UNIVERSITY-NATIONAL OCEANOGRAPHIC LABORATORY SYSTEM
Moss Landing Marine Laboratories 8272 Moss Landing Road, Moss Landing, CA 95039
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RF Spectrum use within the UNOLS Oceanographic community
A report to the National Science Foundation

Submitted by Richard Perry
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Palisades, NY
Chairperson – RVTEC RF Spectrum Use Committee

The U.S. Oceanographic community is formed of widely disparate organizations that conduct a wide variety of scientific research over all portions of the globe.

Constituents of this community include organizations classed as governmental agencies such as the National Science Foundation, US Navy, US Coast Guard and The National Oceanographic and Atmospheric Administration (NOAA) and also organizations connected to either publicly or privately funded academic Institutions.

The University-National Oceanographic Laboratory System (UNOLS) is an organization of 61 academic institutions and National Laboratories involved in oceanographic research and joined for the purpose of coordinating oceanographic ships' schedules and research facilities.

UNOLS institutions operate some twenty-three research vessels; a variety of land based instrumentation as well as both free drifting and moored instrumented buoys. *See Appendix A.*

This report deals primarily with the RF Spectrum use of the UNOLS community. However it should be noted that in many instances, solutions that address problems, which affect the community as a whole, are applied throughout the wider community. Funding issues as well as unique requirements have driven us to seek cost effective solutions for fleet services which can be widely applied.

The vast geographic range of scale over which oceanographic research is carried out dictates that methods for communication of information span geographic locations anywhere on the earth over distances ranging from a few meters to worldwide. As will be evident there have emerged several services developed specifically by and for the UNOLS Community.

Oceanographic vessels require access to the standard suite of communication and navigation services available to any ship. In addition the community has developed several “fleet solutions”.

This would include, but not be limited to:

Communications –

Service	**Frequencies**	**Notes**
Marine VHF	156.050 – 162.025 MHz	*See Appendix B*
Marine SSB -Typical	1.6– 2.9999 MHZ	Typical types of emission - J3E (SSB), J2B (AFSK), F1B (FSK), A1A (CW), H3E
	4.0– 4.9999 MHz	
	6.0– 6.9999 MHz	
	8.0– 8.9999 MHz	
	12.0– 13.9999 MHz	
	16.0– 19.9999 MHZ	
	22.0– 22.9999 MHZ	
	25.0– 27.5000 MHZ	
INMARSAT	TX 1626.5 – 1660.5 MHz	
INMARSAT	RX 1525.0 – 1559.0 MHz	
Iridium - Phone/satellite	1616-1626.5MHz	
Iridium - Phone/pager	1616-1626.5MHz	
Iridium - satellite/satellite	23.18-23.38GHz	
Iridium - satellite/gateway	19.4-19.6GHz	
Iridium –gateway/satellite	29.1-29.3GHz	
Globalstar - downlink	1610.73 - 1625.49 MHz	
Globalstar – uplink	2484.39- 2490.15 MHz	
Globalstar - gateway	6875 - 7055 MHz	
EPIRB	406 MHz & 121.5 MHz	
GSM Cell Phone	824 – 960 MHz	
HiSeasNet		***See Pages 6,7,8***

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Navigation

Service	**Frequencies**	**Notes**
GPS	1559-1610 MHz	
WAAS –L1	1575.42 MHz	*GPS enhancement services*
WAAS – L2	1227.6 MHz	
WAAS – L3	1176.45 MHz	
DGPS	283.5 to 325.0 kHz	
RTK	450-470 MHz	
Loran C	90-110 kHz	
Marine Beacon	200 – 285 KHz	
S Band Radar	2 - 4 GHz	
X Band Radar	8 - 12 GHZ	
SART radar Xpndr	9 GHZ	
GLONASS SP or L1	1602.5625 - 1615.5 MHz	
GLONASS HP or L2	1240 - 1260 MHz	

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Shipboard Science Infrastructure

Service	**Frequencies**	**Notes**
Wireless Winch Readout	802.11 b	
SWAP		
Wireless – general use	5.15 to 5.25	802.11 a - lower
	5.25 to 5.35 GHz	802.11 a - mid
	5.725 to 5.825	802.11 a - upper
	2402 – 2495 MHz	802.11 b / Bluetooth
Lotek Nanotag	147 – 168 MHz	RF identification
Direct Broadcast TV	12.2 – 12.7 GHz	i.e. Echostar
SWAP		***See Pages 11,12***

