Hermes™ IoT Development Platform User Guide

1 Introduction

The Hermes™ IoT Development Platform enables exploration and development of applications using passive wireless sensors built around the Magnus®-S chip. Hermes is built around a BeagleBone (www.beagleboard.org) single-board computer controlling a wireless sensor reader board for communicating with sensor tags.

1.1 Included Components

Hermes includes the following components:

- Motherboard with LCD touchscreen, BeagleBone single-board Linux computer with pre-loaded application software, and wireless sensor-tag reader board.
- USB WiFi adapter (ships pre-connected to the BeagleBone).
- DC power supply and cable.
- Directional reader antenna.
- Coaxial antenna cable.
- SD Card for system restore.
- USB cable for connecting peripherals to the BeagleBone.
- 5 temperature-sensing tags.
- 5 moisture-sensing tags.

2 Hermes Overview

2.1 Setup

Figure 1 shows the Hermes main board and reader antenna. To prepare Hermes for measuring sensor tags, screw the antenna cable to the connector on the Hermes board. Make sure the connection is snug but avoid overtightening. Use an 8-in-lb torque wrench if available. Hand-tighten the other end of the cable to the port on the back of the antenna. Avoid sharp bends in the antenna cable.

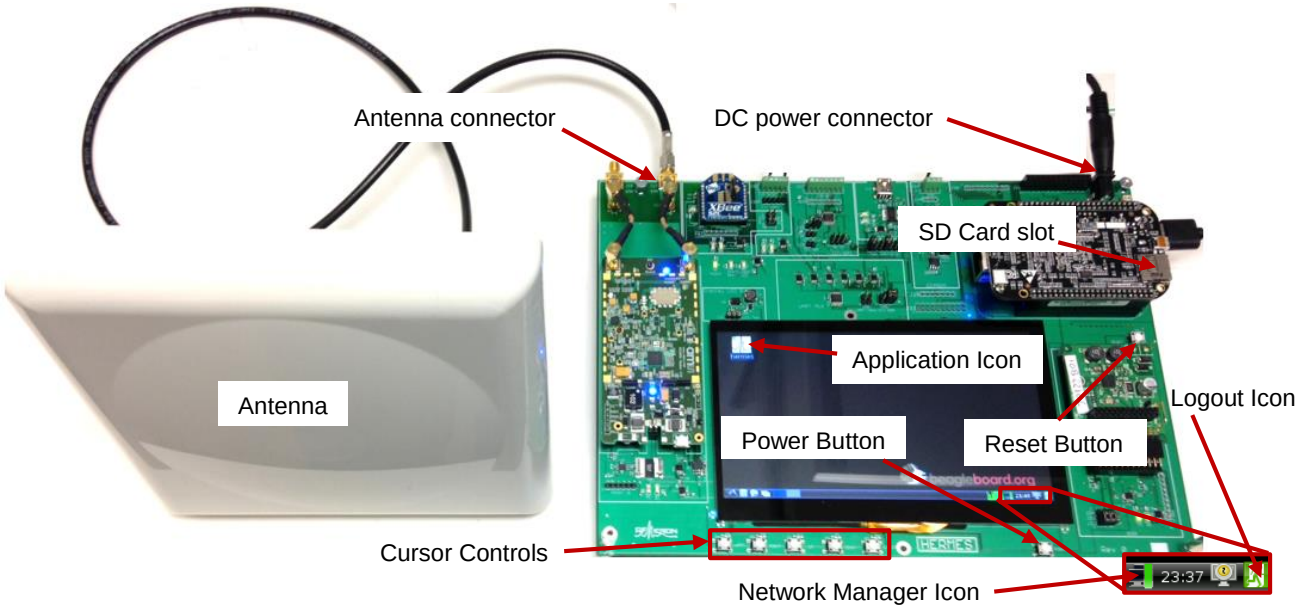

Figure 1. Hermes main board and antenna.

2.2 Turning Hermes On and Off

Hermes will turn on automatically when the power cord is first plugged in. The BeagleBone runs Debian Linux with the LXDE desktop environment (www.lxde.org). After Hermes boots, the LXDE environment will appear on the LCD screen.

To shut down, close all applications and press the power button. Hermes can also be turned off by tapping the Logout icon in the extreme lower right corner of the LCD screen and selecting Shutdown. The power button and Logout icons are labeled in Figure 1.

WARNING: Do not unplug the power connector before properly shutting down as described above, or damage to the system could result.

With the power plugged in but Hermes turned off, pressing the power button will restart the system.

