

Antenna Pattern Measurement Guide

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Last updated February 2020

BACKGROUND

RESOURCES

These are some of the resources provided by CODAR.

- 1) APM Crib_Sheet_rev10.pdf ([link broken on CODAR support site!](#))

CODAR Support website

"Configuring Your Site ..."

"Configuring a SeaSonde Computer at a Radial Site"

"Measuring an Antenna Pattern" section

- 2) Good Practices Training presentation

CODAR Support website

"Training Slides & Video Tutorials"

"Training Slides"

Day2_AntennaPatternMeasurements.pdf

- 3) Video Tutorials ([links broken on CODAR support site!](#))

- a. program transponder

- b. create TRAK file

- c. create LOOP file

- d. bench test transponder

"Training Slides & Video Tutorials"

"Video Tutorial"

"Creating an Antenna Pattern" section

- 4) "Guide_CrossLoopPattern.pdf"

CODAR Support website

"Manuals and Documentation-SeaSonde Release 8"

"Application Guides"

"Manuals and Documentation-SeaSonde Release 7"

"Guides to the Applications"

- 5) APMGeneration.pdf

(contact CODAR)

- 6) CODAR User's Guide for Antenna Pattern Measurement (Dec 2003)

Located in CODAR software suite under

Seasonde/Docs/GuidesToTheHardware/HW6_Antenna_Pattern_Measure.pdf *(has useful info not found in other docs but some info would be outdated now, do not see it available on the support site)*

7) TransponderSetup.pdf

(contact CODAR, Mar 2011 version copied into this document)

8) Pattern File Format

Located in CODAR software suite under

Seasonde/Docs/GuidesToFileFormats/File_AntennaPattern.pdf

9) Personal communications with CODAR Technical Support Staff

In addition to the resources above, this APM guide references notes from CODAR training and Radiowave Operator Working Group (ROWG) meetings. Other information was provided by HF RADAR operators in personal communications.

PUBLICATIONS

Whelan, C., M. Hubbard, D. Trockel, H. Parikh. "Benefits of Multiple Antenna Pattern Measurement Methods for Maintaining a Regional HF Radar Network." Proceedings of the ORCA Conference, Okinawa, Japan (2018).

Washburn, L., E. Romero, C. Johnson, B. Emery, and C. Gotschalk. "Measurement of Antenna Patterns for Oceanographic Radars Using Aerial Drones." Journal of Atmospheric and Oceanic Technology, Vol. 34, No. 5, 971–981 (2017).

Laws, K., J. D. Paduan, and J. Vesecky. "Estimation and Assessment of Errors Related to Antenna Pattern Distortion in CODAR SeaSonde High-Frequency Radar Ocean Current Measurements." American Meteorological Society (1029): 1-15 2010.

De Paolo, T., and E. Terrill. "Properties of HF RADAR Compact Antenna Arrays and Their Effect on the MUSIC Algorithm." Scripps Institution of Oceanography Technical Report, Scripps Institution of Oceanography, UC San Diego, 1-41 (2007). <http://escholarship.org/uc/item/5bw303tj>

Kim, SY, E. Terrill, and B. Cornuelle. "Objectively Mapping HF Radar-derived Surface Current Data Using Measured and Idealized Data Covariance Matrices." Journal of Geophysical Research, Vol. 112, C06021 (2007).

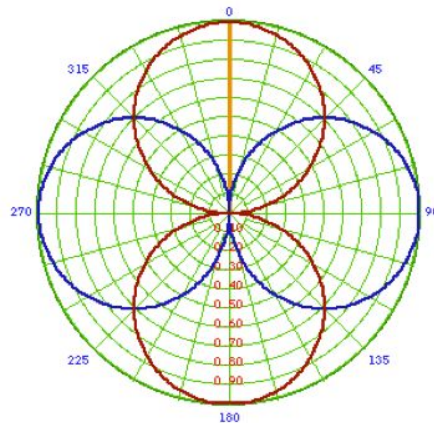
Lipa, B., B. Nyden, D. Ullman, and E. Terrill. "SeaSonde Radial Velocities: Derivation and Internal Consistency." IEEE Journal of Oceanic Engineering, Vol. 31, 850-861 (2006).

For more publications, see Appendix D.

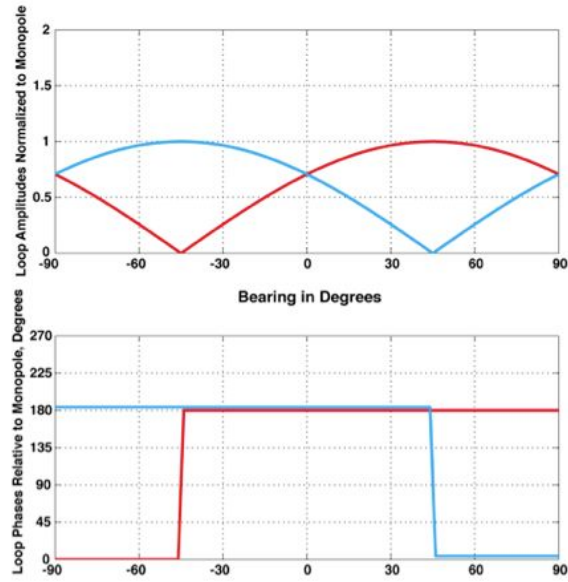
WHAT IS A CODAR ANTENNA PATTERN?

The antenna pattern is the receiver response to a known signal as a function of direction. In order to measure the pattern, the known signal (the transponder) is carried in an arc with fixed radius around the receive antenna so the response can be measured at all directions from where sea echo returns are expected (plus some extra angles for good measure). When applied in SeaSonde processing, the measured pattern improves the direction-finding capabilities of the system. The direction-finding algorithm uses the pattern information to place radial velocities within a range ring into particular angular bins. In the absence of a measured pattern, an ideal pattern is assumed, which may be quite different from the actual pattern.

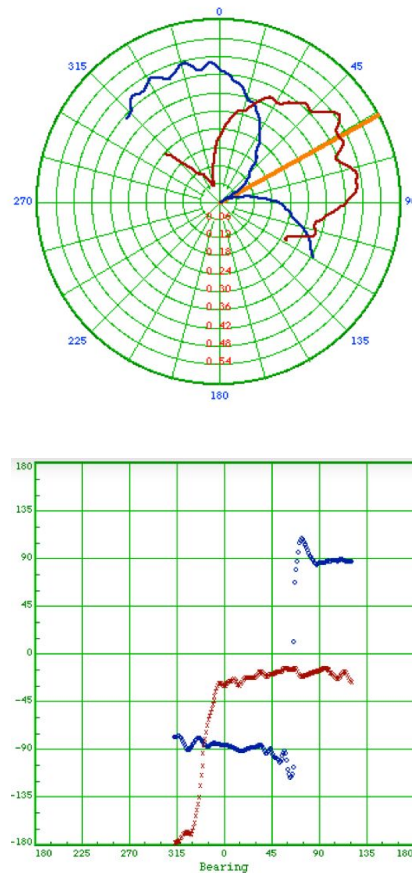
CODAR antenna patterns are comprised of two signal ratios for each directional point. They are the complex ratios of each loop signal divided by the monopole signal, expressed in terms of amplitudes and phases. The ratio *between the Loop 1 & Loop 2* values is important for direction finding.



Ideal pattern amplitudes in polar form, example taken from SeaSonde software CrossLoopPatterner.



*Ideal pattern amplitudes and phases, example taken from “The Mystery of Phases”
written by Don Barrick, and presented at Advanced CODAR training
(Day1.9_What_Are_Phases)*



Example of a measured pattern amplitudes (top) and phases (bottom).

REASONS TO MEASURE

Antenna Pattern Measurements (APMs) improve the results of CODAR's direction finding algorithms.

Excerpt from CODAR Good Practices training presentation:

- *Antennas interact or "couple" with other conductive or ferromagnetic material.*
- *It is difficult to isolate HF antennas from objects with potential to interact - rule of thumb is $> 1 \lambda$ separation.*
- *Distorted antenna patterns cause bearing errors which, in turn, cause current velocity errors.*
- *Radials derived from measured patterns are always more accurate than those derived from ideal - gaps or no.*
- *Sometimes the pattern is too distorted to DF for currents and the antenna must be moved - this may not be evident from radial coverage alone.*

A measured pattern is distorted from ideal because the antenna interacts with nearby conductive material. If an APM is not used in radial processing, the SeaSonde software assumes an ideal pattern, which can cause inaccuracies.

When choosing the antenna receiver location at a site, you generally want to place the antenna at least one wavelength away from any conductive objects. Wavelength (λ) referenced here is the wavelength associated with the operating frequency of the antenna (5 MHz: 60 meters, 12 MHz: 25 meters, 25 MHz: 12 meters). This is not always practical but should be done if at all possible. Vertical elements such as metal poles will interfere more and objects that are physically longer than the wavelength. Conductive objects that are $1/4$ of the wavelength associated with the operating frequency can also cause greater interference because this length is ideal for transmission. Following these general guidelines for antenna placement should help ensure a more ideal antenna pattern.; however, it does not eliminate the need to measure a pattern. In some cases, it is not possible to avoid metal at a site and for those sites measuring a pattern is particularly important.

WHEN TO REMEASURE A PATTERN?

Remeasure a pattern if...

- Antenna has been rotated or moved to a new location.
- New equipment installed (i.e. antenna box, transmitter or receiver)

- New cables or cable lengths changed
- Center frequency has changed by more than 2-3% **
- Amplitude factors and phases over a period of time show a “state change” ***
- If there have been significant physical changes in the environment (particularly if conductive materials have been added or moved in the vicinity, but it can also be necessary in other circumstances, e.g. a significant part of a barrier island beach washed away in a storm)
- Seasonal changes may impact the pattern in certain special cases (e.g. in an area where there is seasonal ice cover)

**Notes from Don Barrick: E.g., if you were operating at 4.54 MHz and wanted to change to 4.62 MHz, I'd say this is OK without re-measuring an APM (this is a 1.75% change). Before one spends the time to re-measure the pattern when the frequency change is small, one could go ahead and change frequency, and look at amplitude/phase changes from the sea echo before and after the frequency change (using the diagnostic display tool). If the amplitude factors change by less than 1 dB and the phases by less than 10 degrees, then the change to the shape of the pattern itself is probably small. If the amplitude and phase factors change by an appreciably larger amount, then this is a wake-up call to remeasure the pattern.

*** Ignore daily volatile changes, this would be a persistent change in diagnostic going from one fairly stable state to another fairly stable state. If factors change by an amount appreciably larger than 1 dB and/or phases change by an amount appreciably larger than 10, there may be something wrong with system/cables or it may be a sign that a new pattern is needed due to some change in the environment.

PREPARATION FOR MEASURING THE PATTERN

EQUIPMENT CHECKLIST

A copy of this checklist can be printed from Appendix B.

- Transponder
- Correct USB cord for transponder
(depends on transponder version, either DB9 to Type A USB or Type B USB to Type A USB)
- Fully charged transponder battery
(a 12-volt 2.9-amp hour SLA battery)
- Spare charged transponder battery
- GPS and spare GPS if possible
(capable of recording tracks with time stamps at least every 5-10 seconds and capable of range to target readout)
- Sighting Compass
 - 4 foot or 8 foot whips for transponder (see Crib sheet)
(WALKING PATTERNS AND 25/42 MHz BOAT PATTERNS)
 - 4 Piece Green Antenna (5/13 MHz BOAT PATTERNS ONLY)
 - Green Antenna Base (5/13 MHz BOAT PATTERNS ONLY)
 - Green Antenna to Transponder Cable (5/13 MHz BOAT PATTERNS ONLY)
 - Transponder Grounding Wire (5/13 MHz BOAT PATTERNS ONLY)
 - Communications Equipment
(walkie talkies, charged VHF radios, or cell phones if coverage is good)
 - Extra Batteries
(e.g. for GPS, walkie-talkies, etc)
- APM instructions including CODAR APM Crib sheet
 - Laptop with SeaSonde software
(for programming transponder, highly recommended, simpler than using site computer and you never know when reprogramming may be necessary)

PLAN THE TRACK

Plan an overland walking track or a boat track. See figure below for factors to consider for each.

