IRIG Document 101-65	"Frequency Standards for Radar Beacons."
IRIG Document 103-65	"IRIG Standard for PRF and Reference Oscillator Frequency for C-Band Radars."
IRIG Document 105-74	"IRIG Tracking Radar Compatibility and Design Standards for G-Band (4 to 6 GHz) Radars."
IRIG Document 114-69	"Doppler and Coherent Radar Standards."
IRIG Document 115-69	"Noncoherent C-Band Transponder Standards."
IRIG Document 116-69	"Inter-Range Radar Synchronization for Global Tracking."

Also MIL-STD-469 was adopted prior to the RSEC (Part 5.3 of the NTIA Manual). Therefore, the RSEC requirements were not considered in the design of some of the systems which came into existence earlier in the band. The Department of Defense uses MIL-STD-469 as a guide for compliance and a reference for procurement of its radars. The Navy is presently taking the lead in updating this Standard. This standard entitled "Radar Engineering Design Requirements, Electromagnetic Compatibility" sets forth engineering design requirements to control spectral characteristics of all new radars operating between 100 MHz and 40 GHz. The MIL-STD-469 also outlines the measurement procedures that are required. In general, the criteria outlined in the MIL-STD-469 are more stringent than those given in RSEC. One of the distinguishing features of MIL-STD-469 is that it requires measurements for compliance. The Technical Subcommittee of IRAC is presently investigating the utility of incorporating similar measurement requirements into the RSEC. It should be mentioned that the requirement of "measurement for compliance" discussed in the MIL-STD-469 is generally for the purpose of DOD procurement. However, the purpose of incorporating the measurement requirements into the RSEC is to develop recommended measurement procedures for each of the thirteen equipment parameters defined in the RSEC (Farrar, 1981).

AMATEUR STANDARDS

Prior to WARC-79 there were no specific international standards for spurious emissions from transmitters operating above 235 MHz. The Conference extended these standards for all services, including the Amateur and Amateur-Satellite Service, to 17.7 GHz. New transmitters installed after January 1, 1985, and all transmitters operating after January 1, 1994, will be required to have their spurious emissions suppressed as follows (where two limits are expressed, the more stringent of the two applies):

960 MHz to 17.7 GHz	
Mean power above 10 watts	50 dB or 100 mW
Mean Power 10 watts or less	100 μW

Frequency tolerance standards do not apply to amateur stations, because they are not assigned to specific channels. Instead, amateur stations simply are required to confine their emissions to the allocated band and to use the minimum bandwidth consistent with good engineering practice.

ISM STANDARDS

The technical standards for Industrial, Scientific, and Medical (ISM) equipment are specified in section 7.10 of the NTIA Manual of Regulations and Procedures and in Part 18 of the FCC Rules and Regulations (CFR 47, 1977a). For the frequency band 5650-5925 MHz the ISM frequency band assigned is: 5800 ±75 MHz.

Although there are at present no known uses of this designated frequency, the following standards are applicable for any planned future use:

1. Industrial Heating equipment shall be adjusted to operate as close to the ISM frequency as practical. Outside of the assigned band, the average electric-field at a distance of one mile must be less than 10 μV/m; within the band there is no limit on the radiated electric field.

2. Medical Diathermy equipment may be operated on the 5800 ±75 MHz frequency with no limit on the radiated electric field within the band. However, any harmonic or spurious radiation outside of the ±75 MHz limits shall not exceed an average electric field of 25 μV/m at a distance of 1000 feet.

3. ISM equipment of all other types may be operated on the ISM frequency provided any harmonic or other spurious radiation outside of the frequency limits is suppressed, i.e., so as not to exceed 15 μV/m at a distance of 1000 feet; or for a radiated power (P) of more than 500 Watts of RF power on the fundamental frequency, 15 μV/m times a factor equal to the square root of P/500, but not to exceed 10 μV/m at a distance of one mile.

Proposed Changes to ISM Standards

The FCC issued a Notice of Proposed Rule Making (NPRM) requesting comments for revising Part 18 governing industrial, scientific and medical equipment (FCC, 1978). There is a second NPRM being drafted at this writing based on comments from the first NPRM. The primary concern of the FCC NPRM is the effect of ISM operation on radio communication. Some of the reasons, identified by the FCC, for revising Part 18 are:

(a) ISM equipment is considered to be the largest source of man made radio noise.

(b) Present limits are inadequate to protect future communication needs. ISM limits are out of line with limits for other equipment.

(c) Requests for tighter limits have been made.

(d) Present ISM specifications are much more liberal than those imposed by other administrations.

(e) Present equipment approval procedure requires clarification.

(f) Responsibility for compliance requires clarification.

(g) Present test procedures are inadequate.

(h) Present equipment classifications are difficult to apply." (FCC, 1978).

The FCC proposed rules in the NPRM are based on the International Special Committee on Radio Interference (CISPR) recommendations on ISM (CISPR, 1975). Significant proposed changes deal with reduced frequency tolerances, in-band and out-of-band emission limits.

Restricted Radiation Devices

Technical standards for restricted radiation devices are included in Part 7.9 (NTIA, 1979) and Part 15 of the FCC Rules and Regulations (CFR 47, 1977b). This class of devices includes field-disturbance sensors and low-power communication equipment. Non-Government users operating such devices in accordance with the standards are exempt from license requirements and Government users do not require a frequency assignment. In any case, all operations of restricted radiation devices are on a non-interference basis to authorized services.

1. Field Disturbance Sensors: These devices may operate at 5800 MHz with a frequency tolerance of ±15 MHz. The carrier frequency is recommended to be kept within the central 80 percent portion of the band. At 100 feet, the average field strength for 5800 MHz is not to exceed 50,000 μV/m.

2. Low-Power Communication: These types of devices in the frequency band 5725-5875 MHz may be used for measurement of characteristics of materials provided that the device shall not be used for voice communication or for the transmission of any other type of message; and the maximum level of emission from the device shall not exceed 500 μV/m at 100 feet on the fundamental frequency, 50 μV/m at 100 feet on harmonic frequencies, and 15 μV/m at 100 feet on any other frequency.

