Si446x and ARIB STD-T108 Compliance at 920 MHz

1. Introduction

This application note demonstrates the compliance of Si446x RFICs with the regulatory requirements of ARIB STD-T108 in the 920 MHz band. Although the Si4460/61/67/68 with other chip revisions (e.g., B1, C0, C1, C2) may also be used to achieve compliance at the lower power levels within this frequency band, the measurements within this document were taken with an Si4463-B0 RFIC mounted on a 4463-TCE20B915 Split TX/RX RF Test Card (see “7. Reference Design Schematic”).

The Si4463 chip was configured to transmit at the desired power levels by appropriate settings of the DDAC[6:0] field in the PA_PWR_LVL property 0x2201 and the OB[5:0] field in the PA_BIAS_CLKDUTY property 0x2202. Various data rates and deviations were chosen in order to comply with the permissible channel spacings and occupied bandwidths. The tests were performed at a supply voltage of V_{DD}=3.3V.

1.1. Summary of Measured Results

A summary of measured results is provided in Table 1. An overview of the measured results may be stated as follows:

- Selection of a modulation protocol with DR=100 kbps and Deviation = 50 kHz makes it difficult to achieve compliance with Adjacent Channel Leakage Power requirements when using one unit radio channel (n=1).
- The phase noise floor of the RFIC makes it difficult to achieve compliance with Spectral Mask and Spurious Emission requirements, when operated at maximum power.

Table 1. Summary of Measured Results

Spec Par	Parameter	Condition	Limit	Measured	Margin
3.2(1)	TX Antenna Power	920.6 to 923.4 MHz	+24 dBm	19.78 dBm	4.22 dB
		923.6 to 928.0 MHz	+13 dBm	+12.91 dBm	0.09 dB
		916.0 to 916.8 MHz 928.15 to 929.65 MHz	0 dBm	–0.05 dBm	0.05 dB
3.2(2)	Tolerance of Antenna Power		+20%/–80%	+0.5/–1.5 dB	Comply
3.2(3)	Radio Channel		n=1 to 5	N/A	Comply
3.2(4)	Frequency Tolerance		±20 ppm	N/A	N/A
3.2(5)	Modulation Method		N/A	N/A	N/A
3.2(6)	Occupied Frequency Bandwidth	928.15 to 929.65 MHz n=1	100 kHz	87.3 kHz	12.7 kHz
		Elsewhere n=1	200 kHz	184.4 kHz	15.6 kHz
3.2(7)	Adjacent Channel Leakage Power	916.0 to 916.8 MHz 1mW, n=1, BxT=0.5	–26 dBm	–25.76 dBm	–0.24 dB

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Table 1. Summary of Measured Results (Continued)

		916.0 to 916.8 MHz 1mW, n=2, BxT=0.5	–26 dBm	–56.50 dBm	30.50 dB
		916.0 to 916.8 MHz 1mW, n=1, BxT=0.4	–26 dBm	–28.59 dBm	2.59 dB
		922.4 to 928.0 MHz 20mW, n=1, BxT=0.5	–15 dBm	–13.06 dBm	–1.94 dB
		922.4 to 928.0 MHz 20mW, n=1, BxT=0.4	–15 dBm	–16.15 dBm	1.15 dB
		922.4 to 928.0 MHz 20mW, n=2, BxT=0.5	–15 dBm	–40.56 dBm	25.56 dB
		922.4 to 923.4 MHz 250mW, n=1, BxT=0.5	–5 dBm	–6.32 dBm	1.32 dB
		922.4 to 923.4 MHz 250mW, n=1, BxT=0.4	–5 dBm	–9.39 dBm	4.39 dB
		922.4 to 923.4 MHz 250mW, n=2, BxT=0.5	–5 dBm	–33.69 dBm	28.69 dB
		920.6 to 922.2 MHz 20mW, n=1, BxT=0.5	–15 dBm	–13.06 dBm	–1.94 dB
		920.6 to 922.2 MHz 20mW, n=1, BxT=0.4	–15 dBm	–15.95 dBm	0.95 dB
		920.6 to 922.2 MHz 20mW, n=2, BxT=0.5	–15 dBm	–43.71 dBm	28.71 dB
		920.6 to 922.2 MHz 250mW, n=1, BxT=0.5	–5 dBm	–6.43 dBm	1.43 dB
		920.6 to 922.2 MHz 250mW, n=1, BxT=0.4	–5 dBm	–9.37 dBm	4.37 dB
		920.6 to 922.2 MHz 250mW, n=2, BxT=0.5	–5 dBm	–36.90 dBm	31.90 dB
		928.15 to 929.65 MHz 1mW, n=1, BxT=0.5	–26 dBm	–27.22 dBm	1.22 dB
		928.15 to 929.65 MHz 1mW, n=1, BxT=0.4	–26 dBm	–30.32 dBm	4.32 dB
		928.15 to 929.65 MHz 1mW, n=2, BxT=0.5	–26 dBm	–55.35 dBm	29.35 dB
3.2(7)	Spectral Mask	916.0 to 916.8 MHz 1mW, n=1, BxT=0.5	–36 dBm/100 kHz	–62.46 dBm	26.46 dB

Table 1. Summary of Measured Results (Continued)

		922.4 to 928.0 MHz 20mW, n=1, BxT=0.5	–36 dBm/100 kHz	–46.26 dBm	10.26 dB
		922.4 to 928.0 MHz 20mW, n=2, BxT=0.5	–36 dBm/100 kHz	–49.90 dBm	13.90 dB
		922.4 to 923.4 MHz 250mW, n=1, BxT=0.5	–29 dBm/100 kHz	–38.89 dBm	9.89 dB
		922.4 to 923.4 MHz 250mW, n=2, BxT=0.5	–29 dBm/100 kHz	–42.45 dBm	13.45 dB
		920.6 to 922.2 MHz 20mW, n=1, BxT=0.5	–36 dBm/100 kHz	N/A	–3.53 dB
		920.6 to 922.2 MHz 20mW, n=1, BxT=0.4	–36 dBm/100 kHz	–41.28 dBm	5.28 dB
		920.6 to 922.2 MHz 20mW, n=2, BxT=0.5	–36 dBm/100 kHz	–49.30 dBm	13.30 dB
		920.6 to 922.2 MHz 250mW, n=1, BxT=0.5	–29 dBm/100 kHz	N/A	–1.32 dB
		920.6 to 922.2 MHz 250mW, n=1, BxT=0.4	–29 dBm/100 kHz	–34.34 dBm	5.34 dB
		920.6 to 922.2 MHz 250mW, n=2, BxT=0.5	–29 dBm/100 kHz	–41.92 dBm	12.92 dB
		928.15 to 929.65 MHz 1mW, n=1, BxT=0.5	–3 dBm/100 kHz	–55.10 dBm	19.10 dB
3.2(8)	Spurious Emissions	F ≤ 710 MHz	–36 dBm/100 kHz	–67.27 dBm	31.27 dB
		710 MHz < F ≤ 900 MHz (Pout = +19.7 dBm)	–55 dBm/1 MHz	–57.13 dBm	2.13 dB
		710 MHz < F ≤ 900 MHz (Pout = +13.0 dBm)	–55 dBm/1 MHz	–64.30 dBm	9.30 dB
		900 MHz < F ≤ 915 MHz	–55 dBm/100 kHz	–63.37 dBm	8.37 dB
		915 MHz < F ≤ 920.3 MHz (Pout = +19.7 dBm)	–36 dBm/100 kHz	–39.51 dBm	3.51 dB
		915 MHz < F ≤ 920.3 MHz (Pout = +13.0 dBm)	–36 dBm/100 kHz	–46.81 dBm	10.81 dB
		920.3 MHz < F ≤ 924.3 MHz	–29 dBm/100 kHz	–38.08 dBm	9.08 dB
		924.3 MHz < F ≤ 930.0 MHz	–36 dBm/100 kHz	–47.79 dBm	11.79 dB
		930 MHz < F ≤ 1000 MHz	–55 dBm/100 kHz	–62.18 dBm	7.18 dB

Table 1. Summary of Measured Results (Continued)

		1000 MHz < F ≤ 1215 MHz	–45 dBm/1 MHz	–58.66 dBm	13.66 dB
		F > 1215 MHz	–30 dBm/1 MHz	–37.21 dBm	7.21 dB
3.3	RX Conducted Spurious Emissions	F ≤ 710 MHz	–54 dBm/100 kHz	–87.6 dBm	33.6 dB
		710 MHz < F ≤ 900 MHz	–55 dBm/1 MHz	–80.88 dBm	25.88 dB
		900 MHz < F ≤ 915 MHz	–55 dBm/100 kHz	–92.46 dBm	37.46 dB
		915 MHz < F ≤ 930 MHz	–54 dBm/100kHz	–92.41 dBm	38.41 dB
		930 MHz < F ≤ 1000 MHz	–55 dBm/100 kHz	–91.18 dBm	36.18 dB
		F > 1000 MHz	–47 dBm/1 MHz	–49.59 dBm	2.59 dB
Ref Only	RX Sensitivity	2GFSK DR=50K Dev=25K	N/A	–108.4 dBm	N/A
		2GFSK DR=100K Dev=50K	N/A	–105.3 dBm	N/A
		2GFSK DR=200K Dev=100K	N/A	–102.2 dBm	N/A
Ref Only	RX Selectivity Adjacent Chan (±1xChanSpacing	2GFSK DR=50K Dev=25K	N/A	42.2 dB	N/A
		2GFSK DR=100K Dev=50K	N/A	41.4 dB	N/A
		2GFSK DR=200K Dev=100K	N/A	39.3 dB	N/A
Ref Only	RX Selectivity Alternate Chan (±2xChanSpacing	2GFSK DR=50K Dev=25K	N/A	47.5 dB	N/A
		2GFSK DR=100K Dev=50K	N/A	47.5 dB	N/A
		2GFSK DR=200K Dev=100K	N/A	39.2 dB	N/A

2. Summary ARIB STD-T108 Requirements in the 920 MHz Band

The main requirements of ARIB STD-T108 in the 920 MHz band are summarized in this section.

2.1. ARIB STD-T108 3.2(1) Antenna Power

The antenna power shall be less than or equal to 250 mW (+24 dBm). However, the antenna power shall be less than or equal to 1 mW (0 dBm) for radio channels consisting of only unit radio channel with center frequencies ranging from 916.0 MHz to 916.8 MHz and from 928.15 MHz to 929.65 MHz, and shall be less than or equal to 20 mW (+13 dBm) with center frequencies ranging from 923.6 MHz to 928.0 MHz.

2.2. ARIB STD-T108 3.2(2) Tolerance of Antenna Power

The tolerance of the antenna power shall be within +20% to –80%.

2.3. ARIB STD-T108 3.2(3) Radio Channel

A radio channel shall consist of up to 5 consecutive unit radio channels. Unit radio channels are channels with bandwidths of 200 kHz with center frequencies of 916.0 MHz + 200 kHz x n (with n = positive integer greater than or equal to zero) for center frequencies between 916.0 MHz to 916.8 MHz, or center frequencies of 920.6 MHz + 200 kHz x n for center frequencies between 920.6 MHz to 928.0 MHz. Within the frequency range of 928.15 MHz to 929.65 MHz, the channel bandwidth is 100 kHz and the center frequency shall be set at 928.15 MHz + 100 kHz x n.

2.4. ARIB STD-T108 3.2(4) Frequency Tolerance

The frequency tolerance shall be within ±20 ppm.

2.5. ARIB STD-T108 3.2(5) Modulation Method

The modulation method is not specified. All measurements performed in this document were taken with 2GFSK modulation.

2.6. ARIB STD-T108 3.2(6) Occupied Frequency Bandwidth

The occupied frequency bandwidth shall be less than or equal to 200kHz x n (with n = the number of unit radio channels constituting the radio channel and is an integer from 1 to 5). However, the occupied frequency bandwidth shall be less than 100 kHz x n when the center frequencies are within the range of 928.15 MHz to 929.65 MHz.

2.7. ARIB STD-T108 3.2(7) Adjacent Channel Leakage Power

The standard provides for a variety of adjacent channel leakage power spectral masks as a function of channel center frequency and output power level.

2.7.1. Antenna Power = 1 mW, Freq Band=916.0 to 916.8 MHz and 920.6 to 928.0 MHz

Within the frequency bands of 916.0 to 916.8 MHz and 920.6 to 928.0 MHz, the channel spectral mask shall be as shown in Figure 1 when operating with antenna power of less than or equal to 1 mW. The adjacent channel leakage power within the 200 kHz bandwidth at the upper and lower edges of the radio channel shall be less than or equal to –26 dBm.

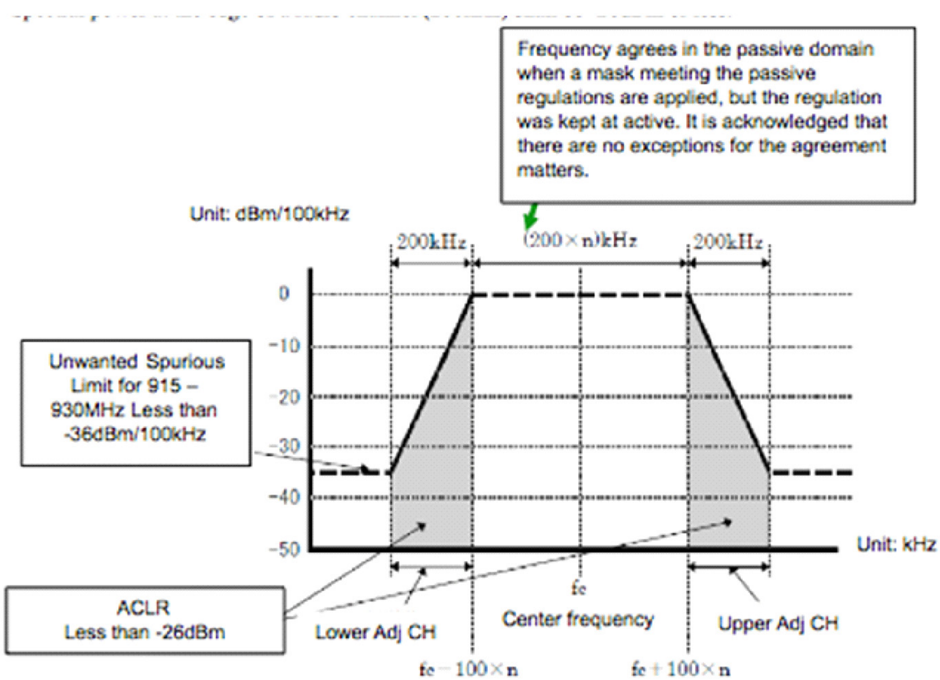


Figure 1. Channel Spectral Mask (1 mW, 916.0 to 916.8 MHz and 920.6 to 928.0 MHz)

2.7.2. Antenna Power=20 mW, Freq Band=922.4 to 923.4 MHz

Within the frequency band of 922.4 to 928.0 MHz, the channel spectral mask shall be as shown in Figure 2 when operating with antenna power of more than 1 mW and less than or equal to 20 mW. The adjacent channel leakage power within the 200 kHz bandwidth at the upper and lower edges of the radio channel shall be less than or equal to –15 dBm.

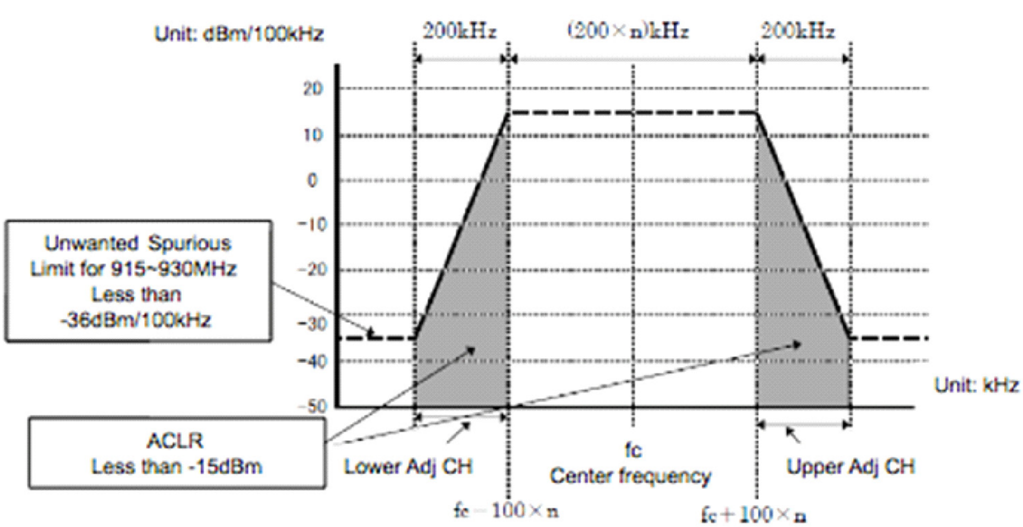


Figure 2. Channel Spectral Mask (20 mW, 922.4 to 928.0 MHz)

2.7.3. Antenna Power = 250 mW, Freq Band=922.4 to 923.4 MHz

Within the frequency band of 922.4 to 923.4 MHz, the channel spectral mask shall be as shown in Figure 3 when operating with antenna power of more than 20 mW and less than or equal to 250 mW. The adjacent channel leakage power within the 200 kHz bandwidth at the upper and lower edges of the radio channel shall be less than or equal to –5 dBm.

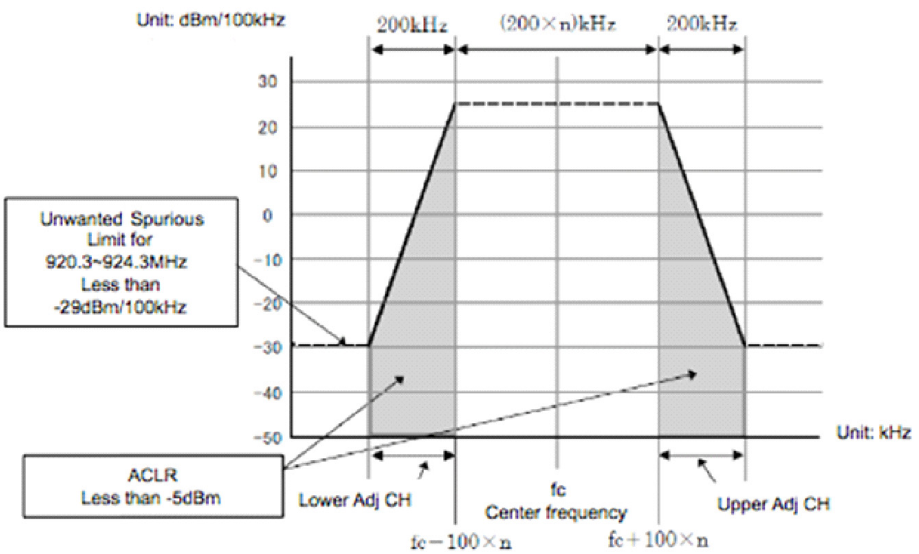


Figure 3. Channel Spectral Mask (250 mW, 922.4 to 923.4 MHz)

2.7.4. Antenna Power=20 mW, Freq Band=920.6 to 922.2 MHz

Within the frequency band of 920.6 to 922.2 MHz, the channel spectral mask shall be as shown in Figure 4 when operating with antenna power of more than 1 mW and less than or equal to 20 mW. The adjacent channel leakage power within the 200 kHz bandwidth at the upper and lower edges of the radio channel shall be less than or equal to –15 dBm.

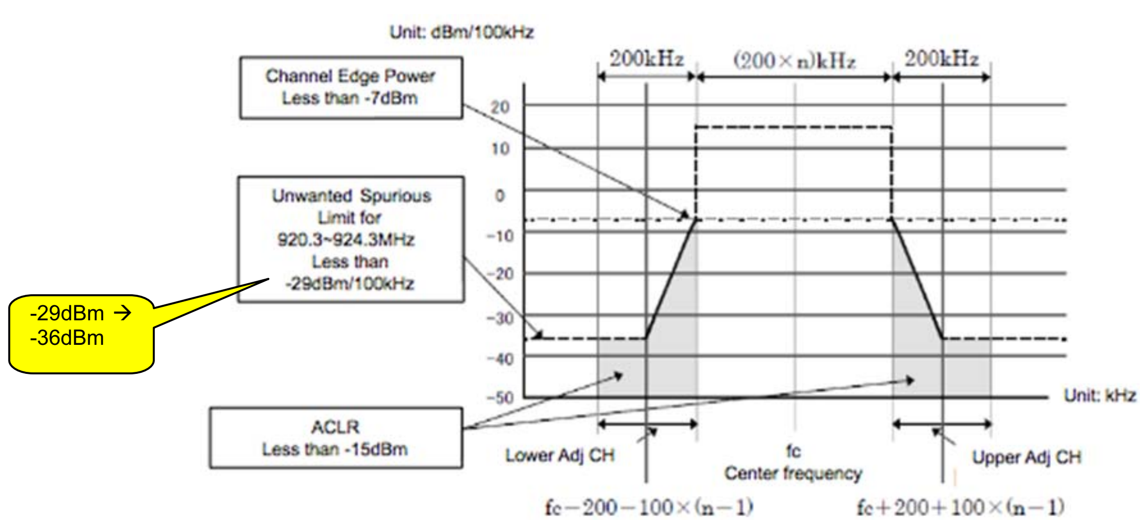


Figure 4. Channel Spectral Mask (20 mW, 920.6 to 922.2 MHz)

2.7.5. Antenna Power =250 mW, Freq Band=920.6 to 922.2 MHz

Within the frequency band of 920.6 to 922.2 MHz, the channel spectral mask shall be as shown in Figure 5 when operating with antenna power of more than 20 mW and less than or equal to 250 mW. The adjacent channel leakage power within the 200 kHz bandwidth at the upper and lower edges of the radio channel shall be less than or equal to –5 dBm.

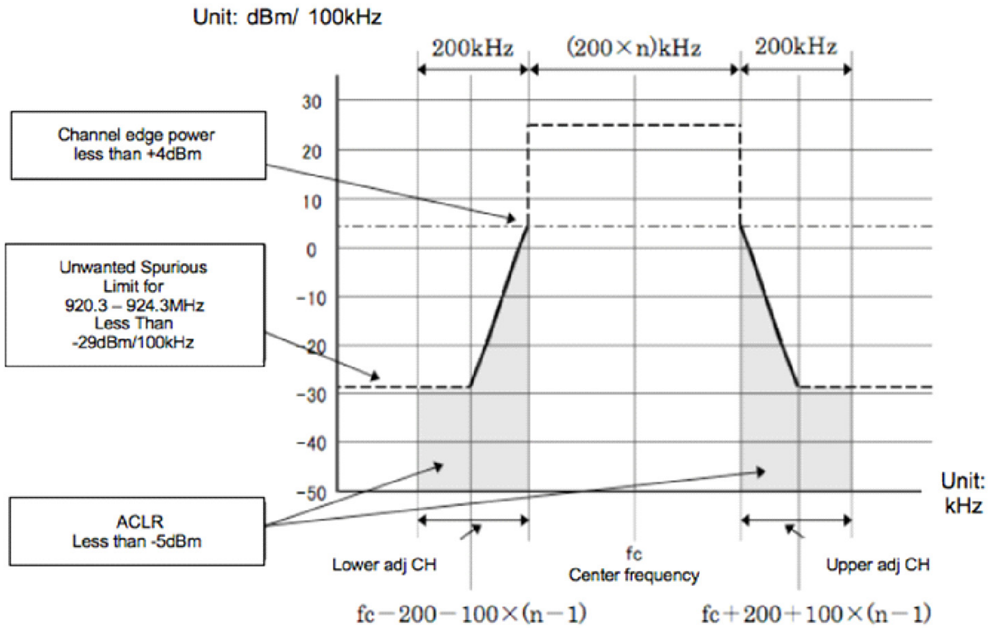


Figure 5. Channel Spectral Mask (250 mW, 920.6 to 922.2 MHz)

2.7.6. Antenna Power=1 mW, Freq Band=928.15 to 929.65 MHz

Within the frequency band of 928.15 to 929.65 MHz, the channel spectral mask shall be as shown in Figure 6 when operating with antenna power of less than or equal to 1 mW. The adjacent channel leakage power within the 100 kHz bandwidth at the upper and lower edges of the radio channel shall be less than or equal to –26 dBm.

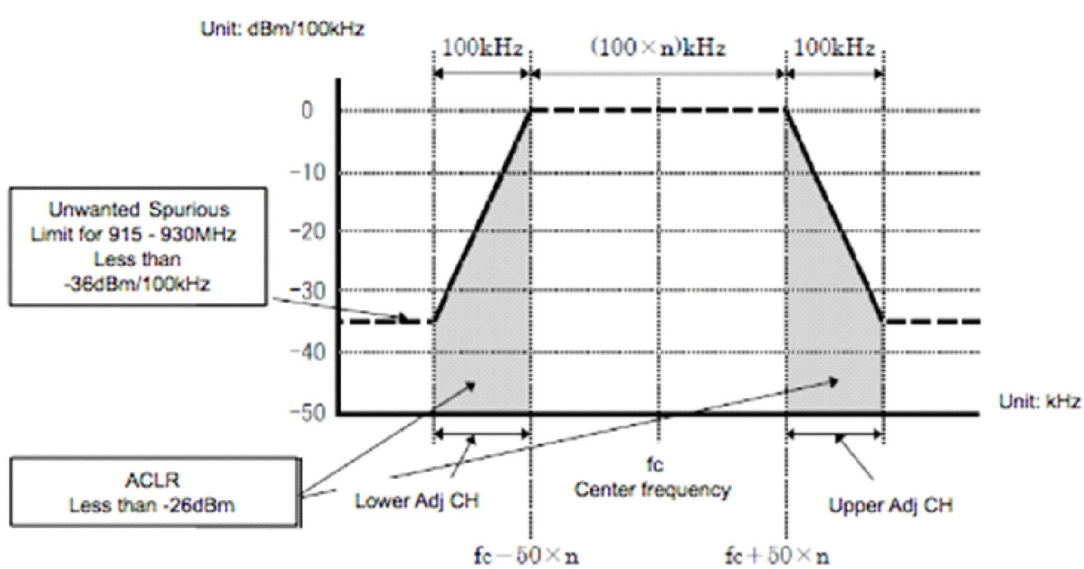


Figure 6. Channel Spectral Mask (1 mW, 928.15 to 929.65 MHz)

2.8. ARIB STD–T108 3.2(8) TX Spurious Emissions

The spurious emission strength at the antenna input in TX mode shall be less than the values shown in Table 2.

Table 2. TX Spurious Emission Specifications

Frequency Band	Spurious Emission Strength (average power)	Reference BW
f ≤ 710 MHz	–36 dBm	100 kHz
710 MHz < f ≤ 900 MHz	–55 dBm	1 MHz
900 MHz < f ≤ 915 MHz	–55 dBm	100 kHz
915 MHz < f ≤ 920.3 MHz	–36 dBm	100 kHz
920.3 MHz < f ≤ 924.3 MHz (except for |f – fc| ≤ 200 + 100 x n kHz)	–36 dBm (Pout ≤ 20 mW)	100 kHz
	–29 dBm (Pout > 20 mW)	100 kHz
924.3 MHz < f ≤ 930.0 MHz (except for |f – fc| ≤ 200 + 100 x n kHz when unit channel bandwidth is 200 kHz)	–36 dBm	100 kHz
924.3 MHz < f ≤ 930.0 MHz (except for |f – fc| ≤ 100 + 50 x n kHz when unit channel bandwidth is 100 kHz)	–36 dBm	100 kHz
930 MHz < f ≤ 1000 MHz	–55 dBm	100 kHz
1000 MHz < f ≤ 1215 MHz	–48 dBm	1 MHz
f > 1215 MHz	–30 dBm	1 MHz

2.9. ARIB STD-T108 3.3 Receiver Conducted Spurious Emissions

The conducted spurious emission strength at the receiver input shall be less than the values shown in Table 3.

Table 3. RX Conducted Spurious Emission Specifications

Frequency Band	Spurious Emission Strength	Reference BW
f ≤ 710 MHz	–54 dBm	100 kHz
710 MHz < f ≤ 900 MHz	–55 dBm	1 MHz
900 MHz < f ≤ 915 MHz	–55 dBm	100 kHz
915 MHz < f ≤ 930 MHz	–54 dBm	100 kHz
930 MHz < f ≤ 1000 MHz	–55 dBm	100 kHz
f > 1000 MHz	–47 dBm	1 MHz

2.10. Receiver Sensitivity

ARIB STD-T108 does not require a minimum value of performance for RX sensitivity. However, it is useful to publish the typical RX sensitivity of Si446x chips for those modulation protocols that may be commonly used in ARIB STD-T108 applications; this aids in comparison of Si446x-based solutions with solutions from other RFIC vendors. As a result, measurements of typical RX sensitivity are presented later in this application note.

2.11. Receiver Adjacent/Alternate Channel Selectivity

ARIB STD-T108 does not require a minimum value of performance for RX adjacent and alternate channel selectivity. However, it is again useful to publish the typical selectivity of Si446x chips for common modulation protocols to aid in comparison of Si446x-based solutions with solutions from other RFIC vendors. As a result, measurements of typical RX selectivity are presented later in this application note.

3. TX Measurement Results

3.1. TX Measurement Details

All TX measurements were done with the following spectrum analyzer settings:

- Anritsu MS2692A Signal Analyzer
- Detector Mode = Peak, ResBW = 10 kHz, VidBW = 30 kHz, unless noted otherwise
- Average with 50 samples
- Amplitude correction for cable loss = 1.0 dB
- Frequency = As Shown, Modulation = 2GFSK
- Data Rate = 100 kbps, Deviation = 50 kHz, unless noted otherwise
- WDS TX Scripts as shown in "5. Wireless Development Suite (WDS) TX Script Files" on page 70.

3.2. ARIB STD-T108 3.2(1) Antenna Power

The allowed transmitter antenna power is specified in ARIB STD-T108 3.2(1) as less than 1 mW (0 dBm) within the frequency range of 916.0 MHz to 916.8 MHz and from 928.15 MHz to 929.65 MHz. The measured transmitter antenna power within this frequency range is shown in Figure 7. The Si4463 chip complies with the requirements of ARIB STD-T108 3.2(1) for Transmit Antenna Power.

- Limit: 1 mW = 0 dBm (max)
- Measured: –0.05 dBm
- Margin: 0.05 dB (PASS)

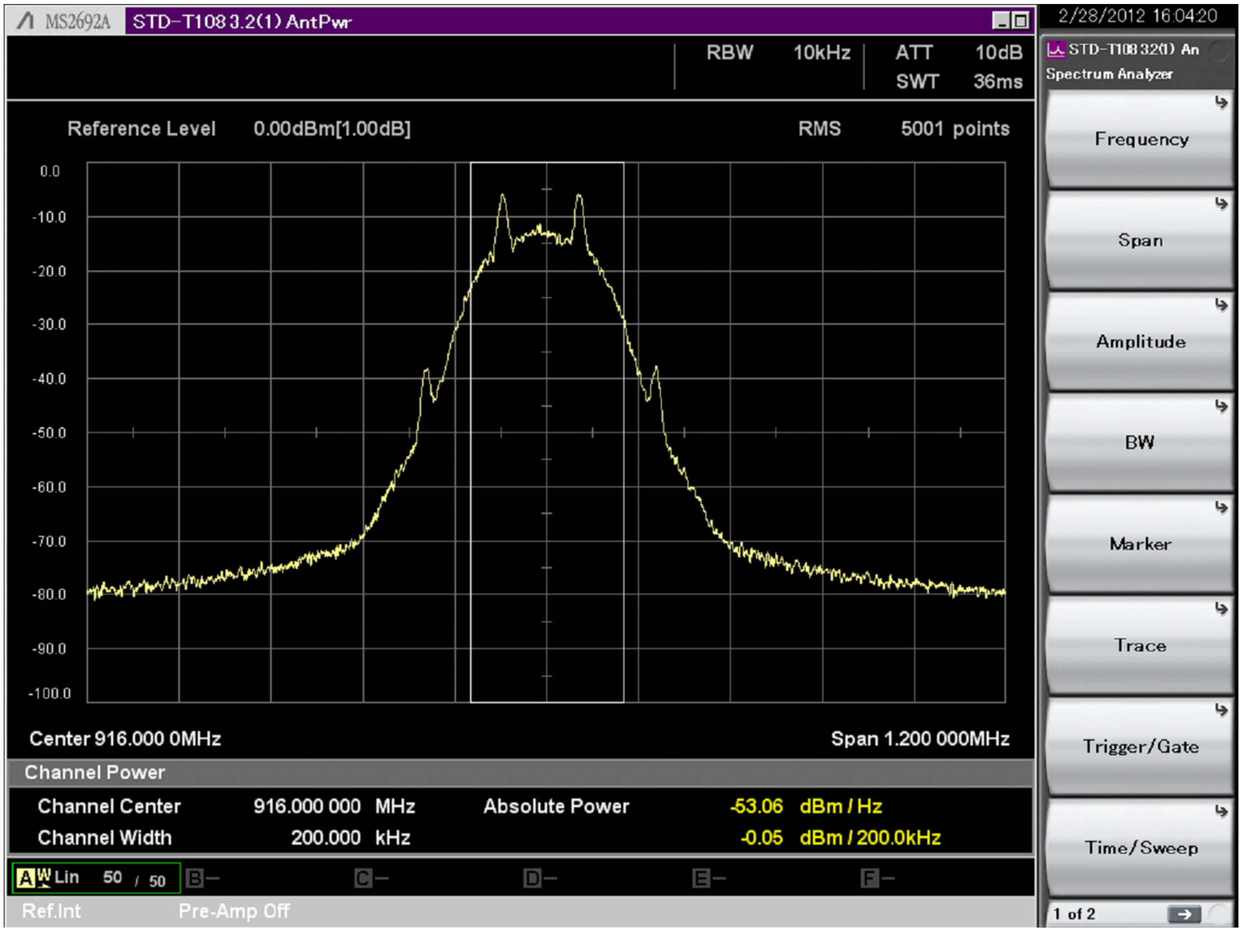


Figure 7. Transmitter Antenna Power (1 mW, 916.0 to 916.8 MHz)

The allowed transmitter antenna power is specified as less than 20 mW (+13 dBm) within the frequency range of 920.6 MHz to 928.0 MHz. The measured transmitter antenna power within this frequency range is shown in Figure 8. The Si4463 chip complies with the requirements of ARIB STD-T108 3.2(1) for Transmit Antenna Power.

- Limit: 20 mW = +13 dBm (max)
- Measured: +12.91 dBm
- Margin: 0.09 dB (PASS)

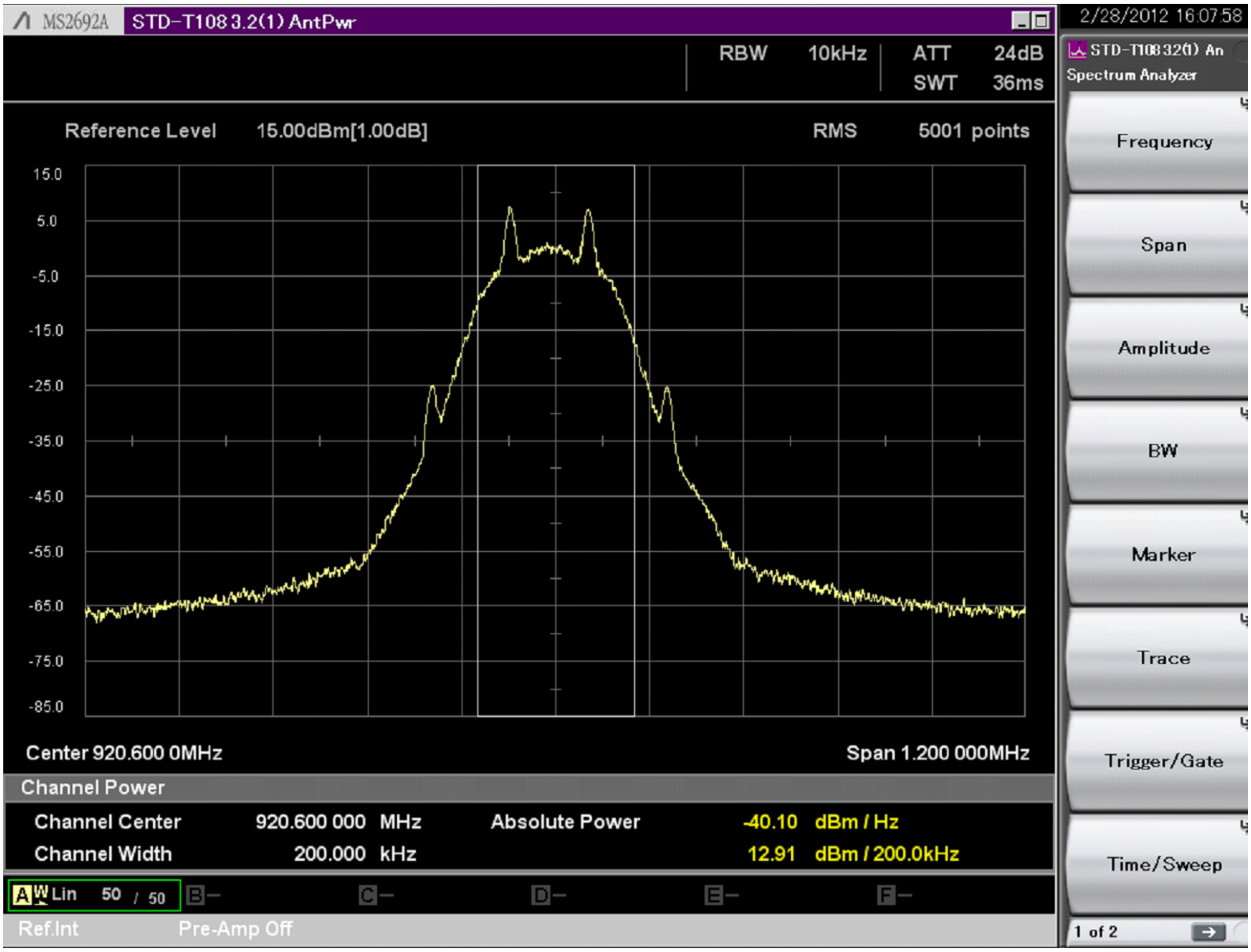


Figure 8. Transmitter Antenna Power (20 mW, 920.6 to 928.0 MHz)

The allowed transmitter antenna power is specified as less than 250 mW (+24 dBm) within the frequency range of 920.6 MHz to 923.4 MHz. The transmit output power of the Si4463 chip is specified as +20 dBm (typical) at the TX output connector. As a result, the Si4463 chip is not capable of operating at the maximum power level allowed by ARIB STD-T108 without use of an external power amplifier.

