AN459

MEASUREMENT RESULTS FOR Si4430-B AND 950 MHz ARIB STD-T96 COMPLIANCE

1. Introduction

This application note demonstrates the compliance of the Si4430-B1 RFIC with the regulatory requirements of ARIB STD T96 (V1.0, dated June 6th 2008). The spurious emission performance measurements are conducted in accordance with TELEC 245, which defines the measurement conditions for ARIB STD-T96 for conducted emissions. In addition radiated emissions are checked up to the 10th harmonic.

The Si4430-B1 chip is programmed to transmit at +10 dBm output power by setting SPI Register 6Dh = 0Eh. A data rate of 100 kbps and deviation of 50 kHz is chosen, in accordance with IEEE 802.15.4d. As will be shown later, selection of this modulation protocol necessitates operation with two unit radio channels (n=2), as provided in ARIB STD-T96 3.2(3)(b)(ii). Additional optimization of the register settings (for PLL loop bandwidth and VCO bias current) is required in order to achieve compliance within the 956–958 MHz frequency region.

The tests are performed at supply voltages of 1.8, 3.3 and 3.6 V. In this document the results for VDD = 3.3 V are presented in detail. The radiation tests are done using a standard ¼-wave monopole antenna. The radiated fundamental output power is +9.3 dBm EIRP. The most critical 2nd harmonic radiation is 3 dB below the –55 dBm EIRP limit. All other harmonics are far below the –30 dBm EIRP limit.

Although the measurements presented here were taken with an Si4430-B1 chip mounted on a Direct Tie reference design board matched for 950 MHz (4430-T-B1-D-950M), the results are also applicable to +13 dBm members of the Si100x/Si101x family of wireless MCUs, if matched in the same fashion.

2. Summary of Measurement Results for TX Performance

A summary of the measured results for TX performance is provided in Table 1.

Table 1. Summary of Measured Results for TX Performance

Freq Band	REF BW	ARIB Limit	Measured (dBm) at 3.3 V	See Fig #	Comments
Selected Channel	integrated	+10 dBm	+9.3 dBm	9	Par. 3.2(1), Transmit Power
OCBW around carrier	99% pow.	200 kHz	183 kHz	1	Par. 3.2(6), Occ BW 99% (n=1)
		400 kHz	183 kHz	1	Par. 3.2(6), Occ BW 99% (n=2)
200K BW @ Fc-200K	integrated	–18 dBm	–19.1 dBm	6	Par. 3.2(7)(b)(ii), ACP (n=1), opt CPCURR
200K BW @ Fc+200K	integrated	–18 dBm	–18.5 dBm	6	Par. 3.2(7)(b)(ii), ACP (n=1), opt CPCURR
200K BW @ Fc-300K	integrated	–18 dBm	–35.9 dBm	5	Par. 3.2(7)(b)(ii), ACP (n=2)
200K BW @ Fc+300K	integrated	–18 dBm	–35.7 dBm	5	Par. 3.2(7)(b)(ii), ACP (n=2)
30 to 710 MHz	100 kHz	–36 dBm	–72.5 dBm	10	Par. 3.2(8), Spurious Emissions
710 to 945 MHz	1 MHz	–55 dBm	–63.3 dBm	11	Par. 3.2(8), Spurious Emissions
945 to 950 MHz	100 kHz	–55 dBm	–72.4 dBm	12	Par. 3.2(8), Spurious Emissions
950.0 to 954.4 MHz	3 kHz	–54.2 dBm	–62.7 dBm	15	Par. 3.2(8), Spurious Emissions (n=2)
955.0 to 956.0 MHz	3 kHz	–54.2 dBm	–63.4 dBm	16	Par. 3.2(8), Spurious Emissions (n=2)
956 to 958 MHz	100 kHz	–55 dBm	–60.1 dBm	17	Par. 3.2(8), Spurious Emissions
958 to 960 MHz	100 kHz	–58 dBm	–70.2 dBm	18	Par. 3.2(8), Spurious Emissions
960 to 1000 MHz	100 kHz	–36 dBm	–72.4 dBm	19	Par. 3.2(8), Spurious Emissions
1.0 to 1.8845 GHz	1 MHz	–30 dBm	–64.8 dBm	20	Par. 3.2(8), Spurious Emissions
1.8845 to 1.9196 GHz	1 MHz	–55 dBm	–64.2 dBm	21	Par. 3.2(8), Spurious Emissions (2xFo)
1.92 to 3.6 GHz	1 MHz	–30 dBm	–61.1 dBm	22	Par. 3.2(8), Spurious Emissions

The Si4430-B1 chip meets all ARIB STD-T96 specifications (with margin), when used in a Direct Tie board configuration matched at 950 MHz and configured for power state 0Eh. The Direct Tie reference design does not require a switch or SAW filter to comply with ARIB STD-T96. All the measurement results summarized in Table 1 were obtained using the SPI register settings shown in "7. Script files" on page 32, with V_{DD} = 3.3 V.

3. TX Conducted Measurement Results

All measurements are performed with SPI Register 6Dh configured for power state 0Eh. This is the power setting recommended for ARIB STD-T96 operation, as this minimizes current consumption while easily complying with the required TX output level. Power levels (for both fundamental and harmonics) and current consumption for other power states are summarized in Table 4 on page 28.

3.1. ARIB STD-T96 3.2(6), Occupied Bandwidth

The allowed occupied bandwidth is specified in ARIB STD-T96 3.2(6), and is specified as less than (n x 200 kHz) where "n" is an integer from 1 to 3, and represents the number of unit radio channels used by the system. The Si4430-B1 easily complies with this specification when transmitting 100 kbps, 50 kHz deviation (per 802.15.4d), even for the case of n=1 and default register settings. The measured occupied bandwidth is shown in Figure 1.

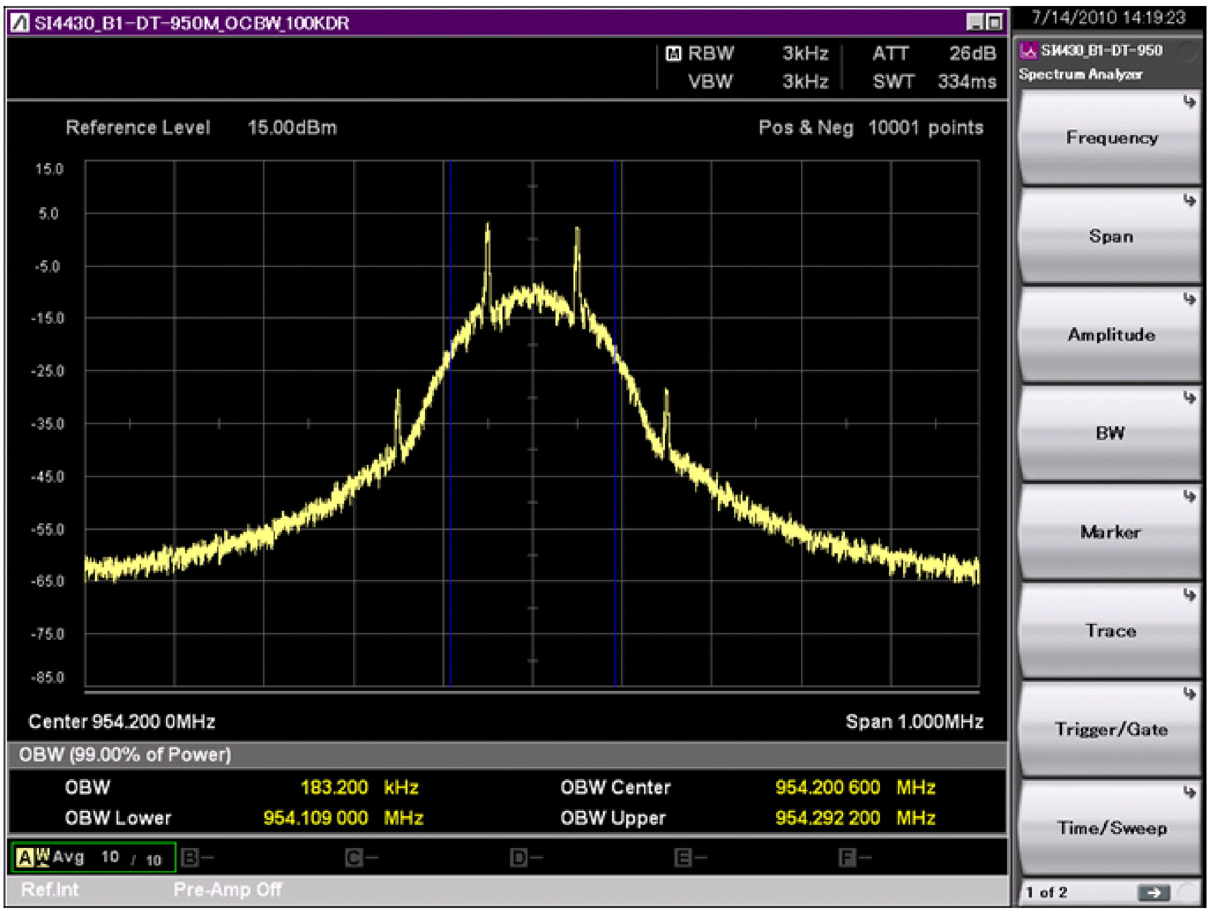

Figure 1. Occupied Bandwidth (~183 kHz, Limit = 200 kHz)

3.2. ARIB STD-T96 3.2(7)(b)(ii), Adjacent Channel Leakage

The allowed adjacent channel leakage is specified in ARIB STD-T96 3.2(7)(b)(ii), and is specified as less than 18 dBm in the upper and lower adjacent channels of 200 kHz bandwidth. The center frequency offset of the adjacent channel depends upon the number of unit radio channels used by the system, and is defined as fc+200+100 x (n-1) kHz. Thus for the case of n=1, the center frequency offset of the adjacent channel would be at ±200 kHz, for n=2 the center frequency offset would be at ±300 kHz, and for n=3 the center frequency offset would be at ±400 kHz.

When using one unit radio channel (n=1), the performance of the Si4430-B1 chip (with default SPI register settings) is marginal, and may even exceed the requirement by 1 to 2 dB. The measured adjacent channel leakage for the case of n=1 and with default register settings is shown in Figure 2.

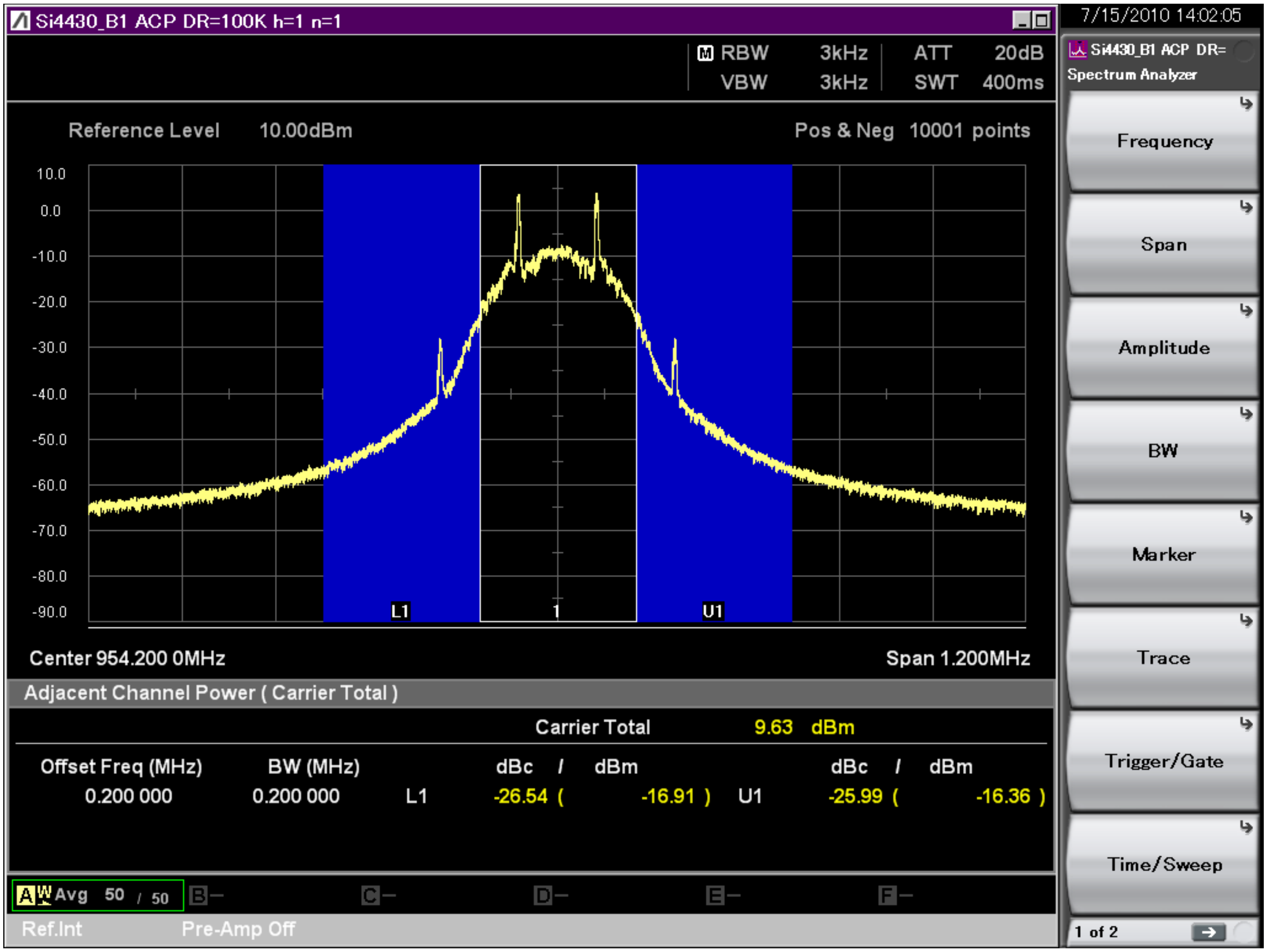

Figure 2. Adjacent Channel Leakage, n=1 (~ –17 dBm, Limit = –18 dBm)

This marginally-failing performance is due to the inherent modulation bandwidth of the 100 kbps, 50 kHz deviation signal itself, 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 3 and is observed to comply with the spec with over 16 dB margin.