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Buoy and Science operations

Service	**Frequencies**	**Notes**
Sonobuoy	162.25 – 173.125 KHz	FM
LoTek Wireless Hydrophone	140.000 – 175.000 MHZ	Factory set
AXCTD	88 – 108 MHz	FM
AXCP	88 - 108 MHz	FM
ARGOS Tracking 'collars'	430 – 460 MHz	Data retrieval from various instrumented platforms
	148 – 174 MHZ	
ORBCOMM satellite data service	TX – 148-150.05 MHz	Various instrumented data platforms – data retrieval & platform control
	RX 137 -138 MHz	
Wireless Modem	902 – 928 MHz	
DataWell WaveRider buoy	27 – 40 MHz	At least 25 units deployed by Scripps, U of Hawaii & others
CODAR		***See pages 9,10 & Appendix C***

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HiSeasNET

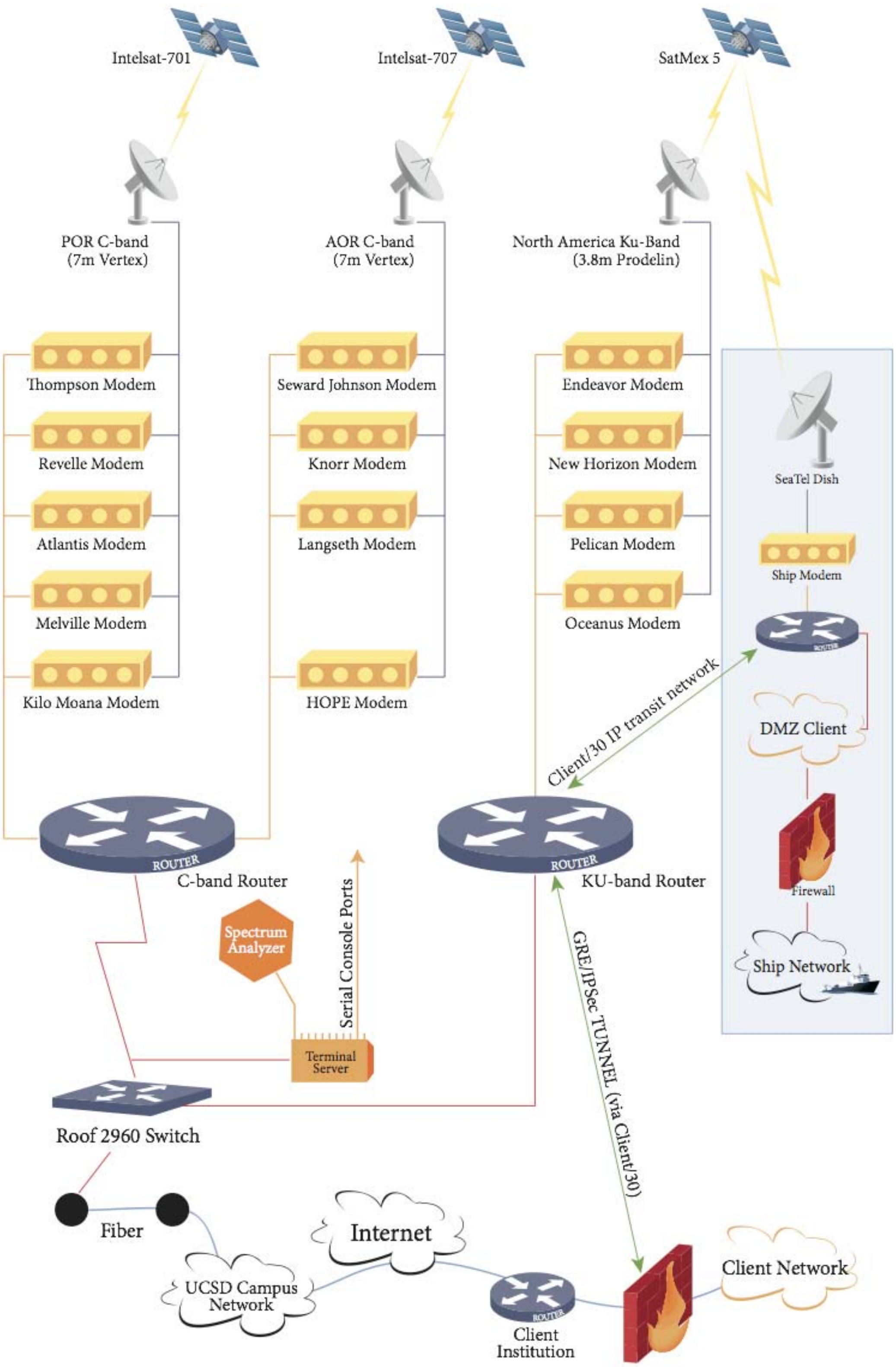
HiSeasNet is a satellite communications network designed specifically to provide continuous Internet connectivity for oceanographic research ships and platforms. Access to the Internet is an integral part of nearly every research lab and office on land; extending this access to oceanographic ships--our seagoing laboratories--will broadly impact seagoing research activities. For the ships, HiSeasNet will provide:

