Ranging & Localization Development Kit Quick Start Guide

TDSR UWB Radios

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Introduction

Welcome to the world of Ultra Wideband (UWB) technology! TDSR is pleased to introduce the latest addition to our P400 product family, the P452. The P452 is the culmination of over a decade of UWB research and product development, including six generations of UWB-enabling silicon. This multi-purpose platform can:

- Provide extremely precise peer-to-peer distance measurements
- Communicate data
- Operate as a ranging network
- Report the X, Y, and Z location of units in the ranging network
- Measure channel impulse response
- Serve as a monostatic, bistatic, or multistatic radar

The TDSR Ranging and Localization Kit allows you to test and exercise the ability of P452s to accurately measure the distance between platforms, communicate data, and operate as the RangeNet network. RangeNet can also be configured to compute and report the location of units in the network.

We designed the P452 to be easy to integrate, with a simple ranging protocol and support for interfacing to both PCs and embedded processors. This *Quick Start Guide* will help you set-up, configure, and test the P452s included in your Development Kit. It will take about 30 minutes to demonstrate ranging and operation as either an ALOHA or TDMA network. Demonstrating the self- localization capability will require additional set-up so, depending on your work environment, this could take an additional hour or so.

Units received from the factory will be at the latest revision level. However, if you already have units and are receiving this document as part of a software upgrade, then your units are most likely at an older revision level. (Check the RangeNet 2.2 release notes for instructions on how to upgrade as well as information on improvements in this release). If you are not at the latest revision level, then all of your existing P4xx units need to be upgraded to this level. In addition, you will need to load your existing units with the system default parameters. This ensures that all units will use the same communications channels, Pulse Integration Indexes (PIIs), Slot Maps, and other settings, thereby ensuring that you will successfully step through this guide. To load the system defaults, connect to one of your P4xx units and open the RangeNet GUI. On the Connect to Node window (the first window that appears after you click the RangeNet icon) you will notice a "Restore unit to default settings" checkbox. Click this checkbox, select the communications approach (USB, Ethernet) and then click the **Connect!** button. It will take a few seconds for the unit to connect, reload the settings, and reboot. Afterwards, the Connect to Node window will reappear. At this point the unit is ready, and you should repeat this process with at least 3 (preferably 4) more units. You will also need to change the node numbers on the units such that they are numbered 100 through 104.

This document assumes that you will be connecting to the unit with USB. Do not use Serial, because it is too slow. If you want to connect through Ethernet, then see Appendix A of the *320-0320 RangeNet User Guide*. However, please try this *after* you have completed the *Quick Start Guide* process.

This guide is divided into the following sections:

- What's in the box?
- What's on the disk?
- What you will need to work with the P452
- Loading the PC Software
- Configuring the P452
- Initial System Power-Up
- Connecting to the P452
- Demo Ranging Between P452s
- Logging Ranging Data
- Configuring the RangeNet Network Parameters
- Using RangeNet as an ALOHA Network
- Using RangeNet as a TDMA Network
- Network Localization
- Where do you go from here?

What's in the box?

Upon receipt of your Development Kit, please inspect the shipping container and contents. If the contents of the Kit appear to be incomplete, or if there is mechanical damage, please notify TDSR immediately.

TDSR has supplied the following items with your kit:

Name	Part #	Qty.
P452 UWB Module	152RM01 or 05	5
BroadSpec Antennas	100ANR4	5
P452 Enclosures	340EN01	5
Rechargeable UWB Batteries	340RB01	5
USB Wall Charger/Supply	N/A	5
USB Cable 6 ft. /1.8 m	N/A	5
USB Power Cable 6 in. / 15 cm	N/A	5
RangeNet Software & Documentation USB Flash Drive	140-0024	1

Table 1: Contents of the TDSR Ranging and Localization Kit

Please note that a Kit with Part #452RL01 is intended for use in areas that conform with the U.S. FCC regulations for UWB transmissions or in areas that require conformance to the European or ETSI standard. In addition, if you are outside the US, you may also have been provided with an adapter to allow the Wall Charger/Supply to plug in your AC wall sockets.

What's on the USB Drive?

The RangeNet Software and Documentation USB Drive contains a directory entitled **140-0024 P4xx RangeNet Sftw & Lit USB Drive**. Within this directory are three sub-directories:

- **1-Embedded**: This directory contains all of the files necessary for updating the embedded code in any P4xx units you might have received prior to receiving this package. The units received in a Kit are already at the latest revision level and do not require updating.

- **2-Host & Sample Code:** This directory contains the file **RangeNet 2.2 Setup.exe.** This is the installer for the Windows-based RangeNet Graphical User Interface (RangeNet GUI). The RangeNet GUI allows the user to edit the configuration of the P452 module and to evaluate its ranging, communications, networking, and localization capabilities. In addition to the RangeNet executable, this sub-directory contains sample code intended to provide the user with additional help in starting development and evaluation efforts, including:

    - **Sample C directories:** Two directories containing sample C code, one for ranging and one for RangeNet.

    - **Sample MATLAB directories:** Two directories containing sample MATLAB code, one for ranging and one for RangeNet. This may be useful to users in jumpstarting system analysis efforts.

- **3 - Documentation:** This directory contains documentation pertaining to RangeNet's functionality and operation:

    - **Ranging and Localization Quick Start Guide**: A soft copy of the manual you are currently reading

    - **RangeNet API Specification:** The Application Programming Interface (API) specification for the P4xx platforms.

    - **RangeNet User Guide:** Document which explains in detail the user interface for the RangeNet GUI.

    - **P452 Data Sheet:** Detailed specification for the P452 UWB platform.

    - **Using the USB and Serial Interface:** Application note describing how to use the USB and 3.3V TTL UART microcontroller interfaces.

    - **Updating PulsON Modules with New Embedded Code:** Instructions on how to update any P4xx when new software releases are introduced.

    - **White Paper:** *RangeNet -ALOHA Guide to Optimal Performance*

    - **Application Note:** *Distributed Calibration of Time Domain UWB Ranging Radios*

What you will need to work with the P452

In order to connect to and control the P452s, the user will need the hardware and software as described below.

- **PC running Windows 7, 8, 10 or 11 –** The RangeNet GUI has been developed to work with Windows 7 (32 and 64 bit), Windows 8 (32 and 64 bit), and Windows 10 (32 and 64 bit).
- **All Hardware provided in the Development Kit.**

Loading the PC Software

The following steps are required to install the RangeNet GUI software on your computer.

1. If necessary, log in as **Administrator** or with administrative privileges.

   Insert the USB flash drive, navigate to and then double-click on **RangeNet 2.2 Setup.exe**. (The .exe file can be found in the directory "140-0024 P4xx RangeNet Sftw &Lit \ 2 – Host & Sample Code.")

2. Click the **Next >** button.

3. Starting with the screen shown in **Figure 1,** a series of routine installation displays will appear. Each will ask the user if they wish to continue. During this process the installer will verify that the needed version of Windows .NET framework is installed on your computer. In most cases the latest version is present, but if it isn't present, then with the user's permission the installer will load .NET. If the user doesn't want to load .NET, then the installation will be terminated and the RangeNet GUI will not install.

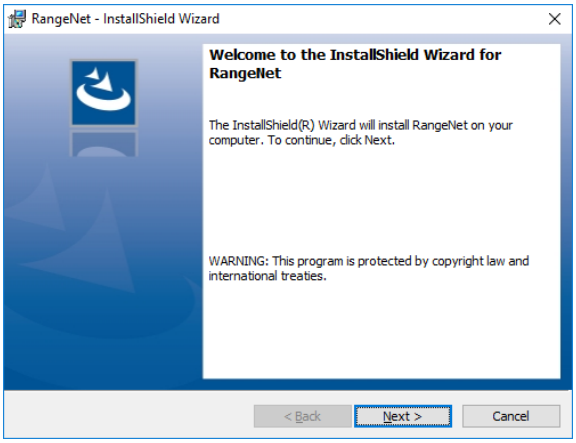


Fig. 1: Initial RangeNet GUI installation display

4. Once the installation of RangeNet has completed, the installer will then load a USB driver. See **Figure 2.**

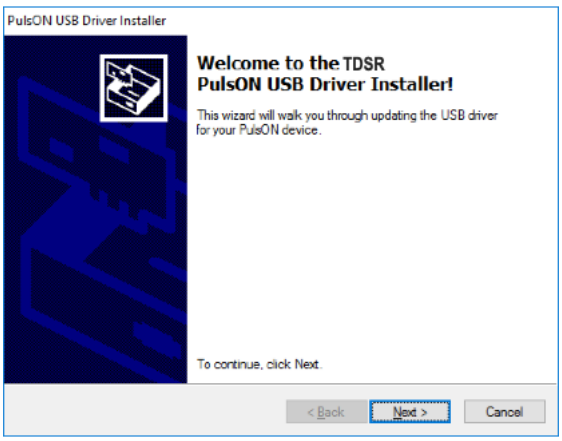


Fig. 2: USB Driver installation display

5. On completion, close the application. During this installation process, the icon shown in **Figure 3** will be installed on the Desktop.

Fig. 3: RangeNet GUI Icon installed on Desktop

The RangeNet GUI should now be successfully installed on your PC. At this time, we recommend that you copy the remaining files from the USB flash drive onto your PC at a location of your choice.

Configuring the P452

Remove a P452 from the box, along with one BroadSpec antenna, one Power Supply, a short USB power cable and long USB cable.

1. When handling the P452, please take care to prevent electrostatic discharge from damaging the unit. We recommend grounding yourself first by touching a piece of metal or touching the P452 SMA connector.

2. Attach the BroadSpec antenna to the SMA port "**A**" (the connector in line with the Ethernet connector; see **Figure 4**). This is the default antenna connection. The BroadSpec antenna is omni-directional.

Each P452 as supplied by TDSR includes four rubber feet to provide a stable base for the module and to prevent slippage. Underneath these rubber feet are mounting holes for 4/40 screws. These may be used to mount the enclosure inside a different housing. Alternatively you can remove the P452 from the plastic enclosure and mount the board in a housing of your choice.

Ensure that the SMA connector on both the antenna and 90-degree connector are firmly tightened over the connection to avoid accidental disconnection. Do NOT over-tighten. Use only your fingers or an approved 5/16" SMA torque wrench (Digi-Key, part number A99929-ND or equivalent) with the P452. The connector center pins on the SMA cables are fragile. If you meet resistance when connecting a cable to a port, either during insertion or when tightening the connector nut, do not force the connection. Abort this attempt and try again. Damage to the SMA connecter caused by over-tightening is not covered by the warranty.

Initial System Power-Up

Use one of the short USB Power cables to connect either an Anker USB Power Supply (itself plugged into an AC socket) or a rechargeable battery to the P452 USB "PWR" connector. To disconnect the power supply from the power interface, simply disconnect the USB power connector from the power interface. (This cable only has power and ground lines so it cannot be used in the USB COM port.)