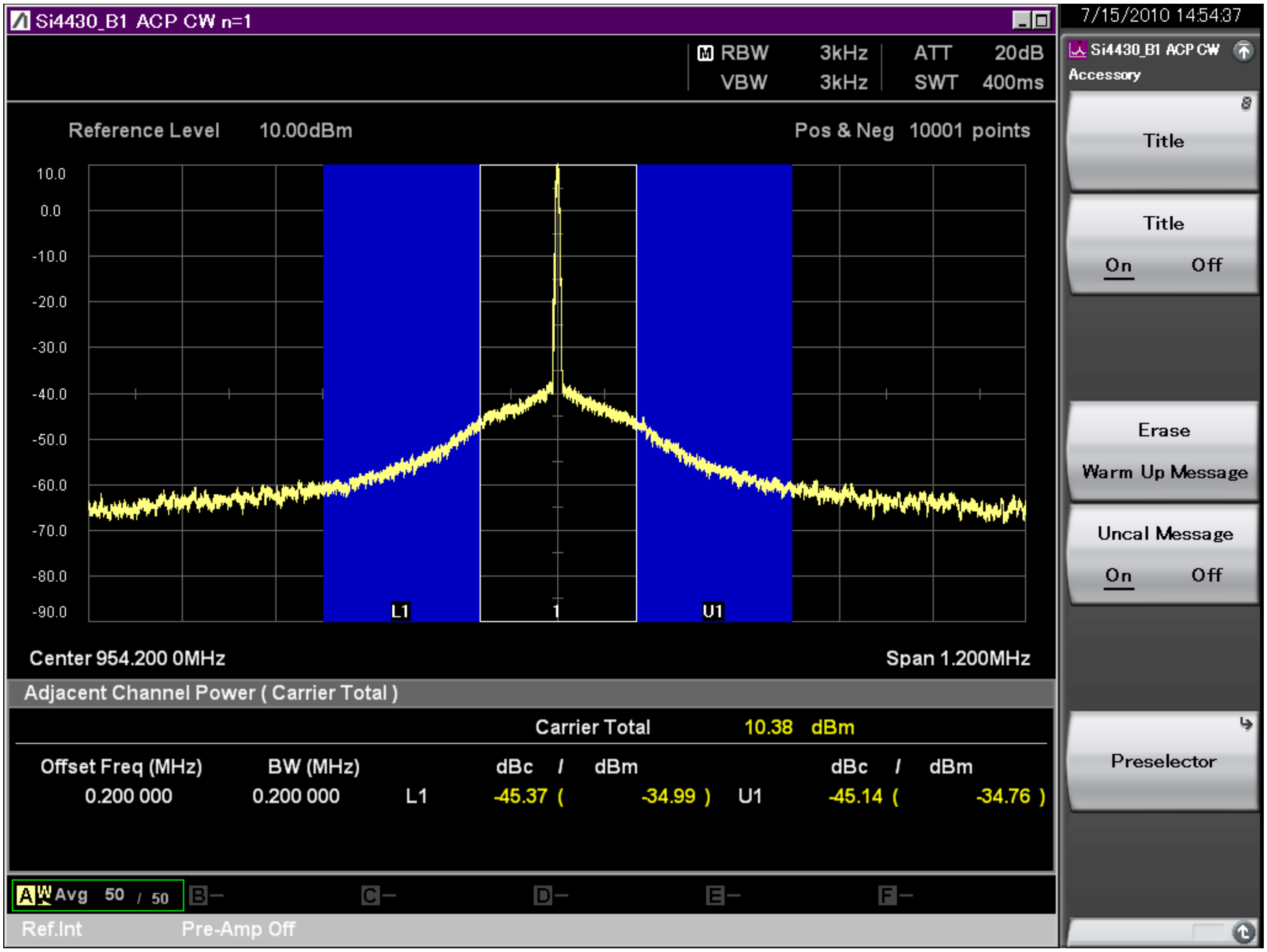

Figure 3. Adjacent Channel Leakage in CW Mode, n=1 (~ -34 dBm, Limit = -18 dBm)

Compliance when using a single unit radio channel (n=1) remains difficult, 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 GFSK BT=0.5 data stream. This performance is shown in Figure 4 and is observed to comply with the spec with only ~3 dB margin. This demonstrates that the inherent modulation bandwidth of the 802.15.4d signal barely complies with the adjacent channel leakage requirements of ARIB STD-T96.

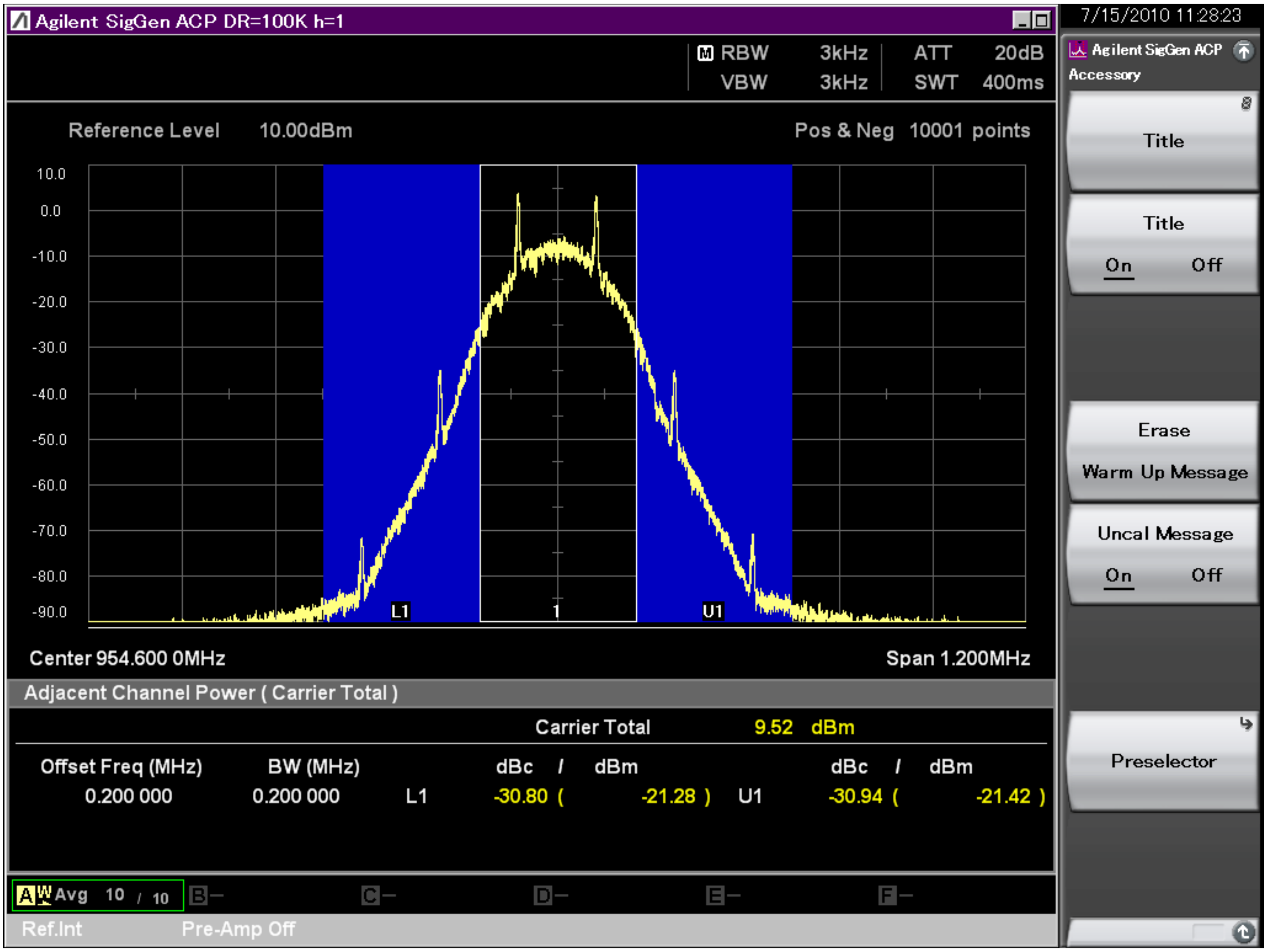

Figure 4. Adjacent Channel Leakage of Agilent SigGen, n=1 (~ -21 dBm, Limit = -18 dBm)

There are two ways in which the Si4430-B1 chip may be operated to comply with the adjacent channel leakage requirements.

- Operate with two (or more) unit radio channels (i.e., n=2 or n=3)
- Optimize PLL loop bandwidth to further filter the modulation spectrum, thus reducing its bandwidth

The Si4430-B1 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 is shown in Figure 5, and is observed to comply with the spec with over 15 dB of margin.

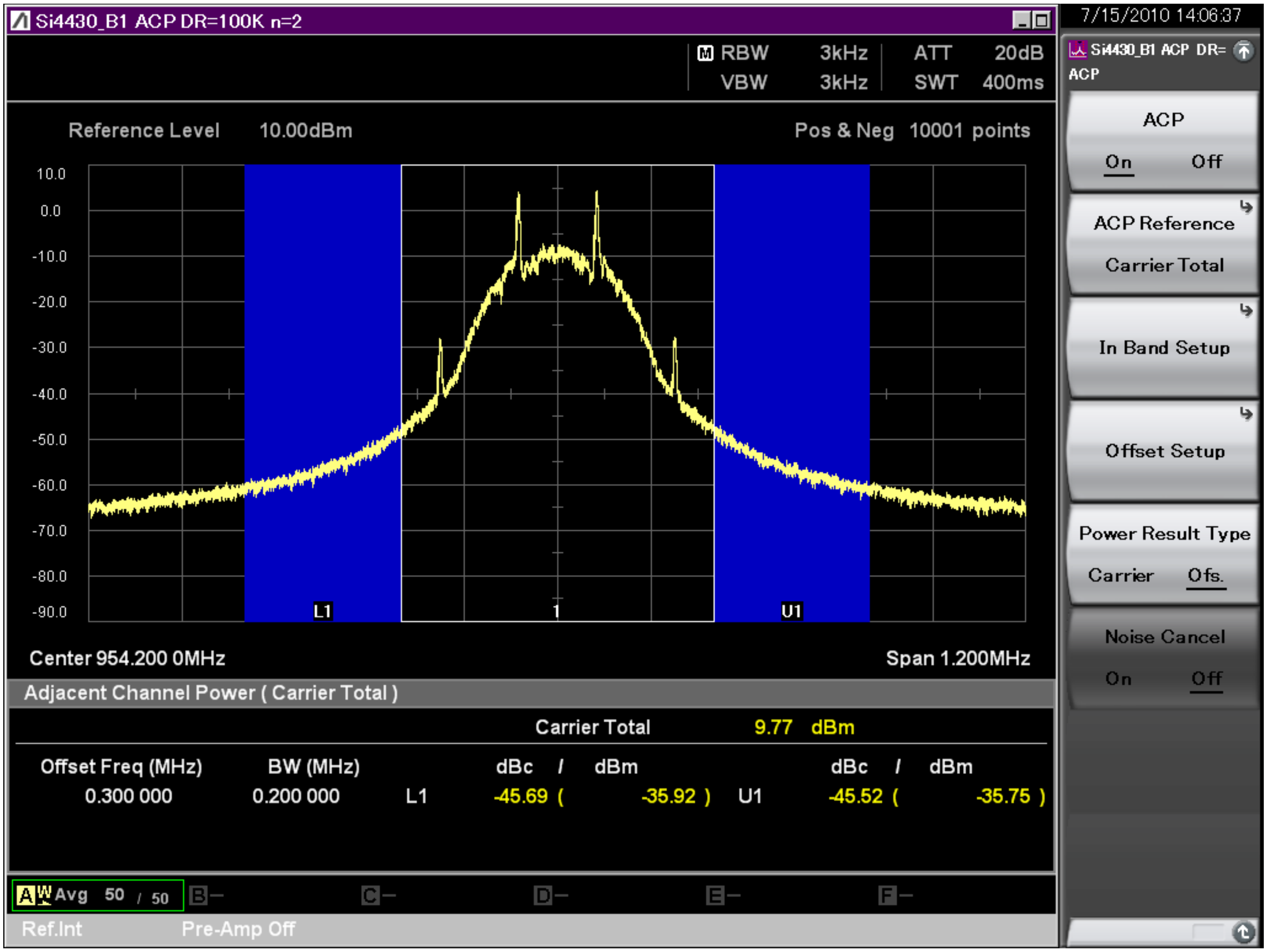

Figure 5. Adjacent Channel Leakage, n=2 (~ –36 dBm, Limit = –18 dBm)

As an alternative, the adjacent channel leakage performance for the case of n=1 may be improved by slightly reducing the PLL loop bandwidth, thus providing further filtering of the modulation and reduction of the modulation bandwidth. The PLL loop bandwidth is controlled by the charge pump current, and is adjusted by programming the CPCURR[1:0] field, found as bits D6-D7 in SPI Register 58h. The default value of the CPCURR field is 2'b10, and thus the default value for this register is Reg 58h = 80h. If the value of the CPCURR field is reduced to 2'b01 (Reg 58h = 40h), the Si4430-B1 chip is observed to comply with the adjacent channel leakage spec even for the case of n=1, as shown in Figure 6.