- Transmission of hot data in real-time to shore-side collaborators
- Basic communications-email, voice and video teleconferencing for scientists, engineers and crew at sea;
- Tools for real-time educational interactions between shipboard scientists, teachers and the classroom, as well as informal science and other education and outreach activities.

Current Installations include:

SHIP	OPERATING INSTITUTION	LENGTH (ft.)
LARGE / GLOBAL Class		
* MELVILLE	Scripps Institution of Oceanography	279
* KNORR	Woods Hole Oceanographic Institution	279
* THOMAS G. THOMPSON	University of Washington	274
* ROGER REVELLE	Scripps Institution of Oceanography	274
* ATLANTIS	Woods Hole Oceanographic Institution	274
* MARCUS G. LANGSETH	Lamont-Doherty Earth Observatory	239
INTERMEDIATE / OCEAN Class		
* SEWARD JOHNSON	Harbor Branch Oceanographic Institution	204
* KILO MOANA	University of Hawaii	185
WECOMA	Oregon State University	185
* ENDEAVOR	University of Rhode Island	184
* OCEANUS	Woods Hole Oceanographic Institution	177
* NEW HORIZON	Scripps Institution of Oceanography	170
REGIONAL Class		
* POINT SUR	Moss Landing Marine Laboratories	135
CAPE HATTERAS	Duke University/UNC	135
ROBERT GORDON SPROUL	Scripps Institution of Oceanography	125
HUGH R. SHARP	University of Delaware	120
ATLANTIC EXPLORER	Bermuda Biological Station for Research	115
* PELICAN	Louisiana Universities Marine Consortium	105

** HiSeasNet • Pending HiSeasNet*


Intelsat-701
Intelsat-707
SatMex 5
POR C-band
(7m Vertex)
AOR C-band
(7m Vertex)
North America Ku-Band
(3.8m Prodelin)
Thompson Modem
Revelle Modem
Atlantis Modem
Melville Modem
Kilo Moana Modem
Seward Johnson Modem
Knorr Modem
Langseth Modem
HOPE Modem
Endeavor Modem
New Horizon Modem
Pelican Modem
Oceanus Modem
SeaTel Dish
Ship Modem
DMZ Client
Firewall
Ship Network
Client/30 IP transit network
ROUTER
C-band Router
ROUTER
KU-band Router
Spectrum Analyzer
Serial Console Ports
Terminal Server
GRE/IPSec TUNNEL (via Client/30)
Roof 2960 Switch
Fiber
UCSD Campus Network
Internet
Client Institution
Client Network

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HiSeasNet - current frequency assignments.

All frequencies are send and receive (but on split frequencies), all are probably used every day at sea if possible. Every hardware suite is a little different, but all the C-band signals are less than 20 watts of power out of their amplifiers (some less than that). The Ku-band systems are much less than that...probably in the <4 watt range, but say 8 watts to be safe (*Endeavor* has a 16W amp for future use). All of the RF gear is made by Codan, using the 5700 series of converters and amplifiers.

