# SC1894 FW4.5.01.00 Release Notes User Guide

*UG7443; Rev 0; 03/21*


## Abstract

This user guide provides information to evaluate the operation and performance of the SC1894A-00N13 with different power amplifiers.

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# Introduction

## Overview

The SC1894A-00N13 RF power amplifier (PA) Linearizer (RFPAL) is a variant of the SC1894A-00C13 RFPAL. The SC1894A-00N13 is designed for use with narrowband signals such as are used in Narrowband Internet of Things (NB-IoT), digital television broadcast, and public safety applications (e.g., TETRA) in contrast with the SC1894A-00C13 which is targeted at cellular infrastructure applications. The SC1894A-00C13 is used with the firmware (FW) version 4.1.03.08. Refer to the *SC1894 FW4.1.03.08 Release Notes User Guide* (Ref [3]) for a detailed description of the SC1894A-00C13.

The SC1894A-00N13 is the same IC as SC1894A-00C13. However, the firmware loaded into the electrically erasable programmable read-only memory (EEPROM) in the factory is the FW version 4.5.01.00. This firmware enables operation with signal bandwidths down to 25kHz, compared to the minimum supported signal bandwidth (BW) of 1.2MHz for SC1894A-00C13. In addition, the SC1894A-00N13 has improved linearization performance in the very high frequency (VHF) band and can be used down to 135MHz carrier center frequency. Also, a so-called “rapid bin switching” feature has been added. This feature allows storage of the state of the analog correction engine (ACE) of the RFPAL in a “bin” or page of memory. These bins can be rapidly swapped between EEPROM, scratch memory, and the ACE by firmware in response to serial peripheral interface (SPI) commands issued by the host. The rapid bin switching feature allows factory calibration over several operating condition variables, such as carrier center frequency, signal bandwidth, PA output power or temperature, and then rapidly switching these pre-determined parameters into the ACE as the current operating conditions require. The FW4.5.01.00 is referred to as the “narrowband firmware” henceforth in this document.

## Scope

Most of the content of the *SC1894 FW4.1.03.08 Release Notes User Guide* (Ref [3]) is applicable to the SC1894A-00N13. However, there are some differences. This user guide assumes the reader is familiar with the SC1894A-00C13, and it focuses on the differences between the SC1894A-00C13/FW4.1.03.08 and the SC1894A-00N13/FW4.5.01.00. Basic knowledge such as how to set up an SC1894 EVK and confirm basic operation is assumed and not repeated in this user guide. One important reference is the *Narrowband Firmware* section of the *SC1894 SPI Programming Guide ver. 3.2* or higher (Ref [1]), which provides detailed information on how to configure the narrowband firmware.

## Firmware–IC Compatibility

It is possible to burn firmware into the EEPROM of the SC1894 either using the RFPAL Advanced GUI or following the instructions in the *SC1894 SPI Programming Guide* (Ref [1]). This is useful for recovering from a corrupted EEPROM for example. The SC1894A-00N13 is configured such that the narrowband firmware runs only on this part. If one burns the narrowband firmware into any other SC1894-variant IC such as the SC1894A-00C13, it does not run, and an error is thrown. One can, however, burn the 4.1.03.08 firmware into an SC1894A-00N13 part and it runs with no problems.

It is not possible to distinguish the SC1894A-00C13 and SC1894A-00N13 parts by visual inspection. The only way to distinguish them is to try running the narrowband firmware on the device. If it is an SC1894A-00N13 device, then the narrowband firmware runs, otherwise, an error is thrown by the firmware. Therefore, it is recommended that if a customer is stocking both kinds of parts, care should be taken to keep them separate so as not to mix them up.

⚠ *SC1894A-00C13 and SC1894-00N13 parts cannot be distinguished by visual inspection.*

The SC1894A-00C13 parts ship from the factory with FW4.1.03.08 loaded in the EEPROM. The SC1894A-00N13 parts ship with FW4.5.01.00 loaded.

## Evaluation Kit

The SC1894A-00N13 uses the same evaluation kits (EV kits) as the other SC1894 part variants. See Table 1.

## Table 1. SC1894 Evaluation Kits

| FREQUENCY (MHz) | EV KITS |
|---|---|
| 3300–3800 | (P/N SC1894-EVK3400) |
| 2300–2700 | (P/N SC1894-EVK2400) |
| 1800–2200 | (P/N SC1894-EVK1900) |
| 1350–1800 | (P/N SC1894-EVK1500) |
| 698–960 | (P/N SC1894-EVK900) |
| 470–928 | (P/N SC1894-EVK500) |
| 135–470 | (P/N SC1894-EVK200) |

Currently and in the future, all SC1894 EV kits ship from the Maxim Integrated factory with SC1894A-00N13 parts populated. The firmware loaded in the factory is FW4.1.03.08. With these EVKs, it is possible to burn the narrowband firmware using the GUI, and the EV kit becomes operational. However, the SC1894 EVKs that have already been shipped to distributors in the past have SC1894A-00C13 parts assembled, and so are incapable of running the narrowband firmware. If one wishes to evaluate the narrowband firmware, the EVK should be ordered through the Maxim Integrated website and Buy Direct from Maxim should be specified.

⚠ *For SC1894 EVKs to evaluate narrowband firmware, order from Maxim Integrated directly.*

### EVK Rework for Narrowband Adaptation

As discussed in the section *Frequency Locked Reference Clock*, in order for the firmware to adapt with signals having bandwidth less than 1.2MHz, it is necessary to provide an external reference clock to the RFPAL instead of using the on-board 20MHz crystal. This requires a small amount of rework to the EVK. The instructions for the rework are provided in the section *EVK Modifications for Narrowband Adaptation*.

### USB Adapter

It is highly recommended to use the SC-USB-SPI-PICO adapter to connect the PC running the GUI to the EVK. In addition to USB2.0 and USB3.0, this adapter supports Windows® 7 and 10. The adapter can be ordered from the Maxim Integrated website.

## GUI

The latest version of the RFPAL Advanced GUI is 3.0.11.0. This can be downloaded from the SC1894 product page on the Maxim Integrated website. If the GUI detects that the SC1894 has narrowband firmware installed, it exposes two extra tabs which enable the user to configure the narrowband operation of the SC1894. The use of the narrowband firmware-specific tabs is discussed in detail in the section *SC1894 GUI Description*. The same GUI is used for all other SC1894 variants, as well as SC1905.

⚠ *It is required to uninstall all previous versions of the RFPAL GUI and all previously installed firmware before installing the latest version of the RFPAL GUI.*

# Narrowband Firmware Detailed Description

### Overview

The narrowband firmware is based on FW4.1.03.08 but with several new features added to support operation with narrowband signals. Henceforth in this document, the term “narrowband signal” refers to a signal having a bandwidth lower than 1.2MHz. The new features are:

- Support for signal bandwidths down to 25kHz
- A rapid bin switching mode
- Extension of operating RF range down to 135MHz

### Operating Modes

The key difference between the narrowband firmware and FW4.1.03.08 is that FW4.1.03.08 behaves in an autonomous fashion with regard to detecting changes in the conditions; for example, PA output power steps, temperature changes, carrier center frequency or carrier configuration change. The 4.1.03.08 firmware automatically detects the change in condition and reacts to it. The narrowband firmware can be operated in the so-called FW4.1.03.08 mode where it essentially behaves the same as FW4.1.03.08. The other mode is called the bin switching mode. In the bin switching mode, a set of 128-byte “bins” or pages of memory are allocated to store the parameters which define the state of the analog correction engine (ACE). The contents of these bins are fixed during factory calibration (this is a similar concept to Smooth Mode calibration of FW4.1.03.08). The bins can be transferred rapidly between EEPROM, scratch RAM, and the ACE through SPI commands issued by the host. Up to 40 EEPROM bins (EBINs) and eight RAM bins (RBINs) are supported.

In the bin switching mode, the SC1894 behaves more as a dumb slave and relies on the host providing information on the current signal and commanding it to load the bin that corresponds most closely to the current operating conditions. The host must have calibrated at least one bin and keep track of which bin corresponds to which set of conditions. In the bin switching mode, one can either just apply the static parameters or else configure the firmware to adapt after loading a bin into the ACE. The host must, therefore, have knowledge of the current operating conditions, and when they change in order to be able to command the firmware to respond to the change.

The Customer Configuration Parameters, scratch variables, and SPI special action commands to support these operating modes are described in detail in the *SC1894 SPI Programming Guide* (Ref [1]). This user guide explains how to use the GUI to operate the SC1894A-00N13 and evaluate the performance.

## SC1894 GUI Description

The main window of the 3.0.11.0 GUI is shown in **Figure 1**.

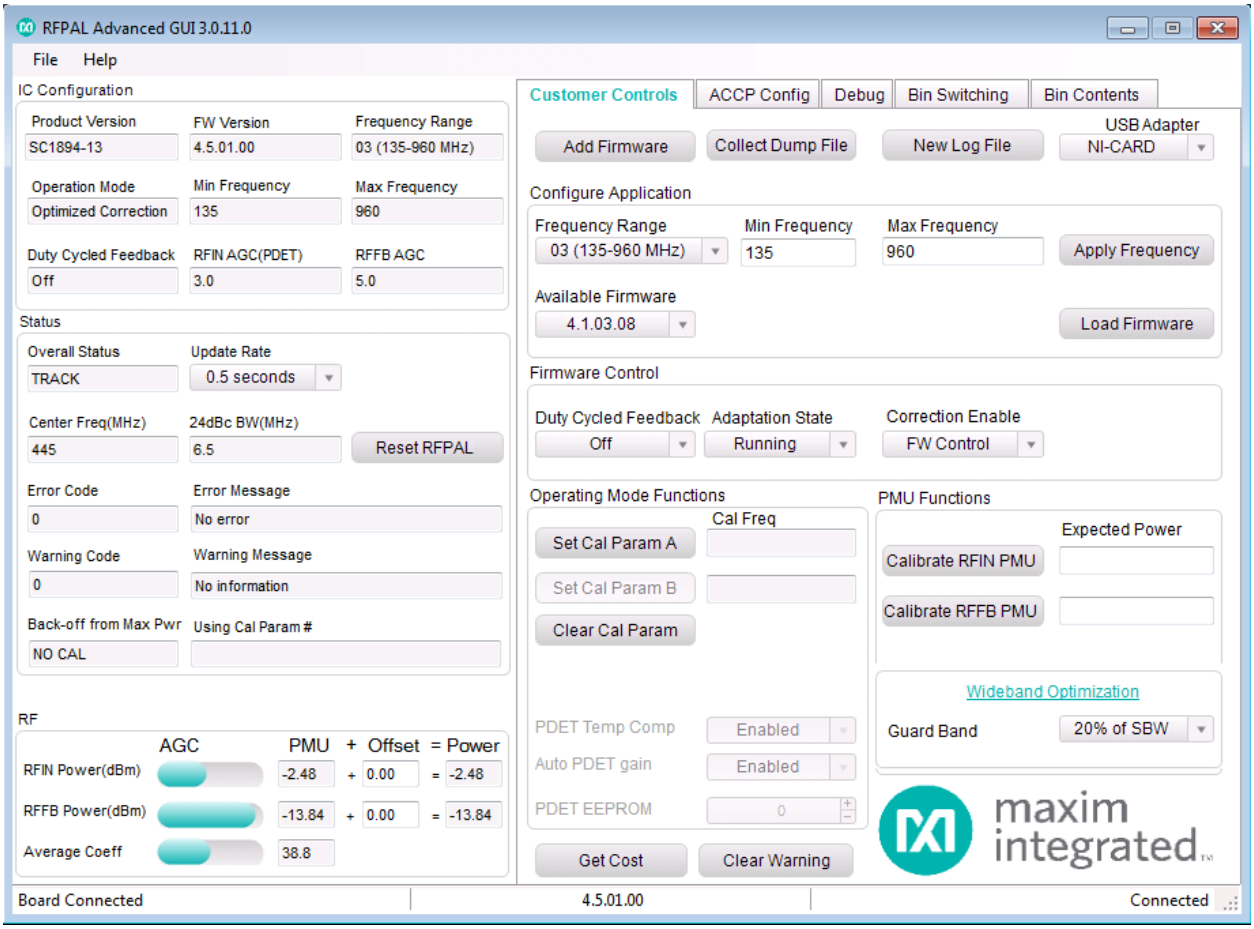


*Figure 1. SC1894 advanced GUI.*

### *Main Window*

The layout of the main window is very similar to previous GUI versions such as 3.0.9.0 and the Scintera 2.5.10 GUI. Since the main features of the **IC Configuration** pane and **Customer Controls** tab are discussed in depth in the *SC1894 FW4.1.03.08 Release Notes User Guide* (Ref [3]), that information is not repeated in this document. For more information, refer to the *SC1894 FW4.1.03.08 Release Notes User Guide*.

