2900-3100 MHz

1. Band Introduction

The Federal Government uses the band 2900-3100 MHz for operating various types of radar systems that perform missions critical to safe and reliable maritime navigation and accurate weather monitoring in the United States. The United States Coast Guard (USCG), Federal agency and commercial vessels operate radar systems and positioning aids in this band for maritime radionavigation for the safe transportation of people and goods, and to facilitate the flow of commerce. The Department of Defense (DoD) develops and uses radionavigation and radiolocation systems for national defense purposes.

A network of Next Generation Weather Radar (NEXRAD) systems operating in the band 2700-3000 MHz provide quantitative and automated real-time information on (rainfall amounts/rates, wind velocity, wind direction, hail, snow ,etc.) with higher spatial and temporal resolution than previous weather radar systems. In addition, the NEXRAD network provides the data which is used to generate thunderstorm, tornado,, hurricane, high wind and flash floods watches and warnings. The NEXRAD systems are operated throughout the United States by the Department of Commerce (DOC) National Weather Service (NWS), the Federal Aviation Administration (FAA), and the DoD.

2. Allocations

2a. Allocation Table

The frequency allocation table shown below is extracted from the Manual of Regulations and Procedures for Federal Radio Frequency Management, Chapter 4 – Allocations, Allotments and Plans.

Table of Frequency Allocations

United States Table

Federal Table	Non-Federal Table	FCC Rule Part(s)
2900-3100 RADIOLOCATION 5.424A G56 MARITIME RADIONAVIGATION 5.427 US44 US316	2900-3100 MARITIME RADIONAVIGATION Radiolocation US44 5.427 US316	Maritime (80) Private Land Mobile (90)

2b. Additional Allocation Table Information

5.424A In the band 2900-3100 MHz, stations in the radiolocation service shall not cause harmful interference to, nor claim protection from, radar systems in the radionavigation service.

5.427 In the bands 2 900-3 100 MHz and 9 300-9 500 MHz, the response from radar transponders shall not be capable of being confused with the response from radar beacons (racons) and shall not cause interference to ship or aeronautical radars in the radionavigation service, having regard, however, to No. 4.9.

G56 Federal radiolocation in the bands 1215-1300, 2900-3100, 5350-5650 and 9300-9500 MHz is primarily for the military services; however, limited secondary use is permitted by other Federal agencies in support of experimentation and research programs. In addition, limited secondary use is permitted for survey operations in the band 2900-3100 MHz.

US44 In the band 2900-3100 MHz, the non-Federal radiolocation service may be authorized on the condition that no harmful interference is caused to Federal services.

US316 The band 2900-3000 MHz is also allocated to the meteorological aids service on a primary basis for Federal use. Operations in this service are limited to Next Generation Weather Radar (NEXRAD) systems where accommodation in the band 2700-2900 MHz is not technically practical and are subject to coordination with existing authorized stations.

3. Federal Agency Use

3a. Federal Agency Frequency Assignments Table

The following table identifies the frequency band, types of allocations, types of applications, and the number of frequency assignments by agency.

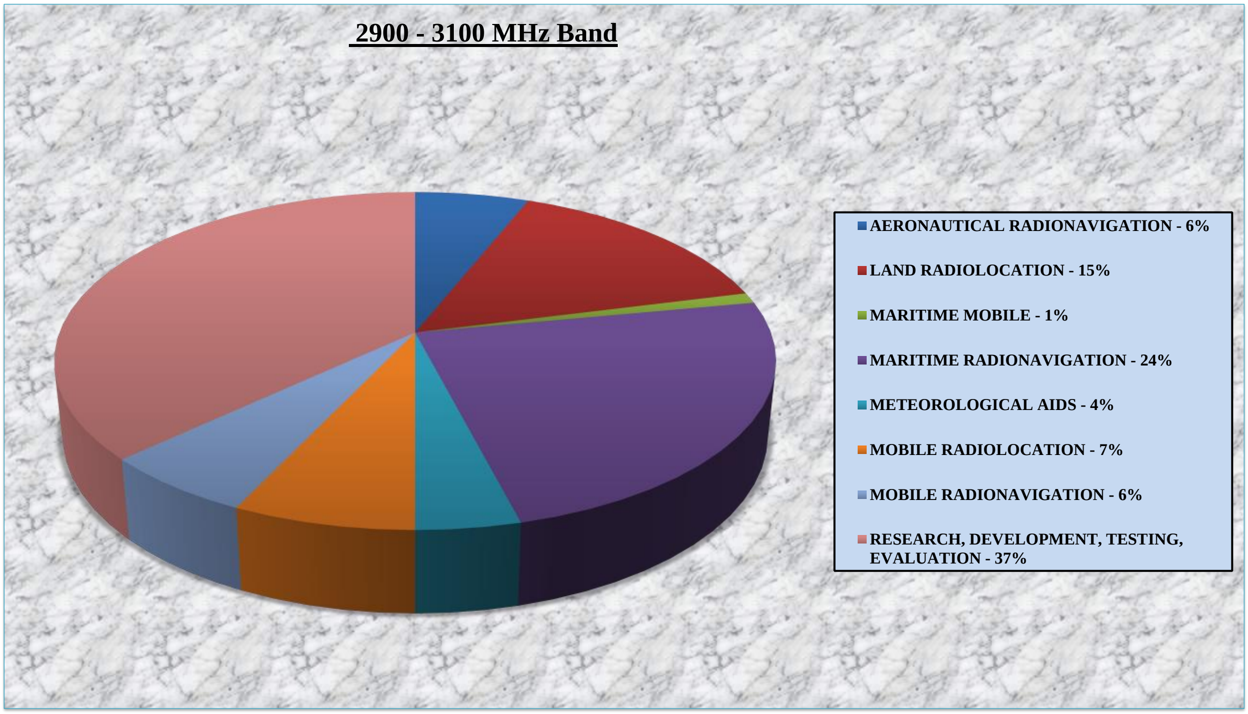
Federal Frequency Assignment Table

2900-3100 MHz Band									
SHARED BAND									
	MARITIME RADIONAVIGATION RADIO LOCATION								
	TYPE OF APPLICATION								
AGENCY	AERONAUTICAL RADIONAVIGATION	LAND RADIOLOCATION	MARITIME MOBILE	MARITIME RADIONAVIGATION	METEOROLOGICAL AIDS	MOBILE RADIOLOCATION	MOBILE RADIONAVIGATION	RESEARCH DEVELOPMENT TESTING EVALUATION	TOTAL
AF	2	32				1		127	162
AR	19	22				11	1	1	54
CG		2		100				4	106
DHS		1							1
DOC		1			14		1		16
DOE		1							1
EPA						1			1
FAA					1				1
N	1	8	3			8	2	20	42
NASA		1					2		3
TRAN							1		1
TOTAL	22	68	3	100	15	21	7	152	388

The number of actual systems, or number of equipments, may exceed and sometimes far exceed, the number of frequency assignments in a band. Also, a frequency assignment may represent, a local, state, regional or nationwide authorization. Therefore, care must be taken in evaluating bands strictly on the basis of assignment countsj or percentages assignment.