SATELLITE COMMUNICATIONS

In November of 1981, the FCC released a Notice of Proposed Rulemaking (FCC, 1981) to make revisions and additions to Part 25 which concerns Satellite Communications. These revisions and additions are intended to update definitions, available frequency bands and other technical standards to conform them to the current National Table of Frequency Allocations and International Radio Regulations. This new revision will speak to the International Satellite Systems to be implemented in the 5850-5925 MHz band. Further rulemaking will be performed in the course of implementation of the Final Acts of the 1979 WARC.

SECTION 4

MAJOR SYSTEMS AND SPECTRUM USAGE

INTRODUCTION

The major portion of the 5650-5925 MHz band has been allocated to the Government (military) Radiolocation Service. There is an ISM designated frequency at 5800 ±75 MHz which, at present, has no documented use. There is an allocation to the amateurs on a secondary basis but no documented use could be found. New allocations to the Amateur-Satellite Service have been proposed as a result of WARC-79 action. There is an up-path allocated at 5650-5670 MHz and a down-path at 5830-5850 MHz both on a secondary non-interference basis. Because this is a new service in the band there is no usage at this time and it will most likely be some years in the future before a satellite with amateur channel assignments will be operable in the 5650-5925 MHz band.

All military services have equipments operating in the band which are considered essential to their basic responsibilities to the national defense. NASA and DOE also have a few systems, primarily radiolocation, operating in this band. There are also a few experimental assignments to Government contractors who conduct research in support of systems development in the band.

The sources of data to identify users and uses within the band are primarily:

- The Government Master File (GMF)
- The Non-Government Master File (NGMF)
- The Systems Review File (SRV)
- Interdepartment Radio Advisory Committee (IRAC)
  - Records and Documents
- Electromagnetic Compatibility Analysis Center (ECAC)
  - Operational Platform Allocation File (OPAF)
  - Nominal Characteristics File (NCF)
  - Frequency Allocations File (FAL)
  - Reports and Documents
- American Radio Relay League (ARRL)
- Contacts with various agency personnel.

The new proposed national table of allocations reflect WARC-79 changes in this band and allocates the 5850-5925 MHz portion of the band to the Non-Government Fixed-Satellite Service on a co-equal primary basis with Government Radiolocation Service. This will change the present characteristics of the band since most of the systems operating in the band have the capability of tuning across the entire band as shown in Figure 1. Figure 1a. shows the unclassified radars in the band and their tuning ranges. New systems being developed for the band should now take the FSS into account while in the development stages so that compatibility can be achieved.

SPECTRUM USAGE

The present usage in the 5650-5925 MHz band is summarized in Table 3. The data used for this table and associated figures were taken from the Government Master File as of February 17, 1982. Of the 461 assignments shown, 222 are

