

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



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PREFACE

The use of HF radar for the collection of ocean surface current information in near-real time is quickly expanding. As this national radar network grows and matures, there will be a need for a defined set of best practices for radar system operations and maintenance. In anticipation of this need, the radar operators for the Southern California Coastal Ocean Observing System (www.sccoos.org) prepared this document titled “The Deployment & Maintenance of a High-Frequency Radar (HFR) for Ocean Surface Current Mapping: Best Practices”. The editors’ intentions are that this document may serve as a stimulus for developing a national set of operational best practices. The document defines a set of best practices developed from the collective experience of the operators usage of compact direction finding radar systems, specifically, the SeaSonde® family of direction-finding HFRs manufactured by CODAR Ocean Sensors, Ltd. (COS). The best practices discussed in this document focus on the installation, operation, and maintenance of CODAR SeaSondes. Further revisions of this document are expected to expand to include other manufacturers of HF radar equipment.

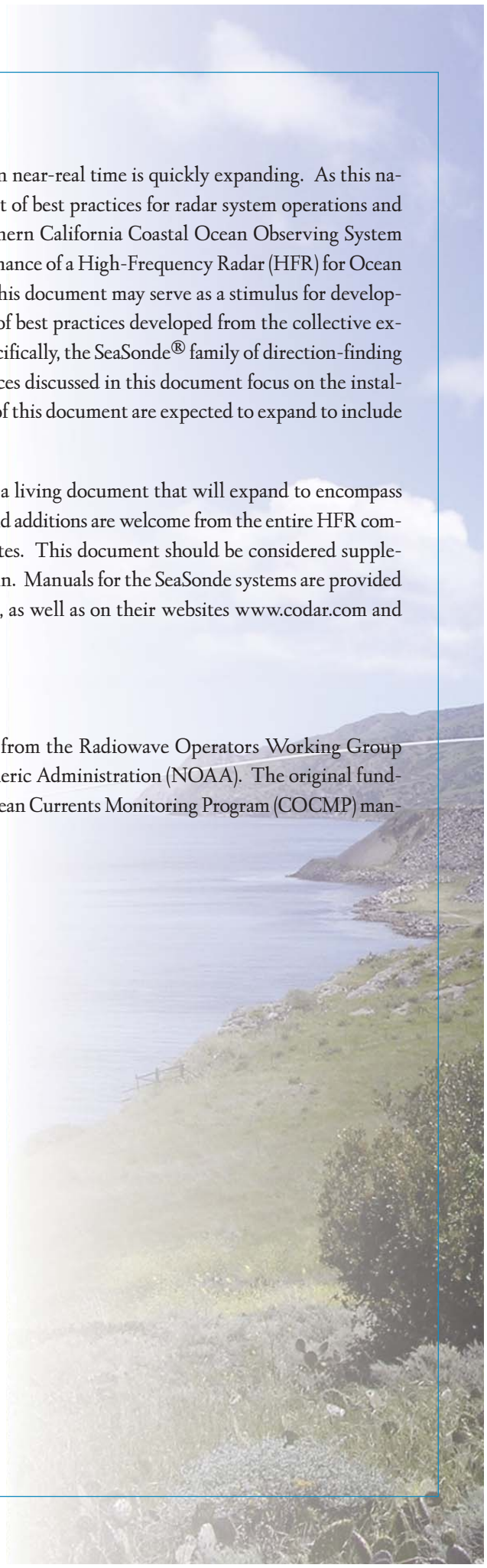
As with all best practice documents, there is an expectation that this will be a living document that will expand to encompass community feedback and suggestions; corrections, modifications, comments, and additions are welcome from the entire HFR community. The below list of editors may be contacted for any changes or updates. This document should be considered supplementary to manufacturer provided documentation for products 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 and www.seasonde.com.

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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 frequency¹
- 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 (λ) based on the center frequency:

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

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

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

¹The 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).

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.

I.I.I 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 loss² 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 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:

²The 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.

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

this translates to a continuous consumption of approximately 306 W of alternating current (A/C) by the HFR site³.

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 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*):

³Power 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.

- 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.

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 chasses 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.



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.

1.3 Support Equipment

1.3.1 DATA ACQUISITION

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 ship 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.

1.3.2 UNINTERRUPTIBLE POWER SUPPLY (UPS)

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.

1.3.2 LIGHTNING PROTECTION

Lightning protection may be installed inline on any antenna (ie Seasonde, GPS, communications) as a safety precaution for personnel and radar electronics. Lightning arrestors provide an alternate path to ground during a high voltage surge from lightning strike. There are a variety of designs, but typically the inline gas discharge types are used for RF communications, including HF radar. Lightning arrestors should be placed where the antenna cables enter the enclosure and properly grounded. The Seasonde receiver and transmitter have different specifications for lightning arrestors, where the transmitter requires a lightning arrestor with 350V sparkover voltage and the receiver requires 90V sparkover voltage. Typically, common lightning arrestors (such as the Altelicon AL-NFNFB) come with gas tubes rated for 90V sparkover voltage. In this case, replacement gas tubes with 350V sparkover voltage can be purchased.

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[®] 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), *APM Crib Sheet for All Systems* (available from 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. COS 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° 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°, 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: COS 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). LLUV file format specifications are published by CODAR and available through their web site (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). 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 (COS) 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.

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 COS.

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.

Table 3. Performance metric recommendations

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

⁽¹⁾Recommendation given by remote site monitoring script rs_warn.pl

⁽²⁾Recommendation given by SeaSonde Documentation

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.

7. REVISION HISTORY

02/26/2007 Concept of Best Practices document was discussed and outline drafted by Scripps Institution of Oceanography (SIO) personnel: Tom Cook, Lisa Hazard, Mark Otero, and Eric Terrill

03/28/2007 Initial draft was completed by California Polytechnic State University (Cal Poly) staff, Brian Zelenke

04/04/2007 Document received was modified by SIO staff, Tom Cook, Lisa Hazard, Mark Otero and University of California, Santa Barbara (UCSB) staff, Brian Emery

01/14/2008 This document has been modified to include input from the Sept. 2007 Radiowave Operators Working Group (ROWG) Workshop funded by the National Oceanic and Atmospheric Administration (NOAA) and hosted at Scripps Institution of Oceanography (SIO). Additions included hardware troubleshooting, quality assurance, and quality control

APPENDIX A: HFR Antenna Mounting with the Krinner Pole Genie

STANDARD-RANGE (BOTH TX AND RX ANTENNAS) AND LONG-RANGE (RX ANTENNA ONLY) SOLUTION

- Purchase 2" diameter EMT, which comes in 10' sections. Cut it so that you have three 40" sections.
- First, mark the location of the auger bushing on the EMT by placing the EMT inside the auger (use a permanent marker).

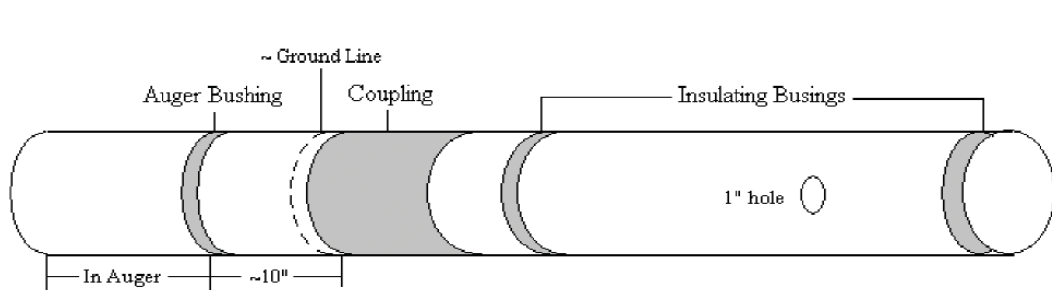


Figure A1. Schematic of the 40" piece of EMT showing the locations of the various parts needed for additional fabrication.

approximately 8" from the bottom of the EMT. Then you can mark the location of the coupling 9.5" up from the auger bushing) and insulating bushings (first one up from the coupling is 1/2"-1" from the coupling, and the second one is at the top of the EMT). The auger bushing is black and is included with the Krinner Auger; the insulating bushings are 2" white nylon bushings.

- In water, boil the insulating bushings and the auger bushing for approximately 5 minutes, so that they expand enough to slide over the EMT.
- The coupling is a 2" Set Screw EMT Coupling (see Figure A2). You will need to file down the out-dented metal ring on the inside until it is able to slide over the EMT. We used 180 grit sand paper, wrapped around a 1/2"-1" diameter hole saw, which filed down the metal ring in approximately 3-5 minutes. You can also use a "rat tail" file.
- Use a 1" hole saw to drill a hole approximately 5" down from the top insulating bushing (drill through both sides), as shown in Figure A3.
- Using a drill and a 7/32" bit, tap four holes through the auger, auger bushing and EMT. Use four #14 x 3/4" sheet metal screws to connect the auger to the EMT (see Figure A4).
- The ground line is approximate, depending on how far you are able to screw the auger into the ground.
- Once in the ground, the CODAR masts simply slide over the screw anchor. Using a 9/32" bit, drill three equidistantly spaced holes through the mast and screw anchor (approximately 12" up from the bottom of the mast). Then insert three 5/16" nylon screws, which serve as "cot pins" to prevent the antenna from rotating (see Figure A5).

