Si470x/1x/2x/3x/4x EVALUATION BOARD TEST PROCEDURE

1. Introduction

The purpose of this document is to describe the test procedures used in Silicon Laboratories for the Si470x/1x/2x/3x/4x evaluation boards (EVB). It is also intended to enable customers to exactly replicate Silicon Laboratories' test environment so that variances in customers' and Silicon Laboratories' measured results can be accurately compared. This document covers AM, FM, and weather band tests for the Si470x/1x/2x/3x/4x receivers and FM tests for Si471x/2x transmitters. The pass/fail criteria for each test are provided in the respective data sheets.

The Si470x/1x/2x/3x/4x evaluation boards and software provide a platform to program, test, and operate the Si470x/1x/2x/3x/4x devices. The system consists of two boards: a baseboard and an RF daughter card. The baseboard provides all necessary support functions, including a USB-based programming interface, digital/analog audio input and output connection points, optional external clock input, and the RF reference clock source. In addition, the baseboard provides an S/PDIF transceiver for converting analog audio input/output to I2S and a codec for converting analog audio input/output to I2S digital input/output. The RF daughter card changes for each device. For devices with receive functionality (Si470x/2x/3x), it contains the tuner, connection points for RF input, and audio amplifier. For devices with transmit functionality, it contains the transmitter, connection points for RF measurement, a trace antenna, and a connection for an external loop antenna. Refer to the individual-EVB User's Guides for detailed explanations of the EVB hardware and software.

Table 1 summarizes the functionality of each device in the family.

Table 1. Product Family Function

Part Number	General Description	FM Transmit	FM Receiver	AM Receiver	SW/LW Receiver	WB Receiver	RDS	RPS	SAME	Digital Input or Output
Si4700	FM Receiver		✓							
Si4701	FM Receiver w/ RDS		✓				✓			
Si4702	FM Receiver		✓							
Si4703	FM Receiver w/ RDS		✓				✓			
Si4704	FM Receiver		✓							
Si4705	FM Receiver w/ RDS		✓				✓			✓
Si4706	RDS Only Receiver						✓			
Si4707	WB Receiver w/ SAME					✓			✓	
Si4708	FM Receiver		✓							
Si4709	FM Receiver w/ RDS		✓				✓			

Table 1. Product Family Function

Part Number	General Description	FM Transmit	FM Receiver	AM Receiver	SW/LW Receiver	WB Receiver	RDS	RPS	SAME	Digital Input or Output
Si4710	FM Transmitter	✓								
Si4711	FM Transmitter w/ RDS	✓					✓			✓
Si4712	FM Transmitter w/ RPS	✓						✓		
Si4713	FM Transmitter w/ RDS & RPS	✓					✓	✓		✓
Si4720	FM Transceiver	✓	✓							
Si4721	FM Transceiver w/ RDS	✓	✓				✓			✓
Si4730	AM / FM Receiver		✓	✓						
Si4731	AM / FM Receiver w/ RDS		✓	✓			✓			✓
Si4734	AM / SW / LW / FM Receiver		✓	✓	✓					
Si4735	AM / SW / LW/ FM Receiver w/ RDS		✓	✓	✓		✓			✓
Si4736	AM / FM / WB Receiver		✓	✓		✓				
Si4737	AM / FM / WB Receiver w/ RDS		✓	✓		✓	✓			✓
Si4738	FM / WB Receiver		✓			✓				
Si4739	FM / WB Receiver w/ RDS		✓			✓	✓			✓

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Table 1. Product Family Function

Part Number	General Description	FM Transmit	FM Receiver	AM Receiver	SW/LW Receiver	WB Receiver	RDS	RPS	SAME	Digital Input or Output
Si4740	AM / FM Receiver		✓	✓						
Si4741	AM / FM Receiver w/ RDS		✓	✓			✓			
Si4742	AM / FM/ LW/ SW Receiver		✓	✓	✓					
Si4743	AM / FM/ LW/ SW Receiver w/ RDS		✓	✓	✓		✓			
Si4749	RDS Only Receiver						✓			

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2. FM Tuner Testing

This section covers testing the FM specs for the Si470x/2x/3x receiver. Table 2 provides a summary of tests and equipment. Refer to the individual figures that show the instrument configurations used to generate test reports for FM testing of each EVB.

Table 2. Si470x/2x/3x/4x FM Tuner Test Equipment

| Test	Equipment
Sensitivity RDS Sensitivity AM Suppression Spurious Response Audio Output Voltage Audio Output L/R Imbalance Audio Band Limits Stereo Separation Audio THD Audio SINAD Audio SNR Pilot Suppression	Rohde & Schwarz UPL Audio Analyzer (with digital audio functionality) Rohde & Schwarz SML01 + Stereo/RDS Signal Generator #1 Agilent E3646A Power Supply* Mini-Circuits Power Combiner
Image Rejection Selectivity IP3	Equipment above plus: Rohde & Schwarz SML01 Signal Generator #2
*Note: You can power up the EVB through the USB port for these tests.	

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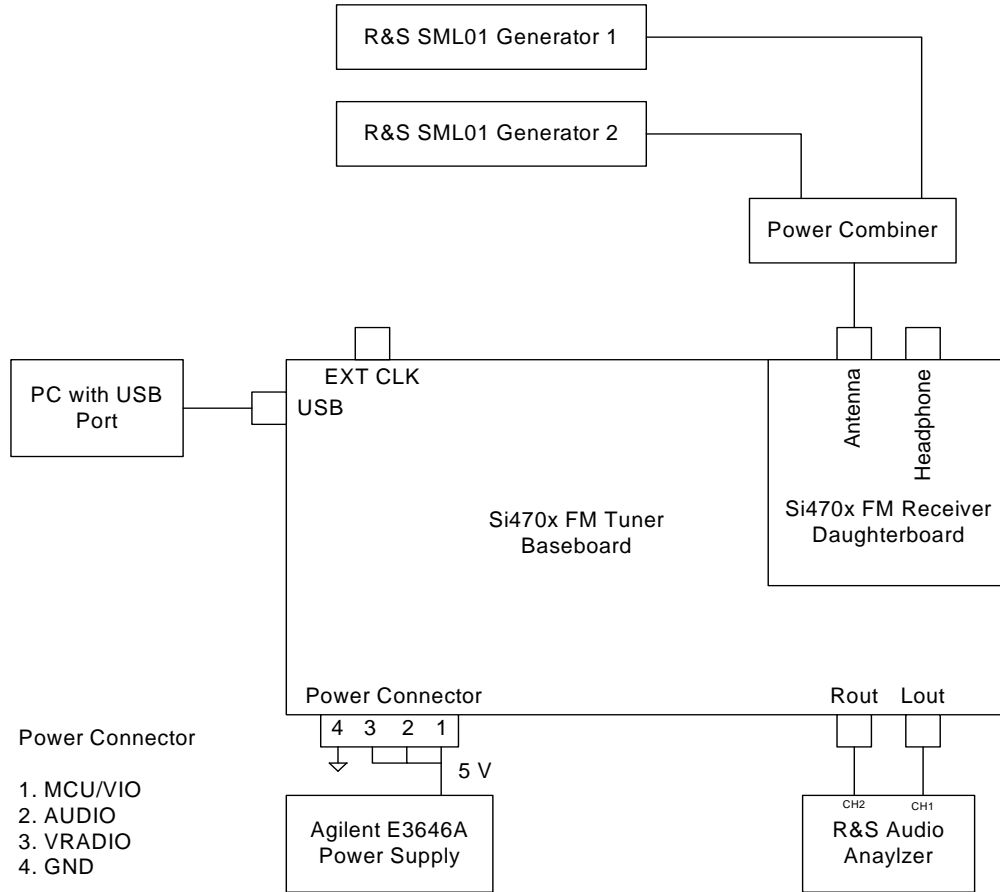
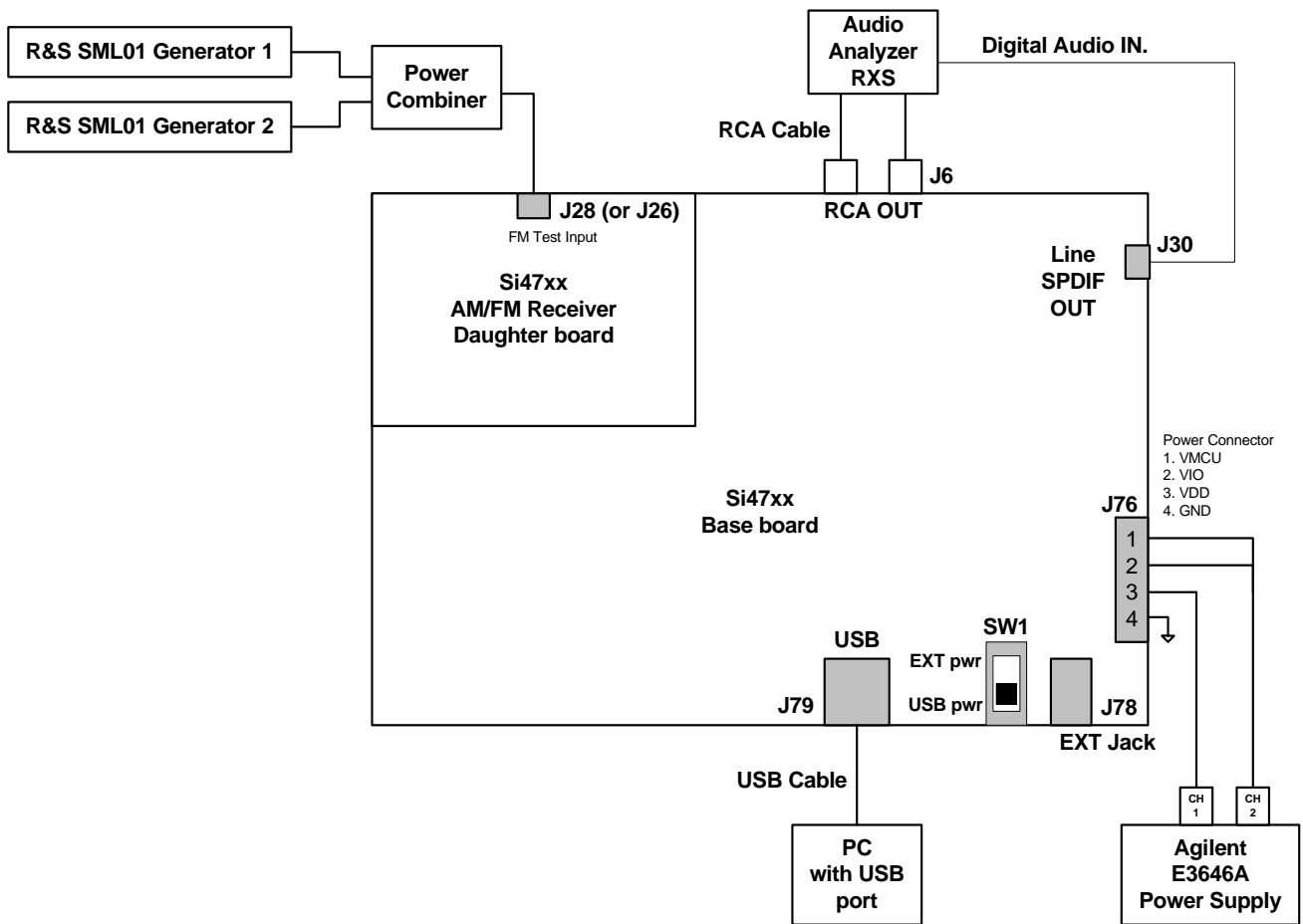**Figure 1. Si4700/01/02/03/08/09 FM Tuner Setup**

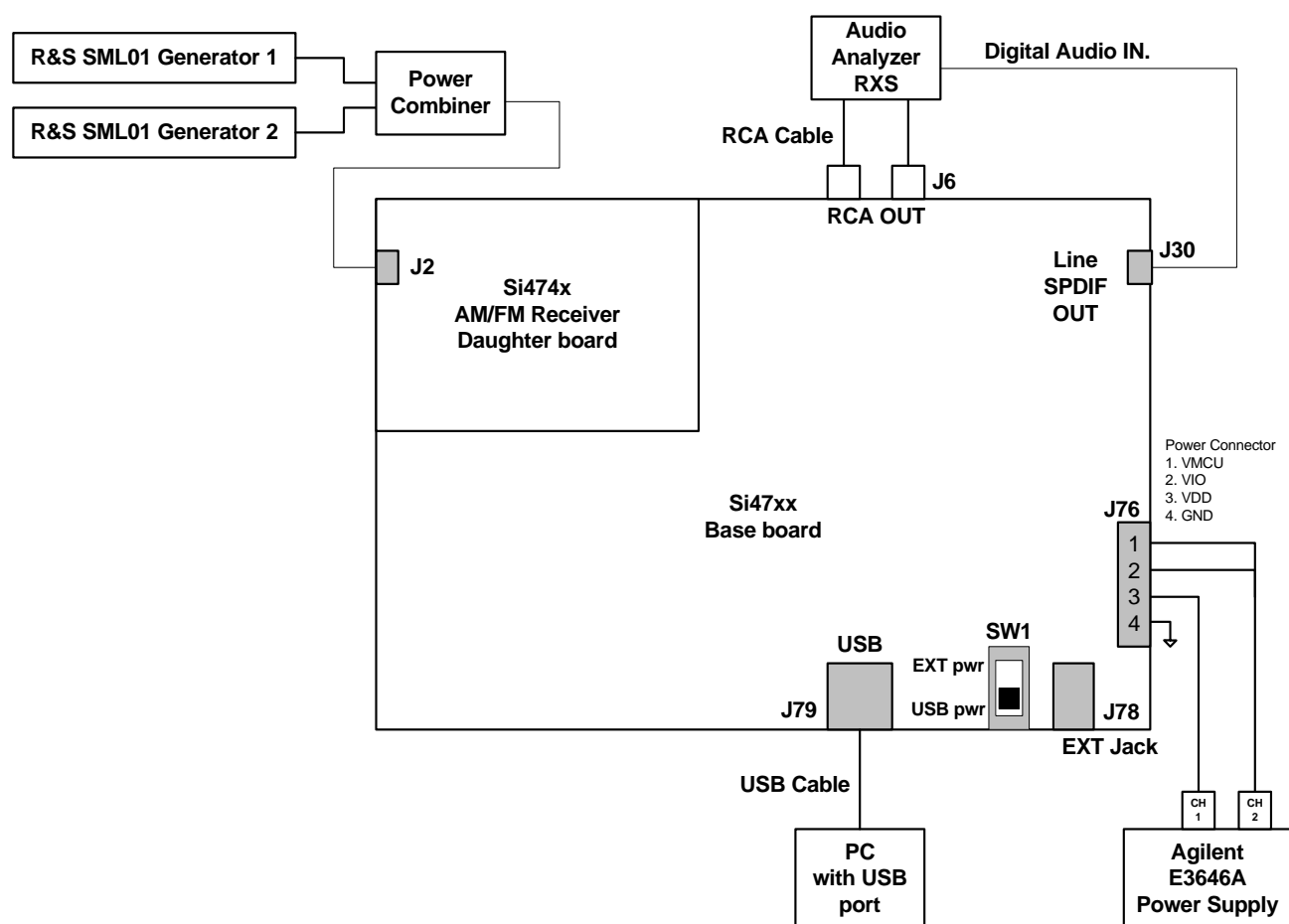**Figure 2. Si4704/05/2x/3x FM Tuner Setup**

Figure 3. Si474x FM Tuner Setup

2.1. FM Tuner Testing Measurement Considerations

Several issues must be considered to make accurate measurements.

First, the power combiner and cable losses must be calibrated and factored into each measurement. The loss for the Mini-Circuit power combiner is approximately 6 dB.

Second, most signal generators display the voltage generated at the input of the device under test (DUT) assuming an input resistance of 50 Ω. For example, if the signal generator displays V_L = 1 µV (0 dBµV), the generator source voltage V_S is 2 µV (6 dBµV). The load voltage V_L is generated from the source voltage V_S by the voltage divider created by the 50 Ω generator source resistance R_S and the 50 Ω load resistance R_L. This distinction is important only for sensitivity, RDS sensitivity, and IP3, which are specified in µV electromotive force (EMF), where EMF refers to the source voltage V_S. Measurements such as AM suppression, selectivity, and spurious response are relative and may be referenced using V_S or V_L. To summarize, the generator displays the voltage at the input of the DUT. In the case of Si47xx FM tuner, input impedance is high; therefore, to convert the value displayed on the signal generator to EMF, double the voltage (add 6 dB).

2.2. FM Tuner Configuration

2.2.1. Si4700/01/02/03/08/09 Standard Configuration

1. Set frequency = 98.1 MHz.
2. Set mono = On.
3. Set AGC = On.
4. Set volume = 0xF.
5. Set de-emphasis = 75 µs.
6. Set soft mute = Off.

