RANGING DEMO

(PC) USER GUIDE

Understanding and using the DecaRanging ranging demo (PC) application

Version 1.3

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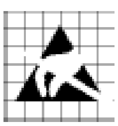

Caution! ESD sensitive device.

Precaution should be used when handling the device in order to prevent permanent damage

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Mailing address: -
Decawave Ltd.,
Adelaide Chambers,
Peter Street,
Dublin D08 T6YA

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1 INTRODUCTION

Decawave's *DecaRanging* is a demonstration application that drives Decawave's DW3XXX families of devices, to demonstrate the accurate range measurement can be made between a pair of DW3XXX devices units using a technique called two-way ranging. The DW3XXX device is a single chip RF transceiver supporting the IEEE 802.15.4 UWB PHY standard.

This document covers the version of Decawave's *DecaRanging* software that runs on a windows PC, describing how to install the software, how to run it, and how to interpret its results. It also discusses the basic operation of the two-way ranging algorithm being employed to measure the range.

The *DecaRanging* PC application to connects and controls the DW3XXX IC on the DW3XXX evaluation boards via either the SPI interface header (and employing a *Cheetah* USB-to-SPI convertor) or the USB/COM port interface via the FTDI chip. Please refer to section *1.2 – DecaRanging control of the DW3XXX transceiver* for more details. The *DecaRanging* PC application essentially has control of the DW3XXX which it drives to exchange messages between a pair of devices, calculate the time-of-flight of those messages and display the resultant distance between the two units.

The pre-built *DecaRanging* PC application (DecaRanging.exe) is built to run on a 64-bit windows PC.

1.1 DecaRanging capabilities

The *DecaRanging* application enables the following DW3XXX capabilities to be observed and tested:

a) General operation of Decawave's 802.15.4 UWB transceiver IC on the supported channels and modes as it sends and receives data frames.
   - IEEE specified preamble codes are supported giving complex channels as per standard
   - Data Rates: 850 kbits/s and 6.8 Mbits/s
   - Mean nominal Pulse Repetition Frequencies (PRF) of 16 MHz, 64 MHz and 100 MHz
   - Use of normal (Ipatov) and optionally STS modes
   - Preamble lengths or Preamble Symbol Repetitions (PSR) from 64 to 4096 symbols for Ipatov sequence and 64 to 2048 for STS.

b) Line-of-Sight (LOS) Range. The operator can check the operational range as the receiver is placed at various distances in LOS from the transmitter. This may be tested in all supported modes.

c) Non-line-of-Sight (NLOS) Range. The operator can check operational range when various obstructions are between the receiver and the transmitter giving a NLOS channel. This may be tested in all supported modes.

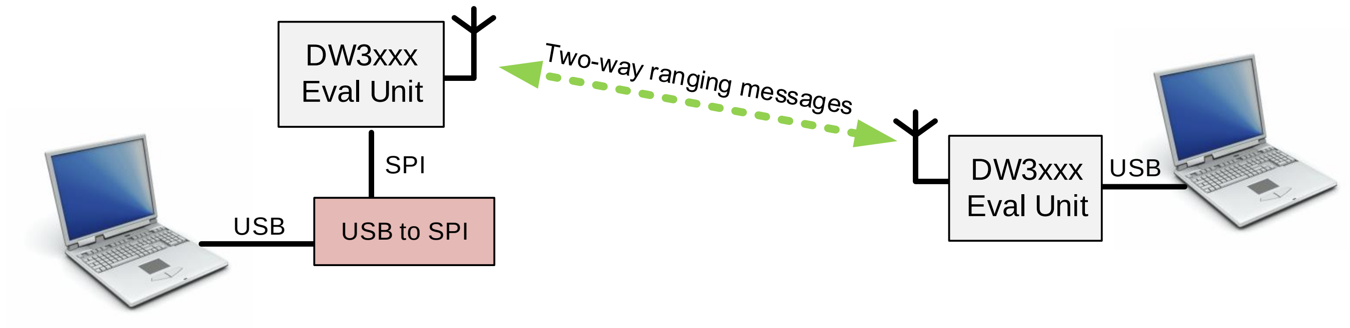
d) Time-of-Flight Ranging Measurements. The *DecaRanging* application performs 2-way ranging between two DW3XXX transceivers (each driven by the *DecaRanging* application) and estimates the distance between them based on the time-of-flight calculations. The operator can check how the distance estimate changes as the two units are moved nearer/further from each other, and when there are walls and other obstructions between the units. Again, this may be tested in all supported modes.

1.2 DecaRanging control of the DW3XXX transceiver

The DW3XXX is controlled via its SPI bus. The *DecaRanging* PC application connect and controls the DW3XXX IC on the EVK3000 evaluation boards, via the USB interface – The EVK3000's on-board ARM microcontroller's preinstalled application can operate as a simple USB to SPI controller, passing the *DecaRanging* PC applications SPI accesses to/from the DW3XXX IC. Please refer to the EVK3000 User Manual document for details of how to configure and enable this mode of operation.

The Decawave's USB-to-SPI converter is an application that runs on the EVK3000 HW. When using the DecaRanging application in this mode, the SPI commands are formatted and sent from the PC DecaRanging application through the Virtual COM port driver (deca_vcspi.c) over the USB interface to the ARM on the EVK3000. There the ARM USB-to-SPI application reads the commands and talks to the DW3XXX though the SPI interface.

With two DW3XXX evaluation units along with two *DecaRanging* applications, the DW3XXX transceiver's capabilities can be demonstrated and verified, the operating arrangement is shown in Figure 1.



Option (a) – VCOM (USB) Nucleo STM, which performs USB to SPI conversion

Option (b) – USB to FTDI, which performs USB to SPI conversion

Option (c) – USB to Cheetah, which performs USB to SPI conversion

Figure 1 – DecaRanging operating arrangement options

2 INSTALLATION AND SET-UP

This installation and setup chapter deals only with the PC version of DecaRanging and the PC software drivers that are necessary for its operation.

2.1 *STM VCOM Driver Installation*

When the EVK3000 board is plugged into the PC, the user should see "STMicroelectronics Virtual COM Port (COMX)" in the list of Ports (COM & LPT) in the Device Manager, see Figure 2. If is the not present then an STM virtual COM port driver may need to be installed available from https://www.st.com/en/development-tools/stsw-stm32102.html.

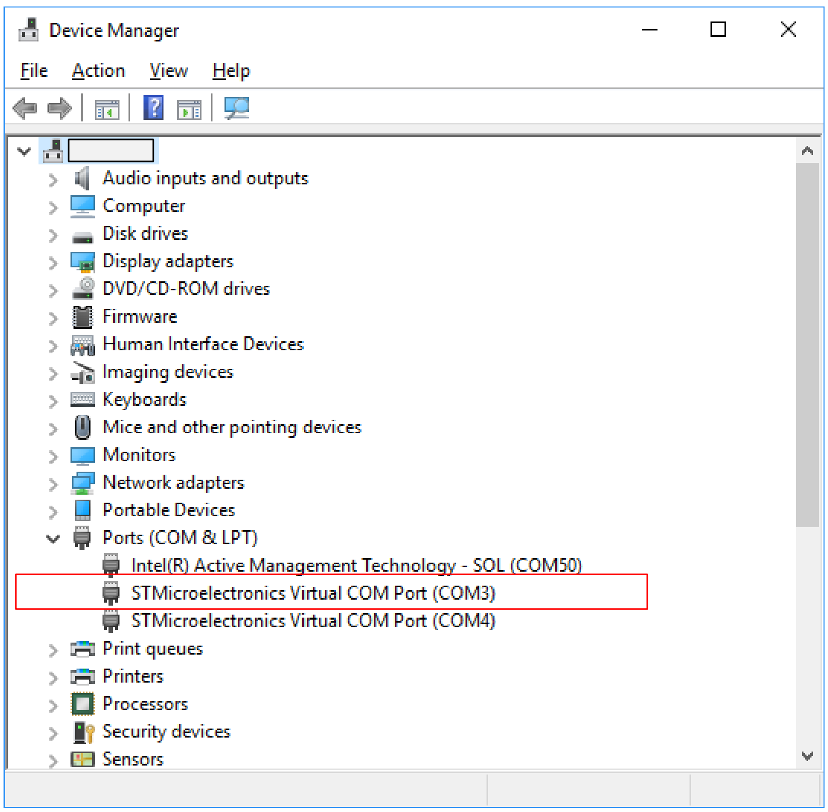


Figure 2 – STM Virtual COM port

2.2 DecaRanging *Application Installation*

The *DecaRanging* application installation is a manual process:

- Simply copy the file DecaRanging.exe to the desired directory on your windows PC hard-drive.