LONG-RANGE (TX ANTENNA ONLY) SOLUTION

- Purchase a 3" Schedule-80 PVC flange with 4 equidistantly spaced bolt holes (big enough to accept 1/2" x 3" stainless steel hex bolts) on its surface. Also purchase a 3" x 2" Schedule-80 PVC bushing, which adapts to the flange and allows for mounting onto the 2" EMT (see Figure A6).
- First, mark the location of the auger bushing on the EMT by placing the EMT inside the auger (use a permanent marker). For this screw anchor, insulating bushings and the 2" Set Screw EMT Coupling are not used.
- In water, boil the auger bushing for approximately 5 minutes, so that it can expand enough to slide over the EMT.
- Use a 1" hole saw to drill a hole near the top of the EMT (drill through both sides).
- Using a drill and a 7/32" bit, tap four holes through the auger, auger bushing and EMT. Use four #14 x 3/4" sheet metal screws to connect the auger to the EMT.
- Once on site, drive the ground screw into the ground as far as possible. Dig a decent size hole around the screw anchor, and using a reciprocating saw (or a hacksaw), cut off the remaining EMT to ground level.

- Using sand paper, scratch the inner and outer surface of the 3"×2" bushing, the inner surface of the 3" flange, and the outer surface of the EMT. Apply J-B Weld® to the outer surface of the bushing and the inner surface of the flange, and mount them together. Then, apply J-B Weld to the inner surface of the bushing and the outer surface of the EMT, and place the flange/bushing onto the EMT, assuring that the flange/bushing is mounted level. The J-B Weld must dry for at least 15 hours.
- On the next site visit, using a 9/32" bit, tap three equidistantly spaced holes through the flange, bushing and EMT, which are all fused by the J-B Weld. Into these holes, place three #14× 2" stainless steel pan head Phillips screws. These serve to provide extra stability as well as protection from any possible rotations, should the J-B Weld lose its adhesion to the EMT (Figure A7).
- The Tx base can now be attached to the 3" Schedule-80 PVC flange using: four 1/2" × 3" stainless steel hex bolts, eight 1/2" stainless steel flat washers (two per bolt), four 1/2" stainless steel lock washers, and four 1/2" stainless steel nuts (Figure A8).



Figure A2. 2" Set Screw EMT Coupling.



Figure A4. Showing two of the four #14 × 2" sheet metal screws that connect the auger to the EMT.



Figure A3. 1" hole required to insert rebar for twisting the screw anchor into the ground.



Figure A5. One of the three 5/16" nylon bolts showing; approximately 12" up from the bottom of the mast.

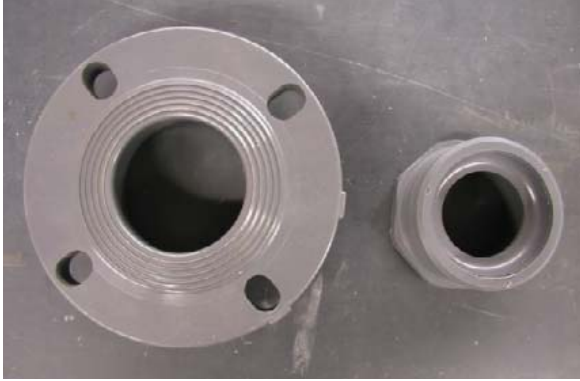


Figure A6. On the left, 3" schedule-80 PVC flange. On the right, 3" × 2" schedule-80 PVC bushing.



Figure A7. Top and side view of the flange and bushing, showing the #14 × 2" screws that serve as cot pins.



Figure A8. CODAR Long-Range Transmit antenna mounted to the 3" schedule-80 PVC flange.

APPENDIX B: *South Coronado Power Supply System*

1. Summary
2. System Requirements
 - 2.1. CODAR Power Consumption
 - 2.2. Auxiliary Components' Electrical Consumption
 - 2.3. Operational Needs And Considerations
3. System Location
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 - 3.2. System Specifications
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 - 4.2.c. Batteries
 - 4.2.d. Battery Housing
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1. SUMMARY

As part of an innovative approach to monitor and assess San Diego's coastal waters extending 30 Kilometers off the coast, the San Diego Coastal Ocean Observing System (SDCOOS : www.sdcoos.ucsd.edu) was established. Scripps Institution Of Oceanography, in a partnership with The State of California, City of Imperial Beach, and the San Diego County Department of Environmental Health developed, installed, and currently operates a coastal monitoring and observing system.

The backbone of the Coastal Ocean and Observing System is an array of high-frequency radars designed to provide a spatial map of the local ocean surface currents on a real-time basis. An immediate application of the current maps is to use the data as a framework for interpreting results from water quality testing programs that are already in place. Because real-time data is available on the web, there is a broad end-user community including scientists, policy and decision makers (city/state), public health responders as well as the general public. The radar array is composed of three sites located at: Border Field State Park, Point Loma, and South Coronado Island on Mexican property. The decision to operate a site on the remote Coronado Island was based on the geometry of the radar array. This site allowed for more accurate determinants of surface currents.

The remoteness of the island dictated that we find an alternative energy source to power the CODAR system. This document represents the research and development evolution of the solar system currently in use on South Coronado Island.

Logistic Timetable

October 2, 2002: South Coronado inspected. Solar system location established.

December 2, 2002: Solar sub-structure installation initiated.

January 16, 2003: Solar sub-structure completed.

February 3, 2003: Solar panels installed.

February 14, 2003: Helicopter drops of solar system equipment.

February 20, 2003: Wind generator installed, final preparation for system initiation.

February 24, 2003: Solar system complete, system producing 24 VDC.

March 11, 2003: CODAR installed, Wireless links complete and transmitting data.

June 27, 2003: Meteorological station complete and transmitting data.

2. SYSTEM REQUIREMENTS

2.1 CODAR Power Consumption

CODAR estimated that the 24 volt system consumes 250 watts continually. This includes the radar transmitter, receiver and the system laptop.

2.2 Auxiliary Electrical Power Consumptions

In addition to the CODAR components mentioned in section 2.1, power consumption requirements for additional scientific instrumentation are described below.

Net Gear switch: 7.5 continuous watts

COR: 25 continuous watts

Amplifier: 10 continuous watts

Cambell meteorological logger: 28 continuous watts

Wavelan: 5.2 continuous watts

2.3 Operational Needs and Considerations

The entire solar system was designed around the newly developed 24 volt CODAR system. The system was developed to produce enough energy for all scientific instrumentation with a surplus of energy for future endeavors.

3. SYSTEM LOCATION

3.1 General Information

Level ground and available space on the island dictated the placement of the solar array. The solar array was placed to the North of an existing concrete structure. The concrete structure would eventually serve to house the CODAR enclosure. Solar system components were placed under the panels in two separate weather-proof enclosures.

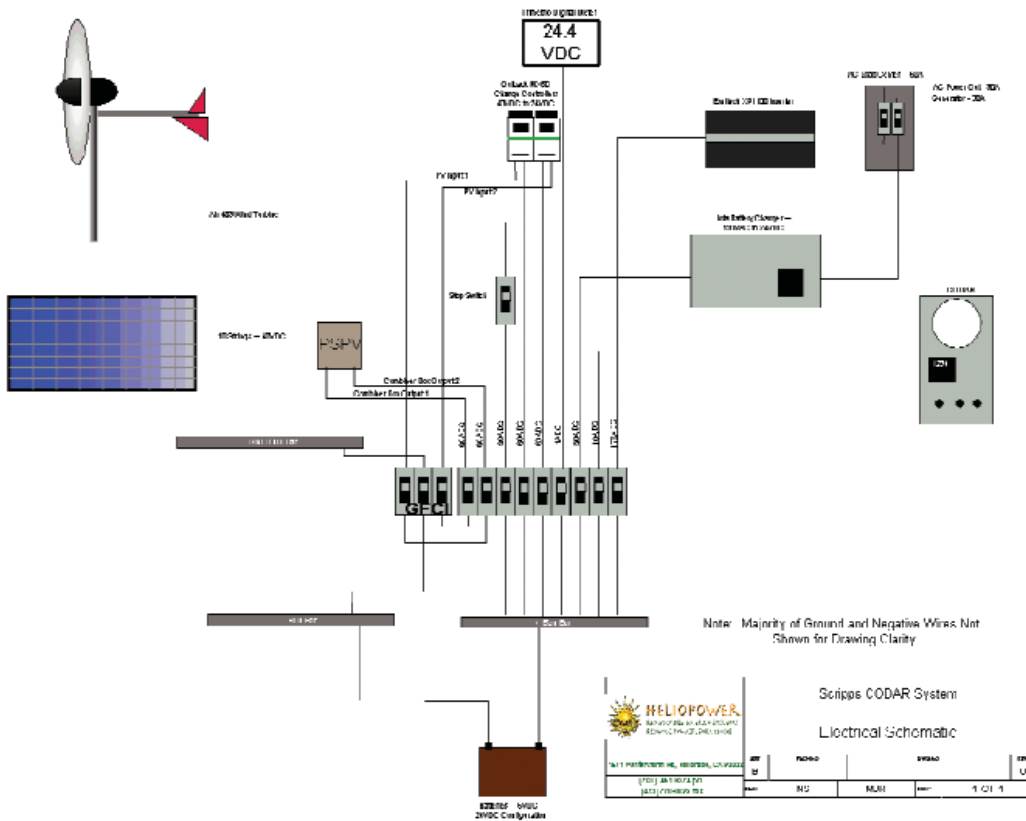


3.2 System Specifications

In order for our solar system to accommodate our needs there were a variety of requirements that went into the design and implementation of the system.. Based on the consumption estimates for both CODAR and auxiliary components (See section 2.1 and 2.2), we designed the solar system to be capable of producing 500 continuous watts, which would supply both our immediate and future power requirements on the island. The system had to supply power to CODAR and auxiliary components continuously with zero down time. Because of the remote location of the island, the system had to be highly reliable. With this in mind we designed the system to generate power with solar and wind components. We also installed an additional component, which allows us to charge the system with a generator if needed (See section 4).