3b. Percentage of Frequency Assignments Chart

The following chart displays the percentage of frequency assignments in the Government Master File (GMF) for the systems operating in the frequency band 2900 – 3100 MHz.



4. Frequency Band Analysis By Application

4a. Maritime Radionavigation

The maritime radionavigation radars provide ships with surface search, navigation capabilities, and tracking services, particularly in foul weather. These radars are used by all categories of commercial and Federal Government vessels, including thousands of foreign and U.S.-flagged cargo, oil tanker and passenger ships operating in U.S. waters, and are vital for safe navigation of waterways.

Maritime radionavigation radars are used on a continuous basis within navigable waters, coastal waters, ports, and inland waterways in the United States and Possessions (US&P). The USCG generally defines navigable waters and territorial waters of the United States to mean territorial seas, internal waters that are subject to tidal influence, and internal waters not subject to tidal influence.[1] The Federal Communications Commission lists the following navigable waters: the Atlantic Ocean, the Pacific Ocean below the Arctic Circle, the Great Lakes, the Gulf of Mexico and Gulf Intracoastal Waterway, the Mississippi River upriver to Brainerd, Minnesota, the Missouri River to Sioux City, Iowa, the Ohio River to Pittsburgh, Pennsylvania, the Tennessee River to Knoxville, Tennessee, the Arkansas River to Tulsa, Oklahoma, the Red River to Fulton, Arkansas, and the Columbia River to Richland, Washington.[2] The USCG also considers the Saint Lawrence Seaway and the Intracoastal Waterway as navigable waterways. The United States has 26,000 miles of commercially navigable waterways serving 361 U.S. ports.[3]

The maritime radionavigation radar systems operating in the 2900-3100 MHz band are used on board ships that support the U.S. domestic and international economy. Over ninety-five percent of the overseas trade enters through U.S. seaports and accounts for over $800 billion of freight each year. Domestic and international trade is expected to double in the next twenty years.[4] Approximately 70,000 International Maritime Organization (IMO) Safety-of-Life at Sea (SOLAS) Convention and thousands of non-SOLAS vessels use radionavigation radars in the 2900-3100 MHz band in coastal port areas and waterways throughout the United States.

The map in Figure 1 indicates the operating areas of maritime radionavigation radars of the continental United States marked in red, and out to the orange lines, 100 nautical miles from the shore. The blue dots show fixed locations of RACONs, for safety of navigation, which operate with the mobile radars. Maritime radionavigation equipment does not operate in the green shaded area of the continental United States.

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1 Title 33 Code of Federal Regulations Section 2.36 - Navigable waters of the United States, navigable waters, and territorial waters.

2 *See* Amendment of the Commission's Rules Concerning Maritime Communications, Second Memorandum Opinion And Order And Fifth Report And Order, PR Docket No. 92-257, 17 FCC Rcd 6685 (2002) at n. 203.

3 Statement of Jeffrey P. High, Department of Homeland Security, United States Coast Guard, on the U.S. Coast Guard's Maritime Domain Awareness Efforts before the Subcommittee on Coast Guard and Maritime Transportation, Committee on Transportation and Infrastructure, U.S. House of Representatives, Oct. 6, 2004.

