

(*2) The level of the desired signal: RX sensitivity + 3dB (-103dBm)

(*3) Interference signal pattern defined by the certification body. (*4) Interference signal pattern without LTF and STF defined by Wi-SUN.

(*5) Interference signal is modulated wave. (*6) IEEE.802.15.4-2020.

(*7) Wi-SUN PHY Technical Specification - Amendment 1VA9 (11 Nov 2022).

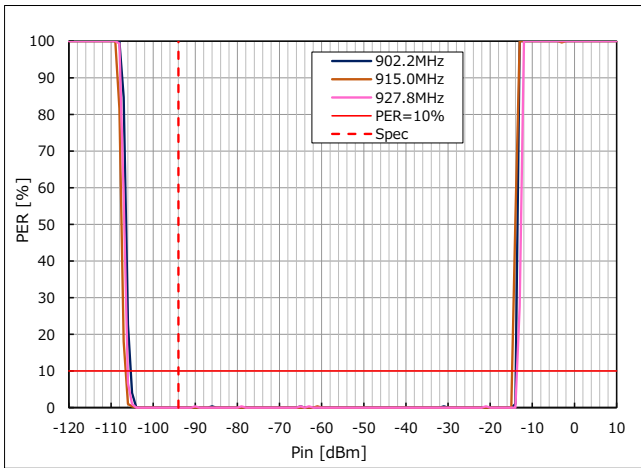


Figure 113 RF Input Level vs. Packet Error Rate
(Frequency = 902.2 / 915.0 / 927.8MHz)

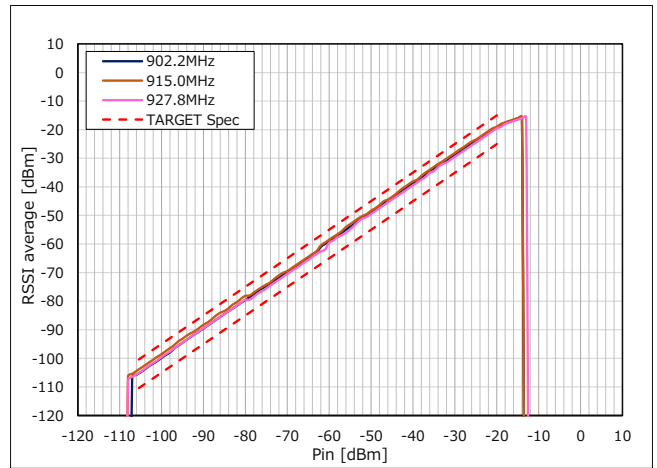


Figure 114 RF Input Level vs. RSSI average
(Frequency = 902.2 / 915.0 / 927.8MHz)

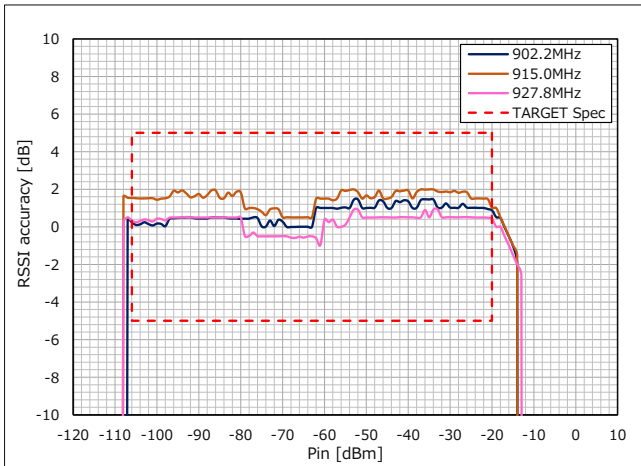


Figure 115 RF Input Level vs. RSSI accuracy
(Frequency = 902.2 / 915.0 / 927.8MHz)

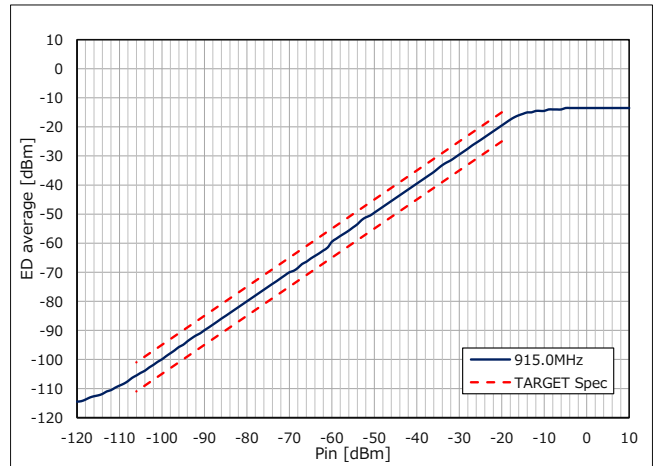


Figure 116 RF Input Level vs. ED average
(Frequency = 915.0MHz)