The measured transmitter antenna power within this frequency range is shown in Figure 9. The Si4463 chip complies with the requirements of ARIB STD-T108 3.2(1) for Transmit Antenna Power.

- Limit: 250 mW = +24 dBm (max)
- Measured: +19.78 dBm
- Margin: 4.22 dB (PASS)

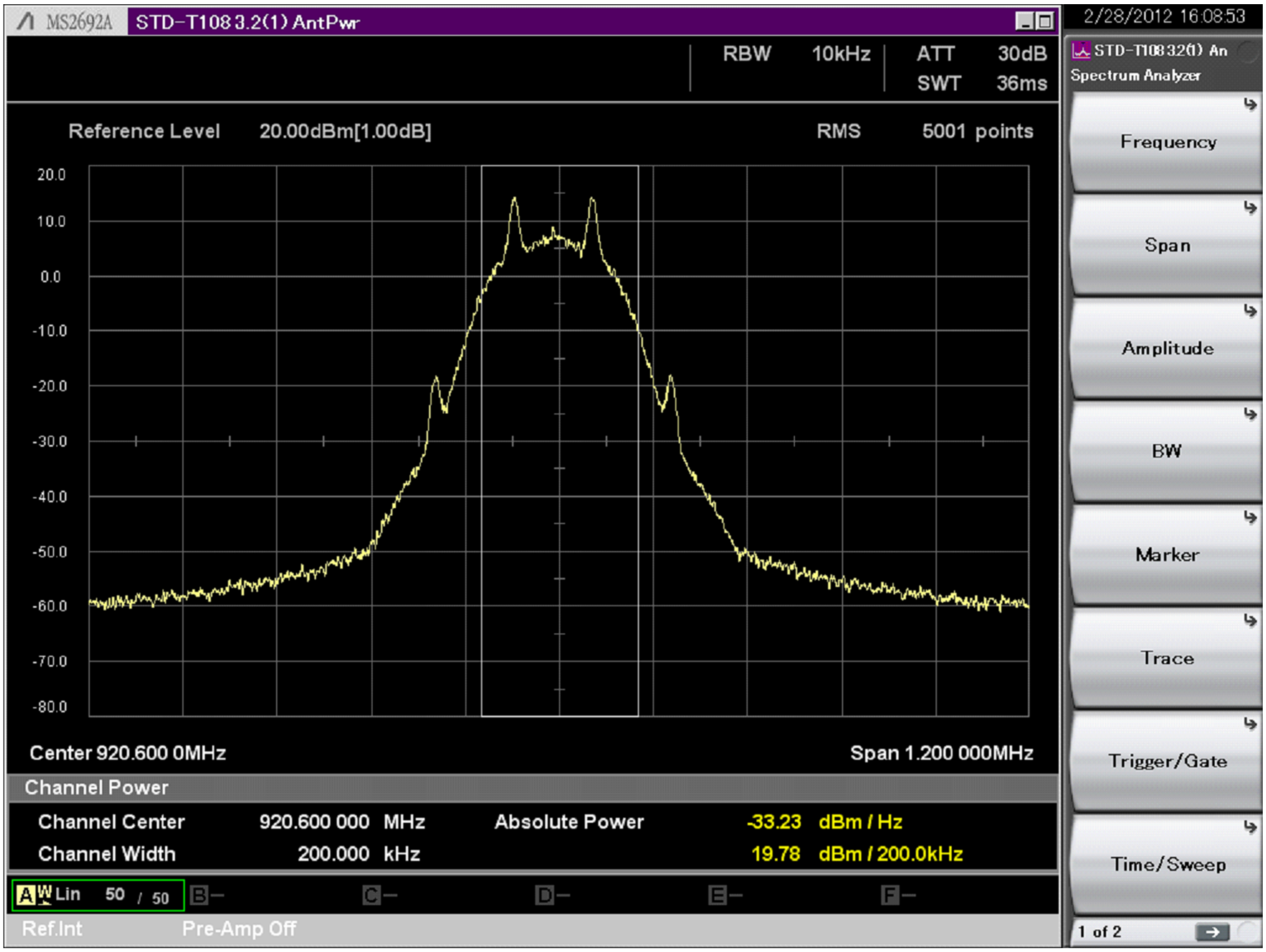


Figure 9. Transmitter Antenna Power (250 mW, 920.6 to 923.4 MHz)

The Si446x family of chips provides for very fine control of the output power when operating near its maximum output power level (e.g. +20 dBm for the Si4463/68 chip and +13 to +14 dBm for the Si4461 chip). The output power on the Si4463 chip is adjusted by selecting the number of output device fingers that are enabled (as set by the PA_PWR_LVL property 0x2201). The value of the PA_PWR_LVL property may range from 0 fingers enabled (minimum output power) to 127 fingers enabled (maximum output power).

The output power shown in Figure 9 was obtained using a Si4463 chip with PA_PWR_LVL = 0x7F = 127 output fingers enabled (but Si4463/68 with B1, C0, C1, and C2 revisions may also be used). The output power levels shown in Table 4 were obtained as the PA_PWR_LVL was decreased from this nominal value.

Table 4. Si4463/68 TX Output Power and Current Consumption vs. Power Settings

PA_PWR_LVL	Device Fingers	Pout (dBm) VDD=3.3V	IDD (mA)
0x7F	127	19.78 dBm	79.55 mA
0x7E	126	19.72 dBm	79.41 mA
0x7D	125	19.68 dBm	79.26 mA
…	…	…	…
0x1E	30	13.17 dBm	42.45 mA
0x1D	29	12.83 dBm	41.62 mA
0x1C	28	12.55 dBm	40.79 mA
…	…	…	…
0x07	7	0.25 dBm	23.02 mA
0x06	6	–1.23 dBm	22.15 mA
0x05	5	–2.95 dBm	21.28 mA

These measurements illustrate the very fine control of output power that may be obtained with the Si446x family of chips, when operated near their maximum output power level. As shown in the table, the output power level may be further reduced to +13 dBm and 0 dBm by adjusting only the PA_PWR_LVL property.

It is apparent that the step size between adjacent power levels is reduced when operated with fewer enabled output device fingers. This is self-evident; the percentage change in output power obtained by reducing the output device fingers from 127 to 126 is much less than when reducing the output device fingers from (e.g.) 30 to 29. If extremely fine control of the output power at levels of +13 dBm or 0 dBm is required, Silicon Labs recommends use of the Si4461 chip. As the Si4461 chip is designed to provide +13 to +14 dBm output power when operated with (nearly) the maximum number of enabled output device fingers, the power level step size within this range is much finer than with the Si4463 chip. This is illustrated by the measured output power levels shown in Table 5.

Table 5. Si4661 TX Output Power and Current Consumption vs. Power Setting

PA_PWR_LVL	Device Fingers	Pout (dBm) VDD=3.3V	IDD (mA)
0x64	100	12.94 mA	30.23 mA
0x63	99	12.86 dBm	30.07 mA
0x62	98	12.78 dBm	29.92 mA
0x61	97	12.70 dBm	29.76 mA
…	…	…	…
0x18	24	–0.25 dBm	18.03 mA
0x17	23	–0.69 dBm	17.89 mA
0x16	22	–1.12 dBm	17.73 mA
0x15	21	–1.48 dBm	17.58 mA

Although ARIB STD-T108 3.2(1) allows up to 250 mW (+24 dBm) output power, the Si446x family of chips cannot provide this level of output power without use of an external power amplifier.

3.3. ARIB STD-T108 3.2(2) Tolerance of Antenna Power

The part-to-part variation of TX output power of the Si446x family of chips is typically +0.5/–1.5 dB at maximum output power, at a given frequency and VDD supply voltage. The Si446x family of chips therefore complies with the requirements of ARIB STD-T108 3.2(2) Tolerance of Antenna Power. As the TX output power of the Si4463 RFIC exhibits a dependence upon VDD supply voltage (due to use of a switching-type power amplifier), it is necessary to operate at a fixed VDD supply voltage.

3.4. ARIB STD-T108 3.2(3) Radio Channel

The Si446x family of RFICs is capable of complying with all requirements of ARIB STD-T108 when operating with one unit radio channel (n=1), and is thus inherently capable of complying with wider radio channels (i.e., n=2 to 5). However, compliance is dependent upon selection of an appropriate modulation protocol (i.e., data rate and deviation).

3.5. ARIB STD-T108 3.2(4) Frequency Tolerance

The frequency accuracy of the Si446x family of RFICs is solely dependent upon the frequency accuracy of the crystal reference signal. Compliance with this requirement is thus largely determined by the frequency tolerance of the selected crystal blank or external reference oscillator.

All measurements within this document were taken with the crystal oscillator adjusted for zero frequency error.

3.6. ARIB STD-T108 3.2(5) Modulation Method

The modulation method is not specified in ARIB STD-T108. All measurements within this document were taken with 2GFSK, data rate = 100 kbps, and deviation = 50 kHz (unless noted otherwise). Compliance with certain requirements of the standard are heavily influenced by the selection of the modulation protocol; a greater margin of compliance may be obtained with a different selection of modulation protocol (e.g., lowering the data rate and/or deviation).

Furthermore, it is not possible (even on a theoretical basis) to ***simultaneously*** comply with all requirements of ARIB STD-T108 with this selection of modulation protocol. For example, the Frequency Tolerance specification of STD-T108 3.2(4) requires operation with up to ±20 ppm frequency error (i.e., ±18.4 kHz at 920 MHz). It is not possible to comply with the Adjacent Channel Leakage Power requirements of ARIB STD-T108 3.2(7) while operating with ±18.4 kHz frequency offset from channel center frequency with selection of data rate = 100 kbps and deviation = 50 kHz. The modulation bandwidth of such a signal is sufficiently wide that any error in frequency will cause in an increase in integrated power in the adjacent channel bandwidth, resulting in failure to comply with the Adjacent Channel Leakage Power spec.

3.7. ARIB STD-T108 3.2(6) Occupied Frequency Bandwidth

The allowed occupied frequency bandwidth is specified in ARIB STD-T108 3.2(6) as less than (n x 100 kHz) within the frequency band from 928.15 MHz to 929.65 MHz, and less than (n x 200 kHz) in all other frequency bands. The integer number ‘n’ represents the number of unit radio channels used by the system, and may range in value from n=1 to n=5.

The measured occupied frequency bandwidth within the frequency range of 928.15 MHz to 929.65 MHz is shown in Figure 10. The selected modulation protocol was 2GFSK, DR = 50 kbps, Deviation = 25 kHz. The Si4463 chip complies with the requirements of ARIB STD-T108 3.2(6) for Occupied Frequency Bandwidth within this frequency band.

- Limit: 100 kHz max (for n=1)
- Measured: 87.3 kHz
- Margin: 12.7 kHz (PASS)

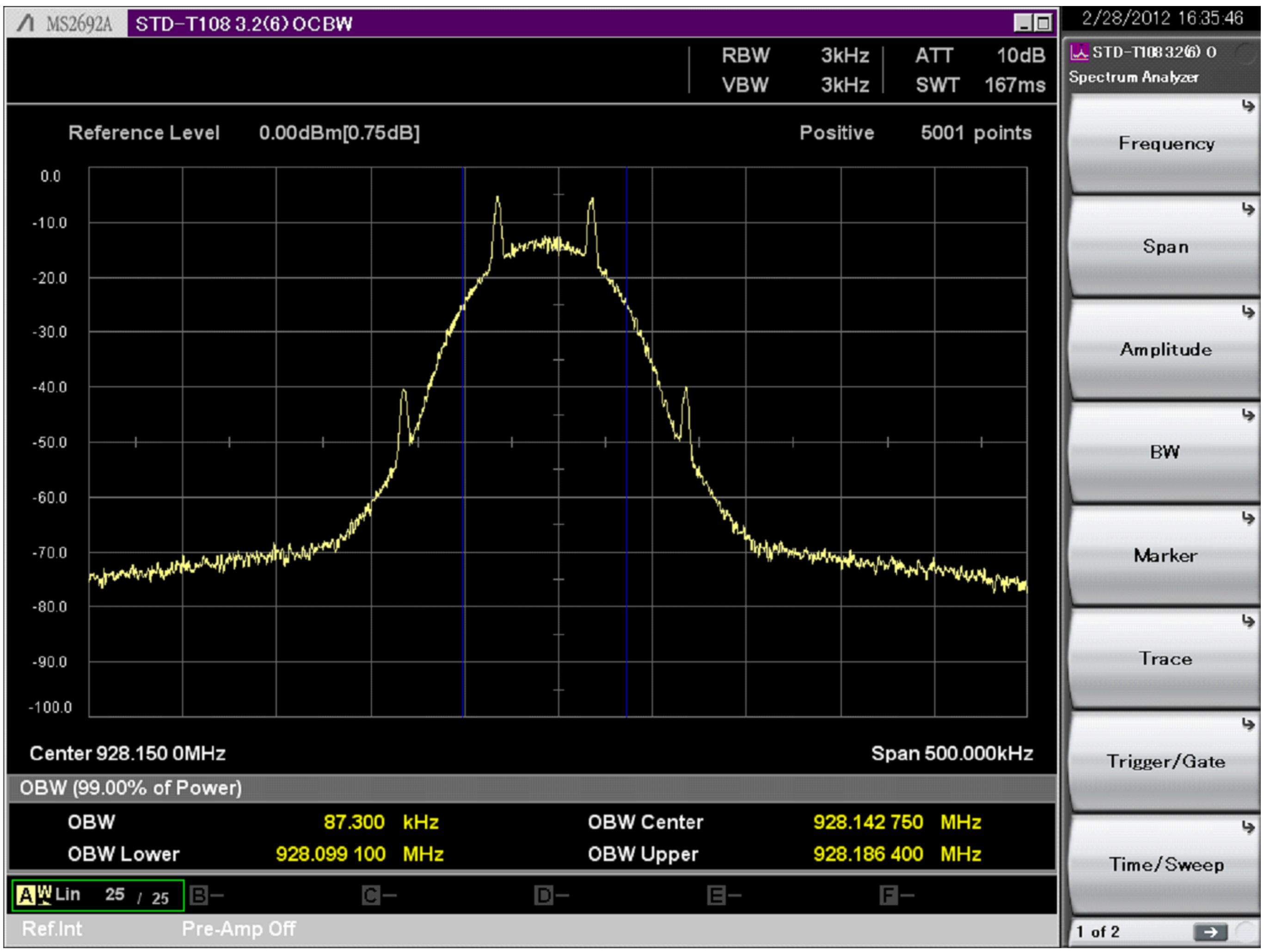


Figure 10. Occupied Bandwidth (DR=50 kbps Dev=25 kHz, 928.15 to 929.65 MHz)

The measured occupied frequency bandwidth within other frequency bands is shown in Figure 11. The selected modulation protocol was 2GFSK, DR = 100 kbps, Deviation = 50 kHz. The Si4463 chip complies with the requirements of ARIB STD-T108 3.2(6) for Occupied Frequency Bandwidth within the other frequency bands.

- Limit: 200 kHz max (for n=1)
- Measured: 184.4 kHz
- Margin: 15.6 kHz (PASS)

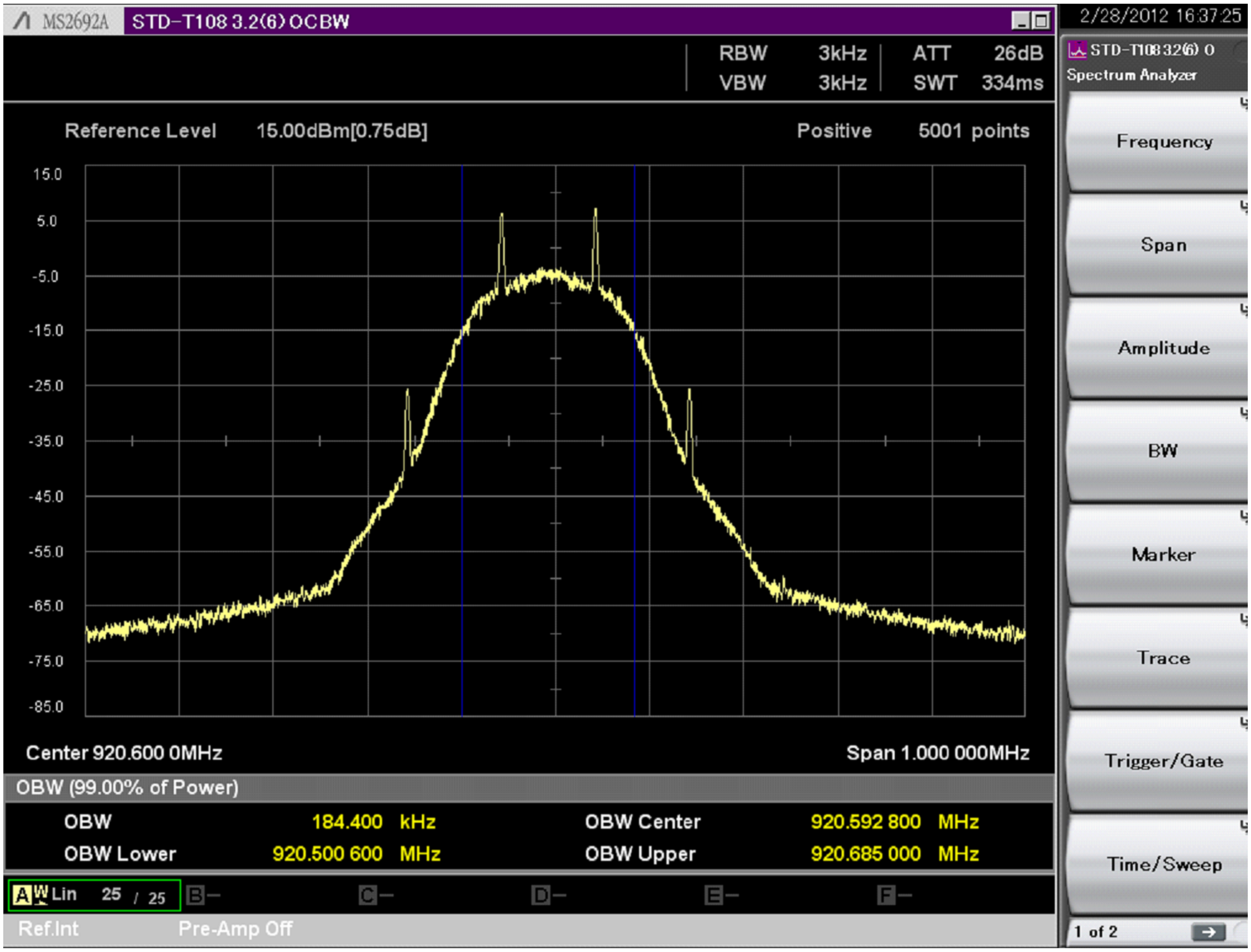


Figure 11. Occupied Bandwidth (DR=100 kbps Dev=50 kHz, other frequency bands)

3.8. ARIB STD-T108 3.2(7) Adjacent Channel Leakage Power

The allowed adjacent channel leakage power is specified in ARIB STD-T108 3.2(7), and is a function of channel center frequency and output power level.

3.8.1. Antenna Power =1 mW, Freq Band=916.0 to 916.8 MHz and 920.6 to 928.0 MHz

Within the frequency bands of 916.0 to 916.8 MHz and 920.6 to 928.0 MHz when operating with antenna power of less than or equal to 1 mW, the integrated adjacent channel leakage power within the 200 kHz bandwidth at the upper and lower edges of the radio channel shall be less than or equal to –26 dBm.

The selected modulation parameters were DR = 100 kbps and Deviation = 50 kHz. The measurement was taken assuming operation with one unit radio channel (n=1). The measured adjacent channel leakage power is shown in Figure 12. The Si4463 chip marginally fails to comply with the requirements of ARIB STD-T108 3.2(7) for Adjacent Channel Leakage Power for the selected modulation protocol.

- Limit: –26 dBm (max)
- Measured: –25.76 dBm
- Margin: –0.24 dB (FAIL)

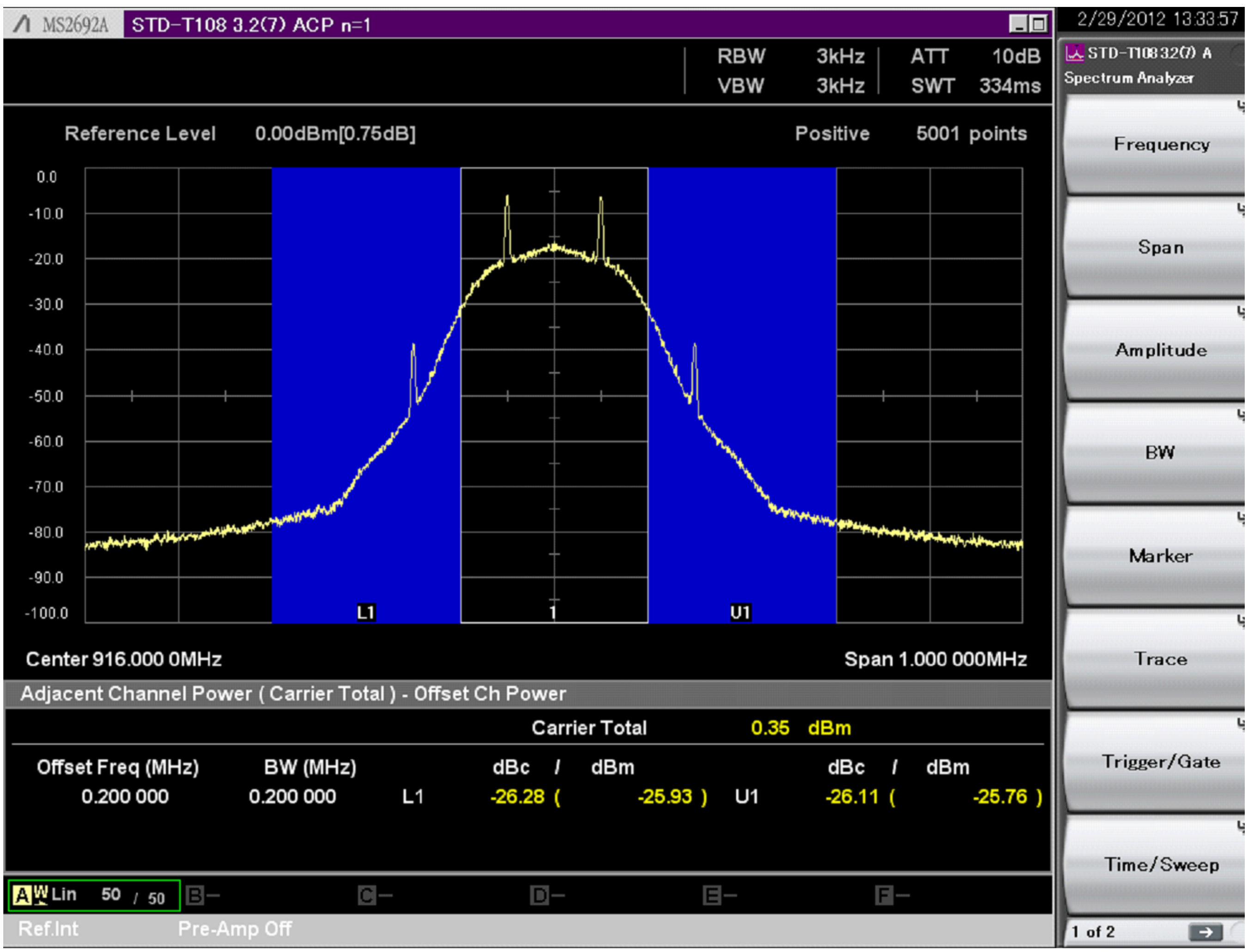


Figure 12. Adjacent Channel Leakage Power (1 mW, 916.0 to 916.8 MHz, n=1)

This marginally-failing performance is due to the inherent modulation bandwidth of the chosen signal (DR=100 kbps Dev=50 kHz), and is ***not*** limited by the phase noise performance of the chip. To illustrate this fact, an additional plot is provided in which the modulation is temporarily disabled (i.e., CW mode). This performance is shown in Figure 13 and is observed to comply with the spec with over 16 dB margin.

- Limit: –26 dBm (max)
- Measured: –55.0 dBm (in CW mode)
- Margin: 29.0 dB (PASS)

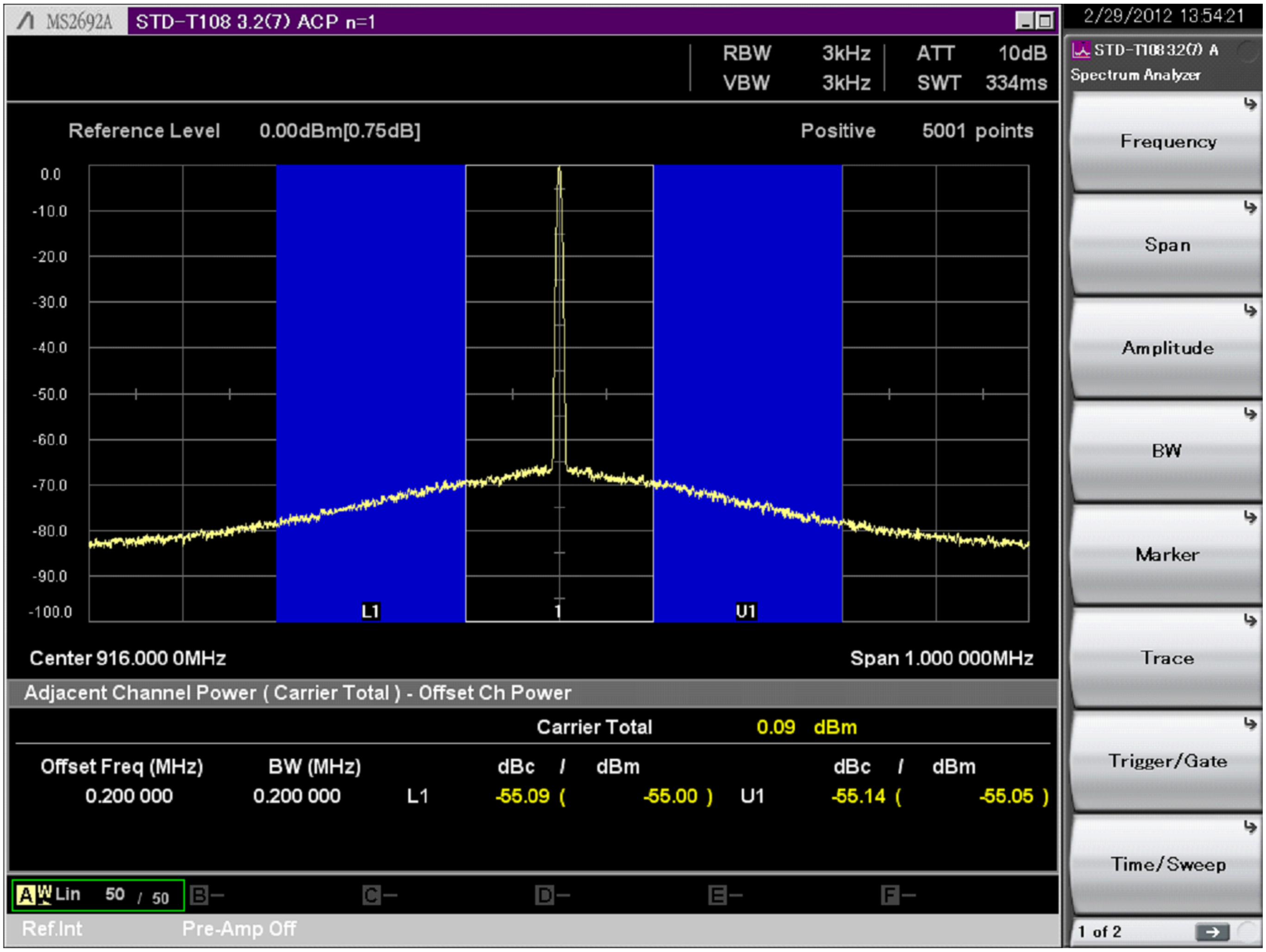


Figure 13. Adjacent Channel Leakage Power in CW Mode (1mW, 916.0 to 916.8 MHz, n=1)

Compliance remains difficult with this chosen modulation protocol when using a single unit radio channel (n=1), even when using a nearly perfect signal source such as an Agilent E4432 signal generator. To illustrate this fact, an additional plot is provided in which an Agilent E4432 signal generator is modulated with a 100 kbps, 50 kHz deviation 2GFSK BT=0.5 pseudo-random data stream. This performance is shown in Figure 14 and is observed to comply with the spec with only ~4 dB margin. This demonstrates that the inherent modulation bandwidth of this selected modulation protocol barely complies with the adjacent channel leakage requirements.

- Limit: –26 dBm (max)
- Measured: –29.82 dBm (in CW mode)
- Margin: 3.82 dB (PASS)

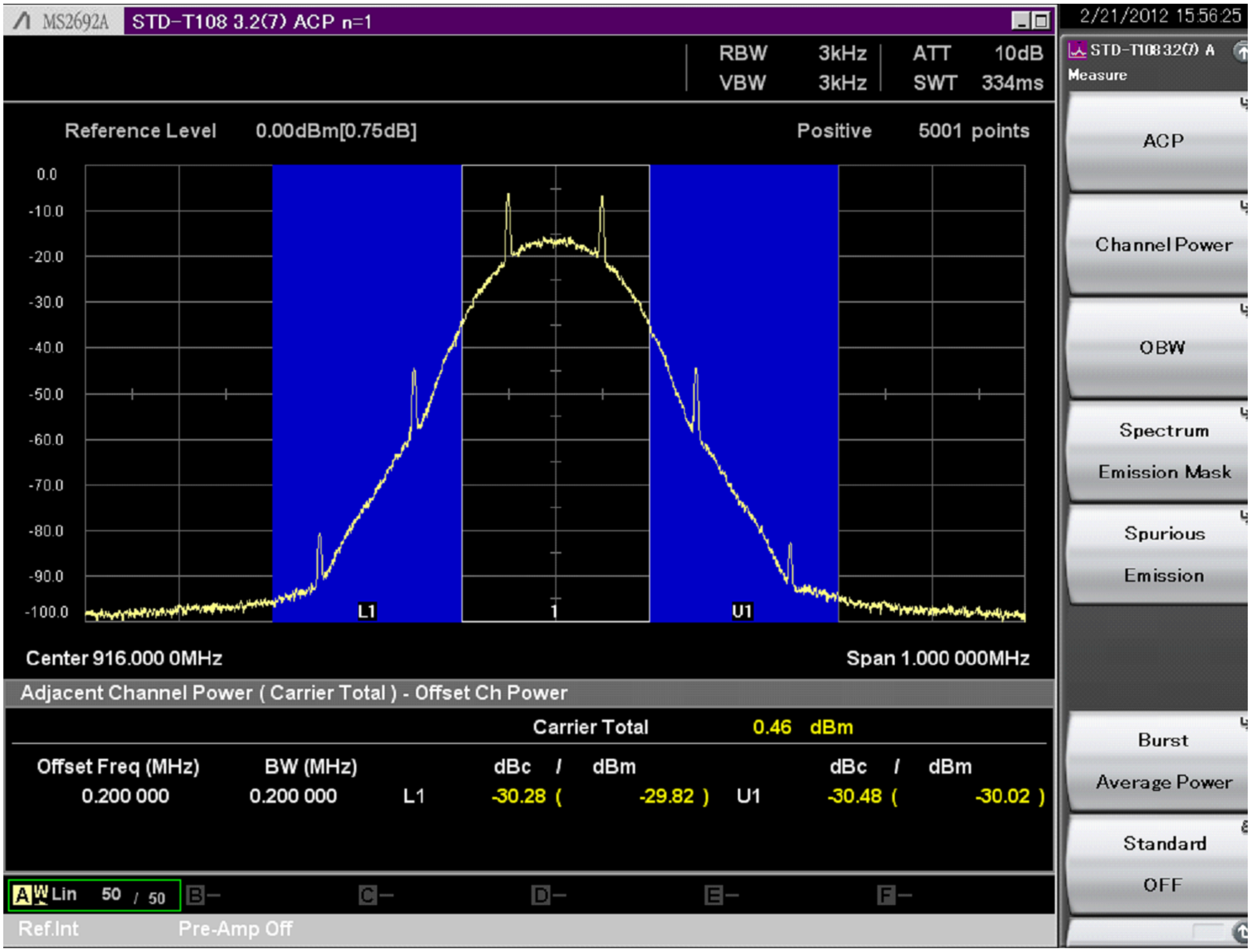


Figure 14. Adjacent Channel Leakage of Agilent SigGen, (1mW, 916.0 to 916.8 MHz, n=1)

There are four ways in which the Si446x chips may be operated to obtain a greater margin of compliance with the adjacent channel leakage requirements:

- Reduce the TX output power (not desirable)
- Operate with two (or more) unit radio channels (i.e., n ≥ 2)
- Reduce the signal modulation bandwidth by reducing the data rate and/or deviation
- Optimize the TX Gaussian filter coefficients to further filter the modulation spectrum

The Si4463 chip easily complies with the adjacent channel leakage specification when using two unit radio channels (n=2). The measured adjacent channel leakage for the scenario of n=2 with DR=100 kbps Dev=50 kHz is shown in Figure 15, and is observed to comply with the spec with over 30 dB of margin. This test also inherently verifies compliance with wider radio channels, such as when using n=3, 4, or 5 unit radio channels.

- Limit: –26 dBm (max)
- Measured: –56.50 dBm
- Margin: 30.5 dB (PASS)

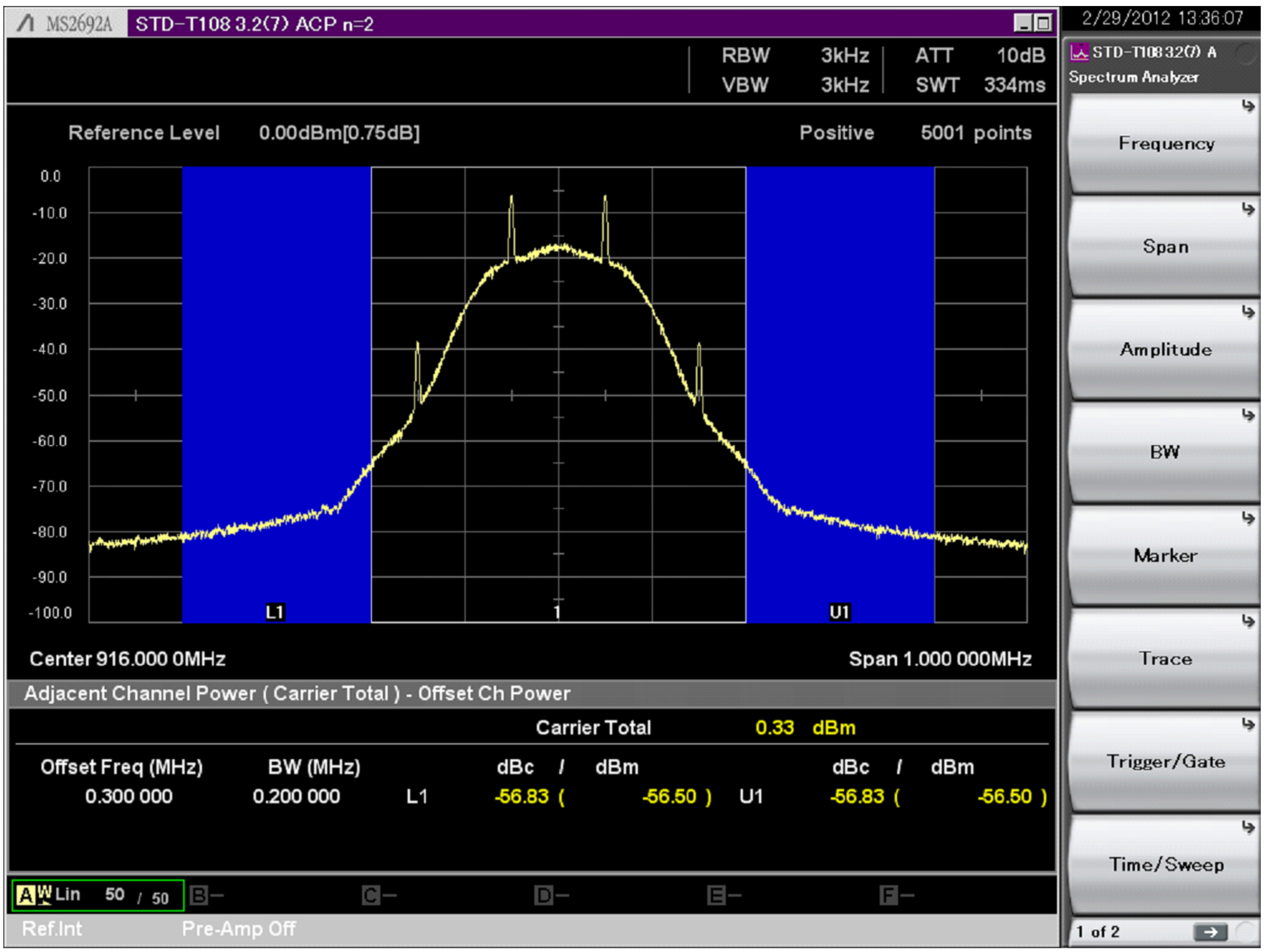


Figure 15. Adjacent Channel Leakage Power (1 mW, 916.0 to 916.8 MHz, n=2)

As an alternative, the adjacent channel leakage performance may be improved by slightly narrowing the TX Gaussian filter bandwidth (i.e., BxT product), thus providing further filtering of the modulation and reduction of the modulation bandwidth. The default value of the TX Gaussian filter bandwidth-time product on Si446x chips is BxT=0.5, but is programmable through the API at properties MODEM_TX_FILTER_COEFF_8_0 (0x200F–0x2017). If the TX Gaussian filter bandwidth-time product is reduced to BxT=0.4, the Si4463 chip is observed to comply with the adjacent channel leakage spec even for the case of n=1, as shown in Figure 16.

