NTIA Report 97-336

Broadband Spectrum Survey at Los Angeles, California

Frank H. Sanders
Bradley J. Ramsey
Vincent S. Lawrence

U.S. DEPARTMENT OF COMMERCE
William M. Daley, Secretary

Larry Irving, Assistant Secretary
for Communications and Information

May 1997

This Page Intentionally Left Blank

This Page Intentionally Left Blank

PREFACE

A spectrum survey often depends upon significant efforts by personnel not directly involved in the measurements. We wish to thank the following people and organizations who made the spectrum survey at Los Angeles, California a success: W. Zehnder, M. Fukumoto, P. Keister, and T. King of the ITT-Gilfillan Corporation, who provided access to the ITT-Gilfillan Angeles Forest antenna range for our measurement location; and H. Grigsby of the Federal Communications Commission for providing valuable background information on spectrum activities in the Los Angeles 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 (NTIA), nor does it imply that the equipment or software identified are necessarily the best available for the application.

This report is available on the World Wide Web through the Institute for Telecommunication Sciences home page. The ITS home page address is: http://www.its.bldrdoc.gov. Descriptions and availability of other NTIA reports are found on the ITS publications page. The publications page address is: http://www.its.bldrdoc.gov/pub/.

CONTENTS

Page

PREFACE iii

FIGURES vi

ABSTRACT 1

1. INTRODUCTION 1
   1.1 Background 1
   1.2 Authority 2
   1.3 Purpose 2
   1.4 Extrapolation of Spectrum Occupancy Data 2

2. LOS ANGELES SPECTRUM SURVEY 3
   2.1 Introduction 3
   2.2 Measurement Site Description 3
   2.3 Data Considerations 5
   2.4 Measured Data 8
   2.5 Observations on Measured Data and Spectrum Use 49

3. REFERENCES 57

APPENDIX A: OVERVIEW OF BROADBAND SPECTRUM SURVEYS 59

APPENDIX B: INTERPRETATION OF SPECTRUM SURVEY DATA 69

APPENDIX C: RADIO SPECTRUM MEASUREMENT SYSTEM 83

APPENDIX D: DATA ACQUISITION SOFTWARE 93

APPENDIX E: RSMS GAIN AND NOISE FIGURE CALIBRATION 99

FIGURES

		Page
Figure 1.	Area map of Los Angeles showing the RSMS measurement site location .	4
Figure 2.	ITS Radio Spectrum Measurement System at the measurement site	6
Figure 3.	Area map of Los Angeles showing line-of-sight areas from the RSMS . .	7
Figure 4.	Spectrum survey graph summarizing swept/m3 measurements in the 108-138 MHz frequency range	9
Figure 5.	Spectrum survey graph summarizing swept/m3 measurements in the 138-162 MHz frequency range	10
Figure 6.	Spectrum survey graph summarizing swept/m3 measurements in the 162-174 MHz frequency range	11
Figure 7.	Spectrum survey graph summarizing swept/m3 measurements in the 174-216 MHz frequency range	12
Figure 8.	Spectrum survey graph summarizing swept/m3 measurements in the 216-225 MHz frequency range	13
Figure 9.	Spectrum survey graph summarizing swept/m3 measurements in the 225-400 MHz frequency range	14
Figure 10.	Spectrum survey graph summarizing swept/m3 measurements in the 400-406 MHz frequency range	15
Figure 11.	Spectrum survey graph summarizing swept/m3 measurements in the 406-420 MHz frequency range	16
Figure 12.	Spectrum survey graph summarizing stepped measurements in the 420-450 MHz frequency range	17
Figure 13.	Spectrum survey graph summarizing swept/m3 measurements in the 450-470 MHz frequency range	18
Figure 14.	Spectrum survey graph summarizing swept/m3 measurements in the 470-512 MHz frequency range	19
Figure 15.	Spectrum survey graph summarizing swept/m3 measurements in the 512-806 MHz frequency range	20

FIGURES (Continued)

Page

Figure 16. Spectrum survey graph summarizing swept/m3 measurements in the 806-902 MHz frequency range 21

Figure 17. Spectrum survey graph summarizing swept measurements in the 902-928 MHz frequency range 22

Figure 18. Spectrum survey graph summarizing stepped measurements in the 902-928 MHz frequency range 23

Figure 19. Spectrum survey graph summarizing swept/m3 measurements in the 928-960 MHz frequency range 24

Figure 20. Spectrum survey graph summarizing swept/m3 measurements in the 960-1215 MHz frequency range 25

Figure 21. Spectrum survey graph summarizing stepped measurements in the 1215-1400 MHz frequency range 26

Figure 22. Spectrum survey graph summarizing swept/m3 measurements in the 1350-1400 MHz frequency range 27

Figure 23. Spectrum survey graph summarizing swept/m3 measurements in the 1400-1530 MHz frequency range 28

Figure 24. Spectrum survey graph summarizing swept/m3 measurements in the 1530-1710 MHz frequency range 29

Figure 25. Spectrum survey azimuth-scan graph of measurements in the 1710-2300 MHz frequency range 30

Figure 26. Spectrum survey graph summarizing swept measurements in the 2300-2500 MHz frequency range 31

Figure 27. Spectrum survey azimuth-scan graph of measurements in the 2500-2700 MHz frequency range 32

Figure 28. Spectrum survey graph summarizing stepped measurements in the 2700-2900 MHz frequency range 33

Figure 29. Spectrum survey graph summarizing stepped measurements in the 2900-3100 MHz frequency range 34

