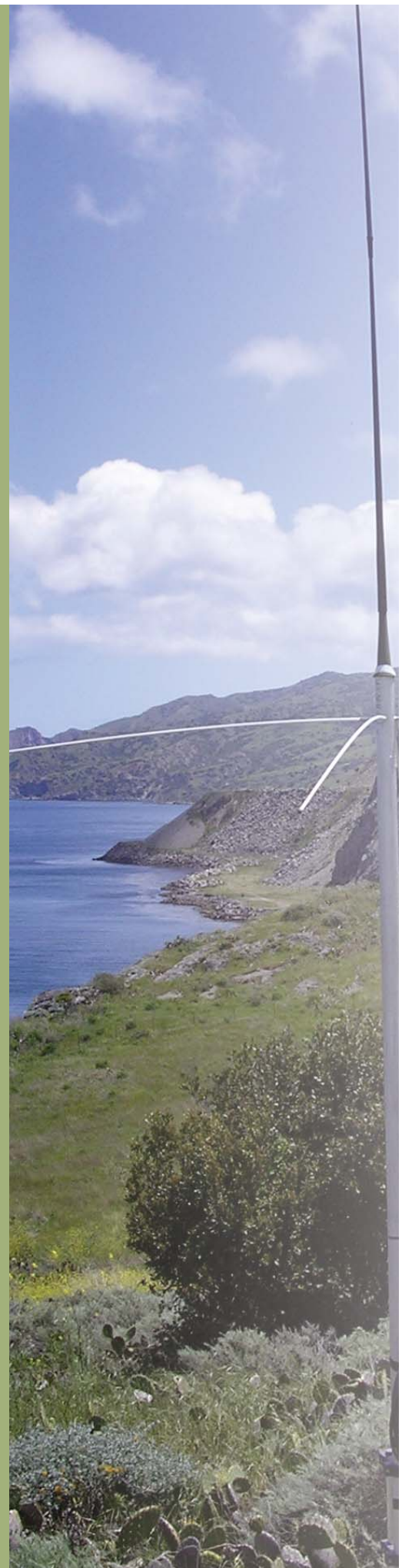


DEPLOYMENT & SETUP  
*of a High-Frequency Radar for*  
Ocean Surface Current Mapping:  
**BEST PRACTICES**



# Deployment & Setup of a High-frequency Radar (HFR) for Ocean Surface Current Mapping: Best Practices

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# PREFACE

In anticipation of the use of the Southern California Coastal Ocean Observing System (SCCOOS) as a model for a national HFR network, SCCOOS has prepared the following document of best practices for deployment and setup of a HFR ocean surface current mapping system. The systems selected by SCCOOS for ocean surface current mapping are the SeaSonde<sup>®</sup> family of direction-finding HFRs manufactured by CODAR Ocean Sensors, Ltd. (COS). The best practices discussed in this document apply to the installation, operation, and maintenance of CODAR SeaSondes. This document has been modified to include input from the recent Radiowave Operators Working Group (ROWG) Workshop hosted by Scripps Institution of Oceanography, September 2007.

This document should be considered a supplement, secondary to the information provided by COS and the other manufactures whose products are discussed herein. Manuals for the SeaSonde systems are provided by COS in the /Codar/SeaSonde/Docs directory on each computer they ship, as well as on their websites [www.codar.com](http://www.codar.com) and [www.seasonde.com](http://www.seasonde.com).

## 1. LOCATING AN HFR

Due consideration needs to be given to the amount of time and money it will take to gain/purchase access to, and use of, the intended HFR site. Additionally, sufficient time and money must be allotted for obtaining the required permits to use the land as a HFR site (e.g., Coastal Development Permit) and to operate the HFR (e.g., Federal Communications Commission broadcast permit). It is recommended that any regulatory or governing agencies into whose purview a HFR installation may fall be contacted, well in advance, to determine the preferred method of application and a realistic timeframe for project approval.

An ideal location for a HFR possesses the following characteristics:

- widest possible unobstructed field-of-view of the ocean
- ample room to accommodate the antennas, electronics, and cable-runs
- site which minimizes distance to the water but is safe from waves and splash
- free of obstructions, particularly electrically conductive (e.g., metallic) objects
- onsite electricity
- flat or gently sloping terrain that is easily traversed and free of hazards (e.g., poison oak)
- no radio interference at your permitted frequency<sup>1</sup>
- onsite broadband internet connectivity
- secure from damage caused by animals (e.g., cows, bears) and human vandalism
- nearby vehicle access

### 1.1 Site Requirements

On SeaSondes with separate receive (Rx) and transmit (Tx) antennas, the Rx and Tx should be separated by a minimum distance of one wavelength ( $\lambda$ ) based on the center frequency:

$$\lambda = \frac{f}{c}$$

where  $c$ , the speed of light in  $\text{m s}^{-1}$  ( $\approx 299792458 \text{ m s}^{-1}$ ), and  $f$ , the center frequency in Hz, will give  $\lambda$  in meters. Additionally, both antennas should be placed no farther from the water than specified in Table 1.

