Broadband Spectrum Survey at San Diego, California

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NTIA Report 97-334

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Vincent S. Lawrence

report series

U.S. DEPARTMENT OF COMMERCE • National Telecommunications and Information Administration

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Mickey Kantor, Secretary

Larry Irving, Assistant Secretary
for Communications and Information

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PREFACE

A spectrum survey often depends upon significant efforts by personnel not directly involved in the measurements. We wish to thank the following people who made the spectrum survey at San Diego, California a success: Commander H. Hugo of the Naval Command, Control and Ocean Surveillance Center (NCCOSC), who granted us permission to use the Battery Ashburn area on Pt. Loma for the survey; T. DiMattio of the Cabrillo National Monument, who granted us access to Monument property; F. Kirtman of the NCCOSC spectrum management office, who provided us with information on individual transmitters on the Point; L. Kilgore of the Naval Research and Development (NRaD) security division, who made physical security arrangements at the site; and H. Grigsby of the San Diego Federal Communications Commission office for providing valuable background information on spectrum activities in the San Diego area.

Certain commercial equipment and software are identified in this report to adequately describe the measurements. In no case does such identification imply recommendation or endorsement by the National Telecommunications and Information Administration, nor does it imply that the equipment or software identified are necessarily the best available for the application.

This report, along with other ITS reports, is available on the World Wide Web through the ITS home page. The home page address is: http://ntia/home.html. The ITS online document page address is: http://ntia/pub/pubs.html.

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BROADBAND SPECTRUM SURVEY AT SAN DIEGO, CALIFORNIA

Frank H. Sanders, Bradley J. Ramsey, and Vincent S. Lawrence'

The National Telecommunications and Information Administration (NTIA) is responsible for managing the Federal Government's use of the radio spectrum. In discharging this responsibility, NTIA uses the Radio Spectrum Measurement System to collect data for spectrum utilization assessments. This report details such a data collection effort spanning all of the spectrum from 108 MHz to 19.7 GHz in the metropolitan area of San Diego, California during February and March of 1995.

Key words: land mobile radio (LMR); radar emission spectrum; radio frequency environment; Radio Spectrum Measurement System (RSMS); spectrum resource assessment; spectrum survey.

1. INTRODUCTION

1.1 Background

The National Telecommunications and Information Administration (NTIA) is responsible for managing the Federal Government's use of the radio spectrum. Part of this responsibility is to establish policies concerning spectrum assignment, allocation, and use; and to provide the various departments and agencies with guidance to ensure that their conduct of telecommunications activities is consistent with these policies [l, part 8.31. In discharging this responsibility, NTIA 1) assesses spectrum utilization, 2) identifies existing and/or potential compatibility problems among the telecommunication systems that belong to various departments and agencies, 3) provides recommendations for resolving any compatibility conflicts that may exist in the use of the frequency spectrum, and 4) recommends changes to promote spectrum efficiency and improve spectrum management procedures.

Since 1973, NTIA has been collecting data on Federal use of the radio frequency spectrum in support of the NTIA Spectrum Analysis Program. The Radio Spectrum Measurement System (RSMS) is used by NTIA to provide technical support for 1) Spectrum Resource Assessments (SRAs), 2) U.S. participation in the International Telecommunication Union (ITU) conferences and ITU Radiocommunication Sector (ITU-R) activities, 3) analysis of electromagnetic compatibility (EMC) problems, 4) interference resolution, and 5) systems review activity related to new Federal Government systems.

'The authors are with the Institute for Telecommunication Sciences, National Telecommunications and Information Administration, U.S. Department of Commerce, Boulder, CO 80303-3328.

1.2 Authority

The RSMS is under the administrative control of the Director of the Institute for Telecommunication Sciences (ITS). The Deputy Associate Administrator of the Office of Spectrum Management (OSM) is responsible for meeting the spectrum management requirements of NTIA, as transmitted to him by the Associate Administrator of OSM. RSMS measurement activities are authorized by the Deputy Associate Administrator of OSM in consultation with the Director of ITS. Federal agencies with spectrum management problems can request support of the RSMS through the Deputy Associate Administrator of OSM.

1.3 Purpose

Under Departmental Organizational Order 25-7, issued October 5, 1992 and amended December 3, 1993, the Office of Spectrum Management is responsible for identifying and conducting measurements necessary to provide NTIA and the various departments and agencies with information to ensure effective and efficient use of the spectrum. As part of this NTIA measurement program, spectrum occupancy measurements are conducted using the RSMS. The spectrum occupancy data presented in this report do not include identification of specific emitters. The measured data are provided for the spectrum management community to:

- enable a better understanding of how telecommunication systems use the allocated spectrum;

- provide timely information on variations in frequency-band usage, e.g., identify frequency bands becoming heavily used;

- support the NTIA system review process by providing information on the availability of spectrum for new systems; and

- assess the feasibility of promoting alternative types of services or systems that result in more effective and efficient use of the spectrum.

1.4 Extrapolation of Spectrum Occupancy Data

The spectrum survey measurements contained in this report cannot be solely used to assess the feasibility of using alternate services or systems in a band. Extrapolation of data in this report to general spectrum occupancy for alternative spectrum uses requires consideration of additional factors. These include spectrum management procedures, types of missions performed in the bands, and new spectrum requirements in the development and procurement stages. Also, measurement area, measurement site, and measurement system parameters should be considered.

The area chosen for a spectrum survey will affect measured spectrum occupancy. For example, measurements made in Denver, Colorado [2] are probably representative of many major metropolitan areas that do not have any maritime radionavigation or heavy military activity.

Other cities, such as San Diego, California, show higher levels of usage in bands that support such activities.

Choice of measurement site within an area can also affect measured spectrum occupancy. An area such as Seattle-Tacoma, Washington (rough terrain, heavy forestation, and widely dispersed transmitters) may require multiple measurement sites to adequately characterize usage.

Spectrum management procedures such as band allotments for functions and missions affect spectrum utilization. For example, channels used for taxi dispatch might show heavy use whereas channels allocated for law enforcement or public safety may show less use. Regardless of usage, dedicated channels for these safety-of-life functions remain a spectrum requirement. Special occurrences such as Olympic games, natural disasters, and Presidential inaugurations also create unique spectrum requirements.

Spectrum measurements provide data on expected signal levels and probability of occurrences that are essential for assessing alternate uses of the spectrum. Such information cannot be obtained from band allocation databases or an understanding of spectrum management procedures.

2. OVERVIEW OF BROADBAND SPECTRUM SURVEYS

2.1 Introduction

Procedures for conducting a broadband spectrum survey using the RSMS are outlined in this section. Site selection factors, significant measurement system parameters, and hardware and software configurations developed for the surveys are described. Detailed information on the system hardware (including the vehicle, instrumentation, antennas, and receiver front-end), measurement software, and other measurement capabilities are provided in Appendices A and B. Measurement system response to various types of signals is described in Appendix C. RSMS calibration theory and application are described in Appendix D.

2.2 Survey Site Selection

A successful spectrum survey (also called a site survey) requires careful selection of a measurement site. Maximum signal intercept probability and minimum logistic problems are the first considerations when locating a site for an RSMS spectrum survey.

The primary signal intercept factors are 1) maximum line-of-sight coverage to increase the probability of weak signal reception such as transmissions from mobile units; 2) limited numbers of nearby transmitters to prevent intermodulation or saturation problems that can arise even though preselection and/or filtering is used for survey measurements; and 3) limited man-made noise such as impulsive noise from automobile ignition systems and electrical machinery that can add to the received signals of interest and give misleading results.

The primary logistic factors are 1) commercial power to increase the probability of completing the spectrum survey (typically two weeks of 24-hr operation) without power interruptions; 2) commercial telephone for relatively inexpensive reliable communications, compared to the RSMS cellular telephone that could possibly contaminate the measurements when transmitting; and 3) security of personnel, vehicle, and electronic hardware.

The ideal site is a well-illuminated, fenced, and patrolled area that satisfies all of the primary site selection factors above and has reasonable access to lodging for the operating personnel.

2.3 Spectrum Survey Measurements

Spectrum surveys are normally conducted for two weeks using the RSMS in an automatic mode. The measurement system is preprogrammed to continuously run software algorithms tailored to the characteristics of the radio emitters that typically occupy measured frequency sub-bands. Two decades of making such measurements in cities across the United States suggest that general patterns of spectrum occupancy tend to be repeated from site to site. Emissions from the following sources are commonly observed during RSMS spectrum surveys:

- land-mobile, marine-mobile and air-mobile communication radios;
- terrestrial, marine and airborne radars, and airborne radio altimeters;
- radionavigation emitters, such as TACAN and VOR;
- cellular and trunked communication systems;
- broadcasting transmitters such as UHF and VHF television, and multipoint distribution systems (wireless cable TV);
- industrial, scientific and medical (ISM) sources, including vehicular tracking systems, welders, and microwave ovens; and
- common carrier (point-to-point) microwave signals.

Emissions that are not normally receivable during spectrum surveys are:

- satellite downlink emissions;
- galactic and solar noise;
- some types of spread spectrum signals; and
- radio transmitters that are turned off.

Although the last category is self-evident, questions exist regarding the extent to which users who have assignments in the radio spectrum either do not operate, or operate very rarely, with those assignments. Appendix C discusses factors related to probability of intercept and addresses matters of measurement time vs. statistical significance of data.

As mentioned above, there are many different types of radio signals within the measurement frequency range. Each is measured with a hardware configuration and measurement algorithm specifically selected to give the most useful description of the particular type of signal(s) expected in a frequency sub-band. The measurement system parameters specially configured for each signal type include: antennas, signal conditioning, tuning speed, measurement bandwidth, detector mode, and measurement repetitions. The RSMS measurement software automatically switches the measurement system to the proper configuration for each sub-band. The measurements are repeated in various sub-bands according to specifications established by consideration of signal intercept probability, signal variability, measurement significance, and expenditure of system resources.

For spectrum surveys, the RSMS normally performs measurements of general spectrum occupancy across a frequency range of 108 MHz to 19.7 GHz. To accomplish this task, measurements are conducted in an automatic mode with the RSMS configured as two measurement systems, identified as “System- 1" for frequency measurements below 1 GHz, and “System-2” for simultaneous measurements above 1 GHz.

The data acquisition (DA) measurement software provides instructions to configure each receiver system, execute measurement routines, record measured data, and maintain a real-time log of the measurements and key parameters. The measurement system configuration parameters used by the software are called “band events” and the automated band event execution procedures are called “band-event schedules.” Unattended operation of the measurement system for extended periods of time is made possible through this use of computer control. Remote control of the RSMS is also possible via a telephone modem linked to the computer. Standardized measurement schedules are used for each spectrum survey, with the measured data stored for post-measurement processing.

2.3.1 Survey Band Events

The spectrum measured by the RSMS is divided into selected frequency ranges (survey bands) that are measured according to a computer-stored list of measurement parameters and instrument settings called a band event. Each band event combines a measurement algorithm ("Swept/m3" for example) with a particular set of signal input ports, front-end configurations, spectrum analyzer (SA) modes and settings, and data-recording options. Band-event parameters and options are detailed in Appendix B. The factors considered when selecting frequency sub-bands, receiver algorithms, and other parameters for the band events are discussed in Appendix C. Spectrum survey “standard” band-event parameters for System-l and System-2 are shown in Tables 1 and 2, respectively.

Table 1. Spectrum Survey Band Events for RSMS System-l

Standard Events		DA Receiver Parameters						DA Spectrum Analyzer Parameters*						Antenna”	
Event Number	Freq. Band (MHz)	Algor-ithm	Start (MHz)	End (MHz)	scans (#of)	sweeps (# of)	Steps (#of)	IFBW (kHz)	Detector Type	VBW (kHz)	RL (dBm)	M H N A (#swps)	Swp/stp (sec)	Type	Gain (dBi)
10,ll***	108-162	sw/m3	104	164	6	100	1	10	sample	10	-20	1	0.3	LPA	5.5
12	162-174	sw/m3	160	180	2	500	1	10	sample	10	-20	1	0.3	LPA	5.5
13	174-216	sw/m3	170	220	1	500	1	100	sample	100	-10	1	0.02	LPA	5.8
14	216-225	sw/m3	216	225	3	60	1	3	sample	3	-30	1	0.9	LPA	5.8
15	225-400	sw/m3	22s	405	6	100	1	30	sample	30	-10	1	0.09	LPA	5.9
16	400-406	swim3	400	406	2	60	1	3	sample	3	-10	1	0.9	LPA	6.0
17	406-420	sw/m3	400	420	2	200	1	10	sample	10	-20	1	0.9	LPA	6.0
18	420-450	stepped	420	450	1	1	30	1000	+peak	3000	-10	1	12	LPA	6.0
19	450-470	sw/m3	450	470	2	200	1	10	sample	10	-20	1	0.9	LPA	6.1
9,20***	470-512	sw/m3	470	520	5	100	1	10	sample	10	-20	1	0.9	LPA	6.1
21	512-806	sw/m3	512	812	3	200	1	100	sample	100	-10	1	0.02	LPA	6.2
22	806-902	sw/m3	806	906	10	60	1	10	sample	10	-20	1	0.3	LPA	6.2
23	902-928	swept	900	930	3	1	1	10	MXMH	10	-10	600	0.3	LPA	6.1
24	902-928	stepped	900	930	1	1	30	1000	+peak	3000	-10	1	12	LPA	6.1
25	928-960	sw/m3	920	960	4	300	1	10	sample	10	-20	1	0.3	LPA	6.1

* For spectrum surveys, attenuation is set to 0 (default), display to 10 dB/div, and the spectrum analyzer in use must measure at least 1000 points per scan.

** For the San Diego survey, all System-l events were measured with a 100 MHz to 1 GHz log periodic antenna (LPA) mounted at a 45” angle for slant polarization (see Section A.4 of Appendix A).

*** In portions of the 108-162 MHz and 470-512 MHz bands, it was necessary to use attenuation to prevent front-end overload. This was accomplished by creating new band events (9 and 10) for the portions requiring attenuation. Thirty dB of attenuation was used for event 9, across 470-490 MHz, and 40 dB attenuation was used for event 10, across 104-114 MHz.

Table 2. Spectrum Survey Band Events for RSMS System-2

Standard Events		DA Receiver Parameters						DA Spectrum Analyzer Parameters*						Antenna**	
Event Number	Freq. Band (MHz)	Algor-ithm	start (MHz)	End (MHz)	scans (#of)	sweeps (# of)	Steps (#of)	IFBW (kHz)	Detector Type	VBW (kHz)	RL (dBm)	MH/VA (#swps)	Swp/stp (sec)	Type	Gain (dBi)
05	960-1215	sw/m3	950	1250	1	500	1	300	+peak	3000	-10	1	0.02	omni	2.1
06	1215-1400	stepped	1200	1400	1	1	200	1000	+peak	3000	-10	1	12	omni	2.2
07	1350-1400	sw/m3	1350	1400	5	100	1	10	sample	10	-20	1	0.3	omni	2.2
08	1400-1530	sw/m3	1400	1550	5	200	1	30	sample	30	-10	1	0.09	omni	2.2
09	1530-1710	sw/m3	1530	1710	6	500	1	30	sample	30	-10	1	0.09	omni	2.2
10	1710-2300	swept	1700	2300	6	1	1	100	MXMH	100	-10	600	0.1	dish	17.5
11	2300-2500	swept	2300	2500	2	1	1	100	MXMH	100	-10	600	0.1		2.5
12	2500-2700	swept	2500	2700	2	1	1	100	MXMH	100	-10	600	0.1	dish	19.8
13	2700-2900	stepped	2700	2900	1	1	200	1000	+peak	3000	-10	1	5+	omni	2.8
14	2900-3 100	stepped	2900	3100	1	1	200	1000	+peak	3000	-10	1	12	omni	2.8
1s	3 100-3700	stepped	3100	3700	1	1	200	3000	+peak	3000	-10	1	12	omni	3.0
16	3700-4200	swept	3700	4200	5	1	1	100	MXMH	100	-10	600	0.1	dish	23.5
17	42004400	sw/m3	4200	4400	1	500	1	300	+peak	3000	-10	1	0.02	ornni	3.0
18	4400-5000	swept	4400	5000	6	1	1	100	MXMH	100	-10	600	0.1	dish	25
19	5000-5250	sw/m3	5000	5300	1	500	1	300	+peak	3000	-10	1	0.02	omni	3.1
20	5250-5925	stepped	5250	5950	1	1	240”	3000	+peak	3000	-10	1	12	omni	3.1
21	5925-7 125	swept	5926	7125	4	1	1	300	MXMH	1000	-10	600	0.1	dish	28

Table 2. Spectrum Survey Band Events for RSMS System-2 (Continued)

Standard Events		DA Receiver Parameters						DA Spectrum Analyzer Parameters*						Antenna**	
Event Number	Freq. Band (MHz)	Algor-ithm	start (MHz)	End (MHz)	scans (#of)	sweeps (# of)	Steps (# of)	IFBW (kHz)	Detector Type	VBW (kHz)	RL (dBm)	MH/VA (#swps)	Swp/stp (sec)	Type	Gain (dBi)
22	7125-8500	swept	7100	8600	5	1	1	300	MXMH	1000	-10	600	0.1	dish	30
23	8500-10550	stepped	8500	10600	1	1	720++	3000	+peak	3000	-10	1	4	omni	3.1
24	10550-13250	swept	10550	13250	1	1	1	3000	MXMH	3000	-10	600	0.1	dish	33
2s	13250-14200	stepped	13250	14250	1	1	340"	3000	+peak	3000	-10	1	4	omni	2.8
26	14200-15700	swept	14200	15700	1	1	1	3000	MXMH	3000	-10	600	0.1	**dish**	**35**
27	15700- 17700	stepped	15700	17700	1	1	700++	3000	+peak	3000	-10	1	4	**omni**	**2.7**
28	17700-19700	swept	17700	19700	1	1	1	3000	MXMH	3000	-10	600	0.1	**dish**	**37**

* For spectrum surveys, attenuation is set to 0 (default), display to 10 dB/div, and the spectrum analyzer in use must measure at least 1000 points per scan.

** A parabolic (dish) antenna is used for azimuth scanning (i.e., "rotating dish" measurements only). See Sections A.4 and B.2 of Appendices A and B, respectively for descriptions of the antennas and the swept/azimuth-scanning algorithm used with the dish antenna.

\+ An increased step time (dwell) may be used to characterize stow rotation-emitters (e.g., weather radars) if they are contributing a significant part of the measured occupancy.

++ The number of steps given is the minimum necessary to ensure full coverage in the measurement bandwidth selected for this event. Since this band has been well-characterized by previous RSMS measurements, fewer steps were used for the San Diego survey to save measurement time for higher priority band events.

Each row in the tables, beginning with an event number, shows the measurement parameters for a specific receiver configuration in the RSMS. Instruction to run the event can come from an operator or from a computer-loaded band-event schedule as explained in Section 2.3.2. The DA software, when instructed, sends the command parameters for an event to the system hardware and initiates measurements for the event. The tables (Table 1 and Table 2) are subdivided into four parts: 1) "Standard Events" identifies the event number and exact frequency range of interest, 2) "DA Receiver Parameters" shows input values for receiver configuration subroutines, 3) "DA Spectrum Analyzer Parameters" lists configuration command values sent to the spectrum analyzer, and 4) "Antenna" identifies the type and gain of the antenna selected for the event. Appendix B describes DA software configuration routines and the associated table parameters found in 2) and 3) above.

2.3.2 Band-Event Schedules

Using RSMS measurement control software, any band event can be executed by an operator at any time. For spectrum surveys, many band events are used to span several gigahertz of spectrum and each event requires a different amount of time to execute. DA software also includes an automated band-event execution mode where any of the band events may be programmed (scheduled) to execute in any sequence for any amount of time (within hardware limits on continuous operation of the measurement system).

There are two types of schedules used for spectrum surveys with the RSMS: a standard band-event schedule of all the survey bands, or a special band-event schedule for a few selected survey bands. For example, if a survey was conducted in a port city, a special schedule might include only survey bands with assignments for maritime communications (this was not, however, done in San Diego). Any number of special schedules can be run during a survey.

Tables 3 and 4 show the standard band-event schedules for RSMS System-l and System-2, respectively. Tables 5 and 6 show special band-event schedules for measurements in survey bands expected to show altered usage during adverse weather. The tables include: 1) schedule number;2 2) band-event number (specifies which band event to "run" in the schedule); 3) priority number (value assigned to the band-event data, with (1) being the highest priority); 4) event time (approximate time in minutes needed to run the event); and 5) accumulative time (approximate time in hours that the sequence has run).

Band-event priority is an important consideration when scheduling standard band events; i.e., some frequency bands in a spectrum survey are of more interest to spectrum managers than others. In fact, an important part of the preparation for a spectrum survey is a review of local frequency assignments and allocations. From this preliminary information, measurement parameters may be modified and band-event priority numbers (1, 2, or 3, with 1 being highest priority) adjusted to optimize survey data.

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*This is a sequence number used by the scheduling subroutine. Only 64 band events may be sequenced, but there is no limit on how many times the sequence runs during a survey.

Table 3. Standard Band-Event Schedule for RSMS System-1

Schedule Number	Band Event Number	Priority Number	Event Time (minutes)	Accumulative Time (hour)
1	12	1	16.3	0.27
2	10	2	1.7	0.30
3	11	2	8.6	0.44
4	17	1	10.8	0.62
5	14	2	5.1	0.71
6	13	3	5.8	0.81
7	19	1	10.8	0.99
8	22	2	10.8	1.17
9	9	1	5.5	1.26
10	20	1	8.3	1.40
11	23	2	5.3	1.48
12	25	1	20.0	1.82
13	18	2	6.7	1.93
14	12	1	16.3	2.20
15	16	3	3.4	2.26
16	17	1	10.8	2.44
17	24	2	6.7	2.55
18	19	1	10.8	2.73
19	10	2	1.7	2.76
20	11	2	8.6	2.90
21	9	1	5.5	2.99
22	20	1	8.3	3.13
23	14	2	5.1	3.22
24	25	1	20.0	3.55
25	21	3	7.3	3.67
26	12	1	16.3	3.94
27	22	2	10.8	4.12
28	17	1	10.8	4.30
29	23	2	5.3	4.39
30	15	3	8.3	4.53
31	19	1	10.8	4.71
32	18	2	6.7	4.82
33	9	1	5.5	4.91
34	20	1	8.3	5.05
35	24	2	6.7	5.16
36	25	1	20.0	5.50

Table 4. Standard Band-Event Schedule for RSMS System-2

Schedule Number	Band Event Number	Priority Number	Event Time (minutes)	Accumulative Time (hours)
1	05	3	5.6	0.09
2	06	3	42.0	0.79
3	07	2	8.6	0.94
4	08	2	12.7	1.15
5	09	1	37.2	1.77
6	11	3	3.0	1.82
7	13	3	18.0	2.12
8	14	2	42.0	2.82
9	15	2	42.0	3.52
10	17	3	5.6	3.61
11	19	3	5.6	3.71
12	20	2	49.0	4.52
13	23	2	49.0	5.34
14	25	1	25.0	5.76
15	27	1	52.0	6.62
16	05	3	5.6	6.72
17	09	1	37.2	7.34
18	17	3	5.6	7.43
19	19	3	5.6	7.52
20	25	1	25.0	7.94
21	27	1	52.0	8.81
22	05	3	5.6	8.90
23	07	2	8.6	9.04
24	08	2	12.7	9.25
25	09	1	37.2	9.87
26	11	3	3.0	9.92
27	14	2	42.0	10.62
28	15	2	42.0	11.32
29	17	3	5.6	11.42
30	19	3	5.6	11.51

Table 5. Adverse Weather Band-Event Schedule for RSMS System-l

Schedule Number	Band Event Number	Priority Number	Event Time (minutes)	Accumulative Time (hours)
1	12	1	16.3	0.27
2	11	2	10.3	0.44
3	12	1	16.3	0.72
4	14	2	5.1	0.80

Table 6. Adverse Weather Band-Event Schedule for RSMS System-2

Schedule Number	Band Event Number	Priority Number	Event Time (minutes)	Accumulative Time (hours)
1	09	1	37.2	0.62
2	23	2	49.0	1.44
3	05	3	5.6	1.53
4	17	3	5.6	1.62
5	20	2	49.0	2.44
6	14	2	42.0	3.14
7	13	3	18.0	3.44

Highly dynamic bands (where occupancy changes rapidly) include those used by mobile radios (land, marine, and airborne) and airborne radars. These bands are assigned a high priority and measured often during a spectrum survey in order to maximize opportunities for signal detection. Bands that are not very dynamic in their occupancy (such as those occupied by commercial radio and television signals or fixed emitters such as air traffic control radars) need not be observed as often, because the same basic occupancy picture will be generated every time. Such bands are given a low priority and less measurement time. An extreme case is that of the common carrier bands, which are essentially nondynamic. Generally, these are only measured once during a survey and are not included in the band-event schedules.

The standard band-event schedules are usually arranged to execute priority 1 events three times more often than priority 3 events. However, some adjustment to this arrangement may be necessary to accommodate total time required to complete the sequenced band-event schedule. For example, if less than two weeks of measurement time were available, a time-consuming priority 1 event (such as Band Event 27; 15.7-17.7 GHz) might not be run three times as often as priority 3 events to ensure that all bands would be measured.

Because of the many land mobile radio (LMR) bands below 1 GHz, System- 1 scheduling reflects some preplanning for time-of-day analysis. The sequenced schedule is prepared so that all events will be run within an 8-hr period; such that, after a few days of 24-hr data collection certain LMR bands will be measured at least once during each hour.

3. SAN DIEGO SPECTRUM SURVEY

3.1 Introduction

This section 1) describes the measurement site selected for a spectrum survey in the San Diego, California area; 2) briefly describes the data processing used to characterize spectrum occupancy across the 108-MHz to 19.7-GHz frequency range; and 3) presents the measured data.

3.2 Measurement Site Description

The RSMS was parked on Point Loma, west of Catalina Drive, about 40 m southwest of the Cabrillo National Monument upper maintenance building and directly above Battery Ashbum. The location was about 9.5 km (6 mi) west-by-southwest of downtown San Diego, on property owned by the U.S. Navy. The site coordinates were 117°14'38.2" W, 32°40' 39.8" N. Base altitude was 116 m MSL. The only structure at the site that was higher than the RSMS antennas was a mast (made of metal and approximately 2 ft in diameter) about 15 m high and about 80 m from the RSMS.

The site was well removed from fixed RF transmitters and man-made noise sources such as vehicular traffic. Mobile communications originating on Point Loma were primarily associated with the Cabrillo Monument maintenance staff, the Navy Public Works Center, and security patrols. Figure 1 shows the location of the RSMS in the San Diego area. Figure 2 shows areas that were line-of-sight (white) to the RSMS from 2 m above ground (typical mobile antenna height) and those areas that were obstructed (shaded with plus (+) signs) from the RSMS due to terrain. Figure 3 shows the RSMS deployed at Point Loma.

The San Diego metropolitan area occupies a low coastal zone that is bounded by high mountains to the east, and rough but lower terrain to the north. It adjoins the city of Tijuana, Mexico on the southern side of the U.S./Mexico border. Prominent physical features in the area include Mission Bay, San Diego Bay, and a large peninsula, named North Island, forming one side of San Diego Bay. North Island and the bays support extensive naval, commercial shipping, and aviation activities that contribute to spectrum usage. (For example, America's Cup qualifying races were being held near Point Loma; during one race, a rescue operation requiring radio communications occurred). Urban development in the area is extensive. Figure 2 shows that the RSMS survey location on Pt. Loma afforded mostly unbroken line-of-sight coverage of the San Diego metropolitan area. Line-of-sight coverage over the ocean extended to a radius of about 40 km (24 mi) from the RSMS location on the Point.

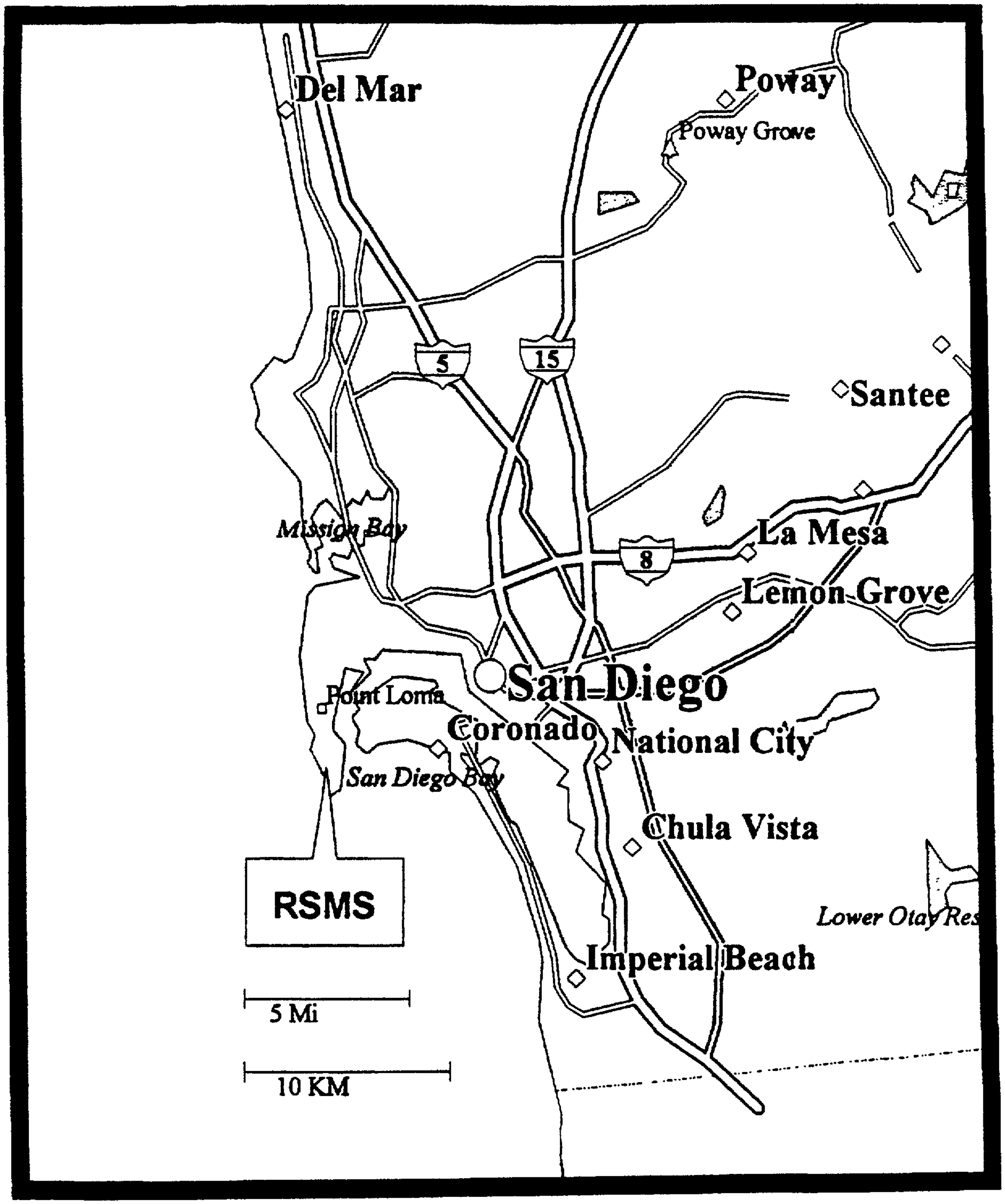

Figure 1. Area map of San Diego, California showing the location of the RSMS on Point Loma. Map produced with MapExpert™ software from DeLorme Mapping.

