3. DENVER SPECTRUM SURVEY

3.1 Introduction

This section 1) describes the measurement site selected for a spectrum survey in the Denver metropolitan area, 2) briefly describes the data processing used to characterize the 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 Hackberry Hill, at 7991 W. 71st Avenue, Arvada, CO, about 12 km (7.3 mi) northwest of downtown Denver. The property was owned by the Lutheran Health Care Center. The site coordinates were 105°04'57.4" W, 39°49'35.4" N. Base altitude was 5610 ft MSL. The Lutheran Care Center buildings were to the west of the RSMS and generally one story high, low enough that they did not obstruct RSMS antennas when those antennas were raised to their full tower heights.

The site was reasonably removed from powerful RF transmitters but was within a few hundred feet of possible sources of random noise (heavy traffic on Wadsworth Boulevard and some construction activity with earth moving equipment just on the other side of Wadsworth Boulevard).

Figure 1 shows the location of the RSMS and its relationship to the Denver area. Figure 2 shows areas that were line-of-sight to the RSMS from six feet above ground (typical mobile antenna height) and those areas that were obstructed from the RSMS due to terrain.

Downtown Denver is in a wide valley along the east side of the South Platte River. Where the river passes through Denver, there are some low hills on the west side, but terrain is mostly flat on the east side. Generally, terrain elevation increases first slowly then sharply when moving west from Denver toward Golden. The sharp rise (foothills of the Rocky Mountains) is a continuous north-south barrier to line-of-sight coverage west of Golden.

3.3 Data Considerations

The Denver survey was performed as outlined in Section 2. The band event tables (Table 1 for System-1 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-1 were measured with a 0.1-1.0 GHz log periodic antenna (LPA) mounted at a 45° angle (for slant polarization) on the small mast and aimed toward downtown Denver. The System-2 survey bands (except for azimuth-scanning bands[4]) were measured with a 0.5-18 GHz slant polarized biconical omni antenna mounted on the large mast. For the azimuth-scanning survey bands (event numbers

[4] 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.

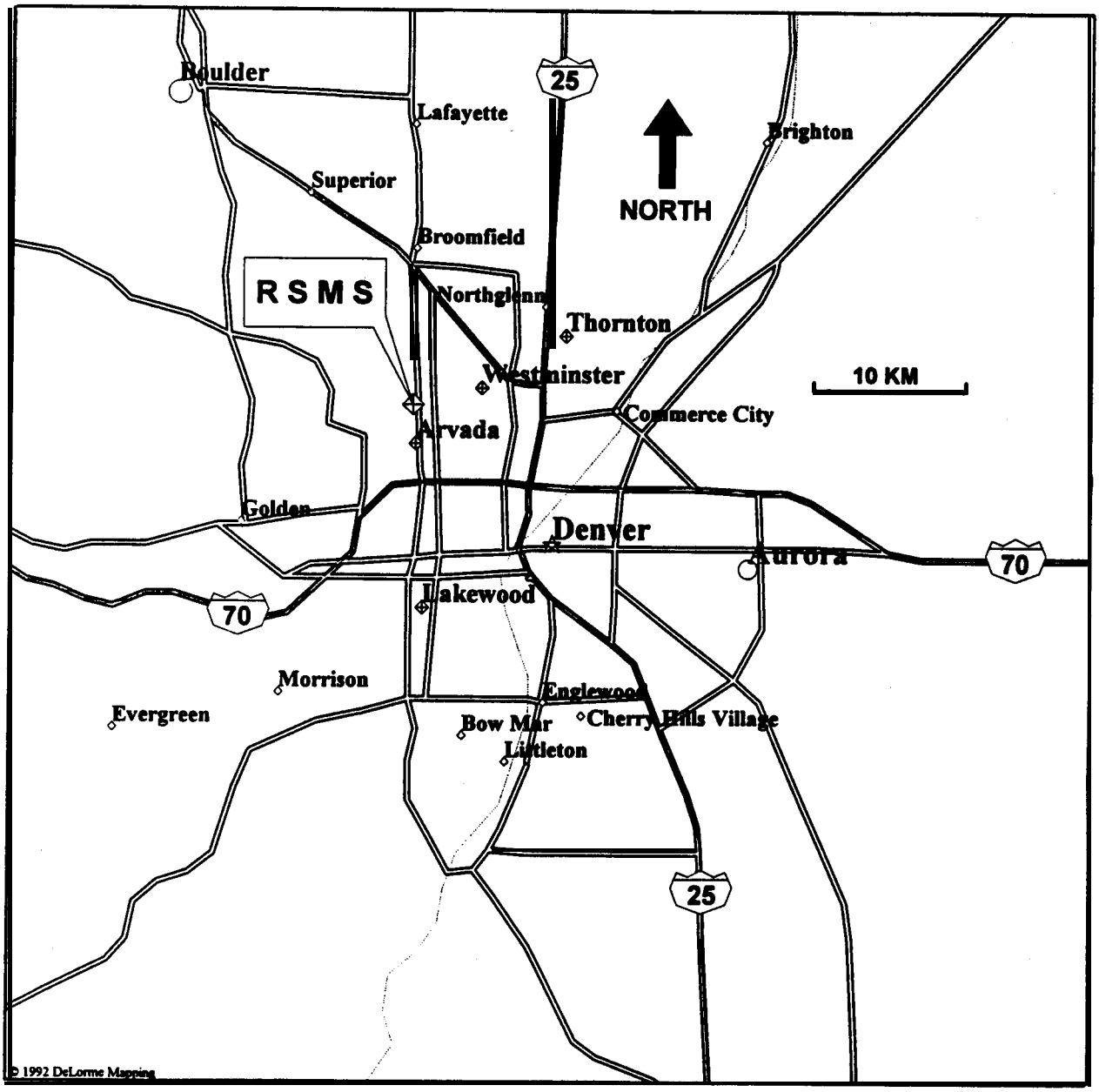

Figure 1. Area map of Denver showing location of the RSMS measurement site. Map produced with MapExpert™ software from DeLorme Mapping.

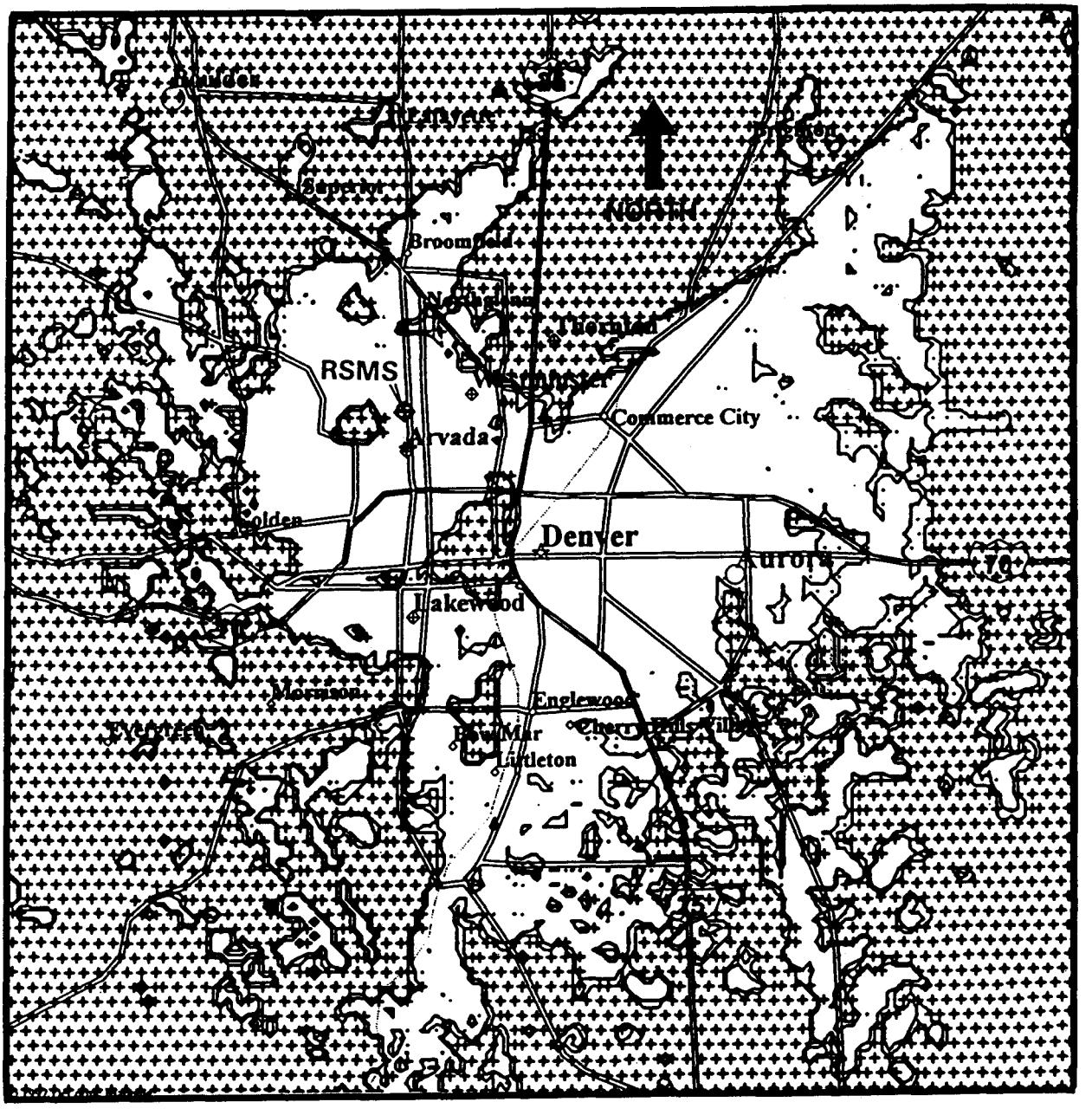

Figure 2. Map of Figure 1 with a SHADOW overlay showing non-line-of-sight regions (from the RSMS raised antennas) as plus (+) signs. Overlay provided by Telecommunications Analysis Services, Institute for Telecommunication Sciences U.S. Department of Commerce, Boulder Co 80303-3328.

10, 12, 16, 18, 21, 22, 24, 26, and 28) a rotating 1-meter 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.

System-1 adverse weather band event data (measured during a snowstorm) were cumed with the standard band event data. Also, the measurement rate for the Denver 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.

Half-way through the measurements, a hardware failure in the System-1 HP 8566 SA forced data collection to continue with a substitute HP 8568 SA. Because of different internal processing, the analyzers' outputs could not be cumed together; only the 8566 data were cumed. Although RSMS spectrum surveys nominally last two weeks, one week of data is considered adequate for valid results; it is assumed that as much as half of the data in a band may be lost due to problems in the field. Thus, the Denver data from System-1 are considered to represent a valid set of survey results.

During measurement analysis, it was discovered that strong received signal levels from FM broadcast stations below 108 MHz had generated intermodulation products in the RSMS front end. These products caused false responses in the 108-114 MHz measurements. Therefore, data collected in the 108-114 MHz range were not reliable and were omitted.

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 3-41). Each survey band page shares 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 MHz on the X-axis vs. received signal level marked at 5-dBm increments on the Y-axis. Noise level indicators (marked on the Y-axis) are explained in Appendix C along with suggestions for interpreting the graphed data.

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."[5] 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 MHz. 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 and data graphs is substantially affected by the measurement parameters and the analysis techniques employed. For example, System-1, band events 11 and 12 (Figures 3 and 4) were made with similar measurement techniques. Band Event 11 appears to show a more dense signal population than Band Event 12, but close examination shows that Band Event 11 covers a 54-MHz range and Band Event 12 covers a 12-MHz range. The apparently denser signal environment of Band Event 11 may be real or may be caused by the fact that it covers more than four times as much frequency range as Band Event 12. Similarly, various band events maybe plotted with different amplitude scales or are measured with different bandwidths and algorithms. This is the case for System-2, band events 6 and 7 (Figures 19 and 20). Band Event 7 covers the same frequency range as the upper 25% of Band Event 6, but the appearance of the two graphs is completely different. The signals in Band Event 7 appear (at first glance) to be much stronger and denser than those in the common part of Band Event 6.

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 Denver metropolitan area during a two-week period spanning the end of September and the beginning of October, 1993. 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,

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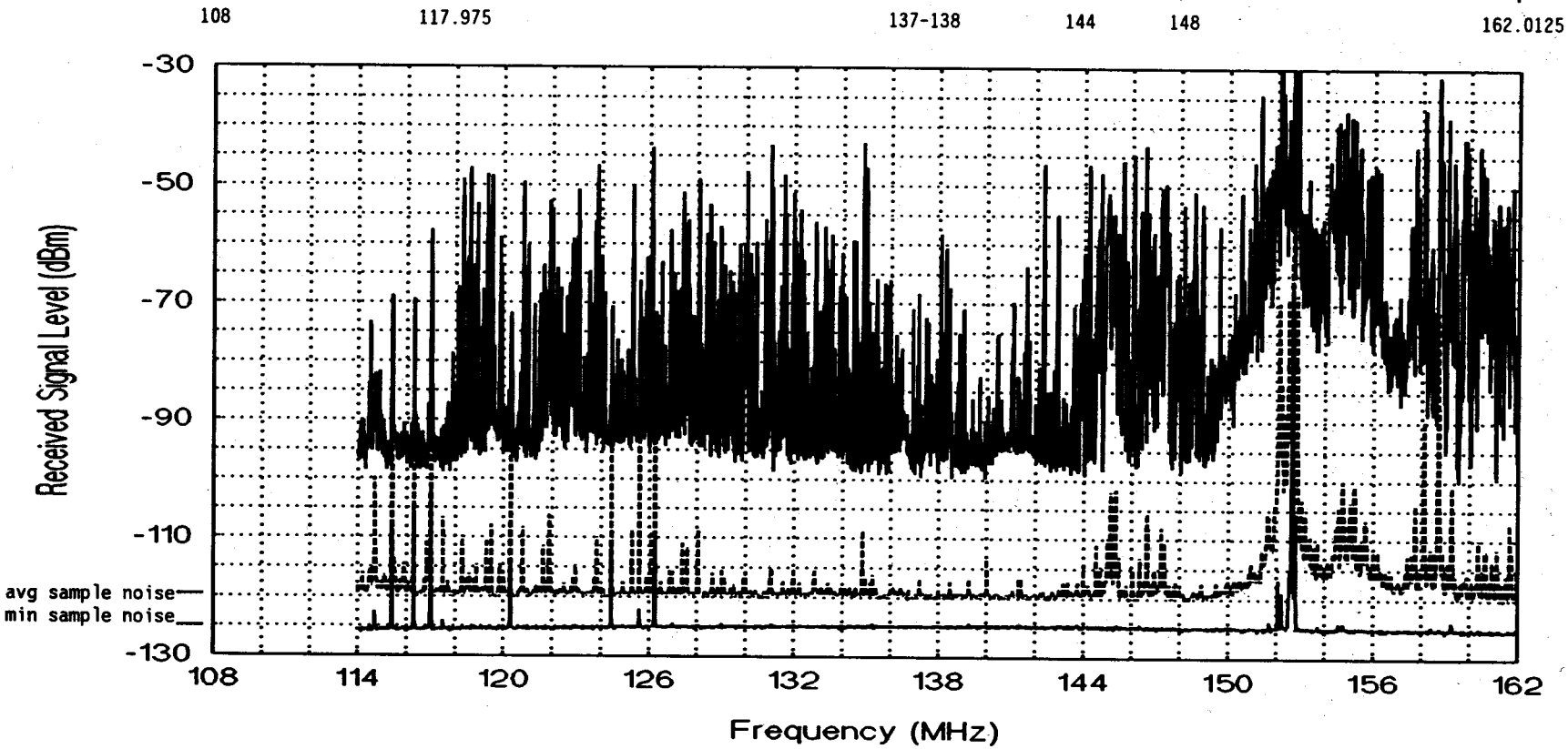
[5] ***NTIA, Manual of Regulations and Procedures for Federal Radio Frequency Management*** **Part 4.1.3, U.S. Department of Commerce, National Telecommunications and Information Administration, Washington, D. C., revised May 1992, January 1993 and May 1993.**

GOVERNMENT ALLOCATIONS:	AERONAUTICAL RADIONAVIGATION.	AERONAUTICAL MOBILE.	2	MOBILE, FIXED.		FIXED, MOBILE, MARITIME MOBILE, RADIONAVIGATION-SATELLITE, 5.
NON-GOVERNMENT ALLOCATIONS:	AERONAUTICAL RADIONAVIGATION.	AERONAUTICAL MOBILE.	2		AMATEUR, 4.	LAND MOBILE, MARITIME MOBILE, RADIONAVIGATION-SATELLITE, 6.
GENERAL UTILIZATION:	VHF Omnidirectional Range (VOR).	Air Traffic Control (ATC), ground control and aeronautical advisories, 1.	2	Non-tactical military, 3.		LMR, TIROS, TRANSIT-SAT, Maritime communications, 7.

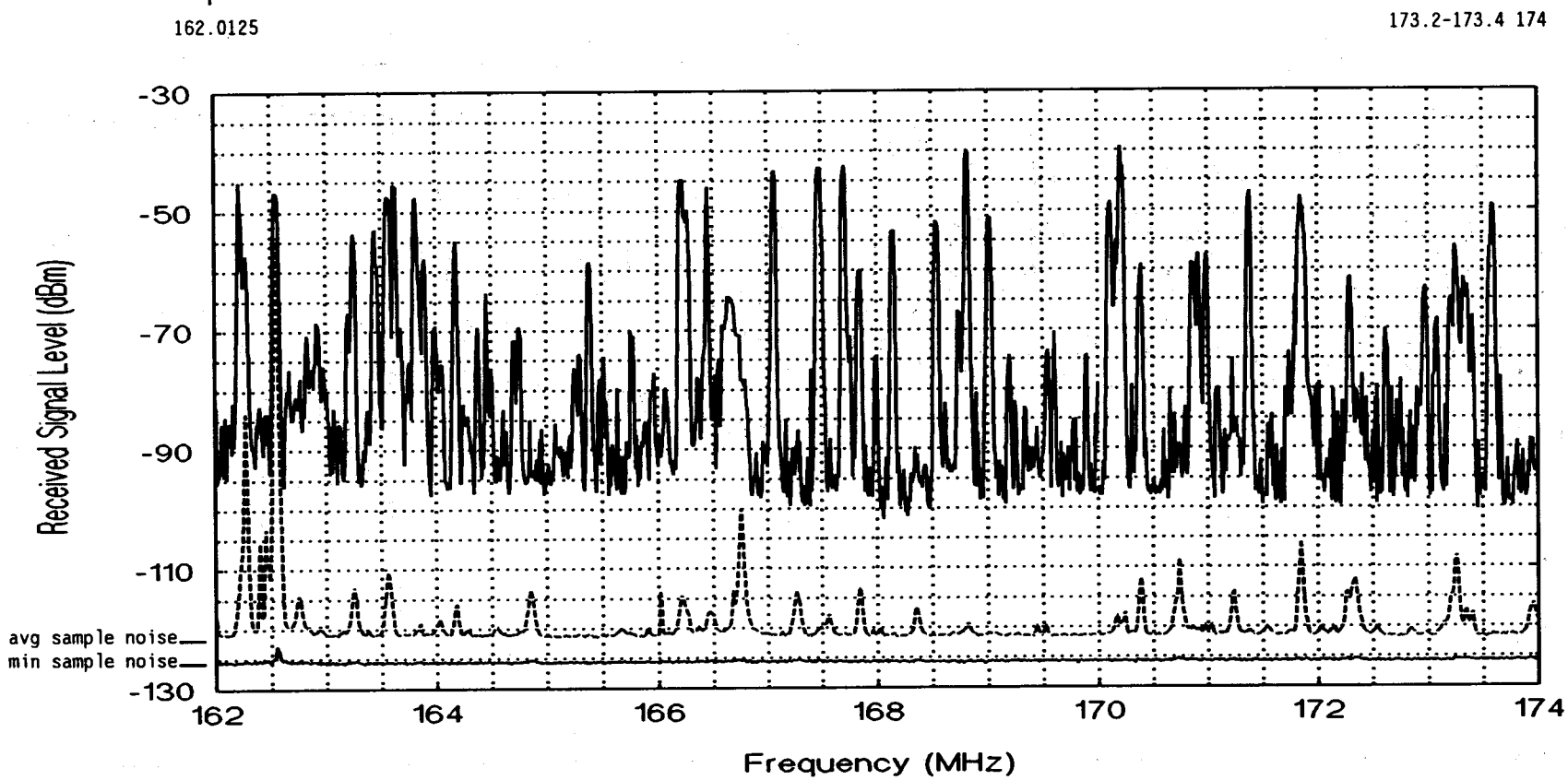


Note: **Concerning 108-114 MHz data, see analysis comment in Section 3.3.**

1. **121.9375-123.0875 MHz: private aircarft. 123.1 MHz: SAR (search and rescue) operations.**
2. **SPACE OPERATION/RESEARCH, METEOROLOGICAL/MOBILE-SATELLITE, Mobile-SateNite. Space-to-Earth; government use includes TIROS downlinks.**
3. **143.75 MHz, 143.9 MHz: Civil Air Patrol.**
4. **144-146 MHz: AMATEUR-SATELLITE.**
5. **148-150.05 MHz: MOBILE-SATELLITE (Earth-to-space).**
6. **FIXED, MOBILE, MOBILE-SATELLITE (Earth-tc-space).**
7. **Land transportation, domestic public, industrial, public safety, etc.**

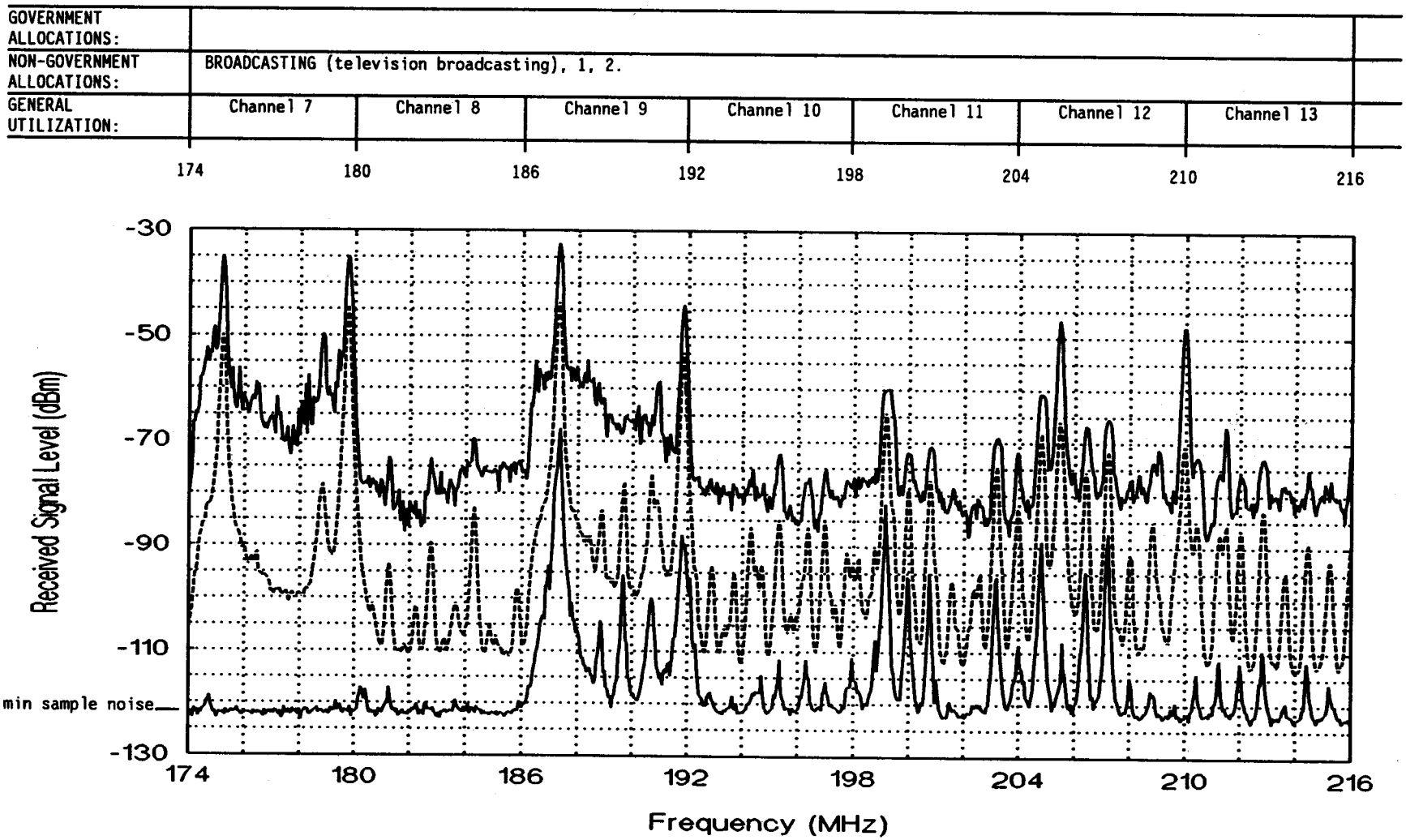
Figure 3. NTIA spectrum survey graph summarizing 8,600 sweeps across the 108-162 MHz range (System-1, band event 11, swept/m3 algorithm, sample detector, 10 kHz bandwidth) at Denver, CO, 1993.