The only difference is that if FW4.5.01.00 is loaded, the Frequency Ranges 01 and 02 are no longer available, and the Frequency Range 03 lower limit has been changed from 225MHz to 135MHz. Furthermore, if FW4.5.01.00 is loaded, the **Bin Switching** and **Bin Contents** tabs appear.

### *ACCP Config Tab*

The GUI, when the advanced customer configuration parameter (**ACCP Config**) tab is selected, is shown in **Figure 2**.

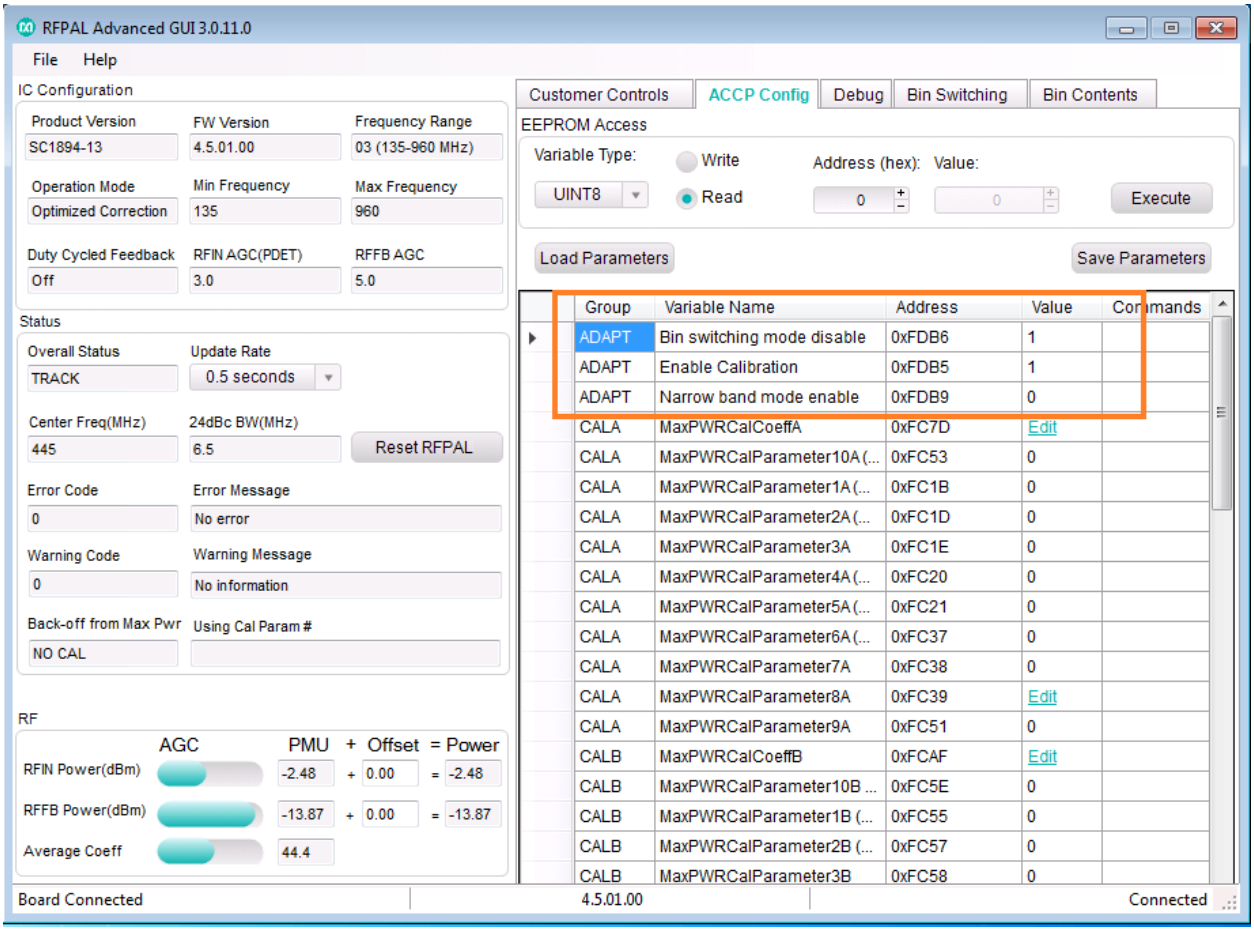


*Figure 2. SC1894 advanced GUI ACCP tab.*

There are three customer configuration parameters that have been added for the narrowband firmware: Enable Calibration, Bin switching mode disable, and Narrow band mode enable. Refer to the *SC1894 SPI Programming Guide* (Ref [1]) for a description of these parameters. As always, after changing the value of any ACCP parameter, it is necessary to reset the SC1894 for the new values to take effect.

### *Bin Switching Tab*

The GUI, when the **Bin Switching** tab is selected, is shown in **Figure 3**.

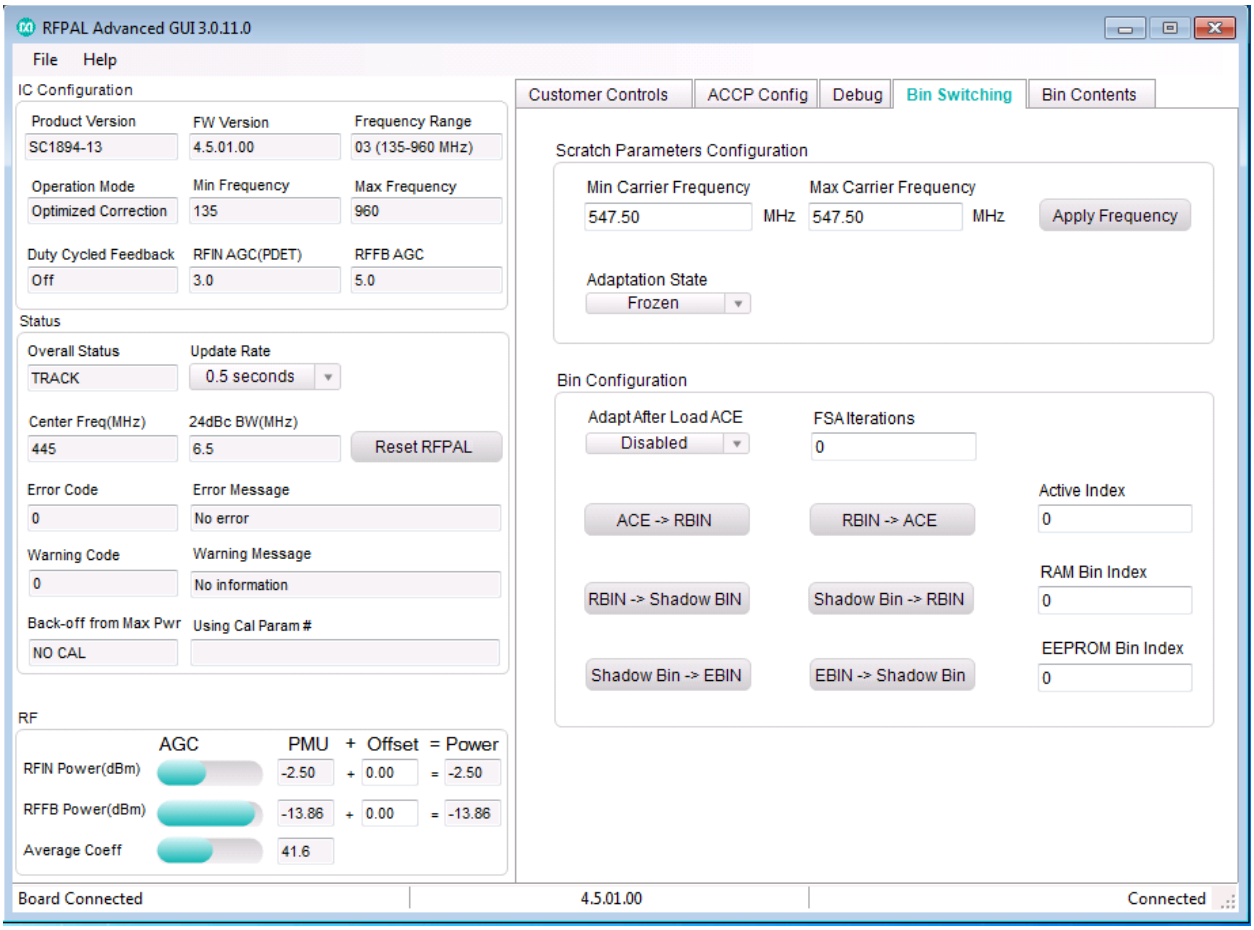


*Figure 3. SC1894 advanced GUI bin switching tab.*

This is the most important tab for operating the narrowband firmware. Each of the widgets are described below. The description starts with the Bin Configuration pane and is followed by the Scratch Parameters Configuration pane.

### *ACE -> RBIN Button*

Clicking the **ACE -> RBIN** button causes the GUI to issue the commands to the firmware to transfer the ACE contents into the RBIN pointed to by the Active Index value. The Active Index value must be written before clicking the **ACE -> RBIN** button. For example, if one wishes to transfer the ACE into RBIN[4], then input 4 in the Active Index field and then click the **ACE -> RBIN** button. The legal range of values for Active Index is 0 through 7 inclusive. The GUI disallows entry of any invalid Active Index value. It is recommended to have adaptation frozen before transferring the ACE to an RBIN. Even though the Adaptation State likely already indicates Frozen, it is necessary to explicitly select it to change the Adaptation State to Frozen.

### *RBIN -> Shadow BIN Button*

Clicking the **RBIN -> Shadow BIN** button causes the GUI to issue the commands to the firmware to transfer the contents of the RBIN pointed to by the RAM Bin Index value to the shadow bin which is RBIN[7]. The RAM Bin Index value must be written before clicking the **RBIN -> Shadow BIN** button. For example, if one wishes to transfer the RBIN[4] into the shadow bin, then input 4 in the RAM Bin Index field and then click the **RBIN ->**

**Shadow BIN** button. The legal range of values for RAM Bin Index is 0 through 6 inclusive (since it does not make sense to transfer the shadow bin to itself). The GUI disallows entry of any invalid RAM Bin Index value.

### *Shadow Bin -> EBIN Button*

Clicking the **Shadow Bin -> EBIN** button causes the GUI to issue the commands to the firmware to transfer the contents of the shadow bin, which is RBIN[7], to the EBIN pointed to by the EEPROM Bin Index value. The EEPROM Bin Index value must be written before clicking the **Shadow Bin -> EBIN** button. For example, if one wishes to transfer the shadow bin to EBIN[21], then input 21 in the EEPROM Bin Index field and then click the **Shadow Bin -> EBIN** button. The legal range of values for EEPROM Bin Index is 0 through 39. The GUI disallows entry of any invalid EEPROM Bin Index value.

### *EBIN -> Shadow Bin Button*

Clicking the **EBIN -> Shadow Bin** button causes the GUI to issue the commands to the firmware to transfer the contents of the EBIN pointed to by the EEPROM Bin Index value to the shadow bin, which is RBIN[7]. The EEPROM Bin Index value must be written before clicking the **EBIN -> Shadow Bin** button. For example, if one wishes to transfer EBIN[15] to the shadow bin, then input 15 in the EEPROM Bin Index field and then click the **EBIN -> Shadow Bin** button. The legal range of values for EEPROM Bin Index is 0 through 39. The GUI disallows entry of any invalid EEPROM Bin Index value.

