Test Report: LRAUV USBL Configuration

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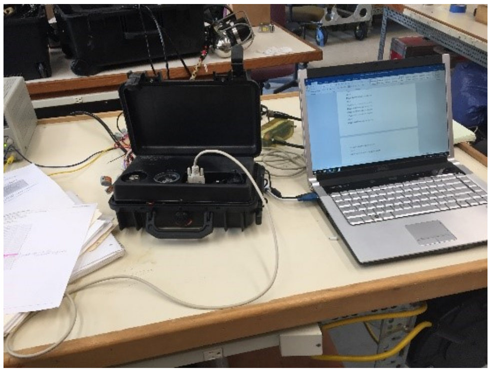
Goal: Determine what micromodem commands will successfully interrogate a REMUS transponder and allow the REMUS Digital USBL (DUSBL) to measure range and bearing to a REMUS transponder. This configuration will be used for LRAUV docking to a line.

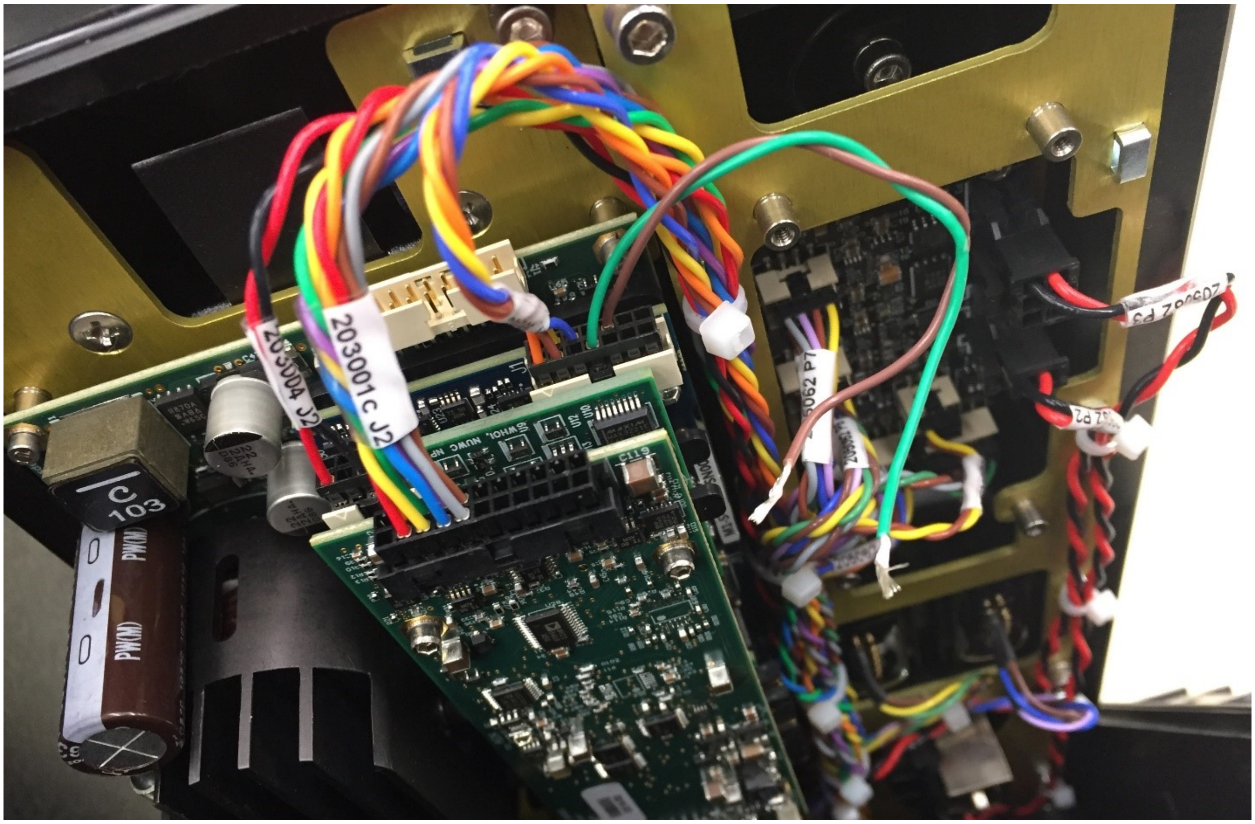


Day 1, set up a 10 kHz micromodem lunchbox, 258062 SN 043, with 10kHz towfish 224072 SN 015 containing GTI M27-930 transducer SN C001666, a plastic-housed R100 25 kHz DT4A transponder, and a X-Y down-DUSBL borrowed from FMAUV2.

The micromodem 2 is loaded with firmware 2.0.27690, newly updated to include the USBL sync pulse at GPIO4 and a bandwidth parameter in the CCPGT command.

Everything worked on the bench in air. Modem pings the transponder and triggers the USBL cycle. USBL hears the reply and calculates range and bearing. This set-up in air is not very repeatable and depends strongly on the exact placement of the transducers, but with a good placement, many pings in a row are completed successfully.

GPIO4 pulse works well. Round trip travel times are very repeatable within +/- one 80 microsecond count as reported by the USBL. A picture shows the inside of the lunchbox with special added wires. Green (micromodem J1 pin 7 GPIO4) and brown (micromodem J1 pin 10 AGND) wires are routed from micromodem J1 to the USBL 3L10 connector sync pin 10 (and ground pin 2).



Modem $CCPDT command does not seem to work with any REMUS transponders we tested. We will use CCPGT instead, which Eric Gallimore has used recently. In order to use CCPGT, specify carrier frequency (26000 for DR1), ping code (4A1C0370 for DR1) and bandwidth (4000 Hz). We used a so-called "DR1" interrogation ping. The modem command that worked well for DT4A was:

$CCPGT,26000,28,4A1C0370,1000,24000,0,0,0,0,4000,0