4. SYSTEM DESIGN

4.1 System Diagram



4.2 Battery Sizing For Load

4.2.A. SYSTEM SIZING WORKSHEET

BATTERY SIZING

Average Daily Load	Inverter Efficiency	DC System Voltage	Average Amp-Hours/Day
12000	0.9	24	500.00
Days of Autonomy	Discharge Limit	Battery Amp-Hour Capacity	Batteries in Parallel
1.00	0.5	370	3.00
DC System Voltage	Battery Voltage	Batteries in Series	Total Batteries
24	6	4	12

Fig. 1 Calculations Supplied By HeliPower
 550 Industrial Way, Unit C, Fallbrook, CA 92028
 Phone: (760) 451-9374, Fax: (760) 451-9393
 www.heliopower.com

4.2.B. GENERAL INFORMATION

The battery sizing calculations aided us in determining the quantity of batteries needed for our application. We wanted our battery bank to give us one day of autonomy. We also had

to produce a battery bank that gave us the required 24 VDC for our CODAR system. We designed our battery bank to have a 50% state of discharge at the end of the day.

4.2.C. BATTERIES

Based on our battery requirements, the Surrette S-460 was the battery of choice. These are 6 volt deep cycle solar batteries (See section 7 for specifications). Based on our calculations, it was determined we would need 12 batteries (See Fig 1). The batteries were placed in series of four giving our necessary 24 volts, which were then placed in a parallel grouping, thus providing the 24 volts dc from three separate series.

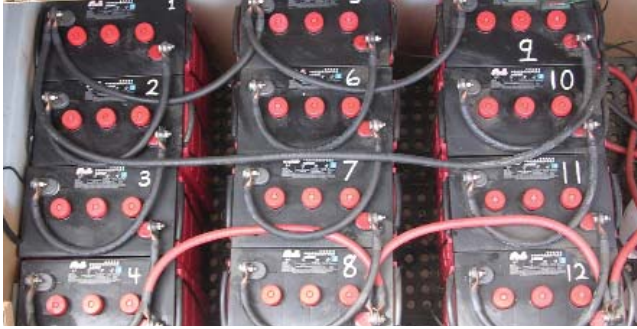


Fig. 2 Battery bank showing series and parallel configurations. 1-4, 5-8, and 9-12 are configured in series, each giving 24 volts DC. These three series are then paralleled.

4.2.D. BATTERY HOUSING

The batteries are housed in a converted Knaack box, (model #3068). The shelf within the box was cut out to provide sufficient space for the 12 solar batteries. A stainless steel vent was also installed to prevent hydrogen gas build up (See figure 5).

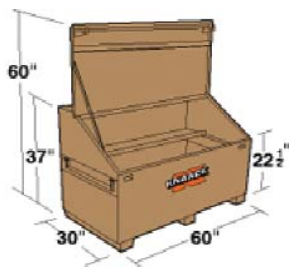


Fig. 3 Knaack box (Model #3068)



Fig. 4 (left) Knaack box prior to primer and paint. Fig. 5 (right) Knaack box ready for battery storage.

4.3. Array Sizing For Battery Charging

ARRAY SIZING

Avg Amp-Hours/Day	Battery Efficiency	Peak Sun Hours/Day	Required Imp Array
500.00	0.9	6	92.59
Peak Amps/Module	Modules in Parallel	DC System Voltage	Nominal Module Voltage
4.45	21	24	24
Modules in Series	Modules in Parallel	Total Modules	
1	21	21	

Fig. 6 Calculations Supplied By HeliPower

4.3.A. GENERAL INFORMATION

Because of the marine environment and obscure light conditions from occasional ocean fog, we selected monocrystalline solar panels. Our panels were wired in a 48volt DC configuration to take advantage of Maximum Power Point Tracking (MPPT) capabilities present in our charge controllers (See section 4.5). The solar array was placed facing due South and fixed at 30°. Because of limited space on the island, the final location of the solar array had the potential for afternoon shadowing by a nearby mountain. The performance of the panels has proved to be sufficient to meet our power demands.



4.3.B. SOLAR PANELS

Based on environmental and solar characteristics of the area, we selected BP 2150S' solar panels from BP Solar. These panels are composed of 72 monocrystalline silicon solar cells in series. BP solar claims they have the strongest frames in the industry and the weatherproof connectors make them an ideal choice for the island environment. These panels have a maximum output of 150 watts each panel. Our array-sizing chart (See figure 6) indicated we would need 21 panels, but we used 20. We opted for the additional power to be supplied by a wind generator (See section 4.4), which was a logical choice on the wind-swept South Coronado Island.



BP 2150S

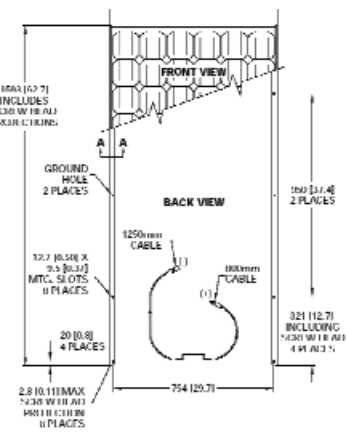


Fig. 8 (left) BP 2150S . Fig. 9 (right) Mechanical Drawing Of BP 2150S

4.3.c. SOLAR PANEL COMBINER BOX

An Outback PSPV combiner box was used to combine the solar panels and bring two lines of 48 volts to the charge controllers. As mentioned in section 4.3.a., we wired the solar panels in a 48 volt configuration to take advantage of the MPPT capabilities of our Outback MX 60 charge controllers.

The combiner box can hold up to 12 breakers. We used 10 Outback OBPV 10 amp breakers to accommodate our 10 strings of 48 volt dc.



Fig. 10 Outback PSPV combiner box with twelve breakers installed.

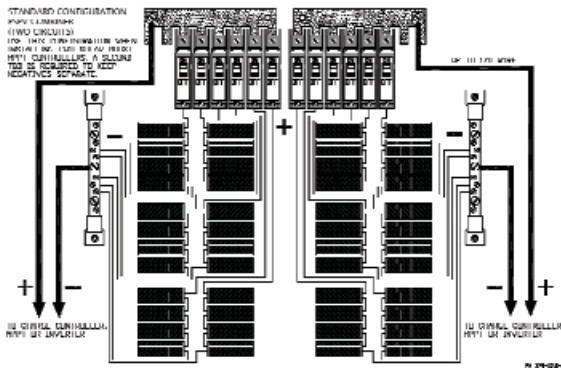


Fig. 11 General wiring diagram for the PSPV showing two circuits, representing our two lines of 48 vdc output to the charge controllers.

4.3.d. SOLAR PANEL MOUNTING SYSTEM

For mounting the solar panels we needed a system that was easy to transport by boat, easily put together, and strong enough to withstand strong winds, which occur frequently on South Coronado Island. The terrain is very rocky in the area we allocated for the solar array. We therefore had to consider which mounting system was most easily secured to the ground. Taking all of these factors into consideration, we selected Ground Trac by Professional Solar Products. This



Fig. 12 Ground Trac System by Professional Solar products, showing aluminum support rails, and pipe sub-structure.

mounting system is composed of light weight aluminum rails, which can then be easily clamped onto a pipe sub-structure. The solar panels are then secured to the rails with patented Slide-n-Clamps. This system requires two days for installation and is relatively easy to assemble. Posts for supporting the substructure are set in concrete the first day, followed by the assembly of the rest of the system the second day. For the sub-structure, we used 1 1/4" schedule 40 aluminum pipe. We selected aluminum for its reduced weight and its ability to better withstand corrosion in the marine environment.

4.4. Wind Turbine



Fig. 13 Ground Trac system being assembled.



Fig. 14 Solar panels secured to Ground Trac system.

4.4.A. GENERAL INFORMATION

According to the array-sizing chart (see figure 6), our system called for 21 solar panels. Instead, we went with 20 panels and supplemented the system with a 24-volt wind turbine. The Coronado Islands regularly receive strong winds, so the use of a wind turbine to make up the additional energy needed was a logical choice.

4.4.B. AIR-X MARINE

The Air-X Marine by Southwest Wind Power was our wind turbine of choice. The construction of the turbine with aluminum and stainless parts makes it ideal for the marine environment. The Air-X was specifically designed for coastal and marine environments where corrosion is a concern. This unit comes equipped with an internal voltage regulator, which automatically stalls blades in high winds and in situations where voltage is at required level. The minimum of moving parts and ease of installation was an added bonus.

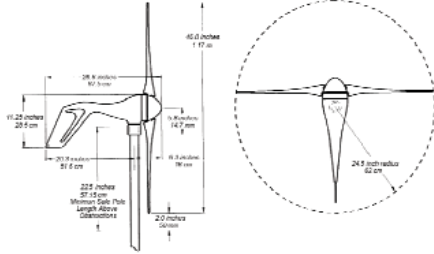


Fig. 15 (left) Air-X On South Coronado Island.
 Fig. 16 (right) Air-X Sphere Of Operation

4.5. Charge Controllers

4.5.A. GENERAL INFORMATION

Charge controllers are necessary components of a solar power system. A charge controller monitors the voltage coming from the solar panels and keeps a steady voltage going to the battery bank. Voltages sent to the batteries depend on the type of battery. In our case, Charge controllers received voltage from a 48-volt solar array and supplied our battery bank with a steady 24 volts. We selected the Outback Power Systems MX60 as our charge controller. Because of the amperage of our system, we had to use two charge controllers.

4.5.b. Outback Power Systems MX60

The Outback Power Systems MX60 has MPPT (See sec.4.3.a.). This feature allows our PV system to achieve its highest possible performance. The MX60 comes equipped with fully adjustable set points and can be used with most battery types. The MX60 also allows for a higher output voltage on the solar array, while charging the battery bank at a lower voltage. We took advantage of this capability with our solar array set at 48 volts D.C. and our battery bank is charged at 24 volts DC. This capability allows for reduced wire size and also reduced power loss from the solar array to the charge controllers. The four line, 80 character backlit display allows for simplistic programming and monitoring.

