

# TIWI TRANSCEIVER MODULE

## *User's Guide*



Last updated  
Saturday, October 23, 2010

---

The information in this document is subject to change without notice.  
Confirm the data is current by downloading the latest revision from [www.lsr.com](http://www.lsr.com).



## Table of Contents

---

<b>1</b>	<b>Introduction .....</b>	<b>3</b>
1.1	<i>Purpose &amp; Scope.....</i>	3
1.2	<i>Audience.....</i>	3
1.3	<i>Applicable Documents.....</i>	3
1.4	<i>Revision History.....</i>	3
<b>2</b>	<b>Quick Start .....</b>	<b>4</b>
2.1	<i>Software.....</i>	4
2.2	<i>Hardware .....</i>	8
2.3	<i>WLAN Test Software Operation .....</i>	12
2.4	<i>Evaluation Board Schematics and Bill of Material.....</i>	30
<b>3</b>	<b>EMC Compliance Application Guide .....</b>	<b>31</b>
3.1	<i>Introduction .....</i>	31
3.2	<i>Module Integration Considerations – Antenna Systems .....</i>	31
3.3	<i>Module Integration Considerations – Circuit Implementation.....</i>	31
3.4	<i>Module Integration Considerations - Top Assembly Considerations. ....</i>	32
3.5	<i>Module Integration Considerations – Firmware.....</i>	32
3.6	<i>Testing Requirements for End-Product.....</i>	32
3.7	<i>Marking Requirements for End-Product.....</i>	32
<b>4</b>	<b>Contacting LS Research.....</b>	<b>35</b>

## 1 Introduction

### 1.1 Purpose & Scope

The purpose of this document is to provide details regarding the setup and use of the TiWi series transceiver module within its companion evaluation board. This document covers a description of the evaluation board and its features and a brief tutorial on how to operate the module evaluation board.

Further, this document will also present application guidance such that the module's EMC compliance will not be degraded.

### 1.2 Audience

This document is intended to be read by engineers and technical management. A general knowledge of common engineering practices is assumed.

### 1.3 Applicable Documents

- [1] *TiWi Datasheet- LS240-WI-01-A20 (LSR)*
- [2] *FCC Test Report # 310117, LS Research, LLC: September 8,2010*
- [3] *SAR Test Report: FCC ID: TFB-TiWi1-01, RF Exposure Lab, San Marcos, CA: September, 2010.*
- [4] *Evaluation Board Schematics*
- [5] *Ethertronics Presetta 1000423 Antenna Data Sheet.*
- [6] *LSR 001-0001 Dipole Antenna Data Sheet.*
- [7] *FCC OET Bulletin 62, "UNDERSTANDING THE FCC REGULATIONS FOR COMPUTERS AND OTHER DIGITAL DEVICES", February 1996.*

### 1.4 Revision History

Date	Change Description	Revision
10/8/2010	Initial release.	0.0

**Table 1 Revision History**

## 2 Quick Start

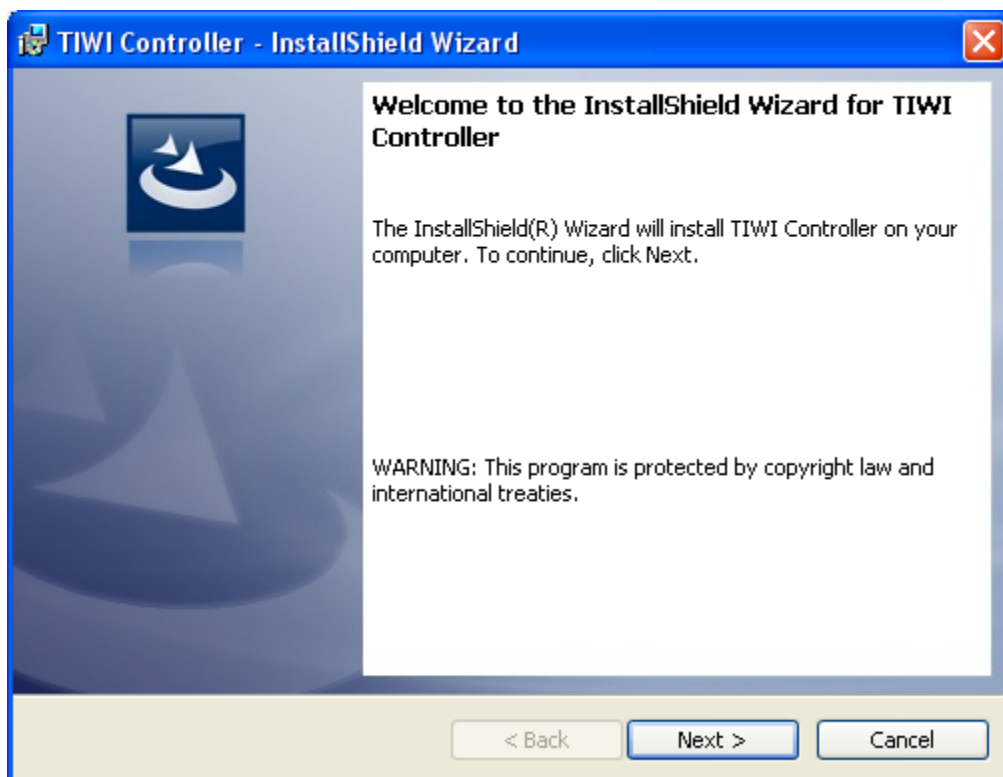
In this section, the initiation of the evaluation board and sample RF tests will be discussed. You will learn how to:

- Install TiWi Controller Tool.
- Run the TiWi Controller Tool.
- Set proper path to test firmware: Fw1273r1c\_sta\_cortex.bin.
- Set proper path to radio parameter file: ini\_file.ini.
- Connect to the TiWi LSEVK-WI-01-A20 Evaluation board.
- Download test firmware to the TiWi Module via the LSEVK-WI-01-A20 Evaluation board.
- Configure and Run WLAN Transmitter Tests.
- Configure and Run WLAN Receiver Tests.
- Place device in listen mode and Extremely Low Power Mode (ELP).

### 2.1 Software

Prior to connecting any hardware to your PC, download and install the latest version (current download: TIWI Controller 3-22-10.zip) of the TIWI Controller Software. The installation procedure is as follows:

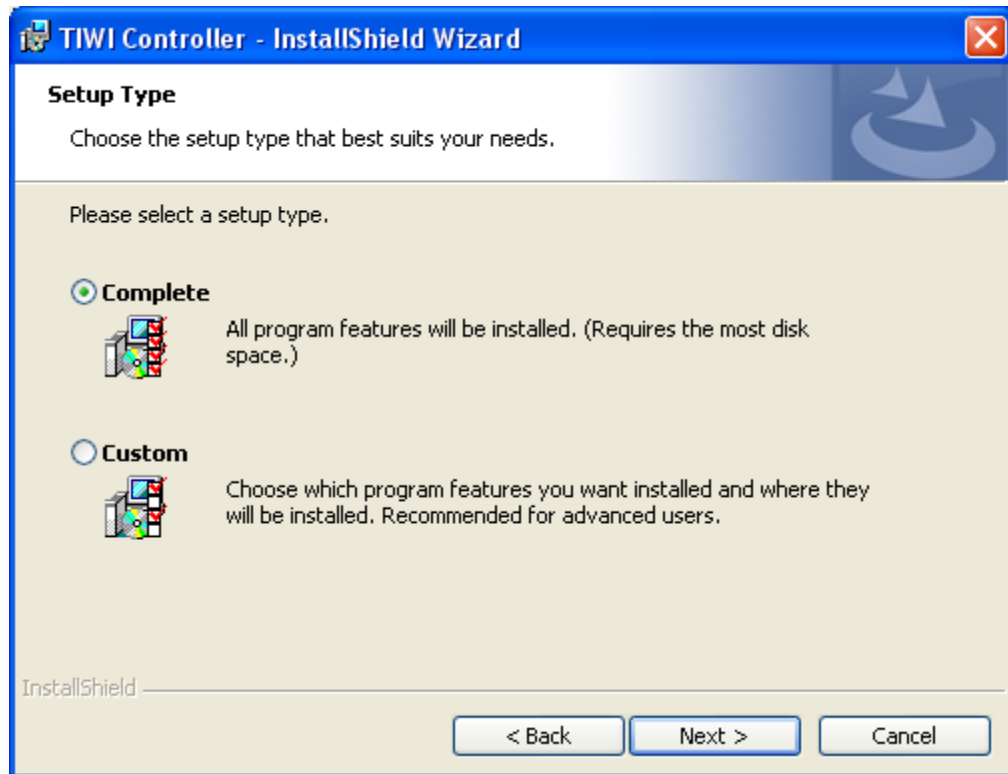
1. Copy TIWI Controller 3-22-10.zip to a convenient directory and extract the file:
2. Run TIWI Controller.msi, the following installation screens should begin:



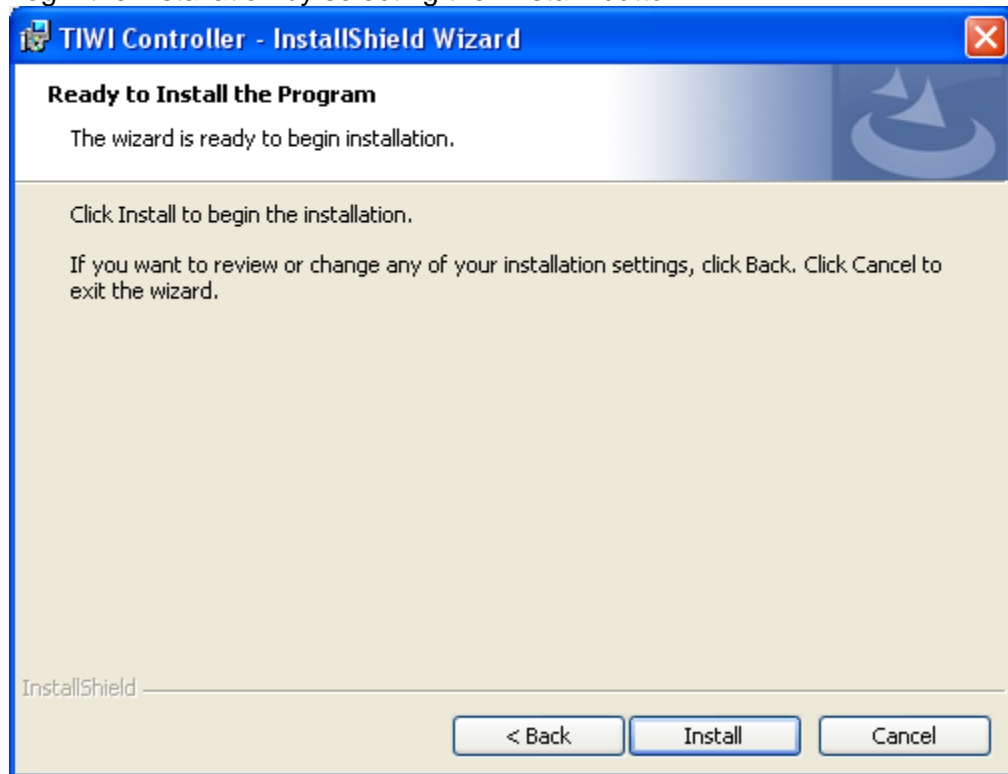
The information in this document is subject to change without notice.  
Confirm the data is current by downloading the latest revision from [www.lsr.com](http://www.lsr.com).