2.3 Running the Application Software

Always connect the reader antenna before launching the application software. To start, tap on the “Hermes” icon in the upper left corner of the screen (labeled in Figure 1). Use of the software is described in Section 3.

2.4 Other Utilities

Clicking the LXDE icon in the extreme lower left corner of the desktop provides access to other useful utilities, including:

- **Accessories > File Manager:** a graphical file management utility.
- **Accessories > Leafpad:** a simple text editor.
- **Accessories > LXTerminal:** Linux terminal.
- **Universal Access > Florence Virtual Keyboard:** a screen-based keyboard for entering text.

2.5 Setting Up a Wireless Connection

In the lower right corner of the desktop, tap the Network Manager icon to find and connect to WiFi networks.

2.6 Adding a Keyboard or Mouse

Hermes ships with a WiFi adapter plugged into the USB type-A receptacle on the BeagleBone. The adapter can be replaced with a keyboard, mouse, or USB hub (not included) for connecting multiple peripherals simultaneously.

2.7 Restoring Factory Defaults

The included SD card allows users to restore the BeagleBone's flash memory to its factory default state. This includes restoring the application software to the version with which Hermes was shipped. **This will delete any new data that was added to flash storage since the last restore.** The procedure is outlined below.

1. Turn Hermes off.
2. Insert the SD card into the slot on the BeagleBone board (on the side of the board opposite the power plug).
3. Turn Hermes on.
4. Wait approximately 7 minutes. Hermes will then automatically power off.
5. With Hermes powered off, remove the SD card from the slot.

2.8 Included Sensor Tags

Hermes includes 5 moisture-sensing and 5 temperature-sensing tags (Figure 2). The tags can be placed on or attached to most non-metal surfaces.

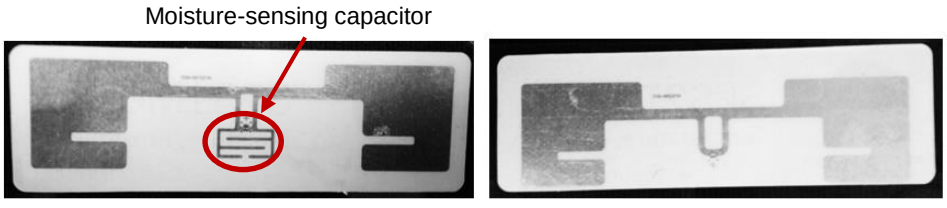

Figure 2. Moisture-sensing (left) and temperature-sensing (right) tags.

The moisture-sensing tag is built with an RFMicron Magnus®-S2 chip. The Magnus-S2 returns a Sensor Code from 0 to 31 which depends on the tag's electromagnetic environment. The tag incorporates a capacitor structure which is particularly sensitive to water. Figure 3 shows the approximate size of a water droplet which reduced the average Sensor Code value by 5. The moisture tags cannot be used to measure temperature.

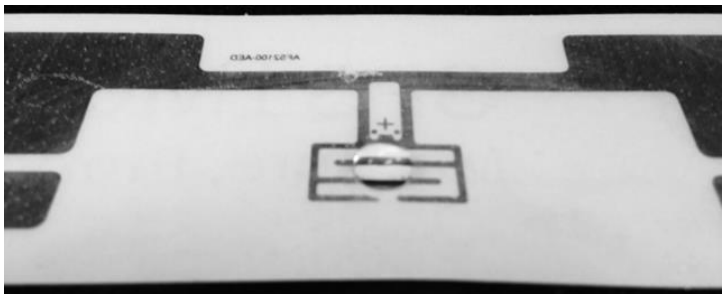

Figure 3. Water droplets on the capacitor lower the Sensor Code.

The temperature-sensing tag is built with the RFMicron Magnus®-S3 chip and returns a Temperature Code which is proportional to the temperature at the chip. Temperature-sensing tags also return a Sensor Code, but in a range from 0 to 511. As with the moisture tags, the Sensor Code depends on the tag's electromagnetic environment, but since the temperature tag does not have a capacitor structure, the Sensor Code has a much weaker response to the presence of water on the tag. More information about sensing with Magnus-S chips is available in RFMicron Application Notes AN002 and AN006.

2.9 Positioning the Reader Antenna and Sensors

The included reader antenna transmits its RF signal in a direction perpendicular to its front plastic face. The antenna should aimed so that its signal is in the direction of the tags to be measured (Figure 4).