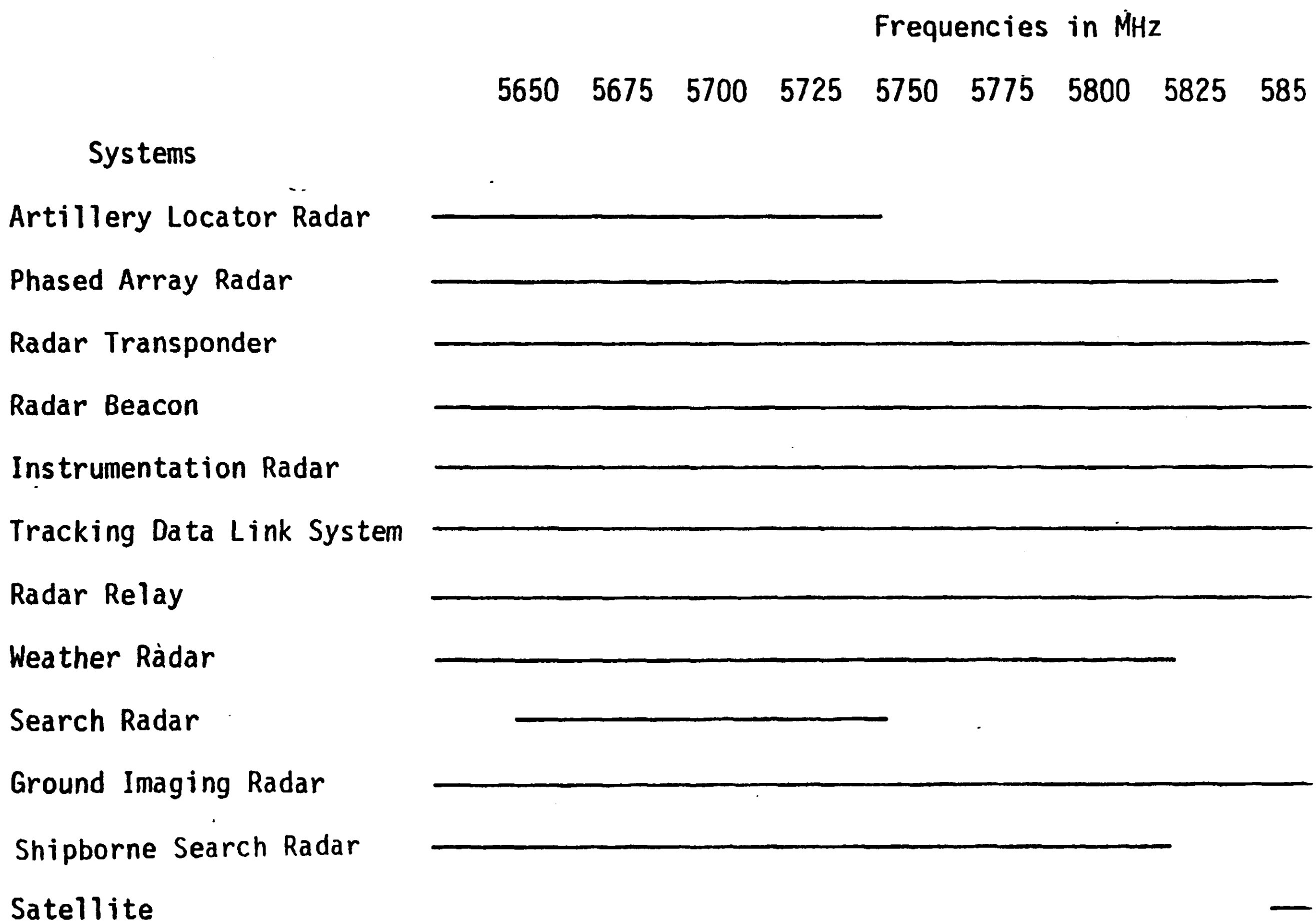

Figure 1. Tuning Range Capabilities of Typical Major Syst

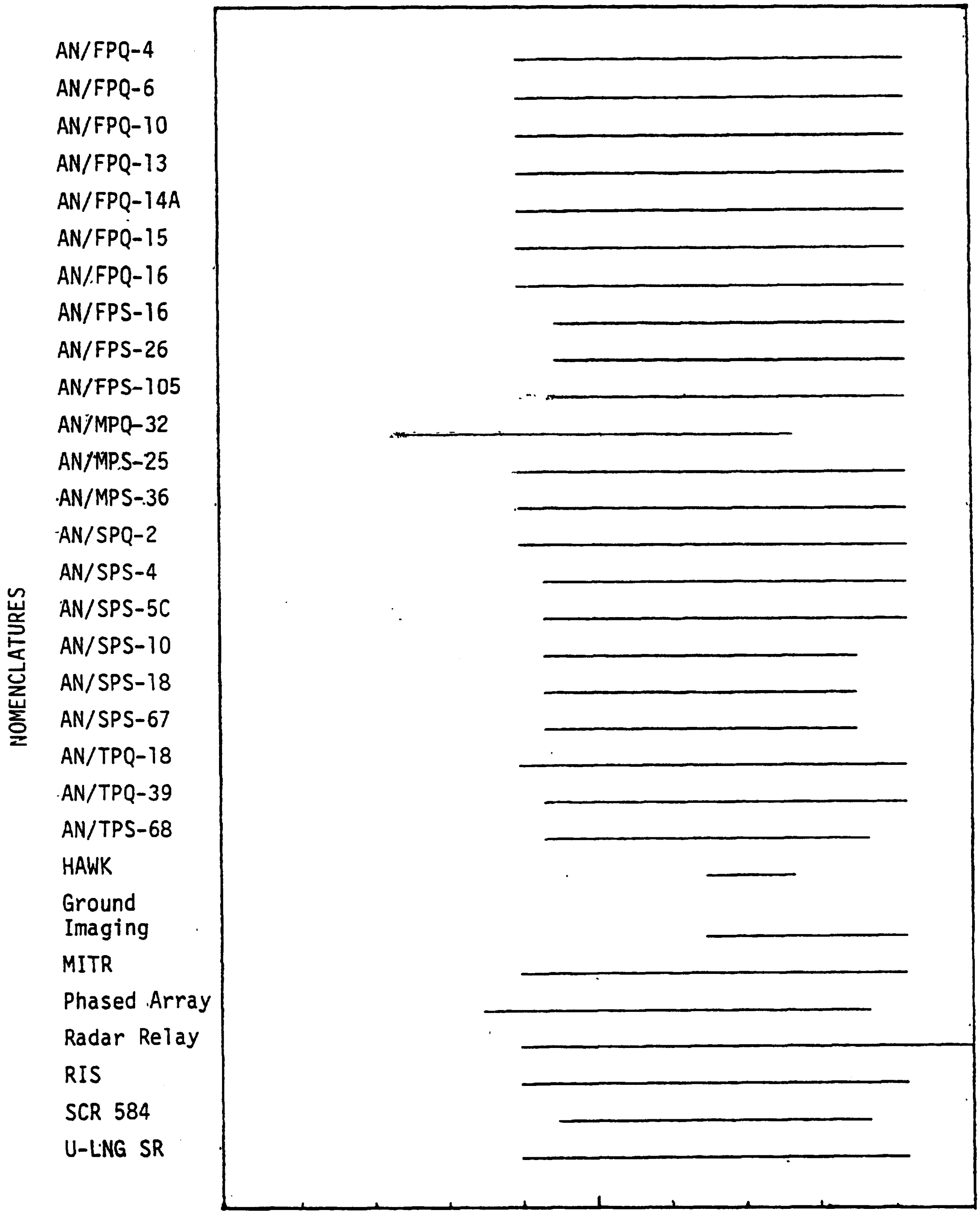

Figure 1a. Tuning Frequency Range for Unclassified Operational Radars in the 5650-5925 MHz band.

Table 3. Government and Non-Government Assignments in the 5650-592

AGENCY/SERVICE	STATION CLASS											N
	LR	MR	RO	MOB	FLD	MOEA	RLS	XC	XD	XR	XT	AS
AIR FORCE	52	99		17	7	7		4		1	21	
ARMY	28	68	15				3	4		3	6	
DOE	2	15									5	
NAVY	24	29		1				1			18	
NASA	5	4								1		
NON-GOVERNMENT								6	8	7		
NUMBER OF ASSIGNMENTS	111	215	15	18	7	7	3	15	8	12	50	
PERCENTAGE OF ASSIGNMENTS	24%	47%	3%	4%	1.5%	1.5%	0.7%	3%	1.7%	2.6%	11%	

LR - Radiolocation Land Station
MR - Mobile Radiolocation Station
RO - Radionavigation Mobile Station
MOB - Radio Beacon Mobile Station

MOEA - Aeronautical Telemetering Mobile Station
RLS - Surveillance Radar Station
FLD - Telecommand Land Station

XC -
XD -
XR -
XT -

*The number of assignments does not represent the actual number of equipments in operation.

listed in the GMF in the 5250-5925 MHz band and can range tune or have assigned operational frequencies by the operating agency anywhere in the band. There are 239 actual assignments in the 5650-5925 MHz band given by GMF. Of the 461 total assignments, 50 are classified and 21 are non-Government contractors. As can be seen, the major users are the military for radiolocation purposes. The experimental assignments (those station classes with an X prefix) deal with research and development and/or test and evaluation of new or modified radiolocation equipment and system and represent 18% of the assignments. Internationally there are operational radars in this band would could include some foreign ships in U.S. waters.