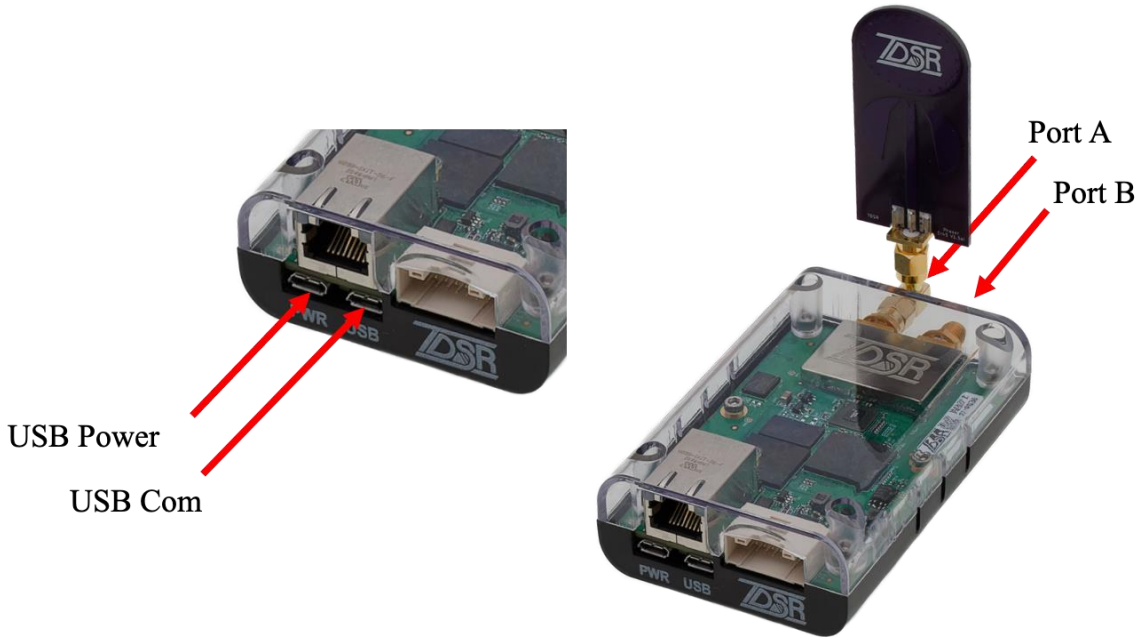


Fig. 4: Side view of the P452 module showing the various connections

The P452 powers up automatically when the power supply is connected and the P452 LEDs (see **Figure 5**) will activate in the following sequence:

1. As soon as the power supply is connected, the Blue LED in the lower-left (Built-in-Test LED or BIT LED) will turn on and stay on for about 10 – 15 seconds. This indicates that the unit is going through a self-test procedure. At the same time, the Green LED on the right side (FPGA LED) of the board will blink about 3 or 4 times per second. This indicates that the FPGA is loaded and ready. The Green LED on the left side of the board (UWB Activity LED) will be off.

2. After this 10-15 second period has elapsed, the UWB Activity LED will turn on and the BIT LED will blink once every 2-3 seconds. This indicates that the P452 processor has successfully booted and it is ready to send and receive UWB packets. Each time a UWB activity occurs (see

Section 4.9 of the *320-0317 P452 Data Sheet* for details) the UWB Activity LED will toggle (i.e., turn off if it is on, or turn on if it is off).

If the LEDs do not behave in this fashion, then the board is not working properly and you should contact TDSR. Examples of problems would include (but are not limited to) the following: the FPGA LED remaining continuously on or off, the BIT LED remaining continuously on or off, or the BIT LED blinking at a very fast rate.

When powered up, the P452 by default is in ranging response mode. This means it is listening for range requests from other P452s and will respond automatically to any such requests.

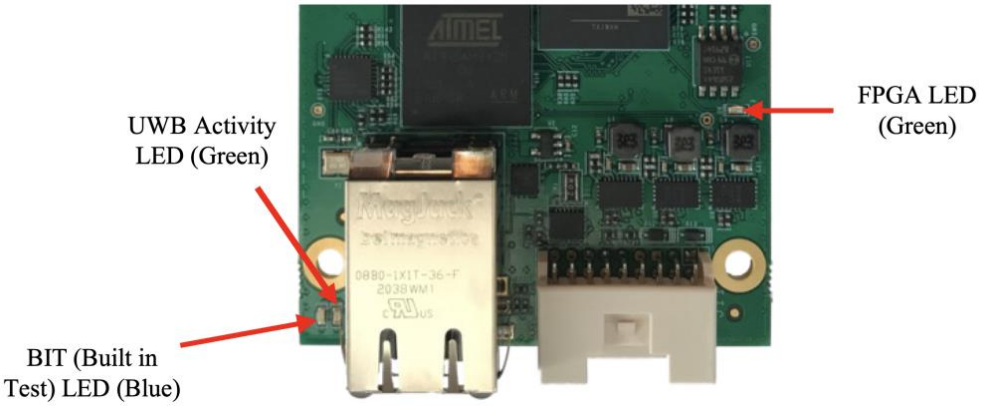


Fig. 5: Indicating LEDs

Connecting to the P452

Once you have loaded the PC software and powered up the P452, you are ready to begin using the RangeNet GUI to conduct a ranging conversation and to collect/log range data. A detailed description of the RangeNet GUI application will not be provided here. For more detailed information on using RangeNet GUI, please refer to the *320-0320 RangeNet User Guide*.

The following procedure will launch the RangeNet GUI and connect to the P452.

1. Double-click on the RangeNet icon. The screen shown below in **Figure 6** will appear.

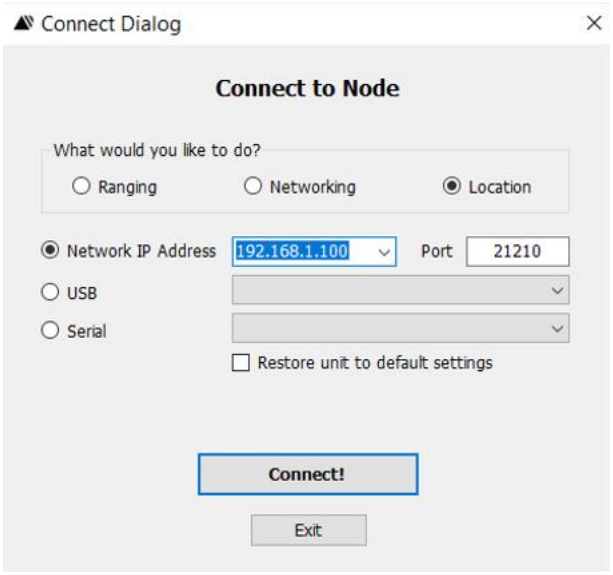


Fig. 6: RangeNet GUI connect screen prior to USB hookup

2. Connect the USB cable from the P452 USB port to the Host computer. A system message should appear indicating that the system has identified a new connection and the correct driver is being connected. This could initially take as long as two minutes but is normally concluded in a few seconds. Once that process is complete, the RangeNet GUI will indicate which COM port is connected to the P452. This is illustrated below in **Figure 7**.

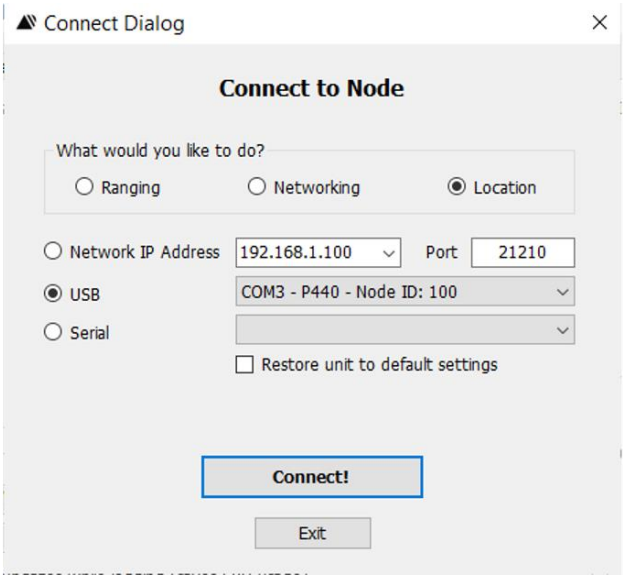


Fig. 7: RangeNet GUI connect screen after USB connection

If the USB connection does not appear, then (a) check the P452 LEDs to confirm that the P452 has successfully powered up and booted, (b) confirm that the USB connector is properly connected to both the P452 and the host USB connector, and (c) confirm that the system recognizes that the USB

port is active. This can be confirmed by clicking on the Windows **Start** Button > Device Manager and confirming that the port is connected. See **Figure 8** for examples of successful and unsuccessful connections.

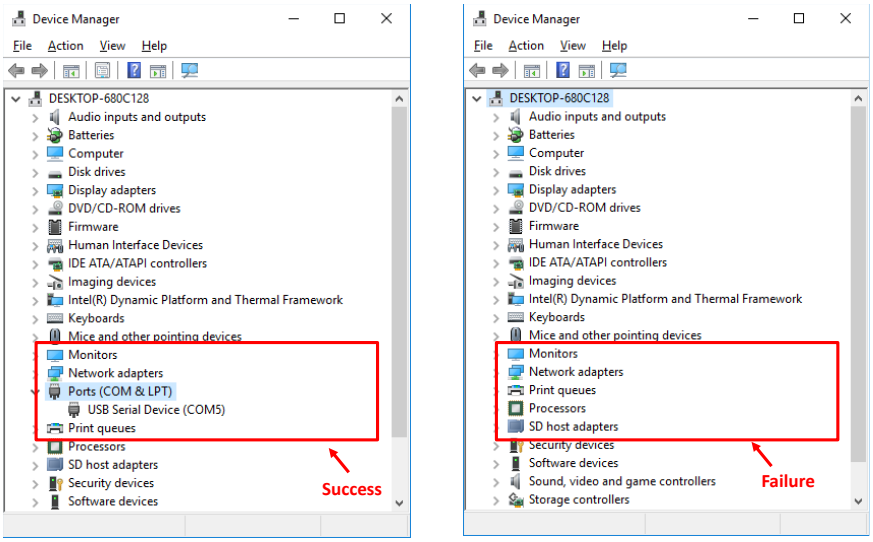


Fig. 8: Successful connection (left), unsuccessful connection (right)

If the P452 is functioning and the Device Manager shows a failure, then either the USB cable or the computer port is defective.

3. If the connection is successful, then select the Location option, click the USB button, and then click the **Connect!** button. The main operating window will open (**Figure 9**). The status window at the bottom should contain a large number of confirm messages.

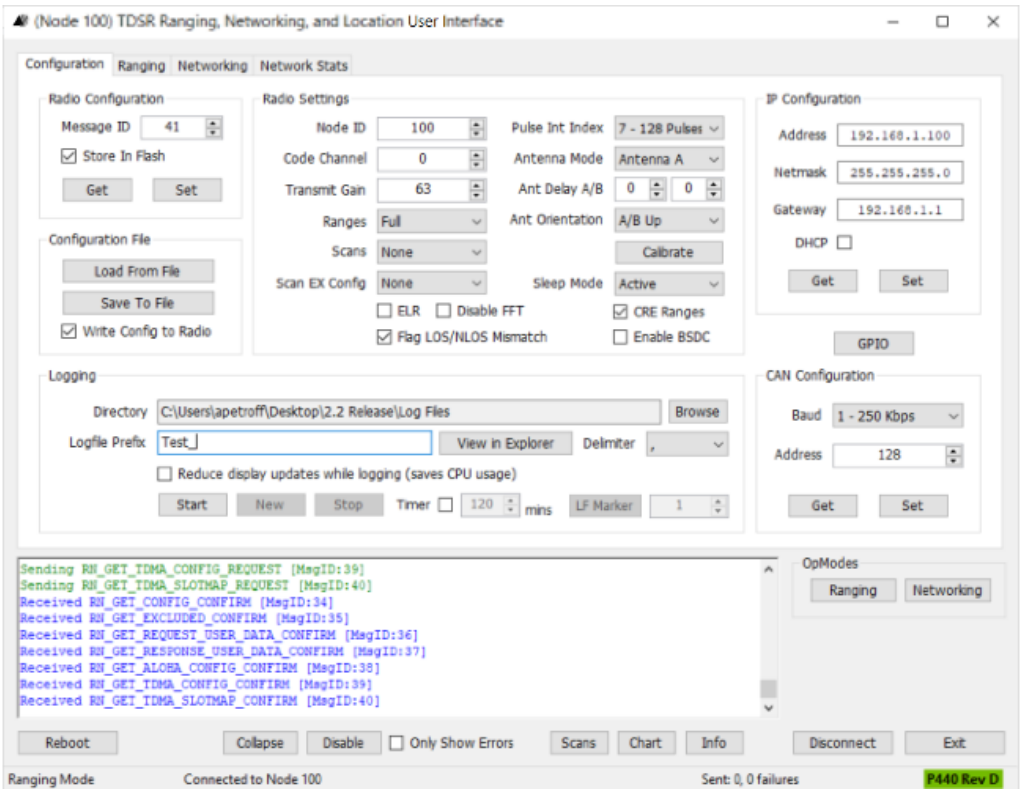


Fig. 9: RangeNet GUI successfully connected to the P452

At this point you have established that the PC and P452 are communicating and that the radio has powered up successfully.