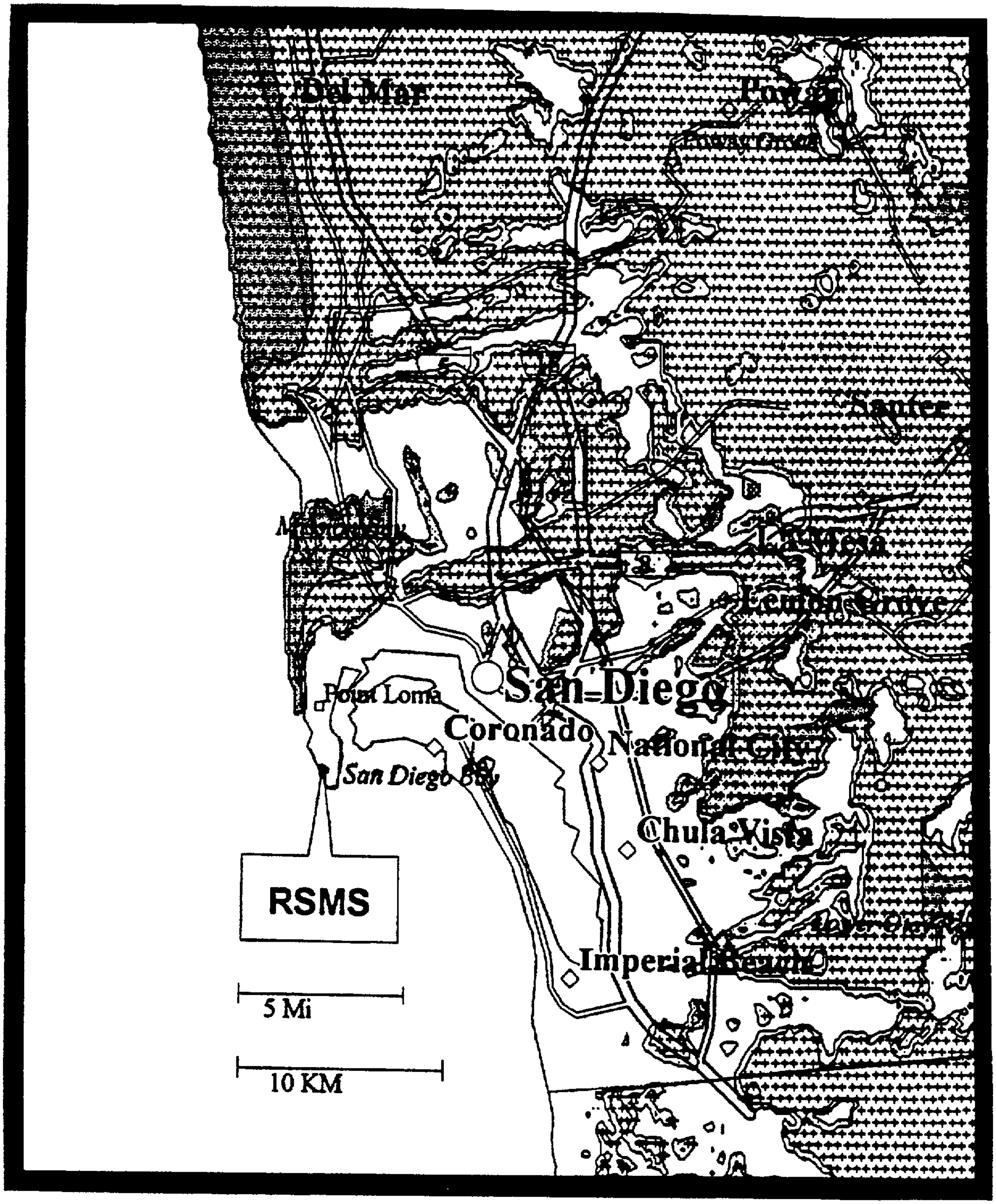

Figure 2. Area map of San Diego, California showing regions that are line-of-sight (white) and nonline-of-sight (terrain shadowed) from the RSMS raised antennas. Terrain shadowing overlay provided by ITS Telecommunications Analysis Services.

Figure 3. ITS Radio Spectrum Measurement System at Point L San Diego, California.

Also shown in Figure 2, RSMS coverage included much of the Tijuana area. Most spectrum usage in Tijuana is thought to occur below 1 GHz. The RSMS measurements in this frequency range were performed with a 6-dBi gain log periodic antenna pointed toward downtown San Diego, thus enhancing RSMS reception of San Diego-area signals relative to signals from Tijuana. However, the spectrum occupancy data from San Diego undoubtedly (and unavoidably) also contain some Tijuana usage, particularly below 1 GHz.

3.3 Data Considerations

The San Diego survey was performed as outlined in Section 2. The band-event tables (Table 1 for System-l and Table 2 for System-2) in Section 2.3.1 list the measurement system parameters used for each survey band. Appendix C contains explanations of the measurement algorithm selections. All survey bands for System-l were measured with a l00-MHz to I-GHz log periodic antenna (LPA) mounted at a 45” angle (for slant polarization) on the small mast and aimed toward downtown San Diego. The System-2 survey bands (except for azimuth-scanning bands[3]) were measured with a 500-MHz to 18-GHz slant polarized biconical omni antenna mounted on the large mast. For the azimuth-scanning survey bands (event numbers 10, 12, 16, 18, 21, 22, 24, 26, and 28) a rotating l-m Tecom dish (dual horizontal/vertical feed) antenna was used. See Appendix A for more on antennas and RF front-end hardware configurations.

All of the measured data, except the azimuth-scanning measurements previously mentioned, underwent an additional cumulative processing (cuming) step before being displayed. Every frequency data point recorded for Swept/m3 measurements was cumulated (cumed) such that the graphed data points (received signal levels; RSLs) show the maximum of maximum RSLs, mean of mean RSLs, and minimum of minimum RSLs (see Section C.3.1 of Appendix C for a discussion of Swept/m3 cumulative processing). Cuming of Stepped and Swept measurements results in graphs showing maximum, mean, and minimum RSLs of all scans. On all graphs of cumed data, maximum and minimum curves are drawn with solid lines and mean curves with dashed lines.

The data collection rate for the San Diego survey was increased by decreasing the number of steps used to measure some survey bands (specifically, band events 20, 23, 25, and 27). This change was made to assess the trade-off between reduced steps and accelerated measurement rate. The reduced-step results are comparable to those of RSMS surveys performed in these bands during the last twenty years.

Strong received signal levels from FM radio broadcast stations below 108 MHz generated intermodulation products in the normally configured RSMS front-end. To eliminate such responses, 40 dB of attenuation was inserted at the RF front-end for measurements below 114 MHz. This desensitized the RSMS measurements by 40 dB at these frequencies.

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[3]The azimuth-scanning measurement routine is a special operator-interactive technique using a rotating dish antenna with the DA Swept measurement algorithm. See Sections B.2 and C.8 in Appendices B and C for more about scanning.

Consequently, the possibility of receiving measurable signals in this range (such as instrument-landing system glideslope transmissions) was greatly reduced. However, a signal at 109.8 MHz was still detected. Similarly, commercial television broadcast signals forced the addition of 20 dB attenuation in the 174-216 MHz range and 30 dB additional attenuation in the 470-490 MHz range.

3.4 Measured Data

Each survey band of measured data is graphically displayed on a single page along with corresponding frequency allocations and assignment information (Figures 4-43). Each survey-band figure has an identical format. The principal band-event parameters and measurement location are included in the figure caption. The survey-band graphs in the middle of the page show frequency in megahertz on the x-axis vs. received signal level marked at 5-dBm increments on the y-axis. Noise level tick marks on the y-axis of some graphs (e.g., "avg sample noise" and "min sample noise" on Figure 4) show measurement noise limits. Measurement system noise and system response to various types of signals are described in Appendix C.

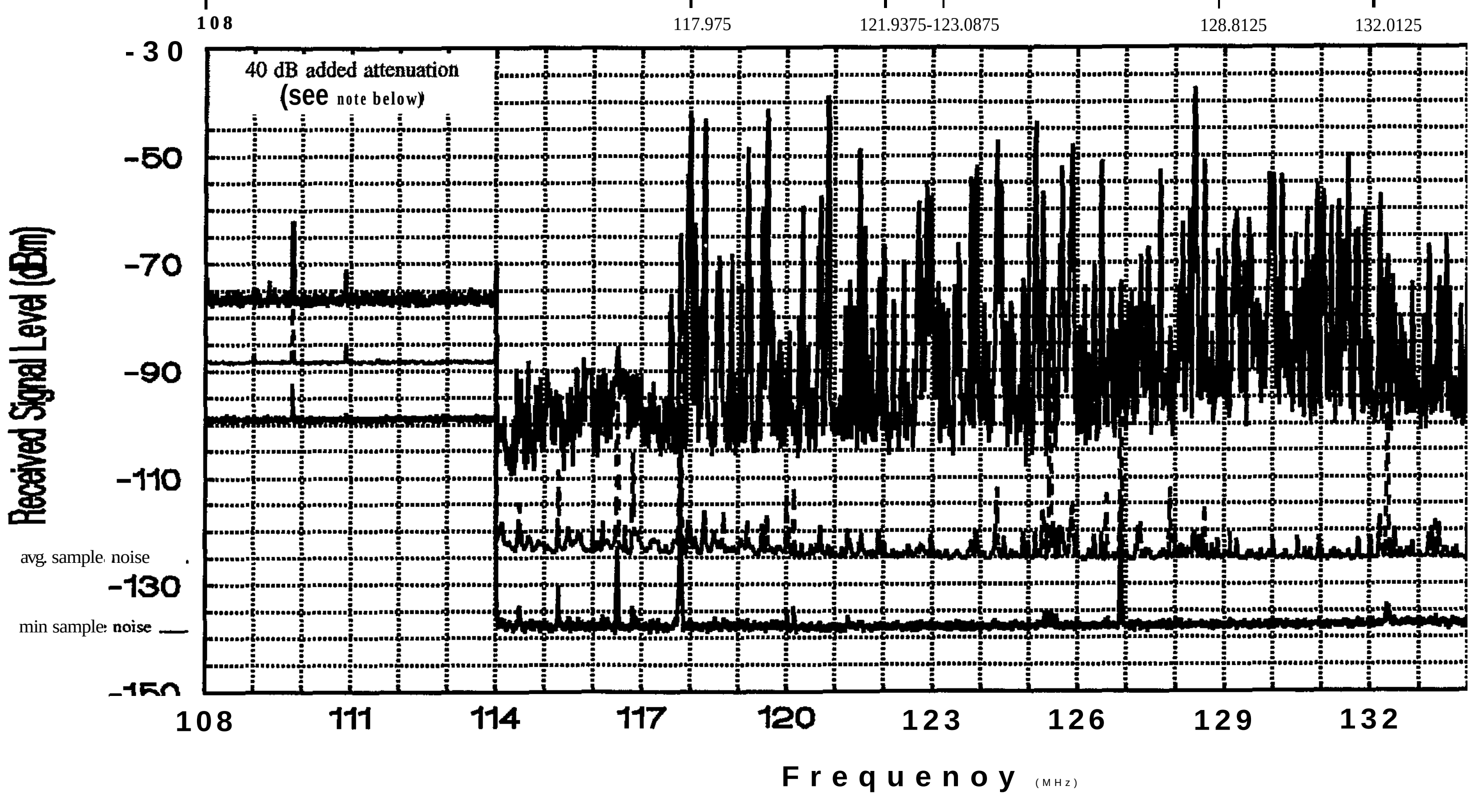
The text above each graph (delimited by horizontal and vertical lines) shows the applicable U.S. Government and non-Government frequency allocations and corresponding typical user information (general utilization) for the survey band. The vertical lines delimit, by frequency, both the allocations and the measured survey-band graph on the same page.

The frequency allocations (services) are entered according to convention just as they appear in the "U.S. Government Table of Frequency Allocations" [1, part 4.1.3]. Briefly summarized: the names of primary services are printed in capital letters; secondary services are printed in normal upper and lower case; and where the allocated service is followed by a function in parenthesis, the allocation is limited to the function shown,

The vertical lines are placed according to frequency separations in the allocation tables. The frequencies are written at the lower end of the vertical lines and are always in megahertz. Any service entry that does not fit within the line-delimited space above the graph is given a number referencing the complete allocation text below the graph on the same page. If there is additional information pertinent to a specific Government or non-Government allocation, it is indicated by a number referencing a note below the graph. General utilization, i.e., typical assignment usage notes (for the Government or non-Government allocations that fall between the same vertical line delimiters) also have a reference number if insufficient space is available. All notes are written in simple text format distinguishable from the allocated service entries that are entered according to convention as explained above.

It should be noted that the appearance of survey-band graphs is substantially affected by the measurement parameters and the analysis techniques employed. For example, data in Figures 5 and 6 were measured with similar techniques; but, Figure 5 appears to show a denser signal population than Figure 6. Closer examination shows that Figure 5 covers twice the frequency range of Figure 6 and this may be a primary reason for the apparently denser signal environment of Figure 5. Similarly, various band events may be plotted with different amplitude scales or

GOVERNMENT ALLOCATIONS:	AERONAUTICAL RADIONAVIGATION.	AERONAUTICAL MOBILE.		AERONAUTICAL MOBILE.		AERONAUTICAL MOBILE.
NON-GOVERNMENT ALLOCATIONS:	AERONAUTICAL RADIONAVIGATION.	AERONAUTICAL MOBILE.	1.	AERONAUTICAL MOBILE.	3.	AERONAUTICAL 3. 4. MOBILE.
GENERAL UTILIZATION:	VHF Omnidirectrional Range. (VOR).	Air Traffic Control.	1.	Aii Traffic Control (ATC). 2.		Aii Traffic



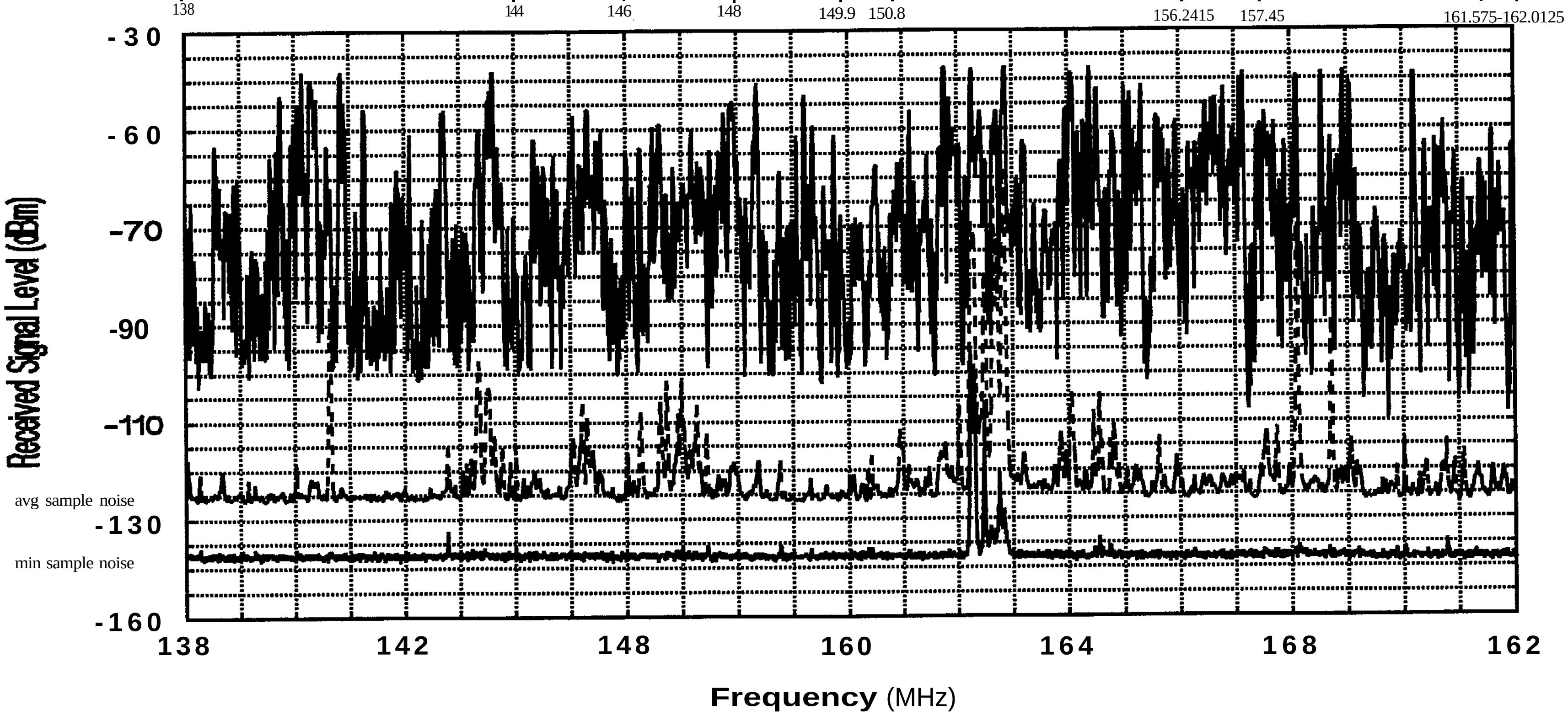
Note: Concerning 108-114 MHz attenuated data, see comments in Table 7 (Section 3.5.1)

1. AERONAUTICAL MOBILE. Private aircraft.
2. 123.1 MHz SAR (search and rescue) operations.
3. AERONAUTICAL MOBILE.
4. SPACE OPERATION space-to-Earth METEOROLOGICAL-STA1 RESEARCH (space-to-Earth)137-137.025 MHz and 137.175-137.825 MHz: MOBILE-SATELLITE, 137.025-137.175 MHz and 137.825-138. Mobile-Satellite.
5. Government use includes TIROS downlinks; non-Government includes nongeostationary satellite systems (Little LEOS).

Figure 4. NTIA spectrum survey graph summarizing 7,000 sweeps across the 108-138 MHz range (System-l, band event 11, swept/m3 algorithm, sample detector, 10-kHz bandwidth) at San Diego, CA, 1995.

	138–144	144–146	146–148	148–149.9	149.9–150.8	150.8–156.2415	156.2415–157.45	157.45–161.575	161.575–162.0125
GOVERNMENT ALLOCATIONS:	FIXED MOBILE.			FIXED, MOBILE, 3	5,6		8		
NON-GOVERNMENT ALLOCATIONS:		AMATEUR, 2.	AMATEUR.	3	5	LAND MOBILE.	8.	LAND MOBILE.	9.
GENERAL UTILIZATION:	Non-tactical military land mobile communications. 1.			4.	1	Land transportation, public safety, industrial, Earth telecommand, etc.		Land transportation, public safety, industrial, etc.	

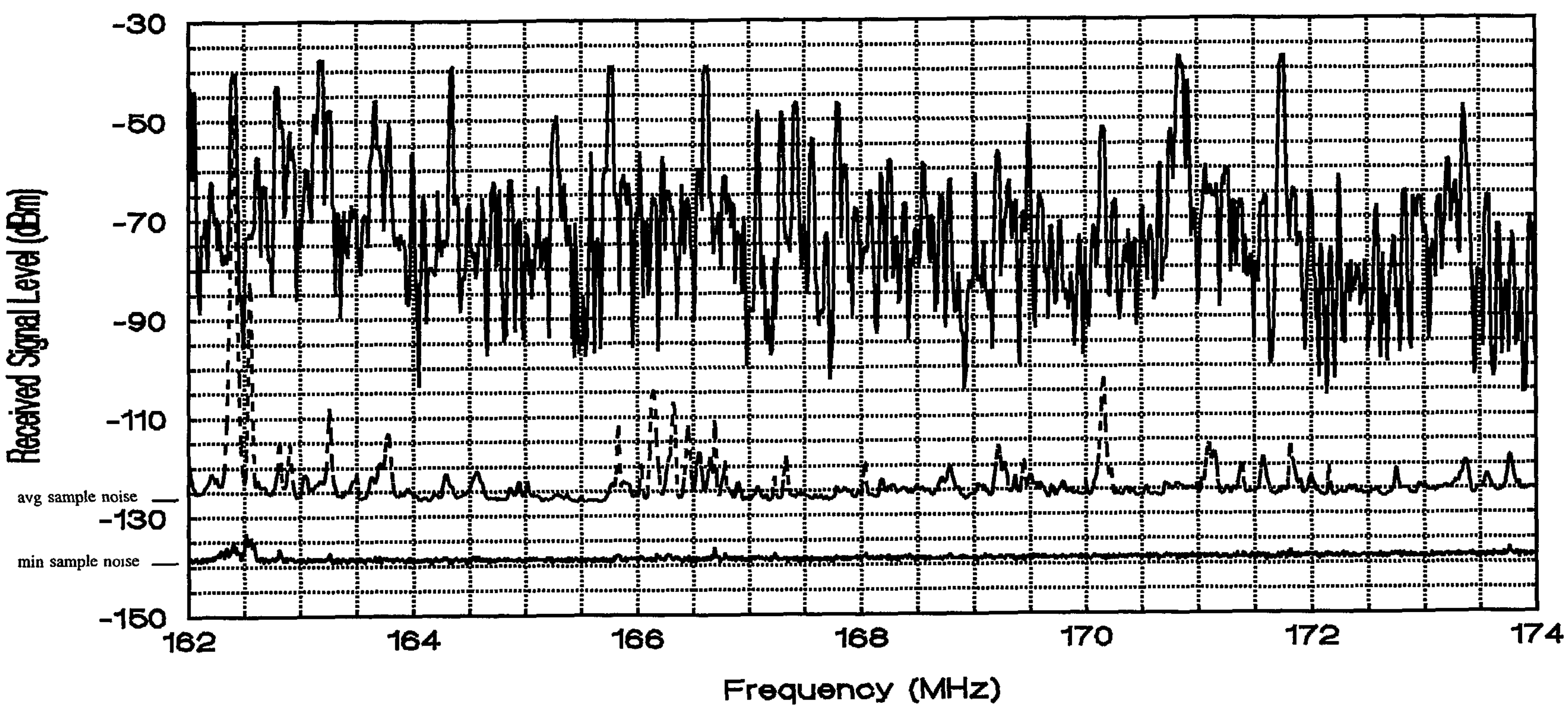
138 144 146 148 149.9 150.8 156.2415 157.45 161.575-162.0125



1. 143.75 MHz and 143.9 MHz: Civil Air Patrol.
2. AMATEUR-SATELLITE.
3. MOBILE-SATELLITE (Earth-to-space).
4. Non-tactical military land mobile communications 148.15 MHz Civil Air Patrol. Government use includes TIROS command links and NASA satellite operations Non-Government use includes nongeostationary nonvoice mobile satellite systems (Little LEOS)
5. 149.9-150 05 MHz RADIONAVIGATION-SATELLITE, MOBIL&SATELLITE (Earth-to space).
6. 150 OS-150 8 MHz FIXED, MOBILE.
7. Government use includes military non-tactical mobile and fixed communications and TRANSIT-SAT downlinks Non-Government use includes "Little LEOS."
8. MARITIME MOBILE 157 0375-157.1875 MHz: Govt only, VHF distress systems communications.
9. MARITIME MOBILE. 161.625-161 775 MHz, LAND MOBILE

Figure 5. NTIA spectrum survey graph summarizing 7,000 sweeps across the 138-162 MHz range (System-l, band event 11, swept/m3 algorithm, sample detector, l0-kHz bandwidth) at San Diego, CA, 1995.

GOVERNMENT ALLOCATIONS:	FIXED, MOBILE		3.
NON-GOVERNMENT ALLOCATIONS:		1	
GENERAL UTILIZATION:	Land Mobile Radio (LMR) including weather radio, public safety, and law enforcement.	2.	
	162.0125	173 2-173.4	174

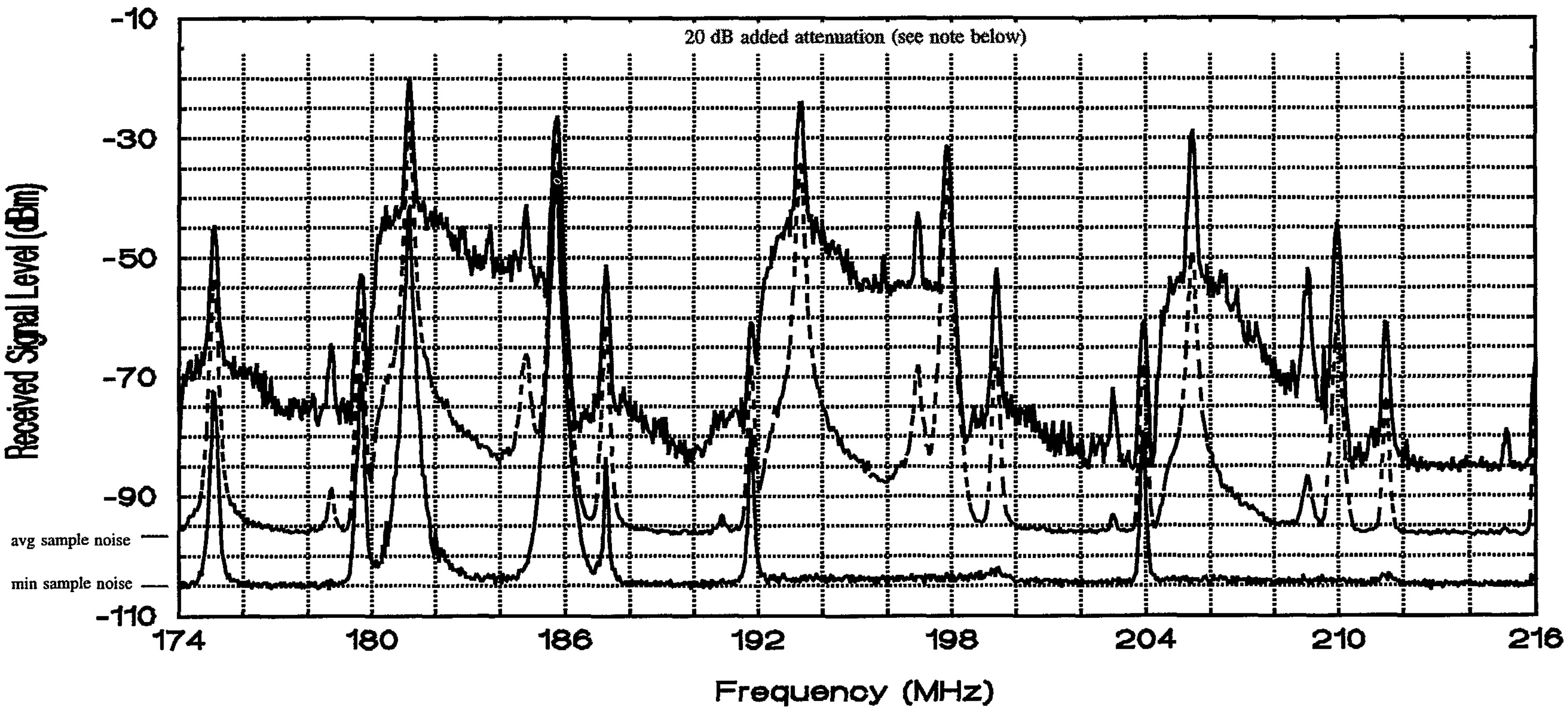


1. FIXED, Land Mobile.
2. Industrial, public safety
3 FIXED, MOBILE.

Figure 6. NTIA spectrum survey graph summarizing 52,500 sweeps across the 162-174 MHz range (System-1, Band Event 12, swept/m3 algorithm, sample detector, 10-kHz bandwidth) at San Diego, CA, 1995.

GOVERNMENT ALLOCATIONS:							
NON-GOVERNMENT ALLOCATIONS:	BROADCASTING (television broadcasting), 1, 2.						
GENERAL UTILIZATION:	Channel 7	Channel 8	Channel 9	Channel 10	Channel 11	Channel 12	Channel 13

174 180 186 192 198 204 210 216



Note: Concerning 174-216 MHz attenuated data, see comments in Table 7 (Section 3.5.1).

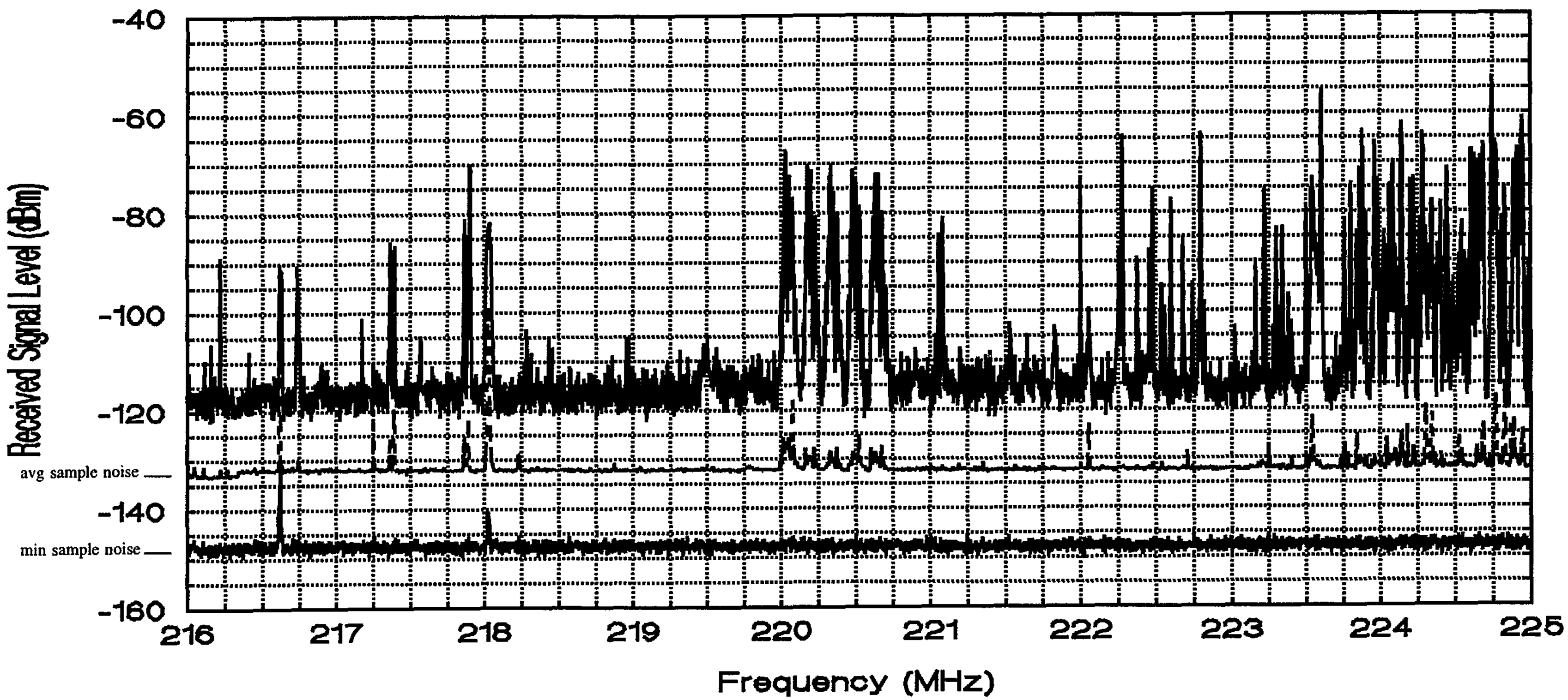
1. Subscription television services and limited wireless microphone operations are also permitted in this band.