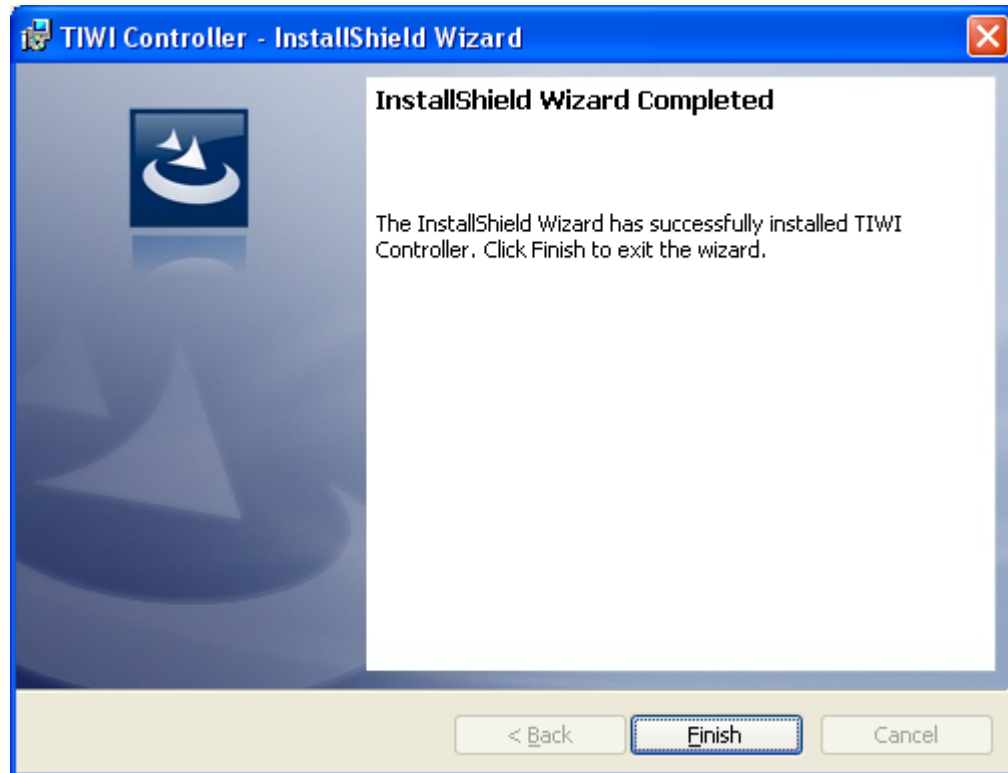
3. Choose Setup Type: Complete



4. Begin the installation by selecting the "Install" button

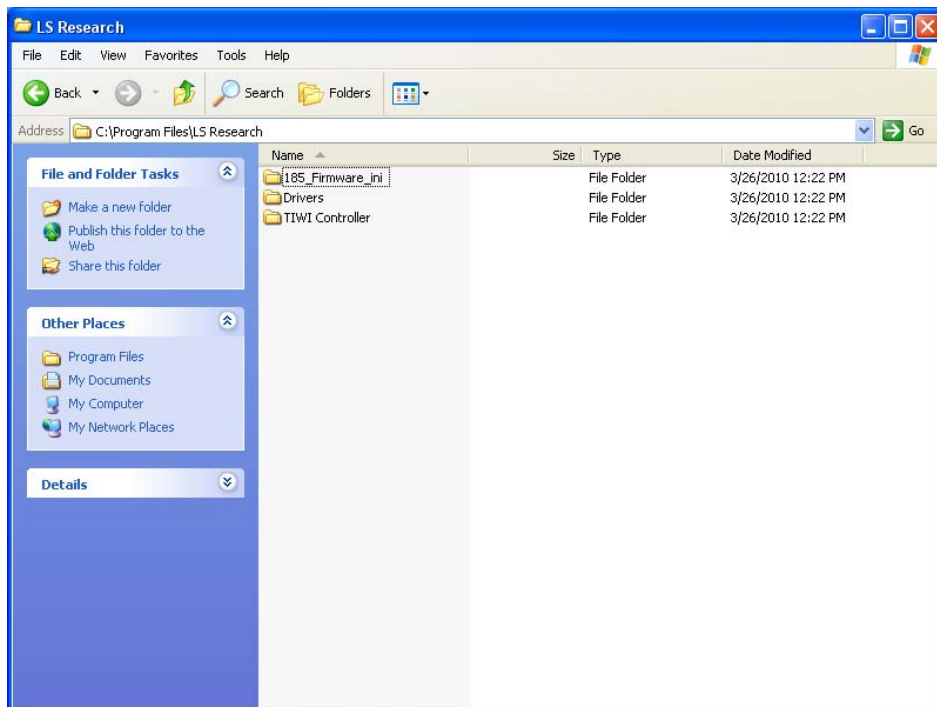


5. Upon completion, the following screen should appear and press "Finish".





6. Change to the directory: C:\Program Files\LS Research:
7. There are three directories: Drivers, TIWI Controller, and 185\_Firmware\_ini. The Drivers directory contains the drivers for USB connection between the PC and the FTDI USB-serial port circuits on the evaluation board. When a physical connection of the USB cable between the PC and the evaluation board is made, it may prompt you for the locations of the necessary drivers. Simply cause the driver search routine associated with the plug-and-play operation to browse into the directory C:\Program Files\LS Research\Drivers in order to install the proper drivers.
8. The Directory TIWI Controller contains the application and its associated support files.
9. Also note the presence of the 185\_Firmware\_ini directory. This contains the TIWI module test firmware and configuration parameters.



10. The TIWI Controller test tool will prompt for the location of the binary test firmware image (Fw1273r1c\_sta\_cortex.bin) and parameter file (ini\_file.ini), which is located in the C:\Program Files\LS Research\185\_firmware\_ini directory.

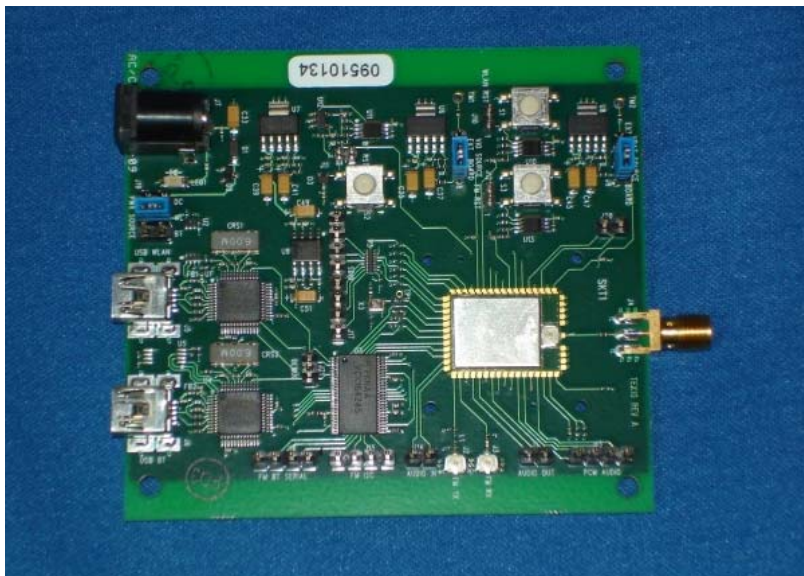


This user guide will now introduce the evaluation board hardware such that it is configured correctly in order connect and operate with the newly installed software. The operation of the software is presented immediately after the hardware introduction.

## 2.2 Hardware

1. Install the software described in the previous section, prior to connecting any hardware to your PC.

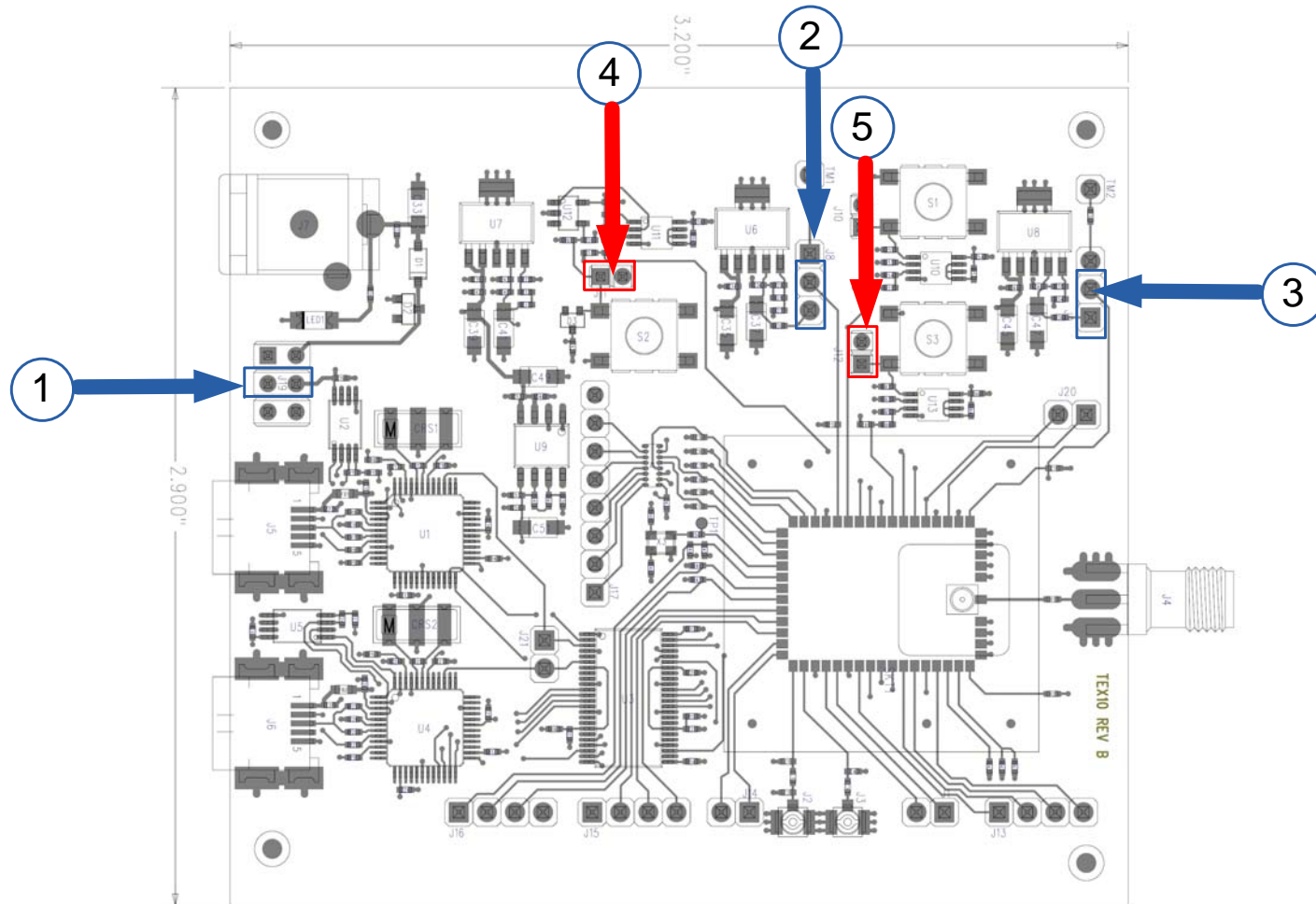
Figure 1 shows the LS Research, LSEVK-WP-01-A2 evaluation board:



**Figure 1 TiWi Evaluation Board, LSEVK-WI-01-A20**

2. Presented on the Next Page in Figure 2, is an annotated assembly drawing of the board to provide a clear reference to various features of the evaluation board:





**Figure 2 TiWi Evaluation Board, LSEVK-WI-01-A20:** Jumper positions(Name)[Selection Options]: 1. Select power source (PWR SOURCE),[DC,WL,BT], 2. Select VIO source (VIO SOURCE),[EXT,BOARD] 3. Select VBAT Source (VBAT SOURCE),[EXT,BOARD]. 4. BT reset (holds BT function in reset). 5. FM reset (holds FM in reset).

The information in this document is subject to change without notice.  
Confirm the data is current by downloading the latest revision from [www.lsr.com](http://www.lsr.com).

3. The jumper positions shown as blue rectangles correspond to the following primary power supply options:
- ① J19: PWR SOURCE: The input + 5VDC primary supply voltage for the interface circuit power supplies and board-derived module power supplies can be selected from 3 different sources.
    - PWR: Apply + 5 VDC to J7 (5V IN).
    - WL: Connect to USB + 5 VDC pin, voltage sourced from WLAN USB port (J5).
    - WL: Connect to USB + 5 VDC pin, voltage sourced from BT USB port (J6).
  
  - ② J8: VIO SOURCE: The input + 1.8VDC primary supply for the digital interface circuitry on the module, can be supplied externally (TM1) or from a regulated 1.8 VDC supply on the board (derived from + 5 VDC input voltage [USB or external]).
    - BOARD: Route board-derived 1.8 VDC power supply to module VIO input.
    - EXT: Supply 1.8 VDC power supply to module VIO from external power supply, e.g. lab supply.
  
  - ③ J9: VBAT SOURCE: The input + 3.6VDC primary supply for the main analog suppl on the module, can be supplied externally (TM2) or from a regulated 3.3 VDC supply on the board (derived from + 5 VDC input voltage [USB or external]).
    - BOARD: Route board-derived 3.6 VDC power supply to module VBAT input.
    - EXT: Supply 3. 6 VDC (nominal) power supply to module VBAT from external power supply, e.g. lab supply.