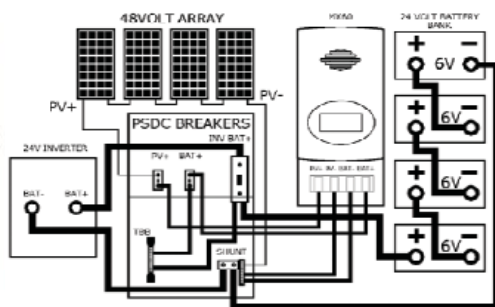


Fig. 17 (left) Outback Power Systems MX60 Charge Controller.
 Fig. 18 (right) MX60 in schematic showing wiring similar to our system.

4.6. Inverter

4.6.A. GENERAL INFORMATION

Our system includes a D.C. to A.C. inverter. We installed this component because of the lack of electricity on the island. As long as our system is operational we can utilize the solar power to operate equipment that requires A.C. input. This inverter eliminates the need for hauling a generator back and forth from the island.

4.6.B. EXELTECH XP 1100

We selected the Exeltech XP 1100 as our inverter. This inverter provides a clean, regulated sine wave. It allows for a wide range of DC input. Our inverter has the capability of 1100 Watts continuously at 30° C. This inverter comes equipped with over and under voltage protection and also comes with over temperature protection.



Fig. 19 The Exeltech XP 1100

4.7. Battery Charger

4.7.A. GENERAL INFORMATION

In addition to the inverter (See sec. 4.6), a battery charger was also incorporated into the system (See sec. 4.1). This allows us to charge the batteries, using a generator, if a problem occurs with the solar array. The battery charger converts 120 VAC to 24 vVDC.

4.7.B. IOTA ENGINEERING DLS-27-25

We selected the Iota Engineering DLS-27-25 battery charger. It has a wide range of input voltages and comes equipped with many protection systems. It has short circuit protection, reverse polarity protection, and thermal protection. With a normally operating system this component is not necessary, but the remote location of the system requires that we have back-up systems in place.

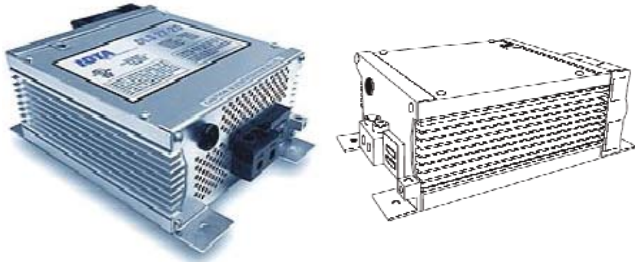


Fig. 20 The Iota Engineering DLS-27-25 Battery Charger.

4.8. Power Center

4.8.A. GENERAL INFORMATION

For all of these components it was necessary to house them in a centralized location. To safeguard them against weather we decided to have a custom weatherproof enclosure built that would accommodate all the components of the system mentioned in sections 4.5-4.7.

4.8.B. ENCLOSURE

The enclosure was built with aluminum and powder-coated to make it weather proof. Dimensions were specifically tailored to accommodate all the components that were to be housed within it (See figure 21).



Fig. 21 Inside and Outside Views Of Weather-Proof Enclosure.

4.8.C POWER CENTER EQUIPMENT

The following are housed within the power enclosure: Outback PSDC, Outback charge controllers, Exeltech power inverter, Iota battery charger, and the Tri-Metric battery state meter. The Outback PSDC serves as a load center for all of the components in the solar array system. This houses wiring and circuit breakers for each of the components in the system. The PSDC provides disconnect capability, over-current protection, and grounding components all within a single, easily accessible enclosure. The PSDC also provides areas to

which charge controllers can be attached (See figure 22).

For a detailed description see section 4.1. The Tri-metric battery state meter is an extra device that gives us a digital read-out of battery status (See figure 22).



Fig. 22 Inside Enclosure Detailing Various Components

5. SUMMARY

In summary, the remote location of the project has been the source of several obstacles in deploying this system. The initial permissions and the transport of the equipment to South Coronado presented the greatest obstacle. Currently the system is running smoothly and requires little maintenance. Routine trips are made to the Island for topping off water in batteries, cleaning solar panels, and computer upgrades. The stability of this system and the data we have received is attributed to the hard work and dedication to all those involved. Special thanks to Mo Rouso and Heliopower for their help on design and installation.

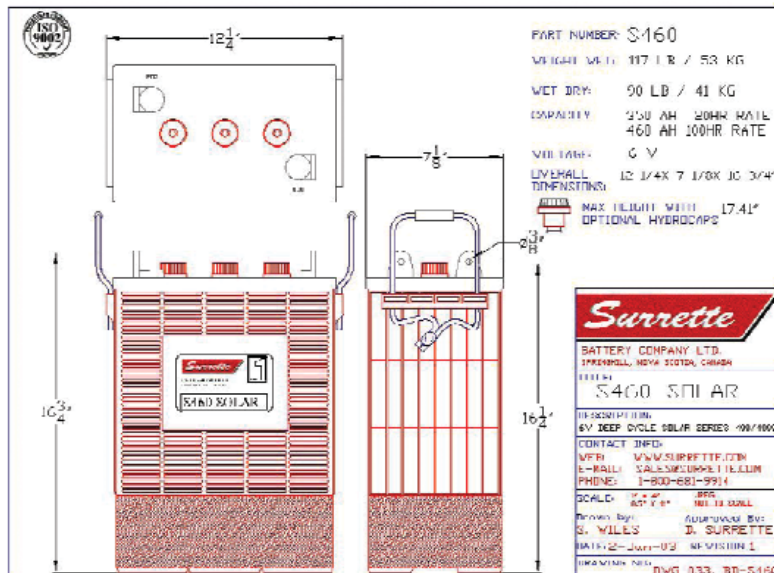
6. SPECIFICATION SHEETS

Batteries



DEEP CYCLE-SOLAR SERIES 4000

BATTERY TYPE	VOLTS	6	S-460
DIMENSIONS			
LENGTH		311 MM	12 1/4 INCHES
WIDTH		181 MM	7 1/8 INCHES
HEIGHT		425 MM	16 3/4 INCHES
WEIGHT DRY		41 KG	90 LBS.
WEIGHT WET		53 KG	117 LBS.
CONTAINER CONSTRUCTION			
CONTAINER		HIGH DENSITY POLYPROPYLENE	
COVER		HIGH DENSITY POLYPROPYLENE	
HANDLES		ROPE	
PLATES PER CELL		15	
ELECTROLYTE RESERVE	ABOVE PLATES	32 MM	1.25 INCHES
DESIGN CRITREA	7 YEAR WARRANTY	1300 CYCLES	10 YEAR LIFE
POSITIVE PLATE DIMENSION			
HEIGHT		273 MM	10.750 INCHES
WIDTH		143 MM	5.625 INCHES
THICKNESS		4.32 MM	0.170 INCHES
NEGATIVE PLATE DIMENSION			
HEIGHT		273 MM	10.750 INCHES
WIDTH		143 MM	5.625 INCHES
THICKNESS		3.05 MM	0.120 INCHES
SEPARATOR INSULATION	SEPARATOR THICKNESS	0.081 INCH	
	0.020" GLASS MAT		
TERMINALS			
	AUTO POST		
COLD CRANK	CCA 0°F / -17.8°C	1066	RESERVE
	MCA 32°F / 0°C	1333	MINUTES AT 25A
			761
CAPACITY	20 HR RATE	350	
			CAP / AH
			CURRENT / AMPS
CAPACITY AT THE 100 HOUR RATE	1.265 SP. GR.	466	4.66
CAPACITY AT THE 72 HOUR RATE	1.265 SP. GR.	441	6.13
CAPACITY AT THE 50 HOUR RATE	1.265 SP. GR.	417	8.33
CAPACITY AT THE 24 HOUR RATE	1.265 SP. GR.	381	10.0
CAPACITY AT THE 20 HOUR RATE	1.265 SP. GR.	350	17.5
CAPACITY AT THE 15 HOUR RATE	1.265 SP. GR.	329	21.9
CAPACITY AT THE 12 HOUR RATE	1.265 SP. GR.	312	26.0
CAPACITY AT THE 10 HOUR RATE	1.265 SP. GR.	298	29.8
CAPACITY AT THE 8 HOUR RATE	1.265 SP. GR.	280	35.0
CAPACITY AT THE 6 HOUR RATE	1.265 SP. GR.	259	43.2
CAPACITY AT THE 5 HOUR RATE	1.265 SP. GR.	245	49
CAPACITY AT THE 4 HOUR RATE	1.265 SP. GR.	228	57
CAPACITY AT THE 3 HOUR RATE	1.265 SP. GR.	207	69
CAPACITY AT THE 2 HOUR RATE	1.265 SP. GR.	179	89
CAPACITY AT THE 1 HOUR RATE	1.265 SP. GR.	126	126



SDSPECS 00

Solar Panels

Quality and Safety

All BP 2150 products are manufactured in BP Solar's ISO 9001-certified factories and conform to European Community Directives 89/33/EEC, 73/23/EEC, and 93/68/EEC. The BP 2150S and 2150U are:

- Listed by Underwriter's Laboratories for electrical and fire safety (Class C fire rating);
- Certified by TÜV Rheinland as Class II equipment;
- Approved by Factory Mutual Research for applications in NEC Class 1, Division 2, Groups C & D hazardous locations;
- Certified as complying with the requirements of IEC 61215, including:
 - repetitive cycling between -40°C and 85°C at 85% relative humidity;

- simulated impact of 25mm (one-inch) hail at terminal velocity;
- a "damp heat" test, consisting of 1000 hours of exposure to 85°C and 85% relative humidity;
- a "hot-spot" test, which determines a module's ability to tolerate localized shadowing (which can cause reverse-biased operation and localized heating);
- static loading, front and back, of 2400 pascals (50 psf); front loading (e.g. snow) of 5400 pascals (113 psf).

