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ITU-R

Radiocommunication Sector of ITU

Recommendation ITU-R M.1874
(04/2010)

Technical and operational characteristics of oceanographic radars operating in sub-bands within the frequency range 3-50 MHz

M Series

Mobile, radiodetermination, amateur and related satellite services

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Note: *This ITU-R Recommendation was approved in English under the procedure detailed in Resolution ITU-R 1.*

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RECOMMENDATION ITU-R M.1874

Technical and operational characteristics of oceanographic radars operating in sub-bands within the frequency range 3-50 MHz

(Question ITU-R 240/5)

(2009-2010)

Summary

This Recommendation provides technical and operational characteristics of oceanographic radars for use in sharing and compatibility studies and spectrum planning and systems deployment within the 3 to 50 MHz band. It provides the relevant characteristics of short-range, standard range, long-range, very-long range and high-resolution oceanographic measurement systems.

The ITU Radiocommunication Assembly,

considering

a) that there is a need to operate oceanographic radar systems in the radiodetermination[1] service, using spectrum in the 3 to 50 MHz frequency range;

b) that oceanographic radar systems have been operated in the 3 to 50 MHz range in some countries under the provision of Radio Regulations No. 4.4 for some years;

c) there is global interest in deploying operational systems on a worldwide basis;

d) that performance, functions and data requirements normally determine the range of spectrum that can be used by ocean observing radar systems,

recognizing

a) that representative technical and operational characteristics of oceanographic radar systems are required for spectrum management and deployment planning,

recommends

1 that the technical and operational aspects of oceanographic radars contained in Annex 1 should be considered when conducting sharing and compatibility studies with systems in other services;

2 that the technical and operational aspects of oceanographic radars contained in Annex 1 should also be taken into consideration for planning purposes.

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[1] The radiolocation and radionavigation services are sub-services of the radiodetermination service.

Annex 1

Technical and operational characteristics of oceanographic radars operating in sub-bands within the frequency range 3-50 MHz

1 Introduction

A significant percentage of the world's population lives within 50 miles of the coastline heightening the need for accurate, reliable and detailed measurements of coastal environmental variables.

Just as the winds in the atmosphere provide information about where and when weather systems occur, ocean currents determine the movement of oceanic events. These two dynamic flows are used to determine where pollutants, man-made or natural, will travel. Presently, ocean current measurements are not as readily available as winds.

Because of this, there is an increasing interest in the ability to accurately measure the currents and waves in coastal waters. Radar systems operating at frequencies higher than 50 MHz are limited in their ability to provide data meeting current range, accuracy and resolution requirements. The global oceanography community is planning for the implementation of coastal sea surface monitoring radar networks. The benefits to society for improved measurement of coastal currents and sea state include a better understanding of issues like coastal pollution, fisheries management, search and rescue, beach erosion, maritime navigation and sediment transport. Coastal radar measurements of the sea surface provide support to meteorological operations through the collection of sea state and dominant ocean wave data. In addition, oceanographic radar technology has applications in global maritime domain awareness by allowing the long range sensing of surface vessels. This will benefit the global safety and security of shipping and ports[2].

The need for additional data to mitigate the effects of disasters, including tsunamis, to understand climate change, and to ensure safe maritime travel has lead to the consideration of operational use of oceanographic radar networks on a global basis.

Implementation of these systems in Japan is shown in Figs 1 and 2.

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[2] Use of Coastal Ocean Dynamics Application Radar (CODAR) Technology in the United States of America Coast Guard Search and Rescue Planning, David Ullman; James O'Donnell; Christopher Edwards; Todd Fake; David Morschauser; Coast Guard Research and Development Center Groton CT.

FIGURE 1

An example of the observed surface current by oceanographic radars in the Tokyo Bay Watch System operated by Ministry of Land, Infrastructure, Transport and Tourism, Japan