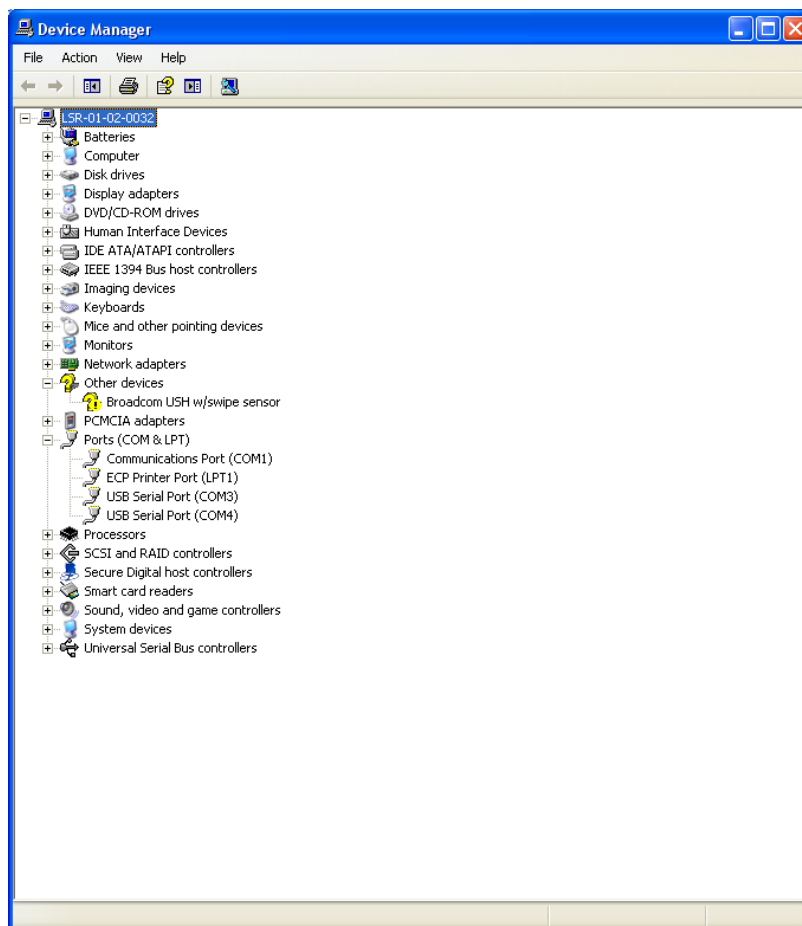


- ④ J11: BT RESET: Placing a jumper across J11 holds the Bluetooth (BT) core in reset. This is useful when making ELP current measurements on the WLAN section of the module. The jumper can be left off, but the BT core will draw a small amount of operating background current. The BT core can be manually held in reset by depressing S2. This jumper can be moved to J10, if holding the WLAN circuit in reset is desired during BT operations. The WLAN circuitry can be held in reset manually by depressing S1.
  
- ⑤ J12: FM RESET: Placing a jumper across J12 holds the FM circuit in reset. The FM feature is not currently supported. If FM support is required or desired, please contact LS Research, for further information. This circuit should always be held in reset.

## 2.3 WLAN Test Software Operation

Assuming that the software has been installed properly per the instructions given in section 2.1 and that the evaluation board hardware is configured properly per the instructions given in section 2.2, a set of basic WLAN hardware tests can now be executed:

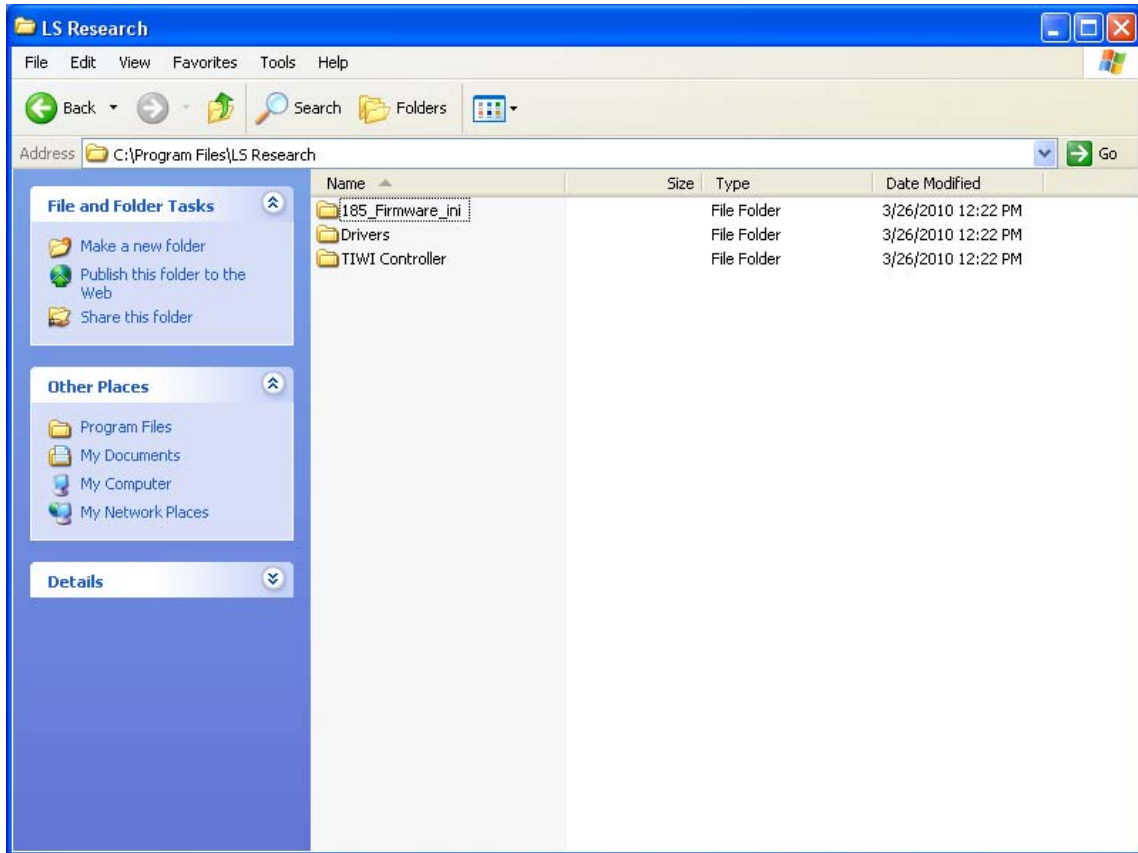
1. Connect the supplied USB cable between a USB port on the PC to the WLAN USB connector on the evaluation kit (J5). Connect a 50 Ohm coaxial cable to SMA connector (J4) and terminate in the 50 ohm test equipment port appropriate to the desired measurement (WLAN test set for TX/RX, Spectrum Analyzer for TX, Vector Signal Analyzer for TX, Vector Signal Generator for RX).
2. If the proper drivers have been installed previously that support the FTDI USB interface circuit, the plug and play mechanism associated with PC Hardware Device manager should recognize two serial ports. It is important to note the port number of the two captured serial ports (there is a low-port and a high-port number). This can be checked by examining: Control Panel → System → (Hardware Tab) → Device Manager. This should display the presence of two, properly configured serial ports. In this case the low-port is COM3 and the high-port is COM4. Note the port number of the low port.



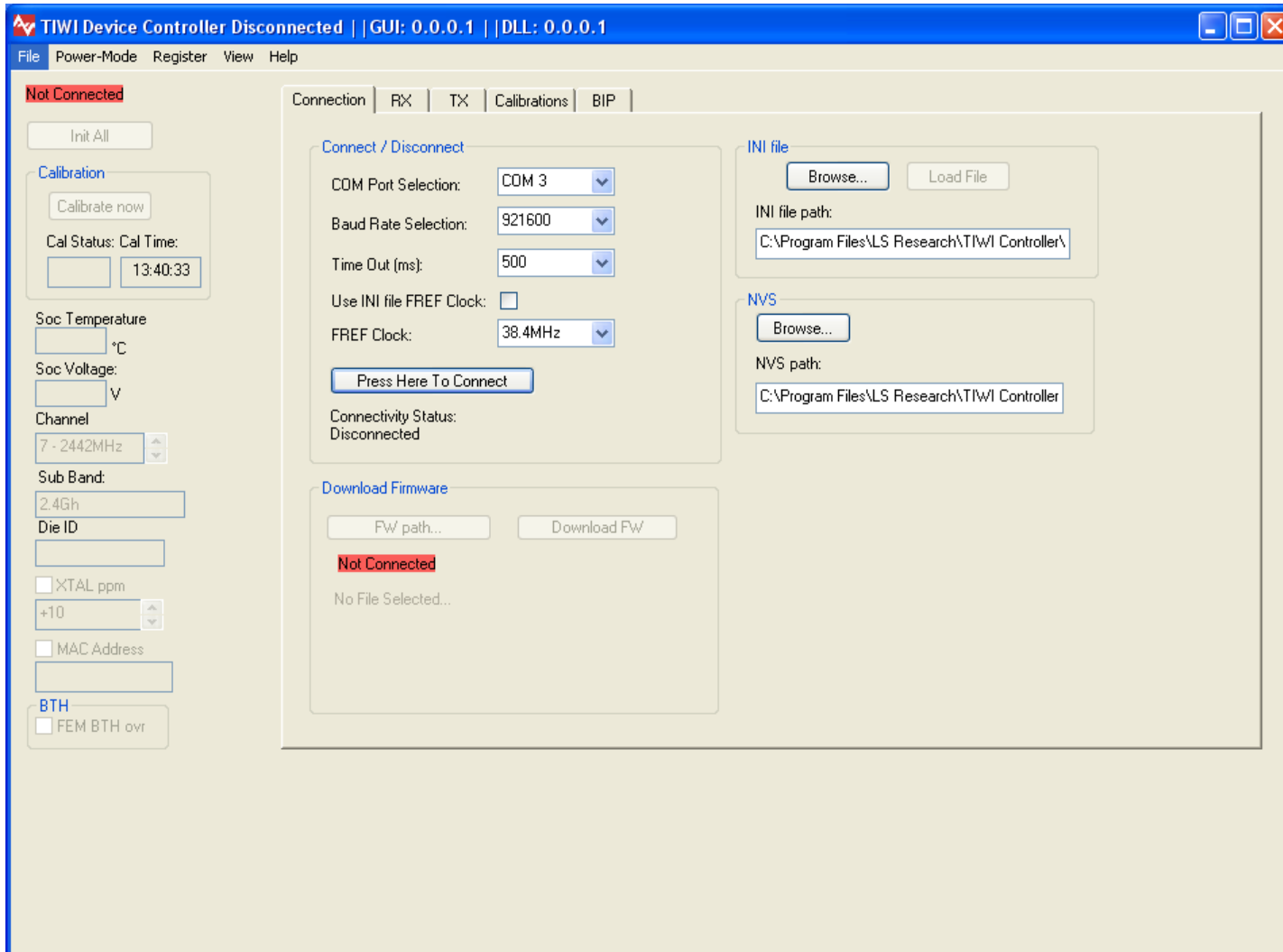
The information in this document is subject to change without notice.  
Confirm the data is current by downloading the latest revision from [www.lsr.com](http://www.lsr.com).



3. If the plug and play mechanism for the USB serial ports requires a path specification for the drivers, please specify the path towards: C:\Program Files\LS Research\Drivers.

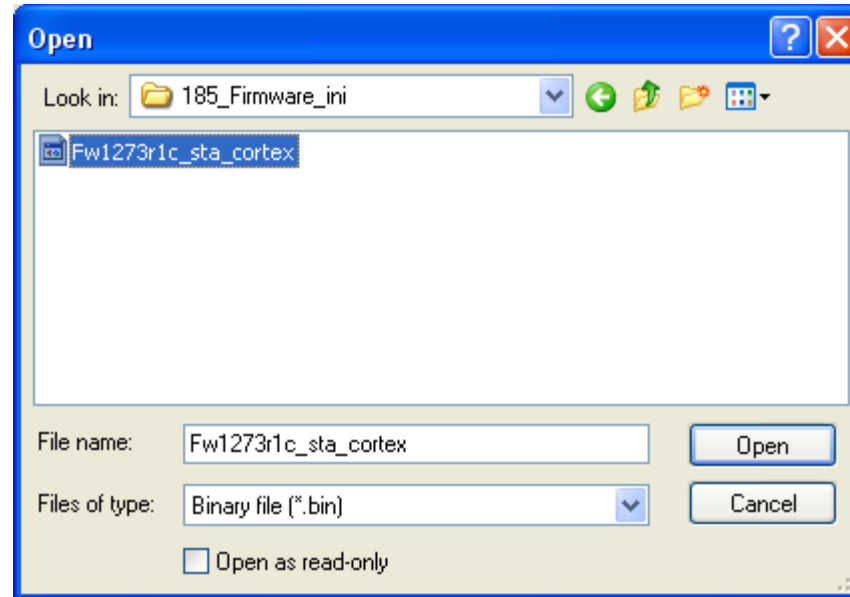


- The installation process should have placed a short-cut icon that is based on the LS Research logo and is labeled TIWI Controller. Use the short-cut to start the TIWI Controller Program:

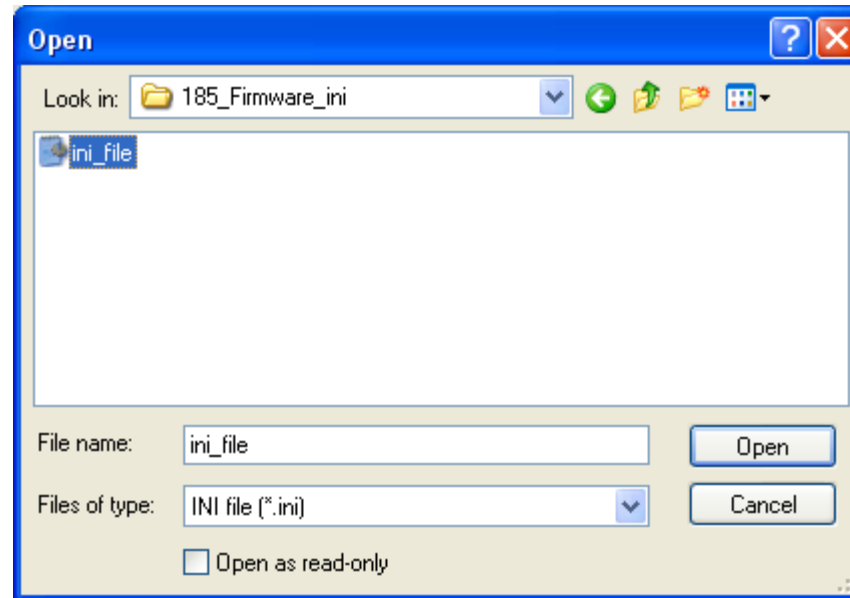


The information in this document is subject to change without notice.  
Confirm the data is current by downloading the latest revision from [www.lsr.com](http://www.lsr.com).