FIGURES (Continued)

Page

Figure 30. Spectrum survey graph summarizing stepped measurements in the 3100-3700 MHz frequency range 35

Figure 31. Spectrum survey azimuth-scan graph of measurements in the 3700-4200 MHz frequency range 36

Figure 32. Spectrum survey graph summarizing swept/m3 measurements in the 4200-4400 MHz frequency range 37

Figure 33. Spectrum survey azimuth-scan graph of measurements in the 4400-5000 MHz frequency range 38

Figure 34. Spectrum survey graph summarizing swept/m3 measurements in the 5000-5250 MHz frequency range 39

Figure 35. Spectrum survey graph summarizing stepped measurements in the 5250-5925 MHz frequency range 40

Figure 36. Spectrum survey azimuth-scan graph of measurements in the 5925-7125 MHz frequency range 41

Figure 37. Spectrum survey azimuth-scan graph of measurements in the 7125-8500 MHz frequency range 42

Figure 38. Spectrum survey graph summarizing stepped measurements in the 8500-10550 MHz frequency range 43

Figure 39. Spectrum survey azimuth-scan graph of measurements in the 10550-13250 MHz frequency range 44

Figure 40. Spectrum survey graph summarizing stepped measurements in the 13250-14200 MHz frequency range 45

Figure 41. Spectrum survey azimuth-scan graph of measurements in the 14200-15700 MHz frequency range 46

Figure 42. Spectrum survey graph summarizing stepped measurements in the 15700-17700 MHz frequency range 47

Figure 43. Spectrum survey azimuth-scan graph of measurements in the 17700-19700 MHz frequency range 48

FIGURES (Continued)

Page

Figure B-1. Functional diagram of the RSMS signal-processing path for cumulated data 73

Figure C-1. Top and side view drawings of the RSMS 84

Figure C-2. Front panel of the RSMS instrument racks 85

Figure C-3. Block diagram of the RSMS receiver 86

Figure E-1. Example calibration graph of noise figure and correction factor curves . . 99

Figure E-2. Typical noise diode solid state noise source 100

Figure E-3. Lumped-component noise diode calibration schematic 101

This Page Intentionally Left Blank

This Page Intentionally Left Blank

BROADBAND SPECTRUM SURVEY AT LOS ANGELES, CALIFORNIA

Frank H. Sanders, Bradley J. Ramsey, and Vincent S. Lawrence[1]

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 funds the Institute for Telecommunication Sciences 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 Los Angeles, California during March, April, and May 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 [1, part 8.3]. 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) conflicts, 4) interference resolution, and 5) systems review activity related to new Federal Government systems.

---

[1]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 needs 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 used solely 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 metropolitan areas that do not have any maritime radionavigation or extensive military activity. A coastal city, such

as San Diego, California [3] with major naval installations, will show higher levels of usage in bands that support such activities.

Choice of measurement site within an area also can 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 events such as natural disasters, olympic games, 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. LOS ANGELES SPECTRUM SURVEY

2.1 Introduction

This section 1) describes the measurement site selected for the Los Angeles, California spectrum survey, 2) briefly describes the data processing used to characterize spectrum occupancy across the 108-MHz to 19.7-GHz frequency range, 3) presents the measured data, and 4) provides band-by-band commentary on the survey results. Appendix A contains a thorough description of the spectrum survey measurement procedure. Appendix B provides details for interpretation of data presented in this report. Appendices C, D, and E provide descriptions of the RSMS hardware and software used to make the measurements.

2.2 Measurement Site Description

The Los Angeles metropolitan area occupies a coastal basin that is open to the Pacific Ocean on the south and west, partially bisected and surrounded by high rugged hills on the northwest and east, and closed by the San Gabriel Mountains on the north. The RSMS was parked on the summit of one of the San Gabriel Mountain peaks in the Angeles National Forest just north of Los Angeles. The location was the deactivated site of a Nike Hercules radar and antiaircraft battery, and is currently part of an (ITT-Gilfillan Corporation) antenna range. The site coordinates were 118ß25’1.7" W, 34ß21’9.7" N and base altitude was 1260 m MSL. Figure 1 shows the location of the RSMS in the Los Angeles area.

The site was well-removed from fixed RF transmitters and man-made noise sources such as vehicular traffic. Mobile communications originating locally were associated primarily with a