4 *See Supra, n. 3.*

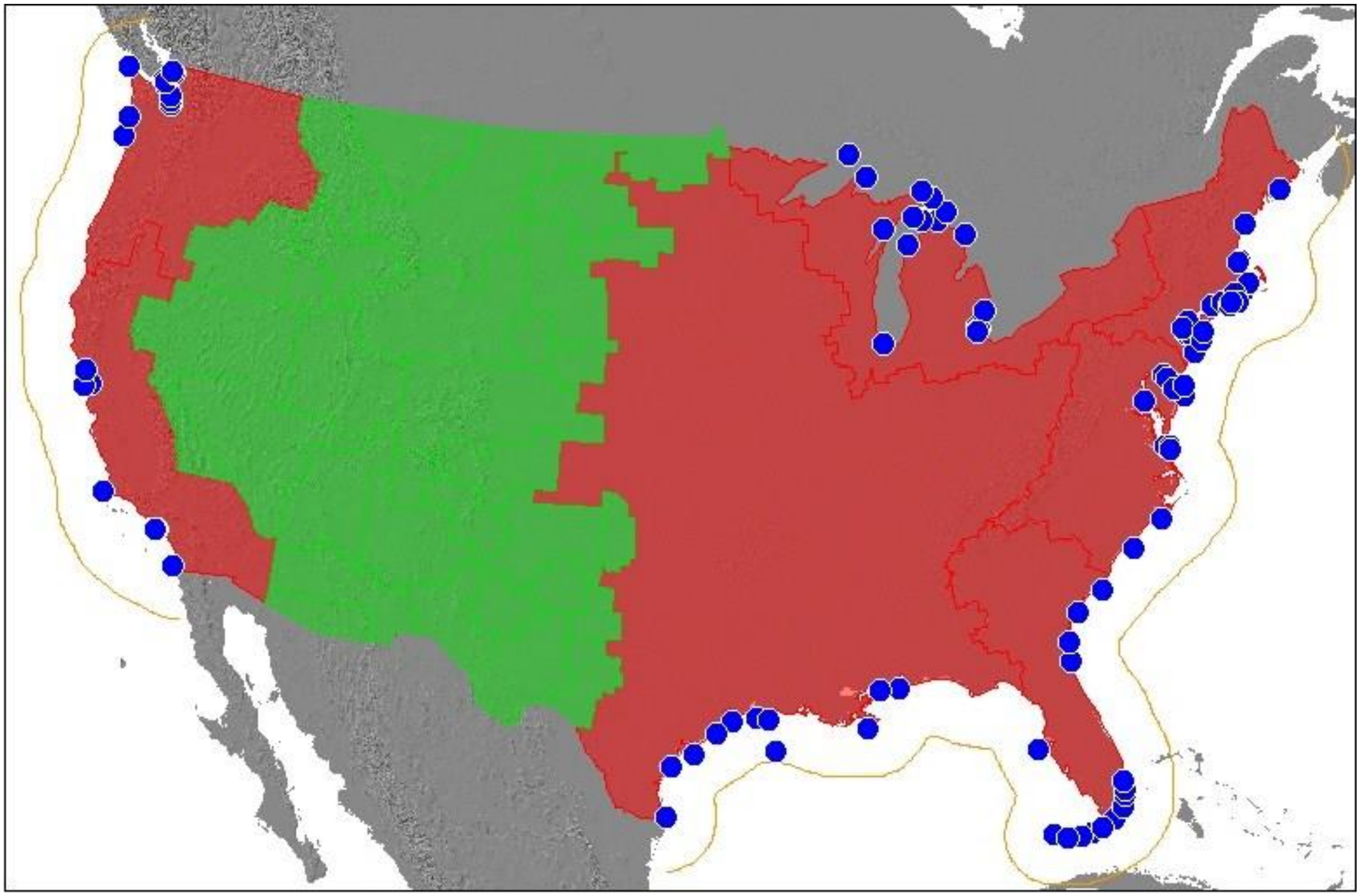

Figure 1. – Area of Operation for Maritime Radionavigation Radars

The U.S. Government, foreign governments, and commercial entities utilize the AN/SPS-73 surface search radar as an advanced navigation and surveillance system for ship or land-based applications in the United States.[5] This radar provides navigational awareness and a comprehensive picture of the maritime environment.[6] The USCG utilizes this radar to monitor commercial shipping in ports and waterways.

4a(1). Shipborne Radionavigation

The USCG is responsible by statute to provide for safe and efficient maritime navigation. The IMO SOLAS Convention requires that ships with large displacements be equipped with a radionavigation radar system that enables them to navigate in coastal areas and

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[5] Raytheon Surface Search Radar, retrieved on March 15, 2011 from, http://www.raytheon.com/capabilities/products/sps73/.

[6] *See Supra n. 5.*

near docks.[7] Shipborne radionavigation radars, to include IMO Type 1 shipborne radars (including fishingvessels), and maritime radar beacons (RACONs) operate in this band.

The operational requirement for shipborne radars is a function of the collision avoidance scenarios - oceanic, coastal or harbor/port navigation. The IMO has developed a revision to the operational performance standards for shipborne radar, which includes new requirements for the detection of specific targets in terms of the radar cross section (fluctuating target) and required range, as a function of radar frequency band. International maritime authorities have stated, without reservation, in their recent update of the IMO SOLAS Convention that radar remains a primary sensor for the avoidance of collisions. Maritime objects, e.g. icebergs, floating debris, wrecks, and other vessels, are potential causes of collision with ships, and need to be detected by ship radars. The ITU-R states that "Radar will therefore remain the primary system for collision avoidance for the foreseeable future."[8]

Tables 1 and 2 depict characteristics of representative shipborne radionavigation systems as contained in ITU-R Recommendation M.1460-1, *Characteristics of and protection criteria for radars operating in the radiodetermination service in the frequency band 2 900-3 100 MHz* (ITU-R M. 1460-1). Table 1 presents transmitter power and number of radars for IMO type shipborne radars operating in the band 2900-3100 MHz.[9]

Table 1. Characteristics of Shipborne Radionavigation Radars

Radar category	Peak power (kW)	Global total
IMO and fishing	≤75	> 300 000

The radar characteristics that affect the efficient use of the spectrum, including protection criteria, are those associated with the radar antenna and transmitter/receiver. Most of the IMO type radars use slotted array antennas,

[7] IMO is the United Nations agency concerned with international maritime activities.

[8] ITU-R Recommendation M.1460-1, *Characteristics of and protection criteria for radars operating in the radiodetermination service in the frequency band 2 900-3 100 MHz* (ITU-R M. 1460-1).

[9] *See Supra, n. 8.*

2900 – 3100 MHz

Table 2 summarizes the technical characteristics for the IMO category radars operating in the band 2900-3100 MHz.[10] The range for each characteristic is expressed in the form of a maximum and minimum value.

Table 2. Characteristics of Maritime Radionavigation Radars
(IMO category – including fishing)
Transmitter/receiver – typical characteristics

Characteristics	**2 900-3 100 MHz**	
	Maximum	**Minimum**
Antenna (for transmission/reception):		
Beamwidth (to –3 dB) (degrees)		
Horizontal	4.0	1.0
Vertical	30.0	24.0
Sidelobe attenuation (dB)		
Within ±10°	28	23
Outside ±10°	32	31
Gain (dB)	28	26
Rotation rate (r.p.m)	60	20
Transmitter:		
Peak power (kW)	75	30
Frequency (MHz)	3 080	3 020
Pulse duration[(1)] (μs)	1.2	0.05
Pulse repetition frequency[(1)] (Hz)	4 000	375
Receiver:		
Intermediate frequency (IF) (MHz)	60	45
IF bandwidth (MHz)		
Short pulse	28	6
Medium/long pulse	6	2.5
Noise figure (dB)	8.5	3

(1) When using this Table to calculate mean power it should be noted that the maximum pulse repetition frequency is associated with the minimum pulse duration and vice versa.

Radionavigation radars are nearly always mobile (on ships transiting littoral waters), and there is no way to know exactly where and when they will operate or what frequencies

[10] *See Supra, n. 8.*

they will use. Many of these radars are operated on commercial vessels that carry non-U.S. registry. There is a limited amount of information on these radars in the GMF. Due to the mobile nature of Federal shipborne radars (e.g., Navy and Coast Guard ships), assignment locations listed in the GMF are usually simply provided as "US&P" (U.S. and Possessions). They are often tuned near 3050 MHz as a default, but individual radars frequently use other frequencies.

4a(2). Shore-Based Radionavigation

The USCG operates Vessel Traffic Services (VTS) in selected harbors with heavy ship traffic. The VTS systems use maritime radars and shore-based RACONs that operate with shipborne radars to aid navigation. The marine radar system provides indications and data on surface craft, obstructions, buoy markers, and navigation marks to assist in navigation and collision avoidance. The RACONs work with shipborne navigation radar systems to electronically identify maritime obstructions and navigation points.