- Optionally copy the file cheetah.dll to the same directory if you want to use a *Cheetah* USB-to-SPI convertor

2.2.1 Installation of Runtime Environment for Visual C++

To run DecaRanging.exe on a computer that does not have Visual C++ 2010 installed, the runtime libraries, "Microsoft Visual C++ 2010 Redistributable Package (x86)" available from Microsoft need to be installed. These are available at:

http://www.microsoft.com/en-us/download/details.aspx?id=5555

Please download and run the *vcredist_x86.exe* installation program to install the runtime libraries necessary to prepare your system to run the *DecaRanging* application.

2.3 System Setup

If the software has been installed following instructions above and the PC is connected to the evaluation units in the arrangement shown in Figure 1, then everything should be ready to go.

Section 3 below details running the *DecaRanging* application.

3 RUNNING THE DECAWAVE RANGING TEST APPLICATION

The *DecaRanging* two-way ranging demonstration application is Microsoft Windows™ software. Chapter 1 – *INTRODUCTION* gives an overview of the capabilities of the *DecaRanging* software and chapter 2 – *INSTALLATION AND SET-UP* describes the installation. This chapter describes the runtime operation of the *DecaRanging* application and its user configurations and controls.

3.1 *Running* DecaRanging

When the DecaRanging.exe executable is run on the PC, the main display window shown below is opened.[1] A user is given an option to enter a desired COM port number through which to connect to an EVK3000 board. If no valid port is given the application will proceed and connect automatically. If there are more than one EVK3000 boards plugged into the PC the application will connect to the one with the lowest COM port number first.

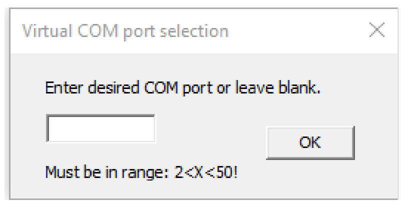


Figure 3: VCOM port selection

Figure 4 - DecaRanging main screen

[1] This assumes that communications with the DW3xxx is established. For troubleshooting see section 3.17.

Before going any further, a brief discussion of the ranging method employed is necessary to understand the operation of the *DecaRanging* application. This is covered in section 3.1.1 directly following below.

3.1.1 Ranging Method Explained

The ranging method uses a set of three messages to complete two-round trip measurements from which the range is calculated. As messages are sent and received the *DecaRanging* application retrieves the message send and receive times from the DW3XXX. These transmit and receive timestamps are used to work out a round trip delay and calculate the range.

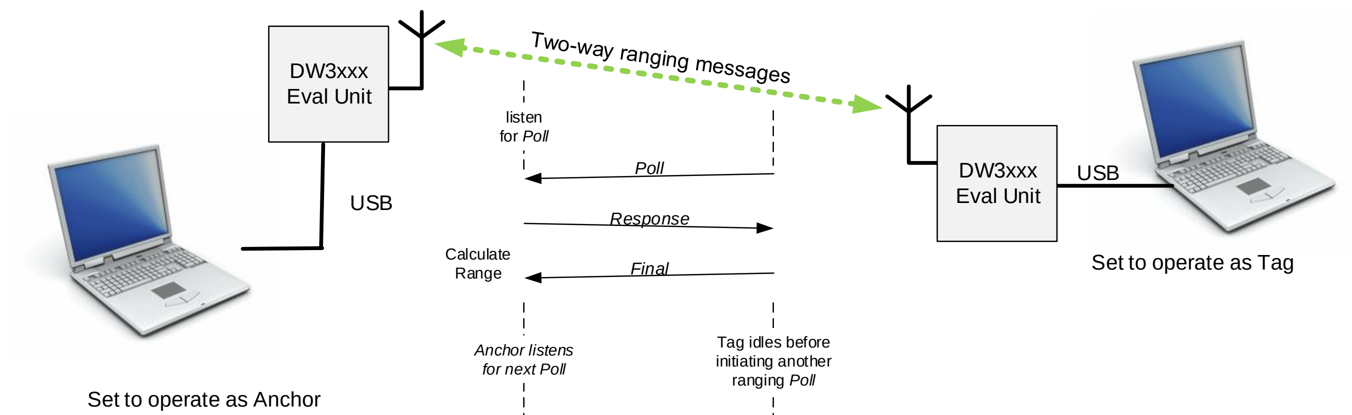
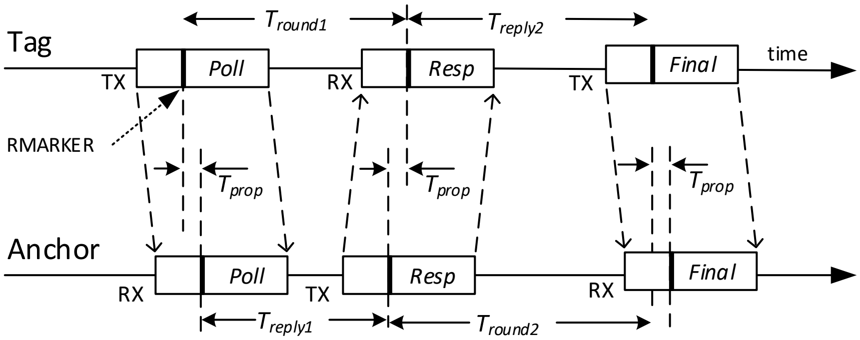


Figure 5 - ranging message exchange

In the ranging algorithm there are two roles, one end is nominated to act as a TAG and the other end is nominated to act as an ANCHOR. The anchor is predominately listening for a message from the tag. A single ranging operation is initiated by the tag sending a poll message. When the anchor receives the poll it sends a response message. The tag then receives the response message and sends a final message with embedded transmit and receive timestamps for the poll, response and the final message itself. The anchor uses this information along with its own transmission and reception timestamps to calculate two round trip times which are used get the one-hop time-of-flight which equates to the distance when multiplied by the speed-of-light (e.g. the speed of the radio waves) in air.

The anchor uses the response message to send a report of the previous calculated range back to the tag so both ends have a result that can be displayed. In a practical use of this algorithm this report may not be necessary or maybe implemented through a specific message.



The *Final* message communicates the tag's T_{round} and T_{reply} times to the anchor, which calculates the range to the tag as follows:

$$T_{prop} = \frac{T_{round1} \times T_{round2} - T_{reply1} \times T_{reply2}}{T_{round1} + T_{round2} + T_{reply1} + T_{reply2}}$$

Figure 6 - range calculation

3.1.2 Running *DecaRanging* (continued)

Initially when the DecaRanging.exe executable is run, the software starts in listener mode where it listens and reports all received messages. In running *DecaRanging* and performing the ranging message exchanges, one end needs to take the role of an Anchor while the other end needs to take the role of a Tag, however because the ranging messages include both source and destination addresses a discovery mechanism is needed for tag and anchor to learn each other's addresses and become paired. This is done according to the pairing method explained in section 3.1.3 below.

3.1.3 Pairing Method Explained

Initially the unpaired anchor and tag are in a discovery phase where the unpaired tag sends a Blink message that contains its own address, after which it listens for a Ranging Initiation response from an anchor. If it does not get one it waits for a period (default value of 1 second) before "blinking" again. The unpaired anchor listens for tag blink messages. The anchor end decides to pair with a tag and sends the Ranging Initiation message to exit from the Discovery Phase and enter the Ranging phase.