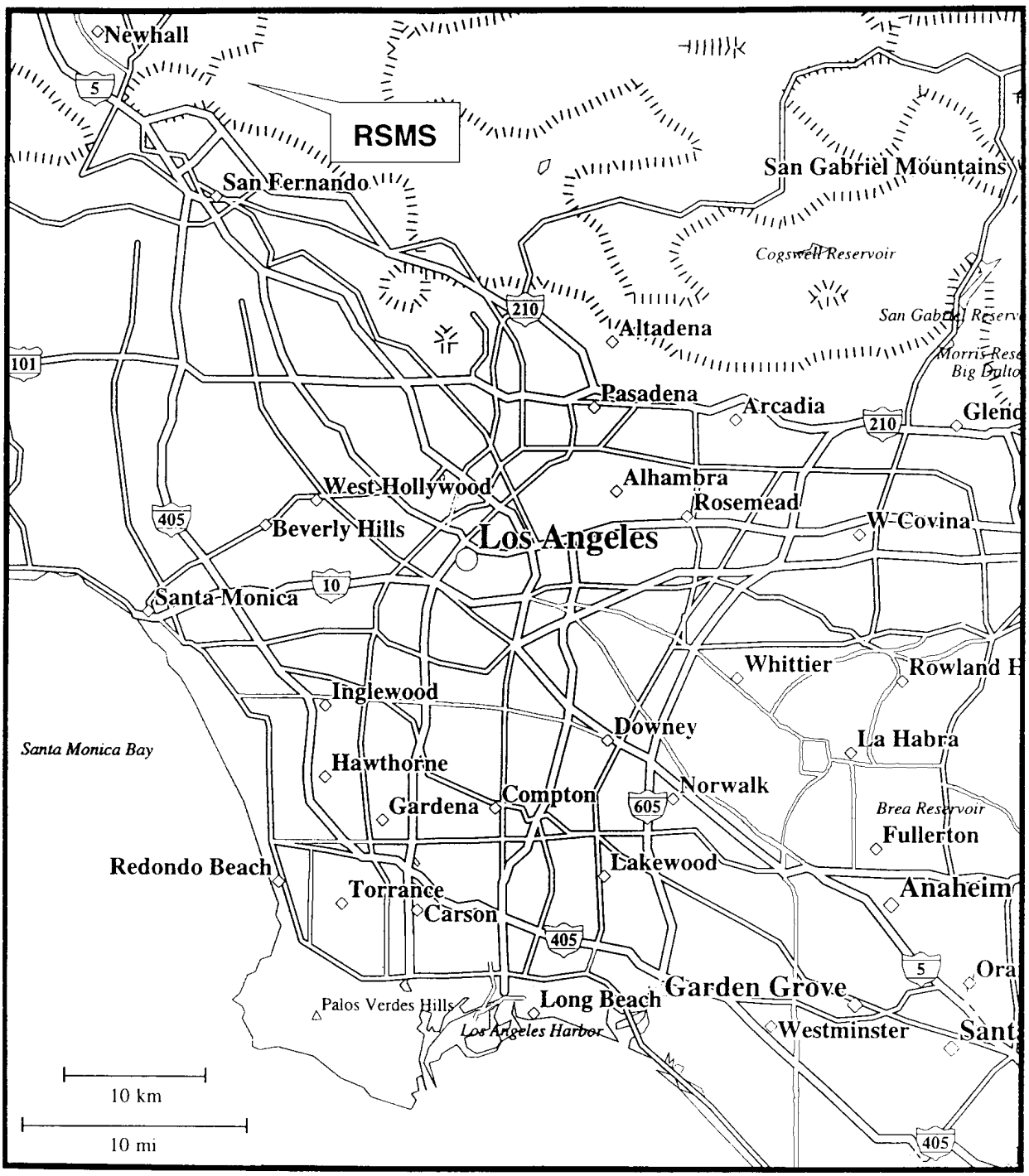

Figure 1. Area map of Los Angeles, California showing the location of the RSMS measurement site. Map produced with MapExpert™ software from DeLorme Mapping.

Los Angeles County fire station below the summit. No ITT-Gilfillan antenna range transmissions occurred during the RSMS measurements. Only one structure at the site was higher than the RSMS antennas: a tower about 30 m high, on the north side of the measurement site, behind the RSMS field of view over the Los Angeles basin. Figure 2 is a view of the RSMS and Los Angeles basin from the tower.

Prominent physical features affecting radio propagation are the Santa Monica Mountains and Beverly Hills that bisect the basin from the west. Although the RSMS site was inland, the RSMS line-of-sight coverage extended to the Pacific Ocean and included most of the Channel Islands. Urban development in the area is some of the most extensive in the United States. Figure 3 shows areas that were line-of-sight (white areas in the Figure) to the RSMS from 2 m above ground (typical mobile antenna height) and those areas that were obstructed (shaded with plus (+) signs in the Figure) from the RSMS due to terrain. The RSMS survey location at Los Angeles afforded extensive line-of-sight coverage of the Los Angeles metropolitan area.

2.3 Data Considerations

The Los Angeles spectrum survey, with the following few exceptions, was performed as described in Appendix A. All System-1[2] frequency bands were measured with a 100-MHz to 1-GHz log periodic antenna (LPA) mounted at a 45ßangle for slant polarization and aimed toward downtown Los Angeles. This improved RSMS detection for emissions from the Los Angeles basin and maximized discrimination against signals originating in the mountains behind the RSMS. System-2 frequencies were measured with a 500-MHz to 18-GHz slant polarized biconical omni antenna, except for azimuth-scanned[3] bands that were measured with a rotating dish antenna (1-m Tecom parabolic reflector with dual horizontal and vertical feed).

Preliminary tests at the measurement site indicated that strong received signal levels from FM radio broadcast stations operating below 108 MHz would generate intermodulation products in the RSMS front-end at some frequencies above 108 MHz. To eliminate such responses, 40 dB of attenuation was inserted ahead of the first RSMS receiver amplifier for measurements between 104-114 MHz. This desensitized the RSMS by 40 dB at these frequencies. Consequently, the possibility of receiving measurable signals in this range (such as instrument-landing system glideslope transmissions) was reduced. However, several signals were detected in this frequency range. Similarly, commercial television broadcast signals forced the addition of attenuation (20 dB) between 174-216 MHz.

---

[2]For spectrum surveys, the RSMS is configured as two measurement systems operating simultaneously. One, identified as "System-1," for frequency measurements below 1 GHz; and the other, "System-2" for measurements above 1 GHz (see Appendix A).

[3]The azimuth-scanning measurement routine is a special operator-interactive technique using a rotating dish antenna with a swept measurement algorithm. See Section B.8 in Appendix B for more about azimuth-scanning.