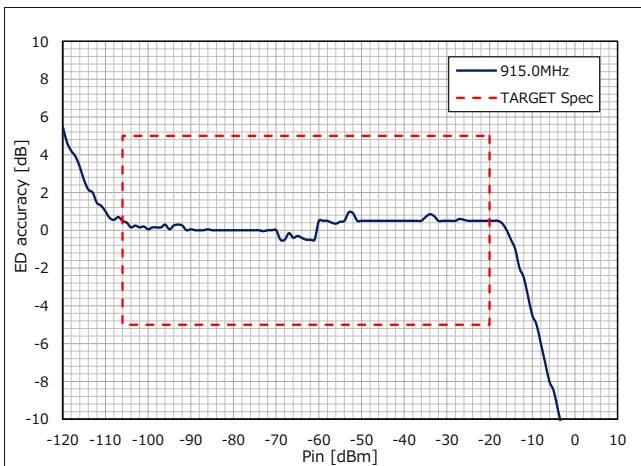


Figure 117 RF Input Level vs. ED accuracy
(Frequency = 915.0MHz)

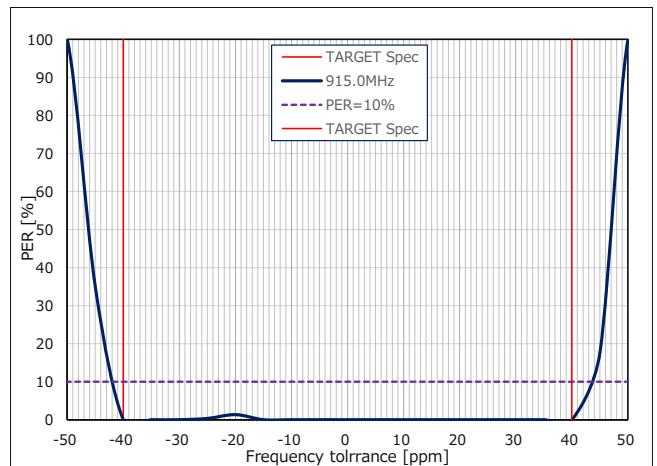


Figure 118 RF Frequency tolerance vs. Packet Error Rate
(Frequency = 915.0MHz)

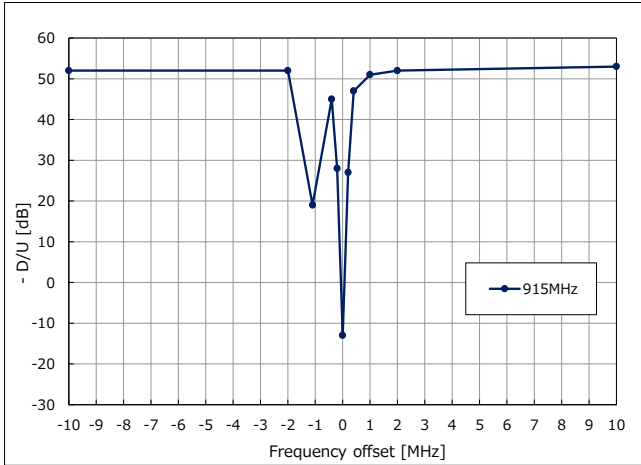


Figure 119 RF Frequency offset vs. Desire/Unwanted Signal Ratio (Frequency = 915.0MHz)

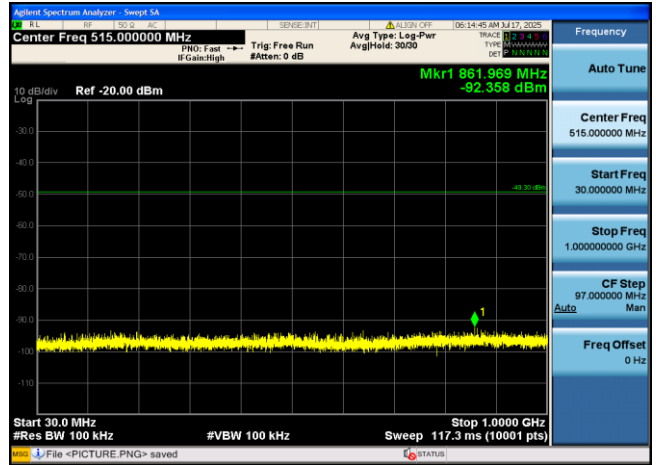


Figure 120 Receiver spurious emission (30MHz -1GHz) (Frequency = 915.0MHz)