Intelsat 701 (POR, uplink(Tx)/downlink(Rx) frequencies in MHz)
Shore-to-Ship: 6354.8000/4129.8000 C-band
Ship Slot 1: 6354.3250/4129.3250 C-band (*Revelle*)
Ship Slot 2: 6369.4600/4144.4600 C-band (*Melville*)
Ship Slot 3: 6369.5725/4144.5725 C-band (*Atlantis*)
Ship Slot 4: 6369.6850/4144.6850 C-band (*Thompson*)
Ship Slot 5: 6369.7975/4144.7975 C-band (*Kilo Moana*)

IS-707 (AOR, uplink(Tx)/downlink(Rx) frequencies in MHz)
Shore-to-Ship: 6315.8525/4090.8525 C-band
Ship Slot 1: 6315.5450/4090.5450 C-band (*Knorr*)
Ship Slot 2: 6315.6350/4090.6350 C-band ()
Ship Slot 3: 6315.7250/4090.7250 C-band (*Seward Johnson*)

Satmex 5 (Ku-band, uplink(Tx) /downlink(Rx) in MHz)
Beam 1
Shore-to-Ship: 14051.587/11751.587
Slot 1: 14051.682/11751.682
Slot 2: 14051.742/11751.742

Beam 2
Shore-to-Ship: 14436.065/12136.065
Ship Slot 1: 14436.215/12136.215 Ku-Band (*Endeavor*)
Ship Slot 2: 14436.275/12136.275 Ku-Band (*New Horizon*)
Ship Slot 3: 14436.335/12136.335 Ku-Band (*Pelican*?)
Slot 4: 14436.395/12136.395

In the future, we may be assigned anything in C-band or Ku-band. Those bands include the following frequencies:

C-band:
Downlink: 11.7 to 12.2 GHz
Uplink: 14.0 to 14.5 GHz

Ku-band:
Uplink: 4.975 to 6.475 GHz
Downlink: 3.7 to 4.2 GHz

CODAR

The Unique Nature of HF Radar - Excerpted from the CODAR Ocean Sensors website

High-frequency (HF) radio formally spans the band 3-30 MHz (with wavelengths between 10 meters at the upper end and 100 meters at the lower end). For our radars, we extend the upper limit to 50 MHz. A vertically polarized HF signal is propagated at the electrically conductive ocean water surface, and can travel well beyond the line-of-sight, beyond which point more common microwave radars become blind. Rain or fog does not affect HF signals.

The ocean is a rough surface, with water waves of many different periods. When the radar signal hits ocean waves that are 3-50 meters long, that signal scatters in many directions. In this way, the surface can act like a large diffraction grating.

But, the radar signal will return directly to its source only when the radar signal scatters off a wave that is exactly half the transmitted signal wavelength, AND that wave is traveling in a radial path either directly away from or towards the radar. The scattered radar electromagnetic waves add coherently resulting in a strong return of energy at a very precise wavelength. This is known as the Bragg principle, and the phenomenon 'Bragg scattering'. At the SeaSonde's HF/VHF frequencies (4-50 MHz), the periods of these Bragg scattering short ocean waves are between 1.5 and 5 seconds.

What makes HF RADAR particularly useful for current mapping is that the ocean waves associated with HF wavelengths are always present. The following chart shows three typical HF operating frequencies and the corresponding ocean wavelengths that produce Bragg scattering.

25 MHz transmission -> 12m EM wave -> 6m ocean wave
12 MHz transmission -> 25m EM wave -> 12.5m ocean wave
5 MHz transmission -> 60m EM wave -> 30m ocean wave

So far three facts about the Bragg wave are known: its wavelegnth, period, and travel direction. Because we know the wavelength of the wave, we also know its speed very precisely from the deep water dispersion relation.

The returning signal exhibits a Doppler-frequency shift. In the absence of ocean currents, the Doppler frequency shift would always arrive at a known position in the frequency spectrum.

But the observed Doppler-frequency shift does not match up exactly with the theoretical wave speed. The Doppler-frequency shift includes the theoretical speed of the speed of the wave PLUS the influence of the underlying ocean current on the wave velocity in a radial path (away from or towards the radar).