RACONs are short-range navigation devices that respond to and provide images on a vessel's maritime navigation radar pulse position indicator display to identify specific locations that are hazardous to maritime navigation. The RACONs transmit when triggered by a radar and at the frequency of the radar. While the RACONs are located at fixed points along major waterways, the ships that receive their signals travel the full length of those waterways emitting radar signals in the band. Although most RACONs are operated by the USCG, private users, e.g., owners of oil platforms, also operate RACONs. The USCG operates RACONS over the frequency ranges 2900-3100 MHz and 9300-9500 MHz**.** RACONs provide important navigation information that is difficult to provide by other means. These systems provide collision avoidance information not otherwise available through Global Positioning System (GPS) or other navigation systems. The technical characteristics for RACONs can be found in ITU-R Recommendation M.824-2.[11]

Figures 2 through 4 indicate the area of operations for RACONs in the continental United States, Alaska, and Hawaii.

[11] ITU-R Recommendation M.824-2, *Technical Parameters of Radar Beacons (RACONS)*.

Figure 2. – Area of Operation for RACONs in the continental United States

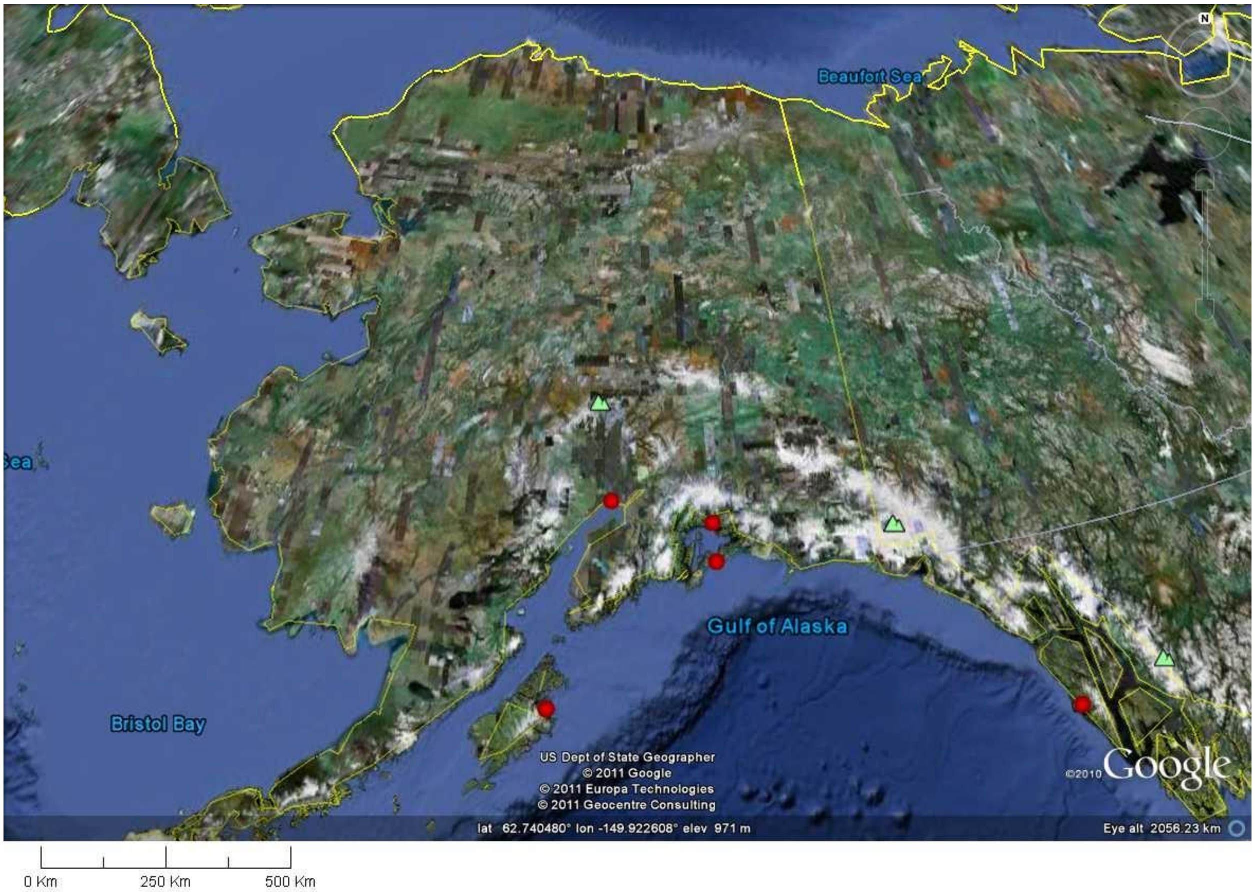

Figure 3. – Area of Operation for RACONs in Alaskaaes

Figure 4. – Area of Operation for RACONs in Hawaii

4b. Meteorological Aids

The NWS, FAA and DoD operate NEXRAD systems in the 2900-3000 MHz portion of this band. The National Oceanographic and Atmospheric Administration (NOAA) maintains an engineering, maintenance, and research facility located in Norman, OK. The National Severe Storms Lab (NSSL) operates a research testbed operating a Phased Array Radar System (SPY-I) operating at 3100 MHz. The Engineering and Maintenance Facility, the Radar Operations Center (ROC), operates a single redundant radar operating at 2950 and 2995 MHz. The 3100 MHz frequency assignment is restricted to the NSSL facility. The research and development conducted at NSSL and ROC includes development and testing of new hardware technologies and signal processing techniques.

The NEXRAD network consists of 159 operational sites within the contiguous United States with radars that provide weather monitoring capabilities. The NEXRAD collects data by transmitting a pulsed radio frequency signal that bounces off the raindrops and returns to the radar. The returned signal conveys three important properties: first, the time it takes for the signal to bounce off the raindrops and return determines the distance from the storm to the radar, and thus the location of the storm; second, the strength of the returned signal, also known as reflectivity, is proportional to the size and number of raindrops in the storm; and third, the frequency of the returned signal reveals whether the winds are moving toward or away from the radar, as well as the speed. The NEXRAD data is converted into visual images and used by the NWS forecasters, the FAA, and the military to provide weather information to the nation. In addition, selected visual images are made available on the web and shown on television weather broadcasts. Local and national television meteorologists use NEXRAD data to keep their viewers informed of real-time weather conditions.[12] NEXRAD data is also used by private companies and studied by university researchers to improve forecasts. Weather forecasters use the continuous, immediate weather information provided by NEXRAD to track storms and warn the public of dangerous weather. NEXRAD allows forecasters to see all types of weather and provide advanced warning for thunderstorms, hail, tornadoes, hurricanes, wildfires, flash floods, snow, and freezing precipitation. The ability of NEXRAD to detect wind patterns in storms and provide real time rainfall amounts providing significant improvements over previous weather radar systems. The NEXRAD operates continuously, and provides severe weather coverage out to 125 statute miles and storm tracking out to 250 statute miles. A map showing the coverage of the NEXRAD network is provided in Figure 5.[13]

Doppler weather radar coverage of CONUS at 4,000, 6,000, and 10,000 feet above radar ground elevation from the nationwide network of WSR-88Ds (Next Generation Weather Radars). (Courtesy of SRI International)

[12] Television stations that operate their own weather radarwill often use regional NEXRAD data to provide a broader view of the weather approaching their area.