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



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

Figure 4. NTIA spectrum survey graph summarizing 68,000 sweeps across the 162-174 MHz range (System-1, Band Event 12, swept/m3 algorithm, sample detector, 10-kHz bandwidth) at Denver, CO, 1993.



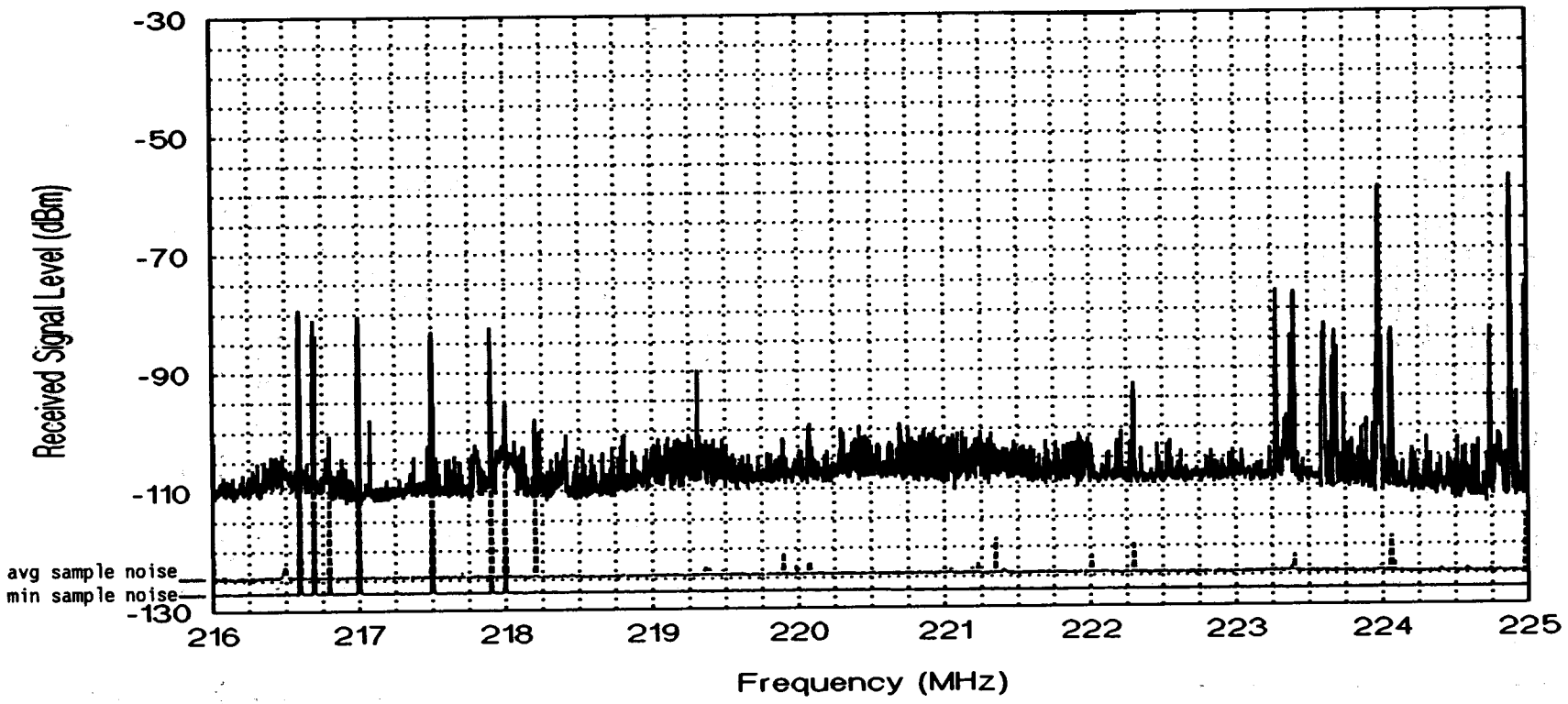
1. Subscription television services and limited wireless microphone operations are also permitted in this band. .

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

Figure 5. NTIA spectrum survey graph summarizing 16,500 sweeps across the 174-216 MHz range (System-1, band event 13, swept/m3 algorithm, sample detector, 100-kHz bandwidth) at Denver, CO, 1993.

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



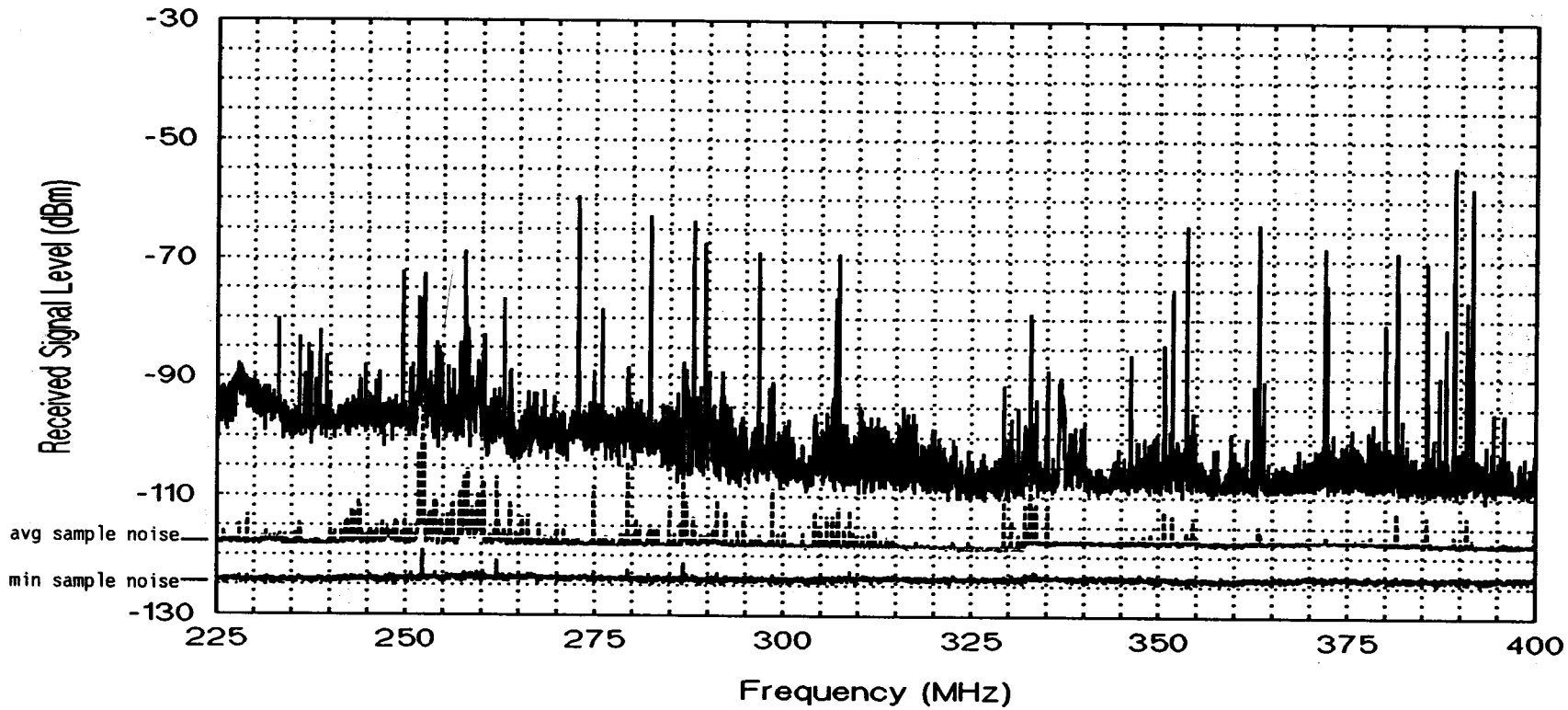
1. Radiolocation is limited to the military services.

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

Figure 6. NTIA spectrum survey graph summarizing 4,980 sweeps across the 216-225 MHz range (System-1, band event 4, swept/m3 algorithm, sample detector, 3-kHz bandwidth) at Denver, CO, 1993.

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

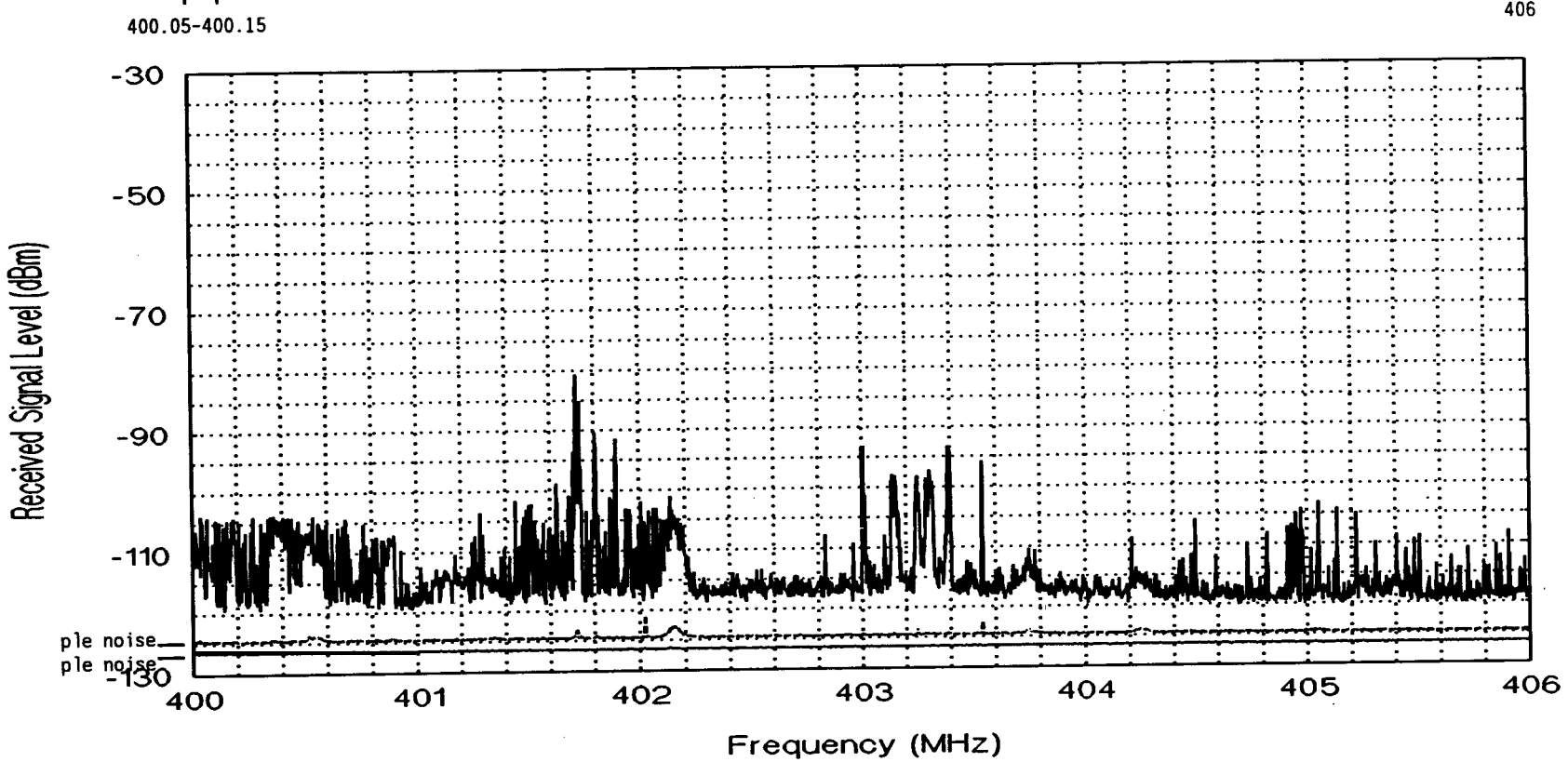


1 Government usage is limited to the military services; additionally, 235-322 MHz is allocated on a primary basis to the mobile-satellite service. 243.0 MHz may be used for search and rescue operations.

2. AERONAUTICAL RADIONAVIGATION, instrument landing systems (ILS) only.
3. 399.9-400.05 MHz: RADIONAVIGATION-SATELLITE.

Figure 7. NTIA spectrum survey graph summarizing 2,900 sweeps across the 225-400 MHz range (System-1, band event 15, swept/m3 algorithm, sample detector, 30-kHz bandwidth) at Denver, CO, 1993.

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

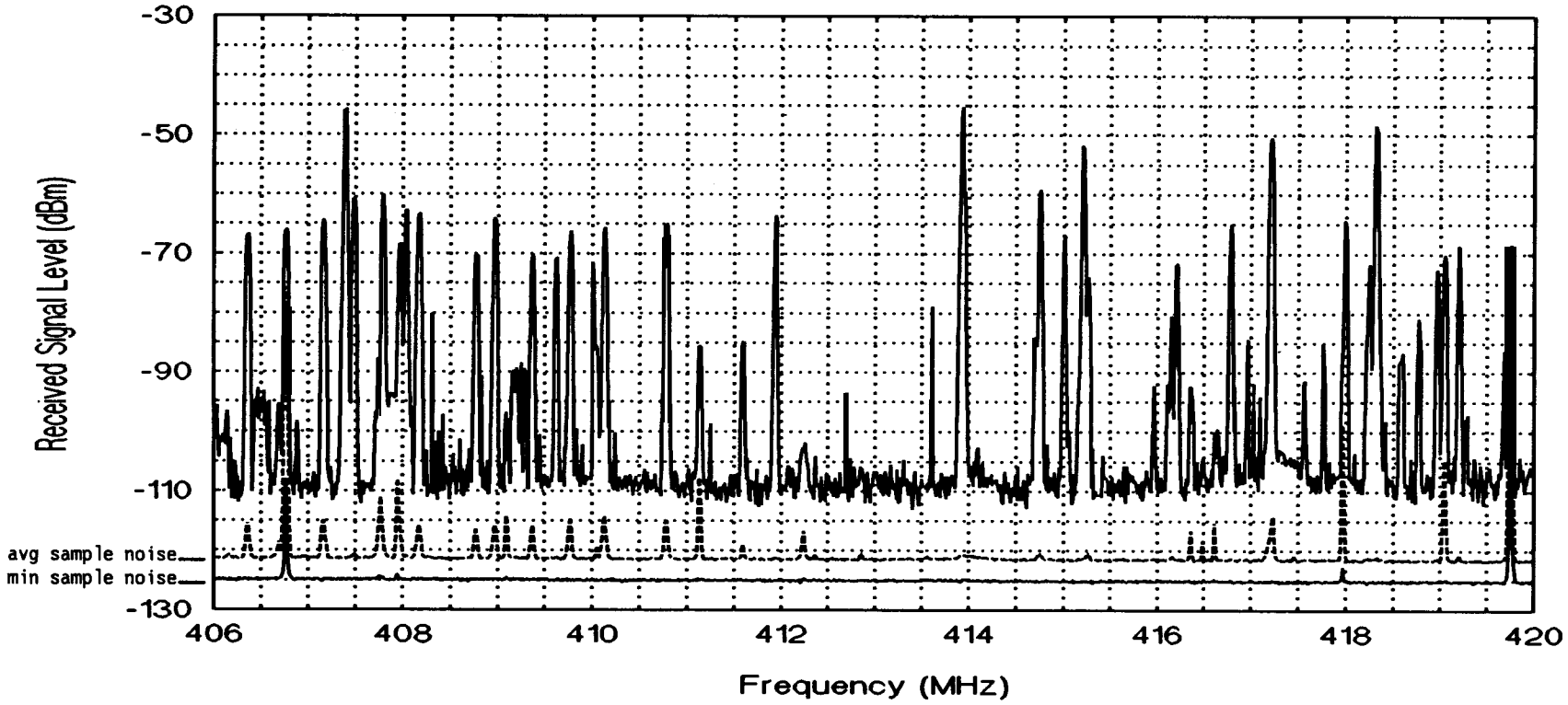


1. STANDARD FREQUENCY AND TIME SIGNAL-SATELLITE (400.1 MHz ±25 kHz).
2. 400.15-401 MHz: METEOROLOGICAL-SATELLITE (space-to-Earth).
3. 400.15-401 MHz: SPACE RESEARCH (space-to-Earth), Space Operation (space-to-Earth).
4. 401-402 MHz: SPACE OPERATION (space-to-Earth), Earth Exploration-Satellite (Earth-to-space), Meteorological-Sat. (Earth-to-space).
5. 402-403 MHz: Earth Exploration-Satellite (Earth-to-space), Meteorological-Satellite (Earth-to-space).

Figure 8. NTIA spectrum survey graph summarizing 1,800 sweeps across the 400-406 MHz range (System-1, band event 16, swept/m3 algorithm, sample detector, 3-kHz bandwidth) at Denver, CO, 1993.

GOVERNMENT ALLOCATIONS:	1	RADIO ASTRONOMY, FIXED, MOBILE, 2.	FIXED, MOBILE, 2.
NON-GOVERNMENT ALLOCATIONS:	1	RADIO ASTRONOMY.	
GENERAL UTILIZATION:	1	LMR, 2.	LMR, 2.

406-406.1 410 420

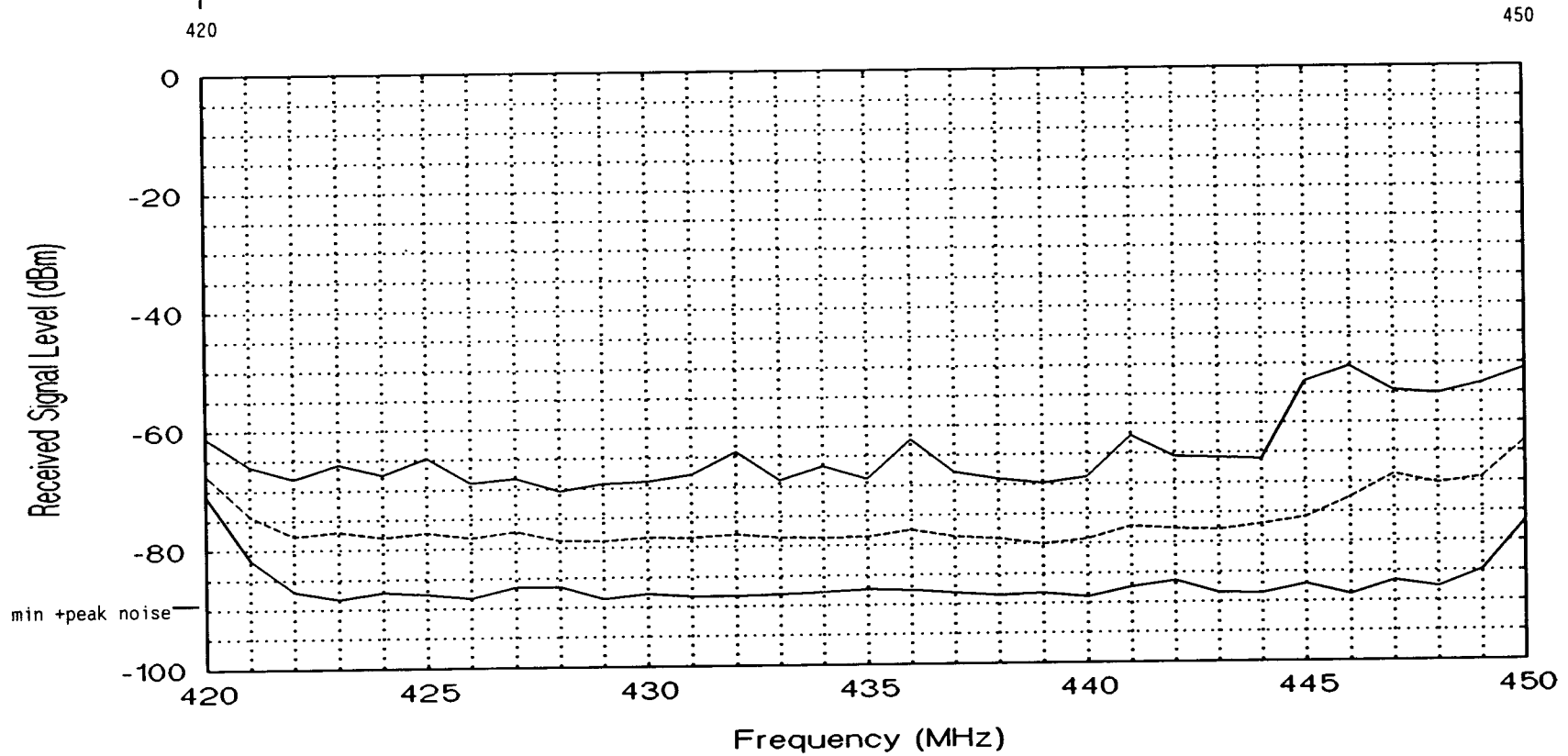


1. MOBILE-SATELLITE (Earth-to-space). Low power satellite emergency position-indicating radiobeacons (EPIRB) only. Supported by the joint U.S. SARSAT/-Soviet COSPAS satellite network.

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

Figure 9. NTIA spectrum survey graph summarizing 14,200 sweeps across the 406-420 MHz range (System-1, band event 17, swept/m3 algorithm, sample detector, 10-kHz bandwidth) at Denver, CO, 1993.