2.2.2. Si4704/05/2x/3x/4x Standard Configuration

1. Set frequency = 98.1 MHz.
2. Set stereo blend mono threshold = 127.
3. Set stereo blend stereo threshold = 127.
4. Set AGC override = Off.
5. Set volume = 63.
6. Set de-emphasis = 75 µs.
7. Set soft mute attenuation = 0.
8. Set soft mute SNR threshold = 0.

2.2.3. Other FM Tuner Settings

Table 3. FM Tuner Settings

Tuner Setting	Si4700/01/02/03	Si4704/05/2x/3x/4x
Set RDS On	Set RDS = On	Set RDS State = On
Set AGC Off	Set AGC = Off	Set AGC Override = On
Set Stereo Mode	Set Mono = Off	Set Stereo Blend Mono Threshold = 0 Set Stereo Blend Stereo Threshold = 0

2.2.4. FM Tuner and EVB CODEC/SPDIF Settings in Digital Mode

These settings are only applicable to Si4704/05/2x/3x tuners and their EVBs whenever digital audio output is selected.

2.2.4.1. Si4704/05/2x/3x/4x Standard Configuration in Digital Audio Output Mode

1. Set frequency = 98.1 MHz.
2. Set stereo blend mono threshold = 127.
3. Set AGC override = Off.
4. Set volume = 63.
5. Set de-emphasis = 75 µs.
6. Set soft mute attenuation = 0.
7. Set digital mono mode enable = On.
8. Set digital format = I2S.
9. Set digital sample precision = 24 bit.
10. Set digital sample rate = 48000.
11. Set CODEC precision = 24 bit.
    a. Set CODEC output format = I2S.
    b. Set CODEC sampling rate = 48 kHz.
    c. Set SPDIF output format = I2S.

2.2.4.2. Other Settings in Digital Audio Output Mode

AGC and RDS settings are the same as analog mode.

To set the stereo mode:

1. Set stereo blend mono threshold = 0.
2. Set stereo blend stereo threshold = 0.
3. Set digital mono mode enable = Off.

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2.3. FM Test Procedures

The following procedures measure analog audio output. All audio measurements can be duplicated for digital audio output where applicable. For audio analyzer settings in digital mode, refer to Section 6.1.

2.3.1. Sensitivity

Sensitivity of a receiver is a measure of its ability to receive weak signals and produce an audio frequency output of usable magnitude and acceptable quality. Sensitivities may be defined with respect to many different characteristics of the output signal. For the purposes of our testing, sensitivity is the minimum RF level required to produce an audio output with a specified signal-to-noise and distortion ratio, 26 dB. Please note that the sensitivity measurement is defined with respect to SINAD and not SNR. Descriptions for these two measurements will be given in the following sections.

1. Connect test equipment as shown in Figures 1, 2, or 3.
2. Configure the tuner in standard configuration.
3. Configure the audio analyzer:
    a. Select Analyze.
    b. Set Function = THD+N / SINAD.
        i. Set Measurement Mode = SINAD.
        ii. Set Unit = dB.
        iii. Set Filter = A-weighting.
        iv. Set Frequency Limit Low = 300 Hz.
        v. Set Frequency Limit High = 15000 Hz.
4. Configure generator #1:
    a. Set carrier frequency = 98.1 MHz.
    b. Select FM Modulation.
        i. Set FM Deviation = 22.5 kHz.
        ii. Set Source = LFGEN.
        iii. Set LFGEN frequency = 1 kHz.
    c. Enable modulation.
    d. Enable carrier.
5. Disable generator #2.
6. Adjust generator #1 RF level, V_{RF0}, until audio analyzer SINAD = 26 dB +/- 1 dB.
7. Sensitivity (µV) = V_{RF0}.

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2.3.2. THD

The total harmonic distortion, or THD, is a measurement of the harmonic distortion present at the audio output and is defined as the ratio of the sum of the powers of all harmonic components calculated in RMS fashion to the power of the fundamental.

1. Connect test equipment as shown in Figures 1, 2, or 3.
2. Configure the tuner in standard configuration.
3. Configure the audio analyzer:
   a. Select Analyze.
   b. Set Function = THD.
      i.   Set Measurement Mode = All di (all harmonics).
      ii. Select Unit = %.
4. Configure generator #1:
   a. Set carrier frequency = 98.1 MHz.
   b. Select FM Modulation.
      i.   Set FM Deviation = 75 kHz.
      ii. Set RF level = 60 dBµV.
      iii. Set source = LFGEN.
      iv. Set LFGEN frequency = 1 kHz.
   c. Enable modulation.
   d. Enable carrier.
5. Disable generator #2.
6. Record THD (%).

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2.3.3. RDS Sensitivity

RDS sensitivity is the minimum RF level required to produce an audio output with a specified Block Error Rate (BLER), 5%. BLER is a ratio of the number of data blocks received with at least one un-correctable bit to the number of blocks received.

1. Connect test equipment as shown in Figures 1, 2, or 3.
2. Configure the tuner in standard configuration.
3. Set RDS ON.
4. Configure generator #1:
   a. Set carrier frequency = 98.1 MHz.
   b. Set RF level = 15 µV (target sensitivity level).
   c. Select stereo modulation.
      i.   Set FM Deviation = 22.5 kHz.
      ii.   Set L = R.
      iii. Set source = LFGEN.
      iv.   Set LFGEN frequency = 1 kHz.
      v.   Set Pre-emphasis = 75 µs.
      vi.   Set Pilot = ON.
      vii. Set Pilot Deviation = 6.75 kHz.
      viii. Set RDS = ON.
      ix.   Set RDS Deviation = 2 kHz.
      x.   Set RDS Data Set = 1.
      xi.   Set Traffic Announcement = OFF.
      xii. Set Traffic Program = OFF.
   d. Enable modulation.
   e. Enable carrier.
5. Disable generator #2.
6. Adjust generator #1 RF level, V_{RF0}, until BLER = 5%.*
7. Sensitivity (µV) = V_{RF0}.

*__Note:__ Block Error Rate (BLER) measurement settles approximately in 20 seconds. Because the Silicon Laboratories automated test system configures the generator after the tuner, the BLER reading should be allowed to update twice before it is considered valid. Alternatively, the tuner could be configured after the generator and the BLER reading would be valid after one update.

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2.3.4. RDS BLER

BLER stands for block error rate, which is a ratio of number of data blocks received with at least one un-correctable bit to the number of blocks received. This test is often used to test the RDS Sensitivity (BLER <5%) specification during production.

1. Connect test equipment as shown in Figures 1, 2, or 3.
2. Configure the tuner in standard configuration.
3. Set RDS ON
4. Configure generator #1:
   a. Set carrier frequency = 98.1 MHz.
   b. Set RF level = 18 uV (target RDS sensitivity level + 3 µV).
   c. Select stereo modulation
      i.   Set FM Deviation = 22.5 kHz.
      ii. Set L=R.
      iii. Set Source = LFGEN.
      iv. Set LFGEN frequency = 1 kHz.
      v.   Set Pre-emphasis = 75 µs.
      vi. Set Pilot = ON.
      vii. Set Pilot Deviation = 6.75 kHz.
      viii.Set RDS = ON.
      ix. Set RDS Deviation = 2 kHz.
      x.   Set RDS Data Set = 1.
      xi. Set Traffic Announcement = OFF.
      xii. Set Traffic Program = OFF.
   d. Enable modulation.
   e. Enable carrier.
5. Read BLER * from the GUI after 22 seconds.

*__Note:__ Block Error Rate (BLER) measurement settles approximately in 20 seconds. Because the Silicon Laboratories automated test system configures the generator after the tuner, the BLER reading should be allowed to update twice before it is considered valid. Alternatively, the tuner could be configured after the generator and the BLER reading would be valid after an update.

2.3.5. RDS Persistence

RDS Sync is influenced by the signal quality and strength. Once the RDS is synchronized, the FM tuner has the ability to maintain its synchronization even with high BLER and fading signal strength. This test measures the ability to maintain RDS Sync in degrading signal condition.

1. Connect test equipment as shown in Figures 1, 2, or 3.
2. Configure the tuner in standard configuration.
3. Set RDS ON.
4. Configure generator #1:
   a. Set carrier frequency = 98.1 MHz.
   b. Set RF level = 15 uV (RDS sensitivity level).
   c. Select stereo modulation.
      i.   Set FM Deviation = 22.5 kHz.
      ii.   Set L=R.
      iii. Set Source = LFGEN.
      iv.   Set LFGEN frequency = 1 kHz.
      v.   Set Pre-emphasis = 75 µs.
      vi.   Set Pilot = ON.
      vii. Set Pilot Deviation = 6.75 kHz.
      viii. Set RDS = ON.
      ix.   Set RDS Deviation = 2 kHz.
      x.   Set RDS Data Set = 1.
      xi.   Set Traffic Announcement = OFF.
      xii. Set Traffic Program = OFF.
   d. Enable modulation.
   e. Enable carrier.
5. Slowly decrease the RF level until green "RDS"display on the main window of the Si47xx GUI goes off.
6. Record the RF level and BLER after 22 seconds.

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2.3.6. SNR

The signal-to-noise ratio of a receiver, under specified conditions, is the ratio of the audio frequency output voltage due to the signal to that due to random noise. The noise may be measured using different filtering techniques. The technique used in this document is the A-weighting filter. Weighting filters are used to determine the loudness of sounds, particularly noise. A-weighting filter is commonly used to emphasize frequencies around 3–6 kHz, where the human ear is most sensitive, while attenuating very high and very low frequencies to which the ear is insensitive. The aim is to ensure that measured loudness corresponds well with subjectively perceived loudness. A-weighting is only really valid for relatively quiet sounds and for pure tones.

1. Connect test equipment as shown in Figures 1, 2, or 3.
2. Configure the tuner in standard configuration.
3. Configure the audio analyzer:
   a. Select Analyze.
      i.   Set Input DISP = RMS.
      ii. Set Units = dBV.
      iii. Set Function = THD+N / SINAD.
         ● Set Measurement Mode = LEVEL NOISE.
         ● Set Units = dBV.
         ● Set Filter = A-weighting.
         ● Set Frequency Limit Low = 300 Hz.
         ● Set Frequency Limit Upper = 15000 Hz.
4. Configure generator #1:
   a. Set carrier frequency = 98.1 MHz.
   b. Set RF level = 60 dBµV.
   c. Select FM Modulation.
      i.   Set FM Deviation = 22.5 kHz.
      ii. Set source = LFGEN.
      iii. Set LFGEN frequency = 1 kHz.
   d. Enable modulation.
   e. Enable carrier.
5. Disable generator #2.
6. Record SNR (dB) = Input RMS(dBV) – Level Noise (dBV).

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2.3.7. SINAD

Signal to noise and distortion (SINAD) is similar to signal to noise ratio, but includes distortion and is a ratio of "signal plus noise plus distortion" to "noise plus distortion." To make the SINAD measurement, a signal modulated with an audio tone is entered into the receiver. A measurement of the whole signal, *i.e.,* the signal plus noise plus distortion, is made by the audio analyzer. The audio tone is then removed by the analyzer and the remaining noise and distortion is measured.

1. Connect test equipment as shown in Figures 1, 2, or 3.
2. Configure the tuner in standard configuration.
3. Configure the audio analyzer:
   a. Select Analyze.
   b. Set Function = THD+N / SINAD.
      i. Set Measurement Mode = SINAD.
      ii. Select Unit = dB.
4. Configure generator #1:
   a. Set carrier frequency = 98.1 MHz.
   b. Set RF level = 60 dBµV.
   c. Select FM Modulation.
      i. Set FM Deviation = 22.5 kHz.
      ii. Set Source = LFGEN.
      iii. Set LFGEN frequency = 1 kHz.
   d. Enable modulation.
   e. Enable carrier.
5. Disable generator #2.
6. Record SINAD (dB).

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2.3.8. IP3

Intermodulation distortion in the detected or decoded audio-frequency signal may be caused by non-linearity in the radio-frequency, intermediate-frequency, and detector stages of the receiver. A good measure of intermodulation distortion is IP3. IP3 is the theoretical RF level at which two blockers (VRF_1), offset from the desired frequency by Δf and $2\Delta f$, and their intermodulation product (VRF_0) would be of the same amplitude, according to the equation $IP3 = VRF_1 + \frac{1}{2}(VRF_1 - VRF_0)$.

VRF_0 is the 26 dB SINAD sensitivity level at the fundamental frequency. VRF_1 is the blocker level required to produce an inter-modulation product at the same sensitivity level.
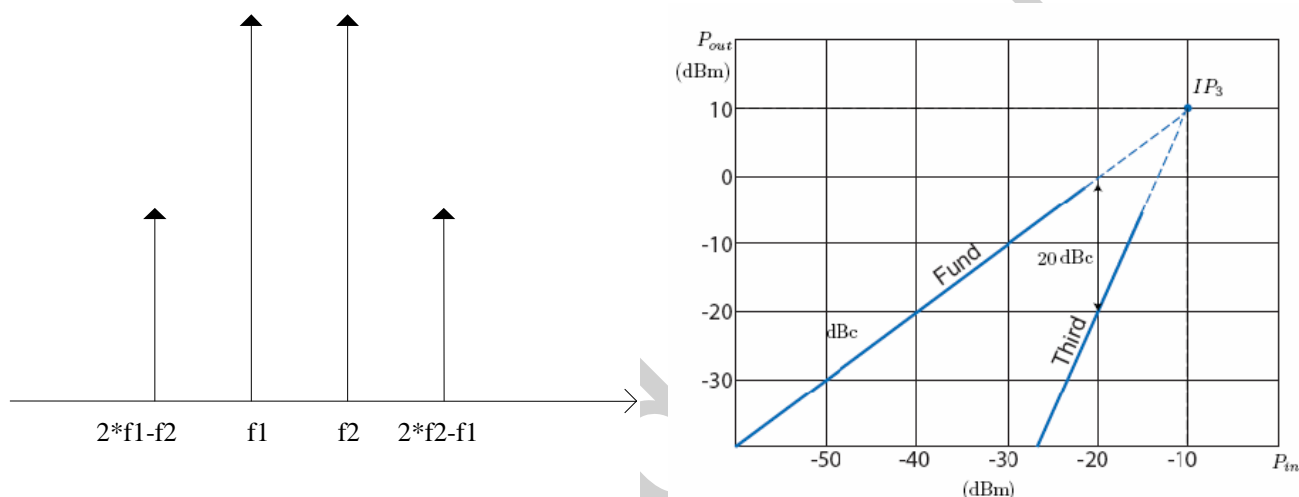

Figure 4. Graphical Representation of IP3

In our test:

f1 = 102.1 MHz (blocker #1)

f2 = 106.1 MHz (blocker #2)

2*f1-f2 = 98.1 MHz (tuner frequency)

1. Connect test equipment as shown in Figures 1, 2, or 3.

2. Make a sensitivity measurement, VRF_0, as described above.

3. Configure the tuner in standard configuration, except for the AGC setting. For this section of the test, set AGC OFF.

4. Configure the audio analyzer:

    a. Select Analyze.

    b. Set Function = THD+N / SINAD.

        i. Set Measurement Mode = SINAD.

        ii. Select Unit = dB.

5. Configure generator #1:

    a. Set carrier frequency = 106.1 MHz.

    b. Set RF level = 70 dBµV.

    c. Select FM Modulation.

        i.   Set FM Deviation = 22.5 kHz.

        ii. Set Source = LFGEN.

        iii. Set LFGEN frequency = 1 kHz.

    d. Enable modulation.

    e. Enable carrier.

6. Configure generator #2:

    a. Set carrier frequency = 102.1 MHz.

    b. Set RF level = 70 dBµV.

    c. Disable modulation.

    d. Enable carrier.

7. Simultaneously adjust the generator #1 and generator #2 RF level, VRF_1, until SINAD = 26 dB.

8. IP3 (dBµV) = $VRF_1 + \frac{1}{2}(VRF_1 - VRF_0)$.

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2.3.9. Adjacent / Alternate Channel Selectivity

Selectivity is a measure of the performance of a radio receiver to respond only to the tuned transmission (such as a radio station) and reject other signals nearby, such as another broadcast on an adjacent channel. Selectivity is usually measured as a ratio in decibels, comparing the signal strength received against that of a similar signal on another frequency. Selectivity measures the ratio of the unwanted to wanted RF input levels at which the audio-frequency, signal-to-interference ratio (S/I ratio) is 30 dB. The audio output produced by the wanted RF signal is the reference level ($VAUDIO_0$). First the audio reference level is measured at high RF input level. Second, the wanted RF level is un-modulated and the unwanted RF level is adjusted until the S/I ratio is 30 dB.