The distribution of frequency assignments from the 5650-5925 MHz GMF, in 5 MHz increments, is shown in Figure 2. This figure does not reflect the 78 range tuned systems from the 5400-5900 MHz band. However, there is some useful information to be gained from such a figure. Of the 383 assignments 85% are between 5650 and 5800 MHz. This is important since the FSS to be operable in the 5850-5925 MHz portion of the band has a better chance for compatible operation with the Radiolocation Service, the larger the frequency separation from active radar systems. There are 55% of the assignments between 5725 and 5875 MHz which are within the ISM frequency designation of 5800 $\pm$ 75 MHz. The distribution of frequency assignments does not represent the total number of equipments or systems operational in the band. Although the location and numbers of some equipments and systems are not available, there are approximately 1200 systems that operate in the 5650-5925 MHz band in the United States.

Figure 3 shows the geographical distribution of the Government frequency assignments in the 5650-5925 MHz band including the range tuned systems from 5250-5925 MHz. The map does not show locations of mobile radars or reflect shipboard use. The major fixed site users are concentrated in the Southwestern portion of the country, mainly California, Nevada, Arizona, and New Mexico. Besides the Government assignments in CONUS there are a number of assignments on islands which constitute the Eastern Down Range Tracking Facility out of the Kennedy Space Flight Center, Florida, such as Grand Bahama Island, Grand Turk, and Bermuda Islands. There are other tracking facilities representing the Pacific Missile Range operations. Woomera, Australia and Pretoria, South Africa, are part of the worldwide space tracking network.

Figure 4 shows the 10 year growth trend for the 5650-5925 MHz band from January 1972 to January 1982. The number of assignments have increased steadily over this period with a 62% increase occurring over the last 5 years. Increased use by the U.S. Air Force accounted for most of this growth trend. This plot shows the trend and does not include range tuned equipments or represent numbers of equipment in operation, but is representative of assigned frequencies in the band 5650-5925 MHz. The SRV shows 12 new systems in development and/or test and evaluation stages in the band over the past 3 years. This includes the AN/TPS-68, Vega 374C, the Aircraft Security Radar System, and AN/SPS-67 systems. This is a band which continues to show growth in Government use, and in checking with the various agencies and departments involved, this trend should continue.

Use of the ISM band at 5725-5875 MHz is very uncertain since there is no licensing requirement by the FCC and no detailed records are kept. However, no documented use of ISM equipment in this band could be found and there is no indication that ISM equipment is being manufactured for the band. There is major use of these frequencies by the Government Radiolocation Service.

Restricted radiation devices may operate in the band as given in Section 3. However, due to the in-band emission limits and the non-interference basis, these systems must conform to standard spectrum management techniques and should keep interference potential to a minimum.