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<sup>1</sup>The frequency spectrum should be measured with a spectrum analyzer for 24 hours or more at a given location before selecting it as a HFR site. This will allow broadcast permission to be sought from the FCC more selectively by applying for use of only those applicable frequencies with the least radio noise. Additionally, measurement of the frequency space at a site beforehand will allow identification of any sources of potential interference in advance. Spectrum analyzers are quite expensive and, if one is not available, the SeaSonde can be run in "spectrum analyzer mode" to serve a similar function (contact COS for details).

Table 1. Maximum distance to the water for SeaSonde Rx and Tx, based on operating frequency (from COS User's Guide for: SeaSonde Radial Site Antenna Site Selection).

Frequency (MHz)	Maximum Distance to Water (m)
4-6	250
12-14	150
24-27	150
47-50	100

A HFR site needs to have enough space to accommodate the minimum antenna separation while remaining within the specified distance from the water. Additionally, electrically conductive objects such as metal structures, trees, and power lines should be avoided as these will distort the antenna pattern, thereby degrading data quality. While distortion of the antenna pattern can in some instances be compensated for with an antenna pattern measurement, more severe distortion can invalidate all the measurements made at a HFR site.

With the exception of the SeaSonde hardware and cables, metal objects longer than 1 m should ideally not be within 100 m of either the Rx or Tx. Any metal objects longer than 1 m (e.g., pipes) buried within 100 m of the Rx or Tx should be 10 m or more underground. Metal objects less than 1 m long should be located at least 4 m from both the Rx and Tx and, within that 4 m radius, any buried metallic objects should be underground deeper than 4 m.

Aboveground obstructions are of particular concern (e.g., other antennas, towers, buildings) as these tend to produce more severe distortion of the HFR antenna pattern. Given the height of an obstruction (H) in meters, the minimum distance (R) to either the Rx or Tx is given in meters from:

$$R = 5 \times H$$

Cliff faces and steeply sloped ground can also degrade the HFR measurements by acting as a reflector of the transmitted radio signal. Gently sloping or level ground is preferred for a HFR site.

Many operating HFR sites do not meet every one of these criteria and still produce acceptable measurements. When an “ideal” site is not available, consideration should be given to mitigating existing obstructions. COS or another experienced HFR technician should be contacted to determine the likely impact existing obstructions might have on the HFR site.

#### 1.1.1 POWER

Electrical power is required at the location of the Tx and Rx chasses. The standard coaxial cables supplied with the SeaSonde HFR system allow a separation of ~250 ft between the Tx and Rx chasses and the Tx and Rx antennas. Ideally a HFR site should have an existing shelter available within 250 ft of the HFR site with electrical power for the SeaSonde and associated electronics.

In the case where electrical service from an existing utility power-grid is not already available at the HFR site, a concerted effort should be made to tie the HFR site into the power grid. The power requirements of a HFR site allow extension cables to provide a link to an electrical outlet up to approximately 150 ft away before voltage loss<sup>2</sup> becomes a concern. Voltage line loss can be compensated for by using a thicker gauge wire for the extension cord.

An economical solution to accessing electrical power up to 1000 ft away or more is a “Buck and Boost” transformer. An electrician

<sup>2</sup>The longer a cable is, the more resistance an electric current encounters. This resistance causes a drop in the voltage of the electric current (i.e., line loss). Too great a drop and the HFR electronics cannot function. An electrician can help determine the voltage drop for a given cable length, with knowledge of the wire gauge and type of electrical connection.

cian can install a Buck and Boost transformer at an existing electrical panel or create a sub-panel and install the Buck and Boost at a point along an electrical cable-run. A Buck and Boost transformer raises the line voltage to compensate for line loss. The Buck and Boost transformer can be complemented by a step-down transformer at the HFR site to return the voltage to the appropriate level. Use of a Buck and Boost often requires a new breaker to be installed at the electrical panel as well as additional cables of thicker gauge wire to be run to the HFR site. The electrical cable-runs may need to be trenched or placed in conduit above-ground in the appropriate grade of polyvinyl chloride (PVC) pipe (e.g., Schedule 80). Another option is to have power poles erected and overhead electrical wires installed to extend the utility power grid directly to the HFR site.

In those locations where utility grid power is not available, a HFR site can be powered using solar panels, windmills, a generator, or a combination thereof. Assuming continuous operation, the cost of creating off-grid electricity to power a HFR site is in the tens of thousands of dollars. Over the course of a week, the power consumption of an operating HFR was measured by the Center for Coastal Marine Sciences at California Polytechnic State University to be 50.96 KWh. From the formula:

$$\frac{\text{KWh}}{\text{time}} = (\text{continuous watts}) = \frac{50.96 \text{ KWh}}{167 \text{ hrs}} = 305.15 \text{ W continuous}$$

this translates to a continuous consumption of approximately 306 W of alternating current (A/C) by the HFR site<sup>3</sup>.