- Limit: –26 dBm (max)
- Measured: –28.59 dBm
- Margin: 2.59 dB (PASS)

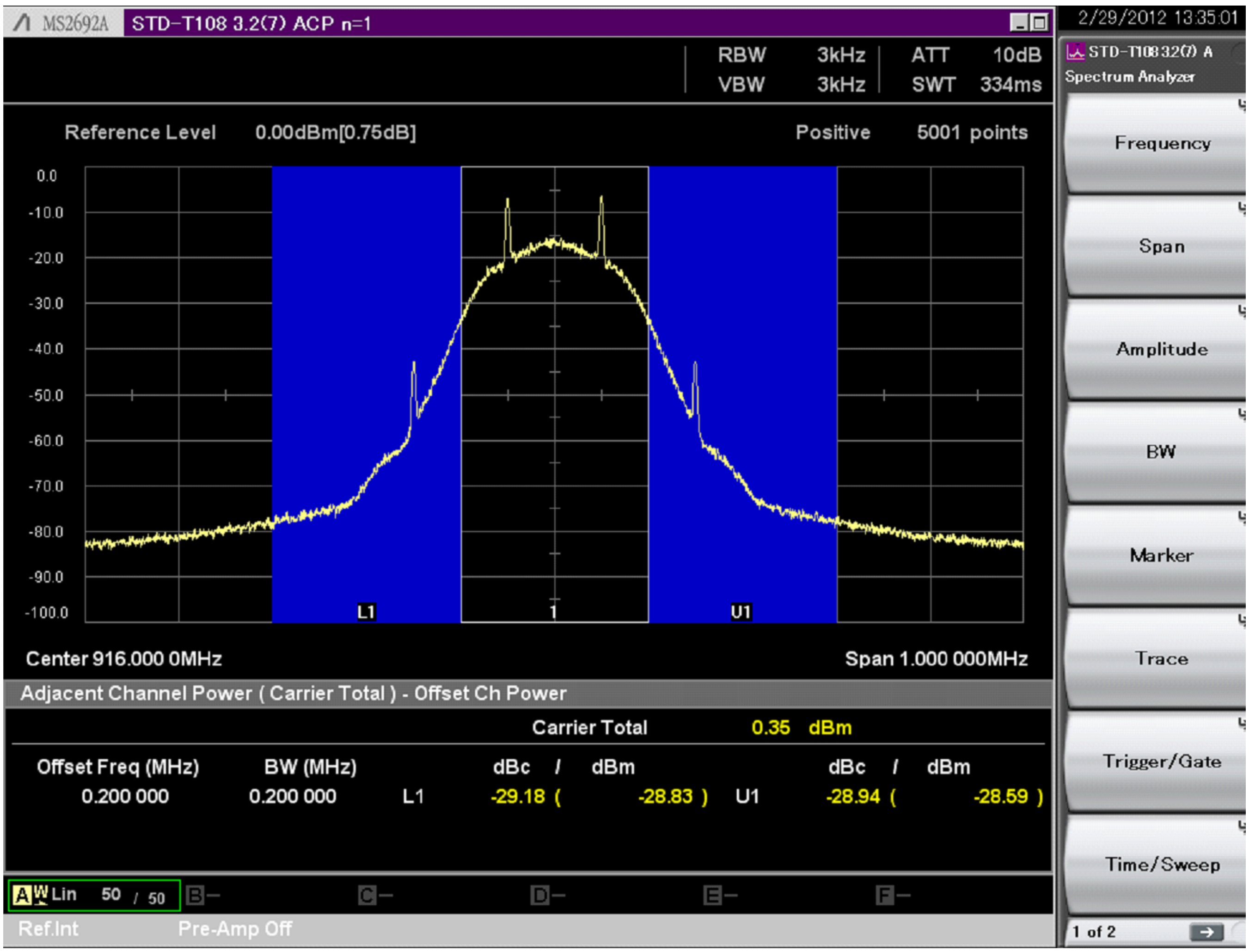


Figure 16. Adjacent Channel Leakage Power (1 mW, 916.0 to 916.8 MHz, n=1, BT=0.4)

Within the frequency band of 915.0 to 930.0 MHz at frequency offsets from the channel center frequency of |f – fc| > 200kHz + n x 100 kHz, the limit of unwanted spurious signals shall be less than or equal to –36 dBm/100 kHz. Although the allowed spurious level is specified in a 100 kHz reference bandwidth, it is not appropriate to use ResBW=100 kHz while taking the measurement due to the proximity to the modulation bandwidth of the desired signal. Accordingly, a ResBW=3 kHz configuration is used for the measurement, and the measurement limit is adjusted downwards by 10 x log(100 kHz/3 kHz) = 15.2 dB, resulting in a modified spec limit of –51.2 dBm/3 kHz bandwidth.

The selected modulation parameters were DR = 100 kbps and Deviation = 50 kHz. The measurement was taken assuming operation with one unit radio channel (n=1). The measured spectral mask is shown in Figure 17. The Si4463 chip easily complies with the requirements of ARIB STD-T108 3.2(7) for Spectral Mask for the selected modulation protocol.

- Limit: –36 dBm /100 kHz = –51.2 dBm/3 kHz (max)
- Measured: –77.66 dBm /3 kHz = –62.46 dBm /100 kHz
- Margin: 26.46 dB (PASS)

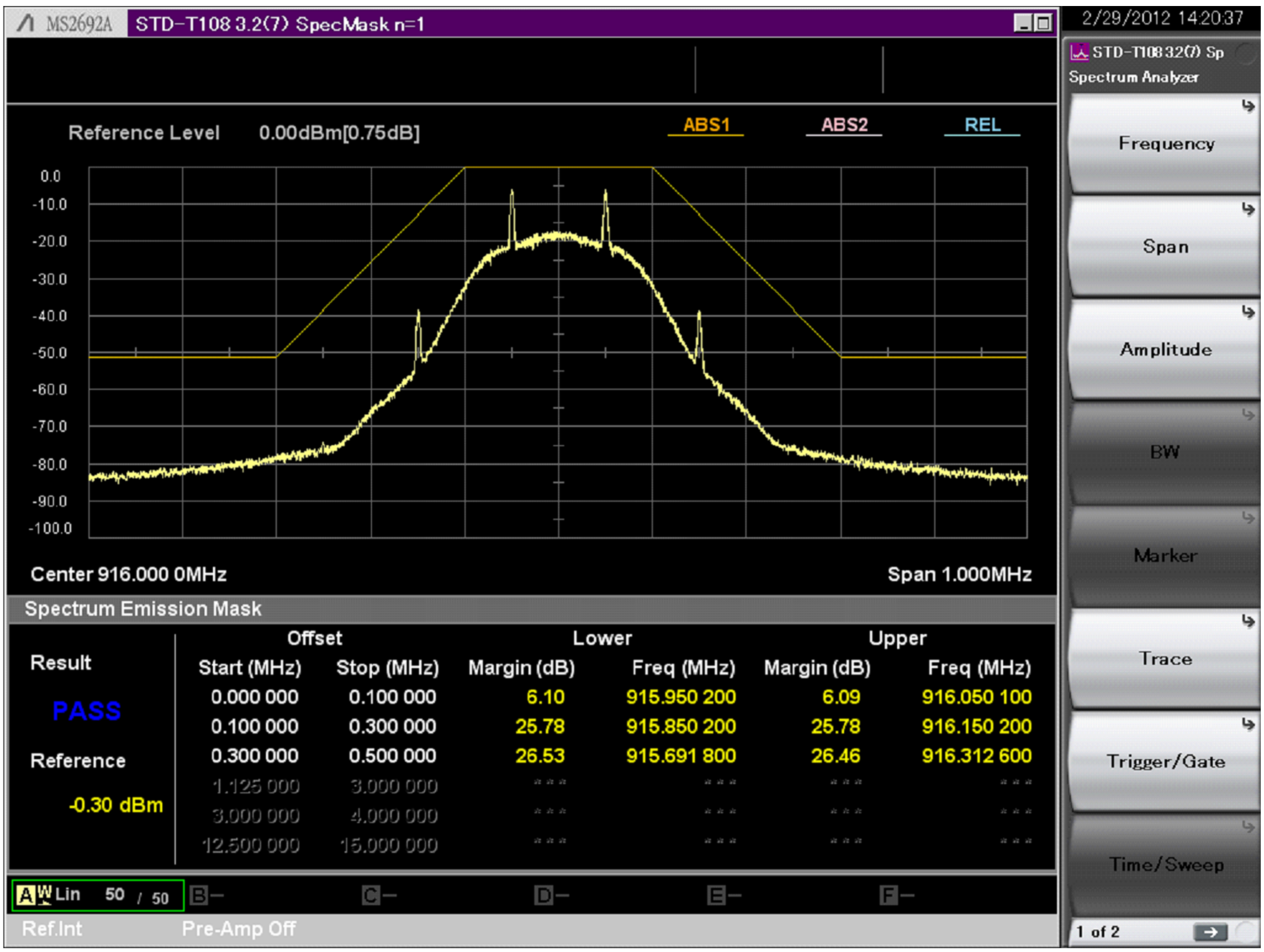


Figure 17. Spectral Mask (1 mW, 916.0 to 916.8 MHz, n=1)

3.8.2. Antenna Power =20 mW, Freq Band=922.4 to 928.0 MHz

Within the frequency band of 922.4 to 928.0 MHz when operating with antenna power of more than 1 mW and less than or equal to 20 mW, the integrated adjacent channel leakage power within the 200 kHz bandwidth at the upper and lower edges of the radio channel shall be less than or equal to –15 dBm.

The selected modulation parameters were DR = 100 kbps and Deviation = 50 kHz. The measurement was taken assuming operation with one unit radio channel (n=1). The measured adjacent channel leakage power is shown in Figure 18. The Si4463 chip again marginally fails to comply with the requirements of ARIB STD-T108 3.2(7) for Adjacent Channel Leakage Power for the selected modulation protocol.

- Limit: –15 dBm (max)
- Measured: –13.06 dBm
- Margin: –1.94 dB (FAIL)

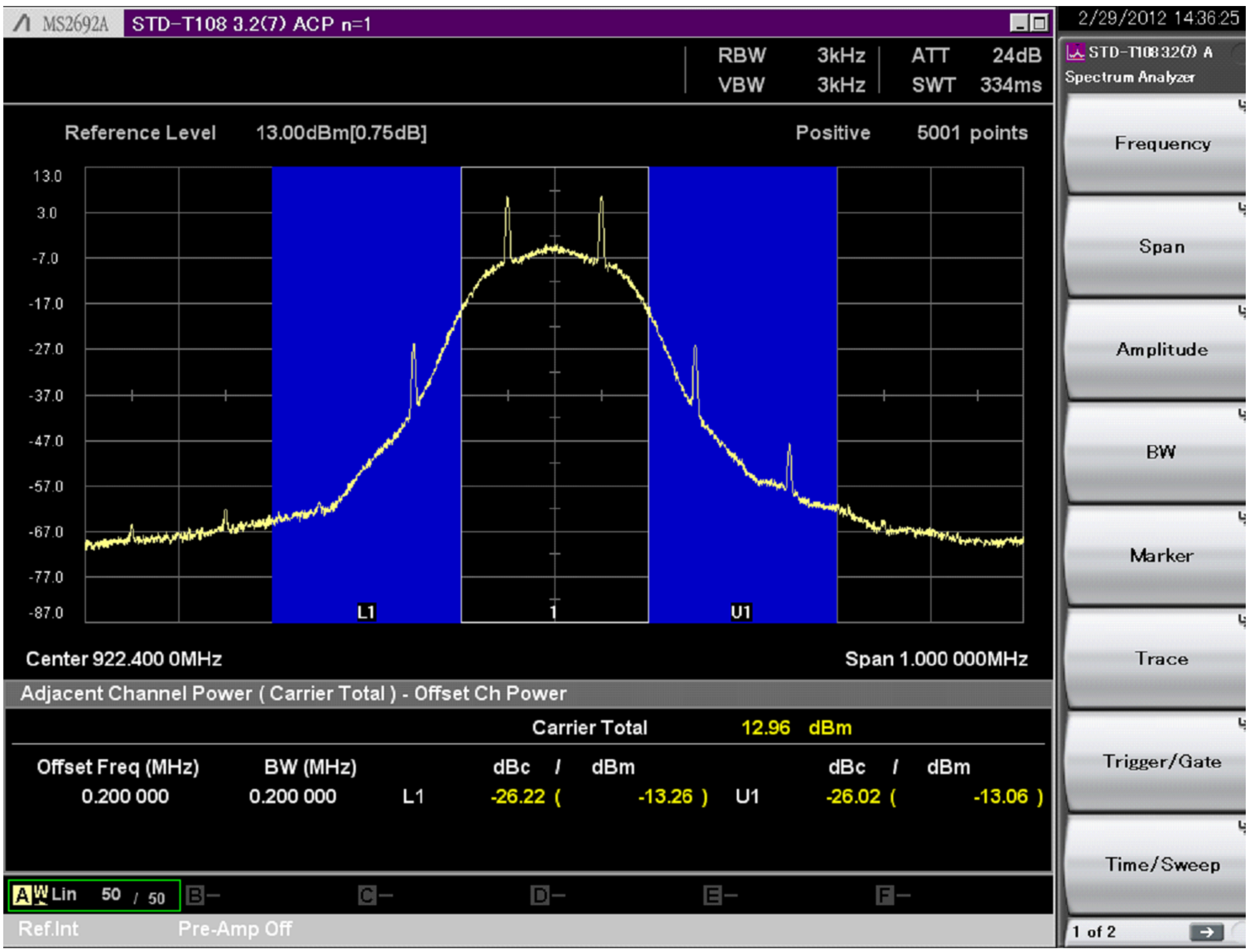


Figure 18. Adjacent Channel Leakage Power (20mW, 922.4 to 928.0 MHz, n=1)

Compliance may again be obtained by reducing the Gaussian filtering bandwidth. If the TX Gaussian filter bandwidth-time product is reduced to BxT=0.4, the Si4463 chip is observed to comply as shown in Figure 19.

- Limit: –15 dBm (max)
- Measured: –16.15 dBm
- Margin: 1.15 dB (PASS)

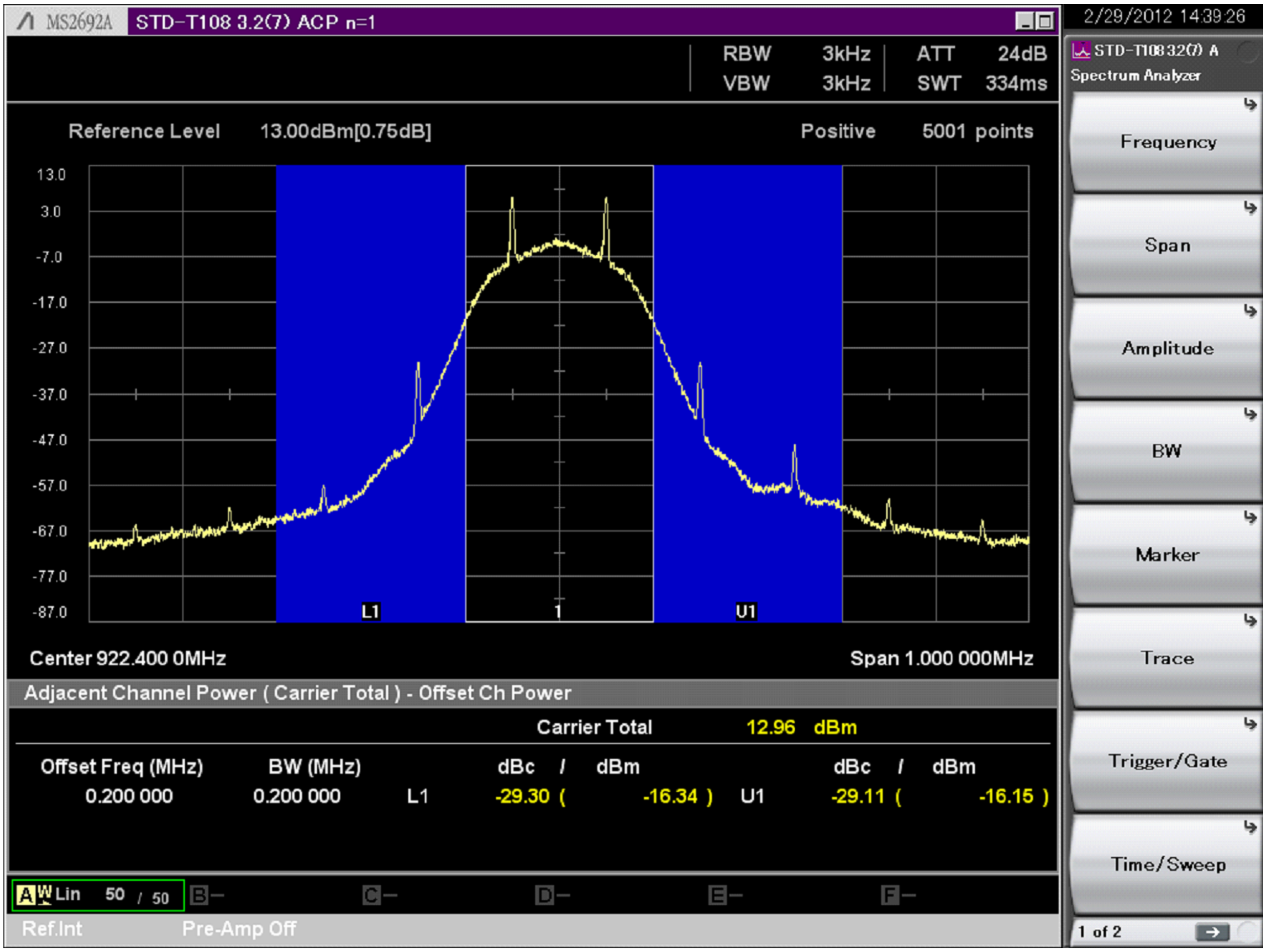


Figure 19. Adjacent Channel Leakage Power (20 mW, 922.4 to 928.0 MHz, n=1, BT=0.4)

The Si4463 chip again easily complies with the adjacent channel leakage specification when using two unit radio channels (n=2). The measured adjacent channel leakage for the scenario of n=2 with DR=100 kbps Dev=50 kHz is shown in Figure 20, and is observed to comply with the spec with over 25 dB of margin. This test also inherently verifies compliance with wider radio channels, such as when using n=3, 4, or 5 unit radio channels.

- Limit: –15 dBm (max)
- Measured: –40.56 dBm
- Margin: 25.56 dB (PASS)

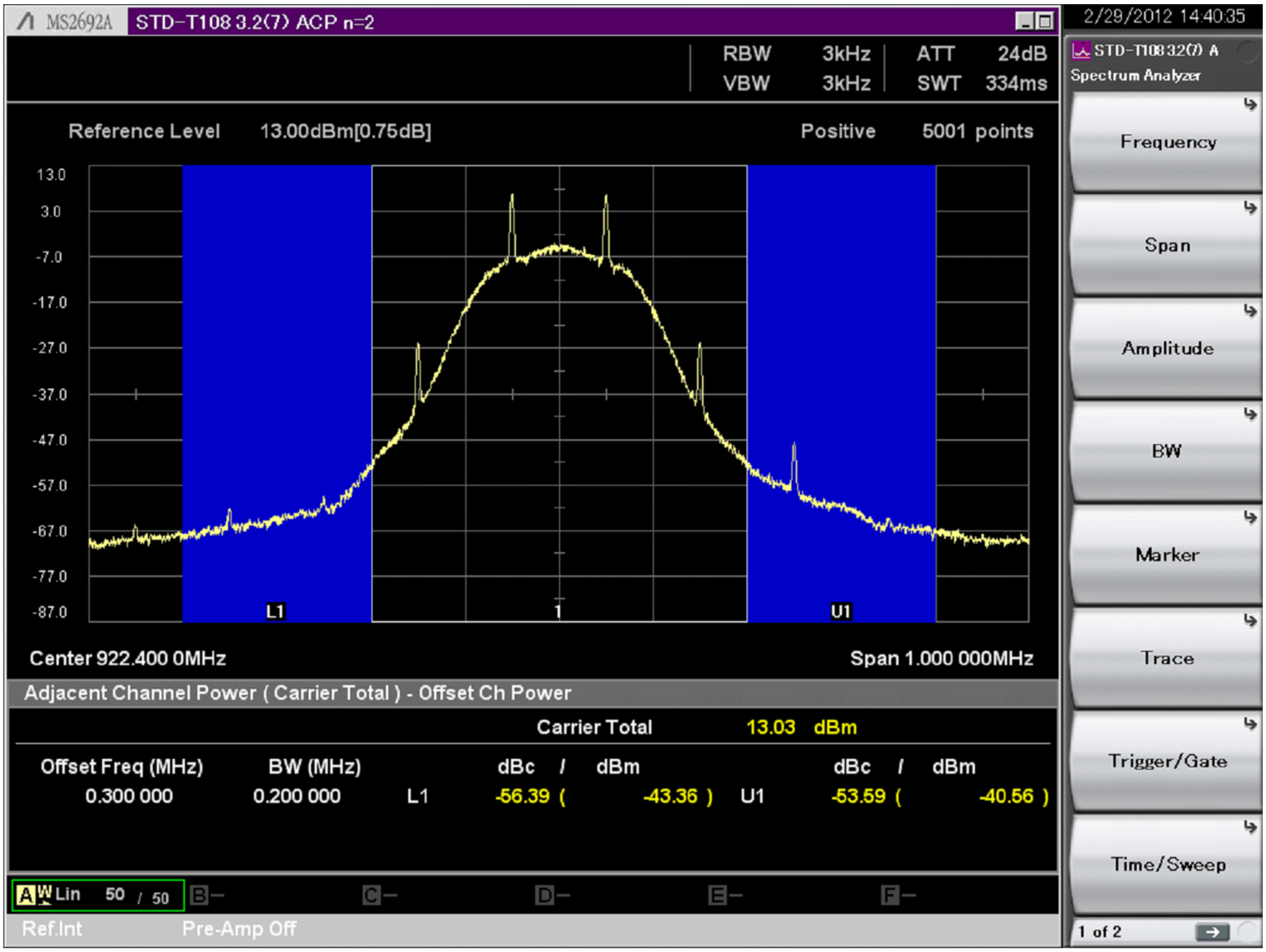


Figure 20. Adjacent Channel Leakage Power (20mW, 922.4 to 928.0 MHz, n=2)

Within the frequency band of 915.0 to 930.0 MHz at frequency offsets from the channel center frequency of |f – fc| > 200 kHz + n x 100 kHz, the limit of unwanted spurious signals shall be less than or equal to –36 dBm/100 kHz. Although the allowed spurious level is specified in a 100 kHz reference bandwidth, it is not appropriate to use ResBW=100 kHz while taking the measurement due to the proximity to the modulation bandwidth of the desired signal. Accordingly, a ResBW=3 kHz configuration is used for the measurement, and the measurement limit is adjusted downwards by 10 x log(100 kHz/3 kHz) = 15.2 dB, resulting in a modified spec limit of –51.2 dBm/3 kHz bandwidth.

The selected modulation parameters were DR = 100 kbps and Deviation = 50 kHz. The measurement was taken assuming operation with one unit radio channel (n=1). The measured spectral mask is shown in Figure 21. The Si4463 chip complies with the requirements of ARIB STD-T108 3.2(7) for Spectral Mask for the selected modulation protocol.

- Limit: –36 dBm /100 kHz = –51.2 dBm /3 kHz (max)
- Measured: –61.46 dBm/3 kHz = –46.26 dBm/100 kHz
- Margin: 10.26 dB (PASS)

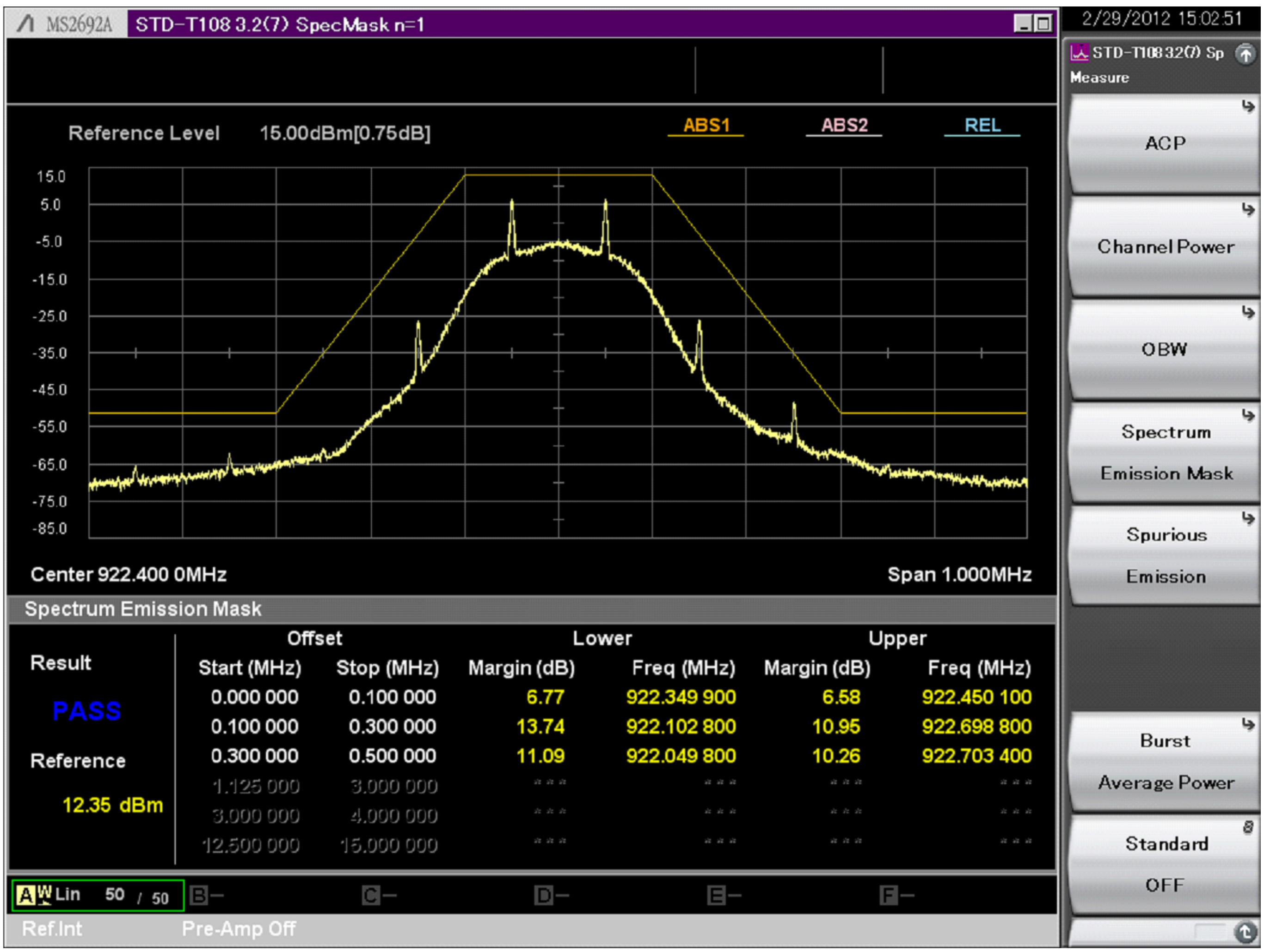


Figure 21. Spectral Mask (20 mW, 922.4 to 928.0 MHz, n=1)

A greater margin of compliance may be obtained when using two unit radio channels (n=2). The measured spectral mask for the scenario of n=2 with DR=100 kbps Dev=50 kHz is shown in Figure 22, and is observed to comply with the spec with over 7 dB of margin. This test also inherently verifies compliance with wider radio channels, such as when using n=3, 4, or 5 unit radio channels.

- Limit: –36 dBm /100 kHz = –51.2 dBm /3 kHz (max)
- Measured: –65.10 dBm/3 kHz = –49.90 dBm /100 kHz
- Margin: 13.90 dB (PASS)

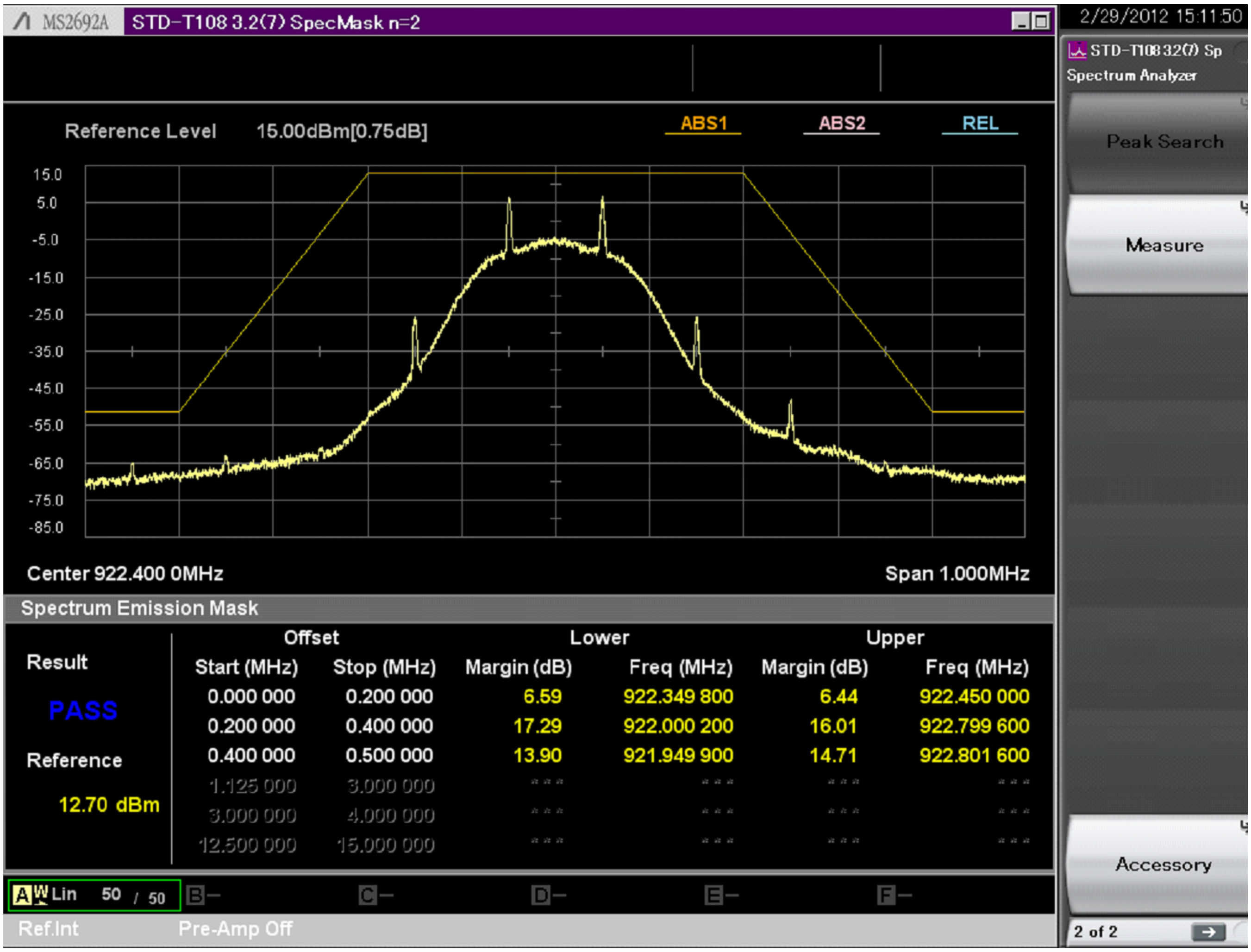


Figure 22. Spectral Mask (20mW, 922.4 to 928.0 MHz, n=2)

3.8.3. Antenna Power = 250 mW, Freq Band=922.4 to 923.4 MHz

Within the frequency band of 922.4 to 923.4 MHz when operating with antenna power of more than 20 mW and less than or equal to 250 mW, the integrated adjacent channel leakage power within the 200 kHz bandwidth at the upper and lower edges of the radio channel shall be less than or equal to –5 dBm.

The selected modulation parameters were DR = 100 kbps and Deviation = 50 kHz. The measurement was taken assuming operation with one unit radio channel (n=1). The measured adjacent channel leakage power is shown in Figure 23. The Si4463 chip complies with the requirements of ARIB STD-T108 3.2(7) for Adjacent Channel Leakage Power for the selected modulation protocol. However, compliance exists primarily because the chip is not operating at the full output power level (i.e., 250 mW) allowed by the regulatory standard. In the event that an external power amplifier were placed after the RFIC to increase the output power by ~4 dB and thus operate at the maximum allowed power level, it is likely that the adjacent channel leakage power would fail the spec by ~3 dB.

- Limit: –5 dBm (max)
- Measured: –6.32 dBm
- Margin: 1.32 dB (PASS)

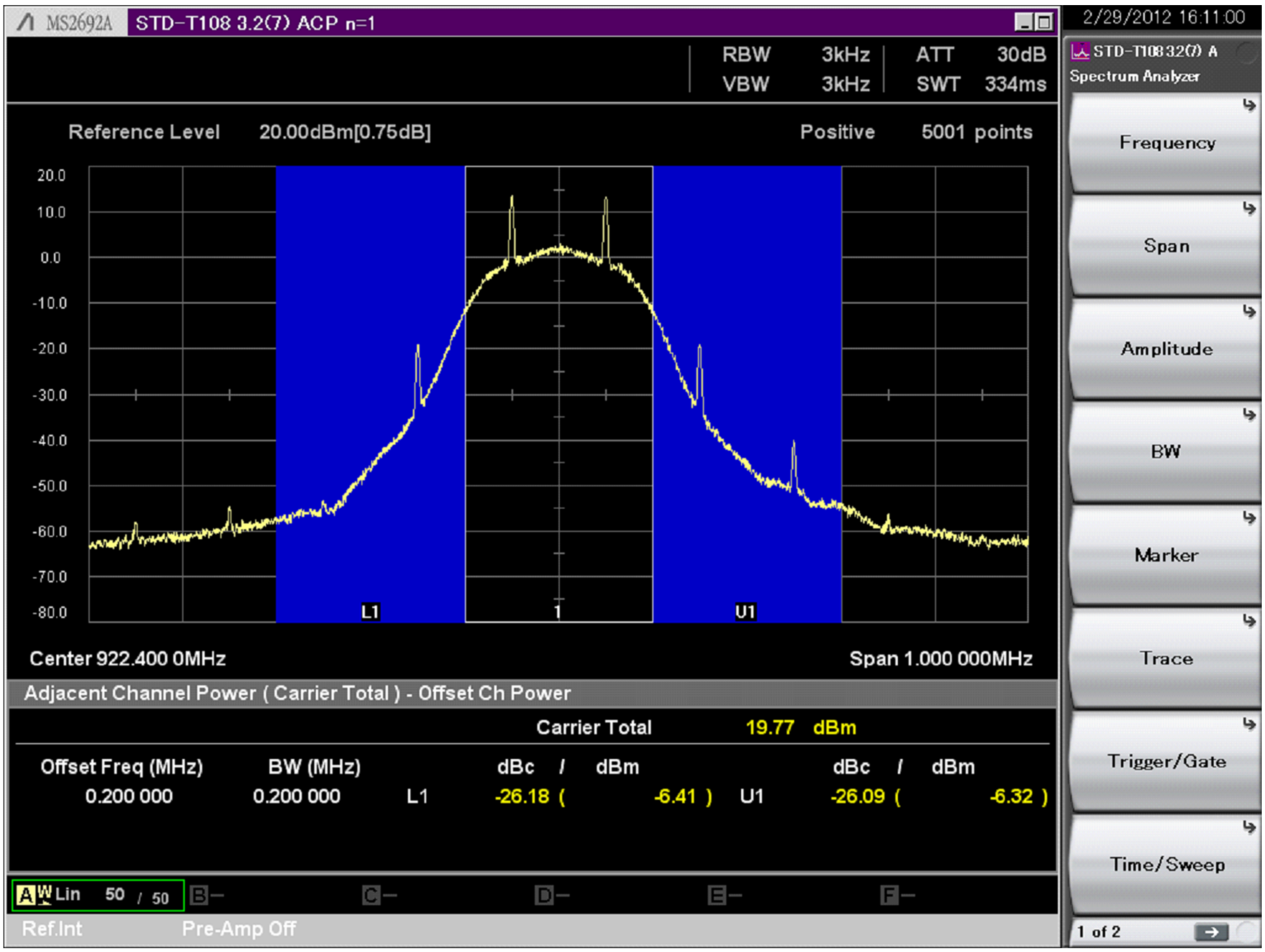


Figure 23. Adjacent Channel Leakage Power (250 mW, 922.4 to 923.4 MHz, n=1)

A greater margin of compliance may again be obtained by reducing the Gaussian filtering bandwidth. If the TX Gaussian filter bandwidth-time product is reduced to BxT=0.4, the Si4463 chip is observed to comply as shown in Figure 24.