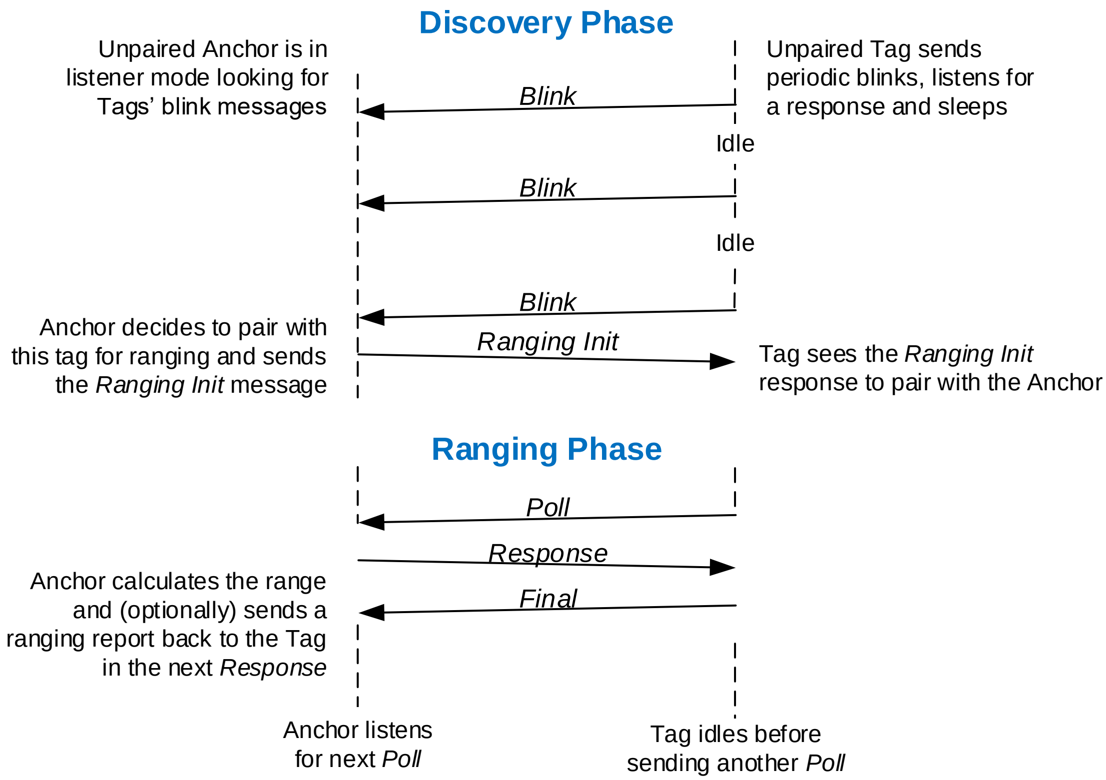


Figure 7 – progression from discovery phase to ranging phase

In the PC *DecaRanging* the program stays in *Listener* mode and reports number of blinks received. The user must choose the tag to range with when changing into *Anchor* mode.

3.1.4 Running *DecaRanging* (continued again)

If both tag and anchor ends are to be paired using PC *DecaRanging* then one end should be set to take on the role of a tag, while the other end should remain in the listener role until some tag blinks are seen, before changing into the anchor role to complete the discovery phase and enter the ranging phase of the operation. Setting the role is covered in section 3.1.5 below.

3.1.5 Setting the role

To enable the ranging function the user must reconfigure one of the ends to be the Tag and then the other to Anchor (after the Listener has received some tag blinks). This role configuration is done using the drop-down list of the Role group to the bottom left of the main *DecaRanging* window.

Figure 8 - role selection

Figure 9 – blink RX report

Note, as described above, the anchor needs to spend some time in the initial Listener role to receive some blink messages from the tag before taking on the Anchor role. The number of blinks received is reported in text just under the Role selection control.

Assuming some blinks have been received then, when anchor mode is selected an additional dialog box opens wherein the tag may be selected via its address. Use the drop-down list to select which tag this anchor should pair and communicate with during the ranging phase.

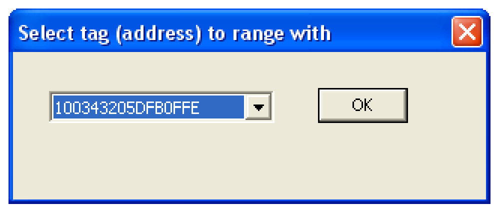


Figure 10 – tag selection by address

3.1.5.1 Listener role

In listener mode the software keeps the receiver turned on and reports (in the area above the main control panel) the contents of the received frames as simple hex dump of the frame octets. This scrolls up with the newest arriving frame displayed at the bottom. The bracketed number on the left is the frame length.

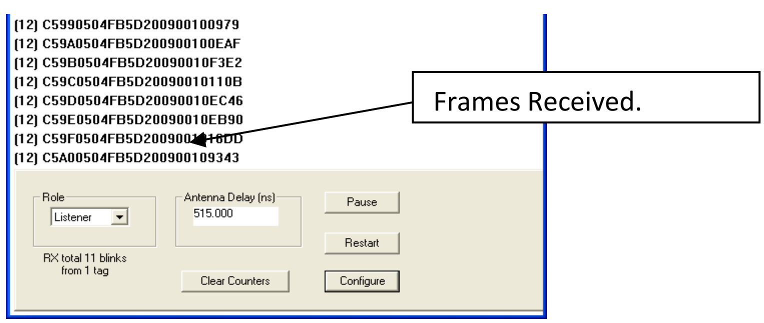


Figure 11 – received frame display in listener mode

Note: In this software following frame reception or frame error the DW3XXX stays in IDLE mode to allow reading of the accumulator data for graphical display (see section 3.6 below) which would otherwise be lost if the receiver was re-enabled. After the PC has read the accumulator data the receiver is re-enabled. The effect of this is that listener mode will not see frames that are arriving in close proximity to one another, i.e. frames arriving between a first frame arrival and the receiver being re-enabled.

3.1.5.2 Tag role

In tag mode (after selection or reset) the tag waits for 1000 ms (by default) and then sends a blink message and listens for a “Ranging Init” response from the anchor to initiate pairing. The tag will return to idle if no response is received. When the “Ranging Init” response is received, the tag is paired with the responding anchor. Once paired the tag will wait for 1000 ms (by default), and then initiates a ranging exchange.

The two periods mentioned above can be altered via the timing configuration dialog (see section 3.4 below).

3.1.5.3 Anchor role

After being in Listener mode and receiving some tag blinks the user may set anchor mode, and select the tag to pair with. After this the anchor remains with its receiver enabled waiting for a poll message from the selected tag, to initiate another two-way ranging exchange.

The result of each two-way ranging is a distance estimate displayed on the anchor screen. The ranging result is also sent back to the tag end for it to display, through the response message of next ranging exchange.

3.1.5.4 TDoA tag role

A TDoA tag will continuously transmit blinks, the tag will never enter reception, and thus cannot range. This mode can be used in TDoA systems, or a TX only test mode.

3.1.5.5 Node role

After being in Listener mode and having received some tag blinks the user may set node mode, and select the tag to pair with. After this the node remains with its receiver enabled waiting for a poll message from the selected tag, to initiate a two-way ranging exchange. The node messages are compatible with a Slotted TWR demo tag application running on an embedded platform. The node will not range with a DecaRanging tag application, anchor, as explained above, should be used for that.

The user controls available within the *DecaRanging* PC application are described below.

3.2 DecaRanging *Main Window Display and Controls*

This section discusses the main elements of operation and functionality available in the *DecaRanging* test and demonstration application.

3.2.1 Status and Statistics report

When the ranging is running the lines at the top of the main window give a status report that indicates count of frames successfully sent and received, and also reports current most recent ranging measurements performed. Figure 12 is a screen capture to show what this might look like in an anchor after a number of messages are exchanged.

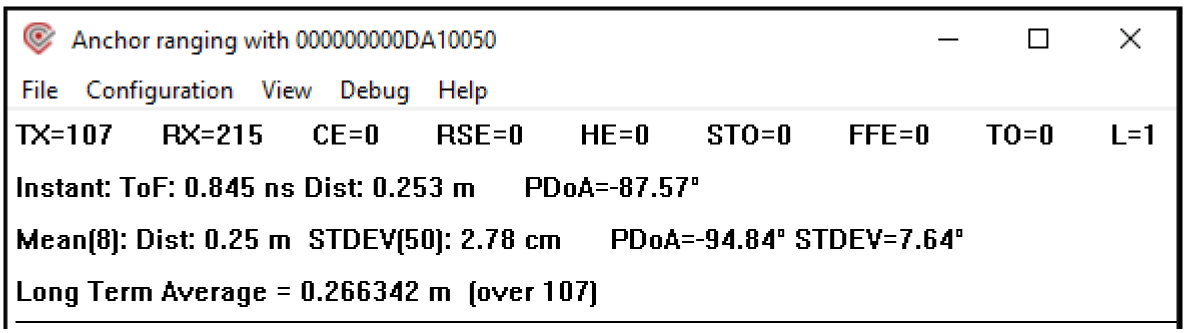


Figure 12 - status and statistics panel

The status information of Figure 12 is described below with reference to the Figure 13 and Figure 14 where the red text is used to identify the changing numeric values reported by the application.