The effective depth of the ocean current influence on these waves depends upon the wave's period or length. The current influencing the Bragg waves falls within the upper meter of the water column (or upper 2.5 meters when transmitting between 4-6 MHz). So, once the known, theoretical wave speed is subtracted from the Doppler information, a radial velocity component of surface current is determined.

By looking at the same patch of water using radars located at two or more different viewing angles, the surface current radial velocity components can be summed to determine the total surface current velocity vector.

Is it that simple?
The basic physics relating the HF radar signal to the nature of the ocean waves and currents is beautifully simplistic, but the task of mapping surface currents with a modern radar sensor is more complex.

UNOLS CODAR Deployments -Partial List

Type	Number	Station License	Frequency
SeaSonde	7	Experimental	12 – 13.7 MHz
SeaSonde	1	Experimental	24 – 25.4 MHz
SeaSonde	1	Experimental	4.5 – 5 MHz
MCR	1	Experimental	4.8 MHz 6.8 MHz 13.8 MHz 22 MHz
? U of SC	4	?	8 MHz
? U of Miami	5	?	12.5 MHZ 16.1 MHz 50 MHz
? U of S. Florida	2	?	8 or 10 MHz Planned

SWAP

SWAP is a collaborative project to provide a working set of hardware; software and networking configurations to facilitate ad-hoc mesh networking between ships, and between ships and shore facilities, within the UNOLS oceanographic research fleet. SWAP is also being developed to facilitate connections between other kinds of nodes, including instrumented buoys, light houses and cabled observatories.

What functionality does SWAP provide?

SWAP provides IP network links between ships or between a ship and shore facility. No manual intervention is required. When a SWAP Device sees another SWAP device, a link is immediately brought up and network traffic can be routed over that link.

SWAP also specifies that each SWAP Device node have its own local SWAP network, and that the second IP address on that network be the SWAP Host. This network acts like a DMZ, allowing connections to the ship or shore facility via the SWAP Host from other networks without exposing the ship or port facility's internal network in an unsecured way.

Physically, a SWAP Device is a single board PC running Pebble Linux, an 802.11b PCMCIA radio card and one (and sometimes two) outdoor 802.11b antennas.

Logically a SWAP Device is an 802.11b access point that creates WDS (Wireless Distribution System) links between itself and other properly configured access points. The WDS portion of the 802.11 standard was designed, in part, to provide wireless bridges between two segments of the same wired subnet. They are point-to-point links. Using the open source Linux drivers we have chosen, these links create a new pseudo network interface on each device when the link is created. Then a process assigns network addresses to those interfaces. Now the SWAP device becomes a router, passing packets between networks, rather than a switch, passing packets between segments.

As mentioned above, a SWAP Device is also a router. An OSPF (Open Shortest Path First) daemon operates on each SWAP Device, monitoring for the creation of new local network interfaces and the status of other OSPF routers in the area. OSPF adds new routes to the local routing table when new network interfaces are created, and then broadcasts those new routes to neighboring OSPF nodes. Each OSPF daemon calculates the shortest path to any network and creates an appropriate routing table for itself.

In this way, as soon as a new SWAP Device associates with another, the entire composite wireless SWAP network is immediately available to it. As a SWAP enabled ship pulls into port and its SWAP Device associates with the port SWAP Node, the composite routable network immediately extends to the combined antenna coverage of the port and ship. Add yet another

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ship, and the effective range of the port facility extends yet again. Think of it like extending a ship's ability to reach another ship or the Internet on shore, one hop at a time.

A SWAP Device is also a firewall and does network address translation. Shore SWAP devices prevent the public from routing onto the wireless SWAP networks by preventing connections from the public internet. Part of this involves translating host IP addresses from clients on the SWAP network, or even those on a ship's internal network a single IP address on the public internet. In addition, ship SWAP Devices prevent hosts on the SWAP networks from accessing the ship's internal network. Again, this involves translating host IP addresses from clients on the ship's internal network, to a single address on the SWAP network.