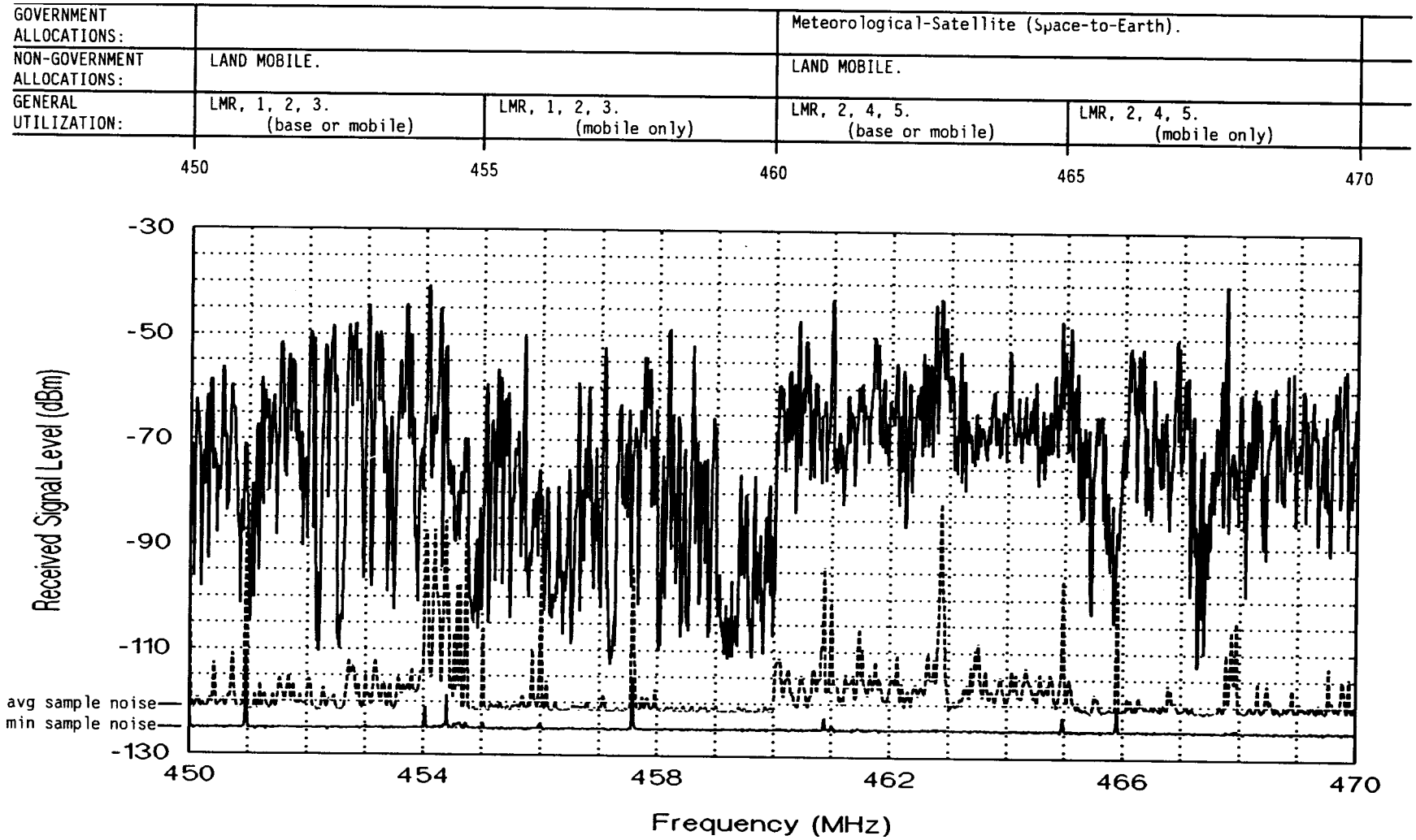
GOVERNMENT ALLOCATIONS:	RADIOLOCATION.
NON-GOVERNMENT ALLOCATIONS:	Amateur.
GENERAL UTILIZATION:	Long-range surveillance radars, 1, 2.



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.

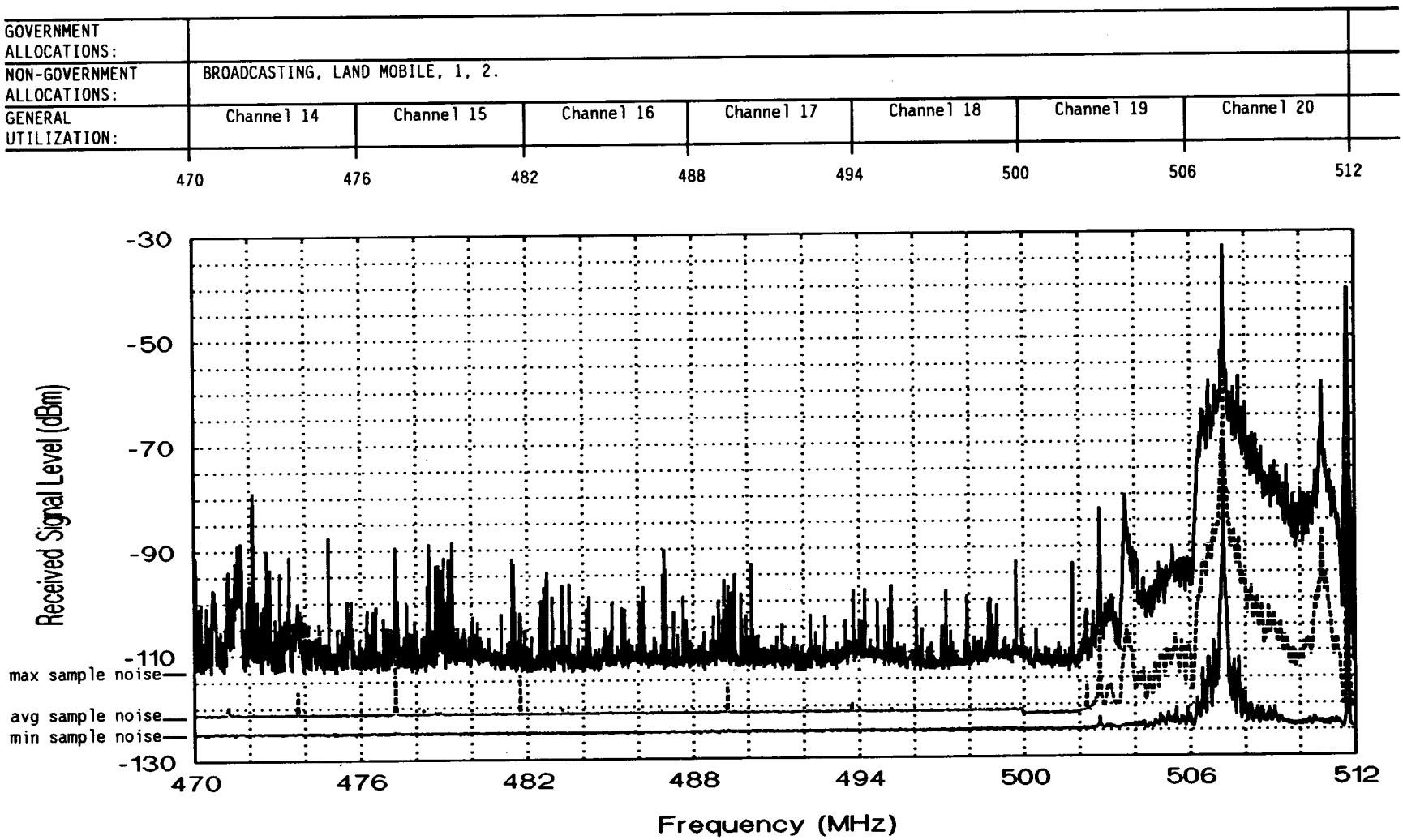
2. There is some non-Government use of spread spectrum modes; also, amateur weak signal modes (432-433 MHz), television (420-432 & 438-444 MHz), repeaters (442-450 MHz), auxiliary links (433-435 MHz), and amateur satellite (435-438 MHz).

Figure 10. NTIA spectrum survey graph summarizing 49 scans across the 420-450 MHz range (System-1, band event 18, stepped algorithm, +peak detector, 1000-kHz bandwidth) at Denver, CO, 1993.



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

Figure 11. NTIA spectrum survey graph summarizing 13,800 sweeps across the 450-470 MHz range (System-1, band event 19, swept/m3 algorithm, sample detector, 10-kHz bandwidth) at Denver, CO, 1993.



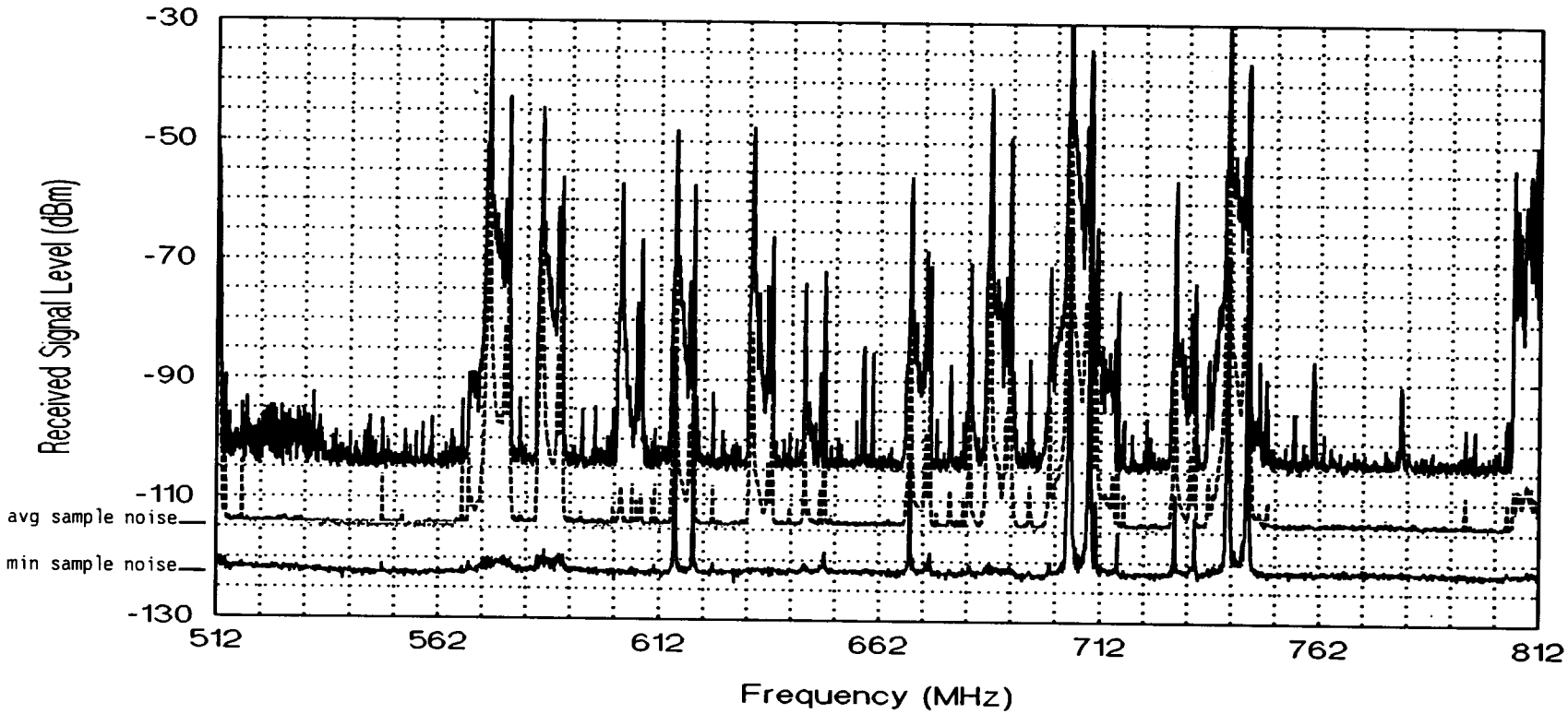
1. Land Mobile Radio Services include Public Safety, Domestic Public, Industrial, and Land Transportation assignments in specific urban areas.

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

Figure 12. NTIA spectrum survey graph summarizing 6,700 sweeps across the 470-512 MHz range (System-1, band event 20, swept/m3 algorithm, sample detector, 10-kHz bandwidth) at Denver, CO, 1993.

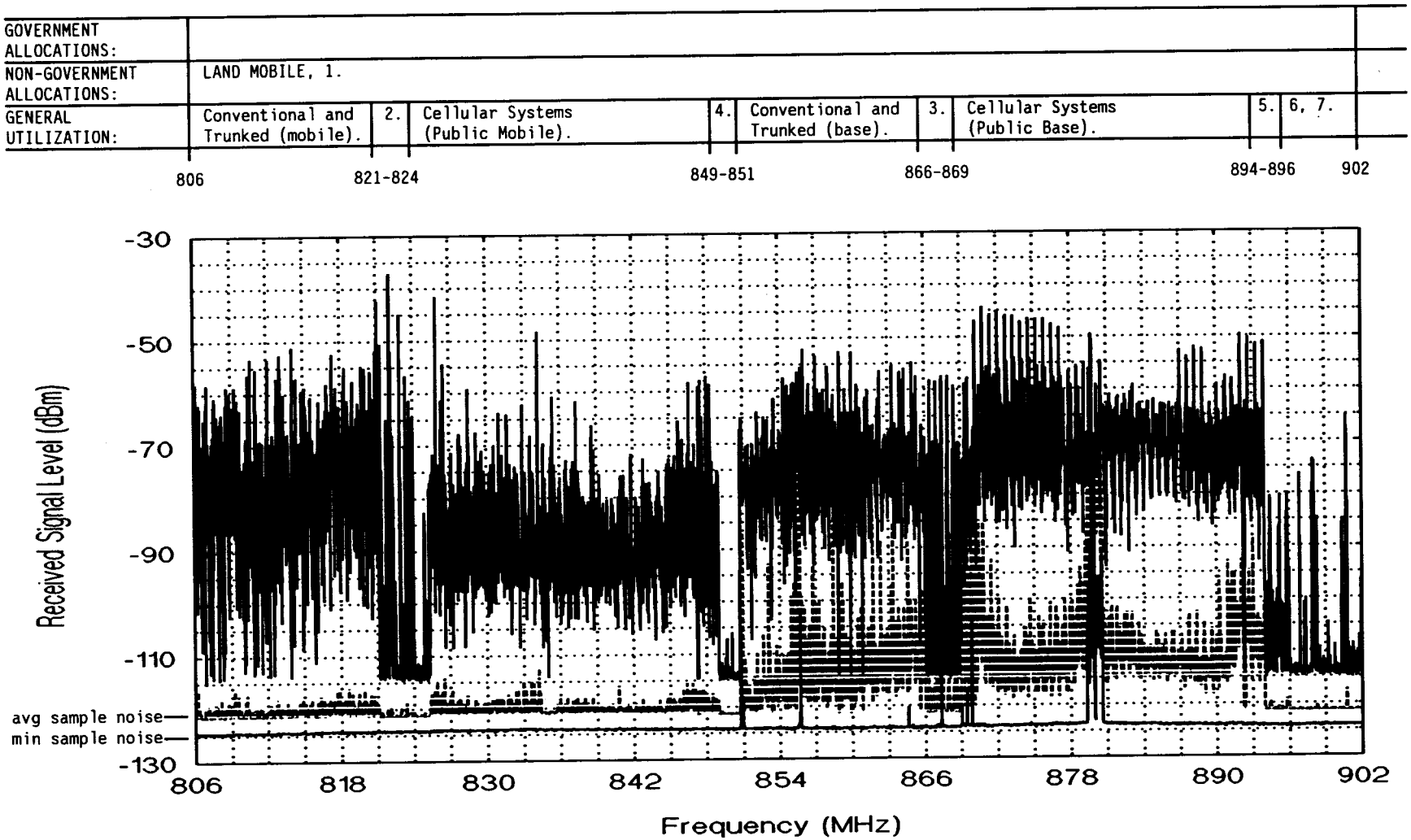
GOVERNMENT ALLOCATIONS:		1.	
NON-GOVERNMENT ALLOCATIONS:	BROADCASTING.	1.	BROADCASTING.
GENERAL UTILIZATION:	TV Channels 21-36.		TV Channels 38-69.

512 608-614 806



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

Figure 13. NTIA spectrum survey graph summarizing 5,600 sweeps across the 512-806 MHz range (System-1, band event 21, swept/m3 algorithm, sample detector, 100-kHz bandwidth) at Denver, CO, 1993.

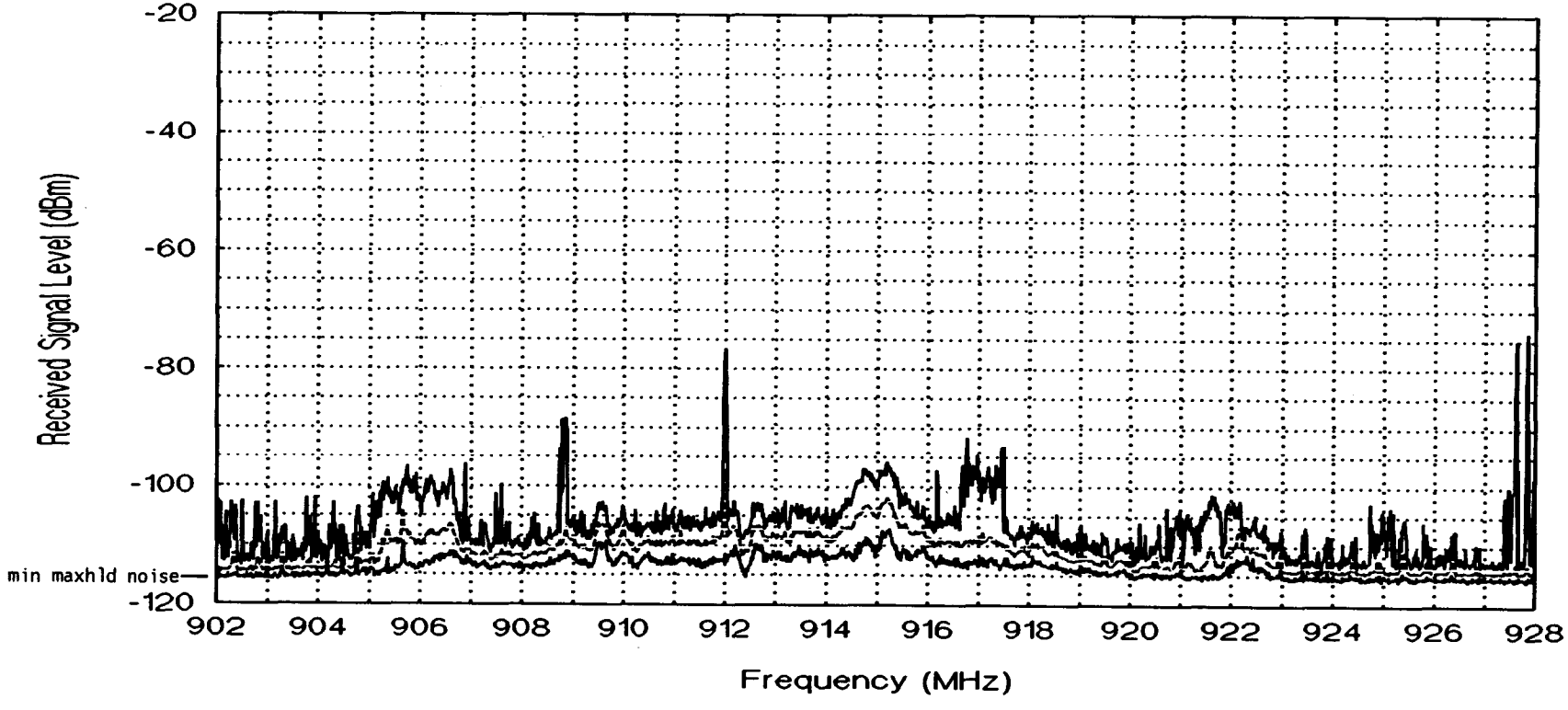


1. 806-890 MHz: Limited allocation is available for TV Channels 70-83.
2. Public Safety (mobile).
3. Public Safety (base).
4. Aeronautical Mobile (ground-to-air).
5. Aeronautical Mobile (air-to-ground).
6. 896-901 MHz: Private Land Mobile (paired with 935-940 MHz).
7. 901-902 MHz: General Mobile.

Figure 14. NTIA spectrum survey graph summarizing 2,880 sweeps across the 806-902 MHz range (System-1, band event 22, swept/m3 algorithm, sample detector, 10-kHz bandwidth) at Denver, CO, 1993.

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

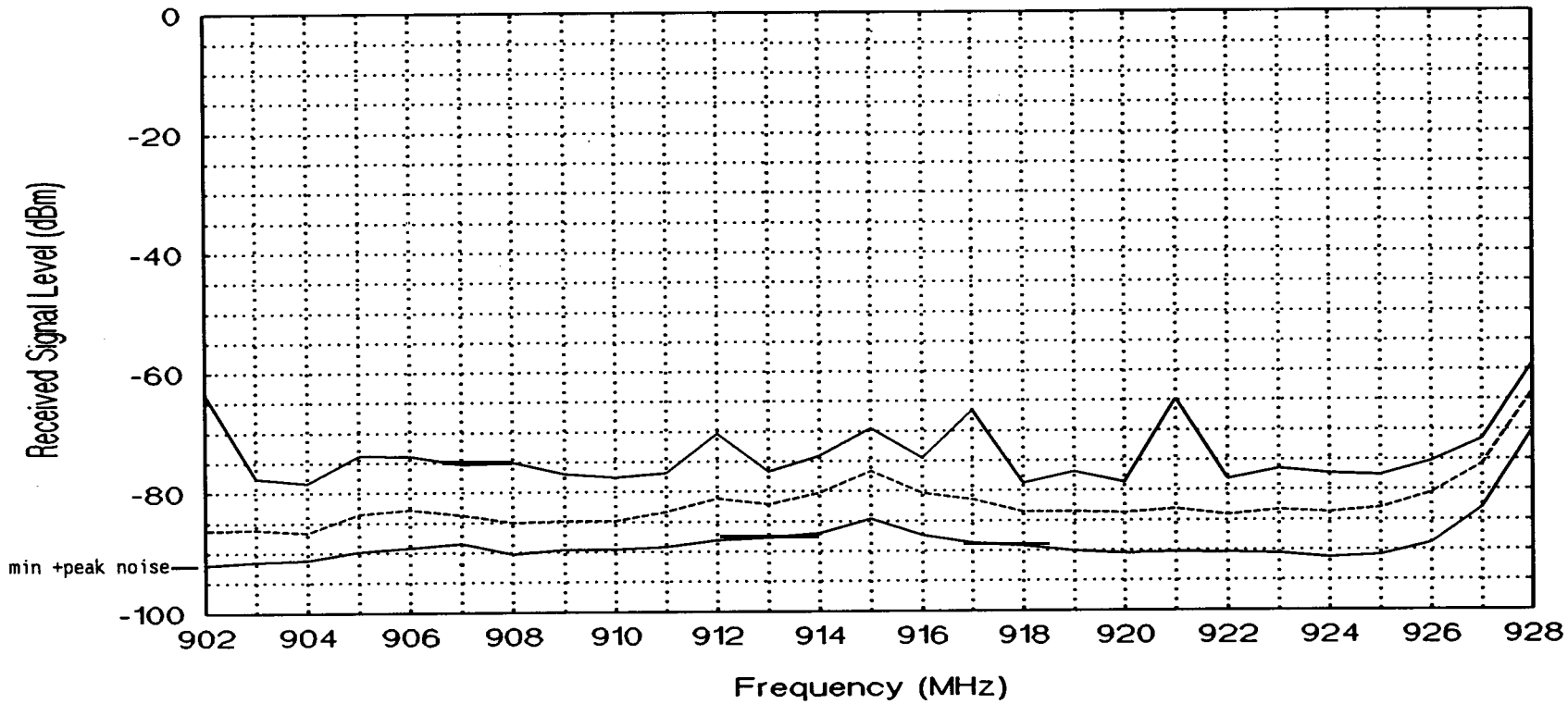


1. Fixed and Mobile radio services are permitted on a secondary basis; however, band utilization is increasing for non-Government ISM, spread spectrum and other modes, amateur, etc., as permitted in Region 2.