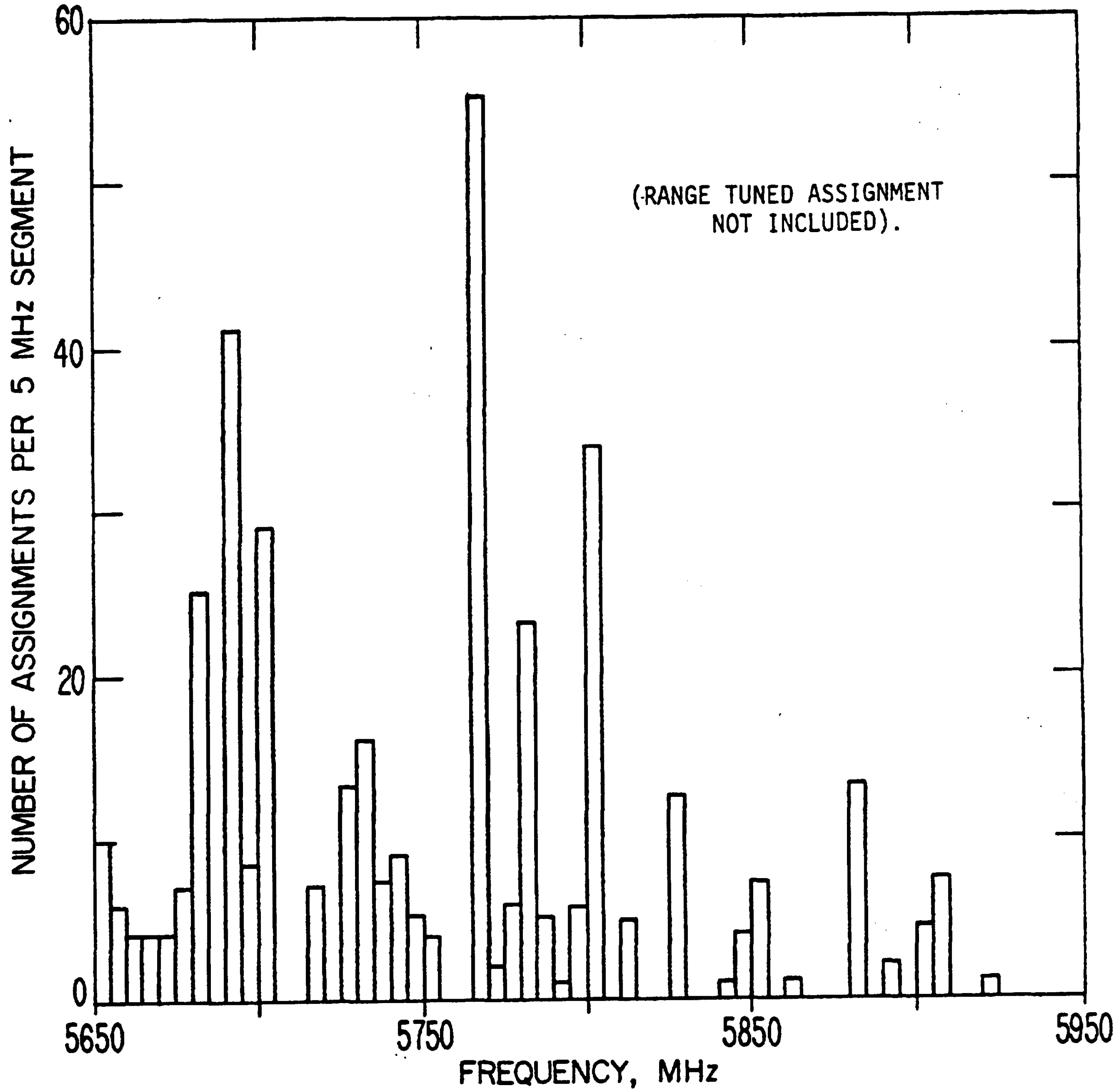

Figure 2. Distribution of Frequency Assignments and 5 MHz Increments between 5650-5950 MHz.

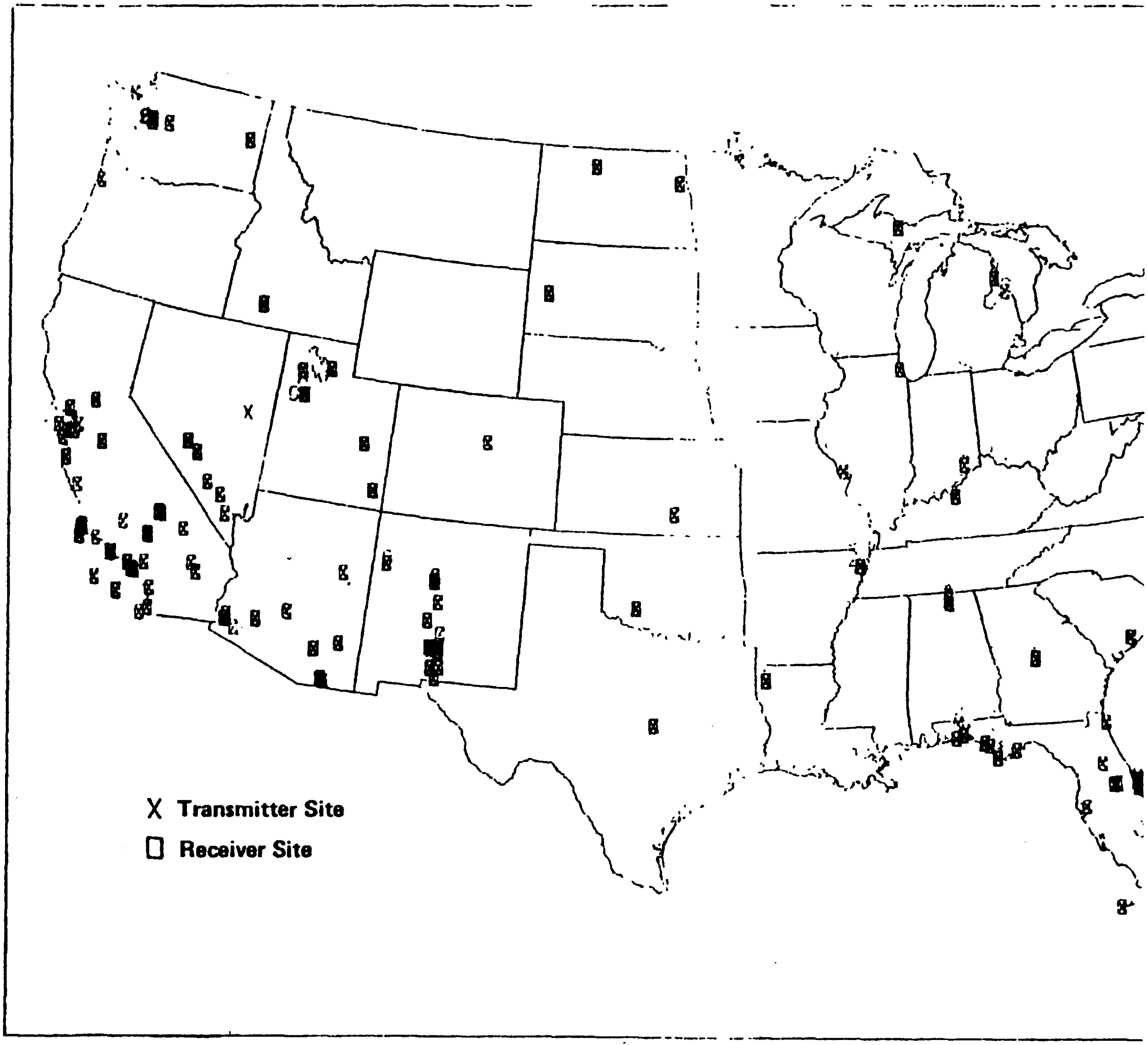

Figure 3. Geographic Distribution of Government Frequency Assignments in the 5650-59