****IMPORTANT**** The P452s in your kit are preconfigured with the following Ethernet IP address: **192.168.1.100.** To range among units, you will need to assign unique IP addresses to each unit. This is easy, and is accomplished by connecting to each unit as described above and then changing the IP address in the IP Configuration section of the main Configuration tab. The final 3 digits of the IP address will represent the P452's unique UWB ID.

One suggestion for an addressing scheme would be to simply change the last 3 digits of the IP address such that you have UWB ID #100 (192.168.1.100), UWB ID #101 (192.168.1.101), UWB ID #102 (192.168.1.102), UWB ID #103 (192.168.1.103), and UWB ID #104 (192.168.1.104). For the sake of the examples in this Guide, that is how we will refer to them going forward.

To change any part of the IP address (Address, Netmask, and/or Gateway) enter the desired changes. Any changes to the IP address information will change the color of the Set button. This is a reminder to the user to download the values by clicking the Set button. Once clicked, the Set button will return to its regular color after it receives a successful confirmation. This will take several seconds. **During this time, it is critical that the user must not disconnect power from the P452.** Doing so will corrupt the memory and the unit will need to be returned to the factory and reset. During this period of vulnerability, a warning message will be prominently displayed.

Note that RangeNet has multiple operating modes including Ranging Mode, Network Mode, and several Location Modes. The current operating mode of the unit is indicated in the lower left-hand corner of the screen. When the P452 is in Ranging Mode, it operates as a point-to-point ranging system in which the

operator is responsible for initiating all conversations. When the unit is in Networking Mode, then the P452 will schedule and perform all range requests independent of the user and Host. The user can, of course, define whether the ranging will be done using either the ALOHA or TDMA protocols, provide guidance on other network behavior, and monitor network operation, but the P452 will execute these instructions independently from the user. Similarly, the localization computations are independent of the Host. Localization functions are resident on the P452 and make use of either the ALOHA or TDMA protocols to collect ranges from the other P452s in the system. **Note: units operating in one mode will NOT respond to units operating in other modes**. Switching between the various modes will be illustrated shortly.

Demo Ranging Between P452s

You are now ready to explore UWB technology in greater detail. The next logical step is to establish a link between two P452 units and begin collecting range measurements.

Range Measurements are taken using the Two-Way Time-of-Flight (TW-TOF) technique. In this process a unit (the Requester) transmits a message to a second unit (the Responder). The Responder takes a measurement and sends a reply message to the Requester. The Requester then takes a measurement, incorporates the Requesters measurement and then computes/reports a range measurement.

For the purposes of this demonstration, we will use a P452 with UWB ID #100 as the range requester and a P452 with UWB ID #101 as the range responder. Power-up the Node #101 and attach an antenna. Observe the LEDs and confirm that the unit has booted properly.

1. Ensure that the P452 with UWB ID #100 is connected to the RangeNet GUI as described in the previous section. Since the P452 with UWB ID #101 will be used as the responder and since response is its default mode, there is no need to connect it to a PC.

2. Separate the P452s by some distance (a meter is fine for demonstration).

3. In the RangeNet GUI, select the Ranging Tab (**Figure 10**).

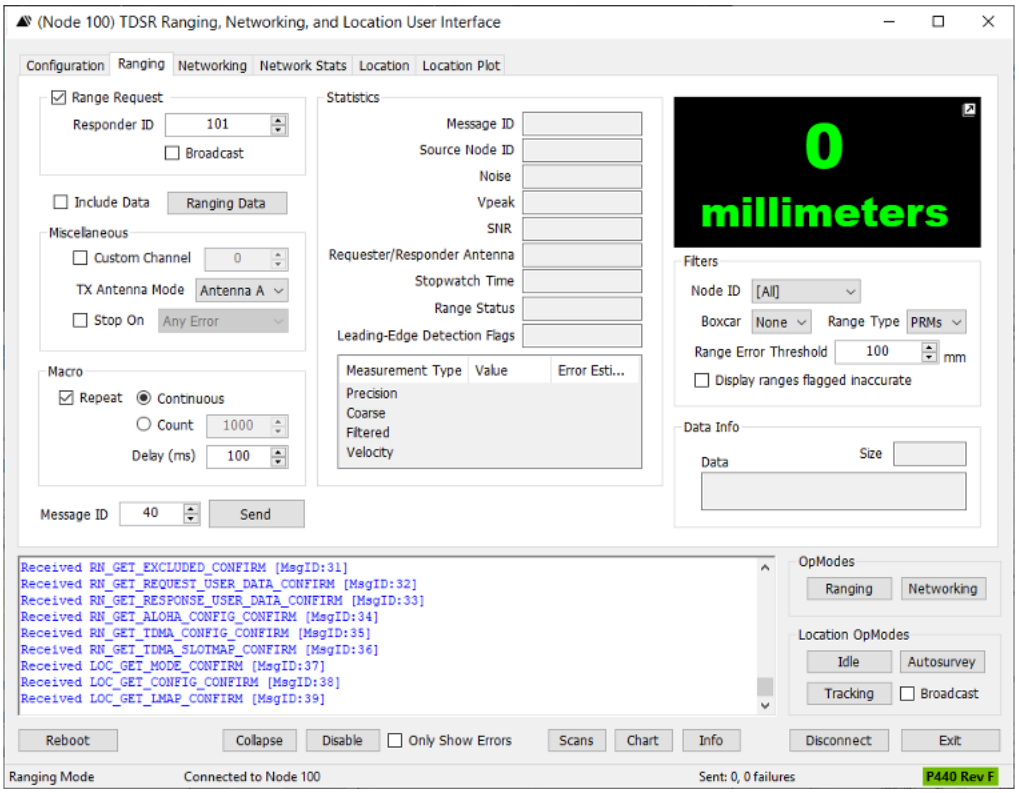


Fig. 10: RangeNet GUI Ranging Tab

4. If it isn't already checked, then please check the box marked "Range Request," enter the responder P452's UWB ID number (in this case #101), select the "Repeat" and "Continuous" options, then set Delay to 100 ms. This sets up the system to measure the range between unit #100 and unit #101 wait 100ms and then repeat. This will continue at a rate of approximately 8 or 9 Hz.

5. Click **Send**. If the range measurement was successful, you will see a confirmation message in the status window ("Range Status from 101: Successful"). An example is shown in **Figure 11.** The range measurement and associated statistics will update at 10 Hz. If, for some reason, the range measurement is consistently unsuccessful ("Range Status: Timeout Error"), then make sure that there is nothing blocking either of the antennas, that the antennas are really both on Port A, and that unit 101 is actually functioning. To change the units of measure, double-click in the black area of the range display. Each double-click will cycle the reported measurement type (millimeters, meters, and feet). The last setting will be saved such that the next time you enter the RangeNet GUI you will be using the same units.

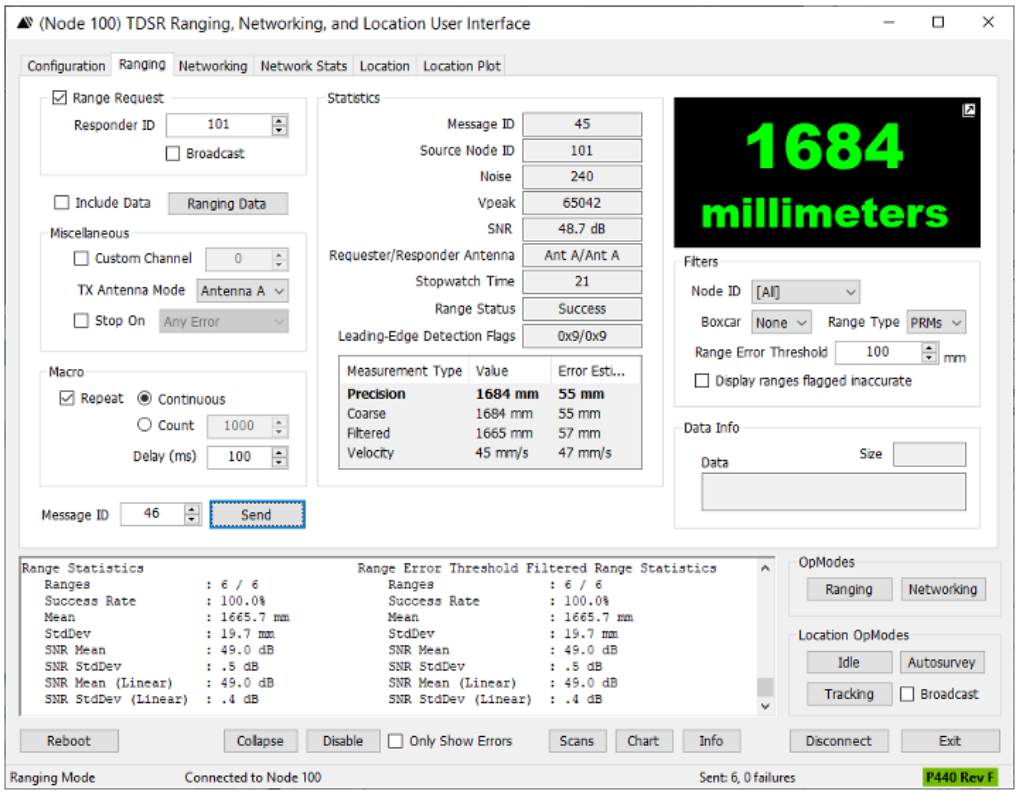


Fig. 11: Illustration of a range measurement

6. Move one unit relative to the other and observe the change in range. When satisfied with these experiments click **Stop**. This ends transmission and produces a short report.

7. If you would like to observe the received waveforms, then perform the following steps.

    a. Enable the reporting of waveforms by clicking on the Configuration Tab and changing the Scans drop-down from None to either Scan or Full Scan. Then click **Set**.
    b. Now initiate the taking of range measurements. Click on the Ranging Tab, confirm that Repeat is checked, and click **Send**.
    c. If you click the **Scans** button at the bottom of the display, the waveform captured for each range measurement will be displayed. See the example shown in **Figure 12**. The green line indicates the leading edge of the waveform and the gray line indicates the zero crossing to which the radio has synchronized. The scales can be changed by holding the left or right mouse buttons down while moving the mouse up or down.

    It should be noted that waveforms taken at such short ranges are compressed and clipped. They can be taken out of compression either by increasing the distance between the units or inserting attenuation between the P452 RF port and the antenna. The top waveform shown in **Figure 12** was taken with no attenuation while the bottom one was taken with a 20 dB attenuator in place.