Figure 15. NTIA spectrum survey graph summarizing 23,400 sweeps across the 902-928 MHz range (System-1, band event 23, swept algorithm, maximum-hold detector, 10-kHz bandwidth) at Denver, CO, 1993.

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

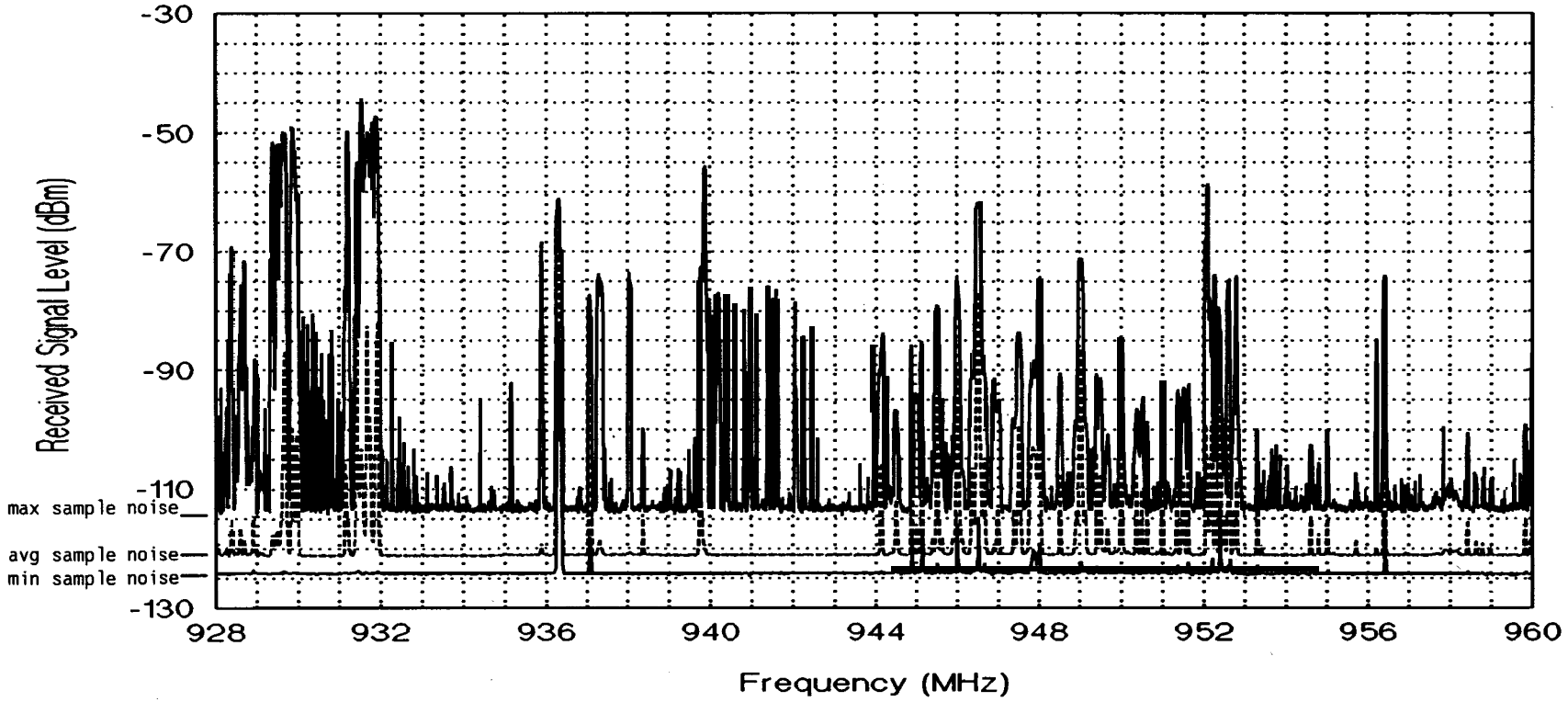


1. Fixed and Mobile radio services are permitted on a secondary basis; however, band utilization is increasing for non-Government ISM, spread spectrum and other modes, amateur, etc., as permitted in Region 2.

Figure 16. NTIA spectrum survey graph summarizing 48 scans across the 902-928 MHz range (System-1, band event 24, stepped algorithm, +peak detector, 1000-kHz bandwidth) at Denver, CO, 1993.

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

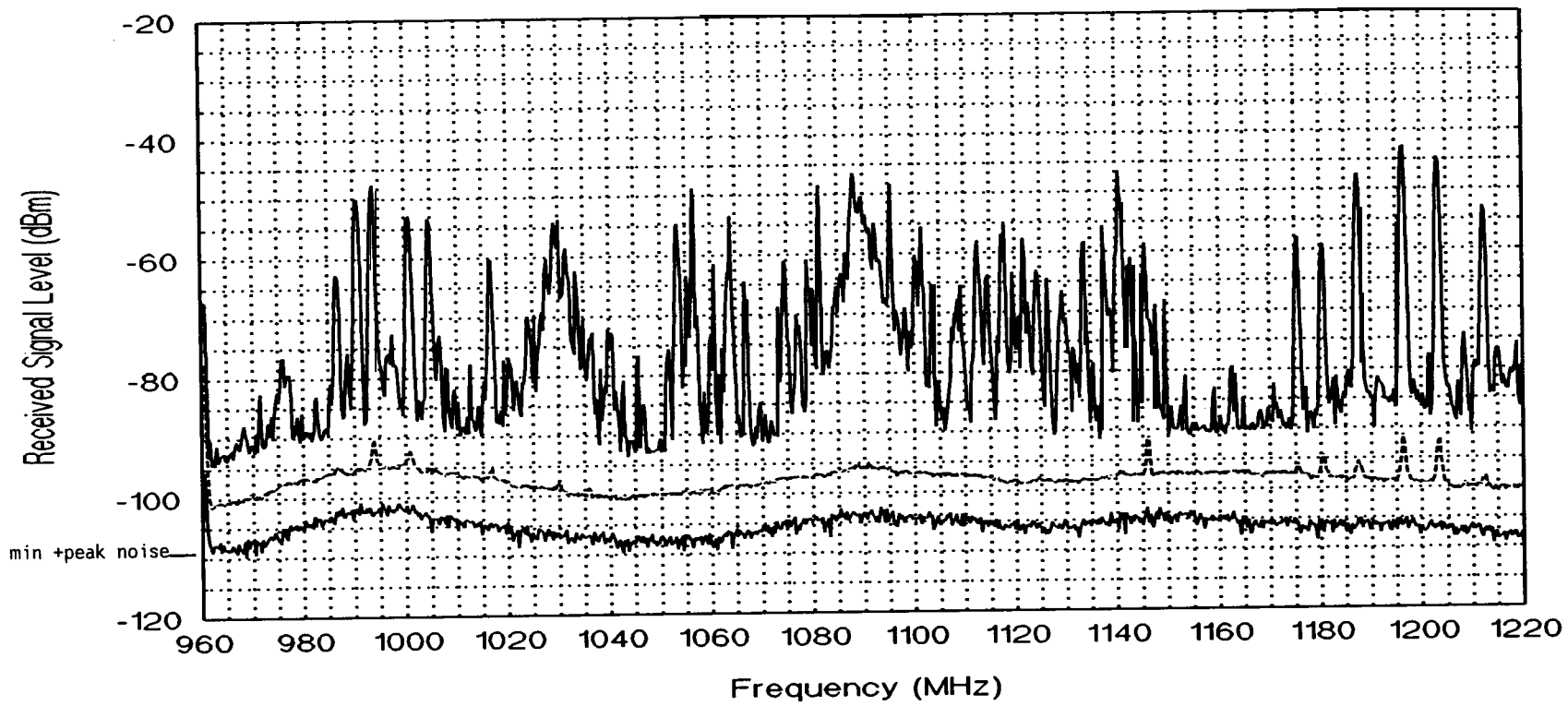


1. FIXED. Private fixed microwave, public and private land mobile, telemetry applications. Two-way services paired with 952-953 MHz.
2. Public and private land mobile.
3. Paired band for point-to-point and point-to-multipoint communications.
4. Trunked and conventional systems in 12.5 kHz channels (paired 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 17. NTIA spectrum survey graph summarizing 17,400 sweeps across the 928-960 MHz range (System-1, band event 25, swept/m3 algorithm, sample detector, 10-kHz bandwidth) at Denver, CO, 1993.

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



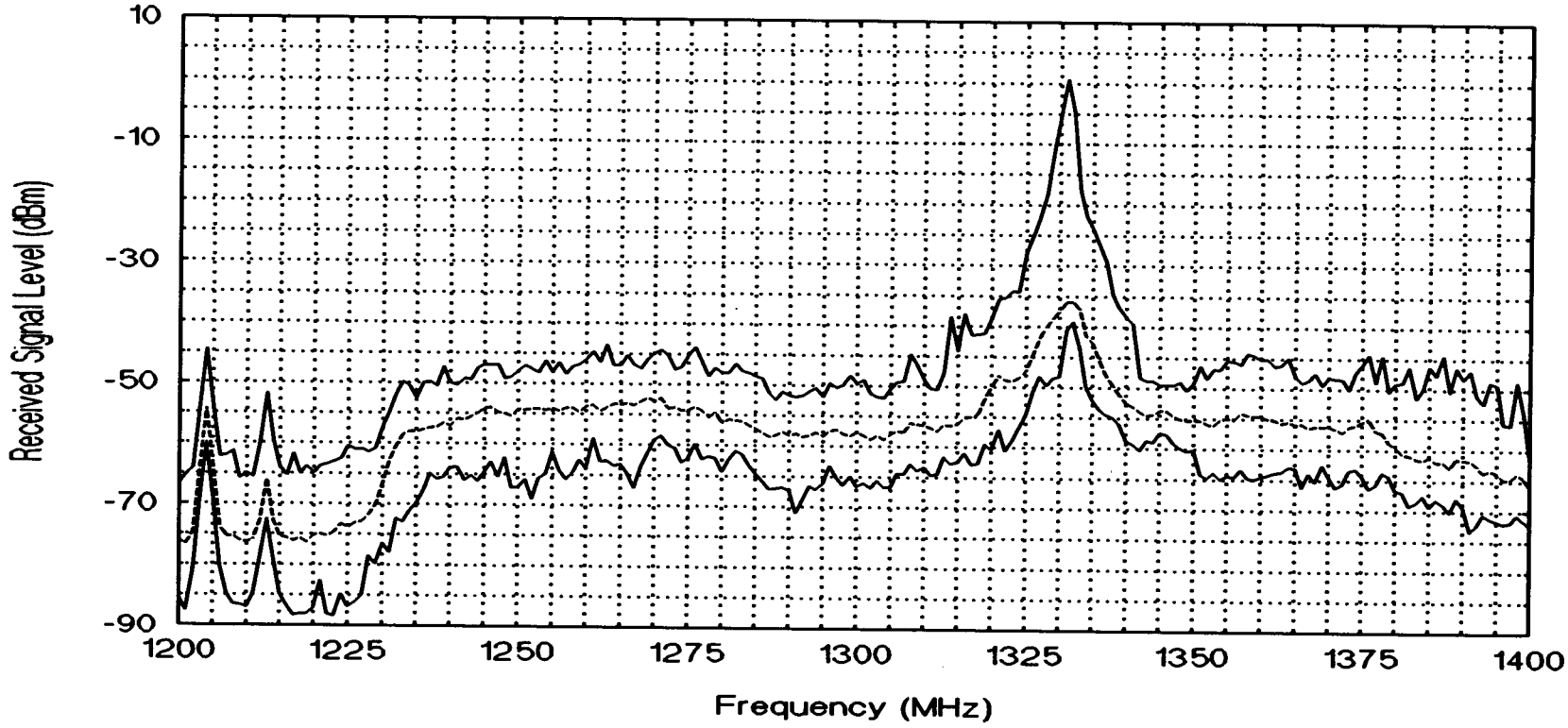
The 960-1215 MHz band is reserved on a worldwide basis for the use and development of electronic aids to air navigation. On a case by case basis, Government systems utilizing spread spectrum techniques for terrestrial communication, navigation and identification may be authorized on condition that aeronautical 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, IFF, etc.). Collision Avoidance System (T-CAS). Joint Tactical Information Distribution System (JTIDS).

Figure 18. NTIA spectrum survey graph summarizing 22,000 sweeps across the 960-1215 MHz range (System-2, band event 05, swept/m3 algorithm, +peak detector, 300-kHz bandwidth) at Denver, CO, 1993.

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.	

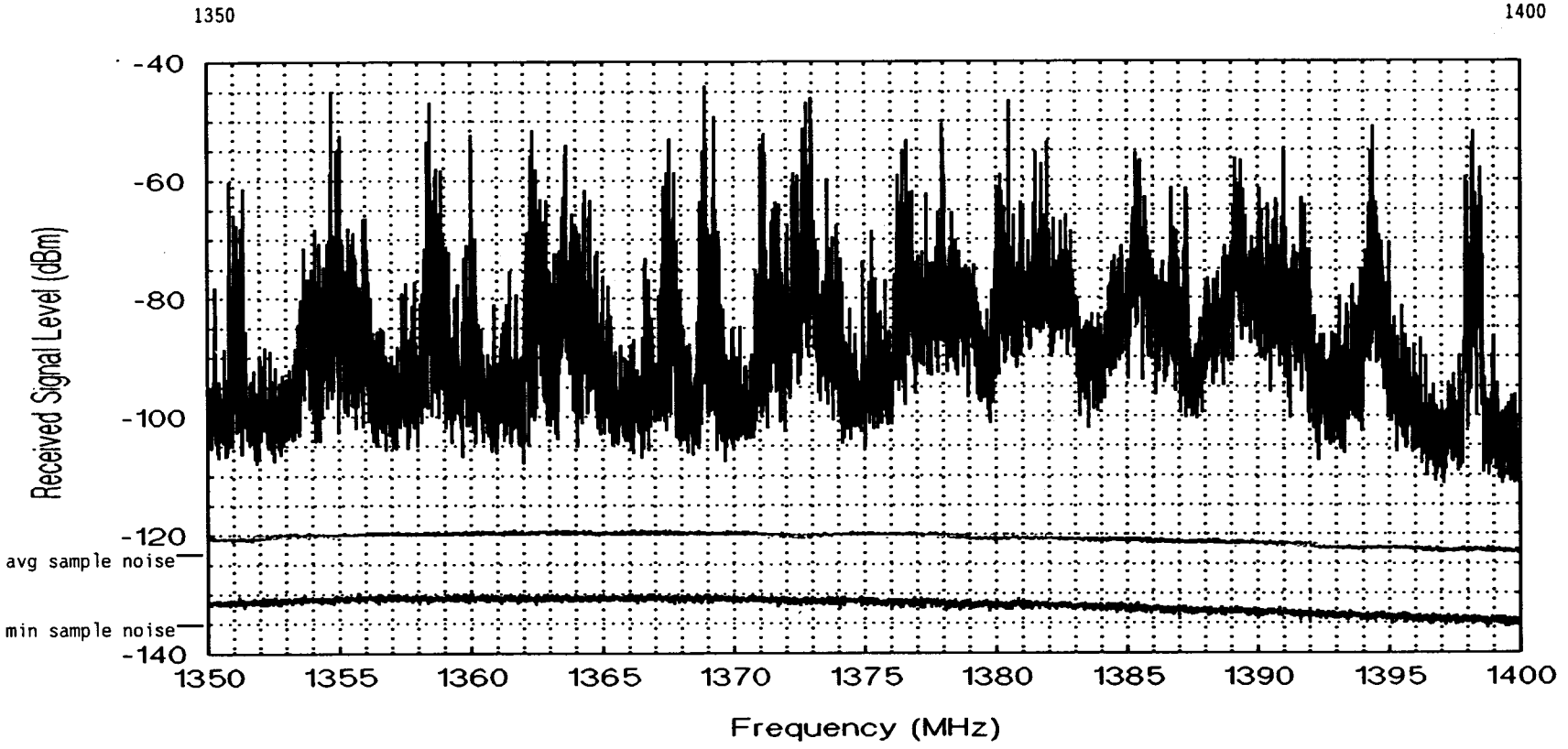
1215 1240 1300 1350 1400



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 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 19. NTIA spectrum survey graph summarizing 27 scans across the 1215-1400 MHz range (System-2, band event 06, stepped algorithm, +peak detector, 1000-kHz bandwidth) at Denver, CO, 1993.

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

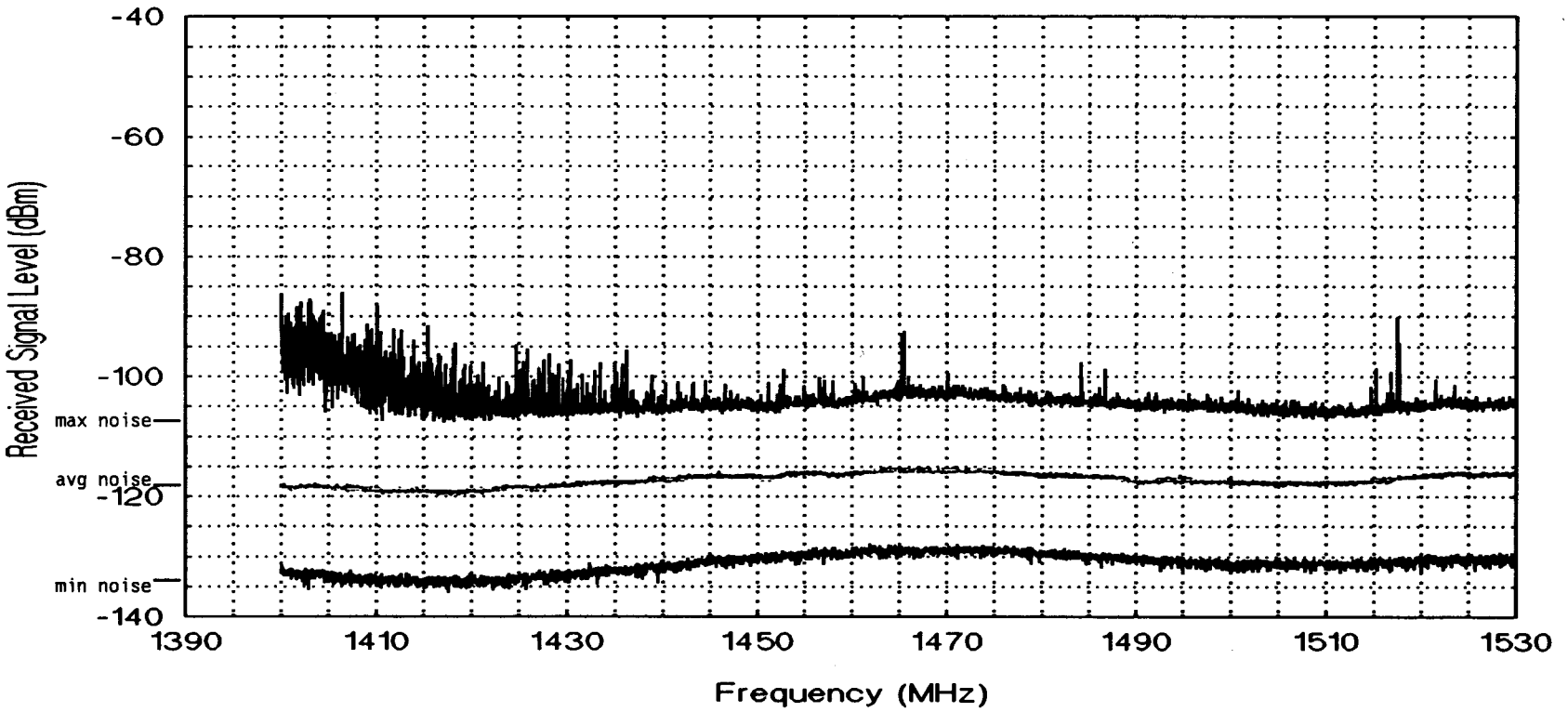


1. 1350-1370 MHz: AERONAUTICAL RADIONAVIGATION (allocation for U.S. and Canada only).
2. Military radiolocation applications are primarily high-power long-range surveillance radars.
3. 1369.05-1393.05 MHz: Fixed and mobile satellite services (space-to-Earth) for the relay of nuclear burst data. GPS operates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

Figure 20. NTIA spectrum survey graph summarizing 5,800 sweeps across the 1350-1400 MHz range (System-2, band event 07, swept/m3 algorithm, sample detector, 10-kHz bandwidth) at Denver, CO, 1993.

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

1400 1427-1429-1435 1530

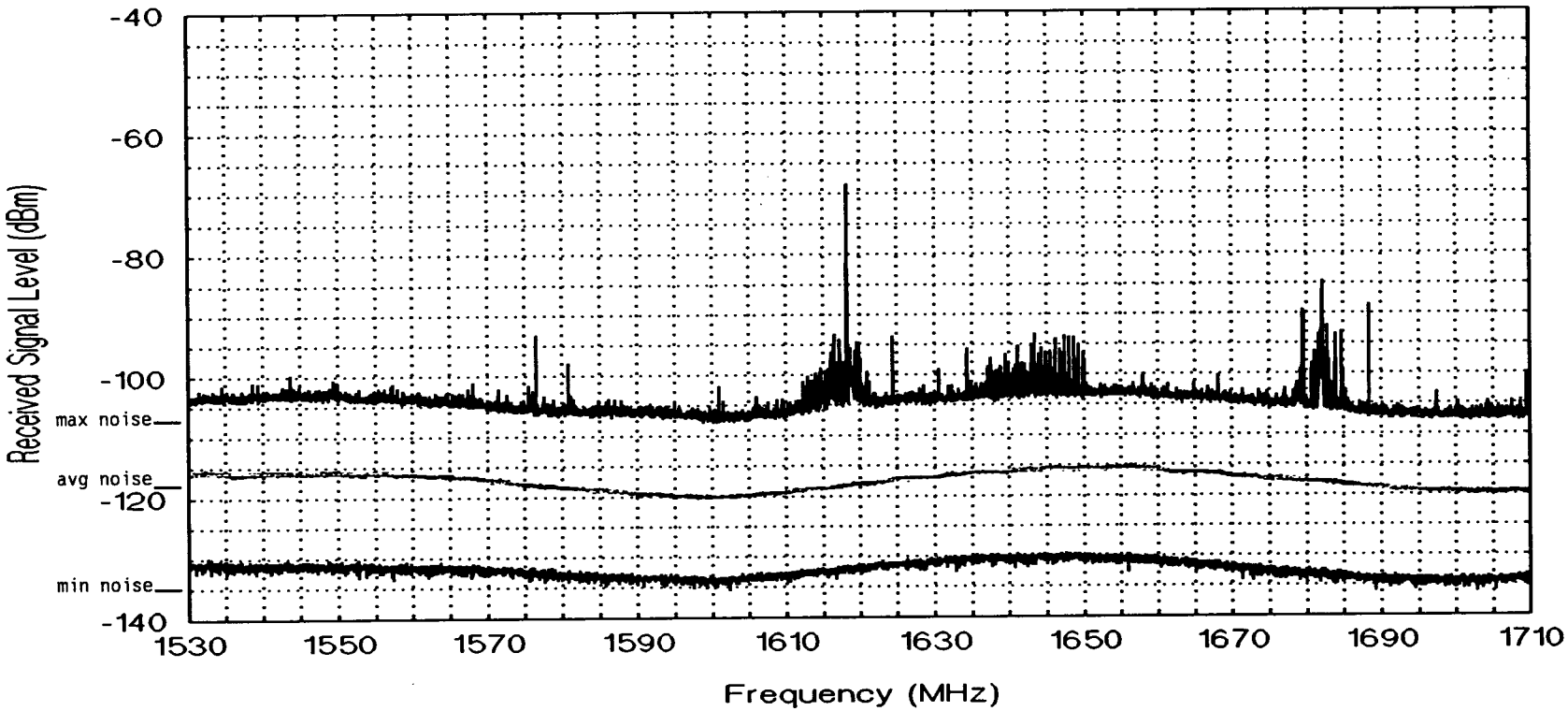


1. EARTH EXPLORATION-SATELLITE (Passive), SPACE RESEARCH (Passive).
2. FIXED, MOBILE (except aeronautical mobile), SPACE OPERATION (Earth-to-space).
3. FIXED, MOBILE.
4. SPACE OPERATION (Earth-to-space), Land Mobile (Telemetering and telecommand), Fixed (Telemetering).
5 Land Mobile (Telemetering and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

Figure 21. NTIA spectrum survey graph summarizing 11,600 sweeps across the 1400-1530 MHz range (System-2, band event 08, swept/m3 algorithm, sample detector, 30-kHz bandwidth) at Denver, CO, 1993.