If local electrical power is unavailable, solar power is a viable alternative. One solar power solution has been developed by Center for Coastal Marine Sciences at California Polytechnic State University. This solar power solution is comprised of 12 solar panels and a full suite of batteries. The panels are mounted on a mobile trailer for ease of placement. Many land owners prefer to have a non-permanent solution that can be moved easily. A full description of two solar power systems can be found in appendices B-C.

#### 1.1.2 COMMUNICATIONS

Communication with the HFR site via a broadband internet connection allows for near real-time data transfer and system control. While manually traveling to the HFR site to periodically download data is possible, an internet connection is functionally considered a prerequisite for a HFR site. Additional benefits of an internet connection at the HFR site include the ability to control the radio transmission (a FCC requirement), remote monitoring of the site's operational status, and reduction in on-site maintenance by allowing computer and support functions to be performed remotely.

Best results are achieved with an on-site 10 Mbps or greater ethernet connection. If such a connection is not available, wireless relay (e.g., 802.11 or 900MHz) antennas can be used to link the remote site to a hardwired network connection over a distance of kilometers. Wireless relay systems work best when the network connection is within line-of-site of the HFR. Additionally, wireless relay antennas can be used to transfer the wireless internet signal around obstacles, but with each additional antenna comes the process of seeking the permission of the landowner at that necessary location as well as the cost of the additional equipment.

Satellite internet or cellular broadband should be considered at those sites without a wired internet connection—or where the only wired connection is a telephone modem—and where wireless relay to another network connection is impractical. Service areas for these connections are limited, so satellite internet and cellular companies should be contacted in advance to see if an intended HFR site falls within their coverage area.

Primarily the internet connection at a HFR site is used to send data and screen images. Accordingly, obtaining the maximum upload speed for the internet connection at the HFR site should be the focus. With an upload speed of 128 Kbps or more, real-time

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<sup>3</sup>Power consumption was logged using a Kill A Watt™ (model #P440), manufactured by P3 International. The components of the HFR site included in this measure of power consumption were: a 12 MHz SeaSonde (Tx and Rx chassis with global positioning system [GPS] synchronization), Apple 12" PowerBook G4 laptop computer, NetGear Router (model #WGR614), LaCie 250 GB hard drive (model #300728U), MFJ-993B Antenna Tuner, and WildBlue satellite internet modem. Running amps were approximately 4.05 at 120 V A/C.

screen control and mirroring is possible as well as transfer of lower-level spectral data files. High-speed DSL, cable modems, satellite internet, and cellular broadband can all provide these speeds if an existing network connection is not available. A telephone modem can provide another wired connection to the internet, but this technology is considered obsolete as connection speeds are so slow as to severely inhibit remote maintenance and transfer of all but the highest level data. At minimum, an internet connection for the HFR site needs to be able to transfer the approximately 300 KB hourly .ruv files of radial velocities.

## 1.2 Climate-controlled Enclosure Specifications

### 1.2.1 HFR ENCLOSURE

The electronics enclosure selected by SCCOOS is a custom stainless-steel enclosure manufactured by EIC Solutions, Inc. (Figures 1-2). The enclosure is used to provide a self-contained, air conditioned environment for the HFR electronics at those locations where a weatherproof, climate-controlled shelter is not already available. Specifications for the enclosure are as follows (*italics indicate additional components to be installed by the customer*):

- Dual-Access, Floor-mount Enclosure, 36" high × 24" wide × 32" deep
- NEMA 4X (indoor/outdoor use) configuration, welded type 304 Stainless Steel construction
- Front and rear doors, each fully gasketed, hinged left, latched right
- Standard 1/4-turn latches on doors, top right latch per door "barrel style" and padlockable (padlocks not included)
- Grounding studs (4) on doors and inside enclosure (customer to attach two (2) flexible copper grounding wires, one between each adjacent wall and door grounding stud bolt; not included)
- Two (2) rectangular air conditioner cut-outs and six (6) mounting holes on rear door for Kooltronic (#KNA4C3P21R) 3000 BTU air conditioner (customer to install air conditioner, not included)
- One (1) cable exit hole, 64 mm diameter, through lower left-hand corner of side wall (to accommodate Roxtec model RG/M63-9 cableway gland, installed by customer, not included)
- Standard 19" rack-mount rails on front and rear sides of enclosure
- Rails to be "side flange style," powder coated (or plated) steel, with punched (not tapped) holes, for use with "clip-nuts" (included)
- Rails to be ~32" high and horizontally-adjustable, front-to-rear (two [2] pairs of Ameri-Rack #ASL-2001 sliding rails are to be installed by customer to mount SeaSonde Rx and Tx chasses, not included)
- 1" thick fiberglass insulation, one side foil-faced, installed throughout enclosure
- External mounting tabs (4), stainless steel, welded in place on bottom of enclosure (two on right, two on left)

The enclosure should be bolted to a pallet to provide ground clearance for front and rear doors. An electrical outlet can be installed inside the enclosure to provide power distribution from electrical wiring entering through the cableway gland.