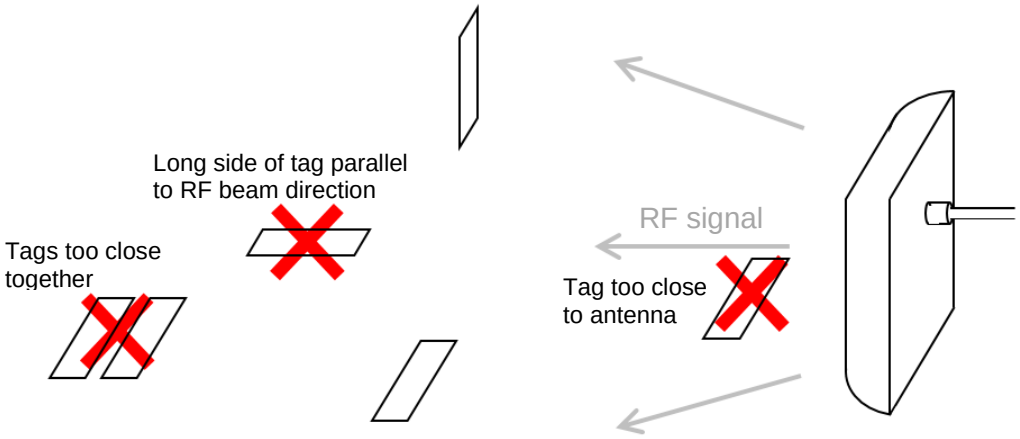

Figure 4. Antenna and tag placement.

Follow the guidelines below in positioning sensor tags:

- The long side of the sensor tags should be perpendicular to the direction of the RF signal from the reader antenna.
- The included sensor tags should not be placed on a metal surface. Only tags specifically designed for on-metal use should be placed on conducting surfaces.
- Tags should be placed at least 30 cm from the reader antenna.
- Individual sensor tags should be placed at least 10-20 cm apart.
- Metal objects and large volumes of water can interfere with or block the signal from the reader antenna. Although the reader signal can penetrate walls and other non-conducting obstacles, tags are easiest to read when there is a clear line-of-sight between the reader antenna and sensor tags.

Note that, in addition to depending on the presence of water on the tag, the Sensor Code returned by a moisture tag can also depend on the material properties of the surface on which the tag is placed.

3 Demonstration Application

Always connect the reader antenna before launching the application software. To start, tap on the “Hermes” icon in the upper left of the LCD touchscreen. It may take a few seconds for the splash screen to appear. When the blue LED lights on the reader board turn on, the application is starting.

When the splash screen appears, the Hermes automatically adjusts itself at each transmit frequency to the characteristics of the antenna. This tuning process can take up to 30 seconds. When tuning is complete, the main screen appears as shown in Figure 5.

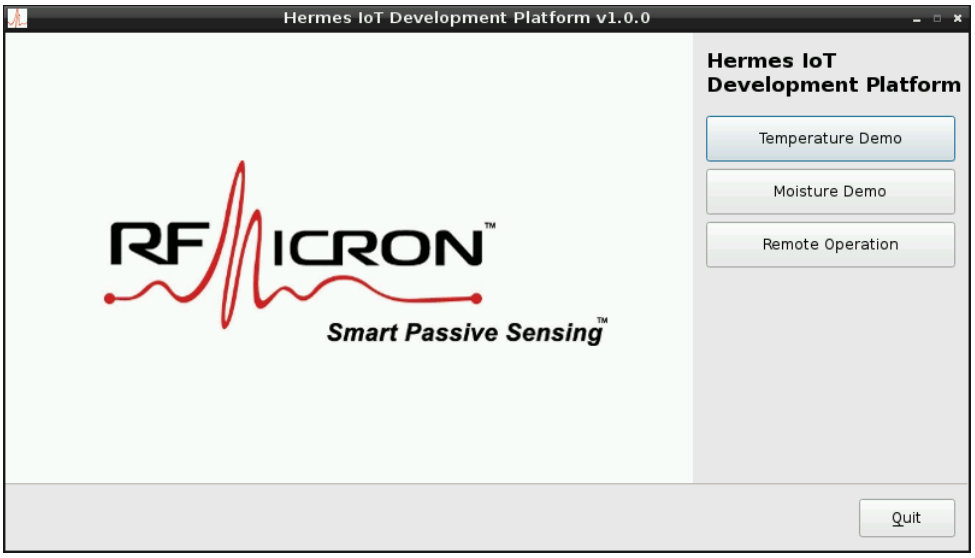

Figure 5. The Hermes main screen.