GOVERNMENT ALLOCATIONS:	1.	2.	AERONAUTICAL RADIONAVIGATION, RADIONAVIGATION-SATELLITE (space-to-Earth).	3.	4.	METEOROLOGICAL AIDS, 5.	FIXED, 6.	
NON-GOVERNMENT ALLOCATIONS:	1.	2.	AERONAUTICAL RADIONAVIGATION, RADIONAVIGATION-SATELLITE (space-to-Earth).	3.	4.	METEOROLOGICAL AIDS, 5.	6, fixed.	
GENERAL UTILIZATION:	INMARSAT.	AMS(R)S.	GPS, GLONASS, (1610-1626.5 MHz Airborne aids to air navigation, only).	INMARSAT.	AMS(R)S.	Radiosondes and satellite imagery.	7.	

1530 1545 1559 1626.5 1646.5 1668.4 1700 1710

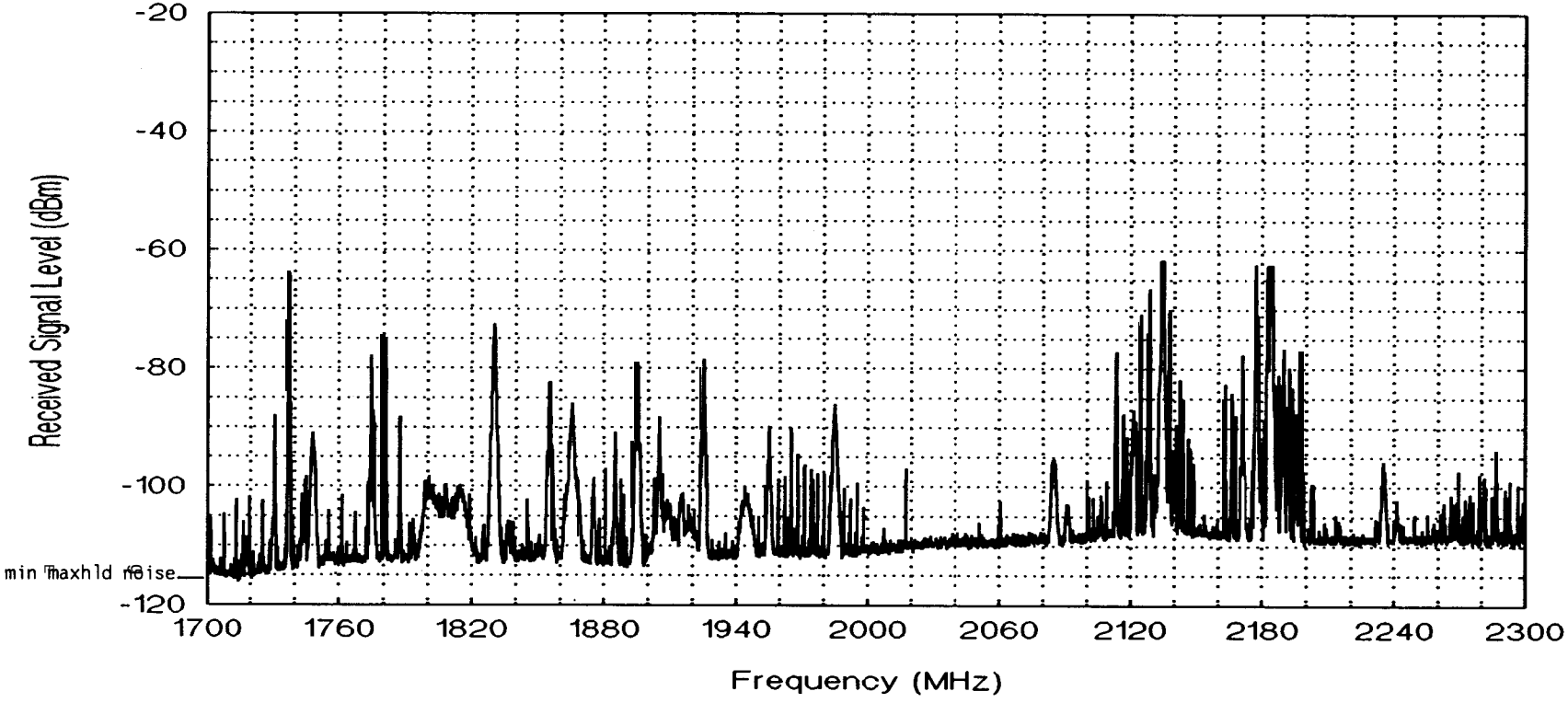


1. MARITIME MOBILE-SATELLITE (space-to-Earth), Mobile (1530-1535 MHz, Aeronautical telemetering), MOBILE-SATELLITE (1544-1545 MHz, space-to-Earth, distress and safety only, SARSAT).
2. AERONAUTICAL MOBILE-SATELLITE (R) (space-to-Earth), MOBILE-SATELLITE (space-to-Earth), Mobile-Satellite (space-to-Earth).
3. MARITIME MOBILE-SATELLITE (Earth-to-space), MOBILE-SATELLITE (1645.5-1646.5 MHz, Earth-to-space, distress and safety only).
4. AERONAUTICAL MOBILE-SATELLITE (R) (Earth-to-space), MOBILE-SATELLITE (Earth-to-space), RADIO ASTRONOMY, Mobile-Satellite (Earth-to-space), 1660-1668.4 MHz: RADIO ASTRONOMY, SPACE RESEARCH (passive).
5. RADIO ASTRONOMY, METEOROLOGICAL-SATELLITE (space-to-Earth).
6. METEOROLOGICAL-SATELLITE (space-to-Earth).
7. GOES, TIROS-N.

Figure 22. NTIA spectrum survey graph summarizing 42,500 sweeps across the 1530-1710 MHz range (System-2, band event 09, swept/m3 algorithm, sample detector, 30-kHz bandwidth) at Denver, CO, 1993.

GOVERNMENT ALLOCATIONS:	FIXED, MOBILE.				FIXED, MOBILE, SPACE RESEARCH.	5
NON-GOVERNMENT ALLOCATIONS:		FIXED.	FIXED, MOBILE.	FIXED.		6
GENERAL UTILIZATION:	LOS fixed links, 1, telemetry, telecommand.	Private fixed microwave.	Auxiliary broadcasting, Cable TV, TDRSS, 2.	Control links, Cellular, 3.	TDRSS, SGLS, 4.	7

1710 1850 1990 2110 2200 2290-2300

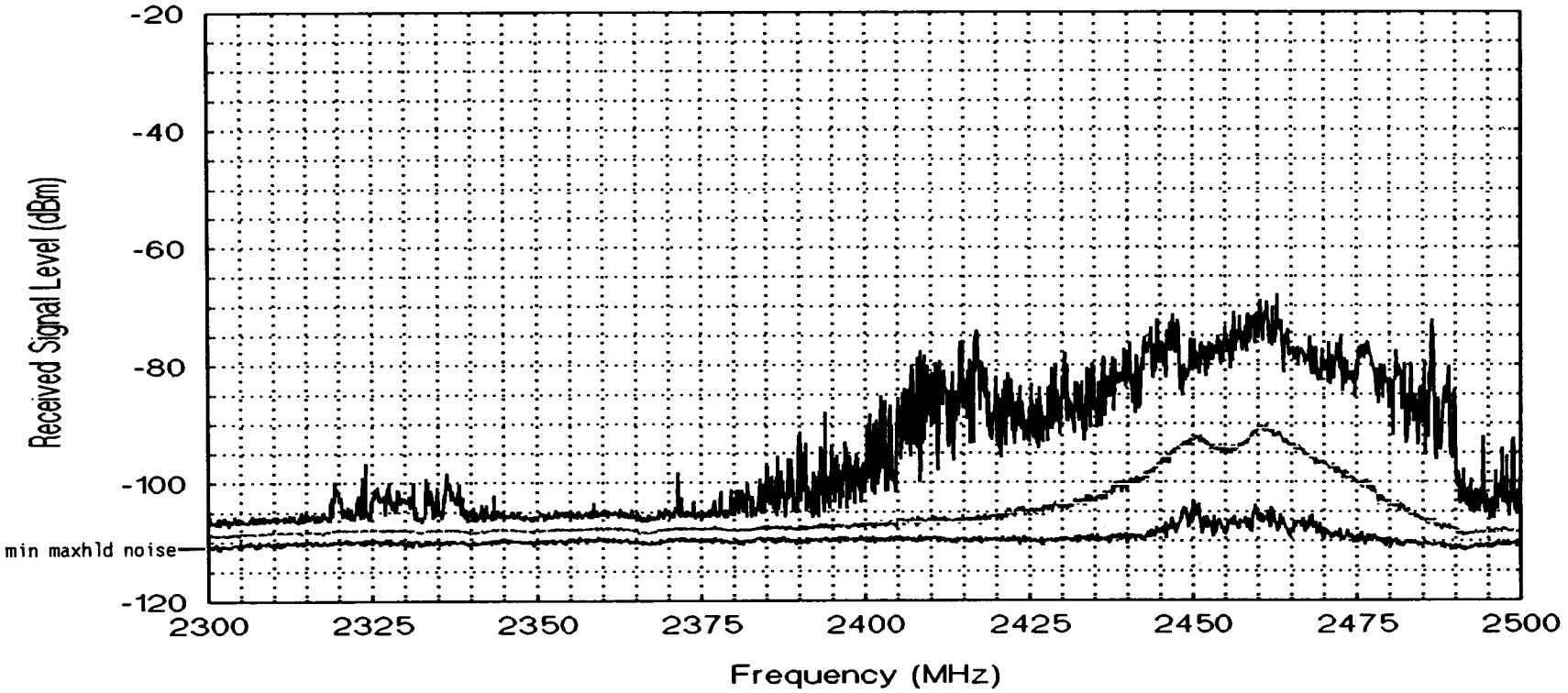


1. Predominantly federal medium-capacity LOS fixed service band.
2. GOES uplink. NASA's global ground network and TDRSS (2025-2110 MHz).
3. Paired fixed links (2110-2130 MHz and 2160-2180 MHz; 2130-2150 MHz and 2180-2200 MHz). Point-to-point and multipoint links (2150-2160 MHz). NASA space and Earth to space command links (2110-2120 MHz).
4. Space telemetry, telecommand and control systems. Fixed microwave.
5. FIXED, MOBILE (except aeronautical mobile), SPACE RESEARCH (space-to-Earth and Deep Space only).
6. SPACE RESEARCH (space-to-Earth and Deep Space only).
7. NASA deep space network space-to-Earth telemetry.

Figure 23. 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 Denver, CO, 1993.

GOVERNMENT ALLOCATIONS:	1.	RADIOLOCATION, MOBILE, Fixed.	RADIOLOCATION, 5.				
NON-GOVERNMENT ALLOCATIONS:	2.	MOBILE.	Amateur, 5.			FIXED, MOBILE, Radiolocation, 5, 7.	
GENERAL UTILIZATION:	3.	Telemetry, telemetry communications, aeronautical telemetry, 4.	6.	ISM, 6.		ISM, 8.	

2300 2310 2390 2400 2450 2500

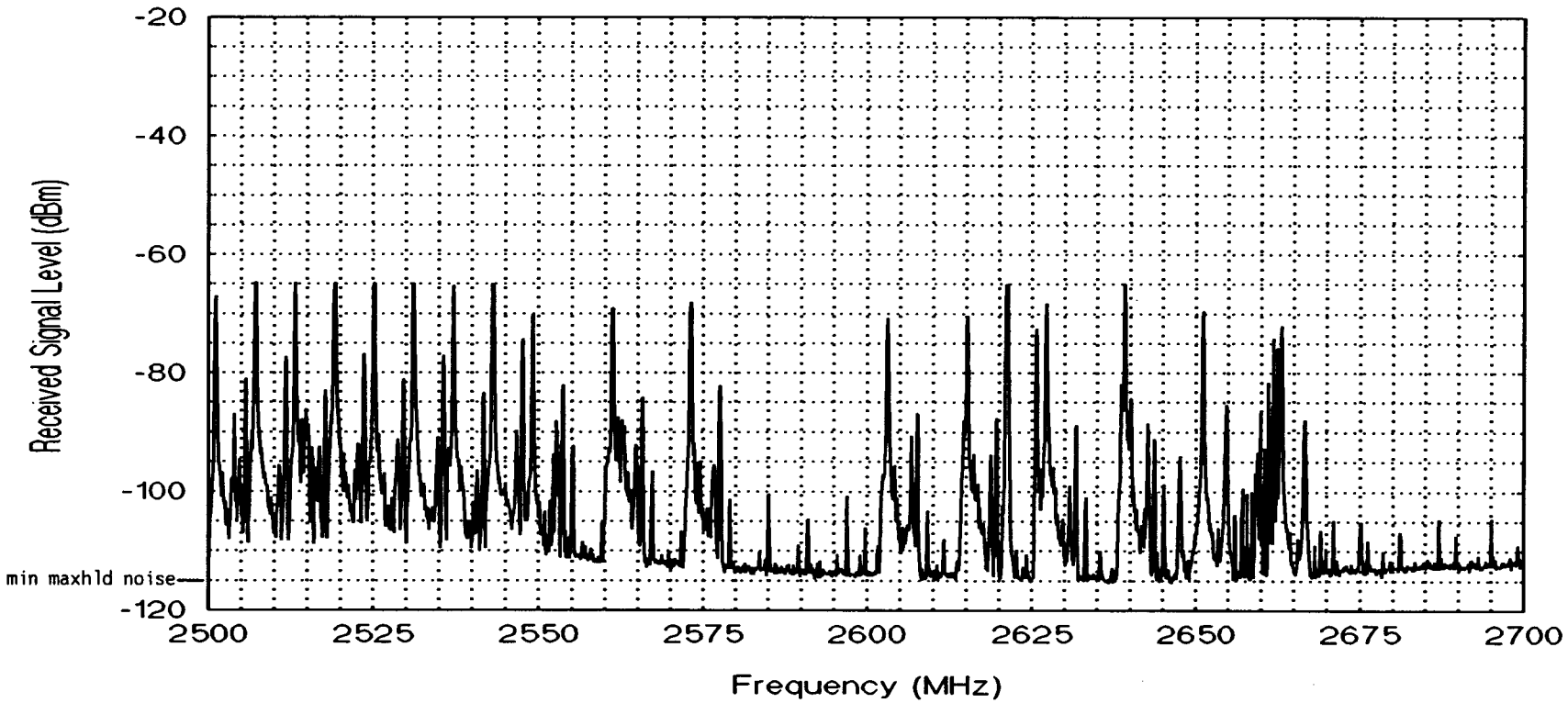


1. RADIOLOCATION, Fixed, Mobile.
2. Amateur.
3. Amateur weak signal modes and other modes.
4. AF High-power long-range surveillance radar and air traffic control radar. Venus Radar Mapper (VRM) synthetic aperture radar.
5. 2400-2500 MHz: Is designated for industrial scientific and medical (ISM) applications including microwave ovens.
6. Amateur mixed modes. Amateur satellite (space-to-Earth).
7. 2483.5-2500 MHz: RADIODETERMINATION-SATELLITE (space-to-Earth).
8. Fixed and portable video tranmission by TV broadcasters.

Figure 24. NTIA spectrum survey graph summarizing 34,800 sweeps across the 2300-2500 MHz range (System-2, band event 11, swept algorithm, maximum-hold detector, 100-kHz bandwidth) at Denver, CO, 1993.

GOVERNMENT ALLOCATIONS:		3.	4.	
NON-GOVERNMENT ALLOCATIONS:	BROADCASTING-SATELLITE, FIXED, 1.	BROADCASTING-SAT., FIXED, 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

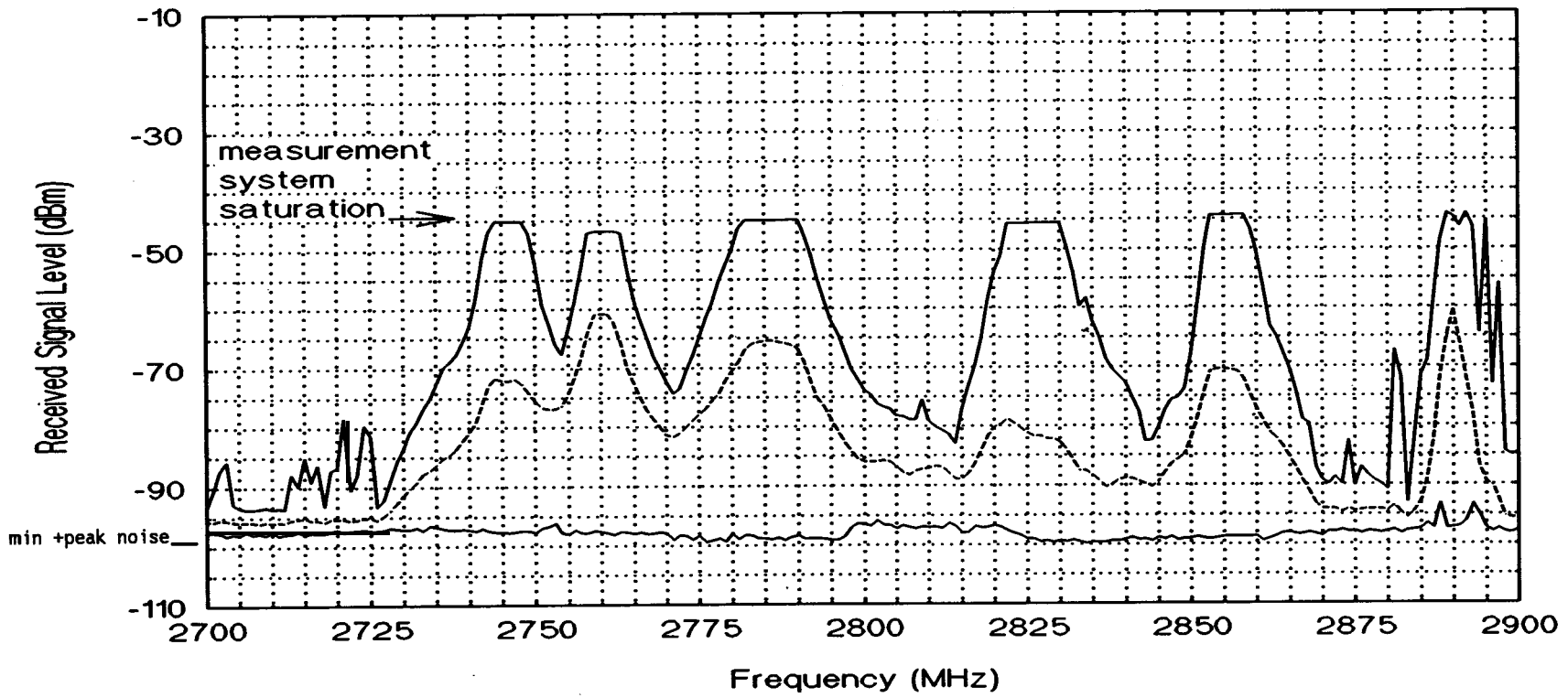


1. Broadcasting-satellite service is limited to community reception of educational and public service television programming.
2. 2500-2686 MHz: Omni transmission of Multipoint MDS that can be contained within 6 MHz channel bandwidths.
3. Earth Exploration-Satellite (Passive), Radio Astronomy, Space Research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

Figure 25. 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 Denver, CO, 1993.

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

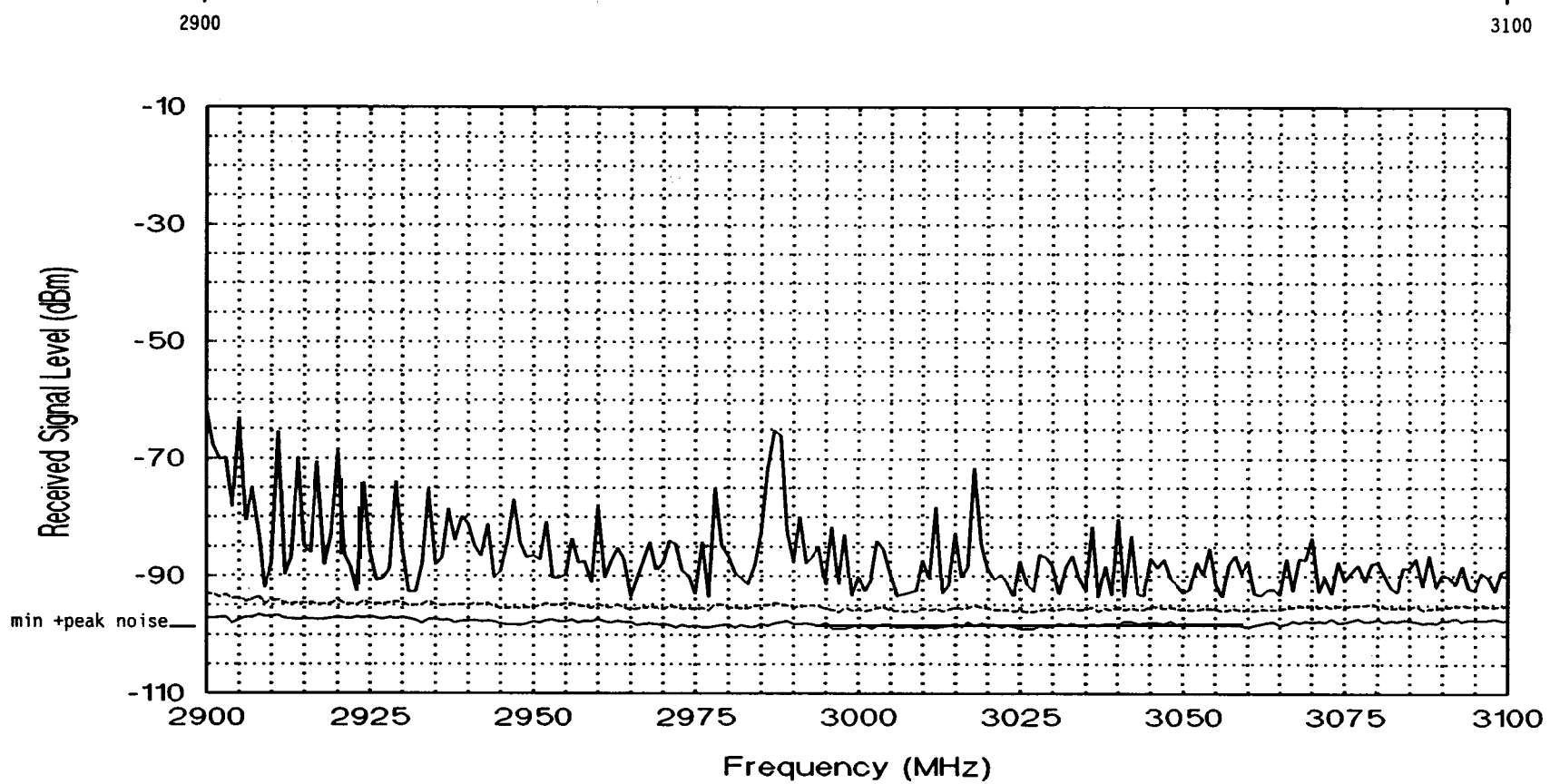


1. The aeronautical radionavigation service is restricted to ground-based radars and associated airborne transponders that transmit only in this band when actuated by these radars.

