Si446x and FCC Part 90 Compliance at 450–470 MHz

1. Introduction

This application note demonstrates the compliance of Si446x RFICs with the regulatory requirements of FCC Part 90 in the 450-470 MHz band. As will be shown, best compliance is obtained when the RFIC is configured for a transmit power level of approximately +10 dBm. Any of the chips within the Si446x family (e.g., Si4460, Si4461, Si4463, Si4464, Si4467, or Si4468) can provide this level of transmit power and could be used to demonstrate compliance; the measurements presented within this document were taken with a Si4463-B1 RFIC mounted on a 4463-PCE20C460-EK RFSW Pico RF Test Card (see "5. Reference Design Schematic" on page 34).

The Si446x chip was configured to transmit at the desired power level(s) by appropriate settings of the PA_PWR_LVL property. Various data rates and deviations were chosen in order to comply with the permissible channel spacings and occupied bandwidths. The tests were performed at room temperature with a supply voltage of V_{DD}=3.3 V.

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:

- The Spectral Emissions Mask D requirements cannot be met on a limited number of mathematically predictable channels, due to spurious sidebands related to harmonics of the crystal oscillator. Compliance with Masks C, D, and E can be achieved on all other channels.
- The Adjacent Channel Power requirements for equipment with 25 kHz channel bandwidth can be met with the chip default PLL loop bandwidth of 200 kHz, but cannot be met for reduced values of PLL loop bandwidth (e.g., 50 kHz, such as may be desirable for improved Spectral Emissions Mask performance).

Table 1. Summary of Measured Results

Spec Par	Parameter	Condition	Limit	Measured	Margin
90.205(h)	Power and Antenna Height Limits		+33 dBm	+10.43 dBm	22.57 dB
90.207	Types of Emissions	2GFSK or 4GFSK	F1D		Comply
90.209(b)(5)	Bandwidth Limitations	2GFSK DR=2.4K Dev=2.0K	6 / 11.25 / 20kHz	5.27 kHz	0.73 kHz
		2GFSK DR=3.6K Dev=3.0K	6 / 11.25 / 20kHz	7.76 kHz	3.49 kHz
		2GFSK DR=4.8K Dev=4.0K	6 / 11.25 / 20kHz	10.29 kHz	0.96 kHz
90.210	Emission Masks	Mask C	(see mask)	(see plots)	Comply
		Mask D	(see mask)	(see plots)	Fails on few channels, complies elsewhere
		Mask E	(see mask)	(see plots)	Comply

Table 1. Summary of Measured Results (Continued)

90.213	Frequency Stability	6.25 kHz Chan BW	±1.0 ppm	N/A	N/A
		12.5 kHz Chan BW	±2.5 ppm	N/A	N/A
		25 kHz Chan BW	±5.0 ppm	N/A	N/A
90.214	Transient Frequency Behavior	6.25 kHz Chan BW	±6.25kHz ±3.125kHz ±6.25kHz	Negligible	Comply
90.217	Exemptions from Technical Standards	F < 800 MHz, P < 120 mW		N/A	N/A
90.221	Adjacent Channel Power	Fofst = 25 kHz	-55 dBc (or -36 dBm)	-63.83 dBc	8.83 dB
		Fofst = 50 kHz	-70 dBc (or -36 dBm)	–36.77 dBm	0.77 dB
		Fofst = 75 kHz	-70 dBc (or -36 dBm)	–38.45 dBm	2.45 dB
90.203 (j)(5)	Spectrum Efficiency	4GFSK SR=2.4K DR=4.8K Dev=0.4K	4.8 kbps/6.25 kHz	(see plots)	Comply

2. Summary of FCC Part 90 Requirements in the 450–470 MHz Band

The main requirements of FCC Part 90 in the 450-470 MHz band are summarized in this section. Many sub-paragraphs of FCC Part 90 are applicable to wider frequency ranges which include the desired 450-470 MHz band; these instances are noted below.

FCC Part 90 is only concerned with performance of the transmitter, and contains no requirements on receiver performance.

2.1. FCC Part 90.205(h) Power and Antenna Height Limits

The maximum allowable station effective radiated power (ERP) is dependent upon the station's antenna height above average terrain (HAAT) and required service area (in kilometers). The standard provides a table which lists the allowed transmit power for several combinations of antenna HAAT and required service area. The lowest power entry in this table is 2 watts maximum ERP for a service area of 3 kilometers and an antenna HAAT of 15 meters. This operational scenario is most applicable to the applications served by the Si446x family of chips and is the power level considered within this application note.

2.2. FCC Part 90.207 Types of Emissions

Modulation type F1D, including 2(G)FSK and 4(G)FSK, is permitted. Most measurements performed within this document were taken with 2GFSK modulation; however, 4GFSK modulation was selected to demonstrate compliance with the Spectrum Efficiency requirements of 90.203 (j)(5). Some measurements were also taken in CW mode for the purpose of demonstrating the effect of the selected modulation protocol upon the measured performance.

2.3. FCC Part 90.209(b) (5) Bandwidth Limitations

The standard provides a table which specifies the channel spacing and bandwidths for each frequency band. Within the 406-512 MHz band, the required channel spacing is 6.25 kHz and the permissible authorized bandwidths are 6 kHz, 11.25 kHz, or 20 kHz. The standard provides for authorizing these bandwidths for older equipment that was designed to operate with 6.25 kHz, 12.5 kHz, or 25 kHz bandwidths.

2.4. FCC Part 90.210 Emission Masks

The standard provides a table which specifies the required spectral emissions mask, depending upon the frequency band of operation and the channel bandwidth. Each emission mask is assigned an alphabetic letter designation (e.g., Mask A, Mask B, etc.) The spectral emission masks that apply to operation within the 421-512 MHz band are Masks C, D, and E. The descriptions of these spectral emission masks are summarized as follows.

2.4.1. Emission Mask C

Equipment designed to operate with a 25 kHz channel bandwidth must meet the requirements of Emission Mask C. The power of any emission must be attenuated below the unmodulated carrier output power (P, in watts) as follows:

- On any frequency removed from the center of the authorized bandwidth by a displacement frequency (f_d in kHz) of more than 5 kHz, but not more than 10 kHz: At least 83 log (f_d / 5) dB.
- On any frequency removed from the center of the authorized bandwidth by a displacement frequency (f_d in kHz) of more than 10 kHz, but not more than 250 percent of the authorized bandwidth: At least 29 log (f_d^2 / 11) dB or 50 dB, whichever is the lesser attenuation.
- On any frequency removed from the center of the authorized bandwidth by more than 250 percent of the authorized bandwidth: At least 43 + 10 log (P) dB, where P is the power in watts.

This spectral emission mask is shown in graphical form in the plot of Figure 1, assuming a transmitter with an output power of P = 1 watt.

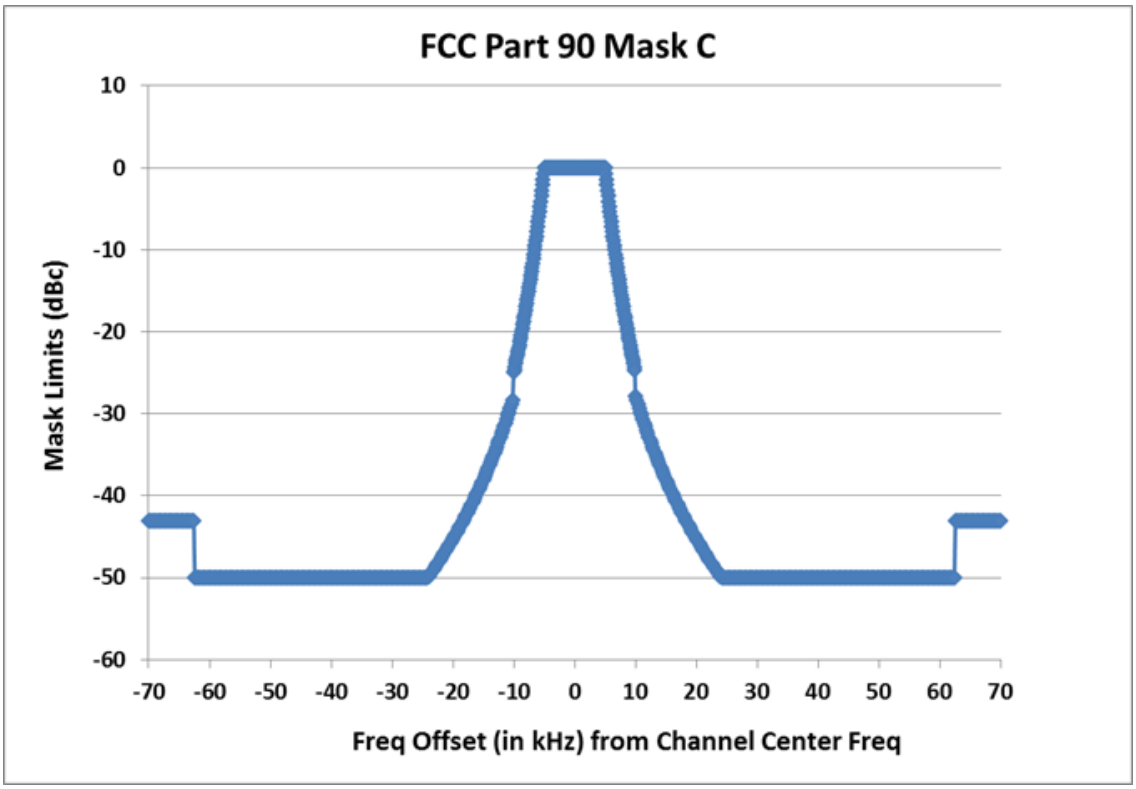


Figure 1. Emission Mask C (Pout=1W)

2.4.2. Emission Mask D

Equipment designed to operate with a 12.5 kHz channel bandwidth must meet the requirements of Emission Mask D. Any emission must be attenuated below the power (P, in watts) of the highest emission contained within the authorized bandwidth as follows:

- On any frequency from the center of the authorized bandwidth f_0 to 5.625 kHz removed from f_0: Zero dB.
- On any frequency removed from the center of the authorized bandwidth by a displacement frequency (f_d in kHz) of more than 5.625 kHz but no more than 12.5 kHz: At least 7.27(f_d −2.88 kHz) dB.
- On any frequency removed from the center of the authorized bandwidth by a displacement frequency (f_d in kHz) of more than 12.5 kHz: At least 50 + 10 log (P) dB or 70 dB, whichever is the lesser attenuation.

This spectral emission mask is shown in graphical form in the plot of Figure 2, assuming a transmitter with an output power of P = 1 watt. The standard requires that the measurement is taken using a spectrum analyzer resolution bandwidth of ResBW=100 Hz and using Peak Hold mode, for frequency offsets up to 50 kHz from the edge of the authorized bandwidth.

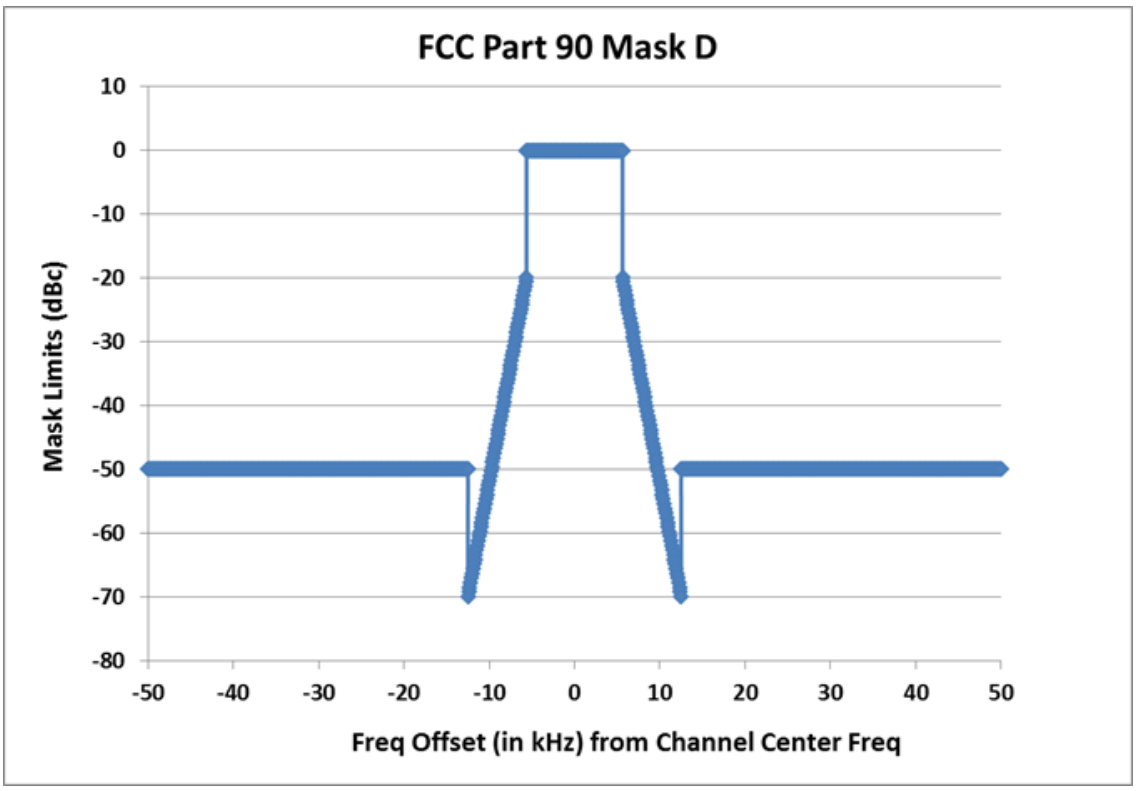


Figure 2. Emission Mask D (Pout=1W)

2.4.3. Emission Mask E

Equipment designed to operate with a 6.25 kHz or less channel bandwidth must meet the requirements of Emission Mask E. Any emission must be attenuated below the power (P, in watts) of the highest emission contained within the authorized bandwidth as follows:

- On any frequency from the center of the authorized bandwidth f_0 to 3.0 kHz removed from f_0 :Zero dB
- On any frequency removed from the center of the authorized bandwidth by a displacement frequency (f_d in kHz) of more than 3.0 kHz but no more than 4.6 kHz: At least 30 + 16.67(f_d −3 kHz) or 55 + 10 log (P) or 65 dB, whichever is the lesser attenuation.
- On any frequency removed from the center of the authorized bandwidth by more than 4.6 kHz: At least 55 + 10 log (P) or 65 dB, whichever is the lesser attenuation.

This spectral emission mask is shown in graphical form in the plot of Figure 3, assuming a transmitter with an output power of P = 1 watt. The standard requires that the measurement is taken using a spectrum analyzer resolution bandwidth of ResBW=100 Hz and using Peak Hold mode, for frequency offsets up to 50 kHz from the edge of the authorized bandwidth.