3.1 Overview of the Measurement Process

The application automatically finds sensor tags and plots results continuously. There are four basic steps the application carries out with each measurement iteration:

1. Find any new tags in the reader's field of view and get their EPC Codes, Tag ID, and temperature calibration data, if any.
2. If Auto Power Adjust is activated, adjust the transmit power for each tag so that the On-Chip RSSI Code returned by the tag falls within a desired range. The On-Chip RSSI Code is a value from 0-31 generated by Magnus-S chips which indicates how much power it is receiving from the reader. (See RFMicron Application Note AN002 and AN006 for more information). Checking the On-Chip RSSI value helps ensure that the tag is receiving a power level ideal for measurements. Readings from a tag with On-Chip RSSI values outside the desired range will be ignored.
3. Measure the Sensor Code or Temperature Code multiple times.
4. Process the raw data (by averaging, for example). For temperature measurements, convert the averaged Temperature Code to a value in degrees C. Then, display the results.

3.2 Measuring Moisture Sensors

Tap the Moisture Demonstration button from the Main screen to run a moisture sensing demonstration. The moisture demonstration screen has a plot which records the Sensor Code value as a function of time, and readouts below the plot indicating the result of the most recent measurement (Figure 6). A "DRY" or "WET" message is displayed for each tag depending on the value of the Sensor Code in relation to the wet/dry threshold value (see Section 3.2.2.2). The moisture tags included in the Hermes IoT Development Platform return a Sensor Code between 0 and 31.

Measurements from up to 5 sensor tags can be simultaneously displayed. The time required for a measurement to complete tends to increase with the number of tags being measured.

Sensor tags are identified in the plot legend by the first two and last four hexadecimal digits of their EPC codes. To ignore a tag and remove its data from the plot, tap on its label in the plot legend. The tag can be returned to the plot by tapping on its label again.

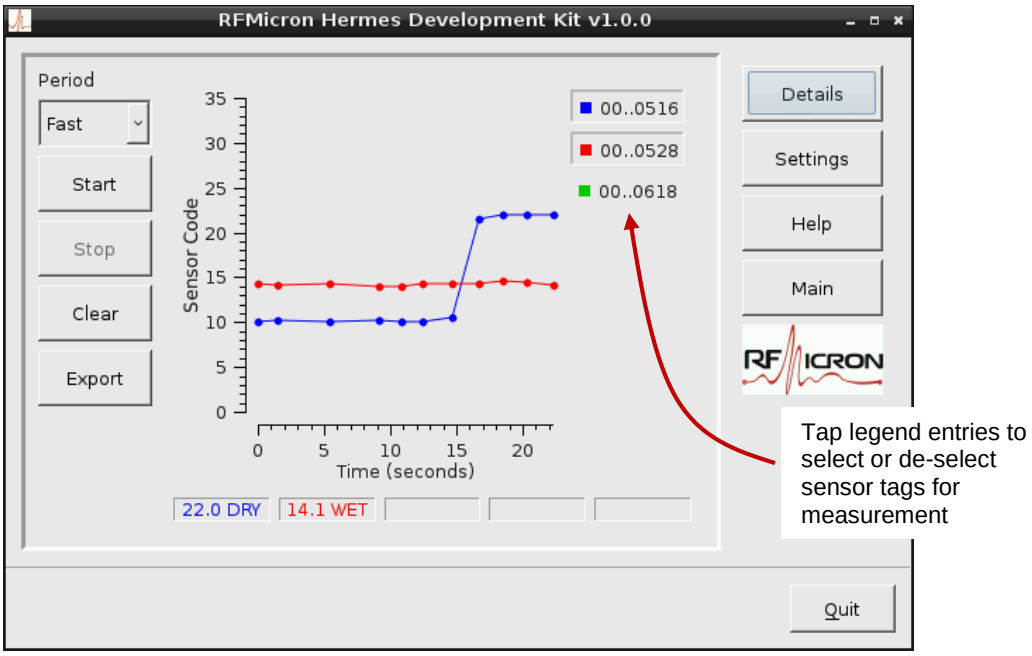

Figure 6. Moisture demonstration screen.

If temperature-sensing tags are visible to the reader, they will also appear in the moisture plot, since they also return a Sensor Code. However, the antenna design of the temperature tags is not optimized for sensing moisture. Temperature tags return a Sensor Code in the range of 0-511. Temperature tags can be de-selected or moved out of the readers field of view if they are a distraction.