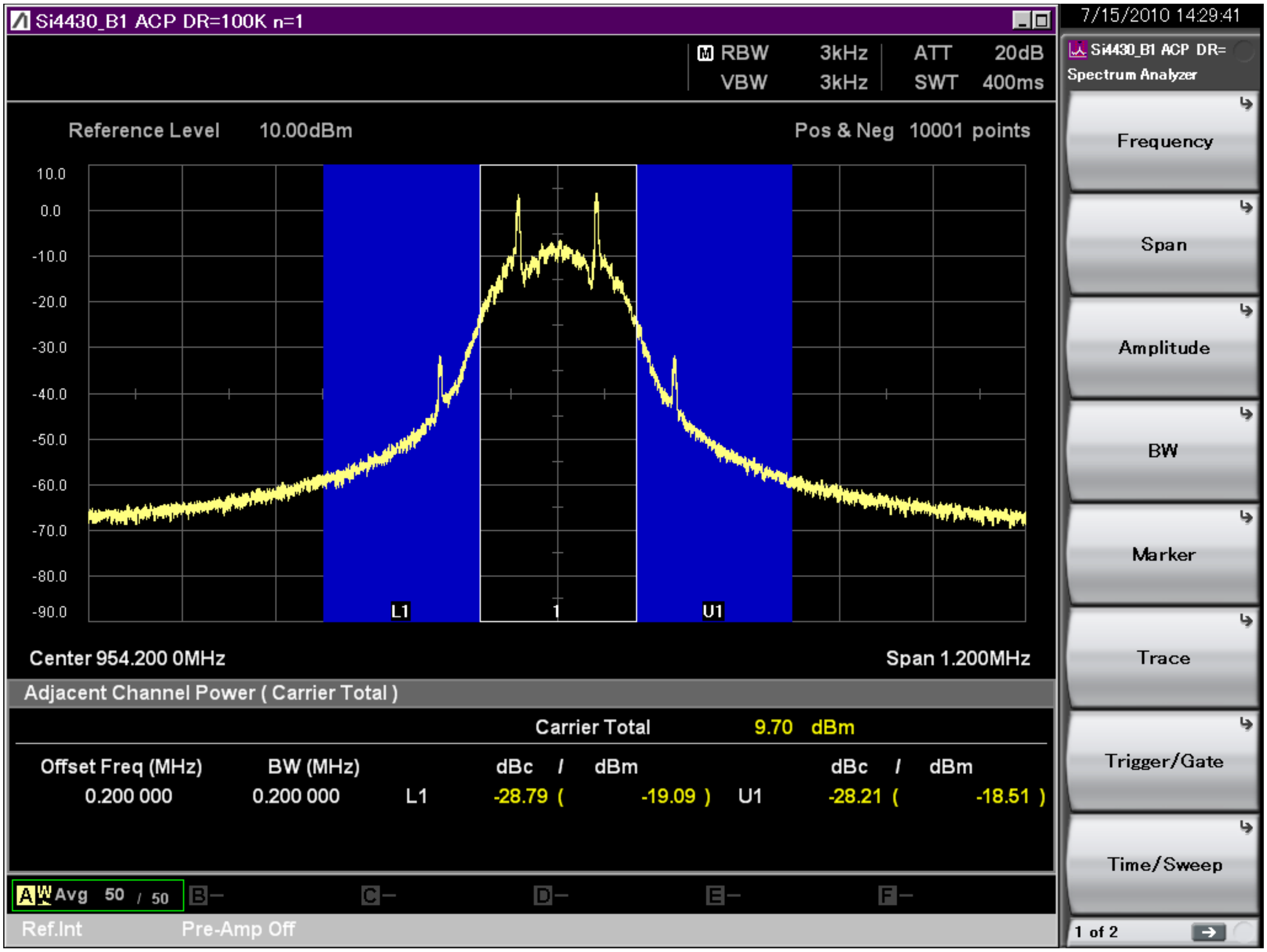

Figure 6. Adjacent Channel Leakage, n=1, Reg 58h=40h (~ –19 dBm, Limit = –18 dBm)

As discussed in ARIB STD-T96 3.2(5), there is no specification or requirement on the modulation type (i.e., data rate or deviation). However, IEEE 802.15.4d imposes limits on variations in the frequency deviation. As all of the EZRadioPRO family of chips implement FSK/GFSK modulation using “inside the loop bandwidth” techniques, any reduction in PLL loop bandwidth may be of potential concern regarding possible closure of the transmit data eye. In Figure 7 and Figure 8, the transmit data eye is shown for the default (80h) and recommended (40h) settings of the CPCURR field in SPI Register 58h. No significant reduction in data eye opening is observed.

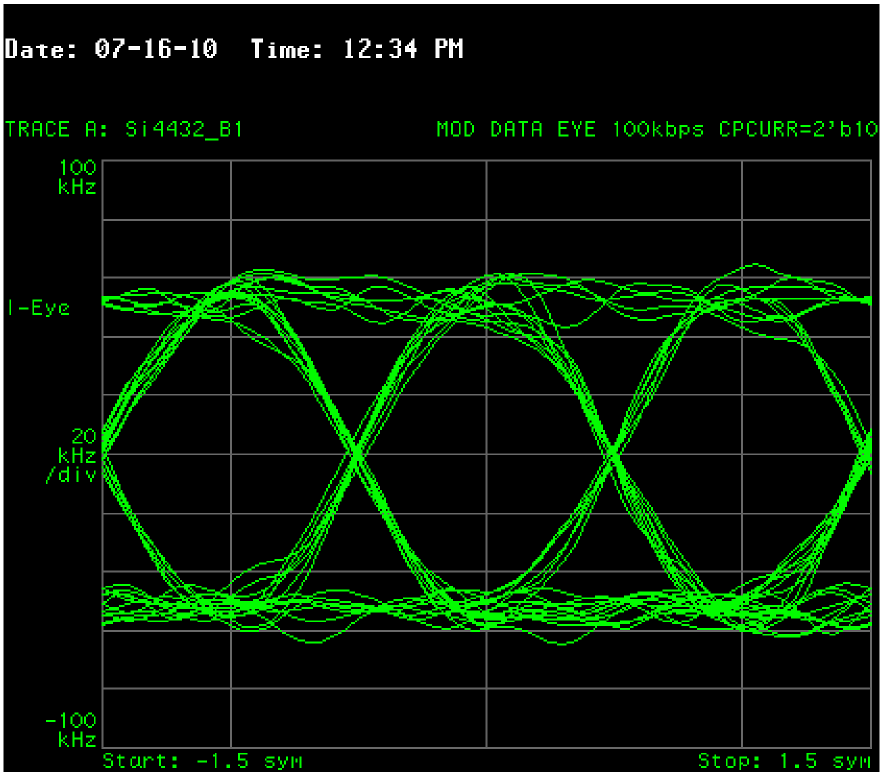

Figure 7. Transmit Data Eye Opening, 100 kbps, Reg 58h=80h

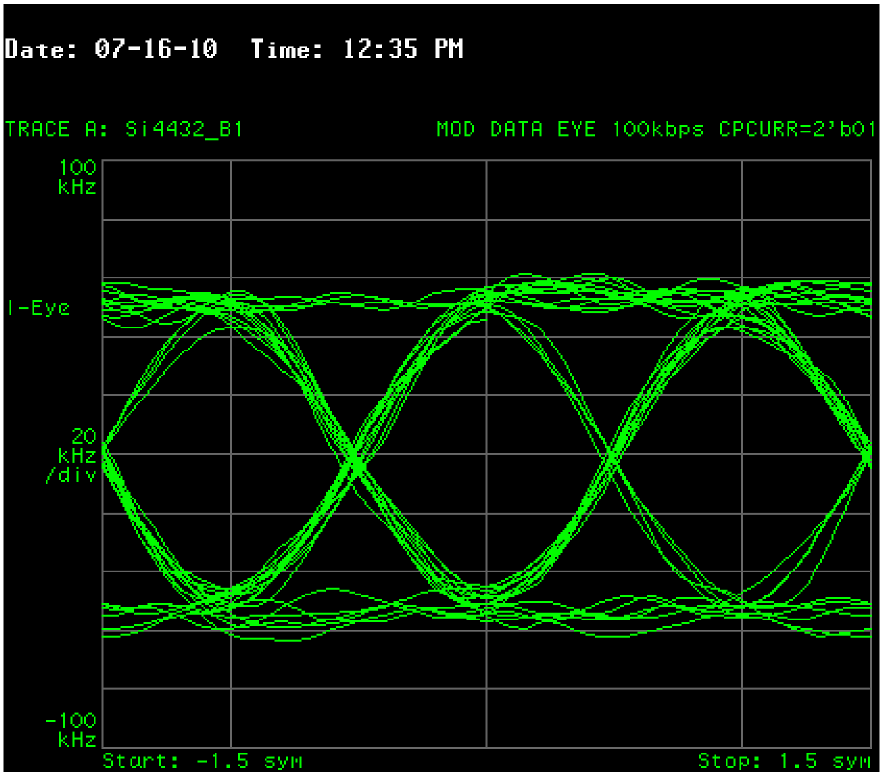

Figure 8. Transmit Data Eye Opening, 100 kbps, Reg 58h=40h

3.3. ARIB STD-T96 3.2(1), Transmitter Antenna Power

The allowed transmitter antenna power is specified in ARIB STD-T96 3.2(1), and is specified as less than 10 mW (+10 dBm). The measured transmitter antenna power is shown in Figure 9.

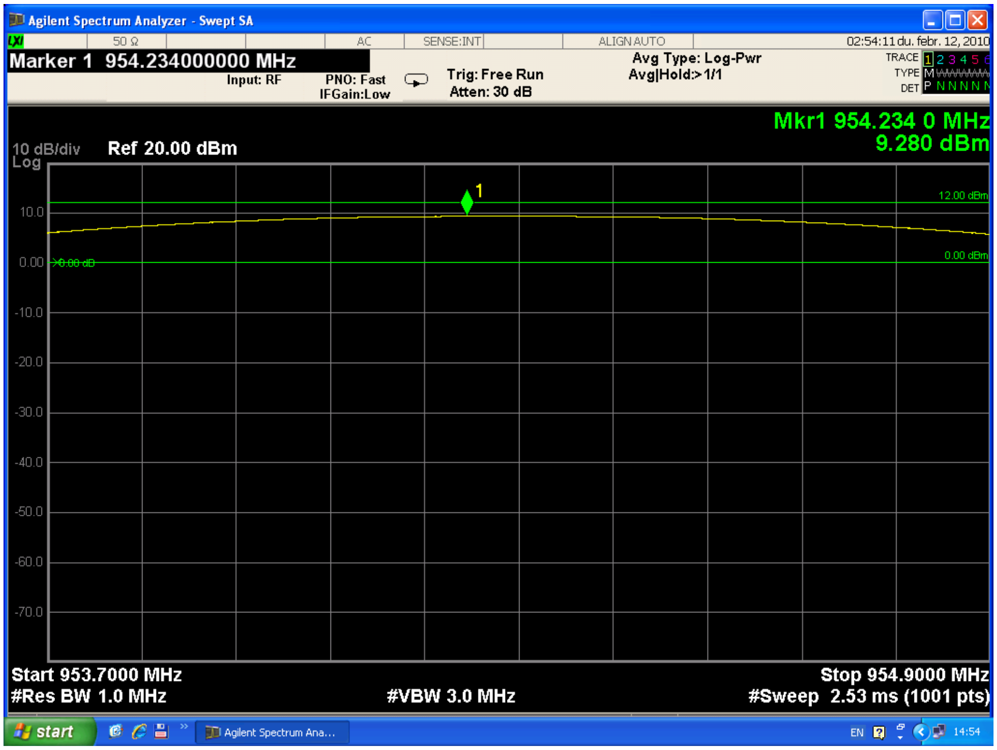

Figure 9. Transmitter Antenna Power (P = ~ +9.3 dBm at VDD=3.3 V)

3.4. ARIB STD-T96 3.2(8), Spurious Emissions

The allowed level of spurious emissions is specified in ARIB STD-T96 3.2(8), and provides for different maximum levels of spurious emissions in different frequency bands. Furthermore, the reference measurement bandwidth also varies from one frequency band to another. The allowed maximum levels of spurious emissions are shown in Table 2.

Table 2. ARIB STD-T96 Spurious Emission Specifications

Frequency Band	Spurious Emission Strength (average power)	Reference Bandwidth
f < 1000 MHz (except for 710 MHz < f ≤ 960 MHz)	–36 dBm	100 kHz
710 MHz < f ≤ 945 MHz	–55 dBm	1 MHz
945 MHz < f ≤ 950 MHz	–55 dBm	100 kHz
950 MHz < f ≤ 956 MHz (except for |f – fc| ≤ 200 + 100 x (n–1) kHz)	–39 dBm	100 kHz
956 MHz < f ≤ 958 MHz	–55 dBm	100 kHz
958 MHz < f ≤ 960 MHz	–58 dBm	100 kHz
1000 MHz < f (except for 1884.5 MHz < f ≤ 1919.6 MHz)	–30 dBm	1 MHz
1884.5 MHz < f ≤ 1919.6 MHz	–55 dBm	1 MHz

The Si4430-B1 chip complies with all of the spurious emission requirements in Table 2 with default register settings when using one single unit radio channel (n=1), except for the frequency range of 950 to 956 MHz (–39 dBm/ 100 kHz requirement). As will be shown here, full compliance may be obtained when using two unit radio channels (n=2) and with further optimization of the SPI register settings. Separate plots are provided for each frequency sub-band.

In the case of using one single unit radio channel (n=1), compliance has been verified at all four channels (Ch17, 18, 19, and 20) as specified in ARIB STD-T96 3.2(3)(b)(i). In the case of using two unit radio channels (n=2), compliance has been verified at all three channels (Ch17-18, 18-19, and 19-20) as specified in ARIB STD-T963.2(3)(b)(ii). In all cases, the plots provided within this section represent the worst-case performance observed among these channels.

3.4.1. Spurious Emissions 30–710 MHz

The allowed level of spurious emissions within the 30–710 MHz frequency band is specified as less than –36 dBm in any 100 kHz bandwidth. The channel center frequency selected for this measurement was Ch17 (954.2 MHz, n=1). The measured spurious emissions within this frequency band is shown in Figure 10. The Si4430-B1 chip easily complies with the specified level of spurious emissions within this sub-band.