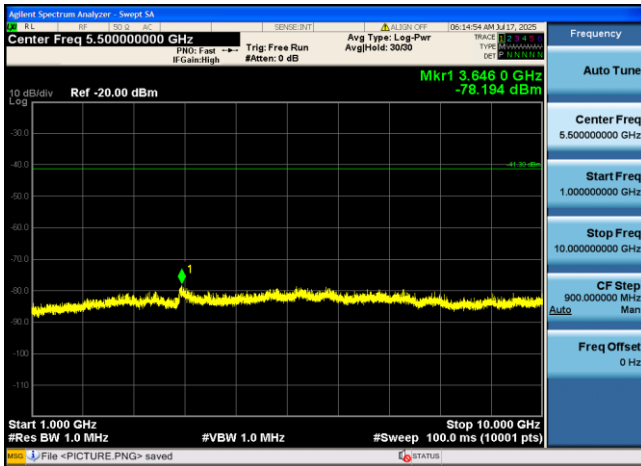


Figure 121 Receiver spurious emission (1GHz -10GHz) (Frequency = 915.0MHz)

3. Characteristics of FHSS operation

3.1 FSK

This chapter describes typical characteristics of FHSS operation.

The signal conditions used for measurement are shown below.

Preamble=8byte, Data Length=20byte, Transmit Interval=2ms, Channel switching=random.

Frequency=915MHz (50kbps) / 915.2MHz (150kbps)

Table 28 Characteristics of FHSS operation

Items		Unit	Result	Spec
20dB Bandwidth	50kbps	kHz	94.8	< 250
	150kbps		182.7	
Carrier Frequency Separation	50kbps	kHz	200	≥ 20dB Bandwidth
	150kbps		400	
Number of Hopping Frequencies	50kbps	ch	129	≥ 50
	150kbps		64	
Average Time of Occupancy	50kbps	ms	121.4	≤ 400 @ 20s
	150kbps		159.1	

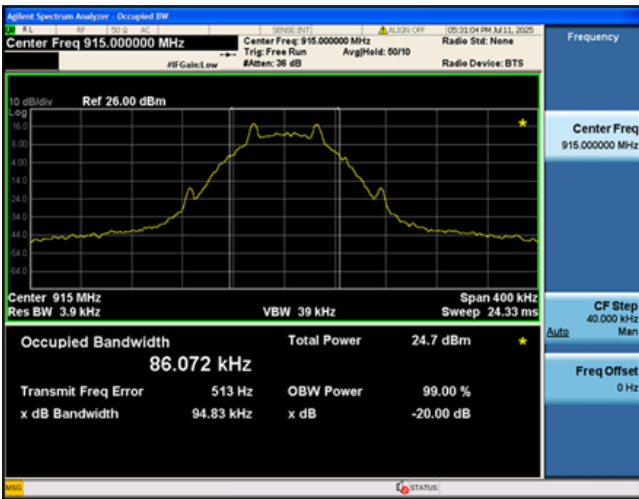


Figure 122 20dB Bandwidth (50kbps)

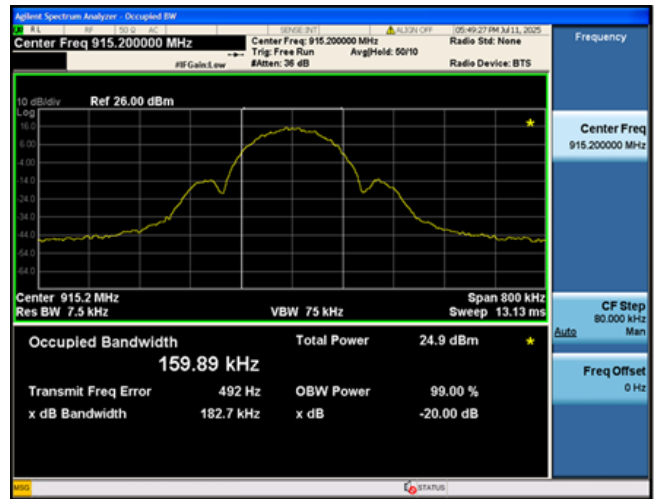


Figure 123 20dB Bandwidth (150kbps)

