

AN0501 - swarm bee LE: Range operation timing

1.2

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1. Introduction

This document shows the time that performing a SDS-TWR cycle takes, that is a two-way-ranging operation. For this, there are two possible scenarios: a) the ranging operation is triggered by the reception of a blink, b) the ranging operation is initiated through the application programming interface (API) via the UART.

In addition the swarm bee nodes have two transmission rates, 1 Mbps or 250 Kbps, which means that it takes 1us to transmit one bit in the first case and 4 us in the second case. It can also transmit using forward error correction (FEC) or not. Thus all the possible combinations, 4 modes, have been measured.

For the measurements an oscilloscope has been used. The pins radio TX_RX and UART_TX and UART_RX have been connected as inputs.

2. Ranging operation triggered by the reception of a blink.

A swarm node A can be set to periodically transmit a blink with its ID. When this blink is received by a swarm node B, the second one will read out the ID of the sender and will initiate a ranging operation with it. Figure 1 depicts the complete ranging procedure (SDS-TWR cycle). Channel 1, in yellow, is the TX_RX pin of node A and channel 4, in green, is the TX_RX pin on node B. The signal level low indicates that an over the air transmission is being carried out by the device. Numbers on the picture correspond with numbers in the text below.

FEC = Forward Error Correction

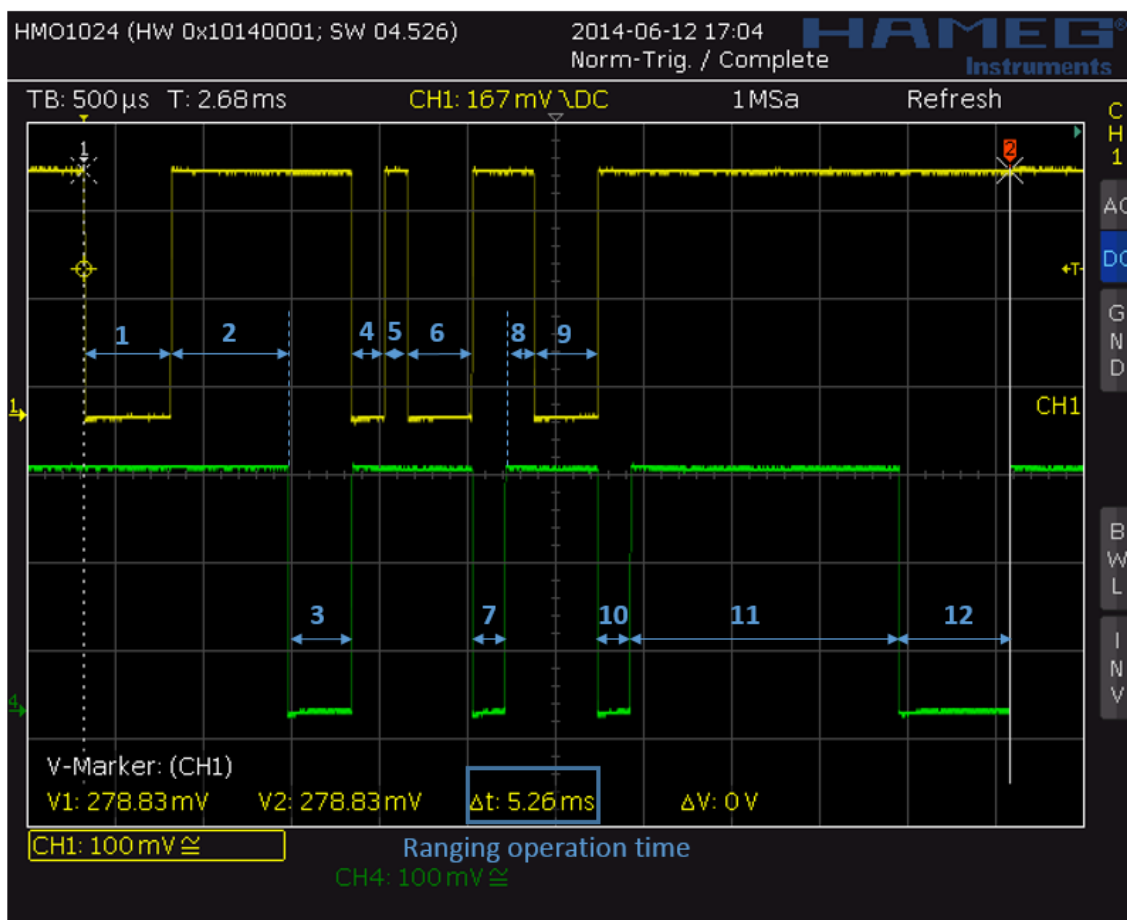


Figure 1. Node A, in yellow, broadcast a blink (1), which is received by node B, in green. At the end of the ranging operation, node B broadcast the range (12) between node A and node B (option broadcast enabled). Settings: 1Mbps transmission rate, FEC off

Node A broadcast a periodic blink (1), which is received by node B. At that moment node B starts a ranging operation with node A by sending a ranging request (3). Node A receives the request and sends an acknowledgement, ACK, (4) back to B followed by a ranging request from A to B (6). Node B will also acknowledge (7) the request made by A. After a while node A sends a last packet to node B including the ranging information is gathered during the process (9). Node B, again, answers with an ACK (10). At that moment the ranging operation will finished. In case the broadcast option is enabled, after processing all the information, node B will broadcast a packet containing the estimated range between node A and node B. When the broadcast option is disabled, no more packet is transmitted over the air.

The time showed corresponds to a ranging operation performed with 1Mbps wireless data rate and FEC off. Changing this parameters the time will be increase: with a lower data rate the transmission time will increase and the number of bits transmitted when the FEC is used will be higher, so also its transmission time. Table 1 shows the transmission times of each packet involved in the ranging procedure as well as the rest of the times represented in Figure 1 for each transmission mode. Table 2 shows the time of the ranging cycle with no range result broadcast.