1. Connect test equipment as shown in Figures 1, 2, or 3.
2. Configure the tuner in standard configuration.
3. Configure the audio analyzer:
   a. Select Analyze.
   b. Set Function = RMS Select.
      i. Set Bandwidth = BP 3%.
      ii. Set Units = dBV.
      iii. Set Frequency Mode = FIX: 1 kHz.
4. Configure generator #1:
   a. Set carrier frequency = 98.1 MHz.
   b. Set RF level VRF_0 = 40 dBµV.
   c. Select FM Modulation.
      i. Set FM Deviation = 22.5 kHz.
      ii. Set source = LFGEN.
      iii. Set LFGEN frequency = 1 kHz.
   d. Enable modulation.
   e. Enable carrier.
5. Record the audio level, $VAUDIO_0$.
6. Disable generator #1 modulation.
7. Configure generator #2:
   a. Set carrier frequency = 97.9 MHz (adjacent channel) or
   b. Set carrier frequency = 97.7 MHz (alternate channel).
   c. Set RF level = 60 dBµV.
   d. Select FM Modulation.
      i. Set FM Deviation = 22.5 kHz.
      ii. Set source = LFGEN.
      iii. Set LFGEN frequency = 1 kHz.
   e. Enable modulation.
   f. Enable carrier.
8. Adjust generator #2 RF level*, VRF_1, until the audio level, $VAUDIO_1 = VAUDIO_0 - 30$ dB.
9. Selectivity (dB) = $VRF_1 - VRF_0$.

*Note: Generator #1 RF level is set to 40 dBµV to be able to get selectivity results greater than 60 dB. This is not a limitation of the FM tuner or the evaluation board. Maximum RF level setting for the R&S SML01 signal generator is 120 dBµV. You cannot increase the RF level beyond this value, so if VRF0 = 60 dBµV, selectivity numbers would be limited to 60 dB.

2.3.10. AM Suppression

AM suppression of an FM receiver represents the ability of the receiver to reject AM of the input signal. AM might be a result of fading multi-path signals, aircraft flutter, AM at the transmitter, and AM introduced in the receiver by pass-band limitations and mistuning. AM suppression is measured as a ratio of voltage measured with an FM modulated signal to that of an AM modulated signal.

1. Connect test equipment as shown in Figures 1, 2, or 3.
2. Configure the tuner in standard configuration.
3. Configure the audio analyzer:
   a. Select Analyze.
   b. Set Function = RMS Select.
      i. Set Bandwidth = BP 3%.
      ii. Set Units = dBV.
      iii. Set Frequency Mode = FIX: 1 kHz.
4. Configure generator #1:
   a. Set carrier frequency = 98.1 MHz.
   b. Set RF level = 60 dBμV.
   c. Select FM Modulation.
      i. Set FM Deviation = 22.5 kHz.
      ii. Set Source = LFGEN.
      iii. Set LFGEN frequency = 1 kHz.
   d. Enable modulation.
   e. Enable carrier.
5. Record the audio level, $VAUDIO_0$.
6. Turn off generator #1 FM modulation.
7. Configure generator #1:
   a. Set carrier frequency = 98.1 MHz.
   b. Set RF level = 60 dBμV.
   c. Select AM Modulation.
      i. Set Depth = 30%.
      ii. Set Source = LFGEN.
      iii. Set LFGEN frequency = 1 kHz.
   d. Enable modulation.
   e. Enable carrier.
8. Record the audio level, $VAUDIO_1$.
9. AM Suppression (dB) = $VAUDIO_0 - VAUDIO_1$.

2.3.11. Spurious Response/Image Rejection

Receivers respond to unwanted signals at the intermediate frequency, at the image frequency, and at harmonics of the signal frequency and other frequencies associated with harmonics of the local oscillator frequency. Audio-frequency output or noise-suppression at the tuning frequency and at the interfering frequencies (image and spurious response frequencies) is measured sequentially. Image-frequency rejection or spurious response rejection ratio shall be determined as the ratio in decibels of the input signal level at interfering frequencies to the input signal level at the tuning frequency for equal values of audio-frequency output voltage. The input signal level at the tuning frequency shall be below the 3 dB limiting level (the input signal level at which the audio-frequency output voltage level is 3 dB below the value at a specified high RF input signal level).

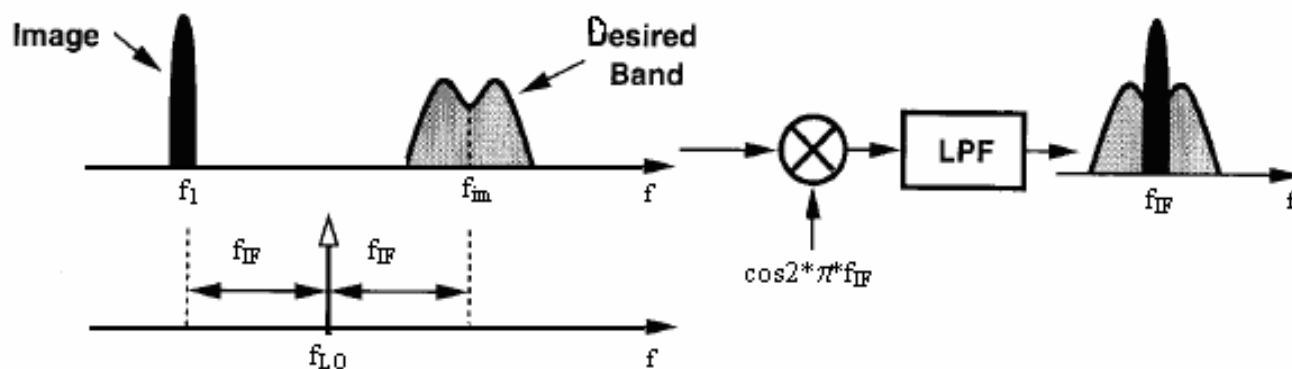To understand the concept of image frequency, please refer to Figure 5:

Figure 5. Image Frequency Spectrum

1. Connect test equipment as shown in Figures 1, 2, or 3.
2. Configure the tuner in standard configuration.
3. Configure the audio analyzer:
   a. Select Analyze.
   b. Set Function = RMS Select.
      i. Set Bandwidth = BP 3%.
      ii. Set Units = dBV.
      iii. Set Frequency Mode = FIX: 1 kHz.
4. Configure generator #1:
   a. Set carrier frequency = 98.1 MHz.
   b. Set RF level = 60 dBµV.
   c. Select FM Modulation.
      i. Set FM Deviation = 22.5 kHz.
      ii. Set Source = LFGEN.
      iii. Set LFGEN frequency = 1 kHz.
   d. Enable modulation.
   e. Enable carrier.
5. Record the audio level, $VAUDIO_0$.
6. Adjust generator #1 RF level, VRF_1, until the audio level, $VAUDIO_1 = VAUDIO_0 - 3$ dB.
7. Turn off generator #1 FM modulation.

8. Configure generator #2:

   a. Set carrier frequency = 76–108 MHz (for spurious response)

   b. Set carrier frequency = 97.844 MHz (image rejection)

   c. Set unit = dBμV.

   d. Select FM Modulation

      i. Set FM Deviation = 22.5 kHz.

      ii. Set Source = LFGEN.

      iii. Set LFGEN frequency = 1 kHz.

   e. Enable generator.

   f. Enable carrier.

9. Adjust generator #2 RF level*, VRF_2, until the audio level, $VAUDIO_2 = VAUDIO_1$.

10. Spurious Response (or image rejection) (dB) = $VRF_2 - VRF_1$.

*Note: Maximum RF level setting for the R&S SML01 signal generator is 120 dBμV. You cannot increase the RF level beyond this value, so please pick 120 dBμV as your RF level. Your image rejection will be better than 120 dBμV – VRF_1.

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2.3.12. Audio Output Voltage

Higher audio output voltage is an indicator of cleaner sound from the tuner. It is measured as an RMS value under standard operating conditions.

1. Connect test equipment as shown in Figures 1, 2, or 3.
2. Configure the tuner in standard configuration.
3. Configure the audio analyzer:
   a. Select Analyze.
   b. Set Function = RMS Select.
      i.   Set Bandwidth = BP 3%.
      ii. Set Units = V_{RMS}.
      iii. Set Frequency Mode = FIX: 1 kHz.
4. Configure generator #1:
   a. Set carrier frequency = 98.1 MHz.
   b. Set RF level = 60 dBµV.
   c. Select FM Modulation.
      i.   Set FM Deviation = 22.5 kHz.
      ii. Set Source = LFGEN.
      iii. Set LFGEN frequency = 1 kHz.
   d. Enable modulation.
   e. Enable carrier.
5. Audio level (V_{RMS}) = $VAUDIO_0$.

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2.3.13. Audio L/R Imbalance

The level deviation between the two stereo channels is a quality criterion of the tuner because level differences shift the center for stereo sound impression. Audio L/R imbalance is the ratio of left to right channel output voltage.

1. Connect test equipment as shown in Figures 1, 2, or 3.
2. Configure the tuner in standard configuration.
3. Configure the audio analyzer:
    a. Select Analyze.
    b. Set Function = RMS Select.
        i. Set Bandwidth = BP 3%.
        ii. Set Units = dBV.
        iii. Set Frequency Mode = FIX: 1 kHz.
4. Configure generator #1:
    a. Set carrier frequency = 98.1 MHz.
    b. Set RF level = 60 dBμV.
    c. Select FM Modulation.
        i. Set FM Deviation = 75 kHz.
        ii. Set RF level = 60 dBμV.
        iii. Set Source = LFGEN.
        iv. Set LFGEN frequency = 1 kHz.
    d. Enable modulation.
    e. Enable carrier.
5. Left channel audio level (dBV) = $VAUDIO_L$.
6. Right channel audio level (dBV) = $VAUDIO_R$.
7. Audio L/R imbalance (dB) = abs ($VAUDIO_L - VAUDIO_R$).

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2.3.14. Audio Band Limits/Audio Frequency Response

The audio frequency response of a tuner is influenced by the quality of the IF section, detector, stereo coder and de-emphasis circuit. The emphasis of 75 µs specified by the standards for VHF FM transmissions is simulated in the signal generator. This means that low-frequency audio signals are modulated with a low deviation. The frequency deviation is then increased by emphasis to the maximum permissible deviation at the upper frequency limit. This effect is compensated by the de-emphasis circuit in the tuner so that the frequency response of the audio signal becomes as linear as possible. Audio frequency response is the measure of linearity of output voltage vs. modulation frequency across the audio band.

The frequency response of pre-emphasis has the effect of a 1st order highpass filter with predefined time constant, in this case 75 µs. Pre-emphasis with this time constant increases the signal by a factor of about 5.3 at 15 kHz relative to low frequencies. It is important to note that the maximum deviation of the system should not be exceeded even at high frequencies while pre-emphasis is on. Therefore, if measurements are performed at the modulation frequency with pre-emphasis on, the deviation should be adjusted so that the maximum permissible deviation is only attained at a modulation frequency of 15 kHz. In this case, the maximum deviation that can be adjusted for frequency response measurements is approximately 14%, 10.5 kHz. This influence must also be taken into account for measurements with the 1 kHz standard test frequency. For 1 kHz test frequency, the setting is approximately 90% at 75 µs pre-emphasis.

1. Connect test equipment as shown in Figures 1, 2, or 3.
2. Configure the tuner in standard configuration.
3. Configure the audio analyzer:
   a. Select Analyze.
   b. Set Function = RMS Select.
      i. Set Bandwidth = BP 3%.
      ii. Set Units = dBV.
      iii. Set Frequency Mode = FIX: 1 kHz.
4. Configure generator #1:
   a. Set carrier frequency = 98.1 MHz.
   b. Set RF level = 60 dBµV.
   c. Select Stereo Modulation.
      i. Set FM Deviation = 10.5 kHz.
      ii. Set L = R.
      iii. Set Source = LFGEN.
      iv. Set LFGEN frequency = 1 kHz.
      v. Set Pre-emphasis = 75 µs.
      vi. Set Pilot = ON.
      vii. Set Pilot Deviation = 6.75 kHz.
   d. Enable modulation.
   e. Enable carrier.
5. Audio 1 kHz level (dBV) = V_{1kHz}.
6. Configure audio analyzer frequency mode through RMS Select Function.* Set Frequency Mode = FIX: 30 Hz.
7. Configure generator #1 LFGEN frequency = 30 Hz.
8. Audio 30 Hz level (dBV) = V_{30Hz}.
9. Configure audio analyzer frequency mode through RMS Select Function. Set Frequency Mode = FIX: 15 kHz.
10. Configure generator #1 LFGEN frequency = 15 kHz.
11. Audio 15 kHz level (dBV) = V_{15kHz}.
12. Audio frequency response (dB) equals the greater magnitude of ($V_{30Hz} - V_{1kHz}$) and ($V_{15kHz} - V_{1kHz}$).

*Note: R&S UPL audio analyzer should be set to 22 kHz analyzer mode to select this frequency mode.

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2.3.15. Audio Stereo Separation

Crosstalk occurs when signal components of a channel are coupled into another audio channel. This reduces channel separation and thus impairs the stereo effect. Audio stereo separation is the level ratio of the wanted signal in a channel to the unwanted signal coupled into the other channel. Only the left channel is modulated and the levels are measured in both channels to obtain the ratio. To suppress the noise components, a selective measurement is carried out.

1. Connect test equipment as shown in Figures 1, 2, or 3.

2. Configure the tuner in standard configuration, except for setting in mono operation. Set the tuner in stereo mode.

3. Configure the audio analyzer:

   a. Select Analyze.

   b. Set Function = RMS Select.

      i. Set Bandwidth = BP 3%.

      ii. Set Units = dBV.

      iii. Set Frequency Mode = FIX: 1 kHz.

4. Configure generator #1:

   a. Set carrier frequency = 98.1 MHz.

   b. Set RF level = 60 dBµV.

   c. Select Stereo Modulation.

      i.   Set FM Deviation = 67.5 kHz.

      ii. Set L = 1, R = 0.

      iii. Set Source = LFGEN.

      iv. Set LFGEN frequency = 1 kHz.

      v.   Set Pre-emphasis = 75 µs.

      vi. Set Pilot = ON.

      vii. Set Pilot Deviation = 6.75 kHz.

   d. Enable modulation.

   e. Enable carrier.

5. Left channel audio level (dBV) = $VAUDIO_L$.

6. Right channel audio level (dBV) = $VAUDIO_R$.

7. Audio Stereo Separation (dB) = abs ($VAUDIO_L$ – $VAUDIO_R$).

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2.3.16. Stereo Pilot Rejection

A pilot tone is transmitted at 19 kHz to identify stereo broadcast transmissions. In order not to disturb instruments such as amplifiers and recorders connected to the tuner, the pilot tone and its subcarriers must be sufficiently suppressed in the tuner. Stereo pilot rejection is the quality criterion of a tuner that is measured as the ratio of wanted audio frequency voltage to pilot frequency voltage according to the equation:

Pilot Rejection = $Vaudio_0$ (1 kHz) + 20*log ($\Delta pilot/\Delta f$) – Vaudio0 (19 kHz)

where Δf is FM frequency deviation and $\Delta pilot$ is pilot frequency deviation.

1. Connect test equipment as shown in Figures 1, 2, or 3.
2. Configure the tuner in standard configuration, except for setting in mono operation. Set the tuner in stereo mode.
3. Configure the audio analyzer:
    a. Select Analyze.
    b. Set Function = RMS Select.
        i.   Set Bandwidth = BP 3%.
        ii.   Set Units = dBV.
        iii. Set Frequency Mode = FIX: 1 kHz.
4. Configure generator #1:
    a. Set carrier frequency = 98.1 MHz.
    b. Set RF level = 60 dBμV.
    c. Select Stereo Modulation.
        i.   Set FM Deviation = 67.5 kHz.
        ii.   Set L = R.
        iii. Set Source = LFGEN.
        iv.   Set LFGEN frequency = 1 kHz.
        v.   Set Pre-emphasis = 75 μs.
        vi.   Set Pilot = ON.
        vii. Set Pilot Deviation = 6.75 kHz.
    d. Enable modulation.
    e. Enable carrier.
5. Audio 1 kHz level (dBV) = V_{1kHz}.
6. Configure audio analyzer frequency mode = FIX: 19 kHz.
7. Audio 19 kHz level (dBV) = V_{19kHz}.
8. Pilot Rejection (relative to pilot) (dB) = V1kHz – V19kHz + 20*log10 ($\Delta pilot/\Delta f$) = V1kHz – V19kHz – 20.
9. Pilot Rejection (relative to 75 kHz) (dB) = V1kHz – V19kHz + 20*log10 (75 kHz/Δf) = V1kHz – V19kHz + 0.91.

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3. AM/Shortwave/Longwave Tuner Testing

This section covers testing the AM/Shortwave/Longwave specs of the Si473x/4x receivers. Table 4 provides a summary of tests and equipment, and Figure 6 and Figure 7 show the instrument configuration used to generate the test report for AM testing of each EVB.