Figure 1. Interior of empty outdoor electronics enclosure without air-conditioner attached.



Figure 2. View of outdoor electronics enclosure with both doors open. Air conditioner is attached and all HFR electronics are mounted within the enclosure.

### 1.2.2 AIR CONDITIONER

The air conditioner designed to fit the enclosure described in Section 1.2.1 is the 3000 BTU model #KNA4C3P21R manufactured by Kooltronic, Inc. Use of the air conditioner is vital with the above enclosure to provide heat dissipation for the HFR electronics and to prevent corrosion by dehumidifying the incoming air. In a sealed enclosure the Tx and Rx chassis can overheat in less than an hour without air conditioning and will stop functioning.

The KNA4C3P21R is part of the Integrity Series 21 NEMA 4/4X air-cooled panel-mounted stainless steel air conditioners manufactured by Kooltronic. It runs on 11.3 A of 115 V A/C, weighing 76 lbs. and is 21.19" high × 12.01" wide × 12.48" deep. Mounting of the air conditioner should be done on-site to minimize stress to the mounting hardware in transit. Additionally, the air conditioner should be kept strictly upright during transport as rough handling, laying the air conditioner sideways, or inverting it will destroy the condenser.

### 1.3 Support Equipment

Included with every SeaSonde COS ships is an Apple computer which controls the HFR system. To accommodate the enclosure described in Section 1.2.1 a laptop, rather than a tower, model needs to be requested from COS. The computers come preconfigured from COS and are ready for on-site installation.

An external back-up hard-drive is recommended for archiving data acquired by the HFR. The interface for the back-up hard-drive can be either FireWire 400 or USB 2.0 to allow for hot-swapping the drive once it nears capacity.

An uninterruptible power supply (UPS) should be used to protect the HFR electronics and provide temporary battery backup in case of power failure. The UPS selected by SCCOOS is Tripp Lite's model #SU1500RTXL2Ua with the optional SNMP-WEBCARD. The SU1500RTXL2Ua is a 1500 W UPS in a 2U rack-mount design which provides approximately 30 minutes of battery backup for the HFR during power outages. The SU1500RTXL2Ua acts as a surge suppressor and ensures pure sine-wave power through over-voltages and brownouts. The SNMPWEBCARD is an internal simple network management protocol (SNMP) accessory card for installation in the SU1500RTXL2Ua. The SNMPWEBCARD upgrade allows the electrical power at the HFR site to be monitored and controlled remotely via the internet through a website interface. Given the SU1500RTXL2Ua's 1500 W maximum output, the air conditioner described in Section 1.2.2 cannot be plugged into the UPS as it draws too much power. All other HFR electronics should be plugged into the UPS. Suggested UPS vendors include TrippLite, APC and Falcon.

Most UPS systems come with software which can be configured to shut down computers that are connected. Results are mixed with the use of the various software products, especially with compatibility with Mac OS. Additionally, remote power management products may be used as a last ditch effort to reboot computers and hardware using a phone line or IP connection. Power Stone remote power systems have been known to cause problems at several Rutgers sites.

### 1.4 Networking

With an ethernet connection at the HFR site, as recommended in Section 1.1.2, a router should be used to act as a gateway for the site's internet connection and to distribute connectivity to the various network-enabled components (i.e., laptop and UPS). Additional network security can be achieved by setting up a virtual private network (VPN), which can also allow secure sharing of an existing network connection at a host facility.

The router should have the following ports opened (i.e., port forwarding) to allow communication via the specified protocols/applications:

22	(secure shell [SSH])
80	(hypertext transfer protocol [HTTP])
407	(Netopia, Inc. Timbuktu®)
409	(Tripp Lite PowerAlert®)
1417-1420	(Netopia, Inc. Timbuktu)

Incoming access to the HFR site will require the remote user to input an internet protocol (IP) address. Some networks and internet service providers offer a static IP address, a numeric address that does not periodically change. For those HFR sites where the internet service is provided with a dynamic IP address, a dynamic domain name service (DDNS) can be used to frequently query the HFR site's IP address and map it to a static alphanumeric IP address. A static IP address is preferred, over a dynamic IP, since network access to the HFR site can be blocked during the window (typically less than five minutes) between when a dynamic IP changes and the DDNS service checks the dynamic IP.

## 1.5 Antenna

### 1.5.1 ANTENNA

Antenna whips for CODAR Ocean Sensor systems are Shakespeare Style 4208 NAVIGATOR Loran C. The main reason for failure is breakage due to over exposure

*Problem:* Arcing between antenna mast sections in 13MHz systems utilizing a balun for tuning caused by build up of salt and/or moisture.

*Recommendation:* Run an uninsulated cable between the two mast sections and insulate the upper terminal of antenna mast to create sparking point.