The Moisture Demonstration main screen has the following controls:

- **Period:** When set to “Fast” the application will begin the next measurement as soon as the current measurement completes. When set to a time value, the application will attempt to evenly space the measurements in time with the chosen period.
- **Start:** Begins measuring sensor tags.
- **Stop:** Stops measuring sensor tags.
- **Clear:** Clears the plot and the internal results history.
- **Export:** Writes a log file with all the measurement results since the Start or Clear button was pressed.
- **Details:** Opens a display giving additional information about the most recent measurement result.
- **Settings:** Adjusts moisture demonstration settings (see Section 3.2.2).
- **Main:** Returns to the Main screen.

3.2.1 Viewing Measurement Details

The Details button opens a window displaying a table of results of the most recent measurement (Figure 7).

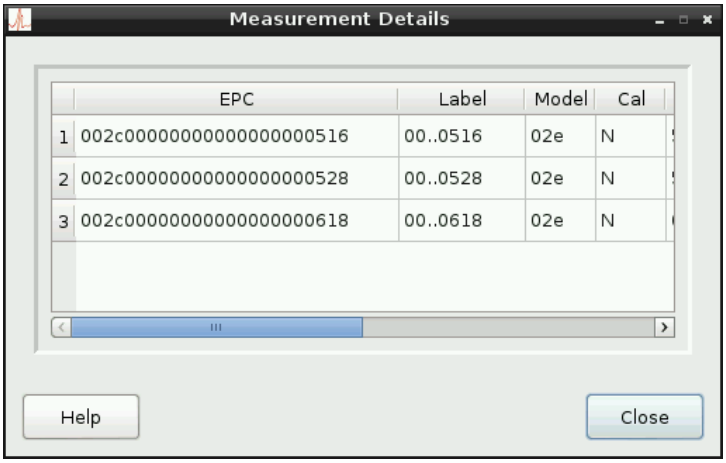

Figure 7. Measurement Details window.

The table is updated whenever a measurement completes. Each row in the table represents a tag. The columns are described below.

- **EPC:** The full Electronic Product Code of the tag, in hexadecimal.
- **Label:** The identifier used in the plot legend.
- **Model:** The three hexadecimal digits in the Tag ID which form the model number. Model numbers beginning with “03” are temperature enabled.
- **Cal:** “Y” indicates that the temperature calibration CRC code agrees with the data, indicating that the tag contains valid temperature calibration data in its user memory. Only tags with valid calibration data can be used for plotting temperature.
- **Valid Reads:** The number of times that the tag successfully returned sensor or temperature data along with an On-Chip RSSI that was within the targets, if Auto Power Adjust is turned on (see Section 3.2.2.1).
- **Invalid Reads:** The number of times in the most recent measurement the tag returned data, but was ignored due to data corruption or an On-Chip RSSI value outside the target values.
- **Sensor Code:** The measured Sensor Code, calculated by averaging all the valid reads, or taking the value at the center of the frequency band of a linear fit (see Section 3.2.2.2).
- **On-Chip RSSI:** The average value of the On-Chip RSSI Code returned over all valid measurements.

3.2.2 Adjusting Settings

Click the Settings button to modify the settings for the demonstration. The two tabs in the Settings dialog are shown in Figure 8.