[13] A description of the NEXRAD coverage plots can be found at the following url: http://www.roc.noaa.gov/WSR88D/Maps.aspx

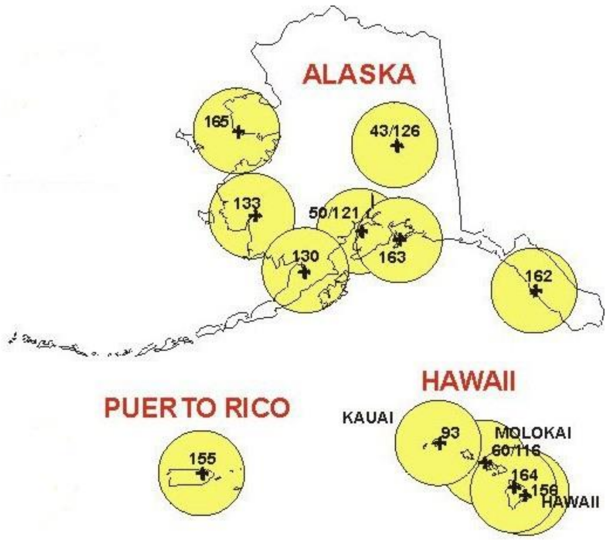

Figure 5. NEXRAD Network Coverage in the United States

The International Telecommunication Union – Radiocommunication Sector (ITU-R) notes that "the 2700-3100 MHz range offers excellent meteorological and propagation characteristics for weather forecast and warning capabilities."[14] The NEXRAD can tune across the entire band 2700-3100 MHz. The occupied channel bandwidth of a NEXRAD is 5 MHz. A single frequency is used at each NEXRAD site location. Frequency re-use (i.e., co-channel operation) by pairs of NEXRAD systems is possible in situations where they are separated by at least 150 nautical miles (173 km).

The peak power of the NEXRAD is 1 Megawatt (1 x 10^6 watts) and it employs a directional antenna with a mainbeam gain of 45 dBi; resulting in a transmitted signal power level of 32 Gigawatts. The NEXRAD has a maximum duty cycle of 0.21 percent and a minimum duty cycle of 0.05 percent.

A typical NEXRAD installation is shown in Figure 6. For a typical installation, the NEXRAD antenna is located on a tower approximately 90 feet above ground level so as to provide a clear view of the sky. The antenna is encapsulated by a radome to protect it from weather as it rotates 360 degrees. While it rotates, it also scans in the vertical direction through 20 degrees every five minutes. The antenna is slightly angled upwards to remove clutter and other objects that could degrade performance. NEXRAD can be operated in three distinct modes. The first of these is the clear-air mode, in which eight full 360 degree azimuthal scans are completed every ten minutes, at elevation angles ranging from 0.5 to 4.5 degrees. The second is the precipitation-detection mode, in which 11 full azimuthal scans occur every six minutes at elevation angles between 0.5 to 19.5 degrees. The third is the severe-weather mode, in which 16 azimuthal scans are performed every five minutes at elevation angles between 0.5 and 19.5 degrees. Each

[14] ITU-R M.1460-1..

NEXRAD site is unique in terms of how the radar is located and arranged to reduce interference and clutter from the local terrain and other radar systems operating in the band.

Figure 6. Typical NEXRAD Installation

4c. Radiolocation

The DoD uses the 2900-3100 MHz band throughout the United States for transportable and land-based three-dimensional air search and surveillance radar systems. The Air Force operates a variety of radiolocation land stations in this band. The Air Force operates radiolocation land stations for air operations in Mississippi, Idaho, Georgia, Wisconsin, Florida, Nevada, Oregon, Utah, Puerto Rico, and Arizona. Some of these radars transmit signals by rapidly switching between many frequencies referred to as frequency hopping.[15] The Air Force operates radiolocation land stations for sustaining base operations in Virginia, Delaware, California, Missouri, and Nevada to warn pilots of hazardous flight conditions associated with bird migration. These radars provide safety-of-flight information for air operations. The Air Force employs land-based radars in Idaho and Arkansas for range control, operations and safety. In Florida and Georgia, the Air Force uses land-based radars for sustaining base operations and training. These radars operate on 15 or more operating frequencies throughout the 2900-3100 MHz band. In Hawaii, these radars are used for air operations.

[15] Frequency hopping techniques are employed to improve radar performance in the presence of interference and to reduce the ability of the radar signals to be intercepted.

The military operates a variety of radiolocation radars in this band. The transportable radiolocation radars in the 2900-3100 MHz band for test ranges. The military operates distance measuring equipment radio beacons on helicopters for multipath measurements. The military uses transportable radiolocation radars to support depot level repair and overhaul of radars. Testing sometimes requires actual tracking of military aircraft. The military also use transportable radars in this band for survey work. The radars operate only a small percentage of time except in a few fixed areas.

The Navy opearates a variety of radiolocation systems in this band. The Navy employs mobile radars throughout this band in Mississippi, Washington, Hawaii, and throughout the pacific ocean for sea and airborne operations. These radars are used as distance measurement equipment to provide high accuracy distance information. The Navy also operates these radars in the Gulf of Mexico for test and measurement in support of sea operations and navigation. The Navy operates land-based radars in this band in Virginia to support air operations and training. In California, the Navy operates land-based sea surveillance radars for range operations, and to support operations within the United States. The Navy uses land-based radars in Alaska for range clearance in support of test range launch operations. In Hawaii, the Navy uses land-based radars for surveillance and reconnaissance training. To improve performance when tracking multiple targets simultaneously radar systems operating in this band employ a transmission technique where the signal is swept linearly in frequency across large segments of the spectrum.[16]

The Department of Homeland Security, Customs and Border Patrol use land-based radars in this band for law enforcement along the United States and Mexico border. The Department of Energy uses this band for land-based surveillance radar to provide security and warning of unlawful airborne entry into special nuclear material storage areas. The Environmental Protection Agency operates mobile radars in coastal waters of the United States and Possessions aboard observation vessels. The Department of Interior, International Border Water Commission operates land-based transportable radar distance measuring equipment in this band within 75 miles of the United States and Mexico border for cadastral, hydrographic, geophysical, and topographic surveys.