2. TV broadcast licencees are permitted to use subcarriers on a secondary basis for both broadcast and non-broadcast purposes.

Figure 7. NTIA spectrum survey graph summarizing 18,500 sweeps across the 174-216 MHz range (System-1, band event 13, swept/m3 algorithm, sample detector, 100-kHz bandwidth) at San Diego, CA, 1995.

	216–220	220–222	222–225
GOVERNMENT ALLOCATIONS:	MARITIME MOBILE, Radiolocation, Fixed, Aeronautical Mobile, 1, 2	LAND MOBILE, Radiolocation, 1.	Radiolocation, 1
NON-GOVERNMENT ALLOCATIONS:	MARITIME MOBILE, Fixed, Radiolocation, Aeronautical Mobile, 2	LAND MOBILE.	AMATEUR.
GENERAL UTILIZATION:	Automated maritime telecommunications systems.	Trunked and conventional systems.	Amateur (1.25 meters)

216 220 222 225



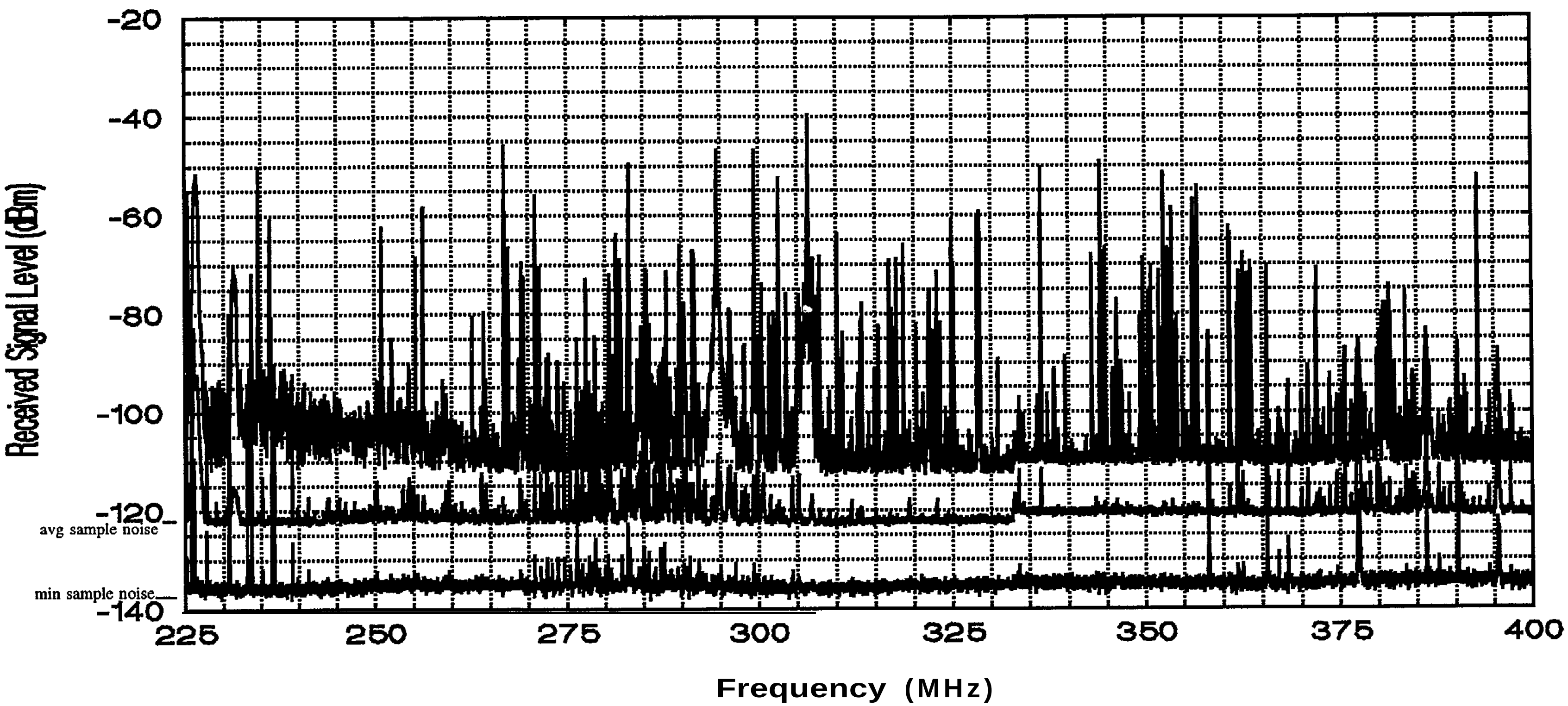
1 Radiolocation is limited to the military services.

2. Secondary services, other than radiolocation, are generally limited to telemetering and associated telecommand operations.

Figure 8. NTIA spectrum survey graph summarizing 4,020 sweeps across the 216-225 MHz range (System-1, band event 14, swept/m3 algorithm, sample detector, 3-kHz bandwidth) at San Diego, CA, 1995.

GOVERNMENT ALLOCATIONS:	FIXED, MOBILE, 1	2	FIXED, MOBILE, 3.	
NON-GOVERNMENT ALLOCATIONS,		2	3.	
GENERAL UTILIZATION:	Military tactical and training communications including air traffic control (ATC)	2.		

225 | 328.6-335.4 | 400 05



1 Government usage is limited to the military services; additionally, 235-322 MHz is allocated on a primary basis to the mobile-satellite service. 243 0 MHz may be used for search and rescue operations

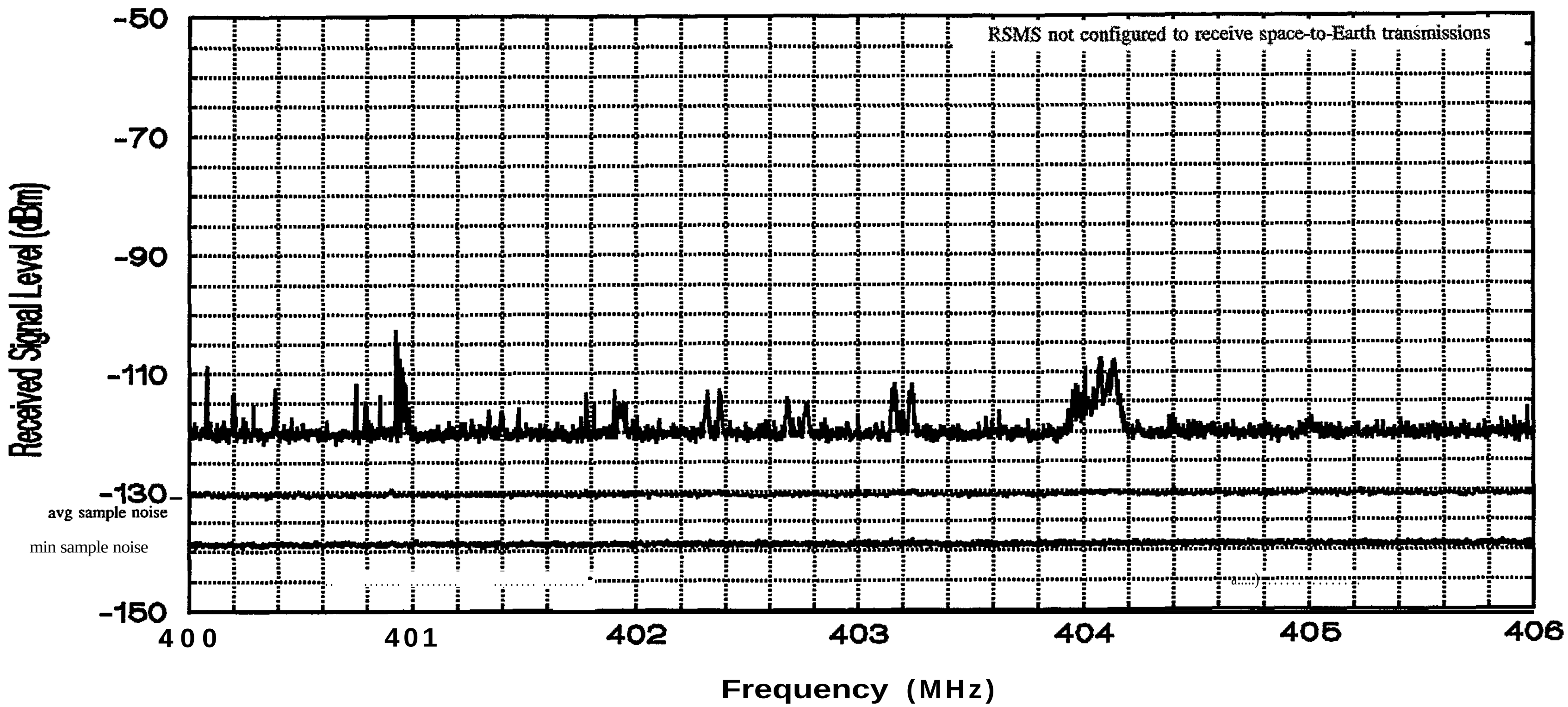
2 AERONAUTICAL RADIONAVIGATION, instrument landing systems (ILS) only.

3. 399.9-400.05 MHz: RADIONAVIGATION-SATELLITE, MOBILE-SATELLITE (Earth-to-space).

Figure 9. NTIA spectrum survey graph summarizing 2,900 sweeps across the 225-400 MHz range (System-l, band event 15, swept/m3 algorithm, sample detector, 30-kHz bandwidth) at San Diego, CA, 1995.

GOVERNMENT ALLOCATIONS:	1.	METEOROLOGICAL AIDS (Radiosonde), 2, 3,4 5.	
NON-GOVERNMENT ALLOCATIONS:	1.	METEOROLOGICAL AIDS (Radiosonde) 3,4, 5.	
GENERAL UTILIZATION:	1.	Meteorological raduisindes and satellite communication including GOES and TIROS-N	

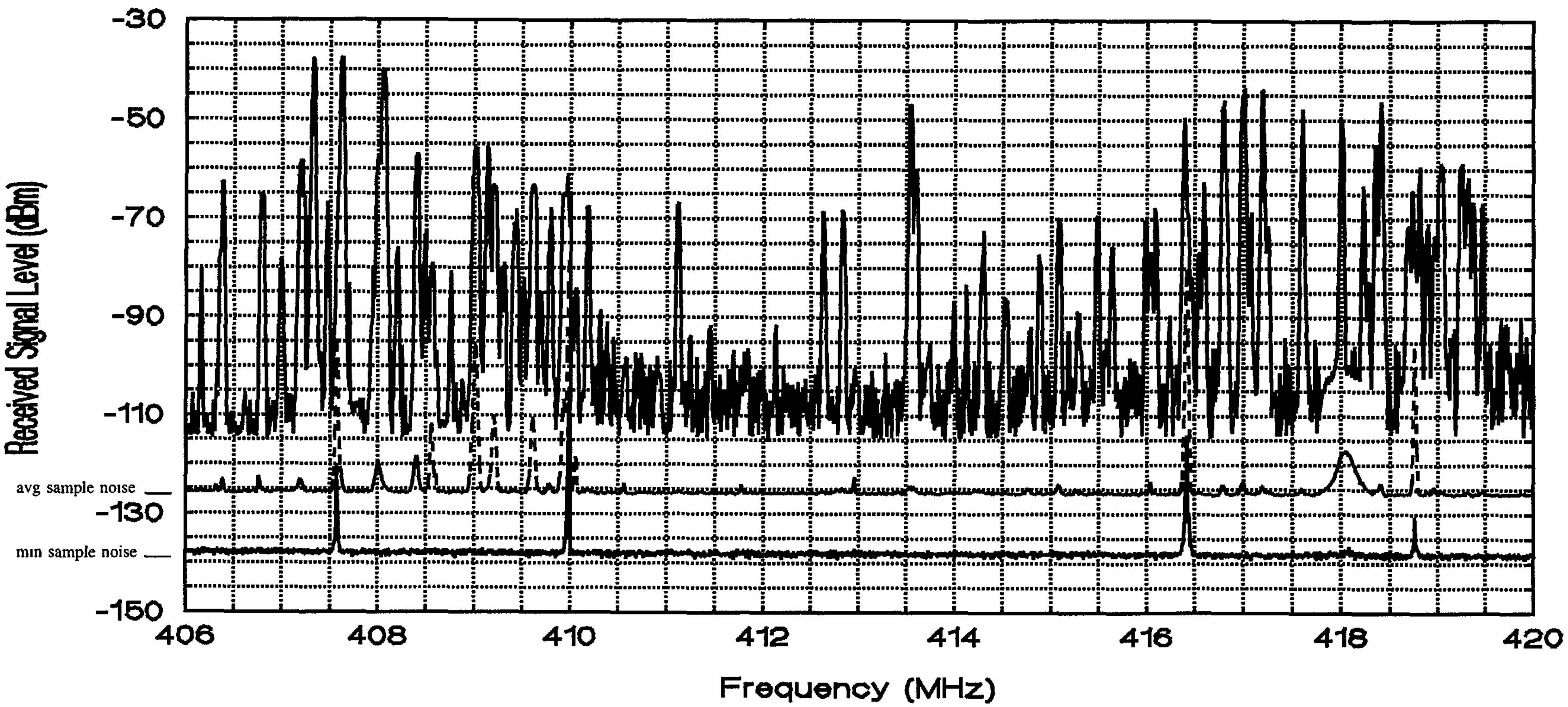
400.05-400.15 406



1. STANDARD FREQUENCY AND TIME SIGNAL-SATELLITE (400.1 MHz +/- kHz).
2. 400.15-401 MHz: METEOROLOGICAL-SATELLITE (space-to-Earth).
3. 400.15-401 MHz: SPACE RESEARCH (space-to-Earth), MOBILE-SATELLITE (space-to Earth). Space Operation (space-to-Earth)
4. 401-402 MHz: SPACE OPERATION (space-to-Earth), Earth Exploration-Satellite (Earth-to-space), Meteorological-Satellite. (Earth-to-space).
5. 402-403 MHz: Earth Exploration-Satellite (Earth-to-space), Meteorological-Satellite (Earth-to-space).

Figure 10. NTIA spectrum survey graph summarizing 2,040 sweeps across the 400-406 MHz range (System-l, band event 16, swept/m3 algorithm, sample detector, 3-kHz bandwidth) at San Diego, CA, 1995.

GOVERNMENT ALLOCATIONS·	1	FIXED, MOBILE, RADIO ASTRONOMY, 2	FIXED, MOBILE, Space Research (space-to-space), 2
NON-GOVERNMENT ALLOCATIONS:	1	RADIO ASTRONOMY.	
GENERAL UTILIZATION:	1	LMR, 2	LMR, 2
	406-406.1	410	420



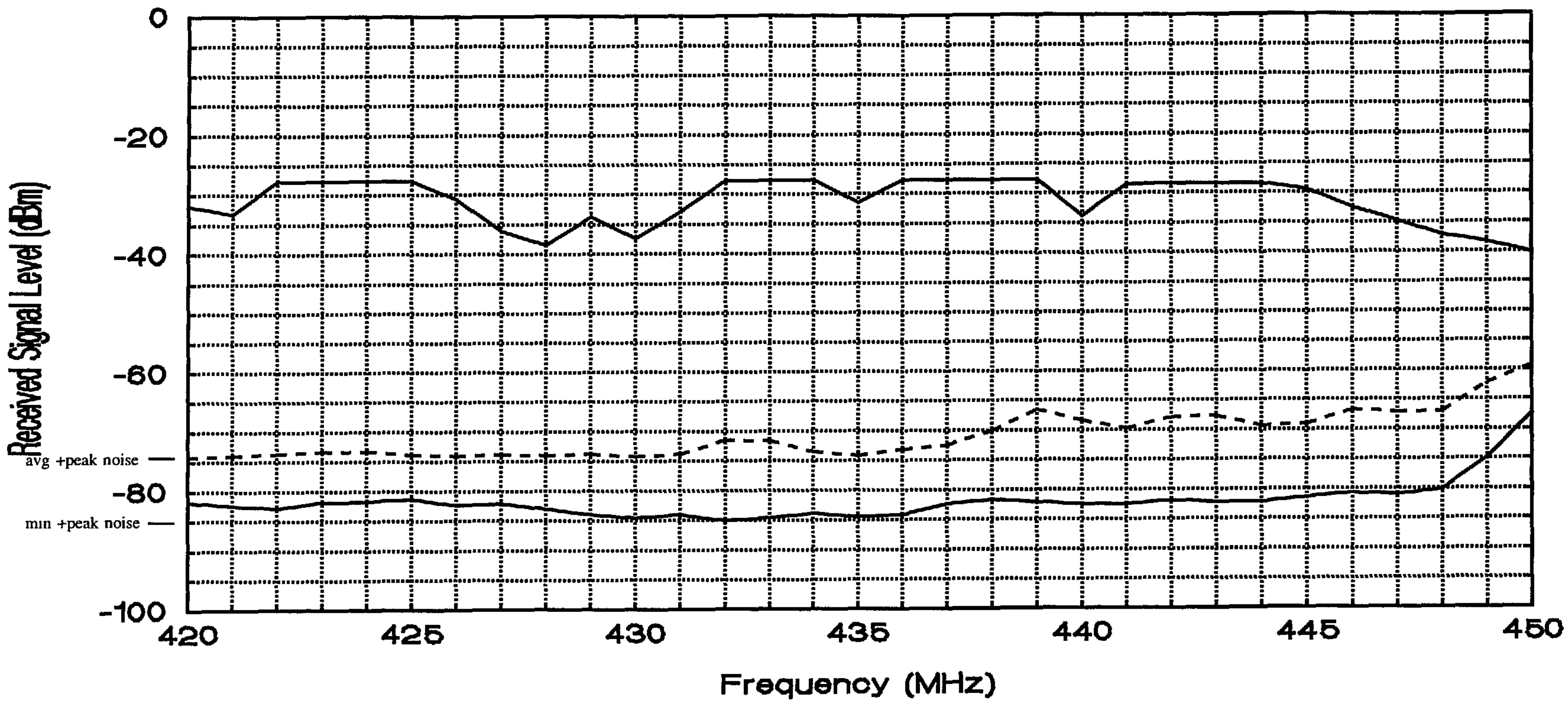
1 MOBILE-SATELLITE (Earth-to-space) Low power satellite emergency position-indicating radiobeacons (EPIRB) only Supported by the joint U.S. SARSAT/Russian COSPAS satellite network.

2. Fixed and mobile services are allocated for Government nonmilitary agencies. Military use may be authorized on a local-coordinated, secondary, noninterfering basis

Figure 11. NTIA spectrum survey graph summarizing 20,600 sweeps across the 406-420 MHz range (System-1, band event 17, swept/m3 algorithm, sample detector, 10-kHz bandwidth) at San Diego, CA, 1995.

GOVERNMENT ALLOCATIONS·	RADIOLOCATION
NON-GOVERNMENT ALLOCATIONS·	Amateur
GENERAL UTILIZATION:	Long-range surveillance radars, 1, 2

420 450



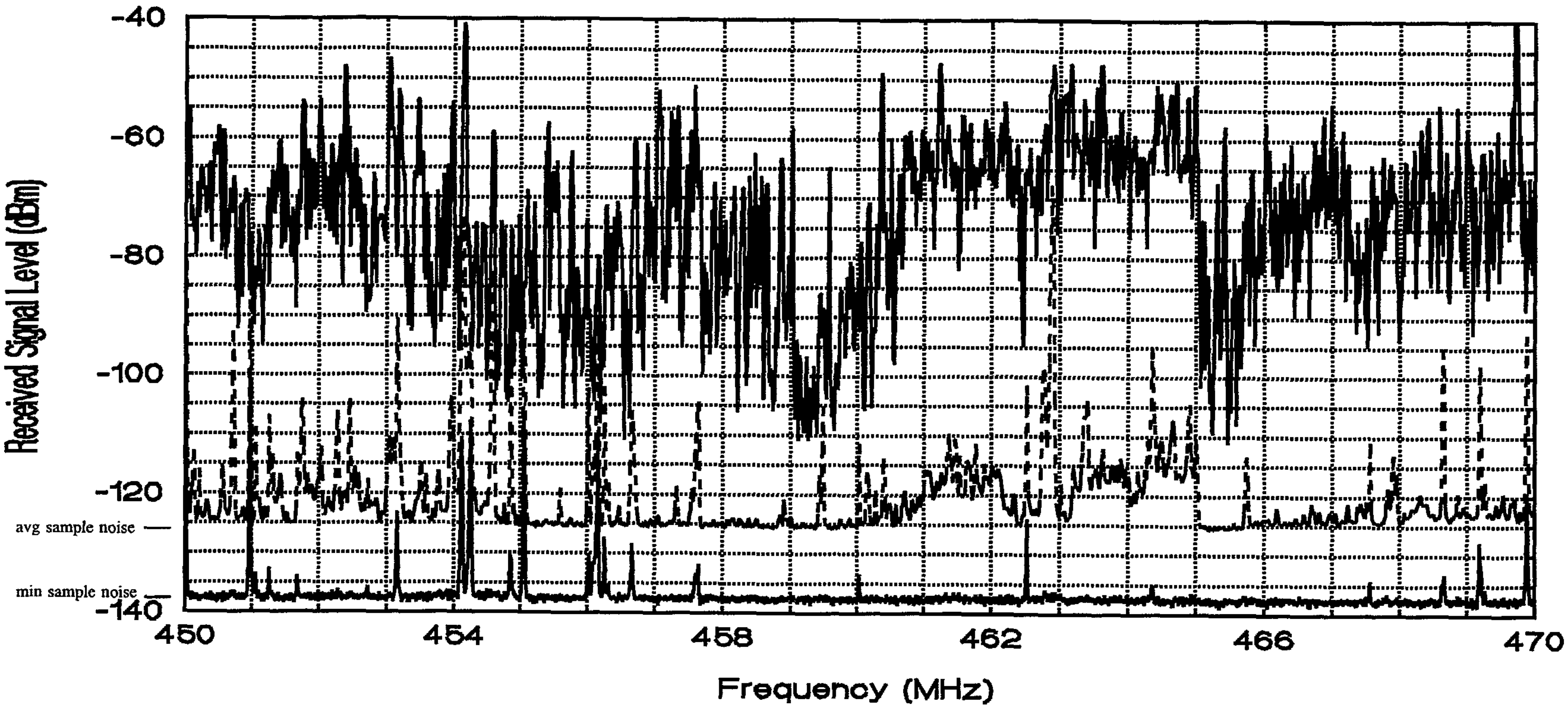
1. Radiolocation is limited to military services. Primarily, long-range radar systems essential to the nations early warning capability, law enforcement, and tracking objects in space. These systems use very high power and wide bandwidths Low power radio control operations are permitted in the band. NASA and military use of telemetry and telecommand is also extensive.

2. There is some non-Government use of spread spectrum modes; also, amateur weak signal modes (432-433 MHz), television (420-432 & 438-444 MHz), repeaters (442-450 MHz), auxiliary links (433-435 MHz), and amateur satellite (435-438 MHz).

Figure 12. NTIA spectrum survey graph summarizing 68 scans across the 420-450 MHz range (System-1, band event 18, stepped algorithm, +peak detector, 1000-kHz bandwidth) at San Diego, CA, 1995.

	450–455	455–460	460–465	465–470
GOVERNMENT ALLOCATIONS:			Meteorological-Satellite (space-to-Earth)	
NON-GOVERNMENT ALLOCATIONS:	LAND MOBILE		LAND MOBILE.	
GENERAL UTILIZATION:	LMR, 1, 2, 3. (base or mobile)	LMR, 1, 2, 3 (mobile only)	LMR, 2, 4, 5. (base or mobile)	LMR, 2, 4, 5. (mobile only)

450 455 460 465 470

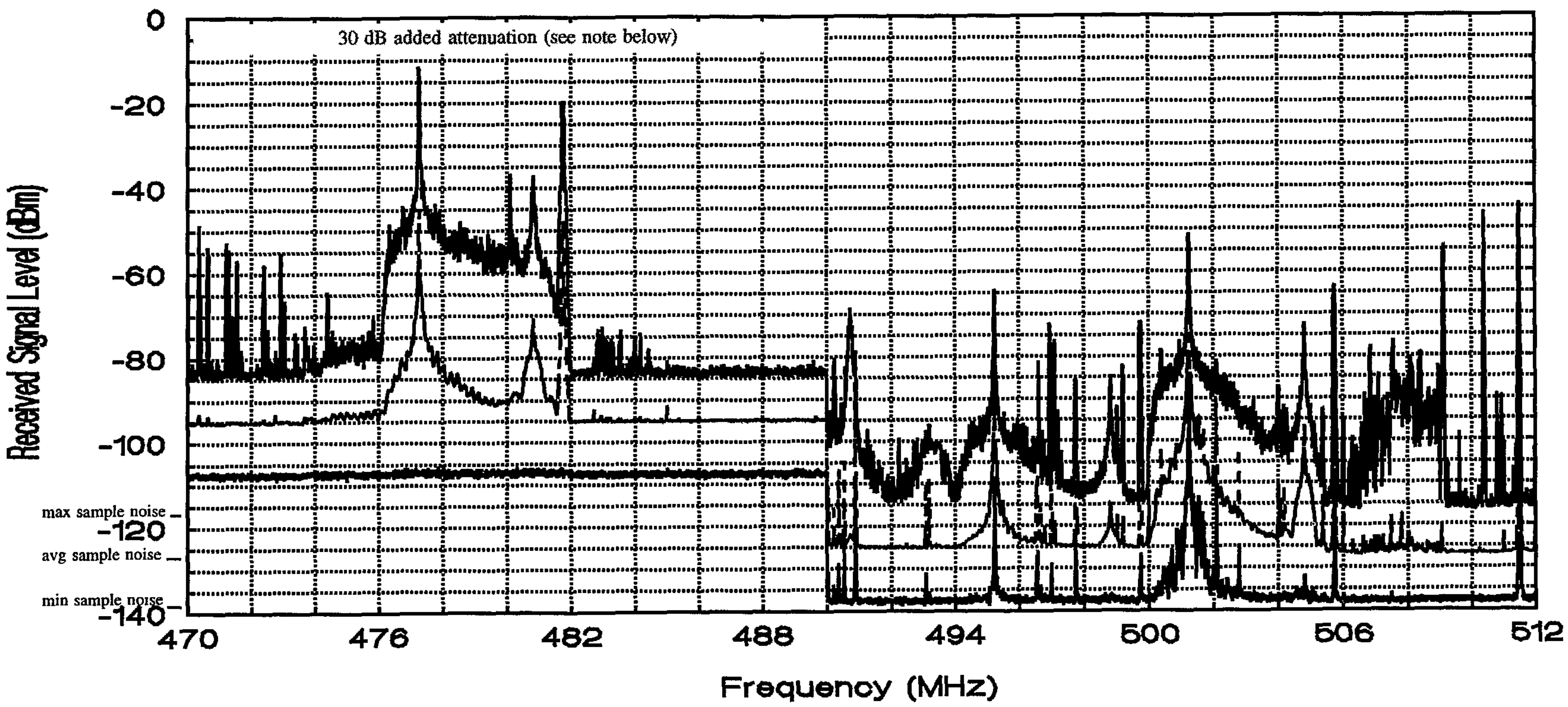


1 450-451 MHz and 455-456 MHz: Remote pickup broadcast.
2. 451-454 MHz, 456-459 MHz, 460-462.5375 MHz, 462.7375-467.5375 MHz, and 467.7375-470 MHz: Public Safety, Industrial, Land Transportation
3 454-455 MHz and 459-460 MHz. Domestic Public.
4. 462.5375-462.7375 MHz and 467 5375-467 7375 MHz: Personal.
5 460-470 MHz: GOES and TIROS satellite downlinks.

Figure 13. NTIA spectrum survey graph summarizing 20,400 sweeps across the 450-470 MHz range (System-1, band event 19, swept/m3 algorithm, sample detector, 10-kHz bandwidth) at San Diego, CA, 1995.