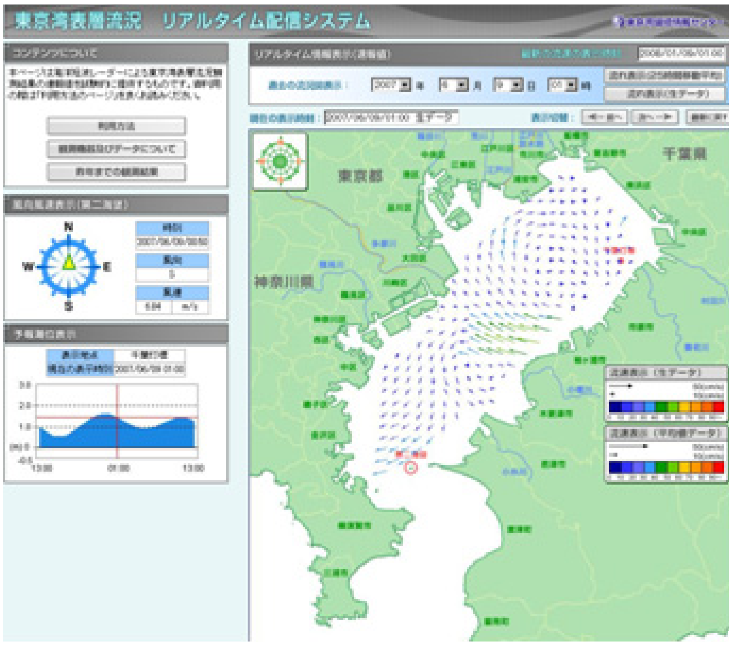

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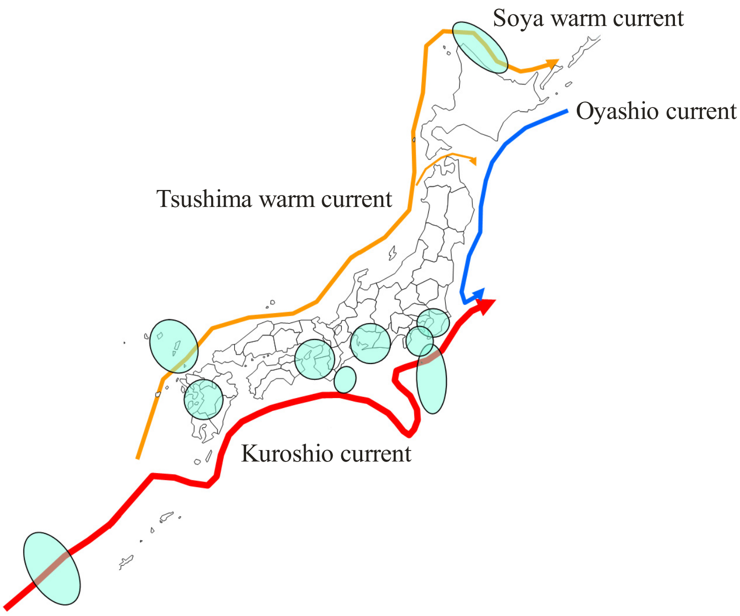
FIGURE 2

Oceanographic radars in Japan (observation areas are shown for each fixed radar site)



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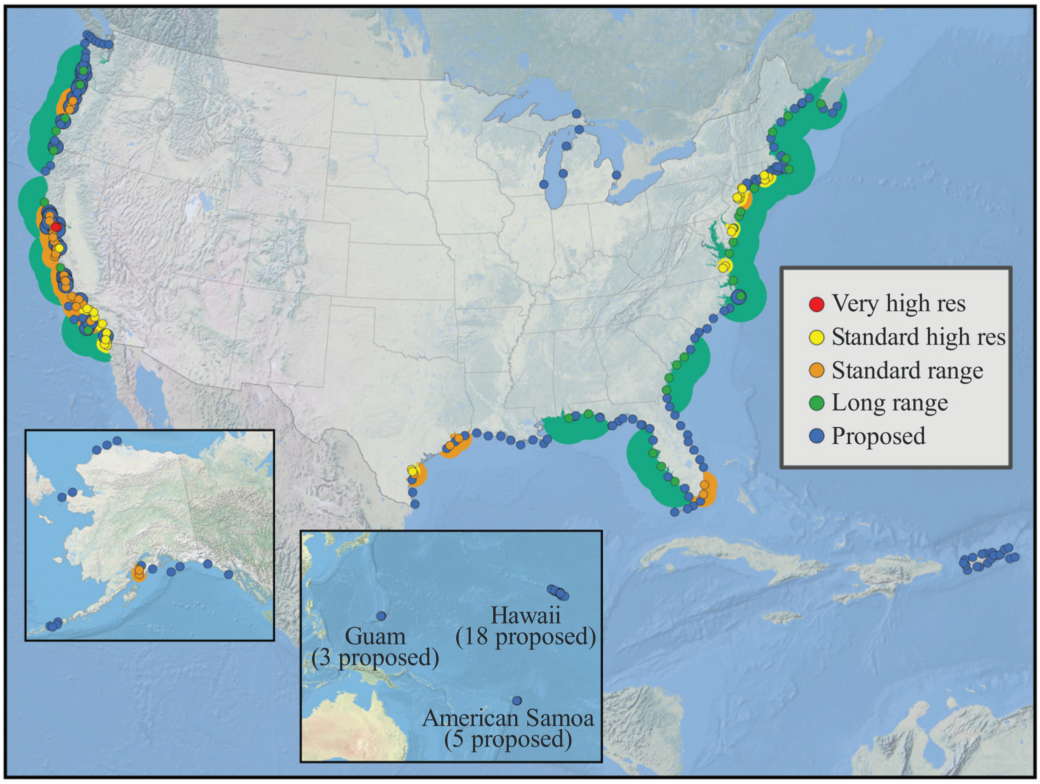
As of 2009, 143 oceanographic radars spread unevenly throughout the United States of America coastal regions (this total includes radars that are not currently operating on a regular basis). Nearly all of the oceanographic radar systems in the United States of America are owned and operated by university research departments. Existing and proposed oceanographic radar sites for the United States of America, the Pacific Islands and the Caribbean Regions are shown in Fig. 3.