5. In the Connect / Disconnect Field, ensure that COM Port selection is selected to the low-port number determined through the use of the Hardware Device Manager.
6. Set the Baud Rate to 921600 bits per second.
7. Set the time out value to 500 mS.
8. Ensure that the FREF clock is set to 38.4 MHz.
9. In the Download Firmware Field, select Firmware path to specify the location of the firmware binary image file:

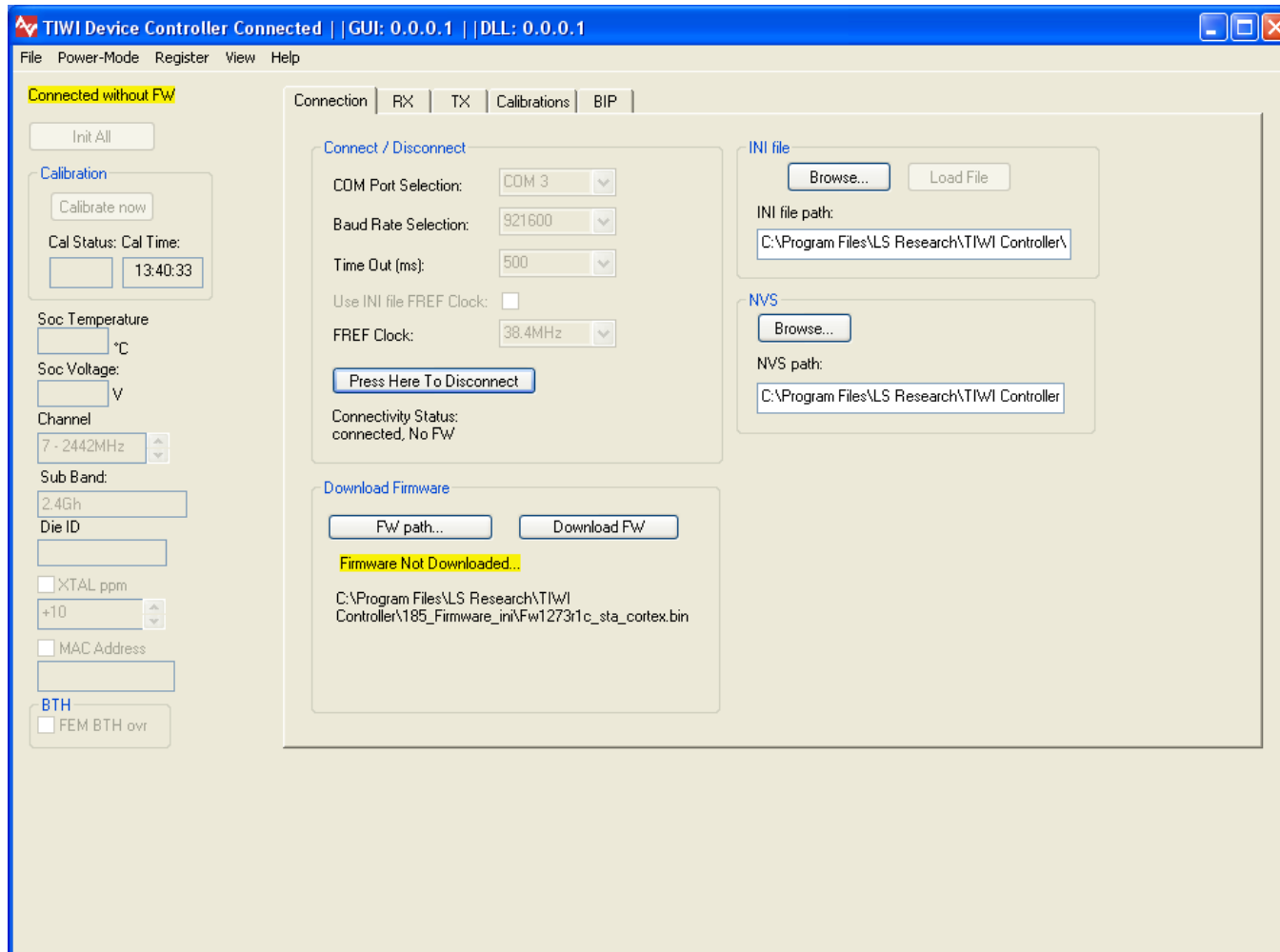


10. In the INI file Field, select Browse to specify the path for the location of the ini\_file.ini configuration file:





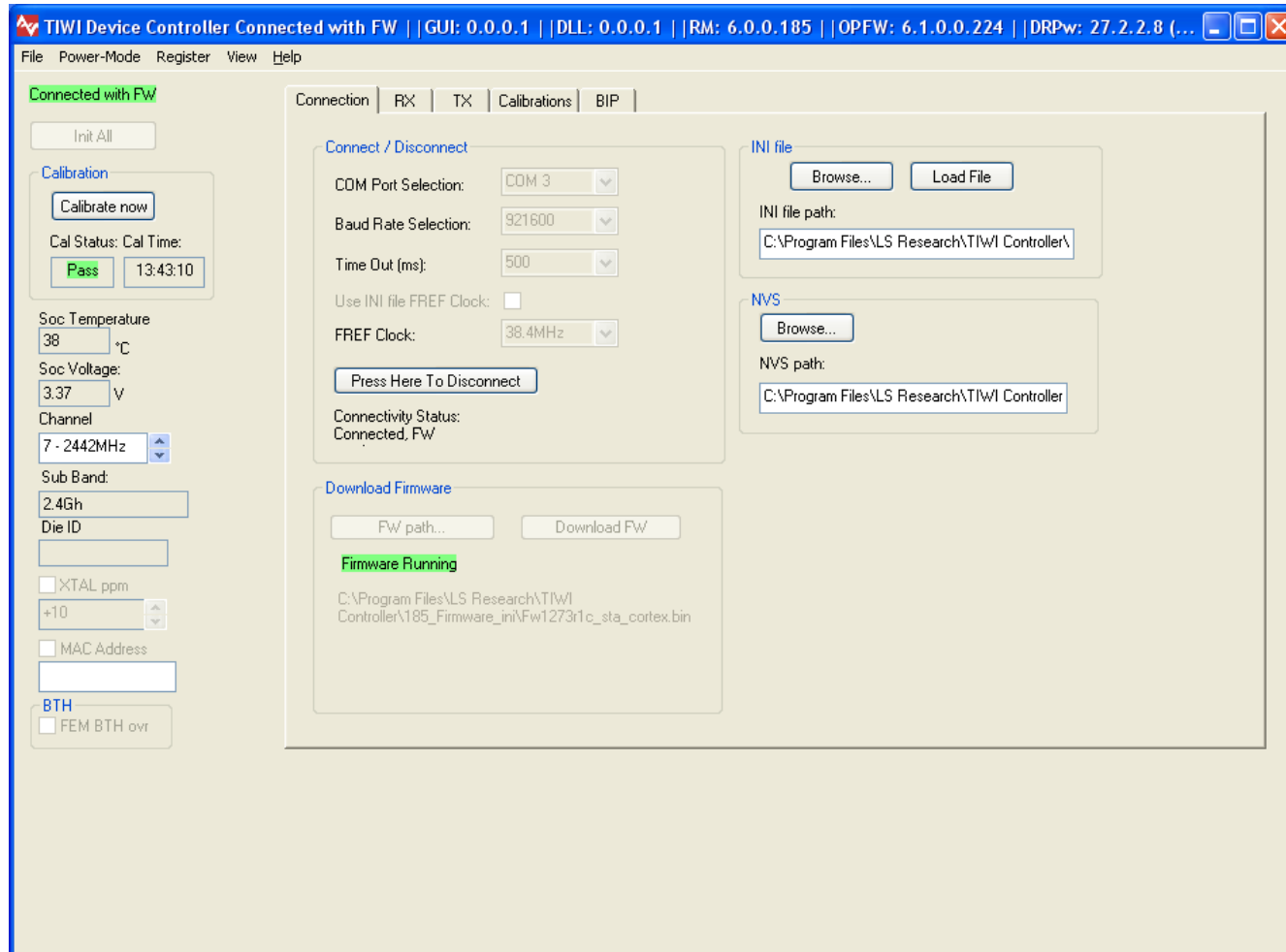
11. Return to the Connect / Disconnect Field and select the “Press Here to Connect” button:



The connection indicator in the upper left hand corner should change from “**Disconnected**” and Red to “**Connected without FW**” and turn yellow. Also note in the Download Firmware field that an indicator also changes from “**Not Connected**” to “**Firmware Not Downloaded**”...

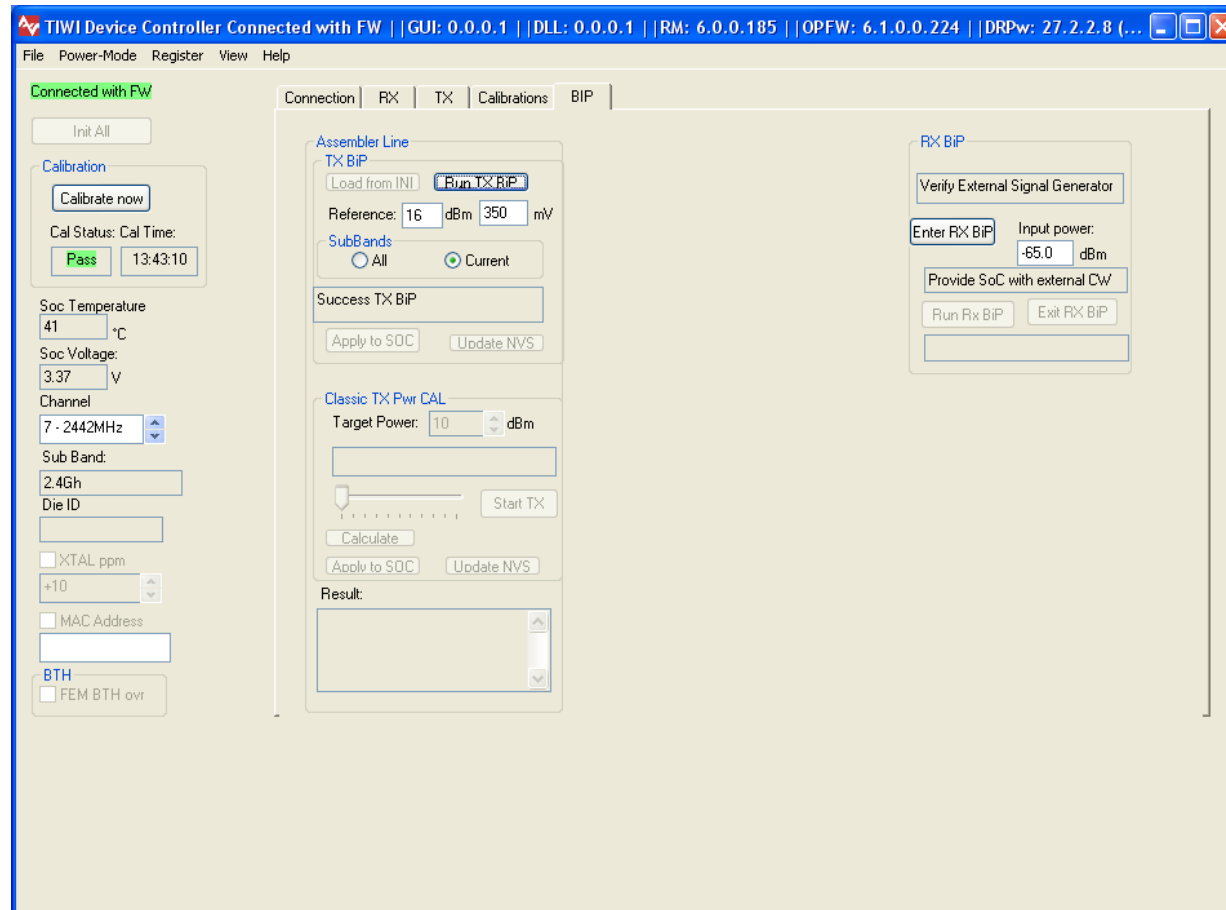
The information in this document is subject to change without notice.  
Confirm the data is current by downloading the latest revision from [www.lsr.com](http://www.lsr.com).