- Limit: –5 dBm (max)
- Measured: –9.39 dBm
- Margin: 4.39 dB (PASS)

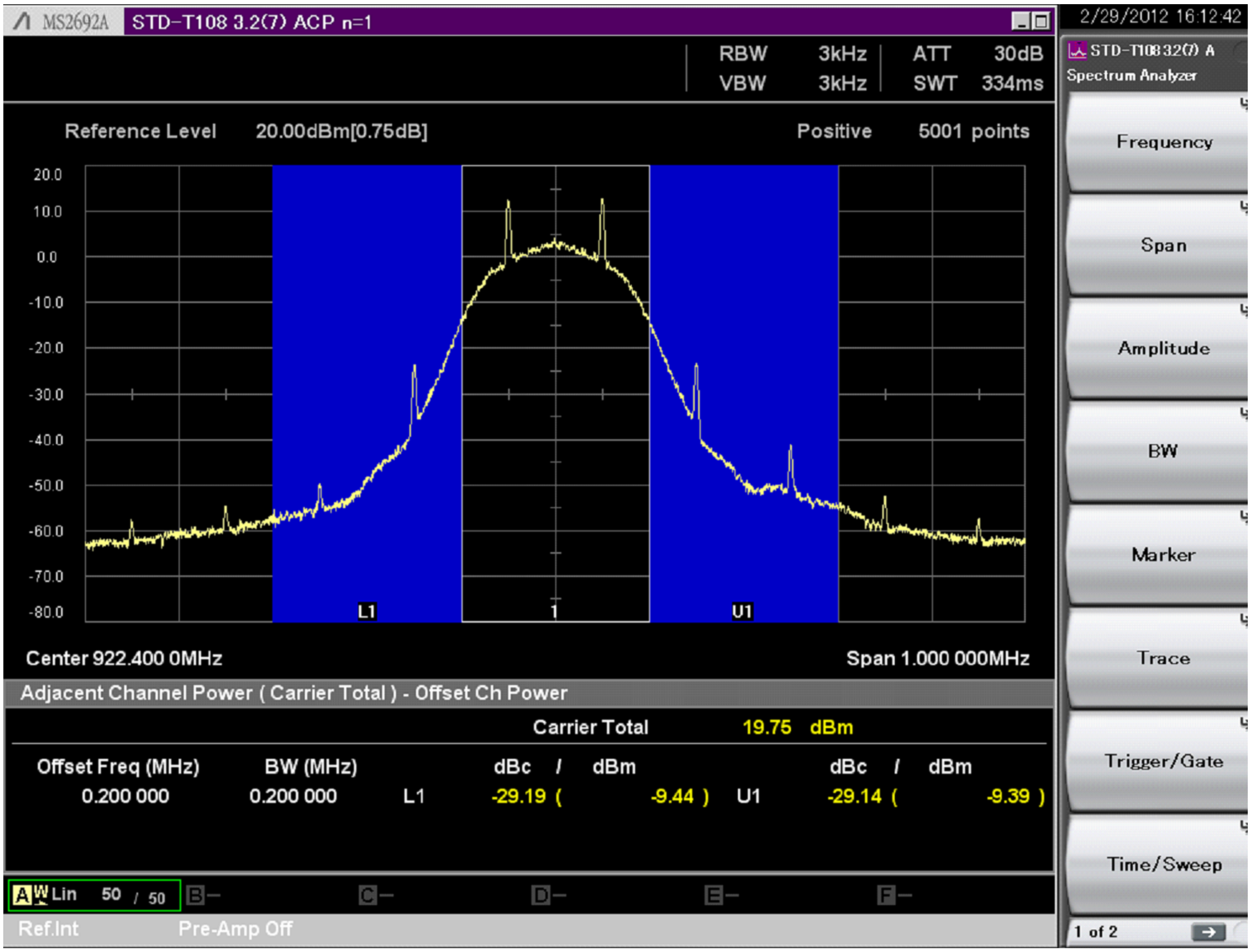


Figure 24. Adjacent Channel Leakage Power (250 mW, 922.4 to 923.4 MHz, n=1, BT=0.4)

The Si4463 chip again easily complies with the adjacent channel leakage specification when using two unit radio channels (n=2). The measured adjacent channel leakage for the scenario of n=2 with DR=100 kbps Dev=50 kHz is shown in Figure 25, and is observed to comply with the spec with over 28 dB of margin. This test also inherently verifies compliance with wider radio channels, such as when using n=3, 4, or 5 unit radio channels.

- Limit: –5 dBm (max)
- Measured: –33.69 dBm
- Margin: 28.69 dB (PASS)

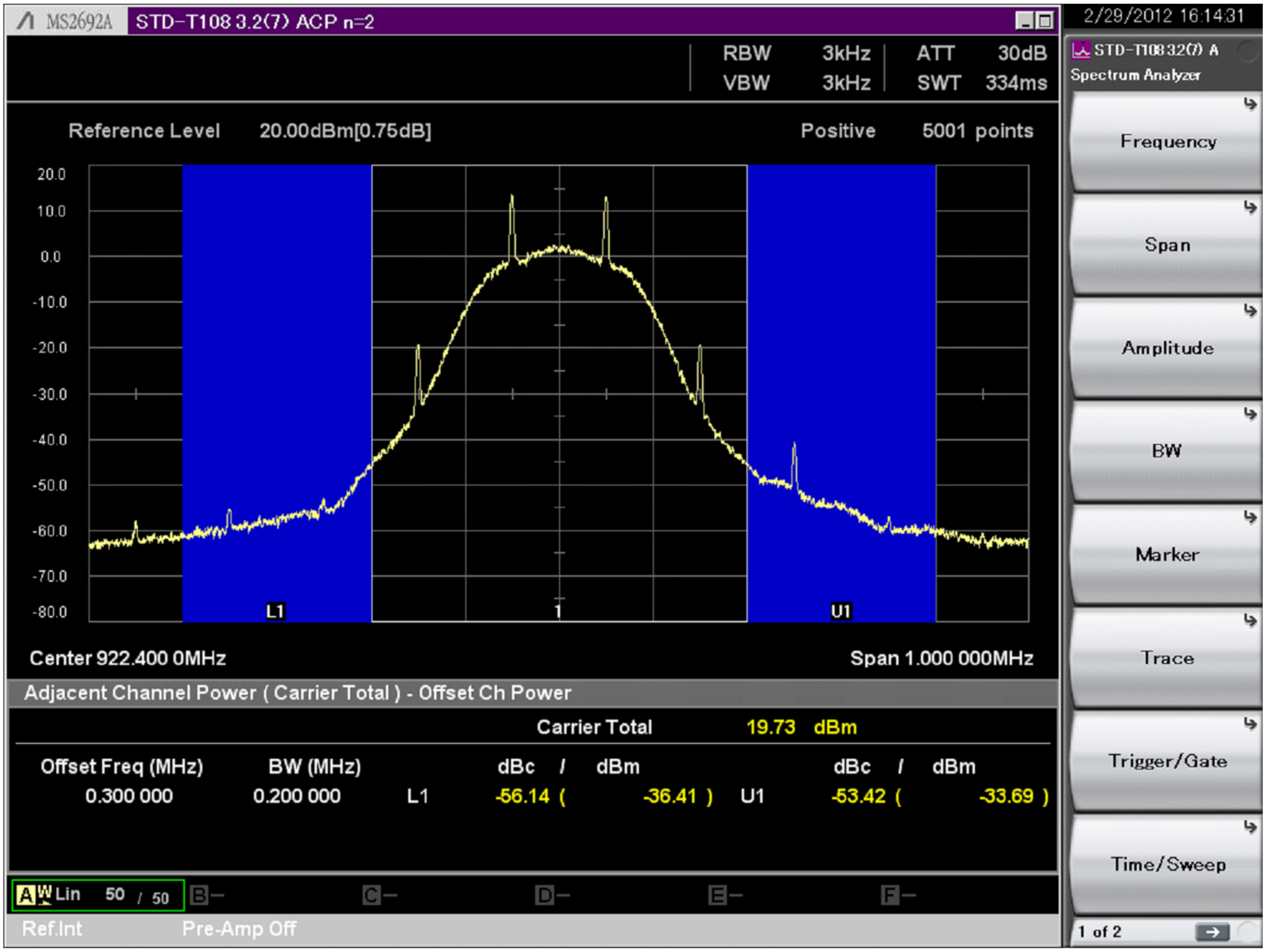


Figure 25. Adjacent Channel Leakage Power (250 mW, 922.4 to 923.4 MHz, n=2)

Within the frequency band of 920.3 to 924.3 MHz at frequency offsets from the channel center frequency of |f – fc| > 200 kHz + n x 100 kHz, the limit of unwanted spurious signals shall be less than or equal to –29 dBm/100 kHz. Although the allowed spurious level is specified in a 100 kHz reference bandwidth, it is not appropriate to use ResBW=100 kHz while taking the measurement due to the proximity to the modulation bandwidth of the desired signal. Accordingly, a ResBW=3 kHz configuration is used for the measurement, and the measurement limit is adjusted downwards by 10 x log(100 kHz/3 kHz) = 15.2 dB, resulting in a modified spec limit of –44.2 dBm/3 kHz bandwidth.

The selected modulation parameters were DR = 100 kbps and Deviation = 50 kHz. The measurement was taken assuming operation with one unit radio channel (n=1). The measured spectral mask is shown in Figure 26. The Si4463 chip easily complies with the requirements of ARIB STD-T108 3.2(7) for Spectral Mask for the selected modulation protocol. The margin of compliance is sufficient to allow operation at the full output power level (i.e., 250mW) allowed by the regulatory standard by addition of an external power amplifier.

- Limit: –29 dBm /100 kHz = –44.2 dBm /3 kHz (max)
- Measured: –54.09 dBm/3 kHz = –38.89 dBm/100 kHz
- Margin: 9.89 dB (PASS)

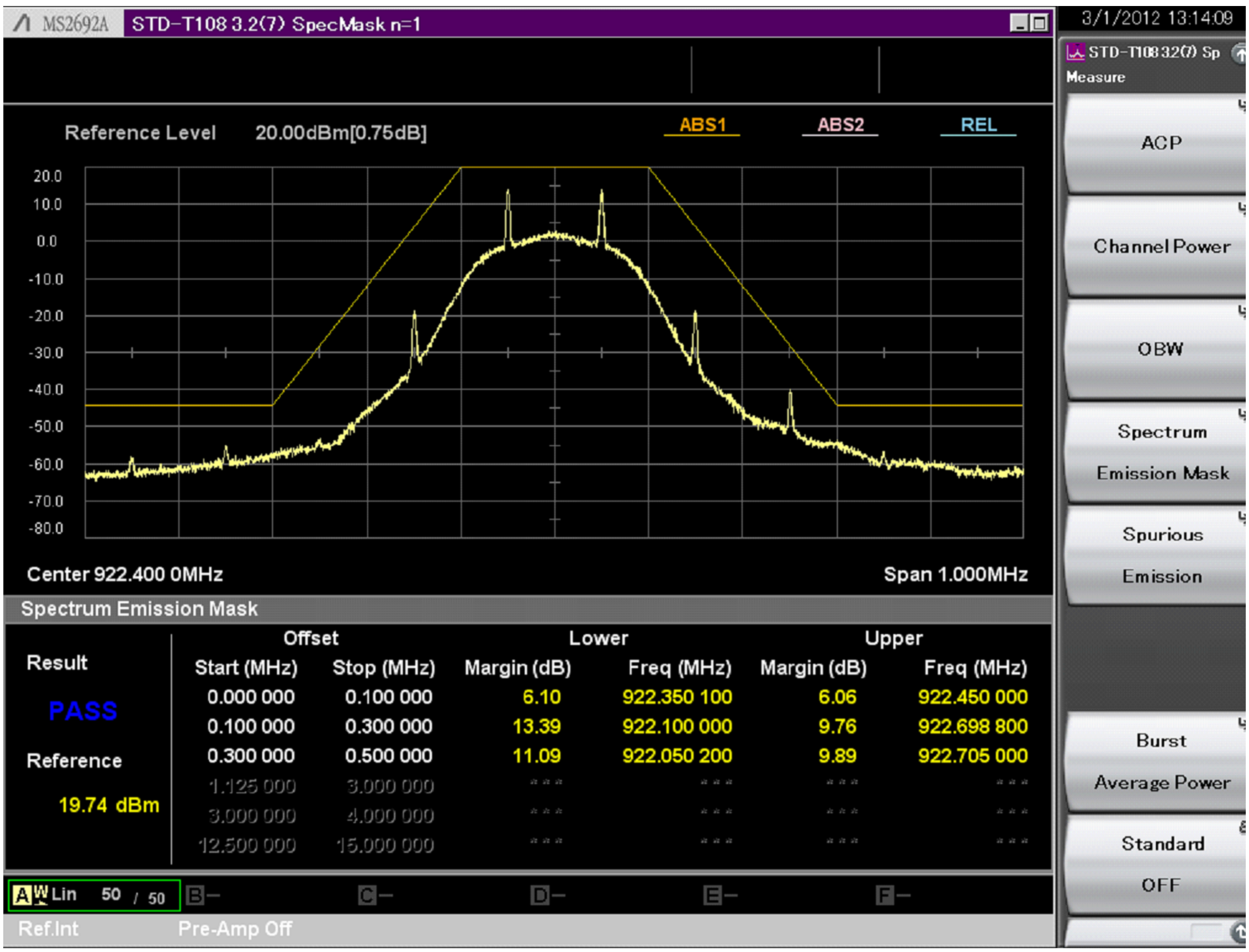
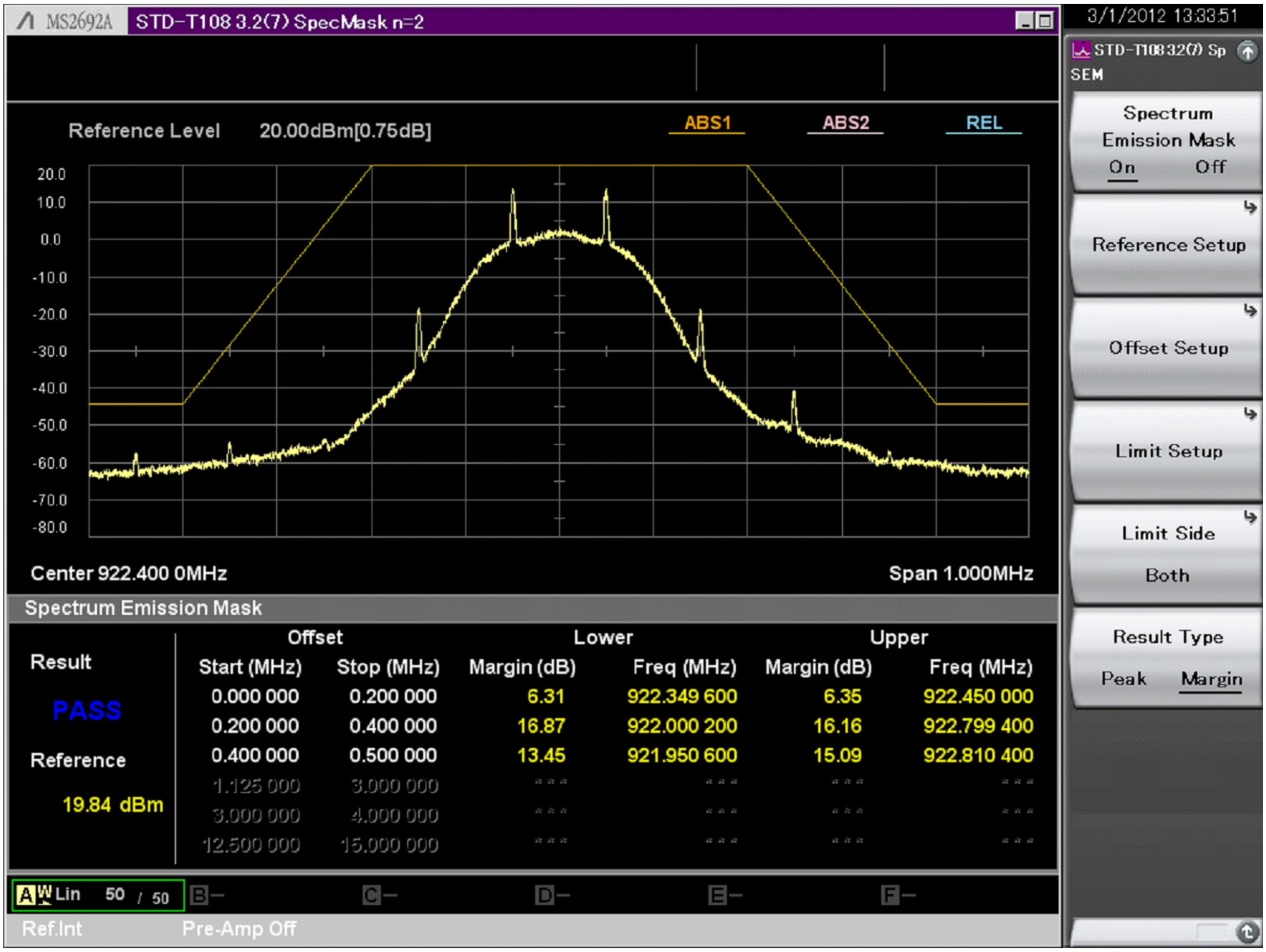


Figure 26. Spectral Mask (250 mW, 922.4 to 923.4 MHz, n=1)

A greater margin of compliance may be obtained when using two unit radio channels (n=2). The measured spectral mask for the scenario of n=2 with DR=100 kbps Dev=50 kHz is shown in Figure 27, and is observed to comply with the spec with ~13 dB of margin. This test also inherently verifies compliance with wider radio channels, such as when using n=3, 4, or 5 unit radio channels.

- Limit: –29 dBm /100 kHz = –44.2 dBm/3 kHz (max)
- Measured: –57.65 dBm/3 kHz = –42.45 dBm/100 kHz
- Margin: 13.45 dB (PASS



Offset Start (MHz)	Offset Stop (MHz)	Lower Margin (dB)	Lower Freq (MHz)	Upper Margin (dB)	Upper Freq (MHz)
0.000 000	0.200 000	6.31	922.349 600	6.35	922.450 000
0.200 000	0.400 000	16.87	922.000 200	16.16	922.799 400
0.400 000	0.500 000	13.45	921.950 600	15.09	922.810 400
1.125 000	3.000 000	***	***	***	***
3.000 000	4.000 000	***	***	***	***
12.500 000	15.000 000	***	***	***	***

Figure 27. Spectral Mask (250 mW, 922.4 to 923.4 MHz, n=2)

3.8.4. Antenna Power = 20 mW, Freq Band = 920.6 to 922.2 MHz

Within the frequency band of 920.6 to 922.2 MHz when operating with antenna power of more than 1 mW and less than or equal to 20 mW, the integrated adjacent channel leakage power within the 200 kHz bandwidth at the upper and lower edges of the radio channel shall be less than or equal to –15 dBm.

The selected modulation parameters were DR = 100 kbps and Deviation = 50 kHz. The measurement was taken assuming operation with one unit radio channel (n=1). The measured adjacent channel leakage power is shown in Figure 28. The Si4463 chip marginally fails to comply with the requirements of ARIB STD-T108 3.2(7) for Adjacent Channel Leakage Power for the selected modulation protocol.

- Limit: –15 dBm (max)
- Measured: –13.06 dBm
- Margin: –1.94 dB (FAIL)

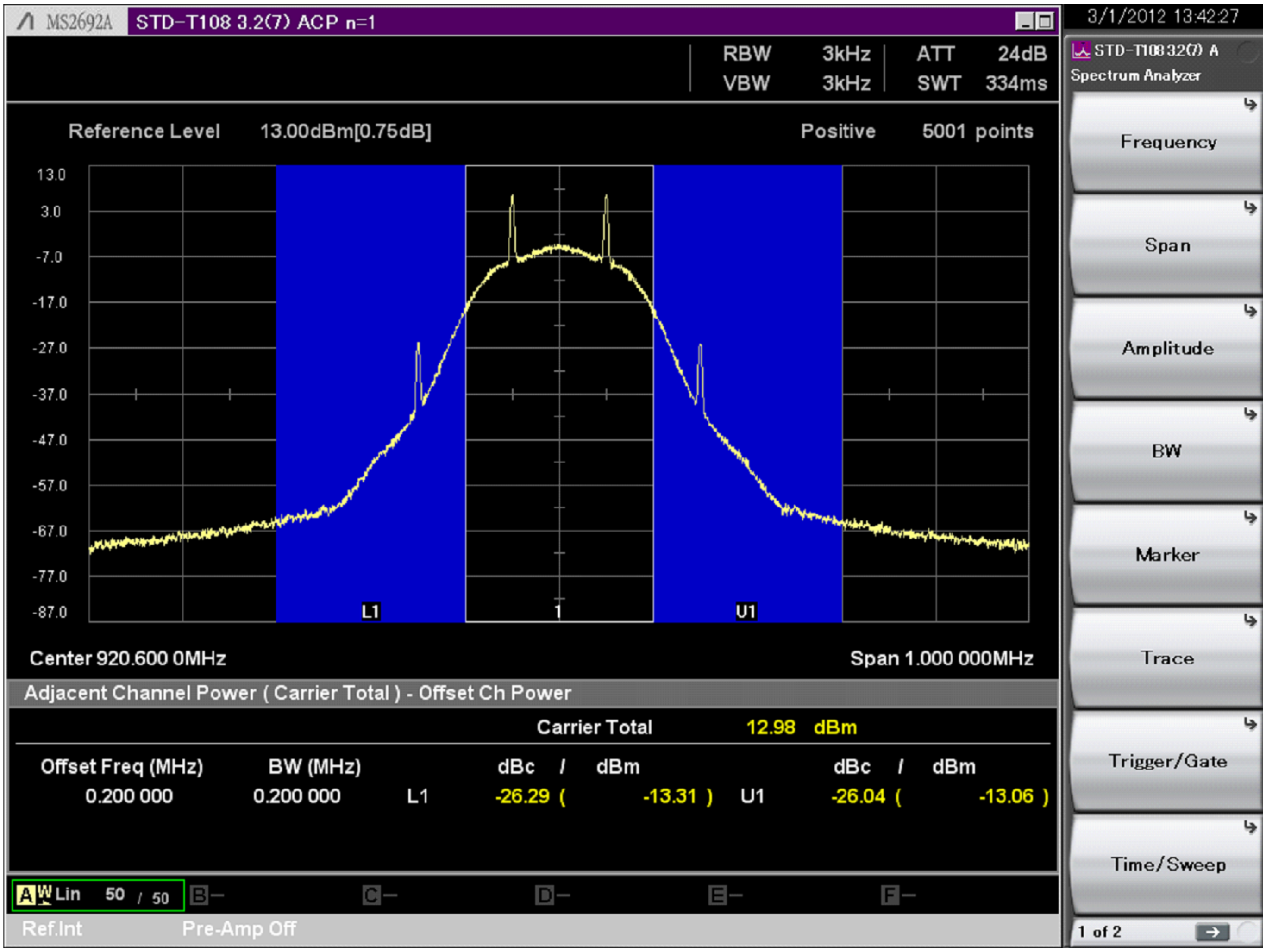


Figure 28. Adjacent Channel Leakage Power (20 mW, 920.6 to 922.2 MHz, n=1)

Compliance may be obtained by reducing the Gaussian filtering bandwidth. If the TX Gaussian filter bandwidth-time product is reduced to BxT=0.4, the Si4463 chip is observed to comply with the requirements of ARIB STD-T108 3.2(7) for Adjacent Channel Leakage Power for the selected modulation protocol as shown in Figure 29.

- Limit: –15 dBm (max)
- Measured: –15.95 dBm
- Margin: 0.95 dB (PASS)

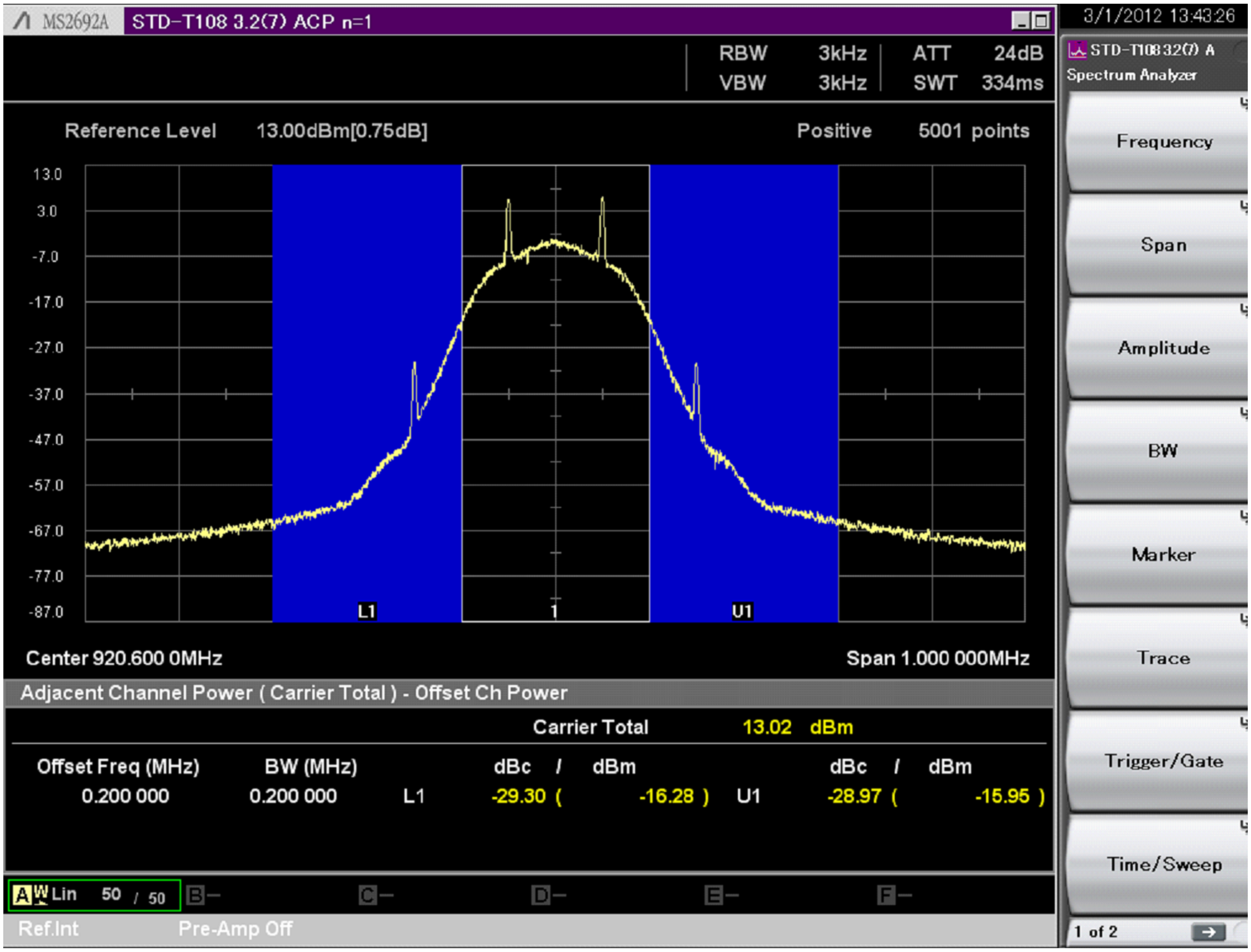


Figure 29. Adjacent Channel Leakage Power (20 mW, 920.6 to 922.2 MHz, n=1, BT=0.4)

The Si4463 chip again easily complies with the adjacent channel leakage specification when using two unit radio channels (n=2). The measured adjacent channel leakage for the scenario of n=2 with DR=100 kbps Dev=50 kHz is shown in Figure 30, and is observed to comply with the spec with over 28 dB of margin. This test also inherently verifies compliance with wider radio channels, such as when using n=3, 4, or 5 unit radio channels.

- Limit: –15 dBm (max)
- Measured: –43.71 dBm
- Margin: 28.71 dB (PASS)

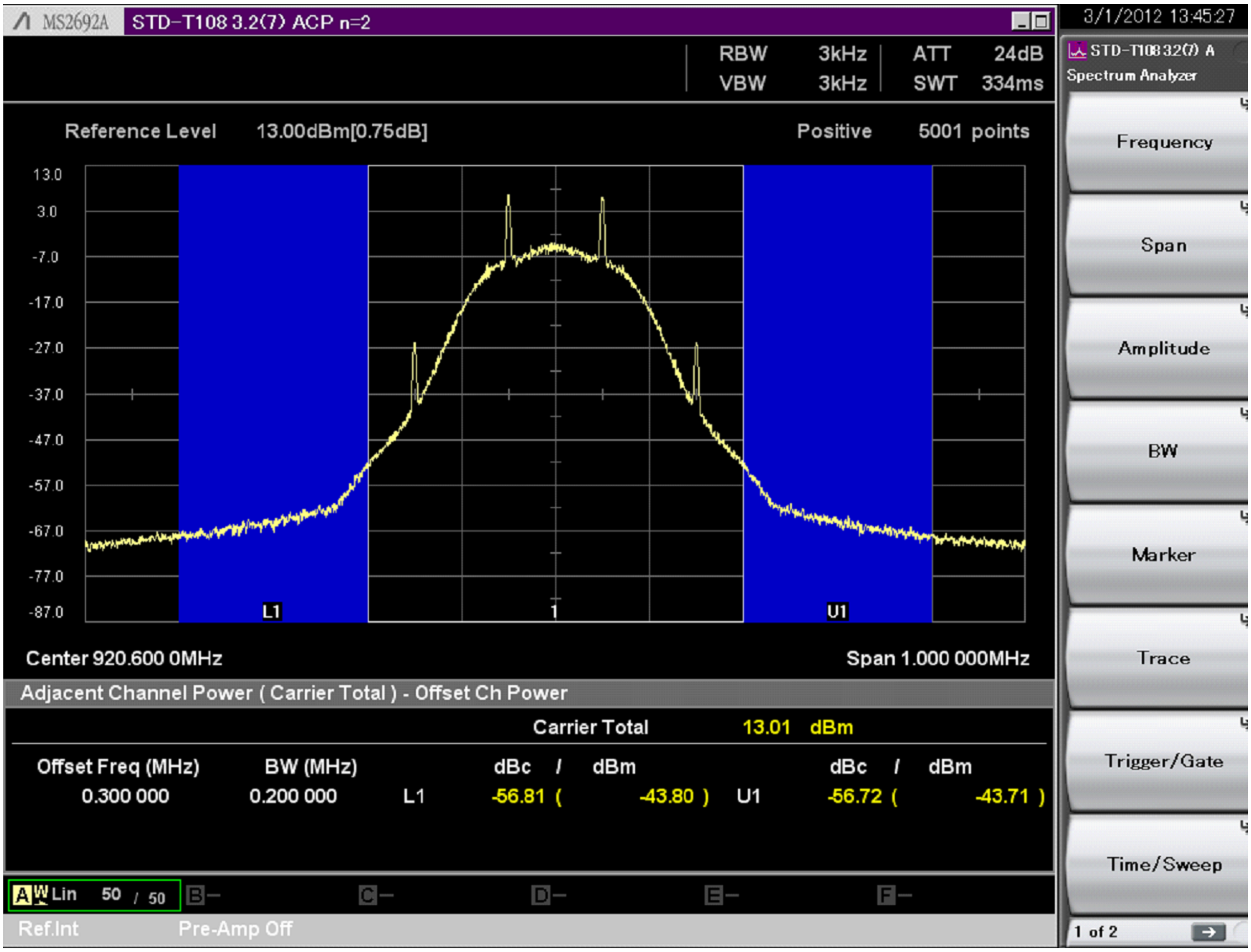


Figure 30. Adjacent Channel Leakage Power (20 mW, 920.6 to 922.2 MHz, n=2)

Within the frequency band of 915.0 to 930.0 MHz at frequency offsets from the channel center frequency of |f – fc| > 200 kHz + (n–1) x 100 kHz, the limit of unwanted spurious signals shall be less than or equal to –36 dBm/ 100 kHz. Although the allowed spurious level is specified in a 100 kHz reference bandwidth, it is not appropriate to use ResBW=100 kHz while taking the measurement due to the proximity to the modulation bandwidth of the desired signal. Accordingly, a ResBW=3 kHz configuration is used for the measurement, and the measurement limit is adjusted downwards by 10 x log(100kHz/3kHz) = 15.2 dB, resulting in a modified spec limit of –51.2 dBm/3 kHz bandwidth.

The selected modulation parameters were DR = 100 kbps and Deviation = 50 kHz. The measurement was taken assuming operation with one unit radio channel (n=1). The measured spectral mask is shown in Figure 31. The Si4463 chip fails to comply with the requirements of ARIB STD-T108 3.2(7) for Spectral Mask for the selected modulation protocol. The limiting factor in performance is the selected modulation protocol which contains discrete tones that exceed the limits of the spectral mask.

- Margin: –3.53 dB (FAIL)

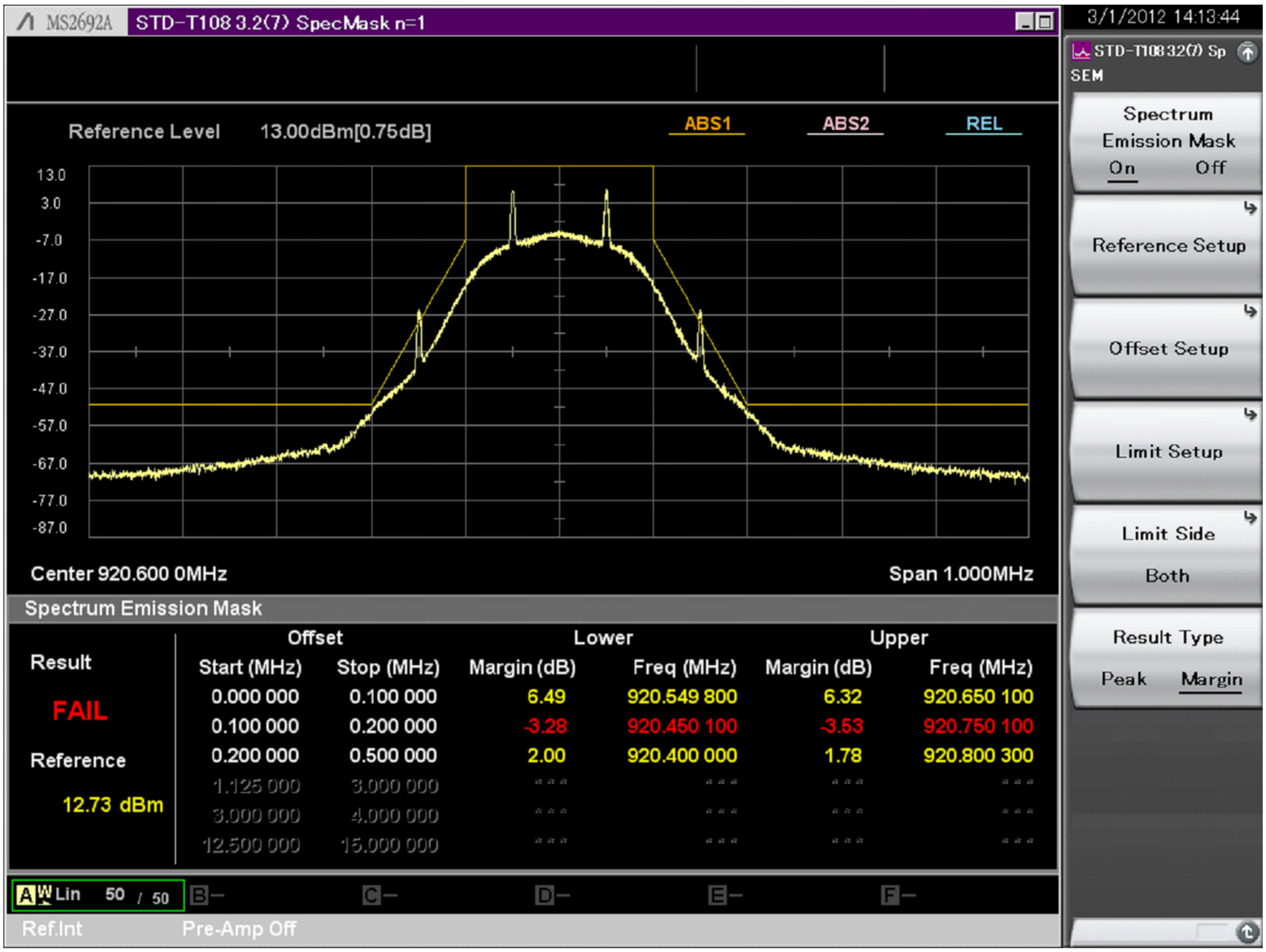


Figure 31. Spectral Mask (20 mW, 920.6 to 922.2 MHz, n=1)

Compliance may be obtained by reducing the Gaussian filtering bandwidth. If the TX Gaussian filter bandwidth-time product is reduced to BxT=0.4, the Si4463 chip is observed to comply with the requirements of ARIB STD-T108 3.2(7) for Spectral Mask for the selected modulation protocol as shown in Figure 32.