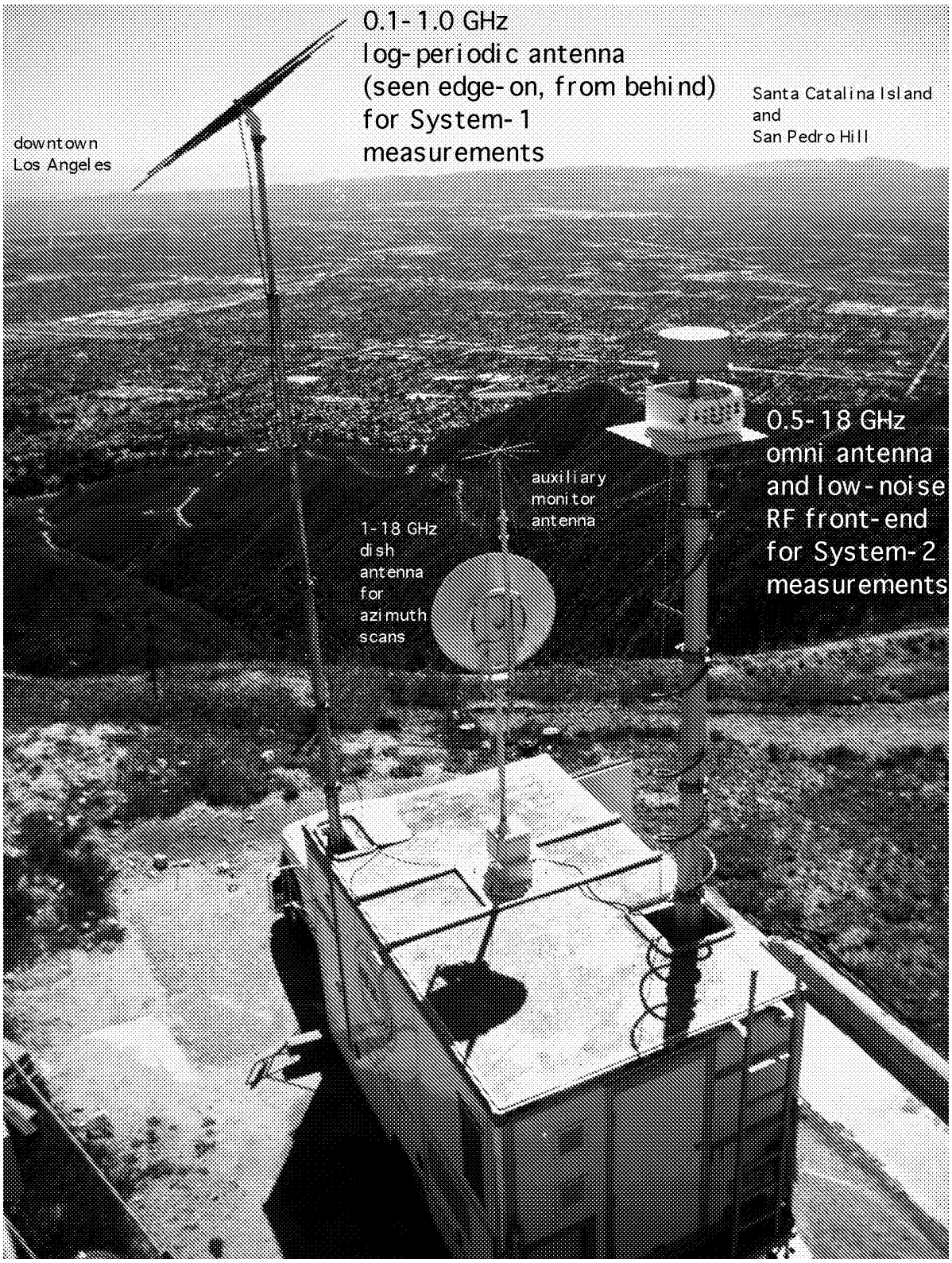

Figure 2. ITS Radio Spectrum Measurement System at the Los Angeles measurement site.