### *Shadow Bin -> RBIN Button*

Clicking the **Shadow Bin -> RBIN** button causes the GUI to issue the commands to the firmware to transfer the contents of the shadow bin which is RBIN[7] to the RBIN pointed to by the RAM Bin Index value. The RAM Bin Index value must be written before clicking the **Shadow Bin -> RBIN** button. For example, if one wishes to transfer the shadow bin to RBIN[2], then input 2 in the RAM Bin Index field and then click the **Shadow Bin -> RBIN** button. The legal range of values for RAM Bin Index is 0 through 6 inclusive. The GUI disallows entry of any invalid RAM Bin Index value.

### *RBIN -> ACE Button*

Clicking the **RBIN -> ACE** button causes the GUI to issue the commands to the firmware to transfer the contents of the RBIN pointed to by the Active Index value to the ACE. The Active Index value must be written before clicking the **RBIN -> ACE** button. For example, if one wishes to transfer RBIN[6] to the ACE, then input 6 in the Active Index field and then click the **RBIN -> ACE** button. The legal range of values for Active Index is 0 through 7 inclusive. The GUI disallows entry of any invalid Active Index value.

### *Adapt After Load ACE*

The Adapt After Load ACE widget provides two selections: Enabled and Disabled. If Enabled is selected, then adaptation automatically starts as soon as the RBIN is loaded into the ACE. One must ensure that the spectral parameters have been updated (if required) to reflect the carrier configuration by using the Scratch Parameters Configuration pane prior to loading the RBIN into the ACE if the Enabled option is selected. If Disabled is selected, then adaptation does not automatically start after loading the RBIN to the ACE.

### *FSA Iterations*

One controls how much Full Speed Adaptation (FSA) is done after loading of an RBIN to the ACE (providing that Adapt After Load ACE = Enabled) with the FSA Iterations widget. This basically controls how aggressively the firmware adapts the coefficients that have just been loaded to match the current conditions. The FSA Iterations variable is an unsigned 16-bit value and represents the number of FSA iterations to be executed after an ACE load. For example, if one inputs a value of 200 into the FSA Iterations widget, then whenever the ACE is loaded into an RBIN, the FSA Iterations parameter written into the RBIN is 100 (the parameter represents half the actual number of FSA iterations to be run). When the contents of that bin are applied to the ACE, 200 iterations of FSA are run.

### *Adaptation State*

There is a new scratch variable provided in the narrowband firmware to freeze and unfreeze adaptation. The Adaptation State widget controls the state of this variable. There are two selections: Frozen and Running. If Frozen is selected, the firmware does not adapt any of the parameters in the ACE. If Running is selected, the firmware is adapting. One can tell if firmware is adapting or not by observing the Average Coeff indicator in the RF pane of the main window. If the Average Coeff value is fluctuating, then one knows the firmware is adapting. If the value is static, adaptation is frozen. The GUI changes the state of the adaptation only when one explicitly clicks the down arrow of the widget and selects the state. This action triggers the GUI to write to the corresponding scratch variable.

This adapt freeze function is similar to the Adaptation State widget in the **Customer Controls** tab. The Adaptation State widget in the **Customer Controls** tab prevents proper operation of the narrowband firmware and should not be used for freezing adaptation when the narrowband firmware is being used. Just leave the Adaptation State widget in the **Customer Controls** tab always in Running state when using the narrowband firmware.

⚠ *Do not use the Adaptation State widget in the Customer Controls tab with the narrowband firmware. Just leave the state as Running always.*

### *Min and Max Carrier Frequencies*

When an RBIN is loaded into the ACE for the first time after RFPAL is reset, in Bin Switching mode, the firmware does not know anything about the carrier configuration or the center frequency of the signal. This information is conveyed to the firmware by inputting the frequencies of the outermost subcarriers in the Min Carrier Frequency and Max Carrier Frequency widgets. In the case of multiple narrowband carriers, one enters the frequency of the lowest frequency carrier in the Min Carrier Frequency widget and the frequency of the highest frequency carrier in the Max Carrier Frequency widget. For example, referring to **Figure 4**, there are three narrowband subcarriers. These could be TETRA subcarriers. One would input $f_1$ (in MHz) for the Min Carrier Frequency and $f_3$ for the Max Carrier Frequency. The bandwidth is defined as $f_3 - f_1$. In this example, if $f_1$ = 850MHz and $f_3$ = 850.1MHz, one would input 850 into the Min Carrier Frequency widget and 850.1 into the Max Carrier Frequency widget. The bandwidth is 100kHz.

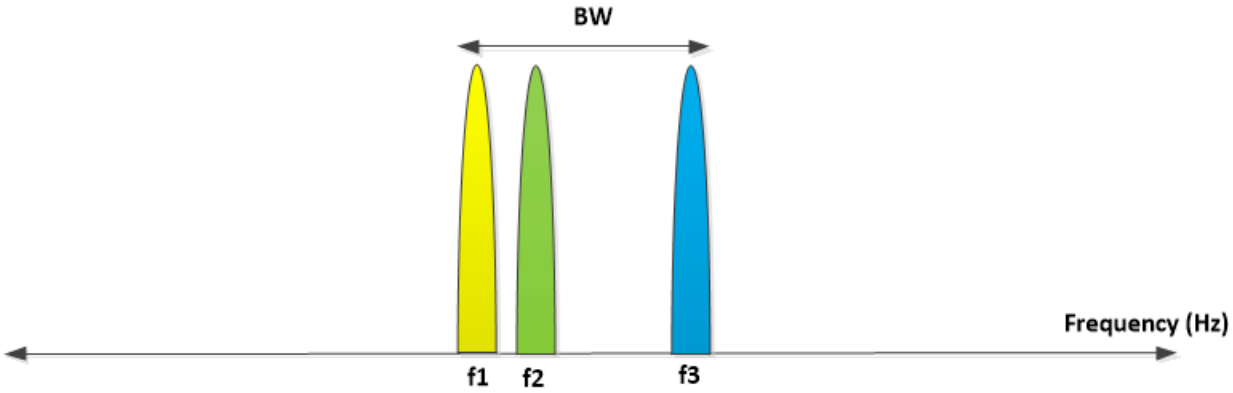


*Figure 4. Carrier frequency input for narrowband carriers.*

In the case of a single wideband carrier, such as an LTE 10MHz wide carrier as shown in **Figure 5**, one enters the frequency (in MHz) of the lower edge of the carrier in the Min Carrier Frequency widget and of the upper edge of the carrier in the Max Carrier Frequency widget. It is thus possible to use a consistent approach for both traditional single-carrier wideband signals and multiple narrowband carrier signals.

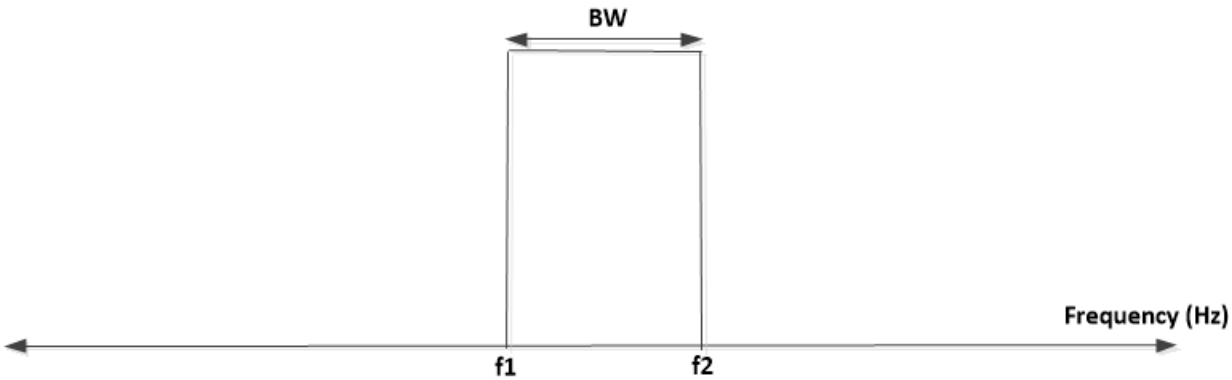


*Figure 5. Carrier frequency input for single wideband carrier.*

The Wideband Optimization feature described in the *SC1894 SPI Programming Guide* (Ref [1]) has been removed in the narrowband firmware, so good correction performance with carrier configurations consisting of multiple discontinuous wideband carriers may not be achievable. However, multiple contiguous wideband carriers, such as two contiguous 10MHz LTE carriers are supported. One just treats the signal like a single carrier. See **Figure 6**. In this example, one would input $f_1$ (in MHz) for the Min Carrier Frequency and $f_3$ for the Max Carrier Frequency.

Using these bandwidth definitions, the narrowband firmware can support bandwidths from 25kHz to 75MHz in the RF range 400MHz–2700MHz and 1.2MHz to 75MHz in the RF range 2700MHz–3800MHz.

Below 400MHz RF, the bandwidth range is 25kHz to 40MHz. The reduction in bandwidth below 400MHz is a tradeoff made to improve the correction performance in the VHF band. The dependence of supported signal bandwidth versus RF frequency for Bin Switching with adaptation mode is shown in Table 2.

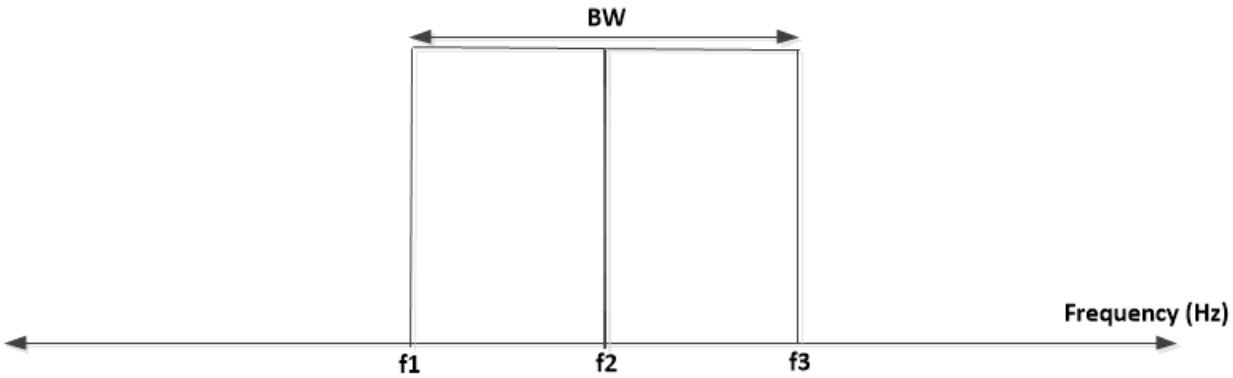


*Figure 6. Carrier frequency input for multiple contiguous wideband carriers.*

## Table 2. Supported Signal Bandwidths vs RF Frequency

| RF RANGE (MHz) | MIN BW (MHz) | MAX BW (MHz) |
|---|---|---|
| 135–400 | 0.025 | 40 |
| 400–2700 | 0.025 | 75 |
| 2700–3800 | 1.2 | 75 |

### *Apply Frequency*

When one clicks the **Apply Frequency** button, the GUI calculates the six spectral parameters, CSP_Param0 through CSP_Param5 which are described in the *SC1894 SPI Programming Guide* (Ref [1]). The resulting values are displayed. The GUI also writes these values to scratch memory and issues the Change Spectral Parameters SPI command to the firmware. The pseudocode of the function which calculates the six spectral parameters is provided in the *SC1894 SPI Programming Guide* (Ref [1]). Customer-developed host software needs to implement this calculation, and the GUI-calculated values can serve as a useful check on the correctness of the host software implementation.