- Limit: –36 dBm /100 kHz = –51.2 dBm/3 kHz (max)
- Measured: –56.48 dBm/3 kHz = –41.28 dBm/100 kHz
- Margin: 5.28 dB (PASS)

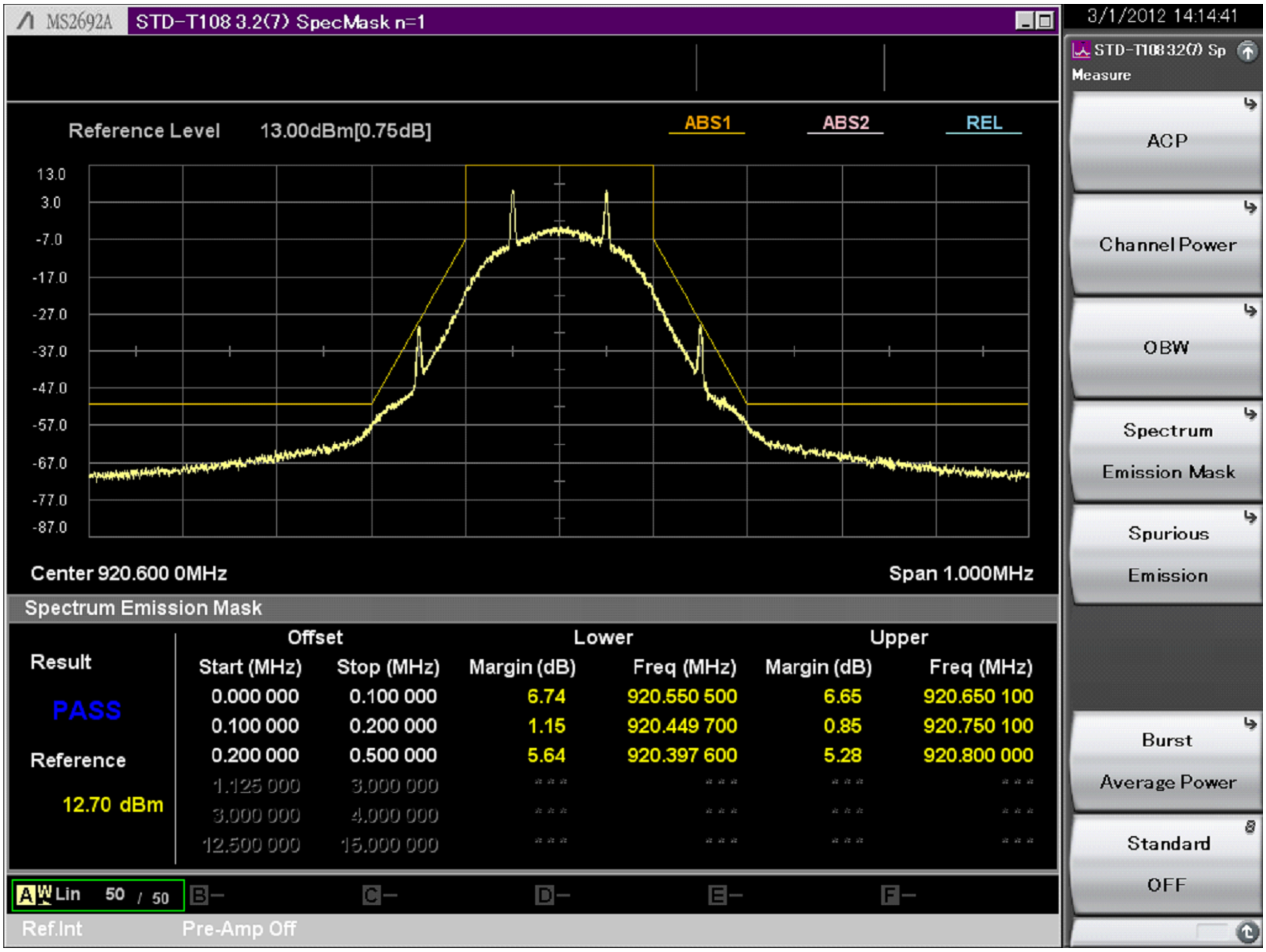


Figure 32. Spectral Mask (20 mW, 920.6 to 922.2 MHz, n=1, BT=0.4)

Compliance may also be obtained when using two unit radio channels (n=2). The measured spectral mask for the scenario of n=2 with DR=100 kbps Dev=50 kHz is shown in Figure 33, and is observed to comply with the spec with over 13 dB of margin. This test also inherently verifies compliance with wider radio channels, such as when using n=3, 4, or 5 unit radio channels.

- Limit: –36 dBm/100 kHz = –51.2 dBm/3 kHz (max)
- Measured: –64.50 dBm/3 kHz = –49.30 dBm/100 kHz
- Margin: 13.30 dB (PASS)

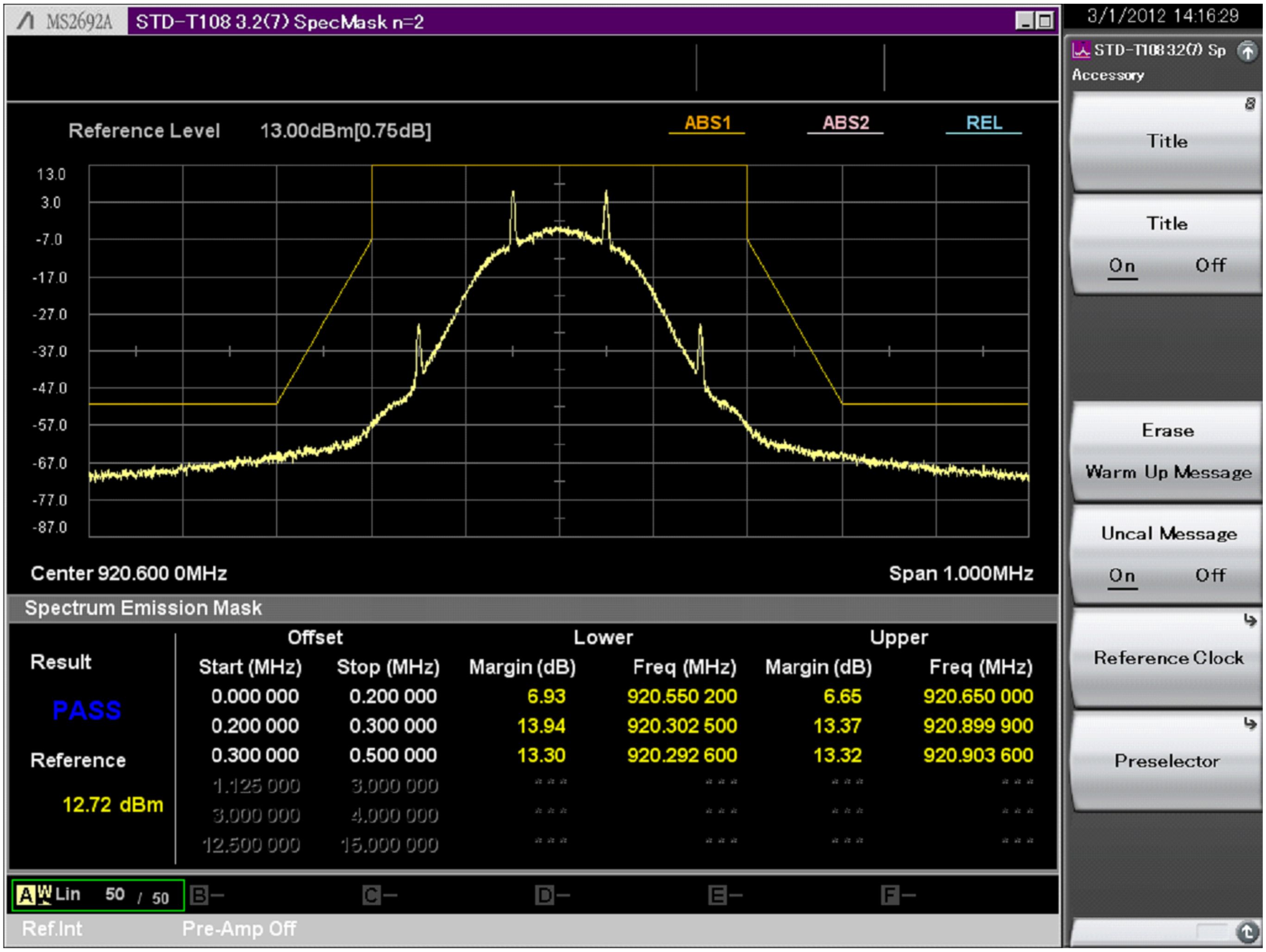


Figure 33. Spectral Mask (20 mW, 920.6 to 922.2 MHz, n=2)

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3.8.5. Antenna Power = 250 mW, Freq Band=920.6 to 922.2 MHz

Within the frequency band of 920.6 to 922.2 MHz when operating with antenna power of more than 20 mW and less than or equal to 250 mW, the integrated adjacent channel leakage power within the 200 kHz bandwidth at the upper and lower edges of the radio channel shall be less than or equal to –5 dBm.

The selected modulation parameters were DR = 100 kbps and Deviation = 50 kHz. The measurement was taken assuming operation with one unit radio channel (n=1). The measured adjacent channel leakage power is shown in Figure 34. The Si4463 chip complies with the requirements of ARIB STD-T108 3.2(7) for Adjacent Channel Leakage Power for the selected modulation protocol. However, compliance again exists primarily because the chip is not operating at the full output power level (i.e., 250 mW) allowed by the regulatory standard.

- Limit: –5 dBm (max)
- Measured: –6.43 dBm
- Margin: 1.43 dB (PASS)

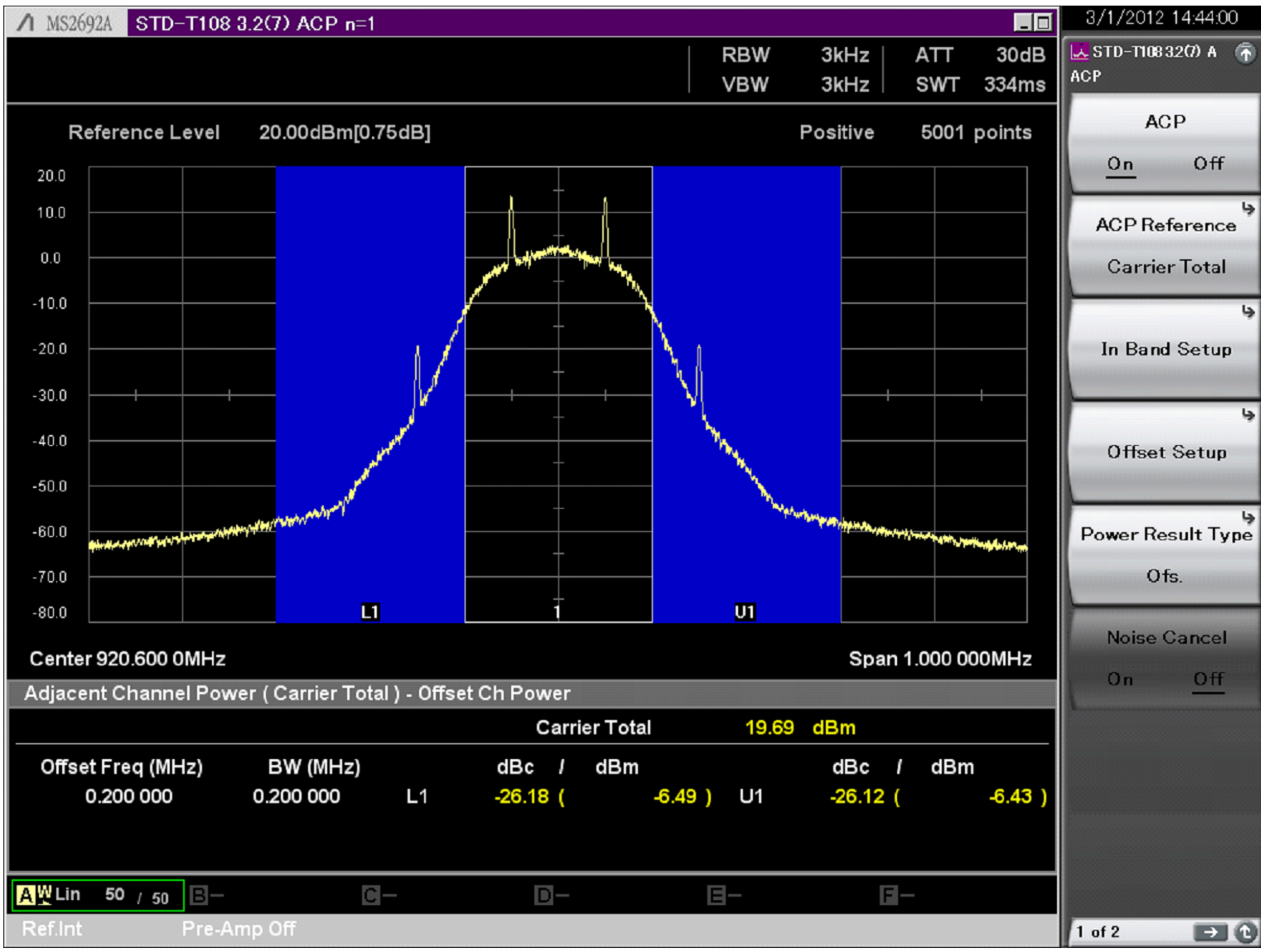

Figure 34. Adjacent Channel Leakage Power (250 mW, 920.6 to 922.2 MHz, n=1)

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A greater margin of compliance may be obtained by reducing the Gaussian filtering bandwidth. If the TX Gaussian filter bandwidth-time product is reduced to BxT=0.4, the Si4463 chip is observed to comply with the requirements of ARIB STD-T108 3.2(7) for Adjacent Channel Leakage Power for the selected modulation protocol as shown in Figure 35.

- Limit: –5 dBm (max)
- Measured: –9.37 dBm
- Margin: 4.37 dB (PASS)

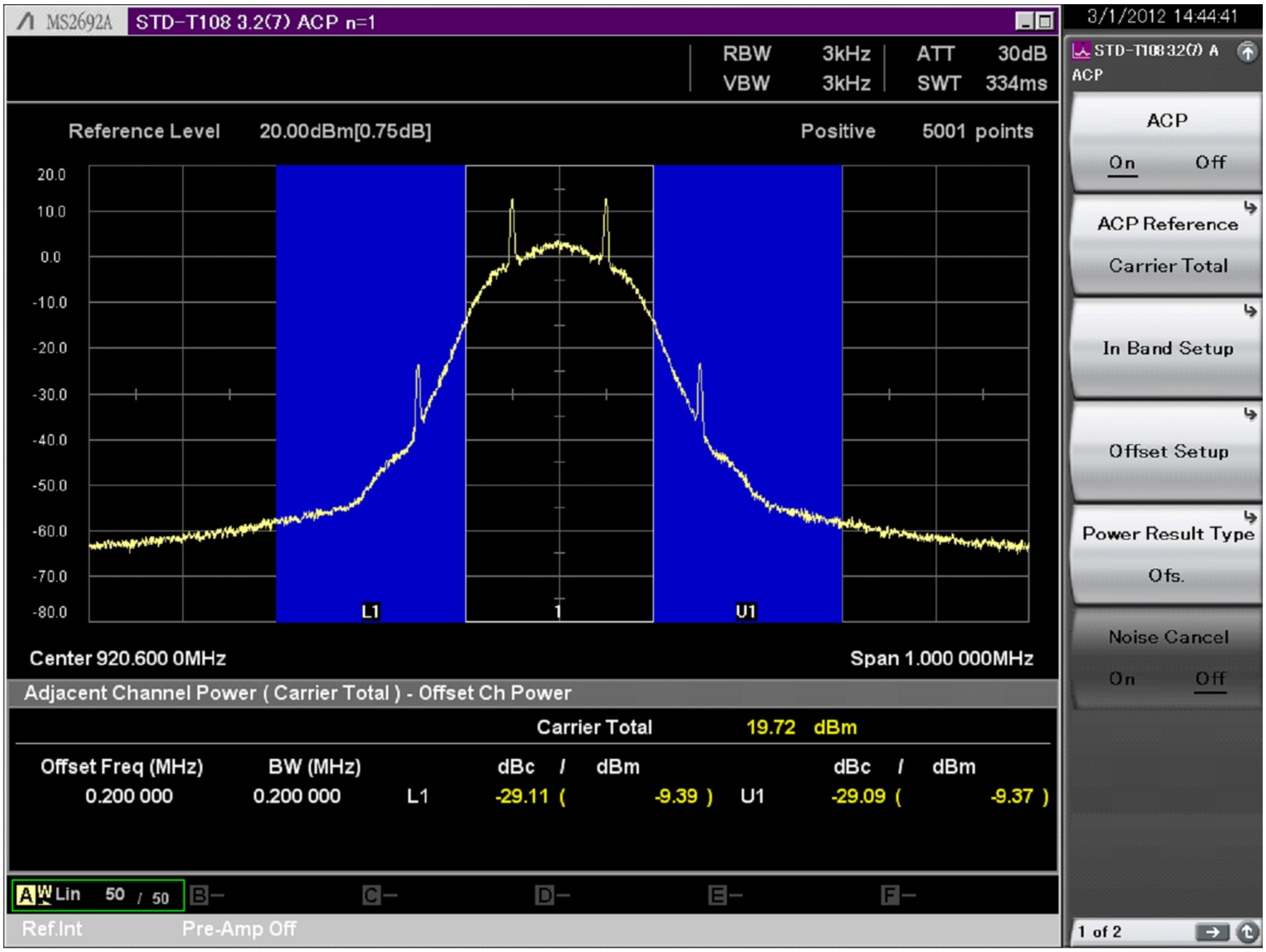


Figure 35. Adjacent Channel Leakage Power (250 mW, 920.6 to 922.2 MHz, n=1, BT=0.4)

The Si4463 chip again easily complies with the adjacent channel leakage specification when using two unit radio channels (n=2). The measured adjacent channel leakage for the scenario of n=2 with DR=100 kbps Dev=50 kHz is shown in Figure 36, and is observed to comply with the spec with over 30 dB of margin. This test also inherently verifies compliance with wider radio channels, such as when using n=3, 4, or 5 unit radio channels.

- Limit: –5 dBm (max)
- Measured: –36.90 dBm
- Margin: 31.90 dB (PASS)

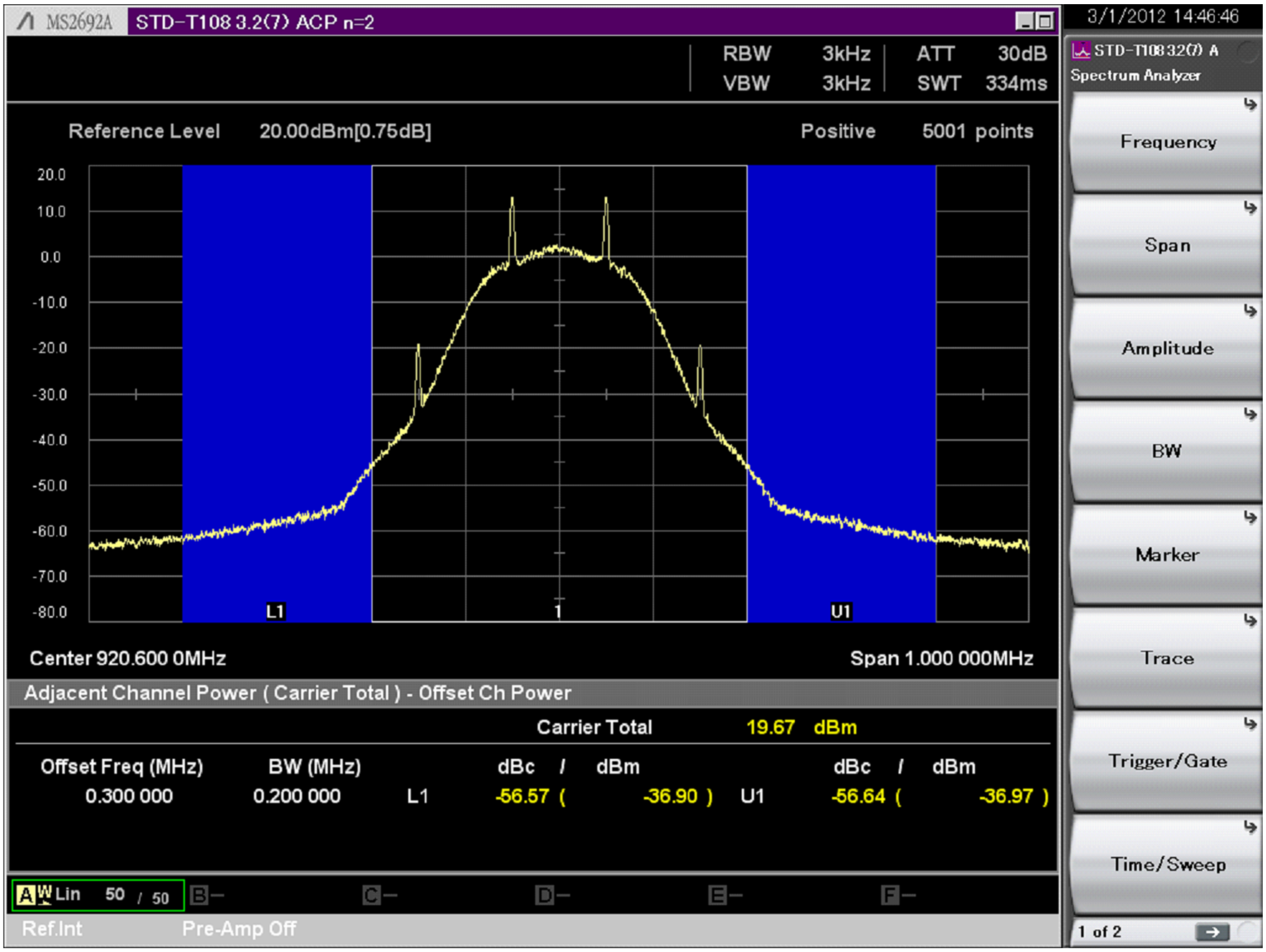


Figure 36. Adjacent Channel Leakage Power (250 mW, 920.6 to 922.2 MHz, n=2)

Within the frequency band of 920.3 to 924.3 MHz at frequency offsets from the channel center frequency of |f – fc| > 200kHz + (n–1) x 100 kHz, the limit of unwanted spurious signals shall be less than or equal to –29 dBm/ 100 kHz. Although the allowed spurious level is specified in a 100 kHz reference bandwidth, it is not appropriate to use ResBW=100 kHz while taking the measurement due to the proximity to the modulation bandwidth of the desired signal. Accordingly, a ResBW=3 kHz configuration is used for the measurement, and the measurement limit is adjusted downwards by 10 x log(100 kHz/3 kHz) = 15.2 dB, resulting in a modified spec limit of –44.2 dBm/ 3 kHz bandwidth.

The selected modulation parameters were DR = 100 kbps and Deviation = 50 kHz. The measurement was taken assuming operation with one unit radio channel (n=1). The measured spectral mask is shown in Figure 37. The Si4463 chip fails to comply with the requirements of ARIB STD-T108 3.2(7) for Spectral Mask for the selected modulation protocol. The limiting factor in performance is the selected modulation protocol which contains discrete tones that exceed the limits of the spectral mask.

- Margin: –1.32 dB (FAIL)

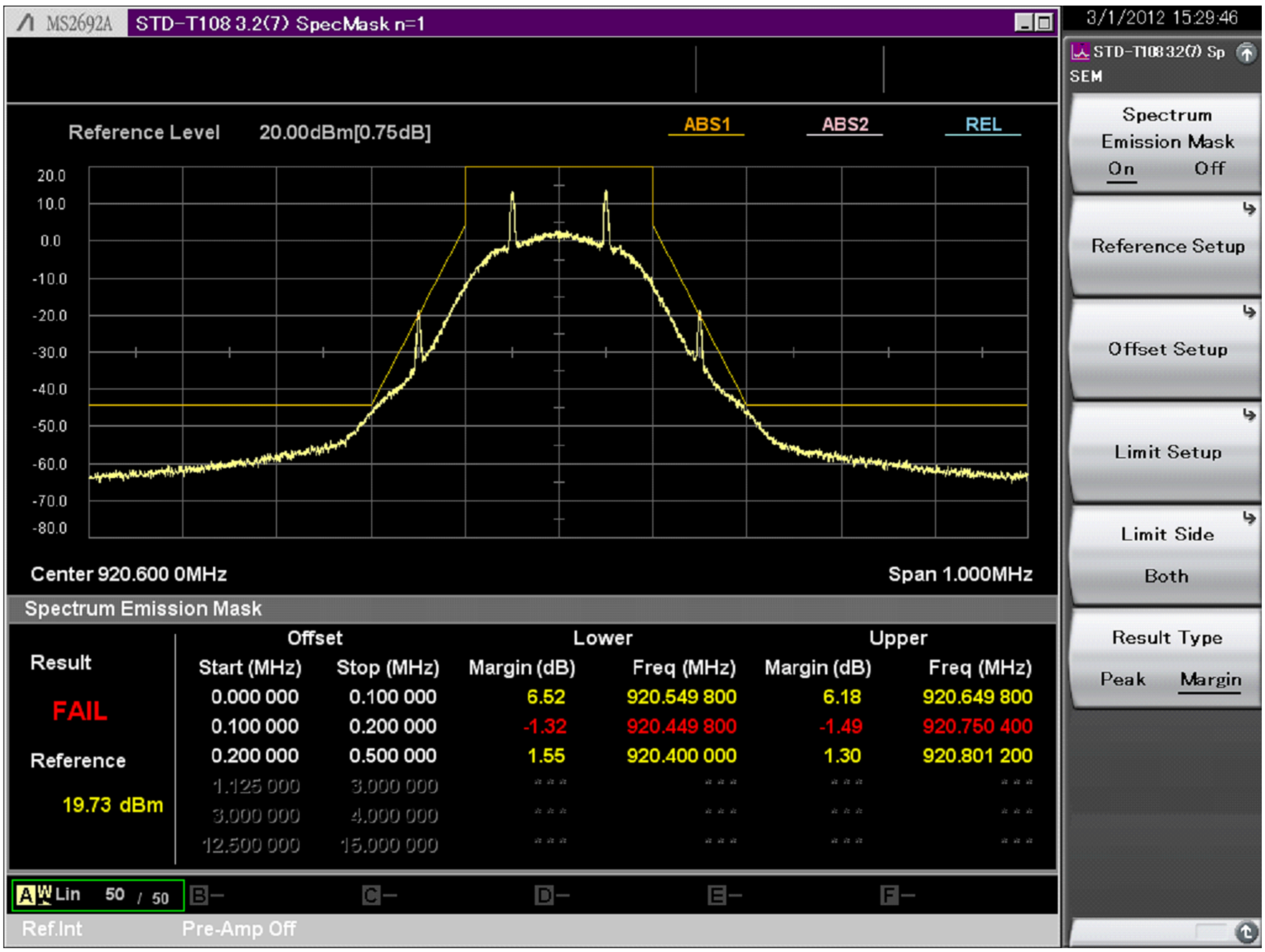


Figure 37. Spectral Mask (250 mW, 920.6 to 922.2 MHz, n=1)

Compliance may be obtained by reducing the Gaussian filtering bandwidth. If the TX Gaussian filter bandwidth-time product is reduced to BxT=0.4, the Si4463 chip is observed to comply with the requirements of ARIB STD-T108 3.2(7) for Spectral Mask for the selected modulation protocol as shown in Figure 38.

- Limit: –29 dBm/100 kHz = –44.2 dBm/3 kHz (max)
- Measured: –49.54 dBm/3 kHz = –34.34 dBm/100 kHz
- Margin: 5.34 dB (PASS)

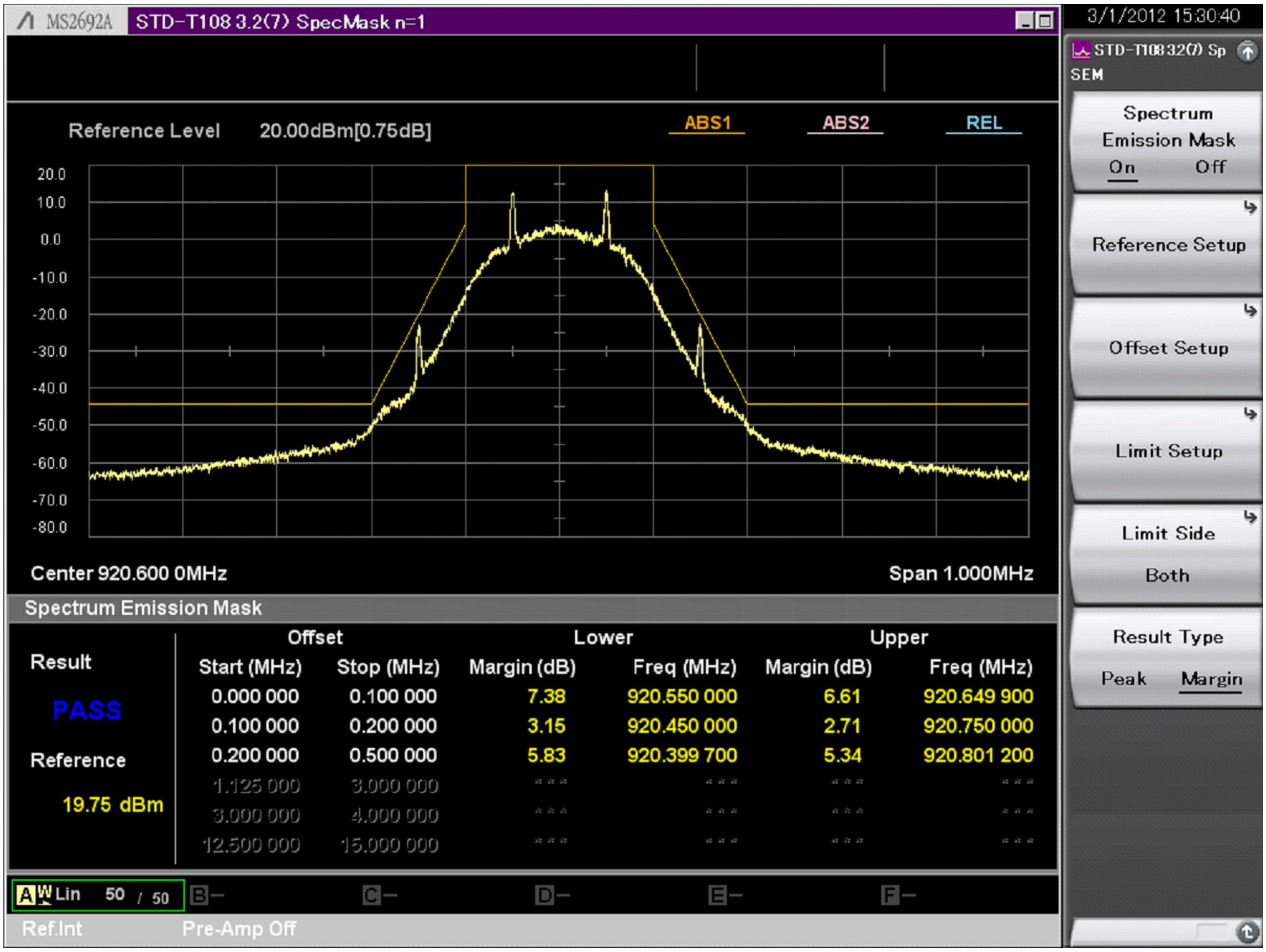
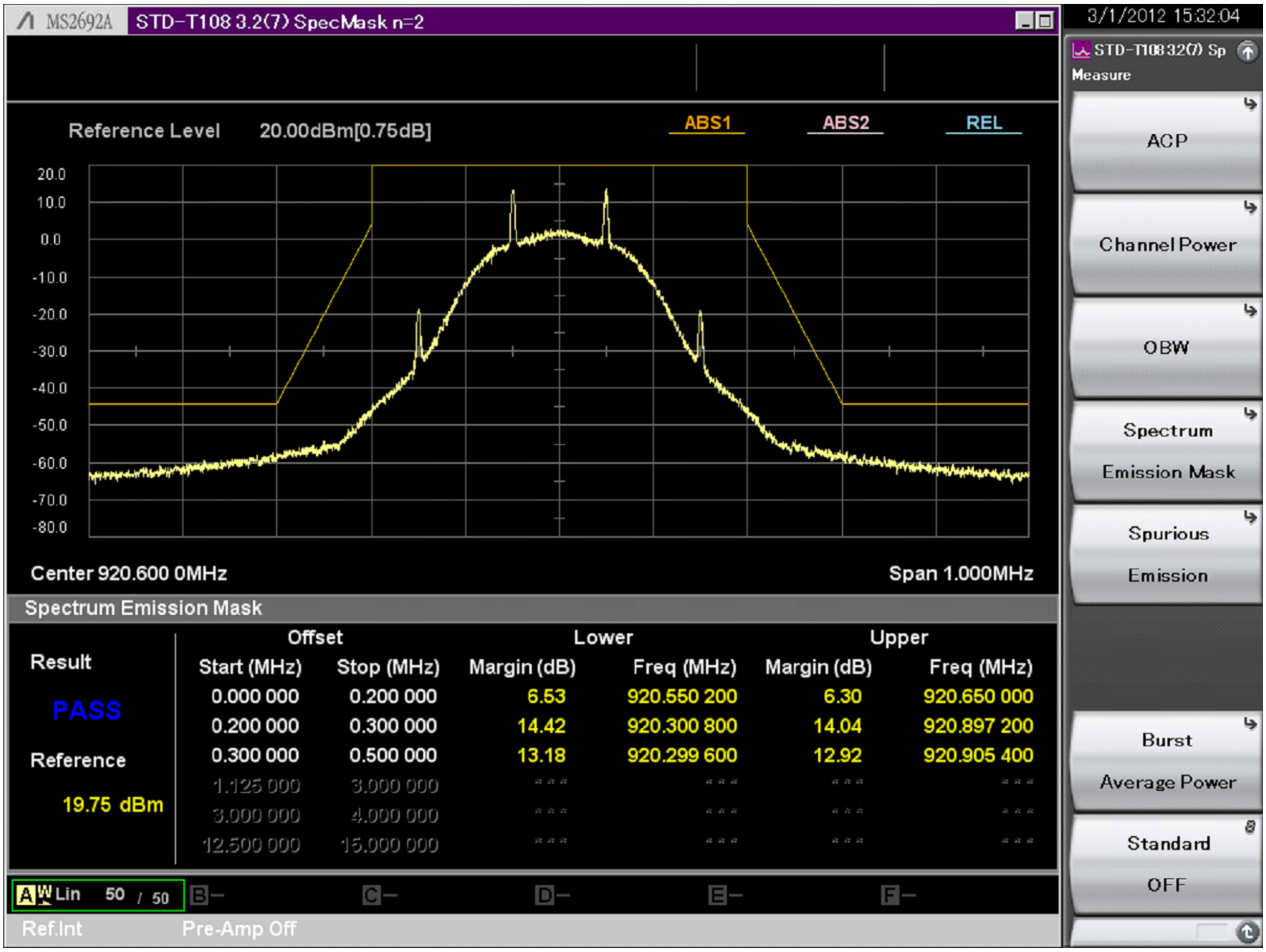


Figure 38. Spectral Mask (250 mW, 920.6 to 922.2 MHz, n=1, BT=0.4)

Compliance may also be obtained when using two unit radio channels (n=2). The measured spectral mask for the scenario of n=2 with DR=100 kbps Dev=50 kHz is shown in Figure 39, and is observed to comply with the spec with ~13 dB of margin. This test also inherently verifies compliance with wider radio channels, such as when using n=3, 4, or 5 unit radio channels.

- Limit: –29 dBm/100 kHz = –44.2 dBm/3 kHz (max)
- Measured: –57.12 dBm/3 kHz = –41.92 dBm/100 kHz
- Margin: 12.92 dB (PASS)



Offset		Lower		Upper	
Start (MHz)	Stop (MHz)	Margin (dB)	Freq (MHz)	Margin (dB)	Freq (MHz)
0.000 000	0.200 000	6.53	920.550 200	6.30	920.650 000
0.200 000	0.300 000	14.42	920.300 800	14.04	920.897 200
0.300 000	0.500 000	13.18	920.299 600	12.92	920.905 400
1.125 000	3.000 000	***	***	***	***
3.000 000	4.000 000	***	***	***	***
12.500 000	15.000 000	***	***	***	***

Figure 39. Spectral Mask (250 mW, 920.6 to 922.2 MHz, n=2)

3.8.6. Antenna Power = 1 mW, Freq Band=928.15 to 929.65 MHz

Within the frequency band of 928.15 to 929.65 MHz when operating with antenna power of less than or equal to 1 mW, the integrated adjacent channel leakage power within the 100 kHz bandwidth at the upper and lower edges of the radio channel shall be less than or equal to –26 dBm.