Table 4. Si473x/4x Tuner Test Equipment for AM Reception

Test	Equipment
Sensitivity Audio SNR Audio THD Audio Output Voltage	Rohde & Schwarz UPL Audio Analyzer (with digital audio functionality) Rohde & Schwarz SML01 Signal Generator #1 Mini-Circuits Power Combiner
Selectivity	Equipment above plus: Rohde & Schwarz SML01 Signal Generator #2
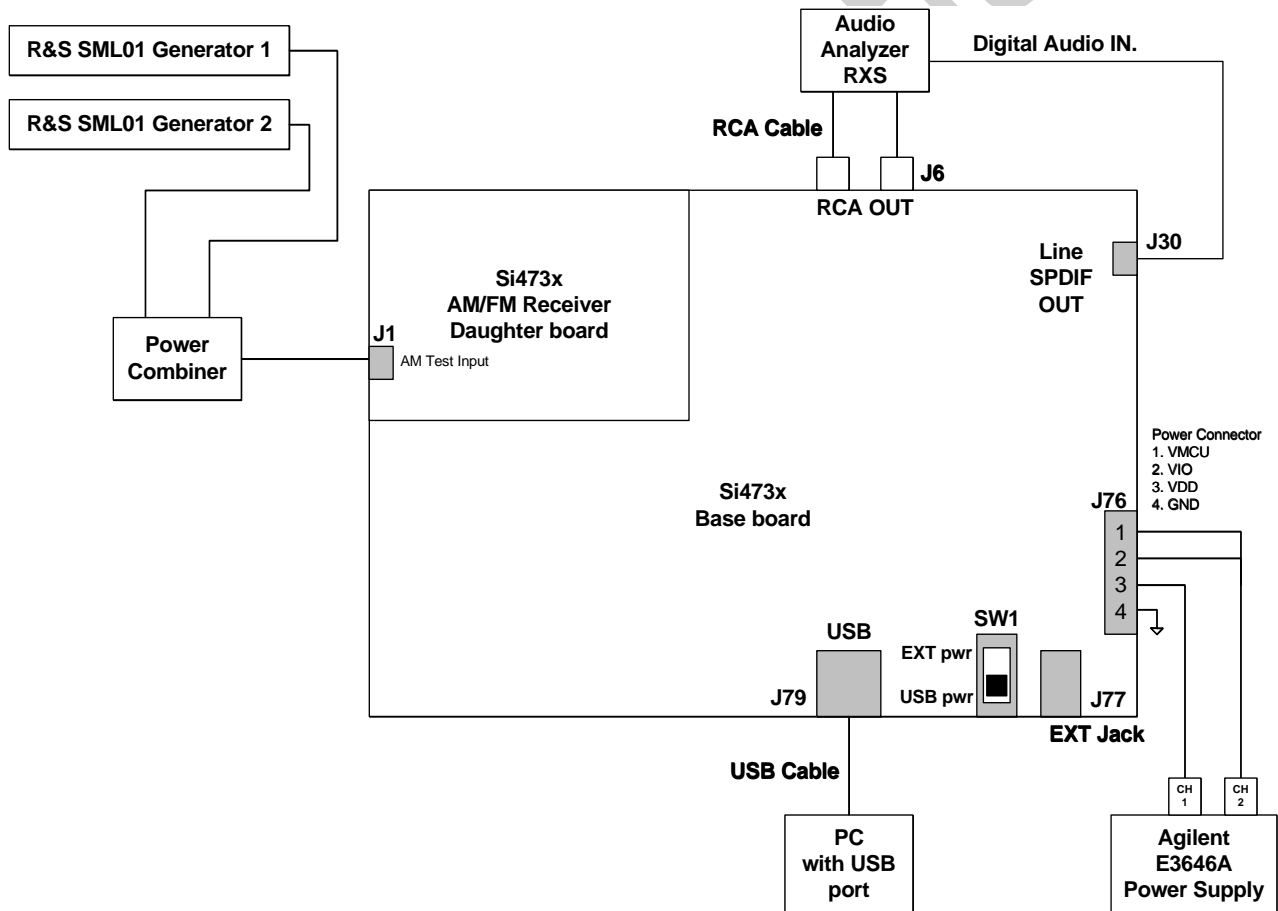
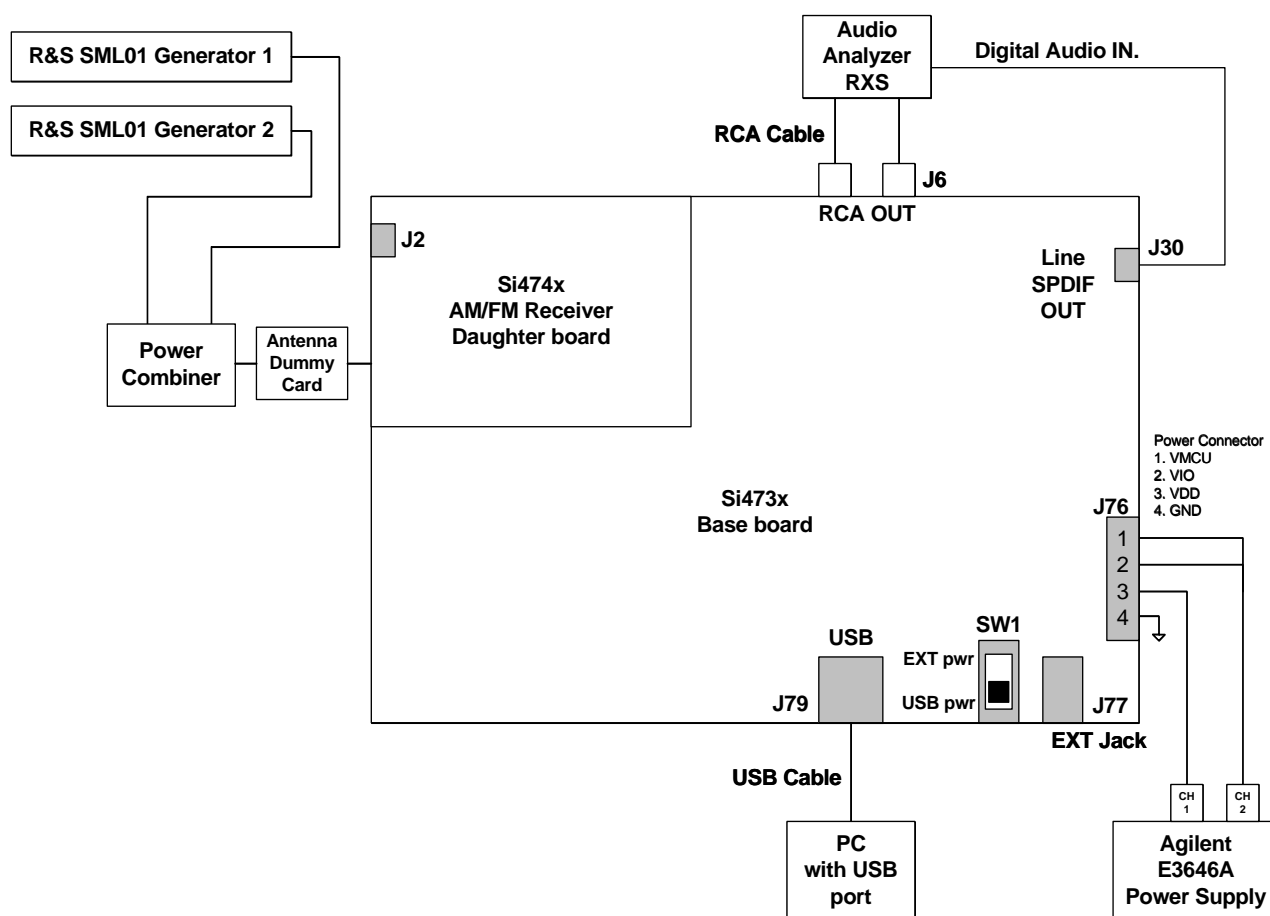**Figure 6. Si473x AM Tuner Setup**

Figure 7. Si474x AM Tuner Setup

3.1. AM Tuner Testing Measurement Considerations

Several issues must be considered to make accurate measurements.

First, the power combiner and cable losses must be calibrated and factored into each measurement. The loss for the Mini-Circuits power combiner is approximately 6 dB for the entire AM band.

Second, most signal generators display the voltage generated at the input of the DUT assuming an input resistance of 50 Ω. For example, if the signal generator displays VL = 1 µV (0 dBµV), the generator source voltage VS is 2 µV (6 dBµV). The load voltage VL is generated from the source voltage VS by the voltage divider, which is created by the 50 Ω generator source resistance RS and the 50 Ω load resistance RL. This distinction is important only for sensitivity, which is specified in µV EMF, where EMF refers to the source voltage VS. Measurements such as selectivity are relative and may be referenced using VS or VL. To summarize, the generator displays the voltage at the input of the DUT. In the case of the Si473x FM tuner, input impedance is high; therefore, to convert the value displayed on the signal generator to EMF, double the voltage (add 6 dB). In the case of the Si474x FM tuner, the test setup includes an antenna dummy card so that the load the generator sees is not high impedance. Therefore, you can use the value displayed on the generator as the EMF value.

3.2. AM/Shortwave/Longwave Tuner Testing Procedures

The following procedures measure analog audio output. All audio measurments can be duplicated for digital audio output where applicable. For audio analyzer settings in digital mode, refer to Section 6.1.

3.2.1. Sensitivity

Sensitivity of a receiver is a measure of its ability to receive weak signals and produce an audio frequency output of usable magnitude and acceptable quality. Sensitivities may be defined with respect to many different characteristics of the output signal. For the purposes of our testing, sensitivity is the minimum RF level required to produce an audio output with a specified signal-to-noise and distortion ratio, 26 dB. Please note that the sensitivity measurement is defined with respect to SINAD and not SNR. Descriptions for these two measurements will be given in the following sections.

1. Connect test equipment as shown in Figures 6 or 7.
2. Configure the tuner:
   a. Set frequency = 1 MHz. (10 MHz for shortwave and 216 kHz for longwave.)
   b. Set volume = 63.
3. Configure the audio analyzer:
   a. Select Analyze.
   b. Set Function = THD+N / SINAD.
      i.   Set Measurement Mode = SINAD.
      ii. Set Unit = dB.
      iii. Set Filter = A-weighting.
      iv. Set Frequency Limit Low = 300 Hz.
      v.   Set Frequency Limit High = 15000 Hz.
4. Configure generator #1:
   a. Set carrier frequency = 1 MHz. (10 MHz for shortwave and 216 kHz for longwave.)
   b. Select AM Modulation.
      i.   Set AM Modulation Depth = 30%.
      ii. Set source = LFGEN.
      iii. Set LFGEN frequency = 1 kHz.
   c. Enable AM modulation.
   d. Enable RF carrier.
5. Disable generator #2.
6. Adjust generator #1 RF level, VRF_0, until audio analyzer SINAD = 26 dB ± 1 dB.
7. Sensitivity (µVrms) = VRF_0.

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3.2.2. SNR

The signal-to-noise ratio of a receiver, under specified conditions, is the ratio of the audio frequency output voltage due to the signal to that due to random noise. The noise may be measured using different filtering techniques. The technique used in this document is the A-weighting filter. Weighting filters are used to determine the loudness of sounds, particularly noise. A-weighting filter is commonly used to emphasize frequencies around 3–6 kHz where the human ear is most sensitive, while attenuating very high and very low frequencies to which the ear is insensitive. The aim is to ensure that measured loudness corresponds well with subjectively perceived loudness. A-weighting is only really valid for relatively quiet sounds and for pure tones.

1. Connect test equipment as shown in Figures 6 and 7.
2. Configure the tuner:
    a. Set frequency = 1 MHz. (10 MHz for shortwave and 216 kHz for longwave.)
    b. Set volume = 63.
3. Configure generator #1:
    a. Set carrier frequency = 1 MHz. (10 MHz for shortwave and 216 kHz for longwave.)
    b. Select AM Modulation.
        i.   Set AM Modulation Depth = 30%.
        ii. Set Source = LFGEN.
        iii. Set LFGEN frequency = 1 kHz.
        iv. Set RF level = 74 dBµV.
    c. Enable AM modulation.
    d. Enable RF carrier.
4. Disable generator #2.
5. Configure the audio analyzer to record noise.
    a. Select Analyze.
    b. Set Function = THD+N / SINAD.
        i.   Set Measurement Mode = Level Noise.
        ii. Set Unit = dBV.
        iii. Set Filter = A-weighting.
        iv. Set Frequency Limit Low = 300 Hz.
        v.   Set Frequency Limit High = 15000 Hz.
6. Record Level Noise (dBV).
7. Configure the audio analyzer to record signal.
    a. Select Analyze.
        i.   Set Function = RMS Select.
        ii. Set Unit = dBV.
        iii. Set Filter = BP 3%.
    b. Record Signal (dBV).
8. Record SNR (dB) = Input RMS (dBV) – Level Noise (dBV).

3.2.3. THD

The total harmonic distortion, or THD, is a measurement of the harmonic distortion present at the audio output and is defined as the ratio of the sum of the powers of all harmonic components calculated in RMS fashion to the power of the fundamental.

1. Connect test equipment as shown in Figure 6 or Figure 7.
2. Configure the tuner:
   a. Set frequency = 1 MHz. (10 MHz for shortwave and 216 kHz for longwave.)
   b. Set volume = 63.
3. Configure the audio analyzer:
   a. Select Analyze.
   b. Set Function = THD.
      i. Set Measurement Mode = All di (all harmonics).
      ii. Set Unit = %.
4. Configure generator #1:
   a. Set carrier frequency = 1 MHz. (10 MHz for shortwave and 216 kHz for longwave.)
   b. Select AM Modulation.
      i. Set AM Modulation Depth = 30%.
      ii. Set Source = LFGEN.
      iii. Set LFGEN frequency = 1 kHz.
   c. Set RF level = 74 dBµV.
   d. Enable AM modulation.
   e. Enable RF (carrier).
5. Disable generator #2.
6. Record THD (%).

3.2.4. Output Voltage

Higher audio output voltage is an indicator of cleaner sound from the tuner. It is measured as an RMS value under standard operating conditions.

1. Connect test equipment as shown in Figure 6 or Figure 7.
2. Configure the tuner:
    a. Set frequency = 1 MHz. (10 MHz for shortwave and 216 kHz for longwave.)
    b. Set volume = 63.
3. Configure the audio analyzer:
    a. Select Analyze.
    b. Set Function = RMS Select.
        i.   Set Bandwidth = BP 3%.
        ii.   Set Units = dBV.
        iii. Set Frequency Mode = FIX: 1 kHz.
4. Configure generator #1:
    a. Set carrier frequency = 1 MHz. (10 MHz for shortwave and 216 kHz for longwave.)
    b. Select AM Modulation.
        i.   Set AM Modulation Depth = 30%.
        ii.   Set Source = LFGEN.
        iii. Set LFGEN frequency = 1 kHz.
    c. Set RF level = 74 dBµV.
    d. Enable AM modulation.
    e. Enable RF (carrier).
5. Disable generator #2.
6. Record audio level (mVrms) from the analyzer.

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3.2.5. Adjacent/Alternate Channel Selectivity

Selectivity is a measure of the performance of a radio receiver to respond only to the tuned transmission (such as a radio station) and reject other signals nearby, such as another broadcast on an adjacent channel. Selectivity is usually measured as a ratio in decibels (dBs), comparing the signal strength received against that of a similar signal on another frequency. Selectivity measures the ratio of the unwanted to wanted RF input levels at which the audio-frequency signal-to-interference ratio (S/I ratio) is 30 dB. The audio output produced by the wanted RF signal is the reference level ($VAUDIO_0$). First the audio reference level is measured at high RF input level. Second, the wanted RF level is un-modulated and the unwanted RF level is adjusted until the S/I ratio is 30 dB.

Adjacent channel selectivity measures the interference from an unwanted signal present one band spacing away (9 kHz away). Alternate channel selectivity measures the interference from an unwanted signal present three band spacing away (27 kHz away).

1. Connect test equipment as shown in Figure 6 or Figure 7.
2. Configure the tuner:
   a. Set frequency = 1 MHz. (10 MHz for shortwave and 216 kHz for longwave.)
   b. Set volume = 63.
3. Configure the audio analyzer:
   a. Select Analyze.
   b. Set Function = RMS Select.
      i. Set Bandwidth = BP 3%.
      ii. Set Units = dBV.
      iii. Set Frequency Mode = FIX: 1 kHz.
4. Configure generator #1:
   a. Set carrier frequency = 1 MHz. (10 MHz for shortwave and 216 kHz for longwave.)
   b. Select AM Modulation.
   c. Set AM Modulation Depth = 30%.
      i. Set Source = LFGEN.
      ii. Set LFGEN frequency = 1 kHz.
   d. Set RF level V_{RF0}= 40 dBμV.
   e. Enable AM modulation.
   f. Enable RF carrier.
5. Disable generator #2:
   Record the audio level, $VAUDIO_0$.
6. Disable generator #1 modulation.
7. Configure generator #2:
   a. Set carrier frequency = 1.009 MHz* (adjacent channel), or
   b. Set carrier frequency = 1.027 MHz* (alternate channel).
   c. Set RF level = 60 dBμV.
   d. Select AM Modulation.
      i. Set AM Modulation Depth = 30%.
      ii. Set Source = LFGEN.
      iii. Set LFGEN frequency = 1 kHz.
   e. Enable AM Modulation.
   f. Enable RF carrier.