### *Bin Contents Tab*

The GUI, when the **Bin Switching** tab is selected, is shown in **Figure 7**. This tab allows reading of any RBIN or EBIN. To read an RBIN, first input the index of the RBIN in the RAM Bin Index widget, then click the **Execute** button in-line to the right of this widget. The values in the displayed array are updated with the current contents of the RBIN that is pointed to by the RBIN index. To read an EBIN, first input the index of the EBIN in the EEPROM Bin Index widget, then click the **Execute** button in-line to the right of this widget. The values in the displayed array are updated with the current contents of the EBIN that is pointed to by the EBIN index. The GUI checks for valid values for the RBIN and EBIN indices and disallows invalid values. The main purpose of including this tab is just to allow the user to confirm that a particular bin's contents have changed, or a certain RBIN matches a certain EBIN.

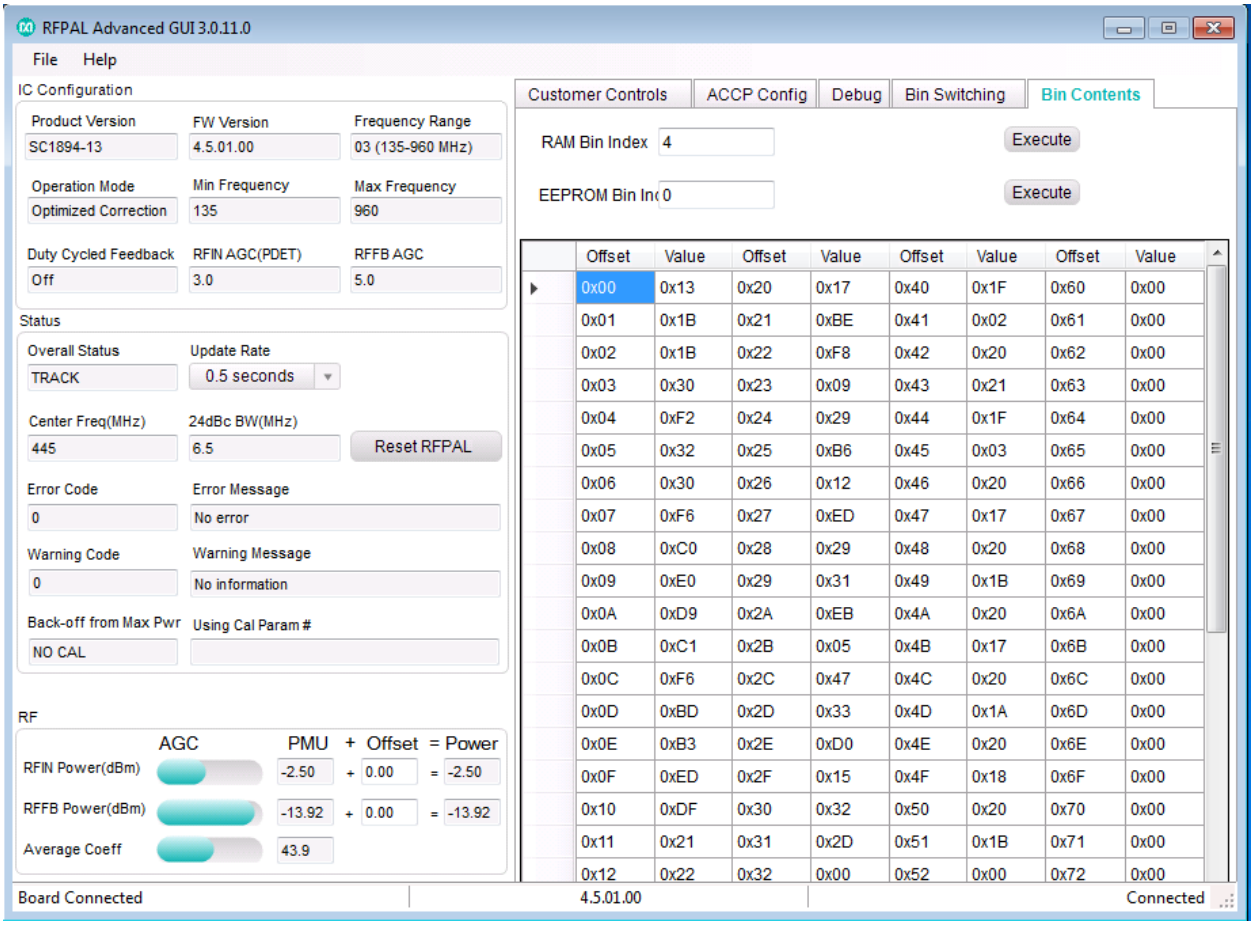


*Figure 7. SC1894 advanced GUI bin contents tab.*

## Quick Start to Using GUI

This section provides a guide to using the GUI to calibrate an EBIN, then applying the EBIN in field operation with a narrowband signal. Let us assume for the example that the field operation signal is two TETRA carriers at frequencies of 444.95MHz and 445.05MHz. Furthermore, an SC1894-EVK900 that has been modified for narrowband adaptation, as described in the section *EVK Modifications for Narrowband Adaptation*, is being used with the 3.0.11.0 RFPAL GUI. Each carrier is assumed to have an average power of 35dBm so the total average power amplifier (PA) output power will be 3dB higher than this or 38dBm.

1) The first step is to calibrate an EBIN. Usually, one would calibrate a set of EBINs corresponding to different conditions. The dimensions over which one calibrates could include PA output power, carrier center frequency, signal bandwidth, temperature, etc. This example just calibrates one EBIN to illustrate the procedure.

   For the calibration signal, two TETRA carriers at frequencies of 442.5MHz and 447.5MHz are used. This provides an effective signal bandwidth of 5MHz which satisfies the requirement of the calibration signal bandwidth being at least 1.2MHz. Furthermore, the carriers are centered about 445MHz which provides a good match to the field signal in terms of carrier center frequency. The power levels are set to have

38dBm total average output power from the PA. This satisfies the requirement that the PA average output power with the calibration signal should not be lower than the average output power with the field signal.

2) Once the calibration signal is being transmitted, put the firmware in FW4.1.03.08 operation mode by setting both Enable Calibration and Bin switching mode disable EEPROM calibration parameters to 1 in the **ACCP Config** tab of the GUI. See **Figure 8**. Reset the RFPAL and confirm the firmware gets to TRACK state, and there are no warnings or errors. Note that the RFPAL must be in Optimized Correction mode and not Smooth mode. Also confirm by observing the PA output on a spectrum analyzer that the intermodulation distortion (IMD) products are at an acceptable level. If not, wait for a few more seconds.

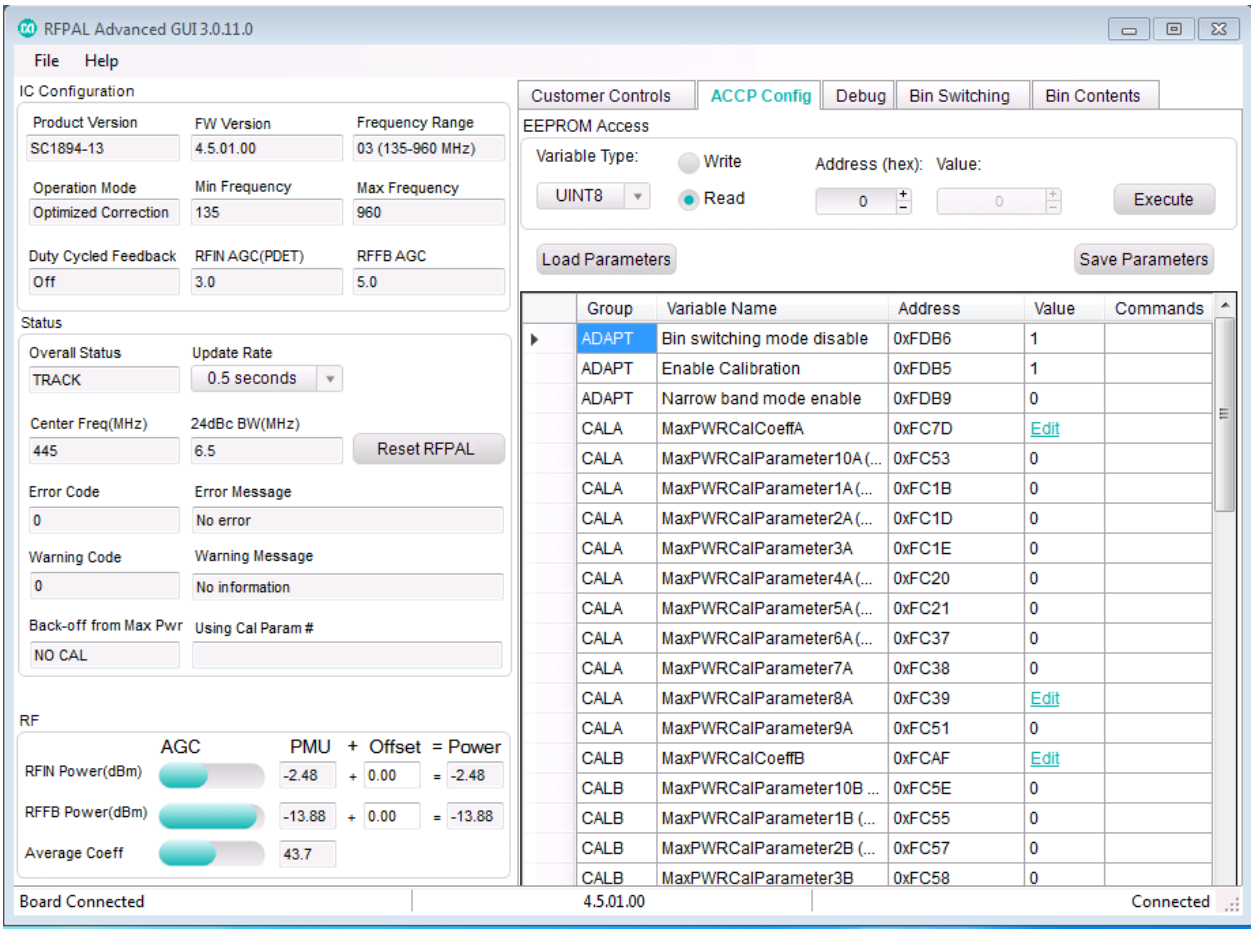


*Figure 8. GUI during EBIN calibration ACCP config tab.*

3) Select the **Bin Switching** tab. See **Figure 9** (Step 1). First freeze the adaptation by selecting Disabled in the Adaptation State widget. Until one does this, it can be observed that the Average Coeff value in the RF pane is fluctuating. Even though the Adaptation State likely already indicates Frozen, it is necessary to explicitly select it in order to change the adaptation state to frozen. After doing this, it is observed that the Average Coeff value stops fluctuating.