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

Figure 26. NTIA spectrum survey graph summarizing 31 scans across the 2700-2900 MHz range (System-2, band event 13, stepped algorithm, +peak detector, 1000-kHz bandwidth) at Denver, CO, 1993.

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.

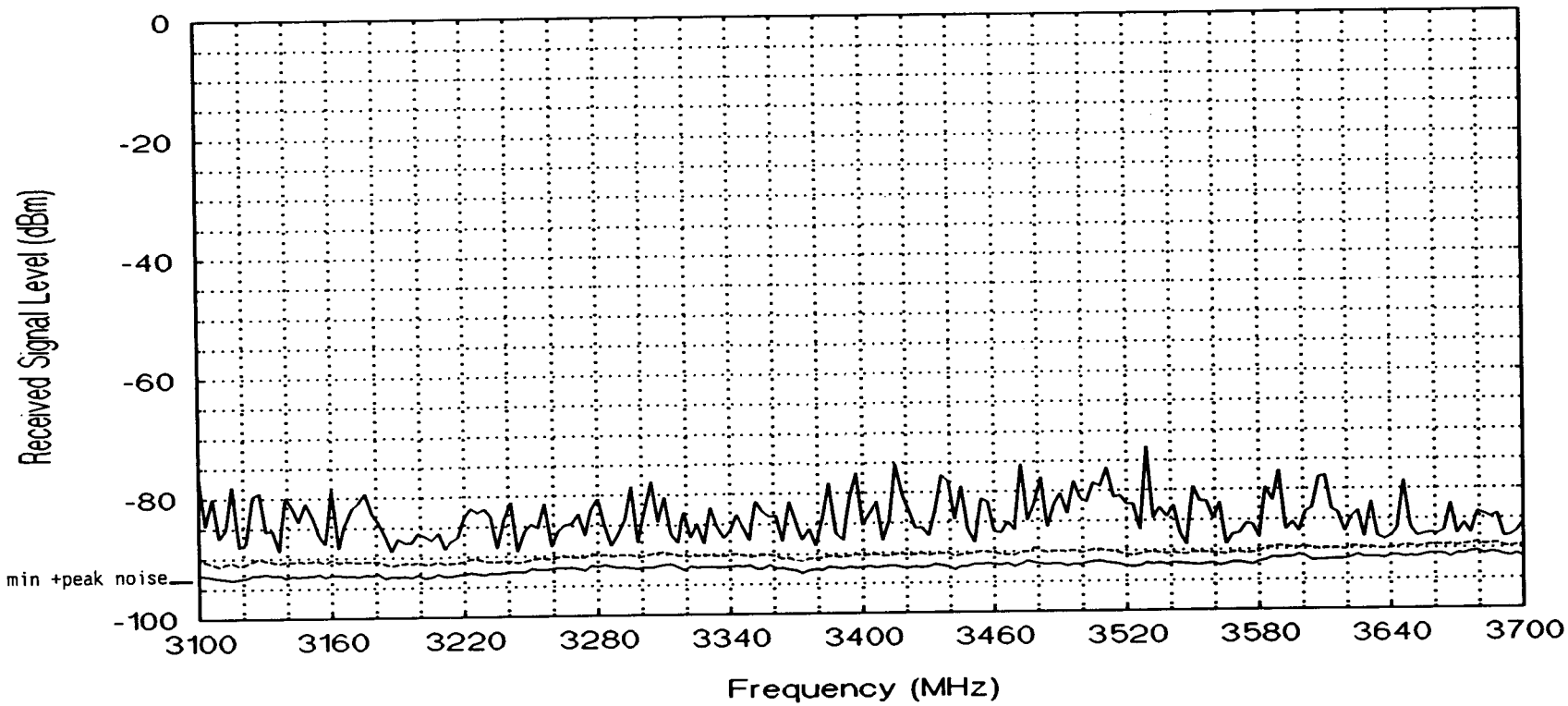


1. Radiolocation assignments are primarily for the military; however, other agency use is permitted for experimentation, research, and survey operations, if no harmful interference occurs.

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

Figure 27. NTIA spectrum survey graph summarizing 57 scans across the 2900-3100 MHz range (System-2, band event 14, stepped algorithm, +peak detector, 1000-kHz bandwidth) at Denver, CO, 1993.

GOVERNMENT ALLOCATIONS:	RADIOLOCATION.	RADIOLOCATION.	RADIOLOCATION, 1.	RADIOLOCATION, 1.	
NON-GOVERNMENT ALLOCATIONS:	Radiolocation.	Amateur, Radiolocation.	Radiolocation.	FIXED-SATELLITE (space-to-Earth), 2.	
GENERAL UTILIZATION:	3.	3.	3.	INMARSAT, INTELSAT.	
	3100	3300	3500	3600	3700



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

Figure 28. NTIA spectrum survey graph summarizing 57 scans across the 3100-3700 MHz range (System-2, band event 15, stepped algorithm, +peak detector, 3000-kHz bandwidth) at Denver, CO, 1993.

GOVERNMENT ALLOCATIONS:	
NON-GOVERNMENT ALLOCATIONS:	FIXED, FIXED-SATELLITE (space-to-Earth).
GENERAL UTILIZATION:	Common carrier microwave radio-relay and television receive only (TVRO) Earth stations.

3700 4200

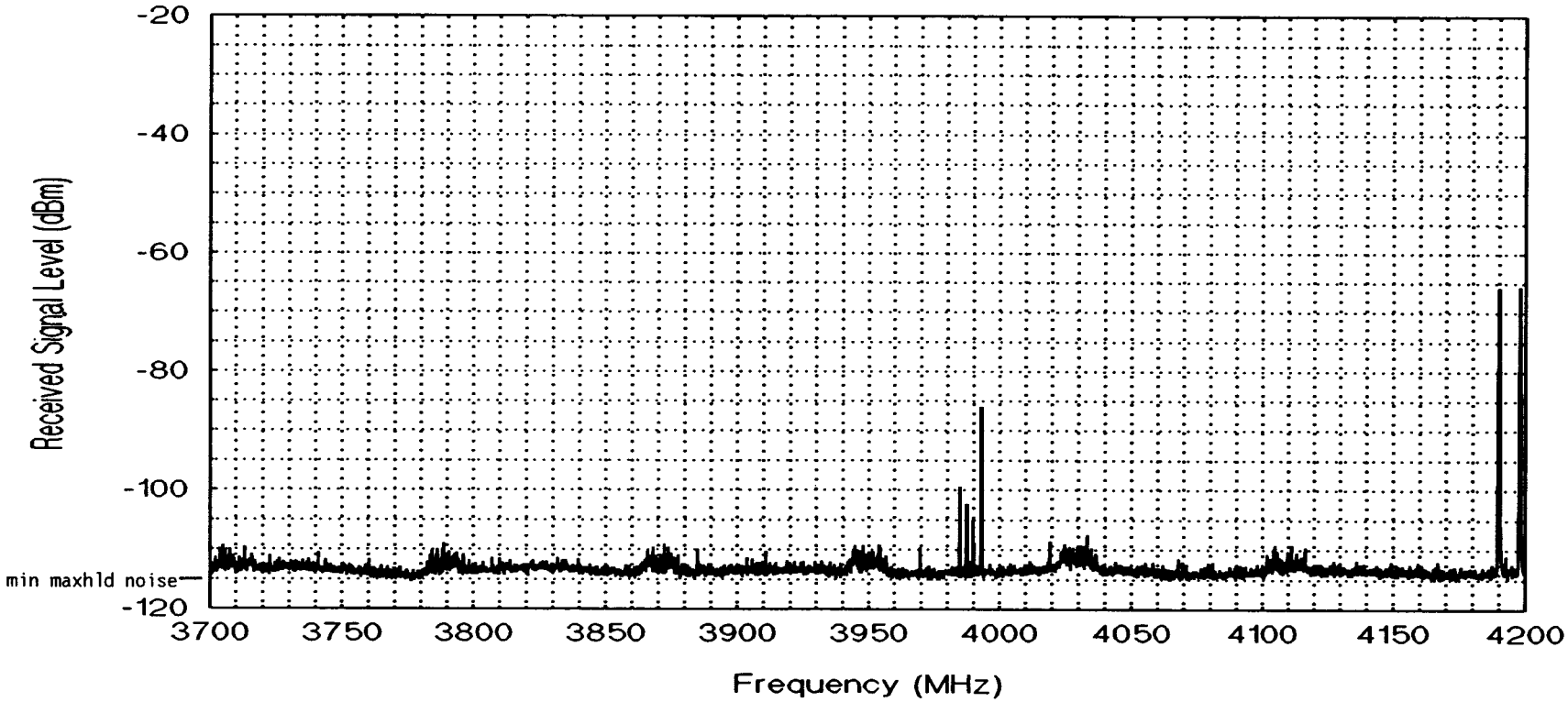
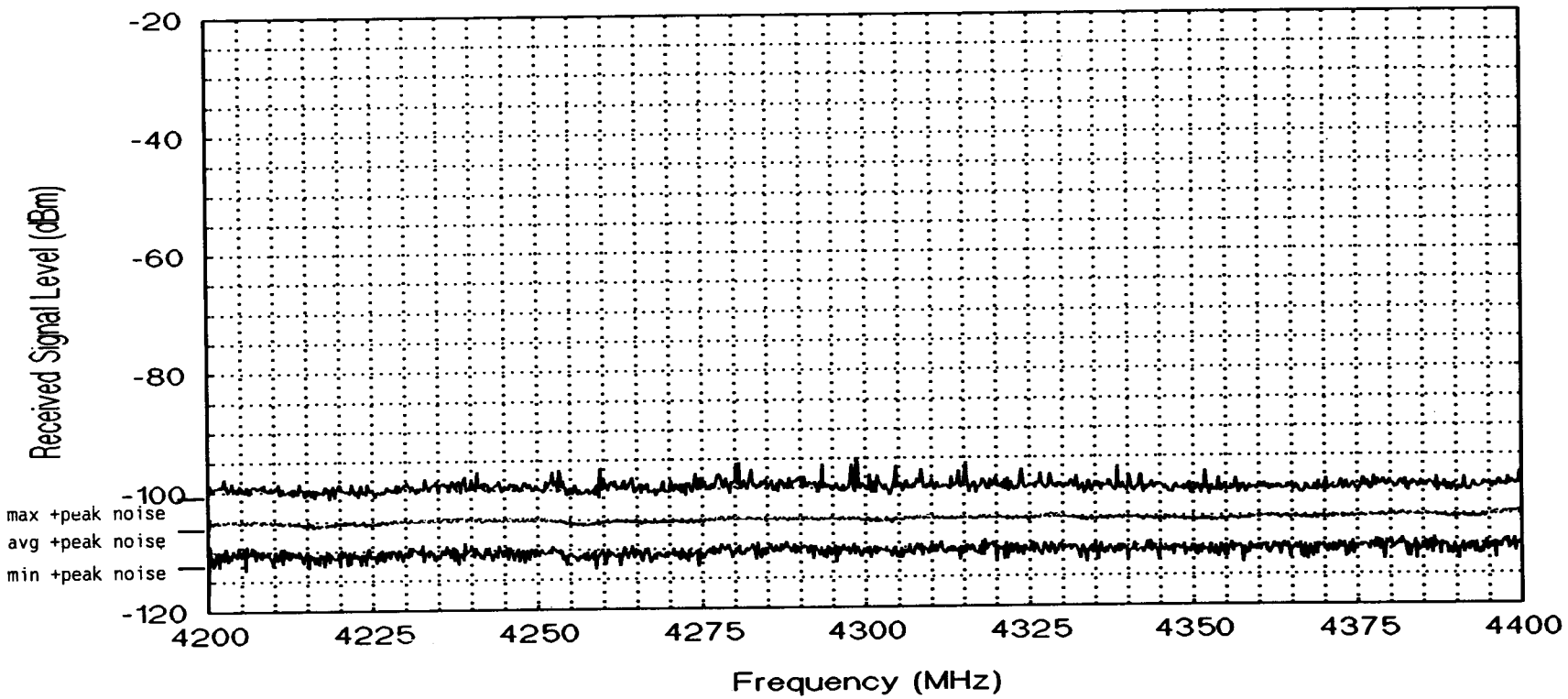


Figure 29. NTIA spectrum survey azimuth-scan graph of the 3700-4200 MHz range (System-2, band event 16, swept algorithm, maximum-hold detector, 100-kHz bandwidth) at Denver, CO, 1993.

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

4200 4400

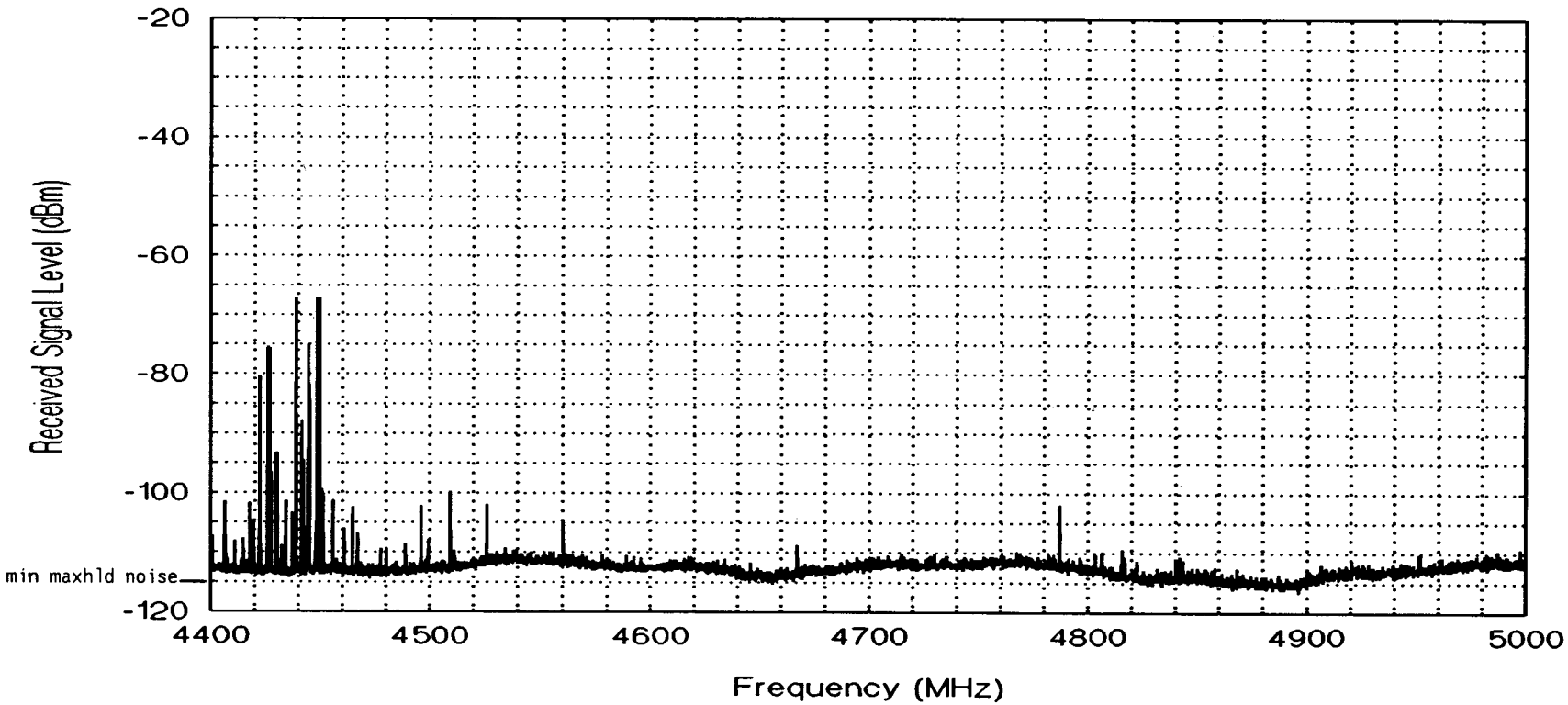


1. 4202 ±12 MHz: Standard frequency and time satellite service (space-to-Earth), permitted.

Figure 30. 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 Denver, CO, 1993.

GOVERNMENT ALLOCATIONS:	FIXED, MOBILE.			1.
NON-GOVERNMENT ALLOCATIONS:		FIXED-SATELLITE (space-to-Earth). 4500-4800 MHz.		1.
GENERAL UTILIZATION:	Military tactical communications, both line-of-sight and troposcatter.			

4400 — 4990-5000

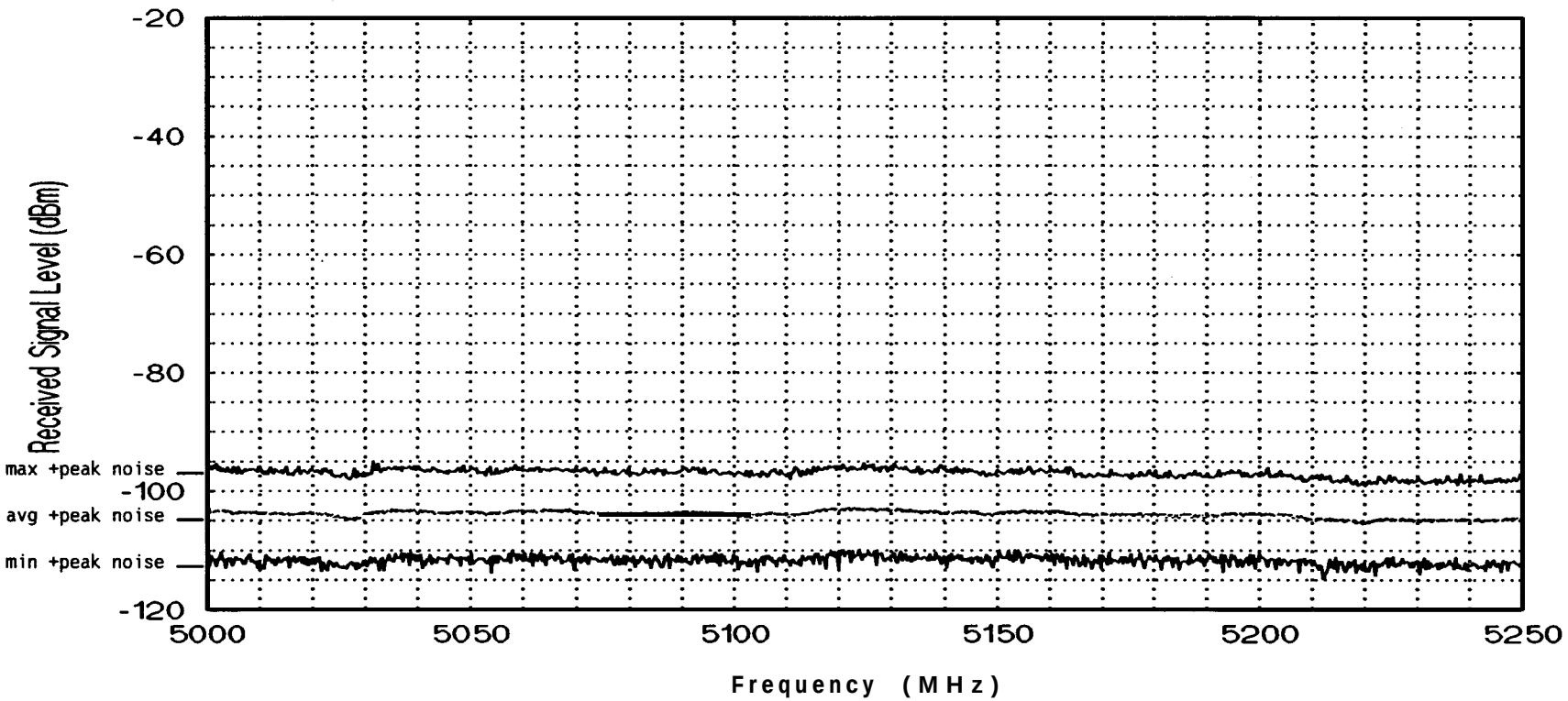


1. RADIO ASTRONOMY, Space Research (Passive).

Figure 31. 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 Denver, CO, 1993.

GOVERNMENT ALLOCATIONS:	AERONAUTICAL RADIONAVIGATION, AERONAUTICAL MOBILE-SATELLITE , 1.	
NON-GOVERNMENT ALLOCATIONS:	AERONAUTICAL RADIONAVIGATION . AERONAUTICAL MOBILE-SATELLITE. 1.	
GENERAL UTILIZATION:	Microwave landing systems.	

5000 5250

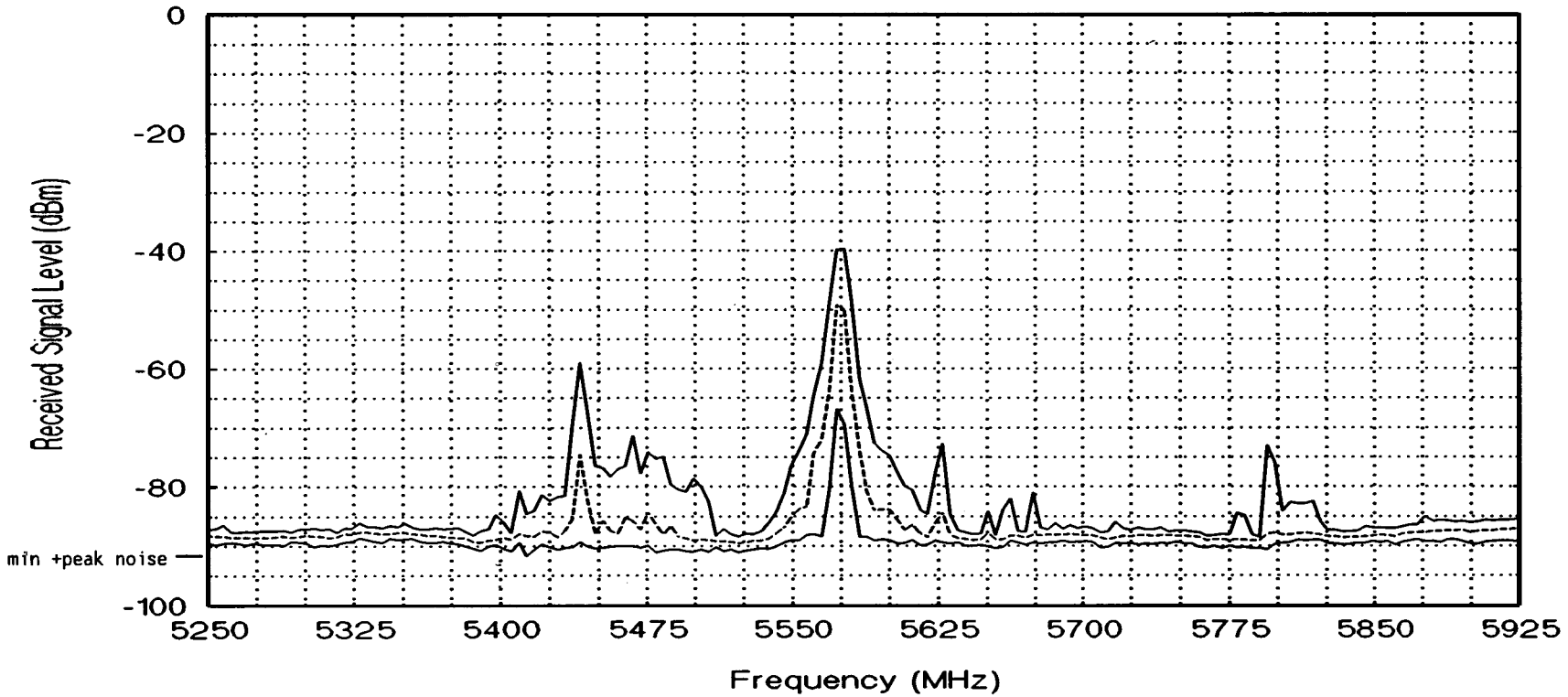


1. Also, 5150-5216 MHz: Fixed-Satellite service (space-to-Earth).

Figure 32. NTIA spectrum survey graph summarizing 42,000 sweeps across the 5000-5250 MHz range (System-2, band event 19, swept/m3 algorithm, + peak detector, 300-kHz bandwidth) at Denver, CO, 1993.