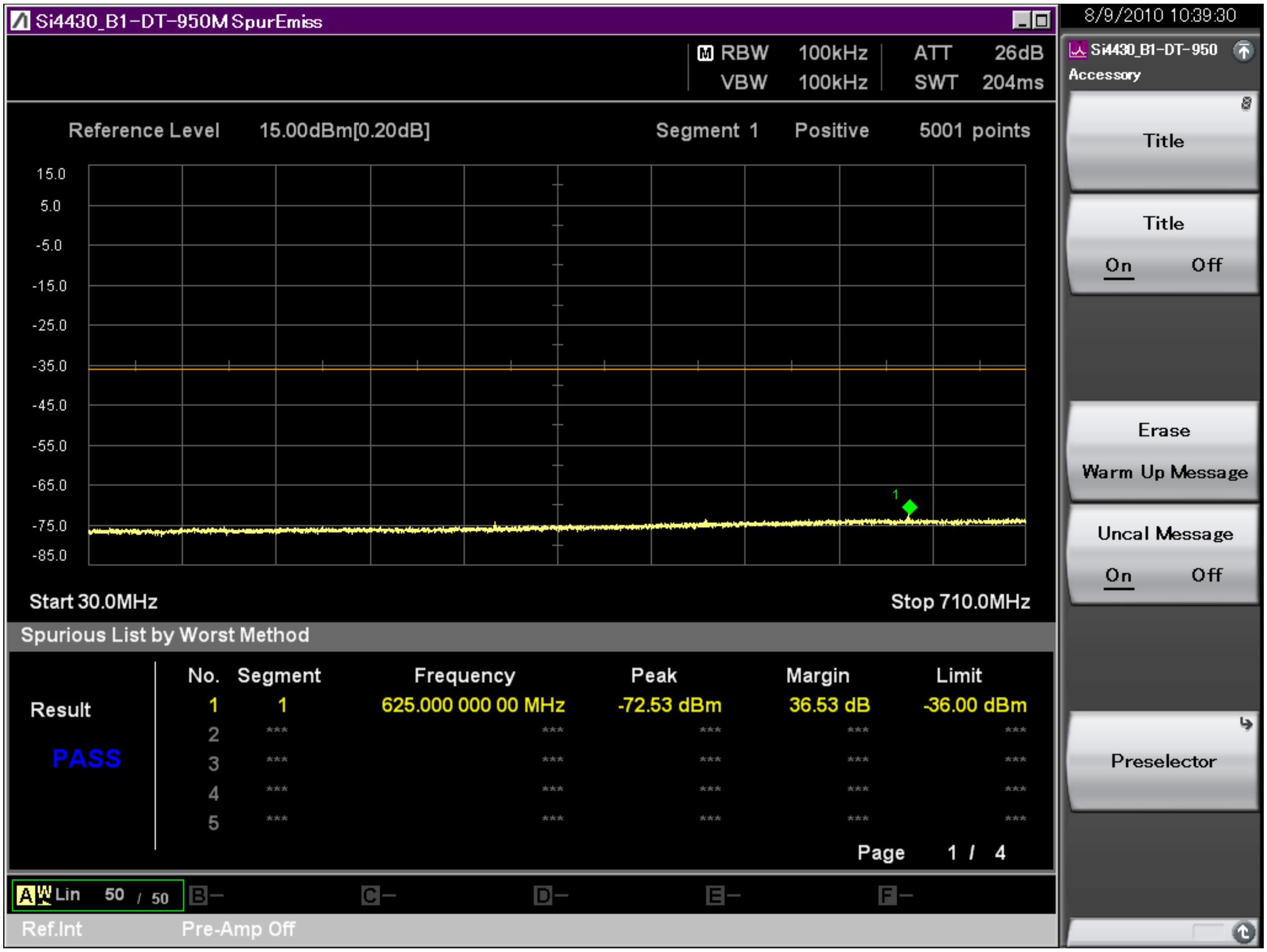

Figure 10. Spurious Emission (30–710 MHz)

3.4.2. Spurious Emissions 710–945 MHz

The allowed level of spurious emissions within the 710–945 MHz frequency band is specified as less than –55 dBm in any 1 MHz bandwidth. The channel center frequency selected for this measurement was Ch17 (954.2 MHz, n=1). The measured spurious emissions within this frequency band is shown in Figure 11. The Si4430-B1 chip complies with the specified level of spurious emissions within this sub-band.

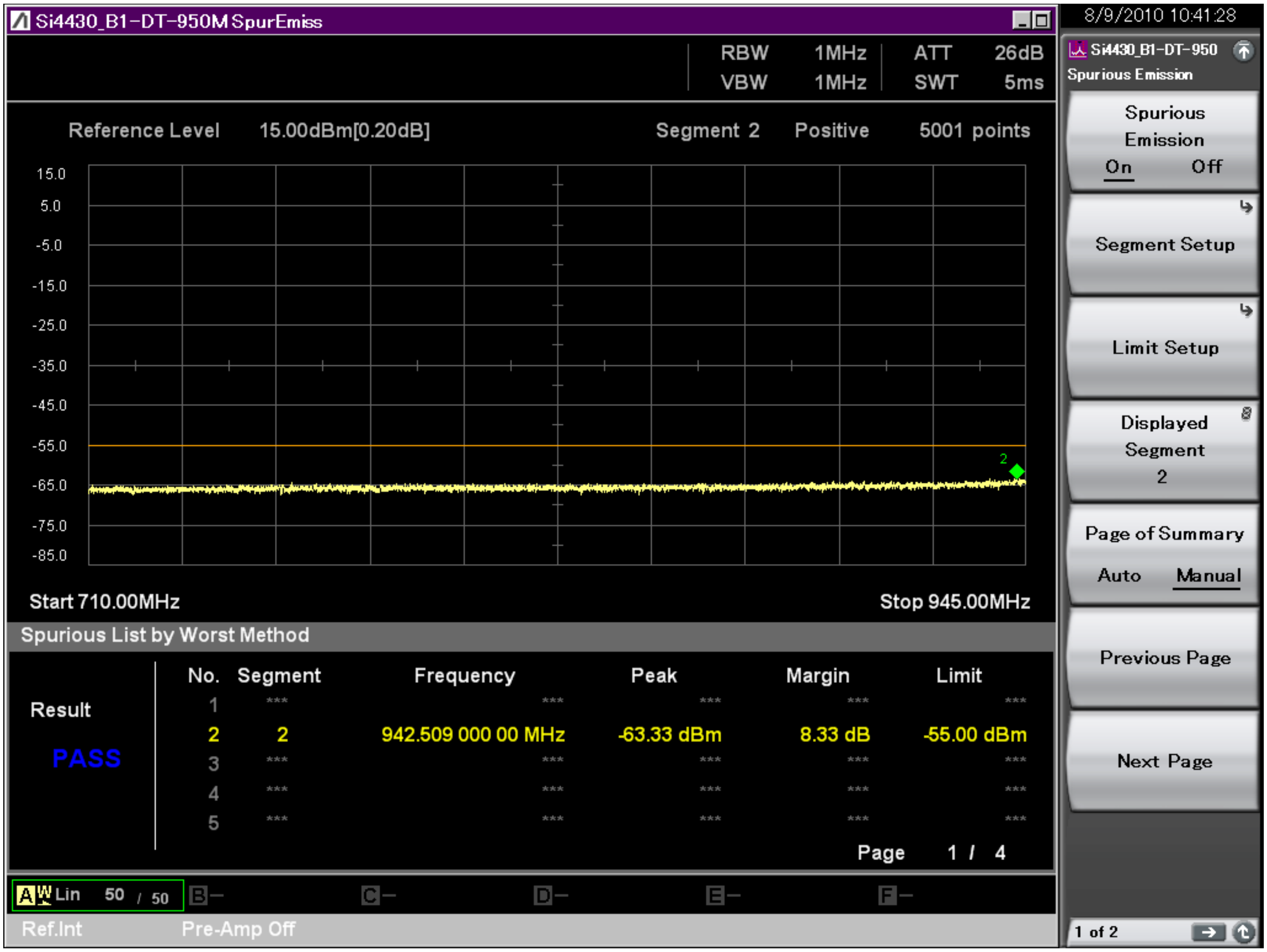

Figure 11. Spurious Emission (710–945 MHz)

3.4.3. Spurious Emissions 945–950 MHz

The allowed level of spurious emissions within the 945–950 MHz frequency band is specified as less than –55 dBm in any 100 kHz bandwidth. The channel center frequency selected for this measurement was Ch17 (954.2 MHz, n=1). The measured spurious emissions within this frequency band is shown in Figure 12. The Si4430-B1 chip complies with the specified level of spurious emissions within this sub-band.

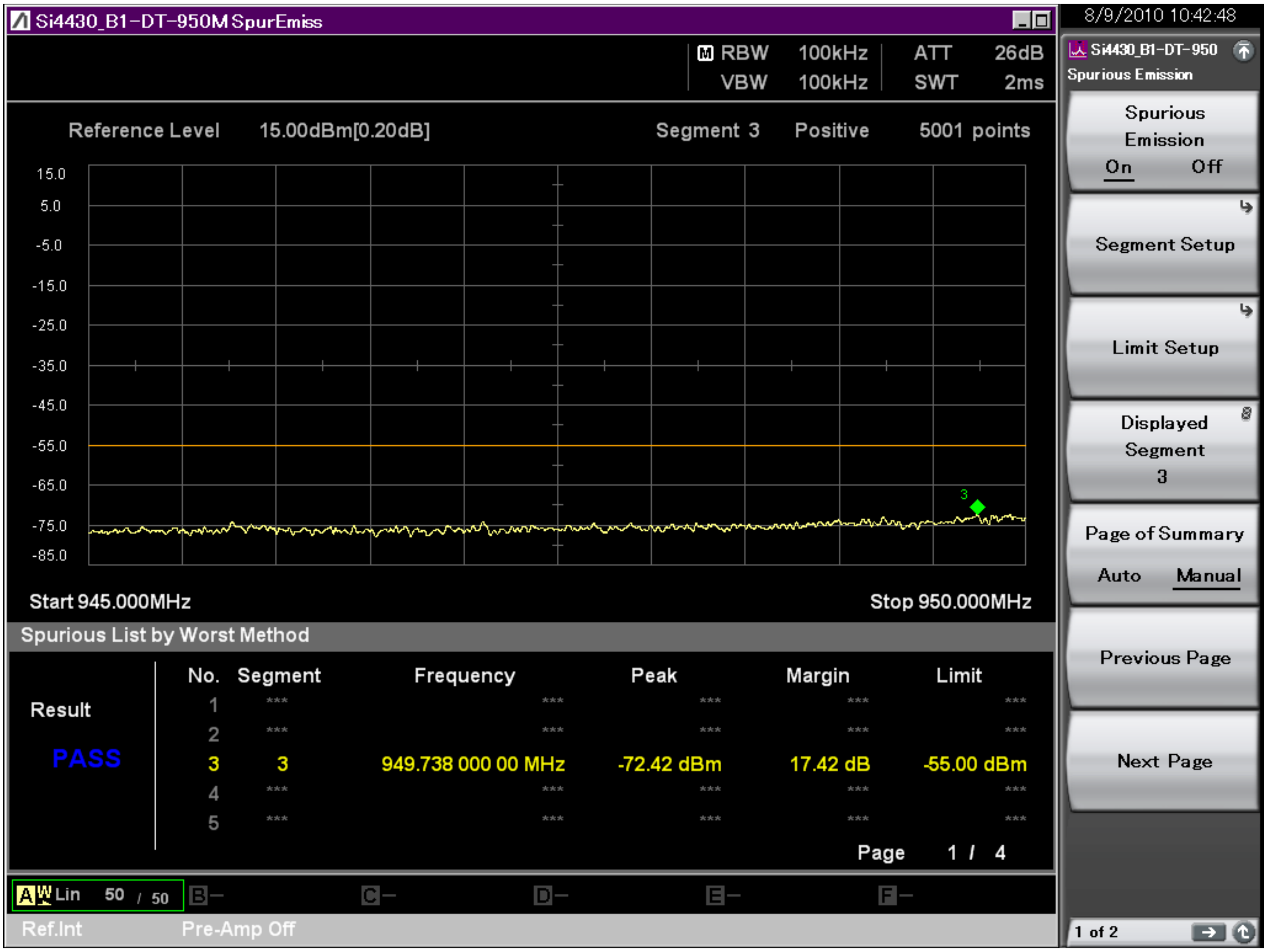

Figure 12. Spurious Emission (945-950 MHz)

3.4.4. Spurious Emissions 950–956 MHz

The allowed level of spurious emissions within the 950–956 MHz frequency band is specified as less than –39 dBm in any 100 kHz bandwidth. A frequency band centered around the desired channel is excluded from this measurement; the width of this excluded frequency band is equal to the number of unit radio channels in use (nx200 kHz), plus the upper and lower 200 kHz-wide adjacent channels. Although the allowed spurious level is specified in a 100 kHz reference bandwidth, it is not possible to use ResBW=100 kHz while taking this measurement due to the proximity to the modulation bandwidth of the desired signal. Accordingly, a ResBW = 3 kHz is used for the measurement (as called for in TELEC 245), and the measurement limit is adjusted downwards by 10*log(100 kHz/3 kHz) = 15.2 dB, resulting in a modified spec limit of –54.2 dBm/3 kHz bandwidth.

The worst-case channel center frequency selected for this measurement was Ch20 (954.8 MHz, n=1). The measured spurious emissions within this frequency band is shown in Figure 13 and Figure 14. The Si4430-B1 chip fails to comply with the specified level of spurious emissions within this sub-band, when using a single unit radio channel (n=1). The primary reason for non-compliance is due to a combination of the inherent modulation bandwidth of the 802.15.4d signal (as discussed previously in "3.2. ARIB STD-T96 3.2(7)(b)(ii), Adjacent Channel Leakage" on page 4) and the phase noise of the Si4430-B1 chip itself. Both performance parameters may be optimized by modification of the charge pump current and VCO bias current (SPI Registers 58h, 59h, and 5Ah). However, compliance may remain marginal to failing even with this register optimization. Thus Silicon Labs recommends use of two unit radio channels (n=2) in order to achieve compliance.