The selected modulation parameters were DR = 50 kbps and Deviation = 25 kHz. The measurement was taken assuming operation with one unit radio channel (n=1). The measured adjacent channel leakage power is shown in Figure 40. The Si4463 chip complies with the requirements of ARIB STD-T108 3.2(7) for Adjacent Channel Leakage Power for the selected modulation protocol, although with little margin.

- Limit: –26 dBm (max)
- Measured: –27.22 dBm
- Margin: 1.22 dB (PASS)

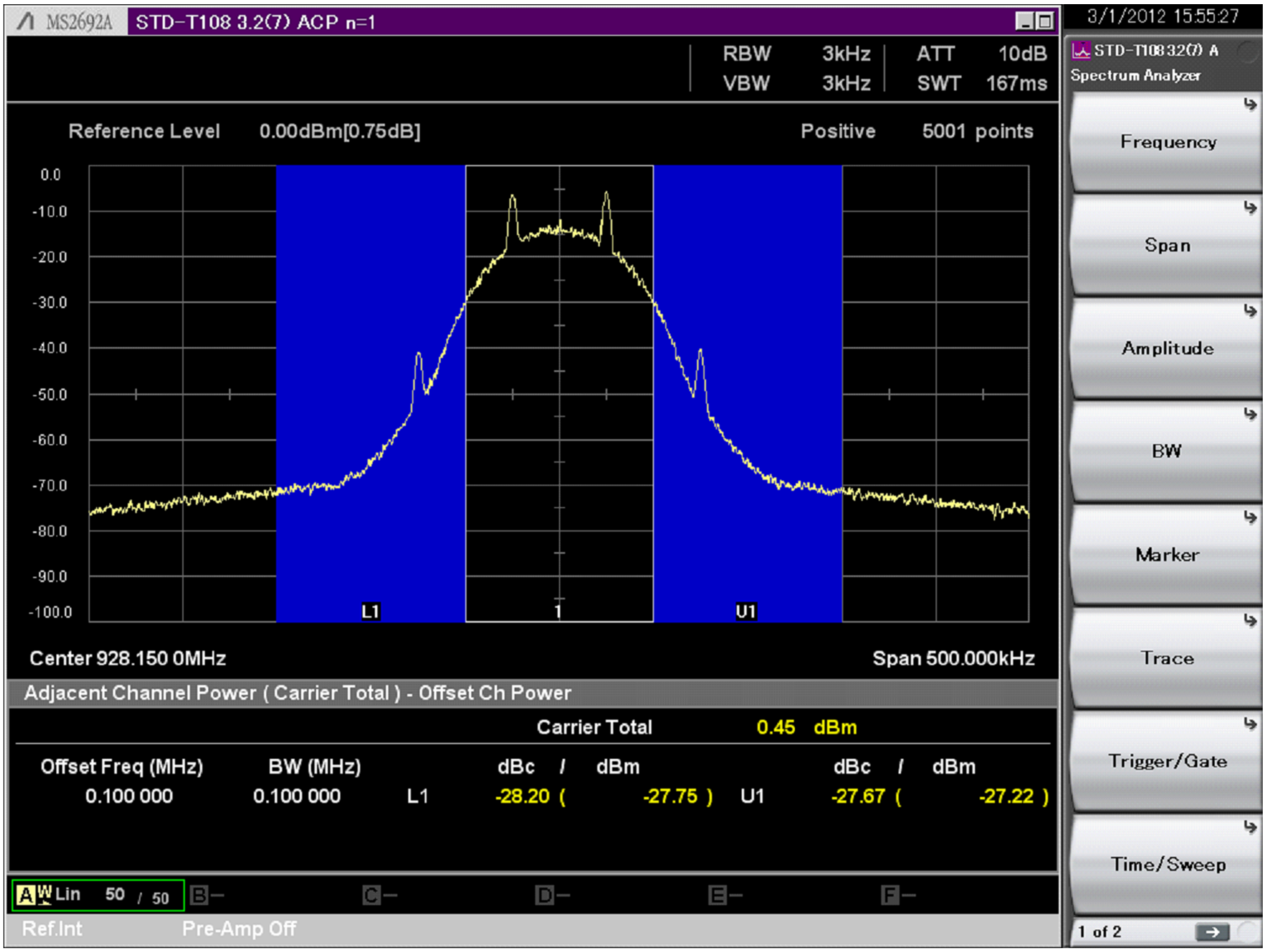


Figure 40. Adjacent Channel Leakage Power (1 mW, 928.15 to 929.65 MHz, n=1)

The margin of compliance may again be improved by reducing the Gaussian filtering bandwidth. If the TX Gaussian filter bandwidth-time product is reduced to BxT=0.4, the Si4463 chip is observed to comply with greater margin as shown in Figure 41.

- Limit: –26 dBm (max)
- Measured: –30.32 dBm
- Margin: 4.32 dB (PASS)

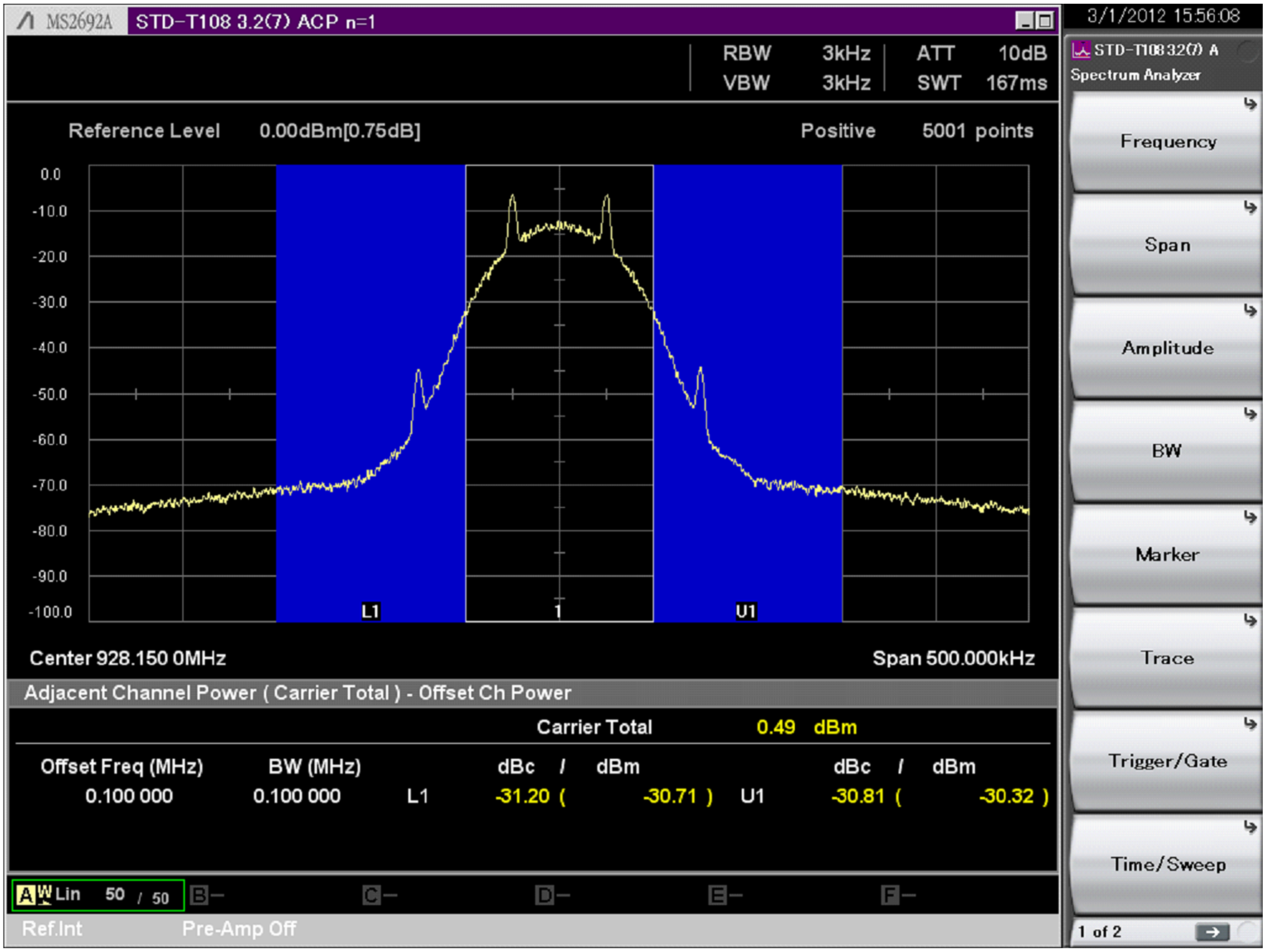


Figure 41. Adjacent Channel Leakage Power (1 mW, 928.15 to 929.65 MHz, n=1, BT=0.4)

The Si4463 chip again easily complies with the adjacent channel leakage specification when using two unit radio channels (n=2). The measured adjacent channel leakage for the scenario of n=2 with DR=50 kbps Dev=25 kHz is shown in Figure 42, and is observed to comply with the spec with nearly 30 dB of margin. This test also inherently verifies compliance with wider radio channels, such as when using n=3, 4, or 5 unit radio channels.

- Limit: –26 dBm (max)
- Measured: –55.35 dBm
- Margin: 29.35 dB (PASS)

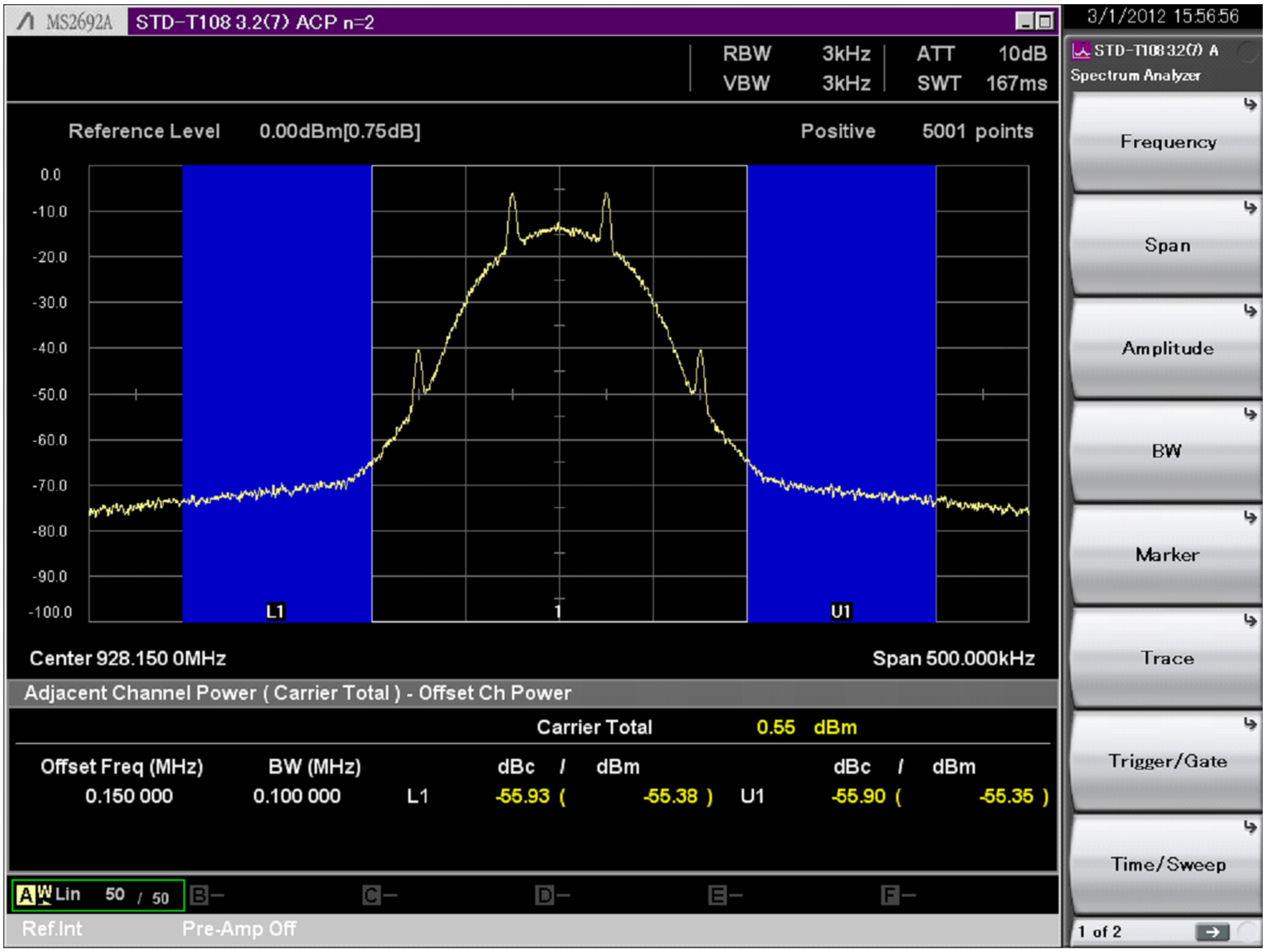
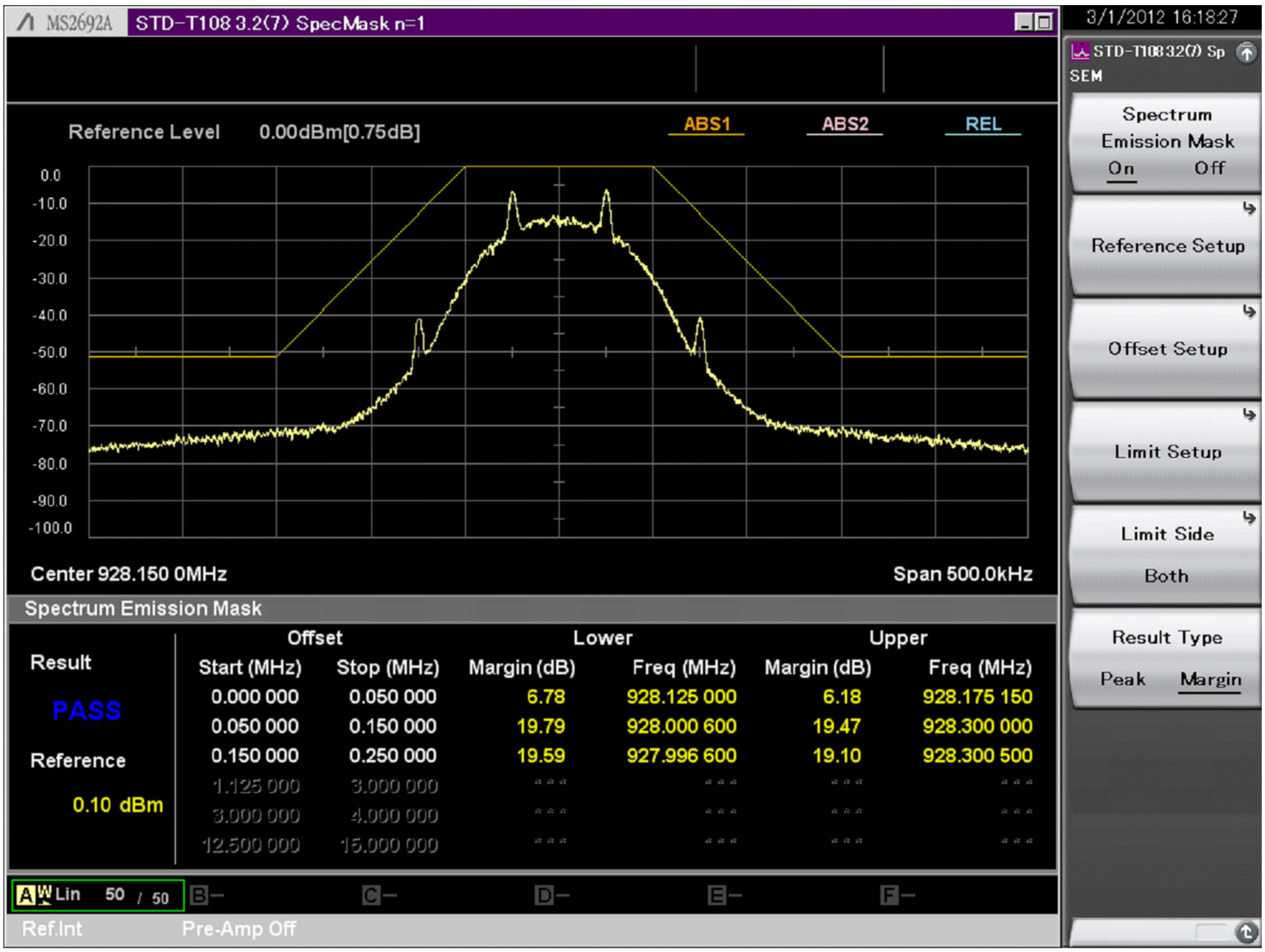


Figure 42. Adjacent Channel Leakage Power (1 mW, 928.15 to 929.65 MHz, n=2)

Within the frequency band of 915.0 to 930.0 MHz at frequency offsets from the channel center frequency of |f – fc| > 100kHz + n x 50kHz, the limit of unwanted spurious signals shall be less than or equal to –36 dBm/100 kHz. Although the allowed spurious level is specified in a 100 kHz reference bandwidth, it is not appropriate to use ResBW=100 kHz while taking the measurement due to the proximity to the modulation bandwidth of the desired signal. Accordingly, a ResBW=3 kHz configuration is used for the measurement, and the measurement limit is adjusted downwards by 10 x log(100 kHz/3 kHz) = 15.2 dB, resulting in a modified spec limit of –51.2 dBm/3 kHz bandwidth.

The selected modulation parameters were DR = 50 kbps and Deviation = 25 kHz. The measurement was taken assuming operation with one unit radio channel (n=1). The measured spectral mask is shown in Figure 43. The Si4463 chip complies with the requirements of ARIB STD-T108 3.2(7) for Spectral Mask for the selected modulation protocol.

- Limit: –36 dBm/100 kHz = –51.2 dBm/3 kHz (max)
- Measured: –70.30 dBm/3 kHz = –55.10 dBm/100 kHz
- Margin: 19.10 dB (PASS)



Offset		Lower		Upper	
Start (MHz)	Stop (MHz)	Margin (dB)	Freq (MHz)	Margin (dB)	Freq (MHz)
0.000 000	0.050 000	6.78	928.125 000	6.18	928.175 150
0.050 000	0.150 000	19.79	928.000 600	19.47	928.300 000
0.150 000	0.250 000	19.59	927.996 600	19.10	928.300 500
1.125 000	3.000 000	***	***	***	***
3.000 000	4.000 000	***	***	***	***
12.500 000	15.000 000	***	***	***	***

Figure 43. Spectral Mask (1 mW, 928.15 to 929.65 MHz, n=1)

3.9. ARIB STD-T108 3.2(8) Spurious Emissions

The allowed level of spurious emissions is specified in ARIB STD-T108 3.2(8) and shall not exceed the limits shown in Table 2. The specification does not provide for a relaxation of the spurious limits as the output power is increased (e.g., to 250 mW) and thus compliance must be demonstrated at the maximum power level. As a result, the Si4463 device was configured for an output power level of +20 dBm on a channel center frequency of 922.4 MHz for all tests within this section, unless noted otherwise. The selected modulation protocol was DR = 100 kbps and Deviation = 50 kHz.

3.9.1. F ≤ 710 MHz

The allowed level of spurious emissions at frequencies below 710 MHz is specified as less than –36 dBm in any 100 kHz bandwidth. The measured spurious emissions within this frequency band are shown in Figure 44. The Si4463 chip easily complies with the specified level of spurious emissions within this sub-band.

- Limit: –36 dBm/100 kHz (max)
- Measured: –67.27 dBm
- Margin: 31.27 dB (PASS)

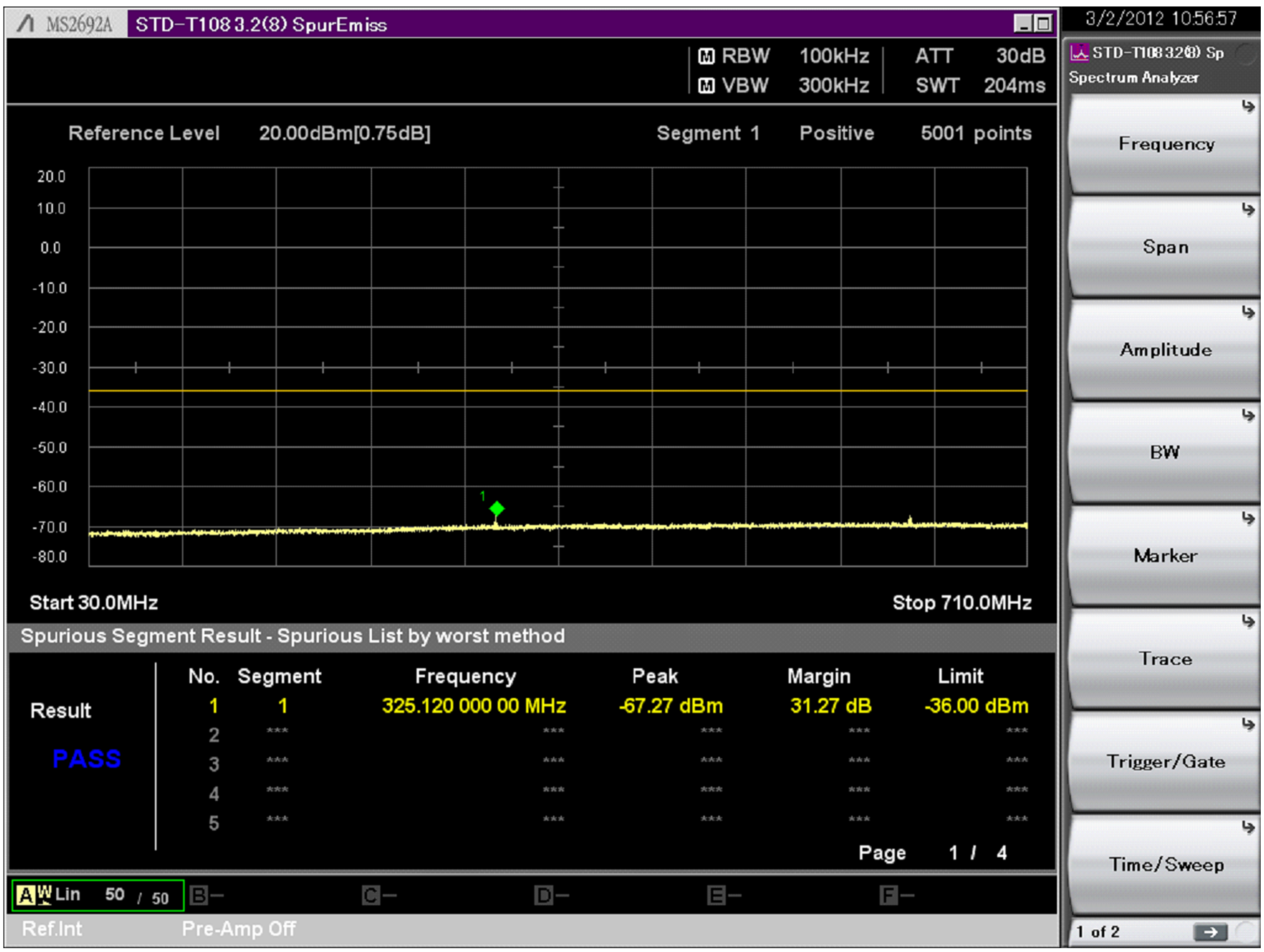


Figure 44. Spurious Emissions (250 mW, F≤710 MHz)

3.9.2. 710 MHz < F ≤ 900 MHz

The allowed level of spurious emissions within the 710–900 MHz frequency band is specified as less than –55 dBm in any 1 MHz bandwidth. The measured spurious emissions within this frequency band are shown in Figure 45. The Si4463 chip complies with the specified level of spurious emissions within this sub-band, although with little margin. The limiting factor in performance is the phase noise of the RFIC.

- Limit: –55 dBm/1 MHz (max)
- Measured: –57.13 dBm
- Margin: 2.13 dB (PASS)

Figure 45. Spurious Emissions (250 mW, 710–900 MHz)

The phase noise floor of the Si446x family of chips is approximately –137 dBc/Hz at large frequency offsets (i.e., greater than 10 MHz offset). While this performance is quite good for an integrated RFIC, it does not allow for compliance with this spurious limit at high levels of output power. The spec limit of –55 dBm/1 MHz is equivalent to –115 dBm/Hz or –135 dBc/Hz relative to a +20 dBm output signal. As a result, the typical phase noise performance of the Si446x family of chips does not allow for compliance within this frequency sub-band at TX output power levels exceeding approximately +22 dBm. In order to achieve compliance with reasonable margin within this sub-band, it is necessary to reduce the TX output power or provide bandpass filtering of the output signal. The measured spurious emissions within this frequency band for a reduction in TX output power level to 20 mW (+13 dBm) are shown in Figure 46, and demonstrate compliance with reasonable margin (~9 dB).

- Limit: –55 dBm/1 MHz (max)
- Measured: –64.30 dBm
- Margin: 9.30 dB (PASS)

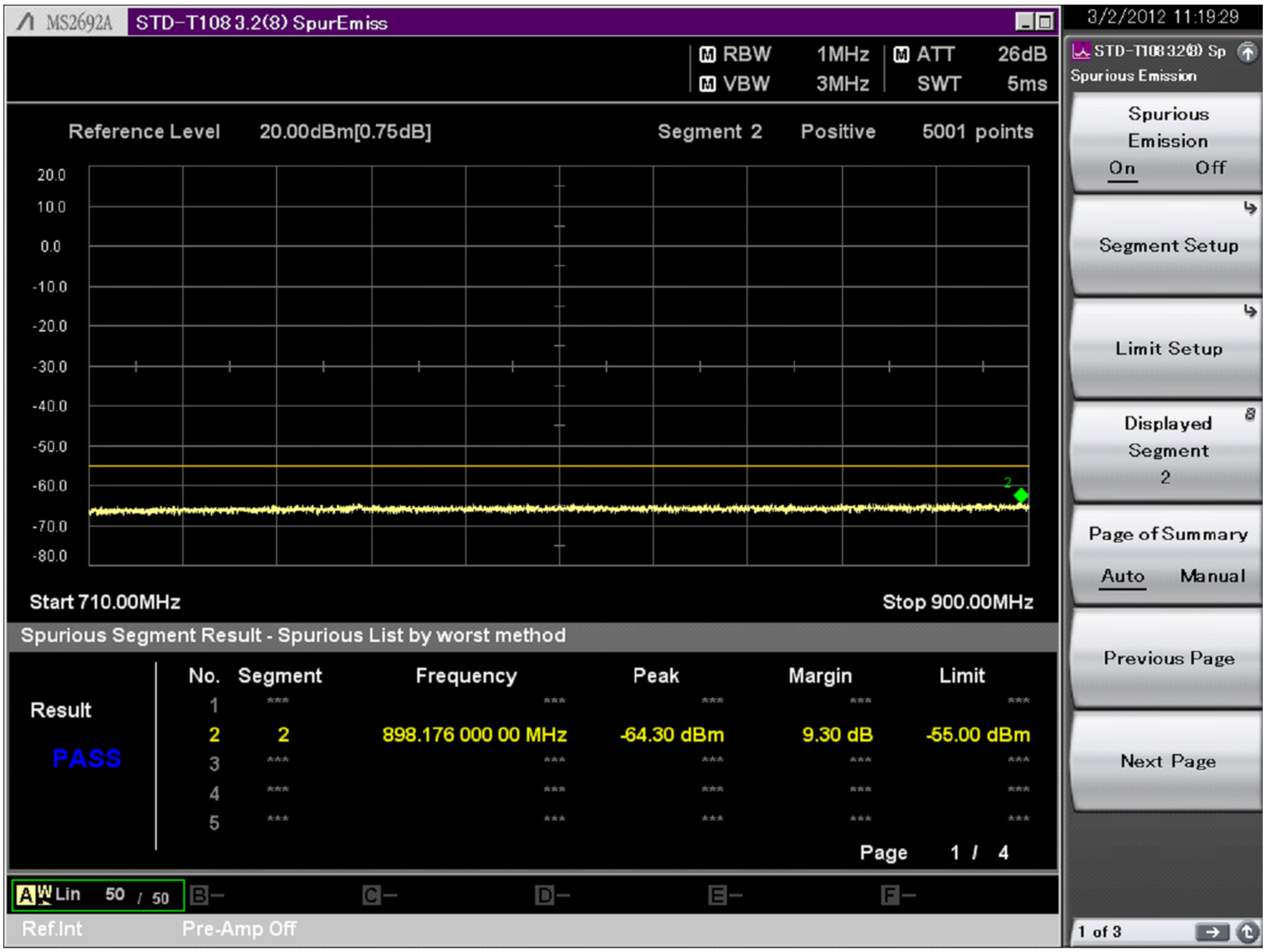


Figure 46. Spurious Emissions (20 mW, 710–900 MHz)

3.9.3. 900 MHz < F ≤ 915 MHz

The allowed level of spurious emissions within the 900–915 MHz frequency band is specified as less than –55 dBm in any 100 kHz bandwidth. The measured spurious emissions within this frequency band are shown in Figure 47. The Si4463 chip complies with the specified level of spurious emissions within this sub-band.

- Limit: –55 dBm/100 kHz (max)
- Measured: –63.37 dBm
- Margin: 8.37 dB (PASS)

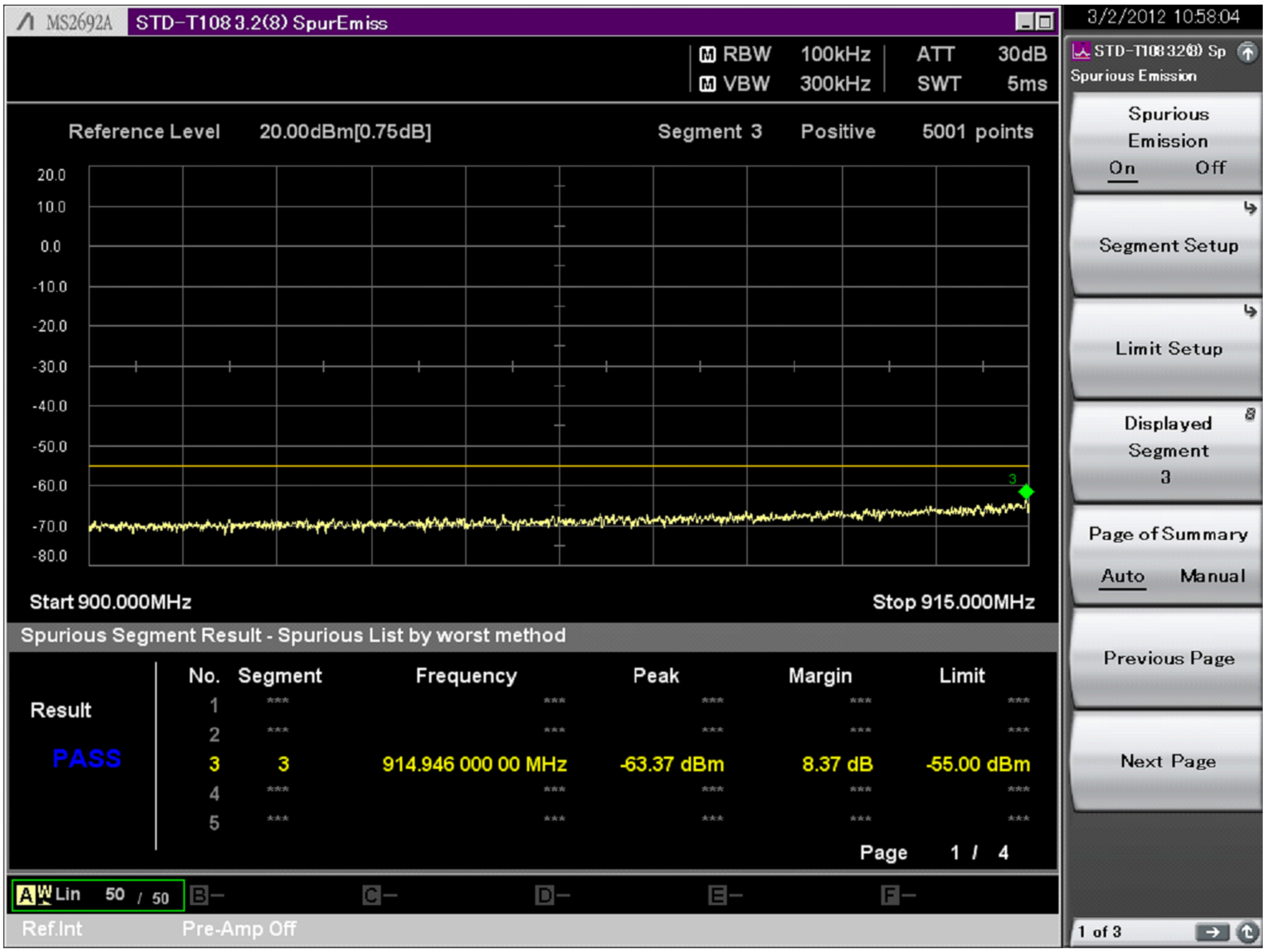


Figure 47. Spurious Emissions (250 mW, 900–915 MHz)

3.9.4. 915.0 MHz < F ≤ 920.3 MHz

The allowed level of spurious emissions within the 915–920.3 MHz frequency band is specified as less than –36 dBm in any 100 kHz bandwidth. Although the allowed spurious level is specified in a 100 kHz reference bandwidth, it is not appropriate to use ResBW=100 kHz while taking the measurement due to the proximity to the modulation bandwidth of the desired signal. Accordingly, a ResBW=3 kHz configuration is used for the measurement, and the measurement limit is adjusted downwards by 10 x log(100 kHz/3 kHz) = 15.2 dB, resulting in a modified spec limit of -51.2 dBm/3 kHz bandwidth.

Compliance within this frequency sub-band is limited primarily by the phase noise of the RFIC. The worst-case measurement condition is thus when the chip is operating at maximum power level and at the channel frequency closest to the edge of this sub-band (i.e., 920.6 MHz). The measured spurious emissions within this frequency band for these conditions are shown in Figure 48. The Si4463 chip complies with the specified level of spurious emissions within this sub-band, although with little margin.

- Limit: –36 dBm/100 kHz = –51.2 dBm/3 kHz (max)
- Measured: –54.71 dBm/3 kHz = –39.51 dBm/100 kHz
- Margin: 3.51 dB (PASS)

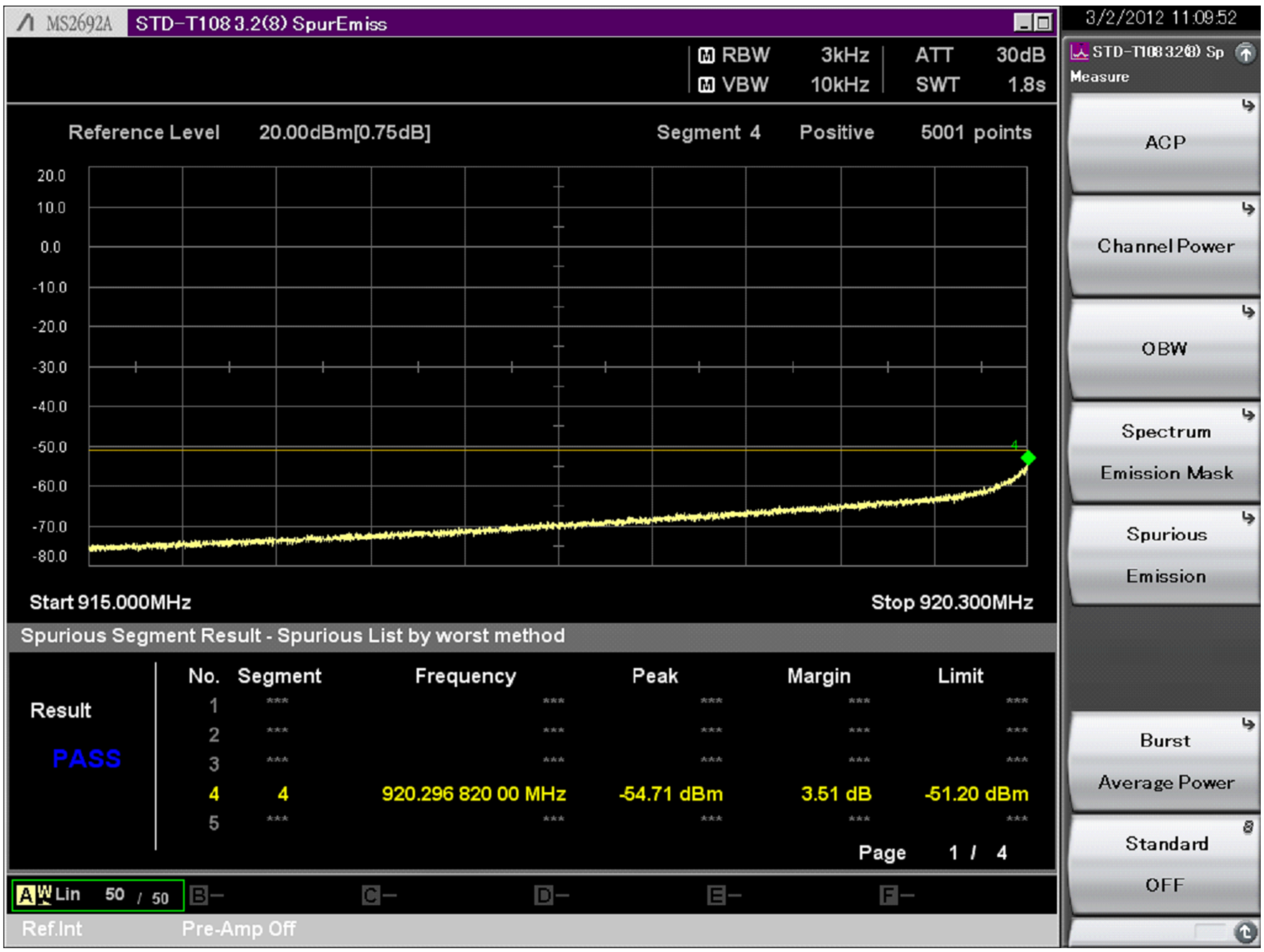


Figure 48. Spurious Emissions (250 mW, 915–920.3 MHz)

A greater margin of compliance may be obtained by operating a reduced TX output power levels. The measured spurious emissions within this frequency band for a reduction in TX output power level to 20 mW (+13 dBm) are shown in Figure 49.