Source: CODAR Good Practices training presentation.

"Day3.4_PatternMeasurements_GoodPractices_2011.pdf"

Note that for a walking pattern not only is the requirement to be at least one wavelength away from the antennas (5 MHz: 60 meters, 12 MHz: 25 meters, 25 MHz: 12 meters) but it is also recommended that you avoid being within that same distance of other objects (e.g. buildings, metal fencing) on the walking track.

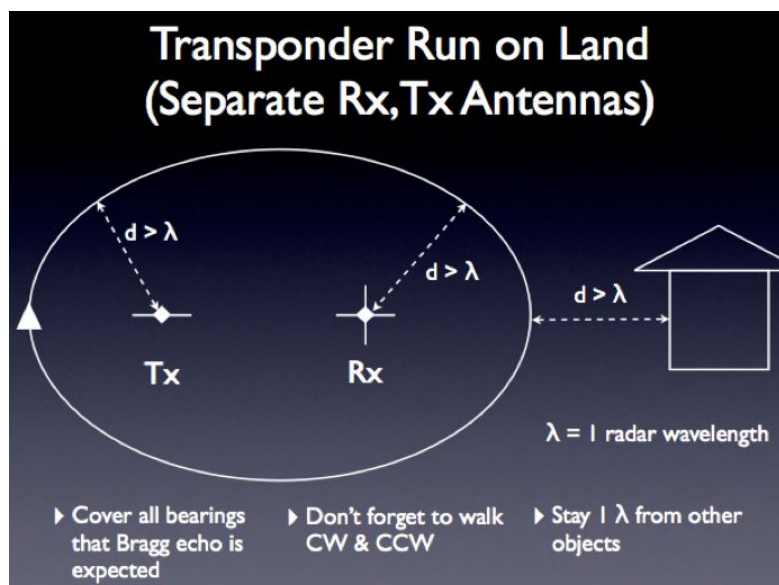
Notes from Don Barrick:

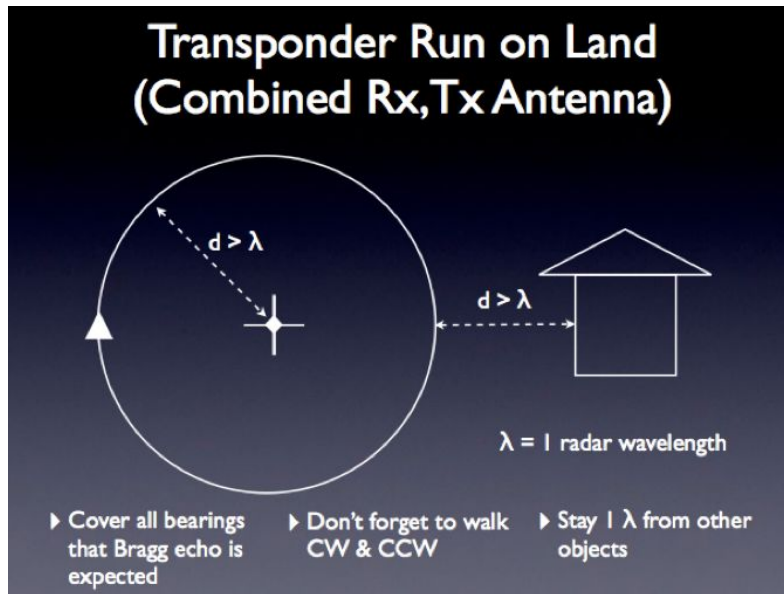
"Try to keep the transponder path and antenna away from horizontally extended obstacles, like chain-link fences, low hanging overhead wires, and large horizontally extended buildings. If these pick up the transponder signal or reflect part of it, then the transponder is no longer a "point source" at a discrete bearing denoted by the GPS. Signals from the transponder may reach the Rx antenna from a broad angle sector. If this sector spans greater than 5 - 10 degrees looking out from the Rx antenna, then the meaning of the point source is compromised. Also, such reflections and interactions will pick up and radiate horizontal polarization (e.g., low hanging power lines), which, ... are picked up by the loops; we don't want that to happen.

A vertical post or pole near the path of the transponder as it is walked around in the circle may not be that big a deal. Unless perhaps it is well greater than $1/4$ wavelength. A case where it could be a problem would be a very high metal pole or tower (e.g., a wavelength high) that is a wavelength away. This can pick up and reflect the transponder signal, creating a multi-path situation so the Rx sees the signal as coming from different directions, not confined to the direction corresponding to the GPS position. "

	Land	Boat
Signal Strength	✓	
Space required around antenna	At least 1λ from antenna(s)	✓
Transponder Isolation from Other Objects	Harder to avoid nearby metal objects	✓
Angular Coverage	✓*	
Angular Resolution	Less due to poor GPS DOP	✓
Antenna Required	Inefficient OK	Must be Matched
Observe RF Path Losses		✓

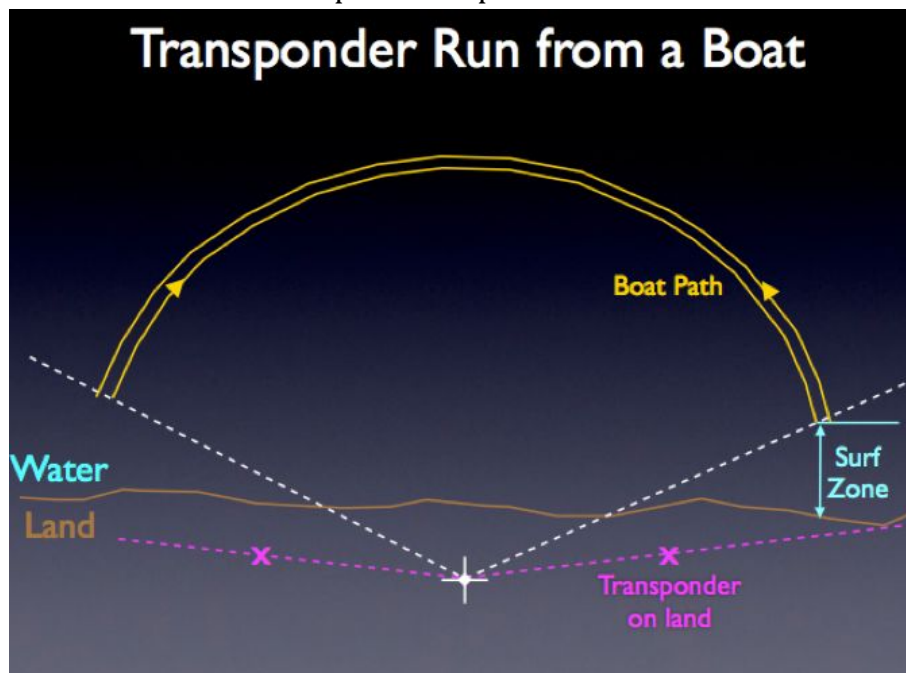
Source: CODAR Good Practices training presentation.
 "Day2_AntennaPatternMeasurements.pdf"





Source: CODAR Good Practices training presentation.
"Day2_AntennaPatternMeasurements.pdf"

Plan to go 10-15 degrees beyond where you expect Bragg echo! "Bunching" of radial vectors at the edge of the field could result if the pattern is not extended far enough (believe this was more of an issue in earlier versions of CODAR software but good practice nonetheless). It is a good idea to extend a boat pattern by taking a transponder out to the site and gathering a couple data points on land. These land points can be used to extrapolate the pattern onto shore.



Source: CODAR Good Practices training presentation.
"Day2_AntennaPatternMeasurements.pdf"

There are a few factors to consider when planning the track radius (distance from the receive antenna) for a boat run. At closer distances, there will be fewer measurements located in each angular bin. Greater distances allow for greater data density within each bin; however, the strength of the transponder signal is weaker plus the time and fuels costs are greater.

CODAR recommends maintaining a radius of 0.5 to 2 km when using a standard transponder. For tracks with radius distances greater than 2 km, a different transmitter is needed (the CODAR supertransponder see section VI). Concerning speed of the boat, a rule of thumb recommendation is to plan for 1 minute for every 10 degrees of arc so 18 minutes for a one-way 180-degree semicircle and 36 minutes to run the arc both clockwise and counterclockwise.

Radius		Circumference		Max Speed
km	nmi	km	nmi	knots
0.5	0.27	3.1	1.7	2.8
0.75	0.40	4.7	2.5	4.2
1	0.54	6.3	3.4	5.7
1.25	0.67	7.9	4.2	7.1
1.5	0.81	9.4	5.1	8.5

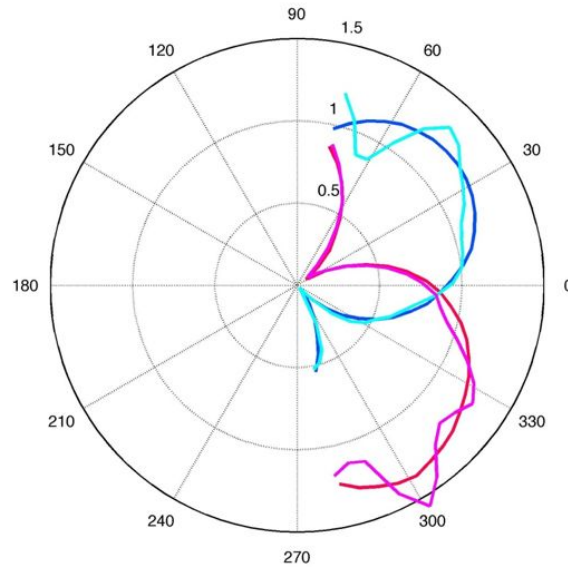
Table: Maximum boat speed for different radii using the 1 minute per 10-degree rule.

The track must be traveled clockwise and counterclockwise (in any order) to remove a systemic bias in time. The bias occurs because of delays and offsets in processing. The synching of the GPS and computer are generally only good to the second. The GPS records position versus time. The SeaSonde measures antenna response versus time. In processing the pattern, the goal is to remove the time factor entirely to achieve position versus antenna response.

ADDITIONAL NOTES:

A pattern measured with a signal propagating over land alone may not show the same characteristics as a pattern measured with a signal propagating over a mixed ground cover of land and water. This is illustrated in the figure below, which compares a walking pattern at CEDR with a boat pattern measured at a distance of 750 m from the receiver. In the case of the boat APM, the signal path crossed a mixture of land and water and distortions appear in the pattern. "The mixed-path problem appears exacerbated when path distances are short (e.g., 200 - 600 meters

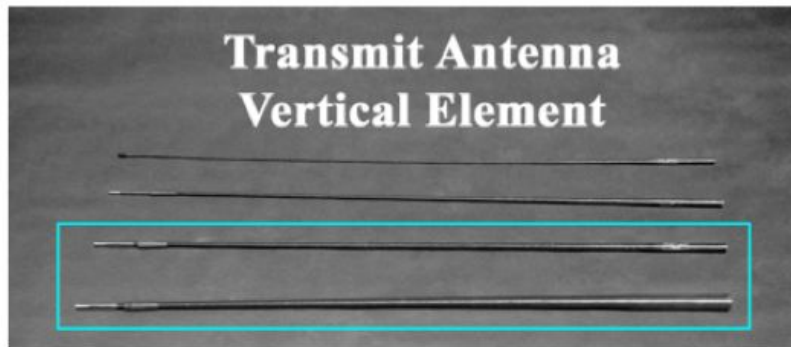
land out of a total of 800 m arc).” (Barrick, personal communication). These same distortions may not exist at greater distances due to a “propagation recovery effect”. In this case, it is important to know what the receiver response is at a greater range if we are to assume that the pattern measurement is valid for the receiver’s response to a signal of first order sea echo coming from distances of 6+ km.