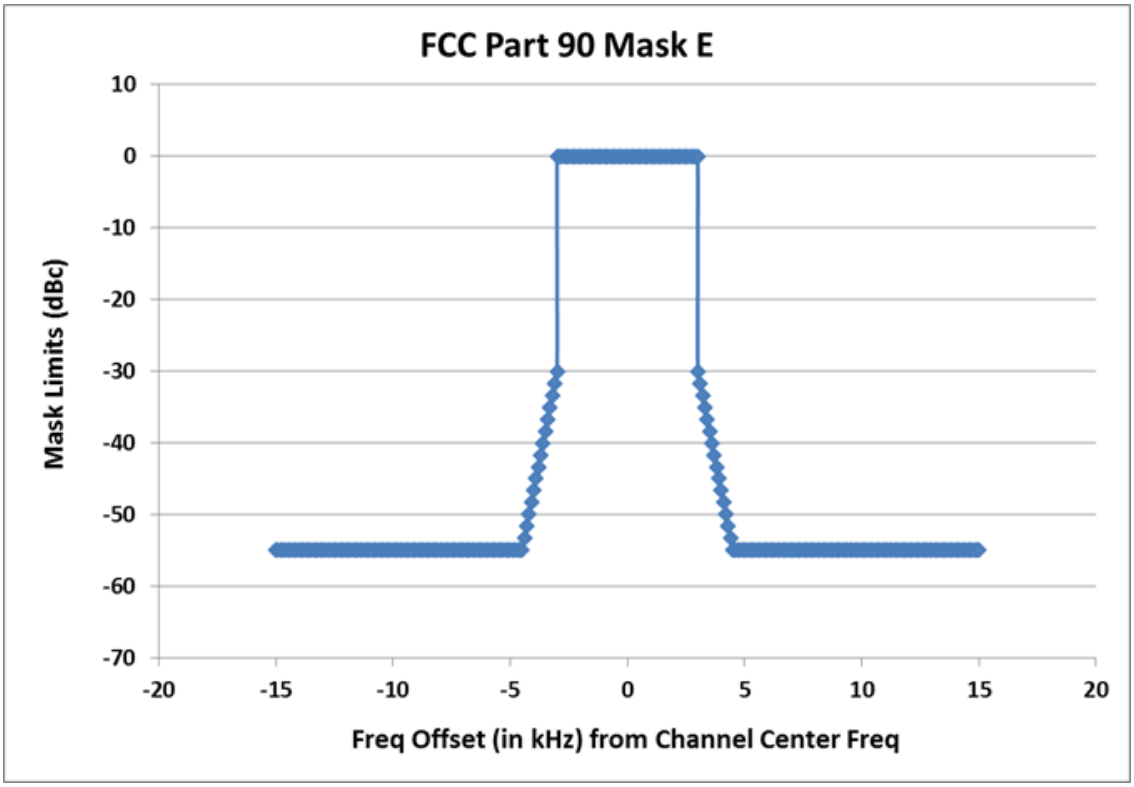


Figure 3. Emission Mask E (Pout=1W)

2.5. FCC Part 90.213 Frequency Stability

The standard provides a table which specifies the required minimum frequency stability for each frequency band, station type (e.g., fixed or mobile), and transmit output power level. In the 421-512 MHz band, mobile stations with output power of 2 watts or less must have the following minimum frequency stability:

- ±5.0 ppm, when designed to operate with a 25 Hz channel bandwidth
- ±2.5 ppm, when designed to operate with a 12.5 kHz channel bandwidth
- ±1.0 ppm, when designed to operate with a 6.25 kHz channel bandwidth

2.6. FCC Part 90.214 Transient Frequency Behavior

The standard provides a table which specifies the required maximum transient frequency difference (from the assigned transmitter frequency) during certain time intervals of the transmission, including turn-on and turn-off. The requirements vary depending upon the channel bandwidth, frequency band, and transmit output power level.

In the 421-512 MHz band, transmitters designed to operate with a 25 kHz channel bandwidth shall maintain a transient frequency difference of less than:

- ±25 kHz, for the first 10 msec after turn-on
- ±12.5 kHz, for the next 25 msec period
- ±25 kHz, for the first 10 msec after turn-off

In the 421-512 MHz band, transmitters designed to operate with a 12.5 kHz channel bandwidth shall maintain a transient frequency difference of less than:

- ±12.5 kHz, for the first 10 msec after turn-on
- ±6.25 kHz, for the next 25 msec period
- ±12.5 kHz, for the first 10 msec after turn-off

In the 421-512 MHz band, transmitters designed to operate with a 6.25 kHz channel bandwidth shall maintain a transient frequency difference of less than:

- ±6.25 kHz, for the first 10 msec after turn-on
- ±3.125 kHz, for the next 25 msec period
- ±6.25 kHz, for the first 10 msec after turn-off

2.7. FCC Part 90.217 Exemptions from Technical Standards

The standard provides exemptions from the technical standards (including the difficult spectral emissions masks) for certain devices, depending upon operating frequency range and transmit output power level. Transmitters used at stations licensed below 800 MHz on any frequency listed in subparts B and C of this part or licensed on a business category channel above 800 MHz which have an output power not exceeding 120 milliwatts are exempt from the technical requirements, but must instead comply with the following:

- For equipment designed to operate with a 25 kHz channel bandwidth, the sum of the bandwidth occupied by the emitted signal plus the bandwidth required for frequency stability shall be adjusted so that any emission appearing on a frequency 40 kHz or more removed from the assigned frequency is attenuated at least 30 dB below the unmodulated carrier.
- For equipment designed to operate with a 12.5 kHz channel bandwidth, the sum of the bandwidth occupied by the emitted signal plus the bandwidth required for frequency stability shall be adjusted so that any emission appearing on a frequency 25 kHz or more removed from the assigned frequency is attenuated at least 30 dB below the unmodulated carrier.
- For equipment designed to operate with a 6.25 kHz channel bandwidth, the sum of the bandwidth occupied by the emitted signal plus the bandwidth required for frequency stability shall be adjusted so that any emission appearing on a frequency 12.5 kHz or more removed from the assigned frequency is attenuated at least 30 dB below the unmodulated carrier.

2.8. FCC Part 90.221 Adjacent Channel Power Limits

The standard provides Adjacent Channel Power (ACP) limits for equipment designed to operate with a 25 kHz channel bandwidth. The ACP requirements vary as a function of the displacement from the channel center frequency and as a function of the transmit output power. The measurement bandwidth is 18 kHz.

- At 25 kHz offset from the channel center frequency, the ACP shall not be more than -55 dBc for devices with transmit power of 1 watt or less, and shall not be more than -60 dBc for devices with transmit power of greater than 1 watt.
- At 50 kHz offset from the channel center frequency, the ACP shall not be more than -70 dBc for devices with transmit power of 1 watt or less, and shall not be more than -70 dBc for devices with transmit power of greater than 1 watt.
- At 75 kHz offset from the channel center frequency, the ACP shall not be more than -70 dBc for devices with transmit power of 1 watt or less, and shall not be more than -70 dBc for devices with transmit power of greater than 1 watt.

However, the adjacent channel power shall not be required to be below -36 dBm in any case.

2.9. FCC Part 90.203(j)(5) Spectrum Efficiency

The standard requires equipment to achieve a certain minimum efficiency in the use of the spectrum. If the equipment is capable of transmitting data, has transmitter output power greater than 500 mW, and has a channel bandwidth of more than 6.25 kHz, the equipment must be capable of supporting a minimum data rate of 4800 bits per second per 6.25 kHz of channel bandwidth.

3. .Measurement Results

All measurements were taken with an Anritsu MS2692A signal analyzer. The analyzer settings used for each measurement are noted within each measurement section. The WDS scripts used to configure the RFIC are shown in shown in "4. Wireless Development Suite (WDS) TX Script Files" on page 27.

A significant challenge for any manufacturer of RFICs is the integration of both the VCO and crystal oscillator on the same die or substrate. Some amount of coupling between these circuits may occur, even when significant care is taken during the design and layout of the chip. The Si446x family of chips is known to experience some amount of such undesired coupling between the on-chip VCO and XtalOsc circuits. This coupling manifests itself as low-level spurious sidebands on the transmit output signal. These spurious sidebands occur ***only*** at (or very near) tuned frequencies that are mathematically predictable, given the frequency of the crystal oscillator reference signal. This predictability allows the user to partially mitigate the problem by appropriate selection of the crystal frequency, such that the locations of the affected channels are chosen advantageously. The formula to calculate the affected frequencies within the 450-470 MHz band is given by:

$$F_{SPUR} = \frac{N \times F_{XTAL}}{8}$$

Equation 1

The spurious sideband level is also proportional to the TX output power, and thus a reduction in transmit output power level can help reduce the relative level of the sidebands. This relationship holds true until the transmit power level is reduced to approximately +10 dBm, below which no significant further decrease in relative spurious level is observed. For this reason, optimal performance is obtained when the Si446x chip is operated at +10 dBm output power level. Most FCC Part 90 applications operate at significantly higher output power (e.g., 1 to 2 watts) than even Si4463/64 chips (+20 dBm) can provide. The addition of an external power amplifier or Front End Module (FEM) is expected in either case, and thus operation of the Si446x chip at only +10 dBm is not considered a burdensome factor.

All measurements within this section were taken with the RFIC configured for an output power level of +10 dBm. However, the spectrum analyzer was configured (unless noted otherwise) to offset the measured power level by 20

dB, thus emulating the scenario where an external power amplifier is added to the chip to boost the power level to +30 dBm (1 watt). The measurements shown here thus represent the performance of the RFIC and assume the addition of an external power amplifier will not further degrade the performance

Additionally, it may be shown that optimal performance (again with regards to spurious sidebands) is obtained when the chip is configured for a narrower PLL loop bandwidth (e.g., 50 kHz) than its default setting (200 kHz). Spurious sidebands that fall at greater frequency offsets from the carrier benefit from increased attenuation with the narrower loop bandwidth configuration. The measurements shown here are taken (unless noted otherwise) with a chip configuration resulting in a PLL loop bandwidth of ≈50 kHz.

Although appropriate selection of the crystal frequency and operation at a reduced power level can help decrease the relative level of the spurious signals, they cannot be eliminated completely. There is ***no choice of crystal frequency*** that will result in a perfectly clean spectrum within the entire 450-470 MHz band; a small number of channels (5 to 6 channels) will always remain affected.

3.1. FCC Part 90.205(h) Power and Antenna Height Limits

The allowed transmitter antenna power is specified in FCC Part 90.205(h) as less than 2 W ERP (+33 dBm ERP), assuming a service area of 3 kilometers and antenna HAAT of 15 meters. The measured transmitter power is shown in Figure 4. This measurement was taken ***without*** emulation of an external power amplifier (by offsetting the spectrum analyzer by 20 dB, as discussed previously). The Si446x family of chips complies with the requirements of FCC Part 90.205(h) for Power and Antenna Height Limits.

- Limit: 2 W ERP = +33 dBm ERP (max)
- Measured: +10.43 dBm
- Margin: 22.57 dB (PASS)

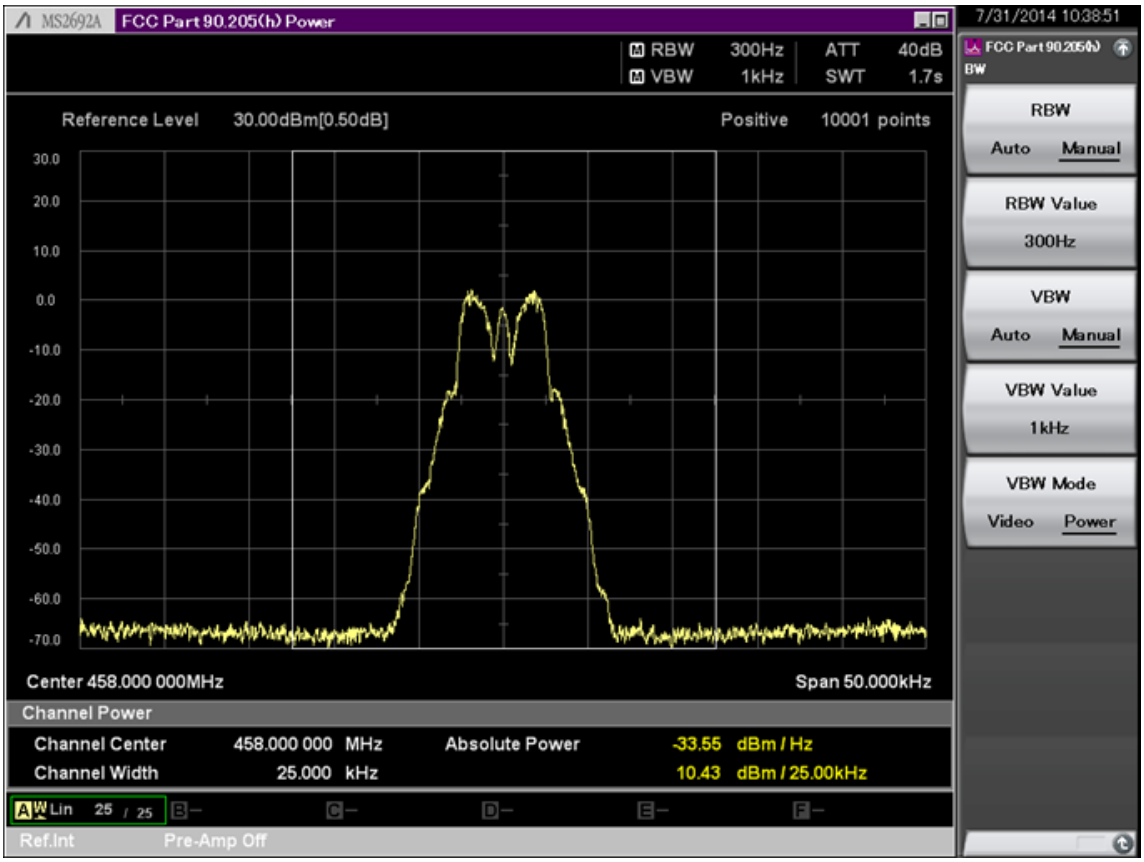


Figure 4. Transmitter Power

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 Si4463/64 chip, +13 to +14 dBm for the Si4461 chip, and +10 dBm for the Si4460 chip). The output power on the Si446x family of chips is adjusted by selecting the number of output device fingers that are enabled (as set by the PA_PWR_LVL property).

3.2. FCC Part 90.207 Types of Emissions

The standard allows multiple types of emissions (i.e., modulation methods), including F1D = 2(G)FSK or 4(G)FSK. The data rate and deviation are not specified in the standard, except that the unit must additionally comply with the authorized bandwidth and applicable spectral emission mask.

All measurements within this document were taken with 2GFSK, data rate = 2.4 kbps, and deviation = 2.0 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).

3.3. FCC Part 90.209 (b)(5) Bandwidth Limitations

The permissible bandwidth is specified in FCC Part 90.209(b)(5). Within the 406-512 MHz band, the permissible authorized bandwidths are 6 kHz, 11.25 kHz, or 20 kHz. The standard does not provide clear guidance on the measurement method used to verify the bandwidth of the signal. In the absence of such guidance, the measurements shown below demonstrate the occupied bandwidth using the 99% power calculation method.

It is self-evident that any desired value of occupied bandwidth may be obtained by the appropriate selection of data rate and/or deviation. The plots shown here demonstrate regulatory compliance for a variety of selected modulation protocols, but they should not be construed as the ***only*** possible modulation protocols that achieve compliance. It is ultimately the responsibility of the user to select the data rate and deviation so as to maintain compliance with bandwidth limitations, as well as the Spectral Emissions Mask requirements of Part 90.210. Allowance must also be made to maintain compliance in the presence of the frequency stability limits of FCC Part 90.213.

The measured occupied bandwidth (99.0%) for a modulation protocol of 2GFSK, DR=2.4 kbps, Deviation=2.0 kHz is shown in Figure 5. The Si446x family of chips complies with the requirements of FCC Part 90.209(b)(5) for Bandwidth Limitations for this selected modulation protocol.