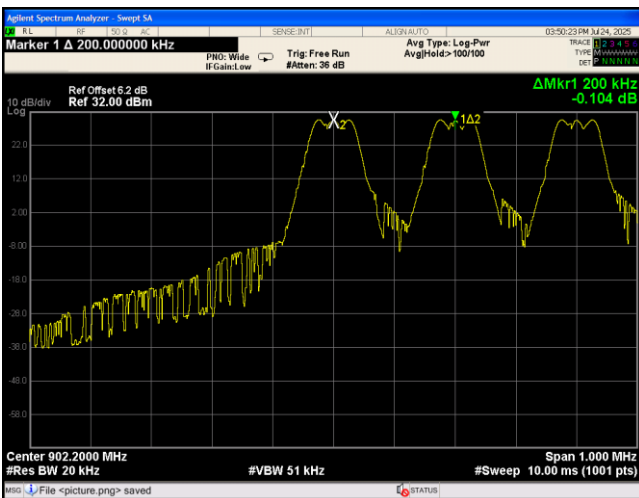


Figure 124 Carrier Frequency Separation (50kbps)

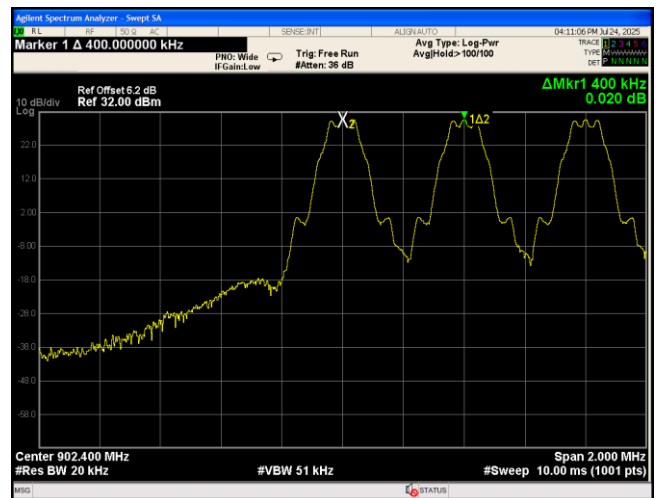


Figure 125 Carrier Frequency Separation (150kbps)

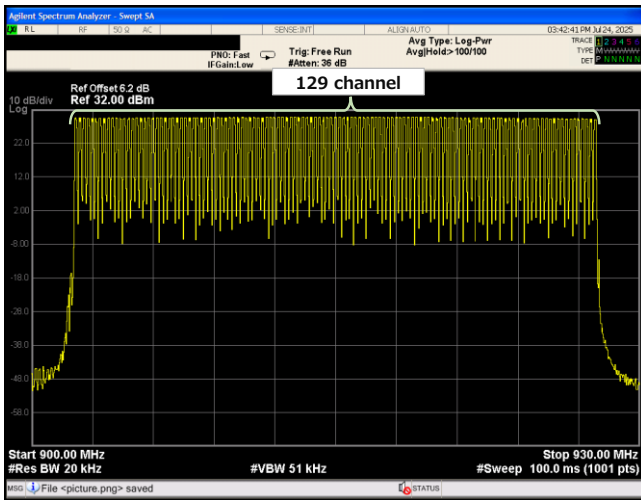


Figure 126 Number of Hopping Frequency (50kbps)

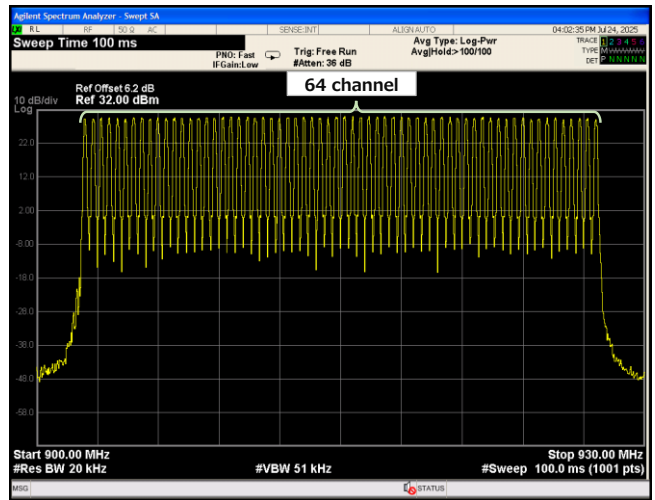


Figure 127 Number of Hopping Frequency (150kbps)