Packet number	1 us, FEC off	1 us, FEC on	4 us, FEC off	4 us, FEC on
1	500 us	790 us	1900 us	3040 us
2	660 us	320 us	780 us	320 us
3	360 us	560 us	1360 us	2160 us
4	190 us	250 us	680 us	920 us
5	130us	90 us	300 us	280 us
6	360 us	560 us	1360 us	2160 us
7	190 us	250 us	680 us	920 us
8	160us	180 us	160 us	120 us
9	360 us	560 us	1360 us	2160 us
10	190 us	250 us	680 us	920 us
11	1520 us	1470 us	1680 us	1660 us
12	630us	1020 us	2440 us	4020 us

Table 1. Timing of the transmitted packets and other parameters represented in Figure 1 for the four possible transmission modes.

Transmission mode	1 us, FEC off	1 us, FEC on	4 us, FEC on	4 us, FEC on
SDS-TWR cycle	1.94 ms	2.7 ms	6.58 ms	9.64 ms

Table 2. SDS-TWR cycle time for the four transmission modes and no broadcast.

3. Ranging operation initiated by the API

When one of the nodes is connected to a host, it is possible to initiate a ranging operation by sending a command in the application programming interface (API). This is send from the host to the node through an **UART interface at 115.2 kbaud**.

Figure 2 depicts the packet exchange through the UART and over the air during a complete ranging procedure. Channels 1, in yellow, and 4, in green, correspond, as previously, to the transmission over the air of Node A and B respectively. **Channels 2, in blue, and 3, in pink, correspond to the pins UART_RX and UART_TX respectively, on node A.** the signals indicate transmission when their level is low.

The procedure starts when a ranging command coming though the UART is received at node A (blue pulses). The command should also include the node ID of node B. Then node A does not wait any more for a blink and starts a ranging operation with the node whose ID he received. For that it sends it a ranging request, which will be answered by node B with an ACK. The whole procedure continues as in the previous case until node A gathers all the required information for its range calculation. Then, depending on whether the broadcast option is enabled or disabled, it will send the last broadcast packet (as previously described). The ranging operation will finalize when node A estimates the range between node B and itself and send the

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information to the host through the UART port (pink pulses). The transmission time over the UART port is independent of the transmission mode over the air and will only change with the number of bits transmitted, that is, with the instruction that it is sent.

Notice that the only difference between the case and the previously described is that one packet less is sent over the air, the blink, and that the operation starts and finish with some transmission over the UART interface.