- Limit: 6 kHz / 11.25 kHz / 20 kHz
- Measured: 5.27 kHz
- Margin: 0.73 kHz (PASS)

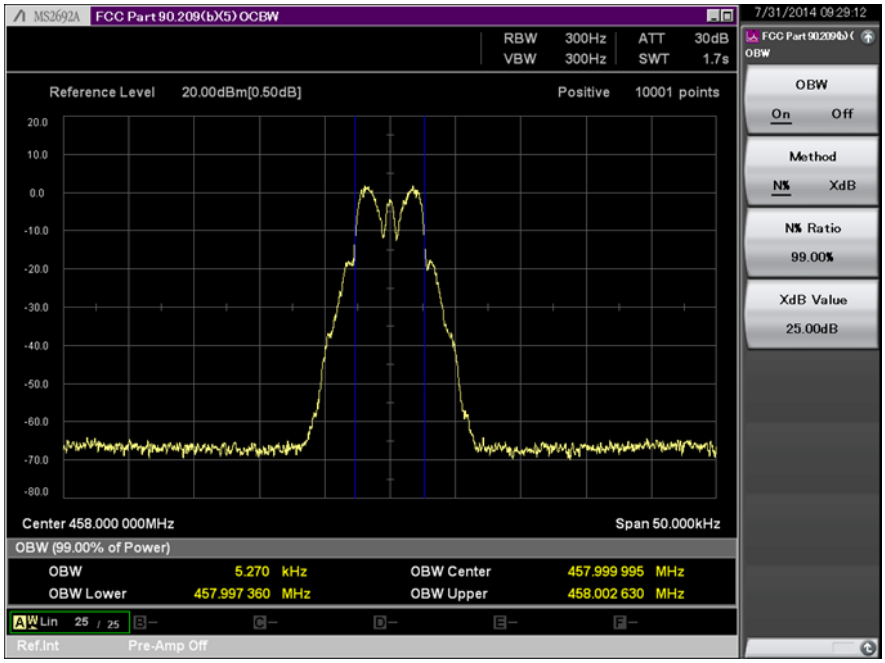


Figure 5. Occupied Bandwidth (2GFSK DR=2.4 kbps Dev=2.0 kHz)

The measured occupied bandwidth (99.0%) for a modulation protocol of 2GFSK, DR=3.6 kbps, Deviation=3.0 kHz is shown in Figure 6. The Si446x family of chips complies with the requirements of FCC Part 90.209(b)(5) for Bandwidth Limitations for this selected modulation protocol.

- Limit: 6 kHz / 11.25 kHz / 20 kHz
- Measured: 7.76 kHz
- Margin: 3.49 kHz (PASS)

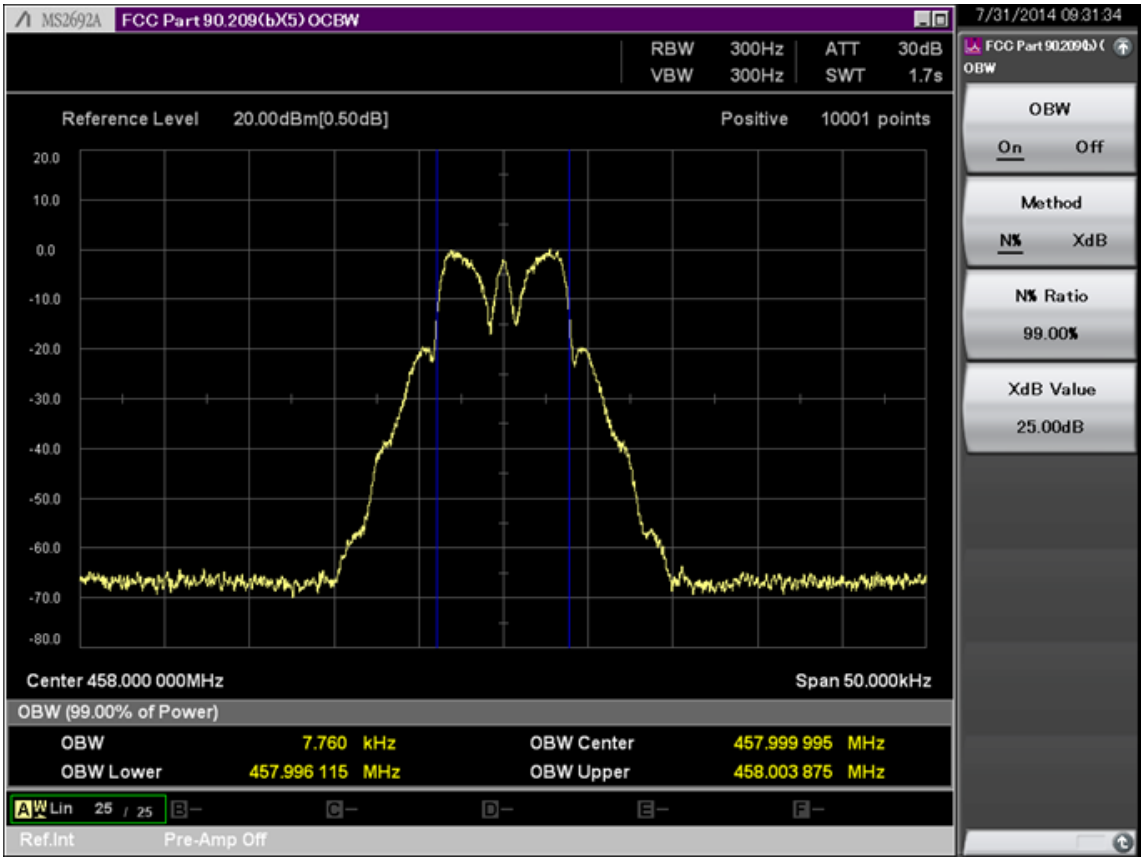


Figure 6. Occupied Bandwidth (2GFSK DR=3.6 kbps Dev=3.0 kHz)

The measured occupied bandwidth (99.0%) for a modulation protocol of 2GFSK, DR=4.8 kbps, Deviation=4.0 kHz is shown in Figure 7. The Si446x family of chips complies with the requirements of FCC Part 90.209(b)(5) for Bandwidth Limitations for this selected modulation protocol.

- Limit: 6 kHz / 11.25 kHz / 20 kHz
- Measured: 10.29 kHz
- Margin: 0.96 kHz (PASS)

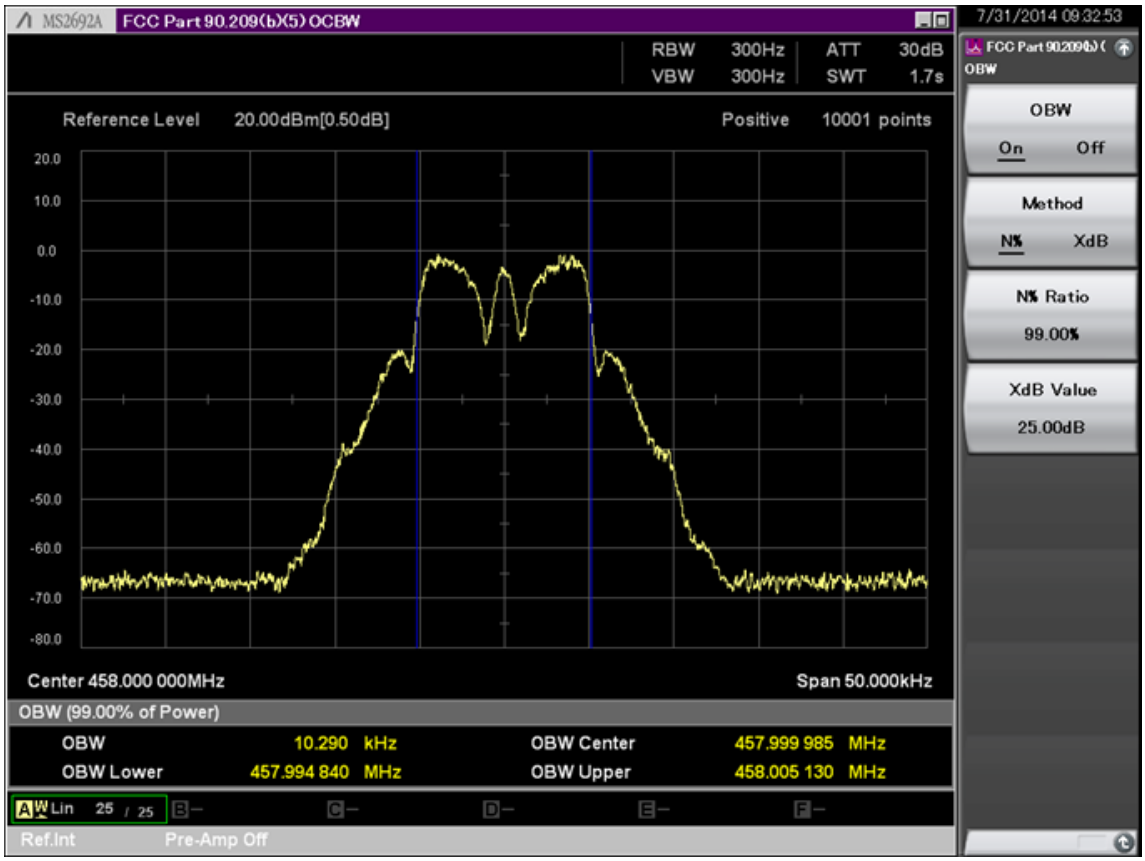


Figure 7. Occupied Bandwidth (2GFSK DR=4.8 kbps Dev=4.0 kHz)

3.4. FCC Part 90.210 Emission Masks

The allowed level of spectral emissions is specified in FCC Part 90.210. Compliance is required with a variety of emissions masks, depending upon the frequency band of operation and the channel bandwidth.

3.4.1. Emission Mask C

Equipment designed to operate with a 25 kHz channel bandwidth must meet the requirements of Emission Mask C. The limits of Mask C are defined in "2.4.1. Emission Mask C" and are shown in graphical form in Figure 1.

Multiple measurements were taken and are summarized below. The plots demonstrate the ability of Si446x chips to readily comply with the emissions mask on the great majority of channels (i.e., channels unaffected by spurious sidebands). The plots further illustrate the expected level of performance on those limited number of affected channels. The spectrum analyzer was configured for:

- Detector Mode = Peak, ResBW = 100 Hz, VidBW = 300 Hz
- Max Hold
- Amplitude correction = 20.5 dB (0.5 dB for cable loss, 20 dB to emulate External PA)

The measured spectral emissions mask at 458.0 MHz in CW mode is shown in Figure 8. The Si446x family of chips complies with the requirements of FCC Part 90.210(c) for Spectral Emission Mask C at this frequency. This is an example of the performance on the great majority of frequencies that are not affected by spurious sidebands.

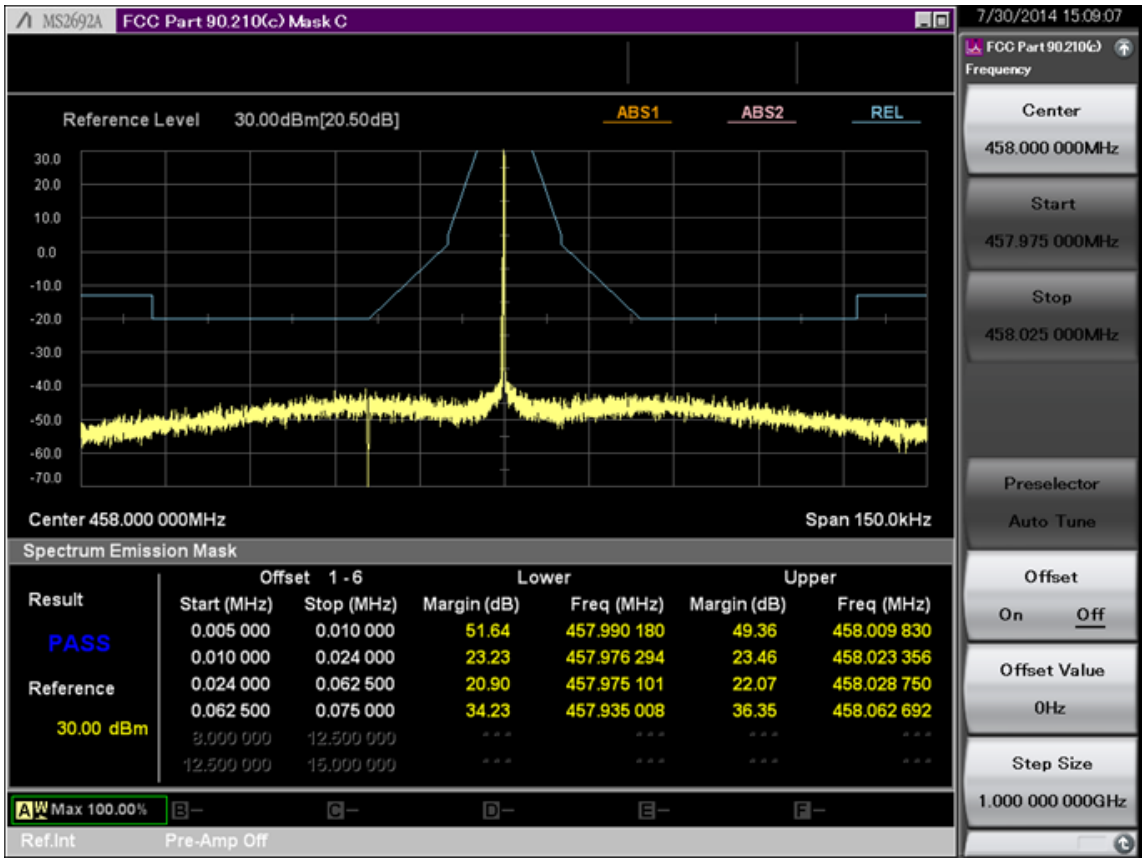


Figure 8. Emission Mask C (Pout = +10dBm, 458.0M, CW)

The measured spectral emissions mask at 458.0 MHz in the presence of modulation is shown in Figure 9. The selected modulation protocol was 2GFSK B*T=0.5 DR=2.4 K Dev=2.0 K. The Si446x family of chips complies with the requirements of FCC Part 90.210(c) for Spectral Emission Mask C at this frequency. This is a further example of the compliant performance on most frequencies.