The BP 2150L is recognized by Underwriter's Laboratories for electrical and fire safety.

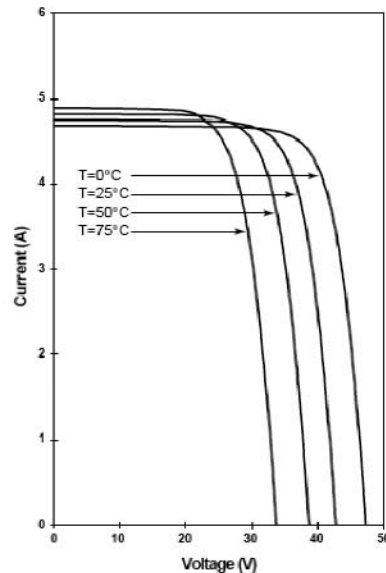
Electrical Characteristics¹

	BP 2150	BP 2140 ⁴
Maximum power (P_{max}) ²	150W	140W
Voltage at P_{max} (V_{mp})	34.0V	34.0V
Current at P_{max} (I_{mp})	4.45A	4.16A
Minimum P_{max}	140W	130W
Short-circuit current (I_{sc})	4.75A	4.48A
Open-circuit voltage (V_{oc})	42.8V	42.8V
Temperature coefficient of I_{sc}	(0.065±0.015)%/°C	
Temperature coefficient of voltage	-(160±20)mV/°C	
Temperature coefficient of power	-(0.5±0.05)%/°C	
NOCT ³	47±2°C	
Maximum series fuse rating	15A (S, L versions) 20A (U version)	
Maximum system voltage	600V (U.S. NEC rating) 1000V (TÜV Rheinland rating)	

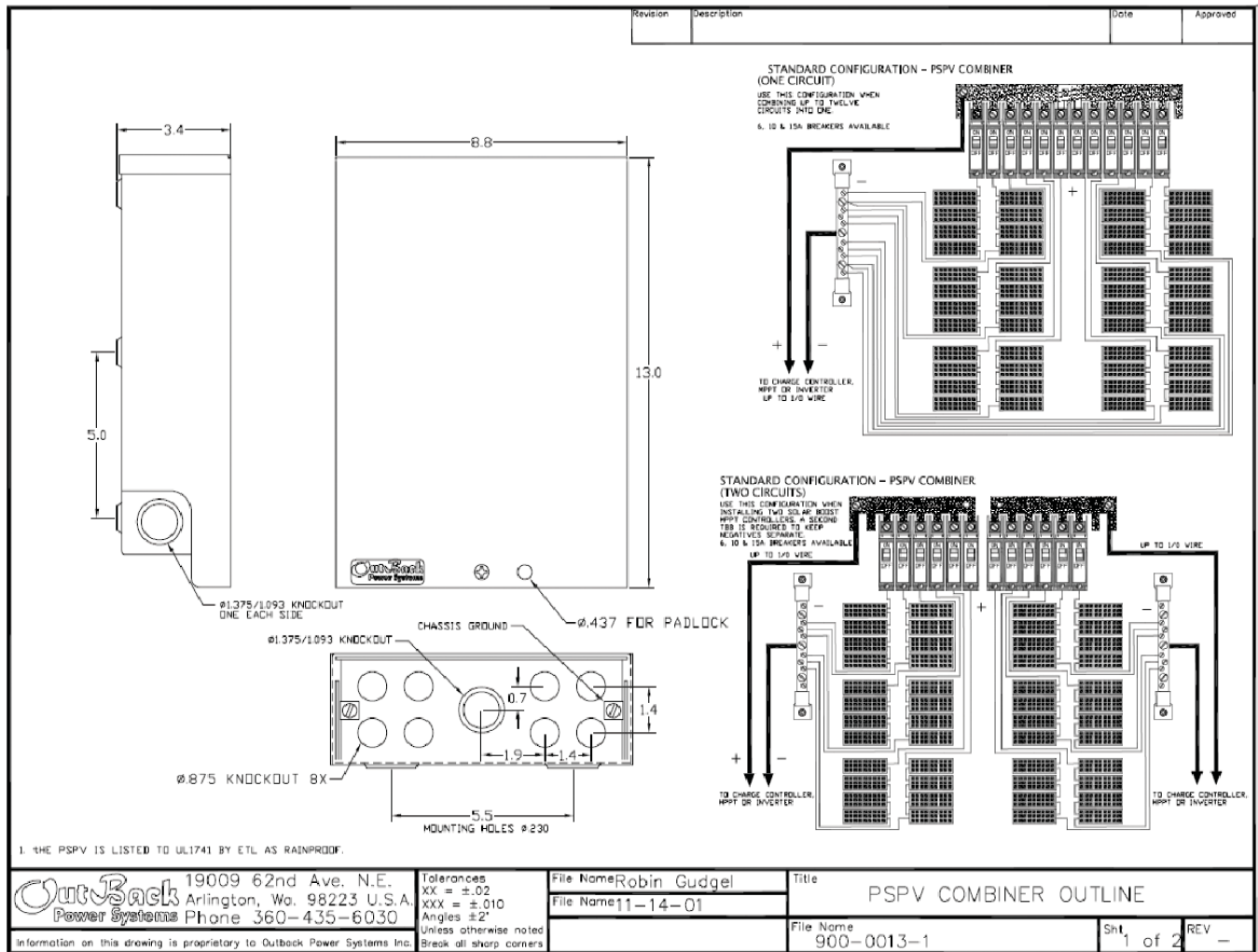
Notes

- These data represent the performance of typical BP 2140 and BP 2150 products as measured at their output connectors. The data are based on measurements made in accordance with ASTM E1036 corrected to SRC (Standard Reporting Conditions, also known as STC or Standard Test Conditions), which are:
 - illumination of 1 kW/m² (1 sun) at spectral distribution of AM 1.5 (ASTM E892 global spectral irradiance);
 - cell temperature of 25°C.
- During the stabilization process which occurs during the first few months of deployment, module power may decrease approximately 3% from typical P_{max} .
- The cells in an illuminated module operate hotter than the ambient temperature. NOCT (Nominal Operating Cell Temperature) is an indicator of this temperature differential, and is the cell temperature under Standard Operating Conditions: ambient temperature of 20°C, solar irradiation of 0.8 kW/m², and wind speed of 1m/s.
- The power of solar cells varies in the normal course of production; the BP 2140 is assembled using cells of slightly lower power than the BP 2150.

BP 2150 I-V Curves

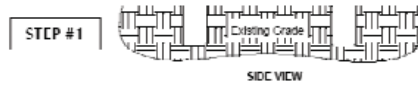


Combiner Box

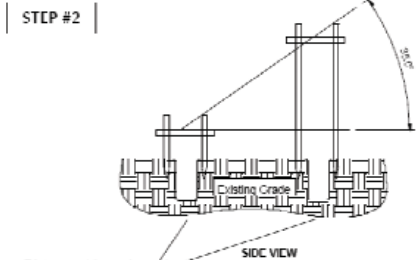


Ground Trac[®]

Ground Mount System
By: Professional Solar Products



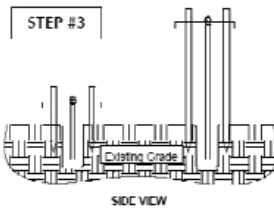
Excavate footings as per detail or engineered plan



Determine the proper angle for the module array and install grade stakes as illustrated (left), do not exceed 5 ft. of vertical post length from grade.

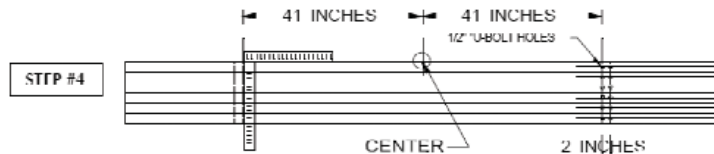
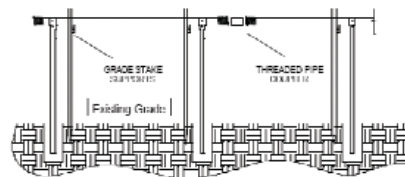
Installing the supports braces will hold the pipe at the proper fixed angle until the footings are poured. We recommend the use of drywall screws to hold the horizontal brace in place until concrete sets. Install the end braces and then set up a string line to ensure alignment. Place supports at a distance that will allow the pipe beam to be supported without sagging.

Distance of base depends upon the angle of support channel.

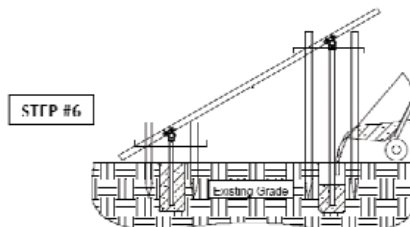
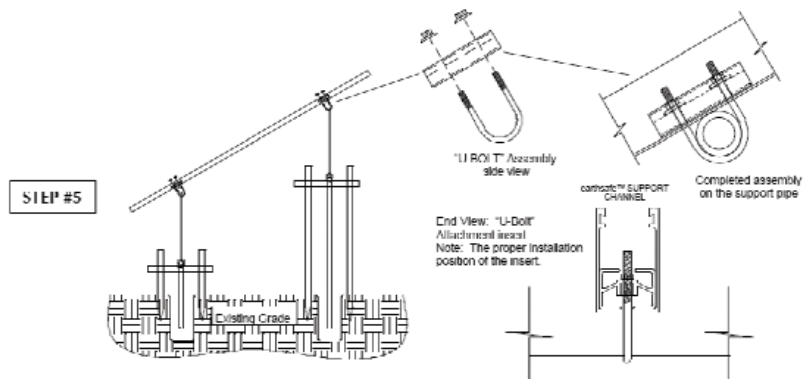


Illustrated (left) pipe support beams and vertical post supports can now be assembled and rest on the support footing. Using two pipe wrenches and 3/16" hex wrench, the pipe and support legs can be assembled and are ready for the Roof Trac[®] module channel to be installed.