FIGURE 3

Existing and proposed oceanographic radar sites for the United States of America, the Pacific Islands and the Caribbean Regions



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The establishment of a network of oceanographic radar monitoring sites is included in the integrated ocean observing system (IOOS) Development Plan and is part of the global ocean observing system (GOOS) which, in turn, is a substantial component of the global Earth observing system of systems (GEOSS).

2 Principle of operation

In oceanographic radars using Bragg scattering[3], the frequency range of 3 to 50 MHz (wavelength of 100 to 6 m) is very useful in measuring ocean waves driven by wind (see Fig. 4). Spatial resolution of the radar is limited by the bandwidth of the signal e.g. the bandwidths of 100 and 300 kHz give resolutions of 1.5 km and 500 m, respectively[4].

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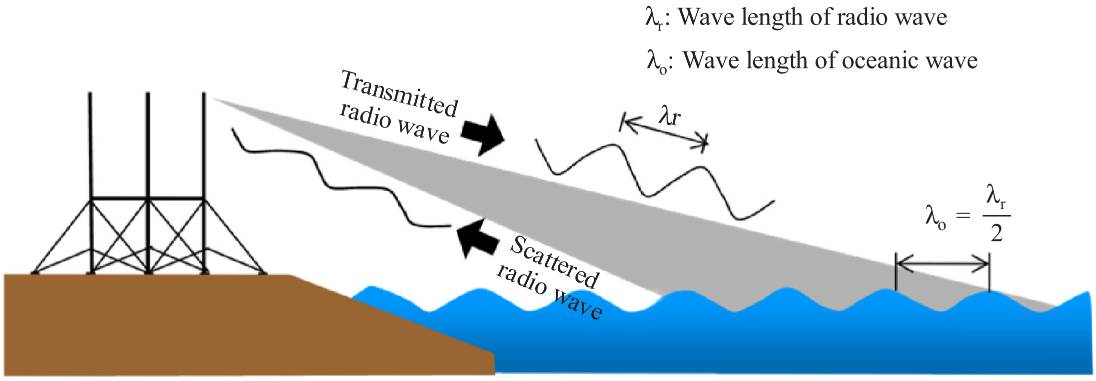
[3] When the transmitted surface wavelength is equal to the half-wavelength of the surface wave in the ocean, a strong reflected signal will be reflected back in the direction of the radar.

[4] Resolution L, speed of light c (= 300 000 km/s) and bandwidth fc has relation of $fc = c/2L$.

FIGURE 4

Schematic image of radio wave propagation and a Bragg scattering



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The objectives of these systems are to: obtain continuous, real-time information for environmental operation (e.g. pollution collection and control), provide disaster-mitigation services (e.g. tsunami wave detection), provide maritime-safety services (e.g. oceanic-current monitoring sea state observation) by oceanographic radars.

The physical parameters that are measured by oceanographic radars and associated performance requirements dictate the frequency ranges that will support data collection. Oceanographic radars for ocean observing utilize the rough surface of the ocean to measure ocean currents and sea state. When the wave spacing on the ocean surface is equal to the half wavelength of the frequency used by the oceanographic radar, a strong signal is reflected back in the direction of the radar. This is the phenomenon known as Bragg scattering. The frequency range 3 to 50 MHz is very useful for oceanographic observing radar operations since ocean waves are always present where the wave spacing matches the radar's operational frequency. The higher temporal resolution is to be pursued for disaster-mitigation purposes while the higher spatial resolution is to be pursued for environmental operation. In addition, measurement of Doppler shift of the signal returns allows operators to measure other properties of sea state and currents.

The two main transmission techniques which are used in oceanographic radars are CW pulses and linear FMCW chirps. Table 1 is a list of the parameters which are associated with a typical oceanographic radar.