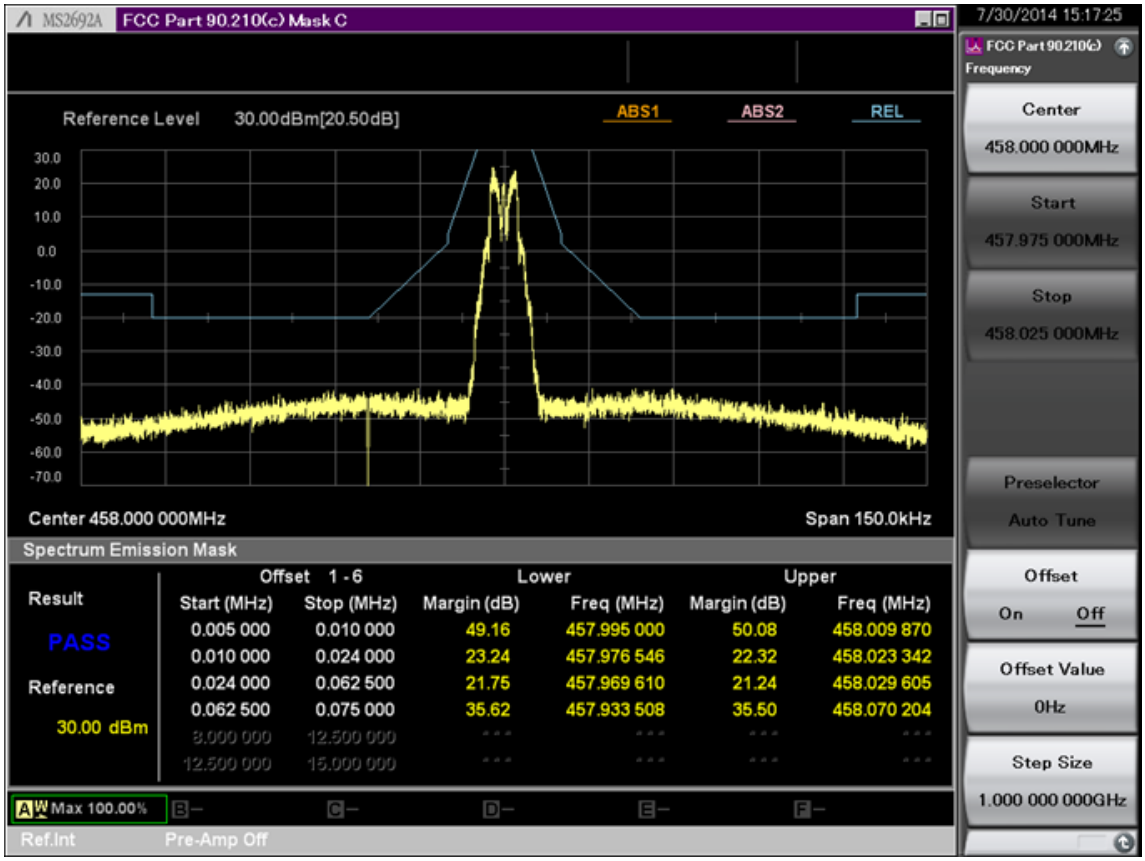


Figure 9. Emission Mask C (Pout=+10dBm, 458.0M, 2GFSK DR=2.4K Dev=2.0K)

The measured spectral emissions mask at 457.50625 MHz in CW mode is shown in Figure 10. The frequency of F=457.5 MHz is calculated as an affected channel using Equation 1 with N=122 and Fxtal = 30.0 MHz; the frequency chosen here is one channel (6.25 kHz) away and results in the spurious sidebands “walking out” from the carrier as the frequency offset is increased. As the selected operating frequency is moved further away from the exact spurious frequency, the spurious sidebands also appear at greater frequency offsets and are rapidly attenuated by the filtering action of the PLL loop bandwidth. Thus it is advantageous to reduce the loop bandwidth to improve the attenuations of these signals; the performance shown in Figure 10 is with the chip configured for a reduced PLL loop bandwidth of ≈50 kHz. The Si446x family of chips complies with the requirements of FCC Part 90.210(c) for Spectral Emission Mask C in CW mode at this frequency, but with reduced margin. Measurement in CW mode is the worst case condition as the energy in the sidebands is “spread” when modulation is applied.

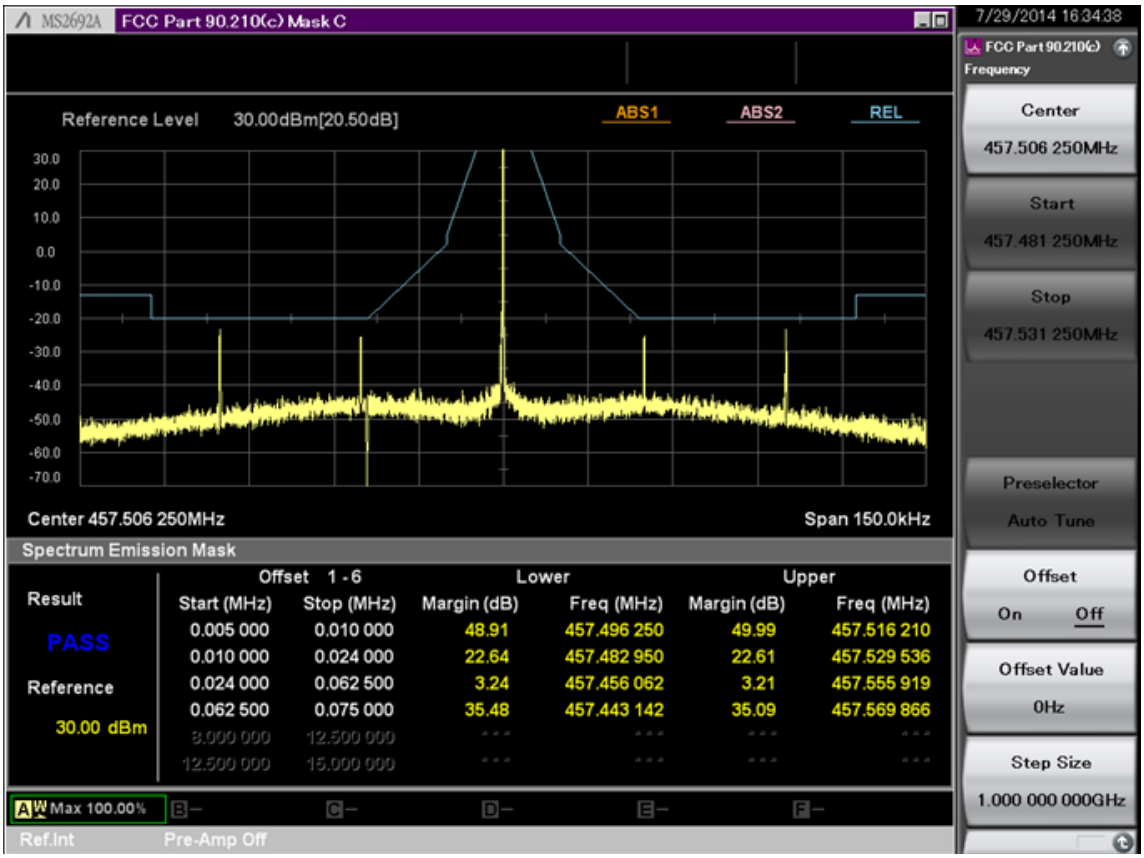


Figure 10. Emission Mask C (Pout=+10 dBm, 457.50625M, CW)

3.4.2. Emission Mask D

Equipment designed to operate with a 12.5 kHz channel bandwidth must meet the requirements of Emission Mask D. The limits of Mask D are defined in "2.4.2. Emission Mask D" and are shown in graphical form in Figure 2.

Multiple measurements were taken and are summarized below. The plots demonstrate the ability of Si446x chips to readily comply with the emissions mask on the great majority of channels (i.e., channels unaffected by spurious sidebands). The plots further illustrate the expected level of performance on those limited number of affected channels. The spectrum analyzer was configured for:

- Detector Mode = Peak, ResBW = 100 Hz, VidBW = 300 Hz
- Max Hold
- Amplitude correction = 20.5 dB (0.5 dB for cable loss, 20 dB to emulate External PA)

The measured spectral emissions mask at 458.0 MHz in CW mode is shown in Figure 11. The Si446x family of chips complies with the requirements of FCC Part 90.210(d) for Spectral Emission Mask D at this frequency. This is an example of the performance on the great majority of frequencies that are not affected by spurious sidebands.

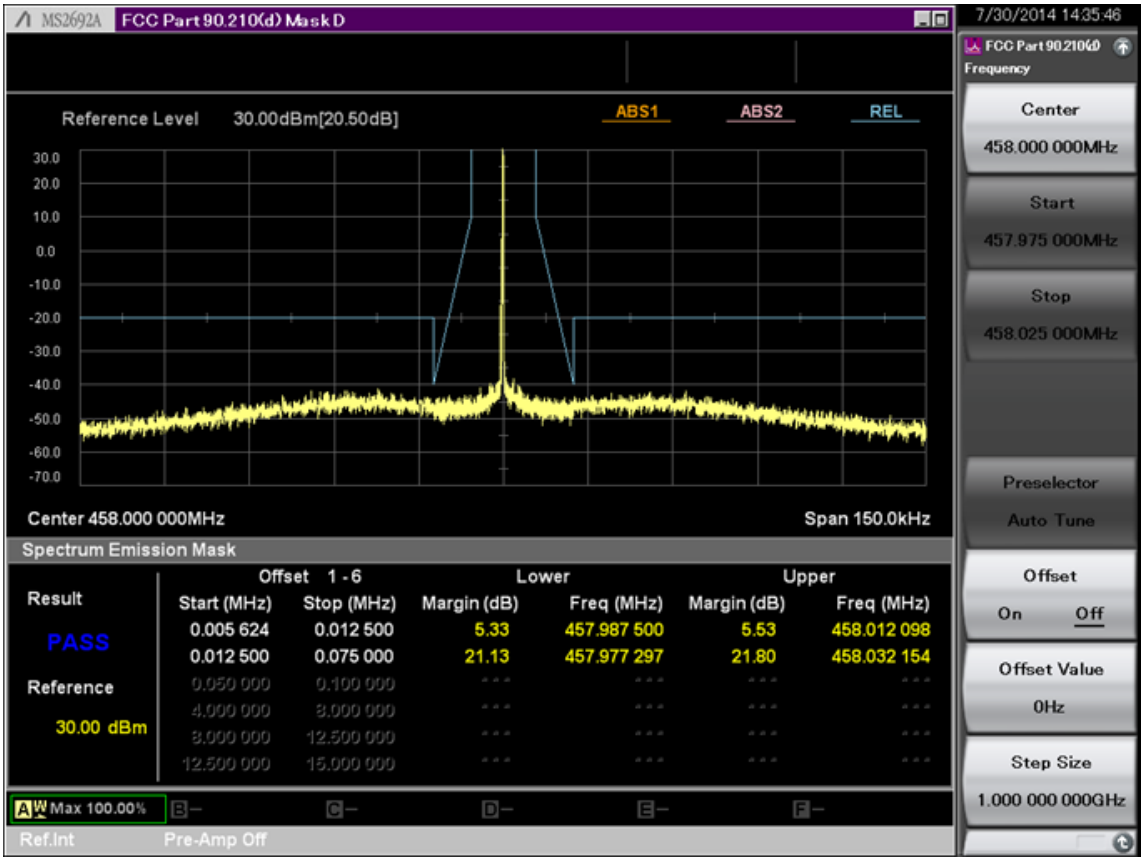


Figure 11. Emission Mask D (Pout=+10 dBm, 458.0M, CW)

The measured spectral emissions mask at 458.0 MHz in the presence of modulation is shown in Figure 12. The selected modulation protocol was 2GFSK B*T=0.5 DR=2.4K Dev=2.0K. The Si446x family of chips complies with the requirements of FCC Part 90.210(d) for Spectral Emission Mask D at this frequency. This is a further example of the compliant performance on most frequencies.

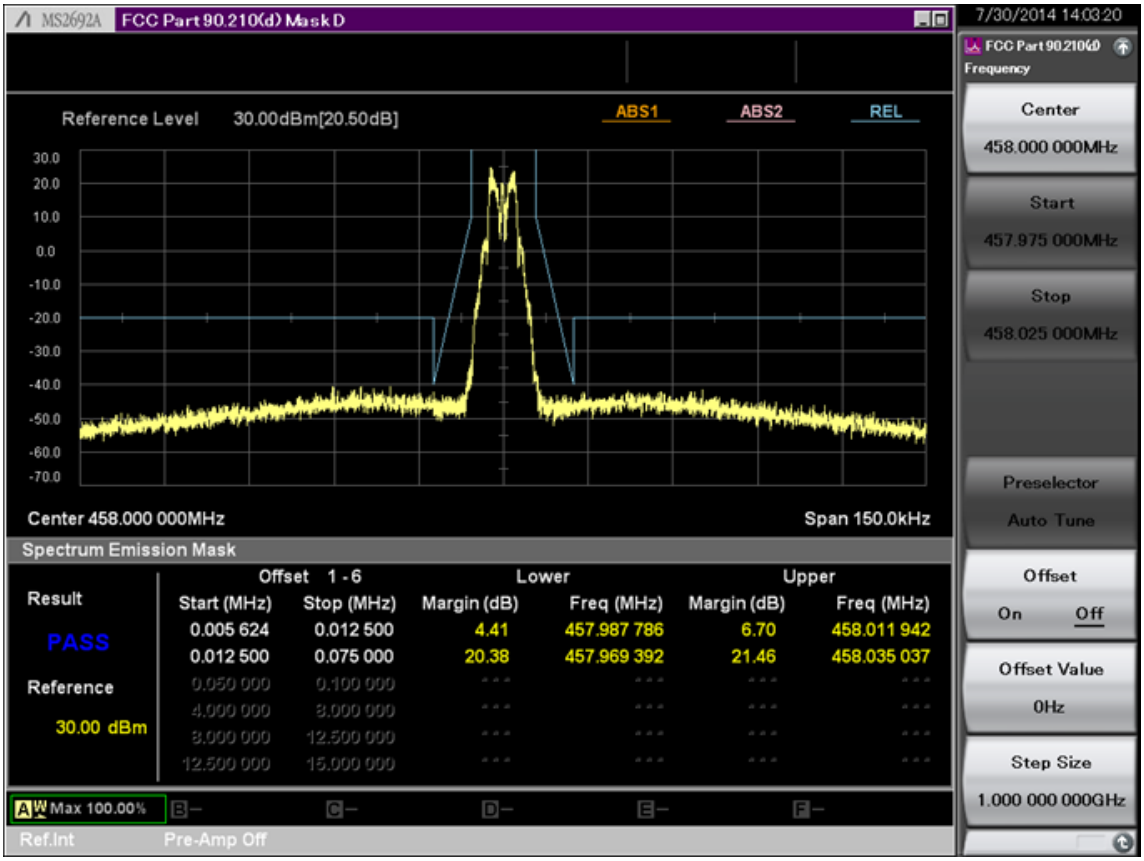


Figure 12. Emission Mask D (Pout=+10dBm, 458.0M, 2GFSK DR=2.4K Dev=2.0K)

The measured spectral emissions mask at 457.50625 MHz in CW mode is shown in Figure 13. The frequency of F=457.5 MHz is calculated as an affected channel using Equation 1 with N=122 and Fxtal = 30.0 MHz; the frequency chosen here is one channel (6.25 kHz) away and results in the spurious sidebands “walking out” from the carrier as the frequency offset is increased. As the selected operating frequency is moved further away from the exact spurious frequency, the spurious sidebands also appear at greater frequency offsets and are rapidly attenuated by the filtering action of the PLL loop bandwidth. Thus it is advantageous to reduce the loop bandwidth to improve the attenuations of these signals; the performance shown in Figure 13 is with the chip configured for a reduced PLL loop bandwidth of ≈50 kHz. Measurement in CW mode is the worst case condition as the energy in the sidebands is “spread” when modulation is applied. Therefore, this demonstrates the ability of Si446x chips to comply with the requirements of FCC Part 90.210(d) for Spectral Emission Mask D on all frequencies other than the calculated affected channels.