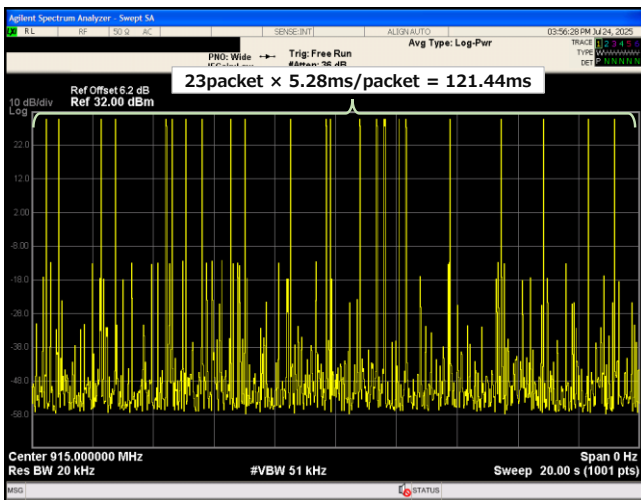


Figure 128 Average Time of Occupancy (50kbps)

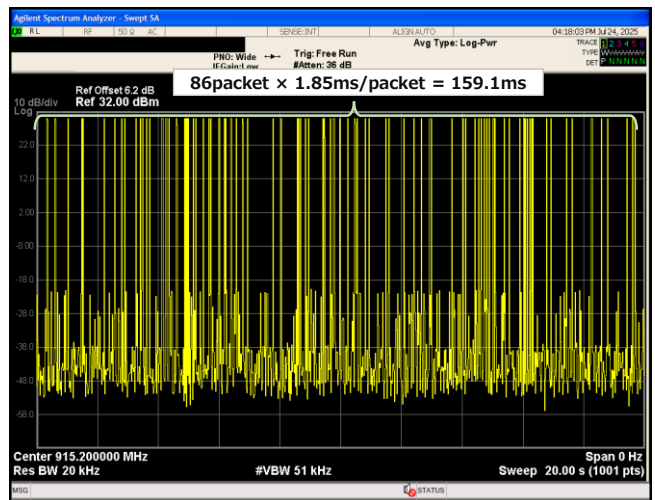


Figure 129 Average Time of Occupancy (150kbps)

3.2 OFDM

This chapter describes typical characteristics of FHSS operation.

The signal conditions used for measurement are shown below.

STF=4symbols (default), LTF=2symbols (fixed), Data Length=20byte (default), Transmit Interval=2ms (default), Channel switching=random.

Frequency=915.2MHz (Option3 MCS6) / 915MHz (Option4 MCS6)

Table 29 Characteristics of FHSS operation

Items	Unit	Result	Spec
20dB Bandwidth	Option3 MCS6	317.8	< 500
	Option4 MCS6	181.2	< 250
Carrier Frequency Separation	Option3 MCS6	400	≥ 20dB Bandwidth
	Option4 MCS6	200	
Number of Hopping Frequencies	Option3 MCS6	64	≥ 25
	Option4 MCS6	129	≥ 50
Average Time of Occupancy	Option3 MCS6	48.1	≤ 400 @ 10s
	Option4 MCS6	75.1	≤ 400 @ 20s

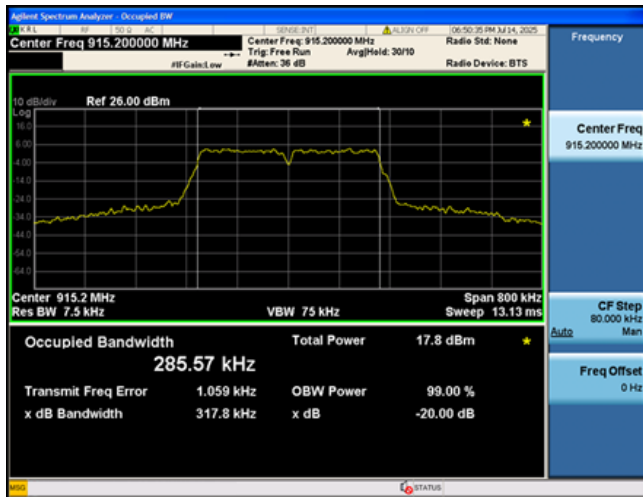


Figure 130 20dB Bandwidth (Option3 MCS6)

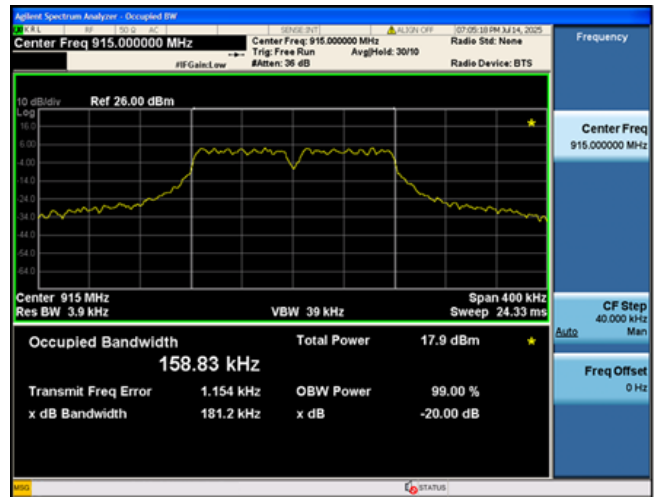


Figure 131 20dB Bandwidth (Option4 MCS6)