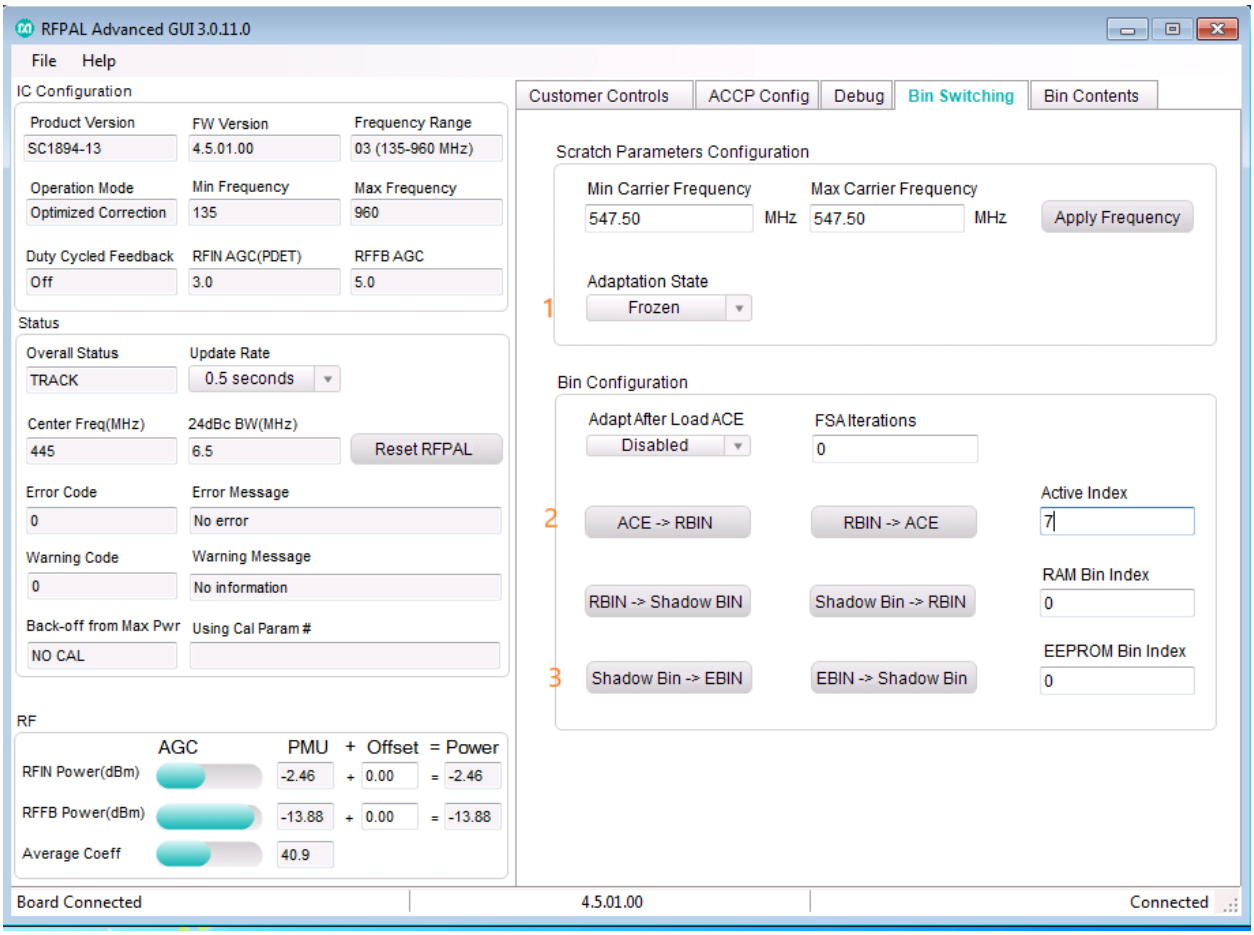


*Figure 9. GUI during EBIN calibration bin switching tab.*

4) Input 7 in the Active Index widget and then click the **ACE -> RBIN** button (Step 2). This causes the contents of the ACE to be loaded into the shadow bin (RBIN[7]).

5) Click the **Shadow Bin -> EBIN** button (Step 3). In this case, just leave the EEPROM Bin Index as the default value of 0. If you want to calibrate a different EBIN, first input the index of the EBIN in the EEPROM Bin Index widget before clicking the **Shadow Bin -> EBIN** button. The GUI opens a window confirming the transfer was successful. Click OK. At this point, the EBIN[0] contains the contents of the ACE and calibration of this EBIN is completed.

6) Change the signal to the field operation signal.

7) Next, switch the firmware from FW4.1.03.08 mode to Bin Switching mode. Set both Enable Calibration and Bin switching mode disable EEPROM parameters to 0 in the **ACCP Config** tab of the GUI. See **Figure 10**. Note that in this example, the Narrow band mode enable parameter is left as 0. One can optionally set this parameter to a non-zero value and possibly get improved correction performance.

Reset the RFPAL. The firmware indicates FSA status in the Overall Status widget. This FSA does not progress to TRACK and adaptation is automatically frozen. The IMD products observed in the spectrum of the PA output have no correction. Also, the GUI indicates a 0 for Center Frequency. Furthermore, although the PMU values in the RF pane are fluctuating, they are inaccurate potentially by many dB. Also, the Average Coeff value is 0 and unchanged. See **Figure 11**. These are all consequences of the firmware not yet having any information on the spectrum of the PA output.

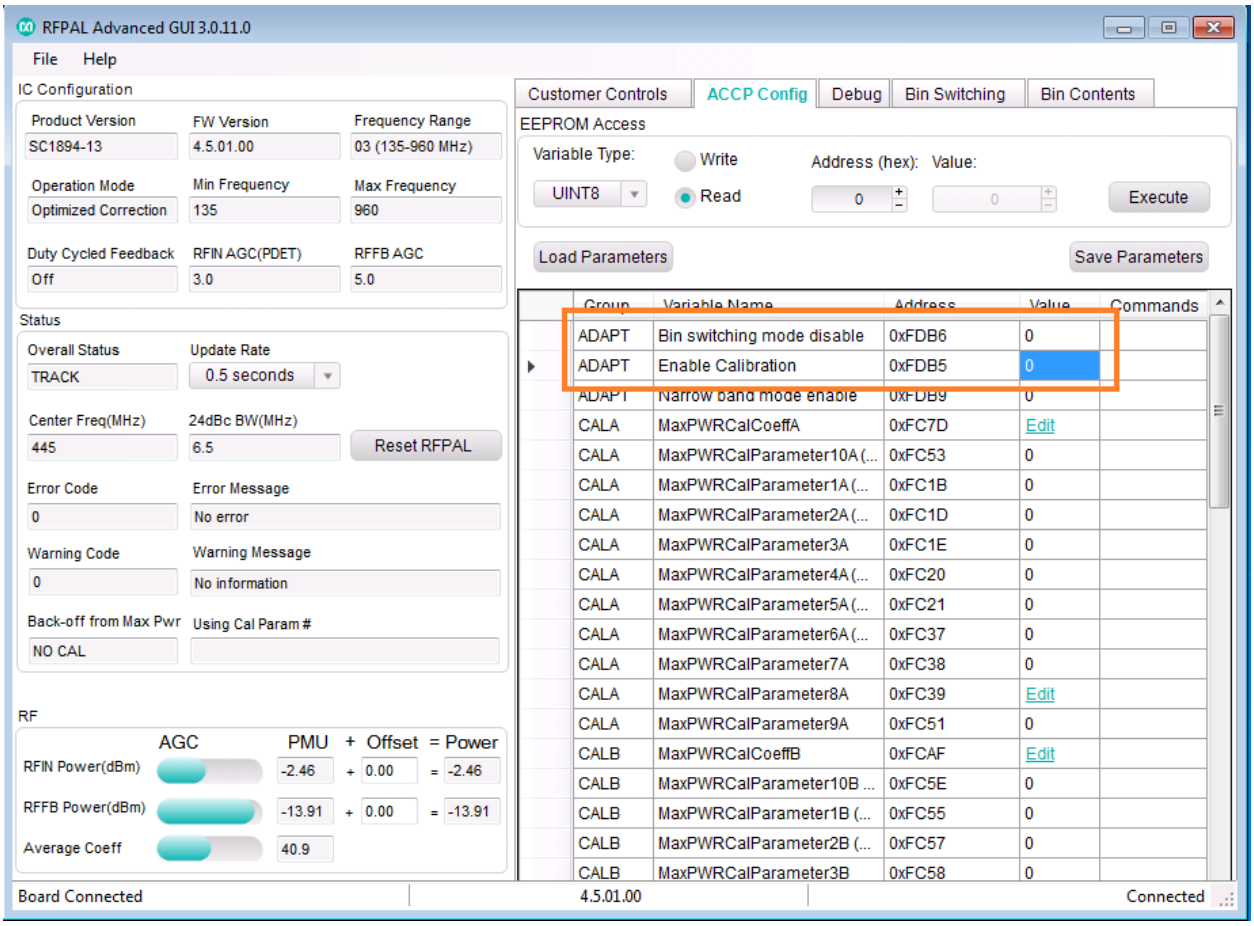


*Figure 10. GUI during field operation ACCP tab.*

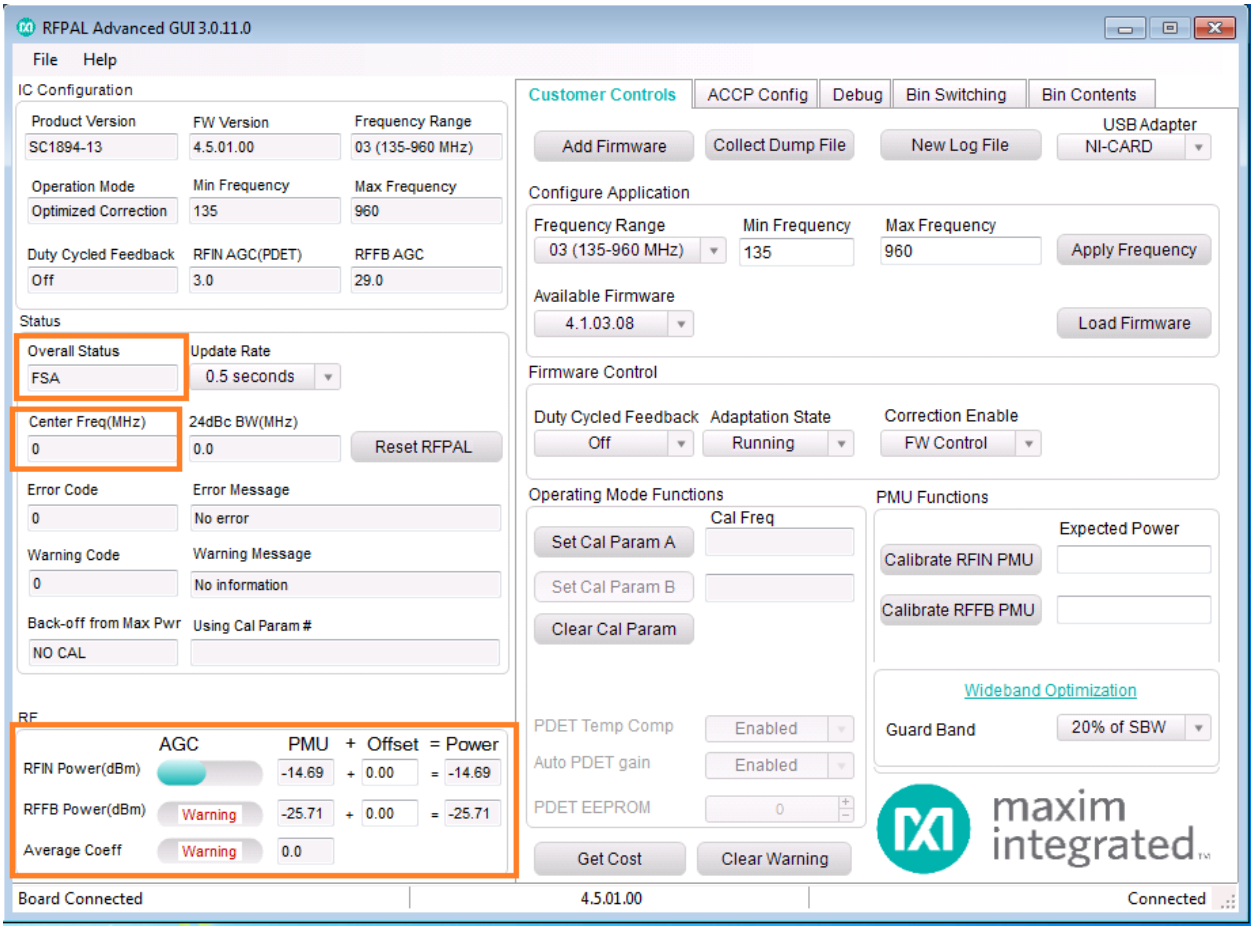


*Figure 11. GUI during field operation before loading bin.*

8) Next, the EBIN that was just calibrated is loaded into the ACE. See **Figure 12**. Select the **Bin Switching** tab. The EBIN[0] is first transferred to the shadow bin (RBIN[7]). Then, the shadow bin is transferred to RBIN[3]. Finally, RBIN[3] is loaded into the ACE. One could skip using RBIN[3] and directly load the shadow bin into the ACE by setting the Active Index = 7. It is much faster to load an already populated RBIN into the ACE than retrieving it from EEPROM, so one may wish to populate several RBINs with parameter sets that are likely to be required in the near-term. The Adapt After Load ACE widget has Disabled selected so after loading the bin into the ACE, adaptation remains frozen.