GOVERNMENT ALLOCATIONS:							
NON-GOVERNMENT ALLOCATIONS:	BROADCASTING, LAND MOBILE, 1, 2						
GENERAL UTILIZATION:	Channel 14	Channel 15	Channel 16	Channel 17	Channel 18	Channel 19	Channel 20
	470	476	482	488	494	500	506

512



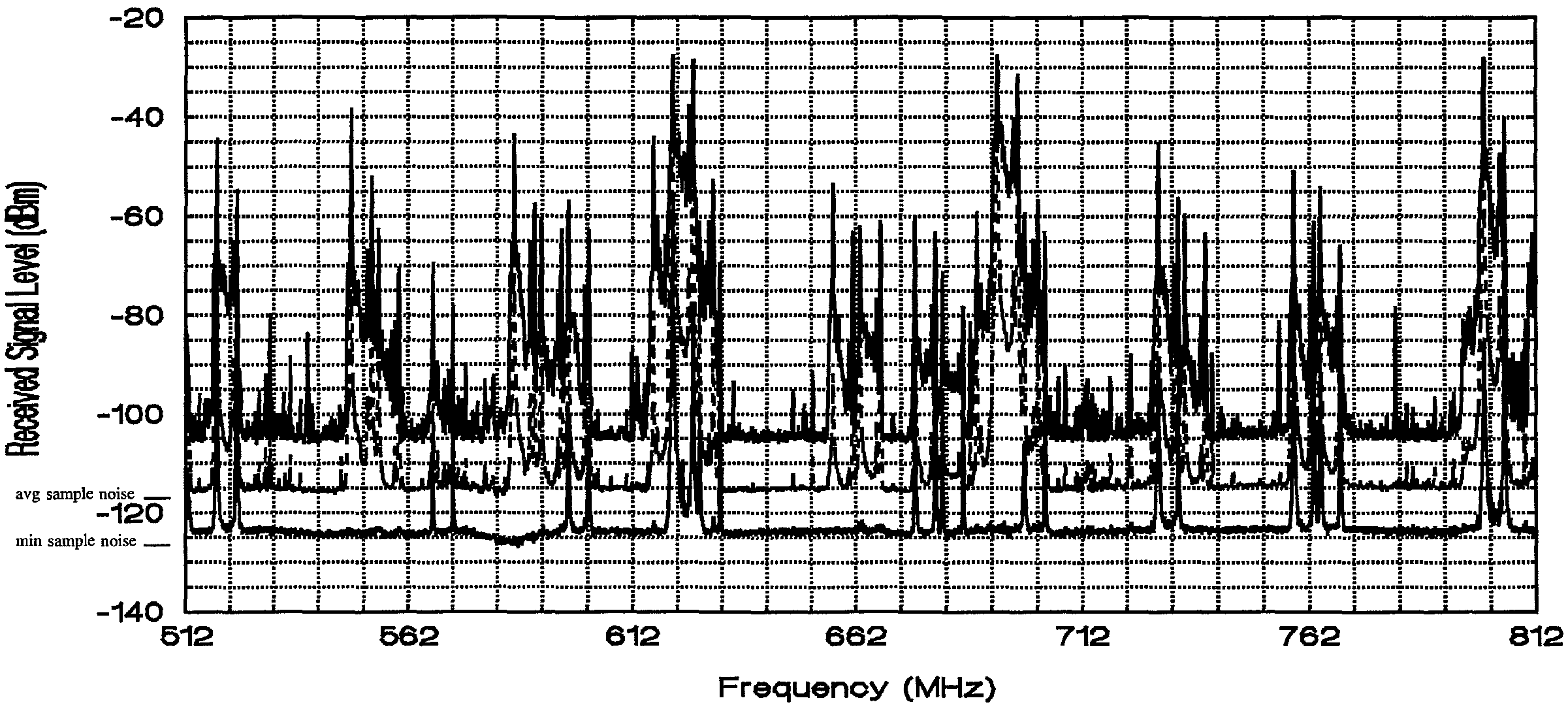
Note: Concerning 470-490 MHz attenuated data, see comments in Table 7 (Section 3.5.1).

1. Land Mobile Radio Services include Public Safety, Domestic Public, Industrial, and Land Transportation assignments in specific urban areas.

2. The band is also allocated to the fixed service to permit subscription television operations.

Figure 14. NTIA spectrum survey graph summarizing 9,600 sweeps across the 470-512 MHz range (System-1, band event 20, swept/m3 algorithm, sample detector, 10-kHz bandwidth) at San Diego, CA, 1995.

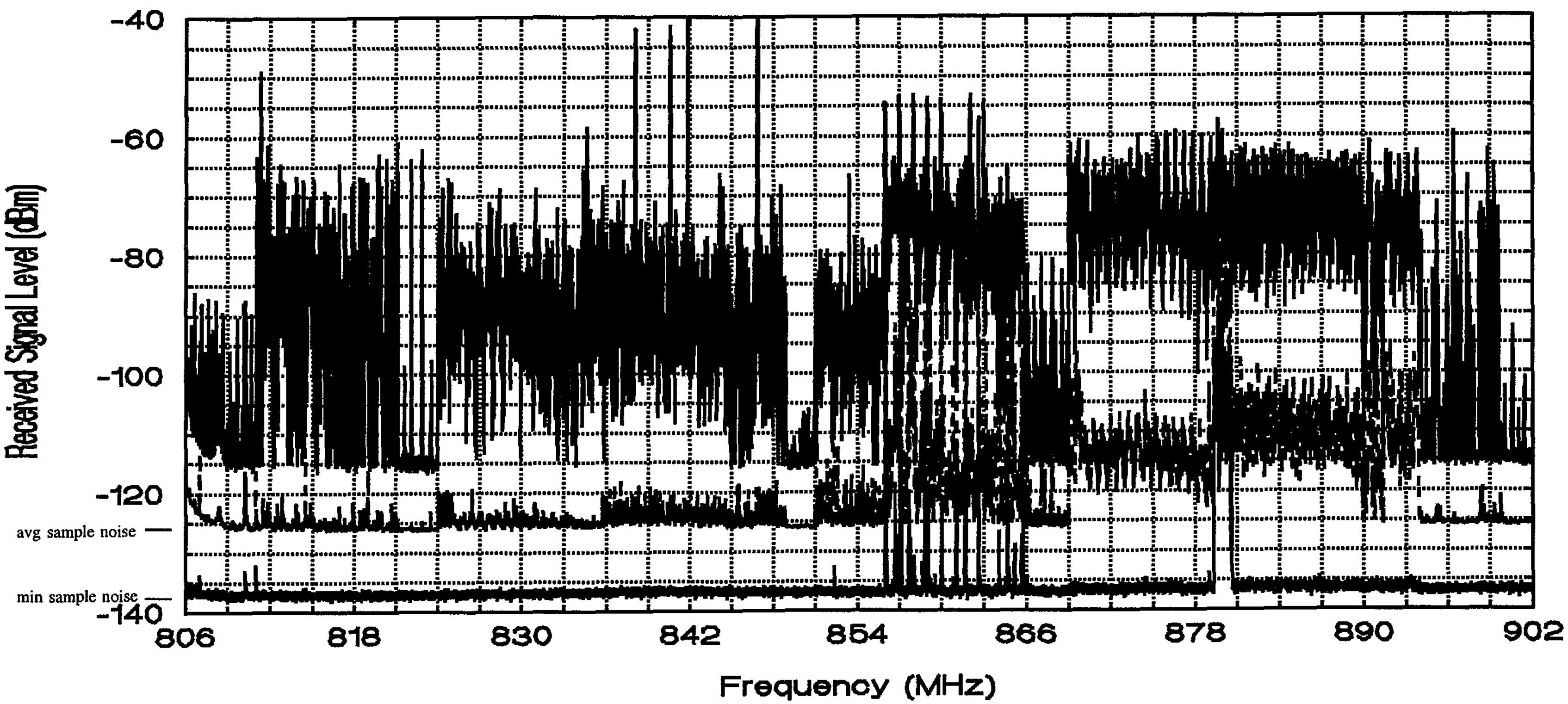
GOVERNMENT ALLOCATIONS:		1.		
NON-GOVERNMENT ALLOCATIONS:	BROADCASTING.	1.	BROADCASTING	
GENERAL UTILIZATION:	Television broadcasting (channels 21-36)		Television broadcasting (channels 38-69).	
	512	608-614		806



1. RADIO ASTRONOMY No stations are authorized to transmit in this band

Figure 15. NTIA spectrum survey graph summarizing 5,800 sweeps across the 512-806 MHz range (System-1, band event 21, swept/m3 algorithm, sample detector, 100-kHz bandwidth) at San Diego, CA, 1995.

GOVERNMENT ALLOCATIONS:										
NON-GOVERNMENT ALLOCATIONS:	LAND MOBILE, 1									
GENERAL UTILIZATION:	Conventional and Trunked (mobile).	2.	Cellular Systems (Public Mobile).	4.	Conventional and Trunked (base).	3.	Cellular Systems (Public Base).	5.	6, 7.	
	806	821	824	849-851		866	869	894	896	902

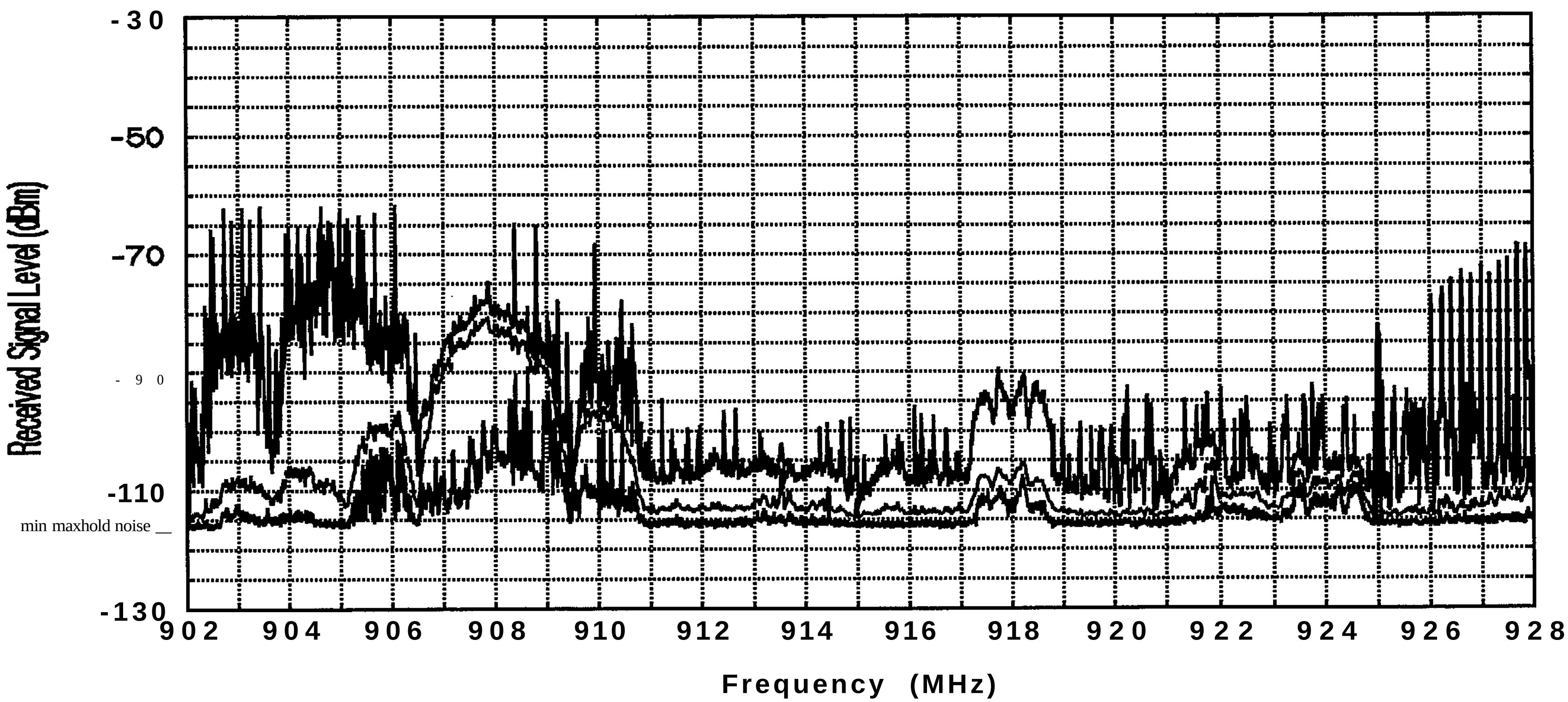


1. 806-890 MHz: Limited allocation is available for TV Channels 70-83.
2. Public Safety (mobile).
3. Public Safety (base)
4. Aeronautical Mobile (ground-to-air).
5. Aeronautical Mobile (air-to-ground).
6. 896-901 MHz: Private Land Mobile (paired with 935-940 MHz).
7. 901-902 MHz General Mobile.

Figure 16. NTIA spectrum survey graph summarizing 4,020 sweeps across the 806-902 MHz range (System-1, band event 22, swept/m3 algorithm, sample detector, 10-kHz bandwidth) at San Diego, CA, 1995.

GOVERNMENT ALLOCATIONS:	RADIOLOCATION
NON-GOVERNMENT ALLOCATIONS:	
GENERAL UTILIZATION:	Military radiolocation systems, Industrial scientific and medical (ISM), Automatic Vehicle Monitoring (AVM), spread spectrum devices, microwave ovens, digital communications, repeaters, 1

902 928

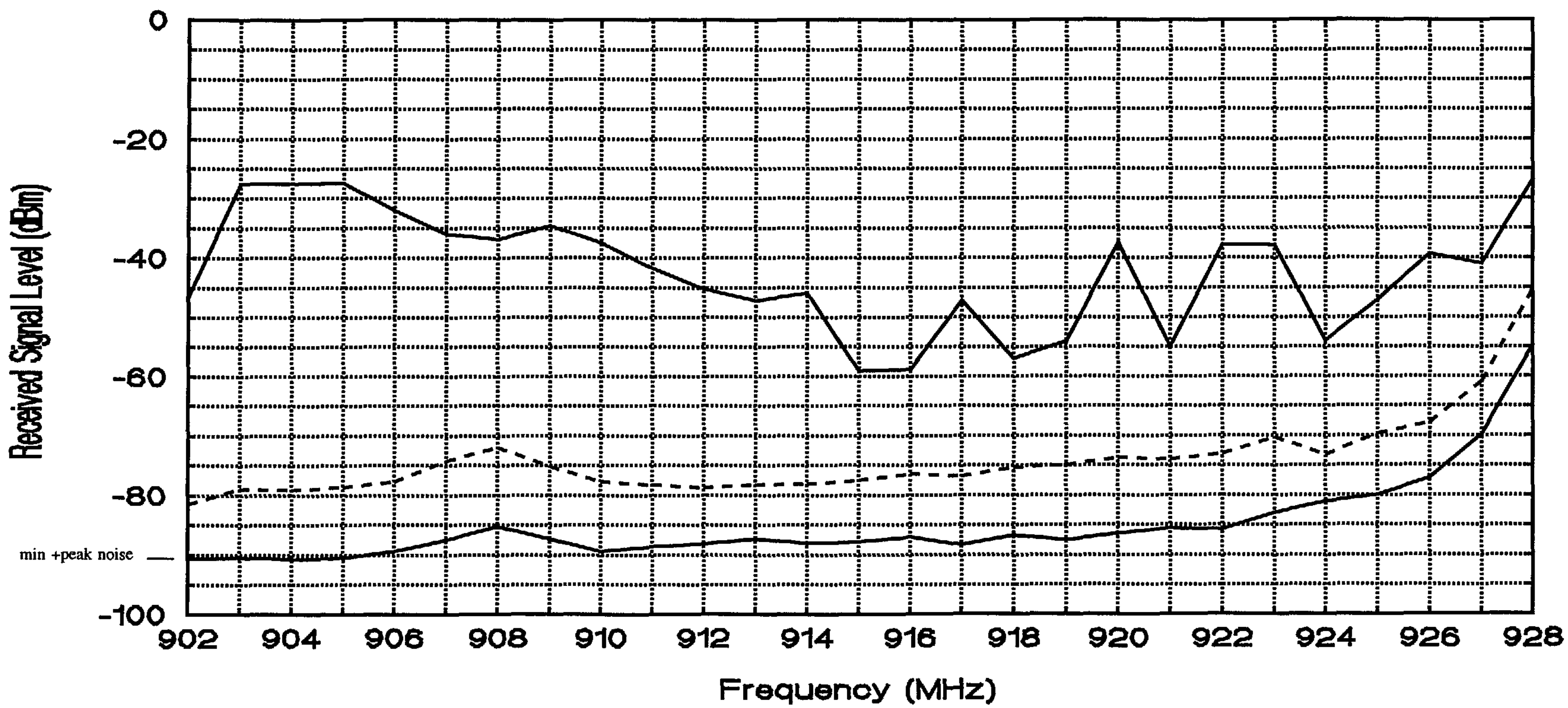


1. Fixed and mobile radio services are permitted on a secondary basis. however, band utilization is increasing for non-Government ISM, spread spectrum and other modes, amateur, etc., as permitted in Region 2.

Figure 17. NTIA spectrum survey graph summarizing 16,800 sweeps across the 902-928 MHz range (System-l, band event 23, swept algorithm, maximum-hold detector, 10-kHz bandwidth) at San Diego, CA, 1995.

GOVERNMENT ALLOCATIONS:	RADIOLOCATION
NON-GOVERNMENT ALLOCATIONS:	
GENERAL UTILIZATION:	Military radiolocation systems, Industrial scientific and medical (ISM), Automatic Vehicle Monitoring (AVM), spread spectrum devices, microwave ovens, digital communications, repeaters, 1.

902 928

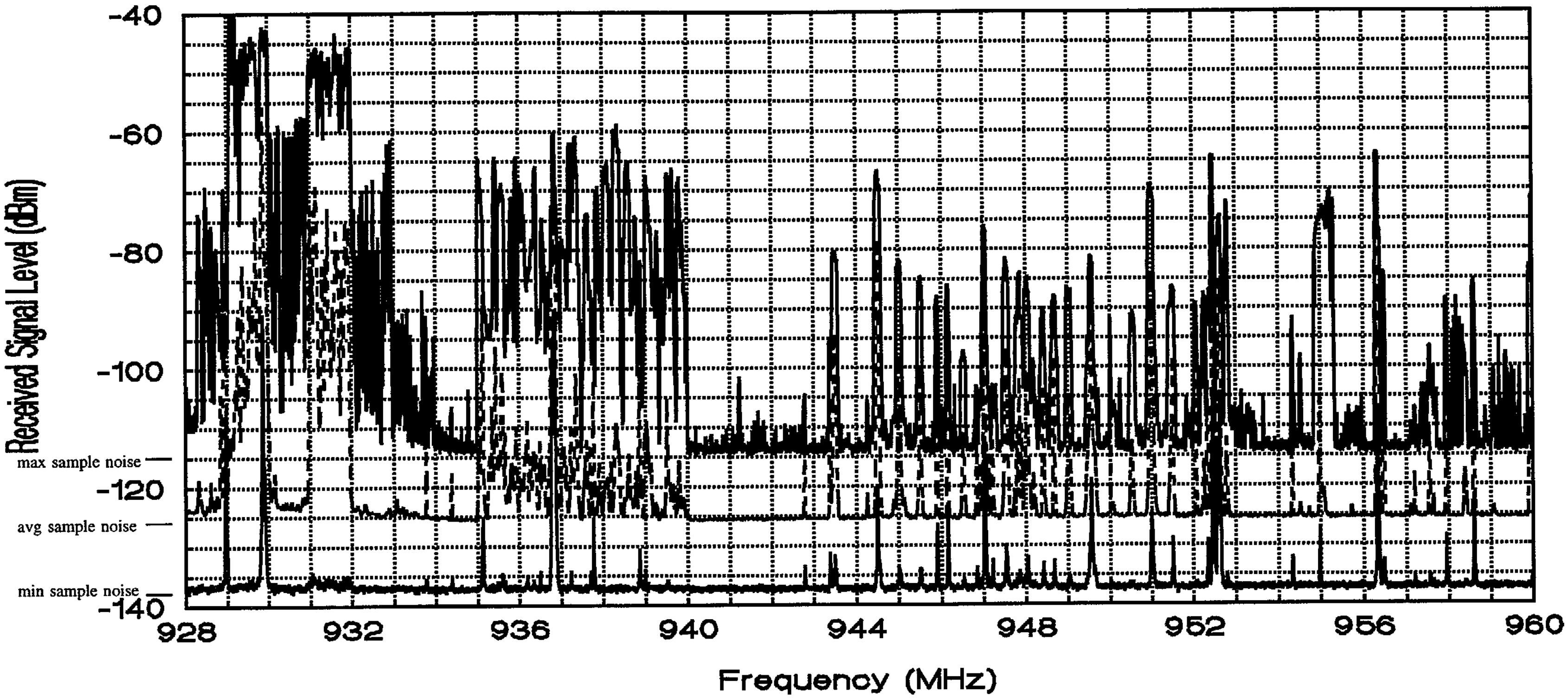


1. Fixed and mobile radio services are permitted on a secondary basis; however, band utilization is increasing for non-Government ISM, spread spectrum and other modes, amateur, etc., as permitted in Region 2

Figure 18. NTIA spectrum survey graph summarizing 63 scans across the 902-928 MHz range (System-1, band event 24, stepped algorithm, +peak detector, 1000-kHz bandwidth) at San Diego, CA, 1995.

	928–929	929–932	932–935	935–940	940–941	941–944	944–960
GOVERNMENT ALLOCATIONS:			FIXED.			FIXED.	
NON-GOVERNMENT ALLOCATIONS:	1	LAND MOBILE	FIXED	LAND MOBILE.	5.	FIXED	FIXED.
GENERAL UTILIZATION:	1.	2.	3	Private land mobile (base), 4.		3	Auxiliary broadcasting, private fixed microwave, studio-to-transmitter links (STL's), 6.

928 929 932 935 940 941 944 960

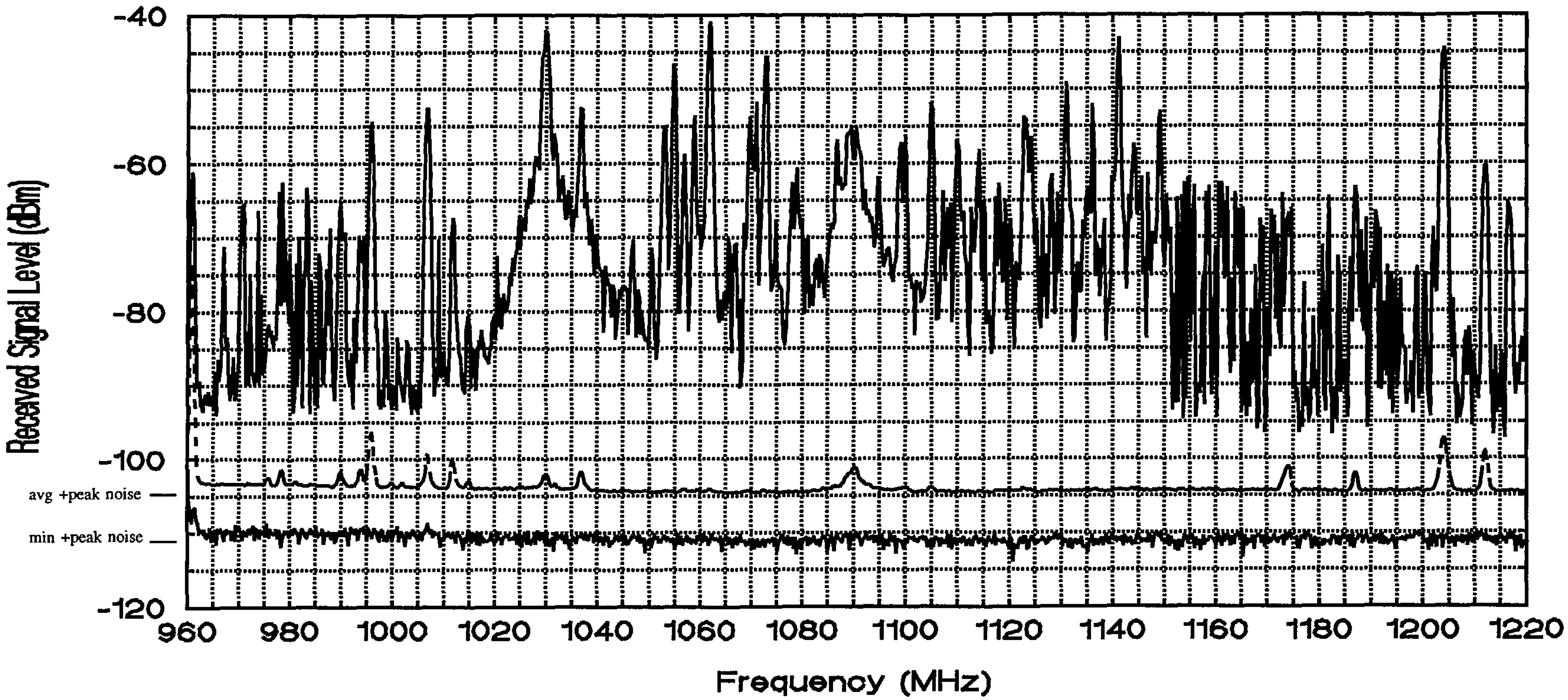


1 FIXED. Private fixed microwave, public and private land mobile, telemetry applications. Two-way services paired with 952-953 MHz
2 Public and private land mobile
3 Paired band for point-to-point and point-to-multipoint communications
4 Trunked and conventional systems in 12.5 kHz channels (paired with 896-901 MHz).
5 MOBILE
6. 944-952 MHz: Primarily STL's. 952-953 MHz paired with 928-929 MHz. 953-960 MHz: Primarily, fixed point-to-point communications

Figure 19. NTIA spectrum survey graph summarizing 27,600 sweeps across the 928-960 MHz range (System-1, band event 25, swept/m3 algorithm, sample detector, 10-kHz bandwidth) at San Diego, CA, 1995.

GOVERNMENT ALLOCATIONS	AERONAUTICAL RADIONAVIGATION, 1
NON-GOVERNMENT ALLOCATIONS:	AERONAUTICAL RADIONAVIGATION, 1.
GENERAL UTILIZATION:	TACAN, DME, MLS, ATCRBS, MODE-S, T-CAS, JTIDS, 2

960 1215



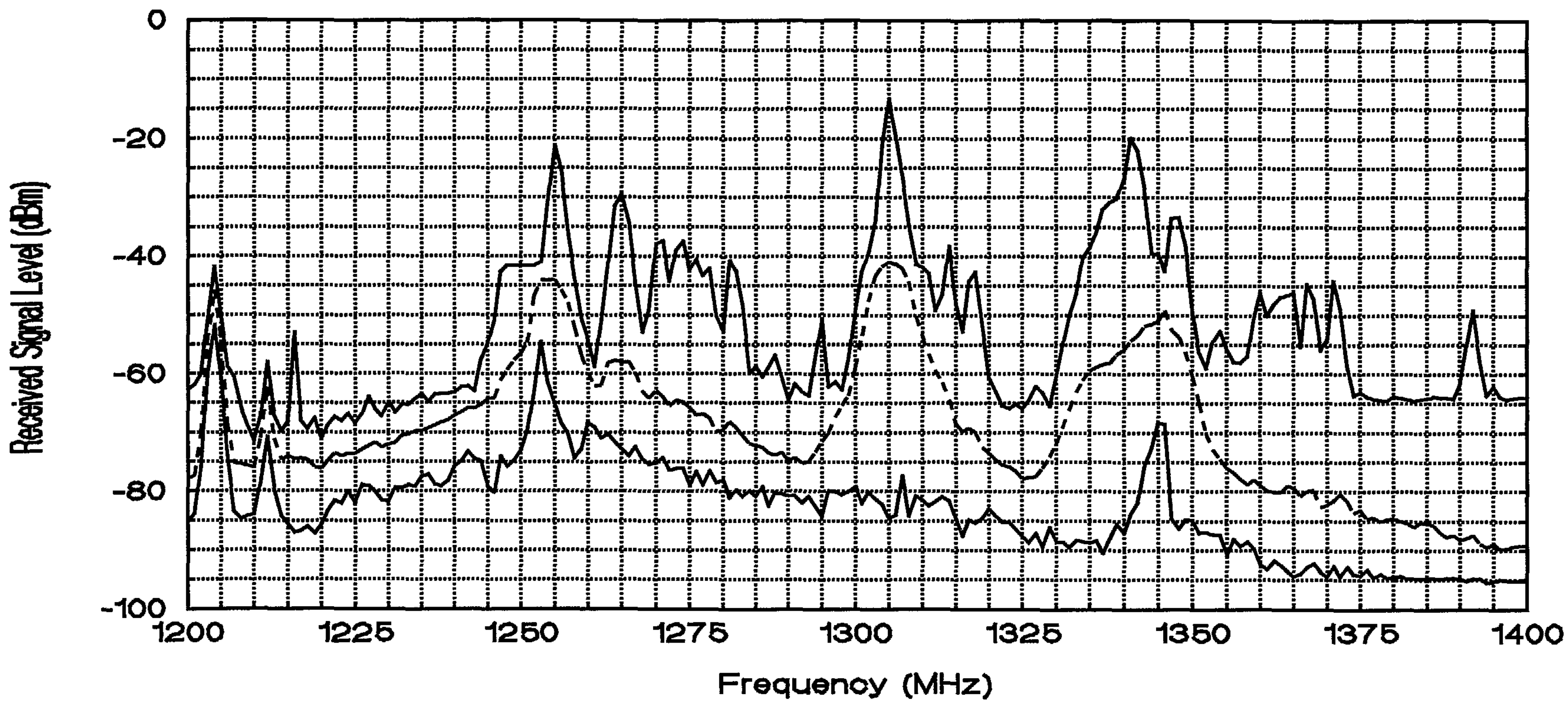
1. The 960-1215 MHz band is reserved on a worldwide basis for the use and development of electronic aids to air navigation. On a case by case basis, Government systems utilizing spread spectrum techniques for terrestrial communication, navigation and identification may be authorized on condition that aeronautical radionavigation services not experience harmful interference

2. Tactical Air Navigation (TACAN). Distance Metering Equipment (DME). Microwave Landing System (MLS). Air Traffic Control Radar Beacon system (ATCRBS, MODE-S, and IFF). Collision Avoidance System (T-CAS) Joint Tactical Information Distribution System (JTIDS).

Figure 20. NTIA spectrum survey graph summarizing 36,500 sweeps across the 960-1215 MHz range (System-2, band event 05, swept/m3 algorithm, +peak detector, 300-kHz bandwidth) at San Diego, CA, 1995.

GOVERNMENT ALLOCATIONS:	RADIOLOCATION, 1	RADIOLOCATION	AERONAUTICAL RADIONAVIGATION, Radiolocation	FIXED, MOBILE, RADIOLOCATION.
NON-GOVERNMENT ALLOCATIONS:		Amateur.	AERONAUTICAL RADIONAVIGATION.	
GENERAL UTILIZATION:	2, 3, 4.	3, 4, 5.	3, 4.	3, 6, Fixed and Mobile links.