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8. Adjust generator #2 RF level, VRF1, until the audio level = VAUDIO0 – 30 dB.

9. Selectivity (dB) = $V_{RF1} - V_{RF0}$.

*Note: For shortwave, the adjacent channel will be 5 kHz away (10.005 MHz) and the alternate channel will be 15 kHz away (10.015 MHz).

*Note: For longwave, the adjacent channel will be 9 kHz away (225 kHz) and the alternate channel will be 27 kHz away (243 kHz).

3.2.6. Radiated Sensitivity

In order to avoid environmental noise issues, it is best to conduct radiated tests in a shielded room.

1. Connect test equipment as shown in Figure 8.
2. Configure the tuner:
    a. Set frequency = 1 MHz. (10 MHz for shortwave and 216 kHz for longwave.)
    b. Set volume = 63.
3. Configure the audio analyzer:
    a. Select Analyze.
    b. Set Function = THD+N / SINAD.
        i.   Set Measurement Mode = SINAD.
        ii. Set Unit = dB.
        iii. Set Filter = A-weighting.
        iv. Set Frequency Limit Low = 300 Hz.
        v.   Set Frequency Limit High = 15000 Hz.
4. Configure generator #1:
    a. Set carrier frequency = 1 MHz. (10 MHz for shortwave and 216 kHz for longwave.)
    b. Select AM Modulation.
        i.   Set AM Modulation Depth = 30%.
        ii. Set Source = LFGEN.
        iii. Set LFGEN frequency = 1 kHz.
    c. Enable AM modulation.
    d. Enable RF carrier.
5. Disable generator #2:
6. Disconnect the USB connection through the GUI while keeping the device ON.
7. Remove the laptop from the room in which the testing is conducted.
8. Adjust generator #1 RF level, VRF_0, until audio analyzer SINAD = 26 dB ± 1 dB.
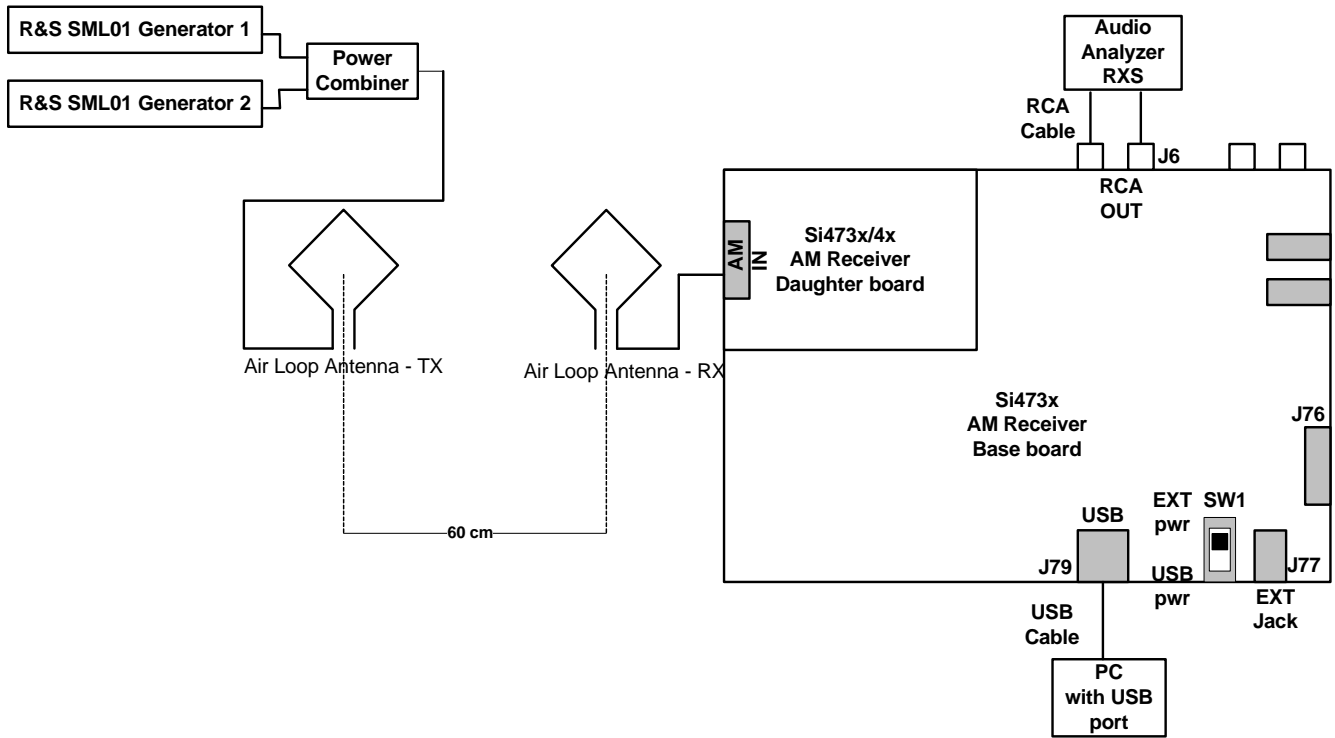9. Sensitivity (μV) = VRF_0.

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Figure 8. Test Setup for AM Radiated Sensitivity

3.2.7. Large Signal Voltage Handling

1. Connect test equipment as shown in Figure 9.

2. Configure the tuner:

   a. Set frequency = 1 MHz. (10 MHz for shortwave and 216 kHz for longwave.)

   b. Set volume = 63.

3. Make a sensitivity measurement ad described in Section 8.6. Record the RF Level from the generator in dBμV as VRF0.

4. Get the RSSI reading from the tuner under these conditions. Record it as VRF1.

   The gain through the radiated system is VRF_1-VRF_0. You will use this number to adjust the signal generator level for 300 mVrms (109.54 dBμV) radiated measurement.

5. Configure generator #1:

   Set RF level VRF2= [109.54 – (VRF_1-VRF_0)] dBμV.

6. Configure the audio analyzer:

   a. Select Analyze.

   b. Set Function = THD.

      i. Set Measurement Mode = All di (all harmonics).
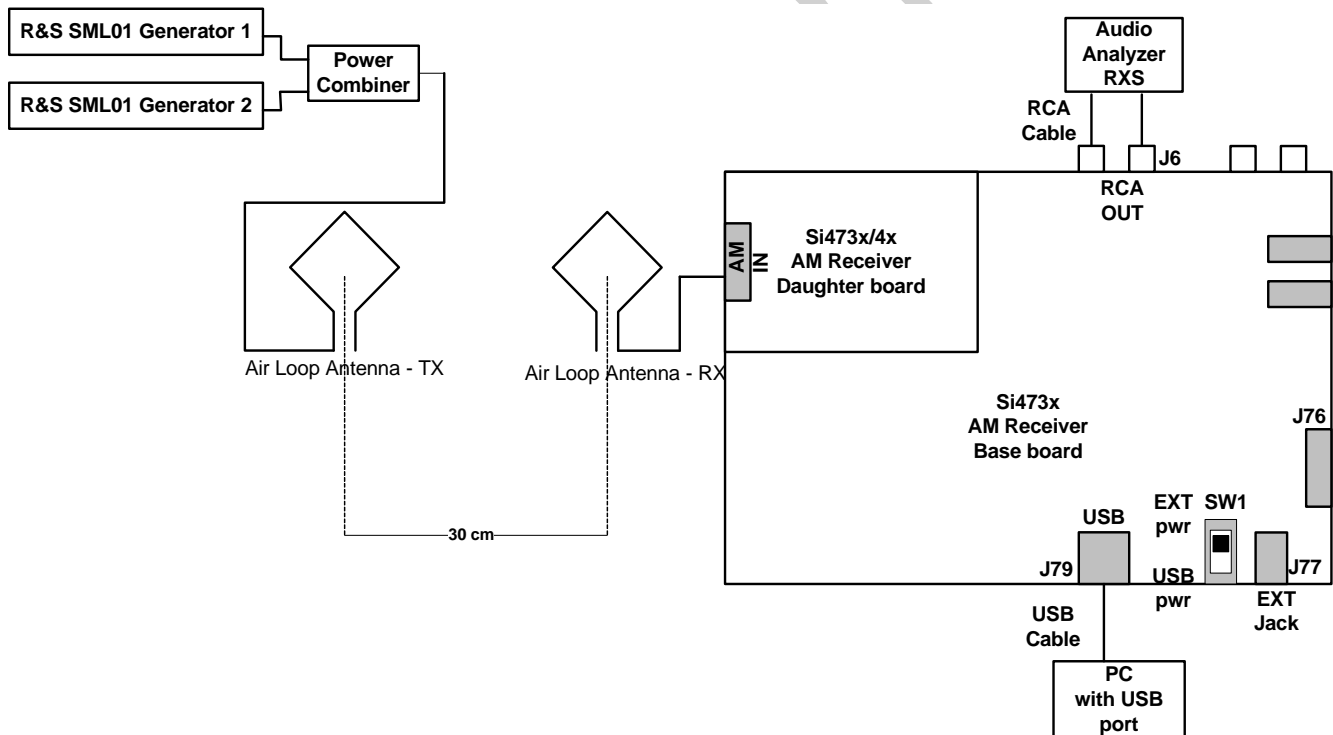
      ii. Set Unit = %.

7. Record THD Level.

Figure 9. Large Signal Voltage Handling Test Setup

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4. Weather Band Testing

Weather band receiver daughter cards use the same test port connection as the FM receivers. The test equipment used for weather band testing is identical to FM receiver test equipment in Table 2. For test setup, please refer to Figure 2. FM tuner testing measurement considerations from Section 2.1 also apply to weather band testing.

4.1. Weather Band Test Procedures

The following procedures measure analog audio output.

4.1.1. Sensitivity

Sensitivity of a receiver is a measure of its ability to receive weak signals and produce an audio frequency output of usable magnitude and acceptable quality. Sensitivities may be defined with respect to many different characteristics of the output signal. For the purposes of our testing, sensitivity is the minimum RF level required to produce an audio output with a specified signal-to-noise and distortion ratio, 12 dB. Please note that the sensitivity measurement is defined with respect to SINAD and not SNR. Descriptions for these two measurements will be given in the following sections.

1. Connect test equipment as shown in Figure 2.
2. Configure the tuner:
    a. Set Frequency = 162.4 MHz.
    b. Set Volume = 63.
3. Configure the audio analyzer:
    a. Select Analyze.
    b. Set Function = THD+N / SINAD.
        i.   Set Measurement Mode = SINAD.
        ii. Set Unit = dB.
        iii. Set Filter = A-weighting.
        iv. Set Frequency Limit Low = 300 Hz.
        v. Set Frequency Limit High = 15000 Hz.
4. Configure generator #1:
    a. Set carrier frequency = 162.400 MHz.
    b. Select FM Modulation.
        i.   Set FM Deviation = 3 kHz.
        ii. Set Source = LFGEN.
        iii. Set LFGEN frequency = 1 kHz.
    c. Enable modulation.
    d. Enable carrier.
5. Disable generator #2.
6. Adjust generator #1 RF level, VRF_0, until audio analyzer SINAD = 12 dB +/- 1 dB.
7. Sensitivity (μV) = VRF_0.

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4.1.2. SNR

The signal-to-noise ratio of a receiver, under specified conditions, is the ratio of the audio frequency output voltage due to the signal to that due to random noise. The noise may be measured using different filtering techniques. The technique used in this document is the A-weighting filter. Weighting filters are used to determine the loudness of sounds, particularly noise. A-weighting filter is commonly used to emphasize frequencies around 3–6 kHz, where the human ear is most sensitive, while attenuating very high and very low frequencies to which the ear is insensitive. The aim is to ensure that measured loudness corresponds well with subjectively perceived loudness. A-weighting is only really valid for relatively quiet sounds and for pure tones.

1. Connect test equipment as shown in Figure 2.
2. Configure the tuner:
    a. Set Frequency = 162.4 MHz.
    b. Set Volume = 63.
3. Configure the audio analyzer:
    a. Select Analyze.
    b. Set Input DISP = RMS.
    c. Set Units = dBV.
    d. Set Function = THD+N / SINAD.
        i. Set Measurement Mode = LEVEL NOISE.
        ii. Set Units = dBV.
        iii. Set Filter = A-weighting.
        iv. Set Frequency Limit Low = 300 Hz.
        v. Set Frequency Limit Upper = 15000 Hz.
4. Configure generator #1:
    a. Set carrier frequency = 162.400 MHz.
    b. Set RF level = 60 dBµV.
    c. Select FM Modulation.
        i. Set FM Deviation = 3 kHz.
        ii. Set source = LFGEN.
        iii. Set LFGEN frequency = 1 kHz.
    d. Enable modulation.
    e. Enable carrier.
5. Disable generator #2.
6. Record SNR (dB) = Input RMS (dBV) – Level Noise (dBV).

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4.1.3. SINAD

Signal to noise and distortion (SINAD) is similar to signal to noise ratio, but includes distortion and is a ratio of "signal plus noise plus distortion" to "noise plus distortion." To make the SINAD measurement, a signal modulated with an audio tone is entered into the receiver. A measurement of the whole signal, *i.e.,* the signal plus noise plus distortion, is made by the audio analyzer. The audio tone is then removed by the analyzer and the remaining noise and distortion is measured.

1. Connect test equipment as shown in Figure 2.
2. Configure the tuner:
    a. Set Frequency = 162.4 MHz.
    b. Set Volume = 63.
3. Configure the audio analyzer:
    a. Select Analyze.
    b. Set Function = THD+N / SINAD.
        i. Set Measurement Mode = SINAD.
        ii. Select Unit = dB.
4. Configure generator #1:
    a. Set carrier frequency = 162.400 MHz.
    b. Set RF level = 60 dBµV.
    c. Select FM Modulation.
        i.   Set FM Deviation = 3 kHz.
        ii. Set Source = LFGEN.
        iii. Set LFGEN frequency = 1 kHz.
    d. Enable modulation.
    e. Enable carrier.
5. Disable generator #2.
6. Record SINAD (dB).

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4.1.4. Adjacent/Alternate Channel Selectivity

Selectivity measurement in weather band is slightly different than the selectivity measurement in FM band. In weather band, adjacent channel selectivity is a measure of the capability of the receiver to receive a wanted modulated signal without exceeding a given degradation due to the presence of an unwanted signal that differs in frequency from the wanted signal by an amount equal to the adjacent channel separation for which the equipment is intended. Two generators are setup with the same FM deviation but with two separate modulation frequencies. A sensitivity measurement is done with the wanted signal only. The unwanted signal is then turned on and its level is increased until SINAD =12 dB.

1. Connect test equipment as shown in Figure 2.
2. Configure the tuner:
    a. Set frequency = 162.4 MHz.
    b. Set VOLUME = 63.
3. Configure generator #1:
    a. Set carrier frequency = 162.4 MHz.
    b. Select FM Modulation.
        i.   Set FM Deviation = 3 kHz.
        ii. Set Source = LFGEN.
        iii. Set LFGEN frequency = 1 kHz.
    c. Enable modulation.
    d. Enable carrier.
4. Make a sensitivity measurement.
5. Record the generator # 1 RF level at sensitivity as V_{RF0}.
6. Increase generator #1 RF level by 3 dB.
7. Configure generator #2:
    a. Set carrier frequency = 162.425 MHz (adjacent channel)
    b. Select FM Modulation.
        i.   Set FM Deviation = 3 kHz.
        ii. Set Source = LFGEN.
        iii. Set LFGEN frequency = 400 Hz.
    c. Set RF level = 10 dBμV.
    d. Enable modulation.
    e. Enable carrier.
8. Adjust generator #2 RF level*, VRF_1, until the SINAD is 12 dB.
9. Selectivity (dB) = $VRF_1 - VRF_0$.

4.1.5. Audio Band Limits/Audio Frequency Response

The audio frequency response of a tuner is influenced by the quality of the IF section, detector, and de-emphasis circuit. The tuner has a de-emphasis filter with a 6 dB per octave curve over the audio frequency range of 300 Hz to 3 kHz. The SML generator only has a pre-emphasis filter for FM band with 75 µs or 50 µs. Since those cannot be used for the weather band pre-emphasis, a correction will need to be applied to the frequency response results to account for the lack of pre-emphasis.