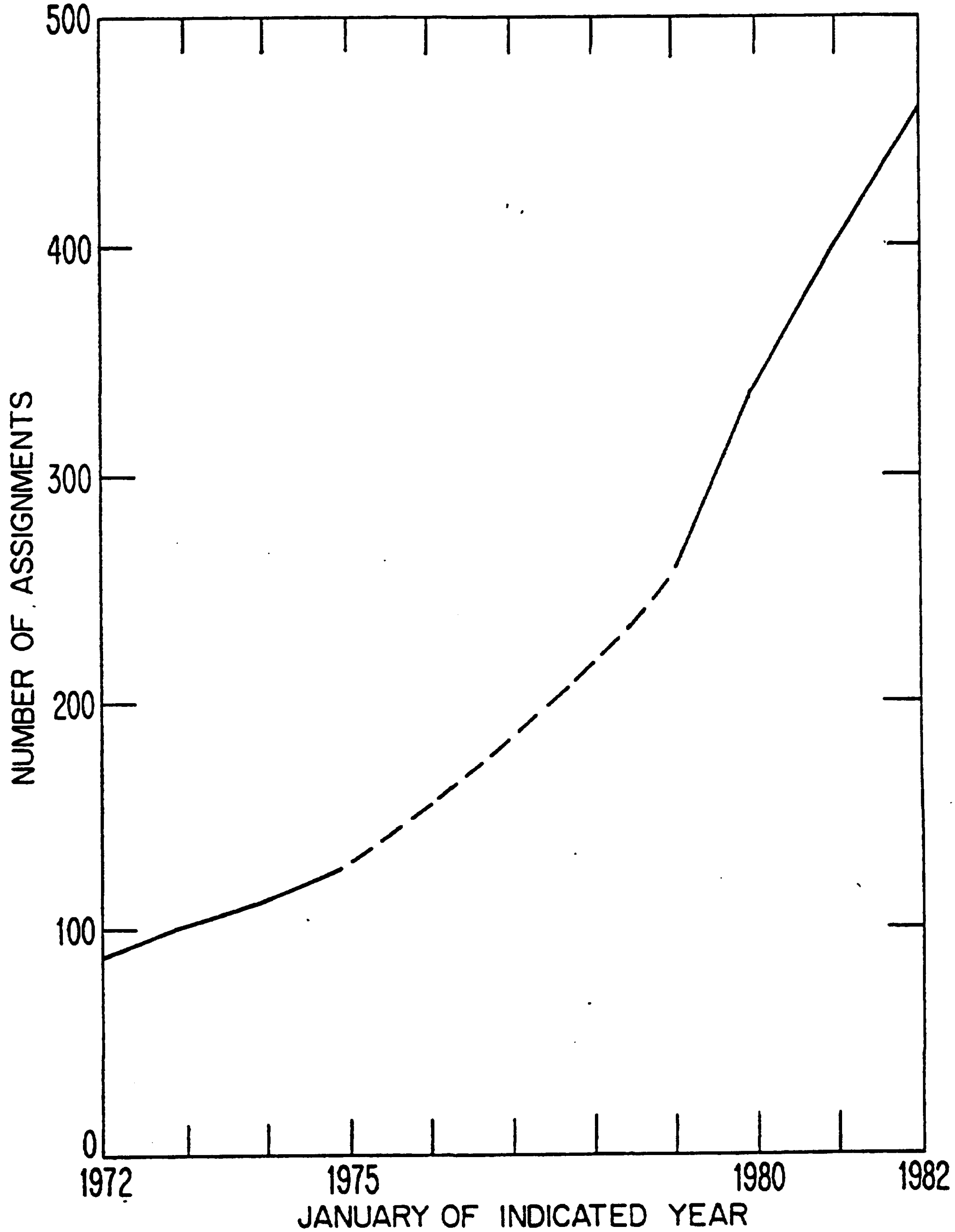

Figure 4. Growth Trend for the 5650-5925 MHz Band

RSMS MEASUREMENTS

There were measurements made by the RSMS Van in the 5650-5925 MHz band in 10 different areas of CONUS. Measurements were made from December 1974, in the Los Angeles, California area to various places including the East Coast and the latest at Seattle, Washington in 1982. There were active radars measured at San Diego, Seattle, Los Angeles, San Francisco, and WSMR sites. The WSMR is by far the most active measured area in the band. Most port areas such as San Diego, Los Angeles, and San Francisco measured Navy shipboard radars such as the AN/SPS-10 and AN/SPS-4. Figures 5 through 8 show typical occupancy measurements in San Diego, White Sands, and Seattle area for the frequencies from 5600-5925 MHz. In Figure 5 the first peak at 5513 MHz is an AN/SPS-10 shipboard radar. The peak at 5630 MHz is a weather radar and the other larger peaks are shipboard radars. Figure 9 is another AN/SPS-10 radar showing its measured antenna pattern which is useful in the type of analysis as given in Section 6 of this report.

The antenna pattern measurement program measures the peak energy received from the radar in 500 equally-spaced measurement periods. These 500 periods are timed so that the total measurement time matches a measurement time selected by the operator. The operator chooses a measurement period and starts the system, so that the measurements are made over an interval beginning just before the mainbeam of the radar is seen and ending slightly after the succeeding mainbeam has passed. These two mainbeams are assumed to be 0° and 360°, and the rest of the measurement points are assigned an antenna angle by interpolation. Similarly, the elapsed time for the block of 500 measurements is precisely measured, and the time between mainbeams is computed.

Several statistics are measured for the antenna pattern, including the average level for the entire pattern (between 0° and 360°), the average level for the side-lobes (between 3° and 25° and between 335° and 357°), and the average for backlobes (between 25° and 335°). In addition, the measurement frequency is printed out and the time elapsed between the mainbeams is calculated and printed.

The antenna patterns are plotted relative to the power received at 0°, so the pattern is actually plotted in terms of dB below mainbeam gain. In addition, a statistical antenna pattern, Figure 10, is plotted, which shows how much of the time the antenna pattern is suppressed certain amounts below the mainbeam. This sort of plot furnishes an EMC figure of merit for the antenna, since it tends to show what chance there would be for the antenna to radiate or receive interference on its sidelobes or backlobe if it were operated in a multi-radar environment.

Figure 11 shows the emission spectrum (short pulse mode) for the AN/SPS-10 a common shipboard radar. Figure 12 shows the same radar emission spectrum using long pulse mode. Figure 13 shows the emission spectrum for the AN/FPS-16, a common radar on the various missile and rocket test ranges. The measured emission spectrum shows a spurious emission (TE 121 mode) in the satellite band 5850-5925 MHz which is only 50 dB below the peak power of the carrier. Figure 14 is the radar signature of the WSR 74-C weather radar at Boston. This pattern shows spikes between 5720 and 5750 MHz which slightly exceed the RESC suggested limit. This has not been a problem in the 5650-5925 MHz band, but is given here to show the utility of the van measurements. The analysis in Section 6 uses the above military radar measured spectrum to accomplish levels of interference potential.