1215 1240 1300 1350 1400

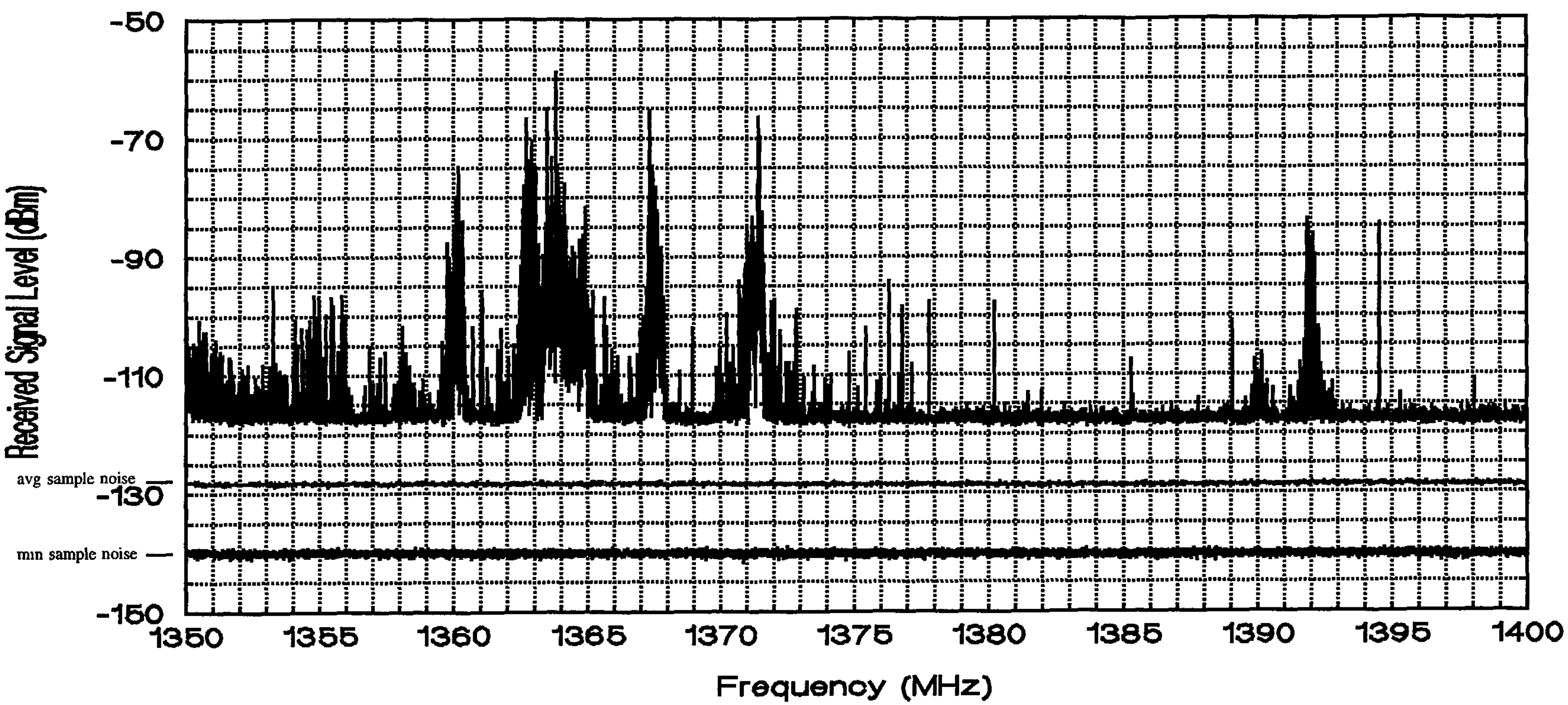


1 RADIONAVIGATION-SATELLITE (space-to-Earth).
2. 1227.6 MHz: Global Positioning System (GPS).
3. High-power long-range surveillance radars including FAA Air-Route Surveillance Radar (ARSR)
4. Tethered balloon mounted radar for drug interdiction.
5. Amateur television. Amateur weak signal modes and other modes. Amateur satellite (Earth-to-space)
6 1381.05 MHz: GPS data relay.

Figure 21. NTIA spectrum survey graph summarizing 28 scans across the 1215-1400 MHz range (System-2, band event 06, stepped algorithm, +peak detector, 1000-kHz bandwidth) at San Diego, CA, 1995.

GOVERNMENT ALLOCATIONS:	FIXED, MOBILE, RADIOLOCATION, 1	
NON-GOVERNMENT ALLOCATIONS:	1.	
GENERAL UTILIZATION:	Military radiolocation, fixed and mobile links, GPS, aeronautical radionavigation, 2, 3	

1350   1400

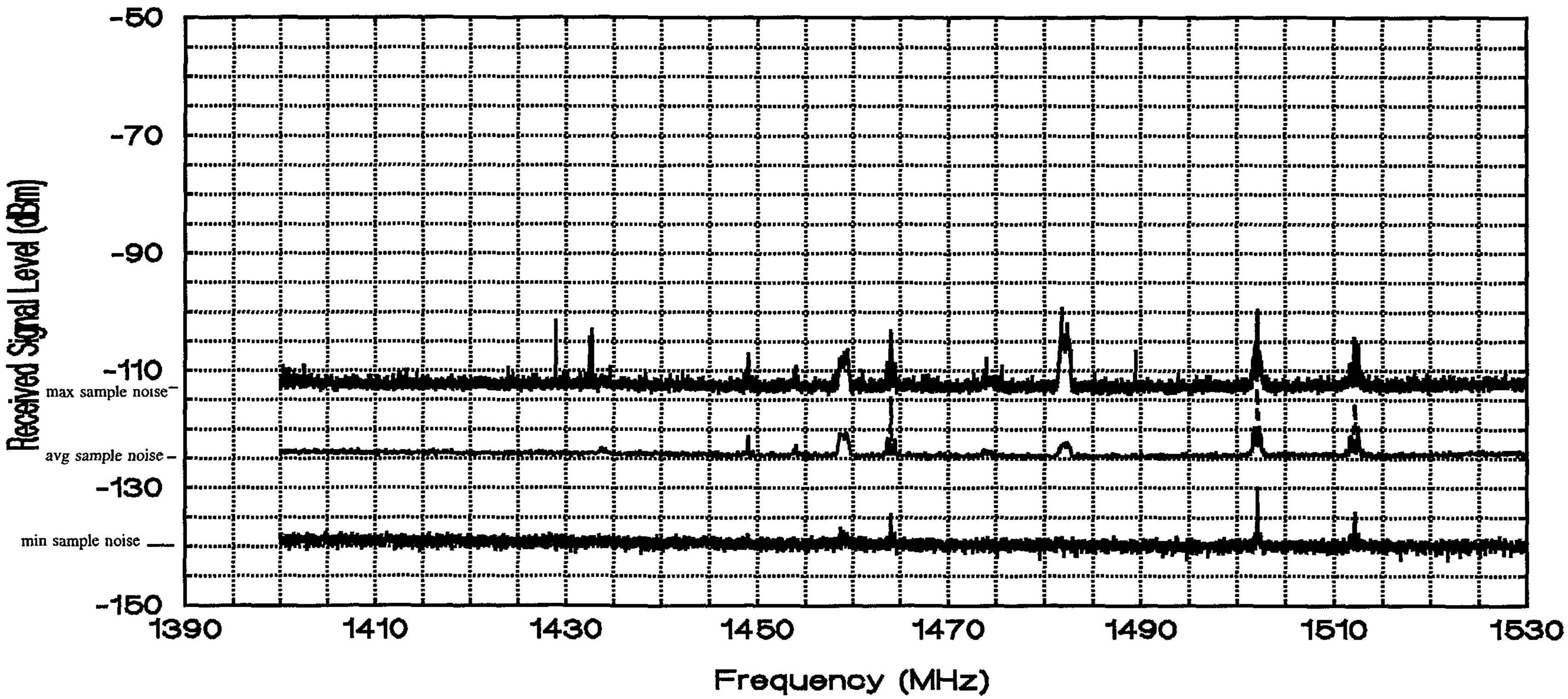


1. 1350-1370 MHz: AERONAUTICAL RADIONAVIGATION (allocation for U.S. and Canada only).
2. Military radiolocation applications are primarily high-power long-range surveillance radars.
3. 1369.05-1393.05 MHz: Fixed and mobile satellite services (space-to-Earth) for the relay of nuclear burst data. GPS operates at 1381.05 MHz to relay data detected by orbiting satellites

Figure 22. NTIA spectrum survey graph summarizing 4,900 sweeps across the 1350-1400 MHz range (System-2, band event 07, swept/m3 algorithm, sample detector, 10-kHz bandwidth) at San Diego, CA, 1995.

GOVERNMENT ALLOCATIONS:	RADIO ASTRONOMY, 1.	2.	3	MOBILE (Aeronautical telemetering).	
NON-GOVERNMENT ALLOCATIONS:	RADIO ASTRONOMY, 1.	4.	5	MOBILE (Aeronautical telemetering).	
GENERAL UTILIZATION:	Passive.			Aeronautical telemetry and telecommand	

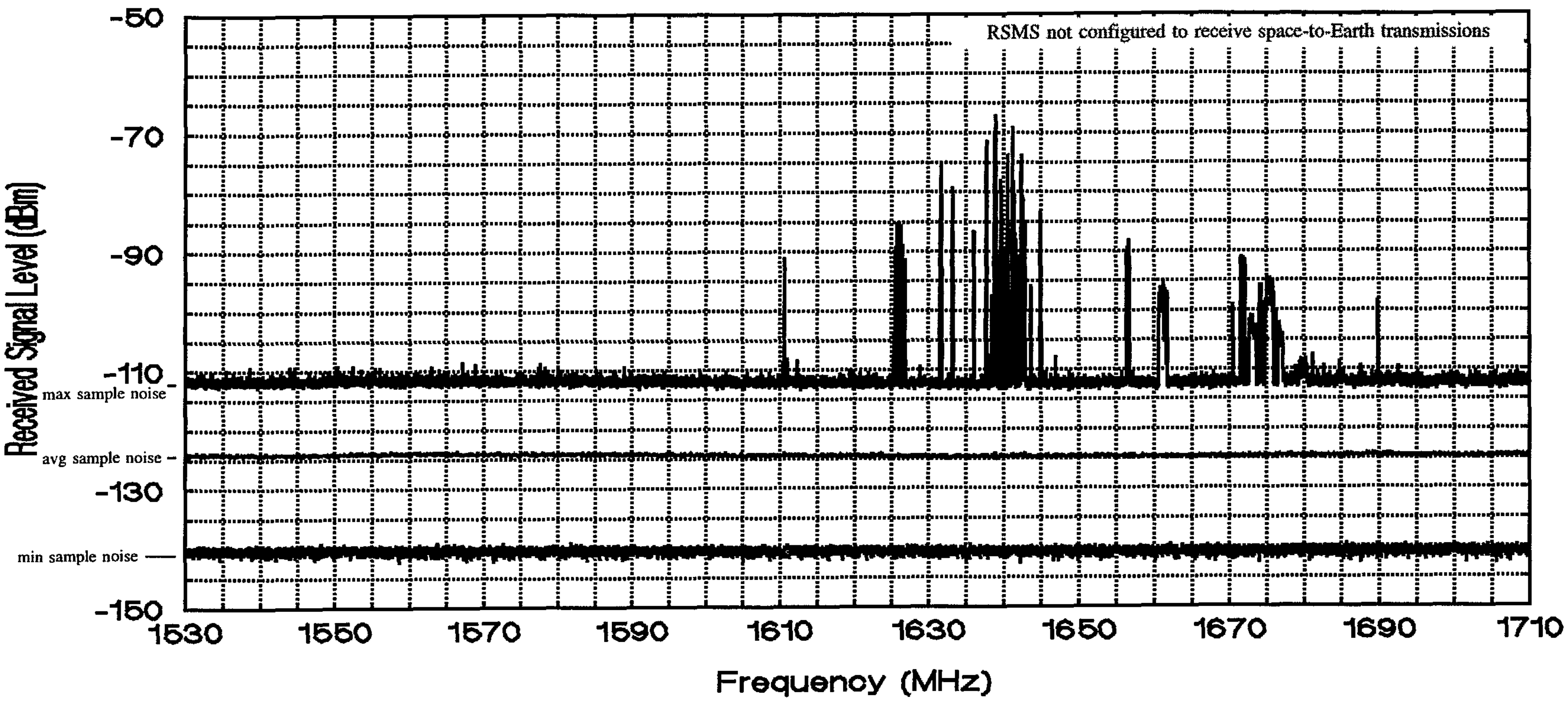
1400 1427-1429 1435 1530



1. EARTH EXPLORATION-SATELLITE (Passive), SPACE RESEARCH (Passive)
2. FIXED, MOBILE except aeronautical mobile, SPACE OPERATION (Earth-to-space).
3. FIXED, MOBILE.
4. SPACE OPERATION (Earth-to-space), Land Mobile (Telemetering and telecommand), Fixed (Telemetering).
5. Land Mobile (Telemetering and telecommand), Fixed (telemetering).

Figure 23. NTIA spectrum survey graph summarizing 9,600 sweeps across the 1400-1530 MHz range (System-2, band event 08, swept/m3 algorithm, sample detector, 30-kHz bandwidth) at San Diego, CA, 1995.

GOVERNMENT ALLOCATIONS.	1	2.	AERONAUTICAL RADIONAVIGATION, RADIONAVIGATION-SATELLITE (space-to-Earth, 1559-1610 MHz)	3.	4	5.	METEOROLOGICAL AIDS, (Radiosonde), 6.	FIXED, 7.	
NON-GOVERNMENT ALLOCATIONS:	1	2	AERONAUTICAL RADIONAVIGATION, RADIONAVIGATION-SATELLITE (space-to-Earth, 1559-1610 MHz).	3.	4.	5	METEOROLOGICAL AIDS, (Radiosonde), 6	7, Fixed	
GENERAL UTILIZATION.	INMARSAT, SARSAT	AMS(R)S	1559-1610 MHz: GPS, GLONASS 1610-1626.5 MHz: Airborne aids to air navigation, only.	INMARSAT	AMS(R)S.		Radiosondes and satellite imagery	8.	
	1530	1545	1559	1626.5	1646.5	1660	1668.4	1700	1710

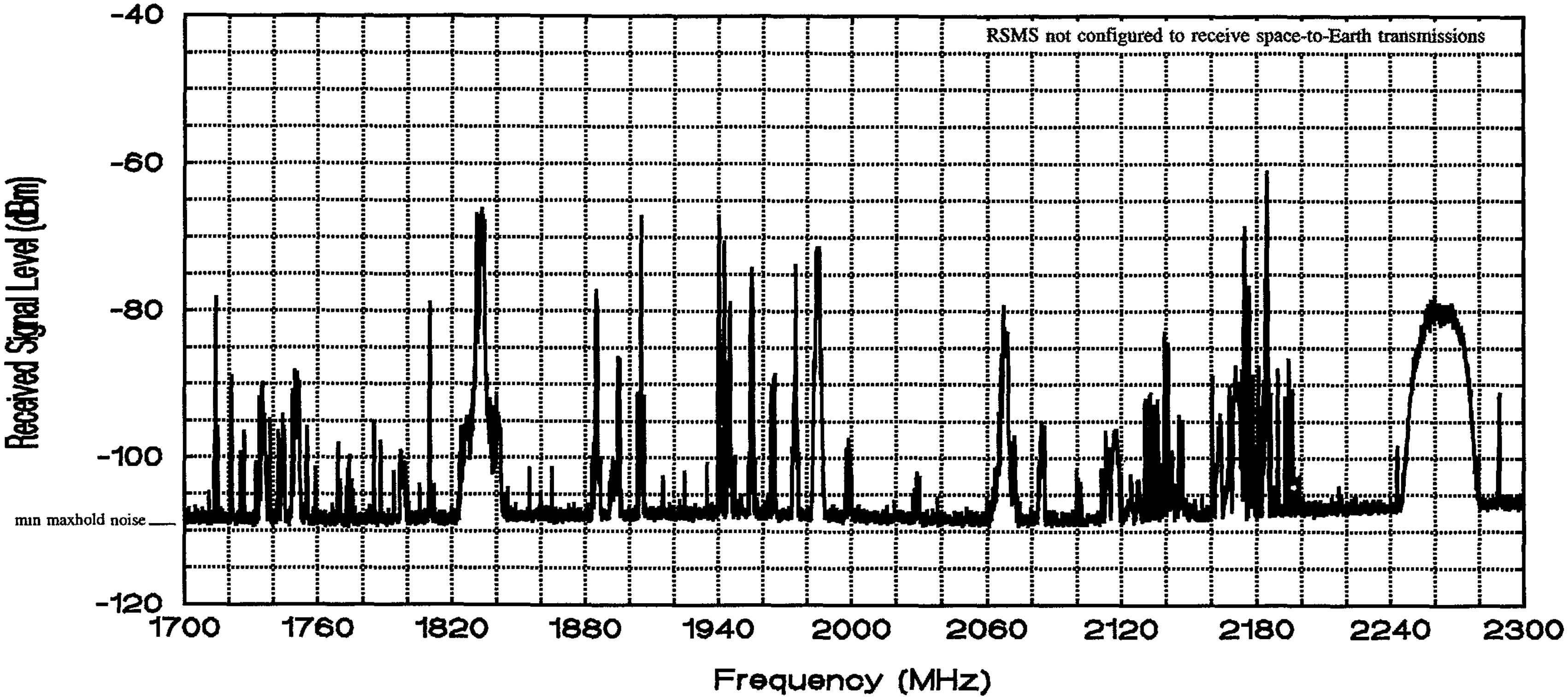


1. 1530-1544 MHz: MARITIME MOBILE-SATELLITE (space-to-Earth). 1530-1535 MHz: Mobile (Aeronautical telemetering). 1544-1545 MHz: MOBILE-SATELLITE (space-to-Earth).
2. AERONAUTICAL MOBILE-SATELLITE (space-to-Earth) 1545-1549 5 MHz. Mobile-Satellite (space-to-Earth). 1549 5-1558.5 MHz: MOBILE-SATELLITE (space-to-Earth).
3. 1626.5-1645.5 MHz. MARITIME MOBILE-SATELLITE (Earth-to-space). 1645 5-1646.5 MHz: MOBILE-SATELLITE (Earth-to-space, distress and safety only).
4. AERONAUTICAL MOBILE-SATELLITE (Earth-to-space). 1646 5-1651 MHz Mobile-Satellite (Earth-to-space) 1651-1660 MHz: MOBILE-SATELLITE (Earth-to-space).
5. RADIO ASTRONOMY. 1660-1660.5 MHz: AERONAUTICAL MOBILE-SATELLITE (Earth-to space). 1660.5-1668.4 MHz: SPACE RESEARCH (Passive).
6. 1668.4-1670 MHz: RADIO ASTRONOMY. 1670-1700 MHz: METEOROLOGICAL-SATELLITE (space-to-Earth).
7. METEOROLOGICAL-SATELLITE (space-to-Earth).
8. GOES, TIROS-N.

Figure 24. NTIA spectrum survey graph summarizing 35,000 sweeps across the 1530-1710 MHz range (System-2, band event 09, swept/m3 algorithm, sample detector, 30-kHz bandwidth) at San Diego, CA, 1995.

GOVERNMENT ALLOCATIONS:	FIXED, MOBILE			FIXED (LOS only), MOBILE (LOS only), 3.	5.	
NON-GOVERNMENT ALLOCATIONS:		FIXED.	MOBILE, Fixed.		6.	
GENERAL UTILIZATION:	LOS fixed links, telemetry, telecommand, 1.	Private fixed microwave. Future PCS	Auxiliary broadcasting, domestic public fixed, cable TV, control and repeater links, point to multipoint video, cellular, 2.	TDRSS, SGLS, 4	7.	

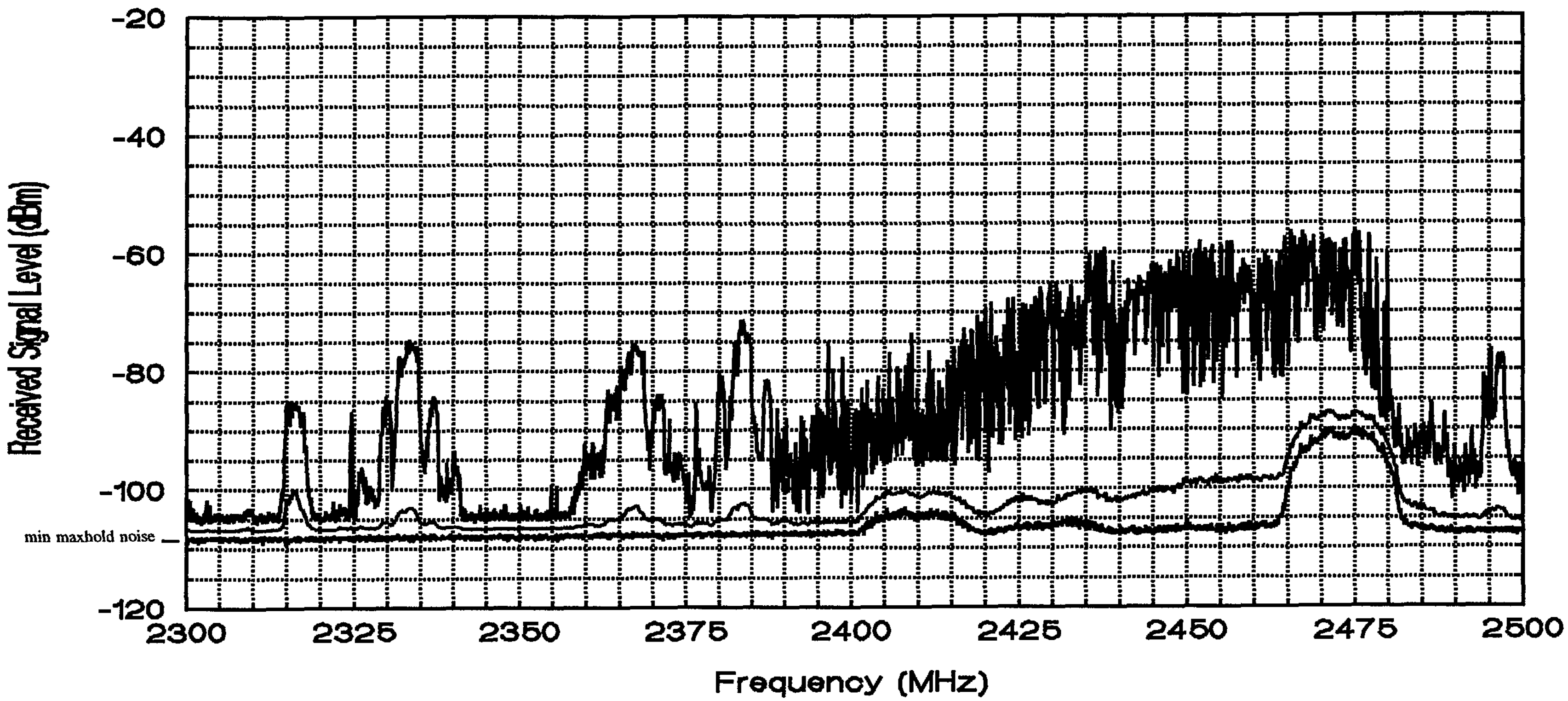
1710 1850 1990 2200 2290-2300



1. Predominantly federal medium-capacity line of sight (LOS) fixed service band
2. 1990-2110 MHz: Electronic news gathering (ENG). GOES uplink, NASA's global ground network and TDRSS (2025-2110 MHz). 2110-2200 MHz: NASA space and Earth to space command links support Pioneers, Voyagers, MAGELLAN, GALILEO, and ULYSSES (2110-2120 MHz) Paired fixed links (2110-2130 MHz with 2160-2180 MHz; 2130-2150 MHz with 2180-2200 MHz) Point-to-point and point to multipoint links (2150-2160 MHz).
3. SPACE RESEARCH (space-to-Earth) (space-to-space), SPACE OPERATION (space-to-Earth) (Earth-to-space), EARTH EXPLORATION-SATELLITE space-to-Earth)(space-to-space)
4. Space telemetry, telecommand and control systems Fixed microwave
5. FIXED, MOBILE except aeronautical mobile, SPACE RESEARCH (space-to-Earth) (Deep Space only).
6. SPACE RESEARCH (space-to-Earth) (Deep Space only)
7. NASA deep space network space-to-Earth telemetry Radio astronomy observations

Figure 25. NTIA spectrum survey azimuth-scan graph of the 1710-2300 MHz range (System-2, band event 10, swept algorithm, maximum-hold detector, 100-kHz bandwidth) at San Diego, CA, 1995.

GOVERNMENT ALLOCATIONS:	1.	RADIOLOCATION, MOBILE, Fixed.	RADIOLOCATION, 5.				
NON-GOVERNMENT ALLOCATIONS:	2.	MOBILE.	6.	Amateur.	FIXED, MOBILE, Radiolocation.	8.	
GENERAL UTILIZATION:	3.	Telemetry, telemetry communications, aeronautical telemetry, 4.		Amateur Satellite (space-to-Earth). Amateur mixed modes, 7.	7.	7, 9	
	2300	2310	2390	2400	2450	2483.5	2500

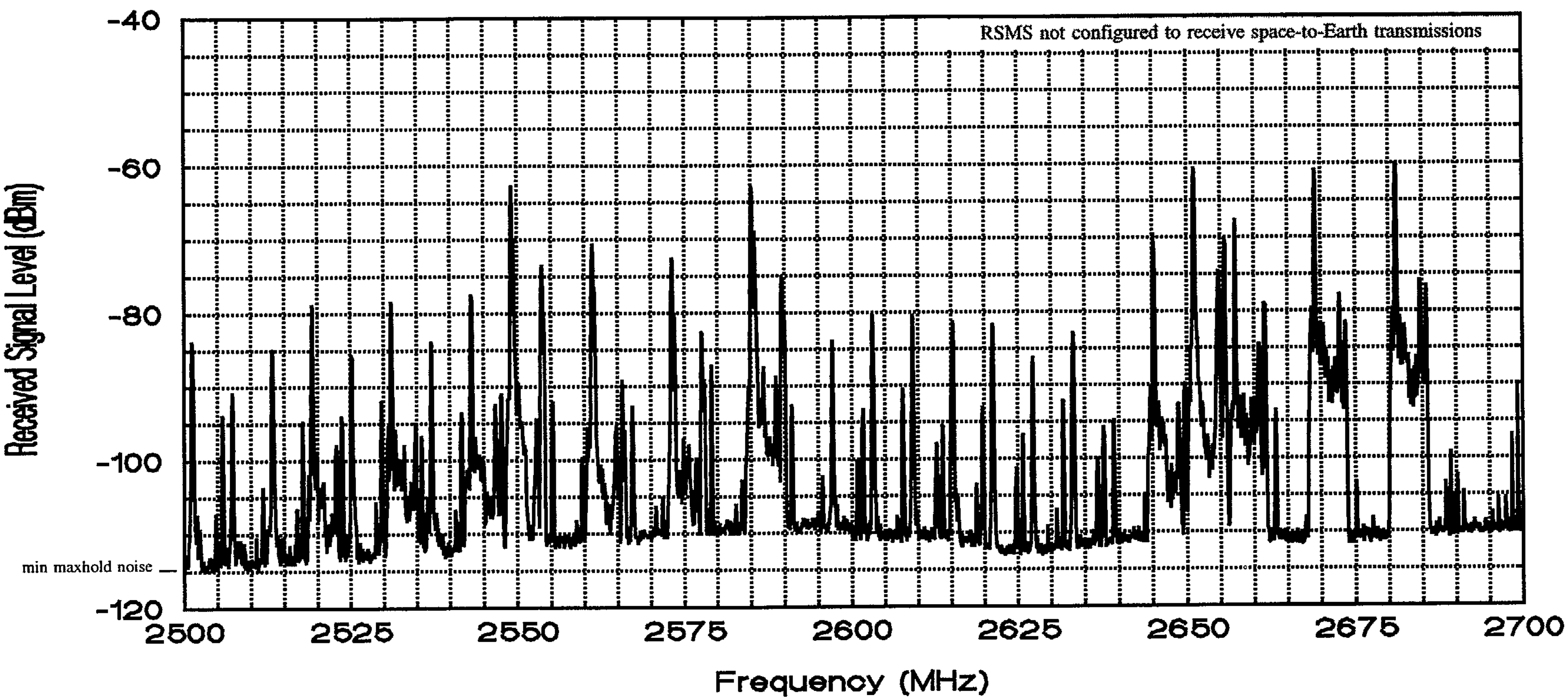


1. RADIOLOCATION, Fixed, Mobile.
2. Amateur.
3. Amateur weak signal modes and other modes.
4. AF High-power long-range surveillance radar and air traffic control radar. Venus Radar Mapper (VRM) synthetic aperture radar.
5. No Government allocations in this band after August 1995.
6. AMATEUR.
7. 2400-2500 MHz: Is also used for industrial scientific and medical (ISM) applications including microwave ovens
8. RADIODETERMINATION-SATELLITE (space-to-Earth).
9. Satellite downlinks and multichannel fixed and portable video transmission by TV broadcasters

Figure 26. NTIA spectrum survey graph summarizing 28,800 sweeps across the 2300-2500 MHz range (System-2, band event 11, swept algorithm, maximum-hold detector, 100-kHz bandwidth) at San Diego, CA, 1995.

GOVERNMENT ALLOCATIONS·		3	4.
NON-GOVERNMENT ALLOCATIONS	BROADCASTING-SATELLITE, FIXED, 1	FIXED, BROADCASTING-SATELLITE, 1, 3	4.
GENERAL UTILIZATION:	Auxiliary broadcasting, pay television distribution, private video teleconferences, educational television (ITSF), 2.	Private fixed microwave, 2.	