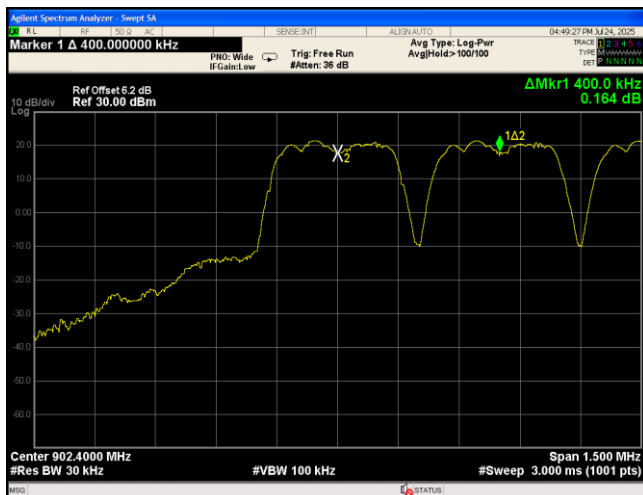


Figure 132 Carrier Frequency Separation (Option3 MCS6)



Figure 133 Carrier Frequency Separation (Option4 MCS6)

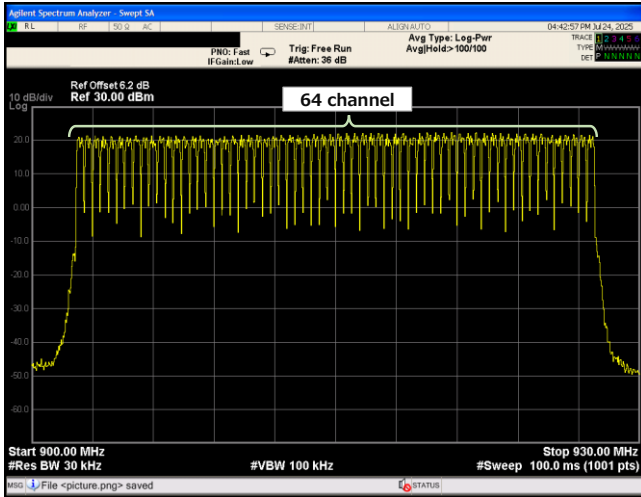


Figure 134 Number of Hopping Frequency (Option3 MCS6)

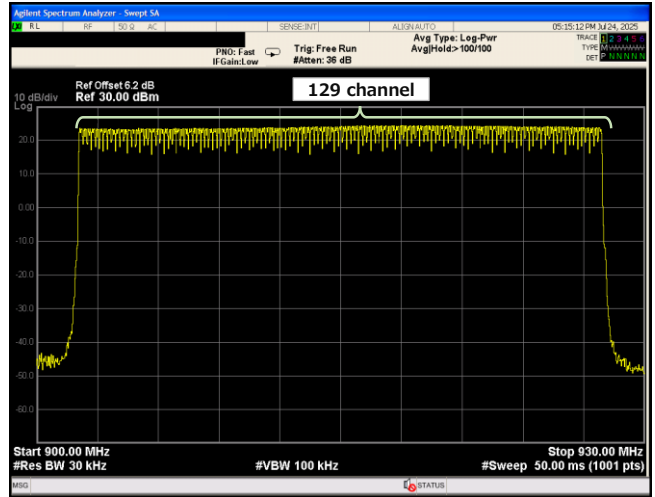


Figure 135 Number of Hopping Frequency (Option4 MCS6)

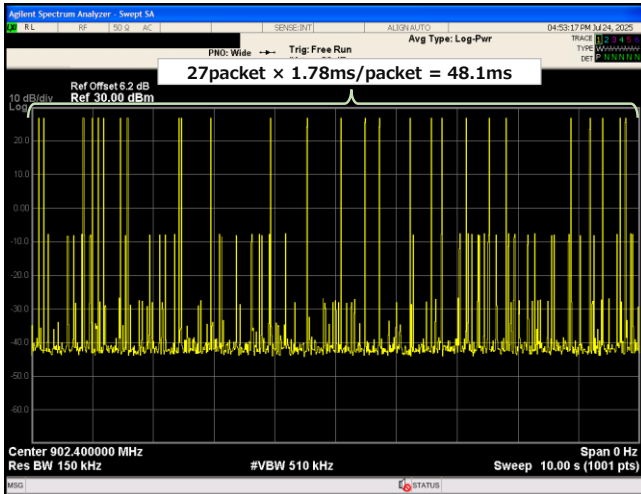


Figure 136 Average Time of Occupancy (Option3 MCS6)