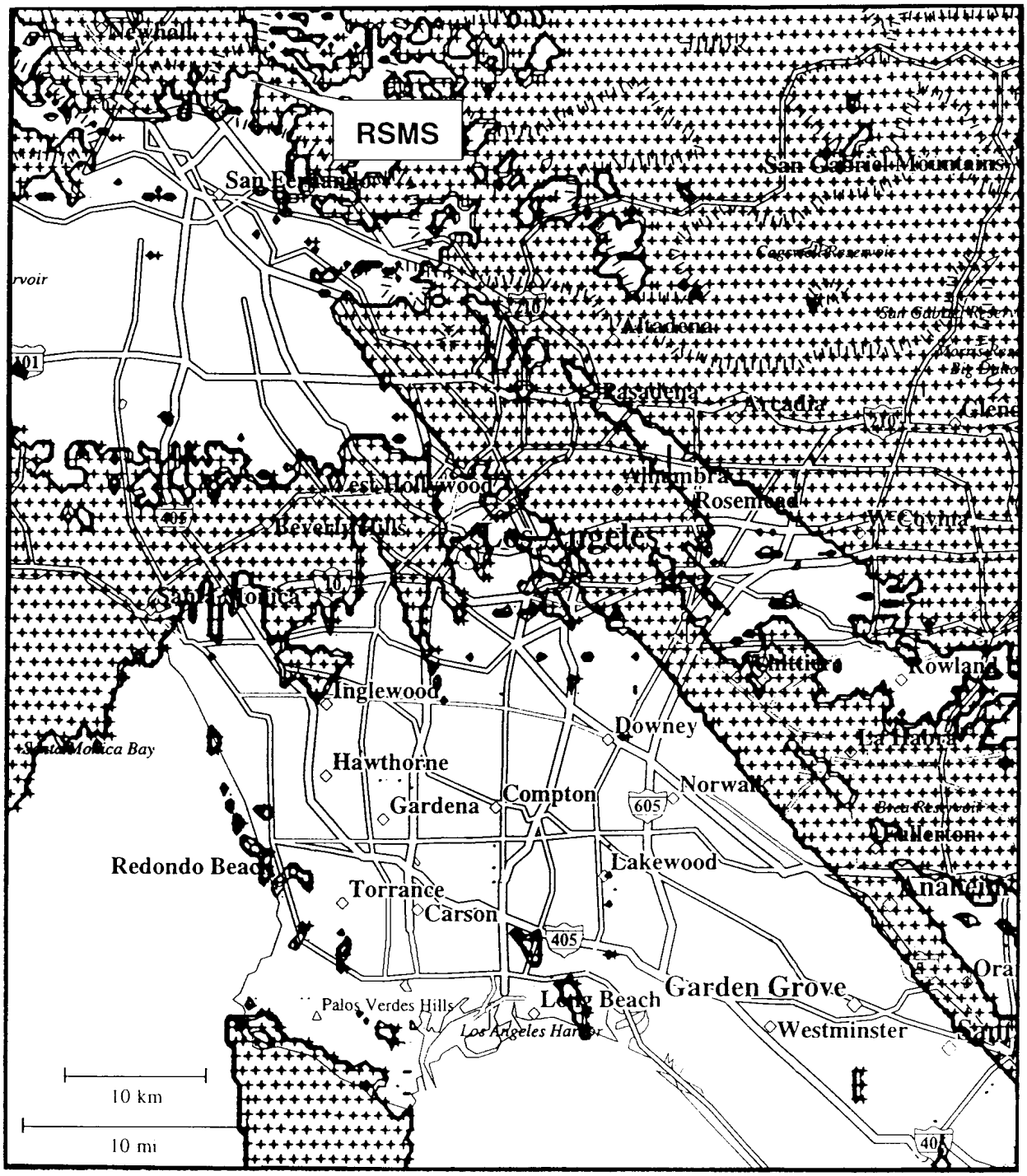

Figure 3. Area map of Los Angeles, California showing regions that are line-of-sight (white) and nonline-of-site (terrain shadowed) from the RSMS raised antennas. Terrain shadowing overlay provided by ITS Telecommunications Analysis Services.

All measured data, except the azimuth-scanning measurements, underwent a postmeasurement cumulative processing (cuming) step before being displayed. Every frequency data point recorded was cumulated (cumed) according to the measurement algorithm[4] used to collect the data. Swept and stepped measurements were cumed such that the graphed data points (received signal levels; RSLs) show the maximum, mean, and minimum RSLs of all scans. Swept/m3 data already contained this information, so cuming resulted in graphs showing maximum of maximum RSLs, mean of mean RSLs, and minimum of minimum RSLs. On all survey band graphs of cumed data, maximum and minimum curves are drawn with solid lines and mean curves are drawn with dashed lines. Azimuth-scan data were not cumed, per se, but horizontally and vertically polarized scans were combined in postmeasurement processing so the graphed data show only one solid line curve.

2.4 Measured Data

Each survey band of measured data is displayed graphically on a single page along with corresponding frequency allocations and assignment information (Figures 4-43). Each survey band figure has an identical format. The survey band graph in the middle of the page shows 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 system noise limits. Measurement system response to different types of signals and system noise limits are described in Appendix B. The figure caption includes the survey location and principle measurement parameters.

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 upper and lower case; and where the allocated service is followed by a function in parentheses, the allocation is limited to the function shown.

The vertical lines are placed according to frequency separations in the allocation tables. The frequencies (in megahertz) are written at the lower end of the vertical lines. 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., a description of how the frequency allotment is typically used) also will show a reference number if insufficient space is available

[4]Appendix B contains operational descriptions of the RSMS measurement algorithms, including swept, stepped, and swept/m3.

This is a placeholder for Figures 4-43, pages 9-48

This is a placeholder for Figures 4-43, pages 9-48

within the vertical line delimiters. All notes are written in simple text format distinguishable from the allocated service entries that are entered according to convention, as previously explained.

It should be noted that the appearance of survey band graphed data is affected substantially by the measurement parameters and the analysis techniques employed. For example, data in Figures 5 and 6 were measured with similar techniques; however, 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 survey bands may be plotted with different graph scales or measured with different bandwidths and algorithms. This is the case for Figures 17 and 18. Both figures cover the same frequency range, but the bandwidths and measurement algorithms are completely different.

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 band-by-band summary observations of Section 2.5 should help in interpreting the data graphs.

2.5 Observations on Measured Data and Spectrum Use

It is important to understand those aspects of spectrum use that can be extrapolated from the RSMS data presented in this report, and also those aspects of spectrum use that cannot be inferred from these data. First, the data acquisition was performed at a single location in the Los Angeles metropolitan area during a two-week period spanning the end of March through mid April of 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 accumulative measurement time during the survey typically was 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 Los Angeles metropolitan area. Maximum and minimum activity levels measured in the spectrum probably are 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 also can be used to qualitatively assess the relative density of channel occupancy on a band-by-band basis. Likewise in the azimuth-scan bands, the single plotted curve provides a density estimate 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 Los Angeles. Results of those measurements will be published separately.