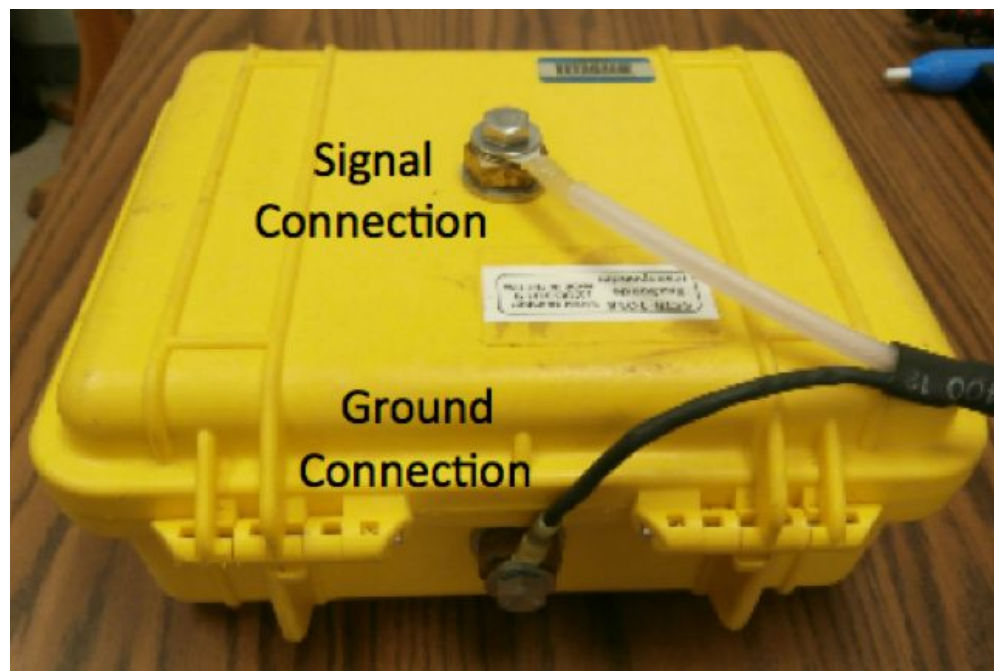
Antenna pattern at CEDR showing mixed-path distortions at edges of pattern (pink and cyan), which are not present when the pattern is measured over land alone (red and blue).

TRANSPONDER EQUIPMENT

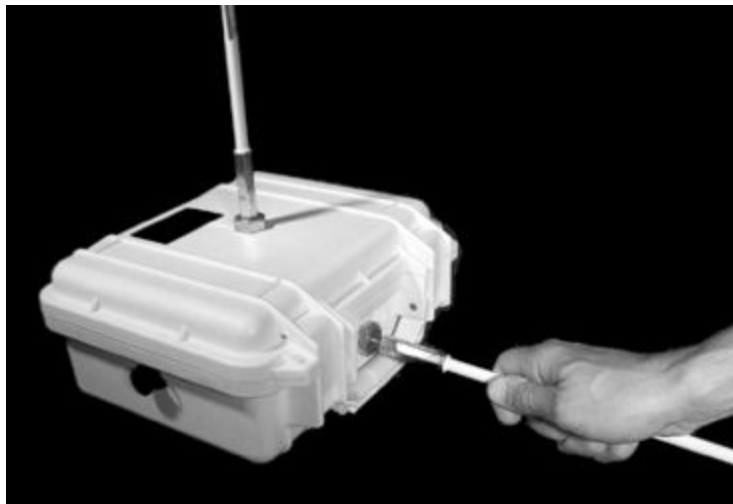
Use the appropriate transponder antenna setup for frequency of SeaSonde and the type of track (walking/boat). See the CODAR Crib sheet guidance. For 5 & 13 MHz boat patterns, use the SeaSonde Transmit Antenna Vertical Element and Antenna Base. Assemble and tighten by hand. Hook to transponder with the CODAR Transponder extension kit cable.



Source: HW6_Antenna_Pattern_Measure.pdf



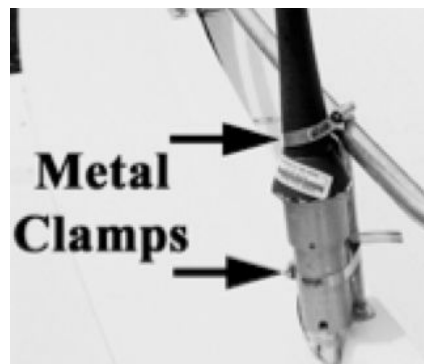
For 25 & 42 MHz systems and for walking patterns at any frequency, use the antenna whips that screw directly into the transponder. Again, see recommendations on the Crib sheet and the note that only a single whip may be needed for walking pattern if peak signal strength seen in the range display is high.



Source: HW6_Antenna_Pattern_Measure.pdf

PLAN FOR SECURING TRANSPONDER ON BOAT

Plan to set up the transponder antenna where its signal will not be blocked by boat superstructure on either the clockwise or counterclockwise arc. For 25 MHz and above, position the transponder so the horizontal whips will point toward port and starboard.



Source: HW6_Antenna_Pattern_Measure.pdf

The figure above shows the green antenna secured to a boat railing with metal clamps. See Appendix C for an example of a design to use with a boat that has no railings.

Set up a grounding from the antenna to the ocean if using the green antenna. Use a grounding wire and “make sure that the outer insulator is stripped so that at least a couple feet under the sea are bare wire, and the end in the ocean is weighted by a

moderately heavy sinker, so that when the boat is underway, the grounding wire does not pop out of the sea” (Don Barrick). If the bilge water is electrically connected to the ocean, you can set a wire weighted by a heavy nut into the bilge water.



PREPARATION FOR GPS

Verify that receive antenna location in SeaSondeRadialSetup and in GPS are the same.

Make sure the GPS is capable of storing tracks including position and time. CODAR recommends logging GPS information every 5-10 seconds during the pattern measurement. The idea behind the timing is that there must be at least one measurement per angular bin.

Install fully charged new batteries in GPS if necessary.

Confirm that you have the necessary storage space on the GPS for the track data. You may be able to set the GPS to “stop when full” so that if there is a storage problem, the GPS does not automatically overwrite previously recorded data.

Datum used by handheld GPS and datum used by site receiver GPS should match. “The “native” datum for GPS is WGS84 and this datum should always be used when exporting the data (from the GPS). WGS84 is also the datum used for plotting vectors in SeaSonde software. It does not matter if the GPS is set for a non-standard datum while the data are being acquired. However, exporting data from a GPS configured for a non-standard datum (e.g. State plane) can result in positional shifts

of 200-400m in x, y when the data are plotted. It is prudent to export your GPS track data in WGS84 coordinates BEFORE deleting the data from the GPS' active memory.” (Bruce Nyden per comm)

TRANSPONDER PROGRAMMING

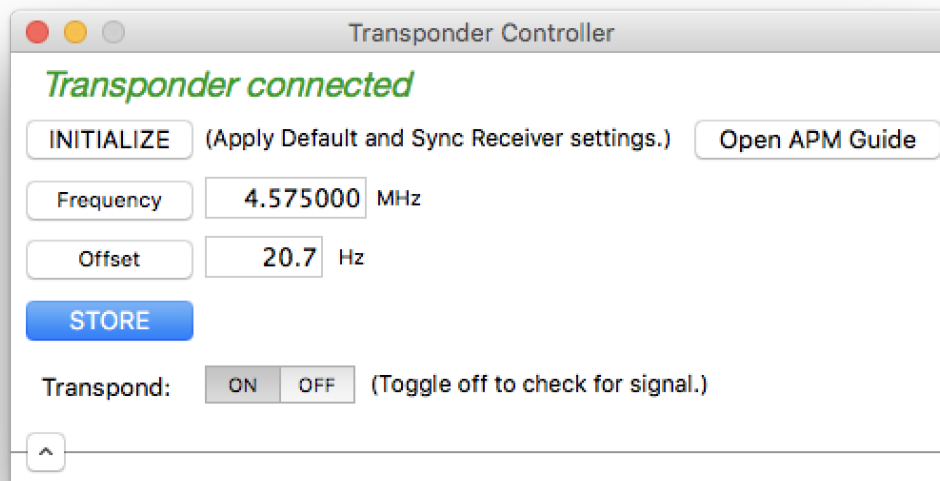
HOW TO PROGRAM THE TRANSPONDER

Check the transponder battery voltage with a multimeter to make sure it is fully charged (> 12 volts) OR check the battery for charge with CODAR transponder charger: Plug transponder charger into the "Charger" port on the main board of the transponder. Look at the indicators, if the fast charge light is illuminated your battery is not at full charge.

Program the transponder before going to the site. It is best to program with a computer other than the station computer.

Hook up the battery, connect the transponder to the computer with USB cable and turn it on. On the transponder board, look for a red steady light that indicates power on and a steady yellow status light.

Open the SeaSondeTransponder application located in the /Codar/SeaSonde/Apps/RadialTools folder.



Transpond ON should be selected.

Type the center frequency for the site, then click on the “Freq” button.

Click on “Open APM Guide” button to find the offset setting for your transponder based on your antenna frequency. Type in the offset from the guide, then click the “Offset” button.

Click “Store”. Close the SeaSondeTransponder application.

Verify that the settings remain after a power cycle: Turn off the transponder and then turn it back on. Open SeaSondeTransponder and check for correct settings. Close application, turn off transponder and finally disconnect the USB cable.

If problems are encountered, clicking the “Initialize” button several times and re-programming will sometimes solve the issue. See CODAR instructions for more details. Bring a laptop computer on the day of the measurement in case adjustments to the offset are needed (e.g. to move the peak to a better location in the spectra window).

CHECK FOR TRANSPONDER PEAK AT RADAR SITE

ENTER RECEIVER APM SETTINGS

Open SeaSondeController and set the receiver settings according to directions on the CODAR APM Crib sheet:

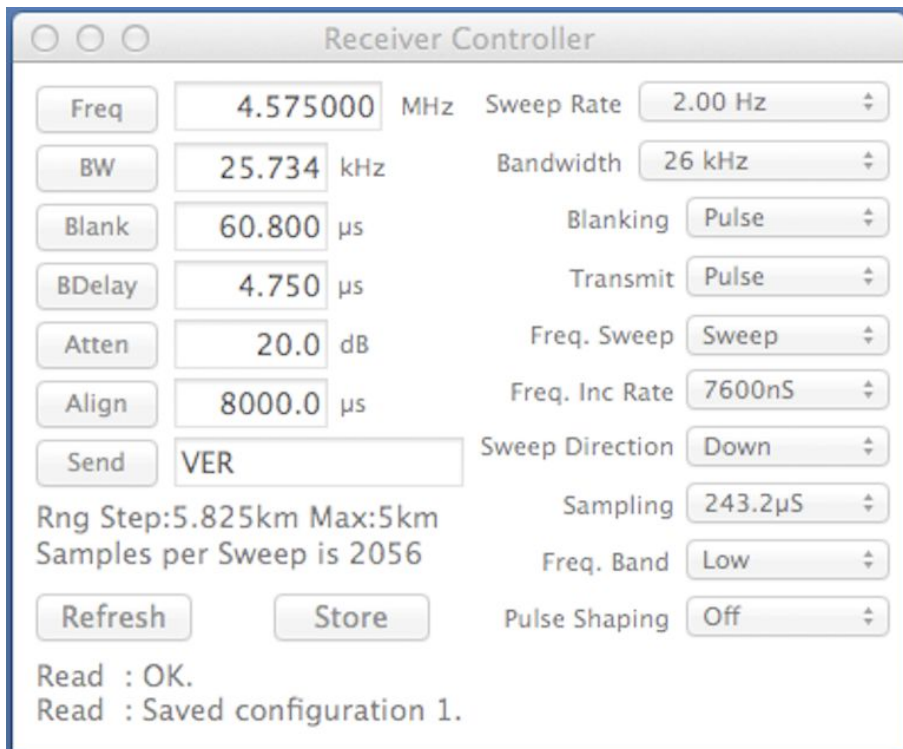
Software Release 7/8: Go to the “Receiver Controller” menu and select “Advance Control”

Capture an image (shift-apple-4) of your receiver settings window for recordkeeping OR write all the values down. Take a screenshot of the settings by pressing shift-option-4, move mouse cursor over the settings window, press the spacebar wait for camera icon to appear and then click; the image appears on the desktop.