TX=T RX=R CE=c RSE=r HE=h STO=s FFE=e TO=o L=L

Instant: ToF: fff.ff ns Dist: ddd.dd m PDoA: ppp.pp°

Mean(8): Dist: hhh.hh m STDEV: gg.gg cm PDoA: aaa.aa° STDEV: bb.bb°

Long Term Average = xx.xxxx m (over yyy)

Figure 13 - status and statistics panel fields in Anchor/Tag roles

TX=T RX=R CE=c RSE=r HE=h STO=s PREJ=p TO=o L=L

Instant: ToF: fff.ff ns Dist: ddd.dd m PDoA: ppp.pp°

Mean(8): Dist: hhh.hh m STDEV: gg.gg cm PDoA: aaa.aa° STDEV: bb.bb°

Long Term Average = xx.xxxx m (over yyy)

Figure 14 - status and statistics panel fields in Listener role

On the first line then:

- Value **T** is the number of frames transmitted (TX).
- Value **R** is the number of frames received, (with good CRC = RX).
- Value **c** is a count of CRC errors (CE).
- Value **r** is a count of unrecoverable errors in the Reed Solomon decoder (RSE).
- Value **h** is count of uncorrectable errors detected in the PHY header SECDED code (HE).
- Value **s** is count of SFD timeout events (STO).
- Value **e** is the number of frame filtering errors. (These will occur if the destination address is incorrect i.e. not for this device = FFE).
- Value **p** is the number of preamble rejection events. (These will occur if the preamble detection has not been confirmed while device is looking for preamble = PREJ).
- Value **o** is the number of times the Tag has timed out from receiving without getting a response frame. This results in another transmission attempt, (incrementing **T**).
- Value **L** is a count of late TX enables and late RX enables. These can occur in the delayed transmission and reception. If this happens frequently (and not as a result of user menu activity) then it probably means that the response time configuration needs to be increased.

The 2nd and 3rd lines are similar in function, except that while the 2nd line reports a single instantaneous value, the 3rd line reports a mean (or average) value. On these 2nd and 3rd lines then:

- Value fff.ff is the measured time of flight in nanoseconds.
- Value ddd.dd is distance in metres. This is value fff.ff multiplied by 299,702,547.0 which is the speed of light in air.
- Value gg.gg is the standard deviation of the calculated distance (of last 50 range values) in centimetres.
- Value ppp.pp is the measured PDoA in degrees. **Will only be valid when PDoA modes are used and device is a PDoA supported device e.g. DW3x2x.**
- Value aaa.aa is the average PDoA in degrees. Average of last eight values.
- Value bb.bb is the standard deviation of the calculated PDoA (of last 50 PDoA measurements) in degrees.

The averaging of the 3rd line is the mean of the last eight values (hhh.hh).

The 4th line is reports a long term average of the instantaneous distance measurements, giving the average value xx.xxxx in metres, and indicating over how many readings yyy this has been averaged.

NOTE: The distance estimates are from antenna to antenna, see section 3.2.2.3 for details of antenna delay setting.

NOTE: With respect to the receiver error conditions counted above: An SFD timeout typically results from a false detection of preamble, where the subsequent expected SFD is not detected. PHY header errors may result from either a real error in the PHR or, after a false detection of preamble and/or SFD. Reed Solomon errors and CRC errors indicate problems in data recovery. Typically frame reception is aborted at the earliest error detected so CRC error may not be counted if an earlier PHR or Reed Solomon has already aborted reception.

3.2.2 Main Controls

The main controls are in a panel on the bottom of the main window.

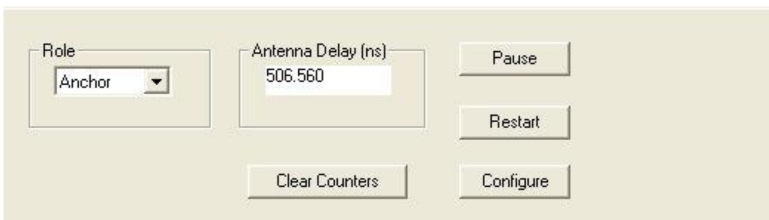


Figure 15 - main controls

3.2.2.1 Role

The *Role* group is used to select whether the application acts as the Listener, TDoA Tag, Tag, Anchor or Node. Role selection is covered in section 3.1.5 above.

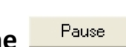
3.2.2.2 Restart

The 

button may be used at any time to reset the software and start again. There is also a “Soft Reset (and Restart)” option, see section 3.13, which additionally performs an IC reset.

3.2.2.3 Antenna Delay

The antenna delay entry box is designed to allow for setting the delays to and from the antenna so that these may be subtracted from the round trip. The value specified here is used to correct the reported message send and receive times, half in the transmitter and half in the receiver, compensating for the system delays between physical timestamp and signal presence at the antenna.

NOTE: When changing this value on a Tag instance the application needs to be PAUSED first. (Press the 

button before changing the value.) If this is not done the value will not be correctly applied.

In the EVK3000 kits the boards have not been calibrated and the default IC's antenna delay is displayed in the antenna delay panel.

The value can be recalibrated if necessary (e.g. due to change in antenna) as follows:

a) Position the two units some distance apart (not too close, say 3 metres apart).
b) Run the *DecaRanging* application at each end setting one to the Tag and the other to Anchor role so that ranging is done and range measurements are being reported.
c) Using a tape measure, accurately measure the antenna to antenna distance between the antennas of the two units. Without disturbing the boards.
d) Use the Clear Counters button to clear the measurement averages. Without obstructing the line-of-sight path between the units, observe the reported range average converges to a good agreement with the tape measured value. If it doesn't, then it is possible to change the antenna delay value to improve this. The value is a decimal value in nanoseconds. After typing new value use "Enter" key to apply the change. Each nanosecond change (when applied at both ends) gives 30 cm difference in range.
e) It is recommended that the same value is programmed at each end. After the antenna delay is changed (at both ends), the Clear Counters button can be used to clear the measurements, and the long term average can be observed to verify that the new antenna delay setting is giving a better average distance measurement agreeing with the manually measured distance.

3.2.2.4 Other Main Panel Buttons

The other main panel buttons are fairly self explanatory. The Clear Counters button clears the counters and values reported on the status lines, as described in section 3.2.1 above. The Pause button disables all activity in the lower layer application state machine, essentially halting all sending and all receive processing. When the pause is active the Pause button changes to a Resume button which may be used to resume activity. The Configure button opens the Channel Setup dialog, (see section 3.3 below for details), which is the same dialog reached via Configuration – Channel Setup menu.

3.3 Configuration – Channel Setup

This section describes the configurable items that appear on the Channel Setup dialog box accessed via either the main panel Configure button or via the Configuration menu's *Channel Setup* option. Figure 16 shows the Channel Setup dialog box.

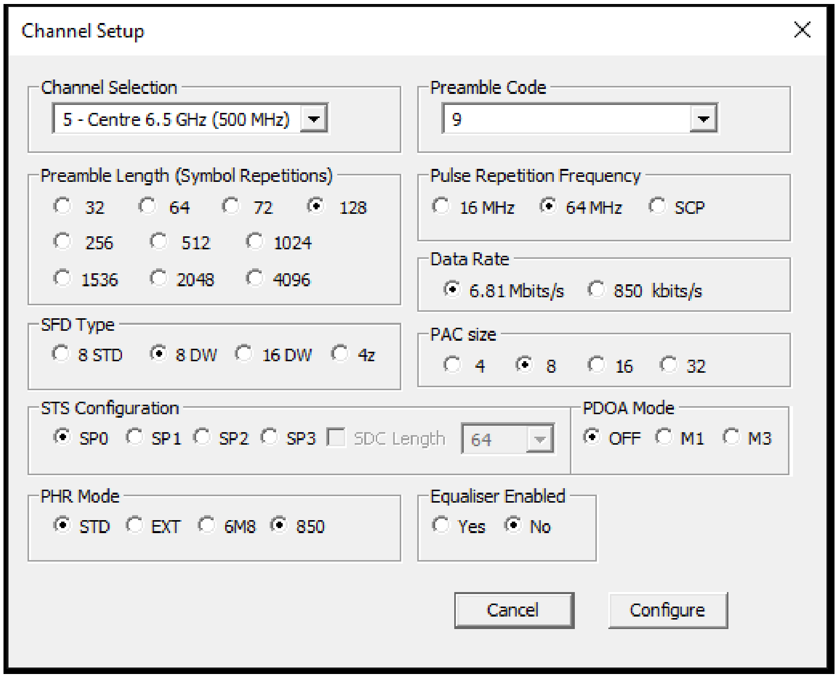


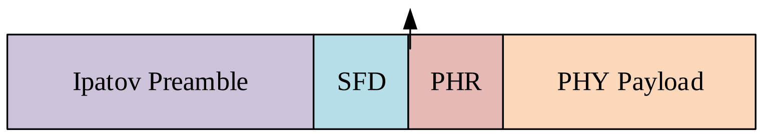
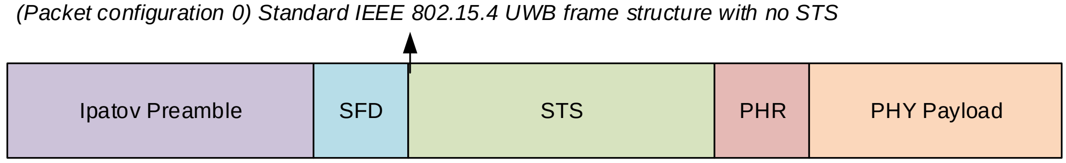
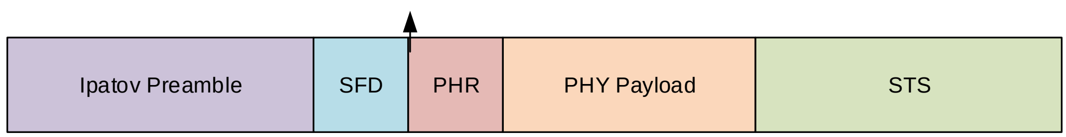
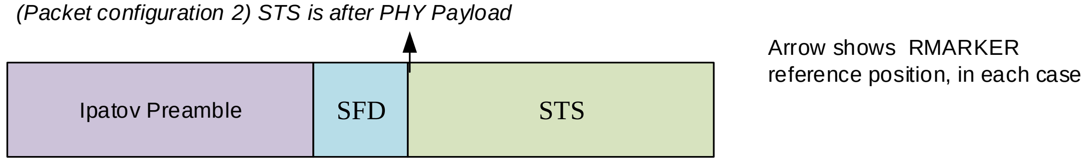
Figure 16 – channel setup configuration dialog box