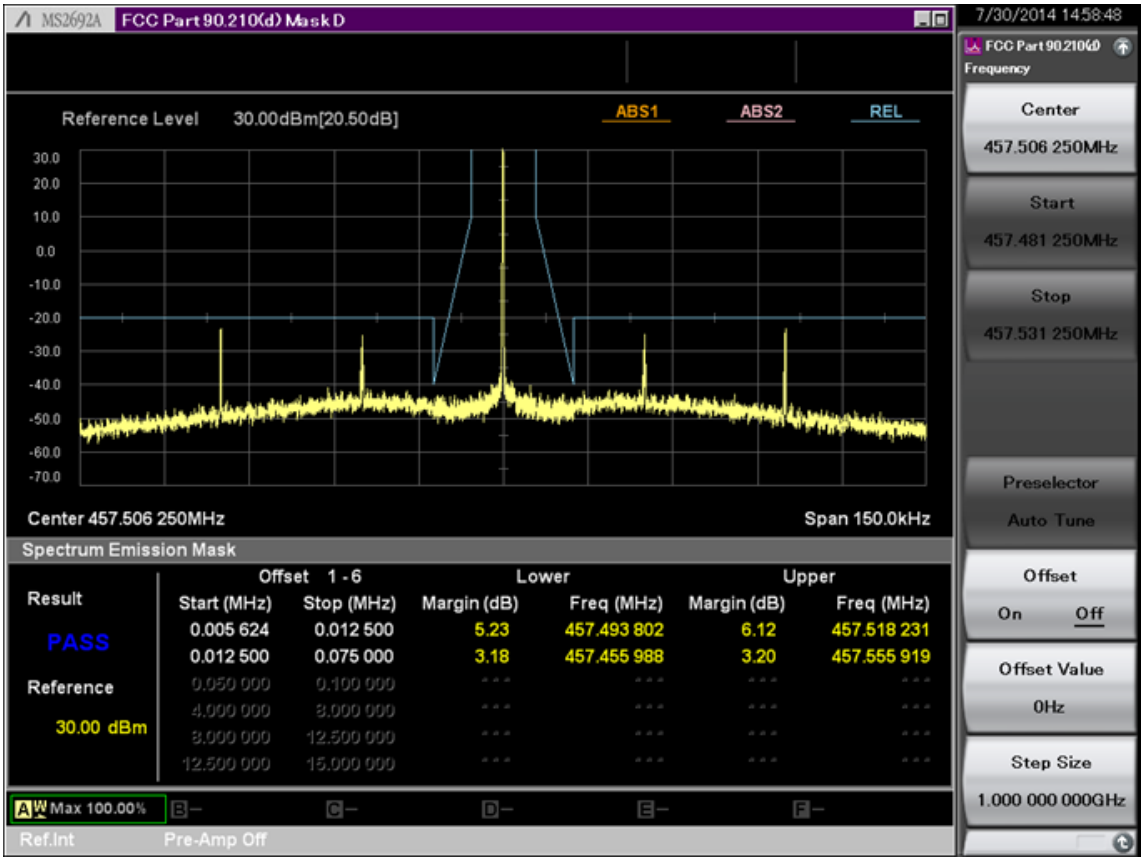


Figure 13. Emission Mask D (Pout=+10dBm, 457.50625M, CW)

The measured spectral emissions mask when tuned exactly to an affected channel (e.g., 457.5 MHz) is shown in Figure 14 for a modulation protocol of 2GFSK B*T=0.5 DR=2.4 K Dev=2.0 K. The frequency of F=457.5 MHz is calculated as an affected channel using Equation 1 with N=122 and Fxtal = 30.0 MHz. The instantaneous frequency deviation of the modulation signal gives rise to spurious sideband artifacts that fall near the deepest notch of the spectral mask. As a result, the Si446x family of chips fails to comply with the requirements of FCC Part 90.210(d) for Spectral Emission Mask D on this limited set of affected frequencies, as calculated by Equation 1.

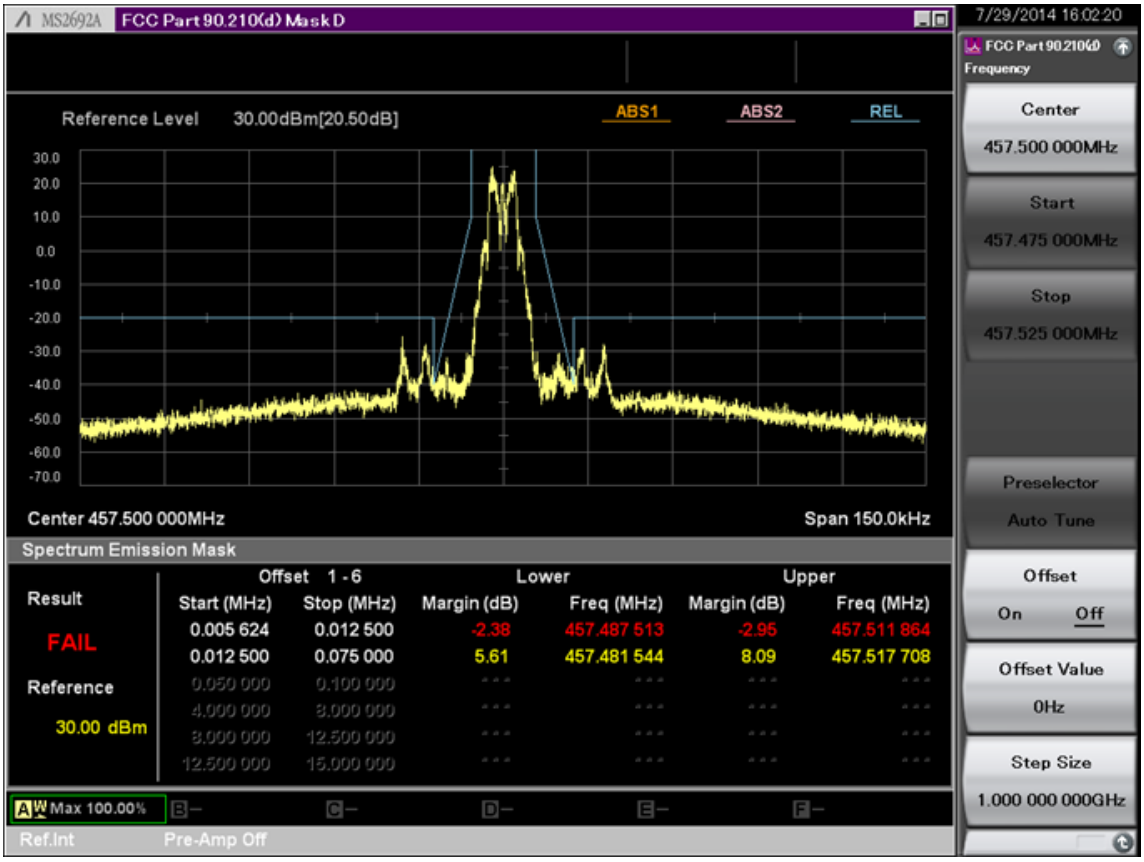


Figure 14. Emission Mask (Pout=+10 dBm, 457.5 M, 2GFSK DR=2.4 K Dev=2.0 K)

3.4.3. Emission Mask E

Equipment designed to operate with a 6.25 kHz channel bandwidth must meet the requirements of Emission Mask E. The limits of Mask E are defined in "2.4.3. Emission Mask E" and are shown in graphical form in Figure 3.

Multiple measurements were taken and are summarized below. The plots demonstrate the ability of Si446x chips to readily comply with the emissions mask on the great majority of channels (i.e., channels unaffected by spurious sidebands). The plots further illustrate the expected level of performance on those limited number of affected channels. The spectrum analyzer was configured for:

- Detector Mode = Peak, ResBW = 100 Hz, VidBW = 300 Hz
- Max Hold
- Amplitude correction = 20.5 dB (0.5 dB for cable loss, 20 dB to emulate External PA)

The measured spectral mask at 458.0 MHz in CW mode is shown in Figure 15. The Si446x family of chips complies with the requirements of FCC Part 90.210(e) for Spectral Emission Mask E at this frequency. This is an example of the performance on the great majority of frequencies that are not affected by spurious sidebands.

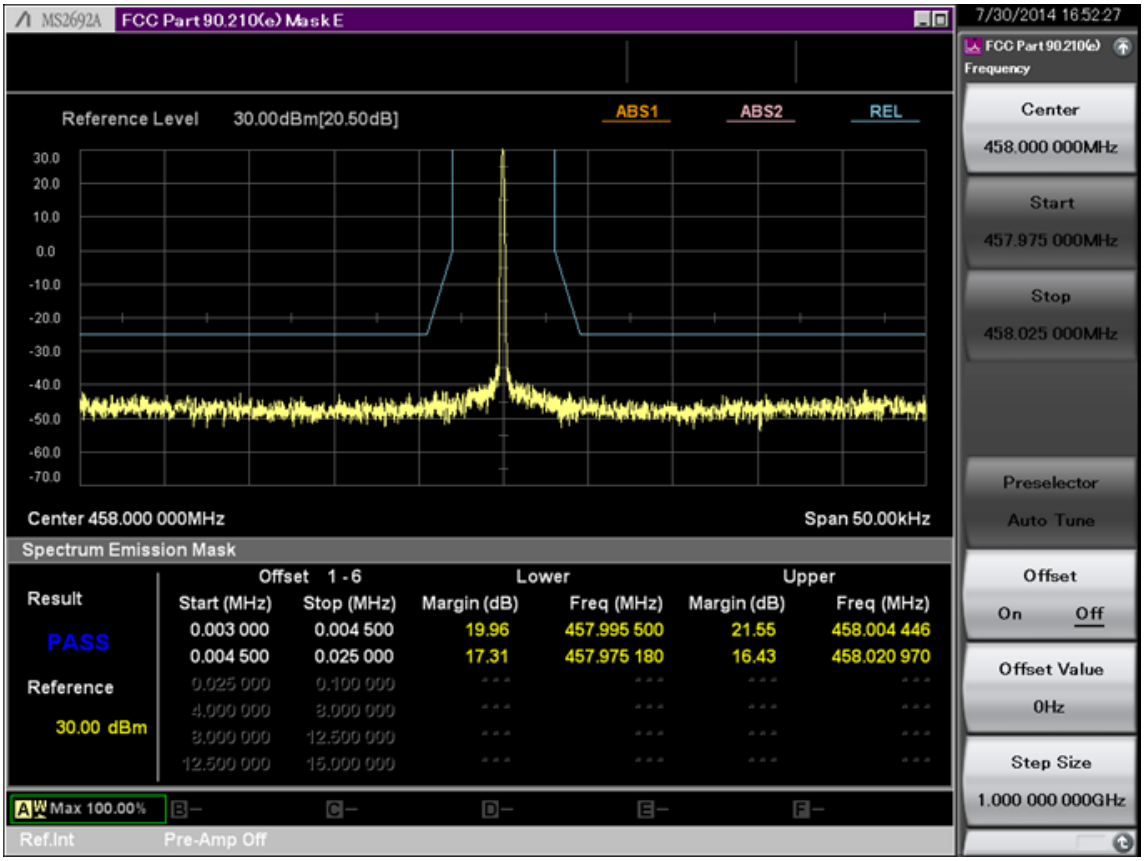


Figure 15. Emission Mask E (Pout=+10dBm, 458.0M, CW)

The measured spectral emissions mask at 458.0 MHz in the presence of modulation is shown in Figure 16. Due to the narrower authorized bandwidth for operation with Mask E, the selected modulation protocol was reduced to 2GFSK B*T=0.5 DR=2.0 K Dev=1.0 K. The Si446x family of chips complies with the requirements of FCC Part 90.210(e) for Spectral Emission Mask E at this frequency. This is a further example of the compliant performance on most frequencies.

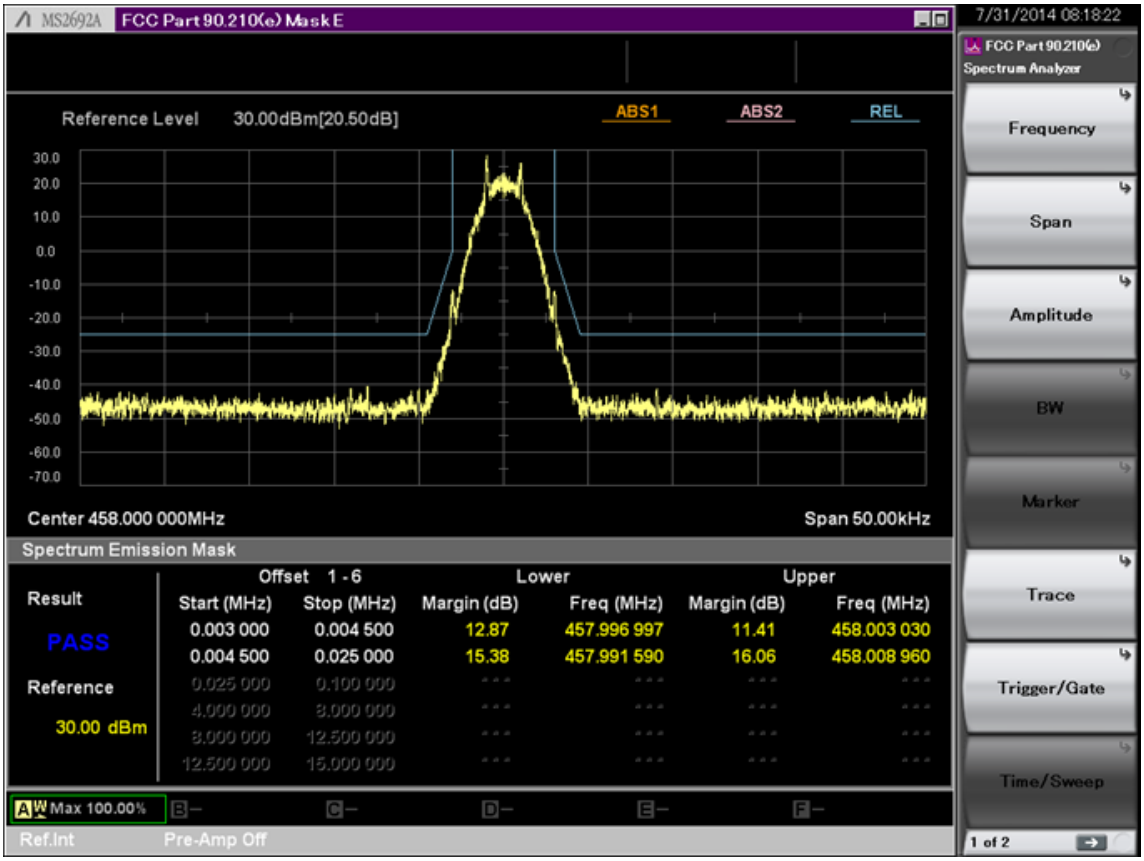


Figure 16. Emission Mask E (Pout=+10 dBm, 458.0M, 2GFSK DR=2.0 K Dev=1.0 K)

The measured spectral emissions mask when tuned exactly to an affected channel (e.g., 457.5 MHz) is shown in Figure 17 for a modulation protocol of 2GFSK B*T=0.5 DR=2.0K Dev=1.0 K. The frequency of F=457.5 MHz is calculated as an affected channel using Equation 1 with N=122 and Fxtal = 30.0 MHz. The instantaneous frequency deviation of the modulation signal gives rise to spurious sideband artifacts that fall near the deepest notch of the spectral mask. However, these spurious sidebands are low enough that the Si446x family of chips remains in compliance with the requirements of FCC Part 90.210(e) for Spectral Emission Mask E on this limited set of affected frequencies, as calculated by Equation 1.