2.5.1 Band-by-band Observations on Spectrum Use in the Los Angeles Area

The Table contains band-by-band observations on spectrum occupancy in the Los Angeles 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].

Comments on Los Angeles Spectrum Occupancy Measurement Results

Spectral Range	Figure	Comments
108-138 MHz	4	Across the 108-114 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 108-114 MHz range by the same amount. Instrument landing system (ILS) localizers transmit in the 108-112 MHz range, so detection of ILS localizers was degraded by the high RSMS noise figure in this range. Some ILS localizers, including Burbank airport, were nevertheless observed. Across 108-118 MHz, very high frequency omnidirectional range (VOR) aeronautical navigation beacons were observed as 100% emitters. These are seen as vertical lines on 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 usually are not receivable by the RSMS. However, the National Oceanic and Atmospheric Administration (NOAA) weather satellite signal at 137.62 MHz showed a received signal level as high as -70 dBm.

Comments on Los Angeles Spectrum Occupancy Measurement Results (Continued)

Spectral Range	Figure	Comments
138-162 MHz	5	A large number of mobile signals were observed in the 138-144 MHz portion of the spectrum. The average curve is raised significantly across the 144-148 MHz band, used by amateurs. Between 148-162 MHz, a large percentage of available channels also showed use. Transmitters between 152-153 MHz were in operation continuously during the survey period. Maritime mobile signals occurred between 156.2475-162.0125 MHz. All of these channels showed some occupancy; this is consistent with expectations for the RSMS coverage of the Pacific coastal area near Los Angeles. During the Los Angeles survey, routine station identification monitoring indicated unauthorized use of frequencies at and near the 150 MHz Transit satellite allocation. This information was sent to the FCC Field Enforcement Bureau, where further investigation revealed several unauthorized signal sources in southern California, including fishing boats offshore.
162-174 MHz	6	A variety of fixed and mobile signals were observed. The signal near 162.5 MHz is a public broadcast weather information channel. Most channels in this band showed some usage during the survey period, and many channels were occupied enough to raise the average curve. The minimum curve shows that several channels were active during every measurement sweep, indicating that some of the channels might be used all the time.
174-216 MHz	7	Television broadcast channels 7, 9, 11, and 13 are occupied by Los Angeles stations. Channels 8, 10, and 12 are occupied by San Diego stations. Attenuation of 20 dB was used to prevent front-end overload in the RSMS.
216-225 MHz	8	Some channels are used in the 216-220 MHz maritime mobile allocation. Signals, possibly from a trunked system, occurred between 220-220.75 MHz. Identical received amplitudes of signals between 220.0-220.7 MHz may indicate a single fixed location of origin. These signals might have been from a mobile radio base station. Amateur signals were observed above 222 MHz, and the relative density of channel occupancy increased above 223.3 MHz. No military radiolocation occurred in this band in the Los Angeles area.
225-400 MHz	9	Military ATC and other communications were observed. Many of these signals are 100% transmissions from fixed locations. Many signals that were observed less often than 100% were seen enough of the time to significantly affect the average curve. An ILS glideslope signal was observed at about 332 MHz.
400-406 MHz	10	A few dozen signal frequencies showed occupancy in this meteorological aids band for brief intervals during the survey period. The relatively low amplitude and number of observed signals is consistent with low effective isotropic radiated power and intermittent operation of most systems that use this band (e.g., radiosondes).
406-420 MHz	11	A number of fixed and mobile signals, about 40 of them affecting the minimum and average curves, were observed. Eight of the signals were observed in 100% of the RSMS data scans.

Comments on Los Angeles Spectrum Occupancy Measurement Results (Continued)

Spectral Range	Figure	Comments
420-450 MHz	12	High-power air search radar signals produce essentially all usage observed in this band. Most 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 Los Angeles area with similarly high usage in San Diego [3] and practically nonexistent activity in the Denver, Colorado area [2].
450-470 MHz	13	A large number of land mobile signals were observed, and many of them affect the average curve. The band edges of the 460-465 MHz base station allocation are very distinct. The 454-455 MHz domestic public base stations also were distinctly observed.
470-512 MHz	14	Television broadcast channel 18 is a Los Angeles area station. Television channel 15 is occupied by a San Diego station. 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 showed use by the Los Angeles T-band land mobile radio allocation, as defined in the CFR [4, Part 90.311], 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 showed use by Los Angeles County public safety base stations for land mobile radio. Although the T-band allocations are for Los Angeles, which is well beyond line-of-sight from an earlier RSMS measurement location at Point Loma, San Diego, spectrum occupancy by these systems was readily observed in the San Diego area [3].
512-806 MHz	15	All of the signals observed in this band are UHF television broadcast. At least nine of them were observed in 100% of RSMS scans. Both Los Angeles and San Diego area stations were observed.
806-902 MHz	16	Cellular, trunked, and public safety portions of this part of the spectrum are clearly delineated in the Figure. Mobile and base parts of the band also are clearly identifiable. Within the 806-821 MHz (mobile conventional and trunked) band segment, most occupancy occurred between 811-821 MHz. The 821-824 MHz mobile public safety band showed relatively low usage, 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 showed enough use by mobile units to raise the average curve slightly. The 849-851 MHz ground-to-air allocation showed lower usage, but the POI for such signals by the RSMS is low. The 851-866 MHz base conventional and trunked band showed usage that significantly raises the average curve. The 866-869 MHz base public safety showed usage on most channels, and the average curve was affected. The 869-894 MHz band, occupied by cellular base stations, was 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 was observed, confirming that low POI probably prevents the RSMS from measuring corresponding ground-to-air signals. A few signals was observed in the 896-901 MHz private land mobile band, and in the 901-902 MHz general mobile allocation.