The Channel Setup dialog box allows for the configuration of all the parameters controlling the format of 802.15.4 messages. **The configurable items are described in Table 1 below**.

Table 1 - channel setup dialog elements

Item	**Description and Notes**
Channel Selection	This is a drop down list for selection of the operating channel. The applicable centre frequency and bandwidth is also shown for convenience.
Preamble code	The Channel Selection in conjunction with the configured Preamble Code defines the *Complex Channel* for the inter device communication. The preamble codes offered in this drop-down list change depending on the Channel Selection NB: For good communication and ranging, both units must have the same Complex Channel configurations.

Item	Description and Notes
Preamble length	The preamble length is set here. Longer preambles make it easier for the receiver to lock to the message improving the channel matching and the first path determination, hence increasing the viable communications range and the accuracy of ranging measurements at that communications range. Preamble lengths of 64, 1024 and 4096 are defined in the IEEE 802.15.4 standard. The additional preamble lengths provided by the DW3XXX allow designers more opportunity to optimise system performance trade-offs. Ideally the same preamble length should be set at both ends to give a balanced communications range, set to be consistent with the data rate. For long range at the 850 kbps data rate one would use a preamble of 1024 (or more) symbols, while at the 6.8 Mbps data rate a long preamble will bring no benefit and a shorter preamble would be used in practice to save power and air-time (increasing network capacity).
SFD type	This tick box enables the use of either standard 8-bit SFD or non-standard SFDs. The SFD is the component of the IEEE 802.15.4 UWB frame marking the end of the preamble and the start of the data frame, which is actually a certain pattern of normal, inverted and deleted preamble symbols. Decawave has found an alternative SFD pattern that is more robust than the one defined in the IEEE 802.15.4 standard, giving an extra dB or so of performance. There is also an option to select IEEE 802.15.4z SFD type when operating in 4z mode.
Pulse Repetition Frequency	This selects the Pulse Repetition Frequency to be used in the transmitter and receiver. NB: both units need the same PRF configuration setting. The SCP is Decawave’s non-standard compressed packet mode, with frequency of approx. 100 MHz.
Data Rate	The data rate may be selected to be any one of the data rates available here. For optimised performance both units/devices need the same data rate setting.

Item	**Description and Notes**
STS mode (packet type) and length configuration	The DW3XXX supports four packet formats, the IEEE802.15.4 standard [1] packet format, and three new IEEE802.15.4z amendment [3] defined formats where a scrambled timestamp sequence (STS) is introduced into the packet as shown. When the STS modes are enabled the DW3XXX transmitter will insert the STS in the position shown:  *(Packet configuration 0) Standard IEEE 802.15.4 UWB frame structure with no STS*  *(Packet configuration 1) STS follows SFD with PHR and PHY Payload*  *(Packet configuration 2) STS is after PHY Payload*  *(Packet configuration 3) STS with no PHR or PHY Payload* SP0 = packet configuration 0 – this disables the STS SP1 = packet configuration 1 – this enables the STS mode where the STS follows SFD and comes before the PHR. SP2 = packet configuration 2 – this enables the STS mode where the STS follows the data payload. SP3 = packet configuration 3 – this enables the STS mode where the STS follows SFD and STS ends the packet. There is no PHR or PHY Payload. When STS modes are used the length of the STS can be set from the pulldown menu. The available lengths are: 64, 128, 256, 512, 1024 and 2048. The same STS mode and length MUST be set at both ends for correct interworking. The Super Deterministic Code (SDC) can be used with STS, this means that the two units do not need to have the STS KEY/IV pairs synchronised. The STS code is a pre-programmed code inside the DW3XXX. The STS KEY and IV are ignored in this case.

Item	Description and Notes
PAC	Preamble Acquisition Chunk, group of preamble symbols which are correlated together in the preamble detection process in the receiver. See DW3000 User Manual for further details. Preamble acquisition chunk size, this should be set to 8 or 4 when preamble length is <=128, to 16 for preamble length of 256 and 32 for greater preamble lengths.
PDOA Mode	The PDOA parts of the DW3XXX families can optionally enable PDOA mode of operation. M0 this means the PDOA mode is disabled. When using mode 3 (M3) the STS length should be twice as long, as for modes 1.
PHR Mode	The DW3XXX supports either STD (up to 127 bytes) or EXT (extended data frames, up to 1023 bytes) The PHR can be sent at either nominal 850 kbps rate or at higher datarate when using 6.81 Mbps. Sending at higher rate means the frames will take less air time, and thus use less power/allow for greater capacity. Both units have to have the same PHR rate selected.
Equaliser Enabled	QM33120 also supports an internal equalizer, which when enabled will adjust the CIR to give improved receive timestamp results when the remote transmitter is using a Symmetric Root Raised Cosine pulse shape. Normally, this should be disabled (the default value), which gives the best receive timestamp performance when interworking with devices (like this IC) that use the IEEE 802.15.4z recommended minimum precursor pulse shape.

Two buttons are provided: (a) The Cancel button to escape from and close the Channel Setup dialog without making any changes, and, (b) The Configure button to apply the changed configuration to the DW3XXX, which resets everything including the counters to start again with the modified configuration.

3.4 Configuration – Timing Setup

Timing configuration is selectable from Configuration menu's *Timing Setup* menu option

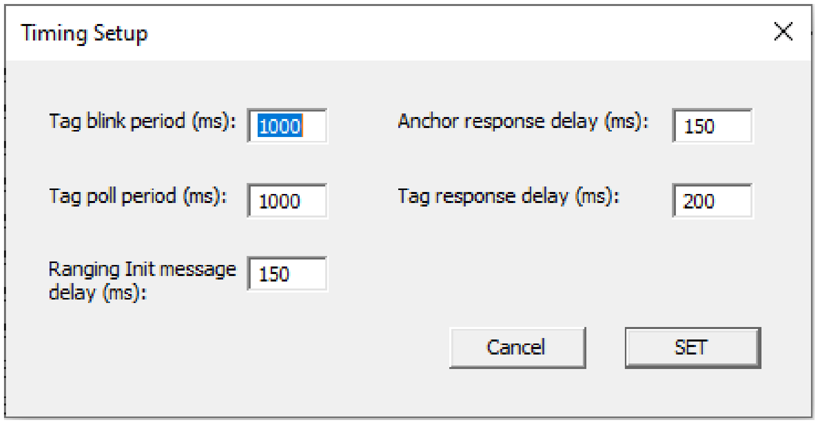


Figure 17 - Timing setup configuration

The timing setup dialog is used to configure certain parameters of the tag and anchor message interactions use during the two-way ranging measurement and reporting.

The configurable items are described in Table 2 below.

Table 2 - Timing setup dialog elements

Item	**Description and Notes**
Tag blink period:	This sets the time for which the tag waits between the blinks that are sent while the tag has not been paired with an anchor. See section 3.1.3 above for details.
Tag poll period:	This sets the time for which the tag waits between ranging attempts. See 3.1.1 above.
Anchor response delay:	This sets the response delay used in anchor for sending the response to the tag poll message. **This can be set only at anchor end and before a ranging exchange has been started.** The time required relates to the responsiveness of the PC. The default 150 ms is good for most reasonably new machines. With older slower PC this may need to be increased to get reliable ranging interactions (e.g. a value of 300 ms might be sufficient). The “L=” error count in the status display may be an indication that the response time is too low. See 3.2.1 above.