12. Now select the “Download Firmware” Button. A firmware downloading progress bar should display the state of downloading progress. When the downloading process is complete, the device will run the firmware and perform a series of calibrations. In the Calibration Field, a summary Cal Status should indicate “Pass” and the connection status should change from “Connected without FW” to “Connected with Firmware” and the indicator in Dowload Firmware Field should change from “Firmware Not Downloaded”... to “Firmware Running”.



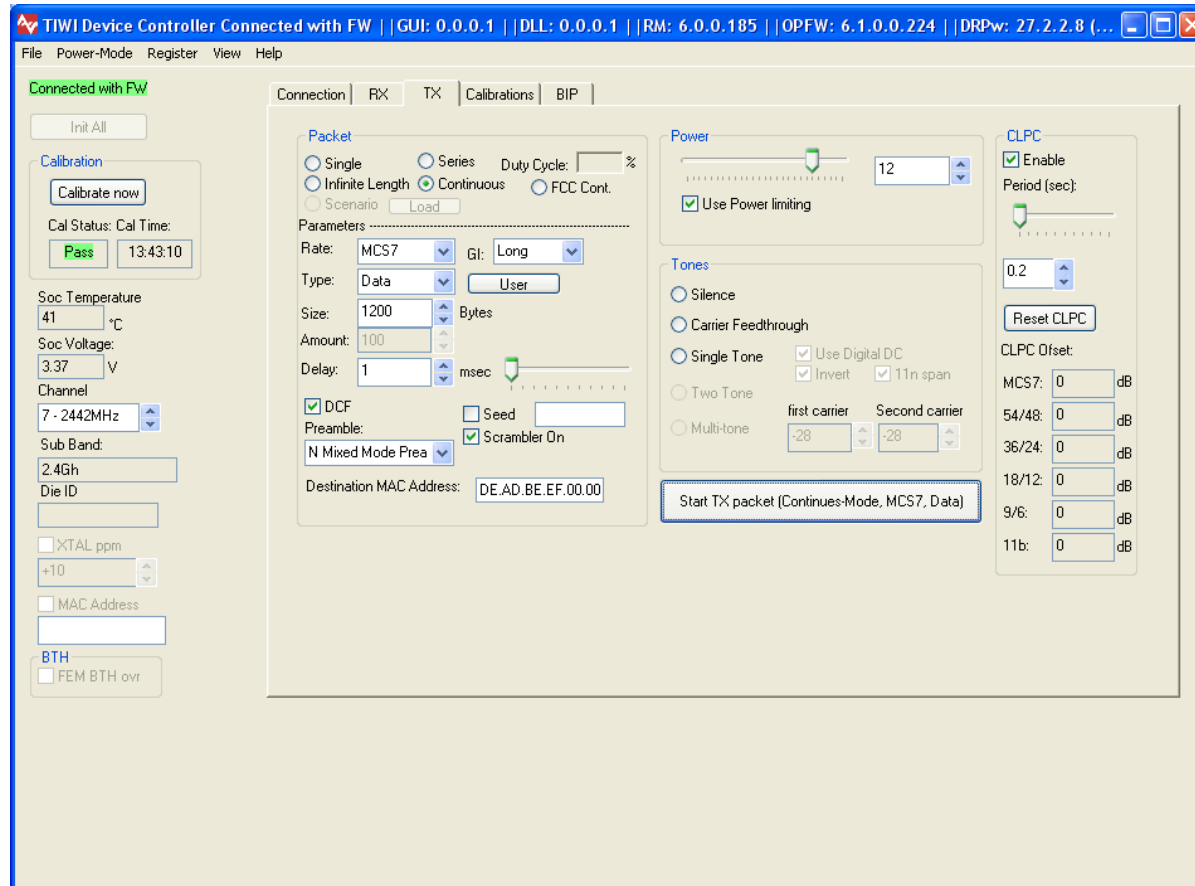
The information in this document is subject to change without notice.  
Confirm the data is current by downloading the latest revision from [www.lsr.com](http://www.lsr.com).

13. Note on the right hand side of the user interface that the device reports back an estimate of the SoC (system on chip) temperature and SoC terminal voltage. These quantities are monitored throughout the device operation and are updated periodically. Note below the Soc voltage is a drop-down selector that can be used to manually change the frequency channel of the transceiver. The default channel is Channel 7 – 2442 MHz. Next Select the BIP tab (Built-In PLT) (PLT=Production Line Testing). Set the reference power level to 16 dBm and its associated power detector reference voltage of 350 mV and select the “Run TX BiP” button. This runs a calibration routine to calibrate the power detector associated with the transmit (TX) power leveling loop for closed-loop power control (CLPC). No action is required with the RX BiP.



The information in this document is subject to change without notice.  
Confirm the data is current by downloading the latest revision from [www.lsr.com](http://www.lsr.com).

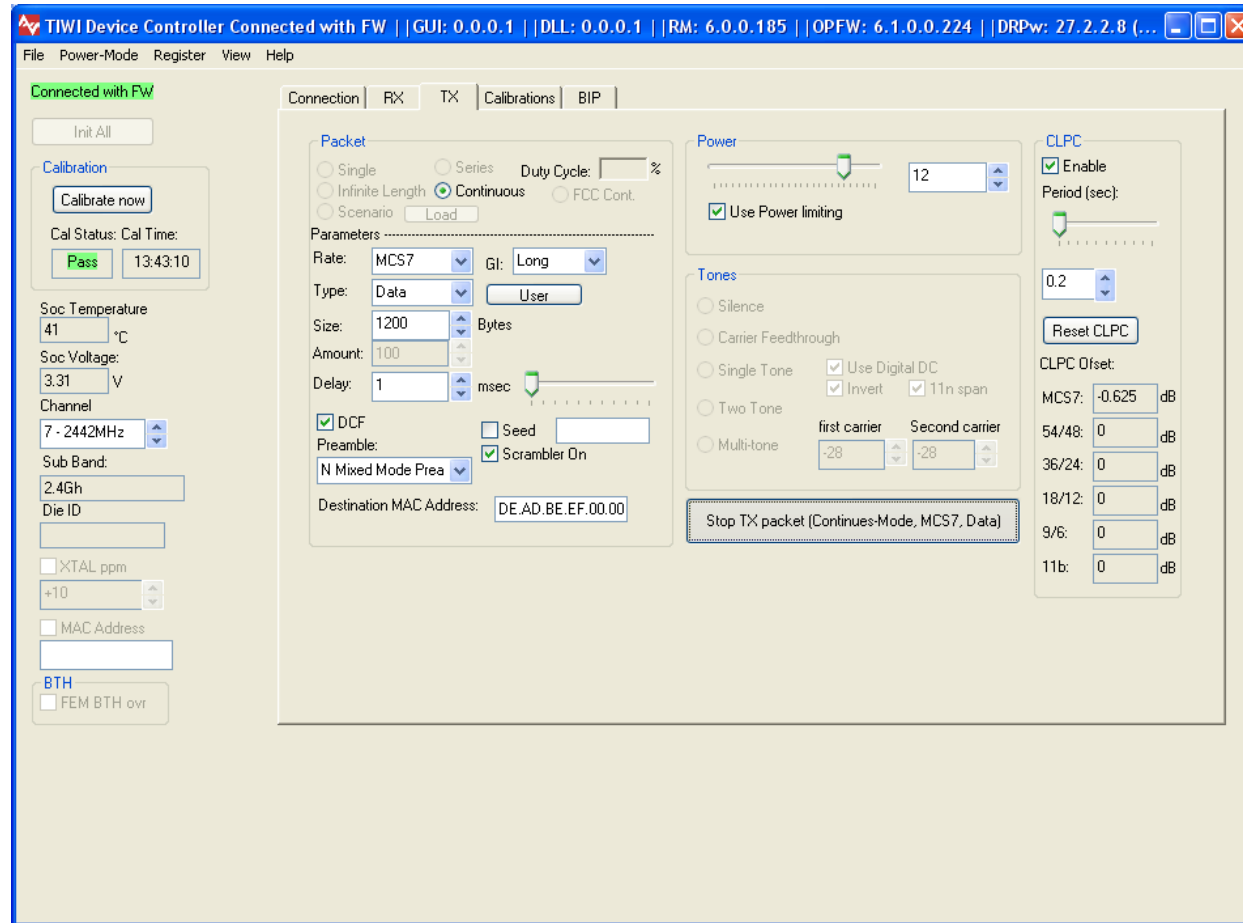
14. Upon completion of the BiP CLPC calibration the indication panel should read “Success TX BiP”. At this point the device is ready to be configured and tested for basic RF performance. Beginning with the TX function, select the TX tab:



15. The various 802.11 b/g/n rates can be selected and the Guard Interval Type (GI). For this example, a 802.11n rate MCS7 (65 Mbps) is selected to operated with long guard interval. Set the payload size (1200 bytes here) and the time duration (Delay) of the inter-packet idle time (1 msec here). The packet type should be selected as “Continuous”. Preamble types can be changed in accordance to preamble options offered for each modulation type (b/g/n).

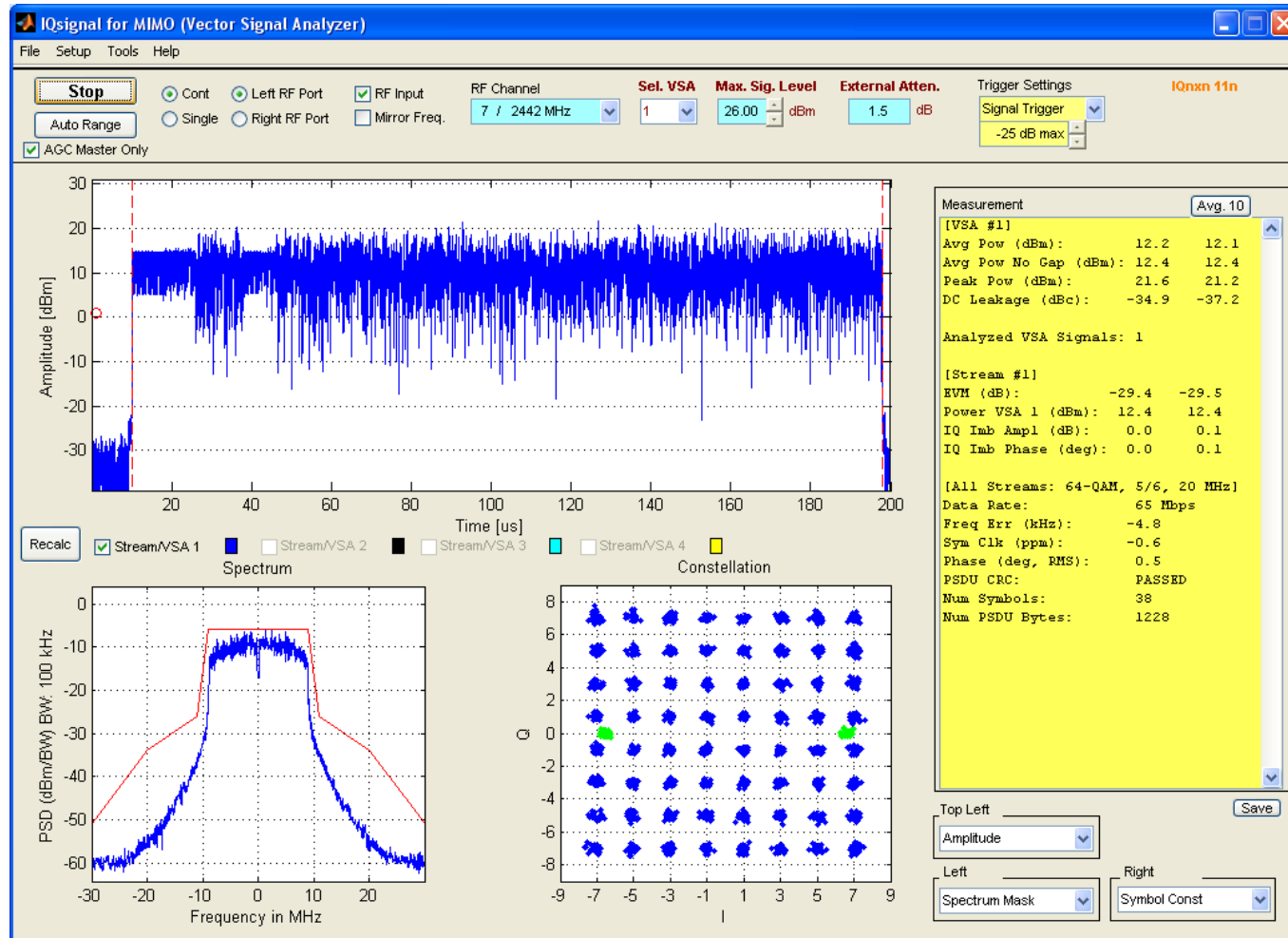
The information in this document is subject to change without notice.  
Confirm the data is current by downloading the latest revision from [www.lsr.com](http://www.lsr.com).