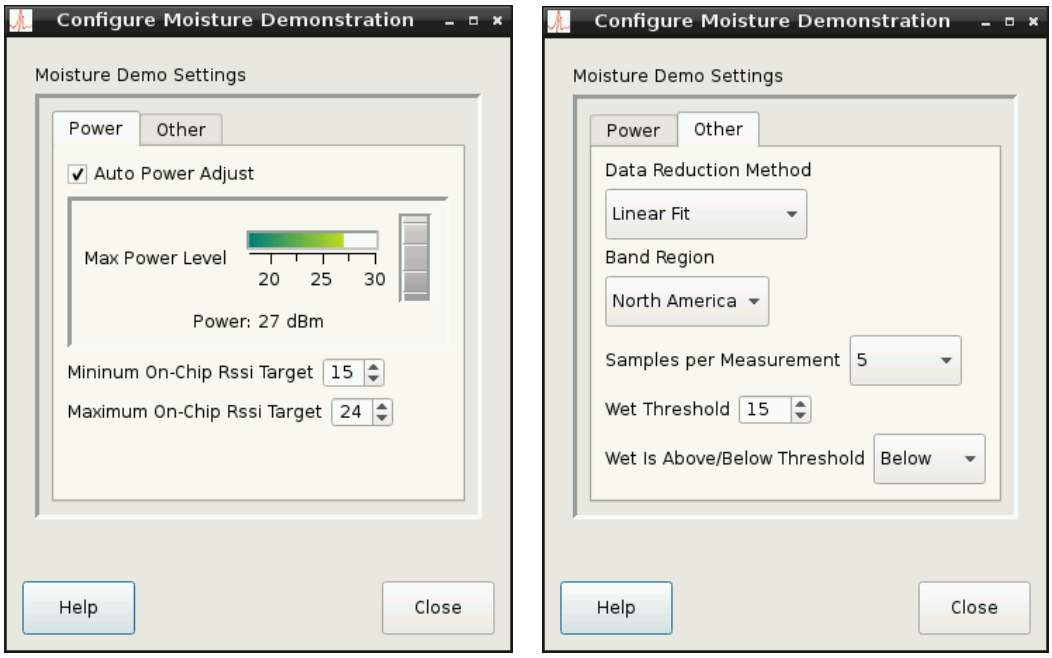

Figure 8. Moisture sensing settings dialog.

3.2.2.1 Power Settings Tab

The Power tab contains the following controls:

- **Auto Power Adjust:** When this box is checked, the application will automatically adjust the transmit power to try to achieve On-Chip RSSI values from the sensor tags within the target range. This is the recommended setting to avoid distortion of the Sensor Code due to excess power.
- **Max Power Level:** When Auto Power Adjust is checked, the reader will not transmit at powers above this level (but may transmit at lower powers.) When Auto Power Adjust is not checked, the reader will measure at only this power. The default value of 27 dBm is fine for most situations when Auto Power Adjust is turned on, but for reading tags at a maximum distance this can be set up to 30 dBm. When reading nearby tags, this value can be turned down to avoid seeing more distant, unwanted tags.
- **Minimum and Maximum On-Chip RSSI Targets:** When Auto Power Adjust is checked, the application will automatically adjust the transmit power until the tag being read returns an On-Chip RSSI value in between the minimum and maximum values indicated in the boxes. For reading tags at the maximum range, set the minimum value to 1. Setting the minimum and maximum values close to each other, such as 15 and 17, results in improved repeatability of measured results at the expense of more difficulty in reading the tags.

3.2.2.2 Other Settings Tab

The Other tab contains the following controls:

- **Data Reduction Method:**
  - ”Average Over Frequency”: Form a measurement by averaging the multiple individual Sensor Code readings retrieved at different frequency channels.
  - “Linear Fit”: Fit a linear regression line to the set of measured Sensor Codes as a function of channel frequency, then form a measurement by taking the value of the regression line at the center of the regulatory band. Often, this reduces noise in the measurement results over the averaging method.
- **Band Region:** Controls the set of frequencies on which the reader transmits, for compliance with local regulatory requirements. The average sensor code for a particular tag will depend on the chosen band.
- **Samples Per Measurement:** The application will attempt to collect this many valid individual sensor code reads for each tag before plotting a measurement point.
- **Wet Threshold:** The Sensor Code value above or below which the tag is considered wet.
- **Wet Is Above/Below Threshold:** Controls whether the tag is considered wet when the Sensor Code value is higher or lower than the threshold.

3.3 Measuring Temperature Sensors

Tap the Temperature Demonstration button on the main screen to take temperature measurements (Figure 9). The controls mostly work the same way as those for moisture-sensing demonstrations. The few differences are described in below.

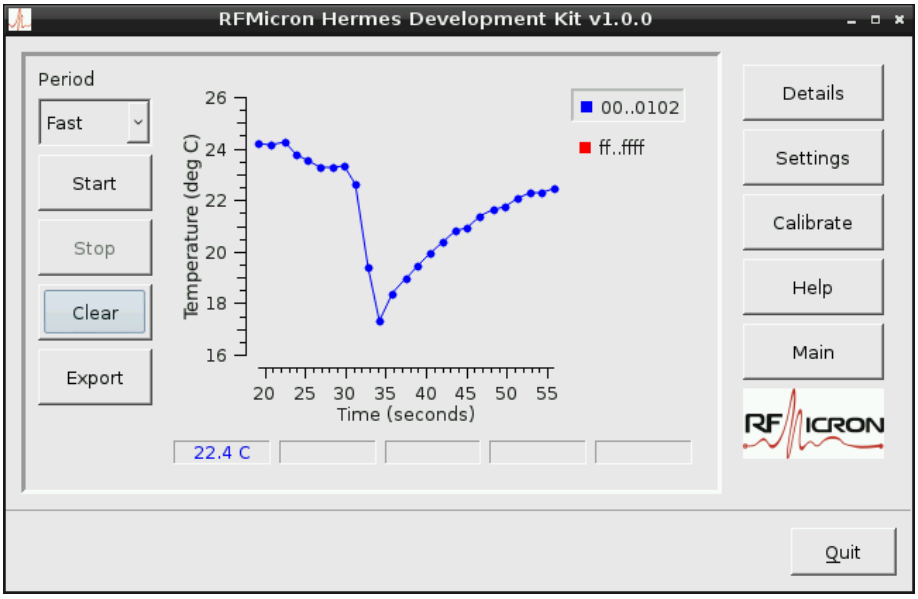

Figure 9. Temperature demonstration screen.