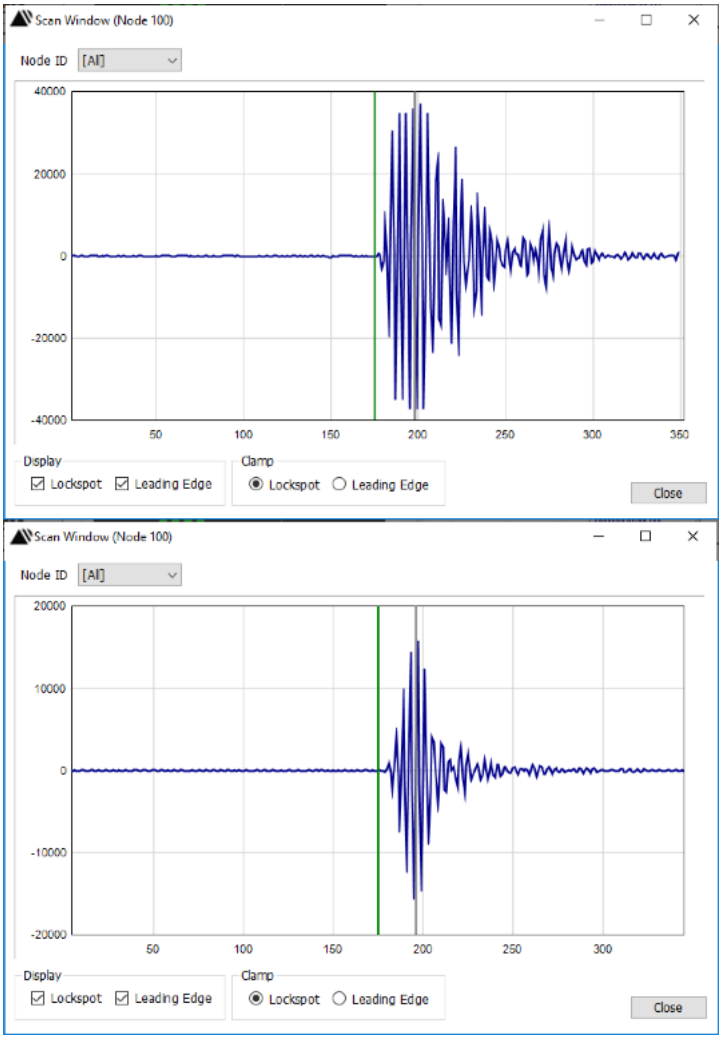


Fig. 12: Example of captured waveforms. Compressed waveform (top), uncompressed signal (bottom).

Logging Ranging Data

The process to collect ranging data using the RangeNet GUI is simple.

1. Click the Configuration Tab.

2. You will need to specify a location where the collected ranging data can be stored. In the Logging block, use the browser to select or create a target directory for the logfile. The RangeNet GUI will provide a default but this example assumes that you have created a directory on your desktop called 2.1 release\logs and defaults. The directory can be created either through Windows or through the browser.

3. You will need to specify a file name for the logfile. A default will be provided in the field called Logfile Prefix, but this example assumes that you have entered the file name Ranging Logs. Click **Start Logging**. The message "Logging to File: Ranging Logs000.csv" will appear.

4. Select the Ranging Tab. In the Macro section, check the box marked “Repeat” and select “Count.” Enter a value for the count (e.g., 100).

5. Click **Send**. The status will scroll while the ranges are being measured.

6. Open your ranging data destination folder. You should see a text document titled “Ranging Logs000.csv.” This is your logfile. (Each successive logfile with this filename will be numbered sequentially.)

7. Click the logging **Stop** button and open the logfile. An example is shown in **Figure 13.** Each row contains data from one message that was sent from the Host to the P452 or from the P452 to the Host. There are several different message types. Each time a new type of message is entered, it will be preceded by a message that contains header information describing each column. (For details on the exact format of all messages, review the *320-0313 RangeNet API Specification* and *320-0320 RangeNet User Guide*).

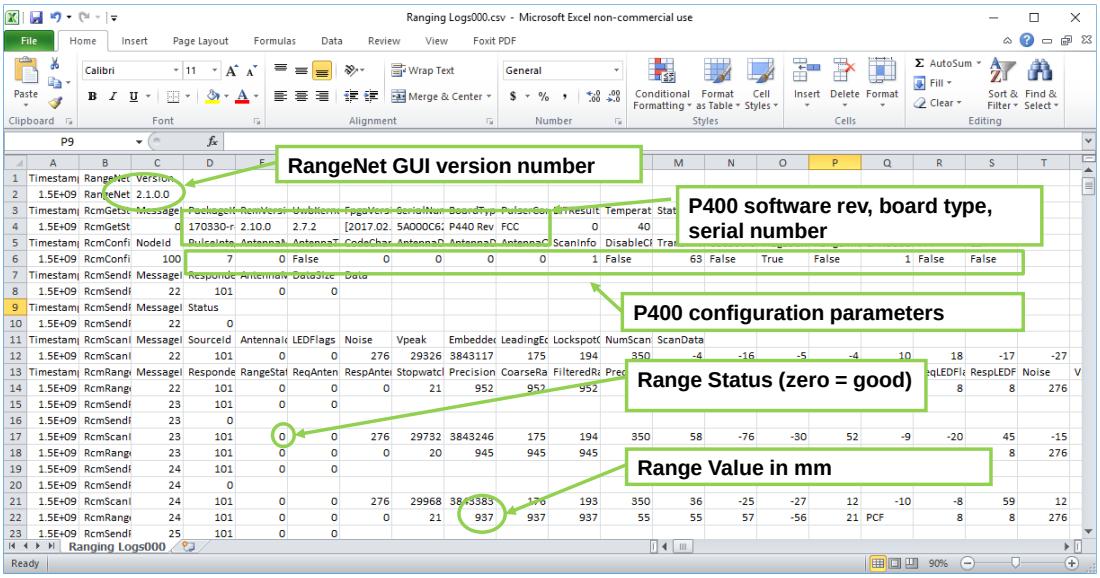


Fig. 13: Text logfile containing RangeNet GUI range data

You have now completed the installation and demonstration of standalone ranging.

Configuring the RangeNet Network Parameters

All P452 units are shipped from the factory with the defaults set such that clicking the **Networking** button (lower-right corner of the RangeNet GUI) will engage RangeNet networking using the ALOHA protocol. Furthermore, the TDMA Slot Map has been configured such that the units will operate in a round robin fashion.

This section will (1) demonstrate how to configure RangeNet, and then (2) operate your P442s as a 4-node network. This assumes that all four of the P452s have the same transmit power. In other words they are all high-power units or they are all regular units.

If they are the same type then skip this paragraph. If some of the units have standard power and others are high-power, then they will communicate but each time a high-power and regular unit try to communicate, they will produce warning messages indicating that the RF channel is asymmetric. To prevent this from happening, set the Transmit Gain on each high power units to 0 (this parameter is on the Configuration Tab) and click the **Set** button.

Using RangeNet as an ALOHA Network

Using the RangeNet GUI, connect to Node #100. Click the **Networking** button in the OpModes control block located in the lower-right corner of the display. The **Set** button will turn yellow and the mode (lower-left corner) will change to RN ALOHA Mode. Click **Set** button. (Clicking the **Set** button is important because doing so will ensure that the unit will return to the ALOHA Mode if the power is interrupted or if the unit is rebooted.) The unit will now start searching for neighboring P4xx units.

Click on the Neighbor Stats Tab. This window (see **Figure 14)** shows range and range-related data received from all of the range messages received from other units in the network. Since this is the first unit on the network, there is no information to report.

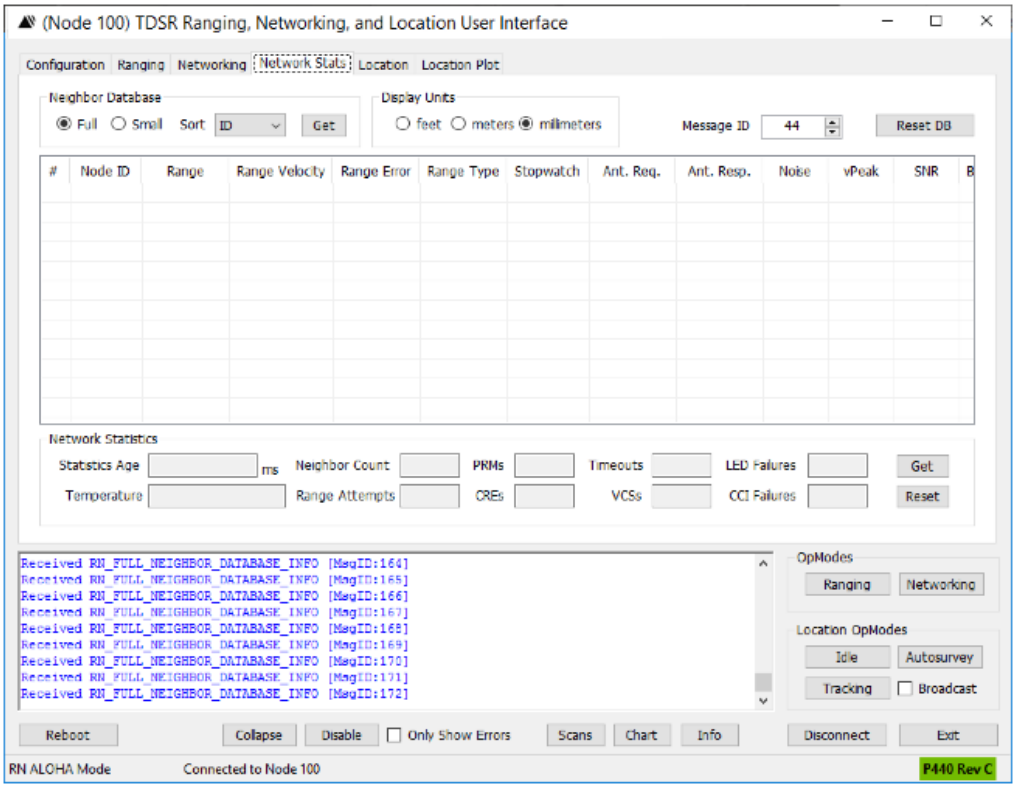


Fig. 14: Unit 100 RangeNet Neighbor Database showing the 16 left-most database values

Without shutting down the connection to unit #100, open a new instance of the RangeNet GUI and connect to Node #101. Then, while observing the Network Stats Tab on unit #100, click the **Networking** button on unit #101. Node #100 should now be reporting the ranging data from Node #101. Click the Network Stats Tab on unit #101. It will be reporting range data from #100. Your display should resemble the example shown in **Figure 15**.