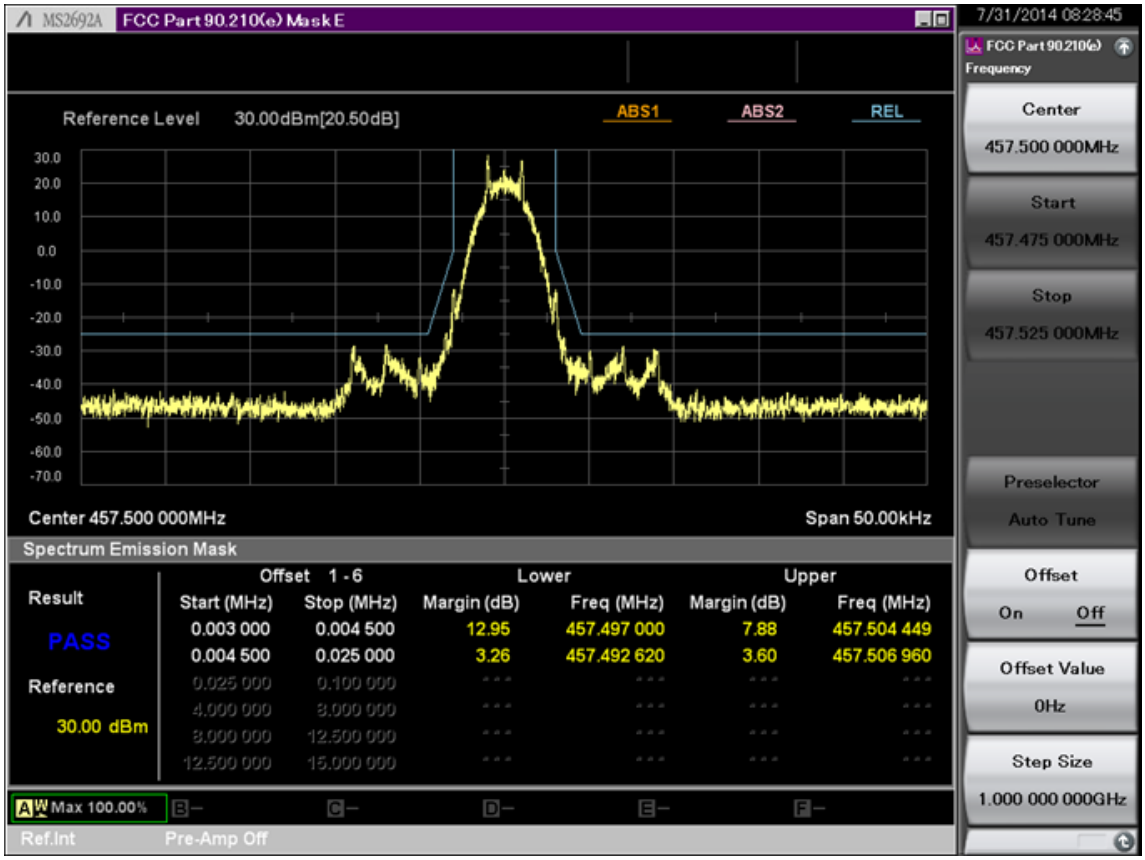


Figure 17. Emission Mask E (Pout =+10 dBm, 457.5 M, 2GFSK DR=2.0K Dev=1.0K)

3.5. FCC Part 90.213 Frequency Stability

The frequency accuracy of the Si446x family of RFICs is primarily dependent upon the frequency accuracy of the crystal reference signal (except for the limits of tuning resolution of the PLL Synthesizer, i.e., 14.3 Hz in the 450-470 MHz band for Fxtal = 30 MHz). Compliance with this requirement is thus determined by the frequency tolerance of the selected crystal blank or external reference oscillator, and is not considered a parameter to be verified in this application note.

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

3.6. FCC Part 90.214 Transient Frequency Behavior

The permissible transient frequency behavior is specified in FCC Part 90.214. The requirements vary depending upon the channel bandwidth, frequency band, and transmit output power level. The limits are defined in "2.6. FCC Part 90.214 Transient Frequency Behavior" on page 6.

A dummy packet (consisting of Preamble, Sync Word, and Payload fields) was transmitted with a selected modulation protocol of 2GFSK B*T=0.5 DR=2.4K Dev=2.0K. The spectrum analyzer was configured to simultaneously display Frequency-vs-Time and Power-vs-Time. The measured transient frequency behavior is shown in Figure 18. The Si446x family of chips complies with the requirements of FCC Part 90.214 for Transient Frequency Behavior, even for the most stringent requirement of 6.25 kHz channel bandwidth.

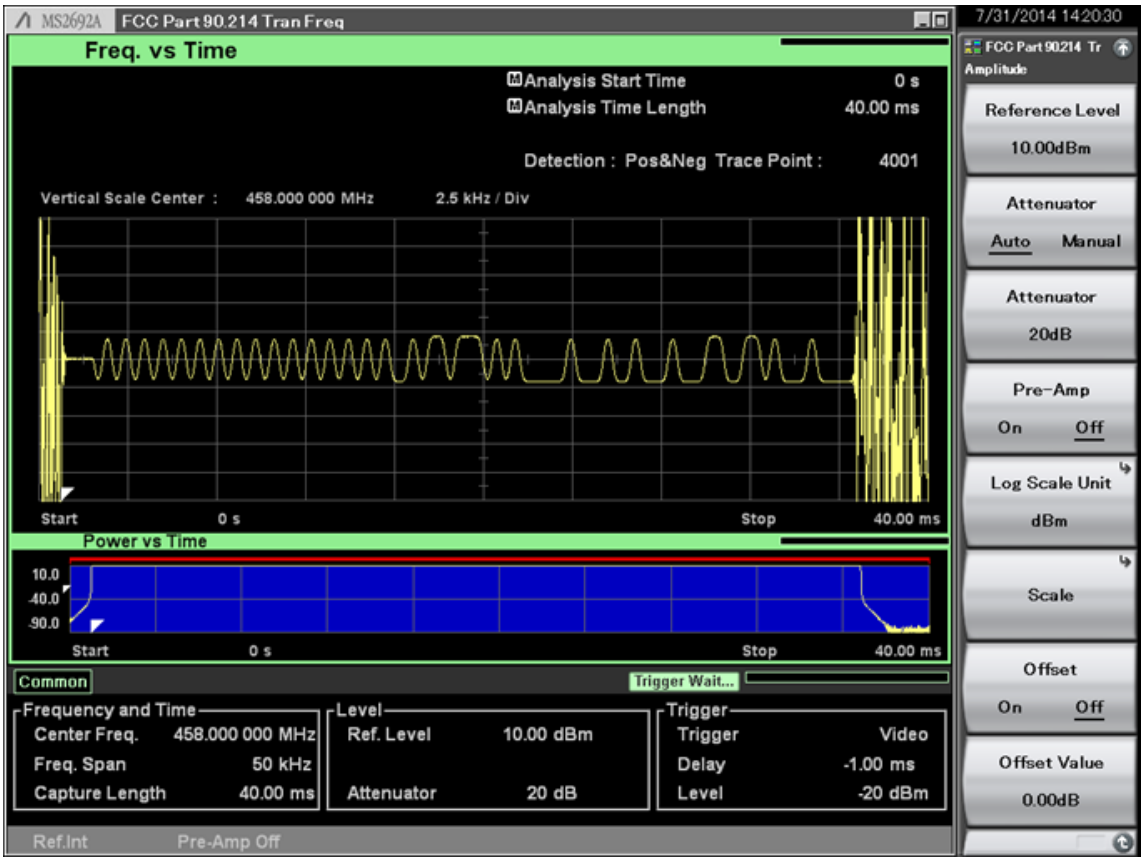


Figure 18. Transient Frequency (Pout=+10 dBm, 458.0 M, 2GFSK DR=2.4 K Dev=2.0 K)

3.7. FCC Part 90.217 Exemptions from Technical Standards

The standard provides exemptions from the technical standards (including the difficult spectral emissions masks) for certain devices, depending upon operating frequency range and transmit output power level. The purpose of this application note is to demonstrate compliance of the Si446x family of chips for applications which do ***not*** fall under Part 90.217, and thus compliance with this sub-paragraph is not demonstrated.

3.8. FCC Part 90.221 Adjacent Channel Power Limits

The allowed adjacent channel leakage power for equipment designed to operate with a 25 kHz channel bandwidth is specified in FCC Part 90.221, and is a function of the displacement from the channel center frequency and the transmit output power. The limits of adjacent channel leakage power are defined in "2.8. FCC Part 90.221 Adjacent Channel Power Limits" on page 7. The measurement bandwidth is 18 kHz. The spectrum analyzer was configured for:

- Detector Mode = Peak, ResBW = 300 Hz, VidBW = 1 kHz
- Averaging
- Amplitude correction = 20.5 dB (0.5 dB for cable loss, 20 dB to emulate External PA)

The measured adjacent channel power at 458.0 MHz in the presence of modulation with the default PLL loop bandwidth of ≈200 kHz is shown in Figure 19. The selected modulation protocol was 2GFSK B*T=0.5 DR=2.4K Dev=2.0 K. The Si446x family of chips complies with the requirements of FCC Part 90.221 for Adjacent Channel Power for a transmit output power level of 1 W, as the absolute ACP limit of -36 dBm is met at the critical frequency offsets.

- Limits: -55 dBc at 25 kHz offset, -70 dBc at 50 kHz offset, -70 dBc at 75 kHz offset, or -36 dBm (absolute)
- Measured: -63.83 dBc (25kHz), -66.02 dBc or -36.77 dBm (50kHz), -67.70 dBc or -38.45 dBm (75 kHz)
- Margin: +8.83 dB at 25 kHz (PASS), +0.77 dB at 50 kHz (PASS), +2.45 dB (PASS)

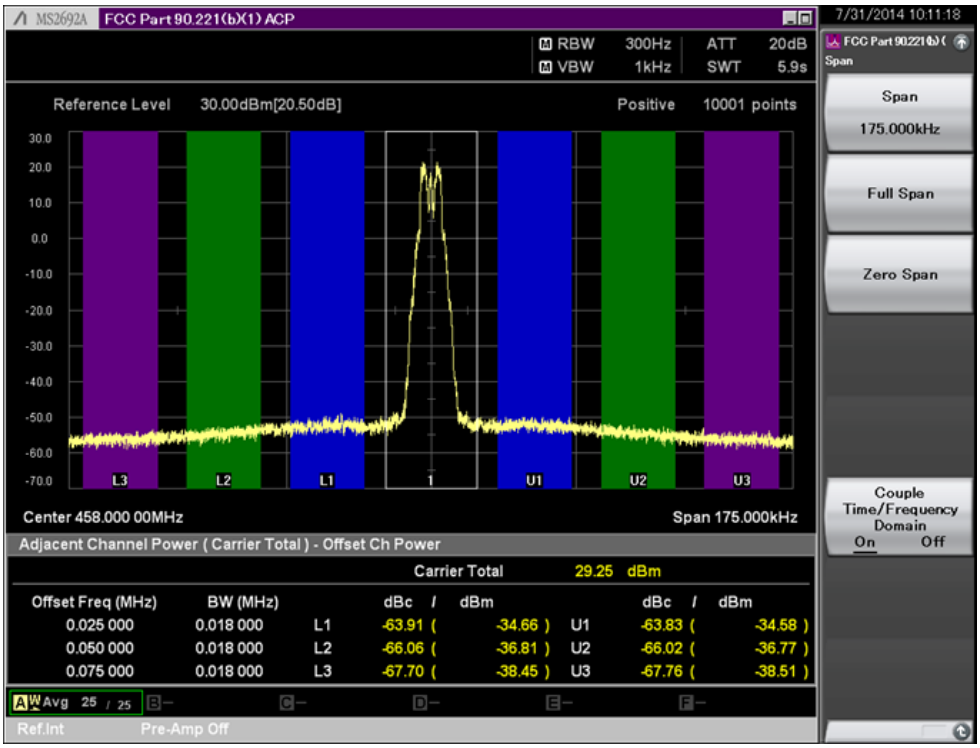


Figure 19. Adjacent Channel Power (Pout=+10 dBm, 458.0 M, 2GFSK DR=2.4 K Dev=2.0 K, BW=200kHz)

The compliant performance shown in Figure 19 was obtained with the chip configured for its default PLL loop bandwidth of ≈200 kHz. However, the Spectral Emissions Mask performance benefits from reducing the PLL loop bandwidth to ≈50 kHz. The phase noise at low frequency offsets (e.g., within the loop bandwidth) degrades as the loop bandwidth is reduced. The user must select a PLL loop bandwidth that balances the ACP performance with the Spectral Emissions Mask performance.

The measured adjacent channel power at 458.0 MHz in the presence of modulation with a PLL loop bandwidth of ≈50 kHz is shown in Figure 20. The selected modulation protocol was 2GFSK B*T=0.5 DR=2.4 K Dev=2.0 K. The Si446x family of chips fails to comply with the requirements of FCC Part 90.221 for Adjacent Channel Power at a frequency offset of 50 kHz for a transmit output power level of 1Ω.

- Limits: -55 dBc at 25 kHz offset, -70 dBc at 50 kHz offset, -70 dBc at 75 kHz offset, or -36 dBm (absolute)
- Measured: -59.00 dBc (25kHz), -62.81 dBc or -33.61 dBm (50 kHz), -66.97 dBc or -37.77 dBm (75 kHz)
- Margin: +4.00 dB at 25 kHz (PASS), -2.39 dB at 50 kHz (FAIL), +1.77 dB (PASS)

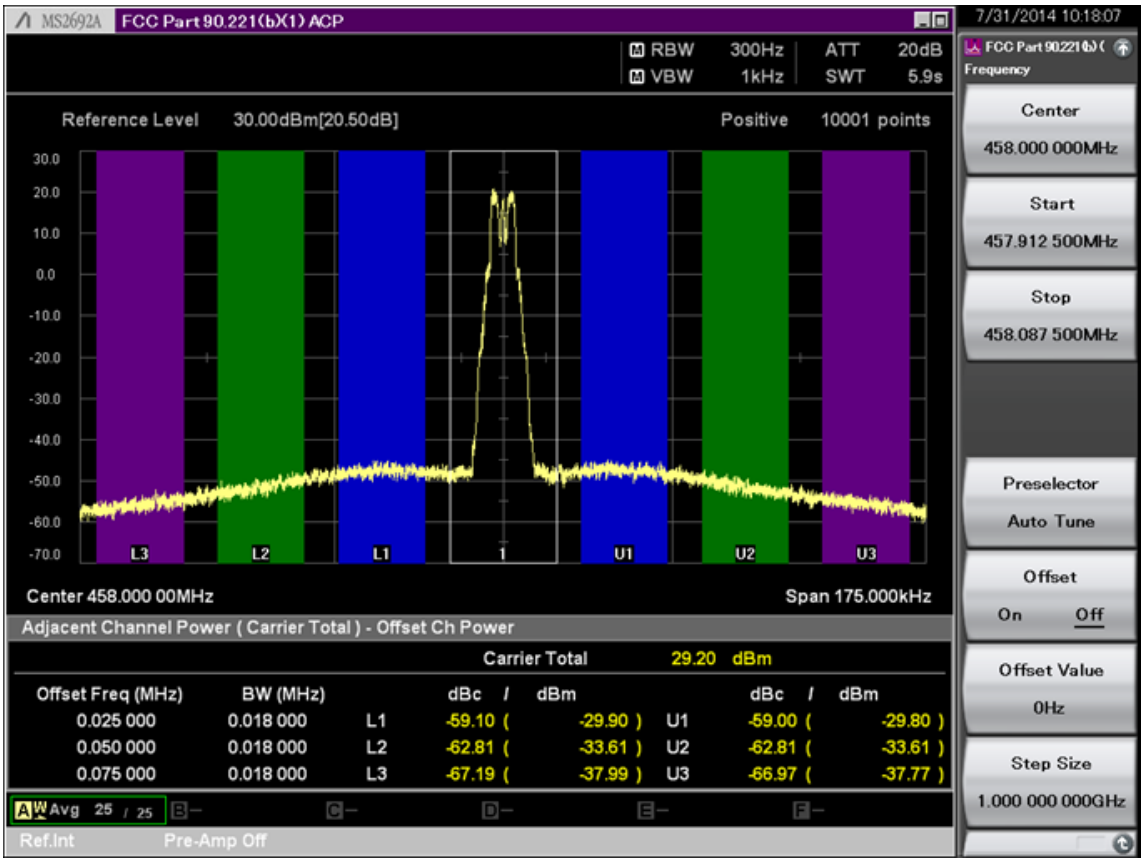


Figure 20. Adjacent Channel Power (Pout=+10 dBm, 458.0 M, 2GFSK DR=2.4 K Dev=2.0 K, BW=50 kHz)

3.9. FCC Part 90.203(j)(5) Spectrum Efficiency

Equipment capable of transmitting data, having transmitter output power greater than 500 mW, and having a channel bandwidth of more than 6.25 kHz must be capable of supporting a minimum data rate of 4800 bits per second per 6.25 kHz of channel bandwidth.