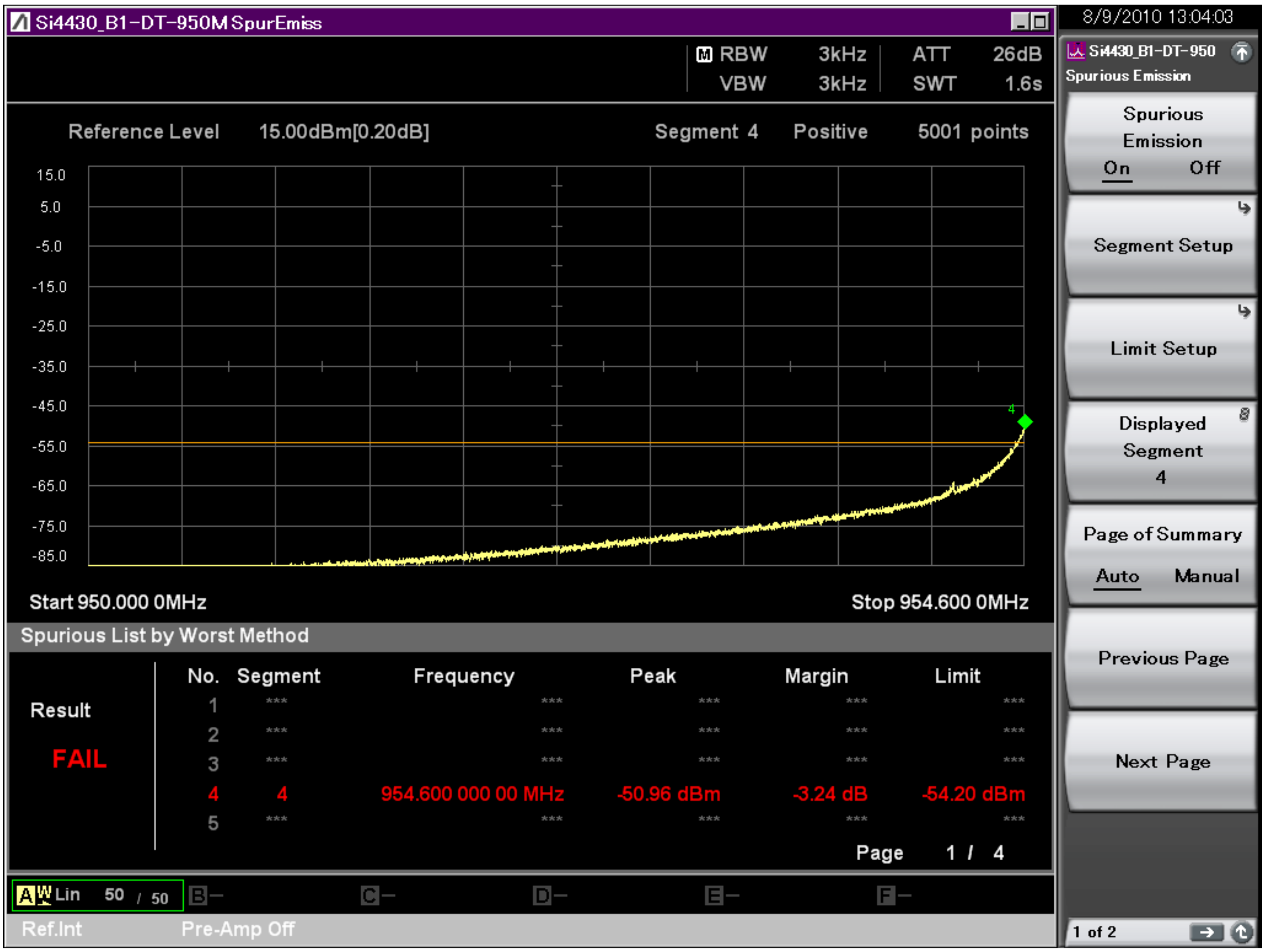

Figure 13. Spurious Emission (950–956 MHz, n=1, Low Side)

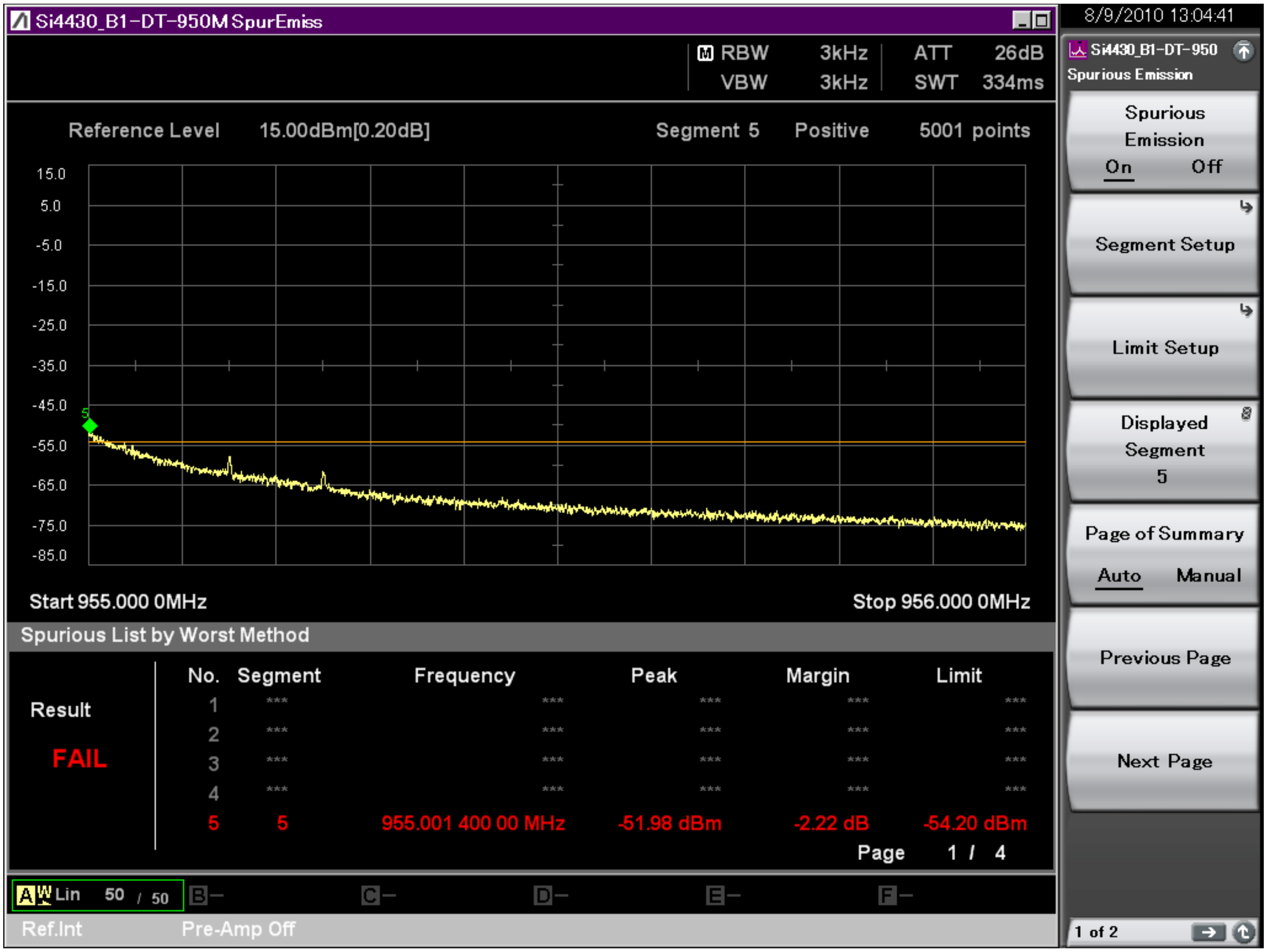

Figure 14. Spurious Emission (950–956 MHz, n=1, High Side)

The worst-case channel center frequency selected for measurement for the condition of two unit radio channels was Ch19-20 (954.7 MHz, n=2). The measured spurious emissions within this frequency band is shown in Figure 15 and Figure 16. The Si4430-B1 chip now complies with the specified level of spurious emissions within this sub-band, when using two unit radio channels (n=2). The following register modifications were made to further optimize performance, resulting in better phase noise and greater suppression of some internal spurious signals near 955.0 MHz.

- SPI Reg 58h = 40h (CPCURR = 2'b01)
- SPI Reg 59h = 80h (txcorrboosten = 1)
- SPI Reg 5Ah = 81h (txcurrboosten = 1, VCOCURR = default value of 2'b01)

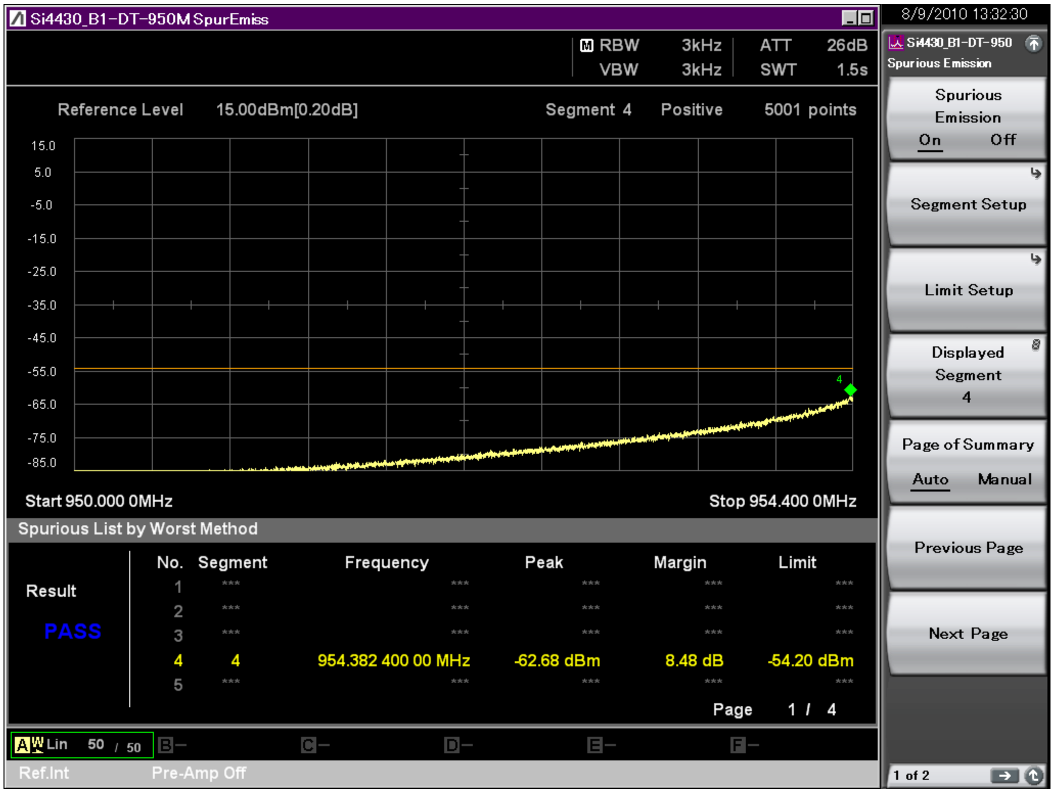

Figure 15. Spurious Emission (950–956 MHz, n=2, Low Side)

Figure 16. Spurious Emission (950–956 MHz, n=2, High Side)

3.4.5. Spurious Emissions 956–958 MHz

The allowed level of spurious emissions within the 956–958 MHz frequency band is specified as less than –55 dBm in any 100 kHz bandwidth. The worst-case channel center frequency selected for this measurement was Ch20 (954.8 MHz, n=1). The measured spurious emissions within this frequency band is shown in Figure 17. The Si4430-B1 chip complies with the specified level of spurious emissions within this sub-band.

Figure 17. Spurious Emission (956-958 MHz)

3.4.6. Spurious Emissions 958–960 MHz

The allowed level of spurious emissions within the 958–960 MHz frequency band is specified as less than –58 dBm in any 100 kHz bandwidth. The worst-case channel center frequency selected for this measurement was Ch20 (954.8 MHz, n=1). The measured spurious emissions within this frequency band is shown in Figure 18. The Si4430-B1 chip complies with the specified level of spurious emissions within this sub-band.

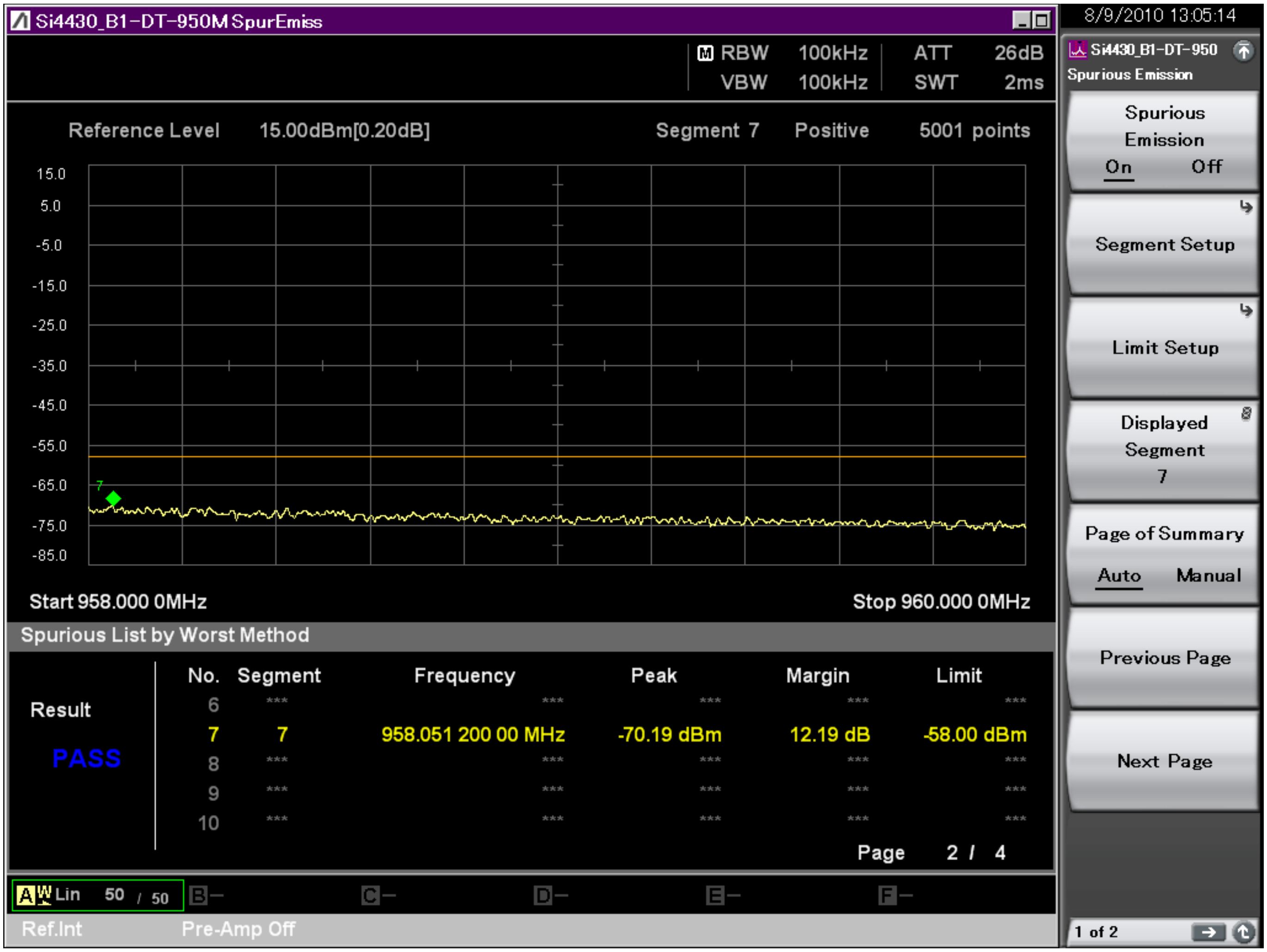

Figure 18. Spurious Emission (958–960 MHz)

3.4.7. Spurious Emissions 960–1000 MHz

The allowed level of spurious emissions within the 960–1000 MHz frequency band is specified as less than –36 dBm in any 100 kHz bandwidth. The worst-case channel center frequency selected for this measurement was Ch20 (954.8 MHz, n=1). The measured spurious emissions within this frequency band is shown in Figure 19. The Si4430-B1 chip complies with the specified level of spurious emissions within this sub-band.