Special Note: Use only schedule 40 galvanized pipe, fence tube is not recommended



Drilling of the support channels. Align the support ends with the built-in scale up on a flat surface. Using a framing square as illustrated, measure from the center of the channel 41" outward and mark a line on the channel. Mark another line exactly 2" outward from center from the first line. Now drill the "U-Bolt" holes in alignment with the marked line and the specially extruded "V" groove on the channel. We recommend the use of a 1/2" "Uni-Dit[®]" bit for this. You will now have perfectly aligned holes ready for installation on the support pipe beams.

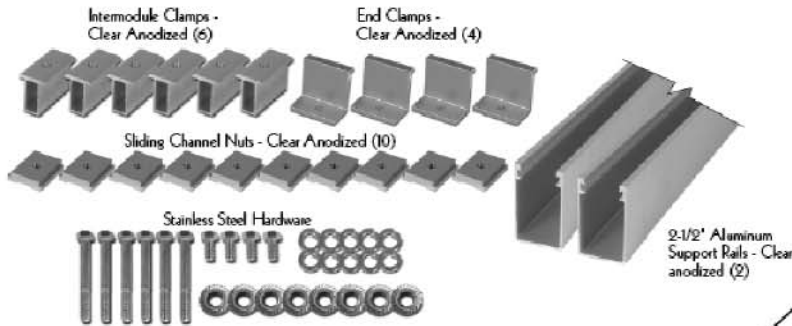


Align the end of the channel using a string line. Tighten all the "U-Bolt" assemblies, and recheck alignment the vertical pipe supports. You are now ready to pour concrete into the footings. Tap the concrete to ensure contact with the vertical pipe support. Remove the support footing after the concrete has set. You are now ready to install your modules.

CAUTION: Extruded edges of the aluminum can be sharp. It is highly recommended the installer buff the edges after installation to prevent injury.

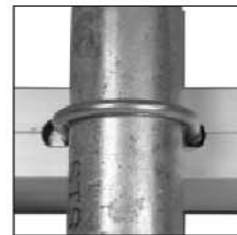
Ground Trac®

PRODUCT SPECIFICATIONS

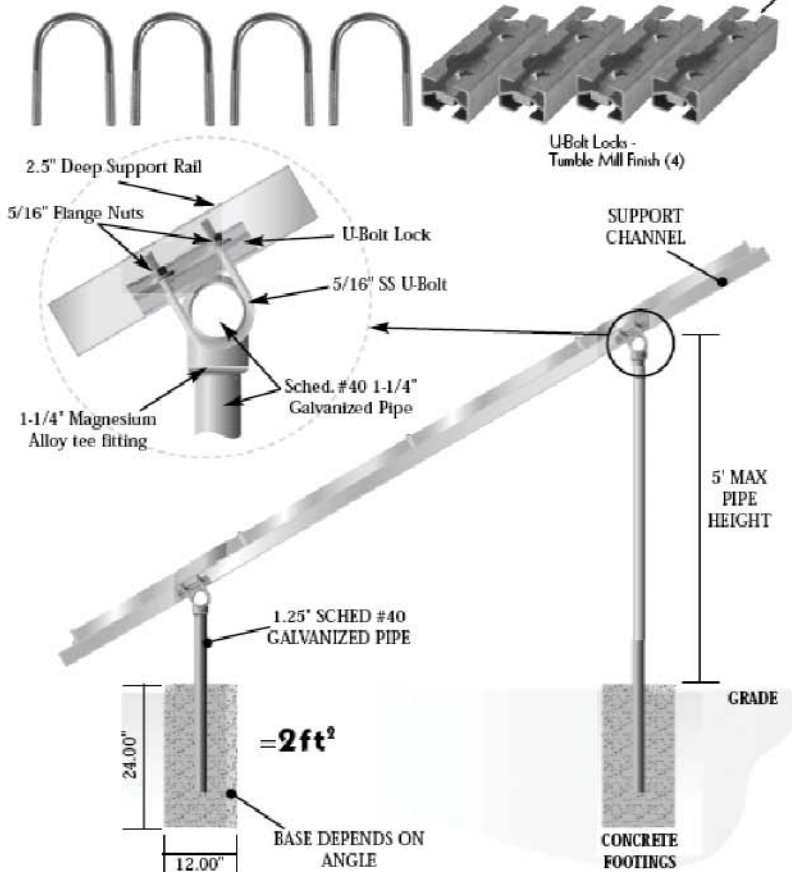


U-bolt lock is designed to push outward into the rail when fully engaged to provide a stronger, more structural system.

The design also allows for water to flow through the channel to prevent freeze damage in colder climates.



U-bolt attachment is clean and seamless - all hardware is concealed in the channel for an aesthetically pleasing array.



ENGINEERING:

System has been engineered & tested to 100mph wind load under the supervision of a California licensed structural engineer.

CAPACITY/SPECIFICATIONS:

- Each kit supports 4 modules
- Specifies 1-1/4" Sched. #40 Galvanized Pipe (available at any plumbing supply)
- 2 cu. ft. concrete footings
- Requires 1-1/4" Magnesium alloy tee fittings (Sold Separately from Kit)
- Max height 5' from grade
- Max cantilever 24"
- Max spans 10' on center (non snow load conditions)

professional
SOLAR
products inc.

(800) 84-SOLAR
4630 Calle Quetzal
Camarillo, CA 93012
www.RoofTrac.com

Black Anodized clips, clamps and hardware available for select modules. All clamping hardware sizes are proprietary to the module manufacturer. Please call for details on where to purchase and availability. Support rail and Clamping system design covered under pat. #6,360,491

July 2003

7. SPECIFICATIONS

7.1 TECHNICAL SPECIFICATIONS

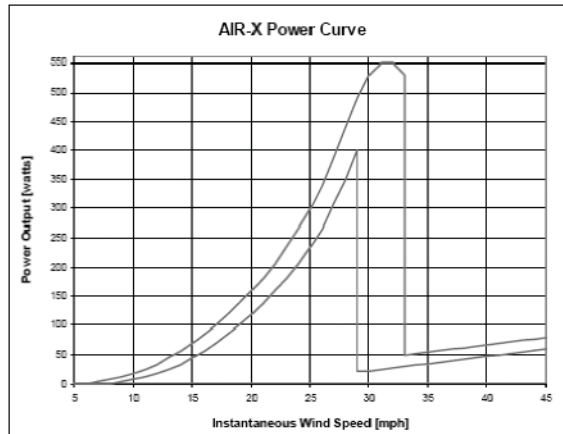
Rotor Diameter: 46 inches (1.17 meters)
 Weight: 13 lb. (6kg)
 Start up wind speed: 7 mph (3.0 m/s)
 Rated Power: 400 watts at 28 mph (12.5 m/s)
 Regulator Set Range: 12v 13.6V – 17.0V preset to 14.1V
 24v 27.2V – 34.0V preset to 28.2V
 Recommended Fuse Size: 12v - 50 amps slow-blow
 24v - 30 amps slow-blow
 Yaw Wire Size: #10 AWG (American Wire Gage) stranded.
 Pole Dimensions: 1½ Schedule 40 pipe (outside diameter 1.875 inch, 48mm)

7.2 PERFORMANCE SPECIFICATIONS

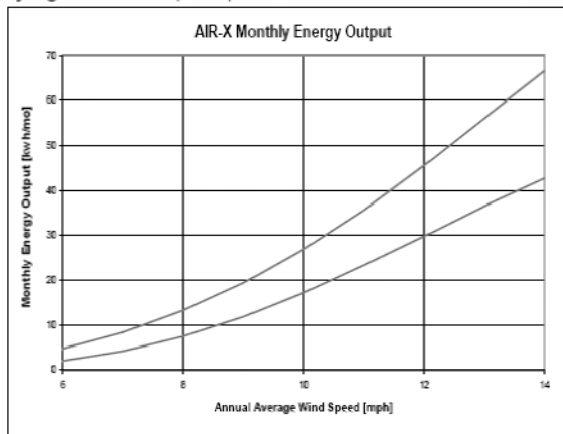
The following curve shows the performance you should expect from your **AIR-X** wind turbine. The **AIR-X** is rated with a “band-width” of power for a given wind speed. This is an attempt to cover the variability in turbine output due to different levels of wind turbulence. During smooth, steady wind, you should expect to see outputs along the upper curve. During turbulent wind conditions, the power output could drop towards the lower curve.

To convert between power [watts] and current [amps] use the following formula:

$$\text{POWER} = \text{VOLTAGE} * \text{AMPS}$$



The power curve band-width shown above gives the range of monthly energy production shown below. The energy calculations were done with standard statistical wind speed distributions (Rayleigh distribution, k=2.).



PV MPPT CHARGE CONTROLLER

MX60



The OutBack MX60 Maximum Power Point Tracking (MPPT) charge controller enables your PV system to achieve its highest possible performance. The MPPT feature can give you up to **30% or more power** from your PV panels!

Rated for up to **60 amps** of DC output current, the OutBack MX60 can be used with battery systems from 12 to 60 vdc with PV open circuit voltage as high as **140 voc**. The MX60's setpoints are fully adjustable to allow use with virtually any battery type, chemistry and charging profile.

The OutBack MX60 allows you to use a higher output voltage PV array with a lower voltage battery - such as charging a 24 vdc battery with a 48 vdc PV array. This reduces wire size and power loss from the PV array to the battery location while maximizing the performance of your system and **saving you money!**

The OutBack MX60 comes standard with an easy to use and understand display. The four line, 80 character, backlit LCD display is used for programming and monitoring of the system's operation including built-in **Data Logging** with 64 days of memory. Daily and Total PV production in Amp hours & kWh and is user resettable.