UNOLS SWAP Locations

Organization	Fixed Nodes	Mobile Nodes
U of Hawaii	UH Marine Center	R/V Kilo Moana
Scripps Institute of Oceanography	Nimitz Marine Facility	R/V Revelle, R/V Melville, R/V New Horizon, R/V Sproul
Oregon State University	Hatfield MSC, Southbeach, Yaquina Head	R/V Wecoma, R/V Elakha, loaner
U of Washingtion	Dock	R/V Thompson, R/V Barnes
MBARI	???	R/V Western Flyer
Moss Landing	???	R/V Point Sur
U of Delaware	Cape Henlopen Pilot Tower, Buoy A, Buoy B	R/V Cape Henlopen
Center for Coastal Margin Observation & Prediction	Merts Campus, Tongue Point, Cape Disappointment	R/V Forerunner
Woods Hole Institute of Oceanography	Martha's Vinyard, Dock, Clark Build	R/V Tioga, R/V Oceanus, R/V Knorr, R/V Atlantis, Shuttle Van

Appendix A

UNOLS Research Vessels Inventory

OPERATING INSTITUTION	SHIP	LENGTH (ft)
Scripps Institution of Oceanography	MELVILLE	279
Woods Hole Oceanographic Institution	KNORR	279
University of Washington	THOMAS G. THOMPSON	274
Scripps Institution of Oceanography	ROGER REVELLE	274
Woods Hole Oceanographic Institution	ATLANTIS	274
Lamont-Doherty Earth Observatory	MARCUS LANGSETH	235
University of Hawaii	KILO MOANA	186
Harbor Branch Oceanographic Institution	SEWARD JOHNSON	204
Oregon State University	WECOMA	185
University of Rhode Island	ENDEAVOR	185
Woods Hole Oceanographic Institution	OCEANUS	177
Scripps Institution of Oceanography	NEW HORIZON	170
Bermuda Institute for Ocean Sciences	ATLANTIC EXPLORER	168
University of Delaware	HUGH R. SHARP	146
Moss Landing Marine Laboratories	POINT SUR	135
Duke University/UNC	CAPE HATTERAS	135
Scripps Institution of Oceanography	ROBERT GORDON SPROUL	125
Louisiana Universities Marine Consortium	PELICAN	116
University of Miami	WALTON SMITH	96
Smithsonian Tropical Research Institute	URRACA	96
University System of Georgia	SAVANNAH	92
University of Minnesota - Duluth	BLUE HERON	86
University of Washington	CLIFFORD A. BARNES	66
NOAA	RONALD H. BROWN*	274
USCG	USCGC HEALY *	420
USCG	USCGC POLAR STAR *	399
USCG	USCGC POLAR SEA *	399

* These ships are not UNOLS vessels, but they are often used as research support platforms for the academic oceanographic community.

Appendix B - VHF Channels

Channel Number	Ship Transmit MHz	Ship Receive MHz	Use
01A	156.050	156.050	Port Operations and Commercial, VTS. Available only in New Orleans/Lower Mississippi area.
05A	156.250	156.250	Port Operations or VTS in the Houston, New Orleans and Seattle areas.
6	156.300	156.300	Intership Safety
07A	156.350	156.350	Commercial
8	156.400	156.400	Commercial (Intership only)
9	156.450	156.450	Boater Calling. Commercial and Non-Commercial.
10	156.500	156.500	Commercial
11	156.550	156.550	Commercial. VTS in selected areas.
12	156.600	156.600	Port Operations. VTS in selected areas.
13	156.650	156.650	Intership Navigation Safety (Bridge-to-bridge). Ships >20m length maintain a listening watch on this channel in US waters.
14	156.700	156.700	Port Operations. VTS in selected areas.
15	--	156.750	Environmental (Receive only). Used by Class C EPIRBs.
16	156.800	156.800	International Distress, Safety and Calling. Ships required to carry radio, USCG, and most coast stations maintain a listening watch on this channel.
17	156.850	156.850	State Control
18A	156.900	156.900	Commercial
19A	156.950	156.950	Commercial
20	157.000	161.600	Port Operations (duplex)
20A	157.000	157.000	Port Operations
21A	157.050	157.050	U.S. Coast Guard only
22A	157.100	157.100	Coast Guard Liaison and Maritime Safety Information Broadcasts. Broadcasts announced on channel 16.
23A	157.150	157.150	U.S. Coast Guard only
24	157.200	161.800	Public Correspondence (Marine Operator)
25	157.250	161.850	Public Correspondence (Marine Operator)
26	157.300	161.900	Public Correspondence (Marine Operator)
27	157.350	161.950	Public Correspondence (Marine Operator)
28	157.400	162.000	Public Correspondence (Marine Operator)
63A	156.175	156.175	Port Operations and Commercial, VTS. Available only in New Orleans/Lower Mississippi area.
65A	156.275	156.275	Port Operations
66A	156.325	156.325	Port Operations
67	156.375	156.375	Commercial. Used for Bridge-to-bridge communications in lower Mississippi River. Intership only.
68	156.425	156.425	Non-Commercial
69	156.475	156.475	Non-Commercial
70	156.525	156.525	Digital Selective Calling (voice communications not allowed)
71	156.575	156.575	Non-Commercial
72	156.625	156.625	Non-Commercial (Intership only)
73	156.675	156.675	Port Operations
74	156.725	156.725	Port Operations
77	156.875	156.875	Port Operations (Intership only)
78A	156.925	156.925	Non-Commercial
79A	156.975	156.975	Commercial. Non-Commercial in Great Lakes only
80A	157.025	157.025	Commercial. Non-Commercial in Great Lakes only
81A	157.075	157.075	U.S. Government only - Environmental protection operations.
82A	157.125	157.125	U.S. Government only
83A	157.175	157.175	U.S. Coast Guard only
84	157.225	161.825	Public Correspondence (Marine Operator)
85	157.275	161.875	Public Correspondence (Marine Operator)
86	157.325	161.925	Public Correspondence (Marine Operator)
AIS 1	161.975	161.975	Automatic Identification System (AIS)
AIS 2	162.025	162.025	Automatic Identification System (AIS)
88A	157.425	157.425	Commercial, Intership only.