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

5250 5350 5460-5470 5600 5650 5850 5925

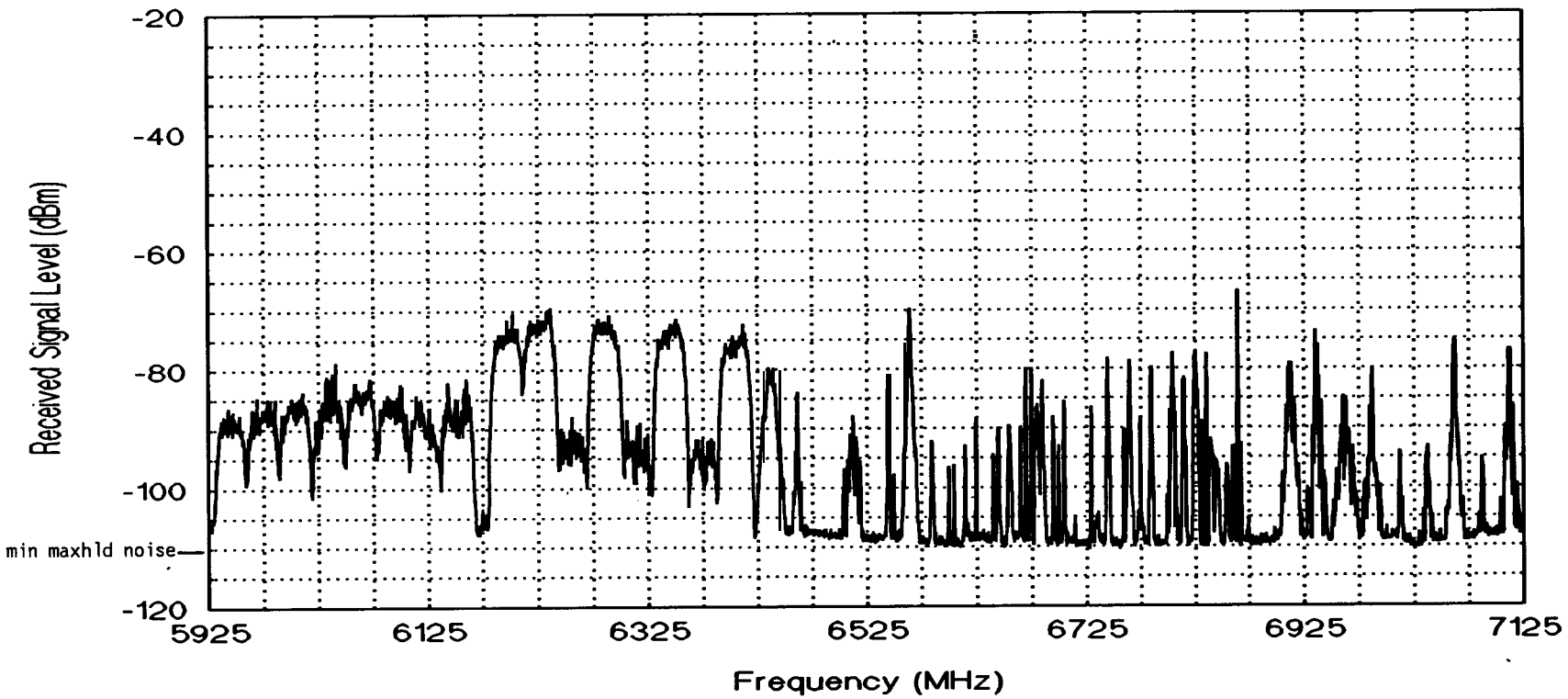


1. RADIOLOCATION.
2. Radiolocation.
3. RADIONAVIGATION, Radiolocation.
4. MARITIME RADIONAVIGATION, METEOROLOGICAL AIDS, Radiolocation.
5. Government weather radars, e.g., Terminal Doppler Weather Radar (TDWR).
6. FIXED-SATELLITE (Earth-to-space), Amateur.

Figure 33. NTIA spectrum survey graph summarizing 26 scans across the 5250-5925 MHz range (System-2, band event 20, stepped algorithm, +peak detector, 3000-kHz bandwidth) at Denver, CO, 1993.

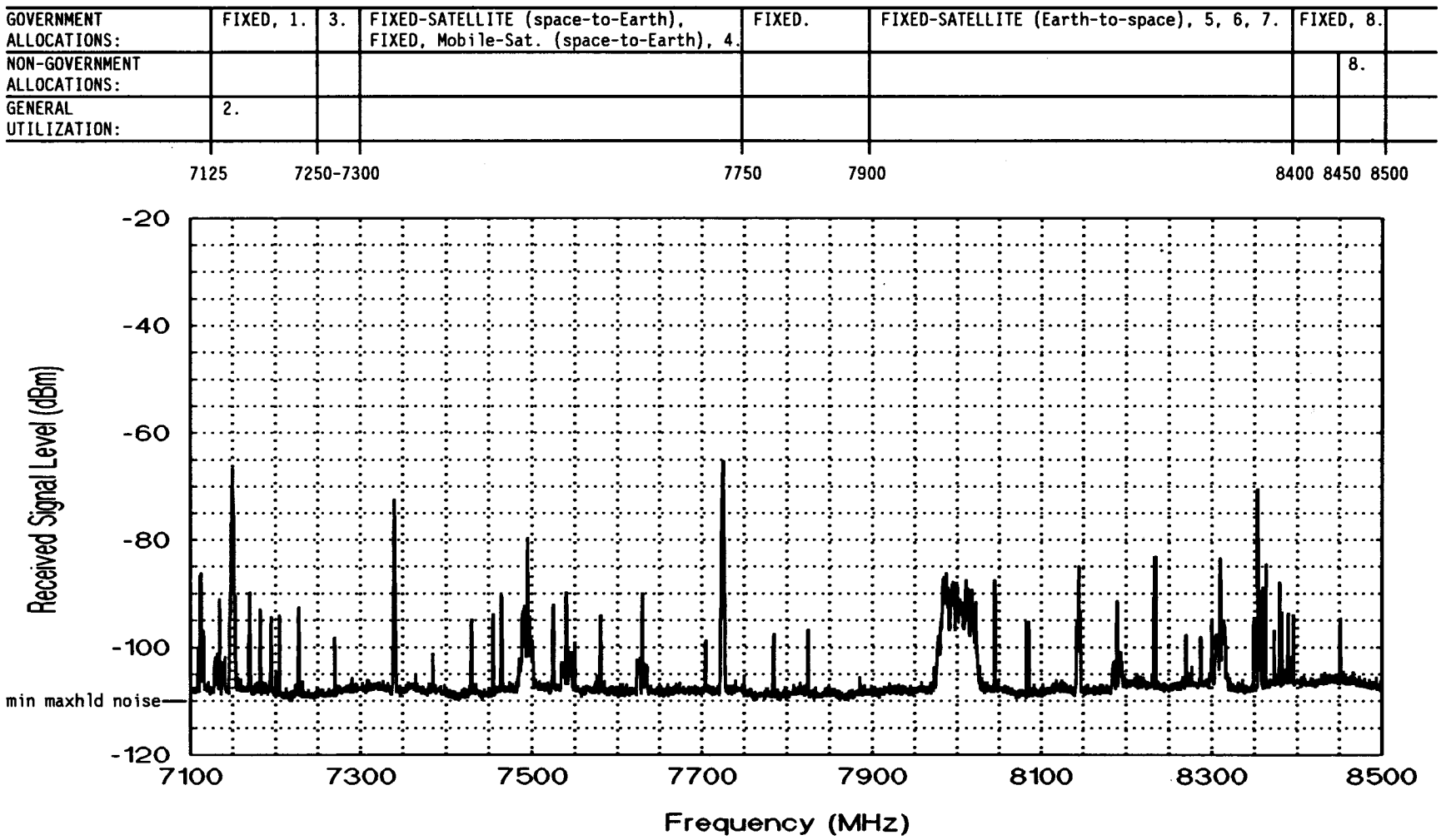
GOVERNMENT ALLOCATIONS:					
NON-GOVERNMENT ALLOCATIONS:	FIXED, FIXED-SATELLITE (Earth-to-space).	2.	FIXED, FIXED-SATELLITE (Earth-to-space).	3, FIXED-SATELLITE (Earth-to-space).	3.
GENERAL UTILIZATION:	Common carrier, cellular, satellite uplinks for television and data, VSAT systems.		Public safety, common carrier, Auxiliary broadcasting.	Auxiliary broadcasting, 4.	

5925 6425 6525 6875 7075 7125



1. 6415-6439 MHz: Standard frequency and time signal (Earth-to-space).
2. FIXED-SATELLITE (Earth-to-space), MOBILE.
3. FIXED, MOBILE.
4. Studio-to-transmitter links (STL), intercity relays (ICR), electronic news gathering (ENG), cable TV pickup stations, TV translator relay stations permitted on a secondary basis.

Figure 34. 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 Denver, CO, 1993.

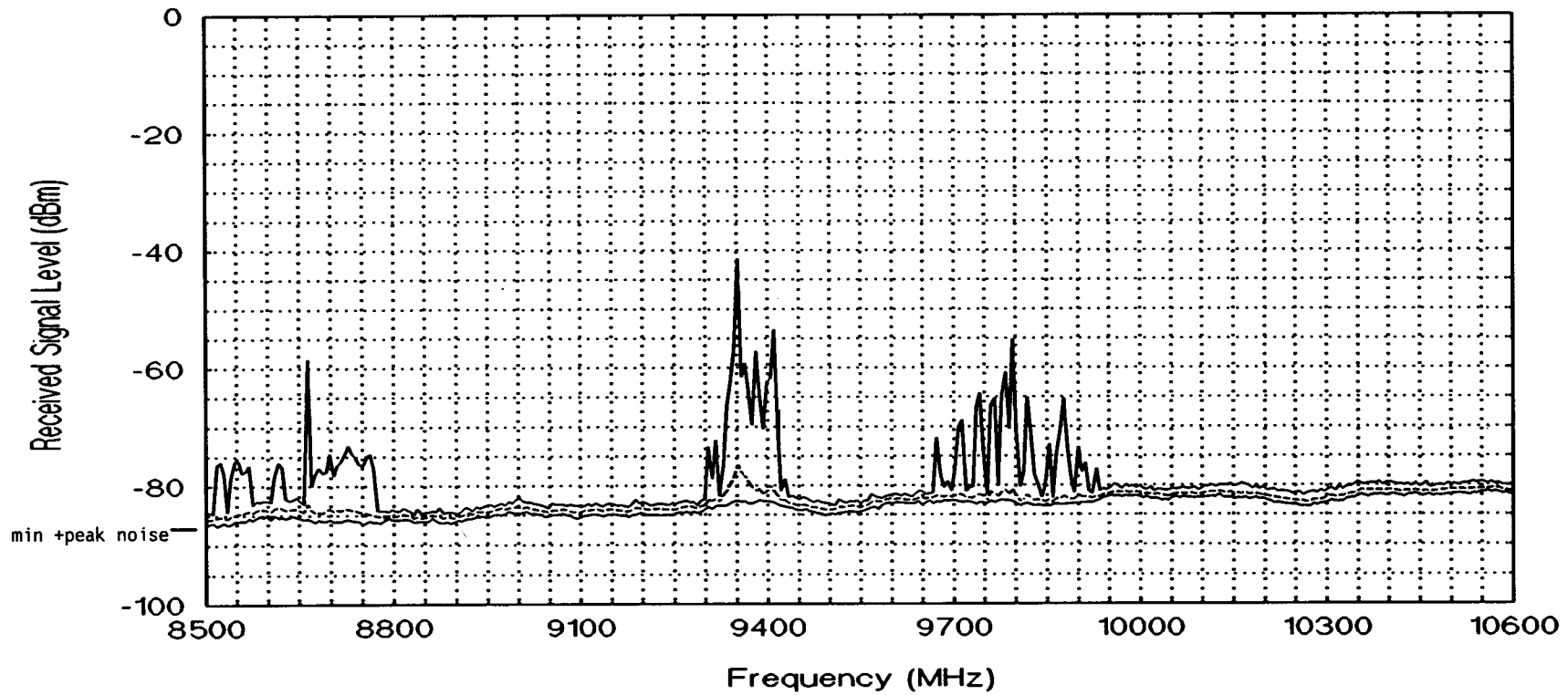


1. 7190-7235 MHz: SPACE RESEARCH (Earth-to-space).
2. 7125-8500 MHz: Government point-to-point microwave voice/data links, military satellite communications systems, miscellaneous space links.
3. FIXED-SATELLITE and MOBILE-SATELLITE (space-to-Earth), Fixed.
4. 7450-7550 MHz: METEOROLOGICAL-SATELLITE (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 (Earth-to-space) (no airborne transmissions).
7. 8175-8215 MHz: METEOROLOGICAL-SATELLITE (Earth-to-space).
8. SPACE RESEARCH (space-to-Earth) (8400-8450 MHz deep space only).

Figure 35. 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 Denver, CO, 1993.

GOVERNMENT ALLOCATIONS:	RADIOLOCATION.	1.	2.	3.	RADIOLOCATION.			
NON-GOVERNMENT ALLOCATIONS:	Radiolocation.	1.	2.	3.	Radiolocation.	Amateur, Radiolocation.	5.	
GENERAL UTILIZATION:	Military Ground Control Approach (GCA) radar.			4.				

8500 9000 9200 9300 9500 10000 10450 10550

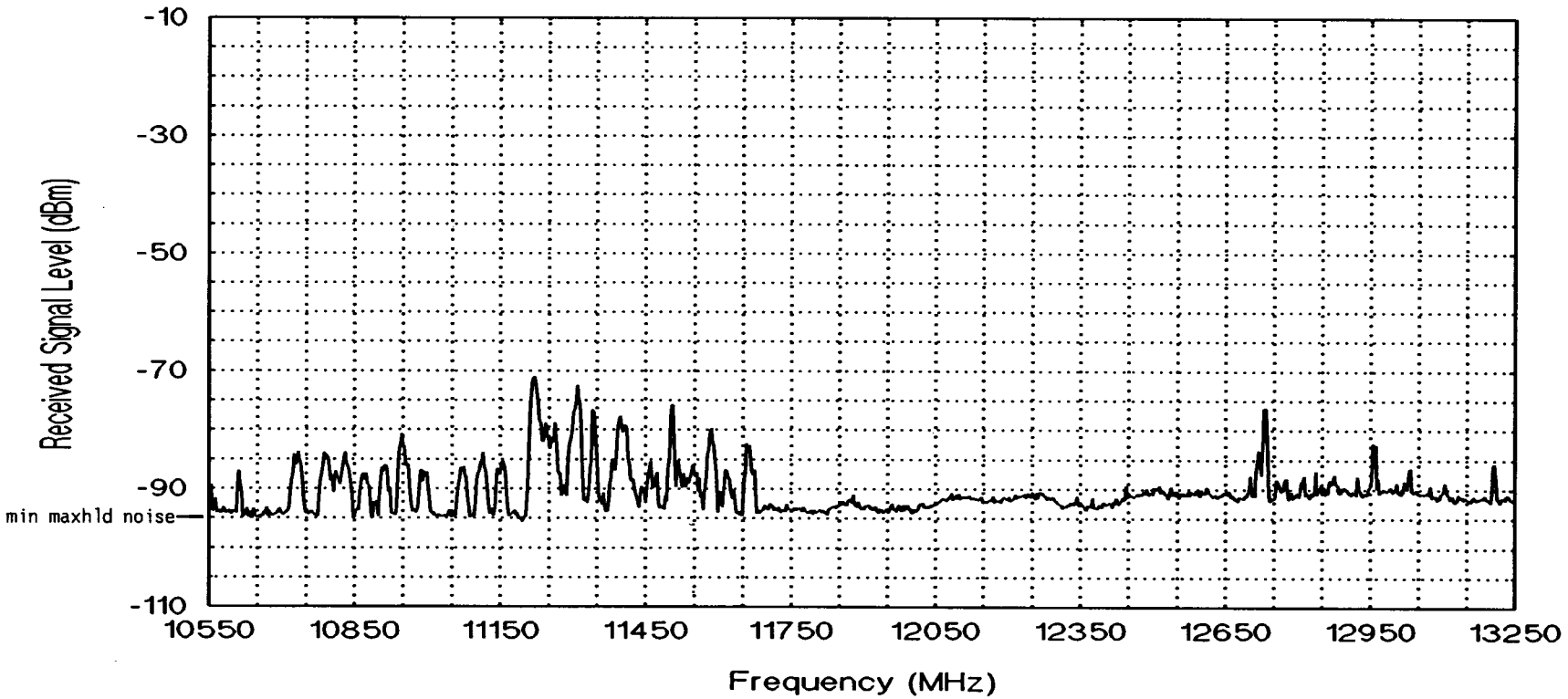


1. AERONAUTICAL RADIONAVIGATION, Radiolocation.
2. MARITIME RADIONAVIGATION, Radiolocation.
3. RADIONAVIGATION, Meteorological Aids, Radiolocation.
4. Maritime radionavigation radar, airborne weather radar.
5. RADIOLOCATION, Amateur, Amateur-Satellite.

Figure 36. NTIA spectrum survey graph summarizing 24 scans across the 8500-10550 MHz range (System-2, band event 23, stepped algorithm, +peak detector, 3000-kHz bandwidth) at Denver, CO, 1993.

GOVERNMENT ALLOCATIONS:	1.					
NON-GOVERNMENT ALLOCATIONS:	2.	FIXED, FIXED-SATELLITE (space-to-Earth).	FIXED-SATELLITE (space-to-Earth), 4.	BROADCASTING-SATELLITE, FIXED.	FIXED, MOBILE, 5.	
GENERAL UTILIZATION:	3.	Common carrier point-to-point microwave links, TV studio-to-transmitter links.		Private point-to-point microwave.	Cable Relay Systems (CARS), 6.	

10550 10700 11700 12200 12700 13250

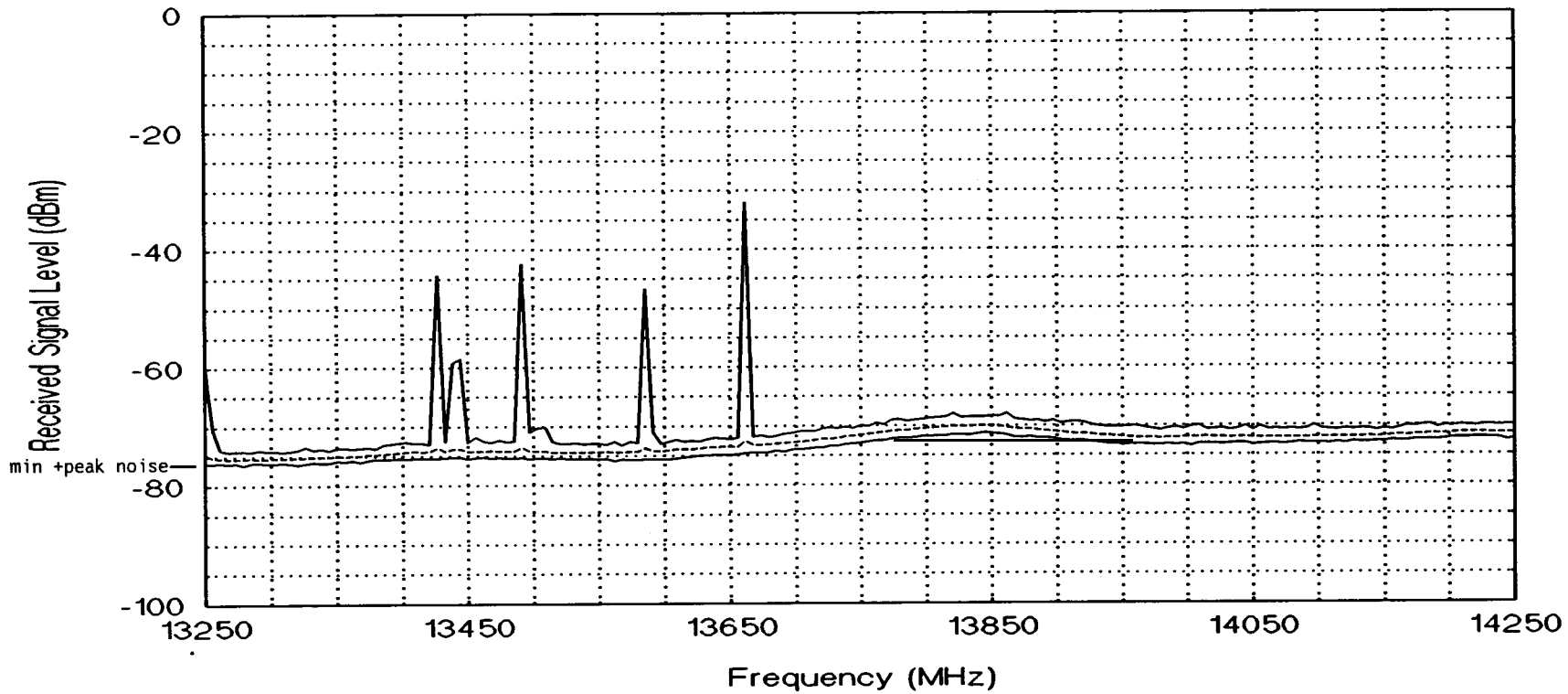


1. 10600-10700 MHz: EARTH EXPLORATION-SATELLITE (Passive), SPACE RESEARCH (Passive), RADIO ASTRONOMY (10680-10700 MHz).
2. FIXED (10550-10680 MHz, only), 10600-10700 MHz: EARTH EXPLORATION-SATELLITE (Passive), SPACE RESEARCH (Passive), RADIO ASTRONOMY (10680-10700 MHz, only).
3. Point-to-point microwave stations. Narrowband cellular links.
4. Mobile (except aeronautical mobile).
5. FIXED-SATELLITE (Earth-to-space).
6. TV auxiliary broadcasting (includes: SHL, STL, ENG, and ICR's).

Figure 37. 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 Denver, CO, 1993.