ITU-R Recommendation M.1460-1, provides additional technical characteristics for shipborne radars. Table 3 summarizes the tuning range, tuning options, frequency at horizon, peak transmitter power level, emission bandwidth, mainbean antenna gain, and other characteristics for the shipborne radars operating in the band 2900-3100 MHz.[17]

Table 3. Characteristics of Shipborne Radiolocation Radars in the 2900-3100 MHz Band

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[16] These transmission techniques are referred to as linear frequency modulation or chirp modulation.

[17] ITU-R M.1460-1.

Characteristics	Radar No. 1	Radar No. 2	Radar No. 3
Overall tuning range (MHz)	2 910-3 100.5	Nominally 2 900-3 100	2 910-3 100.5
Characteristics	**Radar No. 1**	**Radar No. 2**	**Radar No. 3**
Tuning options and frequency/elevation relationship	Deterministic: High frequency ⇐⇒ low elevation angle		
Frequency at horizon (MHz)	Smooth sea: 3 048-3 051	Smooth sea: 3 055	Smooth sea: 3 051
Coverage/performance modes	Long-range Long-range/limited elevation Short-range Short-range/limited elevation (each with normal, coincident video, or MTI beams/pulses)	Normal (≤ 45° elevation) 5° Burn-thru: 1 fixed 1.6° beam Chirp-thru: 1 beam with chirped waveform Long-range MTI, 3-pulse; 5° or 45° Short-range MTI, 4-pulse; 5° or 45° Passive	Long-range (≤ 12.8° elevation) Long-range/low-elevation (≤ 4.8°) High-angle (≤ 41.6°) Limited-elevation (≤ 12.8°) High-data-rate (≤ 41.6°) MTI (≤ 36.9°)
Tx pulse waveform-type	Unmodulated	Normal, 5°, and MTI modes: 9 stepped-frequency sub-pulses (1.5 MHz between adjacent subpulses); Burn-thru mode: unmodulated Chirp-thru mode: linear FM	Unmodulated
Tx RF output device(s)	Klystron	Cross-field amplifier (amplitron)	Klystron
Tx filter		High-pass; f_{co} ≥ 2 840 MHz	
Tx maximum peak power	0.9-1 MW at horizon to 35°	2.2 MW at horizon to 5°	1.0-1.5 MW at horizon to 35°
Tx peak powers at higher elevations and/or reduced-range modes	Power decreases smoothly from circa 1 MW at 35° to 300 kW at 41.6°	600 kW at 5.5° to 21°; 60 kW above 21° and at horizon in most MTI pulses	Power decreases smoothly from circa 1 MW at 35° to 300 kW at 41.6°
Tx pulse/subpulse width (μs)	Early units: 4 and 3 or 2 Later units: 10, 4.6, and 2.5	Normal, 5°, and MTI: 27 (9 contiguous 3 μs sub-pulses); Burn-thru and chirp-thru: 27	Long-range and long-range/ low-elevation: 10 High-angle and limited-elevation: 4.6 High-data-rate and MTI: 2.5
Pulse-compression ratio	Not applicable	Normal, MTI, and burn-thru: not applicable Chirp-thru: 9	Not applicable
Tx 3 dB bandwidth	10 μs PW: approx. 100 kHz 4.6 μs PW: approx. 225 kHz 2.5 μs PW: approx. 700 kHz	Normal and MTI: 300 kHz/ sub-pulse Chirp-thru: 300 kHz Burn-thru: 34 kHz	10 μs PW: approx. 100 kHz 4.6 μs PW: approx. 225 kHz 2.5 μs PW: approx. 700 kHz

Tx 20 dB bandwidth		Normal and MTI: 2 MHz/ sub-pulse Chirp-thru: 700 kHz Burn-thru: 240 kHz	
Characteristics	**Radar No. 1**	**Radar No. 2**	**Radar No. 3**
PRI (μs)[(1)]	Varied: 2 050 to 500 (2 050 at horizon) Fixed: 2 116	Normal: variable 2 830-732 (2 830 at horizon) Burn-thru, chirp-thru, and low-elevation: fixed at 2 830, 4 850, or 6 180	Varied: 3 106-426 (3 106 at horizon)
Average PRI of full-power pulses containing horizon-level beams (μs)		Normal mode: 5 120 5° mode: 4 977 Long-range 3-pulse MTI: 5°: 4 357 45°: 6 760 Short-range 4-pulse MTI: 5°: 10 534 45°: 19 695 (1 or 2 subpulses/pulse reach horizon)	Long-range: 7 491 Long-range/low-elevation: 6 190 High-angle: 10 972 Limited-elevation: 7 383 High-data-rate: 14 020 MTI: 9 886 or 10 903 (on alternate azimuth scans)
Polarization	Horizontal		
Antenna gain (dBi)	Early units: 33.5 Later units: 37	38.5	37
Antenna beamwidths (degrees)	Azimuth: 1.9 Elevation: 2.25	Azimuth: 1.5 Elevation: 1.6	Azimuth: 1.9 Elevation: 2.25
Frequency shift for 1/2 BW elevation change	2.25 MHz (0.5° per MHz)	4.1 MHz (0.39° per MHz)	2.25 MHz (0.5° per MHz)
1st side-lobe suppression (dB)	Early units: Azimuth: 16 Elevation: 20 Later units: Azimuth: 25 Elevation: 25	Azimuth: 25 Elevation: 15	Azimuth: 25 Elevation: 25
Remote side-lobe suppression	Often limited by structure scattering		
Antenna azimuth scan type (degrees)	Continuous 360		
Characteristics	**Radar No. 4**	**Radar No. 5**	**Radar No. 6**
Antenna frame (revisit) time (s)	Early units: Normal: 4 MTI: 5.2 Coincident video: 12.5 Later units: 8, 6, 4	4 and 8	8, 6, and 4
Antenna elevation scan (degrees)	Early units: 0-48 Later units: 0.3-41.6	0-45	0.3-41.6