### 1.5.2 ANTENNA MOUNT

Stability is maximized when the Rx and Tx antennas are mounted in level concrete pads constructed at the HFR site (without metal rebar to distort the antenna pattern). Anchors for the Rx and Tx antenna guy wires can be incorporated into the concrete pad as well. Cableways can be trenched from the pads to the electronics enclosure to eliminate exposed aboveground wiring. The construction permits, soil disturbance, and additional labor this mounting entails limit its applicability to many HFR sites.

An excellent alternative, innovated by Jim Pettigrew (San Francisco State University, Romberg Tiburon Center for Environmental Studies), is an antenna mount consisting of a length of electrical metallic tubing (EMT) bolted into the 26" Pole Genie® manufactured by Krinner USA, Inc. (Appendix A). By drilling a hole through the EMT, the Pole Genie/EMT "spear" can be screwed down into the soil at the HFR site using a metal bar. The antenna mast is then sheathed over the EMT pipe now sticking straight up out of the ground. By electrically isolating the EMT from the antenna mast with plastic bushings, galvanic corrosion is inhibited and the antenna pattern is unaffected. Rotation of the antenna mast on the EMT pole is prevented by drilling holes through the antenna mast, on through the EMT, and then screwing in nylon screw to serve as cotter pins.

For long-range (5 MHz) Tx antennas, a hole needs to be dug around the screw anchor and the EMT cut off just beneath the rim of the hole (former ground level). A Schedule 80 PVC bushing is then used to fit a Schedule 80 PVC flange to the EMT tube. With the flange and bushing secured level to the EMT pipe with epoxy and screws, the flange at the base of the long-range Tx antenna can be mated to the PVC flange and bolted in place. The PVC flange mounted to the ground screw electrically isolates the Tx from the mounting.

*Problem:* Antenna rotation causing receive antenna to lose data.

*Recommendation:* Incorporate gyroscope or compass to avoid rotation errors due to wind.



## 2. HFR SETUP

Setup of the HFR site consists of both the hardware and the software. The location and placement of the HFR is discussed in Section 1, including components used and physical layout. With the HFR hardware in place as required by the SeaSonde design, site-specific configuration customizes the HFR to the environment and intended application.

### 2.1 Long, Medium, and Short-range Configuration

The SeaSondeController and SeaSondeRadialSetup applications, part of COS's radial site software suite, are used to specify the settings necessary for operation of the HFR site (Table 2). The SeaSondeController settings are largely governed by your permitted center frequency and bandwidth, as well as by the amount of forward and reflected power measured by the Transmit Drive Control panel. These values will dictate further settings/setup within the SeaSondeController application.

Table 2. Table of suggested SeaSondeRadialSetup settings for high-resolution, standard-range, and long-range SeaSonde Systems.

Frequency	Radial Coverage	Radial Output	Angle Resolution
4-6 MHz	180 minutes	60 minutes	5°
12-14 MHz	75 minutes	60 minutes	5°
24-27 MHz	75 minutes	60 minutes	5°
47-50 MHz	75 minutes	60 minutes	5°

### 2.2 Antenna Tuning

On Standard-range and High-resolution SeaSondes, adjusting the position of the balun up or down the Rx cable at the antenna can optimize the ratio of forward to reflected power. A prefabricated tuning coil is available from COS for their long-range SeaSonde systems. Given advance notice of the intended center frequency, COS can fabricate a tuning coil for installation with the Tx antenna. The tuning coil is installed as a coupler between the upper and lower halves of the long-range Tx antenna and secured with hex screws.

In systems without a balun, or when tuning with the balun is insufficient (Voltage Standing Wave Ratio [VSWR]>2), an antenna tuner can be used to minimize the reflected power. The antenna tuner selected by SCCOOS is the Dual 300/150 Watt IntelliTuner<sup>®</sup> Automatic Antenna Tuner (model # MFJ-993B) manufactured by MFJ Enterprises, Inc. The MFJ-993B is installed as an intermediary between the Tx chassis and the Tx antenna. By turning off blanking and sweeping in SeaSondeController and appropriately increasing the attenuation to bring transmit power within the tuning limits of the MFJ-993B, the IntelliTuner can automatically tune the antenna to the center frequency. The “semi-automatic” tuning function of the MFJ-993B allows the tuning settings, automatically set when the SeaSonde's transmission was constant, to remain static when blanking, sweeping, and attenuation are restored. The semi-automatic setting also ensures the MFJ-993B will not re-tune the antenna in the event the antenna environment changes (e.g., the Tx falls over).

Regardless of tuning method, it is important to monitor the transmitted and reflected power to diagnose transmitter health and function. Special care should be taken when using automatic tuners, since during a tuner malfunction reflected power will spike.

### 2.3 Antenna Pattern Measurement

An antenna pattern measurement (APM) is vital to ensuring the accuracy of the surface current data and should be regarded as part of site setup. While the assumption of an “ideal” antenna pattern allows maps of radial currents to be produced by the HFR, this does not account for distortions in the antenna patterns. Often these distortions cause enough inaccuracy in the measurements that the data are invalid without an APM.