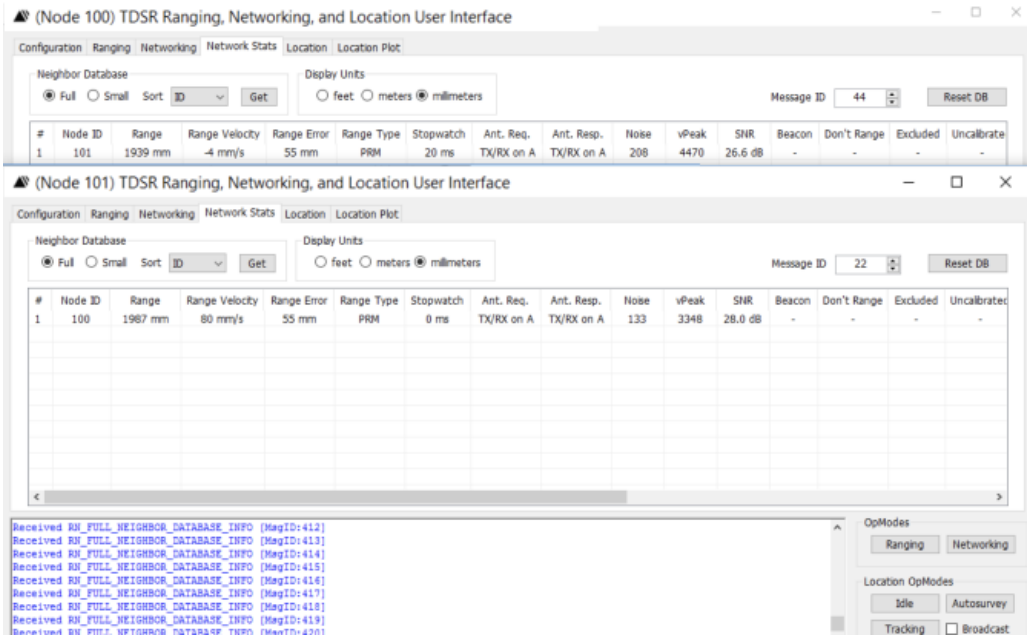


Fig. 15: Network Stats (contents of the Neighbor Database) from Units #100 and #101

Repeat this process for units #102, # 103, and #104. You will see that each node is communicating with the other four. This is illustrated in **Figure 16.**

To view all five units at the same time will require a hub. If you are using a USB hub you may have issues connecting this many units to the hub. We have noticed that USB hubs and the Windows operating system do not always work well and Windows will sometimes drop units. If and when this happens you will notice USB connections randomly disconnecting and sometimes failing to reconnect unless either the unit or the computer is rebooted. If this happens, then either change hubs, connect to only one or two units at a time, or monitor using multiple Host computers. You may also consider operating with Ethernet. We have found that communications through Ethernet hubs is very reliable.

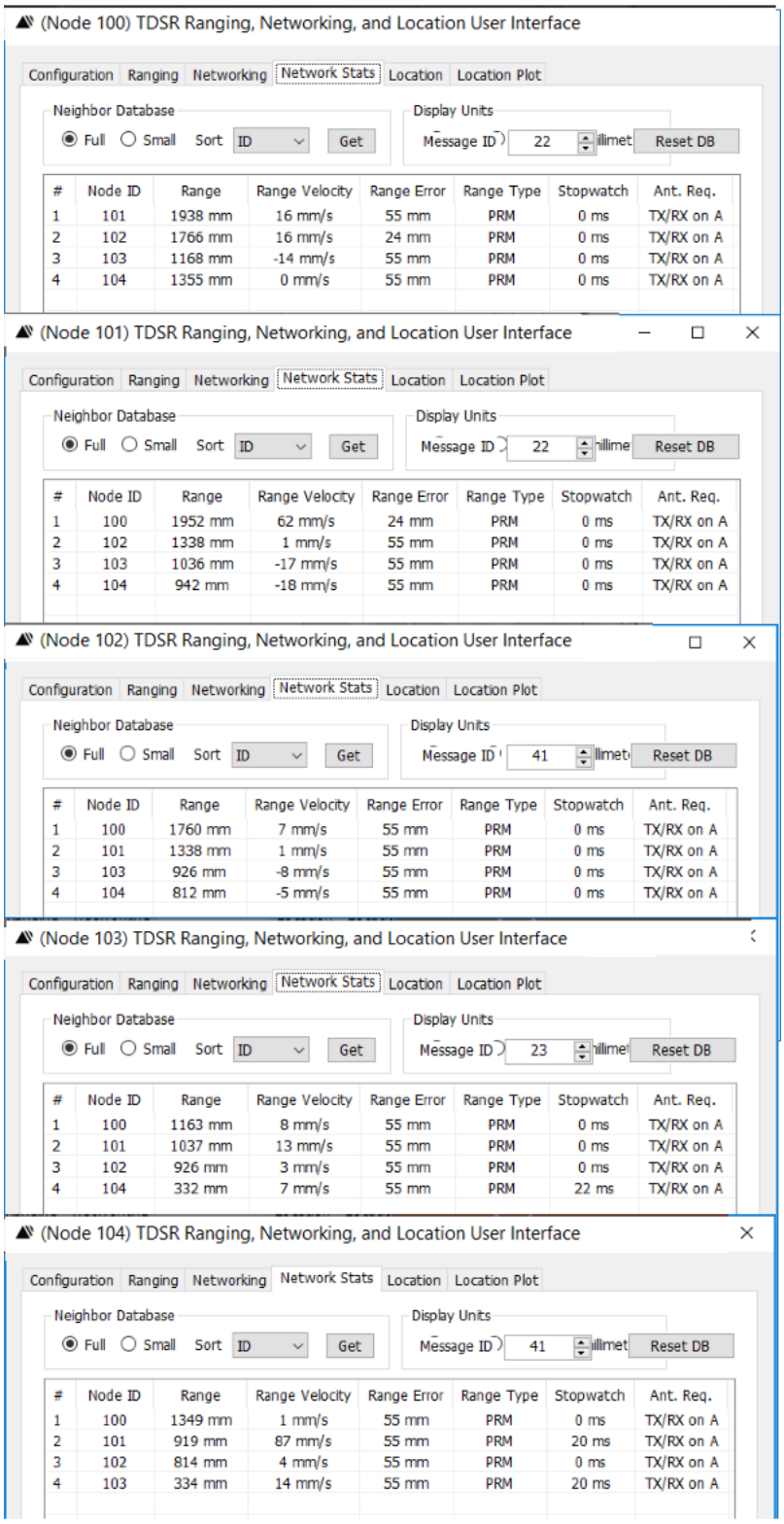


Fig. 16: Example ALOHA Network with five members

Now experiment with the units in the network. Move them apart and observe how the range information changes as the units move. Connect and disconnect units from the network and observe how long it takes units to drop out and rejoin the system. (With the default settings it should take about 10 seconds to drop out and 1 second to rejoin.) There are several ways to connect and disconnect from the network. For example:

a. In the OpModes corner of the display, you can click on the **Ranging** button.
b. You can go to the Configuration Tab and change the Code Channel.
c. You can do a software reboot.
d. You can remove the power from one unit.

Note: If you are testing with the standard (~1.8 m cables), then the units will be rather close to each other. So close, in fact, that they will actually be saturating each other's receivers. While this will not damage the radios in any way, operating the radios in saturation may slightly degrade the ranging performance. Either add some attenuation between the P4xx and the antenna or move them farther apart. This degradation will decrease quickly and is largely gone once the units are separated by a few meters. (The test performed in **Figure 16** was done so with 10 dB attenuators installed between the antenna and RF port of each unit.)

Using RangeNet as a TDMA Network

We will now transition the network from the ALOHA protocol to the TDMA (Time Division Multiple Access) protocol. But first, please note the following items.

If you click on the Configuration Tab of any unit you will see that the units are communicating using Code Channel 0. If you click on the Networking Tab and enlarge the screen you will see that the TDMA Slot Map is configured to operate in a round-robin fashion using Code Channel 2. See **Figure 17.**

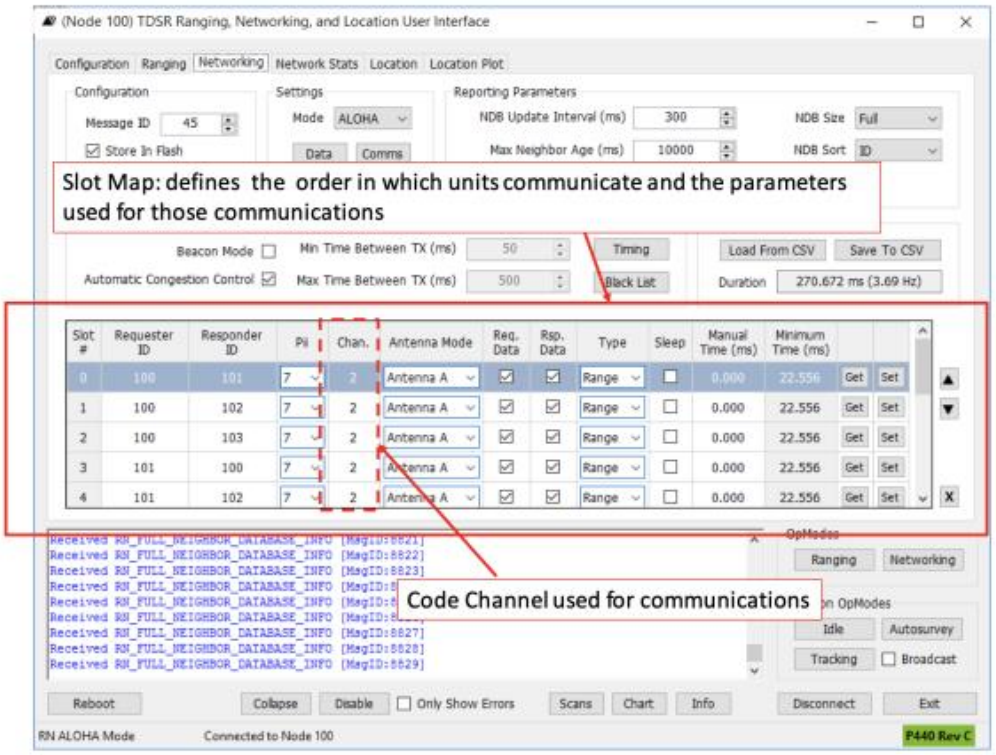


Fig. 17: Networking Tab shows Slot Map and operation using Code Channel 2

Next, pull up the RangeNet GUI connected to Node #100 and click on the Network Tab. In the Settings block find the "Mode" drop-down box. It will be showing ALOHA. Click on the drop-down arrow and change the setting to TDMA.

While observing the RangeNet GUI for #100 and the Network Stats Tab on Node #103, click the yellow **Set** button on Node #100. You will notice that:

- Node #100 is now in RN TDMA Mode.
- Node #100 is no longer updating on Node #103 Network Stats Tab.
- After 10 seconds, Node #100 will disappear from Node #103 Network Stats.

At this point in time, units 101, 102, and 103 are operating as an ALOHA network on Code Channel 0, while unit 100 is operating a TDMA network on Channel 2. Clicking on Node #100's Network Stats Tab will confirm that Node #100 is alone.

Next, pull up the RangeNet GUI instance connected to Node #101 and click the Network Tab. Change the Mode setting to TDMA and click the yellow **Set** button.

As a result of this, Node #101 will immediately appear in the Network Stats of Node #100 and after 10 seconds will disappear from Node #103's Network Stats Tab.

You now have two populated networks operating at the same time. One is running ALOHA on Channel 0 and the second is running TDMA on Channel 2.

Next connect to each of the remaining units (#102 and #104) and, while changing their network mode to TDMA, observe the Network Stats Tab of Node #100. You will notice that units 101 through 103 are displaying statistics but that Node #104 is not shown. If you review the Slot Map you will see that Node #104 is not included in any of the slots. Therefore, it is not allowed to transmit. However, it is able to listen. This can be confirmed by viewing the Network Stats Tab of Node #104. Notice that it shows the statistics for all of the other units but does not show ranges. It is not able to show ranges because it is not allowed a time slot within which to range to others. If you wish to add Node #104 to the network, you should update the Slot Map so that #104 has an opportunity to transmit, and then modify the Slot Map in each of the units. All units must operate from the same Slot Map otherwise there will be chaos.

At this point you can change the operating mode of units, update the Slot Map, or transition the TDMA units back to ALOHA. To transition from TDMA to ALOHA, you will need to do the following steps:

1. Click on the Networking Tab, change the Mode from TDMA to ALOHA and click **Set**.
2. Click on the Configuration Tab and click **Set**.

If you wish to return to Ranging Mode, just click the Ranging button in the lower-right corner of any tab.

This concludes the Network demonstration.