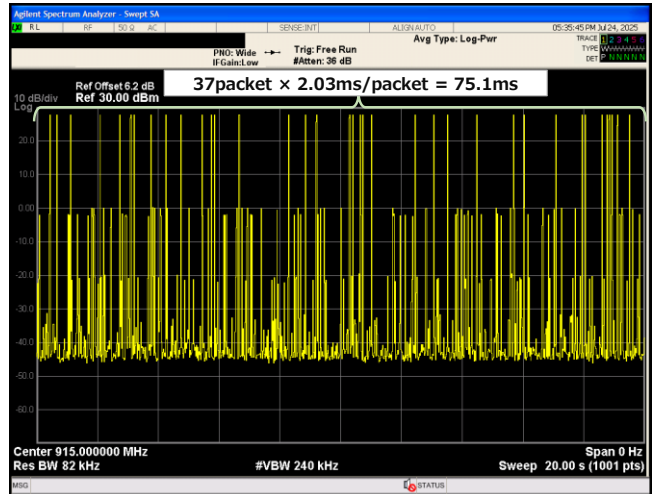


Figure 137 Average Time of Occupancy (Option4 MCS6)

4. Example of Peripheral Circuit

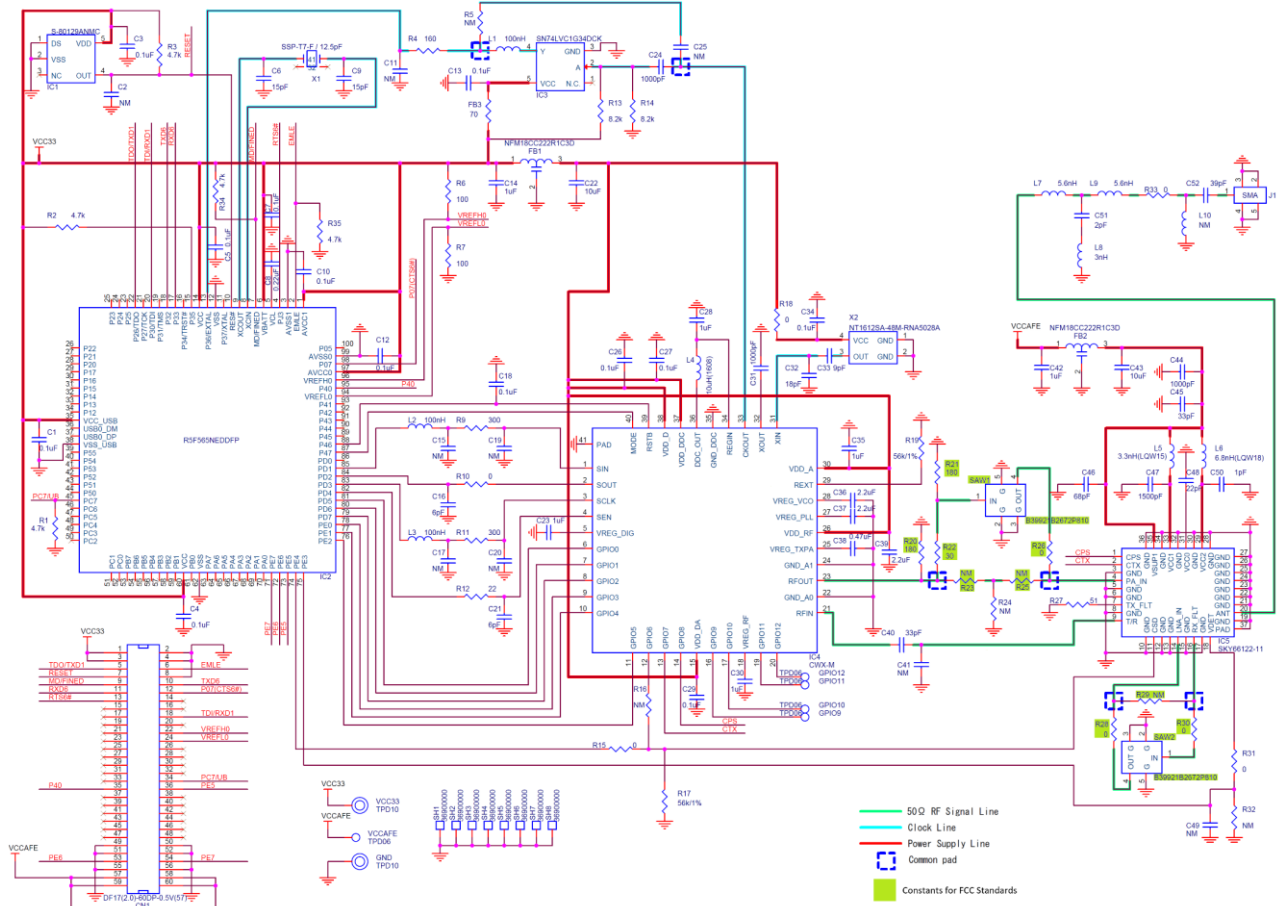


Figure 138 Example of Peripheral Circuit

Table 30 BOM Lists

Part	Description	Parts number	Part	Description	Parts number
CN1	60-pin board connector	DF17(2.0)-60DP-0.5V(57)	L2,L3,L1	100nH	LQP03TNR10H02D
C1,C3,C4,C5,C7,C10,C12,C13,C18,C26,C27,C29,C34	0.1uF	GRM033R61C104KE84D	L4	10uH(1608)	MLZ1608M100WT
C2,C11,C15,C17,C19,C20,C25,C41,C49	Not mounted		L5	3.3nH(LQW15)	LQW15AN3N3C80
C6,C9	15pF	GRM0332C1H150JA01D	L6	6.8nH(LQW18)	LQW18AN6N8C00
C8	0.22uF	GRM033R61A224KE90D	L7,L9	5.6nH	LQG15HS5N6B02D
C14,C23,C28,C30,C35,C42	1uF	CL03A105KP3NSNC	L8	3nH	LQG15HS3N0B02D
C16,C21	6pF	GRM0335C1H6R0BA01D	L10	Not mounted	
C22,C43	10uF	GRM155R61A106ME11D	R1,R2,R3,R34,R35,	4.7k ohm	RK73B1HTTC472J
C24,C31,C44	1000pF	GRM033R71H102KA12D	R6,R7,	100 ohm	RK73B1HTTC101J
C32	18pF	GRM0332C1H180JA01D	R5,R16,R23,R24,R25,R29,R32	Not mounted	
C33	9pF	GRM0335C1H9R0BA01D	R10,R15,R18,R26,R28,R30,	0 ohm	RK73Z1HTTC
C36,C37,C39	2.2uF	GRM033R61A225KE47D	R31		
C38	0.47uF	LMK063BBJ474KPLF	R9,R11	300 ohm	RK73B1HTTC301J
C40,C45	33pF	GRM0332C1H330JA01D	R13,R14	8.2k ohm	RK73B1HTTC822J