   Step 1: Ensure that the EEPROM Bin Index widget contains 0, then click the **EBIN -> Shadow Bin** button.

   Step 2: Ensure that the RAM Bin Index widget contains 3, then click the **Shadow Bin -> RBIN** button.

   Step 3: Ensure that the Active Index widget contains 3, then click the **RBIN -> ACE** button. As soon as one clicks the **RBIN -> ACE** button, the IMD products observed in the spectrum of the PA output should decrease.

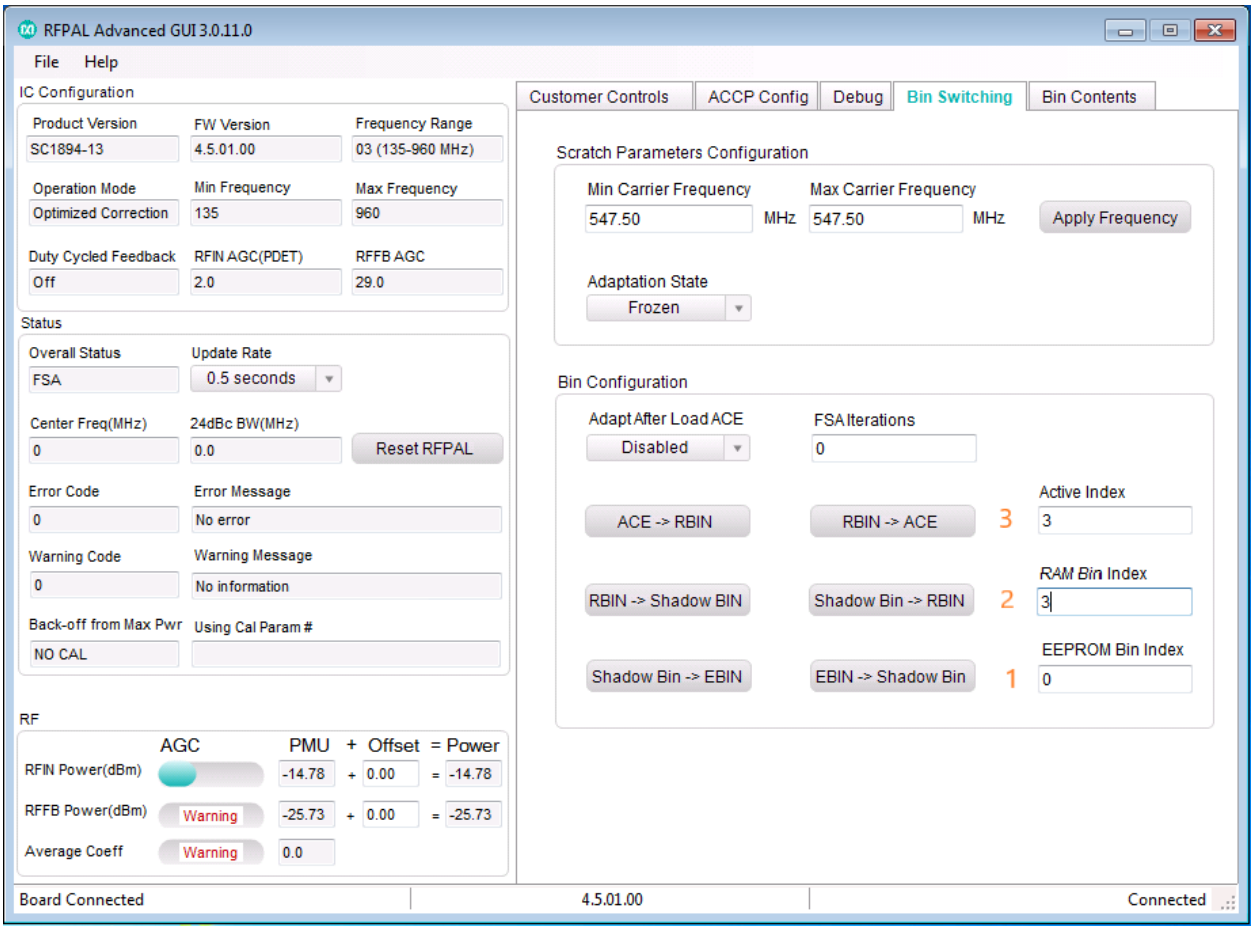


*Figure 12. GUI during field operation loading bin.*

9) Input the frequencies of the outermost carriers into the Min Carrier Frequency and Max Carrier Frequency widgets. In this case, there are only two carriers. Input 444.95 for Min Carrier Frequency and 445.05 for Max Carrier Frequency, then click the **Apply Frequency** button. The GUI opens a dialog box showing the six CSP_Param scratch variables. Click OK to close the dialog box. See **Figure 13**.

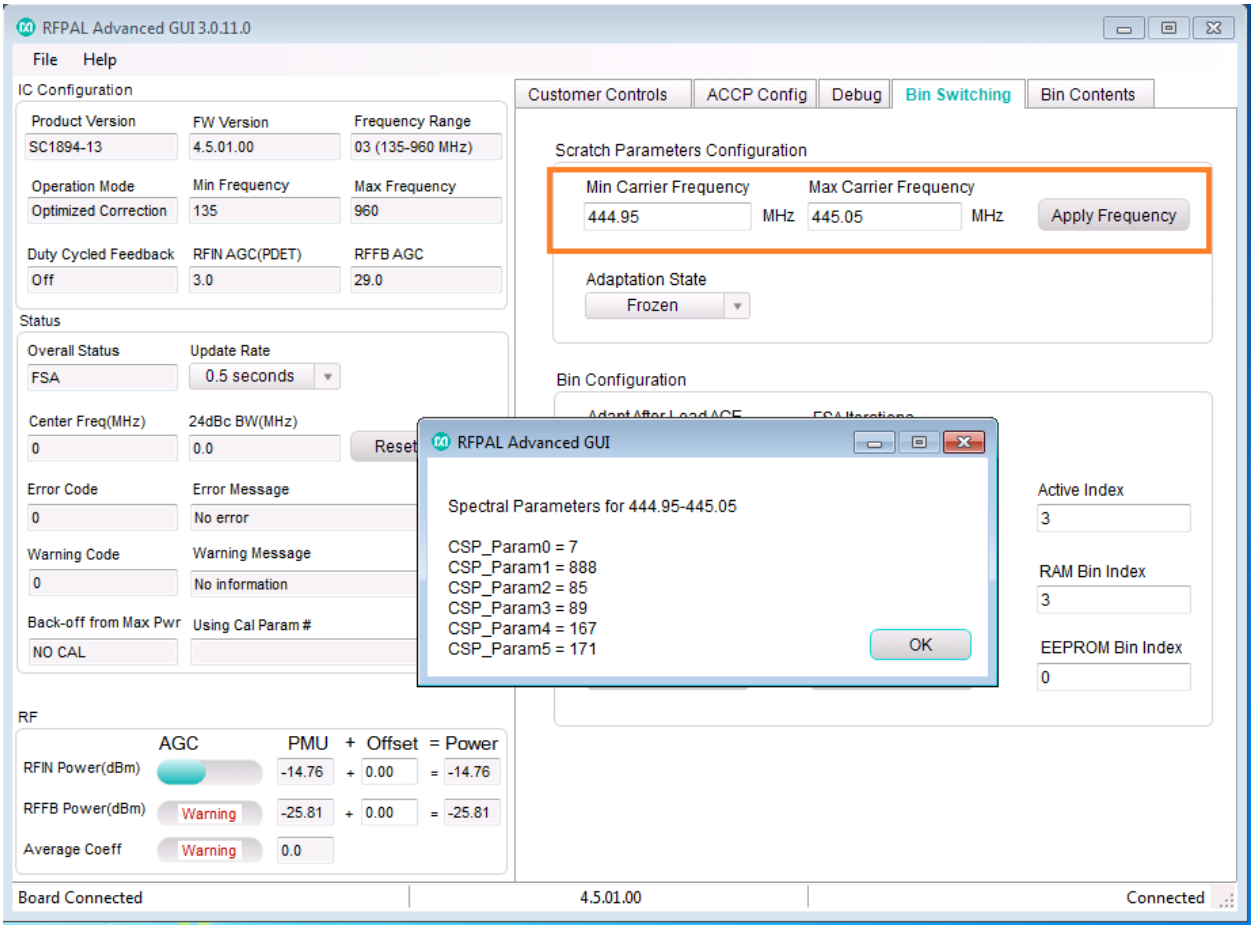


*Figure 13. GUI setting spectral parameters.*

10) Once the new spectral parameters are applied, note that the Center Freq widget indicates a value close to the carrier center frequency. It will not be exact, but within one MHz or so. The 24dBc BW widget is never accurate with narrowband signals. The PMU values are now accurate. See **Figure 14**.

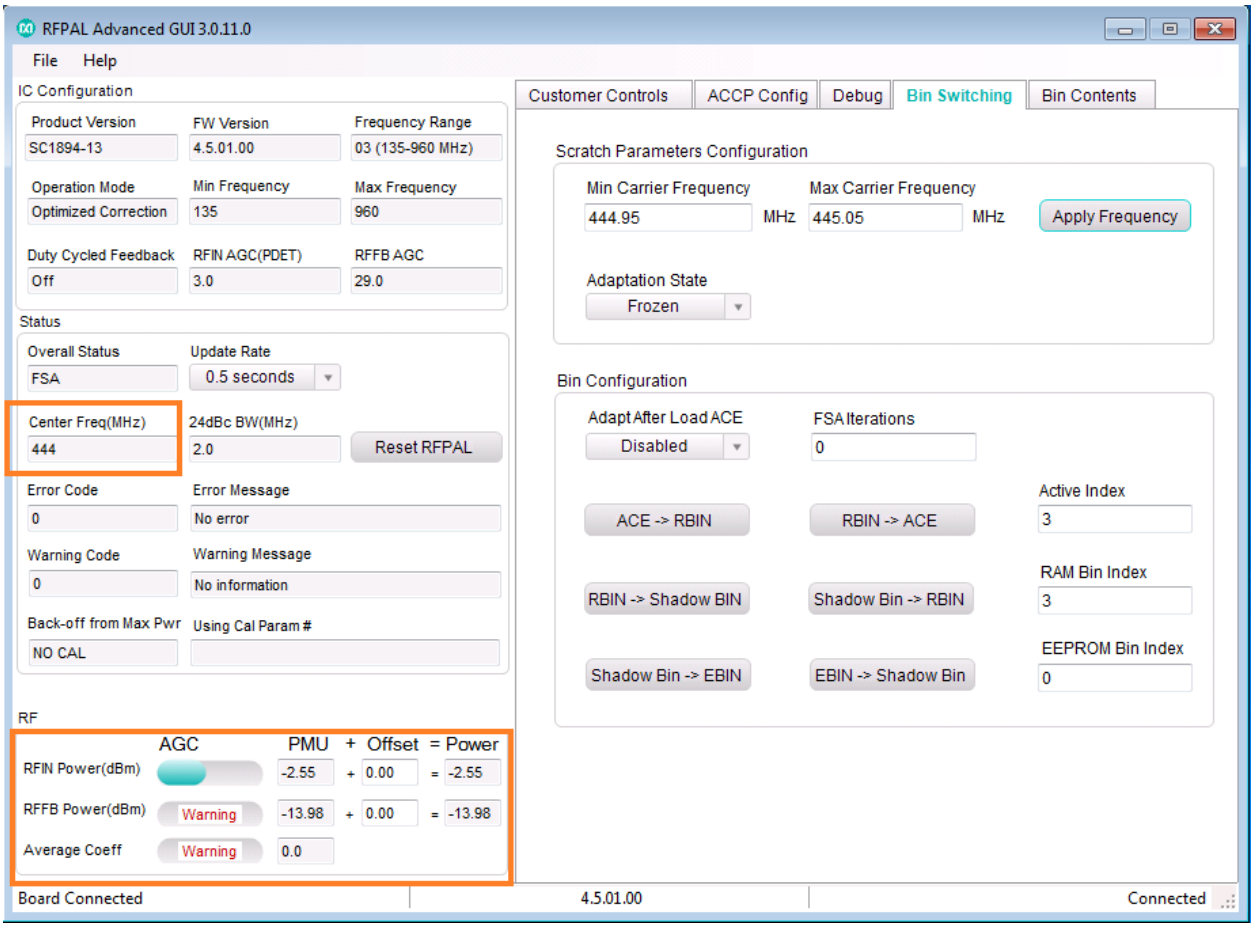


*Figure 14. GUI after setting spectral parameters.*

11) The final step is to enable adaptation. Select Running in the Adaptation State widget. One sees that the IMD products in the spectrum of the PA output start to fluctuate and hopefully decrease to some extent. This can be expected if the calibrated bin conditions are quite different from the operating field conditions. In this example, they are very close so little, if any, change is expected in the IMD levels. However, the RFPAL is now tracking and adapting to changes in temperature. The Average Coeff value takes on a meaningful value and is fluctuating. The firmware status, as indicated in the Overall Status, should eventually reach TRACK state. See **Figure 15**.