The transponder and antenna whips needed to perform an APM are available from COS. Additionally, a GPS, boat, and seawater ground will be needed to perform the APM (backup batteries for the transponder are also recommended). Typically the boat will start 1.5 km down-shore of the HFR site and travel, maintaining the 1.5 km radius, in a semi-circle 1.5 km up-shore and back again (in the case where the HFR is on an island, the boat will make a full circle around the island).

COS produces three documents regarding APMs: *User's Guide for: SeaSonde Radial Site Antenna Pattern Measurement* (available from [www.codar.com](http://www.codar.com)), *APM Crib Sheet for All Systems* (available from [www.seasonde.com](http://www.seasonde.com)), and *APM Generation and Application* (available by request from COS). These documents should be referred to for instructions on how to perform an APM and apply the measured patterns to the HFR. Additionally, COS should be contacted prior to performing the APM for the latest information and for assistance in processing the measured pattern for the HFR site.

## 3. HFR SOFTWARE

### 3.1 *SeaSonde software configuration*

For the most part, the default SeaSonde software settings have been proven to work well for a typical deployment. In the case that changes are required, it is advisable to check all the configuration files in the RadialConfigs directory for the altered setting, as duplicates exist among the various configuration files. For example, there is an entry for Ionospheric Removal in both the Header.txt and AnalysisOptions.txt files.

### 3.2 *SeaSonde Data Files*

The SeaSonde software can produce a variety of output files. Not all of these files are required to be stored during typical operations. A list of SeaSonde data files follows below:

*TimeSeries (Lvl)*: Rawest form of data. Not typically stored.

*RangeSeries (Rng)*: Output of first FFT. Not typically stored.

*CrossSpectra (CSQ)*: Output of second FFT. Should be retained if space allows.

*Time Averaged CrossSpectra (CSS)*: Running average of CSQ files. Should be retained.

For 13 and 25 MHz systems, the CSS files are a 10 minute average, which include 3 CSQ files. For 5 MHz systems, the CSS files are a 30 minute average, which include 3 CSQ files. Radial files are constructed from a series of CSS files and can be produced for ideal and measured beam patterns. It is recommended to produce and store both radial files.

### 3.3 *On site archiving*

SeaSonde software includes an archival program called Archivalist. This program can be configured to move files from working directories to archive directories. It is recommended that the archive directories exist on a separate internal disk or partition. Additionally, this archive directory can be easily mirrored to an USB or FireWire connected external hard drive using the rsync utility. One issue when archiving the CSS files is that the CSS file writes information to the resource fork of the file. The resource fork is only supported by Apple HFS or HFS+ file systems and will be lost when transferring to other file systems. The rsync utility is aware of the resource fork and can be configured to retain this data.

### 3.4 *Remote Settings for ingestion into National Network*

Recent radial files should be kept in a single static path for acquisition by the COCMP/National Network. The standard CODAR configuration keeps recent radial files in `/Codar/SeaSonde/Data/Radials`. In addition, archivalist should be set to leave enough data in the recent radial data directory to span the longest anticipated network outage length, typically 2-4 weeks. This way, data is locally buffered and remains available for near-real time acquisition routines when connectivity is restored.

### 3.5 Diagnostic reporting

The SeaSonde software provides hardware and software diagnostics that are saved in the DIAG files. An extension of .hdt refers to hardware diagnostics and an extension of .rdt refers to radial diagnostics. Many of these diagnostics are reported within the LLUV radial file. CODAROS is working on a remote site warning script to alert users of out of range variables. This warning script will email users once variables reach a particular threshold, such as low signal to noise. On all the SIO sites, a script independent of the diagnostics files queries the receiver and transmitter to receive pertinent information such as the temperatures, voltages and transmitted power output. This script is configured to provide information on the laptop as well to include disk use and other laptop specific information. Rutgers University developed a site script for checking file size and timestamp accuracy. Emails and text messages are sent based on a size or offset limitation. Other options include posting near real-time radial images and parsed diagnostic data to a web site that can be monitored daily for offsets. One diagnostic utility could be based on antenna phase amplitude changes. Ideally phases remain consistent although jumps may occur due to wind waves. A median phase change of  $10^\circ$  is considered significant and may warrant a site visit or new beam pattern. If measured antenna phases differ from sea echo by more than  $30^\circ$ , the measured antenna pattern should be examined. The signal to noise (SNR) and noise floor radial diagnostics are based on one range cell. These errors should be calculated for each range cell.

*Problem:* Remote sites lack automated diagnostic error checking alerts.

*Recommendation:* Develop and implement automated diagnostic scripts based on variable threshold limits which trigger email or text message warning to users.

*Problem:* Radiation exposure documentation is incomplete.

*Recommendation:* CODAROS should provide field monitoring documentation and testing of equipment.

## 4. SITE MAINTENANCE

While the HFR systems deployed by SCCOOS are automated, regular maintenance is necessary to ensure continuous operation. With an internet connection as described in Sections 1.1.2 and 1.4, system status can be checked remotely and indeed the data acquisition should be checked daily for each site. Remote access, however, is not a substitute for routine on-site inspections.