1. Connect test equipment as shown in Figure 2.
2. Configure the tuner:
   a. Set frequency = 162.4 MHz.
   b. Set VOLUME = 63.
3. Configure the audio analyzer:
   a. Select Analyze.
   b. Set Function = RMS Select.
      i. Set bandwidth = BP 3%.
      ii. Set units = dBV.
      iii. Set frequency mode = FIX: 1 kHz.
4. Configure generator #1:
   a. Set carrier frequency = 162.4 MHz.
   b. Set RF level = 60 dBµV.
   c. Select FM Modulation.
      i. Set FM Deviation = 3 kHz.
      ii. Set source = LFGEN.
      iii. Set LFGEN frequency = 1 kHz.
   d. Enable modulation.
   e. Enable carrier.
5. Audio 1 kHz level (dBV) = V1kHz.
6. Configure audio analyzer frequency mode = 300 Hz.
7. Configure generator #1 LFGEN frequency = 300 Hz.
8. Audio 300 Hz level (dBV) = V300Hz.
9. Configure audio analyzer frequency mode = 3 kHz.
10. Configure generator #1 LFGEN frequency = 3 kHz.
11. Audio 3 kHz level (dBV)= V3kHz.
12. Audio frequency response (dB) equals the greater magnitude of (V30Hz – V1kHz – 7.82) and (V15kHz – V1kHz + 9.21).

*Note: 7.82 and 9.21 are the correction factors applied to account for the lack of a pre-emphasis filter.

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5. FM Transmitter Testing

This section covers testing the FM specifications for the Si471x/2x transmitter. Table 5 presents the list of equipment necessary to conduct FM transmit measurements.

Table 5. Si471x/2x FM Transmit Test Equipment

Test	Equipment
Maximum Voltage Voltage Accuracy Pre-emphasis Time Constant Audio SNR Audio THD Audio Stereo Separation Sub Carrier Rejection Ratio Audio Input Imbalance Modulation Rate Accuracy	Rohde & Schwarz FMAS Modulation Analyzer Agilent E3646A Power Supply
Voltage Step Channel Edge Power Adjacent Channel Power Alternate Channel Power Transmit Emissions	Agilent E4402A Spectrum Analyzer Agilent E3646A Power Supply For Analog Audio Input: Rohde & Schwarz FMAS Modulation Analyzer
Output Power Accuracy	Agilent E4418A Power Meter Agilent E4412A Power Sensor

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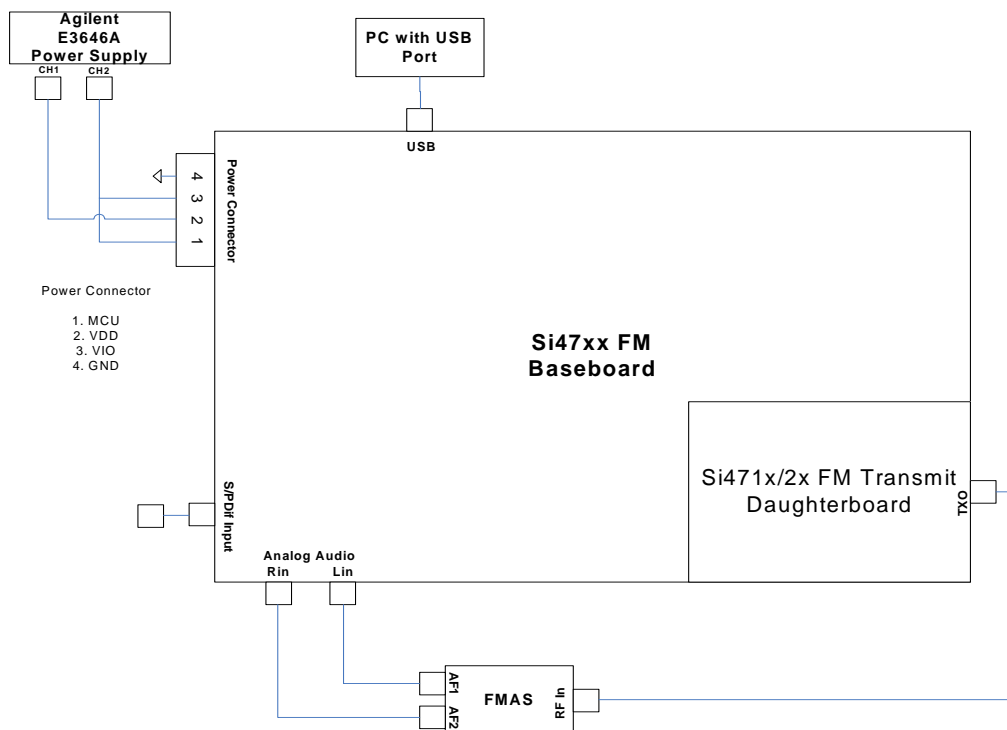
Figure 10. Si471x/2x Transmitter Measurement Analyzer Setup
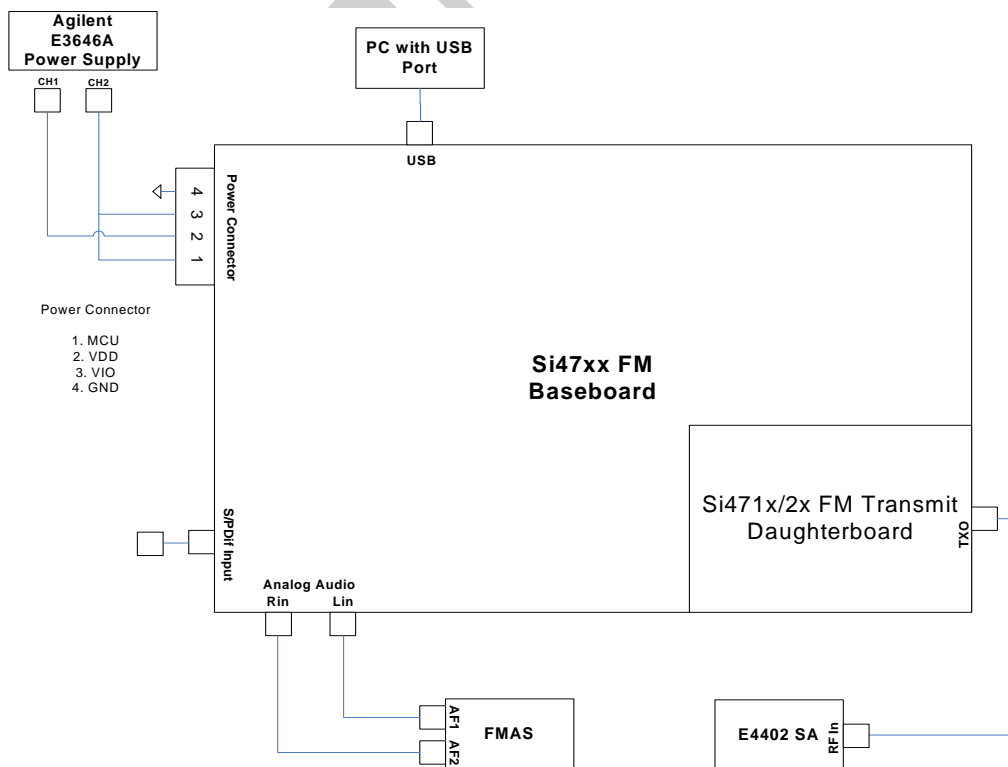
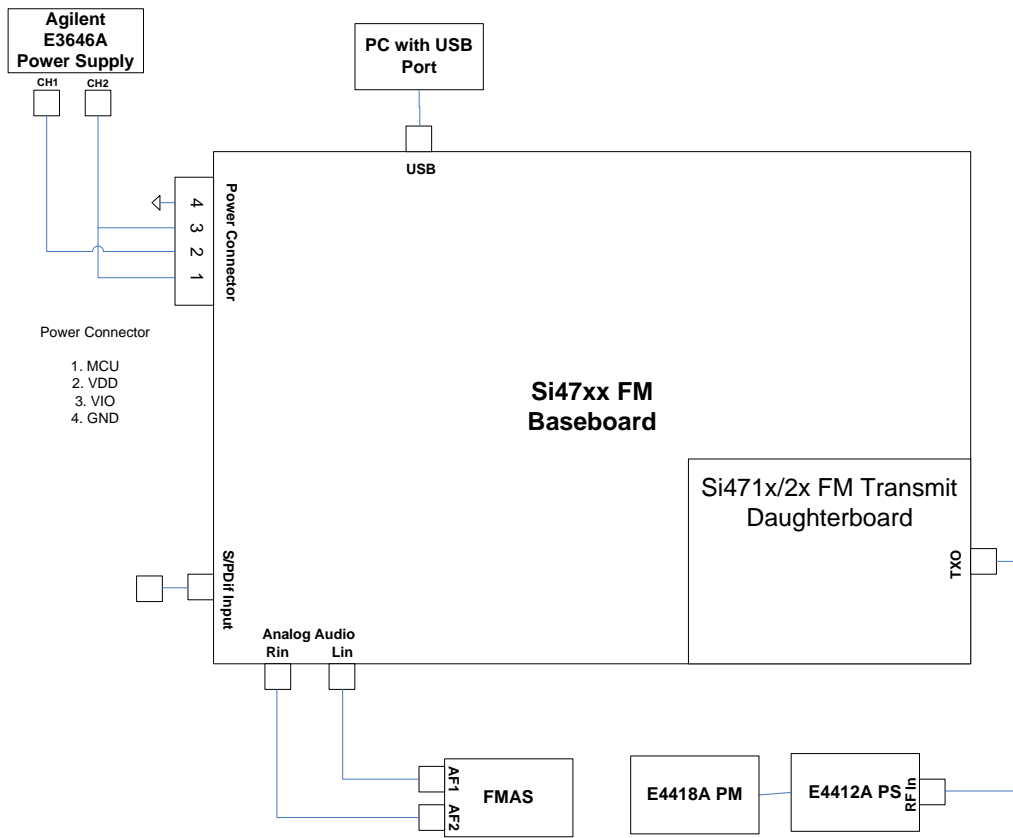**Figure 11. Si471x/2x Transmitter Spectrum Analyzer Setup**

Figure 12. Si471x/2x Transmitter Power Meter Setup

5.1. FM Transmit Testing Measurement Considerations

For the power meter measurements, the power loss of the connection between the power meter and TXO on the RF daughtercard must be calibrated into the measurement. This calibration value should be added to the measurement values returned from the Power Accuracy and Maximum Output Power measurements.

5.2. FM Transmit Testing Procedures

5.2.1. Maximum Voltage

1. Connect test equipment as shown in Figure 12.
2. Configure the transmitter:
   a. Set frequency = 98.1 MHz.
   b. Set Pilot state = ON.
   c. Set (L–R)/2 State = ON.
   d. Set Pre-emphasis = 75 µS.
   e. Set Output Voltage = 115 dBuV.
   f. Set Pilot modulation rate = 6.75 kHz.
   g. Set audio modulation rate = 68.25 kHz.
   h. Set maximum line input voltage = 636 mV.
   i. Set line input attenuation = 60 kΩ.
   j. Set dynamic range control = OFF.
3. Configure the power meter:
   a. Zero and calibrate the power sensor.
   b. Set the frequency = 98.1 MHz.
4. Configure the power supply:
   a. Configure the power supply to output 5 V on channel 2.
   b. Configure the power supply to output 3.3 V on channel 1.
5. Configure the modulation analyzer output:
   a. Set AF output = unbalanced 1 and 2.
   b. Set AF impedance = 20 Ω.
   c. Set AF tone 2 state = OFF.
   d. Set AF tone 1 state = ON.
   e. Set AF tone 1 frequency = 1 kHz.
   f. Set AF tone 1 level = 449.65 mVrms for analog audio input or 990 mVrms for digital audio input.
6. Record measured power P_{meas}, dBm.
7. Maximum Output Voltage (dBµV) = measured power (dBm) + 107 + 27.77 (dB)

*Note: 107 dB is a conversion factor from dBm to dBµV. When using the 2 pF and 50 Ω circuit on the Si471x/2x EVB, 27.7 dB is a correction factor at 98.1 mHz.

5.2.2. Voltage Accuracy

1. Connect test equipment as shown in Figure 12.

2. Configure the transmitter:

    a. Set frequency = 98.1 MHz.

    b. Set Pilot state = ON.

    c. Set (L–R)/2 State = ON.

    d. Set Pre-emphasis = 75 µS.

    e. Set Output Voltage = 115 dBuV.

    f. Set Pilot modulation rate = 6.75 kHz.

    g. Set audio modulation rate = 68.25 kHz.

    h. Set maximum line input voltage = 636 mV.

    i. Set line input attenuation = 60 kΩ.

    j. Set dynamic range control = OFF.

3. Configure the power meter:

    a. Zero and calibrate the power sensor.

    b. Set the frequency = 98.1 MHz.

4. Configure the power supply:

    a. Configure the power supply to output 5 V on channel 2.

    b. Configure the power supply to output 3.3 V on channel 1.

5. Configure the modulation analyzer output:

    a. Set AF output = unbalanced 1 and 2

    b. Set AF impedance = 20 Ω.

    c. Set AF tone 2 state = OFF.

    d. Set AF tone 1 state = ON.

    e. Set AF tone 1 frequency = 1 kHz.

    f. Set AF tone 1 level = 449.65 mVrms for analog audio input or 990 mVrms for digital audio input.

6. Record measured power P_{meas}, dBm.

7. Transmit Voltage Accuracy (dBuV) = measured power (dBm) + 107 + 27.77 (dB) – 115 (dBuV).

*__Note:__ 107 dB is a conversion factor from dBm to dBµV. When using the 2 pF and 50 Ω circuit on the Si471x/2x EVB, 27.7 dB is a correction factor at 98.1 mHz.

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5.2.3. Audio SNR

1. Connect test equipment as shown in Figure 10.
2. Configure the transmitter:
   a. Set frequency = 98.1 MHz.
   b. Set Pilot state = OFF.
   c. Set (L–R)/2 State = OFF.
   d. Set Pre-emphasis = 75 µs.
   e. Set Output Voltage = 115 dBuV.
   f. Set audio modulation rate = 22.5 kHz.
   g. Set maximum line input voltage = 636 mV.
   h. Set line input attenuation = 60 kΩ.
   i. Set dynamic range control = OFF.
3. Configure the modulation analyzer:
   a. Set RF counter resolution = 1 Hz.
   b. Set RF tune frequency = 98.1 MHz.
   c. Set receiver state = ON.
   d. Set receiver mode = Low Distortion.
   e. Set RF Filter = FM Narrow.
   f. Set FM decoder state = ON.
   g. Set demodulation measurement time = 100 ms.
   h. Set detector mode = RMS.
   i. Set Low Pass Filter = 23 kHz.
   j. Set High Pass Filter = 300 Hz.
   k. Set FM de-emphasis = 75 µs.
   l. Set FM pre DSP state = ON.
   m. Set FM demodulation range = AUTO.
4. Configure the power supply:
   a. Configure the power supply to output 5 V on channel 2.
   b. Configure the power supply to output 3.3 V on channel 1.
5. Configure the modulation analyzer output:
   a. Set AF output = unbalanced 1 and 2.
   b. Set AF impedance = 20 Ω.
   c. Set AF tone 2 state = OFF.
   d. Set AF tone 1 state = ON.
   e. Set AF tone 1 frequency = 1 kHz.
   f. Set AF tone 1 level = 449.65 mVrms for analog audio input or 990 mVrms for digital audio input.
6. Set FM range mode = fixed (Manual mode with last measured value set as reference).
7. Set FM measurement mode = Relative.
8. Set FM relative reference = measured value.
9. Turn off the audio generator.
10. Record Audio SNR in dB.

5.2.4. Audio THD

1. Connect test equipment as shown in Figure 10.
2. Configure the transmitter:
    a. Set frequency = 98.1 MHz.
    b. Set Pilot state = OFF.
    c. Set (L–R)/2 State = OFF.
    d. Set Pre-emphasis = 75 µs.
    e. Set Output Voltage = 115 dBuV.
    f. Set audio modulation rate = 75 kHz.
    g. Set maximum line input voltage = 636 mV.
    h. Set line input attenuation = 60 kΩ.
    i. Set dynamic range control = OFF.
3. Configure the modulation analyzer:
    a. Set RF counter resolution = 1 Hz.
    b. Set RF tune frequency = 98.1 MHz.
    c. Set receiver state = ON.
    d. Set receiver mode = Low Distortion.
    e. Set RF Filter = FM Narrow.
    f. Set FM decoder state = ON.
    g. Set demodulation measurement time = 100 ms.
    h. Set detector mode = RMS.
    i. Set Low Pass Filter = 23 kHz.
    j. Set High Pass Filter = 300 Hz.
    k. Set FM de-emphasis = 75 µs.
    l. Set FM pre DSP state = ON.
    m. Set FM demodulation range = AUTO.
    n. Set THD measurement state = ON.
    o. Set max harmonic = 8.
    p. Set units = %.
4. Configure the power supply:
    a. Configure the power supply to output 5 V on channel 2.
    b. Configure the power supply to output 3.3 V on channel 1.
5. Configure the modulation analyzer output:
    a. Set AF output = unbalanced 1 and 2.
    b. Set AF impedance = 20 Ω.
    c. Set AF tone 2 state = OFF.
    d. Set AF tone 1 state = ON.
    e. Set AF tone 1 frequency = 1 kHz.
    f. Set AF tone 1 level = 449.65 mVrms for analog audio input or 990 mVrms for digital audio input.
6. Record Audio THD (%).