16. The “Power” field allows the user to set the CLP output power set point. Select “Power Limiting” and check “Enable” in the CLPC field. The update rate of the CPLC (in sec) can be set, but is typically used at the default setting of 0.2 seconds. The user can reset the CPLC at any time. At this time, press the button: “Start TX packet (Continuous Mode, Type, Data)”:



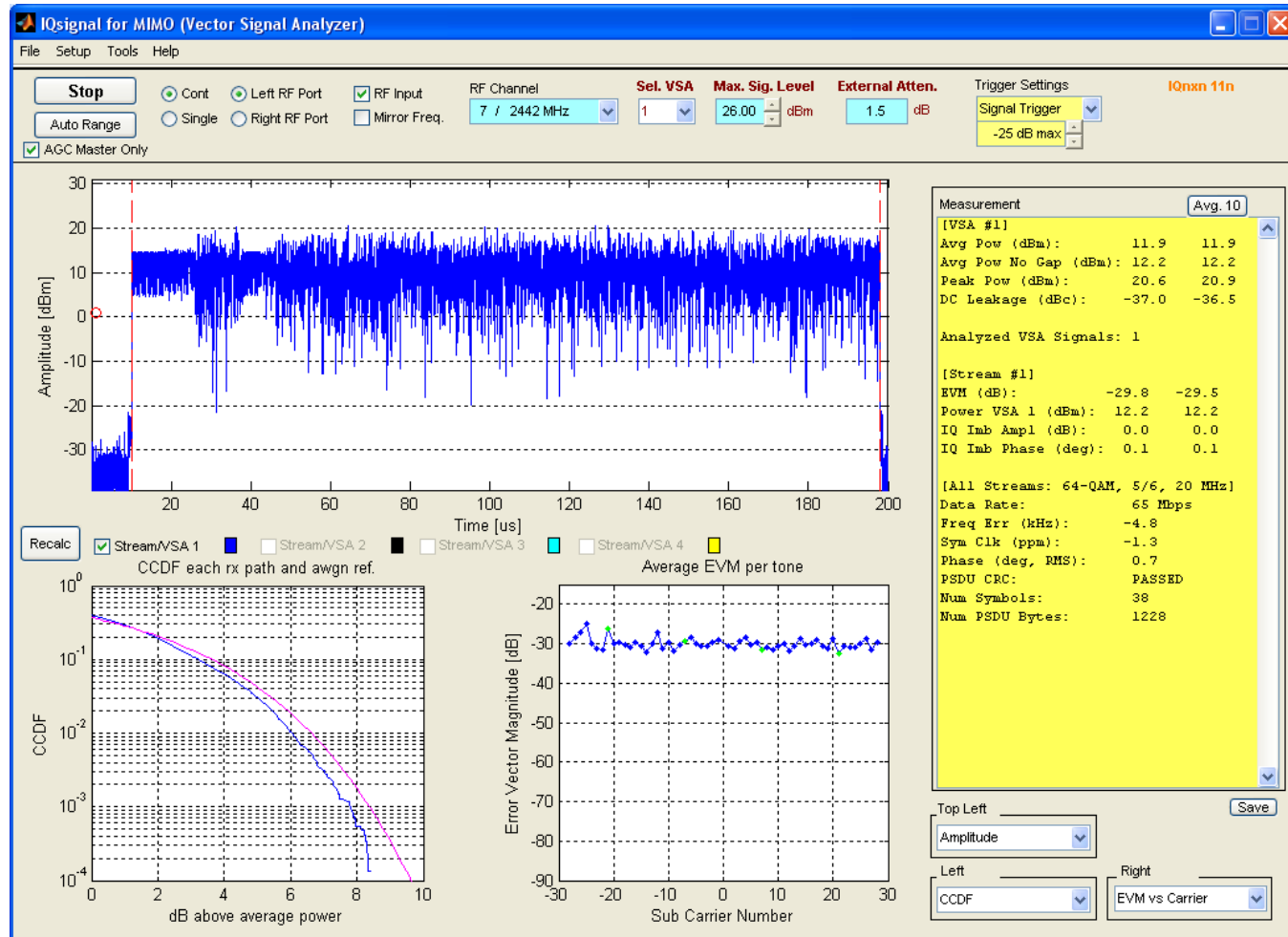
17. Upon initiation of the “Start TX packet...” the button should change to “Stop TX packet...” and indication of the CLPC offset should be indicated in the in box associated with the appropriate modulation type / data rate.

18. Presented below is a typical indication for the settings shown using a Litepoint WLAN test set with associated application software IQsignal for MIMO:



These same measurement indications may be obtained by direct use of Spectrum Analyzers and Vector Signal Analyzers (VSAs).

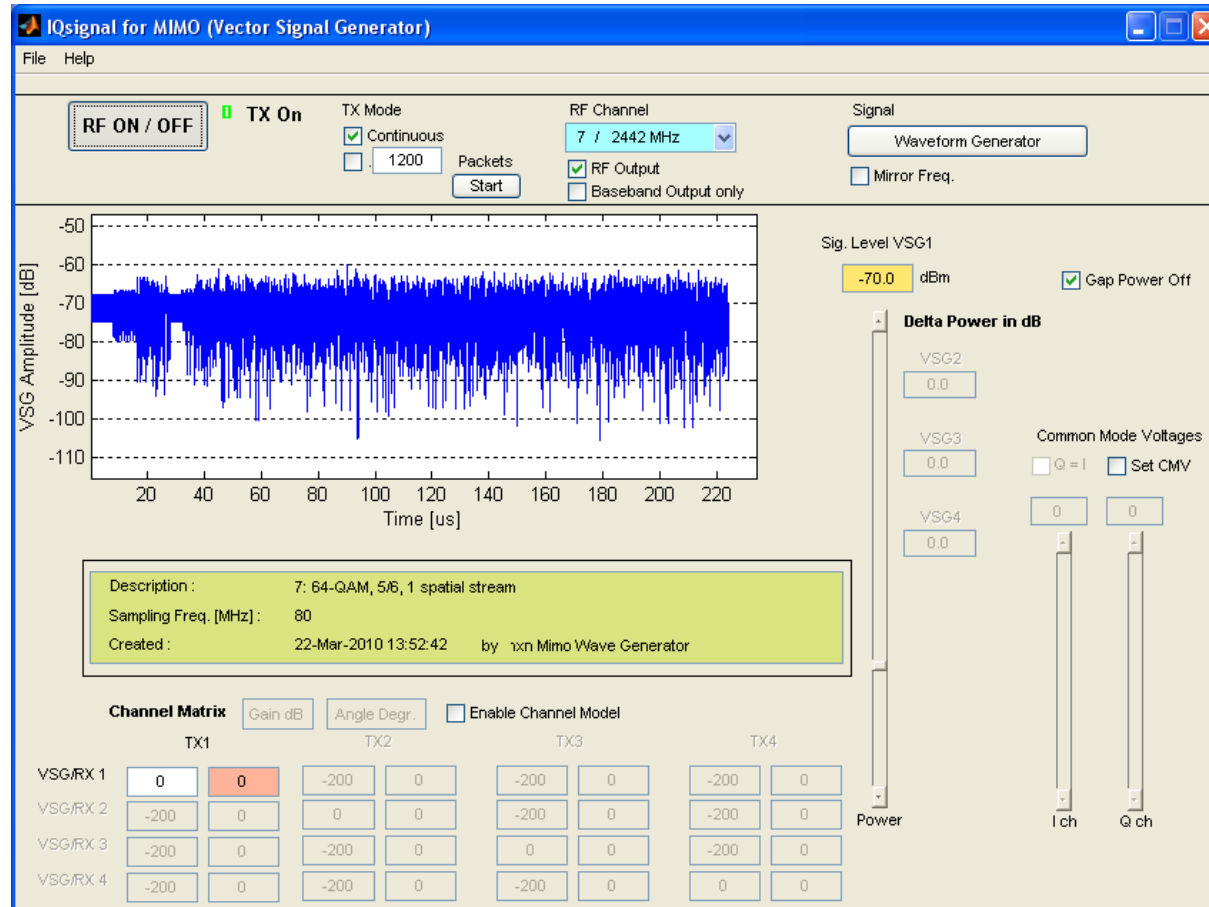
The information in this document is subject to change without notice.  
Confirm the data is current by downloading the latest revision from [www.lsr.com](http://www.lsr.com).



These same measurement indications may be obtained by direct use of Spectrum Analyzers and Vector Signal Analyzers (VSAs).

The information in this document is subject to change without notice.  
Confirm the data is current by downloading the latest revision from [www.lsr.com](http://www.lsr.com).

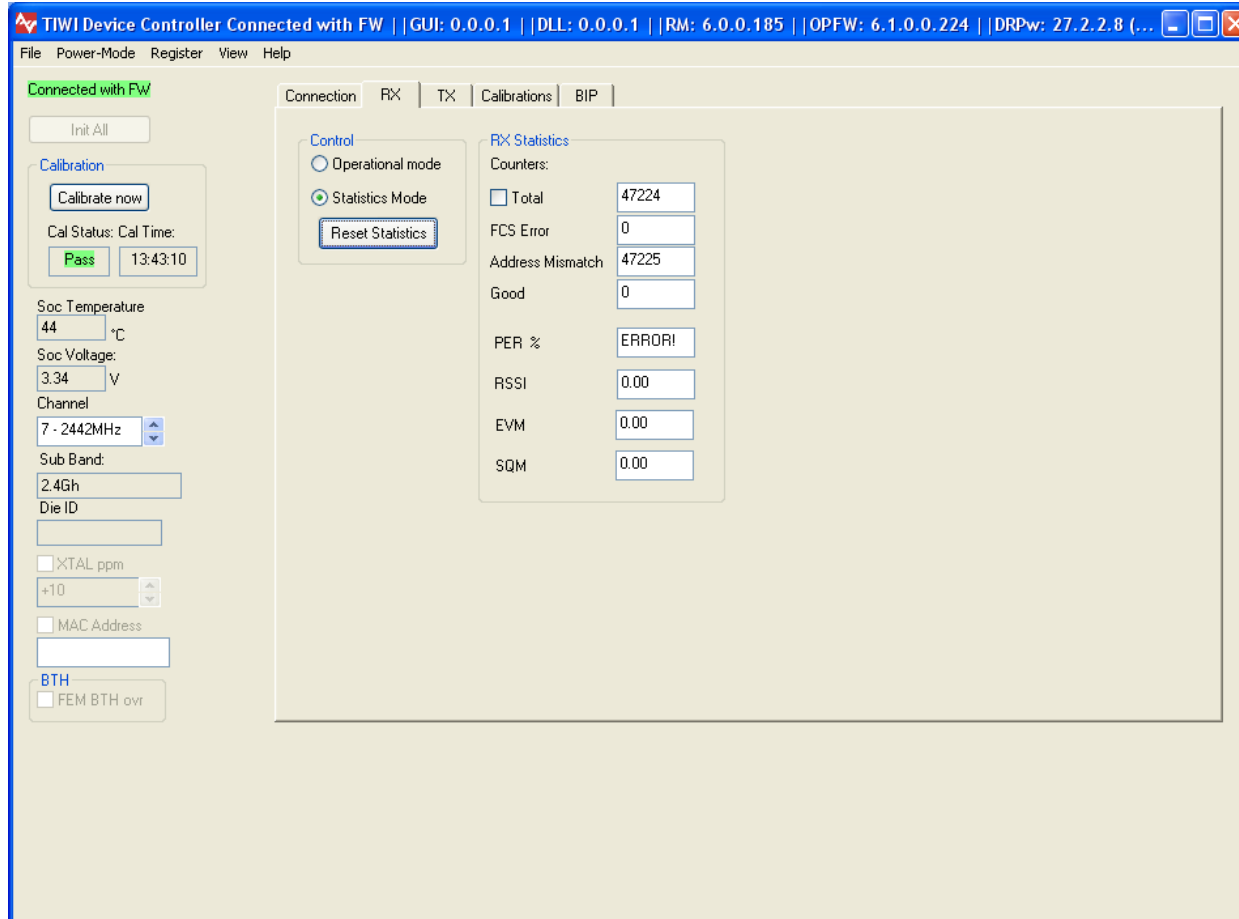
19. Stop TX packet transmission and select the RX tab. For receiver (RX) tests configure the Vector Signal Generator (VSG) to generate an appropriately formatted signal and apply it to the receiver. For this example, the VSG associated with the Litepoint IQsignal for MIMO is used. Set the power for a signal level well above the sensitivity level and below the overload level (in this case -50 dBm) to validate that the generator transceiver link is at zero PER (Packet Error Ratio).