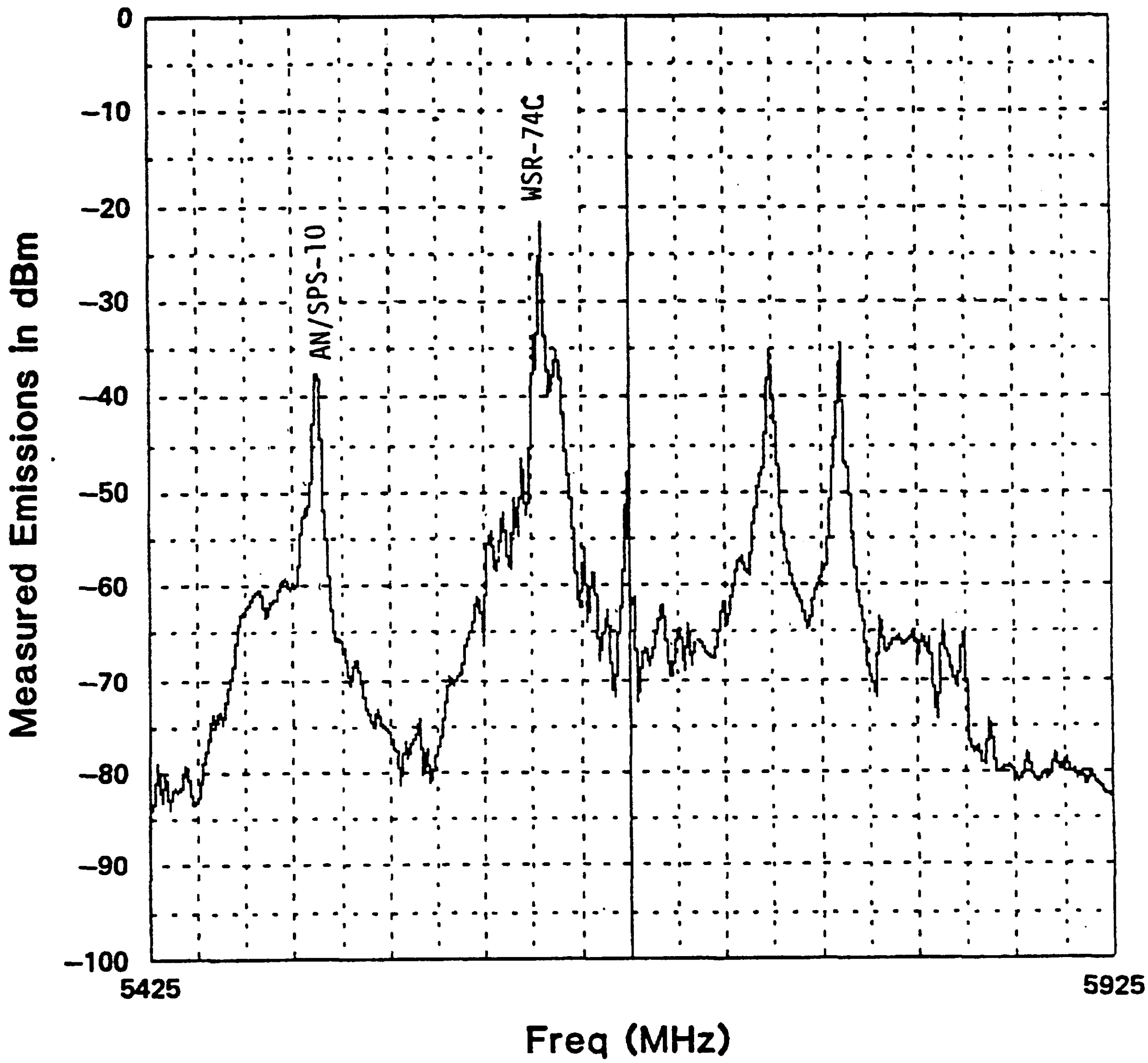

Figure 5. Occupancy Measurement for 5425-5925 MHz Band in the San Diego, CA Area.