We did not get the micromodem to reliably receive a reply from any transponder. There were many receptions reported but it was not clear which ones were legitimate and which were spurious. The micromodem command above will certainly not receive anything accurately because all four receive codes are zeroed out. But we didn't spend time on this because the DUSBL is the important listener.

We did not find any micromodem command that could interrogate a REMUS LF (10 kHz) transponder. We have no documentation of LF signals so it would have been extremely lucky for this to work. We tried a few combinations of carrier (11, 12, 13, 13.5, 14 kHz) coding (same 28-bit codes as used on 25 kHz) and bandwidth (2 kHz? 4 kHz?) but none of these ever provoked a reply from a REMUS LF transponder.

We did also test a DT4B and did get it to ping reliably and the DUSBL could range to it. The micromodem command for A and B transponders is the same because the DR1 interrogation is the same for all four REMUS transponders A,B,C,D. However, the DUSBL must listen for a different B transponder reply signal. The "DR1-B" reply code is known to the USBL as signal number 03 but the modem documentation refers to it as signal 22.

USBL Command to listen for A transponder (DT4A):	USBL Command to listen for B transponder (DT4B):
#U1,P,02,014,800,20,00,00,578	#U1,P,03,014,800,20,00,00,578

Other parameters in the DUSBL command include tx lockout, set to 0x14=20 ms. If it is set shorter then USBL may be triggered by outgoing interrogation ping. If set longer than 50 ms, which is the turn-around-time of the transponder, then the reply may occur during lockout and DUSBL will not detect the reply.

Range gate is set to 0x800 = 2048 ms = 3 km round trip or 1.5 km one-way. This may be longer than necessary; maximum operating range is untested with this configuration. The USBL can be commanded to wait twice as long, up to 4 seconds.

Detection threshold of 0x20 seemed to work OK. Threshold above 0x79 seems to be invalid and caused erratic operation of the USBL, although this is not documented anywhere. It is not clear what is the relationship between reported SNR and this threshold. A threshold of 0x40 also worked, but DUSBL missed some valid replies. It may need to be set even lower than 0x20 for best range.