TABLE 1

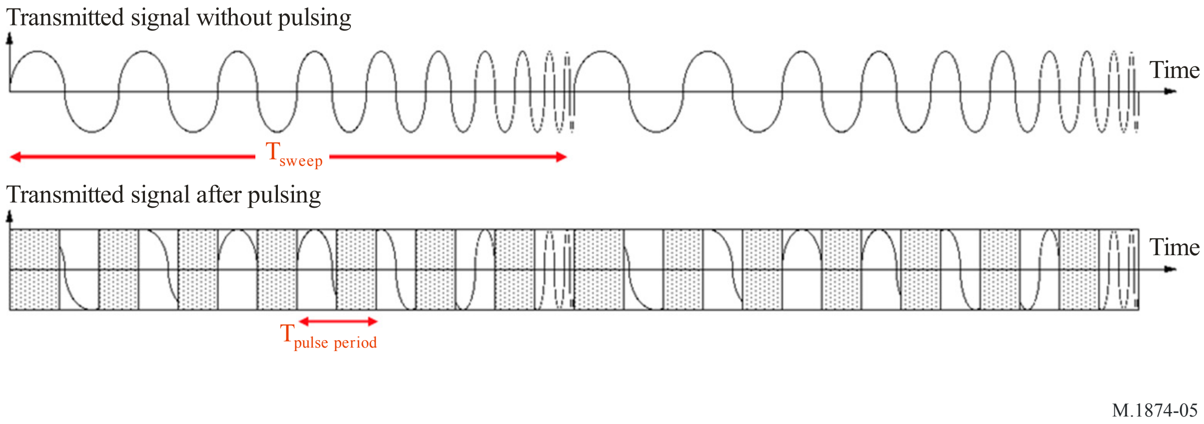
List of parameters of typical oceanographic radar waveforms

Centre frequency (MHz)	Sweep bandwidth (kHz)	Sweep time (Tsweep) (s)	Pulse period (Tpulse period) (μs)	Duty cycle (%)
4.53	25.6	1	1 946	50
13.46	49.4	0.5	669	50
24.65	101	0.5	486	50

Figure 5 illustrates the waveform structure of typical oceanographic radars. The waveform at the top of the picture represents an FMCW signal. The waveform on the bottom is representative of a gated signal.

FIGURE 5

Typical oceanographic waveform structures



3 Oceanographic radar antennas

A variety of antenna types are currently used with oceanographic ocean observing radar systems. Some systems utilize either a 3-element Yagi antenna or phased-array system to sweep in the azimuthal direction using multiple sets of Yagi antenna for transmission, limiting the geography over which the oceanographic radar signal is propagated. Figs 6, 7 and 8 illustrate some typical oceanographic radar antenna patterns.

FIGURE 6

Typical oceanographic radar antenna patterns
(4 vertical monopole array)

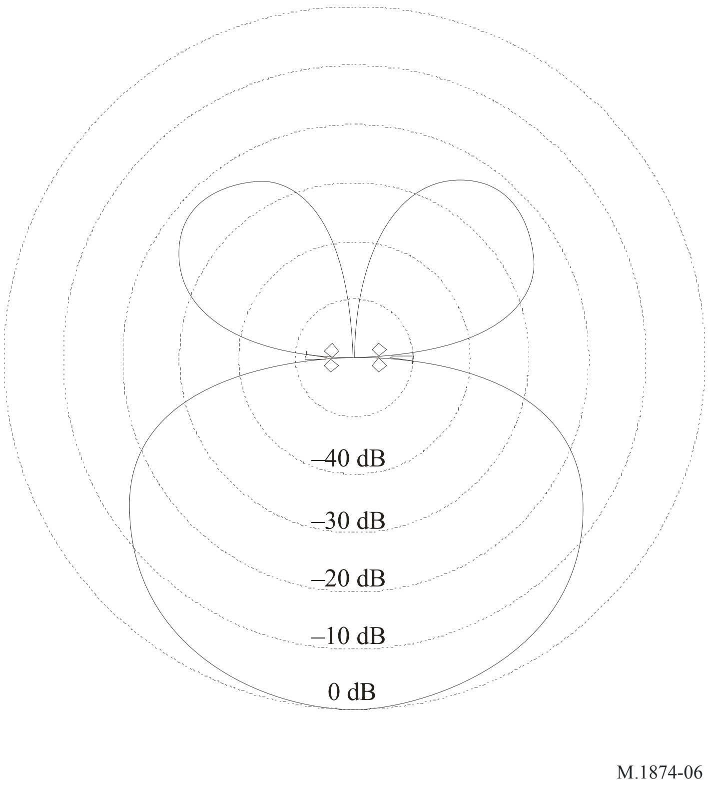


FIGURE 7

Typical oceanographic radar antenna patterns
(omnidirectional; left: azimuthal, right: vertical)