The OutBack MX60 can also be connected to the OutBack MATE system controller and display to allow monitoring from a distant location - **up to 1000 feet (305M) away**. The MATE also includes an opto-isolated RS232 port for connection to a PC computer for system monitoring. Please see; www.RightHandEng.com/OutBack for a free PC software trial version!

SPECIFICATIONS	MX60
Output Current	60 amps DC Rated Adjustable to 70 amps Maximum
Nominal Battery Voltage	12, 24, 32, 36, 48, 54 or 60 VDC (programmable)
PV Open Circuit Voltage	140 VDC Maximum
Standby Power Consumption	1 watt typical
Charging Regulation Methods	Five Stage: Bulk, Absorption, Float, Silent, Equalization
Voltage Regulation Setpoints	13 - 80 VDC
Equalization Voltage	Up to to 5.0 VDC above Absorb Setpoint Adjustable Timer - Auto Terminate
Temperature Compensation	-5.0mV/°C/Cell
Voltage Step-Down Capability	Can charge a 12 or 24 VDC battery from a 48V nominal PV array
Power Conversion Efficiency (typical)	99% @ 50 amps Output, 48V battery and 48V array
Digital Display	4 line 80 character backlit LCD Display (30 different screens also available in Spanish!)
Remote Interface	RJ 45 Modular Connector CAT 5 Cable 8 wire
Operating Temperature Range	-40° to 60°C Power derated above 25°C
Environmental Rating	Indoor Type 1
Conduit Knockouts	Two 1/2" & 3/4" on the back; One 3/4" & 1" on each side; Two 3/4" & 1" on the bottom
Warranty	Two years parts and labor Optional Extended Warranty Available
Dimensions	Enclosure: 14.5" H x 5.75" W x 5.75" D Shipping box: 17.75" H x 10" W x 7" D
Shipping Weight	12 lbs. - 5.4 kg

Specifications subject to change without notice. Please check our web site for additional specifications and application guidelines.

MX60 60 Amp MPPT Charge controller.....\$649.00
 RTS Remote Temperature Sensor.....\$29.00



- Arlington WA 98223 USA Tel 360-435-6030 www.outbackpower.com

XP600/1100 INSTALLATION AND OPERATION MANUAL

APPENDIX A

Input Power Requirements:

MODEL	NORMAL VDC	MINIMUM VDC CUT-OFF / ALARM	MAXIMUM VDC	RATED CURRENT	PEAK CURRENT
XP-600 / 12VDC	13.8 VDC	10.4 / 10.6 VDC	16.5 VDC	58.8 A	66.6 A
XP-600 / 24VDC	27.6 VDC	19 / 21 VDC	33 VDC	29.4 A	33.6 A
XP-600 / 48VDC	55.2 VDC	41.5 / 42.5 VDC	62 VDC	14.7 A	16.6 A
XP-600 / 66VDC	75.9 VDC	57.5 / 58.5 VDC	91 VDC	10.7 A	12.1 A
XP-600 / 108VDC	124.0 VDC	94 / 95 VDC	149 VDC	6.5 A	7.4 A
XP-1100 / 12VDC	13.8 VDC	10.4 / 10.6 VDC	16.5 VDC	107.8 A	122.1 A
XP-1100 / 24VDC	27.6 VDC	19 / 21 VDC	33 VDC	53.9 A	61.6 A
XP-1100 / 48VDC	55.2 VDC	41.5 / 42.5 VDC	62 VDC	27 A	30.5 A
XP-1100 / 66VDC	75.9 VDC	57.5 / 58.5 VDC	91 VDC	19.6 A	22.1 A
XP-1100 / 108VDC	124.0 VDC	94 / 95 VDC	149 VDC	12 A	13.6 A

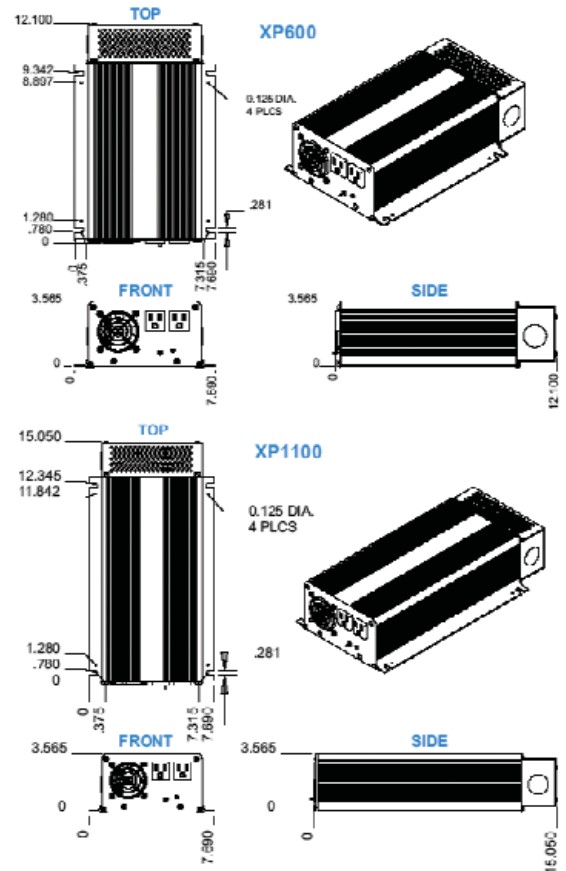
Recommended Input Wire Sizes (For Variable Distances from the Battery):

MODEL	LESS THAN 5'	LESS THAN 10'	LESS THAN 15'	LESS THAN 20'
XP-600 / 12VDC	4 AWG	0 AWG	0 AWG	00 AWG
XP-600 / 24VDC	10 AWG	6 AWG	4 AWG	4 AWG
XP-600 / 48VDC	16 AWG	12 AWG	10 AWG	10 AWG
XP-600 / 66VDC	18 AWG	16 AWG	14 AWG	12 AWG
XP-600 / 108VDC	18 AWG	18 AWG	18 AWG	16 AWG
XP-1100 / 12VDC	0 AWG	00 AWG	0000 AWG	0000 AWG
XP-1100 / 24VDC	6 AWG	4 AWG	2 AWG	0 AWG
XP-1100 / 48VDC	12 AWG	10 AWG	8 AWG	6 AWG
XP-1100 / 66VDC	16 AWG	12 AWG	10 AWG	10 AWG
XP-1100 / 108VDC	18 AWG	16 AWG	14 AWG	14 AWG

Note: The table specifies standard wire sizes (not smaller than 18 AWG) that will provide less than a 2% voltage drop at Low-line Input voltage and Rated Output Power.

XP600/1100 INSTALLATION AND OPERATION MANUAL

APPENDIX A



Battery Charger

DLS-Series Models	27 VOLT DLS			36 VOLT DLS ¹	42 VOLT DLS ¹	48 VOLT DLS ¹	
	DLS 27-15	DLS 27-25	DLS 27-40 [†]	DLS 36-20	DLS 42-18	DLS 48-15	DLS 48-20
DC Output Voltage (No Load) approx.	27.2 V (DC)	27.2 V (DC)	27.2 V (DC)	36V (DC)	42V (DC)	48V (DC)	48V (DC)
Output Voltage Tolerance (No Load)	+0% - .5%	+0% - .5%	+0% - .5%	+0% - .5%	+0% - .5%	+0% - .5%	+0% - .5%
Output Amperage, Max Continuous	15 Amps	25 Amps	40 Amps	20 Amps	18 Amps	15 Amps	20 Amps
Output Voltage (Full Load) approx.	>27.0V (DC)	>27.0 V (DC)	>27.0 V (DC)	>35.8V (DC)	>41.8V (DC)	>47.8V (DC)	>47.8V (DC)
Maximum Power Output, Continuous	400 Watts	675 Watts	1100 Watts	720 Watts	750 Watts	720 Watts	960 Watts
Ripple and Noise	<50 mV rms	<50 mV rms	<50 mV rms	<50 mV rms	<50 mV rms	<50 mV rms	<50 mV rms
Input Voltage Range	100 - 132 AC	108 - 132 AC	108 - 132 AC	108 - 132 AC	108 - 132 AC	108 - 132 AC	100 - 132 AC
Input Voltage Frequency	47-63	47-63	47-63	47-63	47-63	47-63	47-63
Maximum AC Current	7.0 Amps	11.6 Amps	20 Amps	11.6 Amps	12.0 Amps	11.6 Amps	15 Amps
Typical Efficiency	>80%	>80%	>80%	>80%	>80%	>80%	>80%
Max Inrush Current, Single Cycle	8 Amps	16 Amps	20 Amps	25 Amps	25 Amps	25 Amps	32 Amps
Short Circuit Protection	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Overload Protection	>100%	>100%	>100%	>100%	>100%	>100%	>100%
Line Regulation	100 mV rms	100 mV rms	100 mV rms	100 mV rms	100 mV rms	100 mV rms	100 mV rms
Load Regulation	<1%	<1%	<1%	<1%	<1%	<1%	<1%
Fan Control*	PROPORTIONAL	PROPORTIONAL	PROPORTIONAL	PROPORTIONAL	PROPORTIONAL	PROPORTIONAL	PROPORTIONAL
Thermal Protection	YES	YES	YES	YES	YES	YES	YES
Working Temperature Range	0 - 40C	0 - 40C	0 - 40C	0 - 40C	0 - 40C	0 - 40C	0 - 40C
Storage Temperature	-20 to 80C	-20 to 80C	-20 to 80C	-20 to 80C	-20 to 80C	-20 to 80C	-20 to 80C
Withstand Voltage	1240V @ leads	1240V @ leads	1240V @ leads	1240V @ leads	1240V @ leads	1240V @ leads	1240V @ leads
Dimensions**	7" x 6.5" x 3.5"		10" x 6.5" x 3.5"	7" x 6.5" x 3.5"	7" x 6.5" x 3.5"	7" x 6.5" x 3.5"	10" x 6.5" x 3.5"
Weight	5.5 lbs	5.5 lbs	7.8 lbs	5.5 lbs	5.5 lbs	5.5 lbs	7.8 lbs