2500 2655 2690 2700

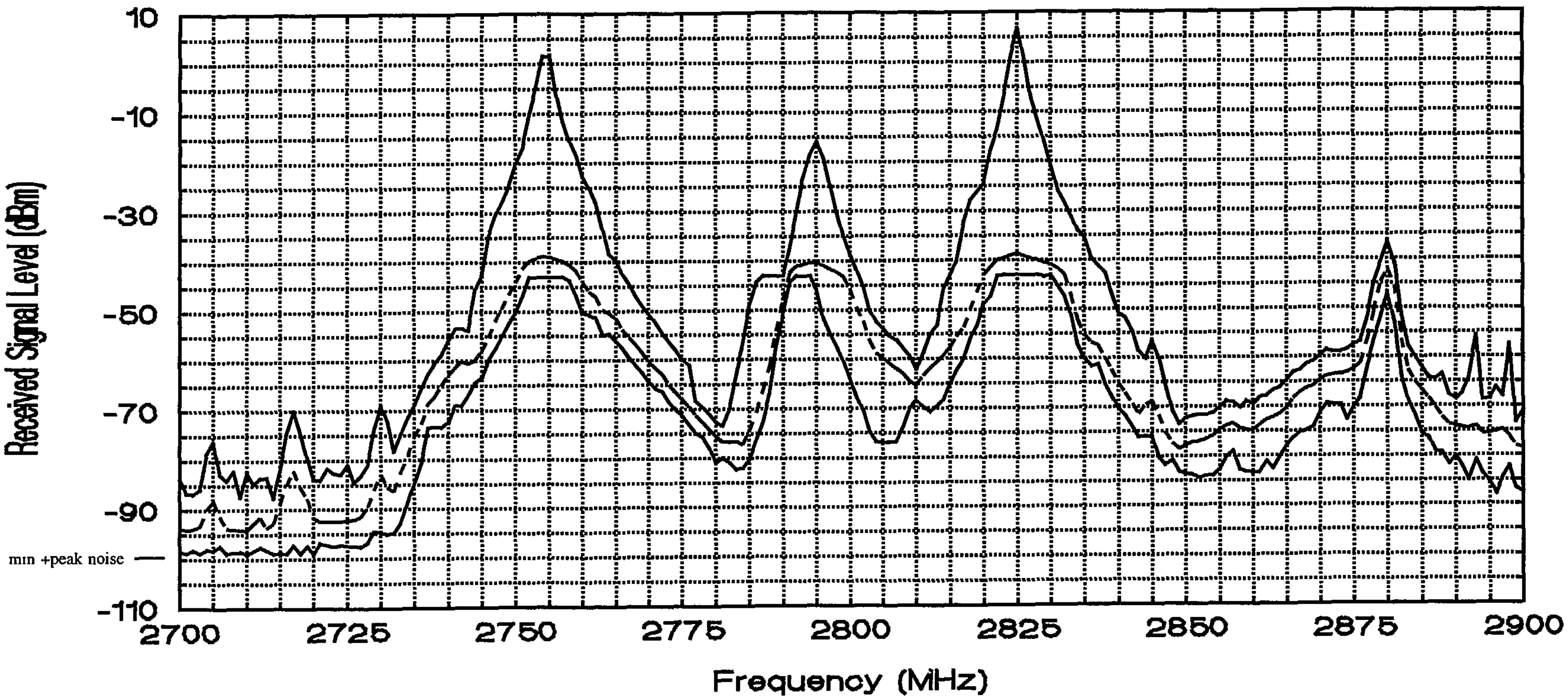


1. Broadcasting-satellite service is limited to community reception of educational and public service television programming
2. 2500-2686 MHz· Omnidirectional transmission of multipoint MDS that can be contained within 6 MHz channel bandwidths.
3. Earth Exploration-Satellite (Passive), Radio Astronomy, Space Research (Passive).
4. EARTH EXPLORATION-SATELLITE (Passive), RADIO ASTRONOMY, SPACE RESEARCH (Passive).

Figure 27. NTIA spectrum survey azimuth-scan graph of the 2500-2700 MHz range (System-2, band event 12, swept algorithm, maximum-hold detector, 10-kHz bandwidth) at San Diego, CA, 1995.

GOVERNMENT ALLOCATIONS:	AERONAUTICAL RADIONAVIGATION, METEOROLOGICAL AIDS, Radiolocation, 1, 2
NON-GOVERNMENT ALLOCATIONS:	
GENERAL UTILIZATION:	Airport surveillance radars (ASRs), military ground control approach radars (GCAs), NWS weather radars (NEXRAD, etc), long-range surveillance radars and air traffic control radars.

2700 2900



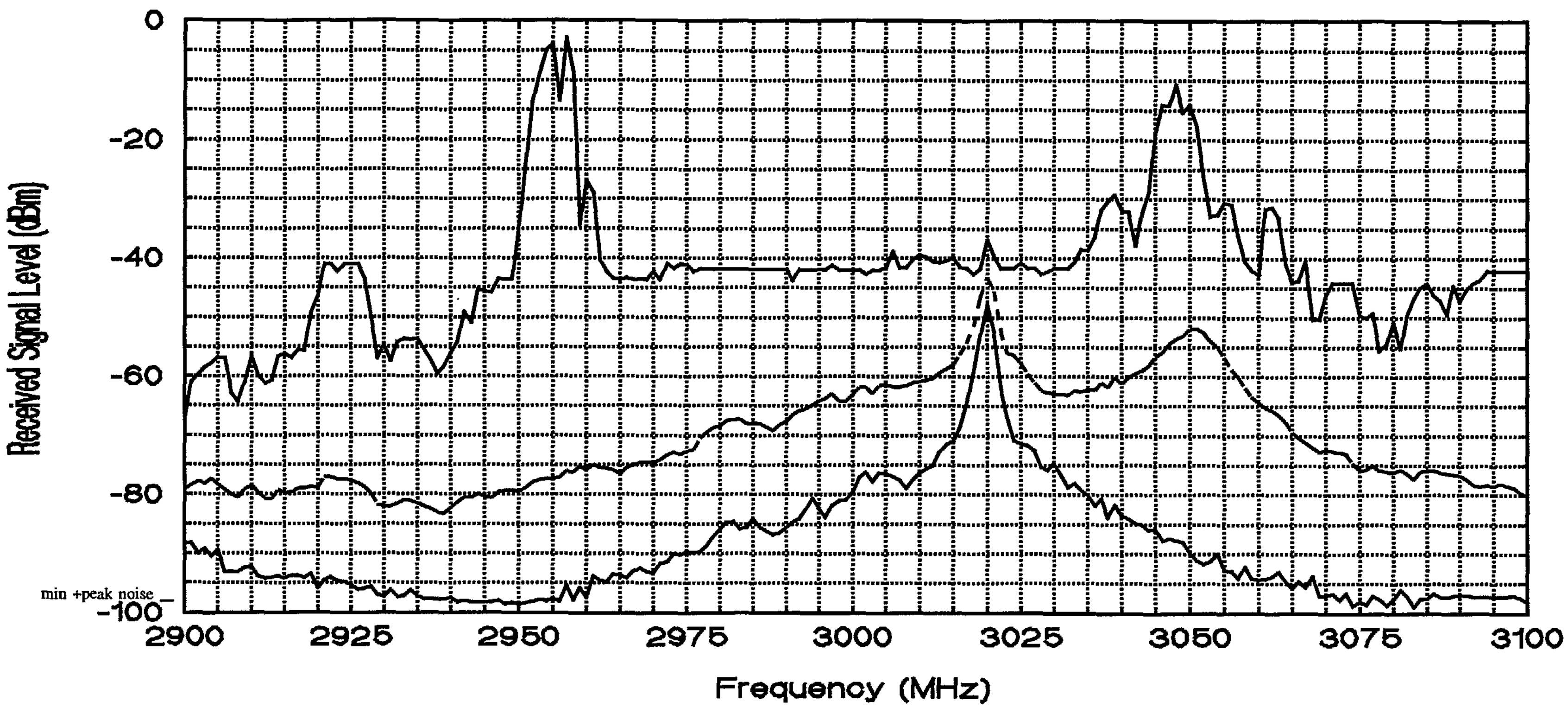
1. The aeronautical radionavigation service is restricted to ground-based radars and associated airborne transponders that transmit only in this band when actuated by these radars

2. The secondary radiolocation service is limited to the military and must be fully coordinated with the primary services.

Figure 28. NTIA spectrum survey graph summarizing 28 scans across the 2700-2900 MHz range (System-2, band event 13, stepped algorithm, +peak detector, 1000-kHz bandwidth) at San Diego, CA, 1995.

GOVERNMENT ALLOCATIONS:	MARITIME RADIONAVIGATION, Radiolocation, 1, 2
NON-GOVERNMENT ALLOCATIONS:	MARITIME RADIONAVIGATION, Radiolocation, 1, 2.
GENERAL UTILIZATION:	Maritime radars and radar beacons (racons), military high-power 3-D long-range surveillance radars and air traffic control radars.

2900 3100



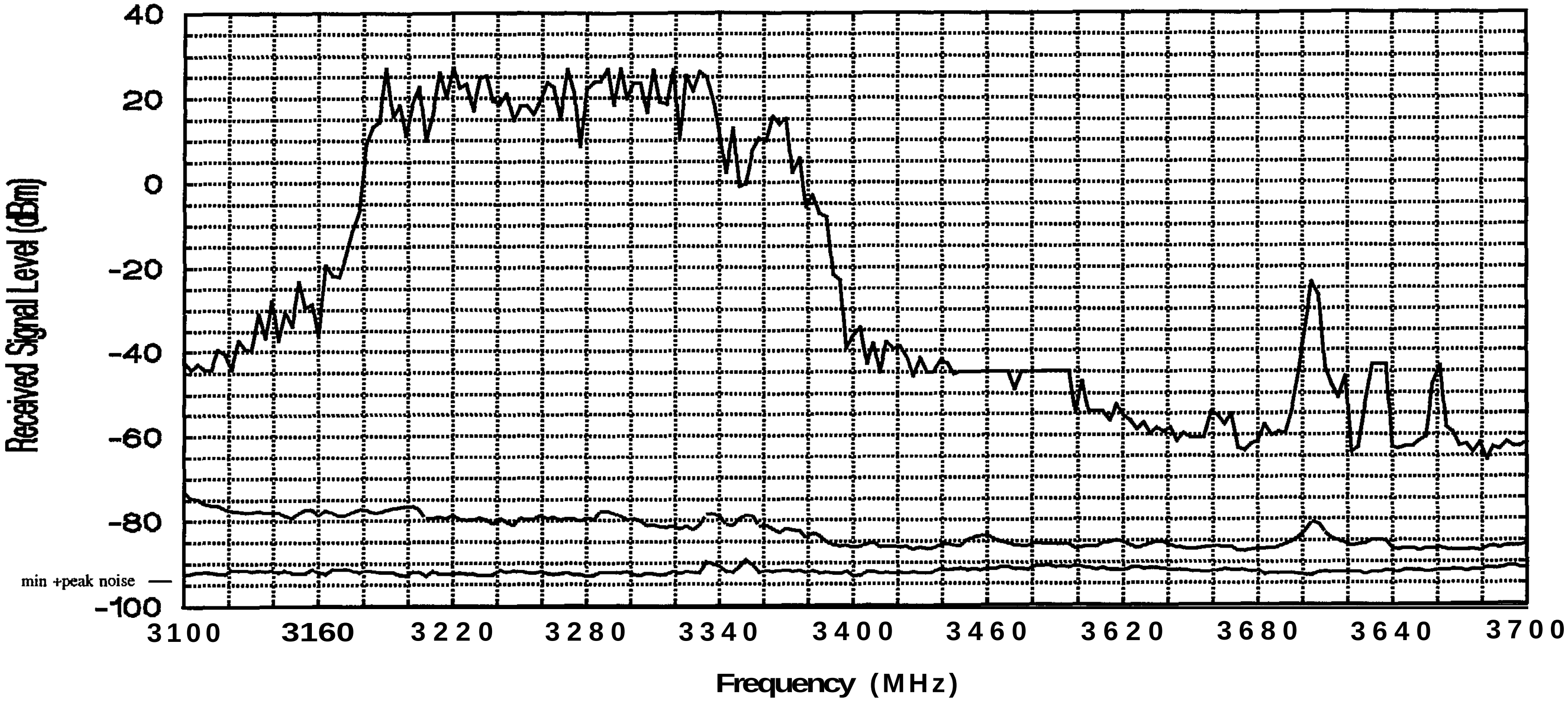
1 Radiolocation assignments are primarily for the military; however, other agency use is permitted for experimentation, research, and survey operations, if no harmful interference occurs.

2 2900-3000 MHz: Also, allocated for next generation weather radar (NEXRAD) systems

Figure 29. NTIA spectrum survey graph summarizing 48 scans across the 2900-3100 MHz range (System-2, band event 14, stepped algorithm, +peak detector, 1000-kHz bandwidth) at San Diego, CA, 1995.

GOVERNMENT ALLOCATIONS:	RADIOLOCATION	RADIOLOCATION.	RADIOLOCATION,	RADIOLOCATION,
NON-GOVERNMENT ALLOCATIONS:	Radiolocation.	Amateur, Radiolocation.	Radiolocation.	FIXED-SATELLITE (space-to-Earth), 2
GENERAL UTILIZATION:	3.	3.	3.	INMASAT, INTELSAT

3100 3300 3500 3600 3700



1. AERONAUTICAL RADIONAVIGATION (Ground-based)
2. Radiolocation.
3. Primarily military airborne, land-based, and shipborne defense radars.

Figure 30. NTIA spectrum survey graph summarizing 46 scans across the 3100-3700 MHz range (System-2, band event 15, stepped algorithm, +peak detector, 3000-kHz bandwidth) at San Diego, CA, 1995.

GOVERNMENT ALLOCATIONS·		
NON-GOVERNMENT ALLOCATIONS:	FIXED, FIXED-SATELLITE (space-to-Earth)	
GENERAL UTILIZATION·	Domestic public fixed, satellite communications.	

3700 4200

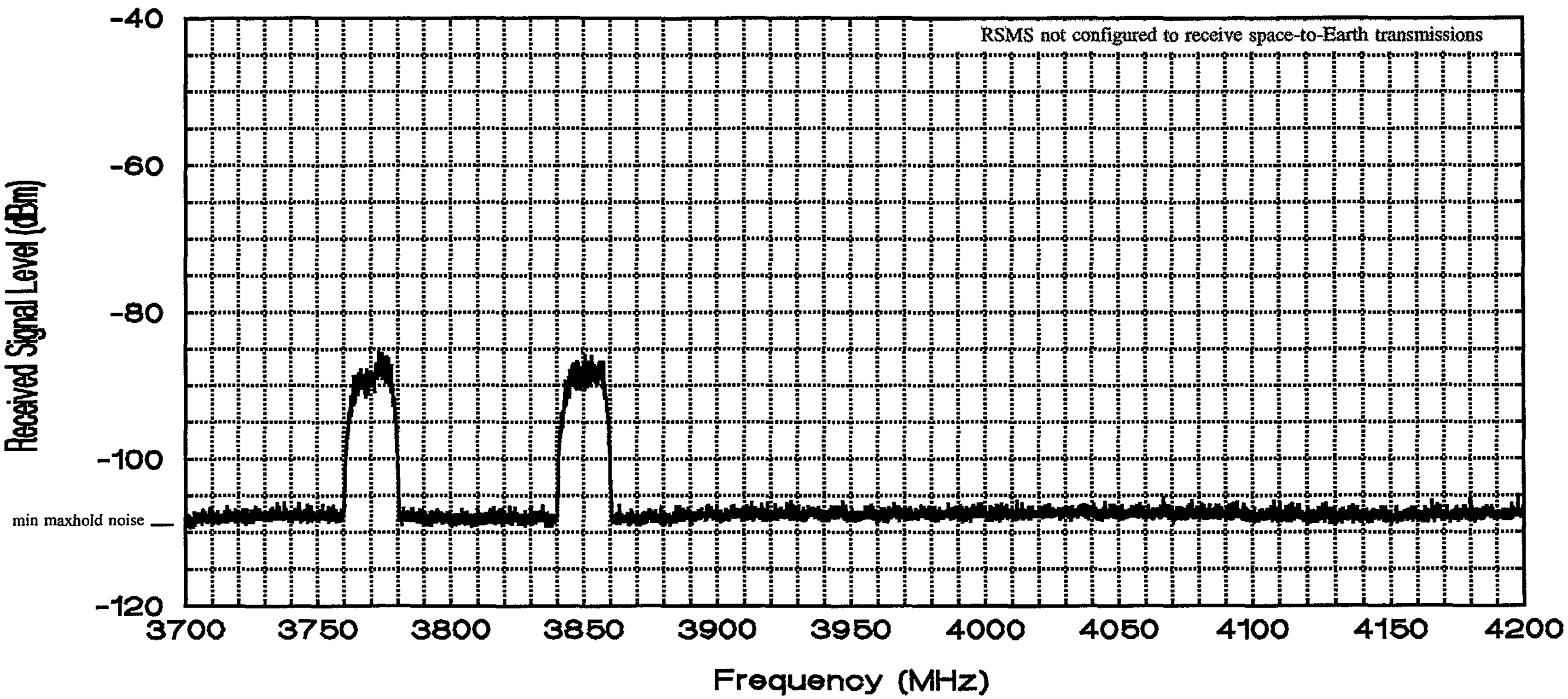
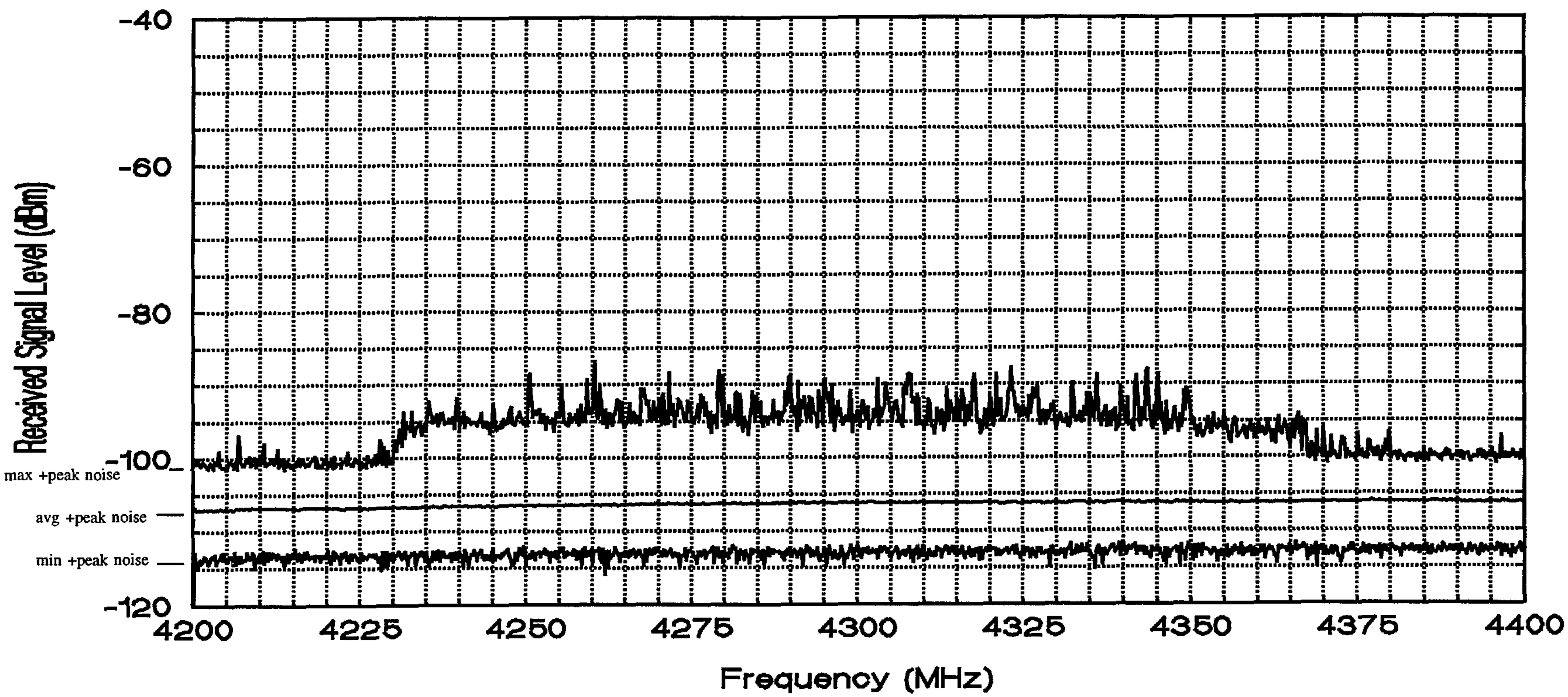


Figure 31. NTIA spectrum survey azimuth-scan graph of the 3700-4200 MHz range (System-2, band event 16, swept algorithm, maximum-hold detector, 100-kHz bandwidth) at San Diego, CA, 1995.

GOVERNMENT ALLOCATIONS:	AERONAUTICAL RADIONAVIGATION, 1
NON-GOVERNMENT ALLOCATIONS:	AERONAUTICAL RADIONAVIGATION, 1.
GENERAL UTILIZATION:	Airborne radio altimeters.

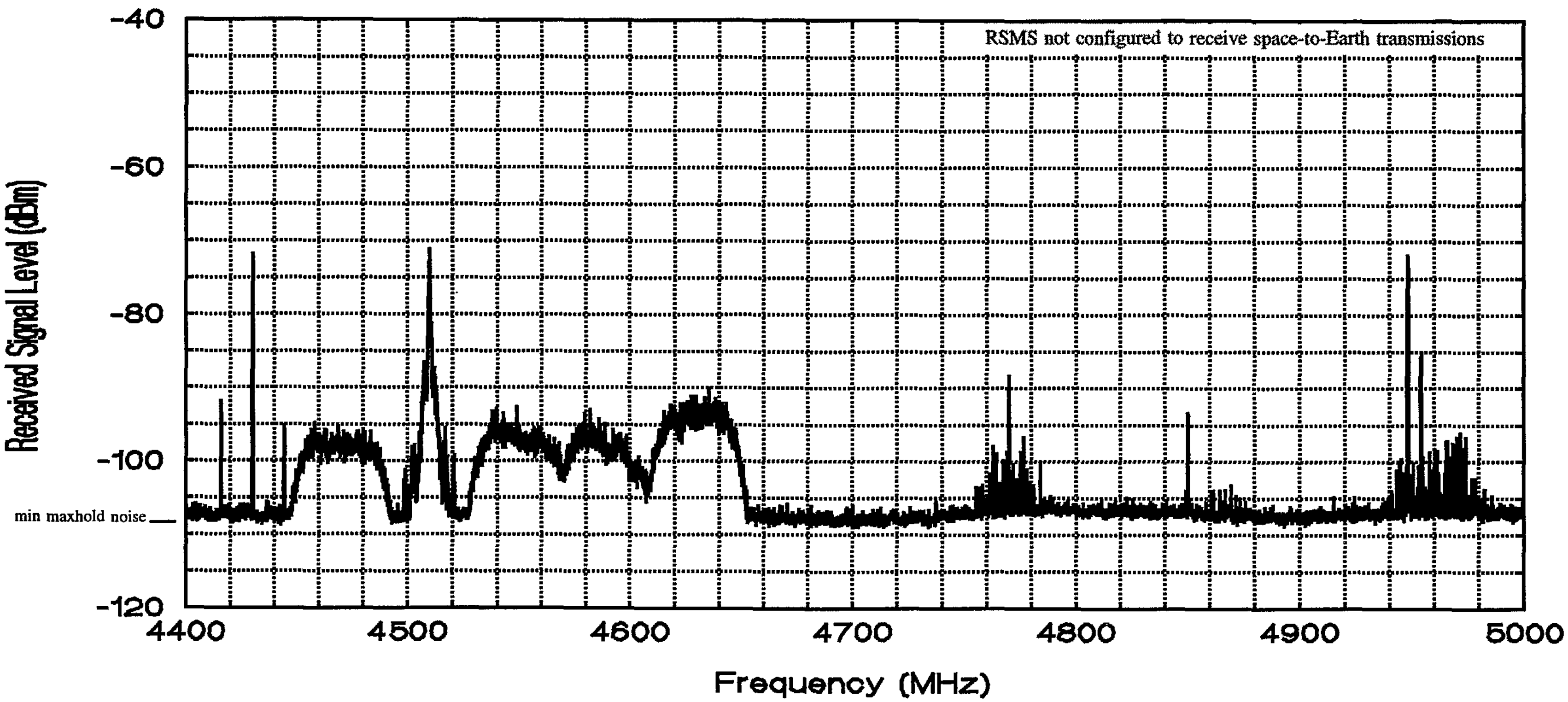
4200 4400



1. 4202 ±12 MHz: Standard frequency and time satellite service (space-to-Earth), permitted.

Figure 32. NTIA spectrum survey graph summarizing 32,500 sweeps across the 4200-4400 MHz range (System-2, band event 17, swept/m3 algorithm, +peak detector, 300-kHz bandwidth) at San Diego, CA, 1995.

GOVERNMENT ALLOCATIONS:	FIXED, MOBILE, 1.			2.	
NON-GOVERNMENT ALLOCATIONS:		FIXED-SATELLITE (space-to-Earth).		2.	
GENERAL UTILIZATION:	Narrowband and wideband uplinks and downlinks				
	4400	4500	4800	4990-5000	



1. 4660-4685 MHz: No Government allocation after August 1994.

2. RADIO ASTRONOMY, Space Research (Passive).

Figure 33. NTIA spectrum survey azimuth-scan graph of the 4400-5000 MHz range (System-2, band event 18, swept algorithm, maximum-hold detector, 100-kHz bandwidth) at San Diego, CA, 1995.

GOVERNMENT ALLOCATIONS:	AERONAUTICAL RADIONAVIGATION
NON-GOVERNMENT ALLOCATIONS:	AERONAUTICAL RADIONAVIGATION.
GENERAL UTILIZATION:	Microwave landing systems

5000 5250

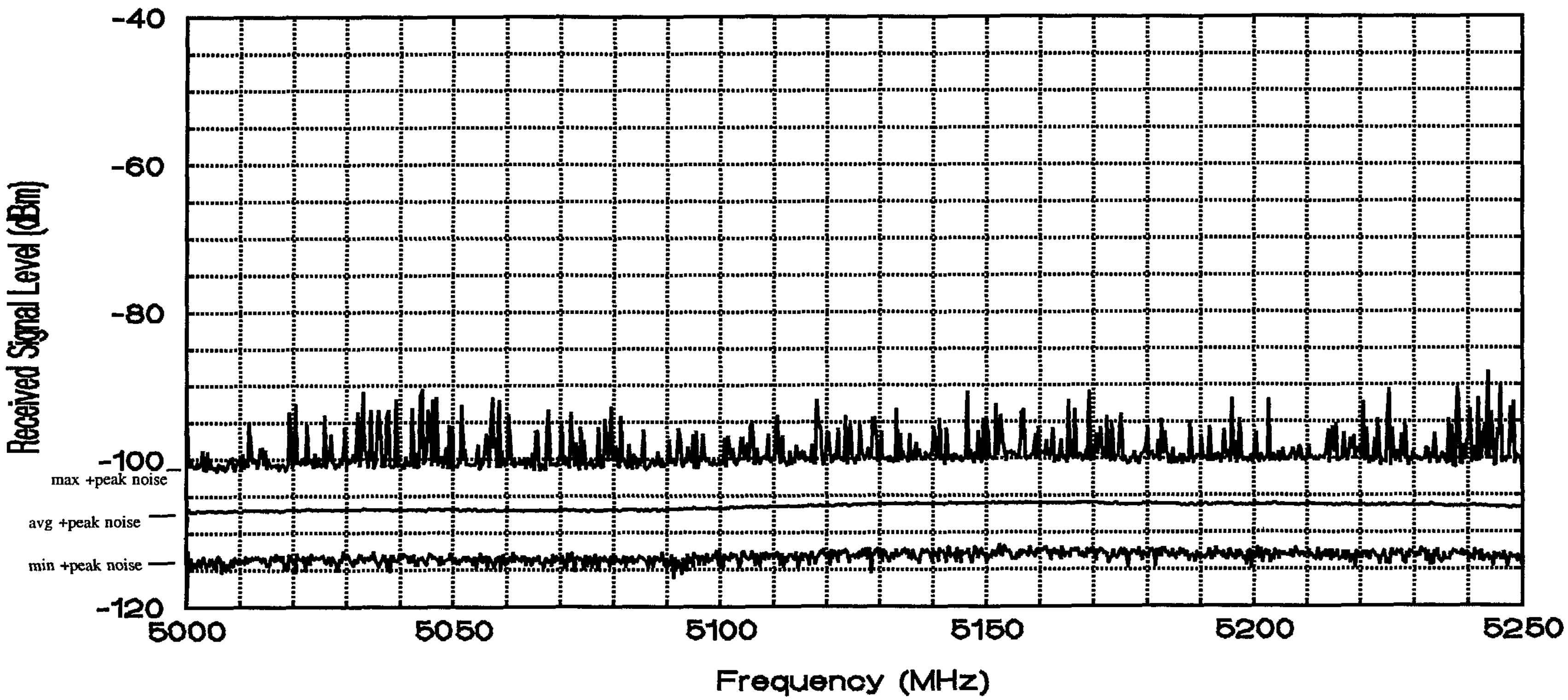
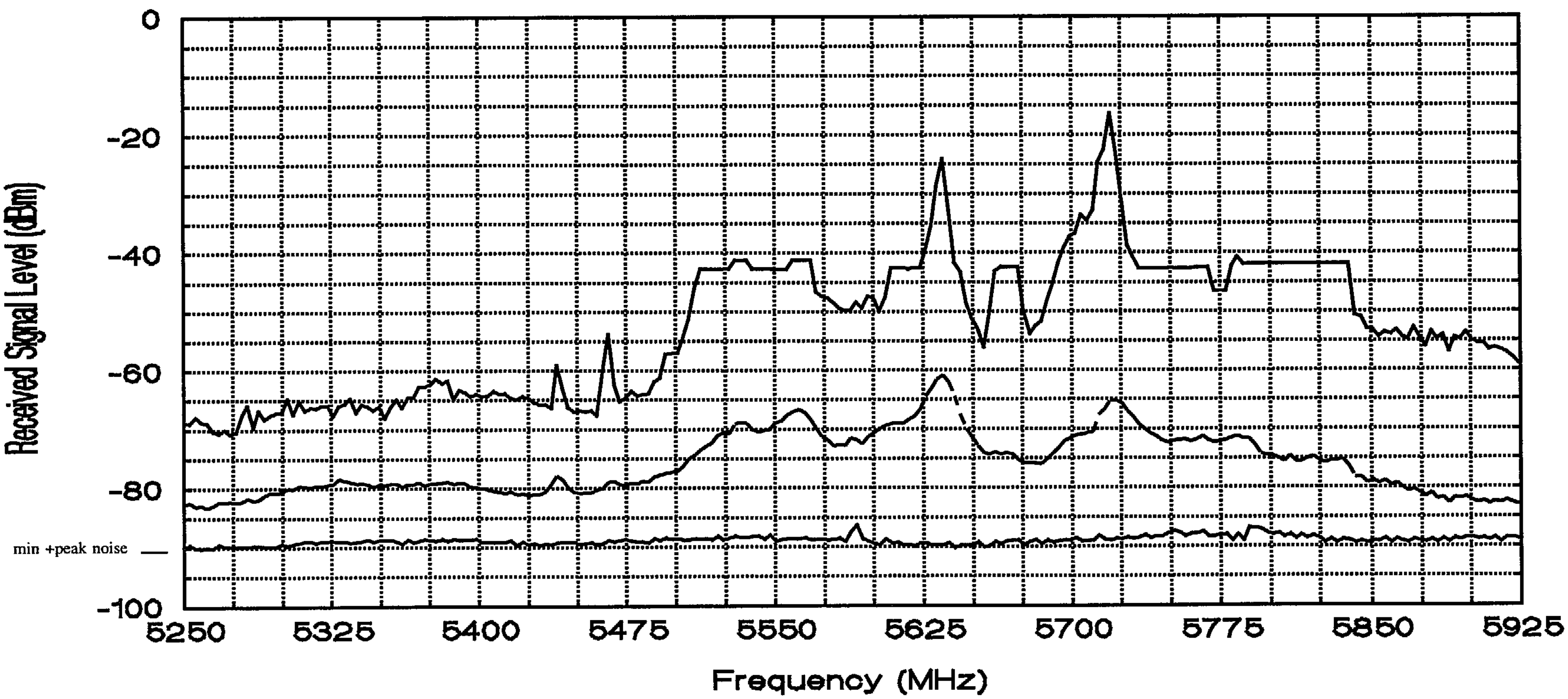


Figure 34. NTIA spectrum survey graph summarizing 32,000 sweeps across the 5000-5250 MHz range (System-2, band event 19, swept/m3 algorithm, +peak detector, 300-kHz bandwidth) at San Diego, CA, 1995.