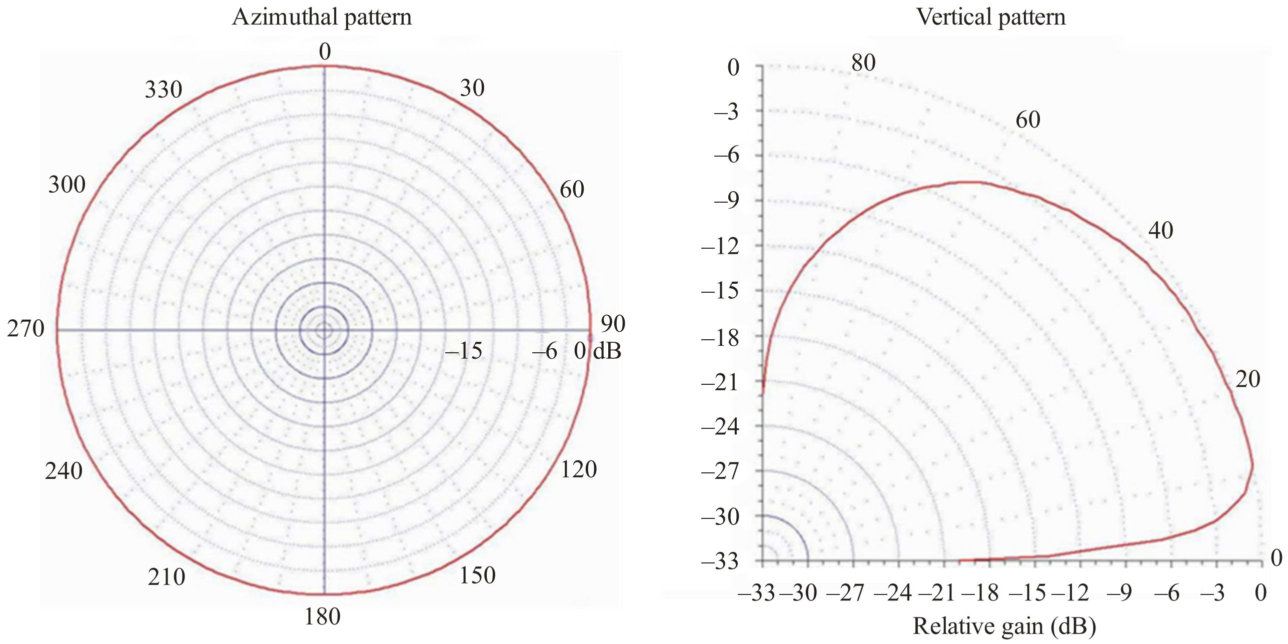


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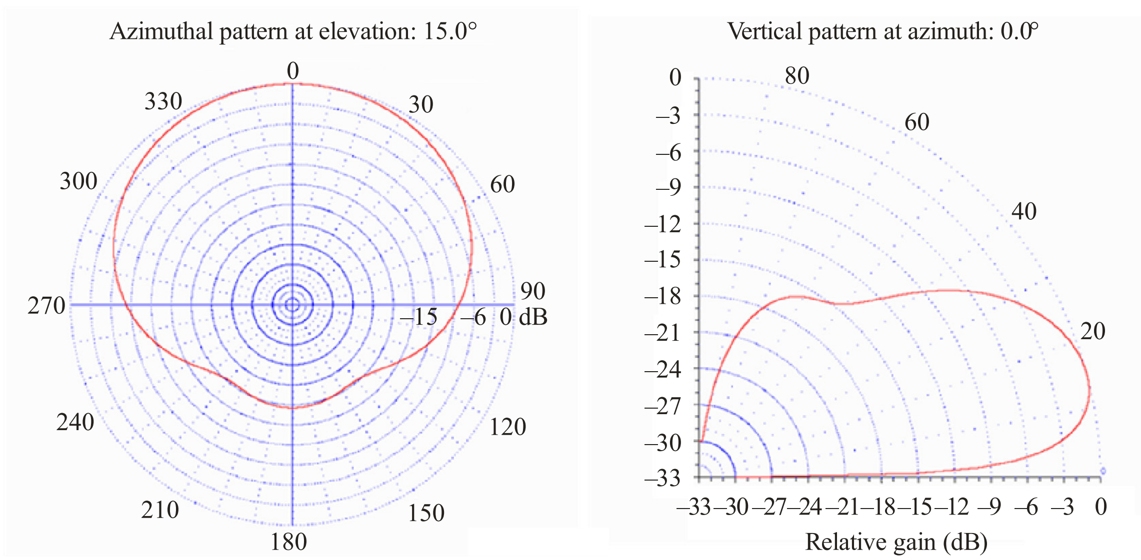
FIGURE 8

Typical oceanographic radar antenna patterns
(directional, 3 elements Yagi; left: azimuthal, right: vertical)



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4 Transmitter emissions

Figures 9 and 10 illustrate typical 4.5 MHz and 24 MHz oceanographic radar emissions.