X and Y center are both set to 0x00. The significance of these parameters are unknown.

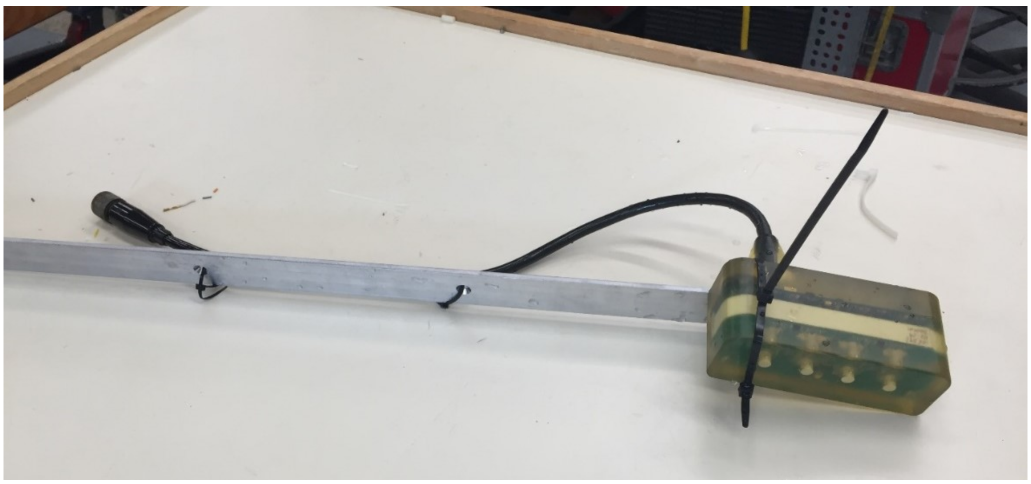
Sound speed of 0x578 is 1400 m/s, this should be replaced with a more accurate estimate.

Useful to know, the USBL will not acknowledge the next cycle start command (#U1,P) until after the timeout time of the previous cycle has elapsed, even if the USBL reports a return significantly earlier than that. Also, if there is too long a delay between the cycle start (#U1,P) and the trigger pulse from the modem, the USBL will go into an unresponsive state where it does not acknowledge the pulse and also does not send a timeout message. A new cycle must be started and a new pulse sent. Some malformed messages were observed from the USBL, though they may be due to invalid arguments in the #U1,P command.

There exists a special multi-band LF-HF transponder that was previously used in a similar docking application. It listens on LF (10 kHz) and replies on HF (25 kHz). However, this special transponder is difficult to work with because even if the micromodem could emit the correct ping, the reply is in a different band so the micromodem's CCPGT command cannot be used to listen for it. No known device can interrogate one of these special transponders and also hear its reply. Human ears are not very good at listening for the 25 kHz reply, especially when it almost simultaneous with the louder 10 kHz interrogation ping and it's in a bucket. So we decided to use one of the much more common HF (20-30 kHz) REMUS transponders because we can test them with a Ranger or a REMUS vehicle, the LF umodem can interrogate them, and the USBL is designed to work with this. Note that the DUSBL cannot hear the Ranger-initiated transponder reply because this unique signal is not one of the available ping codes in USBL's ROM memory. So the transponder must be interrogated by a vehicle's DR1 ping, or by a micromodem emulating a DR1 ping.

DOCK TEST IN THE WATER

Day 2, Set up a similar set of gear on the WHOI dock. Instead of XY USBL we now use a linear DUSBL, borrowed from SS-DTE Atlas nose. The USBL has a version string of !U1,V,O (that's a capital o, not zero). This should be identical to the unit that was built for LRAUV and is at MBARI right now. USBL is mounted on an aluminum bar to dip into water off the dock without getting the connector wet.