GOVERNMENT ALLOCATIONS:	RADIOLOCATION	AERONAUTICAL RADIONAVIGATION, 1.	3.	MARITIME RADIONAVIGA-TION, Radiolocation.	4.	RADIOLOCATION.	
NON-GOVERNMENT ALLOCATIONS:	Radiolocation.	AERONAUTICAL RADIONAVIGATION, 2.	3.	MARITIME RADIONAVIGA-TION, Radiolocation	4	Amateur.	6.
GENERAL UTILIZATION.				Weather radars	5.	Military radars, 7	7.

5250 5350 5460-5470 5600 5650 5850 5925

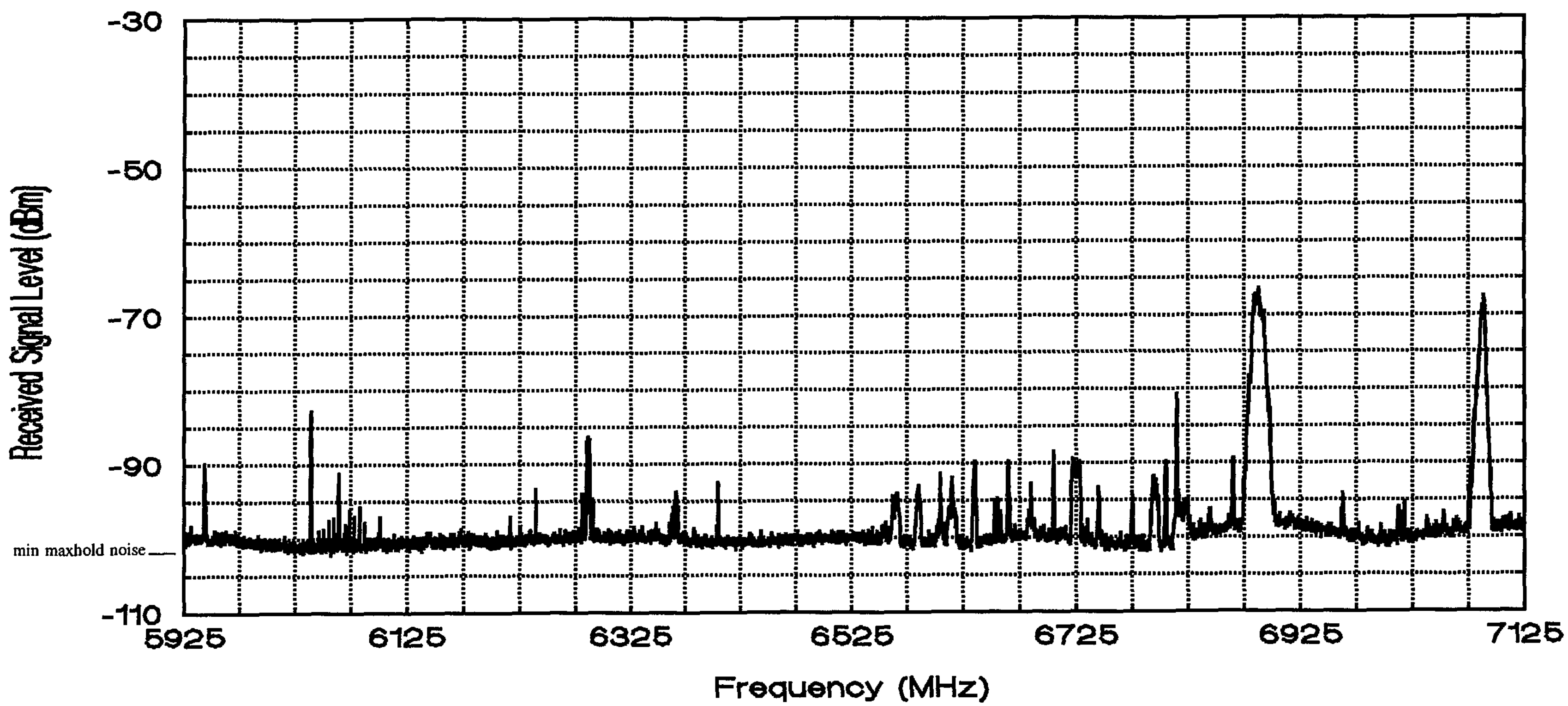


1. RADIOLOCATION
2. Radiolocation.
3. RADIONAVIGATION, Radiolocation
4. MARITIME RADIONAVIGATION, METEOROLOGICAL AIDS, Radiolocation
5. Government weather radars, e g , Terminal Doppler Weather Radar (TDWR).
6. FIXED-SATELLITE (Earth-to-space), Amateur.
7. 5725-5875 MHz: Industrial, scientific, and medical (ISM).

Figure 35. NTIA spectrum survey graph summarizing 22 scans across the 5250-5925 MHz range (System-2, band event 20, stepped algorithm, +peak detector, 3000-kHz bandwidth) at San Diego, CA, 1995.

	5925–6425	6425–6525	6525–6875	6875–7075	7075–7125
GOVERNMENT ALLOCATIONS:					
NON-GOVERNMENT ALLOCATIONS:	FIXED, FIXED-SATELLITE (Earth-to-space).	1	FIXED, FIXED-SATELLITE (Earth-to-space).	FIXED-SATELLITE (Earth-to-space), 2.	2.
GENERAL UTILIZATION:	Common carrier fixed links		Common carrier fixed links	Common carrier fixed links.	

5925 6425 6525 6875 7075 7125

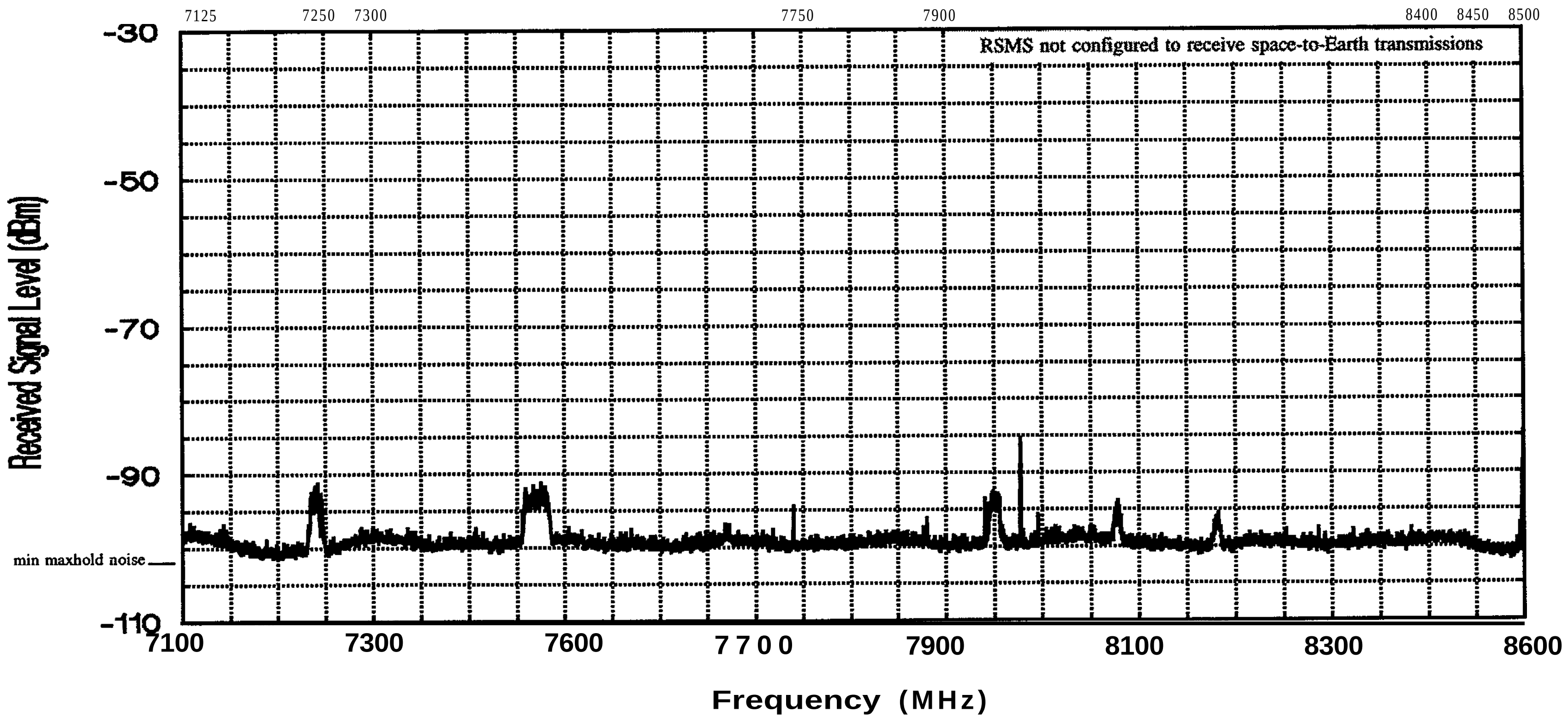


1. FIXED-SATELLITE (Earth-to-space), MOBILE

2. FIXED, MOBILE

Figure 36. NTIA spectrum survey azimuth-scan graph of the 5925-7125 MHz range (System-2, band event 21, swept algorithm, maximum-hold detector, 300-kHz bandwidth) at San Diego, CA, 1995.

	7125–7250	7250–7300	7300–7750	7750–7900	7900–8400	8400–8450	8450–8500
GOVERNMENT ALLOCATIONS:	FIXED 1.	3.	FIXED FIXED-SATELLITE (Space -to-Earth) Mobile-Satellite (space-to-Earth), 4.	FIXED	FIXED-SATELLITE (Earth-to space) 5. 6. 7.	FIXED 8, 9.	
NON-GOVERNMENT ALLOCATIONS:							8
GENERAL UTILIZATION:	2	2.	2.	2.	2.	2.	2.

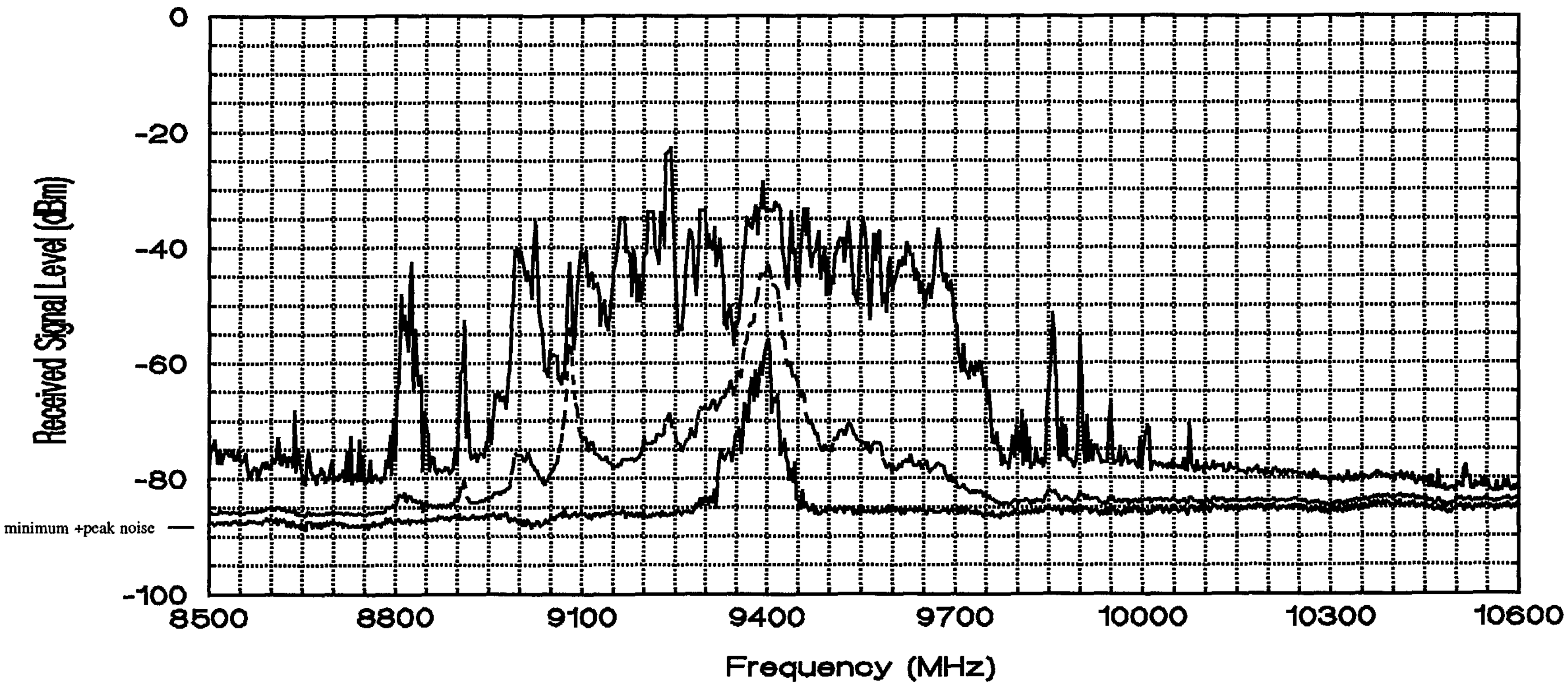


1. 7190-7235 MHz: SPACE RESEARCH (Earth-to-space).
2. Point-to-point microwave voice/data links defense satellite communications systems (DSCS)
3. FIXED-SATELLITE (space-to-Earth), MOBILE_SATELLITE (space-to-Earth), Fixed.
4. 7450-7550 MHz: METEOROLOGICAL-SATELLITE (space-to-Earth).
5. 7900-8025 MHz: MOBILE-SATELLITE (Earth-to-space), fixed.
6. 8025-8400 MHz: EARTH EXPLORATION-SATELLITE (space-to-Earth). FIXED, Mobile-Satellite (Earrh-to-space) (no airborne transmissions).
7. 8175-8215 MHz: METEOLOGICAL-SATELLITE (Earth-to-space).
8. SPACE RFSEARCH (space-to-Earth) (Government: 8400-8450 MHz deep space only)
9. 8400-8450 MHz: Deep space only

Figure 37. NTIA spectrum survey azimuth-scan graph of the 7125-8500 MHz range (System-2, band event 22, swept algorithm, maximum-hold detector, 300-kHz bandwidth) at San Diego, CA, 1995.

	8500–9000	9000–9200	9200–9300	9300–9500	9500–10000	10000–10450	10450–10550
GOVERNMENT ALLOCATIONS:	RADIOLOCATION	1	2	3	RADIOLOCATION.		
NON-GOVERNMENT ALLOCATIONS:	Radiolocation.	1.	2	3.	Radiolocation.	Amateur, Radiolocation.	6.
GENERAL UTILIZATION:	Military use is primary.			4.	5		

8500 9000 9200 9300 9500 10000 10450 10550

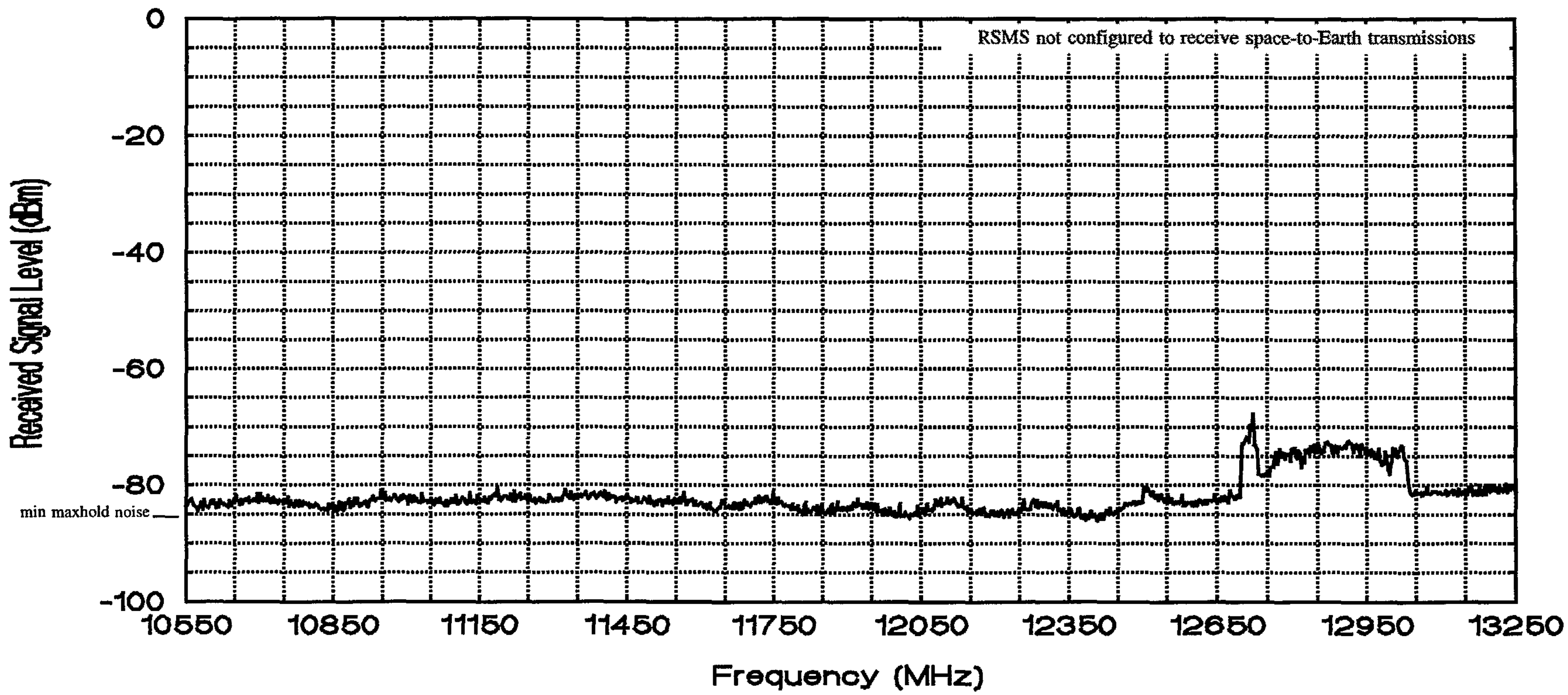


1. AERONAUTICAL RADIONAVIGATION, Radiolocation.
2. MARITIME RADIONAVIGATION, Radiolocation.
3. RADIONAVIGATION, Meteorological Aids, Radiolocation
4. Maritime radionavigation radar, airborne weather radar, radar transponder beacons (RACONS)
5. Military airborne radar.
6. RADIOLOCATION. 10450-10500 MHz: Amateur, Amateur-Satellite.

Figure 38. NTIA spectrum survey graph summarizing 23 scans across the 8500-10550 MHz range (System-2, band event 23, stepped algorithm, +peak detector, 3000-kHz bandwidth) at San Diego, CA, 1995.

GOVERNMENT ALLOCATIONS:	1.					
NON-GOVERNMENT ALLOCATIONS:	2	FIXED, FIXED-SATELLITE (space-to-Earth).	FIXED-SATELLITE (space-to-Earth), 3.	FIXED, BROADCASTING-SATELLITE	FIXED, FIXED-SATELLITE (Earth-to-space), MOBILE.	
GENERAL UTILIZATION:		Common carrier point-to-point microwave links, television studio-to-transmitter links.		Direct broadcast satellite services (DBS).	Cable Relay Systems (CARS), 4	

10550 10700 11700 12200 12700 13250



1 10600-10700 MHz: EARTH EXPLORATION-SATELLITE (Passive), SPACE RESEARCH (Passive)
10680-10700 MHz: RADIO ASTRONOMY

2 10550-10680 MHz: FIXED 10600-10700 MHz: EARTH EXPLORATION-SATELLITE (Passive), SPACE RESEARCH (Passive). 10680-10700 MHz RADIO ASTRONOMY

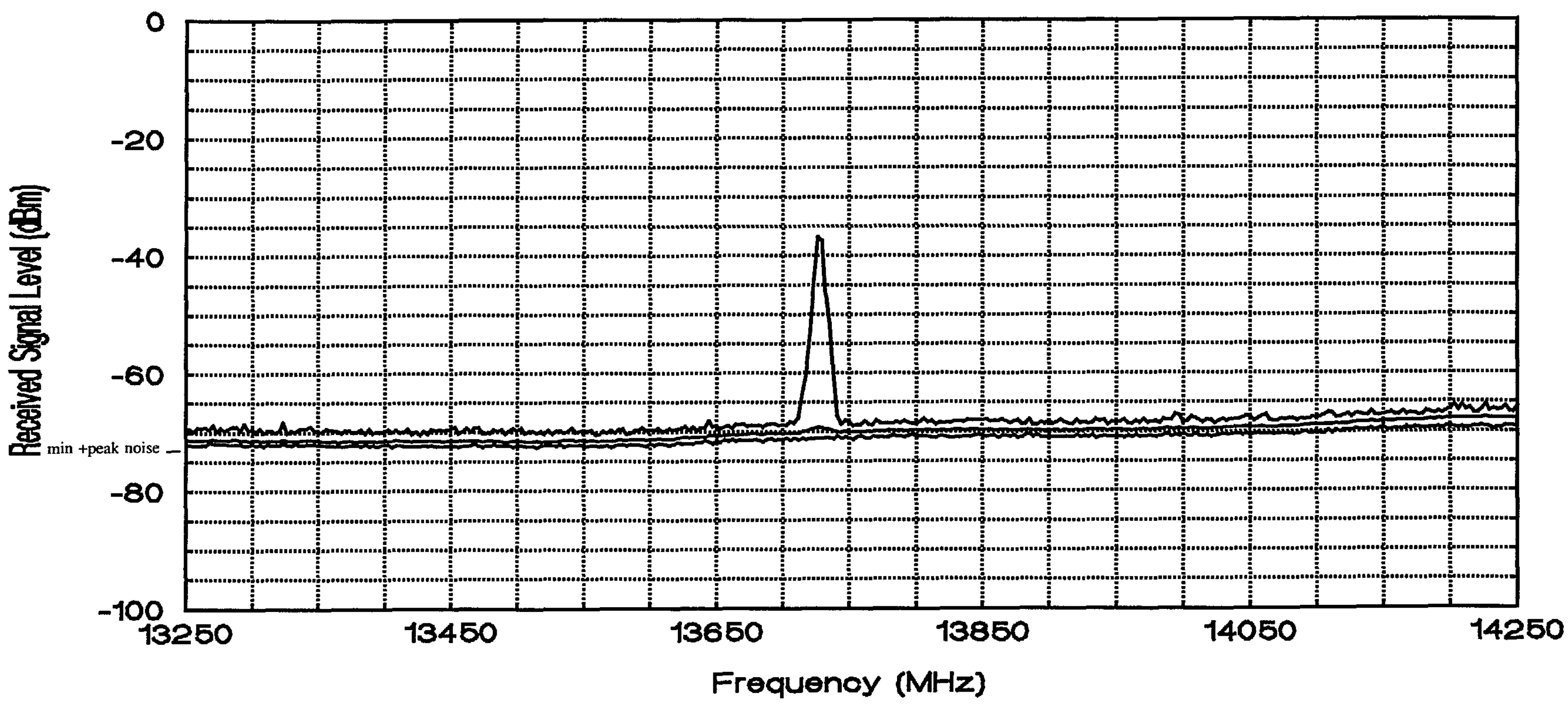
3 Mobile except aeronautical mobile.

4. Television auxiliary broadcasting (includes: SHL, STL, ENG, and ICR's)

Figure 39. NTIA spectrum survey azimuth-scan graph of the 10550-13250 MHz range (System-2, band event 24, swept algorithm, maximum-hold detector, 3000-kHz bandwidth) at San Diego, CA, 1995.

GOVERNMENT ALLOCATIONS:	AERONAUTICAL RADIONAVIGATION, 1	RADIOLOCATION, Space Research, Standard Frequency and Time Signal-Satellite (Earth-to-space).	RADIONAVIGATION, Space Research.	
NON-GOVERNMENT ALLOCATIONS:	AERONAUTICAL RADIONAVIGATION, 1.	Radiolocation, Space Research, Standard Frequency and Time Signal-Satellite (Earth-to-space).	RADIONAVIGATION, Space Research, 2.	
GENERAL UTILIZATION:		Military airborne radars.		

13250 13400 14000 14200



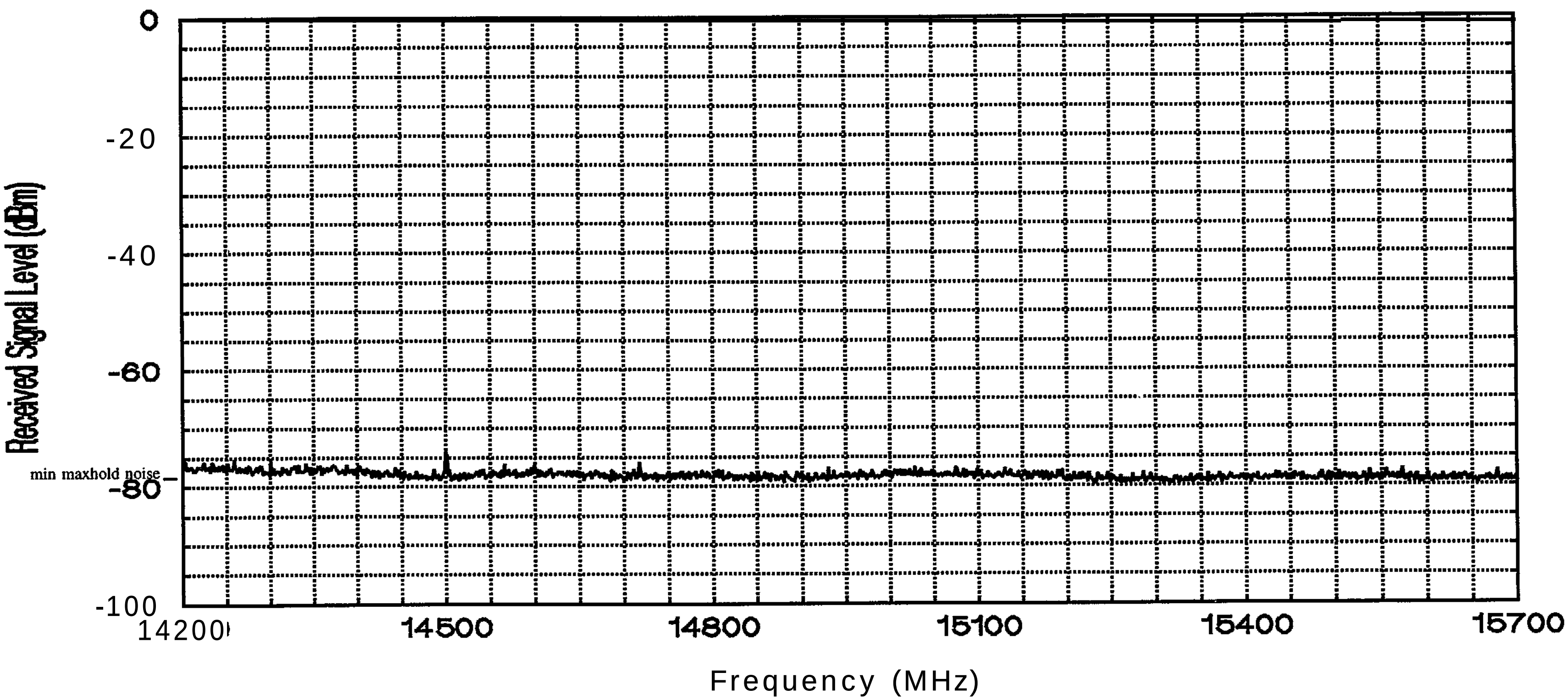
1 Space Research (Earth-to-space).

2. FIXED-SATELLITE (Earth-to-space).

Figure 40. NTIA spectrum survey graph summarizing 40 scans across the 13250-14200 MHz range (System-2, band event 25, stepped algorithm, +peak detector, 3000-kHz bandwidth) at San Diego, CA, 1995.