Network Localization

These instructions will walk the reader through the process of setting up P452s as a 3D self-localizing network. This network will consist of four Anchors (reference units which remain stationary) and one Mobile (a unit which can be moved). The exact location of the Anchors will need to be measured. While the locations can be manually surveyed by the user and entered through the RangeNet GUI, in this exercise, the Autosurvey capability of RangeNet will be used to determine the location of the Anchors. While Autosurvey will measure the location of the Anchors in the X and Y dimensions, the user will need to enter the elevation of the units from the ground. Once Autosurvey has completed, the user will then instruct the RangeNet GUI to distribute the reference information throughout the system. At that point, the user can transition the system to Tracking and will then be able to monitor the how the Mobile moves through the system. The localization algorithm uses the range measurements in conjunction with a Kalman filter and motion model to compute the device's location. **Sections 11** and **12** of the *320-0320 RangeNet User Guide* describe this in more detail.

1. **Plan how and where the Anchors will be placed.** Prior to placing the Anchors, plan where and how you will set the Anchors up. This is probably the most time-consuming part of the demonstration. Ideally all of the units should be mounted on tripods. Once the units have been powered and configured, the tripods would then be arranged such that the Anchors were about 2 meters (6 ft.) above the floor and Mobiles are about a meter (3 ft.) above the ground and about 300 mm (1 ft.) away from RF reflective metal surfaces. The use of tripods will make it very easy to quickly set the system up almost anywhere and experiment in many different environments.

   But right now you may not have 5 tripods and if you do, then there would be the question of how best to attach the radios to the tripods. We have found that simple solutions such as tape or Velcro work adequately. But a more robust and secure method would involve making use of the 4-40 mounting holes on the bottom of the enclosures. For example, for our own internal testing we use a simple metal plate with 6 holes. Four of the holes in the plate align with the 4-40

mounting holes on the enclosure. The fifth hole has a thread which matches a camera tripod mount. The sixth hole aligns with the tripod stabilization set pin. See **Figure 18.**

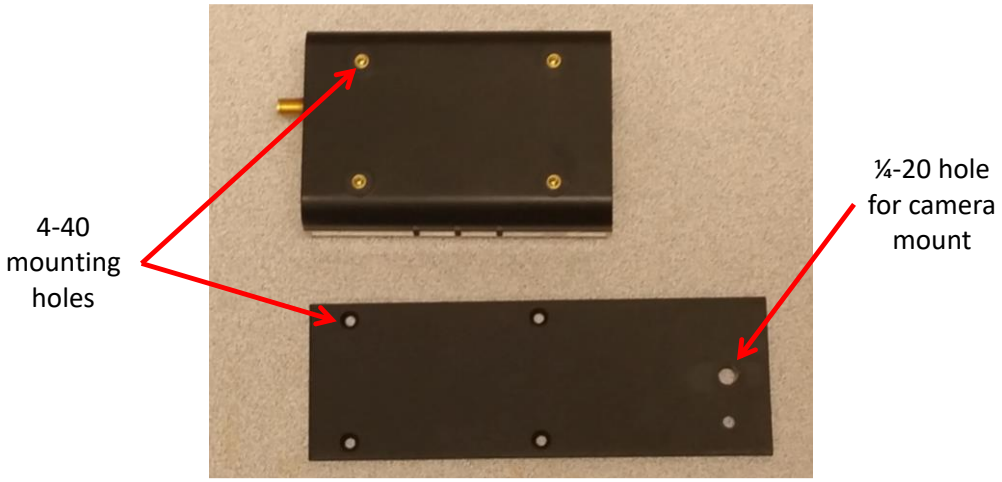


Fig. 18: Example mounting plate

Without tripods, the logistics of set-up will limit the places where you can operate. But it is possible to mount the units on the corner of furniture and on boxes. You can even tape units to the wall.

But regardless of how you position the P452s, you will need to follow these guidelines.

- Try an easy environment first. Outside is ideal. Inside in a large hall or conference room also works well. Operating in small rooms is more difficult. You should avoid operating through walls, because in these situations you will generally get better results using a laser system to survey the location of the Anchors rather than using the Autosurvey capability.
- Configure the software in the units.
- Place the Anchors about 2 meters (6 ft.) above the ground. They do not need to be at the same elevation, but the lowest one should be about 1 meter (3 ft.) above the Mobile.
- The antenna of each Anchor should be:
    - About 30 cm (1 ft.) from any RF-reflective surface
    - Clearly visible by other antennas and there should be no obstructions within about 30 cm (1 ft.) of the direct line-of-sight between the Anchors' antennas.
    - About 2-4 meters (12 ft.) from any other Anchor. If your area isn't large enough to support this then the units will be operating in compression. This will result in additional bias errors and a higher standard deviation. You have two options. **Option 1:** Place the units where you can and ignore the errors, after all this is just a demonstration. While the results will not be ideal, they will be surprisingly good. **Option 2:** Install a 6 or 10 dB attenuator between the RF port and antenna of each unit. This will prevent compression and improve the standard deviation. It will also increase the bias error (the attenuators will add about 2.54 cm to each reported range) but this effect is minor.
    - Arranged in a square or rectangular pattern.

- The location of the Mobile will be most accurately reported when the Mobile is within the rectangle formed by the antennas. Outside the rectangle the performance will degrade slightly. The performance will start to fail when the distance between the Mobile and Anchors exceeds about 10x the separation between the Anchors. This is not due to the radios' performance. At these distances the errors associated with the geometry of the Anchor locations can get quite large.

2. **Load the configuration file into the units.** Before actually positioning the units, power the units and then connect to unit #100 with the RangeNet GUI. Click on the Configuration Tab, confirm that the **Write Config to Radio** box is checked, and then click the **Load From File** button. You should see the screen shown in **Figure 19**. If not, then use the browser to navigate to the directory shown. Select the file

   RangeNetConfig_Location_3D_Kalman_4Anchors_1Mobile.rnl

   and click the **Open** button. This will load the 4 Anchor, 1 Mobile configuration. Localization will be computed using the Kalman filter. Finally, click the **Idle** button (lower-right corner) then click the yellow **Set** button. This will put the unit in the Location Idle Mode. After this, click the Reboot button. Repeat this process for the remaining units.

Important Note: In principle, one should not need to Reboot in the previous step. However, when transitioning from a Network Mode (ie operating from the Network tab without any localization functions enabled) to any Location Mode or from any Location Mode to a Network mode it is necessary to reboot the P4xx after making the transition. This is a known bug and will be fixed in a later release. Therefore, since the previous step in the Quick Start Guide was operation in Network mode, it is necessary to reboot after the unit is placed in Location Idle mode. There are no issues with transitions from or to Ranging Mode from or to either Location or Network Mode.

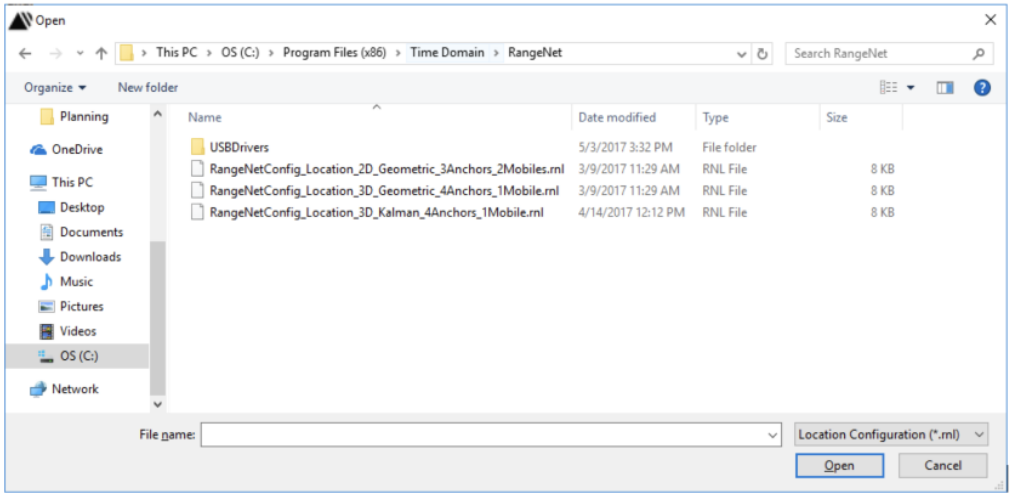


Fig. 19: Load the configuration files

3. **Position the radios**. Once the units have been configured, they are ready for Autosurvey. Autosurvey requires that you define a frame of reference so that the locations of the units can be displayed in a logical manner. In other words, locations which you see on the display should be consistent with what you see as you look across your field of view. An improper frame of

reference would result in the display being rotated or inverted relative to reality. While this does not damage the equipment or generate improper data, it will make it more confusing to relate movement of the Mobile in real time with what appears on the screen. **Figure 20** illustrates how the units should ideally be positioned relative to the Host computer so that the view from the computer matches the field of view.

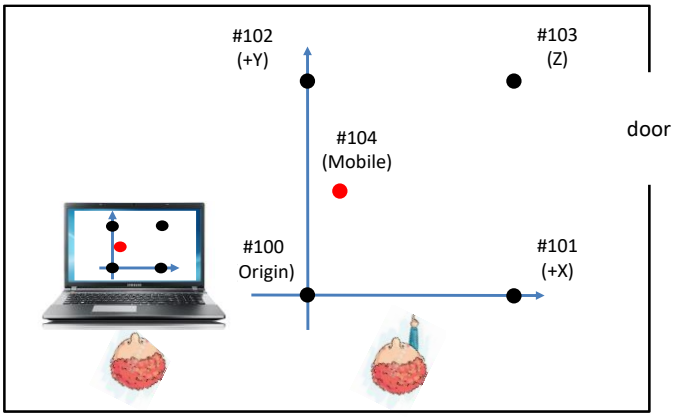


Fig. 20: Establishing a frame of reference

4. **Load the Location Map (LMAP) with initial locations.** Using the RangeNet GUI, connect to unit #104 and click on the Location Tab. See example in **Figure 21**. Note that the node numbers in the display match the positions shown in **Figure 20**. Note that the Network Mode shown is TDMA – Auto. This means that the system will operate using the PII and communications Code Channel shown on the Configuration Tab. The Mobile will compute locations based on the PII selected and operate at the fastest rate supported by that PII. For example, since the Configuration Tab has set the PII to 7 then the unit will range and compute the location once every 22 ms (~45 Hz rate). Note the Z column. For each of the units you will need to measure the distance from the floor to the middle of the antenna. (For this exercise it doesn't matter what point on the antenna you use as long as it is the same spot for all antennas.) Enter the values (in millimeters) into the Z column. When entering the Z values, do not set them all to the exact same value. Identical values can cause issues with the initializer. (Even a mm difference in Z is enough to avoid any issues.) If you accidentally add a fifth row it can be deleted by navigating over to the far-left column and then clicking the delete button. If you delete the table, then reload the configuration table (see **Step 2**) for just this unit.