C46	68pF	GRM0332C1H680JA01D	R17,R19	56k ohm /1%	RK73H1HTTC5602F
C47	1500pF	GRM033R71H152KA12D	R4	160 ohm	RK73B1HTTC161J
C48	22pF	GRM0332C1H220JA01D	R12	22 ohm	RK73B1HTTC220J
C50	1pF	GRM0335C1H1R0BA01D	R20,R21	180 ohm	RK73B1HTTC181J
C51	2pF	GRM1555C1H2R0BA01D	R22	30 ohm	RK73B1HTTC300J
C52	39pF	CL05C390JB5NNNC	R27	51 ohm	RK73B1HTTC510J
FB1,FB2	EMI Filter 2200pF/DC16V	NFM18CC22R1C3D	R33	0 ohm	RK73Z1ETTP
FB3	Ferrite Bead 70 ohm	BLM03AG700SN1	SAW1,SAW2	SAW Filter for FCC	B39921B2672P810
IC1	Reset IC	S-80129ANMC-JCOxU	X1	CRYSTAL 32.7680KHz	SSP-T7-F / 12.5pF
IC2	RX65N	R5F565NEDDFP	X2	TCXO 48MHz	NT1612SA-48M-RNA5028A
IC3	Clock Buffer IC	SN74LVC1G34DCK	SH1,SH2,SH3,SH4,SH5,SH6,SH7,SH8	Shielding Cabinet Clip	36900000
IC4	CWX-M	R9A06G062GNP	VCC33,GND	Pin header vias	TPD10
IC5	front-end-module	SKY66122-11	GPIO9,GPIO10,GPIO11,	Pin header vias	TPD06
J1	SMA Connector	73251-1150	GPIO12,VCCAFE		

Green text: Applicable to FCC standards

Revision History

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		Page	Summary
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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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