Configure the receiver settings for the pattern measurement and then “Store”.

See the CODAR APM Crib sheet for settings based on antenna frequency.

The system must be set for down sweep.



The screenshot shows the "Receiver Controller" window with the following settings:

Parameter	Value	Unit
Freq	4.575000	MHz
BW	25.734	kHz
Blank	60.800	μs
BDelay	4.750	μs
Atten	20.0	dB
Align	8000.0	μs
Send	VER	
Rng Step	5.825	km
Max	5	km
Samples per Sweep	2056	
Sweep Rate	2.00	Hz
Bandwidth	26	kHz
Blanking	Pulse	
Transmit	Pulse	
Freq. Sweep	Sweep	
Freq. Inc Rate	7600	nS
Sweep Direction	Down	
Sampling	243.2	μS
Freq. Band	Low	
Pulse Shaping	Off	

Buttons: Refresh, Store

Status: Read : OK. Read : Saved configuration 1.

Example of Receiver Controller set-up for a long range antenna system.

USER TIP: A good practice is to enter all the settings manually. The “save” and “load” features in SeaSondeController can be convenient but have had some bugs in the past versions of SeaSonde software. Use caution with these features and ALWAYS confirm the correct settings after loading or saving a register. In some versions of Seasonde software, the PulseShape settings often do not “save” or “load” correctly on the first try.

USER TIP: By not storing, there is some risk that the receiver may revert to stored settings by some actions of the operator during the prep for the pattern. If this goes unnoticed and the pattern is run with standard settings, this will ruin the pattern measurement. A safe practice is to store APM settings and at the end of the pattern run, restore the system to its proper original stored settings.

CHECK FOR TRANSPONDER SIGNAL IN SEASONDE ACQUISITION

In SeaSonde Acquisition, follow these steps:

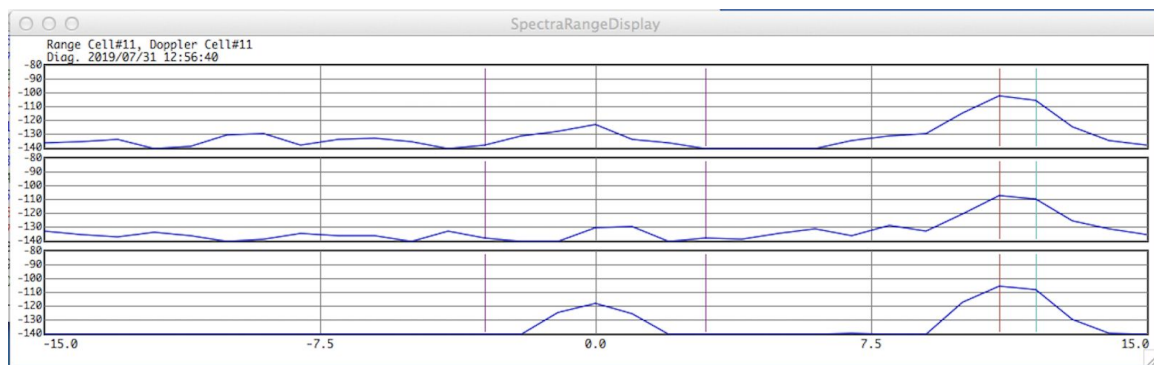
Software Release 7 and 8:

-- Go to the "Processing" menu and "Enable Loop Diagnostics". The "SpectraRangeDisplay" and "Loop Diagnostics" windows automatically appear. when the diagnostic processing mode is enabled.

Turn off transmit at other sites operating on the same center frequency. Test the transponder at least one wavelength away from the receive and transmit antenna (5 MHz > 60 meters, 12 MHz > 25 meters, 25 MHz > 12 meters):

Attach three eight-foot whips for this land test, one vertical on top and two horizontal on the sides of the transponder.

Verify that transponder is turned on and look for peak in spectra and range displays. Adjust displays / change axes as needed to view the peak easily. It is important to see the transponder peak in the "Cross Spectra" or "SpectraRangeDisplay" window.

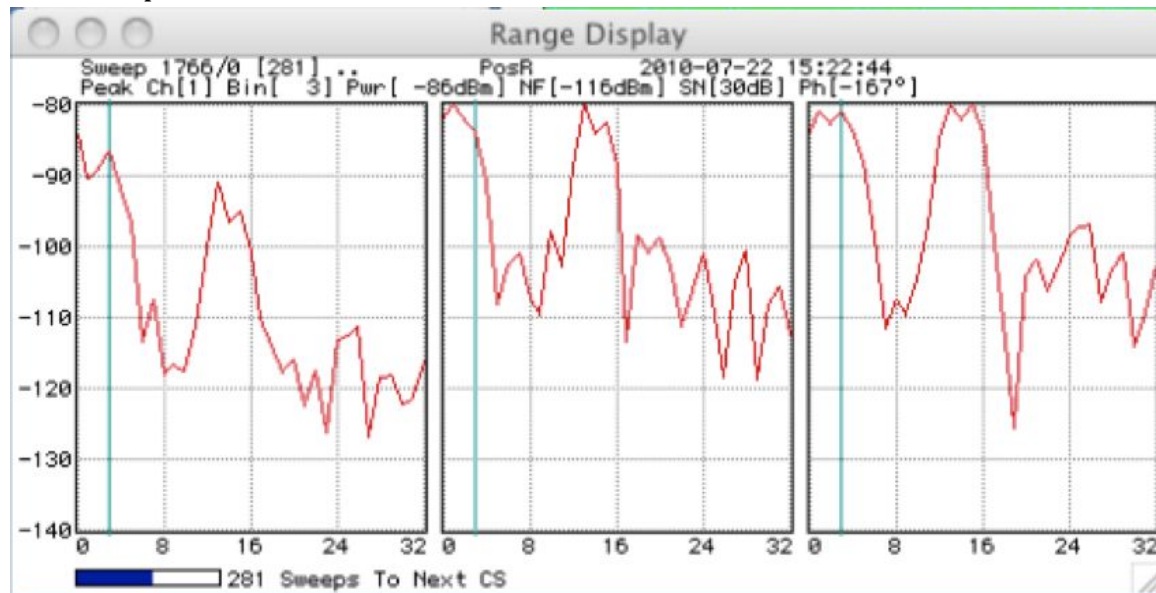


Cross spectra diagnostic window showing transponder peak in channels 1, 2 and 3 in range cell 11.

Turn off transponder and verify that the peak disappears. Turn on again and see the peak reappear. If peak is not located between range cells 8-12 or appears too close to Bragg region or right next to edge of window, see next section to refine settings.

The previous checks should be sufficient, but for additional verification, you can look at the peak in range displays:

--Go to the “Monitors” menu, and open “Range Display” - “Range Display”
 --Return to “Monitors” menu, and open “Range Series Power Map” - “Range Series Power Map”



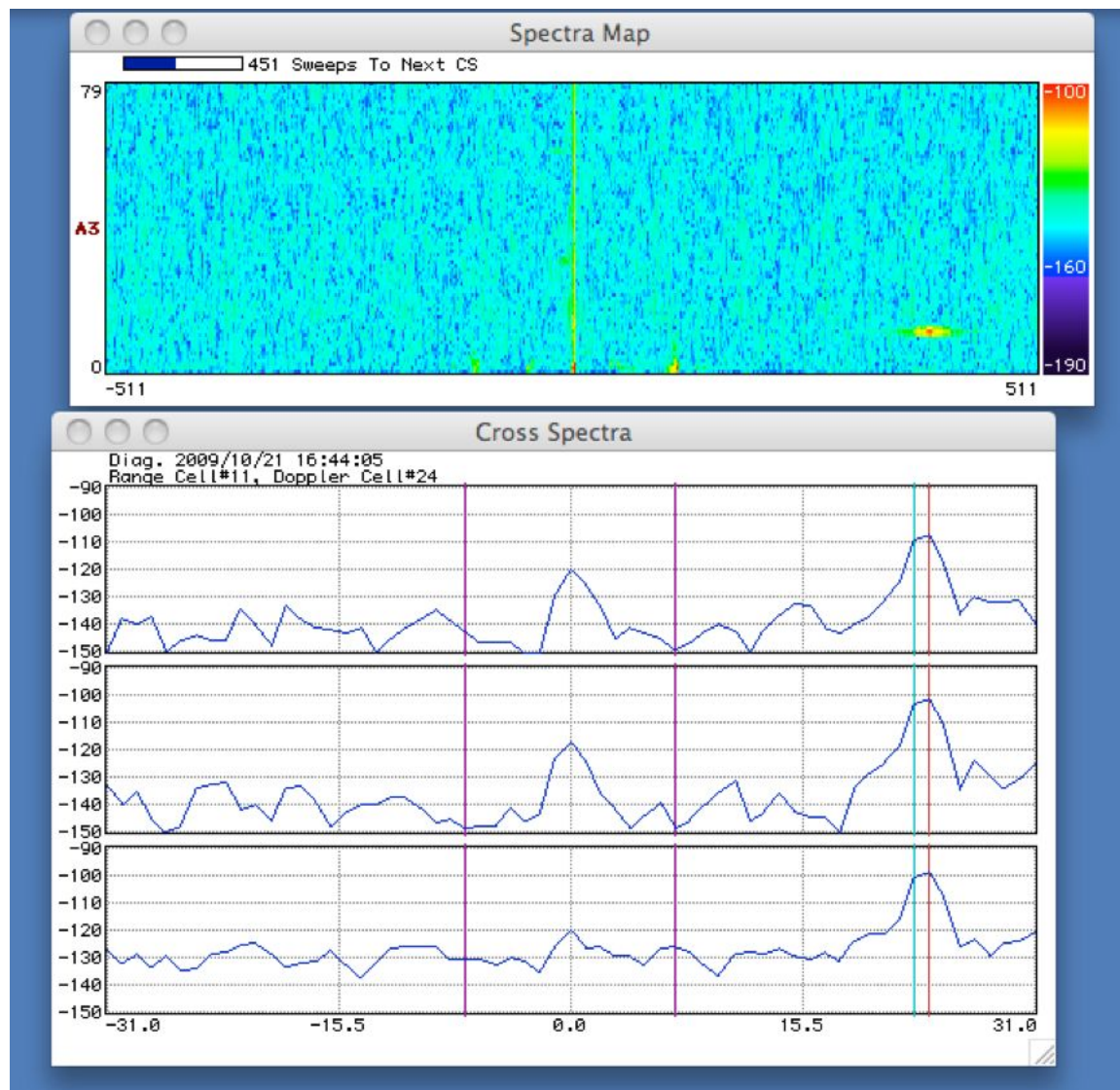
Range Display window showing transponder peak at range cell 13 in channels 1, 2 and 3.



Range Color Map window showing transponder peak signal (yellow band near range cell 13.)