Formation of distinct elevation beams	Sequential Rx via single channel	Simultaneous Rx via 9 parallel channels, plus sequential stepping from pulse-to-pulse	Sequential Rx via single channel
Rx RF bandwidth(2)	200 MHz (estimated)	≥ 200 MHz	200 MHz
Characteristics	**Radar No. 1**	**Radar No. 2**	**Radar No. 3**
Rx IF bandwidth(2)	500 kHz	350 kHz per channel 12 MHz overall	Long-range: 80 kHz High-angle: 174 kHz High-data-rate and MTI: 348 kHz
Processing gain relative to noise (dB)		Chirp mode: 9	
Desired-signal sensitivity or noise level (dBm) (referred to antenna port)	Noise level: –109		
Interference-suppression features	Coincident video MTI Later units: sidelobe blanking	STC FTC AGC INT CSG WPB Sidelobe blanking Single-beam blanking Pulse-to-pulse correlation Noise clipping (Dicke fix)	Sidelobe blanking Log video Dicke Fix Jam strobe(3)
Years in use	1960 – ... (superseded by radars No. 2 and No. 3)	1965 – present	1966 – present

(1) In most modes of radars Nos. 1, 2, and 3, the interpulse interval, along with the peak power, decreases as the beam scans upward.

(2) Rx RF and IF saturation levels are referred to antenna port.

(3) The jam strobe displays a visible radial line identifying the direction of sources of certain kinds of interference.

Although these radars' emissions are individually wide, they operate with a high degree of mutual compatibility with other radars in the 2900-3100 MHz band and the adjacent radar bands of 2700-2900 and 3100-3650 MHz. This is due to their receivers' capability to preferentially detect the pulse echoes of their own transmissions and to reject pulse echoes received from other radars.[18] This immunity to low duty cycle pulsed emissions allows radar systems to operate compatibly in the band. However higher duty cycle solid state radars may increase the likelihood of radar to radar interference. ITU-R Recommendation M.1460-1 states that these shipborne radiolocation radars likely operate a high percentage of the time when their ships are underway.

[18] "Effects of RF interference on radar receivers", NTIA Technical Report TR-06-444, Sep. 2006. http://www.its.bldrdoc.gov/pub/ntia-rpt/06-444/

2900 – 3100 MHz

Table 4 summarizes the tuning range, tuning options, peak transmitter power level, emission bandwidth, mainbeam antenna gain, and other characteristics for the land-based radiolocation radars operating in the band 2900-3100 MHz.

Table 4. Characteristics of Land-Based Radiolocation Radars in the 2 900-3 100 MHz Band

Characteristics	**Radar No. 4**	**Radar No. 5**	**Radar No. 6**
Overall tuning range (MHz)	2 905-3 080	2 901.5-3 098.4	2 900-3 100
Tuning options and frequency/elevation relationship	Deterministic: Low frequency ⟺ low elevation angle 0.1°-0.15° per MHz	a) fixed frequency b) pulse-pulse frequency agile (≤ 16 frequencies): – environment-sensed – random c) MTI (12-pulse bursts): frequency agile (environment-sensed or random)	a) fixed frequency b) pulse-pulse frequency agile (16 frequencies from among 4 sets of 16 each): – environment-sensed – random c) MTI (4-pulse bursts): frequency agile (environment-sensed or random)
Frequency at horizon (MHz)	2 924-2 935	Independent of elevation angle	
Coverage/performance modes	Normal (0°-18°) Coded-pulse (pulse compression at 0°-2.24°, normal above 2.24°) MTI (≤ 18°) Burn-thru (one selected 0.8° elevation beam)	Pulse-compression (0°-20°) MTI with pulse-compression (0°-20°)	240 nautical miles instrumented range Pulse-compression (0°-20°) MTI with pulse-compression (0°-20°)
Tx pulse waveform type	Normal and MTI: stepped-frequency subpulses (frequency/ elevation-scanned within pulse) Low-elevation/high-power pulses have 6 subpulses; high-elevation pulses and low-power MTI pulses have 9 subpulses. Both have approximately 2.8 MHz step between adjacent subpulses Coded-pulse: three contiguous 9.9 μs subpulses, each comprised of 13 coded chips Burn-thru: unmodulated	Bi-phase coded (Barker 13)	
Tx RF output device(s)	Cross-field amplifier	Twystron	
Tx filter	High-pass		None 2nd harmonic suppressed 60 dB 3rd harmonic suppressed 50 dB
Tx maximum peak power	2.2 MW from 0° to 7.2° elevation except 60 kW in MTI beams from 0° to 3°	2.8 MW	3.0 MW

Characteristics	Radar No. 4	Radar No. 5	Radar No. 6
Tx peak powers at higher elevations and/or reduced-range modes	665 kW from 7.2° to 12.6° elevation 60 kW at 12.6° elevation	Tx power is distributed among multiple beams so as to form approximately $cosec^2$ pattern	Tx power is distributed among multiple beams over 0° to 20° elevation
Tx pulse/subpulse width	Normal: 6 contiguous 5 µs subpulses at low elevation and high power; 9 contiguous 3 µs subpulses at high elevation MTI: 9 contiguous 3.3 µs subpulses Coded-pulse: 3 contiguous 9.9 µs pulses, each with 13 subpulses (0.76 µs chips)	6.5 µs	6.5 µs coded pulse
Pulse-compression ratio	Coded-pulse: 13	13	
Tx 3 dB bandwidth	Normal and MTI: 350 kHz per subpulse Coded-pulse: 1.3 MHz for beams with pulse compression	Approximately 2 MHz	1.4 MHz
Tx 20 dB bandwidth		9.5 MHz	2.7 MHz (5.9 MHz at 40 dB, 40 MHz at 60 dB)
PRI(1)	Varied: 3 772 µs at horizon to 1 090 µs at 18°, except 1 090 µs for MTI	Fixed: 4 082, 4 000, or 3 876 µs Deterministically staggered: 3 597→3 788→4 255→4 405→ 3 876 →4 082 µs→repeat	Fixed PRFs include 245, 250, and 258 pps (4.082, 4.0 or 3.876 ms) Pulse-to-pulse jittered interval sequence is typically 4.08→ 3.59→3.79→4.25→4.40→ 3.87 ms→repeat Two other interpulse-interval jitter patterns may be used
Average PRI of full-power pulses containing horizon-level beams	Normal: approximately 9 670 µs (1 or 2 subpulses/pulse reach the horizon)	All pulses cover 0°-20°	272.5 pps
Polarization	Horizontal	Vertical	Horizontal
Antenna gain (dBi)	41	Tx: 34.5 Rx: 38 (Tx power is divided among 13 beams; returns are combined into only 6 Rx channels.)	Tx: 35 (Tx energy is spread over 0.5°-20°) Rx: 36.7, 35.7, 35.3, 35.5, 32.1, and 31.9, from low beam to high beam
Antenna beamwidths (degrees)	Azimuth: 2.15 Elevation: 0.84	Azimuth: 1.1 Elevation: 20 $cosec^2$	Azimuth: 1.6 Elevation: 20 on transmit; 2.3 to 6.0 on receive
Frequency shift for 1/2 BW elevation change			Frequency independent