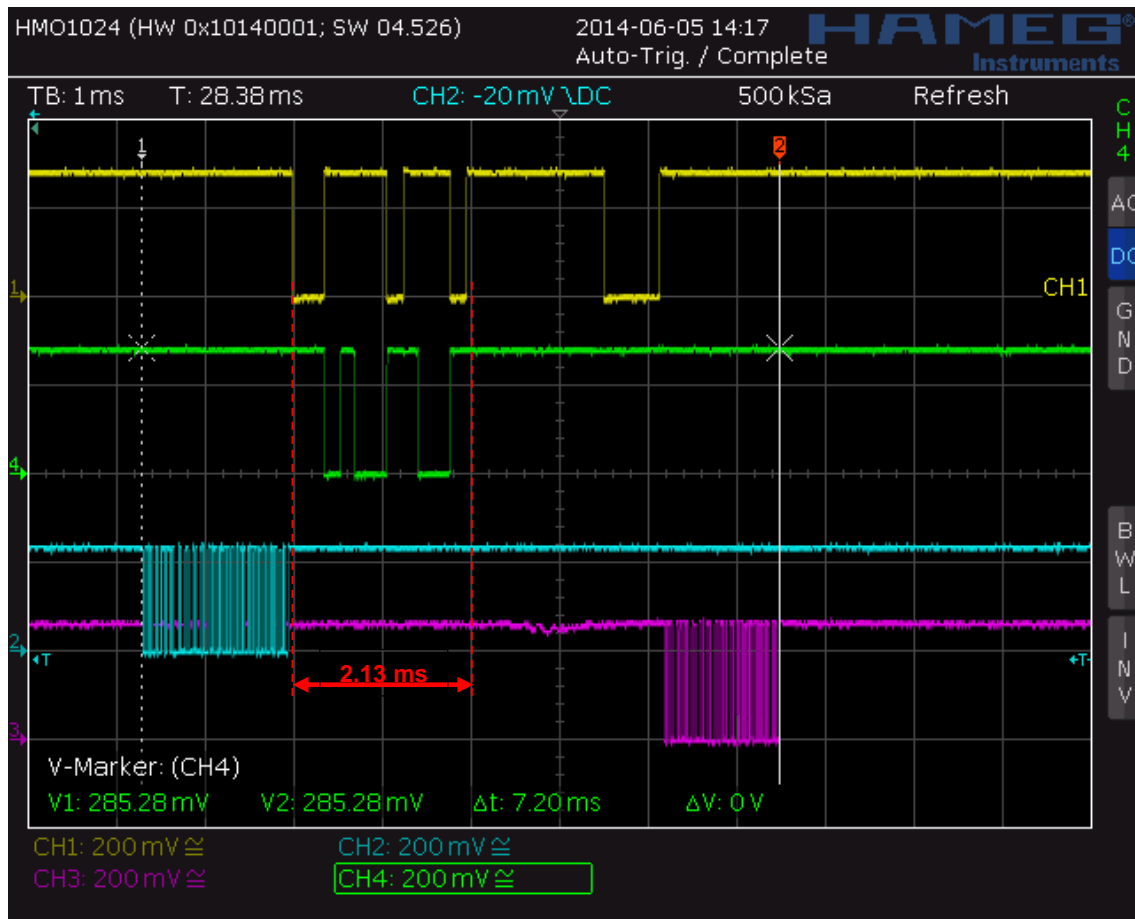


Figure 2. Ranging operation initiated by the API for a transmission mode of 1Mbps and FEC off and broadcasting option enabled. Channel 1 (yellow) represents the time that node 1 is transmitting over the air, TX_RX1, and channels 2 (blue) and 3 (pink) correspond to its USART_RX and USART_TX lines respectively; these are the lines used for communication with the API. Channel 4 (green) represents the time that node 2 is transmitting over the air, TX_RX2.