Comments on Los Angeles Spectrum Occupancy Measurement Results (Continued)

Spectral Range	Figure	Comments
902-928 MHz	17 & 18	This band was measured two different ways: with the positive peak detector in maximum hold mode and 10-kHz IF bandwidth, as shown in Figure 17, and with the positive peak detector in stepped mode and 1-MHz bandwidth, as shown in Figure 18. The narrow-IF bandwidth, maximum-hold measurement was intended to show industrial, scientific, and medical (ISM) and Part 15 device operations, while the wide-IF bandwidth, stepped algorithm was intended to optimize the RSMS for measurement of radar signals in the band. For the Los Angeles area, both algorithms produced measured occupancy data that showed a higher level of usage than was indicated in the Denver, Colorado survey measurements [2]. The data showed also that usage density was similar to San Diego [3], but the measured spectra of the transmitters differs from San Diego. 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 use either spread spectrum or frequency-hopping transmitters), automatic vehicle monitoring, digital communication systems, repeaters, and amateurs. The measurements shown in Figure 17 were designed to discriminate against radar signals and show the cumulative effect of nonradar devices on spectrum usage in this band. Radar emissions tend to be discriminated out of these data by the narrowband (10-kHz) IF. Maximum observed signal amplitude in this bandwidth was about -60 dBm on an omni antenna. Note that many of the signals were observed in 100% of RSMS data scans. Figure 18, made with positive peak detection in a 1-MHz IF bandwidth, primarily showed 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 exceeded a value of -15 dBm in 50 ohms, as received on the RSMS omnidirectional antenna.
928-960 MHz	19	Paging systems were observed between 928-932 MHz. The 932-935 MHz point-to-point and point-to-multipoint band clearly is delineated, as is the 935-940 MHz land mobile band. Two signals were present constantly 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.

Comments on Los Angeles 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 appeared as bumps in the average curve at (approximately) 982, 986, 1113, 1159, 1165, 1170, 1191, 1195, 1206, and 1211 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 Figure. Because emissions in this band primarily are pulsed, the average curve essentially was unaffected by all signals except TACAN.
1215-1400 MHz	21	This band showed occupancy by high-power, long-range air search radars. Frequencies occupied by distinctly identifiable radar signals are 1255 MHz and 1346 MHz. The radar at 1255 MHz also was measured from the earlier San Diego RSMS location [3]. All of the measured signals between these peaks are spurious emissions from these radars, and they primarily are generated by the 1346 MHz radar. The emissions are generated by a crossed-field amplifier used by that radar. Emission parameters vary, but values measured by the RSMS crew typically were as follows: mechanical beam rotation time, 9-12 s; pulse width, 1-6 μs; and transmitted pulse repetition rate, 300-600 pps. These radars usually were observed to emit staggered pulse trains, to enhance moving target indicator processing of target returns. The emissions roll-off below 1230 MHz and above 1375 MHz in the Figure is due to the presence of a bandpass filter in the output of the 1346 MHz radar.
1350-1400 MHz	22	Unlike the measurements made in the 1215-1400 MHz band, measurements in this band were optimized to observe nonradar emissions. Nevertheless, most of the activity observed in this band is from radars. The prominent features at 1350-1383 MHz and 1392 MHz are generated by the air search radars. Because they are pulsed signals, received approximately every 9-12 s, the average and minimum curves were unaffected.
1400-1530 MHz	23	Telemetry signals, probably from flight activity associated with a test range north of the RSMS, were observed.
1530-1710 MHz	24	Numerous signals were observed above 1559 MHz. Although the RSMS was not configured explicitly to receive space-to-earth signals, some apparently were received in the 1559-1610 MHz band. We infer that the other signals are from earth-to-space allocations for maritime mobile satellite (1626.5-1646.5 MHz), aeronautical mobile satellite (1646.5-1668.4 MHz), and radiosondes (1668.4-1700 MHz).
1710-2300 MHz	25	All signals observed in this band were terrestrial point-to-point communications, as measured with the RSMS azimuth-scanning technique (see Section B.8 in Appendix B). The measurement system noise floor varied across this frequency range, as evidenced by the dip centered at 2090 MHz. Note that all signals observed in this band in Los Angeles were analog, except for the digital signal at approximately 1955 MHz.

Comments on Los Angeles Spectrum Occupancy Measurement Results (Continued)