The DT4A was borrowed from Amy's R100 stock:

Same LF towfish and lunchbox from the lab test. The towfish was hung at the far corner of the dock. USBL was hung about 8 ft away. Transponder was hung initially next to the towfish, for a total travel distance of approximately 8 ft.

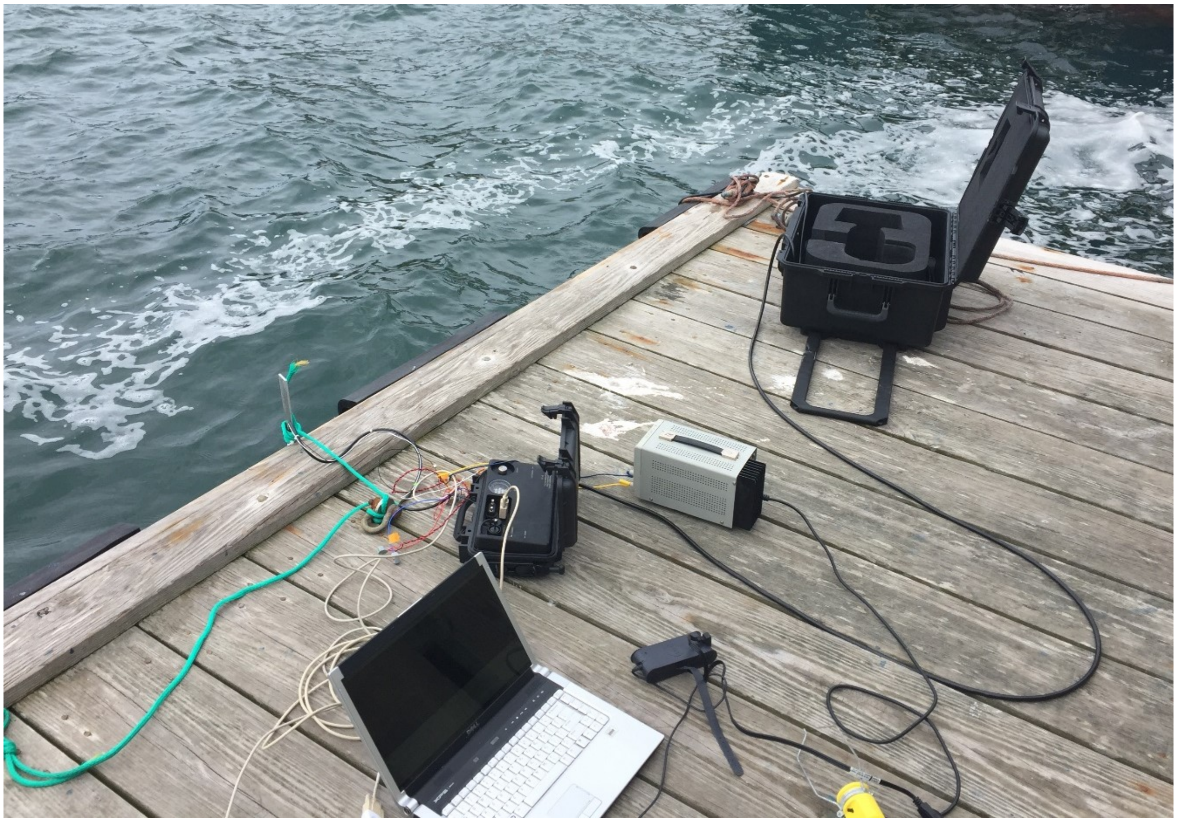


Table of total round trip distance vs total travel time as reported by USBL:

Estimated surface distance, ft, approx.	Surface distance in meters	Total travel time reported by USBL, 80 us counts, hex	TTT in milliseconds	Acoustic range estimate, assuming 1500 m/s and 50 ms transponder turn-around-time, meters
8	2.4	0x28C	52.16	3.24
32	9.7	0x2D4	57.92	11.88
64	19.5	0x325	64.40	21.6

These errors are small and are likely due to eyeball measurement error, different depths, layback, sound speed error etc. The reported TTT was steady and repeatable for each transponder test location, demonstrating good synchronization between the outgoing ping and the listening USBL.