Note: This VSG display is set to a level near sensitivity (-70 dBm). Set to mid-scale level within receiver dynamic range for zero PER validation.

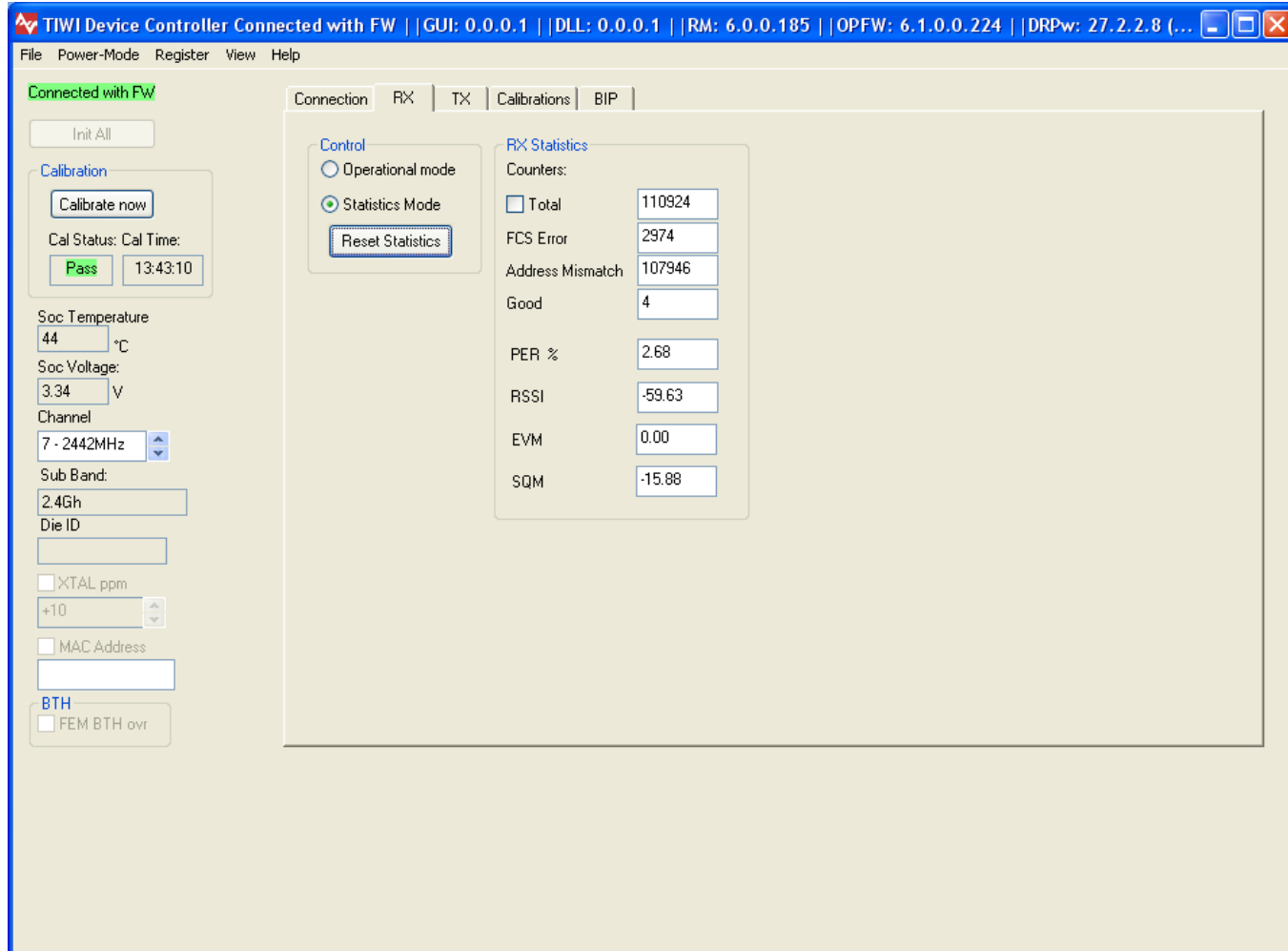


20. Returning to the TIWI device controller and the selection of the RX tab, select the statistics mode and Reset statistics. The RX statistic counters should be actively incrementing upon a reception of a packet. Generally speaking, there will be address mismatches and Good Packets will not be indicated. However the PER is computed by the ratio of FCS (Frame Check Sequence) errors to total number of packets transmitted. As long as the FCS errors are zero, the link is considered to be error free. At a power level of -50 dBm, all of the data rates/modulation coding schemes should be error free. PER may indicate a computational ERROR! , when it is at the 0% PER level.



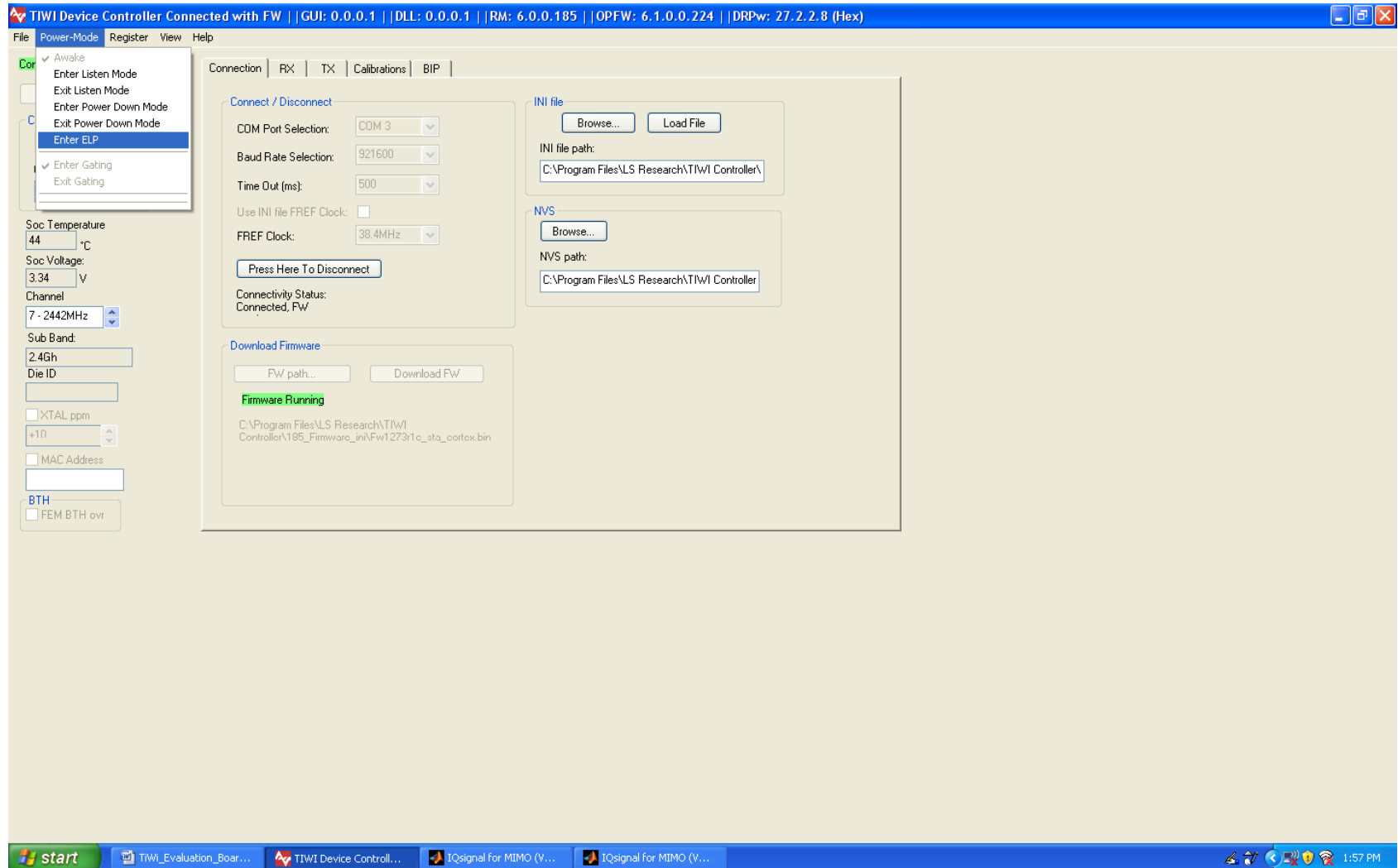
The information in this document is subject to change without notice.  
Confirm the data is current by downloading the latest revision from [www.lsr.com](http://www.lsr.com).

21. By decreasing the available power to the receiver (receiver input power) to near the expected sensitivity level. FCS errors will start be indicated and the PER will increase:



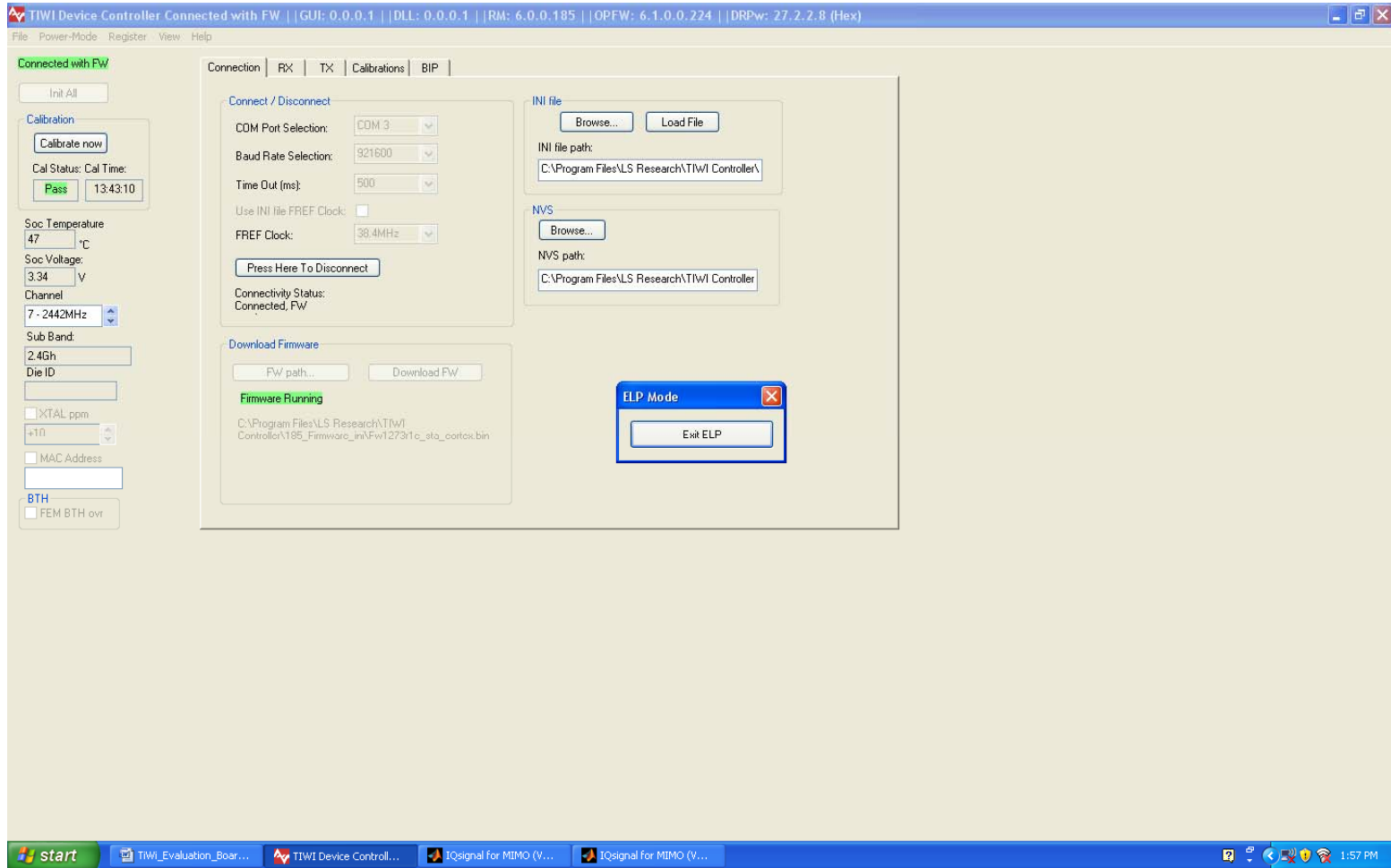
Generally, the receiver input power is incrementally decreased until the PER reaches its maximum level with respect to the sensitivity level declaration criterion. In this case, the power could be lowered since the maximum PER level is 10%.