Compliance with this requirement is shown by demonstrating compliance with Mask E (e.g., a spectral mask with bandwidth=6.25 kHz) while operating with a data rate of DR=4.8 kbps. Compliance with this requirement is not possible when operating with 2GFSK; it is necessary to use 4GFSK modulation to provide the required level of spectral efficiency.

The spectrum analyzer was configured for:

- Detector Mode=Peak, ResBW=100 Hz, VidBW=300 Hz
- Max Hold
- Amplitude correction=20.5 dB (0.5dB for cable loss, 20dB to emulate External PA)

The measured spectral emissions mask at 458.0 MHz in the presence of 4GFSK modulation (B*T=0.5 SR=2.4K DR=4.8K Dev=0.4K) is shown in Figure 21. The Si446x family of chips complies with the requirements of FCC Part 90.203(j)(5) for Spectrum Efficiency at this frequency.

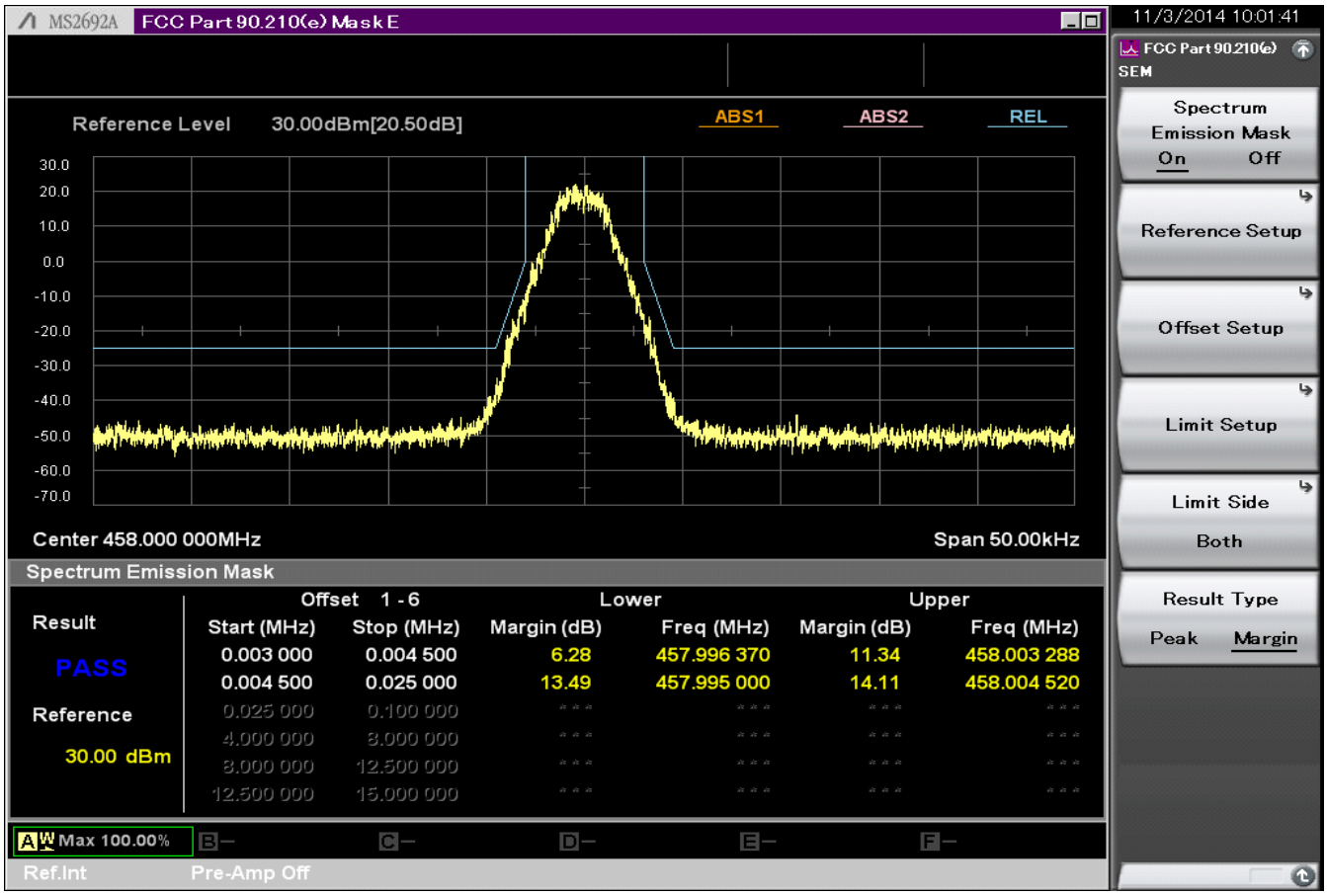


Figure 21. Emission Mask E (Pout=+10dBm, 458.0M, 4GFSK SR=2.4K DR=4.8K Dev=0.4KK)

.

4. Wireless Development Suite (WDS) TX Script Files

4.1. WDS Script for TX 458.0 MHz +10 dBm CW Configuration

TX measurements at F=458.0 MHz with output power = +10 dBm in CW mode used the following WDS script.

```
#BatchName TX 458.0 MHz ClassE +10dBm CW
# XO30M LoopBW=50kHz
# Revision Date:  7/31/2014, ModemCalc 1.1.0.2
# Start
RESET
'POWER_UP' 01 00 01 C9 C3 80
'PART_INFO'
'FUNC_INFO'
# Adjust Crystal Osc cap bank to center oscillator frequency
'SET_PROPERTY' 'GLOBAL_XO_TUNE' 4A
# Modem control group = CW
'SET_PROPERTY' 'MODEM_MOD_TYPE' 00
'SET_PROPERTY' 'MODEM_CLKGEN_BAND' 0A
# Synth control group = 50 kHz Loop BW, increased tuning range
'SET_PROPERTY' 'SYNTH_PFDCP_CPFF' 25
'SET_PROPERTY' 'SYNTH_PFDCP_CPINT' 0A
'SET_PROPERTY' 'SYNTH_VCO_KV' 0A
'SET_PROPERTY' 'SYNTH_LPFILT3' 03
'SET_PROPERTY' 'SYNTH_LPFILT2' 1F
'SET_PROPERTY' 'SYNTH_LPFILT1' 7F
'SET_PROPERTY' 'SYNTH_LPFILT0' 03
# Freq control group = 458.0 MHz, XO=30M
'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, +10 dBm
'SET_PROPERTY' 'PA_MODE' 08
'SET_PROPERTY' 'PA_PWR_LVL' 10
'SET_PROPERTY' 'PA_BIAS_CLKDUTY' 00
# GPIO configuration to control RFSW
# RX-State/NoChg/TX-State
'GPIO_PIN_CFG' 21 00 20 00 00 00
# Start transmitting
'START_TX' 00 00 00
```

4.2. WDS Script for TX 458.0 MHz +10 dBm 2GFSK DR=2.4 K Dev=2.0 K Configuration

TX measurements at F=458.0 MHz with output power = +10 dBm with modulation of 2GFSK DR=2.4 kbps Dev=2.0 kHz used the following WDS script.

```
#BatchName TX 458.0 MHz ClassE +10 dBm 2GFSK PN9
# XO30M DR=2.4kbps Dev=2.0kHz LoopBW=50kHz
# Revision Date:  7/31/2014, ModemCalc 1.1.0.2
# Start
RESET
'POWER_UP' 01 00 01 C9 C3 80
'PART_INFO'
'FUNC_INFO'
# Adjust Crystal Osc cap bank to center oscillator frequency
'SET_PROPERTY' 'GLOBAL_XO_TUNE' 4A
# Modem control group = 2GFSK PN9
'SET_PROPERTY' 'MODEM_MOD_TYPE' 13
'SET_PROPERTY' 'MODEM_CLKGEN_BAND' 0A
# Synth control group = 50 kHz Loop BW, increased tuning range
'SET_PROPERTY' 'SYNTH_PFDCP_CPFF' 25
'SET_PROPERTY' 'SYNTH_PFDCP_CPINT' 0A
'SET_PROPERTY' 'SYNTH_VCO_KV' 0A
'SET_PROPERTY' 'SYNTH_LPFILT3' 03
'SET_PROPERTY' 'SYNTH_LPFILT2' 1F
'SET_PROPERTY' 'SYNTH_LPFILT1' 7F
'SET_PROPERTY' 'SYNTH_LPFILT0' 03
# Freq control group = 458.0 MHz, XO=30M
'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, +10 dBm
'SET_PROPERTY' 'PA_MODE' 08
'SET_PROPERTY' 'PA_PWR_LVL' 10
'SET_PROPERTY' 'PA_BIAS_CLKDUTY' 00
# Tx parameters, DR=2.4kbps, Dev=2.0kHz
'SET_PROPERTY' 'MODEM_DATA_RATE_2' 01
'SET_PROPERTY' 'MODEM_DATA_RATE_1' 77
'SET_PROPERTY' 'MODEM_DATA_RATE_0' 00
'SET_PROPERTY' 'MODEM_TX_NCO_MODE_3' 05
'SET_PROPERTY' 'MODEM_TX_NCO_MODE_2' C9
'SET_PROPERTY' 'MODEM_TX_NCO_MODE_1' C3
'SET_PROPERTY' 'MODEM_TX_NCO_MODE_0' 80
'SET_PROPERTY' 'MODEM_FREQ_DEV_2' 00
'SET_PROPERTY' 'MODEM_FREQ_DEV_1' 00
'SET_PROPERTY' 'MODEM_FREQ_DEV_0' 8C
# GPIO configuration to control RFSW
# RX-State/NoChg/TX-State
'GPIO_PIN_CFG' 21 00 20 00 00 00
```

```
# Start transmitting
'START_TX' 00 00 00
```

4.3. WDS Script for TX 457.5 MHz +10 dBm DR=2.4 K Dev=2.0 K Configuration

TX measurements at F=457.5 MHz with output power = +10 dBm with modulation of 2GFSK DR=2.4 kbps Dev=2.0 kHz used the following WDS script.

```
#BatchName TX 457.5 MHz ClassE +10dBm 2GFSK PN9
# XO30M DR=2.4kbps Dev=2.0kHz LoopBW=50kHz
# Revision Date:  7/31/2014, ModemCalc 1.1.0.2
# Start
RESET
'POWER_UP' 01 00 01 C9 C3 80
'PART_INFO'
'FUNC_INFO'
# Adjust Crystal Osc cap bank to center oscillator frequency
'SET_PROPERTY' 'GLOBAL_XO_TUNE' 4A
# Modem control group = 2GFSK PN9
'SET_PROPERTY' 'MODEM_MOD_TYPE' 13
'SET_PROPERTY' 'MODEM_CLKGEN_BAND' 0A
# Synth control group = 50 kHz Loop BW, increased tuning range
'SET_PROPERTY' 'SYNTH_PFDCP_CPFF' 25
'SET_PROPERTY' 'SYNTH_PFDCP_CPINT' 0A
'SET_PROPERTY' 'SYNTH_VCO_KV' 0A
'SET_PROPERTY' 'SYNTH_LPFILT3' 03
'SET_PROPERTY' 'SYNTH_LPFILT2' 1F
'SET_PROPERTY' 'SYNTH_LPFILT1' 7F
'SET_PROPERTY' 'SYNTH_LPFILT0' 03
# Freq control group = 457.5 MHz, XO=30M
'SET_PROPERTY' 'FREQ_CONTROL_INTE' 3C
'SET_PROPERTY' 'FREQ_CONTROL_FRAC_2' 08
'SET_PROPERTY' 'FREQ_CONTROL_FRAC_1' 00
'SET_PROPERTY' 'FREQ_CONTROL_FRAC_0' 00
'SET_PROPERTY' 'FREQ_CONTROL_W_SIZE' 20
# PA control group = Class-E, +10 dBm
'SET_PROPERTY' 'PA_MODE' 08
'SET_PROPERTY' 'PA_PWR_LVL' 10
'SET_PROPERTY' 'PA_BIAS_CLKDUTY' 00
# Tx parameters, DR=2.4kbps, Dev=2.0kHz
'SET_PROPERTY' 'MODEM_DATA_RATE_2' 01
'SET_PROPERTY' 'MODEM_DATA_RATE_1' 77
'SET_PROPERTY' 'MODEM_DATA_RATE_0' 00
'SET_PROPERTY' 'MODEM_TX_NCO_MODE_3' 05
'SET_PROPERTY' 'MODEM_TX_NCO_MODE_2' C9
'SET_PROPERTY' 'MODEM_TX_NCO_MODE_1' C3
'SET_PROPERTY' 'MODEM_TX_NCO_MODE_0' 80
'SET_PROPERTY' 'MODEM_FREQ_DEV_2' 00
'SET_PROPERTY' 'MODEM_FREQ_DEV_1' 00
'SET_PROPERTY' 'MODEM_FREQ_DEV_0' 8C
```

```
# GPIO configuration to control RFSW
# RX-State/NoChg/TX-State
'GPIO_PIN_CFG' 21 00 20 00 00 00
# Start transmitting
'START_TX' 00 00 00
```

4.4. WDS Script for TX 457.50625 MHz +10dBm CW Configuration

TX measurements at F=457.50625 MHz with output power = +10 dBm in CW mode used the following WDS script.

```
#BatchName TX 457.50625 MHz ClassE +10dBm CW
# XO30M LoopBW=50kHz
# Revision Date:  7/31/2014, ModemCalc 1.1.0.2
# Start
RESET
'POWER_UP' 01 00 01 C9 C3 80
'PART_INFO'
'FUNC_INFO'
# Adjust Crystal Osc cap bank to center oscillator frequency
'SET_PROPERTY' 'GLOBAL_XO_TUNE' 4A
# Modem control group = CW
'SET_PROPERTY' 'MODEM_MOD_TYPE' 00
'SET_PROPERTY' 'MODEM_CLKGEN_BAND' 0A
# Synth control group = 50 kHz Loop BW, increased tuning range
'SET_PROPERTY' 'SYNTH_PFDCP_CPFF' 25
'SET_PROPERTY' 'SYNTH_PFDCP_CPINT' 0A
'SET_PROPERTY' 'SYNTH_VCO_KV' 0A
'SET_PROPERTY' 'SYNTH_LPFILT3' 03
'SET_PROPERTY' 'SYNTH_LPFILT2' 1F
'SET_PROPERTY' 'SYNTH_LPFILT1' 7F
'SET_PROPERTY' 'SYNTH_LPFILT0' 03
# Freq control group = 457.50625 MHz, XO=30M
'SET_PROPERTY' 'FREQ_CONTROL_INTE' 3C
'SET_PROPERTY' 'FREQ_CONTROL_FRAC_2' 08
'SET_PROPERTY' 'FREQ_CONTROL_FRAC_1' 01
'SET_PROPERTY' 'FREQ_CONTROL_FRAC_0' B4
'SET_PROPERTY' 'FREQ_CONTROL_W_SIZE' 20
# PA control group = Class-E, +10 dBm
'SET_PROPERTY' 'PA_MODE' 08
'SET_PROPERTY' 'PA_PWR_LVL' 10
'SET_PROPERTY' 'PA_BIAS_CLKDUTY' 00
# GPIO configuration to control RFSW
# RX-State/NoChg/TX-State
'GPIO_PIN_CFG' 21 00 20 00 00 00
# Start transmitting
'START_TX' 00 00 00
```