Spectral Range	Figure	Comments
2300-2500 MHz	26	Two communications signals, one digital and one analog, were observed at 2369 and 2384 MHz. Their significant effect on the average curve suggests that they likely are fixed links. Above 2387 MHz, all of the observed activity is background radiation generated by ISM devices, and especially by aggregate emissions from microwave ovens in the Los Angeles area. This background has been observed at other RSMS spectrum survey locations [2,3]. See also Gawthrop, *et al.* [5], for further information on emission characteristics of microwave ovens.
2500-2700 MHz	27	At least 20 fixed transmitters were observed in this band. Some of the carriers are low-amplitude, and difficult to discern at the graphic resolution presented in Figure 27, but were distinguishable in the RSMS raw data scans. The individual signal spectra are standard NTSC television broadcast, so these are multichannel multipoint distribution systems (MMDS, also called wireless cable television) transmitters. Note variation in RSMS system noise floor across this frequency range.
2700-2900 MHz	28	All signals in this band were generated by high-power air-search radars. Eleven frequencies were easily discernable (2705, 2730, 2755, 2780, 2795, 2810, 2815, 2833, 2845, 2855, and 2885 MHz). Because automatic attenuation was not yet implemented in the RSMS, many of these radars saturated 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 (two radar frequencies, 2795 MHz and 2833 MHz were not used during the manually attenuated scans, and they show saturation effects). 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. Radars in this band, as measured by the RSMS crew, typically have the following characteristics: mechanical rotation, no elevation scanning, about a 5 s rotation time, about a 1 μs pulse width, and about 1000 pps emitted at a high-order stagger, presumably for doppler processing of target returns.
2900-3100 MHz	29	High-power air-search radars were observed in this band. Compare the high levels of activity observed in Los Angeles to similarly high levels in San Diego [3] and to nonexistent levels of activity in Denver, Colorado [2]. The high peak and average values recorded at 3050 MHz were 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.
3100-3700 MHz	30	Numerous high-power radars were observed in this band. A single type of radar was observed across the frequency range of 3100-3500 MHz. Compare the high levels of activity observed in Los Angeles to similarly high activity in San Diego [3] and to the nonexistent activity in Denver, Colorado [2].
3700-4200 MHz	31	RSMS azimuth scans indicate four fixed, point-to-point microwave links in this band. The spectra showed that the links were using analog modulation. The RSMS noise floor showed variation between 3860-4000 MHz.

Comments on Los Angeles Spectrum Occupancy Measurement Results (Continued)

Spectral Range	Figure	Comments
4200-4400 MHz	32	Airborne radio altimeter signals, transmitted by aircraft on approach and departure from nearby airfields, were observed between 4245-4350 MHz. Two modulations predominate: pulsed and FM-CW. Because the signals occurred very intermittently, and some were pulsed, the average and minimum curves were not affected. The source of the signal at 4292 MHz is not known.
4400-5000 MHz	33	Only a single fixed, point-to-point microwave link was observed in this band, as measured with the RSMS azimuth-scanning technique. The narrow emission spectrum in the Figure indicates an analog signal.
5000-5250 MHz	34	No signals were observed in this band during the Los Angeles spectrum survey. No microwave landing system (MLS) is currently deployed in the Los Angeles area. This band was measured similarly with no detectable signals in Denver [2] and San Diego [3], although some radar spurious emissions did bleed over from an adjacent band in San Diego [3].
5250-5925 MHz	35	All emissions in this band are produced by radars (typically, maritime surface-search and weather surveillance units). Because automatic attenuation was not yet implemented in the RSMS, a few of these radars saturated the RSMS front-end at their center frequencies, as evidenced by clipped peaks in the maximum curve.
5925-7125 MHz	36	Numerous fixed links (all analog) were observed between 5925-6425 MHz in a fixed and fixed-satellite band in the RSMS azimuth-scan measurement. Additional links (all but one of them analog) were observed between 6550-6875 MHz in another fixed and fixed-satellite band. Three or four links (all analog) occurred between 6875-7100 MHz in the fixed-satellite/auxiliary broadcasting band. Overall, slightly more occupancy was observed in Los Angeles than San Diego [3], and less occupancy was observed in Los Angeles than in Denver [2].
7125-8500 MHz	37	Only two fixed links (both analog) were observed in the RSMS azimuth-scan measurement. Substantially less occupancy was observed in this band in Los Angeles than in either the Denver or San Diego surveys [2,3]. The dip between 7850-8000 MHz in the Figure is due to a decrease in the RSMS noise floor across that range.
8500-10550 MHz	38	All signals observed in this band are generated by radars. The radars observed in this band in Los Angeles are maritime surface-search and airborne search and navigation units. A land-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, were: mechanical rotation time, 2-4 s; pulse width, less than 300-ns; pulse repetition rate, several thousand pps (no pulse staggering present). Airborne radars have similar pulse characteristics, but employ mechanical sector scans. Measured occupancy of this band in Los Angeles is remarkably similar to that observed in San Diego [3], and much higher than that observed in Denver [2].

Comments on Los Angeles Spectrum Occupancy Measurement Results (Continued)

Spectral Range	Figure	Comments
10550-13250 MHz	39	No signals were observed in this band in Los Angeles. Observed occupancy was similar to San Diego [3], and lower than was observed in Denver [2].
13250-14200 MHz	40	A ship-based radar was observed at 13360 MHz. Radars in this band are short-range, and are often used for weapons-control functions.
14200-15700 MHz	41	No signals were observed in the azimuth scan. In general, the probability of intercept by the RSMS for signals in this band is low (see Appendix B).
15700-17700 MHz	42	No signals were observed in this band. In general, the probability of intercept by the RSMS for signals in this band is low (see Appendix B).
17700-19700 MHz	43	No signals were observed; the change in the RSMS noise floor at 19300 MHz was 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 B).

4. REFERENCES

[1] *Manual of Regulations and Procedures for Federal Radio Frequency Management*, revised Jan. and May 1996, 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] F.H. Sanders, B.J. Ramsey, and V.S. Lawrence, "Broadband spectrum survey at San Diego, California," NTIA Report 97-334, Dec. 1996.

[4] *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).

[5] P.E. Gawthrop, F.H. Sanders, K.B. Nebbia, and J.J. Sell, "Radio Spectrum Measurements of Individual Microwave Ovens," NTIA Report 94-303 Vol 1 & 2, Mar. 1994.