Item	Description and Notes
Tag response delay:	This sets the response delay used in tag between receiving the anchor response and sending the final message. **This can be set only at anchor end and before a ranging exchange has been started.** The time required relates to the responsiveness of the PC. The default 200 ms is good for most reasonably new machines. With older slower PC this may need to be increased to get reliable ranging interactions (e.g. a value of 300 ms might be sufficient). The "L=" error count in the status display may be an indication that the response time is too low. See 3.2.1 above.
Ranging Init message delay	This sets the Ranging Init message response delay. The default value is 150 ms. See 3.1.3 above for more details.

3.5 Configuration – STS KEY/IVSetup

STS KEY/IV configuration is selectable from Configuration menu's *STS KEY/IV Setup* menu option

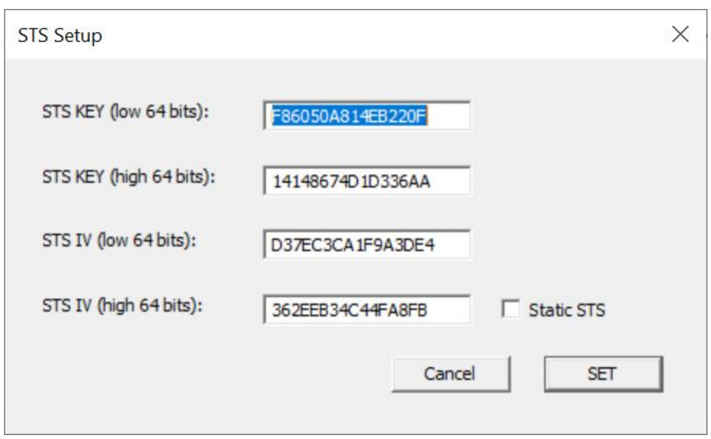


Figure 18 – STS KEY/IV setup configuration

The STS setup dialog is used to configure the STS 128-bit key and 128-bit initial value, (in hexadecimal).

The configurable items are described in Table 3 below.

Table 3 - STS setup dialog elements

Item	Description and Notes
STS KEY (low 64 bits):	The low 64-bits of the STS KEY (128-bit value) can be set here in hexadecimal.
STS KEY (high 64 bits):	The high 64-bits of the STS KEY (128-bit value) can be set here in hexadecimal.
STS IV (low 64 bits):	The low 64-bits of the STS IV (128-bit value) can be set here in hexadecimal.
STS IV (high 64 bits):	The high 64-bits of the STS IV (128-bit value) can be set here in hexadecimal.
Static STS	When set the STS will be reset to the initial value prior to sending Blink message in the Tag application) and prior to enabling receiver in Listener application.

3.6 View – Channel Response View Enable

Selecting the Channel Response View Enable opens a panel in the middle of the main window into which it the Channel Response values are drawn graphically. Figure 19 shows a typical channel impulse response graphic. The channel response is an array of complex values, the red line is the plot of the real values, the green line is the imaginary values, and the blue line is the computed magnitude values. This graphing shows the DW3XXX's view of the channel impulse response. The graphic also indicates with a vertical orange line where the DW3XXX finds the leading path. In normal operation of the DW3XXX there is no need to access this channel impulse response data, which is quite a lot of data, doing so will slow down system responsiveness. The hardware reported RX timestamp is accurate and is all that is needed.

When the channel impulse response display is active, it is possible to zoom in and out using a mouse with a wheel. Make sure the *DecaRanging* application has focus (i.e. is the selected application). Then move the mouse pointer to a particular point over the graph and move the mouse wheel up (away from you) to zoom in on the X-coordinate frame. The zoom uses the mouse position to decide where to zoom. Move the wheel down (towards you) to zoom out again. Holding CTRL while moving the mouse wheel zooms on the Y scale. This Y zoom acts to keeps the graph centred between selected –Y and +Y values, (i.e. max plus and minus are increased/decreased at the same rate).

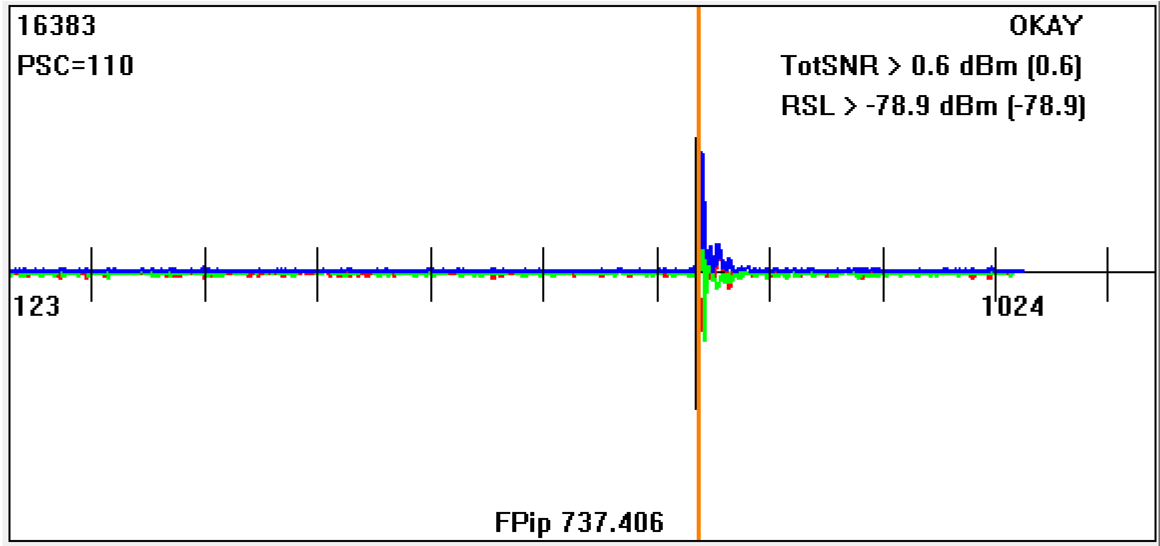


Figure 19 – Ipatov preamble channel response view

The view menu has an option for *Channel Response First Path Align*, which is on by default. The view menu also has an option for *Channel Response Only Show Magnitudes* which is self-explanatory. When zoomed in on the Magnitude Only display mode, markers indicating individual nanosecond sample intervals are added to the curve displayed. Deselecting Channel Response View removes the panel and stops the graphing display.

The top-left number is an indication of the height of display max-amplitude. The PSC number indicates the number of preamble symbols accumulated.

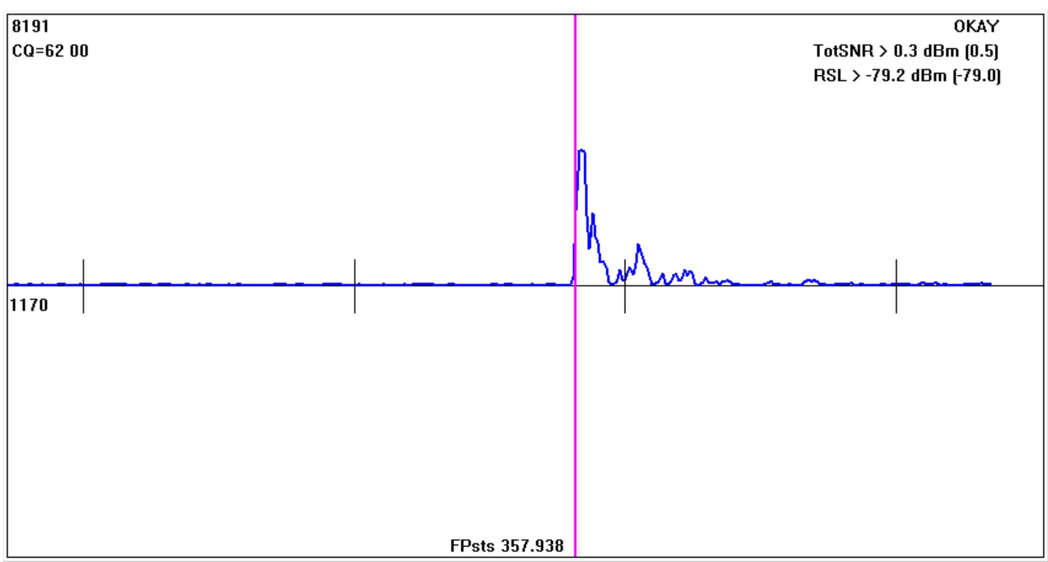


Figure 20 - STS preamble channel response view

Selecting the *STS Channel Response View Enable* opens a panel in the middle of the main window into which it the STS channel response values are drawn graphically (Figure 20). This view is only available when operating in STS modes. The top-left number is an indication of the height of display max-amplitude. Underneath this is the STS quality index, followed by the STS status bits.