	14200–14400	14400–14500	14500–14714.5	14714.5–15136.5	15136.5–15350	15350–15400	15400–15700
GOVERNMENT ALLOCATIONS:		Fixed, Mobile.	FIXED, Mobile, Space Research.	MOBILE, Fixed, Space Research.	FIXED, Mobile, Space Research	3	AERONAUTICAL RADIONAVIGATION
NON-GOVERNMENT ALLOCATIONS:	FIXED-SATELLITE (Earth-to-space)	1.				3.	AERONAUTICAL RADIONAVIGATION
GENERAL UTILIZATION:			2.		2		

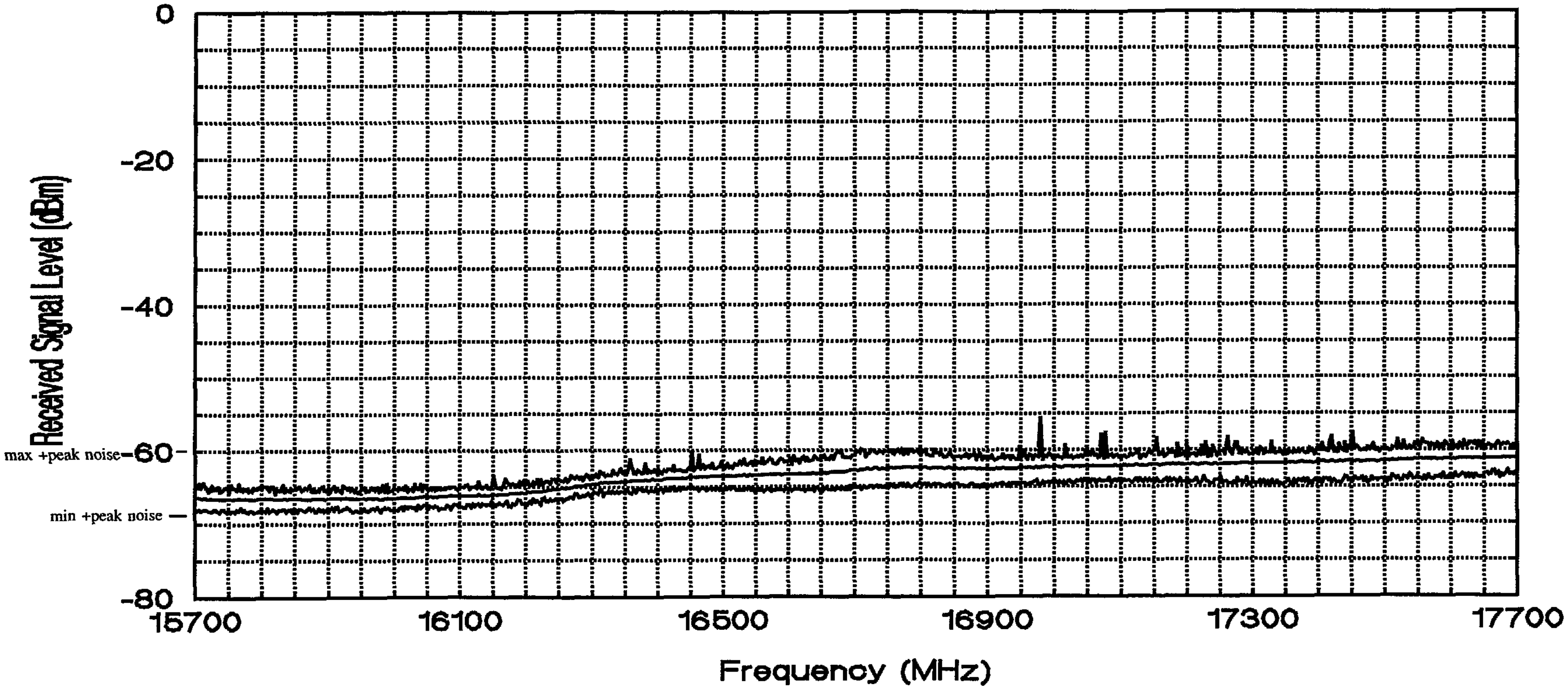
14200 14400 14500 14714.5 15136.5 15350-15400 15700



1. FIXED-SATELLITE (Earth-to-space).
2. Military communication links and microwave Inks. Air traffic control links, including video data.
3. EARTH EXPLORATION-SATELLITE (Passive), RADIO ASTRONOMY, SPACE RESEARCH (Passive).

Figure 41. NTIA spectrum survey azimuth-scan graph of the 14200-15700 MHz range (System-2, band event 26, swept algorithm, maximum-hold detector, 3000-kHz bandwidth) at San Diego, CA, 1995.

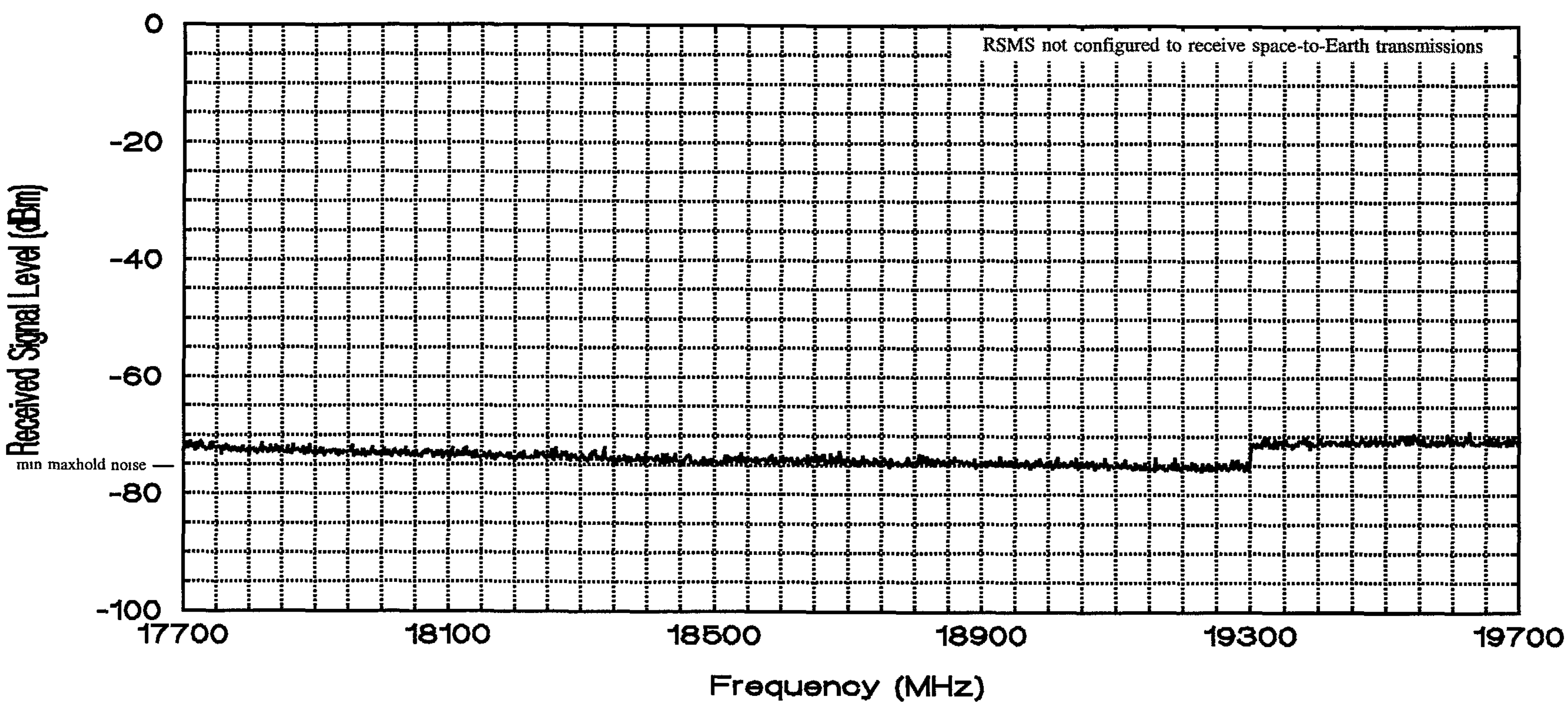
GOVERNMENT ALLOCATIONS:	RADIOLOCATION.	RADIOLOCATION, Space Research (Deep Space) (Earth-to-space)	1.	3	Radiolocation.
NON-GOVERNMENT ALLOCATIONS:	Radiolocation.	Radiolocation.	2.	4.	FIXED-SATELLITE (Earth-to-space).
GENERAL UTILIZATION·	Military airborne radars.	Military airborne radars.			
	15700	16600	17100	17200	17300 — 17700



1. RADIOLOCATION.
2. Radiolocation.
3. RADIOLOCATION, Earth Exploration-Satellite (Active), Space Research (Active)
4. Earth Exploration-Satellite (Active), Radiolocation, Space Research (Active)

Figure 42. NTIA spectrum survey graph summarizing 39 scans across the 15700-17700 MHz range (System-2, band event 27, stepped algorithm, +peak detector, 3000-kHz bandwidth) at San Diego, CA, 1995.

GOVERNMENT ALLOCATIONS		2.		
NON-GOVERNMENT ALLOCATIONS	FIXED, MOBILE, FIXED-SATELLITE (space-to-Earth), 1	3	FIXED, FIXED-SATELLITE (space-to-Earth), MOBILE	
GENERAL UTILIZATION:	General purpose point-to-point microwave band including private, common carrier, cable television relay systems (CARS), studio-to-transmitter (STL) television links, Digital Electronic Message Services (DEMS), etc			
	17700	18600	18800	19700



1 17700-17800 MHz. FIXED-SATELLITE (Earth-to-space)
2 EARTH EXPLORATION-SATELLITE (Passive), SPACE RESEARCH (Passive)
3. FIXED, FIXED-SATELLITE (space-to-Earth), EARTH EXPLORATION-SATELLITE (Passive), MOBILE (exc. aeronaut mobile), SPACE RESEARCH (Passive)

Figure 43. NTIA spectrum survey aximuth-scan graph of the 17700-19700 MHz range (System-2, band event 28, swept algorithm, maximum-hold detector, 3000-kHz bandwidth) at San Diego, CA, 1995.

measured with different bandwidths and algorithms. This is the case for Figures 21 and 22. Figure 22 covers the same frequency range as the upper 25% of Figure 21, but the appearance of the two graphs is completely different. The signals in Figure 22 appear (at first glance) to be much stronger and denser than those in the common part of Figure 21.

The previous two examples are given as a caution to the reader that each survey band is intended to best describe the signal environment within its frequency range and is not, generally comparable to other survey bands. The summary observations of Section 3.5 should be of help with interpretation of the data graphs.

3.5 Observations on Measured Data and Spectrum Use

It is important to understand what aspects of spectrum use can be extrapolated from the RSMS data presented in this report, and also what aspects of spectrum use cannot be inferred from these data. First, the data acquisition was performed at a single location in the San Diego metropolitan area during a two-week period spanning the end of February and the beginning of March 1995. In most measured bands, the RSMS data presented in this report show maximum, minimum, and average measured power levels of received signals. In these bands, the cumulative measurement time during the survey was typically several hours, spread uniformly over the diurnal cycle. For some bands that were nondynamic and measured with the azimuth-scanning technique, only a single occupancy curve is shown.

Based on the measurement and sampling techniques used, we believe that these data represent an extremely good statistical sampling of the activity in the radio spectrum in the San Diego metropolitan area. Maximum and minimum activity levels measured in the spectrum are probably very good representations of actual activity levels. The average curves provide a good qualitative estimate of the typical received power as a function of frequency. The maximum, minimum, and average curves can also be used to qualitatively assess the relative density of channel occupancy on a band-by-band basis. In the azimuth-scan bands, the single curve which is shown likewise provides a good estimate of the density of spectrum occupancy in the survey area.

However, while the data presented here can be used to infer the density of frequency occupancy, these data ***cannot*** be used to infer the statistical percentage of time that channels are occupied. A good analogy is to imagine counting houses while driving along a street: one can easily count the number of houses that have been built on each block (analogous to counting the number of frequencies that show activity in each band in the RSMS survey), but one cannot tell, on the basis of that count, what percentage of time the houses are occupied. Signals that are observed in 100% of the scans can be determined, because the minimum curve will show such activity. Other than 100% signals, the average curves provide a qualitative, not quantitative, measure of occupancy for the measured frequencies.

There is an RSMS measurement technique for obtaining absolute channel occupancy statistics. Measurements of this type were performed (in mobile radio bands) in conjunction with the RSMS occupancy survey in San Diego. Results of those measurements will be published separately.

3.5.1 Band-by-band Observations on Spectrum Use in the San Diego Area

Table 7 contains band-by-band observations on spectrum occupancy in the San Diego area. The comments are based on examination of the RSMS data collected during the spectrum survey and frequency allocation information in the NTIA Manual [1, Chapter 4].

Table 7. Comments on San Diego Spectrum Occupancy Measurement Results

Spectral Range	Figure	Comments
108-138 MHz	4	Across the 108-l 14 MHz range, 40 dB of RF attenuation were used in the RSMS front-end to prevent overload by signals in the adjacent 88-108 MHz commercial FM radio broadcast band. This raised the RSMS noise floor in this range by 40 dB relative to the rest of the band, and reduced RSMS sensitivity to signals in the 108-l 14 MHz range by the same amount. Instrument landing system (ILS) localizers transmit in the 108-112 MHz range, but detection was not expected due to the high RSMS noise figure in this range. However, an ILS glideslope signal is observed at 333 MHz. Across 108-118 MHz, very-high frequency omnidirectional range (VOR) aeronautical navigation beacons are observed as 100% emitters. These are seen as vertical lines coming up from the minimum curve. Also, in the air traffic control (ATC) band across 118-136 MHz, automated terminal information service transmissions appear as high-average or 100% signals. Frequently used ATC frequencies also appear as high points on the average curve. Air mobile frequencies that were used at least once during the survey are observed on the maximum curve. A large number of the available channels in the ATC band were used during the survey period. In the 137-138 MHz band, television infrared observation satellite signals are not receivable by the RSMS. NOAA weather satellites operate at 137.62 MHz. Signal occupancy observed at 137.6 MHz (at about -60 dBm) is stronger than expected for a NOAA weather satellite.
138-162 MHz	5	A large number of mobile and amateur signals are observed in the 138-148 MHz portion of the spectrum. The average curve is significantly raised across 144-148 MHz, used by amateurs. Between 148-162 MHz, a large percentage of available channels also show use. Transmitters between 152-153 MHz were in operation continuously during the survey period. Maritime mobile signals occur between 156.2475-162.025 MHz. All of these channels show some occupancy, consistent with expectations for the San Diego area. During the survey, routine station identification monitoring indicated unauthorized use of frequencies at and near 150 MHz in the San Diego area. This information was sent to the FCC Field Enforcement Bureau, which later located several unauthorized sources in southern California, including fishing boats offshore.

Table 7. Comments on San Diego Spectrum Occupancy Measurement Results (Continued)

Spectral Range	Figure	Comments
162-174 MHz	6	A variety of fixed and mobile signals are observed. The signal near 162.5 MHz is a public broadcast weather information channel. Essentially all of the channels in this band show some occupancy during the survey period, and many channels raise the average curve.
174-216 MHz	7	Television broadcast channels 8, 10, and 12 are occupied. Adjacent broadcast channels are unoccupied, in accordance with FCC regulations. Twenty dB attenuation was used to prevent front-end overload in RSMS.
216-225 MHz	8	Some channels are used in the 216-220 MHz maritime mobile allocation. Signals that are possibly from a trunked system occur between 220-220.75 MHz. Identical received amplitudes of five signals between 220-220.7 MHz implies the possibility of a single, fixed location of origin. These signals may be from an LMR base station. Amateur signals are observed above 221 MHz, and the relative density of channel occupancy increases above 223.5 MHz. No military radiolocation occurs in this spectral range in the San Diego area.
225-400 MHz	9	Military ATC communications are observed. Many of these signals are 100% transmissions from fixed Iocations. Even signals that are less than 100% often are used enough of the time to significantly affect the average curve. ILS glideslope signal is observed at about 333 MHz.
400-406 MHz	10	Fifteen to twenty signals are observed in this meteorological aids band for brief intervals during the survey period. The relative paucity of observed signals is consistent with typically low EIRP and typically intermittent operation of most systems that use this band (e.g., radiosonde).
406-420 MHz	11	A number of fixed and mobile signals (about 30) affecting the minimum and average curves, are observed. Four of the signals are observed in 100% of RSMS data scans.
420-450 MHz	12	High-power radar signals produce essentially all of the occupancy observed in this band. Some of these signals saturated the RSMS at amplitudes in excess of -25 dBm in 50 ohms, with the omnidirectional receiving antenna. The radars are on ships and naval aircraft. Compare the high level of activity in this band in the San Diego area with practically nonexistent activity in the same band in the Denver, Colorado area [2].
450-470 MHz	13	A large number of land mobile signals are observed, and many of them affect the average curve. The band edges of the 460-465 MHz base station allocation are very distinct.

Table 7. Comments on San Diego Spectrum Occupancy Measurement Results (Continued)

Spectral Range	Figure	Comments
470-512 MHz	14	Between 470-490 MHz, the RSMS front-end was operated with 30 dB RF attenuation to prevent front-end overload by the TV broadcast channel 15 signal. The rest of this band was measured without RF attenuation. The result is a noise floor that is 30 dB higher across 470-490 MHz than across the rest of the band. Television broadcast channels 15 and 19 are occupied by local San Diego stations. Channel 18 is occupied by station KSCI in Los Angeles. The rest of the occupancy observed in this band is generated by nontelevision transmitters. Spectrum nominally allocated for television broadcast channels 14, 16 and 20 shows use by the Los Angeles T-band land mobile radio allocation, as defined in the CFR [3, Part 90.3111, for ten major urban areas in the United States. Base stations operate in the lower half of each channel, and mobile stations operate in the upper half of each channel. In particular, the lower half of channel 16 shows use by Los Angeles County public safety base stations for land mobile radio. Note that, although the T-band allocations are for Los Angeles, which is nominally well beyond line-of-sight from the RSMS location at Point Loma, spectrum occupancy by these systems is still readily observed in the San Diego area. This may be due to propagation from high terrain in the southern Los Angeles area, and/or to ducting phenomena. Channel 17 shows occupancy by low-power television in the San Diego area, and also by local area networks in Mexico.
512-806 MHz	15	All of the signals observed in this band appear to be UHF television broadcast. At least nine of them were observed in 100% of RSMS scans, the remainder having been turned off at least once during the survey.
806-902 MHz	16	Cellular, trunked, and public safety portions of this part of the spectrum are clearly delineated. Mobile and base parts of the band are also clearly identifiable. Within the 806-821 MHz (mobile conventional and trunked) band segment, most occupancy occurs between 811-821 MHz. The 821-824 MHz mobile public safety band shows occupancy by four signals, but the probability of intercept (POI) for such signals by the RSMS is low (compare to the 866-869 MHz base public safety band, below). The 824-849 MHz cellular mobile band shows enough use by mobile units to raise the average curve slightly. The 849-851 MHz ground-to-air allocation shows no measured occupancy, although the POI for such signals by the RSMS is low. The 851-866 MHz base conventional and trunked band shows occupancy that significantly raises the average curve. The 866-869 MHz base public safety shows occupancy on about twenty channels, and the average curve is affected. The 869-894 MHz band, occupied by cellular base stations, is distinctly observed. The 100% use channels between 879.3-880.5 MHz are probably system control channels. Air-to-ground signals between 894-896 MHz are observed, confirming that low POI probably prevents the RSMS from measuring corresponding ground-to-air signals. A few signals are observed in the 896-901 private land mobile band, and a single signal was recorded in the 901-902 MHz general mobile allocation.

Table 7. Comments on San Diego Spectrum Occupancy Measurement Results (Continued)

Spectral Range	Figure	Comments
902-928 MHz	17 & 18	This band is measured two different ways: with the positive peak detector in maximum hold mode and I0-kHz IF bandwidth, as shown in Figure 17, and with the positive peak detector in stepped mode and I-MHz bandwidth, as shown in Figure 18. The narrow-IF bandwidth, maximum-hold measurement is intended to show industrial, scientific and medical (ISM) and Part 15 device operations, while the wide-IF bandwidth, stepped algorithm is intended to optimize the RSMS for measurement of radar signals in the band. For the San Diego area, both algorithms produce band occupancy measurements that show a higher level of occupancy than was indicated in the Denver, Colorado survey measurements [2]. A wide variety of systems operate in this band. These include, but are not limited to, high-power naval radars (primary allocation in the band), ISM devices, Part 15 devices, wireless local area networks (required to either use spread spectrum or frequency-hopping transmitters), automatic vehicle monitoring, digital communication systems, repeaters, and amateurs. Figure 17 shows the cumulative effect of nonradar devices on spectrum occupancy in this band. Radar emissions tend to be discriminated out of these data by the narrowband (l0-kHz) IF. Maximum observed signal amplitude in this bandwidth is about -60 dBm on an omni antenna. Note that many of the signals are observed in 100% of RSMS data scans. Signals between 926-928 MHz are apparent intermodulation products from pager systems operating between 928-932 MHz. Figure 18, made with positive peak detection in a l-MHz IF bandwidth, primarily shows activity of high-power naval radars. Note that, with the wider measurement bandwidth, which more closely matches the emission bandwidth of the radar signals, the maximum measured amplitude of the signals in the band exceeds a value of -30 dBm in 50 ohms, as received on the RSMS omni antenna.
928-960 MHz	19	Paging systems are observed between 928-932 MHz. Possible intermodulation products from these pagers are observed adjacent to this spectral range, between 926-928 MHz and 932-934 MHz. The 932-935 MHz point-to-point and point-to-multipoint band is clearly delineated, as is the 935-940 MHz land mobile band. Two signals were constantly present in the 941-944 MHz band for fixed, point-to-point, and point-to-multipoint communications. Most signals in the 944-960 MHz fixed band (auxiliary broadcasting, fixed private microwave, and studio-to-transmitter links) were present in 100% of RSMS data scans.

Table 7. Comments on San Diego Spectrum Occupancy Measurement Results (Continued)

Spectral Range	Figure	Comments
960-1215 MHz	20	Activity in this band is produced entirely by aeronautical navigation aids. These include tactical air navigation beacons (TACAN), distance-measuring equipment (DME), and air traffic control radar beacon system (ATCRBS) interrogators and transponders. Probable TACAN signals appear as bumps in the average curve at (approximately) 978, 995, 1007, 1012, 1174, 1187, 1204, and 1212 MHz. DME airborne interrogations occur from 1025- 1150 MHz; DME ground beacons reply between 962-1025 MHz and 1150-1213 MHz. Note the delineation that is visible at 1150 MHz. ATCRBS ground-based interrogations occur at 1030 MHz, and airborne replies occur at 1090 MHz. Both of these peaks are clearly visible in the data. Because the emissions in this band are primarily pulsed, the average curve is essentially unaffected by all signals except TACAN.
1215-1400 MHz	21	This band shows occupancy by high-power, long-range air search radars. Frequencies occupied by distinctly identifiable radar signals are 1255, 1270, (with other peaks noted at 1274-1282, 1314-1318, and 1359-1371 MHz), 1295, 1305, 1342, 1349, and 1392 MHz. The radar at 1255 MHz also operated briefly at 1250 MHz, and this occurred during a scan in which attenuation was not invoked in the RSMS; hence, this peak occurs as a shelf to the left of the peak at 1255 MHz. It is not known which of these radars, if any, genertited the peak at 1265 MHz. All of the measured signals between these peaks are spurious emissions from these radars. Emission parameters vary, but values measured by the RSMS crew are typically as follows: mechanical beam rotation, 9-12 s rotation time, l-6 us pulse widths, and 300-600 pulses per second transmitted. These radars usually are observed to emit staggered pulse trains, probably to enhance doppler processing of target returns.
1350- 1400 MHz	22	Unlike the measurements made in the 1215-1400 MHz band, measurements in this band are optimized to observe nonradar emissions. Nevertheless, most of the activity observed in this band is from radars. The prominent features at 1350-1355, 1360-1372, and 1392 MHz are generated by the air search radars shown in Figure 21. No nonradar signals are noted in this band. Because they are pulsed signals received approximately every 9-12 s, the average and minimum curves are unaffected.
1400-1530 MHz	23	Six distinct signals are observed in this band by the RSMS. The frequencies are 1449, 1459, 1464, 1482, 1502, and 1512 MHz. Four of these signals are present in 100% of RSMS data scans.
1530-1710 MHz	24	Some signals are observed at 1610.5, 1625-1645, 1655-1665, and 1670-1690 MHz. We infer that the other signals are probably earth-to-space for maritime mobile satellite (allocated 1626.5-1646.5 MHz), earth-to-space for aeronautical mobile satellite (allocated 1646.5-1668.4 MHz), and radiosondes (allocated 1668.4-1700 MHz).

Table 7. Comments on San Diego Spectrum Occupancy Measurement Results (Continued)

Spectral Range	Figure	Comments
1710-2300 MHz	25	All signals observed in this band are terrestrial point-to-point communications, as measured with the RSMS azimuth-scanning technique (see Section C.8 in Appendix C). As in the Denver, Colorado survey [2], two parts of this spectral range show a comparatively small number of transmitters: 1990-2110 MHz (terrestrial allocations being auxiliary broadcasting, cable TV, and GOES uplink), where four signals are observed, and 2200-2300 MHz (terrestrial allocation being fixed microwave links), where one digital and one analog signal occur. Note that all signals observed in this band in San Diego are analog, except for the digital signal at approximately 2262 MHz.
2300-2500 MHz	26	Four communications signals, probably analog, are observed at 2315, 2333, 2367, and 2383 MHz. Their significant effect on the average curve suggests that they likely are fixed links. Above 2388 MHz, all of the observed activity is background radiation generated by ISM devices, and especially by aggregate emissions from microwave ovens in the San Diego area. This background is observed at levels 10 dB higher than in the Denver, Colorado measurements [2]. See also Gawthrop, et al. [4], for further information on emission characteristics of microwave ovens.
2500-2700 MHz	27	At least 27 fixed transmitters are observed in this band. Some of the carriers are low-amplitude, and difficult to discern at the graphic resolution presented in Figure 27, but are clearly distinguishable in the RSMS raw data scans. The individual signal spectra are standard NTSC television broadcast, so these are multipoint distribution system (MDS, also called wireless cable television) transmitters.
2700-2900 MHz	28	All signals in this band are generated by high-power air-search radars Four frequencies are easily discernable (2755, 2795, 2825, and 2880 MHz). Additional frequencies that are occupied by radars, as identified by the RSMS crew, are 2705, 2715, and 2855 MHz. Because automatic attenuation is not yet implemented in the RSMS, these radars saturate the RSMS front-end at their center frequencies during most of the measurements. However, a few manually attenuated scans were performed to document the peak received power, and are shown as the maximum curve. So, the average curve reflects the maximum, positive-peak detected amplitudes of the majority of scans (which were unattenuated), while the maximum curve shows the true envelope of radar emissions in this band. Note that the radar at 2795 MHZ was tuned to about 2785 MHz on at least one (unattenuated) scan, resulting in the flat area on the maximum curve at that frequency. Radars in this band as measured by RSMS crew, typically have the following characteristics: mechanical rotation, no elevation scanning, 4.7-5.0s rotation time, about 1-us pulse width, and about 1000 pulses/s emitted at a high-order stagger, presumably for Doppler processing of target returns.
2900-3100 MHz	29	High-power air-search radars are observed in this band. Compare the high levels of activity observed in San Diego to the nonexistent activity in Denver, Colorado [2]. The high peak and average values recorded at 3050 MHz are generated by numerous surface-search radars used for maritime navigation. Most large vessels carry a surface-search radar that operates at or near 3050 MHz.

Table 7. Comments on San Diego Spectrum Occupancy Measurement Results (Continued)

Spectral Range	Figure	Comments
3100-3700 MHz	30	Numerous high-power radars are observed in this band. Compare the high levels of activity observed in San Diego to the nonexistent activity in Denver, Colorado [2].
3700-4200 MHz	31	RSMS azimuth scans observe two fixed, point-to-point microwave links in this band. The spectra show that both of the links are digitally modulated.
4200-4400 MHz	32	Airborne radio altimeter signals, transmitted by aircraft on approach and departure from nearby airfields, are clearly observed between 4230-4370 MHz. Two modulations predominate: pulsed and FM/CW. Because the signals occur very intermittently, and some are pulsed, the average and minimum curves are not affected.
4400-5000 MHz	33	At least thirteen fixed, point-to-point microwave links are observed in this band, as measured with the RSMS azimuth-scanning technique. Narrow emission spectra are analog signals, and wide emission spectra are digital signals. Five of the thirteen identifiable signals are digital.
5000-5250 MHz	34	The signals observed in this band are spurious emissions from radars operating in the 5250-5925 MHz radiolocation band. Because they are pulsed emissions that occur sporadically, depending upon such factors as beam scanning, proximity of the observed radars to the RSMS, and operational times of the radars, the occupancy by the radar spurious emissions in this band looks “spiky” on the graph. (The optimal algorithm for observation of these signals would have been stepped, but the RSMS only uses that algorithm in radiolocation bands during spectrum surveys. This band was measured with the swept/m3 algorithm.) None of the signals in this band are microwave landing system (MLS) signals; there are no MLS deployed in the San Diego area.
5250-5925 MHz	35	All emissions in this band are produced by radars. Radars using this band include maritime surface-search and weather surveillance units. The flat plateaus in the maximum curve are caused by radar emissions that were measured when no personnel were present at the RSMS to invoke attenuation; automatic attenuation is being added to RSMS capabilities.
5925-7125 MHz	36	At least seven fixed links, all of them analog, are observed between 5925-6425 MHz, in a fixed and fixed-satellite band, in the RSMS azimuth-scan measurement. Another sixteen links, most of them analog, are observed between 6550-6875 MHz, in another fixed and fixed-satellite band. Four links, two of them digital, occur between 6875-7100 MHz in the fixed-satellite/auxiliary broadcasting band. Overall, less occupancy is observed from Point Loma by the RSMS than was recorded in Denver, Colorado [2].
7125-8500 MHz	37	Approximately seven fixed links, six of them analog, are observed in the RSMS azimuth-scan measurement. Substantially less occupancy is observed in this band in the RSMS San Diego survey than in the Denver survey [2].

Table 7. Comments on San Diego Spectrum Occupancy Measurement Results (Continued)

Spectral Range	Figure	Comments
8500-10550 MHz	38	All signals observed in this band are generated by radars. The majority of radars observed in this band in San Diego are maritime surface-search units. Some airborne units are also observed. A shore-based navigation radar tuned to 9400 MHz was present in 100% of RSMS scans. Essentially all surface-search radars carried by small vessels operate in this band; larger vessels also frequently carry radars that operate in this band. Typical operational parameters of the surface search radars, as measured by RSMS crew, are: mechanical rotation, 2-4 s rotation, less than 300-ns pulse width, pulse repetition rates of several thousand pulses per second, no pulse staggering present. Compare occupancy in this band in San Diego to much lower occupancy in land-locked Denver, Colorado [2].
10550-13250 MHz	39	One digital signal is observed in this band. Observed occupancy is lower than was observed in Denver, Colorado [2].
13250-14200 MHz	40	A radar is observed at 13730 MHz.
14200-15700 MHz	41	One or two signals are observed in the RSMS azimuth scan. In general, the probability of intercept by the RSMS for signals in this band is low. See Appendix C.
15700-17700 MHz	42	A few signals are observed in the RSMS azimuth scan. In general, the probability of intercept by the RSMS for signals in this band is low. See Appendix C.
17700-19700 MHz	43	No signals are observed; the change in the RSMS noise floor is due to a band edge in the spectrum analyzer. In general, the probability of intercept by the RSMS for signals in this band is low. See Appendix C.

4. REFERENCES

[1] ***Manual of Regulations and Procedures for Federal Radio Frequency Management,*** revised Sep. 1993 and Jan. 1994, NTIA Office of Spectrum Management, U.S. Government Printing Office, Stock No. 903-008-00000-8.

[2] F.H. Sanders and V.S. Lawrence, "Broadband spectrum survey at Denver, Colorado," NTIA Report 95-321, Sep. 1995.

[3] ***Title 47 Code of Federal Regulations, Telecommunications,*** Part 80 to End, revised Oct. 1994, (U.S. Government Printing Office, Superintendent of Documents, Mailstop: SSOP, Washington, DC 20402-9328).

[4] P.E. Gawthrop, F.H. Sanders, K.B. Nebbia, and J.J. Sell, "Radio spectrum measurements of individual microwave ovens," NTIA Report 94-303-1,2, Mar. 1994.