4.5. WDS Script for TX 458.0 MHz +10 dBm 2GFSK DR=2.0 K Dev=1.0 K Configuration

TX measurements at F=458.0 MHz with output power=+10 dBm with modulation of 2GFSK DR=2.0 kbps Dev=1.0 kHz used the following WDS script.

```
#BatchName TX 458.0 MHz ClassE +10dBm 2GFSK PN9
# XO30M DR=2.0kbps Dev=1.0kHz LoopBW=50kHz
# Revision Date:  7/31/2014, ModemCalc 1.1.0.2
# Start
RESET
'POWER_UP' 01 00 01 C9 C3 80
'PART_INFO'
'FUNC_INFO'
# Adjust Crystal Osc cap bank to center oscillator frequency
'SET_PROPERTY' 'GLOBAL_XO_TUNE' 4A
# Modem control group = 2GFSK PN9
'SET_PROPERTY' 'MODEM_MOD_TYPE' 13
'SET_PROPERTY' 'MODEM_CLKGEN_BAND' 0A
# Synth control group = 50 kHz Loop BW, increased tuning range
'SET_PROPERTY' 'SYNTH_PFDCP_CPFF' 25
'SET_PROPERTY' 'SYNTH_PFDCP_CPINT' 0A
'SET_PROPERTY' 'SYNTH_VCO_KV' 0A
'SET_PROPERTY' 'SYNTH_LPFILT3' 03
'SET_PROPERTY' 'SYNTH_LPFILT2' 1F
'SET_PROPERTY' 'SYNTH_LPFILT1' 7F
'SET_PROPERTY' 'SYNTH_LPFILT0' 03
# Freq control group = 458.0 MHz, XO=30M
'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, +10 dBm
'SET_PROPERTY' 'PA_MODE' 08
'SET_PROPERTY' 'PA_PWR_LVL' 10
'SET_PROPERTY' 'PA_BIAS_CLKDUTY' 00
# Tx parameters, DR=2.0kbps, Dev=1.0kHz
'SET_PROPERTY' 'MODEM_DATA_RATE_2' 01
'SET_PROPERTY' 'MODEM_DATA_RATE_1' 38
'SET_PROPERTY' 'MODEM_DATA_RATE_0' 80
'SET_PROPERTY' 'MODEM_TX_NCO_MODE_3' 05
'SET_PROPERTY' 'MODEM_TX_NCO_MODE_2' C9
'SET_PROPERTY' 'MODEM_TX_NCO_MODE_1' C3
'SET_PROPERTY' 'MODEM_TX_NCO_MODE_0' 80
'SET_PROPERTY' 'MODEM_FREQ_DEV_2' 00
'SET_PROPERTY' 'MODEM_FREQ_DEV_1' 00
'SET_PROPERTY' 'MODEM_FREQ_DEV_0' 46
# GPIO configuration to control RFSW
# RX-State/NoChg/TX-State
'GPIO_PIN_CFG' 21 00 20 00 00 00
```

```
# Start transmitting
'START_TX' 00 00 00
```

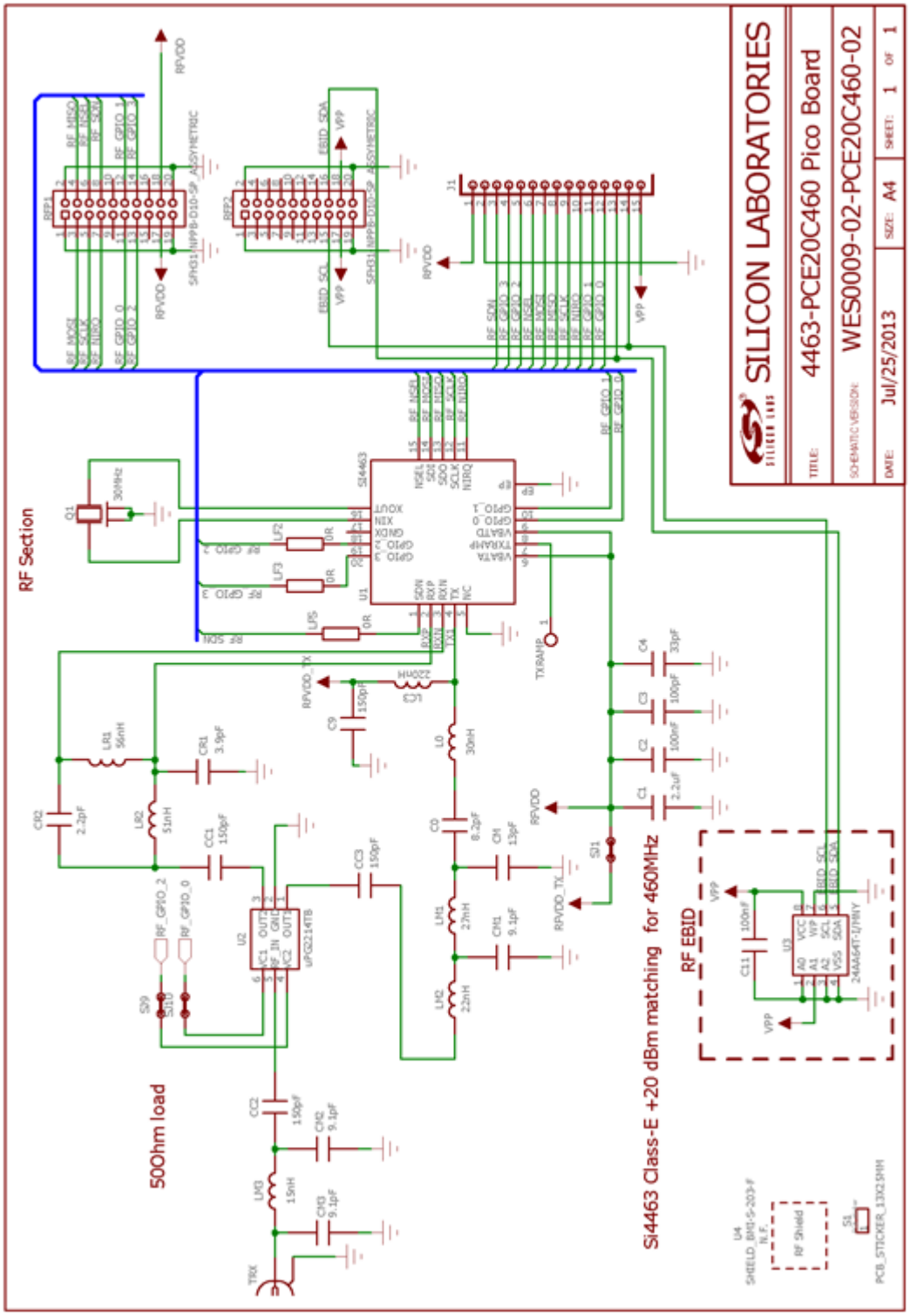
4.6. WDS Script for TX 458.0 MHz +10 dBm 2GFSK DR=2.4 K Dev=2.0 K Packet

TX measurements of packets at F=458.0 MHz with output power=+10 dBm with modulation of 2GFSK DR=2.4 kbps Dev=2.0 kHz used the following WDS script.

```
#BatchName TX 458.0 MHz ClassE +10dBm 2GFSK Packet
# XO30M DR=2.4kbps Dev=2.0kHz LoopBW=50kHz
# Revision Date:  7/31/2014, ModemCalc 1.1.0.2
# Start
RESET
'POWER_UP' 01 00 01 C9 C3 80
'PART_INFO'
'FUNC_INFO'
# Adjust Crystal Osc cap bank to center oscillator frequency
'SET_PROPERTY' 'GLOBAL_XO_TUNE' 4A
# General parameters, Mod Type = 2GFSK, Packet FIFO
'SET_PROPERTY' 'MODEM_MOD_TYPE' 03
'SET_PROPERTY' 'MODEM_CLKGEN_BAND' 0A
# Synth control group = 50 kHz Loop BW, increased tuning range
'SET_PROPERTY' 'SYNTH_PFDCP_CPFF' 25
'SET_PROPERTY' 'SYNTH_PFDCP_CPINT' 0A
'SET_PROPERTY' 'SYNTH_VCO_KV' 0A
'SET_PROPERTY' 'SYNTH_LPFILT3' 03
'SET_PROPERTY' 'SYNTH_LPFILT2' 1F
'SET_PROPERTY' 'SYNTH_LPFILT1' 7F
'SET_PROPERTY' 'SYNTH_LPFILT0' 03
# Freq control group = 458.0 MHz, XO=30M
'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, +10 dBm
'SET_PROPERTY' 'PA_MODE' 08
'SET_PROPERTY' 'PA_PWR_LVL' 10
'SET_PROPERTY' 'PA_BIAS_CLKDUTY' 00
'SET_PROPERTY' 'PA_TC' 5E
# Tx parameters, DR=2.4kbps, Dev=2.0kHz
'SET_PROPERTY' 'MODEM_DATA_RATE_2' 01
'SET_PROPERTY' 'MODEM_DATA_RATE_1' 77
'SET_PROPERTY' 'MODEM_DATA_RATE_0' 00
'SET_PROPERTY' 'MODEM_TX_NCO_MODE_3' 05
'SET_PROPERTY' 'MODEM_TX_NCO_MODE_2' C9
'SET_PROPERTY' 'MODEM_TX_NCO_MODE_1' C3
'SET_PROPERTY' 'MODEM_TX_NCO_MODE_0' 80
'SET_PROPERTY' 'MODEM_FREQ_DEV_2' 00
'SET_PROPERTY' 'MODEM_FREQ_DEV_1' 00
```

```
'SET_PROPERTY' 'MODEM_FREQ_DEV_0' 8C
'SET_PROPERTY' 'MODEM_TX_RAMP_DELAY' 01
# Tx Packet control group
'SET_PROPERTY' 'PREAMBLE_TX_LENGTH' 08
'SET_PROPERTY' 'PREAMBLE_CONFIG' 02
'SET_PROPERTY' 'SYNC_CONFIG' 01
'SET_PROPERTY' 'SYNC_BITS_31_24' B4
'SET_PROPERTY' 'SYNC_BITS_23_16' 2B
# Set fixed packet length, Field-1 = 4 bytes
'SET_PROPERTY' 'PKT_LEN' 00
'SET_PROPERTY' 'PKT_FIELD_1_LENGTH_12_8' 00
'SET_PROPERTY' 'PKT_FIELD_1_LENGTH_7_0' 04
# Load 10-bytes of arbitrary data into TX FIFO
'WRITE_TX_FIFO' 11 22 33 44
# GPIO configuration to control RFSW
# RX-State/NoChg/TX-State
'GPIO_PIN_CFG' 21 00 20 00 00 00
# Start transmitting, return to READY after packet
'START_TX' 00 30 00 00
```

5. Reference Design Schematic



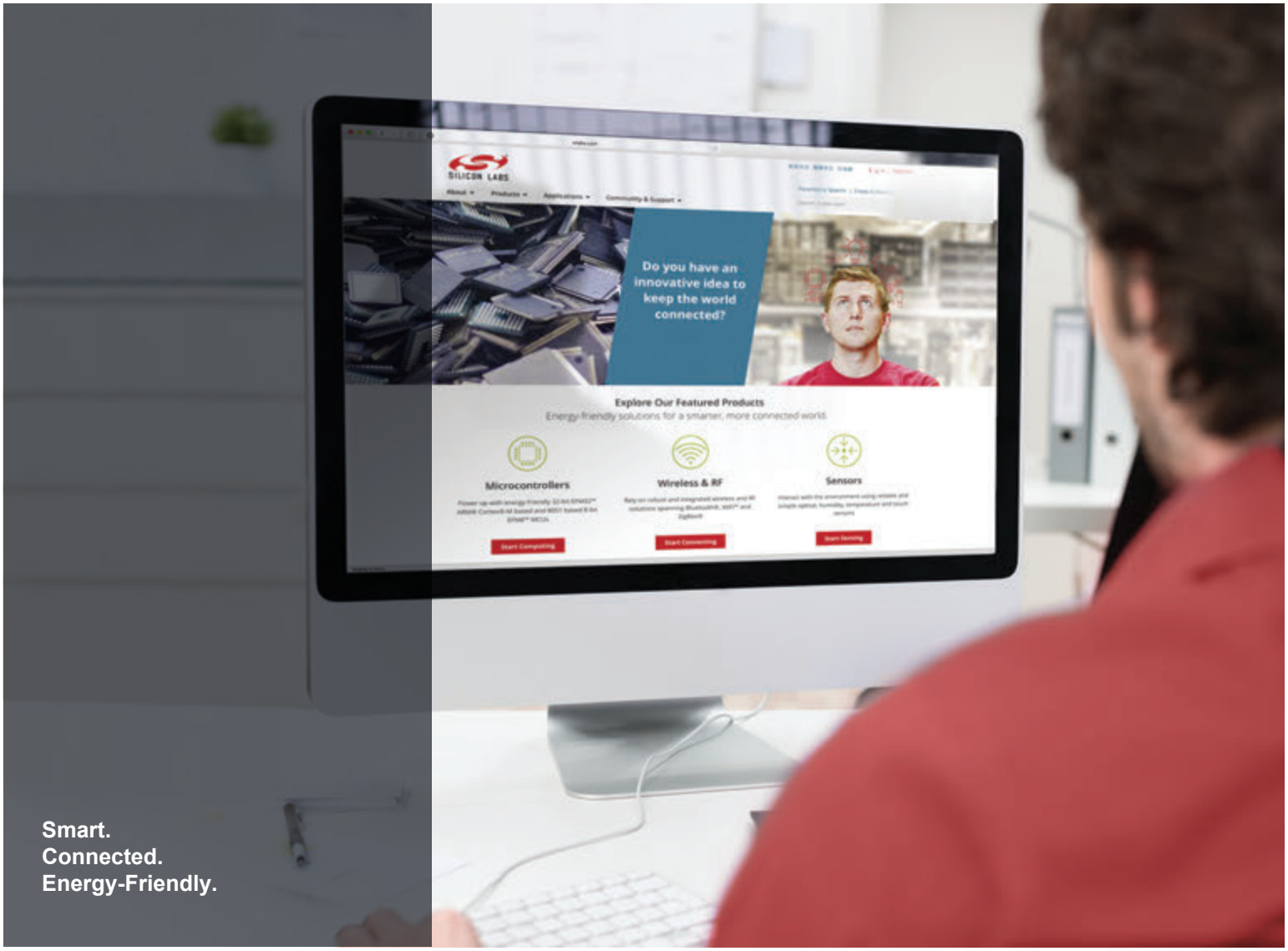
DOCUMENT CHANGE LIST

Revision 0.1 to 0.2

- Added sections for compliance with Part 90.203(j)(5) Spectrum Efficiency

Revision 0.2 to 0.3

- Changed text from FCC Part 15.203(j)(5) to FCC Part 90.203(j)(5) in section 2.9 heading



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