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



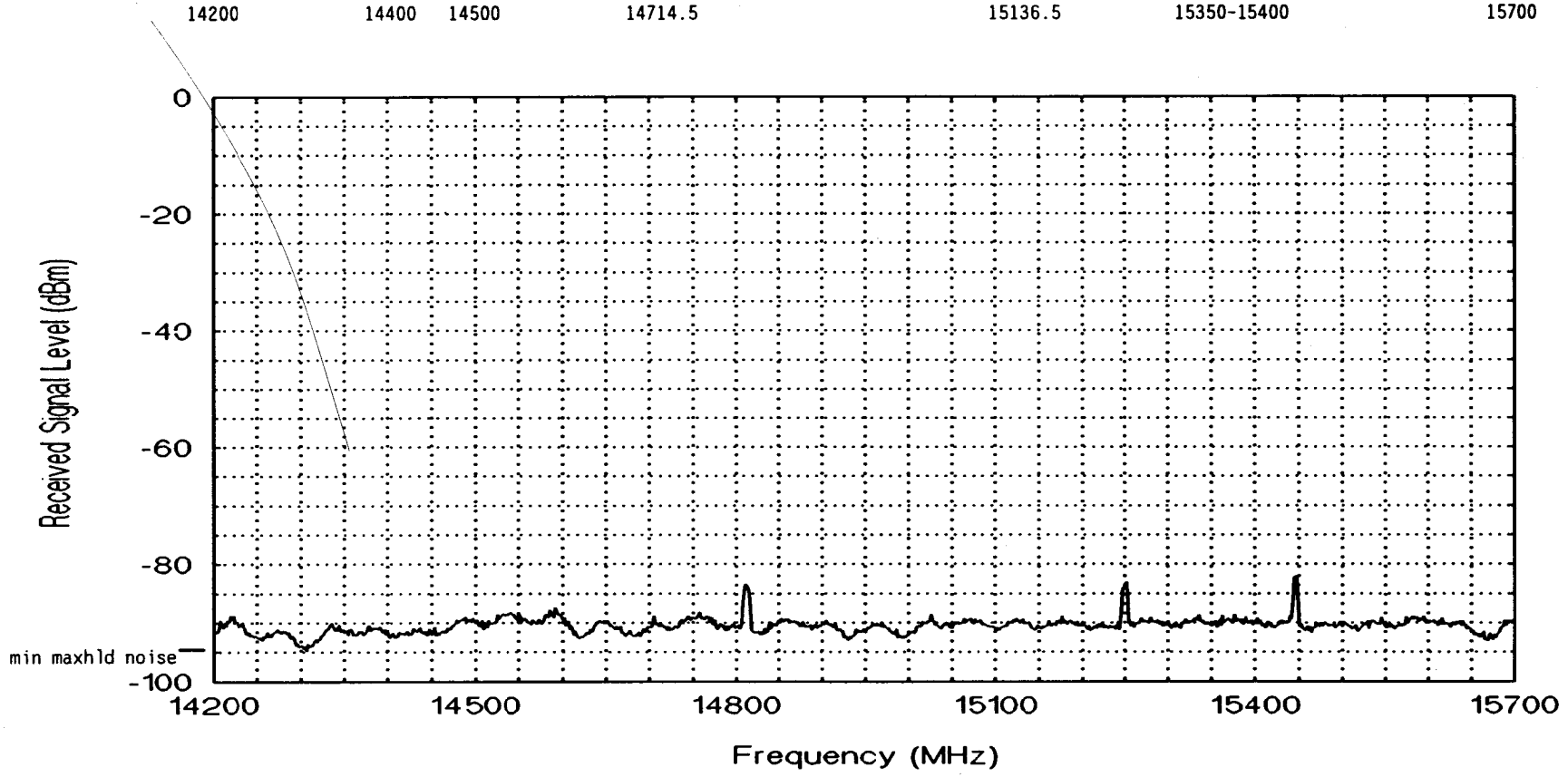
1. Space Research (Earth-to-space).

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

Figure 38. NTIA spectrum survey graph summarizing 42 scans across the 13250-14200 MHz range (System-2, band event 25, stepped algorithm, +peak detector, 3000-kHz bandwidth) at Denver, CO, 1993.

GOVERNMENT ALLOCATIONS:		Fixed, Mobile.	FIXED, Mobile, Space Research.	MOBILE, Fixed, Space Research.	FIXED, Mobile, Space Research.	2.	AERONAUTICAL RADIONAVIGATION.	
NON-GOVERNMENT ALLOCATIONS:	FIXED-SATELLITE (Earth-to-sp.).					2.	AERONAUTICAL RADIONAVIGATION.	
GENERAL UTILIZATION:			1.		1.			

14200 14400 14500 14714.5 15136.5 15350-15400 15700



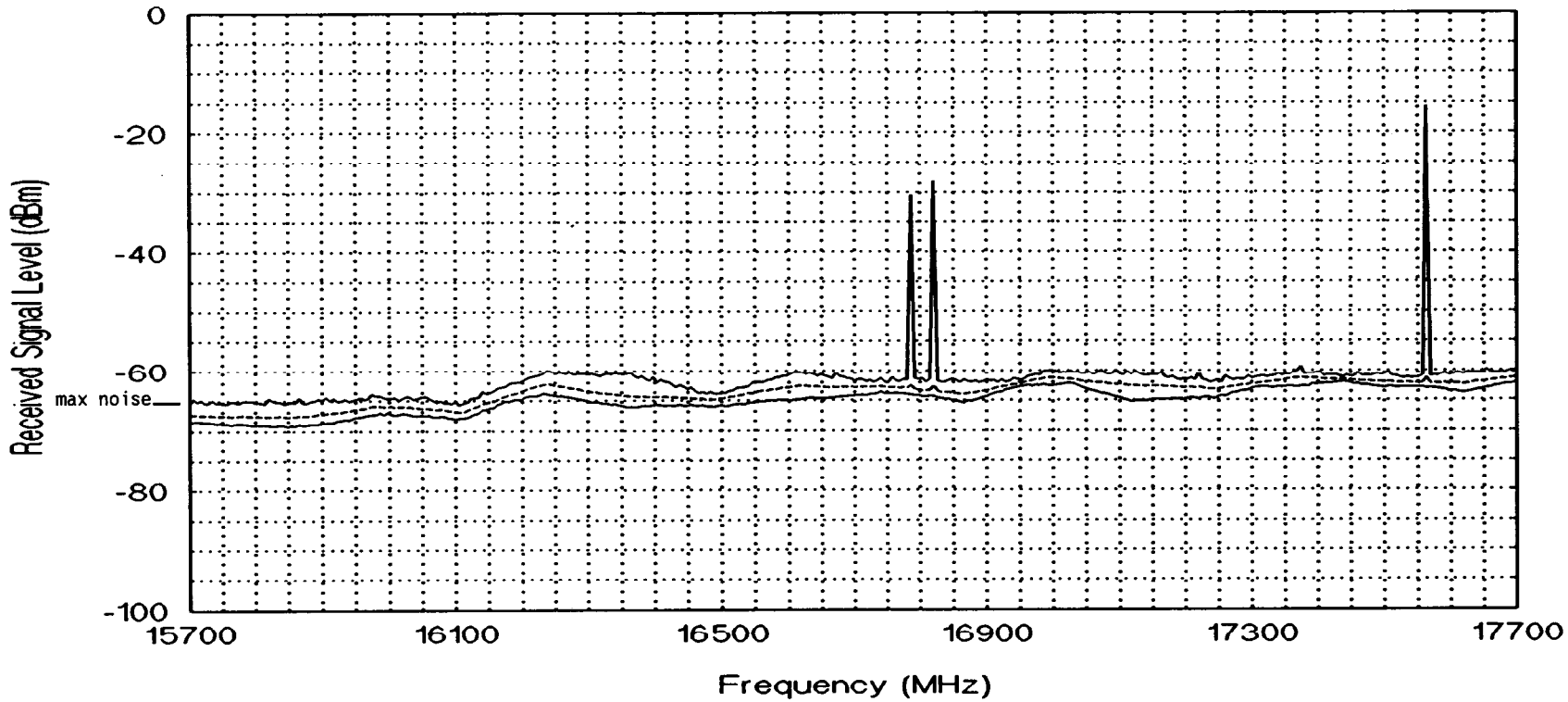
1. Military communication links and microwave links. Air traffic control links, including video data.

2. EARTH EXPLORATION-SATELLITE (Passive), RADIO ASTRONOMY, SPACE RESEARCH (Passive).

Figure 39. 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 Denver, CO, 1993.

GOVERNMENT ALLOCATIONS:	RADIOLOCATION, Space Research (Deep Space) (Earth-to-space).	1.	Radiolocation.	
NON-GOVERNMENT ALLOCATIONS:	Radiolocation.	2.	FIXED-SATELLITE (Earth-to-space).	
GENERAL UTILIZATION:	Military airborne radars.			

15700 17200-17300 17700



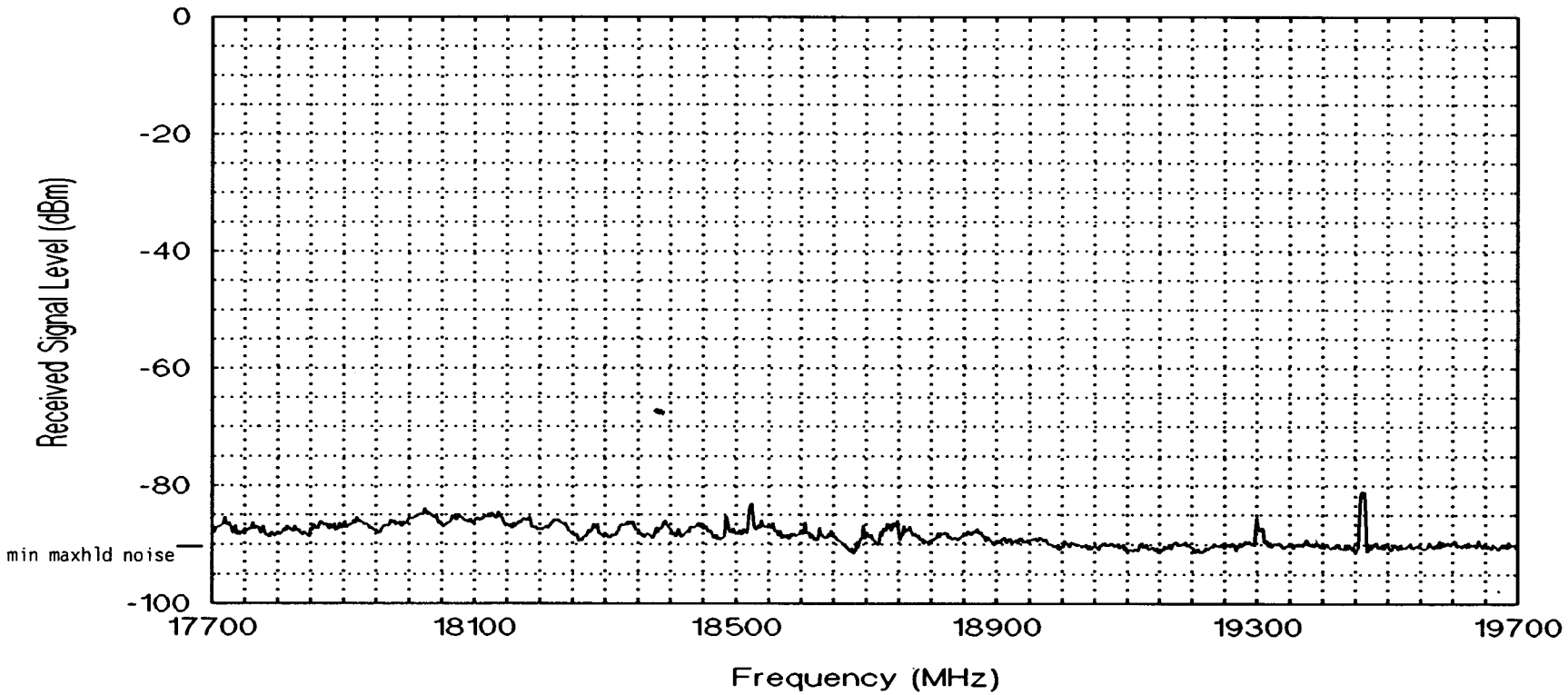
1. RADIOLOCATION, Earth Exploration-Satellite (Active}, space Research (Active).

2. Earth Exploration-Satellite (Active), Radiolocation, Space Research (Active).

Figure 40. NTIA spectrum survey graph summarizing 46 scans across the 15700-17700 MHz range (System-2, band event 27, stepped algorithm, + peak detector, 3000-kHz bandwidth) at Denver, CO, 1993.

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 TV relay systems (CARS), studio-to-transmitter (STL) TV 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 41. 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 Denver, CO, 1993.

the cumulative measurement time during the survey was typically several hours, spread uniformly over the diurnal cycle. In some bands, which are nondynamic and were 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 Denver 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 in these data provide a qualitative, not quantitative, measure of occupancy rates for the measured frequencies.

There does exist an RSMS measurement technique for obtaining absolute channel occupancy statistics. Measurements of this type have been recently performed in mobile radio bands in conjunction with RSMS occupancy surveys in California. However, this technique was not yet implemented when the Denver survey was performed, nor has a presentation format been developed for the release of the channel occupancy statistics data.

No emission sources are specifically identified in this report. RSMS crew members routinely measure emission parameters of selected transmitters, particularly radars, during occupancy surveys, but the notes on those parameters are not released here. The following paragraphs present general information about band occupancy that can be extrapolated from the survey band scans in this report; no reference is made to RSMS field notes on emitter characteristics to produce the comments below.

3.5.1 Band-by-band Observations on Spectrum Use

108-162 MHz: Measured data between 108 MHz and 114 MHz were contaminated by receiver-generated intermod products due to inadequate attenuation of adjacent band FM broadcast signals; those data are not presented here.

Between 108 MHz and 118 MHz, VOR (very high frequency omnidirectional range) aeronautical navigation beacons appear as 100'% emitters. These show on the occupancy scans as vertical lines coming up from the minimum curve. Also, in the air traffic control (ATC) band (up to 136 MHz) ATIS (automated terminal information service) transmissions appear as high-average or 100% signals. Frequently used ATC frequencies also show up as

high points on the average curve, and ATC frequencies which were observed one or more times during the survey show on the maximum curve.

In the 137-138 MHz band, TIROS signals are not receivable by the RSMS. A variety of mobile signals were observed in the 138-148 MHz portion of the spectrum. The average curve increases noticeably at a number of frequencies from 144-148 MHz. In the 148-162 MHz range, a nearby fixed transmitter was observed at about 152.5 MHz. This transmitter came close to, but did not quite exceed, the overload threshold of the RSMS. The sloping average curve on either side of this signal represents a measurement of the noise sideband emission from this transmitter.

162-174 MHz: A variety of fixed and mobile transmitters are observed. The high-average signal at 162.55 MHz is a public broadcast weather information frequency.

174-216 MHz: Television broadcast channels 7 and 9 are readily apparent, Channel 12 and a channel 11 repeater are also evident.

216-225 MHz: A few 100% signals are observed in the 216-220 MHz (maritime mobile) part of this spectrum. Other than that, little signal activity is noted for that band. This is consistent with Denver's land-locked location. Little activity was measured in the 220-222 MHz band. Most of the maximum curve is receiver noise and locally generated noise, as from vehicular traffic. Some signals are observed between 222-225 MHz on the maximum curve, but only four of those have any impact on the average curve.

225-400 MHz: An increased noise level is noted on the maximum curve between 225-325 MHz. Many of the signals observed on the maximum curve also produced an increase on the average curve. Four signals were measured in 100% of the RSMS scans, as shown on the minimum curve.

400-406 MHz: The maximum curve shows occupancy by a number of signals. Most of these signals were apparently observed briefly, as inferred from the fact that the average curve is only affected at a few frequencies,

406-420 MHz: Fixed and mobile signals, many of them showing up on both the maximum and average curves, were observed. At least three of the signals were observed on 100% of scans, as inferred from the minimum curve.

420-450 MHz: Nothing identifiable as a radar signal appears in this band. The three curves are consistent with a measurement mainly of RSMS receiver noise. A few peaks on the maximum curve may represent nonradar signals. The rise in the three curves at 420 MHz and at 450 MHz is caused by signals just outside this band. The measurement bandwidth of 1 MHz is convolving these signals, and the convolution appears in the band. The signals, however, are outside the band. The rise at 420 MHz is probably due to the 100% signal seen in the previous band at 419.75 MHz, and the rise at 450 MHz is probably due to the 100% signal seen in the next band at 451 MHz.

450-470 MHz: A large number of mobile signals are observed in this band, and many of these signals show high levels on the average curve. Note that the allocated band edges at 455 MHz and 460 MHz show very distinctly in the measured data.

470-512 MHz: Some signals are observed between 470-506 MHz, but the average curve is not affected much, and the minimum curve shows no 100% signals. Between 506-512 MHz, television broadcast channel 20 is observed.

512-806 MHz: All of the signals observed in this part of the spectrum appear to be television broadcast. Five of them were observed 100% of the time (although one of those was at a low power level on at least one scan). The others were transmitting enough to significantly raise the average curve, but were off the air during at least one RSMS scan.

806-902 MHz: Cellular and trunked communications are clearly delineated. Note differences between mobile and base systems, and also the differences that delineate public safety and aeronautical mobile parts of this spectrum.

902-928 MHz: This band was measured with two different algorithms: swept/m3 and stepped. The results are shown in Figures 15 and 16. Note the differences that result from changing the bandwidth and the scan algorithm. The reason for doing two different scans is to accommodate the fact that this is both an ISM (industrial, scientific and medical) band and a radiolocation band. The swept/m3, 10-kHz bandwidth measurement is intended to show ISM activity. The stepped, 1 -MHz bandwidth measurement is intended to show radar activity. United States radars which utilize this band are not found in the Denver area. Consequently, while the swept/m3 measurement shows ISM activity, the stepped measurement only indicates RSMS receiver noise. Note that the stepped measurement does clearly show (as a single peak) the pair of signals just below 928 MHz.

928-960 MHz: A variety of mobile and fixed signals, many of them producing high average and minimum responses, are observed. Note the delineation of allocated band edges in the measurement data.

960-1215 MHz: This band shows activity from aeronautical navigation aids. The large features at 1030 MHz and 1090 MHz are air traffic control beacon signals. Interrogations are at 1030 MHz, and replies are at 1090 MHz. The low duty cycle, impulsive characteristics of the signals in this band are such that they affect the peak curve, but not the average or minimum curves. However, beacon signals are observed approximately 100% of the time during RSMS operations. This is a good example of why, with the exception of high duty cycle signals transmitting 100% of the time, the RSMS data shown in this report cannot be used to directly infer a percentage of time that signals use a frequency.

1215-1400 MHz: Aeronautical radionavigation signals are observed below 1215 MHz. Above 1215 MHz, the rest of the band shows occupancy by a radar. The radar center frequency is 1332 MHz. The radar center frequency peaks at O dBm, and was normally receivable at that amplitude. The lack of automatic attenuation routines in the RSMS software meant that most of the scans saturated at this frequency, resulting in an apparent average amplitude that is considerably less than O dBm. Radar spurious emissions are observed between about 1230-1400 MHz. The sharp spurious emission roll-off at 1230 MHz is typical of a bandpass filter characteristic.

1350-1400 MHz: The peak curve shows radar spurious emissions as measured by the swept/m3 algorithm in a 10 kHz bandwidth. These emissions do not affect the average or minimum curves, even though the radar in this measurement operates continuously. Compare

these measurements to the 1350-1400 MHz portion of the preceding 1200-1400 MHz occupancy scans, which were made using a stepped algorithm in a 1-MHz bandwidth.

1400-1530 MHz: The radar spurious emissions from the center frequency at 1332 MHz are observed up to about 1440 MHz. Above that frequency, a few impulsive signals are observed (as evidenced by the fact that the average and minimum curves are not affected).

1530-1710 MHz: A few signals are observed in the 1610 -1626.5 MHz airborne aids to air navigation band. Other signals are observed in earth-to-space bands and in the meteorological aids band. None of these signals affect the average curve. They probably operated for brief durations, and some may have been impulsive.

1710-2300 MHz: This band was measured with the azimuth scan technique, and therefore only a single curve is shown. Analog links show up as narrow spectral features, and digital links are shown as wider spectral features.

2300-2500 MHz: The major spectral feature in this part of the spectrum is the prominent feature centered at about 2550 MHz. The band 2400-2500 MHz is ISM, and the feature shown here is generated by ISM devices, primarily microwave ovens. Other RSMS measurements have been performed in this band at various locations in the United States, and may be released in NTIA reports at a later date.

2500-2700 MHz: This azimuth scan shows a set of multipoint distribution system (MDS) television signals between 2500-2670 MHz. A few lower-amplitude signals are observed.

2700-2900 MHz: This band shows occupancy by radars. Due to lack of automatic attenuation in the RSMS software, the signals were amplitude-limited at -45 dBm received signal level. The radar at 2890 MHz probably rotated more slowly than the 5-sec step time of the scans in this band, leading to a slightly discontinuous envelope measurement.

2900-3100 MHz: The discontinuous envelope which is highest at 2900 MHz and then decreases at higher frequencies is probably produced by the radar at 2890 MHz in the previous band. This emission is not observed above 3000 MHz; above that frequency, only noise is observed. The envelope looks discontinuous because the radar's beam scanning interval is longer than the RSMS stepping interval. Another radar is apparent at 2987.5 MHz.

3100-3700 MHz: Only noise is observed in this radar band in the Denver area.

3700-4200 MHz: Terrestrial point-to-point microwave signals are observed in this band. The six low-amplitude, relatively wide spectral features observed in this azimuth scan are a set of digital links. The even spacing and uniform amplitude of these links implies that they were all located on a single tower. The other signals observed in this scan are analog communications. As with all other RSMS bands, satellite signals in this band (such as for television receive-only systems) are not receivable in RSMS spectrum surveys.

4200-4400 MHz: RSMS surveys can detect airborne radio altimeter signals in this band if aircraft flight patterns carry aircraft over the van. However, in Denver this was not the case, and so no signals were received in this band during the survey.

4400-5000 MHz: A few signals were received in this band. They appear to be analog. The RSMS can receive terrestrial point-to-point microwave in this band.

5000-5250 MHz: No signals were received in this band during the RSMS Denver spectrum survey.

5250-5925 MHz: The signals observed in this band are generated by radars. The radar at 5575 MHz was operating during every RSMS scan.

5925-7125 MHz: Terrestrial point-to-point microwave signals are observed in this band. All of the signals below 6425 MHz appear to be digital. The signals above 6425 MHz appear to be analog. The digital signals appear to fall into distinct groupings. This kind of behavior is the result of all of the transmitters in each group being located on the same tower.

7125-8500 MHz: Terrestrial point-to-point microwave signals are observed in this band. Mostly analog signals and a digital signal are observed.

8500-10550 MHz: The signals observed in this band are all radars.

10550-13250 MHz: The common carrier band between 10700-11700 MHz shows a number of terrestrial point-to-point microwave signals. These signals appear to all be analog.

The fixed band above 12700 MHz also shows a signal. Above 12 GHz, few signals are observed by the RSMS. There are several reasons for this: the RSMS noise figure increases, the typical transmitter power is low, and the transmitters typically use high-gain antennas, operate intermittently, and/or are mobile.

13250-14200 MHz: A few radar signals were received. The received signal comments made for the 10550-13250 MHz band (above) are also true for this band.

14200-15700 MHz: Three signals, probably analog, were observed in this band. The received signal comments made for the 10550-13250 MHz band (above) are also true for this band.

15700-17700 MHz: Three signals, probably radars, were observed in this band. The received signal comments made for the 10550-13250 MHz band (above) are also true for this band.

17700-19700 MHz: One signal, probably analog, was received. The received signal comments made for the 10550-13250 MHz band (above) also are true for this band.