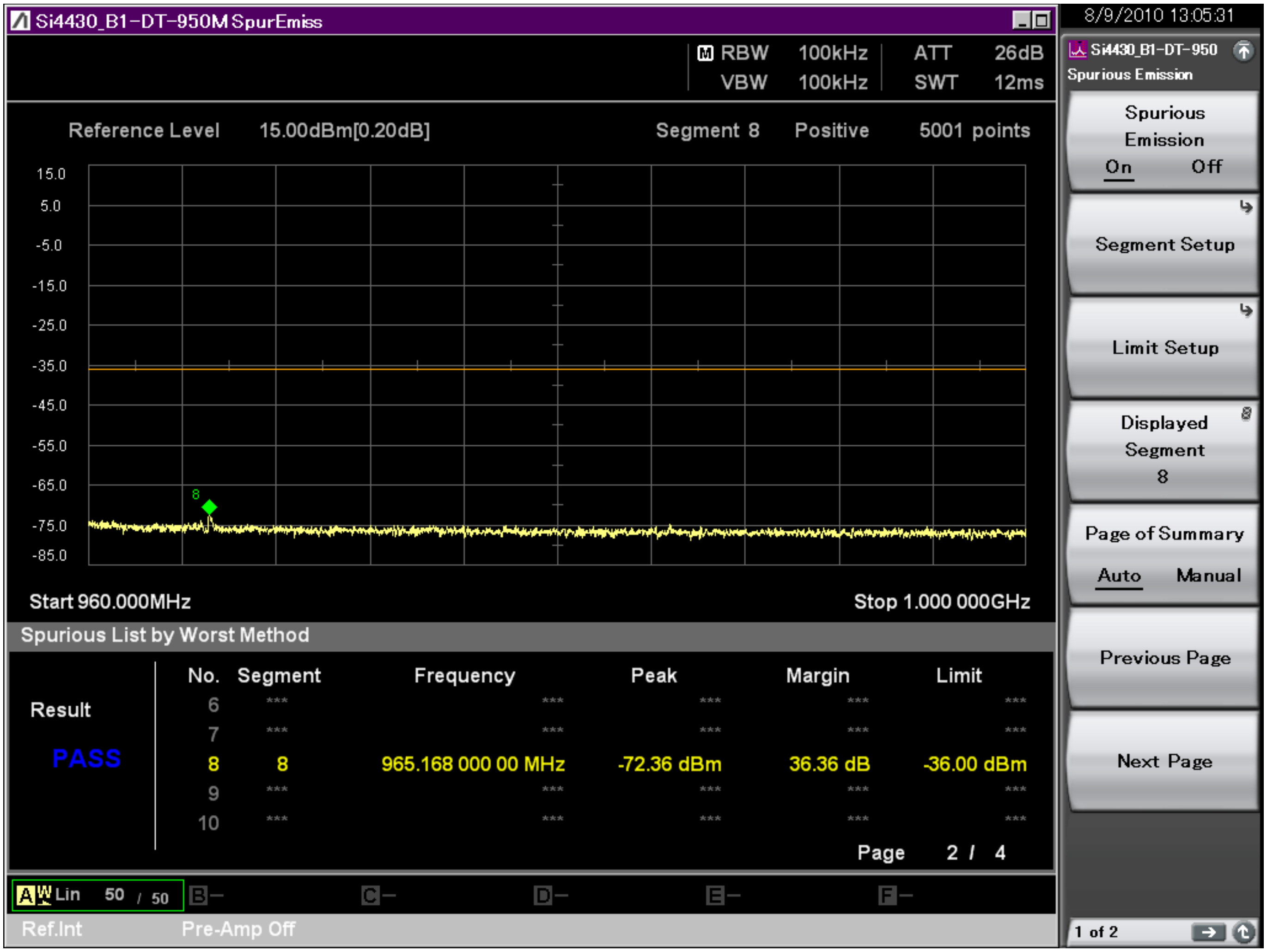

Figure 19. Spurious Emission (960–1000 MHz)

3.4.8. Spurious Emissions 1000–1884.5 MHz

The allowed level of spurious emissions within the 1000–1884.5 MHz frequency band is specified as less than –30 dBm in any 1 MHz bandwidth. The channel center frequency selected for this measurement was Ch20 (954.8 MHz, n=1). The measured spurious emissions within this frequency band is shown in Figure 20. The Si4430-B1 chip complies with the specified level of spurious emissions within this sub-band.

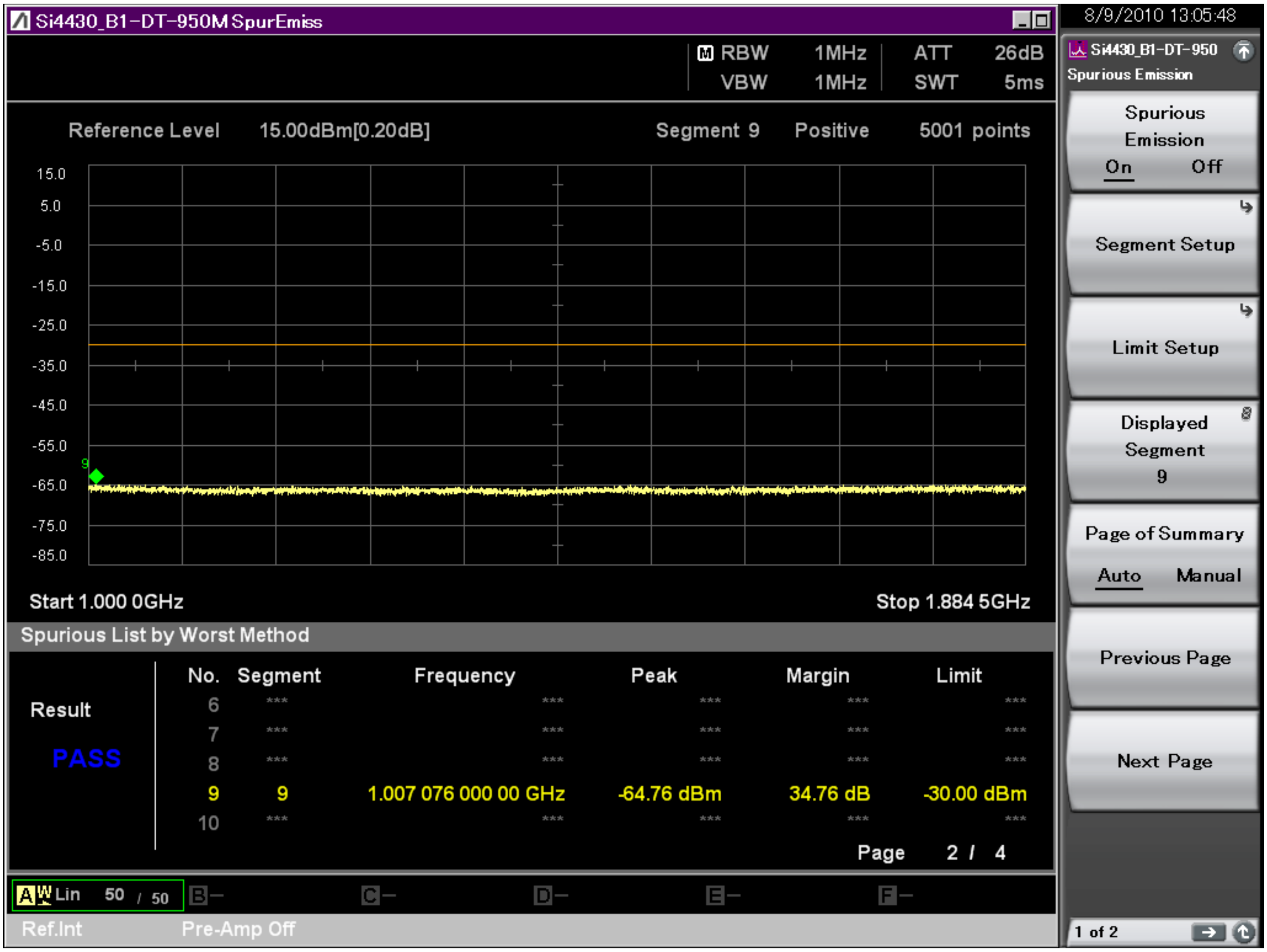

Figure 20. Spurious Emission (1000–1884.5 MHz)

3.4.9. Spurious Emissions 1884.5–1919.6 MHz

The allowed level of spurious emissions within the 1884.5–1919.6 MHz frequency band is specified as less than –55 dBm in any 1 MHz bandwidth. The channel center frequency selected for this measurement was Ch20 (954.8 MHz, n=1). The measured spurious emissions within this frequency band is shown in Figure 21. The Si4430-B1 chip complies with the specified level of spurious emissions within this sub-band.

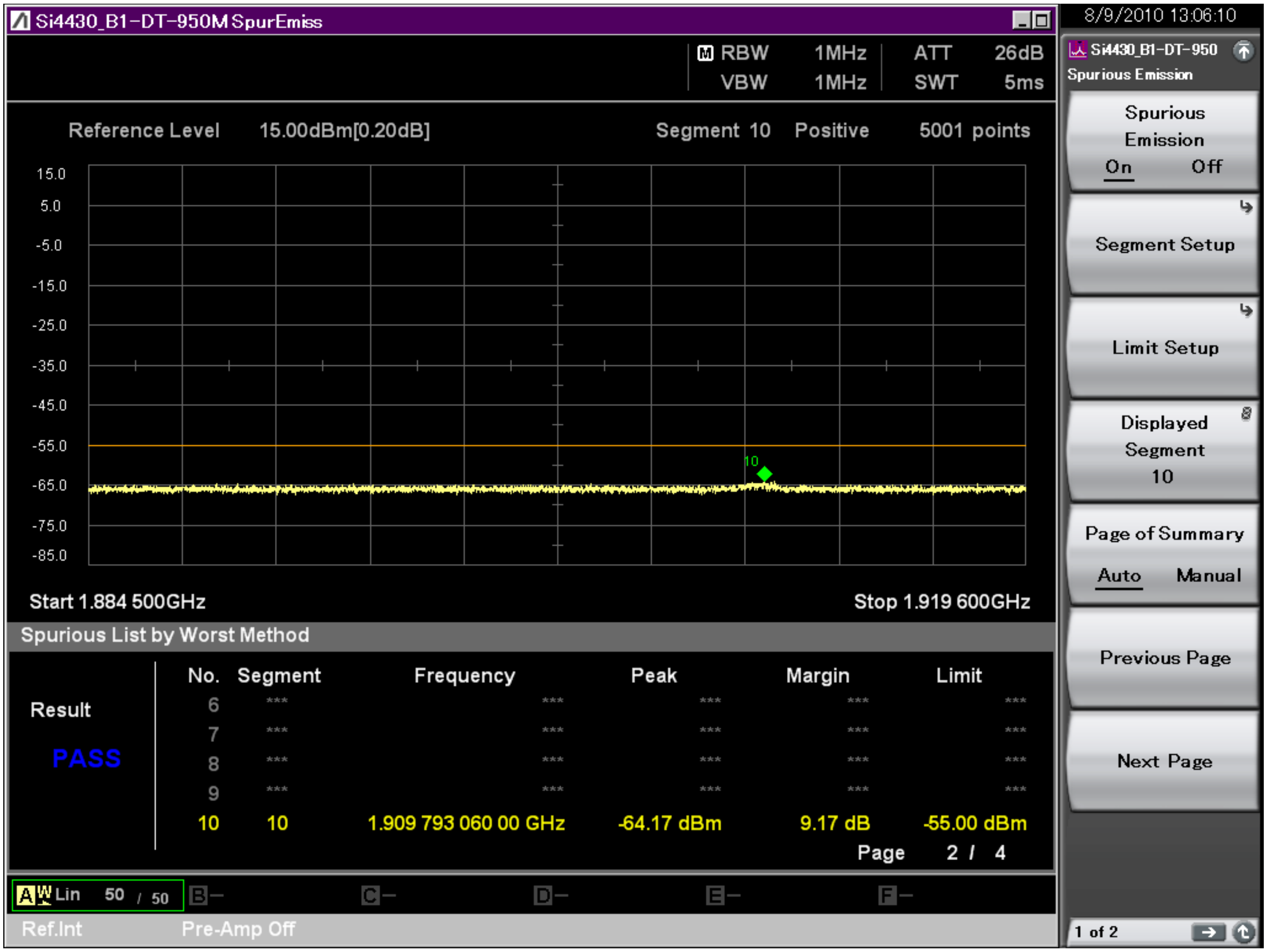

Figure 21. Spurious Emission (1884.5–1919.6 MHz)

3.4.10. Spurious Emissions 1919.6–3600 MHz

The allowed level of spurious emissions within the 1919.6–3600 MHz frequency band is specified as less than –30 dBm in any 1 MHz bandwidth. The measured spurious emissions within this frequency band is shown in Figure 22. The Si4430-B1 chip complies with the specified level of spurious emissions within this sub-band.