### 4.1 Required Maintenance

Each component at the HFR site should be inspected every site visit to ensure that it is performing the function for which it was installed. An inventory of the equipment placed at the HFR site can be used to guide the site inspection via a review of each component's condition. Typical maintenance includes a check of:

- Rx antenna direction (compass bearing changed?)
- Rx and Tx antenna mounting and masts (secure and level?)
- Signs of corrosion or salt accumulation on antennas, connectors, or electronics enclosure (long-range Tx base and ground plane free of salt?)
- Condition of cable-runs (damage to conduits or cables themselves?)
- Tightness of guy wires (all ropes firm, secure, and free of fraying?)
- Condition of enclosure (clean and free of insects? gland weatherproof?)
- Air conditioner and filter (clean and lubricated)
- Electronics within the enclosure (corrosion or signs of overheating?)
- UPS (replace if expired or if remote monitoring indicated they are not holding charge)
- On-site system status vs. remote diagnostics (the same?)
- Status of backup hard-drive (replace onsite if remote monitoring indicates nearing capacity)

While this list is not exhaustive, it contains maintenance items common to most sites. The unique characteristics of each HFR installation will dictate the maintenance necessary for that site.

#### 4.2 Schedule for Site Visit

The frequency of site visits should be quarterly or greater. System outages or anomalies in the remote diagnostics/data stream will necessitate additional site visits. Additionally an inspection of the HFR site is recommended after extreme storm events (e.g., very high winds, hail, ice storms, floods). A plan for access with the HFR site property owner should be agreed upon in advance of the installation, with the understanding that additional maintenance will be required to respond to outages.

## 5. HFR DATA MANAGEMENT

### 5.1 Radial File Requirements & Recommendations

The CODAR LonLatUV (LLUV) file format is the recommended output format because it offers extensive metadata for radial measurements as well as hardware diagnostic data. Radial metadata will likely be used by quality assurance algorithms for total vector processing in the near future while the hardware diagnostic data can be used for near-real time monitoring of system health. The older range-bin format of radial data is acceptable but lacks hardware diagnostic data, radial metadata is minimal and is no longer supported by CODAR. Observed variations in the range-bin file format have been documented and are available through the Radiowave Operators Working Group (ROWG) web site ([www.rowg.org](http://www.rowg.org)). LLUV file format specifications are published by CODAR and available through their web site ([www.codar.com](http://www.codar.com)).

Regardless of the format, CODAR radial files must contain the following information in the file name for compatibility with the COCOMP/national network (satisfied by current CODAR naming conventions):

- 4-letter site code (e.g. SDBP)
- Timestamp (GMT or UTC required)
- Patterntype ('s' or 'z' for range-bin format, 'i' or 'm' for LLUV format)

The following information must be kept within the file for compatibility with the COCOMP/national network (satisfied by current CODAR file formats):

- Timestamp
- Timezone (GMT or UTC required)
- Site Location (Lat/Lon)
- 4-letter site code\*
- FileType\* ( i.e. LLUV)
- Patterntype\*  
\* required in LLUV format only

It is not uncommon to see LLUV files that don't have the timezone explicitly stated within them. This is due to multiple timezone configurations that exist in various SeaSonde software applications. It is important to make sure that Time Zone is set correctly in the Header.txt file as well within SeaSondeRadialConfig software for time zone to be correctly set within the output LLUV file. Recommended metadata that will likely become required in the near future are the range resolution and averaging period of the data. Both of these metadata are currently available in CODAR LLUV format data.

## 5.2 Data Telemetry

Near real time data telemetry has been done over FTP and managed by a custom Perl script run through cron on the remote site. The script determines which files need to be sent by comparing files available in the recent radial directory, normally /Codar/SeaSonde/Data/Radials, with a log of files that have already been successfully sent to the FTP server. Various other options are available for accomplishing this task including rsync over SSH and solutions provided by CODAR. The HFR\_Progs toolbox developed at the Naval Postgraduate School in Monterey, CA and the University of California at Santa Cruz may offer additional options and capabilities for this task.

SIO has phased out its use of its custom Perl scripts used for data telemetry from remote sites in favor of the Antelope solution developed for the COCMP/National Network. The Antelope solution requires no code installation at the remote site. The only requirements are access over SSH and the presence of a single static path for recent radial files (see also section 3). Instead of posting data to an FTP server, Antelope stores data to an orbserver which is capable of serving data to the entire HF-Radar Network in real-time. Additional information on Antelope solution for data telemetry is available in 'Data Management and Real-time Distribution in the HF-Radar National Network', Terrill et. al., IEEE OCEANS06 (available through [www.rowg.org](http://www.rowg.org)). Further integration between Antelope managed data telemetry and CODAR central site processing is being carried out in collaboration with San Francisco State University.