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5.2.5. Audio Stereo Separation

1. Connect test equipment as shown in Figure 10.
2. Configure the transmitter:
   a. Set frequency = 98.1 MHz.
   b. Set Pilot state = ON.
   c. Set (L–R)/2 State = ON.
   d. Set Pre-emphasis = 75 µs.
   e. Set Output Voltage = 115 dBuV.
   f. Set Pilot modulation rate = 6.75 kHz.
   g. Set audio modulation rate = 68.25 kHz.
   h. Set maximum line input voltage = 636 mV.
   i. Set line input attenuation = 60 kΩ.
   j. Set dynamic range control = OFF.
3. Configure the modulation analyzer:
   a. Set RF counter resolution = 1 Hz.
   b. Set RF tune frequency = 98.1 MHz.
   c. Set receiver state = ON.
   d. Set receiver mode = Low Distortion.
   e. Set RF Filter = FM Narrow.
   f. Set stereo decoder state = ON.
   g. Set demodulation measurement time = 100 ms.
   h. Set detector mode = RMS.
   i. Set stereo units = dBm.
   j. Set stereo channel = Left.
   k. Set stereo de-emphasis = 75 µs.
4. Configure the power supply:
   a. Configure the power supply to output 5 V on channel 2.
   b. Configure the power supply to output 3.3 V on channel 1.
5. Configure the modulation analyzer output:
   a. Set AF output = unbalanced 1.
   b. Set AF impedance = 20 Ω.
   c. Set AF tone 2 state = OFF.
   d. Set AF tone 1 state = ON.
   e. Set AF tone 1 frequency = 1 kHz.
   f. Set AF tone 1 level = 449.65 mVrms for analog audio input or 990 mVrms for digital audio input.
6. Record modulation level, P_{left}, in dBm.
7. Set the modulation analyzer stereo channel to right.
8. Record modulation level, P_{right}, in dBm.
9. Audio Stereo Separation (dB) = $P_{left} - P_{right}$.

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5.2.6. Sub Carrier Rejection Ratio

1. Connect test equipment as shown in Figure 10.
2. Configure the transmitter:
   a. Set frequency = 98.1 MHz.
   b. Set Pilot state = ON.
   c. Set (L–R)/2 State = ON.
   d. Set Pre-emphasis = 75 μS.
   e. Set Output Voltage = 115 dBuV.
   f. Set Pilot modulation rate = 6.75 kHz.
   g. Set audio modulation rate = 68.25 kHz.
   h. Set maximum line input voltage = 636 mV.
   i. Set line input attenuation = 60 kΩ.
   j. Set dynamic range control = OFF.
3. Configure the modulation analyzer:
   a. Set RF counter resolution = 1 Hz.
   b. Set RF tune frequency = 98.1 MHz.
   c. Set receiver state = ON.
   d. Set receiver mode = Low Distortion.
   e. Set RF Filter = FM Narrow.
   f. Set stereo decoder state = ON.
   g. Set demodulation measurement time = 100 ms.
   h. Set detector mode = RMS.
   i. Set stereo units = dBm.
   j. Set stereo channel = MPX.
   k. Set high pass filter = 10 Hz.
   l. Set low pass filter = OFF.
4. Configure the power supply:
   a. Configure the power supply to output 5 V on channel 2.
   b. Configure the power supply to output 3.3 V on channel 1.
5. Configure the modulation analyzer output:
   a. Set AF output = unbalanced 1 and 2.
   b. Set AF impedance = 20 Ω.
   c. Set AF tone 2 state = OFF.
   d. Set AF tone 1 state = ON.
   e. Set AF tone 1 frequency = 1 kHz.
   f. Set AF tone 1 level = 449.65 mVrms for analog audio input or 990 mVrms for digital audio input.
6. Record modulation level, Preference, in dBm.
7. Set the modulation analyzer tunable bandpass filter state = ON.
8. Set the modulation analyzer tunable bandpass filter frequency = 38 kHz.
9. Record modulation level, $P_{carrier}$, in dBm.
10. Sub Carrier Rejection Ratio (dB) = $P_{reference} - P_{carrier}$.
11. Set the modulation analyzer tunable bandpass filter state = OFF.

5.2.7. Audio Input Imbalance

1. Connect test equipment as shown in Figure 10.
2. Configure the transmitter:
    a. Set frequency = 98.1 MHz.
    b. Set Pilot state = OFF.
    c. Set (L–R)/2 State = OFF.
    d. Set Pre-emphasis = 75 µS.
    e. Set Output Voltage = 115 dBuV.
3. Configure the modulation analyzer:
    a. Set RF counter resolution = 1 Hz.
    b. Set RF tune frequency = 98.1 MHz.
    c. Set receiver state = ON.
    d. Set receiver mode = Low Distortion.
    e. Set RF Filter = FM Narrow.
    f. Set stereo decoder state = ON.
    g. Set demodulation measurement time = 100 ms.
    h. Set detector mode = RMS.
    i. Set stereo units = dBm.
    j. Set stereo channel = M.
4. Configure the power supply:
    a. Configure the power supply to output 5 V on channel 2.
    b. Configure the power supply to output 3.3 V on channel 1.
5. Configure the modulation analyzer output:
    a. Set AF output = unbalanced 1.
    b. Set AF impedance = 20 Ω.
    c. Set AF tone 2 state = OFF.
    d. Set AF tone 1 state = ON.
    e. Set AF tone 1 frequency = 1 kHz.
    f. Set AF tone 1 level = 449.65 mVrms for analog audio input or 990 mVrms for digital audio input.
6. Record modulation level, P_{left}, in dBm.
7. Set the audio generator to Channel 2 output only.
8. Record modulation level, P_{right}, in dBm.
9. Audio Imbalance (dB) = $P_{left} - P_{right}$.

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5.2.8. Modulation Rate Accuracy

1. Connect test equipment as shown in Figure 10.
2. Configure the transmitter:
   a. Set frequency = 98.1 MHz.
   b. Set Pilot state = ON.
   c. Set (L–R)/2 State = ON.
   d. Set Pre-emphasis = 75 µS.
   e. Set Output Voltage = 115 dBuV.
   f. Set Pilot modulation rate = 6.75 kHz.
   g. Set audio modulation rate = 68.25 kHz .
   h. Set maximum line input voltage = 636 mV.
   i. Set line input attenuation = 60 kΩ.
   j. Set dynamic range control = OFF.
3. Configure the modulation analyzer:
   a. Set RF counter resolution = 1 Hz.
   b. Set RF tune frequency = 98.1 MHz.
   c. Set receiver state = ON.
   d. Set receiver mode = Low Distortion.
   e. Set RF Filter = FM Narrow.
   f. Set stereo decoder state = ON.
   g. Set demodulation measurement time = 100 ms.
   h. Set detector mode = ±Peak/2.
   i. Set stereo units = Hz.
   j. Set stereo channel = Pilot.
4. Configure the power supply:
   a. Configure the power supply to output 5 V on channel 2.
   b. Configure the power supply to output 3.3 V on channel 1.
5. Configure the modulation analyzer output:
   a. Set AF output = unbalanced 1 and 2.
   b. Set AF impedance = 20 Ω.
   c. Set AF tone 2 state = OFF.
   d. Set AF tone 1 state = ON.
   e. Set AF tone 1 frequency = 1 kHz.
   f. Set AF tone 1 level = 449.65 mVrms for analog audio input or 990 mVrms for digital audio input.
6. Record Modulation Rate Accuracy (kHz).

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5.2.9. Voltage Step

1. Connect test equipment as shown in Figure 11.
2. Configure the transmitter:
    a. Set frequency = 98.1 MHz.
    b. Set Pilot state = ON.
    c. Set (L–R)/2 State = ON.
    d. Set Pre-emphasis = 75 μS.
    e. Set Output Voltage = 115 dBuV.
    f. Set Pilot modulation rate = 6.75 kHz.
    g. Set audio modulation rate = 68.25 kHz.
    h. Set maximum line input voltage = 636 mV.
    i. Set line input attenuation = 60 kΩ.
    j. Set dynamic range control = OFF.
3. Configure the spectrum analyzer:
    a. Set number of points = 601.
    b. Set detector state = Average
    c. Set center frequency = 98.1 MHz.
    d. Set measurement mode = Channel Power.
    e. Set integration BW = 200 kHz.
    f. Set channel power span = 300 kHz.
    g. Set averaging state = OFF.
    h. Set resolution bandwidth = 1 kHz.
4. Configure the power supply:
    a. Configure the power supply to output 5 V on channel 2.
    b. Configure the power supply to output 3.3 V on channel 1.
5. Configure the modulation analyzer output:
    a. Set AF output = unbalanced 1 and 2.
    b. Set AF impedance = 20 Ω.
    c. Set AF tone 2 state = OFF.
    d. Set AF tone 1 state = ON.
    e. Set AF tone 1 frequency = 1 kHz.
    f. Set AF tone 1 level = 449.65 mVrms for analog audio input or 990 mVrms for digital audio input.
6. Set first power level = 115 dBuV.
7. Perform auto adjust ref level on spectrum analyzer.
8. Record channel power, P1, in dBm.
9. Decrease chip output power by one step.
10. Record channel power, P2, in dBm.
11. Transmit Power Step (dB) = P1 – P2.
12. Repeat steps 9–12 until the worse case power step is found and record.

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5.2.10. Channel Edge Power

1. Connect test equipment as shown in Figure 11.
2. Configure the transmitter:
    a. Set frequency = 98.1 MHz.
    b. Set Pilot state = ON.
    c. Set (L–R)/2 State = ON.
    d. Set Pre-emphasis = 75 µS.
    e. Set Output Voltage = 115 dBuV.
    f. Set Pilot modulation rate = 6.75 kHz.
    g. Set audio modulation rate = 68.25 kHz.
    h. Set maximum line input voltage = 636 mV.
    i. Set line input attenuation = 60 kΩ.
    j. Set dynamic range control = OFF.
3. Configure the spectrum analyzer:
    a. Set number of points = 601.
    b. Set detector state = Average.
    c. Set center frequency = 98.1 MHz.
    d. Set span = 200 kHz.
    e. Set resolution bandwidth = 3 kHz.
    f. Set averaging state = OFF.
4. Configure the power supply:
    a. Configure the power supply to output 5 V on channel 2.
    b. Configure the power supply to output 3.3 V on channel 1.
5. Configure the modulation analyzer output:
    a. Set AF output = unbalanced 1 and 2.
    b. Set AF impedance = 20 Ω.
    c. Set AF tone 2 state = OFF.
    d. Set AF tone 1 state = ON.
    e. Set AF tone 1 frequency = 1 kHz.
    f. Set AF tone 1 level = 449.65 mVrms for analog audio input or 990 mVrms for digital audio input.
6. Perform marker peak search.
7. Set ref level to marker level.
8. Perform marker peak search.
9. Record marker level, P_{chan}, in dBm.
10. Set the spectrum analyzer start frequency = 98.2 MHz.
11. Set the spectrum analyzer stop frequency = 98.6 MHz.
12. Perform marker peak search.
13. Record marker level, P_{edge}, in dBm.
14. Channel Edge Power (dB) = $P_{chan} - P_{edge}$.
15. Repeat above measurement with start frequency = 97.6 MHz and stop frequency = 98.0 MHz.

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5.2.11. Adjacent/Alternate Channel Power

1. Connect test equipment as shown in Figure 11.
2. Configure the transmitter:
    a. Set frequency = 98.1 MHz.
    b. Set Pilot state = ON.
    c. Set (L–R)/2 State = ON.
    d. Set Pre-emphasis = 75 µS.
    e. Set Output Voltage = 115 dBuV.
    f. Set Pilot modulation rate = 6.75 kHz.
    g. Set audio modulation rate = 68.25 kHz.
    h. Set maximum line input voltage = 636 mV.
    i. Set line input attenuation = 60 kΩ.
    j. Set dynamic range control = OFF.
3. Configure the spectrum analyzer:
    a. Set number of points = 601.
    b. Set detector state = Average.
    c. Set center frequency = 98.1 MHz.
    d. Set measurement mode = Channel Power.
    e. Set integration BW = 200 kHz.
    f. Set channel power span = 300 kHz.
    g. Set averaging state = OFF.
    h. Set resolution bandwidth = 1 kHz.
4. Configure the power supply:
    a. Configure the power supply to output 5 V on channel 2.
    b. Configure the power supply to output 3.3 V on channel 1.
5. Configure the modulation analyzer output:
    a. Set AF output = unbalanced 1 and 2.
    b. Set AF impedance = 20 Ω.
    c. Set AF tone 2 state = OFF.
    d. Set AF tone 1 state = ON.
    e. Set AF tone 1 frequency = 1 kHz.
    f. Set AF tone 1 level = 449.65 mVrms for analog audio input or 990 mVrms for digital audio input.
6. Perform auto adjust ref level on spectrum analyzer.
7. Record channel power, $P_{carrier}$, in dBm.
8. Set center frequency = 98.3 MHz (adjacent channel) or set center frequency = 98.7 MHz (alternate channel).
9. Record channel power, P_{alt}, in dBm.
10. Adjacent/Alternate Channel Power (dB) = $P_{carrier} - P_{alt}$.
11. Repeat steps 9–11 with 97.9 MHz (adjacent channel) or 97.7 MHz (alternate channel).

5.2.12. Transmit Emissions

1. Connect test equipment as shown in Figure 11.

2. Configure the transmitter:
   a. Set frequency = 98.1 MHz.
   b. Set Pilot state = ON.
   c. Set (L–R)/2 State = ON.
   d. Set Pre-emphasis = 75 µS.
   e. Set Output Voltage = 115 dBuV.
   f. Set Pilot modulation rate = 6.75 kHz.
   g. Set audio modulation rate = 68.25 kHz.
   h. Set maximum line input voltage = 636 mV.
   i. Set line input attenuation = 60 kΩ.
   j. Set dynamic range control = OFF.

3. Configure the spectrum analyzer:
   a. Set number of points = 601.
   b. Set detector state = Average.
   c. Set start frequency = 76 MHz.
   d. Set start frequency = 108 MHz.
   e. Set resolution bandwidth = 3 kHz.
   f. Set averaging state = OFF.
   g. Set marker threshold = –110 dBm.

4. Configure the power supply:
   a. Configure the power supply to output 5 V on channel 2.
   b. Configure the power supply to output 3.3 V on channel 1.

5. Configure the modulation analyzer output:
   a. Set AF output = unbalanced 1 and 2.
   b. Set AF impedance = 20 Ω.
   c. Set AF tone 2 state = OFF.
   d. Set AF tone 1 state = ON.
   e. Set AF tone 1 frequency = 1 kHz.
   f. Set AF tone 1 level = 449.65 mVrms for analog audio input or 990 mVrms for digital audio input.

6. Perform marker peak search.

7. Set ref level to marker amplitude.

8. Perform marker peak search.

9. Record marker level, P_{chan}, in dBm.

10. Perform marker next peak search.

11. Record marker frequency.

12. Repeat steps 9 and 10 until f is either less than 98.0 MHz or greater than 98.2 MHz.

13. Record marker level, $P_{emission}$, in dBm.

14. Transmit Emissions (dB) = $P_{chan} - P_{emission}$.

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6. Digital Audio Settings

6.1. Digital Audio Output for AM and FM Receivers

All AM/FM measurements can be done in digital audio output mode as well.

You will need to select the digital analyzer mode and configure the audio analyzer as:

Meas Mode = Audio data

Input: Optical

Sync to: Audio IN

Sample Frq: Value = 48000 Hz

Audio bits: 24

Keep in mind that the units for certain measurements will change in digital mode. For example:

Vrms will be FS (for full scale voltage), and

dB level used for noise measurements will be dBFS.

All relative measurements expressed in dB will remain the same.

6.2. Digital Audio Input for FM Transmitter

All FM transmit measurements can be made using digital audio input or by using the CODEC on the baseboard of the Si471x/2x EVB. The CODEC receives an analog audio input and converts it to digital audio. The user does not need to change any testing setup with the exception of the audio output level:

- A level of 449.65 Vrms is required for analog audio input to reach a 636 mVpk full scale input of the Si471x/2x.
- A level of 990 mVrms is required for digital audio input to reach a –1 dBFS input of the CODEC.

The CODEC can be configured by using the Si47xx GUI.