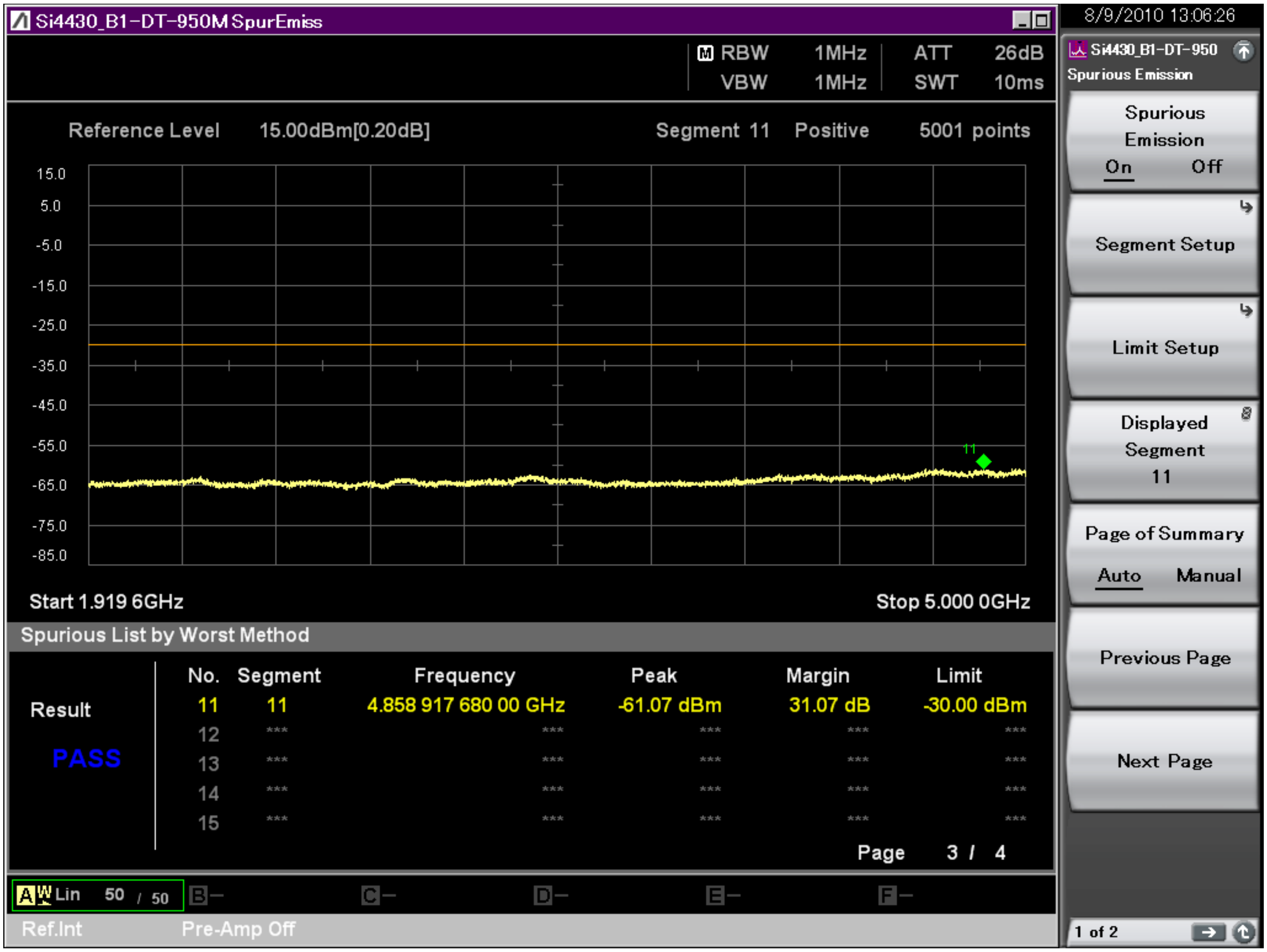

Figure 22. Spurious Emission (1919.6–3600 MHz)

3.5. ARIB STD-T96 3.2(8), Spurious Emissions in Extended Frequency Channels

The existing version of ARIB STD-T96 (version 1.0, dated June 6th 2008) defines 24 radio channels within the frequency range of 951.0 to 955.6 MHz. The transmit output power is limited to 1 mW (0 dBm) on all channels except Channels 17–20 (954.2 to 954.8 MHz), in which the output power limit is 10 mW (+10 dBm). However, there is currently a proposal to modify ARIB STD T96 to expand the allowed frequency range up to 957.4 MHz, thus adding Channels 25–33. Under this new proposal, output power of 10 mW (+10 dBm) would be allowed on all channels within the 954.2 to 957.4 MHz range (Channel 17–33).

The allowed level of spurious emissions within each frequency band would change under this new proposal. The proposed maximum levels of spurious emissions are shown in Table 3.

Table 3. ARIB STD-T96 Spurious Emission Specifications for Extended Channels

Frequency Band	Spurious Emission Strength (average power)	Reference Bandwidth
f < 710 MHz	–36 dBm	100 kHz
710 MHz < f ≤ 945 MHz	–55 dBm	1 MHz
945 MHz < f ≤ 950 MHz	–55 dBm	100 kHz
950 MHz < f ≤ 958 MHz (except for |f - fc| ≤ 200 + 100 x (n-1) kHz)	–39 dBm	100 kHz
958 MHz < f ≤ 1000 MHz	–58 dBm	100 kHz
1000 MHz < f ≤ 1215 MHz	–48 dBm	1 MHz
1215 MHz < f (except for 1884.5 MHz < f ≤ 1919.6 MHz)	–30 dBm	1 MHz
1884.5 MHz < f ≤ 1919.6 MHz	–55 dBm	1 MHz

The most important changes in this proposed table of spurious emissions are the extension of the –39 dBm/100 kHz specification limit up to 958.0 MHz (compared with an upper frequency limit of 956.0 MHz shown previously in Table 2 on page 11), and the spec limit of –58 dBm/100 kHz beginning immediately above this frequency segment. As operation is now allowed up to Channel 33 = 957.4 MHz, this imposes stringent limits upon the phase noise of the transmitter.

Due to limitations of phase noise, the Si4430-B1 chip only complies with the proposed spurious emission requirements in Table 3 when operated at or below Channels 29–30 (956.7 MHz); the spurious emission limits may be exceeded when operated in channels above this frequency. Additionally, it is necessary to use two unit radio channels (n=2) for the same reasons as discussed within "3.4. ARIB STD-T96 3.2(8), Spurious Emissions" on page 11. Optimization of SPI register settings is again required, as previously discussed within "3.4.4. Spurious Emissions 950–956 MHz" on page 15.

The Si4430-B1 chip easily complies with all other provisions of ARIB STD-T96 (e.g., adjacent channel power, occupied bandwidth, and antenna transmit power) within these extended frequency channels, and thus the measurements for these parameters are not duplicated in this section. Plots demonstrating compliance with the spurious emission requirements of Table 3 are provided only for the most difficult frequency sub-bands. Furthermore, plots are provided only for the highest channel pair (n=2, Channels 29-30) in which the Si4430-B1 chip achieves compliance; compliance at higher frequencies is not assured when operating at the maximum allowed output power.

3.5.1. Spurious Emissions 950–958 MHz

The allowed level of spurious emissions within the 950–958 MHz frequency band is specified as less than –39 dBm in any 100 kHz bandwidth. A frequency band centered around the desired channel is excluded from this measurement; the width of this excluded frequency band is equal to the number of unit radio channels in use (nx200 kHz), plus the upper and lower 200 kHz-wide adjacent channels. Although the allowed spurious level is specified in a 100 kHz reference bandwidth, it is not possible to use ResBW=100 kHz while taking this measurement due to the proximity to the modulation bandwidth of the desired signal. Accordingly, a ResBW=3 kHz is used for the measurement (as called for in TELEC 245), and the measurement limit is adjusted downwards by 10*log(100kHz/3kHz) = 15.2 dB, resulting in a modified spec limit of –54.2 dBm/3 kHz bandwidth.

The worst-case channel center frequency selected for measurement for the condition of two unit radio channels was Ch29–30 (956.7 MHz, n=2). The measured spurious emissions within this frequency band is shown in Figure 23 and Figure 24. The Si4430-B1 chip complies with the specified level of spurious emissions within this sub-band, when using two unit radio channels (n=2). The following register modifications were made to further optimize performance, resulting in better phase noise and greater suppression of some internal spurious signals near 955.0 MHz.

- SPI Reg 58h = 40h (CPCURR = 2'b01)
- SPI Reg 59h = 80h (txcorrboosten = 1)
- SPI Reg 5Ah = 81h (txcurrboosten = 1, VCOCURR = default value of 2'b01)

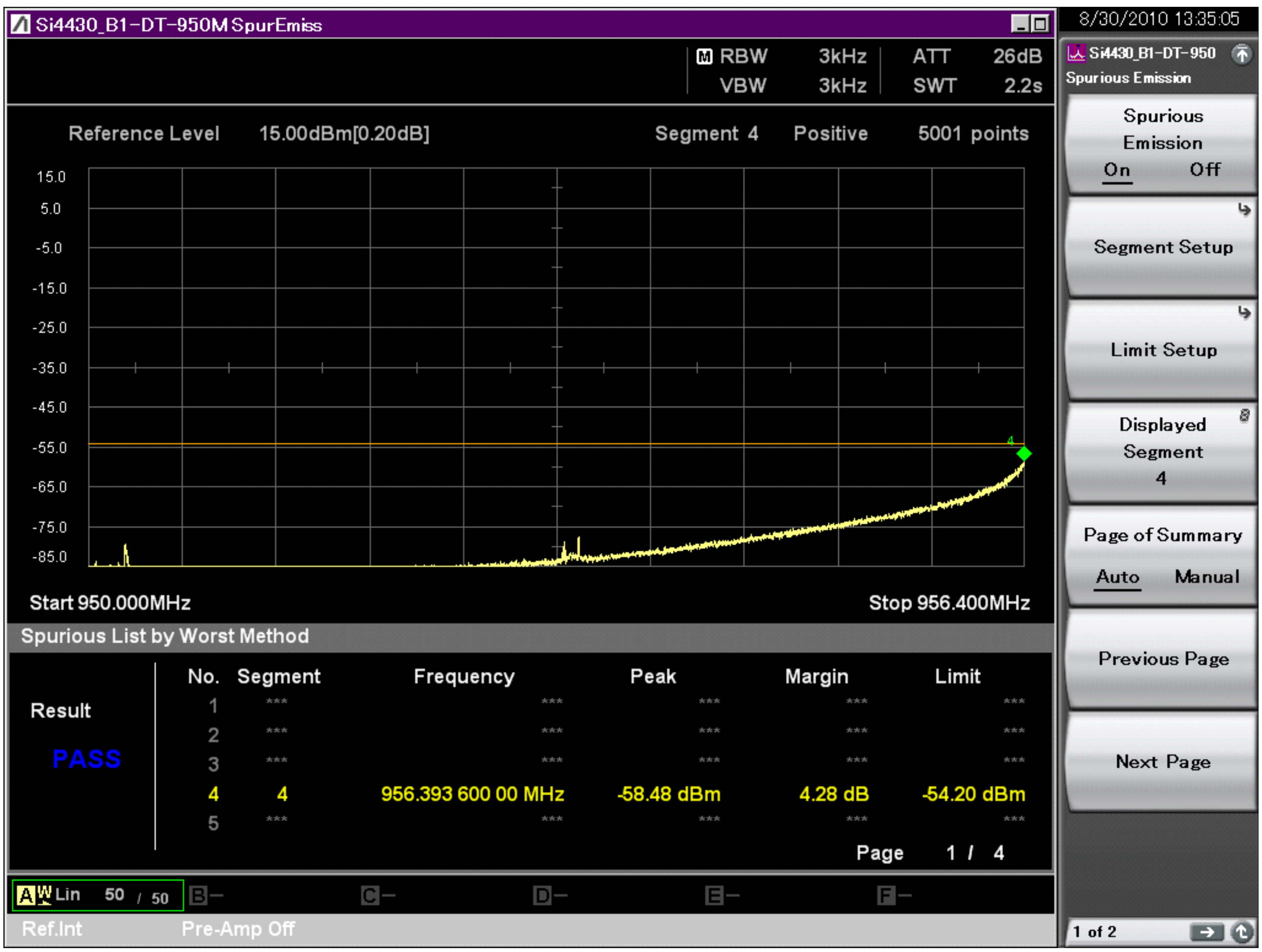

Figure 23. Spurious Emission (950–958 MHz, n=2, Low Side)

Figure 24. Spurious Emission (950–958 MHz, n=2, High Side)

3.5.2. Spurious Emissions 958–1000 MHz

The allowed level of spurious emissions within the 958–1000 MHz frequency band is specified as less than –58 dBm in any 100 kHz bandwidth. The worst-case channel center frequency selected for this measurement was Ch29-30 (956.7 MHz, n=2). The measured spurious emissions within this frequency band is shown in Figure 25. The Si4430-B1 chip complies with the specified level of spurious emissions within this sub-band. Compliance with the spurious emission requirements of Table 3 is most difficult within this frequency sub-band, due to the integrated phase noise power at the lower edge of this frequency band.