The numbers below the mid line are accumulator index (nanosecond) values, while the FPip value (in Figure 19) beside the orange line is the DW3XXX IC reported leading path (sub-nanosecond) position for the Ipatov CIR, while the number in Figure 20 is FPsts value, is the leading path of the STS CIR. The SNR and RSL values are calculated from diagnostic values reported by the DW3XXX (please refer to the DW3XXX user manual for more details of these). Moving average of the last 10 values is reported beside their instantaneous value as shown in Figure 19 and Figure 20.

3.7 View – Display Distance in Feet and Inches

Selecting this menu option appends a bracketed value in feet and inches to both *Instant:* and *Mean(8):* status lines, which is a conversion of the corresponding meter distance reported by each.

3.8 View – Large Text Range Display Enable

Selecting the Large Range Display Enable view menu option opens a panel in the middle of the main window into which the range (distance) estimates are displayed in metres using in a very larger font to make it clearly visible from a distance, especially when the window is maximised. The view menu has options to select the most prominent value (i.e. the largest figure shown at the top of the panel). The options are: the average of 8 range measurements (this is the default), the average of 4 range measurements or the instantaneous range measurement. There is also an option to set the precision of the value displayed to have 2 decimal places, instead of (the default) 1 decimal place.

Optionally if “Large Display show PDoA info” is selected, the PDoA as well as range information will be displayed.

3.9 View – Display Clock Offset

Selecting the Display Clock Offset, will display the clock offset (CO) in ppm between the two ranging units. The devices can estimate the clock offset during a reception of a packet. However, the anchor instance also calculates the offset based on the TWR exchange which will be reported after the reception of the final message. Note: the TWR clock offset result is only valid in good line of sight conditions, where the distance report is stable. On the tag and listener only the CO estimated while receiving packets is displayed, while on the anchor both are displayed.

3.10 Debug – Register Access

This is a facility sometimes used by engineers for debug purposes. In general it is NOT recommend for customers to experiment with this unless directed to do so by Decawave support engineers. Selecting the *Debug - Register Access* menu opens the Low-Level Register Access dialog.

Debug Register Access is only allowed when the normal operation has been suspended, i.e. paused using the 

button in the main control panel – if this is not done then the *Register Access* menu item will be greyed out and unavailable.

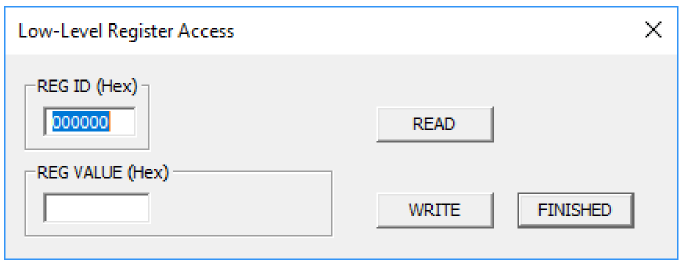


Figure 21 - low-level register access dialog

A hex register ID (00 to 3F7FFF) is set in the REG ID field. The READ button initiates the read and displays the result in the REG VALUE area. The REG VALUE may be changed by the user. The WRITE button writes the current REG VALUE to the register selected by REG ID. The FINISHED button closes the dialog.

Note:

(a) Not all registers values in the above range are present, and some are write-only/red-only.

(b) Writing incorrect values to certain registers can upset operation completely. The only recovery from this is to reset the unit by exiting the *DecaRanging* application and removing (and restoring) power, and restarting the *DecaRanging* application.

3.11 Debug – Log Channel Responses

This log operation opens an automatically named text file and then information about transmitted and received data frames (including the channel impulses data) is dumped into the file. This has proved a useful aid to debugging. The log file format is described in the APPENDIX 1 – Channel Response Log.

When Logging is enabled a 

button appears on right hand side of the main control panel, defined in section 3.2.2 above. This can be used to discontinue logging and close the log file. The default ranging rate is 1 Hz, thus one may log for few minutes to get few hundred CIR logs.

3.12 Debug – Log SPI Activity

This log operation opens an automatically named text file and then records all SPI traffic in the file. This may be useful to debugging or understand the SPI accesses used to drive the IC.

When Logging is enabled a STOP LOGGING button appears on right hand side of the main control panel, defined in section 3.2.2 above. This can be used to discontinue logging and close the log file.

NOTE: Only one logging activity is allowed, so starting an SPI log will close the cannel responses log and vice versa.

3.13 Debug – Soft Reset (and Restart)

In the case of an issue where the software Restart button does not seem to resolve it, then this *Soft Reset (and Restart)* menu option might be successful in resolving the issue. This resets the hardware using a software (SPI) accessible register and then restarts the DecaRanging software. If this fails to resolve the issue after two attempts, then to recover close the DecaRanging application and power off the EVK3000 boards a few seconds before restarting again.

3.14 Debug – Continuous Frame Mode

The continuous frame (transmit power spectrum test) mode is used in TX power spectrum measurements. This test mode is provided to help support regulatory approvals spectral testing. Please consult with Decawave applications support team for details of regulatory approvals considerations. To calibrate the transmit power the user needs to configure the channel parameters though the Channel Configuration menu (section 3.3) and then put the device into continuous frame mode to measure the power spectrum. DW3XXX user manual describes the DW3XXX calibration options in more detail.

3.15 Debug – Continuous Wave Mode

The continuous wave (CW test) mode is used in XTAL trim and calibration measurements. This test mode is provided to help support the calibration testing. Please consult with Decawave applications support team for details of DW3XXX calibration. To calibrate the crystal oscillator's operating frequency the user needs to configure the channel parameters though the Channel Configuration menu (section 3.3), and any other register values through the 3.10 Debug – Register Access configuration and then put the device into continuous wave mode to measure the centre frequency. QM33120/DW3000 user manual describes the devices' calibration options in more detail.

3.16 Keyboard shortcuts

The various menu selections may also be enabled via the following keyboard short-cuts:

KEY	ACTION
R	Open Low-Level Register Access Dialog
A	Toggle Channel Response View Panel On/Off
C	Open Channel Configuration Dialog
P	Toggle Pause (Resume) On/Off
L	Toggle large range display View Panel On/Off
<ctrl-L>	Toggle debug log of channel responses On/Off

3.17 Troubleshooting

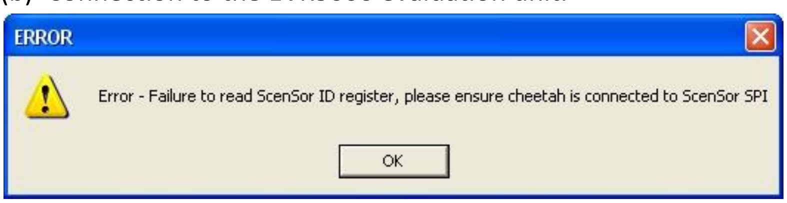
Error messages and recommended actions

(a) Connection to the board

Check USB cable is connected to the EVK3000

Install drivers as described in section 2 above.

(b) Connection to the EVK3000 evaluation unit.



Check the evaluation unit is powered up and that the cheetah is correctly connected to the evaluation unit.

Refer to the separate evaluation unit user guide for details of how to set up the units and connect power and cheetah, etc.

(c) For other issues try a restart as defined in section 3.2.2.2, if that fails try a this *Soft Reset (and Restart)* see section 3.13, and if that fails after two attempts then exit the DecaRanging application and power off the evaluation unit board(s) for a few seconds before restarting again.

(d) If you are getting poor performance please check that you have both ends configured for the same channel and preamble code, preamble length etc. Also please make sure that the antennas are not loose.

(e) If the application does not start up properly this may be because of a conflict on the virtual COM port. To resolve this, go into Windows Device Manager. If the EVB is connected the “Ports (COM and LPT)” options should be visible. Inside this, the "STMicroelectronics Virtual COM Port (COMX)" should be seen (where X is the port number). If there are other devices with lower COM port numbers than the "STMicroelectronics Virtual COM Port (COMX)", please select "STMicroelectronics Virtual COM Port (COMX)", and right click into Properties, go to Port Settings tab and click Advanced. Here a different port number can be selected to be associated with this port. Set the "STMicroelectronics Virtual COM Port (COMX)" to a lower COM port number than any other connected devices. The port number must be in the range 3 to 49.

4 APPENDIX 1 – Channel Response Log

When the logging of the channel responses is enabled, the application will create a log file in which:

a. TX and RX timestamps of each sent/received frame are recorded
b. The accumulator/CIR samples of each received frame

The log file can be found in the same folder from which the executable is run and the name is of the format:

yyyymmdd_hhmmss_DecaWaveAllAccum.log

The figures and tables below show how to interpret the data in the log files.