Appendix C – CODAR Experimental License cover page for some of the units deployed.

Regan Long, 3152 Paradise Dr., Tiburon, CA 94920

United States of America
FEDERAL COMMUNICATIONS COMMISSION
EXPERIMENTAL
RADIO STATION CONSTRUCTION PERMIT
AND LICENSE

EXPERIMENTAL	WD2XVS
(Nature of Service)	(Call Sign)
XR FX	0338-EX-PL-2005
(Class of Station)	(File Number)

NAME San Francisco State University - Romberg Tiburon Center

Subject to the provisions of the Communications Act of 1934, subsequent acts, and treaties, and all regulations heretofore or hereafter made by this Commission, and further subject to the conditions and requirements set forth in this license, the licensee hereof is hereby authorized to use and operate the radio transmitting facilities hereinafter described for radio communications in accordance with the program of experimentation described by the licensee in its application for license.

Operation: In accordance with Sec. 5.3(a, c) of the Commission's Rules

Station Locations
(1) Drakes Beach (MARIN), CA - NL 38-01-40; WL 122-57-39
(2) Big Sur (MONTEREY), CA - NL 36-18-21; WL 121-54-05
(3) Pacific Grove (MONTEREY), CA - NL 36-38-12; WL 121-56-08
(4) Monterey (MONTEREY), CA - NL 36-36-12; WL 121-52-19
(5) Santa Cruz (SANTA CRUZ), CA - NL 36-56-57; WL 122-03-58
(6) Davenport (SANTA CRUZ), CA - NL 37-01-26; WL 122-12-05
(7) Pescadero (SAN MATEO), CA - NL 37-10-58; WL 122-23-37
(8) Montara (SAN MATEO), CA - NL 37-32-12; WL 122-31-22
(9) Sausalito (MARIN), CA - NL 37-48-57; WL 122-31-55
(10) Bolinas (MARIN), CA - NL 37-54-47; WL 122-43-46
(11) San Francisco (SAN FRANCISCO), CA - NL 37-44-10; WL 122-30-28
(12) Carmel (MONTEREY), CA - NL 36-26-24; WL 121-55-20

Frequency Information

Drakes Beach (MARIN), CA - NL 38-01-40; WL 122-57-39

Frequency	Station Class	Emission Designator	Authorized Power	Frequency Tolerance (+/-)
12.06 MHz	FX	170KP0N	40 W (ERP)	0.001 %

This authorization effective February 23, 2006 and will expire 3:00 A.M. EST March 01, 2010

FEDERAL COMMUNICATIONS COMMISSION

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