FIGURE 9

4.5 MHz oceanographic radar emission

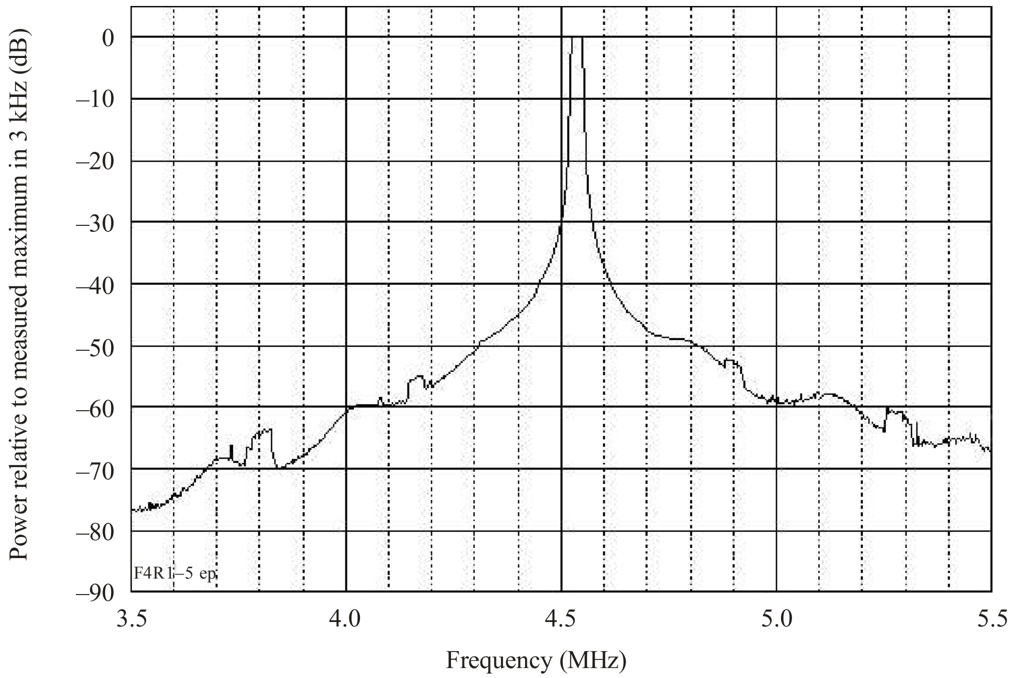

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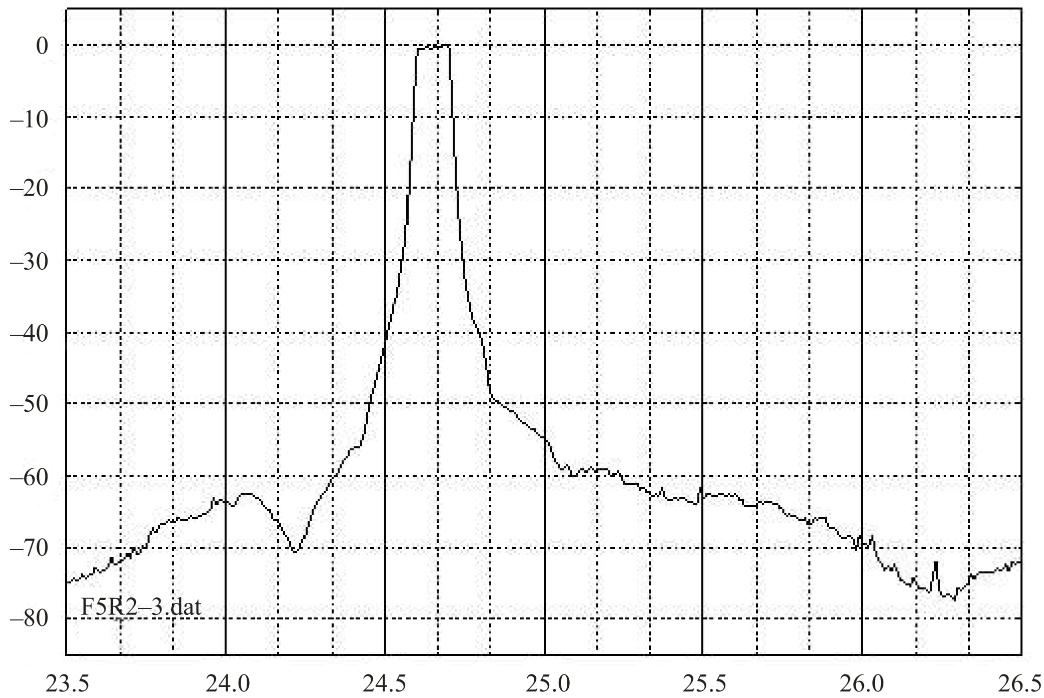
FIGURE 10

24 MHz oceanographic radar emission



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5 System characteristics

Tables 2 through 4 contain a summary of RF characteristics for representative oceanographic radar systems for ocean monitoring at frequency ranges within 3 to 50 MHz.