- Limit: –36 dBm/100 kHz = –51.2 dBm/3 kHz (max)
- Measured: –62.01 dBm/3 kHz = –46.81 dBm/100 kHz
- Margin: 10.81 dB (PASS)

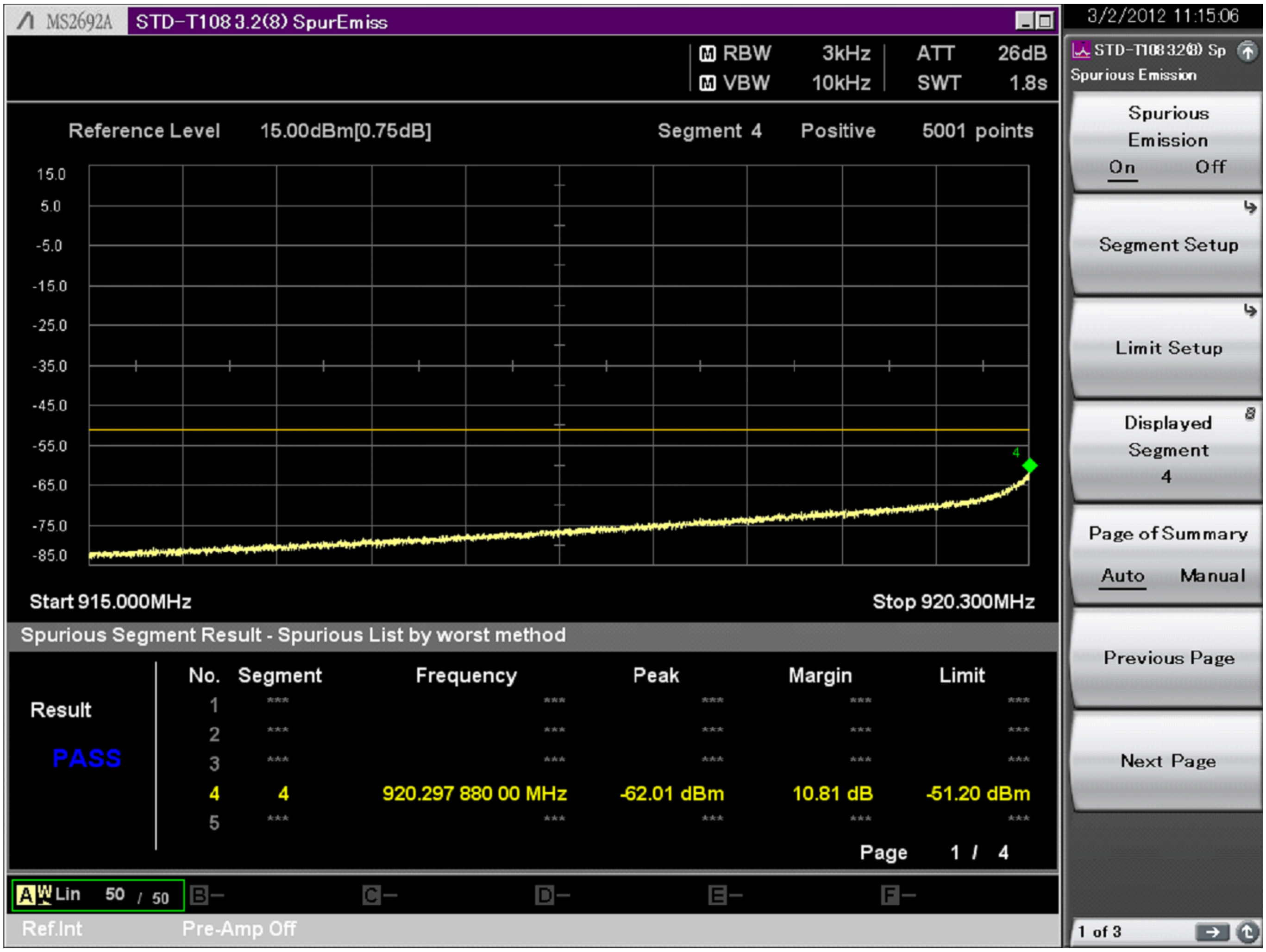


Figure 49. Spurious Emissions (20 mW, 915–920.3 MHz)

3.9.5. 920.3 MHz < F ≤ 924.3 MHz

The allowed level of spurious emissions within the 920.3–924.3 MHz frequency band is specified as less than –29 dBm in any 100 kHz bandwidth (–36 dBm/100 kHz if the output power level is less than or equal to 20 mW). This limit applies at all frequencies within this sub-band except at frequency offsets from the channel center frequency of |f – fc| ≤ 200 kHz + n x 100 kHz. Although the allowed spurious level is specified in a 100 kHz reference bandwidth, it is not appropriate to use ResBW=100 kHz while taking the measurement due to the proximity to the modulation bandwidth of the desired signal. Accordingly, a ResBW=3 kHz configuration is used for the measurement, and the measurement limit is adjusted downwards by 10 x log(100 kHz/3 kHz) = 15.2 dB, resulting in a modified spec limit of -44.2 dBm/3 kHz bandwidth.

As the selected test frequency of F=922.4 MHz falls within this sub-band, it is necessary to verify compliance in two segments: the frequency range below the desired signal, and the frequency range above the desired signal. The measured spurious emissions within the lower range are shown in Figure 50, while the measured spurious emissions within the upper range are shown in Figure 51. The Si4463 chip complies with the specified level of spurious emissions within this sub-band.

- Limit: –29 dBm/100 kHz = –44.2 dBm/3 kHz (max)
- Measured: –53.97 dBm/3 kHz = –38.77 dBm/100 kHz
- Margin: 9.77 dB (PASS)

Figure 50. Spurious Emissions (250 mW, 920.3–924.3 MHz, lower range)

- Limit: –29 dBm/100 kHz = –44.2 dBm/3 kHz (max)
- Measured: –53.28 dBm/3 kHz = –38.08 dBm/100 kHz
- Margin: 9.08 dB (PASS)

Figure 51. Spurious Emissions (250 mW, 920.3–924.3 MHz, upper range)

3.9.6. 924.3 MHz < F ≤ 930.0 MHz

The allowed level of spurious emissions within the 924.3–930.0 MHz frequency band is specified as less than –36 dBm in any 100 kHz bandwidth. This limit applies at all frequencies within this sub-band except at frequency offsets from the channel center frequency of |f – fc| ≤ 200 kHz + n x 100 kHz. Although the allowed spurious level is specified in a 100 kHz reference bandwidth, it is not appropriate to use ResBW=100 kHz while taking the measurement due to the proximity to the modulation bandwidth of the desired signal. Accordingly, a ResBW=3 kHz configuration is used for the measurement, and the measurement limit is adjusted downwards by 10 x log(100 kHz/ 3 kHz) = 15.2 dB, resulting in a modified spec limit of –51.2 dBm/3 kHz bandwidth.

The worst-case measurement condition is when the chip is operating at maximum power level and at the channel frequency closest to the edge of this sub-band (i.e., 923.4 MHz). The measured spurious emissions within this frequency band for these conditions are shown in Figure 52. The Si4463 chip complies with the specified level of spurious emissions within this sub-band.

- Limit: –36 dBm/100 kHz = –51.2 dBm/3 kHz (max)
- Measured: –62.99 dBm/3 kHz = –47.79 dBm/100 kHz
- Margin: 11.79 dB (PASS)

Figure 52. Spurious Emissions (250 mW, 924.3–930.0 MHz)

3.9.7. 930.0 MHz < F ≤ 1000 MHz

The allowed level of spurious emissions within the 930.0–1000 MHz frequency band is specified as less than –55 dBm in any 100 kHz bandwidth. Compliance within this frequency sub-band is limited primarily by the reference sidebands of the RFIC. The measured spurious emissions within this frequency band are shown in Figure 53. The Si4463 chip complies with the specified level of spurious emissions within this sub-band.

- Limit: –55 dBm/100 kHz (max)
- Measured: –62.18 dBm
- Margin: 7.18 dB (PASS)

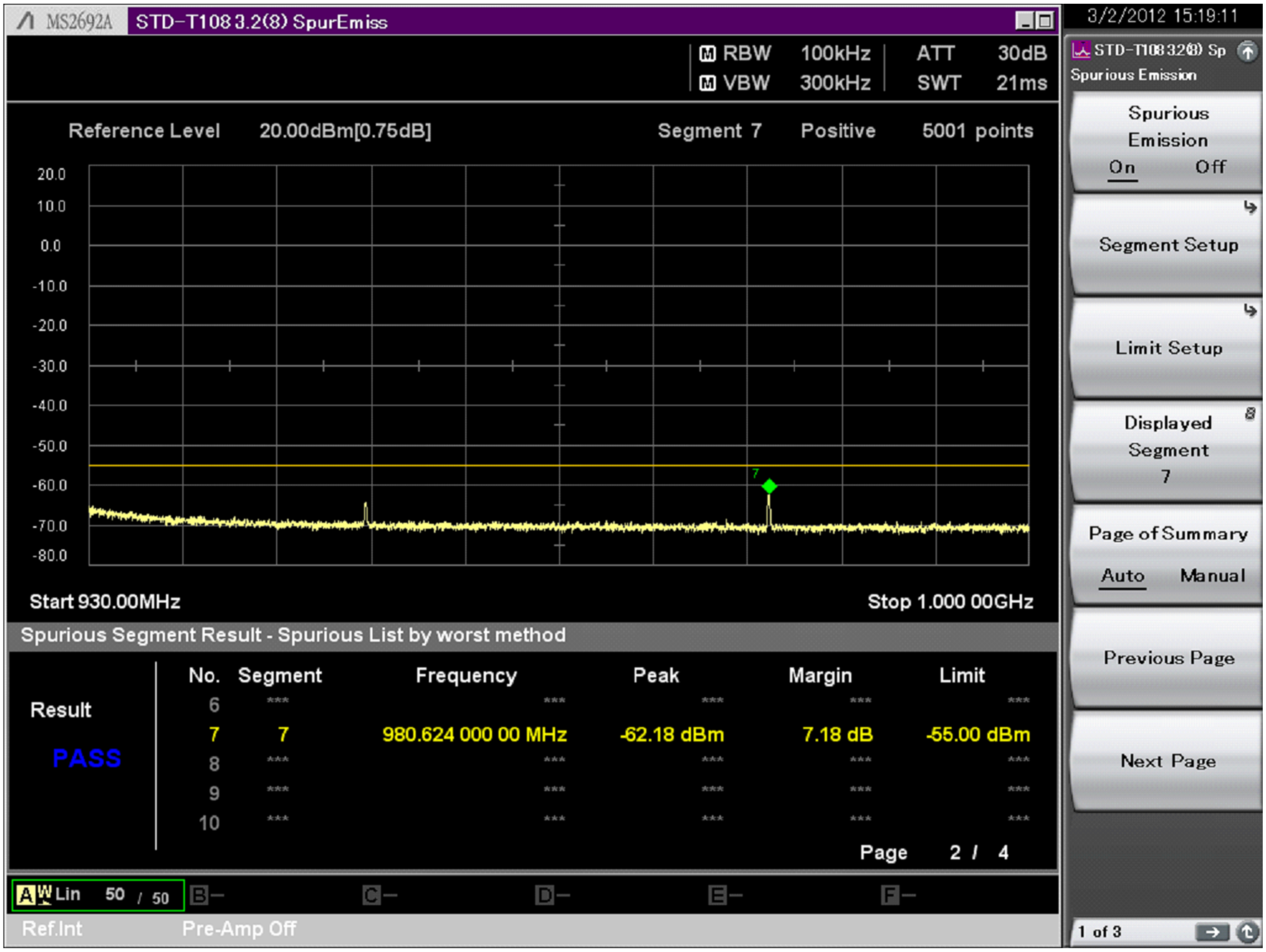


Figure 53. Spurious Emissions (250 mW, 930.0–1000 MHz)

3.9.8. 1000 MHz < F ≤ 1215 MHz

The allowed level of spurious emissions within the 1000–1215 MHz frequency band is specified as less than -45 dBm in any 1 MHz bandwidth. The measured spurious emissions within this frequency band are shown in Figure 54. The Si4463 chip easily complies with the specified level of spurious emissions within this sub-band.

- Limit: –45 dBm/1 MHz (max)
- Measured: –58.66 dBm
- Margin: 13.66 dB (PASS)

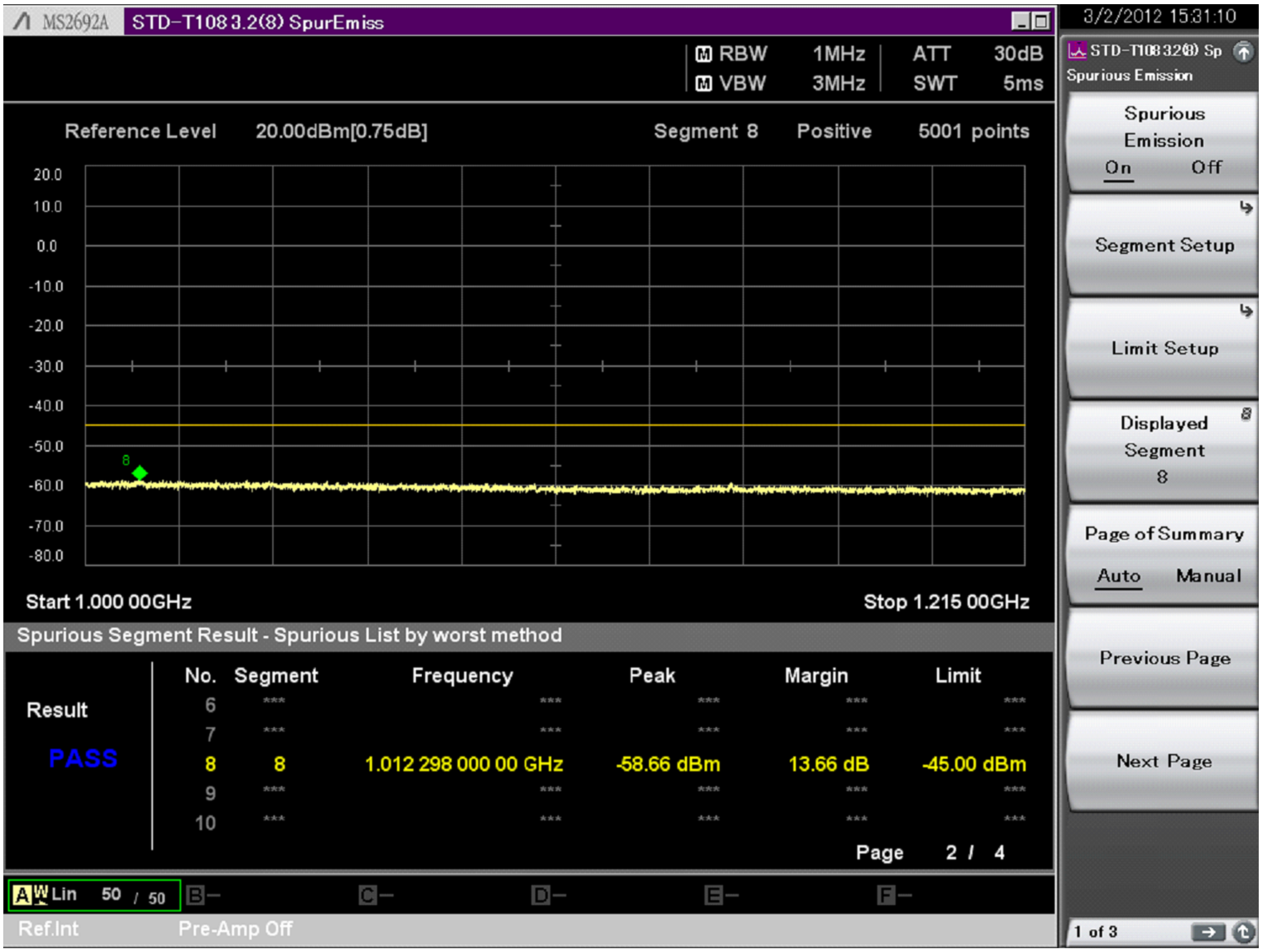


Figure 54. Spurious Emissions (250 mW, 1000–1215 MHz)

3.9.9. F > 1215 MHz

The allowed level of spurious emissions at frequencies above 1215 MHz is specified as less than –30 dBm in any 1 MHz bandwidth. The measured spurious emissions within this frequency band are shown in Figure 55. The Si4463 chip complies with the specified level of spurious emissions within this sub-band. The discrete tone at F=1884 MHz is the 2nd harmonic signal.

- Limit: –30 dBm/1 MHz (max)
- Measured: –37.21 dBm
- Margin: 7.21 dB (PASS)

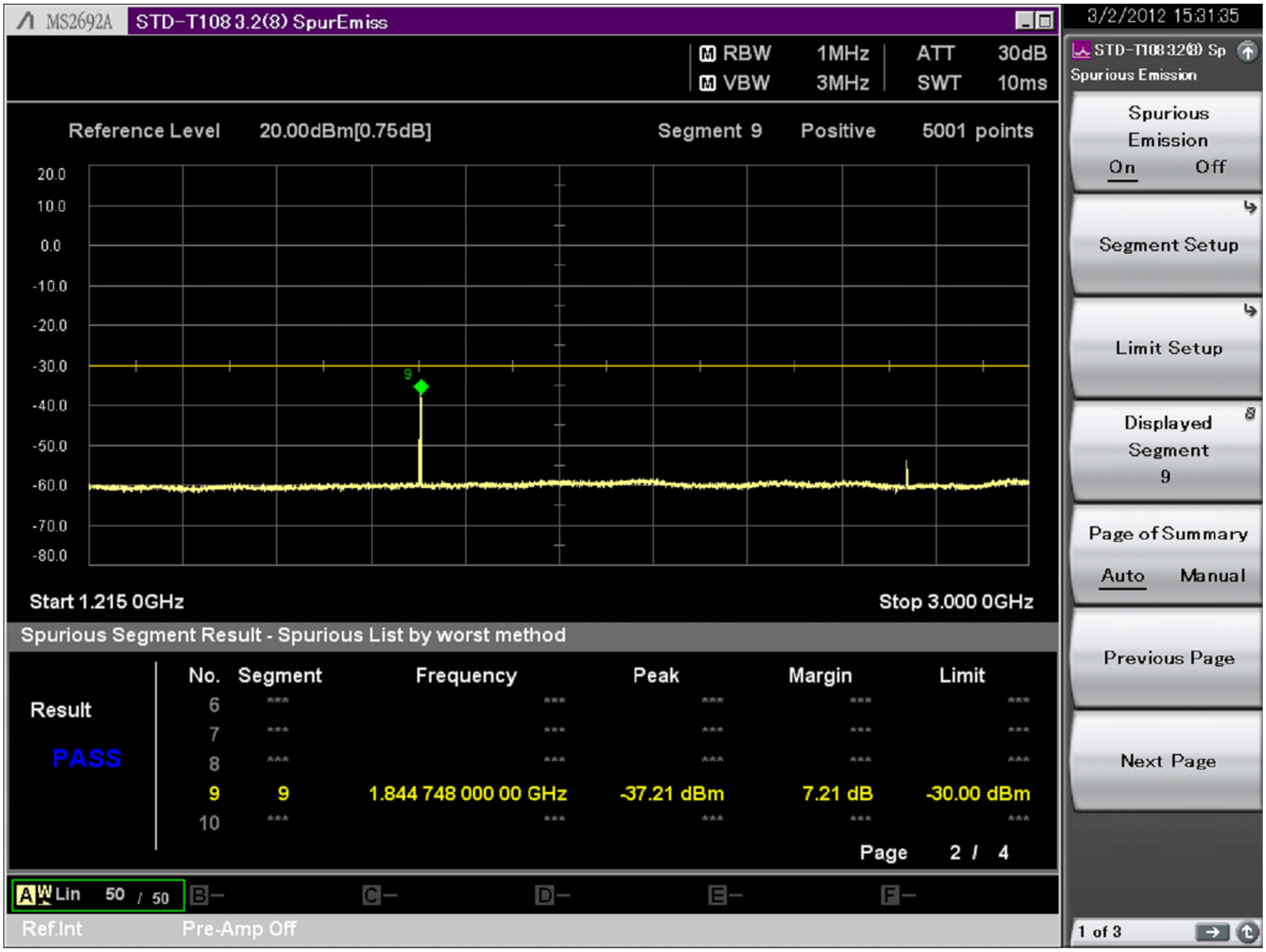


Figure 55. Spurious Emissions (250 mW, above 1215 MHz)

4. RX Measurement Results

4.1. RX Measurement Details

The RX script files used are shown in Section "6. Wireless Development Suite (WDS) RX Script Files" on page 74.

4.2. ARIB STD-T108 3.3 Receiver Conducted Spurious Emissions

The allowed level of conducted spurious emissions at the receiver input is specified in ARIB STD-T108 3.3 and shall not exceed the limits shown in Table 3. The Si4463 device was configured for a channel center frequency of 922.4 MHz for all tests within this section.

4.2.1. F ≤ 710 MHz

The allowed level of spurious emissions at frequencies below 710 MHz is specified as less than –54 dBm in any 100 kHz bandwidth. The measured spurious emissions within this frequency band are shown in Figure 56. The Si4463 chip easily complies with the specified level of spurious emissions within this sub-band.

- Limit: –54 dBm/100 kHz (max)
- Measured: –87.6 dBm
- Margin: 33.6 dB (PASS)

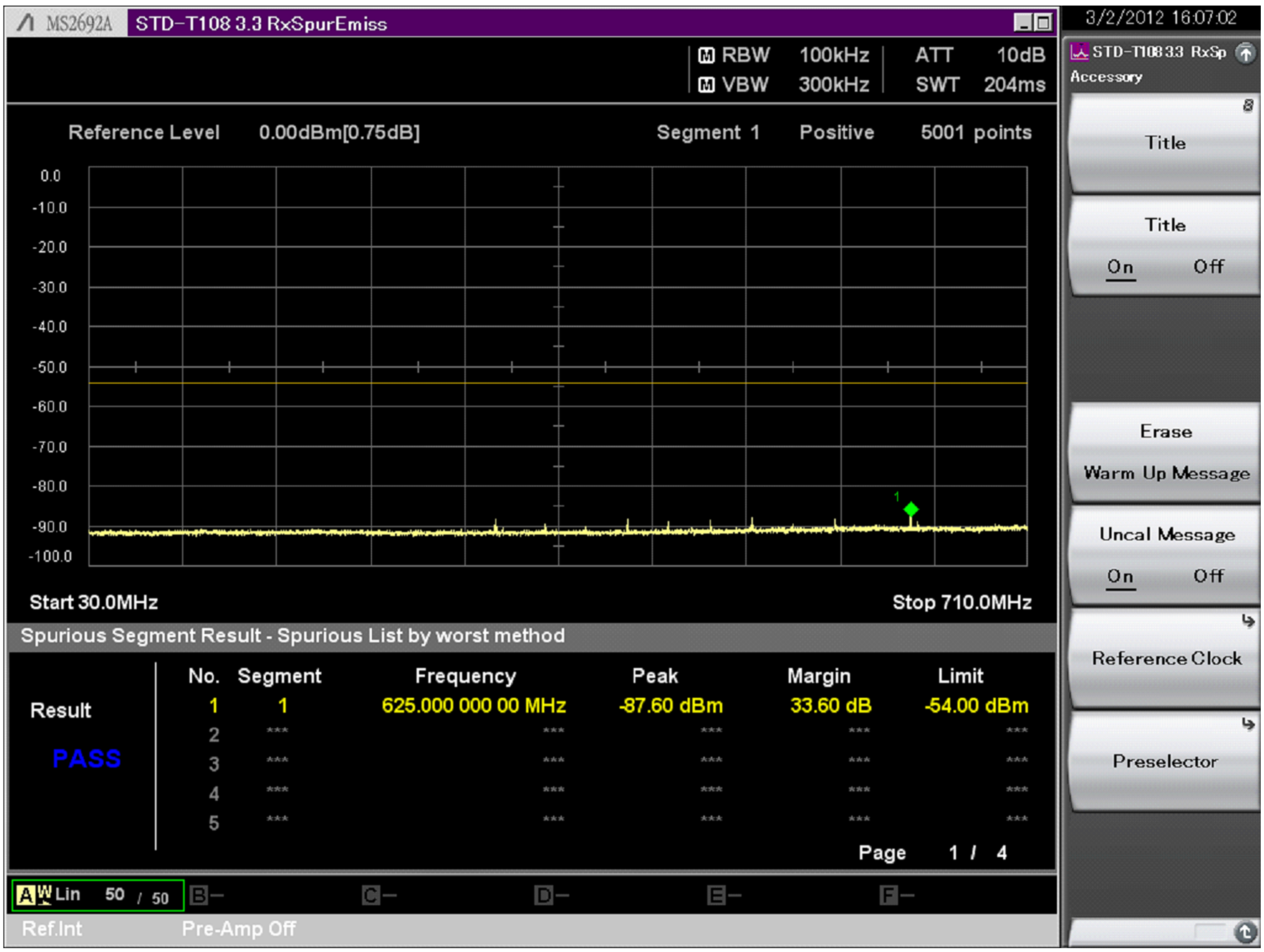


Figure 56. RX Conducted Spurious Emissions (F≤710 MHz)

4.2.2. 710 MHz < F ≤ 900 MHz

The allowed level of spurious emissions within the 710–900 MHz frequency band is specified as less than –55 dBm in any 1 MHz bandwidth. The measured spurious emissions within this frequency band are shown in Figure 57. The Si4463 chip easily complies with the specified level of spurious emissions within this sub-band.

- Limit: –55 dBm/1 MHz (max)
- Measured: –80.88 dBm
- Margin: 25.88 dB (PASS)

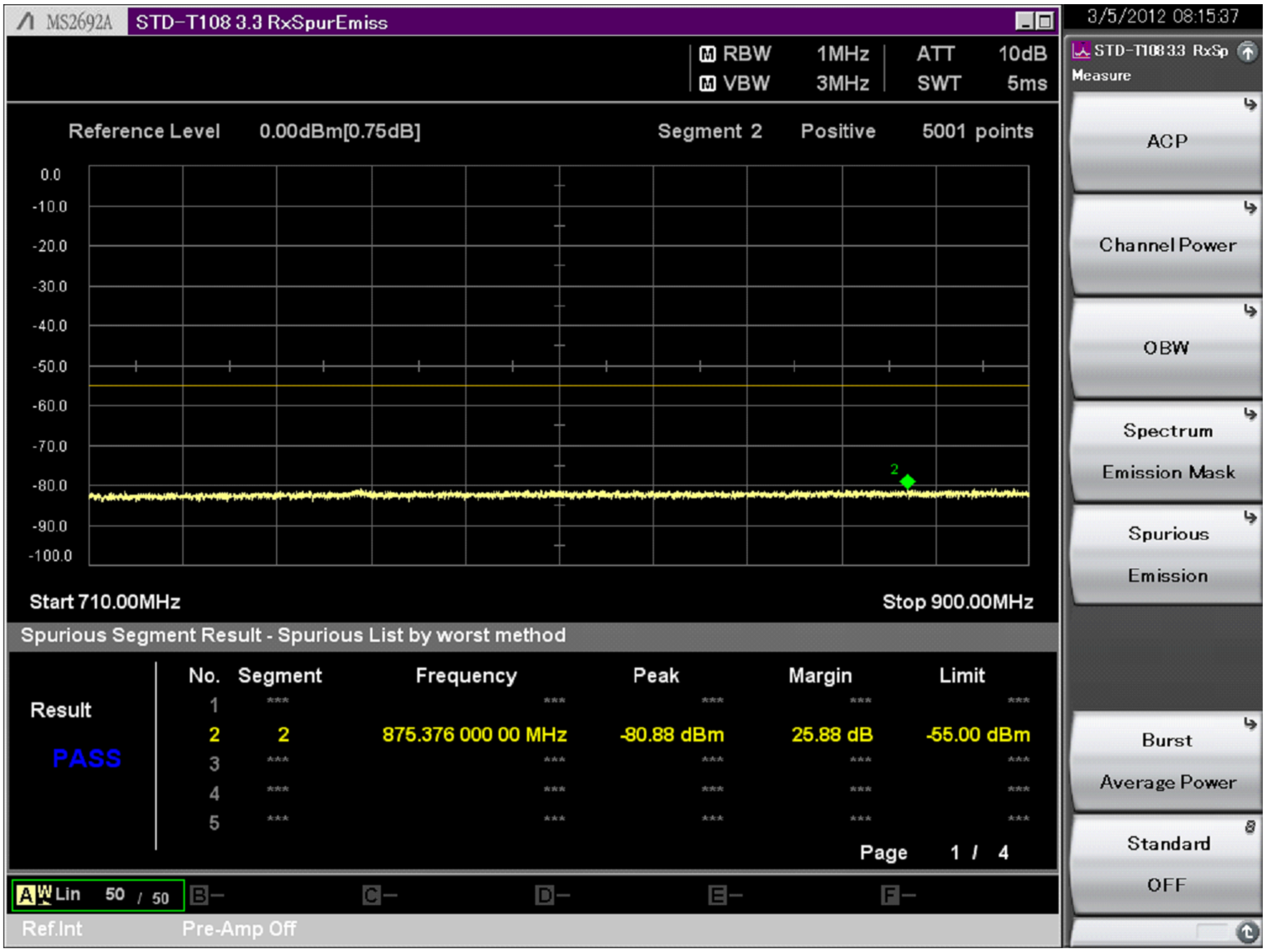


Figure 57. RX Conducted Spurious Emissions (710 MHz F≤900 MHz)

4.2.3. 900 MHz < F ≤ 915 MHz

The allowed level of spurious emissions within the 900–915 MHz frequency band is specified as less than –55 dBm in any 100 kHz bandwidth. The measured spurious emissions within this frequency band are shown in Figure 58. The Si4463 chip easily complies with the specified level of spurious emissions within this sub-band.

- Limit: –55 dBm/100 kHz (max)
- Measured: –92.46 dBm
- Margin: 37.46 dB (PASS)

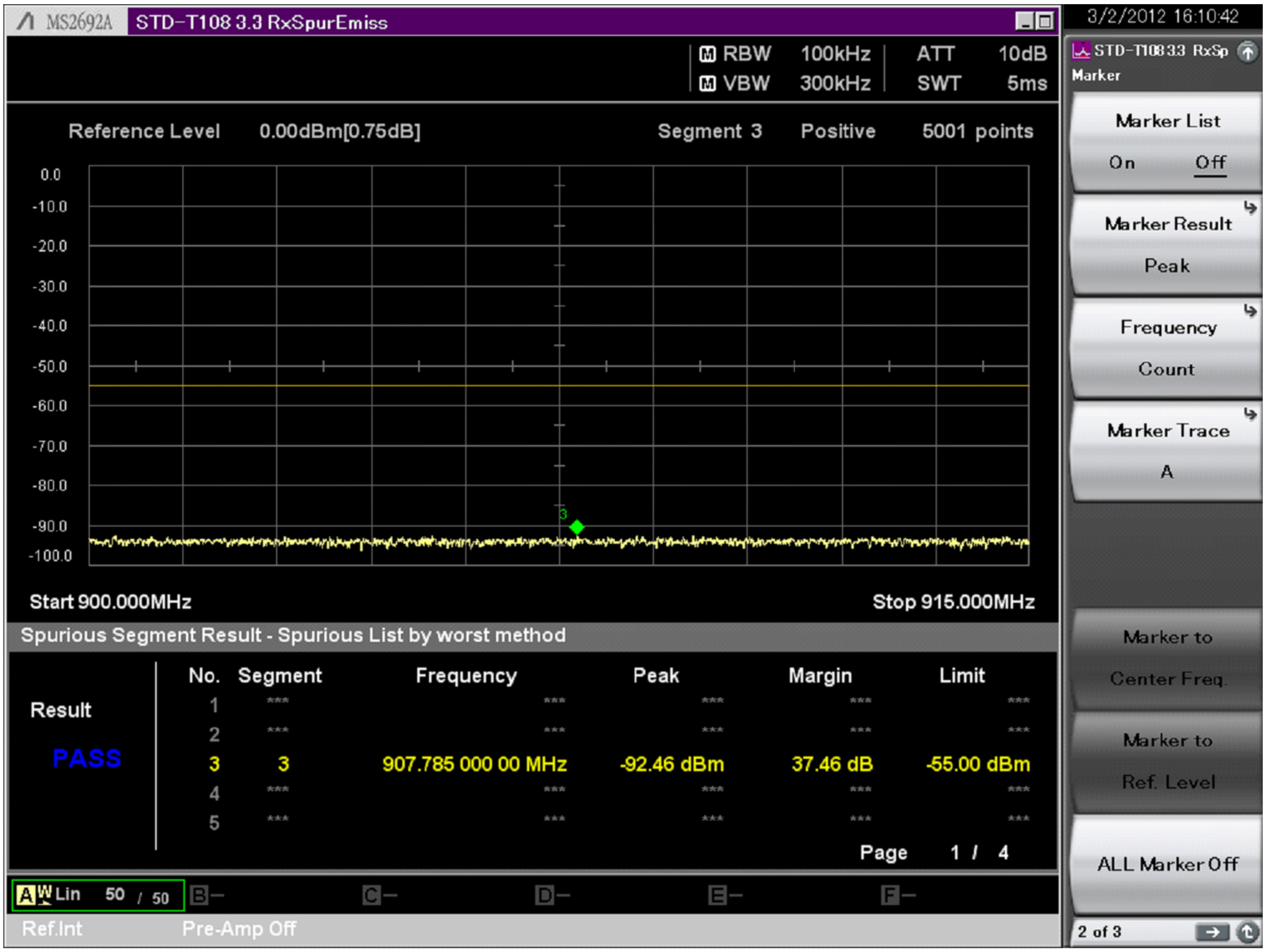


Figure 58. RX Conducted Spurious Emissions (900 MHz F ≤ 915 MHz)

4.2.4. 915 MHz < F ≤ 930 MHz

The allowed level of spurious emissions within the 915–930 MHz frequency band is specified as less than –54 dBm in any 100 kHz bandwidth. The measured spurious emissions within this frequency band are shown in Figure 59. The Si4463 chip easily complies with the specified level of spurious emissions within this sub-band.