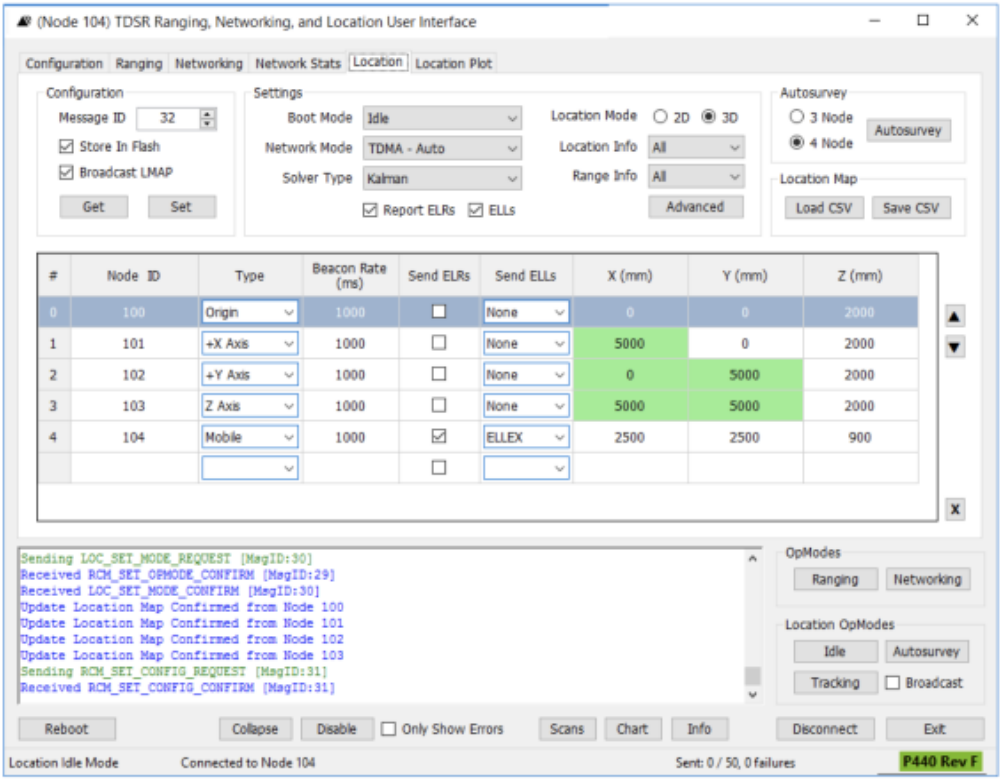


Fig. 21: Load the configuration files

5. **Check that all units are online**. Confirm that the Broadcast box in the lower right has a check mark. If not, then click on the box. Click the **Idle** button in the lower-right. This will broadcast a message to all units ordering them to go to the Idle state. They will then send confirming messages. Observe the messages in the lower part of the screen. You should see a "Change NavNet Mode Confirmed from Node …" message from each of the other units in the system. If one or more is missing, check the battery and repeat **Step 2** for each missing unit. This is illustrated in **Figure 22**.

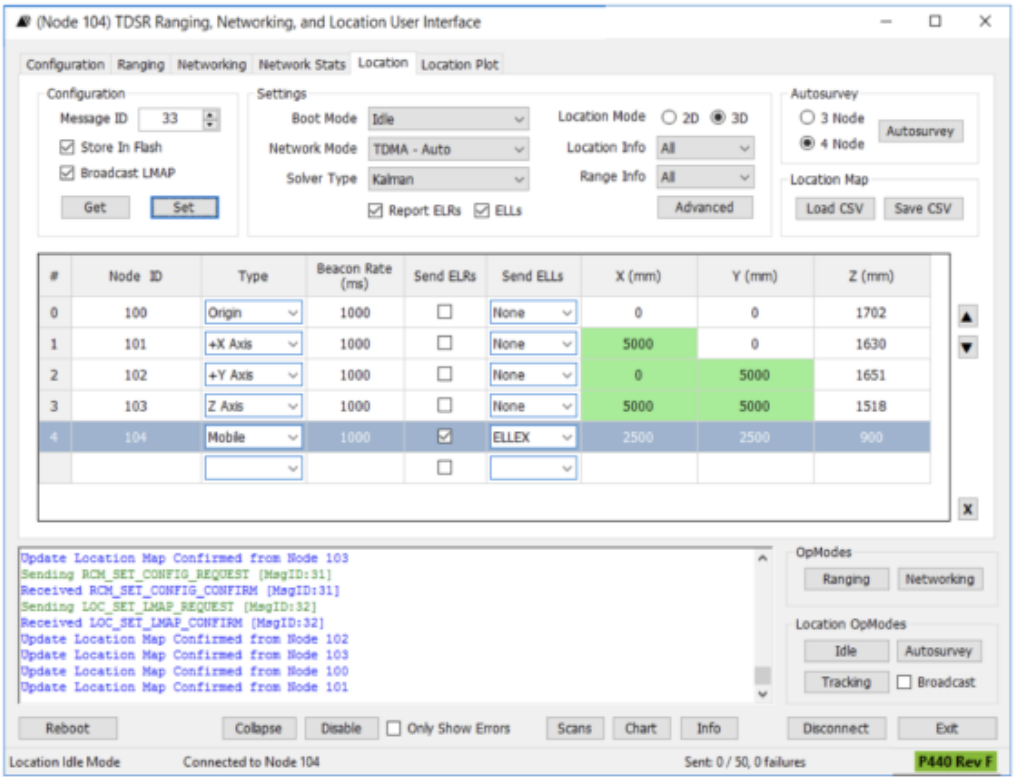


Fig. 22: Messages confirm all units are ready

6. **Execute Autosurvey**. Click the **Autosurvey** button and then the large **Start Autosurvey** button. This starts the Autosurvey process and you will see that many numbers are updating. If you are in a pristine environment, the process will complete in less than 10 seconds. See **Figure 23** for a representative result.

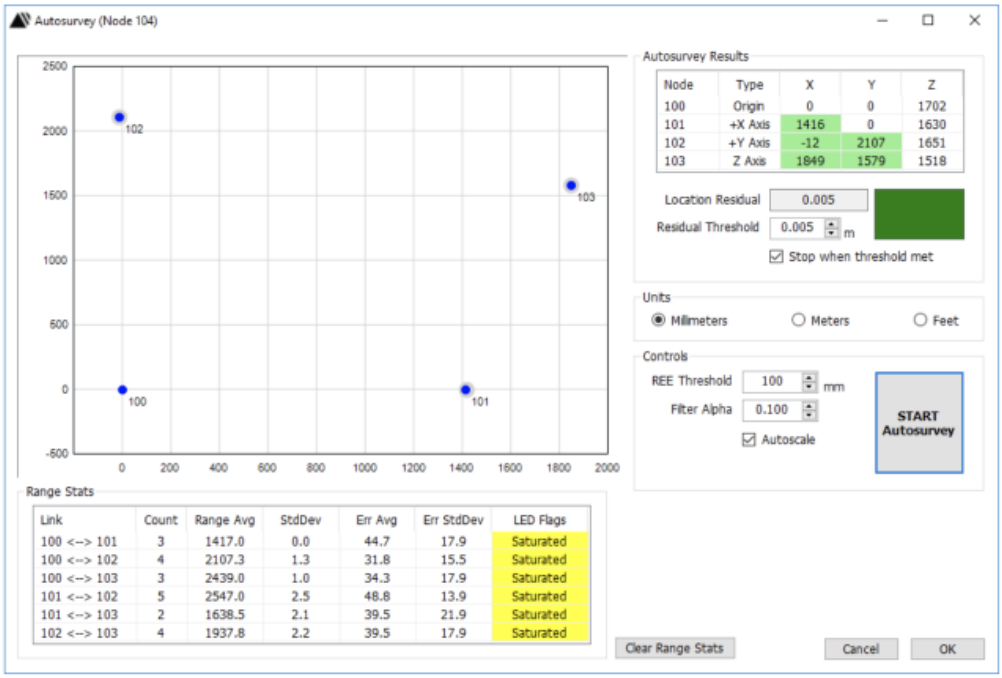


Fig. 23: Successful completion of Autosurvey

If you are in a poor environment, then it will take longer. If you have unsuccessfully waited for 30 seconds, click the Stop Autosurvey button. Then increase the Residual Threshold by 0.01 and click the Start Autosurvey button again. If it doesn't successfully complete in a reasonable amount of time, then repeat. Normally one or two iterations will result in success. If it still doesn't complete, something is wrong with your set-up and you should call the factory for advice. When the process does successfully complete, the red box will turn green and the Autosurvey results will be stable.

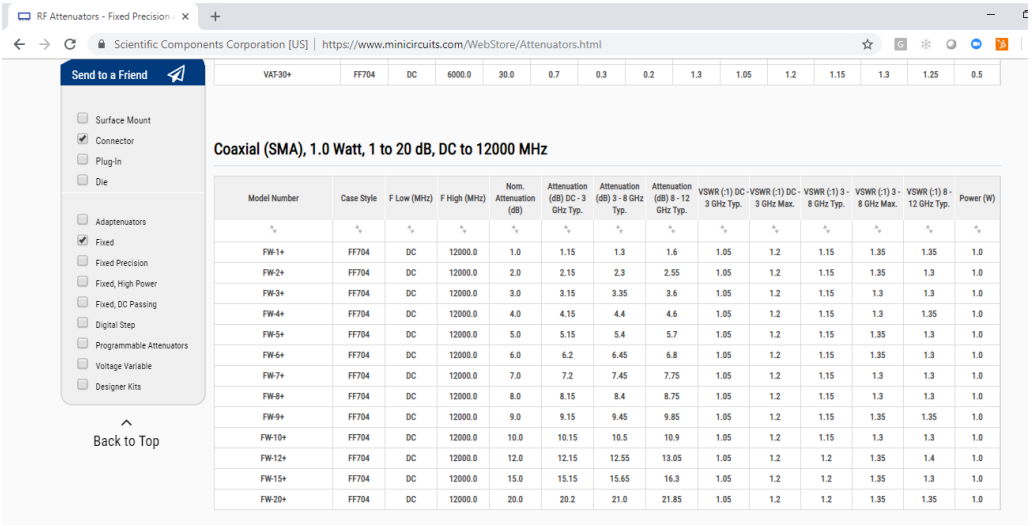
Click the **OK** button in the lower-right corner. This window will close and the unit will then return to the Idle state. If the unit doesn't do so immediately but instead is still sending Autosurvey related messages then read the following note as you wait.

Important Note: When you are in either Autosurvey or Tracking mode, the connected P452 will produce a flood of messages which need to be processed by your computer. This will cause a latency between when the messages were generated and when they appear on the Host's screen. This latency can be as large as 10s of seconds. If you have multiple instances of RangeNet running such that you are connected to several units then the flood of messages will be even larger. Therefore, it is important to minimize the messages produced by the P452s and use the fastest computer you have available. The easiest way to minimize messages is to click the "Only Show Errors" button and if you are satisfied that the errors are occasional then click the "Disable" button as well. Also, avoid using the Charts and Scan functions. While this will help stem the flood, sometimes the only Host computer available will rather slow. In such a case, you will know that latency is the issue because attempting to transition from Autosurvey or from Tracking to Idle will seem unresponsive. To confirm that latency is the reason the system is not responding, click the Enable messages button and observe if messages are being produced. If they are being generated then you will need to wait until the Host catches up. At that point, the system will go to the desired state. (Another way to confirm that there is a latency issue, is to

watch the messages when you disconnect the Host from the P452. If messages continue to arrive after you have disconnected, then you know that you have a latency problem.)

If the units are too close together (as is the case in this situation), then the LED Flags will warn you if any of the links are operating in saturation. In these cases the overall performance of the system will be degraded slightly. However, this may not be apparent to the user because the standard deviation (precision or repeatability) of the range measurements are quite good. What is missing is the effect that compression has on the accuracy or bias. This impact of the bias error would only be observable if the locations calculated were compared with laser survey equipment or some other highly accurate location determination system.

To improve performance either (a) separate the units such that they are far away or (b) add an attenuator between the antenna and the antenna port. A 6 dB attenuator is normally enough to reduce that signal such that the units are no longer in saturation. If you have never used attenuators before or would like to order some, then they are available online. We find that 1-, 3-, 6-, 10- and 20 dB attenuators are very useful. See **Figure 24** for instructions on where to buy attenuators.