3.3.1 Adjusting Settings

The controls in the Power tab operate identically to the moisture demonstration controls, except that the default On-Chip RSSI Targets are slightly more narrow to achieve good temperature accuracy (Figure 10). For best repeatability in the results, set the minimum

RSSI value to 13 and the maximum to 16. The narrower range will make the tags slightly harder to read. For maximum read range, set the power to 30 dBm and the minimum RSSI value to 1.

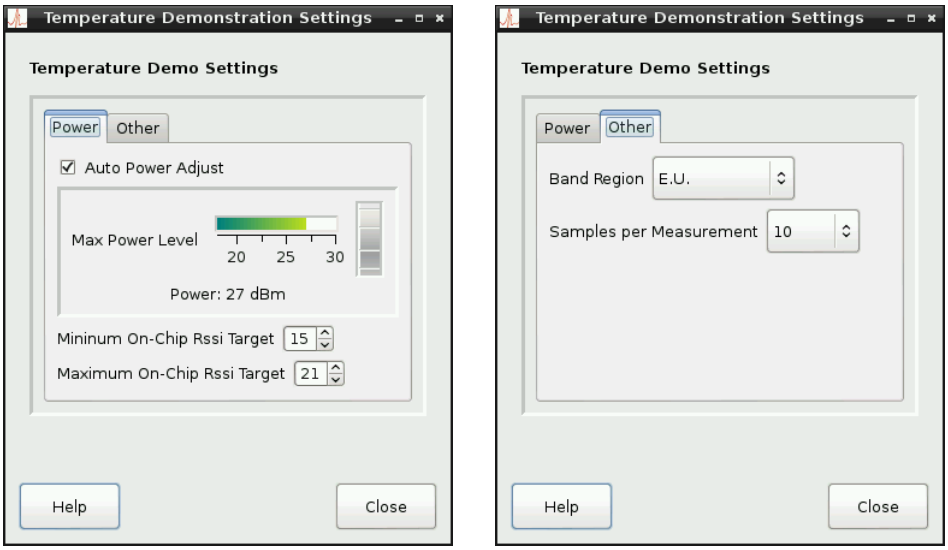

Figure 10. Temperature demonstration settings dialog.

3.3.2 Temperature Calibration Concepts

Converting the unprocessed Temperature Code from a tag to a temperature measurement in degrees requires calibration information for that tag. The Temperature Code varies approximately linearly with temperature, so by specifying the Temperature Code and temperature at 2 points, the linear relationship can be precisely defined. All calibrated temperature tags have this data (2 Temperature Codes and 2 corresponding temperatures) stored in their built-in non-volatile memory.

The slope of the Temperature Code vs. temperature line is reasonably consistent over all tags, so if the exact temperature and corresponding Temperature Code is only known at 1 point, it is possible to estimate the values at the second point. Calibration based on 1 measured and 1 estimated point is called **1-point calibration**. Calibration based on 2 measured points is called **2-point calibration**. All temperature-enabled tags ship with 1-point calibration data stored on them, with the measured point being around room temperature.

The temperature calibration functionality allows users to

- Overwrite the existing 1-point calibration data on a tag. This might be done to improve the accuracy of the tag near a temperature other than the factory calibration. The second (estimated) calibration point will be added to the tag automatically.
- Add 2-point calibration to the tag. This can be done either by keeping the existing measured point and adding a second measured point, or by adding two new points.

3.3.3 Calibrating a Temperature Tag

To calibrate a tag, it must first be in the list of found tags in the temperature plot legend. If multiple tags are in the plot legend, make sure only the tag to be calibrated is selected. It is not necessary to actually plot measurements of the tag. Having it present and selected in the legend is sufficient.

Once a tag is selected, tap the Calibration button, which brings up the dialog shown in Figure 11. For 1-point calibration, enter the known, measured temperature of the tag in degrees C in the indicated box. Then, tap the Read Temp Code button. This will read the average Temperature Code and load the result into the Temperature Code box in the dialog. **The maximum power and On-Chip RSSI targets defined for temperature measurements will be used for the read, so ensure they are set to the desired values.** The Temperature Code box can also be filled in manually.