REFINE TRANSPONDER AND RECEIVER SETTINGS

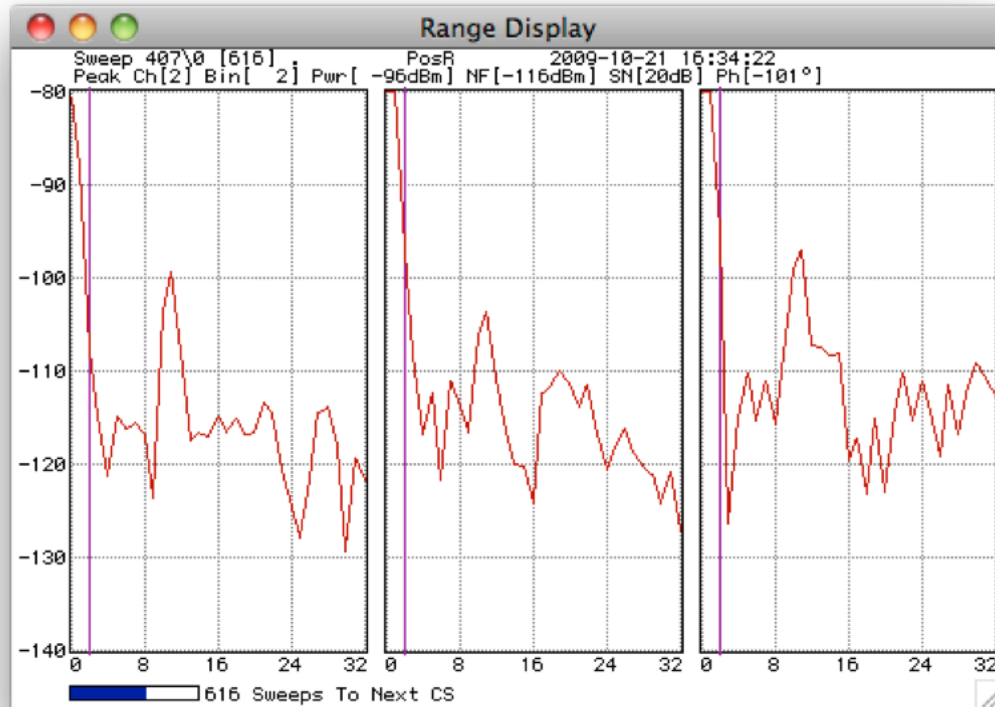
Setting the transponder offset value places the transponder signal peak in a desired location within the range and Doppler spectra of the radar. The desired location in range is around range cells 8-12 and desired location in Doppler is on the right hand side of the spectra between the area where Bragg appears and the edge of the window.



If the transponder signal is too close to the Bragg region or the edge of the display window, adjust the offset value in increments or 0.1 to shift the peak right or left in the spectra. Increasing the offset moves the peak to the right and decreasing moves it to the left. Move in small increments; if the peak reaches the edge of the display, it will wrap to other side of the Doppler.

USER TIP: The recommended offset is not always the perfect value for an individual system. For the best peak placement possible, refine the value by testing on land at the site prior to measurement day or at least prior to set up on the boat. Take a laptop computer to program the transponder so that you can adjust the offset and look at how the peak moves on the site computer in real time. You can always

program with the site computer but having a laptop makes things a little easier and avoids any receiver commands being accidentally sent to the transponder.



In the "Range Display" the maximum value of the peak should not be more than -50 dB and it should be 20dB or more above the background noise. It is easier to see the approximate level of background noise by using the "persistence" feature (looks like this feature is no longer available in release 8). Click on the Range Display and then under the "Monitors" menu, select "persistence". The order of plots in range display from left to right is Loop 1, Loop 2, Monopole. One of the loops will have less of a peak if you happen to be positioned in a null of that loop. This is not a cause for concern.

If the peak signal is too weak, then lower the attenuation or move the transponder closer to the receiver (but not within one wavelength).

If the peak signal is too strong, greater than -50 dB, then increase the attenuation, move the transponder further away from receiver or possibly remove whips/antenna sections from the transponder. For a walking pattern you would remove **both** horizontal whip(s) from the transponder. In a walking pattern situation **never** use only one horizontal whip because while you may have excellent signal strength, " the single, unbalanced horizontal radial will radiate horizontal

polarization, the "pattern response" at the receiver will be contaminated by horizontal polarization, and the pattern will not be a good one" "This is not a factor when the transponder and its antenna are in a boat 500 m out to sea, because the good sea water kills any horizontal polarized component." On the day of measurement if you are planning a boat pattern, check this signal level at the distance you plan to run the track and make adjustments accordingly.

Adjust attenuation on the receiver controller as necessary. Raise the attenuation to suppress Bragg peaks. Lower the attenuation if the transponder signal is too weak.

Note: It is helpful to capture an image (shift-apple-4) of your settings in the transponder window for recordkeeping or write the frequency and offset values down.

USER TIP: If at all possible, take a pre-programmed backup-up transponder!!! A boat APM requires a considerable amount of planning, expense for boat hire, the labor of at least two or three people, good weather, etc. All this planning, expense and time can amount to nothing if the transponder suddenly fails.

TROUBLESHOOTING

NO COMMUNICATION WITH THE TRANSPONDER

A common issue is an inability to communicate with the transponder for programming.

- 1) Try a different cord.
- 2) Try a different computer.
- 3) Open up the transponder and take out the board. On the underside of the board is a USB connection (unless you are using the oldest version of the transponder). You could try that port directly; however CODAR would prefer that users not do this and risk shorting out the equipment while running with the top board removed.
- 4) Mac OS X v10.6 Snow Leopard includes a 64-bit kernel.
Current SeaSonde Release 6 software is not compatible with 64-bit kernel. So you need to boot your MAC with 32-bit kernel.

FIRST STEPS IF NO PEAK IS SEEN

If the transponder peak is not visible on land near the site even at low attenuation, first try these simple checks:

- 1) Doublecheck that the site is set to pulse in SeaSonde Controller and that data collection is started in SeaSondeAcquisition.
- 2) Open transponder, look at board for red steady light indicating power on and a steady yellow status light.

- 3) Make sure nothing is obstructing the signal and that there is a clear path between transponder and receiver.
- 4) Safely check battery voltage with multimeter and/or switch to a fully charged spare battery.
- 5) Make a note of all your receiver site settings in SeaSondeController Advanced Control window. Restore default settings by typing 'default' into the "Send" box and hitting the "Send" button a few times. Then manually re-enter all site APM settings and "Store". Check for peak again.
- 6) Reprogram the transponder. Go back to default settings and re-enter the settings again doublechecking for correct center frequency and offset. Store and check for peak again.

If the transponder peak is not visible from the water at low attenuation, all of the above checks still can apply but you might first try bringing the boat in as close as safely possible to shore to see if it is simply a weak signal issue.

NEXT STEPS

Contact CODAR support at 408-773-8240.

There is a video tutorial for a transponder bench test on the CODAR web site. Note equipment needed for this test first:

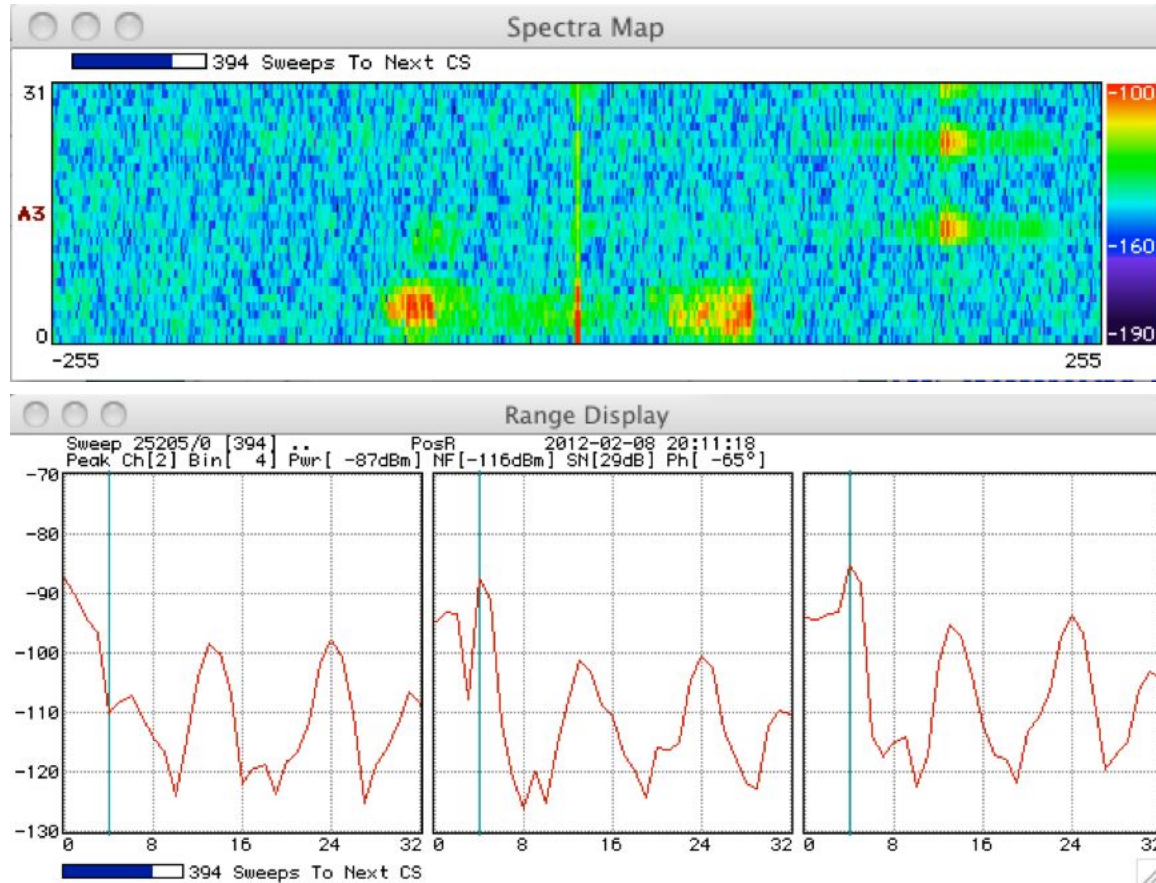
- Transponder and Receiver
- Receiver cable (USB Type B to Type A)
- Standard receiver drive cable (two male BNC connectors)
- CODAR Transponder extension kit cable
- Adapters
 - Male to male BNC
 - BNC T connector with 1 Male connector and 2 Females
 - Female N to Female BNC
- Two 20 db attenuators female BNC to male BNC
- Laptop
- Power cord
- Wrench

The cost of two 20 db attenuators with tax and shipping is ~\$140 (estimated April 2012). Those are the most expensive items. Chances are that even with this test complete you will probably need to send the unit to CODAR for repair under an RMA. The minimum charge for an RMA is \$400 (April 2012).

MULTIPLE PEAKS

First verify all other neighboring SeaSonde sites transmitting at same center frequency are not transmitting. A couple operators have seen the transponder signal repeated at different ranges and the reason for this is unknown. It could be a

sign that something is wrong with the equipment. However, as long as the first peak occurs near range cell 10 and is at a reasonable signal level, it should not cause a problem for the measurement. Report the incident to CODAR and keep an eye out to make sure there are no other problems.



ADDITIONAL INFORMATION

Why are receiver settings modified for the APM?

The "Blank" field is a setting which is used to optimize listening time based on expected range. If the blank value is too high, the receiver is listening past the time when signals can reasonably be expected to return. The transponder signals will be coming from a relatively short distance away and therefore this number is greatly reduced for the pattern measurement. Setting the **blanking time** to (sixty) **60** microseconds during an APM reduces the normal Bragg return, helping to keep the transponder signal from being confused with the Bragg.

The “Bdly” field is the blank delay. It is the time that the system allows for the Transmitter to shut off. It represents a delay before the Receiver can listen, which is why the number is reduced for a transponder.