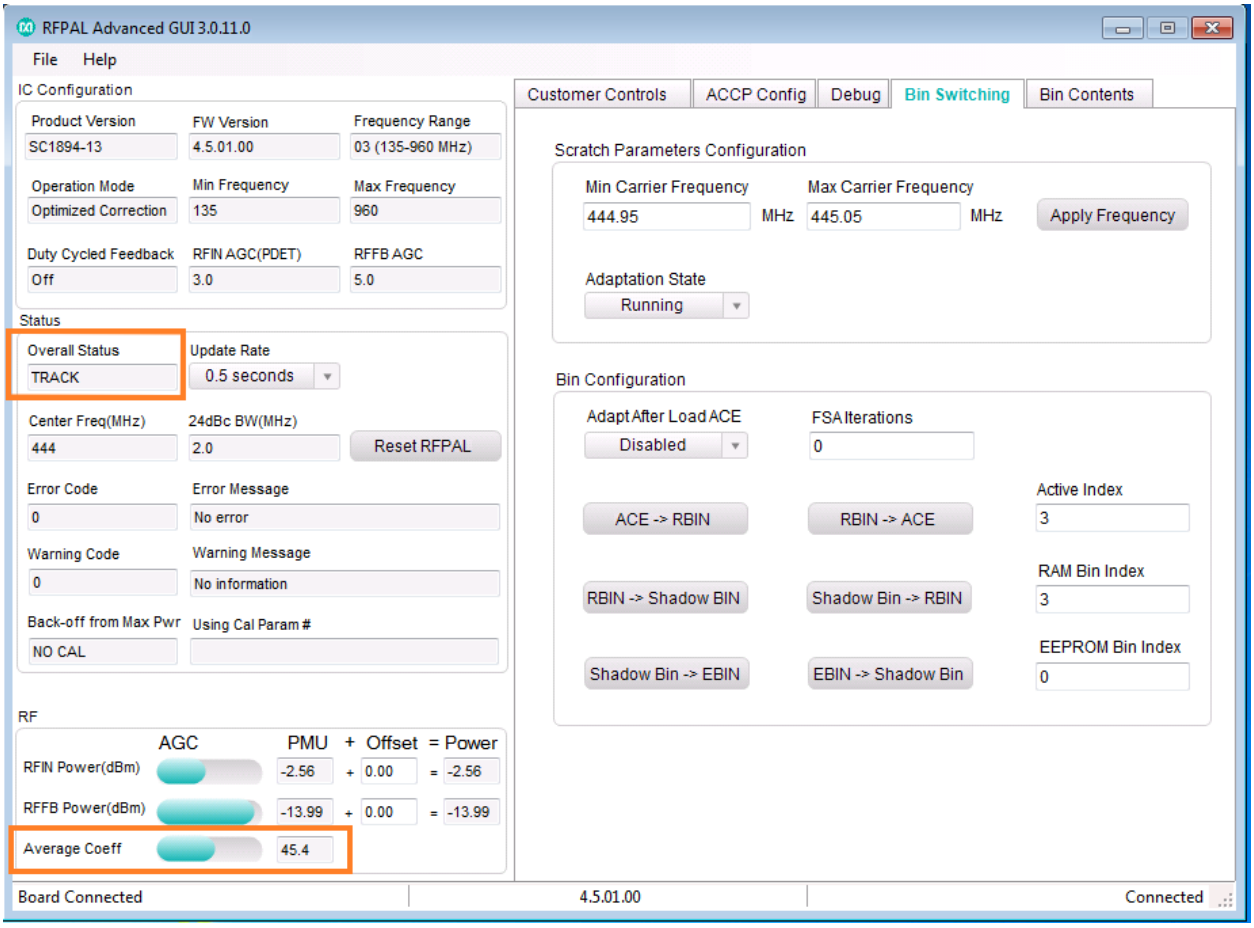


*Figure 15. GUI after enabling adaptation.*

## VHF Band Operation

When running the FW4.1.03.08, the distortion correction performance degrades at low carrier center frequencies. The cause of this degradation is understood and is due to RF impairments inside the SC1894. The narrowband firmware operates the circuitry in a different manner which works around these impairments. This improves the correction at low RF frequencies and the SC1894A-00N13 can be used down to 135MHz carrier center frequency. There is, however, a tradeoff which is a limitation on the maximum signal bandwidth that can be used of 40MHz below 400MHz RF. From 400MHz to 3800MHz, the maximum supported signal bandwidth is 75MHz. For carrier center frequencies below 400MHz, only frequency Band 03 should be used. Band 03 is defined as 135MHz to 960MHz.

⚠ *Maximum supported signal bandwidth is 40MHz below 400MHz for narrowband firmware.*
⚠ *For RF frequencies below 400MHz, use Band 03 only.*

## Narrowband Firmware Limitations

The narrowband firmware imposes some limitations if one wishes to have it adapt after loading a bin to the ACE. These limitations are discussed in this section.

### *Supported Frequency Bands*

Not all the possible frequency bands can be supported in Bin Switching mode when adaptation is enabled and the signal bandwidth is < 1.2MHz. The allowed bands are given in Table 3. If operating in any other mode, or else adapting with signals having bandwidth ≥ 1.2MHz, then all frequency bands except Band 01 and Band 02 can be used.

## Table 3. Supported Frequency Bands for Narrowband Adaptation

| BAND | FREQUENCY RANGE (MHz) |
|---|---|
| 03 | 135–960 |
| 04 | 520–1040 |
| 05 | 1040–2080 |
| 06 | 698–2700 |

### *Reference Clock Frequency*

The SC1894 supports a set of crystal frequencies, specifically 10, 13, 15.36, 19.2, 20, 26, and 30.72MHz. The default frequency is 20MHz. All EV kits are populated with 20MHz crystals. In the Bin Switching mode with adaptation, only a frequency of 20MHz is supported. This applies to any signal bandwidth, not just narrowband signals. If not using the Bin Switching mode, or if in Bin Switching mode, but not using adaptation, any of the crystal frequencies listed earlier can be used.

### *Frequency Locked Reference Clock*

In the Bin Switching mode, if adaptation is enabled, and the signal bandwidth is < 1.2MHz, it is necessary that the reference clock for the SC1894 and the clock used as a reference to generate the local oscillator (LO) signal for the up-conversion mixer in the transmitter be frequency-locked. They do not necessarily need to be the same frequency; however, they must be locked so they move together. If using the Narrowband Mode Enable EEPROM configuration parameter (i.e., the parameter is non-zero), then frequency locking is required. If adapting with narrowband signals, and the Narrowband Mode Enable parameter = 0, then it is sufficient to tightly control the tolerance of the reference clocks. This is best explained with an example.

Assume the base-station reference clock that is used to generate the LO frequency used in the transmit chain up-conversion mixer has a tolerance of $E_B$ ppm. For example, assume the LO is generated by a PLL inside the base station that uses a 50MHz crystal, with ±100ppm tolerance ($E_B$ = 100ppm). Then, the actual carrier center frequency of the signal going into the PA (and RFPAL) could be 2GHz ± 200KHz. Next, assume the RFPAL uses a crystal with $E_R$ ppm tolerance. For example, the RFPAL XTAL is 20MHz ±100ppm. Then, $E_R$ = 100ppm. The LO generated internal to the RFPAL is also 2GHz ± 200KHz. The worst-case difference between the actual carrier center frequency, and what RFPAL is tuned to is $E_B + E_R$ ppm. In this example, the maximum frequency error is 400KHz. This would occur if the base-station crystal was -100ppm and the RFPAL crystal was +100ppm, or vice versa.

If we denote the nominal (i.e., target) carrier center frequency as $f_c$ in Hz, then we need $E_B + E_R$ to meet the requirement shown in the following equation:

$$E_B + E_R < \frac{12 \times 10^{-3}}{f_c}$$

So, in the example where $f_c$ = 2GHz, $E_B + E_R$ must be less than $6x10^{-6}$ or 6ppm. If the carrier center frequency is reduced, the crystal tolerance spec is relaxed. For example, if $f_c$ = 400MHz, then $E_B + E_R$ must be less than 30ppm.

Frequency locking the reference clocks can be achieved by using the same clock or generating one clock from the other by dividing down the higher frequency clock or using a PLL to derive one clock from the other.

In the context of an EV kit being tested on a lab bench, this requirement implies that the EVKIT must be configured to use an external reference clock rather than the on-board crystal oscillator. This is the reason for the modifications discussed in the section *EVK Modifications for Narrowband Adaptation*. Typically, in a lab-bench test setup, the RF signal is generated by an RF signal generator that has very tight frequency tolerance (e.g., < 1 ppm). If one also uses an RF signal generator for the EVK reference clock, this also has similarly tight tolerance. So, especially, at lower RF frequencies, there is no problem with having independent reference clocks. It is suggested to set the EVK reference clock signal generator to a 20MHz unmodulated sinusoidal carrier, with output power of around 0dBm.

To reiterate, the requirement for frequency-locked reference clocks only applies for the case of Bin Switching mode with adaptation for narrowband signals.

***Requirement for a Prescient Host***

Although it has been mentioned elsewhere in the documentation, it is worth emphasizing that in the case of Bin Switching mode operation with adaptation, the host needs to be prescient. It needs to know exactly what the carrier configuration is at any time and know in advance when it can change. This is because the firmware is entirely reliant on the host to configure it for the current carrier configuration. If the carrier configuration changes, and the host continues to allow the firmware to adapt with old spectral parameters, the distortion correction rapidly degrades.

If the use case is such that the host does not have detailed information on the precise carrier configuration, then one should use Bin Switching mode without adaptation.

## EVK Modifications for Narrowband Adaptation

In the event the SC1894 EVK is used for adaptation with narrowband signals, it is necessary to do some rework of the EVK. This is required to allow use of an externally driven reference clock to the RFPAL instead of using the on-board crystal. This section describes the required rework.

1) Solder an edge-mount SMA connector to the EXTCLK position. See **Figure 16**.