The time required to perform a ranging operation when the broadcast option is active and the transmission mode is 1Mbps and FEC on is 7.20 ms (Figure 2), where only 2.13 ms are dedicated to the ranging itself. The complete ranging operation for the same transmission mode takes only 5.36ms (Figure 3) when broadcast option is disabled; of this about 3 ms are due to the transmission over the UART interface

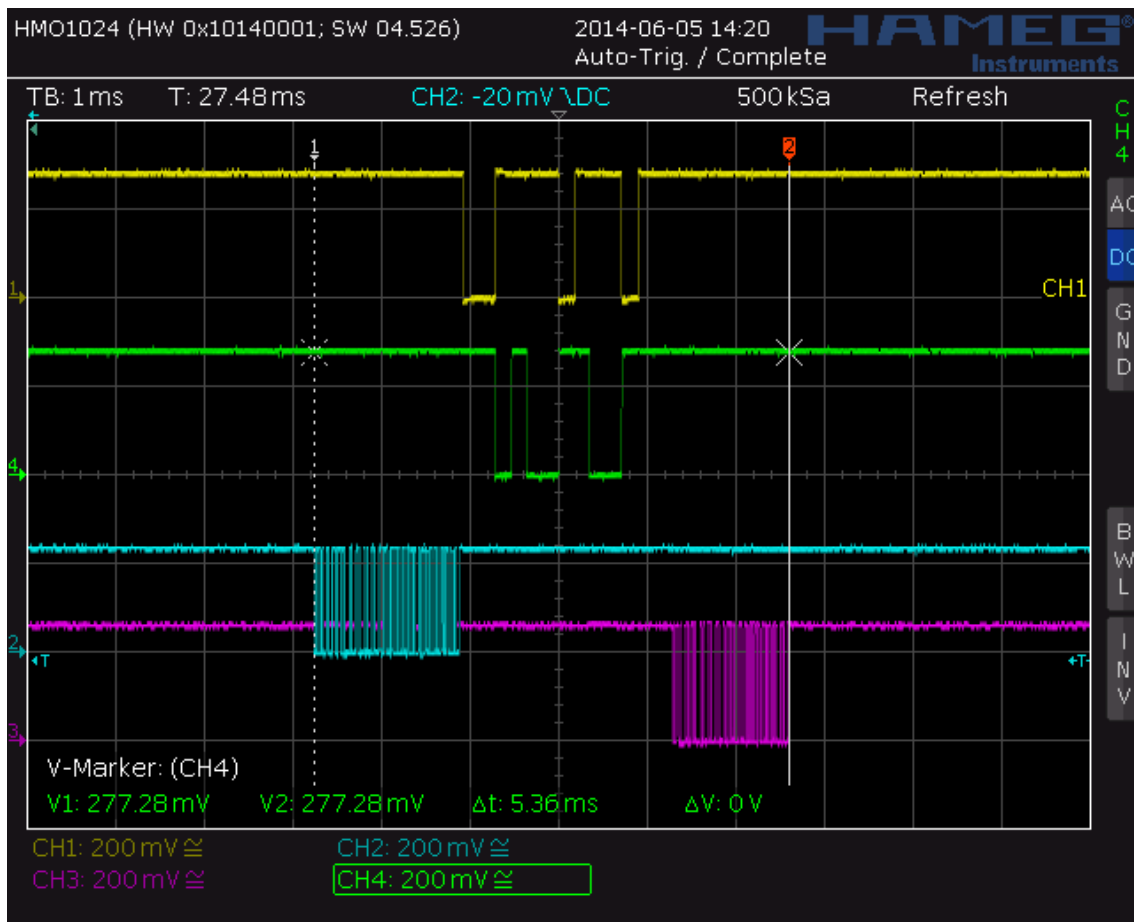


Figure 3. Ranging operation initiated by the API for a transmission mode of 1Mbps and FEC off and broadcasting option deactivated. Channel 1 (yellow) represents the time that device1 is transmitting over the air, TX_RX1, and channels 2 (blue) and 3 (pink) correspond to its USART_RX and USART_TX lines respectively. Channel 4 (green) represents the time that node 2 is transmitting over the air, TX_RX2.

The transmission time over the UART interface has been more precisely measured when sending the instruction 'range to' from the host to the swarm bee node (node receives) and when the ranging result is sent back from the swarm node to the host (node transmits). Table 3 shows the packets sent over the UART and Figure 4 the measured time it takes. As expected, this time on the instruction send, because the number of bits may change, but not on the node transmission mode.