Pulse Shaping is set to off because at a 60us blanking interval, pulse shaping will never allow the transmitter to come up to full power.

The attenuation of the transmit signal is increased so that sea echo returns from greater ranges are diminished. The transponder is close for a boat run and even closer for a walking pattern. It doesn’t require much forward power output from the transmitter to be able to return a strong signal.

“Doubling the sweep rate pulls the first order Bragg peaks closer to DC leaving more “room” for the transponder peak to wander in the Doppler window w/o merging with the FO Bragg peaks.” (Bruce Nyden, per comm)

PATTERN MEASUREMENT

An operator checklist can be printed from Appendix A.

CHECK ANTENNA BEARING

Doublecheck antenna bearing (bearing of arrow on bottom of old style antenna box or bearing of sights for dome style receiver) with the sighting compass. Verify bearing matches current entry in SeaSondeRadialSetup.

TURN OFF OTHER TRANSMITTERS

Turn off transmit at nearby field sites *sharing the same frequency* while performing the pattern measurement.

TIP: If communications between sites is slow, connect to the remote site through ssh in the Terminal window and issue the following three commands in order:
osascript –e ‘tell app “SeaSondeController” to AwgCommand “xoff”
osascript –e ‘tell app “SeaSondeController” to AwgCommand “boff”
osascript –e ‘tell app “SeaSondeController” to AwgCommand “prpt”
(That last bit of the command is a double quote followed by a single quote)
After each command there will be a confirmation “OK”

The first command sets transmit to off, the second turns off blanking and the third displays a power report confirming forward power is off.
Look for the line reading XMVF: 0.0W

DISABLE NORMAL DATA PROCESSING

Quit all applications. A quick way to do this is to go into the Sentinel application "Control" menu and select "Quit All User Applications". Then quit the Sentinel program.

Re-open SeaSondeController and SeaSondeAcquisition.

In SeaSonde Acquisition, disable data processing/acquisition under the "Processing" menu.

Turn off logging of Cross Spectra and Range Series in SeaSonde Acquisition "File" menu.

CONFIGURE RECEIVER APM SETTINGS & CHECK FOR TRANSPONDER PEAK

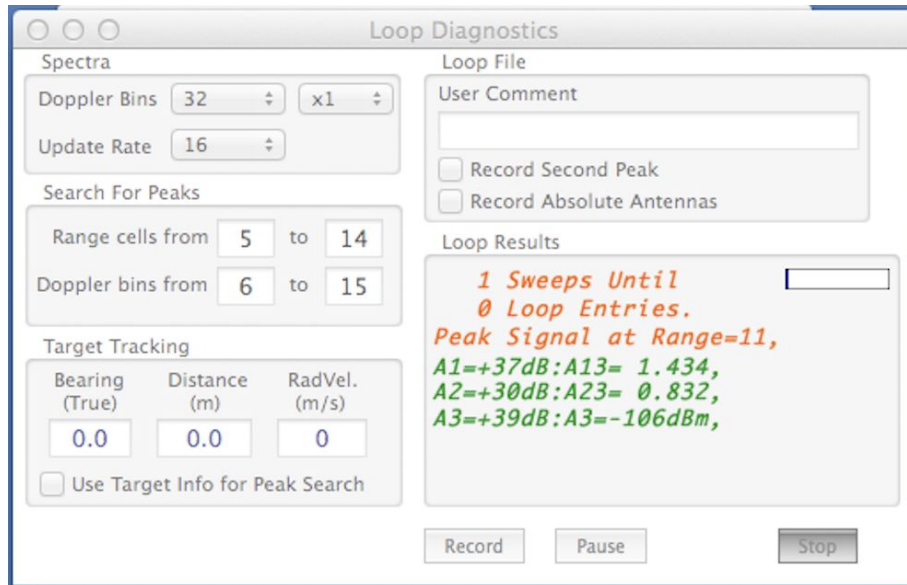
Follow the instructions in the "Check for Transponder Peak at Radar Site" section of this document.

If you have been running enhanced blanking, verify that it is turned off for the APM!

Release 7/8 Software:

To track the peak in the "SpectraRangeDisplay" window, make sure that the "Use Target Info to Set Search" box in the "Loop Diagnostics" window is **unchecked**. Tell "Loop Diagnostics" to look for the peak initially from range cell 8 to range cell 14 and Doppler from + 6 to -6. You could then set a tighter window if you wish based on where you see the peak. Look at the signal strengths reported in the "Range Peak Info Monitor". If needed, refer to steps in the "Refine Transponder and Receiver Settings" section of this document. Write down the range cell number and Doppler cell number for the transponder peak (look in upper left corner of SpectraRangeDisplay).

Also write down the Power (dBm) for channel 3 (A3 in Loop Results section of the "Loop Diagnostics" window.



SYNCHRONIZE COMPUTER CLOCK TO GPS TIME

In SeaSondeController, go to the Control menu, select “Receiver Controller” and then “GPS Monitor.” Check the bottom box. Select “Set Computer Time” in the drop down menu and hit “Send” button.

START LOGGING TIME SERIES DATA

Check one more time that all receiver settings are correct!!

Turn on logging of time series in SeaSondeAcquisition “File” menu.

“Restart Data Acquisition” from the “Processing” menu. *Verify* the recording of LvL files. They will appear in the “TimeSeries” folder under /Codar/SeaSonde/Data/TimeSeries.

Tell the boat captain (or walker) to begin logging with the GPS and begin the track (first arc). Note the start time.

DURING THE RUNS

WALKING OR ON THE BOAT

Verify GPS is secured and logging every 5-10 seconds; 5+ satellites is best.

Follow an arc by entering the exact antenna location as a waypoint and maintaining a constant distance from it along the track. In a perfect world, with a perfect arc there would be no observed Doppler shift due to the movement of the boat/walker because the antenna only detects motion of objects moving directly towards or away from it. It does not “see” any motion in the perpendicular direction described by the arc. If the radial velocity of the boat is too high, it may push the transponder peak off of the spectra display window (and into a different range cell). This should be avoided if possible.

During a walking pattern “do not tip the transponder antenna off from vertical by, say, 30 degrees.” This generates horizontal polarization which the receiver loops are sensitive to but the monopole is not. This will cause a bad measurement. (Don Barrick, per comm)

Check in with site operator at middle and endpoints of arcs.

After both CW and CCW arcs are completed, stop logging GPS, note end time.

AT THE SITE COMPUTER

Make a note if peak disappears for all channels and tell boat operator if it drops out for more than a few seconds. Watch as track crosses nulls. You should see the peaks in channels one and two rise and fall as the transponder travels through the nulls.

Take full screen shots every now and then during the pattern. Do this by pressing the key combination Shift-Apple-3 and an image of the full screen will be saved to the desktop.

CODAR recommends keeping the transponder peak from wrapping around to the other side of the Doppler window by closely following the arc with the boat. Any movements away from or toward the antennas will be included in the measurement. The computer operator should notify the boat operator if this wrapping occurs. The data with excessive boat velocity can be filtered out later in the processing, but this will mean that fewer points will be used to create the pattern.

When both arcs are completed, stop logging the data.

TURN ON OTHER TRANSMITTERS

Turn transmit on again at all sites. If communications between your sites is slow, then you can do this by connecting through ssh in the Terminal window and issuing the following three commands in order

```
osascript -e 'tell app "SeaSondeController" to AwgCommand "xpuls"'
osascript -e 'tell app "SeaSondeController" to AwgCommand "bpuls"'
osascript -e 'tell app "SeaSondeController" to AwgCommand "prpt"'
```

(That last bit of the command is a double quote followed by a single quote)

After each command there will be a confirmation "OK"

The first command sets transmit to pulse, the second sets blanking to pulse and the third displays a power report which allows you to further confirm that forward power is okay. Look for the XMVF line and verify the normal watt reading for the site.

RESTORE SETTINGS FOR STANDARD OPERATION

Re-enter and store the normal operation receiver settings in SeaSondeController. Close all applications and start Sentinel OR restart the computer. Check that the site is operating with correct settings. Check the SeaSondeAcquisition File menu to confirm that the software is saving the desired data files (range, cross spectra).

SAVE FILES TO DISK

Create a folder for this APM. Name the folder with site and date. Put the following files in the folder and save it to disk.

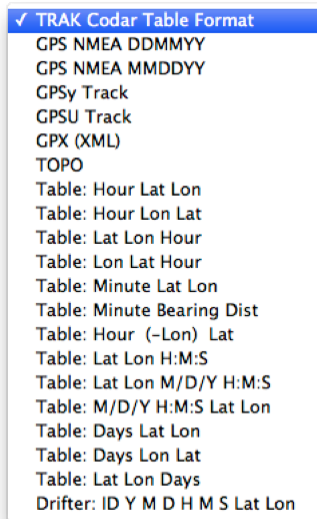
- TimeSeries files in a folder
- Copy of RadialConfigs folder
- GPS Record (add later if not immediately available)
- Screenshots
- Site Log Notes

PROCESSING AND INSTALLING THE PATTERN

CREATE GPS "TRAK" FILE

Use CODAR's GPSTracker program to import the GPS files. See the CODAR video tutorial.

GPS tracker supports these file formats:



Free software programs available from the Internet can easily convert between different GPS formats. See <http://www.gpsbabel.org/download.html>. For example, NMEA 0183 sentences can be converted to GPS XML format, which can then be read by GPSTracker. CODAR support site links to another software called "LoadMyTracks".

For those operators who have radars that operate multi-statically and produce ellipticals, there is a new feature in the SeaSonde Release 7 version of GPS Tracker which allows the user to input a transmit antenna 1 and transmit antenna 2 location.

CREATE LOOP FILE

See the CODAR video tutorial. Contact CODAR support for a email copy of APMGenerationGuide.pdf (I believe latest version was written by Hector Aguilar.)

USER TIP: Copy the RadialConfigs folder used on site during the APM onto your office or processing computer in /Codar/SeaSonde/Configs/. This ensures consistency in the setup (number of range cells, etc.) while creating the loop files.

Additional Notes:

In the Diag. Control window, there are drop down boxes for “Doppler Cells” and “Update Rate” The default values are 32 and 16 respectively.

The “Doppler cells” setting affects the resolution in Doppler space.

The “Update Rate” setting affects resolution in time. Decreasing the rate results in preliminary smoothing before you have the option to smooth in Cross Loop Patternner. There will fewer points in the loop file.

USER TIP: HOW TO ADD LAND POINTS TO EXTEND PATTERN

It is best to use land segments / land point measurements that were collected on the same day as the boat measurements. Create two LOOP files with the land measurements to attach on either side of the boat pattern. Copy and paste lines from those files into the LOOP file for the boat pattern (in the appropriate places according to bearing) before running Cross Loop Patternner.

CREATE PATTERN FILE

Create the pattern file with Cross Loop Patternner (CLP). The two relevant resources are APMGenerationGuide.pdf and “Guide_CrossLoopPatternner.pdf”

CODAR software (so far...up to Release 8) has not included an option to smooth a pattern differently over a specific range of bearings. If a pattern is generally good, with only one bad section or spikes that persist after applying CLP initial filters in the “Filter” window, then this section or the bad points can be eliminated manually to avoid smoothing the entire pattern more than desired. Use a text editor to remove the undesirable bearings and re-plot in CLP to check that the chosen points were removed as intended. The .loop file, SEAS_.patt file or the unsmoothed/uninterpolated MeasPattern.txt file can be edited by hand in a text editor. Editing the loop file will remove points at the earliest stage in the processing and can be great for removing 1 or 2 points spikes before they carry over and affect nearby points in the later files. Once a .patt file is made, the clockwise and counterclockwise arcs have already been combined so if any spikes persisted after applying the filters in the CLP “Filter” window, those points were incorporated into the merged pattern that appears in CLP “Pattern” window and in the .patt file. Choose which text file you would like to edit based on your particular situation. Note that if you remove lines in the .patt file, the number of bearing entries is given in the header line TableRows and must be changed to reflect the number of entries removed. If you choose to directly edit the MeasPattern.txt file, the number of entries is given at the top left-hand side of the file and this number must be changed accordingly.