TABLE 2

Characteristics of generic oceanographic radars for ocean observing using frequency modulated interrupted continuous wave (FMICW)

Characteristics	System 1 5 MHz	System 2 13 MHz	System 3 25 MHz	System 4 42 MHz
Function	Long-range oceanographic measurements	Standard oceanographic measurements	High-resolution oceanographic measurements	
Maximum operational (measurement) range(1)	170-200 km (average during daytime)(2)	60-90 km (average during daytime)(2)	30-50 km (average during daytime)(2)	15-25 km (average during daytime)(2)
Range of user selectable range resolution	3-12 km(3)	2-3 km(3)	0.3-2 km(3)	0.3-1 km(3)
Typical sweep bandwidth	25 kHz(3)	50 kHz(3)	100 kHz(3)	125 kHz(3)
Frequency range(4)	4-6 MHz(4)	12-14 MHz(4)	24-27 MHz(4)	40-44 MHz(4)
Typical peak power used Maximum system capability – Peak power into antenna	50 W 80 W			50 W 80 W(100 W)
Pulse widths (μs)	1 000-2 000	300-600		30-100
Maximum duty cycle	50%			
Pulse rise/fall time (μs)	16/32	16		8/16
Transmitter tuning method	Digital			
Receiver tuning method	Digital			
Output device	Gated FET (Class AB operation)			
Transmitter stability	0.001 ppm			
Receiver stability	0.001 ppm			
Transmit antenna pattern type	Omnidirectional (in horizontal plane)			
Transmit antenna type	Quarter-wave monopole with ground plane			
Antenna polarization	Vertical			
Antenna main beam gain (dBi)	8			
Transmit antenna elevation beamwidth	35°			

TABLE 2 (*end*)

Characteristics	System 1 5 MHz	System 2 13 MHz	System 3 25 MHz	System 4 42 MHz
Transmit antenna azimuthal beam width	Omnidirectional			
Transmit antenna horizontal scan rate	Fixed antenna			
Transmit antenna height (m)	10	4	2	1.2
Receive antenna pattern type	Electric and magnetic dipoles			
Receive antenna type	Two crossed loops and a monopole as single unit			
Receive antenna polarization	Vertical			
Receive antenna main beam gain (dBi)	5			
Receive antenna elevation beamwidth	45°			
Receive antenna azimuthal beamwidth	Beamwidth 90-360°			
Receive antenna horizontal scan rate	Fixed antenna			
Receive antenna height (m)	4			
Receiver IF 3 dB bandwidth (Hz)	500			
Receiver noise figure	12 dB with pulsing			
Minimum discernible signal	–147 dBm (500 Hz RBW[(5)]) (specified system noise level)			
Sweeping interval	0.5 to 1.0 s			
Transmitter emission bandwidth 3 dB 20 dB	 26 kHz 58 kHz	 54 kHz 70 kHz	 105 kHz 150 kHz	 128 kHz 170 kHz
Suppression of harmonics	Yes			

(1) Range depends on a number of environmental factors: external noise, significant wave height, current speed, location of radar (such as proximity to water, nearby obstructions), and the operating frequency.

(2) Range reduces significantly during night time.

(3) While the sweep bandwidth is adjustable (higher bandwidth produces higher resolution data), the systems are normally operated at the typical sweep bandwidths specified due to limited available bandwidth, and the need to coexist with other radio systems.

(4) Specifies the frequency range for optimum performance from a scientific perspective. Entire frequency range not needed for operations.

(5) RBW stands for resolution bandwidth.

TABLE 3

Characteristics of generic oceanographic frequency modulated continuous wave (FMCW) radars

Characteristics	System 5 8 MHz	System 6 12 MHz	System 7 16 MHz	System 8 25 MHz	System 9 42 MHz
Function	Very long-range oceanographic measurements	Long range oceanographic measurements	Standard oceanographic measurements	High-resolution oceanographic measurements	Best resolution short range measurements
Maximum operational (measurement) range	150-300 km (average during daytime)(1)	100-150 km (average during daytime)(1)	50-100 km (average during daytime)(1)	30-60 km (average during daytime)(1)	10-20 km (average during daytime)(1)
Range resolution	3-12 km	1-3 km	1-3 km High resolution mode: 0.5 km	0.5-2 km High resolution mode: 0.25 km	150-500 m
Sweep bandwidth (kHz)	50-12.5	150-50	300-50	600-75	300-1 000
Frequency range (MHz)	6-9	11-14	14-18	24-27	40-44
Average power into antenna (= peak power)	30 W 7 W per antenna				
Pulse widths	No pulse				
Maximum duty cycle	Continuous wave				
Pulse rise/fall time	Continuous wave				
Transmitter tuning method	Digital (DDS)				
Receiver tuning method	Digital (DDS)				
Output device	Solid state, bipolar (Class AB operation)				
Transmitter stability	0.1 ppm/year				
Receiver stability	0.1 ppm/year				
Transmit antenna pattern type	Directional > 90% energy within ±60° beamwidth				
Transmit antenna type	4 vertical monopole rectangular array 0.5 × 0.15 wavelength				