* Proportional - Fan speed proportional to case temperature

** Detailed Mounting Specifications are available online.

[†] Units are not UL Listed

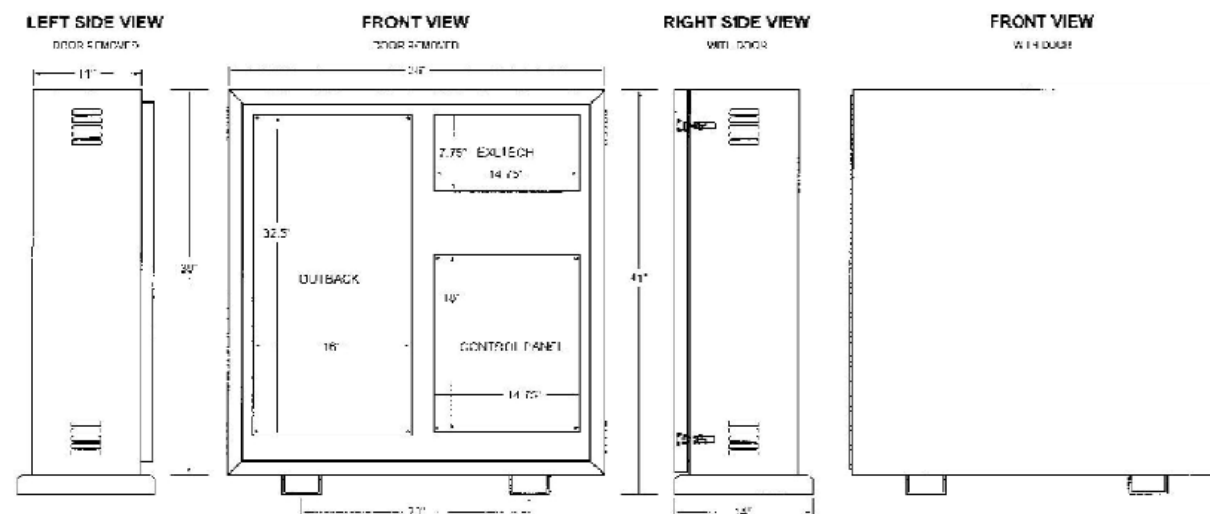
[‡] Can be used as 24V 50 Amp unit

0. BOX 11846 TUCSON, AZ 85734 • 1301 E. WIEDING ROAD TUCSON, AZ 85706 • (520) 294-3292 • FAX (520) 741-2837

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Enclosure



- .125" ALUMINUM
- WHITE POLYESTER POWDER-COAT FINISH
- STAINLESS STEEL CONTINUOUS HINGE
- TWO STAINLESS STEEL PADLOCK HASPS
- SCREENED VENTS
- DOOR GASKET

DIRECT POWER & WATER CORPORATION

TITLE: CUSTOM EQUIPMENT ENCLOSURE

DESIGNED BY	NR	DESIGNED BY	JR
CHECKED BY	11-7-02	CHECKED BY	

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PSDC

POWER SYSTEM DC

OutBack Power Systems has developed a new solution for all of the DC components of a renewable energy power conversion system.

The PSDC saves time, money and space by combining the disconnects, overcurrent protection devices, grounding and control components into an easy to install, single enclosure.

The PSDC is easily modified and expanded as your system grows or changes.



Standard Features and Components

- ETL listed indoor type powdercoated steel enclosure with plenty of conduit knockouts
- Mounting space for up to four large 1.5" wide 175 or 250 amp or six medium 1.0" wide 60 to 100 amp breakers – sizes can be mixed
- Ten spaces for small 0.75" wide 15, 30 or 60 amp breakers and OBDC-GFP/2 (uses 3 spaces)
- 500 amp 50 mV current shunt standard
- Battery negative/ground bus bar standard
- Battery positive bus bar for DC loads and PV arrays included standard
- Designed to mount directly to the DC end of 1 or 2 Trace DR or SW series inverters without needing additional conduit boxes or fittings
- Easily connected to other inverter models and enclosures via conduit or raceway
- Knockouts on top for two RVPP Solar Boost or three C-series controllers
- Available with or without the circuit breakers and other options pre-installed
- For negative or positive ground systems

*Finally
an
alternative
to
Brand
X*

Optional Components

- 15, 30, 60, 100, 175 & 250 amp DC rated breakers for DC inputs/loads and power inverters
- OBDC-GFP/2 - Dual 60 amp PV ground fault protection system for two PV charge controller. Multiple DC-GFP/2 can be used on the same system – up to four can be installed in a PSDC
- CCB - Charge controller bracket for up to three additional C-series controllers on either side
- TBB - Insulated terminal bus bar kit for combining or distributing multiple circuits
- GBB - Ground bus bar kit for isolating the negative from ground (included with GFP/2 system).
- VREA - Adapter plates for direct connection of a PSDC to one Vanner RE inverter/charger
- PSA - Adapter plate for direct connection of a PSDC to one PS series inverter/charger
- MP - Mounting Plate for assembling a complete power system – 36" wide x 50" wide x 1" thick - for one PSDC, one PSAC and one or two inverter/chargers – split design to allow UPS shipping

Physical Dimensions

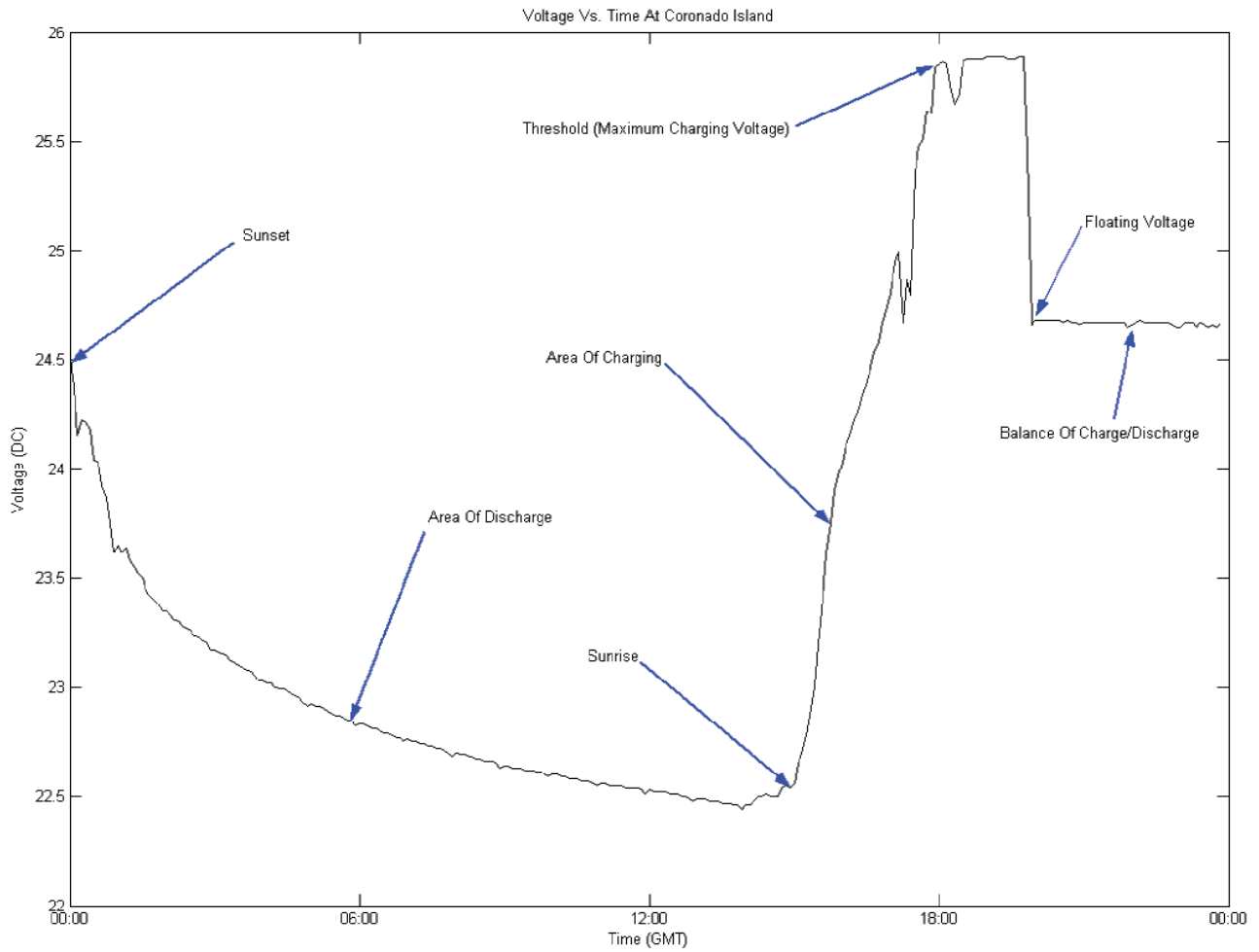
- PSDC enclosure: 16" wide x 9" deep x 32.5" tall (40.6cm x 22.8cm x 82.5cm)
- Shipping size: 12.75" x 36" x 19.5" Weight: 38 pounds (17.3 kg) + options

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7. PERFORMANCE INFORMATION



8. ADDITIONAL PHOTOS