With that done, one may use the interpolation feature in CLP window 3 to interpolate over the removed section and smooth the pattern as desired for the majority of the pattern.

A GOOD PATTERN?

The CODAR AntennaPatternMeasurements presentation reviews and illustrates what makes a good pattern and what characterizes a poor one. This short list summarizes characteristics of a bad pattern:

- Loop pattern is missing nulls
- Loop amplitudes are out of balance
- Loop amplitudes (or phases) couple over angular sector
- Lots of spikes or nulls - multiple valued
- Monopole has sharp spikes or nulls

Ultimately you need to test the pattern and view the radial maps to see how well the pattern performs. Use standard SeaSonde software or the batch reprocessing script (see CODAR support website) and process 24 hours of CSS files with the pattern. Look at the results with SeaDisplay.

TESTING PATTERNS

From email correspondence with CODAR support (March 27 2018):

There is no fixed universal number. (irrespective of boat or walking pattern)
It depends on what kind of distortion or coupling is present in the raw loop file processed for that pattern run.

We usually suggest the following procedure before deciding on the amount of smoothing to apply:

1. Create patterns with No Smoothing, 10°, 15°, 20°. **(Read note below)
2. Process at-least 72 hrs of data (preferably 1 week) with the above patterns and compare the radial distribution and also do at-least a visual check of several radials from different time periods for each pattern type.
3. Based on above comparison, you want to pick the lowest amount of smoothing that gives reasonable radial results for a given site.

Additional Note on Smoothing: Lower the smoothing, the lesser averaging over bearing you are applying for the data and hence higher the accuracy. If the pattern is

so distorted that even with 20° smoothing, you don't see reasonable pattern features and radial results, then try 25° or 30°, but never more than 30°. Usually, if a pattern needs 30° smoothing, then it indicates that it's not a good location in terms of antenna environment and one should consider relocating the antenna.

Rarely there are cases when you will use a pattern with no smoothing(though we have seen such cases before). Usually 10° or 15° often turns out to be a sweet spot based on historical data.

INSTALLING THE PATTERN

The last section of APMGenerationGuide.pdf describes how to install a new pattern on the RADAR site. This description in that guide does not use SeaSondeRadialSetup (SSRS). **USER NOTE:** You may install the pattern with the SSRS program. If you install with SSRS, doublecheck that your correct MeasPattern.txt in is the RadialConfigs folder.

ADDITIONAL NOTES ON PROCESSING

Notes on Smoothing from Bill Rector:

“I think that at least 10deg smoothing should always be applied to get rid of measurement noise. Sharp jumps in the pattern within 10deg sectors are likely NOT pattern distortions. Medium scale (10 to 30) inflections (slope opposite of expected) in the pattern are cause for concern as are huge variances from ideal and possible new site consideration.”

Notes on Smoothing from Bruce Nyden:

“Smoothing is used to mitigate for gaps in the measured radials (a quirk of MUSIC's direction finding). There is no hard and fast rule for minimum/maximum smoothing. If smoothing > 15-20 degrees is required to remove the gaps in the measured radials then the site is probably not well suited for a SeaSonde and you should consider moving it to another location.”

Some operators prefer smoothing radials after on an angular filter (e.g. 3 point average over 15 degrees) instead of smoothing the pattern itself.

The degree reduction from 1 deg to 5 deg is a smoothing operation because it averages; it does not extract points at a 5 degree interval from the loop pattern.

Recent versions of SeaSonde software (release 6+) automatically convert a measured pattern to 1 degree. The values in the MeasPattern.txt will be changed by the software automatically. However the ID code in the file stays the same.

If the site is set to output radials at 1 degree intervals, the degree resolution of the pattern also should be 1 degree. Generally radials are output at 5 degrees.

Notes on Pattern Improvement provided by Mike Muglia/UNC:

1. Ambiguity plots: By making ambiguity plots of measured patterns using the de Paolo, Terril paper "Properties of HF RADAR Compact Antenna Arrays and Their Effect on the MUSIC Algorithm", we were able to identify sections of the pattern that were "bad" where the distance b/w all manifold points in signal space is plotted. Where the inverse squared distance is separated from the diagonal on the plot, and thus not monotonically decreasing, we were able to identify potential problem bearings in the antenna pattern.

2. Extend patterns onshore for archived boat patterns w/o land points

In the case of an older pattern that did not have a walking pattern to complement it, we did this artificially by stitching an ideal antenna pattern (maybe 30 degrees on each end) to the ends of the measure pattern, thus extending the pattern over land artificially.

3. Quantify the quality of an antenna pattern: We implemented the Laws et al method (Laws, Paduan, Vesecky paper "Estimation and Assessment of Errors Related to Antenna Pattern Distortion in CODAR SeaSonde High-Frequency Radar Ocean Current Measurements") to determine the amount a pattern departs from the ideal, and thus measure the quality of a pattern and estimate an uncertainty due to the pattern based directly on Laws' estimate. This is done by comparing a fit of the real and imaginary part of each loop to the corresponding ideal components and getting a fit parameter, the gamma parameter mentioned in their paper.

AIS PATTERN MEASUREMENT

The AIS method matches ships echoes in the spectra with AIS information to perform the calibration. It was developed through a partnership with CODAR and UCSB.

PATTERN MEASUREMENT

This method requires installation of CODAR SeaSonde AISPattern software and a license key to run. The software runs continuously and produces loop files every day. The amount of data and available bearing coverage will depend on ship traffic in the area. At many stations, a few days of loop files are often enough to process a pattern.

PATTERN PROCESSING

Using CODAR software:

Open multiple daily loop files in CLP and the processing is similar to how you would process a transponder pattern, but with more filtering options available.

Using MATLAB:

DRONE PATTERN MEASUREMENT

Drone pattern measurements were developed at University of California Santa Barbara. Eduardo Romero is the lead developer for drone operations and the contact point for more information. This method uses a signal source (called the CSS) designed by Cyril Johnson. See photo below of signal source hanging from the drone.

An advantage to this method is that the signal originates from a location over water at distances of a few hundred meters from the antenna, but it does not require a boat. The CSS has proven reliable and is not as cumbersome as the transponder box that requires the large green antenna (5, 13 MHz) or the whips (25, 42 MHz). Sea state is not a concern; however, wind speeds must be low. For example, in the case of the DJI Phantom 4 drone, a 15 mph sustained wind with up to 20 mph gusts is the upper limit of recommended wind speed considering that battery power is drained more quickly in windier conditions even if programmed flight is executed well. There are also flight restrictions for drones in many areas. It may be necessary to get special permission to fly in certain places (e.g. state and national parks) and it may not be possible to fly in others (e.g. near airports).

To get started in this type of pattern measurement requires

1. Contacting Eduardo Romero (eromero@ucsb.edu)
2. Reading the UCSB AAPM Guide documentation
3. Obtaining CSS and setting up hanging wire (dipole antenna)
4. 3DR or DJI Phantom drone (preferred although others may work)
5. A pilot with FAA commercial drone license (See materials on FAA website and this helpful video* at https://www.youtube.com/watch?v=6_ucCKFJUCU for taking the test. The test costs \$150 and takes 2 hours max. It requires a few days to study and take practice tests.)
6. Permission to fly at the HFR stations.

*Thanks to Patterson Taylor at UNC Coastal Studies Institute for this video recommendation.

USING A SUPER TRANSPONDER

(FOR LONG DISTANCE OR TRANSMIT ANTENNA PATTERN)

Sending a transmit signal with a supertransponder instead of performing the measurement in transponder mode is useful for measuring the pattern from a farther distance and when measuring the pattern of the transmit antenna.

What follows is a copy of a document provided by CODAR Tech Support with user notes inserted in red. The document is called TransponderSetup.pdf. The version reproduced here was last updated on Mar 8 2011. Instructions involving SeaSondeController are written for versions of SeaSonde software release 6 and

earlier. (Some changes were made to SeaSondeController menus and window labels in release 7.)

Setup For Super Transponder

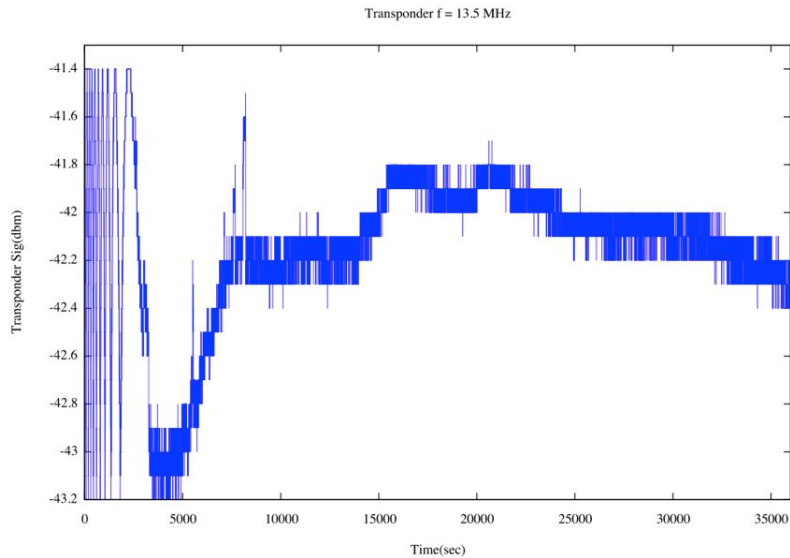
Equipment and Tools Needed

- Super Transponder
- Charger for Super Transponder
- Special “pig tail” Cable Used to Connect Green Antenna to Transponder
- Transponder USB Cable
- Type N to BNC Adapter
- Computer with SeaSonde Controller version 10.2.3 minimum

USER RECOMMENDATION: Use an external 12 Volt, 7 Amp Hour Gel Cell (or bigger). You will need something to charge it with and a cable for connecting the external battery. When using the internal battery, some users found that the super transponder lost communications and did not retain settings when powered down. To charge the 12 Volt, 7 Amp Hour battery, you can use an adjustable bench power supply set to 13.8v (at room temperature) and current limited to $\sim 1/10$ of the amp hour rating of the battery, and charge until the current drops to 0.

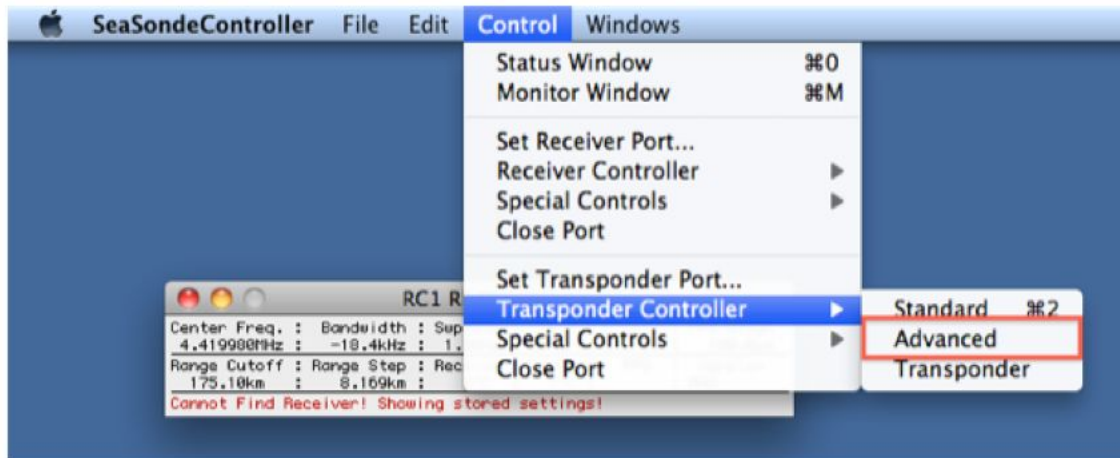
IMPORTANT NOTE: It takes time for the supertransponder equipment to warm up and during this time the frequency may drift causing problems with your offset between the transmitter and the site.