TABLE 3 (*continued*)

Characteristics	System 5 8 MHz	System 6 12 MHz	System 7 16 MHz	System 8 25 MHz	System 9 42 MHz
Antenna polarization	Vertical				
Antenna main beam gain (dBi)	5 to 8				
Transmit antenna elevation beamwidth	25 to 35°				
Transmit antenna azimuthal beamwidth	120°				
Transmit antenna horizontal scan rate	Fixed antenna				
Transmit antenna height (m)	< 10	< 6	< 4	< 3	< 2
Receive antenna pattern type	Directional with beamwidth of ±3 to ±15°				
Receive antenna type	Monopole array (4 to 16 monopoles)				
Receive antenna polarization	Vertical				
Receive antenna main beam gain (dBi)	10 to 18				
Receive antenna elevation beamwidth	35°				
Receive antenna azimuthal beamwidth	6° to 30° depending on array size				
Receive antenna horizontal scan rate	Fixed antenna				
Receive antenna height (m)	< 10	< 6	< 4	< 3	< 2
Receiver IF 3 dB bandwidth	No IF used. Baseband bandwidth is 1.5 kHz				
Receiver noise figure (dB)	8				

TABLE 3 (*end*)

Characteristics	System 5 8 MHz	System 6 12 MHz	System 7 16 MHz	System 8 25 MHz	System 9 42 MHz
Minimum discernible signal	−142 dBm (in 1 500 Hz RBW[(2)] (specified system noise level)				
Instantaneous bandwidth 3 dB 20 dB 60 dB	0.2 kHz 0.6 kHz 30 kHz				
Suppression of harmonics (dBc)	< −60				
Sweep Interval	200 to 500 ms	130 to 500 ms		130 to 250 ms	

(1) Range reduces significantly during night time.

(2) RBW stands for resolution bandwidth.

TABLE 4

Characteristics	System 10 9.2 MHz	System 11 24.5 MHz	System 12 24.5 MHz	System 13 41.9 MHz
Function	Long-range oceanographic measurements	Standard oceanographic measurements		High-resolution oceanographic measurements
Maximum operational (measurement) range (km)	200-300	50-70		20-25
Range resolution (km)	6.8	1.5		0.5
Sweep bandwidth (kHz)	22	100		300
Frequency range (MHz)	9.2	24.5		41.9
Peak power into antenna	1 kW	100 W	200 W	100 W
Pulse width (µs)	1 330	488		244-280
Maximum duty cycle (%)	50			
Pulse rise/fall time	Smoothed(1)			
Transmitter tuning method	Digital			
Receiver tuning method	Digital			
Output device	Gated FET (Class AB operation)			
Transmitter stability	0.03 ppm/year			
Receiver stability	0.03 ppm/year			
Transmit antenna pattern type	Directional			
Transmit antenna type	3-element Yagi	8 sets of 3-element Yagi	3-element Yagi	
Antenna polarization	Vertical			
Antenna main beam gain (dBi)	6	15	6	
Transmit antenna elevation beam width	30°	25°		
Transmit antenna azimuthal beam width	120°	15°	120°	

TABLE 4 (*end*)

Characteristics	**System 10** **9.2 MHz**	**System 11** **24.5 MHz**	**System 12** **24.5 MHz**	**System 13** **41.9 MHz**
Transmit antenna horizontal scan rate	Fixed antenna	Fixed antenna phased array 60 min per 12 direction	Fixed antenna	
Transmit antenna height(2) (m)	10	2-14		
Receive antenna pattern type	Directional			
Receive antenna type	16 sets of 2-element Yagi	8 sets of 3-element Yagi		
Receive antenna polarization	Vertical			
Receive antenna main beam gain (dBi)	16	15		
Receive antenna elevation beam width	30°	25°		
Receive antenna azimuthal beam width	8-10°	15°		
Receive antenna horizontal scan rate	Fixed antenna DBF(3)	Fixed antenna phased array 60 min per 12 direction	Fixed antenna DBF(3)	
Receive antenna height(2) (m)	10	2-14		
Receiver IF 3 dB bandwidth (Hz)	200			
Receiver noise figure	17 dB with pulsing	12 dB with pulsing		13 dB with pulsing
Minimum discernible signal	−157 dBm (1 Hz RBW(4))	−162 dBm (1 Hz RBW(4))		−161 dBm (1 Hz RBW(4))
Transmitter emission band width (kHz)	25	110		320
Suppression of harmonics	Yes			
Sweeping interval	0.7 s	0.5 s		0.25 s

(1) Pulse edges are shaped to control its spectrum. The steepness is specified indirectly via the spectrum.

(2) Feed point height in the antenna array from ground level.

(3) Digital beam forming.

(4) RBW stands for resolution bandwidth.