- Limit: –54 dBm/100 kHz (max)
- Measured: –92.41 dBm
- Margin: 38.41 dB (PASS)

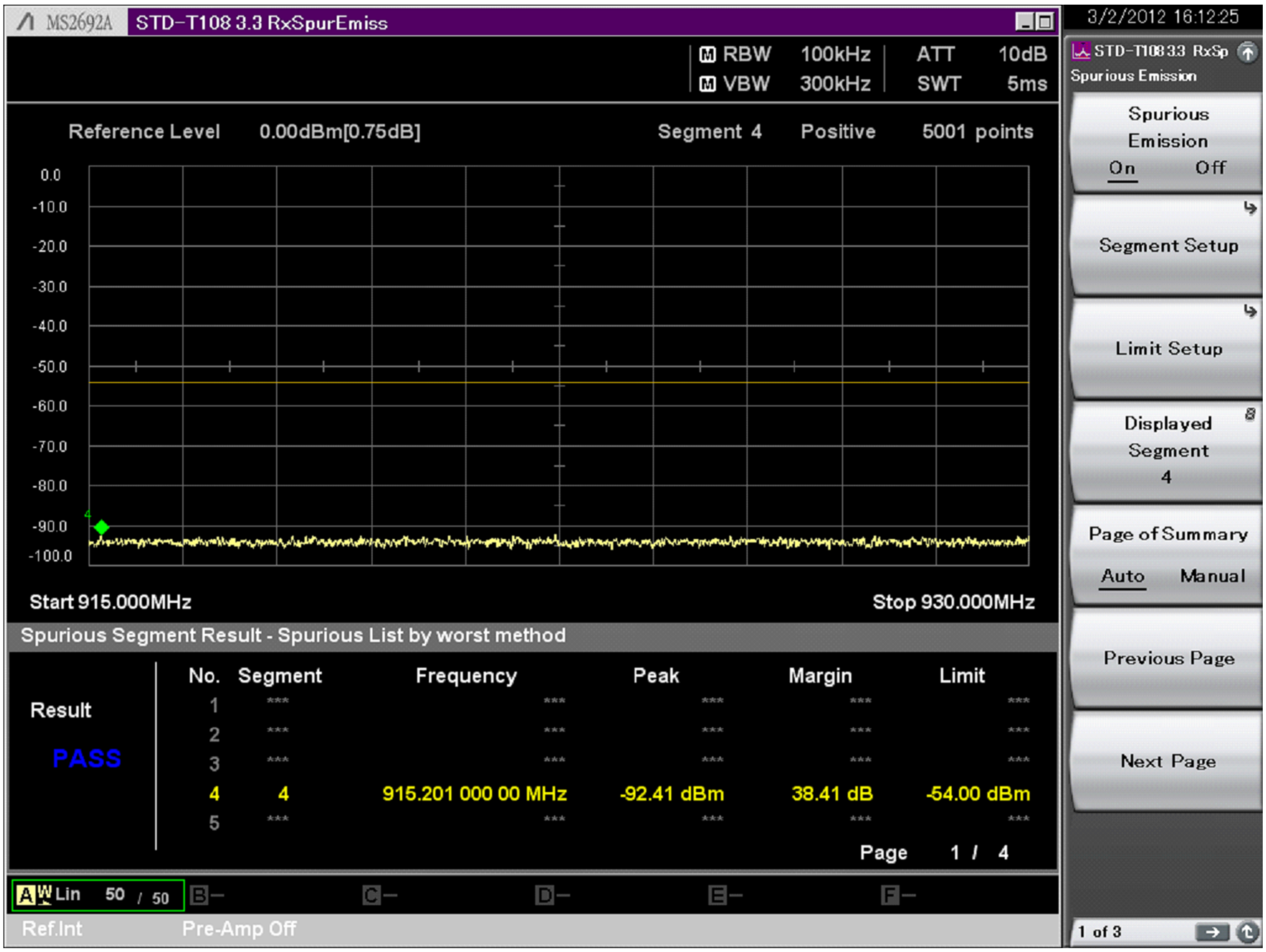


Figure 59. RX Conducted Spurious Emissions (915 MHz F ≤ 930 MHz)

4.2.5. 930 MHz < F ≤ 1000 MHz

The allowed level of spurious emissions within the 915–930 MHz frequency band is specified as less than –55 dBm in any 100 kHz bandwidth. The measured spurious emissions within this frequency band are shown in Figure 60. The Si4463 chip easily complies with the specified level of spurious emissions within this sub-band.

- Limit: –55 dBm/100 kHz (max)
- Measured: –91.18 dBm
- Margin: 36.18 dB (PASS)

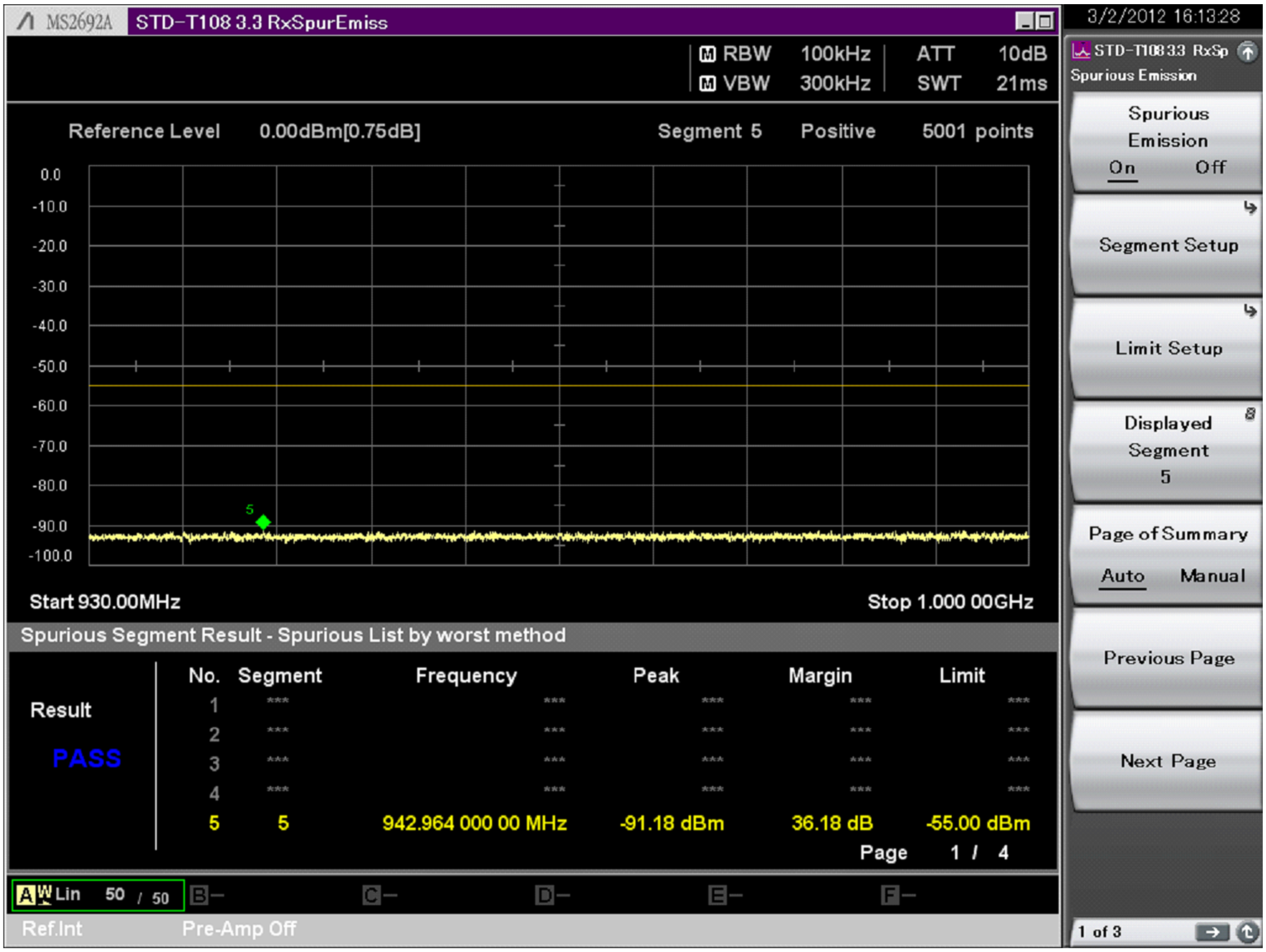


Figure 60. RX Conducted Spurious Emissions (930 MHz F ≤ 1000 MHz)

4.2.6. F > 1000 MHz

The allowed level of spurious emissions at frequencies above 1000 MHz is specified as less than –47 dBm in any 1 MHz bandwidth. The measured spurious emissions within this frequency band are shown in Figure 61. The Si4463 chip complies with the specified level of spurious emissions within this sub-band, although with low margin. The performance within this sub-band is limited by the coupling of the VCO signal (at ~3.6 GHz) to the bond wires of the LNA input (i.e., RXp and RXn). Compliance with greater margin may be obtained by modifying the external RX match to provide greater attenuation at 3.6 GHz.

- Limit: –47 dBm/1 MHz (max)
- Measured: –49.59 dBm
- Margin: 2.59 dB (PASS)

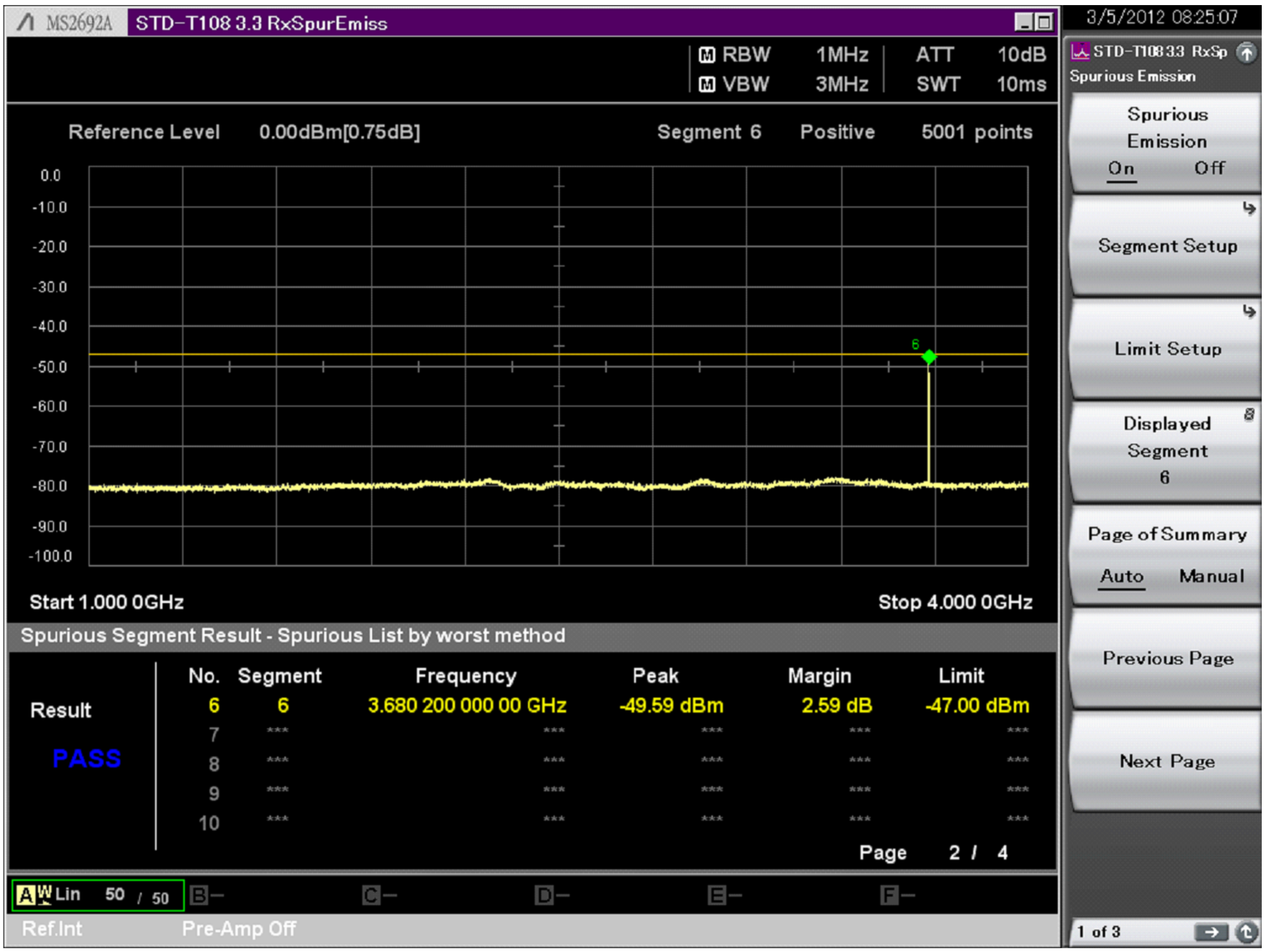


Figure 61. RX Conducted Spurious Emissions (F > 1000 MHz)

4.3. Receiver Sensitivity

ARIB STD-108 does not require a minimum value of performance of RX sensitivity. The measured data presented in this section is representative of typical RX sensitivity of Si446x chips. The Si4463 device was configured for a channel center frequency of 922.4 MHz for all tests within this section. The selected modulation protocol was 2GFSK with the data rate and deviation as shown in Table 6, and using a PN9 sequence as the data stream.

Table 6. Receive BER RX Sensitivity

RX Sensitivity			
Channel Spacing	100.0 kHz	200.0 kHz	400.0 kHz
Data Rate/Dev	50 kbps / 25 kHz	100 kbps / 50 kHz	200 kbps/100 kHz
RX IF BW	103.1 kHz	206.1 kHz	412.3 kHz
RX Sens (BER=1%)	–108.4 dBm	–105.3 dBm	–102.2 dBm

4.4. Receiver Adjacent and Alternate Channel Selectivity

ARIB STD-T108 does not require a minimum value of performance of RX adjacent and alternate channel selectivity. The measured data presented in this section is representative of typical RX selectivity of Si446x chips. The Si4463 device was configured for a channel center frequency of 922.4 MHz for all tests within this section. The selected modulation protocol was 2GFSK with the data rate and deviation as shown in Table 7, and using a PN9 sequence as the data stream for the desired signal. The interfering signal was a CW signal positioned at ± 1x Channel Spacing (Adjacent Channel) or ± 2x Channel Spacing (Alternate Channel) away from the desired signal. The desired signal level was adjusted to 3dB above the RX sensitivity level established in Section 4.3.

Table 7. Receive Adjacent/Alternate Channel Selectivity

Sensitivity @1% BER P_{SENS}	Desired Signal Level P_{DES}	ACS at +1 Ch	ACS at –1 Ch	ACS at +2 Ch	ACS at –2 Ch
Channel Spacing=100 kHz, DR=50 kbps, Dev=25 kHz					
–108.4 dBm	–105.4 dBm	42.2 dB	42.3 dB	47.7 dB	47.5 dB
Channel Spacing=200 kHz, DR=100 kbps, Dev=50 kHz					
–105.3 dBm	–102.3 dBm	41.5 dB	41.4 dB	47.6 dB	47.5 dB
Channel Spacing=400 kHz, DR=200 kbps, Dev=100 kHz					
–102.2 dBm	–99.2 dBm	39.5 dB	39.3 dB	43.1 dB	39.2 dB

The alternate channel selectivity at –2 x Chan spacing for the Channel Spacing = 400 kHz test case falls near the image response, and thus shows a small amount of performance degradation.

5. Wireless Development Suite (WDS) TX Script Files

5.1. WDS Script for 1 mW 916.0 MHz DR=100 kbps Dev=50 kHz TX Measurements

TX measurements at F=916.0 MHz with output power = 1 mW (0 dBm) used the following WDS script.

```
#BatchName TX 916.0MHz CLSE 0dBm 2GFSK PN9 DR=100kbps Dev=50kHz
# Revision Date:  2/29/2012
# Start
RESET
'POWER_UP' 01
'PART_INFO'
'FUNC_INFO'
'SET_PROPERTY' 'GLOBAL_XO_TUNE' 48
# Modem control group = 2GFSK Internal PN Seq
# PN polynomial = PN9 by default
'SET_PROPERTY' 'MODEM_MOD_TYPE' 13
'SET_PROPERTY' 'MODEM_MAP_CONTROL' 00
'SET_PROPERTY' 'MODEM_CLKGEN_BAND' 08
# Freq control group = 916.0 MHz
'SET_PROPERTY' 'FREQ_CONTROL_INTE' 3C
'SET_PROPERTY' 'FREQ_CONTROL_FRAC_2' 08
'SET_PROPERTY' 'FREQ_CONTROL_FRAC_1' 88
'SET_PROPERTY' 'FREQ_CONTROL_FRAC_0' 88
'SET_PROPERTY' 'FREQ_CONTROL_W_SIZE' 20
# PA control group = Class-E, 0 dBm
'SET_PROPERTY' 'PA_MODE' 08
'SET_PROPERTY' 'PA_PWR_LVL' 07
'SET_PROPERTY' 'PA_BIAS_CLKDUTY' 00
# Tx parameters, DR=100kbps, Dev=50kHz, TXOSR=20
'SET_PROPERTY' 'MODEM_DATA_RATE_2' 03
'SET_PROPERTY' 'MODEM_DATA_RATE_1' 0D
'SET_PROPERTY' 'MODEM_DATA_RATE_0' 40
'SET_PROPERTY' 'MODEM_TX_NCO_MODE_3' 08
'SET_PROPERTY' 'MODEM_TX_NCO_MODE_2' 2D
'SET_PROPERTY' 'MODEM_TX_NCO_MODE_1' C6
'SET_PROPERTY' 'MODEM_TX_NCO_MODE_0' C0
'SET_PROPERTY' 'MODEM_FREQ_DEV_2' 00
'SET_PROPERTY' 'MODEM_FREQ_DEV_1' 06
'SET_PROPERTY' 'MODEM_FREQ_DEV_0' D3
# To set Gaussian TX Filtering BxT=0.4, uncomment the following line
#'SET_PROPERTY' 20 09 0F 52 4F 45 37 28 1A 10 09 04
# Start transmitting
'START_TX' 00 00 00
```

5.2. WDS Script for 20 mW 920.6 MHz DR=100kbps Dev=50kHz TX Measurements

TX measurements at F=920.6 MHz with output power = 20 mW (+13 dBm) used the following WDS script.

```
#BatchName TX 920.6MHz CLSE +13dBm 2GFSK PN9 DR=100kbps Dev=50kHz
# Revision Date:  2/29/2012
# Start
RESET
'POWER_UP' 01
'PART_INFO'
'FUNC_INFO'
'SET_PROPERTY' 'GLOBAL_XO_TUNE' 48
# Modem control group = 2GFSK Internal PN Seq
# PN polynomial = PN9 by default
'SET_PROPERTY' 'MODEM_MOD_TYPE' 13
'SET_PROPERTY' 'MODEM_MAP_CONTROL' 00
'SET_PROPERTY' 'MODEM_CLKGEN_BAND' 08
# Freq control group = 920.6 MHz
'SET_PROPERTY' 'FREQ_CONTROL_INTE' 3C
'SET_PROPERTY' 'FREQ_CONTROL_FRAC_2' 0A
'SET_PROPERTY' 'FREQ_CONTROL_FRAC_1' FC
'SET_PROPERTY' 'FREQ_CONTROL_FRAC_0' 96
'SET_PROPERTY' 'FREQ_CONTROL_W_SIZE' 20
# PA control group = Class-E, +13 dBm
'SET_PROPERTY' 'PA_MODE' 08
'SET_PROPERTY' 'PA_PWR_LVL' 1D
'SET_PROPERTY' 'PA_BIAS_CLKDUTY' 00
# Tx parameters, DR=100kbps, Dev=50kHz, TXOSR=20
'SET_PROPERTY' 'MODEM_DATA_RATE_2' 03
'SET_PROPERTY' 'MODEM_DATA_RATE_1' 0D
'SET_PROPERTY' 'MODEM_DATA_RATE_0' 40
'SET_PROPERTY' 'MODEM_TX_NCO_MODE_3' 08
'SET_PROPERTY' 'MODEM_TX_NCO_MODE_2' 2D
'SET_PROPERTY' 'MODEM_TX_NCO_MODE_1' C6
'SET_PROPERTY' 'MODEM_TX_NCO_MODE_0' C0
'SET_PROPERTY' 'MODEM_FREQ_DEV_2' 00
'SET_PROPERTY' 'MODEM_FREQ_DEV_1' 06
'SET_PROPERTY' 'MODEM_FREQ_DEV_0' D3
# To set Gaussian TX Filtering BxT=0.4, uncomment the following line
#'SET_PROPERTY' 20 09 0F 52 4F 45 37 28 1A 10 09 04
# Start transmitting
'START_TX' 00 00 00
```

5.3. WDS Script for 250 mW 922.4 MHz DR=100 kbps Dev=50 kHz TX Measurements

TX measurements at F=922.4 MHz with output power = 250 mW (+20 dBm) used the following WDS script.

```
#BatchName TX 922.4MHz CLSE +20dBm 2GFSK PN9 DR=100kbps Dev=50kHz
# Revision Date:  2/29/2012
# Start
RESET
'POWER_UP' 01
'PART_INFO'
'FUNC_INFO'
'SET_PROPERTY' 'GLOBAL_XO_TUNE' 48
# Modem control group = 2GFSK Internal PN Seq
# PN polynomial = PN9 by default
'SET_PROPERTY' 'MODEM_MOD_TYPE' 13
'SET_PROPERTY' 'MODEM_MAP_CONTROL' 00
'SET_PROPERTY' 'MODEM_CLKGEN_BAND' 08
# Freq control group = 922.4 MHz
'SET_PROPERTY' 'FREQ_CONTROL_INTE' 3C
'SET_PROPERTY' 'FREQ_CONTROL_FRAC_2' 0B
'SET_PROPERTY' 'FREQ_CONTROL_FRAC_1' F2
'SET_PROPERTY' 'FREQ_CONTROL_FRAC_0' 58
'SET_PROPERTY' 'FREQ_CONTROL_W_SIZE' 20
# PA control group = Class-E, +20 dBm
'SET_PROPERTY' 'PA_MODE' 08
'SET_PROPERTY' 'PA_PWR_LVL' 7F
'SET_PROPERTY' 'PA_BIAS_CLKDUTY' 00
# Tx parameters, DR=100kbps, Dev=50kHz, TXOSR=20
'SET_PROPERTY' 'MODEM_DATA_RATE_2' 03
'SET_PROPERTY' 'MODEM_DATA_RATE_1' 0D
'SET_PROPERTY' 'MODEM_DATA_RATE_0' 40
'SET_PROPERTY' 'MODEM_TX_NCO_MODE_3' 08
'SET_PROPERTY' 'MODEM_TX_NCO_MODE_2' 2D
'SET_PROPERTY' 'MODEM_TX_NCO_MODE_1' C6
'SET_PROPERTY' 'MODEM_TX_NCO_MODE_0' C0
'SET_PROPERTY' 'MODEM_FREQ_DEV_2' 00
'SET_PROPERTY' 'MODEM_FREQ_DEV_1' 06
'SET_PROPERTY' 'MODEM_FREQ_DEV_0' D3
# To set Gaussian TX Filtering BxT=0.4, uncomment the following line
#'SET_PROPERTY' 20 09 0F 52 4F 45 37 28 1A 10 09 04
# Start transmitting
'START_TX' 00 00 00
```

5.4. WDS Script for 1 mW 928.15 MHz DR=50 kbps Dev=25 kHz TX Measurements

TX measurements at F=928.15 MHz with output power = 1 mW (0 dBm) used the following WDS script.

```
#BatchName TX 928.15MHz CLSE 0dBm 2GFSK PN9 DR=50kbps Dev=25kHz
# Revision Date:  2/29/2012
# Start
RESET
'POWER_UP' 01
'PART_INFO'
'FUNC_INFO'
'SET_PROPERTY' 'GLOBAL_XO_TUNE' 48
# Modem control group = 2GFSK Internal PN Seq
# PN polynomial = PN9 by default
'SET_PROPERTY' 'MODEM_MOD_TYPE' 13
'SET_PROPERTY' 'MODEM_MAP_CONTROL' 00
'SET_PROPERTY' 'MODEM_CLKGEN_BAND' 08
# Freq control group = 928.15 MHz
'SET_PROPERTY' 'FREQ_CONTROL_INTE' 3C
'SET_PROPERTY' 'FREQ_CONTROL_FRAC_2' 0F
'SET_PROPERTY' 'FREQ_CONTROL_FRAC_1' 03
'SET_PROPERTY' 'FREQ_CONTROL_FRAC_0' 69
'SET_PROPERTY' 'FREQ_CONTROL_W_SIZE' 20
# PA control group = Class-E, 0 dBm
'SET_PROPERTY' 'PA_MODE' 08
'SET_PROPERTY' 'PA_PWR_LVL' 07
'SET_PROPERTY' 'PA_BIAS_CLKDUTY' 00
# Tx parameters, DR=50kbps, Dev=25kHz, TXOSR=20
'SET_PROPERTY' 'MODEM_DATA_RATE_2' 01
'SET_PROPERTY' 'MODEM_DATA_RATE_1' 86
'SET_PROPERTY' 'MODEM_DATA_RATE_0' A0
'SET_PROPERTY' 'MODEM_TX_NCO_MODE_3' 08
'SET_PROPERTY' 'MODEM_TX_NCO_MODE_2' 2D
'SET_PROPERTY' 'MODEM_TX_NCO_MODE_1' C6
'SET_PROPERTY' 'MODEM_TX_NCO_MODE_0' C0
'SET_PROPERTY' 'MODEM_FREQ_DEV_2' 00
'SET_PROPERTY' 'MODEM_FREQ_DEV_1' 03
'SET_PROPERTY' 'MODEM_FREQ_DEV_0' 6A
# To set Gaussian TX Filtering BxT=0.4, uncomment the following line
#'SET_PROPERTY' 20 09 0F 52 4F 45 37 28 1A 10 09 04
# Start transmitting
'START_TX' 00 00 00
```

6. Wireless Development Suite (WDS) RX Script Files

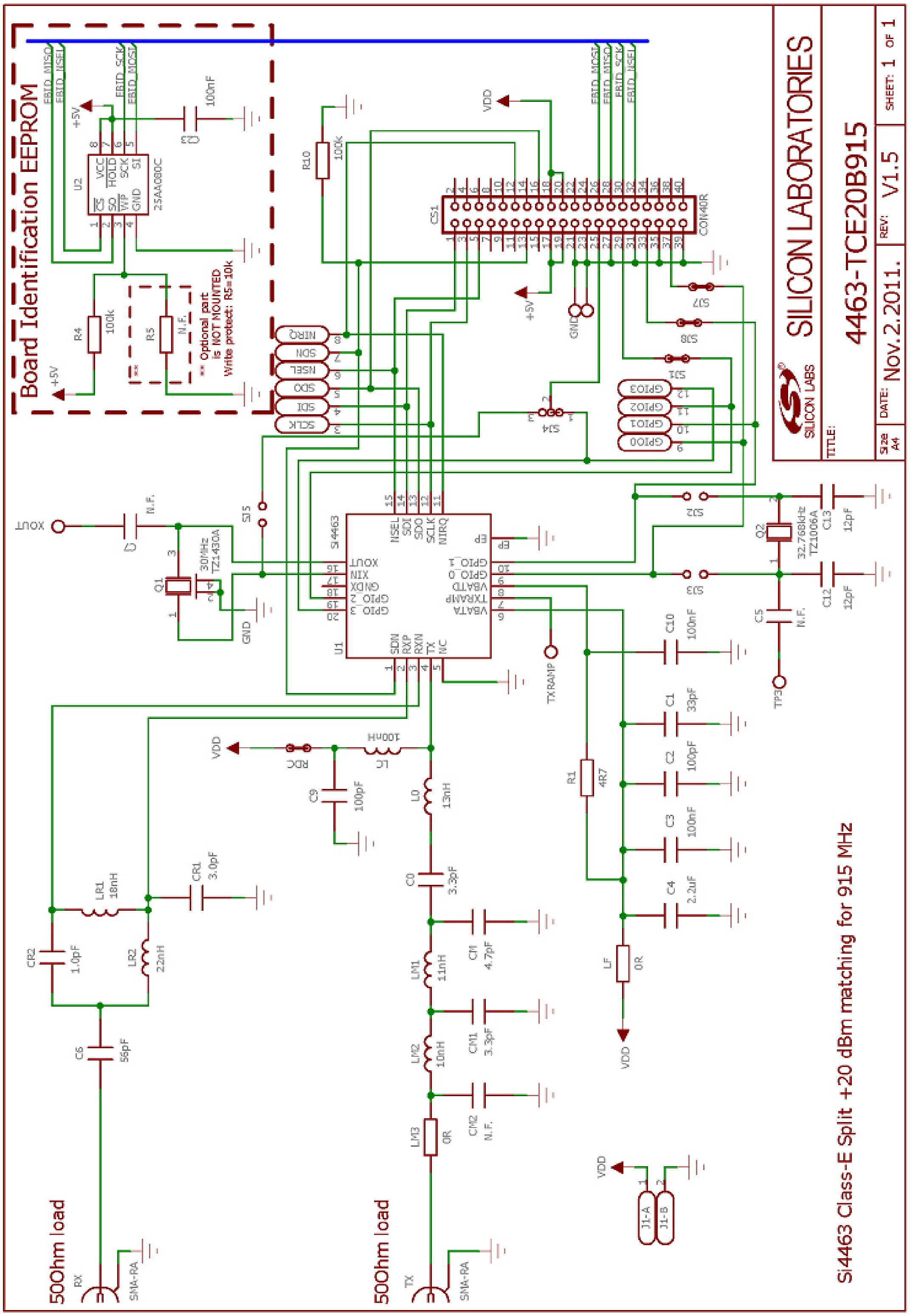
6.1. WDS RX Script File for 200 kHz Channel Spacing RX Measurements

RX measurements at F=922.4 MHz used the following WDS script.

```
#BatchName RX 922.4 MHz BER 2GFSK DR100K Dev50K StdPre
# Revision Date:  10/21/2011
# Start
RESET
'POWER_UP' 01 00 00 00 00
'PART_INFO'
'FUNC_INFO'
# Adjust Crystal Osc cap bank to center oscillator frequency
'SET_PROPERTY' 'GLOBAL_XO_TUNE' 48
# General parameters, Mod Type = 2GFSK
'SET_PROPERTY' 'MODEM_MOD_TYPE' 03
'SET_PROPERTY' 'MODEM_MAP_CONTROL' 00
'SET_PROPERTY' 'MODEM_CLKGEN_BAND' 08
# Freq control group = 922.4 MHz
'SET_PROPERTY' 'FREQ_CONTROL_INTE' 3C
'SET_PROPERTY' 'FREQ_CONTROL_FRAC_2' 0B
'SET_PROPERTY' 'FREQ_CONTROL_FRAC_1' F2
'SET_PROPERTY' 'FREQ_CONTROL_FRAC_0' 58
'SET_PROPERTY' 'FREQ_CONTROL_W_SIZE' 20
# Rx parameters
'SET_PROPERTY' 'FREQ_CONTROL_VCOCNT_RX_ADJ' FF
# Use Standard Detector as source for BCR/Slicer
'SET_PROPERTY' 'MODEM_MDM_CTRL' 00
'SET_PROPERTY' 'MODEM_IF_CONTROL' 08
'SET_PROPERTY' 'MODEM_IF_FREQ_2' 03
'SET_PROPERTY' 'MODEM_IF_FREQ_1' C0
'SET_PROPERTY' 'MODEM_IF_FREQ_0' 00
# ndec2=0, ndec1=1, ndec0=0
'SET_PROPERTY' 'MODEM_DECIMATION_CFG1' 10
# HP ChFilt, dwn3byp=1, dwn2byp=0
'SET_PROPERTY' 'MODEM_DECIMATION_CFG0' 20
'SET_PROPERTY' 'MODEM_BCR_OSR_1' 00
'SET_PROPERTY' 'MODEM_BCR_OSR_0' 4B
'SET_PROPERTY' 'MODEM_BCR_NCO_OFFSET_2' 06
'SET_PROPERTY' 'MODEM_BCR_NCO_OFFSET_1' D3
'SET_PROPERTY' 'MODEM_BCR_NCO_OFFSET_0' A0
'SET_PROPERTY' 'MODEM_BCR_GAIN_1' 06
'SET_PROPERTY' 'MODEM_BCR_GAIN_0' D4
'SET_PROPERTY' 'MODEM_BCR_GEAR' 02
```

```
# bcrfbbyp=1, slcrfbbyp=1, dis_midpt=0
'SET_PROPERTY' 'MODEM_BCR_MISC1' C0
'SET_PROPERTY' 'MODEM_BCR_MISC0' 00
'SET_PROPERTY' 'MODEM_AFC_GEAR' 00
'SET_PROPERTY' 'MODEM_AFC_WAIT' 23
# Disable AFC
'SET_PROPERTY' 'MODEM_AFC_GAIN_1' 03
'SET_PROPERTY' 'MODEM_AFC_GAIN_0' 6A
'SET_PROPERTY' 'MODEM_AFC_LIMITER_1' 00
'SET_PROPERTY' 'MODEM_AFC_LIMITER_0' D3
# enfbpll=0, en2Tb_est=1
'SET_PROPERTY' 'MODEM_AFC_MISC' A0
'SET_PROPERTY' 'MODEM_AGC_CONTROL' E0
'SET_PROPERTY' 'MODEM_AGC_WINDOW_SIZE' 11
'SET_PROPERTY' 'MODEM_AGC_RFPD_DECAY' 10
'SET_PROPERTY' 'MODEM_AGC_IFPD_DECAY' 10
'SET_PROPERTY' 'MODEM_RAW_SEARCH' 56
# unstdpk=0 (use Std Detector), pm_pattern=2'b00 (std
preamble)
'SET_PROPERTY' 'MODEM_RAW_CONTROL' 02
'SET_PROPERTY' 'MODEM_RAW_EYE_1' 00
'SET_PROPERTY' 'MODEM_RAW_EYE_0' A4
## RX channel filter coeff
# WB filter k1=2 (BW=206.1 kHz), NB filter k2=4
(BW=206.1 kHz)
'SET_PROPERTY' 21 0C 00 FF C4 30 7F F5 B5 B8 DE
05 17 16 0C
'SET_PROPERTY' 21 06 0C 03 00 15 FF 00 00
'SET_PROPERTY' 21 0C 12 FF C4 30 7F F5 B5 B8 DE
05 17 16 0C
'SET_PROPERTY' 21 06 1E 03 00 15 FF 00 00
# Skip sync detection, Std Preamble, PreDetTh=9 bits
#  (9-bit preamble may be found in PN9 or higher
sequences)
'SET_PROPERTY' 'PREAMBLE_CONFIG_STD_1' 89
'SET_PROPERTY' 'PREAMBLE_CONFIG' 01
# GPIO configuration
# RxClk/RxData/PreambleDet
'GPIO_PIN_CFG' 11 14 18 00 00 00
# Start receiving
'START_RX' 00 00 00 00 00 01
```

7. Reference Design Schematic



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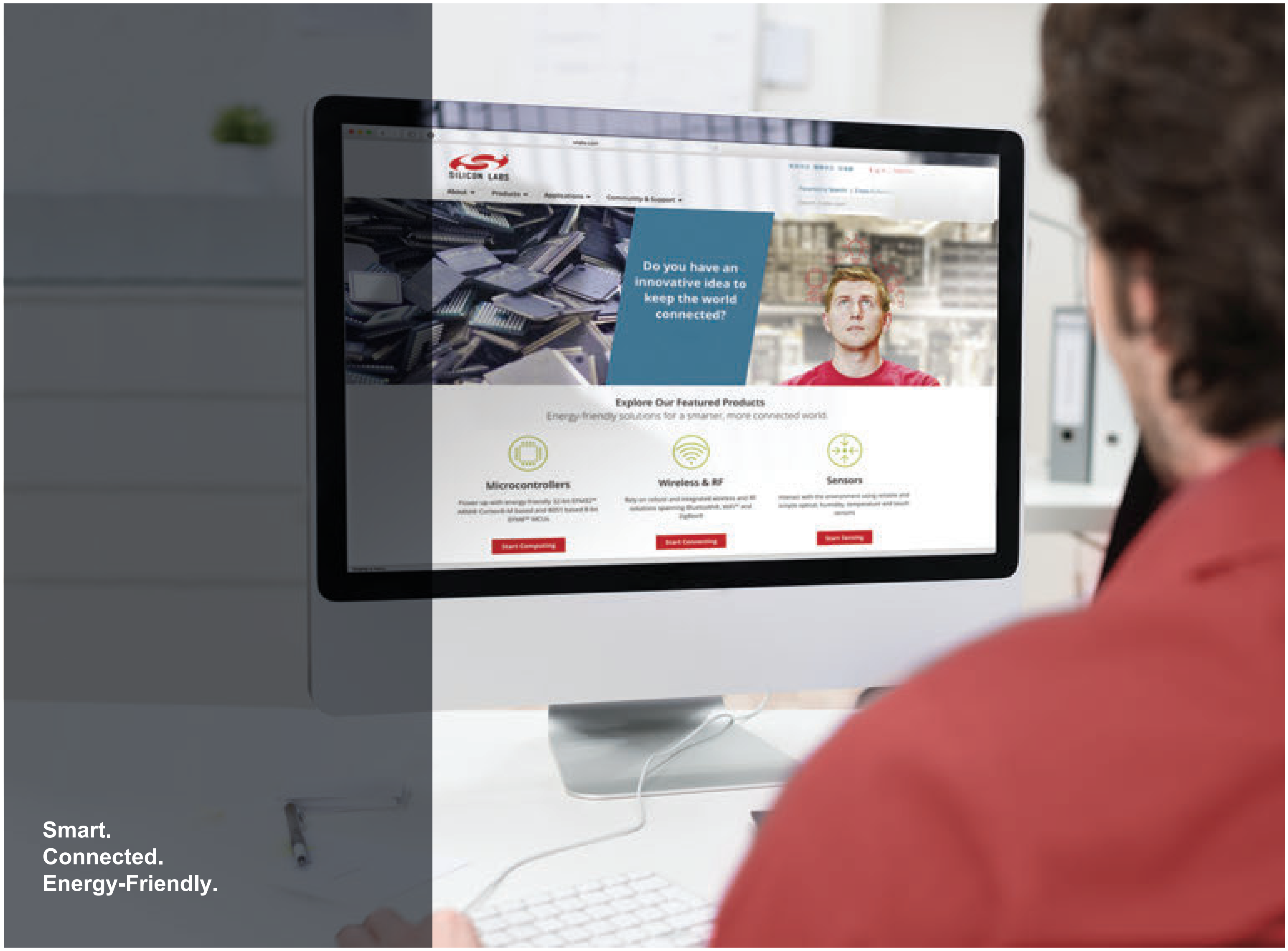
Document Change List

Revision 0.3 to Revision 0.4

- Changed Si4461-B0 to Si4461.
- Changed Si4463-B0 to Si4463.
- On pages 1 and 13, additional chip types (4460/67/68) and revision numbers (B1, C0, C1, and C2) were added in brackets.

Revision 0.4 to Revision 0.5

- Added measured data for RX Sensitivity and Selectivity, as reference for comparison with other vendors.



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