“A 2-hour warmup is recommended based on tests of a single SuperTransponder unit. Although we have no data for a standard Transponder operating in CW mode, it would be prudent to allow a 2-hour warmup as well if CW mode is used. Here is a plot of the warm-up/response of the Super Transponder that was tested in our shop.” (CODAR staff, per comm)



Setup Instructions

- 1) Charge Super Transponder fully before use.
- 2) Power the Super Transponder and connect to the SeaSonde Computer.
- 3) Open the Transponder Port by selecting the option in the SeaSonde Controller Control menu.
- 4) Select the Transponder option in the Select Port for RC2 window that pops up.
- 5) Select the Advanced Control window from the Transponder Controller submenu.

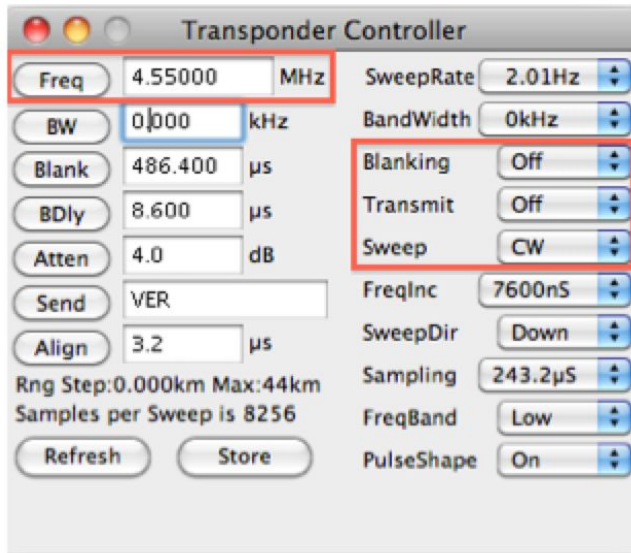


- 6) In the Advanced RC2 Controller set the following settings: - Set the Center Frequency to the center frequency used by the SeaSonde **USER NOTE: Check other settings as well. Blanking and Transmit be "On" NOT "Pulse. The Sweep should be "CW". These values SHOULD be the default and the user should not have to set them. However the supertransponder has been known to have these stored incorrectly in the past and it is worth doublechecking.**
- 7) STORE THE SETTINGS

8) Setup the green whip antenna on the Super Transponder, use the Type-N to BNC adapter to connect to the BNC port on the side of the transponder box, the ground goes to the side connectors. Set the transponder one wavelength from the RX antenna.

9) In the RC1 Advanced Controller: **USER NOTE: These are the RADAR site settings not transponder settings.**

- Set the SeaSonde's center frequency 100 Hz below the normal center frequency -
Set the Transmit setting to Off - Set the Blanking setting to Off - Set the Sweep to CW



10) In SeaSonde Acquisition open a Range Display window.

11) Since you are receiving only and the transponder is transmitting without an offset, you will need to adjust the frequency between the two slightly to force an offset. By having the center frequency 100 Hz below the regular value a secondary strong peak should be visible. Adjust the frequency accordingly to get the stronger peak between range cell 15 and 25 in the range display.

12) Turn off the transponder, make sure it is fully charged before going on the boat. Also as a reminder sync your GPS receiver and computer clocks and don't forget to log time series and GPS tracks when you start your APM.

Appendix A: Pattern Measurement Checklist

Adapted from the Rutgers University APM Checklist

Date _____

Site _____

Transponder Settings

Frequency _____ (5 / 13 / 25 / 42)

Offset _____ (20.7 / 40.7 / 40.7 / 80.7)

Receiver Settings

Frequency _____ (5 / 13 / 25 / 42)

Bandwidth _____ (25 / 50 / 150 / 150)

Blank _____ (60) (or 120 if can't use 60)

Blank Delay _____ (4.75)

Attenuation _____ (15 boat / 30 walk)

Sweep Rate _____ (2 / 4 / 4 / 8)

Pulse Shaping _____ (Off)

Enhanced Blanking Turned Off _____

(only if you have enabled enhanced blanking, this is not a default set up for SeaSonde systems)

Magnetic Bearing of Arrow on Rx _____ degrees

Loop 1 Bearing True Matches

In Header file

Synchronize Clock

Only SeaSondeController and

SeaSondeAcquisition Running

Transponder Peak Signal (Monopole) _____ dB

Turn Off Tx at Sites on Same Frequency

Stop Logging Cross Spectra

Started Logging Time Series at _____ UTC

Take Screenshots (Shift Apple 3)

Stopped Logging Time Series at _____ UTC

Turn On Tx at Sites on Same Frequency

Verify Normal Processing

Saved Files to Disk

(RadialConfigs, TimeSeries, Log, Screenshots, GPS)

Notes:

Appendix B: APM Equipment Checklist

- _____ **Transponder**
- _____ **Spare Transponder** (if possible)
- _____ **Correct USB cord for transponder**
(depends on transponder version, either DB9 to Type A USB or Type B USB to Type A USB)
- _____ **Fully charged transponder battery**
(a 12 volt 2.9 amp hour SLA battery)
- _____ **Spare charged transponder battery**
- _____ **GPS**
(capable of recording tracks with time stamps at least every 5-10 seconds and capable of range to target readout)
- _____ **Spare GPS** (if possible)
- _____ **Sighting Compass**
- _____ **4 and/or 8 Foot Whips for Transponder** (see Crib sheet)
(WALKING PATTERNS AND 25/42 MHz BOAT PATTERNS)
- _____ **4 Piece Green Antenna** (5/13 MHz BOAT PATTERNS)
- _____ **Green Antenna Base** (5/13 MHz BOAT PATTERNS)
- _____ **Green Antenna- Transponder Cable** (5/13 BOAT PATTERNS)
- _____ **Transponder Grounding Wire** (5/13 MHz BOAT PATTERNS)
- _____ **Communications Equipment**
(walkie talkies, charged VHF radios, or cell phones if coverage is good)
- _____ **Spare Batteries**
(e.g. for GPS, walkie-talkies, etc)
- _____ **APM instructions including CODAR APM Crib sheet**
- _____ **Laptop with SeaSonde software**
(for programming transponder, highly recommended, simpler than using site computer and you never know when reprogramming may be necessary)

Other Equipment

- _____ **Portable Disk Drive**
- _____ **Site keys**

Appendix C: Antenna Mount

Contributed by Mark Bushnell, CoastalObsTechServices



§ 2" PVC coupling (Home Depot #189-022)

§ (2) 3/8" x 24 SS bolts

§ 2" floor drain (Home Depot #730-216)

§ (4) 1" pan head SS wood screws

§ 2" PVC pipe, 4" length

§ self-adhesive rubber non-skid pads

§ 2'x 2' 3/4 exterior plywood base

§ (4) 1/8" x 12' braided line

Carve a cable exit hole in the floor drain, making it large enough that the cable easily passes and can be shifted during assembly. Drill four holes in the floor drain for the mounting screws. With the cable in place, fasten the floor drain to the plywood base with the stainless

steel screws. Drill two 1/2" holes in the top half of the PVC coupling for the 3/8" x 24 bolts that fasten to the antenna base. There's no need to glue the PVC assembly together since it's all held in place by guy rope compression. Stick the rubber non-skid pads on the bottom of the plywood base.

Fasten the 1/8" guy ropes to the top of the bottom antenna segment by first using ty-wraps to hold them in place and then wrapping/braiding the line 4 or 5 times "chinese finger" style around the antenna. Secure the braids in place with a wrapping of electrical tape.

Appendix D: Publications

Whelan, C., M. Hubbard, D. Trockel, H. Parikh. "Benefits of Multiple Antenna Pattern Measurement Methods for Maintaining a Regional HF Radar Network." Proceedings of the ORCA Conference, Okinawa, Japan (2018).

Washburn, L., E. Romero, C. Johnson, B. Emery, and C. Gotschalk. "Measurement of Antenna Patterns for Oceanographic Radars Using Aerial Drones." *Journal of Atmospheric and Oceanic Technology*, Vol. 34, No. 5, 971–981 (2017).

Laws, K., J. D. Paduan, and J. Vesecky. "Estimation and Assessment of Errors Related to Antenna Pattern Distortion in CODAR SeaSonde High-Frequency Radar Ocean Current Measurements." *American Meteorological Society* (1029): 1-15 2010.

De Paolo, T., and E. Terrill. "Properties of HF RADAR Compact Antenna Arrays and Their Effect on the MUSIC Algorithm." *Scripps Institution of Oceanography Technical Report*, Scripps Institution of Oceanography, UC San Diego, 1-41 (2007).
<http://escholarship.org/uc/item/5bw303tj>

Kim, SY, E. Terrill, and B. Cornuelle. "Objectively Mapping HF Radar-derived Surface Current Data Using Measured and Idealized Data Covariance Matrices." *Journal of Geophysical Research*, Vol. 112, C06021 (2007).

Lipa, B., B. Nyden, D. Ullman, and E. Terrill. "SeaSonde Radial Velocities: Derivation and Internal Consistency." *IEEE Journal of Oceanic Engineering*, Vol. 31, 850-861 (2006).

Barrick, D. "New Result - Bearing Accuracy with SeaSonde DF Established." *CODAR Technical Report*, (2003).

Kohut, J.T., and S.M. Glenn. "Improving HF Radar Surface Current Measurements with Measured Antenna Beam Patterns." *Journal of Atmospheric and Oceanic Technology*, Vol. 20, 1303-1316 (2003).

Lipa, B. "HF Radar Current Velocity Uncertainties." *Sea Technology*, Vol. 44, (2003).
Lipa, B. "Uncertainties in SeaSonde Current Velocities." *IEEE/OES 7th Working Conference on Current Measurement Technology*, 1-6 (2003).

Paduan, J., D. Barrick, D. Fernandez, Z. Hallock, and C. Teague. "Improving the Accuracy of Coastal HF Radar Current Mapping." *Hydro International*, Vol. 5, (2001).

Barrick, D.E., and B.J. Lipa. "Using Antenna Patterns to Improve the Quality of SeaSonde HF Radar Surface Current Maps." Proceedings of the IEEE Sixth Working Conference on Current Measurement, 5-8 (1999).

Teague, C. C., and K. E. Laws, ``Comparison of MUSIC direction finding and beam formation for HF multifrequency radar," International Union of Radio Science Program and Abstracts. International Union of Radio Science, 311 (1999).

Laws, K. E., D. M. Fernandez, J. D. Paduan, C. C. Teague, and J. F. Vesecky, ``Simulation Studies of Errors in HF Radar Ocean Surface Current Measurements,"IGARSS'98 Sensing and Managing the Environment, Vol. I, A08.09.1-A08.09.3 (1998).

Teague, C. C. and K. E. Laws, ``HF Multifrequency Ocean-Wave Current Radar: MUSIC Direction Finding Vs. Beam Formation," Proceedings of the 8th URSI Commission F Triennial Open Symposium. International Union of Radio Science, 105-108, (1998).

Barrick, D.E. and B.J. Lipa (1997), "Evolution of Bearing Determination in HF Current Mapping Radars", Oceanography, Vol. 10, 72-75 (1997).

Teague, C.C., ``Application of the MUSIC Algorithm to a Multi-Frequency HF Ocean-Wave Radar," North American Radio Science Meeting, 388 (1997).

Barrick, D.E., and B.J. Lipa. "Comparison of Direction-Finding and Beam-Forming in HF Radar Ocean Surface Currentmapping." National Oceanic and Atmospheric Administration (1996).