Model Number	Case Style	F Low (MHz)	F High (MHz)	Nom. Attenuation (dB)	Attenuation (dB) DC - 3 GHz Typ.	Attenuation (dB) 3 - 8 GHz Typ.	Attenuation (dB) 8 - 12 GHz Typ.	VSWR (:1) DC - 3 GHz Typ.	VSWR (:1) DC - 3 GHz Max.	VSWR (:1) 3 - 8 GHz Typ.	VSWR (:1) 3 - 8 GHz Max.	VSWR (:1) 8 - 12 GHz Typ.	Power (W)
VAT-30+	FF704	DC	6000.0	30.0	0.7	0.3	0.2	1.3	1.05	1.2	1.15	1.3	1.25	0.5
FW-1+	FF704	DC	12000.0	1.0	1.15	1.3	1.6	1.05	1.2	1.15	1.35	1.35	1.0
FW-2+	FF704	DC	12000.0	2.0	2.15	2.3	2.55	1.05	1.2	1.15	1.35	1.3	1.0
FW-3+	FF704	DC	12000.0	3.0	3.15	3.35	3.6	1.05	1.2	1.15	1.3	1.3	1.0
FW-4+	FF704	DC	12000.0	4.0	4.15	4.4	4.6	1.05	1.2	1.15	1.3	1.35	1.0
FW-5+	FF704	DC	12000.0	5.0	5.15	5.4	5.7	1.05	1.2	1.15	1.35	1.3	1.0
FW-6+	FF704	DC	12000.0	6.0	6.2	6.45	6.8	1.05	1.2	1.15	1.35	1.3	1.0
FW-7+	FF704	DC	12000.0	7.0	7.2	7.45	7.75	1.05	1.2	1.15	1.3	1.3	1.0
FW-8+	FF704	DC	12000.0	8.0	8.15	8.4	8.75	1.05	1.2	1.15	1.3	1.3	1.0
FW-9+	FF704	DC	12000.0	9.0	9.15	9.45	9.85	1.05	1.2	1.15	1.35	1.35	1.0
FW-10+	FF704	DC	12000.0	10.0	10.15	10.5	10.9	1.05	1.2	1.15	1.3	1.3	1.0
FW-12+	FF704	DC	12000.0	12.0	12.15	12.55	13.05	1.05	1.2	1.2	1.35	1.4	1.0
FW-15+	FF704	DC	12000.0	15.0	15.15	15.65	16.3	1.05	1.2	1.2	1.35	1.3	1.0
FW-20+	FF704	DC	12000.0	20.0	20.2	21.0	21.85	1.05	1.2	1.2	1.35	1.35	1.0

Fig. 24: Web source for attenuators

If you click the **Start Autosurvey** button a second time, then it will resurvey the system. Try doing so a few times and you will get a sense of the repeatability of the system.

When you are satisfied with the settings, then click **OK**.

7. **Distributing the final LMAP through the system**. Note that the X and Y values in the LMAP are reasonable and the **Set** button is yellow. With the exception that your X and Y values are different, your display should be identical to **Figure 25**.

   If the **Broadcast** box in the Location OpModes block isn't clicked then click it and then click the yellow **Set** button. This will distribute the updated location map to all of the units in the system and you should receive an "Update Location Map Confirmed…" message from each node in the system.

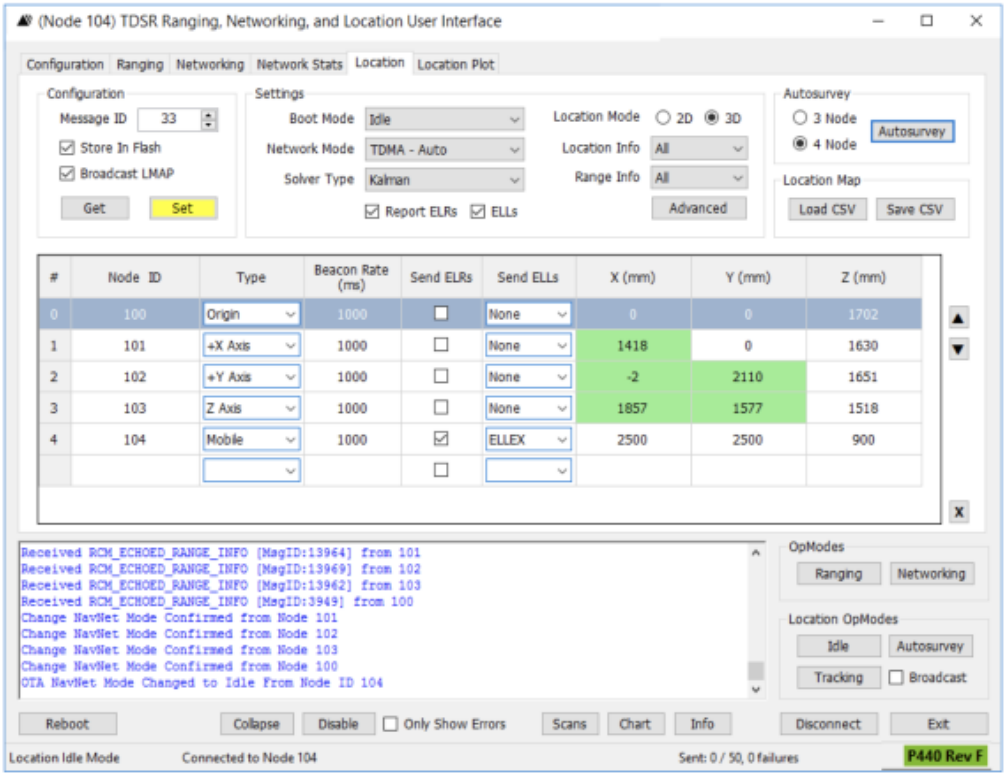


Fig. 25: Broadcast options enable distribution of Location Map (LMAP)

If you wish to confirm that fact, connect to any unit with the RangeNet GUI, click the Location Tab and click the **Get** button.

8. **Transition to Tracking Mode**. Click the Tracking button (lower-right corner). This will transition all units in the system to the Tracking Mode and you will get confirmation messages to that effect. But you will probably not notice them because you will be receiving a flood of ranging and location messages. Click either the **Collapse**, **Disable,** or **Show Only Errors** box. This will prevent the GUI from being overwhelmed by messages.

9. **Monitor the system.** Click the Location Plot Tab, the Misc subtab, and then click the Autoscale box. You should see a rapidly updating display similar to the one shown in **Figure 26.**

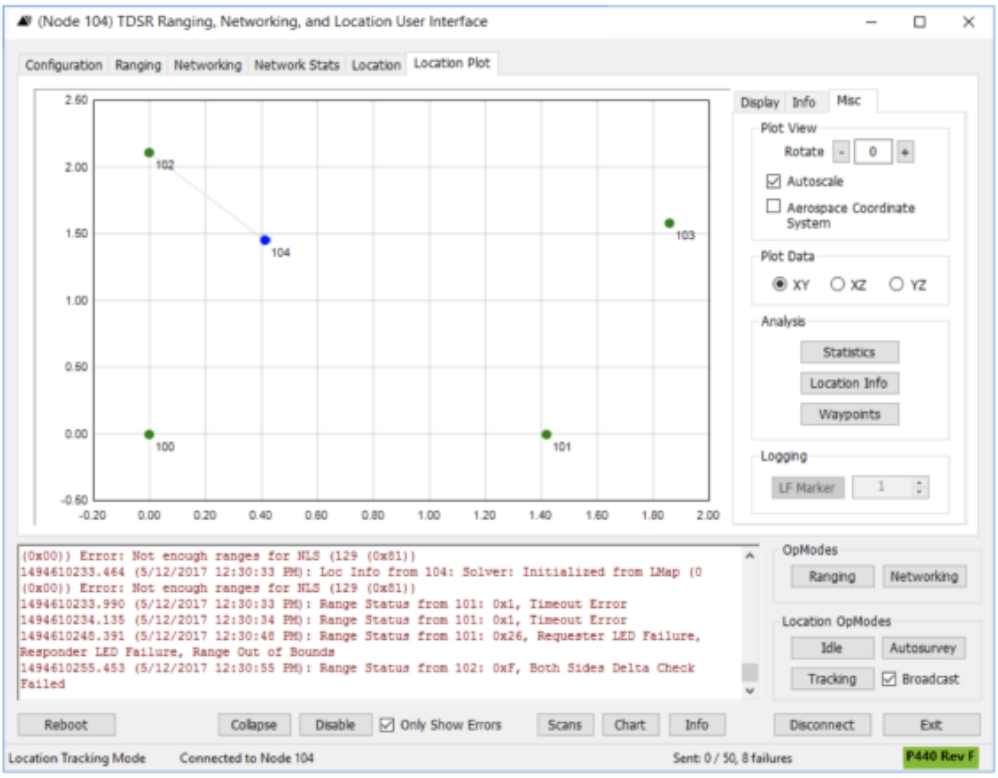


Fig. 26: Monitoring the device locations

Next, experiment with the Display, Info, and Misc Tabs. Most of the fields are rather obvious but if you would like more detail, then please reference the appropriate section of the *320-0320 RangeNet User Guide*.

Next, move the Mobile around and see how it reacts to motion and blockages. On the Misc subtab, click the XZ button and monitor the elevation of the Mobile relative to the Anchors as you raise and lower the Mobile. If all of your Anchors are at the same height then raising the Mobile above the Anchors may confuse the system such that the Mobile is shown on the wrong side of the plane formed by the Anchors. This is caused by a lack of diversity in the relative heights of the Anchors. Basically with all the Anchors at the "same" height, the calculation of position can result in the unit being on either side. The quick fix is to move the system back to Idle and then turn to Tracking. This will cause the system to reinitialize and if the Mobile is well away from the Z plane of the Anchors then it will be located on the correct side. The real solution is to set the system up such that the Anchors are located at substantially different elevations.

Finally, you are currently connected to the Mobile. You can get the same information by connecting to ANY node in the system.

This concludes the demonstration. At this point you should familiarize yourself with all of the commands and parameters as well as operation of the units both in standalone, network and location modes. It is not the intent of this guide to cover the RangeNet GUI in detail; for information on how to configure the various parameters, please refer to the *320-0320 RangeNet User Guide* and the *320-0313 RangeNet API Specification*.

Where do you go from here?

Once you are comfortable with operating the equipment, you should experiment with the following activities. Use the standalone mode to get a feel for how ranging works in your target environment. Check to see if/how mounting configurations may degrade your performance. Learn what each of the parameters on the Receive and Neighbor DB Tabs means. See how the waveforms and reported statistics vary as you move nodes closer and farther away. If you are working outdoors at ranges greater than 250 feet (76 m), learn about Fresnel effects. Understand the trade between Pulse Integration Index (PII) settings and system performance. (As PII is increased, it will take longer to take measurements but the system will operate over longer ranges.) Try sending some data. Log some waveform scans.

Once you have a feel for ranging, experiment with network operation. Try different settings. Send data over the network. Log and examine network messages. Experiment with Echo Last Range (ELR). In ALOHA Mode, try the Automatic Congestion Control (it will make your life easier). In TDMA Mode, try alternate Slot Maps. Experiment with defining units as Beacons.

Then experiment with localization. **Section 11.4 - Autosurvey** and **Appendix G: Maximizing Location Performance** of the *320-0320 RangeNet User Guide* offer advice on how to best set-up a localization network. This *Quick Start Guide* only demonstrated 2D localization with 4 Anchors and 1 Mobile. Try 2 and 3D localization using 4 Anchors and 1 Mobile, with TDMA and ALOHA. Add more Mobiles.

We hope that this document, along with the *320-0320 RangeNet User Guide* and the *320-0313 RangeNet API Specification* provide the information you need to begin using the P452s for ranging, network and localization operation. If you have any problems, please use sales@tdsr-uwb.com as your first point of contact. We offer multiple levels of support depending on your needs. To discuss how we can help you, please feel free to contact us:

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