The angles reported seemed to be consistent although they were not ground-truthed. Angles are affected by the accuracy of the commanded sound speed. And the USBL was not rigidly mounted so its angular displacement contributes to variability in the reported angles:

First trial configuration. Total travel time 8 ft. X-angle reported range F83-05B = -6.25° to +4.55°

```
!U1,R,F7D,000,0028D,186,80,80,D6,FF
!U1,R,FC6,000,0028C,184,80,80,D5,FF
!U1,R,F85,000,0028D,188,80,80,77,FF
!U1,R,F98,000,0028C,186,80,80,CC,FF
!U1,R,FE9,000,0028C,183,80,80,ED,FF
!U1,R,05B,000,0028C,187,80,80,E9,FF
!U1,R,058,000,0028C,184,80,80,A4,FF
!U1,R,F83,000,0028C,186,80,80,EA,FF
!U1,R,FCB,000,0028C,185,80,80,EA,FF
!U1,R,F8B,000,0028C,186,80,80,BF,FF
```

Second set total travel time 32 ft., X-angle reported 0E8-176 = +11.6° to +18.7°

```
!U1,R,13D,000,002D5,186,80,80,CC,FF
!U1,R,105,000,002D5,186,80,80,D6,FF
!U1,R,0E8,000,002D5,186,80,80,A8,FF
!U1,R,0FA,000,002D5,186,80,80,E1,FF
!U1,R,121,000,002D4,186,80,80,C1,FF
!U1,R,176,000,002D3,187,80,80,D4,FF
```

Third trial configuration. Total travel time 64 ft., X-angle reported F07-FA2 = -12.45° to -4.7°

```
!U1,R,F93,000,00325,186,80,80,DC,FF
!U1,R,FA2,000,00324,186,80,80,E8,FF
!U1,R,F35,000,00323,186,80,80,D1,FF
!U1,R,F86,000,00324,187,80,80,EB,FF
!U1,R,F07,000,00325,186,80,80,CB,FF
!U1,R,F71,000,00324,185,80,80,D0,FF
!U1,R,F38,000,00325,187,80,80,E6,FF
!U1,R,F8F,000,00323,186,80,80,D8,FF
!U1,R,F45,000,00325,186,80,80,E8,FF
!U1,R,F58,000,00325,186,80,80,E2,FF
!U1,R,F85,000,00323,186,80,80,A9,FF
```

Table/pictogram showing time sequence of messages between the laptop, micromodem and USBL. Testing was done with RealTerm RS-232 terminal emulator. Two cycles are shown, one with a reply received, “!U1,R…” and one with no reply “!U1,N…”.

Laptop PC to USBL	**USBL to Laptop PC**	**Laptop PC to micromodem**	**Micromodem to laptop PC**
#U1,P,02,014,800,20,00,00,578			
	!U1,P		
		$CCPGT,26000,28,4A1C0370,1000, 24000,4A1C0370,0,0,0,4000,0	
			$SNPGT,26000,28,4A1C0370,1000,24000,4 A1C0370,0,0,0,4000,0*7F $CATXP,280*48 $CATXF,280*5E $SNMFD,01,0439,0535,0082*54 $SNTTA,0.011447,,,,001432.45*42
	!U1,R,FC6,000,0028C, 184,80,80,D5,FF		
#U1,P,02,014,800,20,00,00,578			
	!U1,P		
		$CCPGT,26000,28,4A1C0370,1000, 24000,4A1C0370,0,0,0,4000,0	
			$SNPGT,26000,28,4A1C0370,1000,24000,4 A1C0370,0,0,0,4000,0*7F $CATXP,280*48 $CATXF,280*5E $SNTTA,,,,,001450.08*56
	!U1,N,80,80,37,6C		