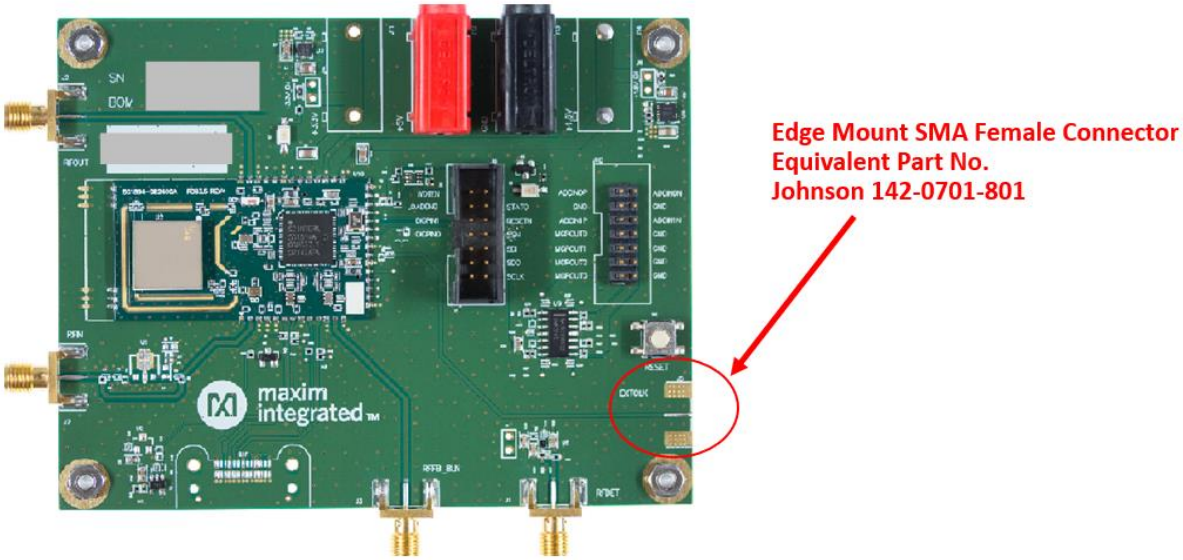


*Figure 16. SC1894 EVK.*

2) Remove the 20MHz crystal, Y1, on the daughter board that contains the SC1894 IC and the delay line. See **Figure 17**. It is recommended to tape the removed crystal to the EVK board for future use if the EVK is to be restored to its original condition.

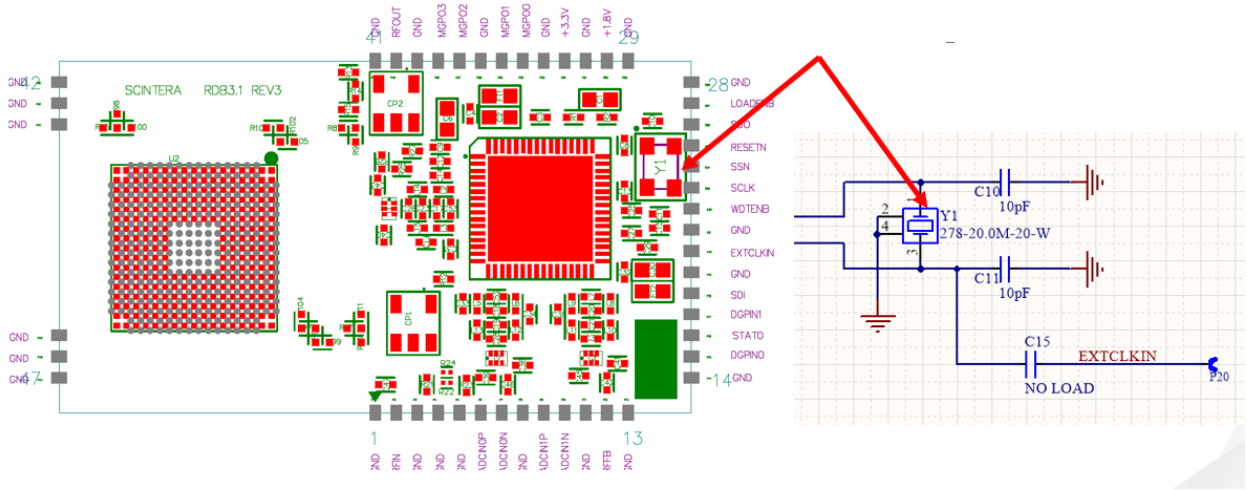


*Figure 17. SC1894 EVK crystal location.*

3) Populate capacitor C15 on the daughterboard. See **Figure 18**. This is a 10pF 0402 component.

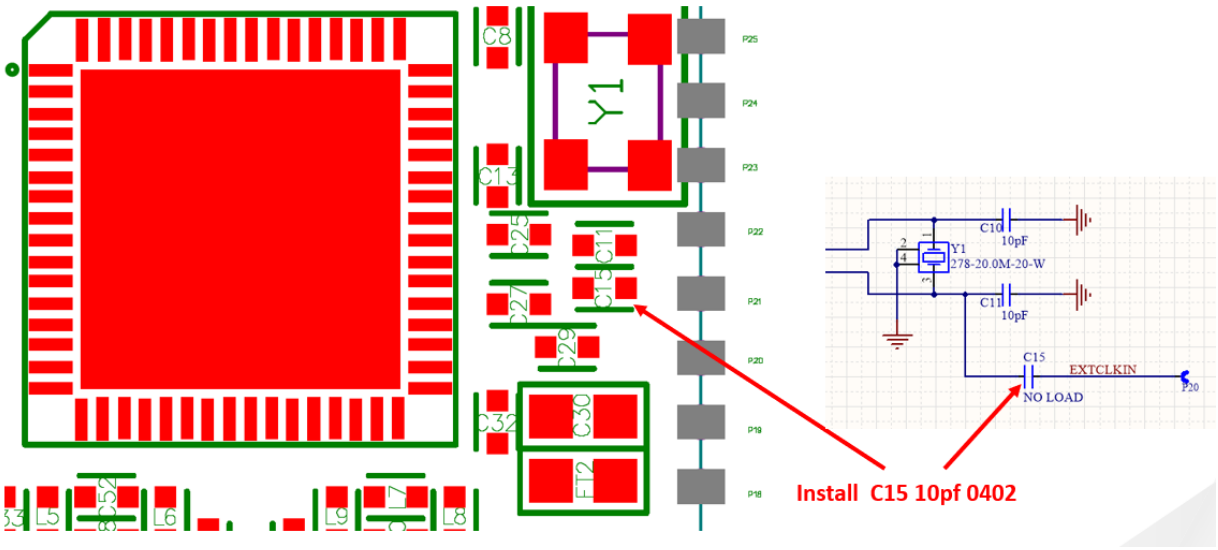


*Figure 18. SC1894 EVK C15 location.*

4) Populate R62 on the motherboard just to the right of the daughterboard. See **Figure 19**. This is a zero-ohm 0402 resistor.

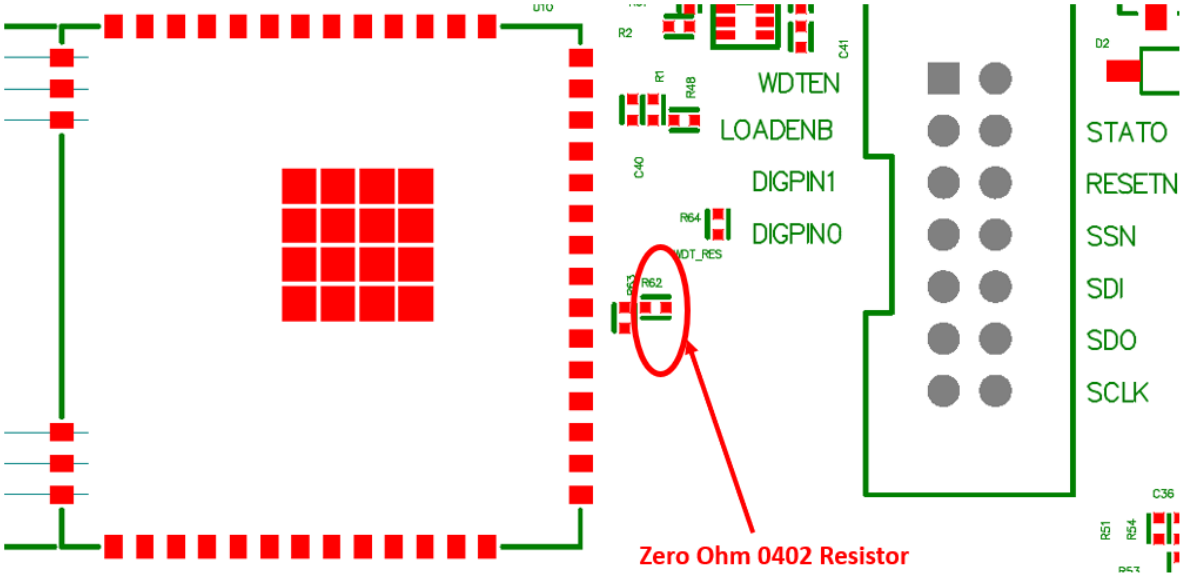


*Figure 19. SC1894 EVK R62 location.*

5) At this point, the board is ready to use. Connect a signal generator to the newly added EXTCLK SMA. Configure the signal generator to output a 20MHz sinusoidal signal. A good choice is an RF signal generator configured to output an unmodulated 20MHz carrier with an RF output power of around 0dBm. After applying the reference clock, power up the EVK. It should be possible to connect with the EVK through the GUI and the EVK should behave normally in every respect.

6) If it is desired to restore the EVK to using the on-board crystal, solder the previously removed Y1 crystal back on the daughterboard. This should be the only change required.

## Error/Warning Codes

The SC1894 provides warning or error codes if these registers are polled over the SPI. Warnings do not interrupt the operation of the IC although a warning typically indicates that optimal performance is not being obtained. Errors indicate that the SC1894 resets itself to clear an error condition.

Different Error and Warning Codes are described in Table 4 and Table 5.

### Table 4. Error Codes

| ERROR CODE | MEANING |
|---|---|
| 0 | No Error |
| 3 | "EEPROM Corrupted"<br>Improper use of the part resulted in EEPROM corruption. Downloading the firmware again using the RFPAL GUI might fix this error. If not, contact the Maxim Technical support team. |
| 5 | "Center Frequency Outside the Defined Frequency Range"<br>Center Frequency is outside the min and max frequency range. Modify the min and max frequency range to fix this error. |
| 13 | "Wrong CLK Setting"<br>Clock rate does not correspond to the external clock configuration EEPROM parameters. Refer to *SPI Programming Guide* **(Ref [1])** for more details. |
| 29 | "Incompatible IC for This Firmware"<br>The firmware is not compatible with this IC. This error is typically encountered if one is trying to load narrowband firmware on any variant of SC1894 other than SC1894A-00N13. |
| Others | "Internal Chip Error"<br>Contact the Maxim Technical support team if you get any other error that does not get fixed after reset or downloading the firmware again. |

### Table 5. Warning Codes

| WARNING CODE | MEANING |
|---|---|
| 0 | No Warning |
| 62 | "IC Temperature Outside Allowed Range"<br>Check ATE Calibration Offset Zone Written flag (0xFDB3) and set to "0." Refer to *SPI Programming Guide* **(Ref [1])** for details. |
| 64 | "Parameter Bin Checksum Mismatch"<br>When the RBIN to ACE Transfer SPI command is issued and the checksum is not correct, the firmware gives this warning. |

| | |
|---|---|
| 66 | “RBIN Index Out of Range”<br>The RBIN Index is outside of the valid range for the SPI command to transfer the RBIN to shadow bin or vice versa. |
| 71 | “EBIN Index Out of Range”<br>The EBIN Index is outside of the valid range for the SPI command to transfer the EBIN to shadow bin or vice versa. |
| Others | “Internal Warning”<br>Contact the Maxim Technical support team for further information. |

When the firmware issues a warning, the GUI does not clear that warning until the **Clear Warning** button is clicked, even if the warning is no longer applicable. After a warning is reported, it is recommended to clear it.

## Trademarks

Windows is a registered trademark and registered service mark of Microsoft Corporation.

## Reference Documents

| DOCUMENT | |
|---|---|
| *[1]* | *SC1894 SPI Programming Guide* |
| *[2]* | *SC1894 Data Sheet* |
| *[3]* | *SC1894 FW4.1.03.08 Release Notes User Guide* |

## Revision History

| REVISION NUMBER | REVISION DATE | DESCRIPTION | PAGES CHANGED |
|---|---|---|---|
| 0 | 03/21 | Initial release | — |
| | | | |
| | | | |
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| | | | |