22. The software tool can also be used to set the device into some of its low-power modes. The transceiver can be set in the listen-mode (a low power mode capable of receiving BSS (Basic Service Set) beacons). Further, the transceiver can be set in an Extremely low-power mode or ELP Mode.



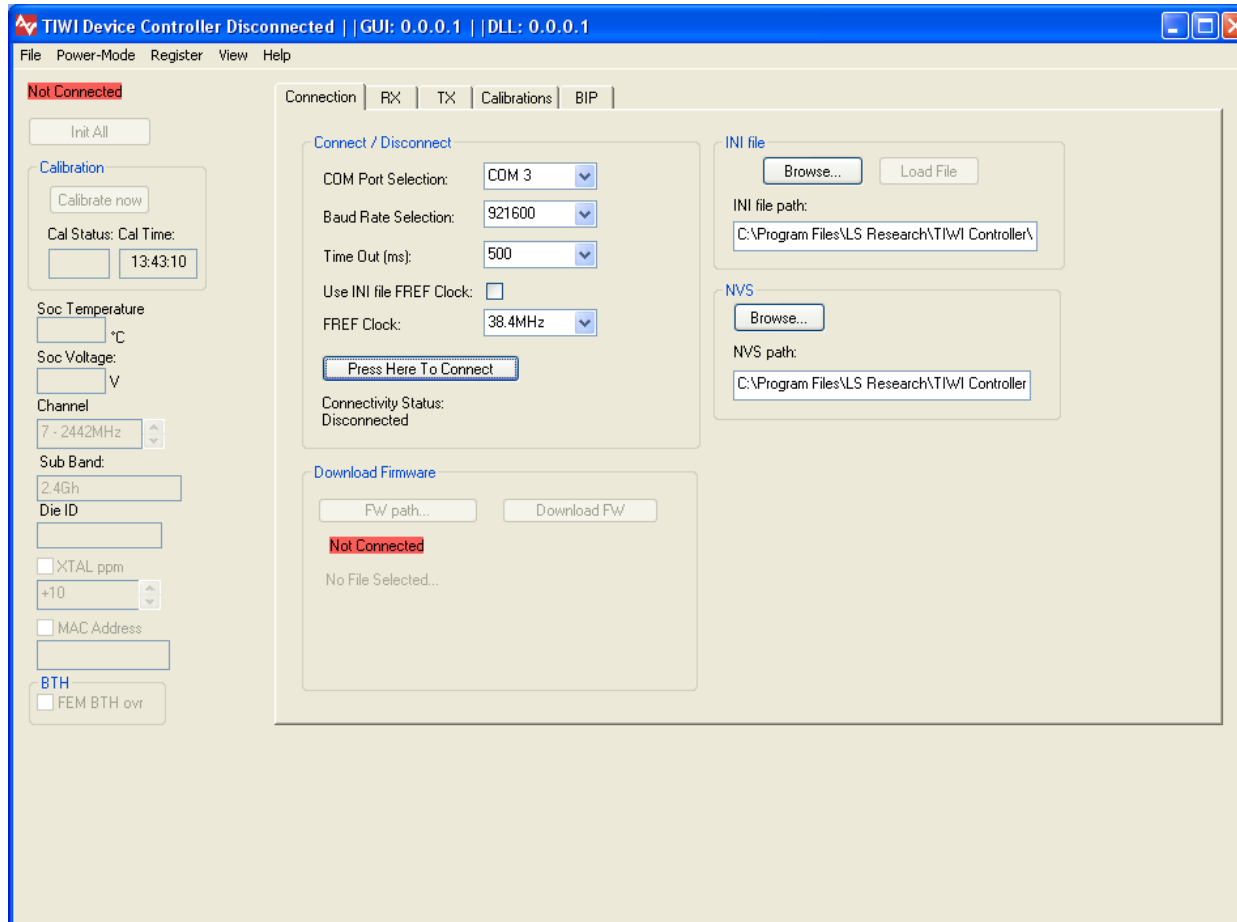
The information in this document is subject to change without notice.  
Confirm the data is current by downloading the latest revision from [www.lsr.com](http://www.lsr.com).

23. The device can be brought out of the ELP mode:



The information in this document is subject to change without notice.  
Confirm the data is current by downloading the latest revision from [www.lsr.com](http://www.lsr.com).

24. To disconnect the device, return to the connection tab and select "Press Here to Disconnect". If one wants to ensure minimum current draw to the device prior to USB or external power supply disconnection, simply reset the WLAN device by depressing and releasing momentary switch, S1. The tool should indicate that is **Not Connected**.



The information in this document is subject to change without notice.  
Confirm the data is current by downloading the latest revision from [www.lsr.com](http://www.lsr.com).



## **2.4 Evaluation Board Schematics and Bill of Material**

The evaluation board schematics are provided on the CD as a \*.pdf file, as a reference in the event that hardware troubleshooting is required or if one requires a proven application circuit for the module. The associated Bill of Material (BOM) is provided as an \*.xlsx file.

## 3 EMC Compliance Application Guide

### 3.1 Introduction

The TiWi module has been tested as Modular Radio in accordance with the FCC [1]. The device has been tested to relevant FCC parts and the results of the testing may be found in the module's test report [2].

Since this module and its associated set of approved antenna has been certified as a Modular Radio, this allows the end user to integrate this module into an end-product and only be responsible for the Unintentional Emissions levels produced by the product. The manufacturer of the module is the responsible for the compliance of the Intentional Emissions produced by the module, as long as, the recommendations presented in this application guide.

### 3.2 Module Integration Considerations – Antenna Systems

the module must be used with one of the approved antennas:

LS Research 001-0001 with LS Research U.FL to Reverse Polarity SMA connector cable (LS Research 080-0001).

1. Ethertronics Presetta 1000423 and Johnson Emerson U.FL. to U.FL coaxial cable 415-0088-150.

The antennas should be placed such that they are minimally disturbed by the product's packaging material. The incorporation of the largest practical free-space clearance around the antenna is important for maximizing overall performance. The clearances associated with the SAR compliance must be maintained.

### 3.3 Module Integration Considerations – Circuit Implementation

The module should be integrated according to either the application circuit found in the device data sheet or in accordance with the circuit provided for the evaluation board, along with best engineering practices to minimize unintentional EMC emissions.

It is recommended that all connection PCB (printed circuit board) traces to the power supply and digital control terminal be as short as possible. Though not necessarily required in all cases, it is a best practice to provide an optional shunt capacitor placement at the module pin on all active and routed power supply and digital control lines. Further, a series damping resistor placement should be incorporated between the module pin/shunt capacitor node and the source/sink of the digital control signals. This provides for effective bypassing and decoupling of digital lines from the radio module, in the event that the application circuit has longer power supply and digital routing.



### **3.4 Module Integration Considerations - Top Assembly Considerations.**

In addition to the recommendations given for the antenna systems and the module placement onto a product PCB, it is recommended that all wiring and interconnect systems within the product be not routed anywhere close the module and its associated circuitry on the PCB, doing so could change the emission characteristics of the module.

### **3.5 Module Integration Considerations – Firmware**

The module must use the specific operational firmware provided by LSR for the module. This firmware includes:

1. Binary image: FW1273r1c\_sta\_cortex.bin (version 185).
2. ini.ini. configuration file.

### **3.6 Testing Requirements for End-Product**

Once the module is integrated and the product realized, the product must be tested and follow the verification process for Unintentional Conducted and Radiated Emissions in accordance to the FCC guidelines [7]. The module is to be placed in the receive mode for this test (see step 20).

### **3.7 Marking Requirements for End-Product and Compliance Statements.**

#### **Federal Communication Commission Interference Statement**

This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help.





This device complies with Part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

**FCC Caution:** Any changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate this equipment.

### **INDUSTRY CANADA STATEMENTS**

Operation is subject to the following two conditions: (1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

To reduce potential radio interference to other users, the antenna type and its gain should be so chosen that the equivalent isotropically radiated power (e.i.r.p.) is not more than that permitted for successful communication.

This device has been designed to operate with the antennas listed in Section 3.2, and having a maximum gain of 4.3 and -0.6 dB. Antennas not included in this list or having a gain greater than 4.3 and 0.6 dB are strictly prohibited for use with this device. The required antenna impedance is 50 ohms.

### **OEM Responsibilities to comply with FCC and Industry Canada Regulations**

The TiWi-R1 Module has been certified for integration into products only by OEM integrators under the following conditions:

1. The antenna(s) must be installed such that a minimum separation distance of 20cm is maintained between the radiator (antenna) and all persons at all times.
2. The transmitter module must not be co-located or operating in conjunction with any other antenna or transmitter.

As long as the two conditions above are met, further transmitter testing will not be required. However, the OEM integrator is still responsible for testing their end-product for any additional compliance requirements required with this module installed (for example, digital device emissions, PC peripheral requirements, etc.).

**IMPORTANT NOTE:** In the event that these conditions cannot be met (for certain configurations or co-location with another transmitter), then the FCC and Industry Canada authorizations are no longer considered valid and the FCC ID and IC Certification Number cannot be used on the final product. In these circumstances, the OEM integrator will be responsible for re-evaluating the end product (including the transmitter) and obtaining a separate FCC and Industry Canada authorization.

### **End Product Labeling**

The TiWi-R1Module is labeled with its own FCC ID and IC Certification Number. If the FCC ID and IC Certification Number are not visible when the module is installed inside another device, then the outside of the device into which the module is installed must also display a label referring to the enclosed module. In that case, the final end product must be labeled in a visible area with the following:

“Contains Transmitter Module FCC ID: TFB-TWI1-01”

“Contains Transmitter Module IC: 5969A-TIWI101”

or

“Contains FCC ID: TFB-TIWI1-01”

“Contains IC: 5969A-TIWI101”

The OEM of the **TiWi-R1** Module must only use the approved antenna(s) listed above, which have been certified with this module.

The OEM integrator has to be aware not to provide information to the end user regarding how to install or remove this RF module or change RF related parameters in the user manual of the end product.

### **The user manual for the end product must include the following information in a prominent location:**

“To comply with FCC and Industry Canada RF radiation exposure limits for general population, the antenna(s) used for this transmitter must be installed such that a minimum separation distance of 20cm is maintained between the radiator (antenna) and all persons at all times and must not be co-located or operating in conjunction with any other antenna or transmitter.”

## 4 Contacting LS Research

<b>Headquarters</b>	LS Research, LLC W66 N220 Commerce Court Cedarburg, WI 53012-2636 USA Tel: 1(262) 375-4400 Fax: 1(262) 375-4248
<b>Website</b>	<a href="http://www.lsr.com">www.lsr.com</a>
<b>Technical Support</b>	<a href="mailto:support@lsr.com">support@lsr.com</a>
<b>Sales Contact</b>	<a href="mailto:sales@lsr.com">sales@lsr.com</a>

The information in this document is provided in connection with LS Research (hereafter referred to as "LSR") products. No license, express or implied, by estoppel or otherwise, to any intellectual property right is granted by this document or in connection with the sale of LSR products. EXCEPT AS SET FORTH IN LSR'S TERMS AND CONDITIONS OF SALE LOCATED ON LSR'S WEB SITE, LSR ASSUMES NO LIABILITY WHATSOEVER AND DISCLAIMS ANY EXPRESS, IMPLIED OR STATUTORY WARRANTY RELATING TO ITS PRODUCTS INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTY OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, OR NON-INFRINGEMENT. IN NO EVENT SHALL LSR BE LIABLE FOR ANY DIRECT, INDIRECT, CONSEQUENTIAL, PUNITIVE, SPECIAL OR INCIDENTAL DAMAGES (INCLUDING, WITHOUT LIMITATION, DAMAGES FOR LOSS OF PROFITS, BUSINESS INTERRUPTION, OR LOSS OF INFORMATION) ARISING OUT OF THE USE OR INABILITY TO USE THIS DOCUMENT, EVEN IF LSR HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES. LSR makes no representations or warranties with respect to the accuracy or completeness of the contents of this document and reserves the right to make changes to specifications and product descriptions at any time without notice. LSR does not make any commitment to update the information contained herein. Unless specifically provided otherwise, LSR products are not suitable for, and shall not be used in, automotive applications. LSR's products are not intended, authorized, or warranted for use as components in applications intended to support or sustain life.

---

The information in this document is subject to change without notice.  
Confirm the data is current by downloading the latest revision from [www.lsr.com](http://www.lsr.com).