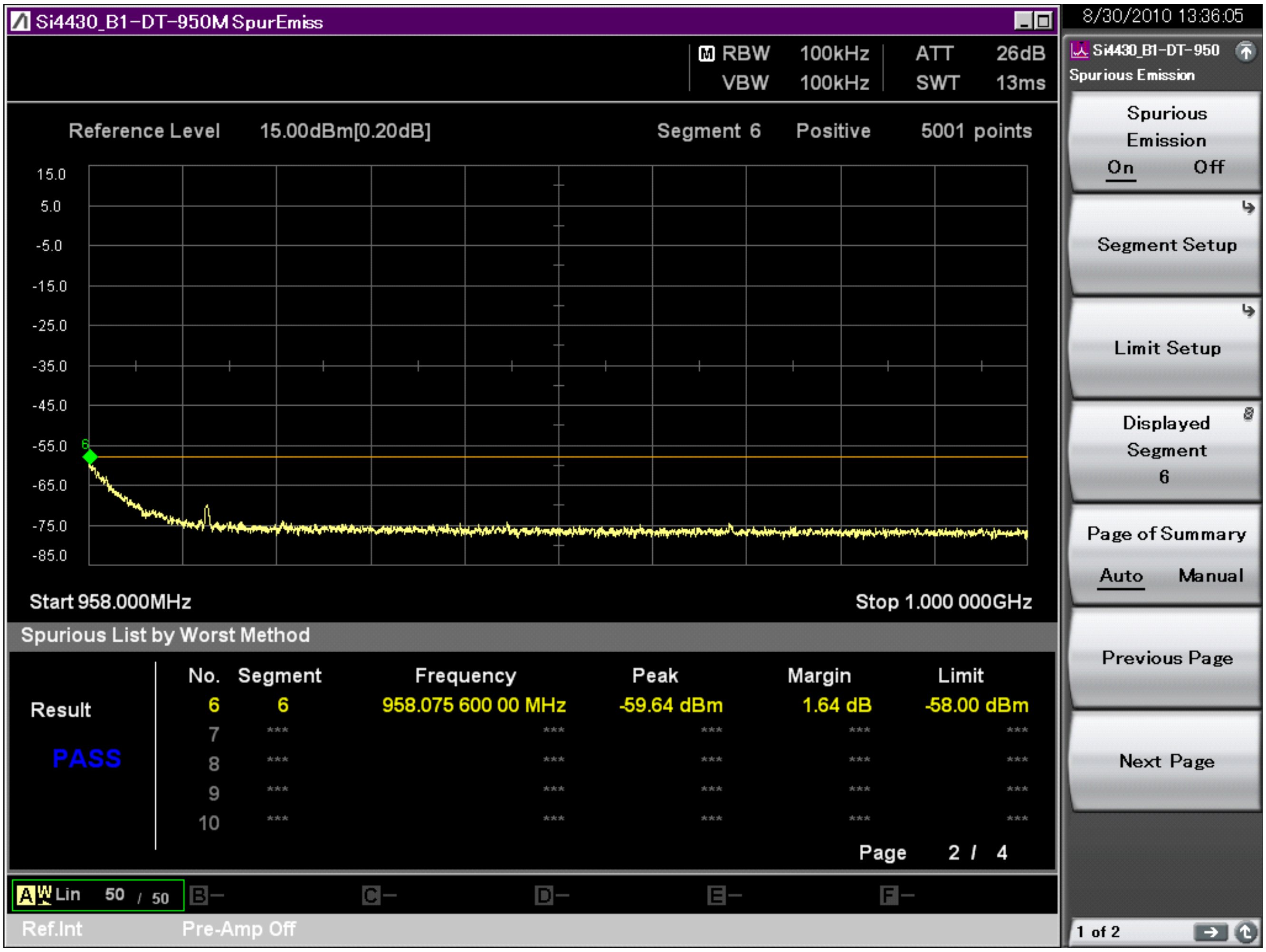

Figure 25. Spurious Emission (958–1000 MHz)

3.6. TX Output Power and Current Consumption vs. Power Setting

The TX output power of the Si4430-B1 chip may be adjusted by programming the TXPOW field in SPI Register 6Dh. Additionally, the output power is dependent upon the supply voltage. Table 4 summarizes the typical conducted TX output power and current consumption for various power settings, as well as for supply voltages of VDD = 1.8, 3.3, and 3.6 V. Additionally, the conducted level of harmonics are shown for the 2nd and 3rd harmonics. Note that with the Direct Tie board configuration and output match recommended for the 950 MHz ARIB band, there is very little difference in output power between power state 0Eh and 0Fh. However, there is an advantage in current consumption by operating in power state 0Eh, and is thus the power state recommended by Silicon Labs.

Table 4. TX Output Power and Current Consumption vs. Power Setting

Power Setting Register 6Dh	TX Output Fund Power (dBm) 3.6 V	TX 2nd Harm Power (dBm) 3.6 V	TX 3rd Harm Power (dBm) 3.6 V	Total Current Consumption (mA) 3.6 V	TX Output Fund Power (dBm) 3.3 V	TX 2nd Harm Power (dBm) 3.3 V	TX 3rd Harm Power (dBm) 3.3 V	Total Current Consumption (mA) 3.3 V	TX Output Fund Power (dBm) 1.8 V	TX 2nd Harm Power (dBm) 1.8 V	TX 3rd Harm Power (dBm) 1.8 V	Total Current Consumption (mA) 1.8 V
08	–4.7	–67.2	–67.2	14.3	–4.6	–65.3	–66.0	14.2	–7.6	–65.4	–67.2	12.7
09	–2.7	–66.5	–67.0	14.8	–2.7	–65.9	–67.3	14.7	–5.7	–65.5	–66.8	13.0
0A	2.1	–65.4	–65.9	17.0	2.2	–65.7	–67.0	16.9	–1.2	–65.2	–67.2	14.6
0B	5.1	–64.7	–66.5	19.2	5.1	–65.5	–67.7	19.1	0.7	–65.6	–65.9	15.6
0C	7.1	–65.7	–67.4	21.3	6.9	–65.5	–67.1	21.1	1.9	–66.4	–66.6	17.0
0D	8.9	–65.4	–67.0	24.0	8.3	–65.5	–66.6	23.3	2.6	–66.1	–66.8	18.3
0E	9.5	–66.1	–66.3	25.9	9.0	–66.1	–67.2	25.0	3.0	–66.4	–67.2	18.9
0F	9.6	–66.4	–66.1	28.2	9.1	–66.6	–67.1	27.4	2.9	–65.9	–67.1	20.1

4. TX Radiated Emission Results

The radiated performance with a quarter wavelength monopole antenna is demonstrated in Table 5. The radiation up to the 10th harmonic is measured in all possible physical orientations, and is measured in both the horizontal and vertical planes of polarization. Table 5 shows the maximum radiated power in EIRP (Equivalent Isotropically Radiated Power) of all orientations at each harmonic frequency. The third row shows the ARIB harmonic limits, as detailed in ARIB STD-T96 3.2(8).

Table 5. Radiated Harmonic Emissions

Radiated power maximum in EIRP (dBm) at 3.6V, power state 0Eh									
Fund.	**2nd**	**3rd**	**4th**	**5th**	**6th**	**7th**	**8th**	**9th**	**10th**
9.3	–56.8	–49.2	–51.3	–53.1	–46.7	–47.6	–47.8	–47.5	–47.0
Limit: 10	–55	–30	–30	–30	–30	–30	–30	–30	–30

5. RX Measurements

The RX sensitivity was measured with both packet error rate (PER) and bit error rate (BER); a summary of the measured results is shown in Table 6. The BER was tested at data rates of 2.4, 50, 100 and 200 kbps, with modulation index of H=1 (1.2, 25, 50 and 100 kHz deviation). The reference BER was 0.1% (1E-3). The PER was tested with the same conditions of data rate and deviation, with a reference PER of 1%. The RX channel select filter bandwidth was adjusted to the optimum bandwidth given by the EZRadioPRO Excel Register Calculator, assuming zero crystal oscillator frequency error. The selected RX channel bandwidths are shown in the second row of Table 6. AFC was not utilized in these measurements.

Table 6. Receive BER

BER (dBm), H=1, 3 V, 0.1%				
Bit Rate, RX BW	2.4 kb–ps, 4.9 kHz	50 kbps, 112.1 kHz	100 kbps, 208.4 kHz	200 kbps, 420.2 kHz
Performance	–116.3 dBm	–104.2 dBm	–101.5 dBm	–98.5 dBm

PER Test Packet Structure

4 bytes preamble (55555555h)

1 byte inverted preamble (AAh)

2 bytes sync (2DD4h)

1 byte length (14h)

20 bytes payload

(0123456789ABCDEF0123456789ABCDEF01234567)

2 bytes CRC (91CEh)

30 byte total

The measured PER curves are demonstrated in Figure 26. With optimal filter performance 1% PER is achieved at –101.5 dBm for 100 kbps.

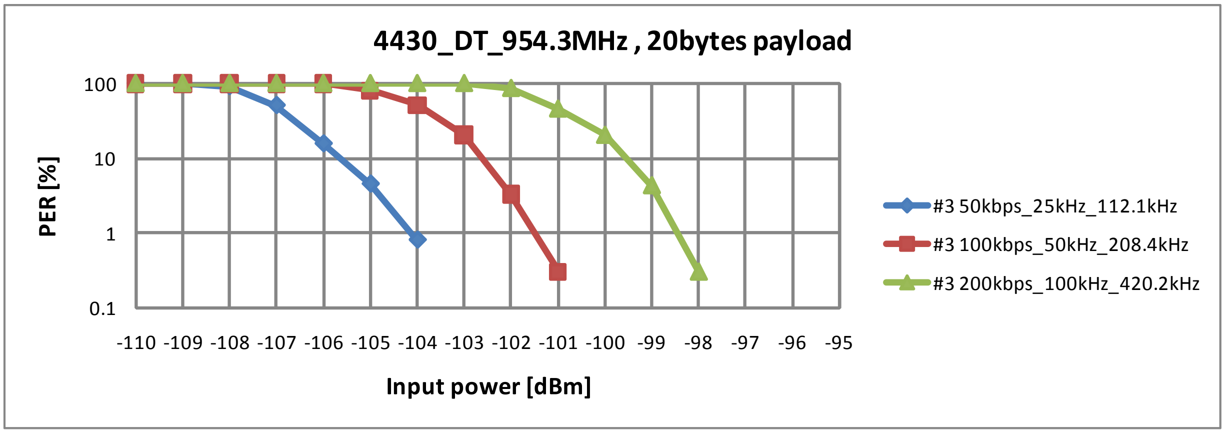

Figure 26. Packet Error Rate Curves

6. Reference Material

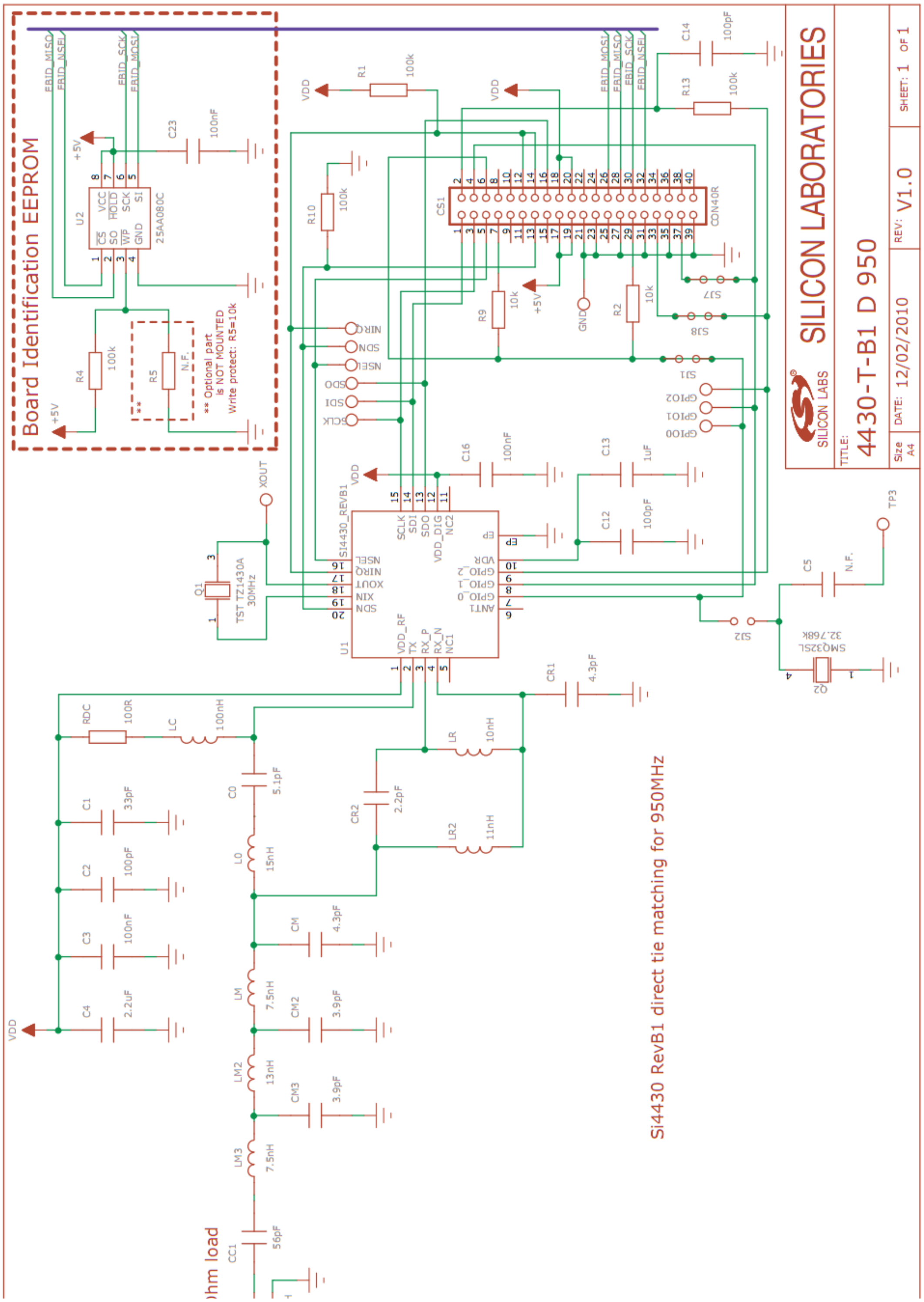

Figure 27. Reference Design Schematic

7. Script files

All measurements were performed using the following script file. Where indicated some lines are used in RX or TX mode only.

```
# SW reset

S2 8780

#Crystal load cap (board specific)

S2 896B

#Set Charge Pump Current (i.e., Loop BW), needed in TX mode

S2 D840

#Boost VCO Bias Current in TX Mode

S2 D980

S2 DA81

#Center frequency: 954.3MHz

S2 F577

S2 F6B2

S2 F7C0

# Set GPIO0=GND

S2 8B1F

# Set GPIO1= RX data, need only in RX mode

S2 8C14

# Set GPIO2=GND

S2 8D1F

#TX deviation: 50KHz, only in TX mode if modulation is on

S2 F250

s2 F100

# TX data rate: 100kbps, only in TX mode if modulation is on
```

```
S2 EE19

S2 EF9A

S2 F00C

# PN9 GFSK, modulation switch only in TX mode

S2 F133

# TX On, only in TX mode

S2 8708

# TX power state 0E, only in TX mode

S2 ED1E

#RX modem settings, Only in RX mode, 2.4kbps, dev=1.2kHz

S2 9C55

S2 A034

S2 A102

S2 A275

S2 A325

S2 A407

S2 A5FF

S2 AA48

# RX On, only in RX mode

S2 8704
```

DOCUMENT CHANGE LIST

Revision 0.3 to Revision 0.4

- Added "3.5. ARIB STD-T96 3.2(8), Spurious Emissions in Extended Frequency Channels" on page 24 to provide measured results for spurious emissions in extended frequency channels.

NOTES:

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