APPENDIX A—PRE-EMPHASIS AND DE-EMPHASIS

A review of FM modulation can be used to understand the effect of pre-emphasis on the spectrum. For a single-tone message,

$$m(t) = A_m \cos(2\pi f_m t) \qquad \text{message signal}$$

$$s(t) = A_c \cos(2\pi f_c t) \qquad \text{RF carrier}$$

the modulated signal can be represented as:

$$s(t) = A_c \cos\left(2\pi f_c t + 2\pi k_f \int_0^t m(t) dt\right)$$

$$= A_c \cos\left(2\pi f_c t + \frac{k_f A_m}{f_m} \sin(2\pi f_m t)\right)$$

with a modulation index, β

$$\beta = \frac{k_f A_m}{f_m} = \frac{\Delta_f}{f_m} = \frac{\text{freq deviation}}{\text{modulating freq}} = \text{modulation index}$$

The bandwidth of this signal would be approximately:

$$BW_{s(t)} \approx 2(\Delta f + f_m)$$

The frequency response of a pre-emphasis filter is shown in Figure 13. Depending on the region, a time constant of either 50 or 75 µs is used. This time constant affects the range of frequencies that will be emphasized by the filter. Also, the increase in signal at higher frequencies depends on the time constant of this filter. For a 75 µs filter, 15 kHz would get an increase of 5.3 times relative to 1 kHz, whereas a 50 µs filter would provide an increase in the order of 4.8 times relative to 1 kHz.

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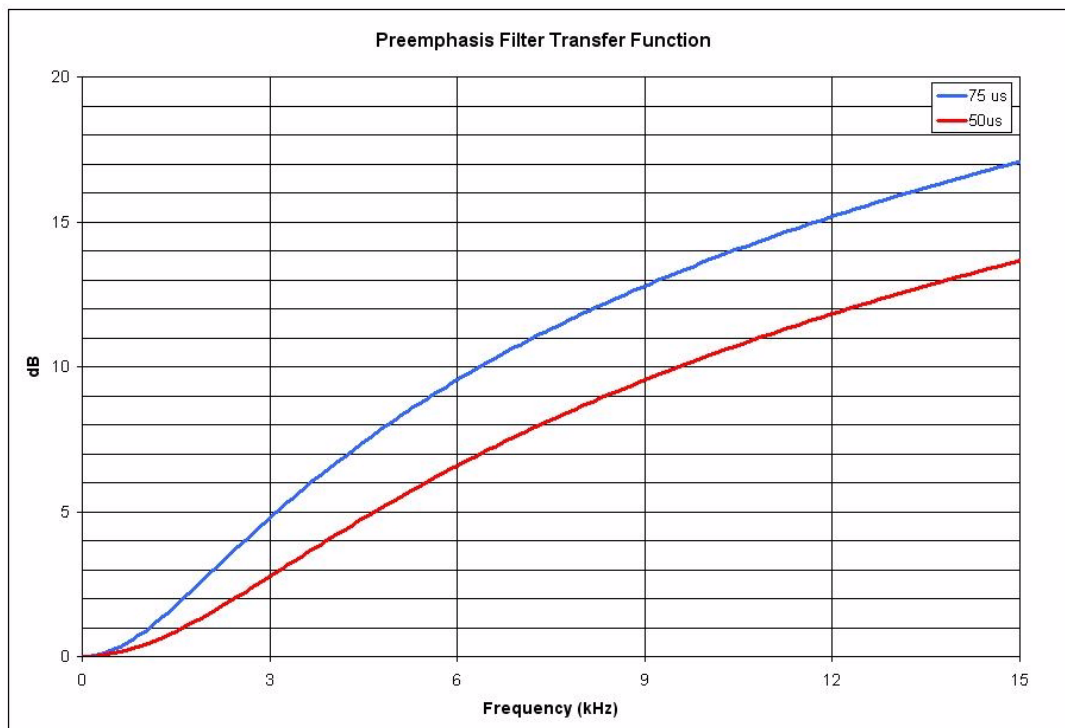
Figure 13. Pre-emphasis Filter Response

To compensate for the effects of pre-emphasis, the tuner has a de-emphasis filter with low pass characteristics. This filter would need to attenuate higher frequency signals to achieve a flat audio frequency response. Frequency response of an ideal de-emphasis filter for both time constants is shown in Figure 14.
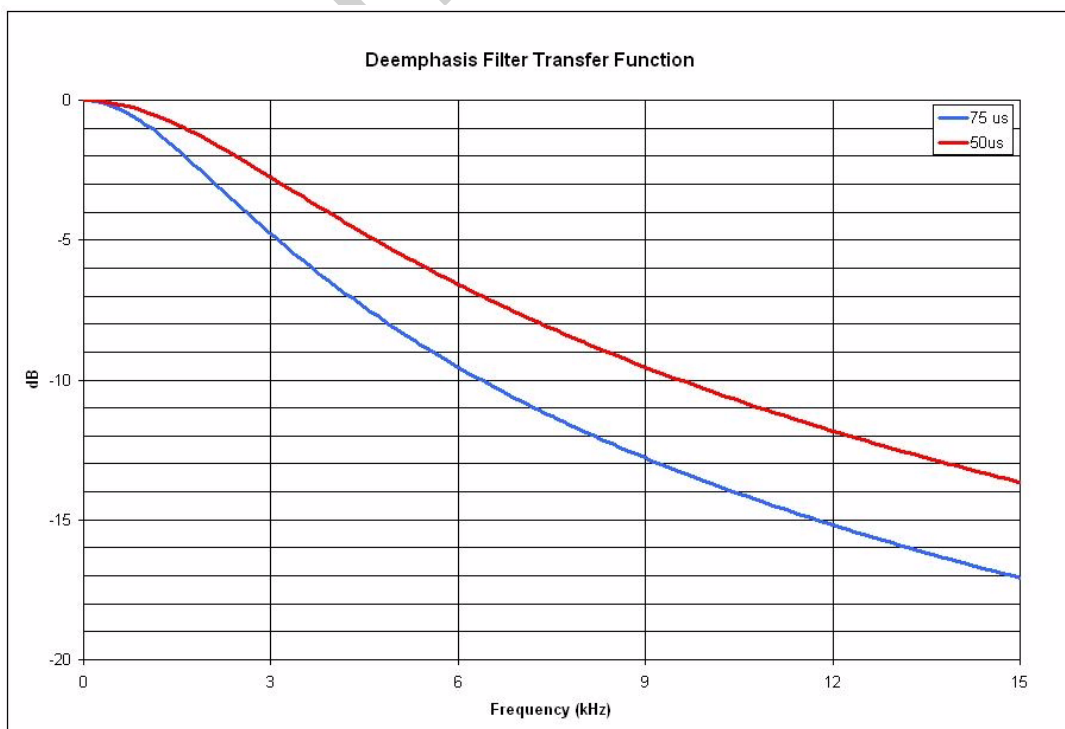

Figure 14. De-emphasis Filter Response

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Figures 15 through 16 are examples of FM spectra with different modulation frequencies and frequency deviations.

With low modulation frequencies, applying a pre-emphasis filter has minimum effect on the FM bandwidth since the filter has high-pass characteristics. In Figure 15 and Figure 16, where the modulation frequency is 1 kHz and deviation is 10.5 kHz, you can see that the overall bandwidth does not change with pre-emphasis. The same is true for Figure 19 and Figure 20.

With higher modulation frequencies, the pre-emphasis filter increases the modulating signal amplitude, AM, which translates into a higher FM bandwidth (Figure 17 and Figure 18.) The effect of the pre-emphasis filter combined with higher deviations increases the bandwidth. This increase in the bandwidth is equivalent to having a modulated signal with a frequency deviation higher than the maximum permissible deviation. That is why the deviation should be adjusted when pre-emphasis is applied such that the overall bandwidth is equal to the bandwidth with maximum deviation at 15 kHz modulation frequency.
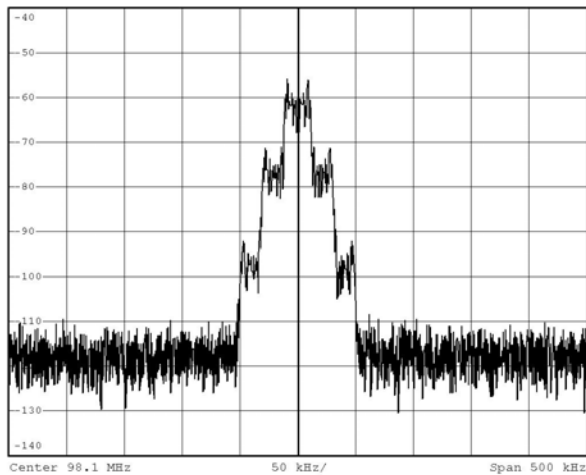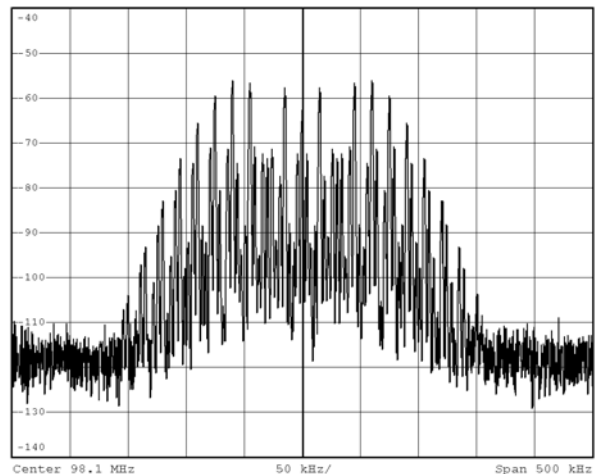

Figure 15. RF Frequency = 98.1 MHz, Frequency Deviation = 10.5 kHz, Modulation Frequency = 1 kHz, Pre-emphasis OFF
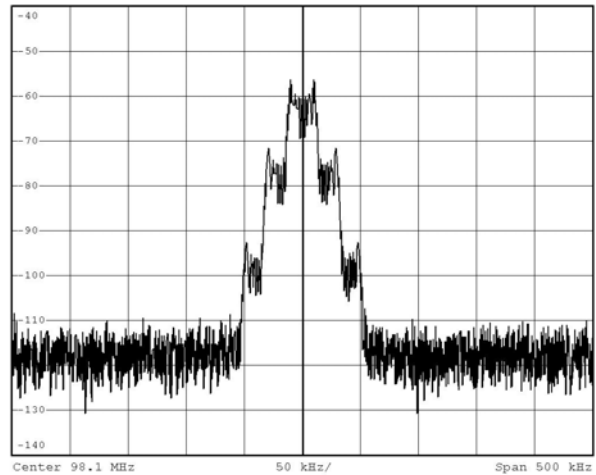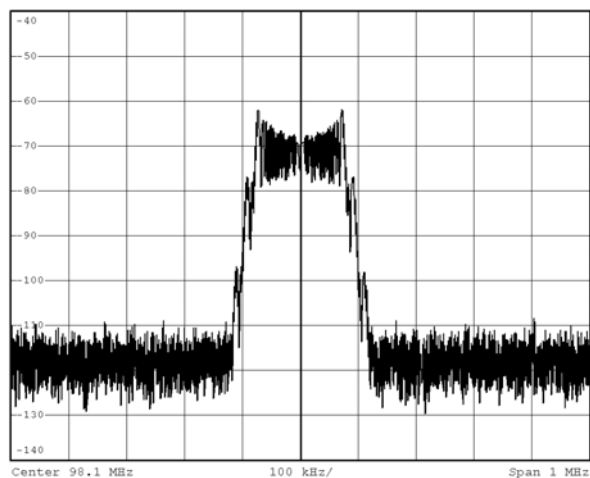

Figure 16. RF Frequency = 98.1 MHz, Frequency Deviation = 10.5 kHz, Modulation Frequency = 1 kHz, Pre-emphasis = 75 µs
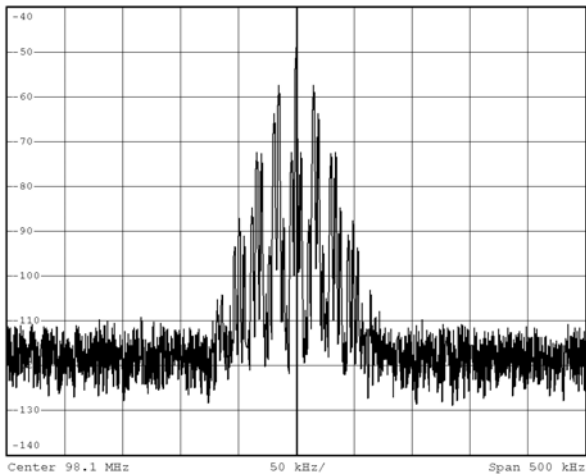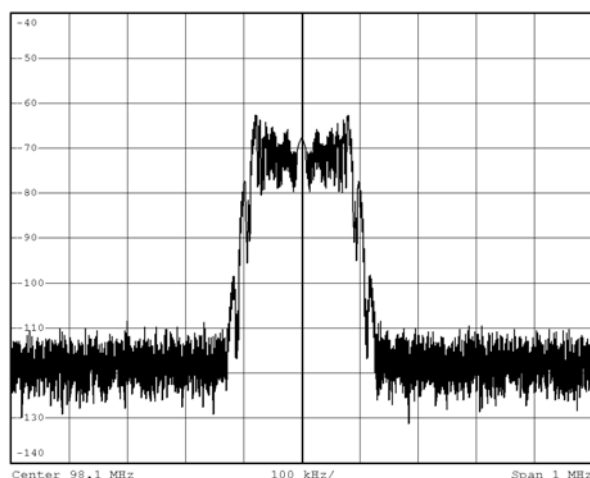

Figure 17. RF Frequency = 98.1 MHz, Frequency Deviation = 10.5 kHz, Modulation Frequency = 15 kHz, Pre-emphasis OFF
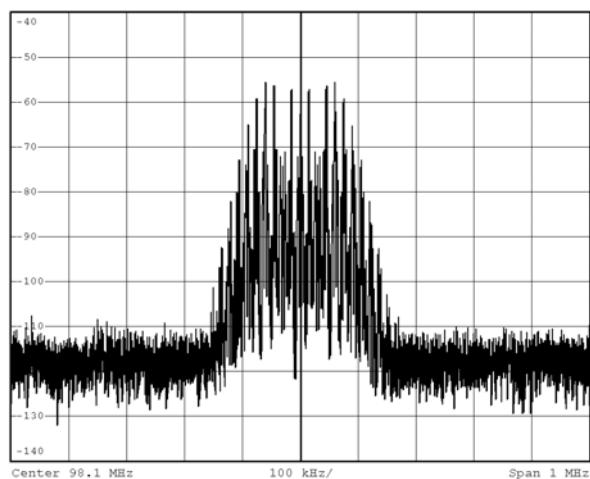

Figure 18. RF Frequency = 98.1 MHz, Frequency Deviation = 10.5 kHz, Modulation Frequency = 15 kHz, Pre-emphasis = 75 µs
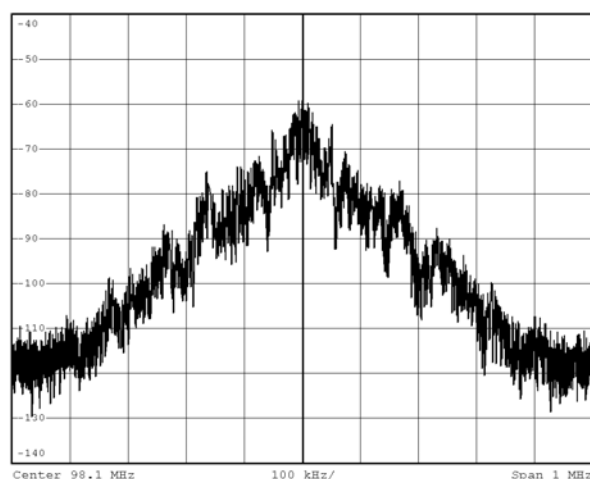
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Figure 19. RF Frequency = 98.1 MHz,
Frequency Deviation = 75 kHz,
Modulation Frequency = 1 kHz,
Pre-emphasis OFF

Figure 20. RF Frequency = 98.1 MHz,
Frequency Deviation = 75 kHz,
Modulation Frequency = 1 kHz,
Pre-emphasis = 75 µs

Figure 21. RF Frequency = 98.1 MHz,
Frequency Deviation = 75 kHz,
Modulation Frequency = 15 kHz,
Pre-emphasis OFF

Figure 22. RF Frequency = 98.1 MHz,
Frequency Deviation = 75 kHz,
Modulation Frequency = 15 kHz,
Pre-emphasis = 75 µs

DOCUMENT CHANGE LIST

Revision 0.1 to Revision 0.2

- Combined AN234 and AN388 under AN388 and restructured the document.
- Added Weather Band Test Procedure.
- Added Test Procedure for LW and SW.
- Added settings for digital audio input and output.

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