<p>Instruction received: RATO 0000BF260468 19 Bytes (10 bits are transmitted per byte) ~ 8us/bit</p> <p>Data sent back to the host: <error code>,<ranging result>,<RSSI> (1+1+6+1+3+2) Bytes (10 bits are transmitted per byte) ~ 10us/bit</p> <p>UART baud rate: 115200Hz → 8.6us per symbol</p>

Table 3. Instructions sent over the UART interface.

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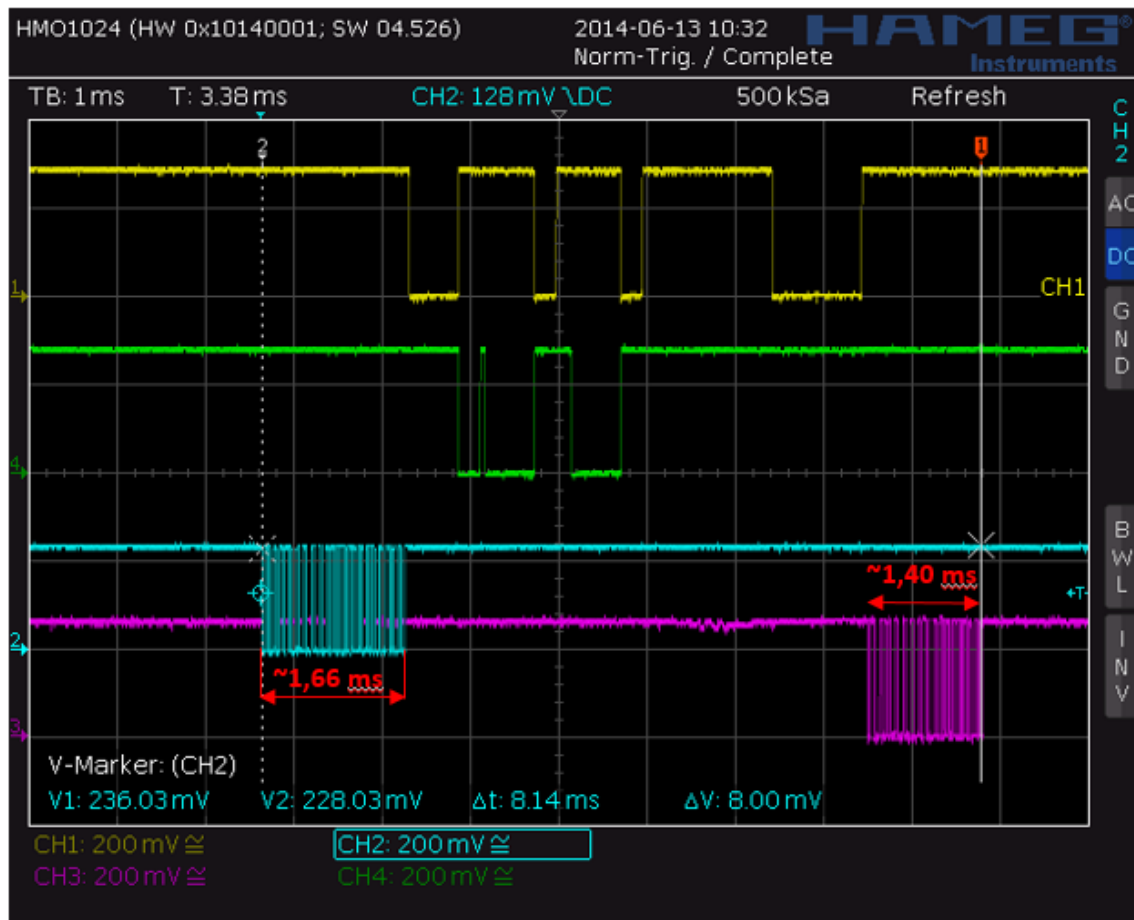


Figure 4. Ranging operation initiated by the API for a transmission mode of 1Mbps and FEC on and with the broadcast option on. Receiving the instruction at the swarm bee takes 1.66ms and sending the range back to the host 1.40ms.

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Document History

Date	Authors	Version	Description
7/30/2014	MLA	V1.0	The document gives the time measured for a ranging operation in different scenarios.
8/7/2015	MLA	V1.1	Format updated
19/9/2016	MLA	V1.2	Small correction

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