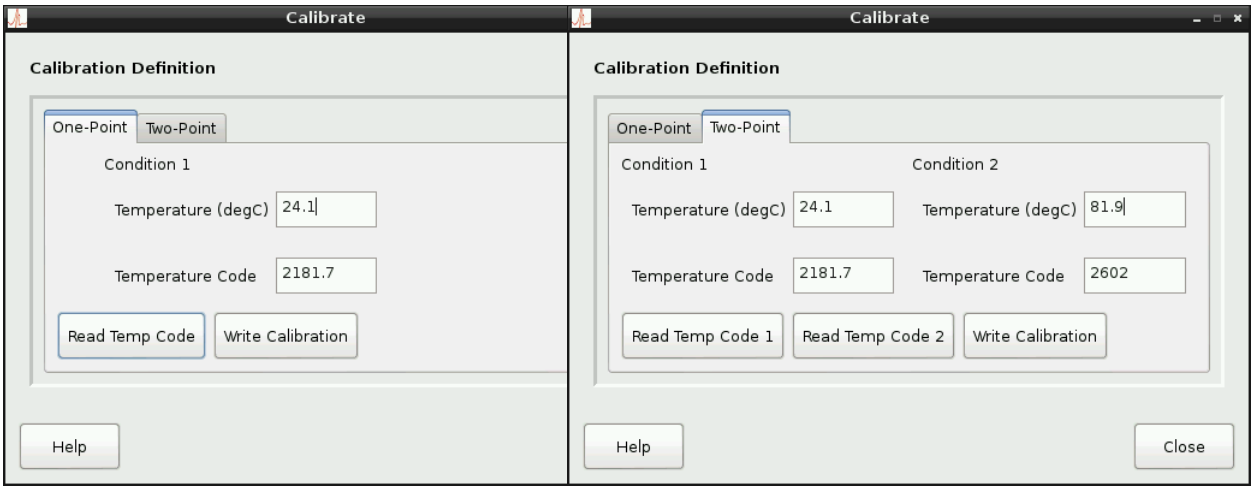

Figure 11. 1- and 2-point temperature calibration dialogs.

When the Temperature and Temperature Code boxes are filled, tap the Write Calibration button to save the calibration data to the tag. The transmit power used for the write will be the maximum power set for temperature measurements. If the write fails, try adjusting the power or changing the distance between the transmit antenna and the tag.

2-point calibration works similarly, except that the temperature and Temperature Code must be measured at two points. It is recommended that the two measured tag temperatures be at least 20 degrees C apart to accurately characterize the slope of the temperature line. The calibration data currently written to a temperature tag can be determined by exporting a log file.

3.4 Remote Operation

Hermes can be controlled remotely through several interface types. Tap the Remote Operation button on the main screen to demonstrate this function (Figure 12). In the Interface pulldown, select the interface type and press the Start button. Hermes will listen

for instructions on the selected interface, execute tag-measuring operations, and return the measured data to the remote controller until the Stop button is pressed. Consult the documentation on the Remote User Interface for more information.

Figure 12. The Remote Operation screen.

3.5 Troubleshooting

- **Application does not start:** Only one instance of the application can run at one time. Hermes may be reacting as if multiple instances are trying to be created. While the application is not running, look for an empty file named “running” and delete it.
- **Sensor tags are not found:** If no sensor tags are found, make sure they are placed according to the guidelines in Section 2.9. Check the maximum power setting and ensure it is set around 25-27 dBm. Start by placing a single tag about 40-50 cm from the antenna. Wait until it is successfully found before moving it to the desired distance and location.
- **Sensor tags are found but no measurements appear on the plot:** Make sure the tag is selected in the plot legend. When Auto Power Adjust is turned on, the application will ignore sensor readings with On-Chip RSSI values which fall outside the desired range. This helps ensure accurate measurements, but can occasionally reduce read reliability.
    - Try widening the On-Chip RSSI Target range and adjusting tag positioning until readings become reliable.
    - Try turning off Auto Power Adjust and manually adjusting the transmit power and tag positioning until the On-Chip RSSI is in the desired range. (The On-Chip RSSI value for the most recent measurement can be seen by tapping the Details button.)
- **Antenna tuning fails at application startup:** See Known Issues below.

3.6 Known Issues

- When the application starts, the antenna tuning process can occasionally fail, requiring the application to be re-launched. This odds of this happening increase if the antenna cable connectors are not sufficiently tightened, but it can happen even if Hermes is properly set up.

4 Notices

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