## 5.3 Local Data Management/Backups

A typical HF Radar deployment produces a variety of files that are updated at a variety of intervals. The first step for a viable data archival strategy is the identification of files to be archived, the interval at which these files are produced or altered, and the amount of space they require compared to your local computing resources. At the very least, it is advisable to save all Cross Spectra (.cs4) data files, and if space allows to save Range Series (.rs) data files. Both of these allow reprocessing radial current and wave data using different configurations, but Range Series can regenerate spectra and diagnostic information. It is also necessary to save deployment specific files contained in the /Codar/SeaSonde/Configs/RadialConfigs, as well as the Track and Time Series files supporting an APM .

# 6. HFR QUALITY ASSURANCE/QUALITY CONTROL

## 6.1 Quality Performance Metrics

UCSB has conducted a preliminary review of performance metrics titled "Evaluation of SeaSonde Hardware Diagnostic Parameters as Performance Metrics". The study examined a set of hardware parameters and the applicability of utilizing parameters as a diagnostic tool for measuring hardware performance. In summary, HFR performance metric recommendations are shown in Table 3. Except where noted, recommendations are based on the standard values collected during the study. Performance metrics were determined for all of the parameters specified in the study statement of work with the exception of the calculated amplitude corrections for loops 1 and 2 to the monopole (AMP1 and AMP2). The manufacturer (CODAROS) recommended that these parameters be monitored for significant changes. The analysis conducted by UCSB was not able to establish a threshold of significance. Quality performance metrics to establish both QA and QC values is an active area of research and will be addressed in future ROW/ROWG meetings.

Table 3. Performance metric recommendations

Parameter	Code	Value	Standard Deviation
Receiver Chassis Temp (°C)	RTMP	<40 <sup>(1)</sup>	6.0
AWG Board Temp (°C)	MTMP	<50 <sup>(1)</sup>	7.0
MTMP - RTMP		<12	
Receiver + VDC Supply	SP05	>4.7 <sup>(2)</sup>	0.1
Receiver - VDC Supply	SN05	>4.7 <sup>(2)</sup>	0.2
Receiver + 12VDC Supply	SP12	12.3	0.1
Transmitter Chassis Temp (°C)	XPHT	28.9	5.2
Transmitter Amplifier Temp (°C)	XAHT	34.5	5.0
XAHT-XPHT (°C)		>10 <sup>(2)</sup>	
Transmitter Forward Power (W)	XAFW	53.0	13.0
Transmitter Reflected Power (W)	XARW	5.0	5.0
Phase Lock Loop Loss	PLL	0 <sup>(2)</sup>	n/a
Run Time (hours)	RUNT	190	400
<b>Total # Radial Vector Solutions</b>			
13 MHz band	RADV	520	310
25 MHz band	RADV	280	110
40 MHz band	RADV	960	470
<b>Average # Solns per Range Cell</b>			
13 MHz band	RAPR	15	5
25 MHz band	RAPR	10	5
40 MHz band	RAPR	30	15
<b>Maximum Radial Range (km)</b>			
13 MHz band	RADR	75.7	18.7
25 MHz band	RADR	29.4	5.2
40 MHz band	RADR	10.6	2.1
<b>Average Bearing of all Radials</b>			
13 MHz band	RABA		80.0
25 MHz band	RABA		80.0
40 MHz band	RABA		70.0

<sup>(1)</sup>Recommendation given by remote site monitoring script rs\_warn.pl

<sup>(2)</sup>Recommendation given by SeaSonde Documentation

## 6.2 Quality Assurance (QA)

In this document, QA refers to the optimal configuration of a SeaSonde site, in terms of physical setup, software settings, and calibration, as well as vendor tests performed prior to instrument shipment. Each SeaSonde system undergoes factory calibration of the electronics consisting of a receiver antenna test, transmitter chassis test, and receiver chassis test. Factory testing is required prior to receipt of a shipment. Further information on these tests should be directed to CODAROS.

Proper location and setup of an HFR site is discussed in section 1, software settings in section 2, and calibration or beam pattern measurements in Section 3.

## 6.3 Quality Control (QC)

In this document, QC refers to assessment of the data output for validity and correctness of measurements. Although using HF Radar to measure surface current velocity and direction has been accepted in the community, the assessment of data quality is an ongoing research area. Members of ROWG have provided discussion notes on this topic and are summarized here.

Needs assessment:

- Establishment of a set of standards for QC of radials, which may not necessarily preclude use from total vector combination
- Development of an automated utility based on specified threshold limits which will notify operator of potential discrepancies in data
- Establishment of a real-time flag for data quality
- Continued comparison with in-situ instrumentation
- Standardized minimum file format and software version for processing on the national server
- Establishment of minimum data storage requirements for reprocessing (e.g. range series, cross spectra)
- Development of a share community HFRtoolbox with formal support
- Establishment of metadata requirements for radial and total vector distribution

Potential QC parameters

- Temporal variability
- Spatial variability
- Signal-to-Noise (SNR)
- ALIM settings
- Direction of Arrival (DOA) from MUSIC algorithm
- Radial rms patterns

The need for quality control algorithms and flags within radial and total vector measurements is unquestionable. What those flags and algorithms are requires further discussions and research.