Characteristics	Radar No. 4	Radar No. 5	Radar No. 6
1st side-lobe suppression (dB)	Azimuth: 25 Elevation: 25	18.5 (azimuth presumed)	Tx: 20 in vertical plane Rx: at least 35 in azimuth; at least 49 in elevation
Remote side-lobe suppression			Ultra-low sidelobes
Antenna azimuth scan type (degrees)	Continuous 360		
Antenna frame (revisit) time (s)	10		9.4 (6.4 rpm)
Antenna elevation scan (degrees)	–1 to 18	Not scanned. Tx beam spans 0°-20° elevation	
Formation of distinct elevation beams	Sequential Rx via single channel	20° Tx beam is subdivided into 6 Rx beams and processed simultaneously in 6 parallel channels	6 stacked Rx beams are processed simultaneously in 6 parallel channels
Rx RF bandwidth (MHz)	200	> 200 (uses image-reject mixer in each channel)	
Rx RF and IF saturation levels, referred to antenna port		–35 dBm	Dynamic ranges: 90 dB, using up to 46.5 dB of STC
Rx IF bandwidth	Normal and MTI: 350 kHz Coded-pulse: 1.3 MHz	1.6 MHz	1.1 MHz at 3 dB 3.4 MHz at 20 dB 12.1 MHz at 60 dB
Processing gain relative to noise	Normal/non-MTI: 3 dB (2-pulse video integration) Coded-pulse: 11 dB	10 dB (pulse compression) + 9 dB (pulse integration) = 19 dB	11 dB (pulse compression) 4-pulse MTI used
Desired-signal sensitivity or noise level (dBm) (referred to antenna port)	Normal mode: noise level: –116 Coded-pulse: noise level: –110	–105	
Interference-suppression features	2-pulse video integration Log FTC Coded-pulse (pulse-compression) mode Pulse-pulse correlation Stationary-target censor	Frequency agility Pulse compression Sidelobe blanking Staggered PRIs with postdetect integration Hard-limiting CFAR (without MTI) or STC (with MTI) Raw signal monitor channel	Extremely low receive antenna sidelobes Others similar to radar No. 5
Years in use	1975 – present	1975 – present	Late 1980s – present

(1) In most modes of radar No. 4, the interpulse interval, along with the peak power, decreases as the beam scans upward.

In the Tables 3 and 4, the following terms and abbreviations are used:

⇐⇒:	correspondence (between carrier frequency and elevation angle)
AGC:	automatic gain control
Burn-thru:	a mode in which power is concentrated in a narrow elevation sector to facilitate detection of targets under difficult conditions
BW:	bandwidth or beamwidth, depending on context
Chirp-thru:	a type of burn-thru mode in which pulse compression is used to reduce return from extended clutter
Coincident video:	coincident video (pulse-to-pulse correlation)
CSG:	clean strobe generation. This is a technique for observing signals from active sources using the radar only as a receiver. It can be used with or without sidelobe blanking applied
Dicke fix:	hard limiting of composite received signal (radar return plus interference) in a bandwidth substantially wider than that of the desired radar signal followed by filtering to a narrow bandwidth. This discriminates against wideband interference
f_{co}:	cut-off frequency of filter
FTC:	fast time constant
INT:	non-coherent (video) multiple-pulse integration
Jam strobe:	similar to CSG
PRI:	pulse-repetition interval
PRF:	pulse-repetition frequency
PW:	pulse width
STC:	sensitivity time control
WPB:	wide-pulse blanking.

All references in Tables 3 and 4 to angles in degrees pertain to elevation angles unless otherwise specified.

4d. Aeronautical Radionavigation

Within DoD, all Services utilize radar systems operating in this band for the purpose of aeronautical radionavigation. These systems are highly mobile, effective all-around radar sets designed for simultaneous long-range search and height finding in a severe weather environment. The Air Force operates radars for air traffic control purposes in Kansas, Ohio, and Iowa. NASA also operates air surveillance radar in the 2900-3100 MHz band in Fairbanks, Alaska for range clearance in support of launch operations.

4e. Maritime Mobile

The Navy operates shipboard direction finding calibration systems transmitting from the coast in support of U.S. Navy ships approximately 20 kilometers off shore of Fort Story, Virginia. Testing includes validating new and upgraded systems, operational performance, testing during at sea trials, correcting deficiencies in ship combat systems, and providing electromagnetic data for engineering analysis. Ships turn in a circle while receiving signals from a shore transmitter facility using a directional antenna pointed out to sea. No transmissions are made from ships. On average, each signal is on the air for 0.85 seconds at 15 second intervals during a 20 minute period for total air time 68 seconds.

5. Planned Use

The 2900-3100 MHz maritime radionavigation radars are expected to continue operating for the foreseeable future.

The spectrum requirements for RACONs in the 2900-3100 MHz will continue for the foreseeable future. The use and corresponding spectrum requirements for Vessel Tracking Systems are expected to continue for the foreseeable future, especially as there are potential security threats from vessels of all sizes.[19]

The existing NEXRAD systems in the band will continue to operate for the foreseeable future. The Federal Government is installing two new radars at Evansville, Indiana and on the Washington Coast that will be part of the nationwide NEXRAD network.

The Federal agencies operate radar systems within the 2900-3100 MHz band for critical national security applications and safety-of-life systems. The spectrum requirements to support these systems will continue for the foreseeable future.

[19] *See*, *Maritime Security: Vessel Tracking Systems Provide Key Information, but the Need for Duplicate Data Should be Reviewed*, Government Accountability Office, GAO 09-337, March 2009, available at http://www.gao.gov/new.items/d09337.pdf (last visited July 27, 2009).