4.1 Log File Header

Log file header is shown in Figure 22 below.

```
File:20160125-155917_DecaWaveAllAccum.log, created by DecaRanging MP Version 3.06 (build:Oct 14 2015, 11:55:02)
Mode: 0, Chan 2, Code 9, PRF 64, Plength 1024, DataRate 1, PAC 2, ic:1000099d, ucode:xxxx, antdl:8078
```

Figure 22 - Log file header for Listener in default configuration

Line 1 prints the file name, application name and version, and line 2 contains the mode of operation as defined in the table below.

Table 4 - Log file header fields

Item	**Description and Notes**
Mode	0 = Listener 1 = Tag (TWR tag, when ranging to an anchor) 2 = Anchor 3 = Tag TDOA (before it pairs to the anchor, i.e. when sending blinks)
Chan	This is the configured channel
Code	This is the configured preamble
PRF	This is the configured PRF 16 or 64 MHz
Plength	This is the configured preamble length
DataRate	This is the configured data rate

Item	Description and Notes
PAC	This is the configured PAC (0, 1, 2, 3 which correspond to 8, 16, 32 or 64 symbols)
ic	This is the 32-bit DW3XXX part ID, see dwt_getpartid API function description
ucode	Reserved
antdl	Antenna delay value, as programmed in OTP or set by the application

4.2 TX Timestamps

The TX timestamp of each transmission is logged as shown in Figure 23. Only the adjusted timestamp is logged (i.e. raw + TX antenna delay (half of the *antdl* value). The adjusted time stamp is a 40-bit hex number (DW3XXX system time) logged as “TX Frame Timestamp Raw” and “Adding Antenna Delay” and is also converted to second format and logged as “Tx time”.

```
TX Frame TimeStamp Raw  = 27 10EF903C
   Adding Antenna Delay = 0027 10EF903C
00 Tx time = 2.625886731708233e+000
```

Figure 23 - TX timestamps

4.3 RX Timestamps

The RX timestamp of each valid frame reception is logged as shown in Figure 24. The “Rx time” is the adjusted RX timestamp (time calculated by the microcode engine in the DW3XXX), the “Rx time (un)” is the raw timestamp (at SFD detection). Both 40-bit hex number and its floating point seconds conversion are given.

```
C5 D2 Rx time = 4.191123923105093e+000 3E5A49D335

C5 D2 Rx time(un) = 4.191124158653846e+000 3E5A4A0E00
```

Figure 24 - RX timestamps

4.4 RX Data

The received frame data is also logged for each received frame, the frame payload starts with “RX DATA:” followed by the received number of bytes (as read by the dwt_readrxdata function in the RX callback).

4.5 Channel Impulse Response (CIR) Data

The accumulator contains complex values, a 32-bit real integer and a 32-bit imaginary integer, for each tap of the accumulator, each of which represents a 1 ns sample interval (or more precisely half a period of the 499.2 MHz fundamental frequency). When STS mode is enabled there are two separate accumulations of CIR; one during the Ipatov sequence and the other during the STS sequence. The Ipatov sequence begins at offset 0 and has a span of one symbol time (This is 992 samples for the nominal 16 MHz mean PRF, or, 1016 samples for the nominal 64 MHz mean PRF). The STS sequence begins at offset 1024 and has a span of half a symbol time (512 samples irrespective of PRF setting). “Accum Len” specifies how many samples follow.

```
RX OK WInd(0735), HLP(0749.0625), PSC(1023), SLP(0000.0000), RC(003E 5A49D335), DCR(0), DCI(0), NTH(03C8), T(7CB9), RSL(-084.8029), FSL(-103.1762), RSMPL(3C)
Accum Len 992
392, 18
380, 85
198, 124
132, 90
154, 92
231, 92
243, 64
...
73, 74
198, 131
89, 167
34, 183
150, 155
232, 44
```

Figure 25 - CIR data for good reception

```
RX Ex WInd(0735), PSC(1002), CE(0000), RSE(0002), HE(0012), STO(0000), FFE(0000), T(7CBA), RSL(-083.8314), FSL(-093.9841), RSMPL(00)
Accum Len 992
132, 80
-27, 128
-85, 49
-1, 7
74, 85
142, 108
```

Figure 26 - CIR log for error frame

The accumulated CIR data is logged as shown in Figure 25 and Figure 26, there are two basic types. Each CIR log of the good frame reception starts with “RX OK” and then a number of diagnostic parameters (as described in table below) followed by the real and imaginary components of the accumulator complex samples. When an error is received the CIR log will start with “RX Ex” as is shown in Figure 26.

Table 5 - CIR header data field descriptions

Item	Description and Notes
CP	This is the STS quality index when STS mode is enabled, if this is < 90% of the length of the STS then the STS reception can be considered as bad.
HLP	This is the index in the accumulator (Ipatov CIR) at which the leading edge is detected (the FP_INDEX value reported in CIA register (CIA_I_FPIX_OFFSET)
CPHLP	This is the index in the accumulator (STS CIR) at which the leading edge is detected (the CP_INDEX value reported in CIA register (CIA_C_FPIX_OFFSET)

Item	Description and Notes
PSC	This is the number of accumulated symbols of the Ipatov preamble as reported in CIA register (CIA_I_NACC_OFFSET)
SLP	N/A
RC	This is the receive timestamp – same as “Rx time” see 4.3
DCR, DCI	N/A
NTH	Noise threshold (LDE_THRESH value reported in LDE_IF register)
T	Temperature and voltage read with dwt_readtempvbat API function at time of reception
RSL, FSL	*RX Level* and *First Path Power Level* as described in DW3XXX User Manual (dBm)
RSMPL	RSMPDEL as reported in RX_TTCKO register
TI	Timing integrator value
CI	Carrier integrator value
CE	Number of CRC errors (same as EVC_FCE in register DIG_DIAG)
RSE	Number of Reed Solomon errors (same as EVC_RSE in register DIG_DIAG)
HE	Number of PHY header errors (same as EVC_PHE in register DIG_DIAG)
STO	Number of SFD timeouts (same as EVC_STO in register DIG_DIAG)
FFE	Number of frame filter rejections (same as EVC_FFR in register DIG_DIAG)

4.6 ToF Data

Time of flight (ToF) data is also logged, see Figure 27 below.

```
Anchor ToF: 9.164 ns Dist: 2.746600 m DistRaw: 2.626600 m DistScal: 2.626600 m Bias: -0.120 m ClockOffset: 2.411 ppm
```

Figure 27 - ToF and clock offset data

Table 6 below describes individual fields.

Table 6 - TOF data fields descriptions

Item	Description and Notes
ToF	Time of flight in nano seconds
Dist	Range calculated from the ToF value and corrected for the range bias (as per relevant table in deca_range_tables.c) in meters
DistRaw	Raw range (not correct for range bias) in meters
DistScal	Scaled range before applying the correction for smart TX power use case
Bias	Range bias correction applied
ClockOffset	Calculated clock offset between the tag and anchor clocks, in ppm.

5 APPENDIX 2 – BIBLIOGRAPHY:

1	IEEE 802.15.4-2011 or "IEEE Std 802.15.4™-2011" (Revision of IEEE Std 802.15.4-2006). IEEE Standard for Local and metropolitan area networks— Part 15.4: Low-Rate Wireless Personal Area Networks (LR-WPANs). IEEE Computer Society Sponsored by the LAN/MAN Standards Committee. Available from http://standards.ieee.org/
2	DW3XXX API User Guide
3	QM33120/DW3000 User Manual

6 DOCUMENT HISTORY

Table 7: Document History

Revision	Description
1.0	First release for DW3XXX
1.1	Updated release for DW3XXX updated figures to match the latest GUI (rev 2.10). Updated "Status and Statistics report" section to add PDoA details, updated Clock Offset description and Large Range/PDoA value description.
1.2	Updated to match the latest DecaRanging application which uses unified DW3xxx API/driver and can support both DW3000 and QM33120 device families.

7 ABOUT DECAWAVE

Decawave is a pioneering fabless semiconductor company whose flagship product, the DW3XXX, is a complete, single chip CMOS Ultra-Wideband IC based on the IEEE 802.15.4 standard UWB PHY. This device is the first in a family of parts.

The resulting silicon has a wide range of standards-based applications for both Real Time Location Systems (RTLS) and Ultra Low Power Wireless Transceivers in areas as diverse as manufacturing, healthcare, lighting, security, transport, and inventory and supply-chain management.

Further Information:

For further information on this or any other Decawave product contact a sales representative as follows: -

Decawave Ltd,
Adelaide Chambers,
Peter Street,
Dublin D08 T6YA
Ireland.

mailto:sales@decawave.com
http://www.decawave.com/