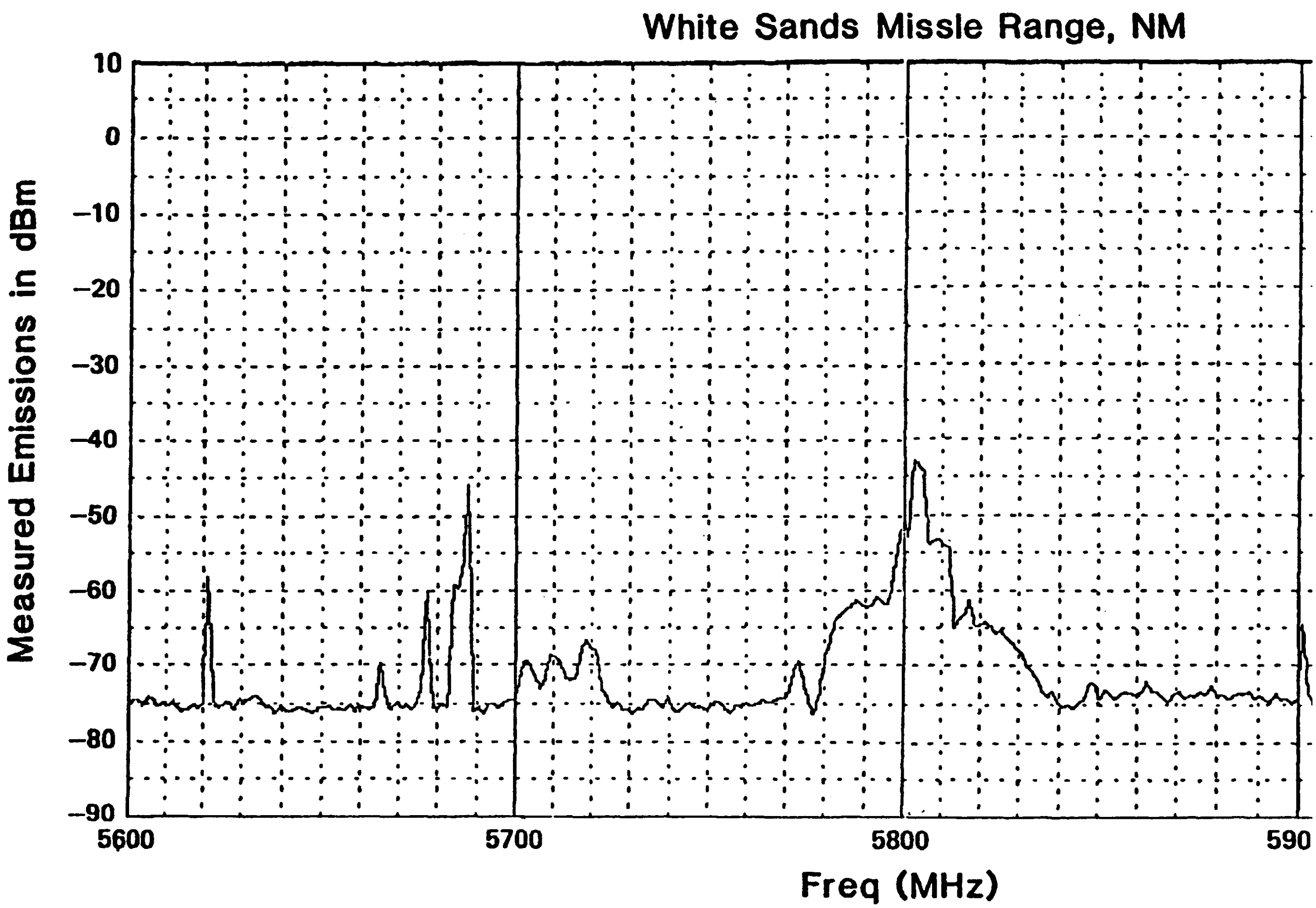

Figure 6. Spectrum Occupancy Measurements at White Sands Missile Range, NM (

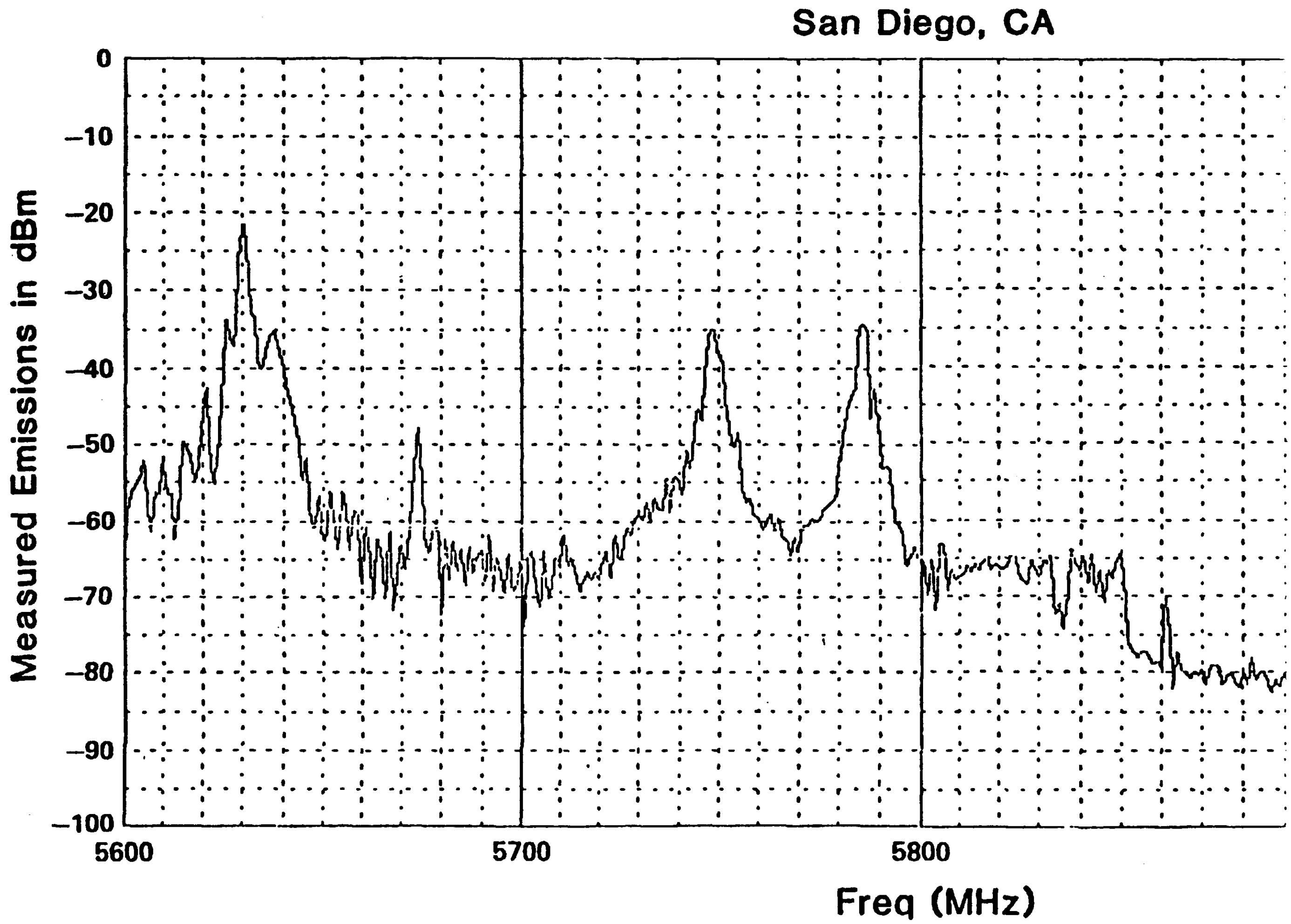

Figure 7. Spectrum Occupancy Measurements at San Diego, CA (A

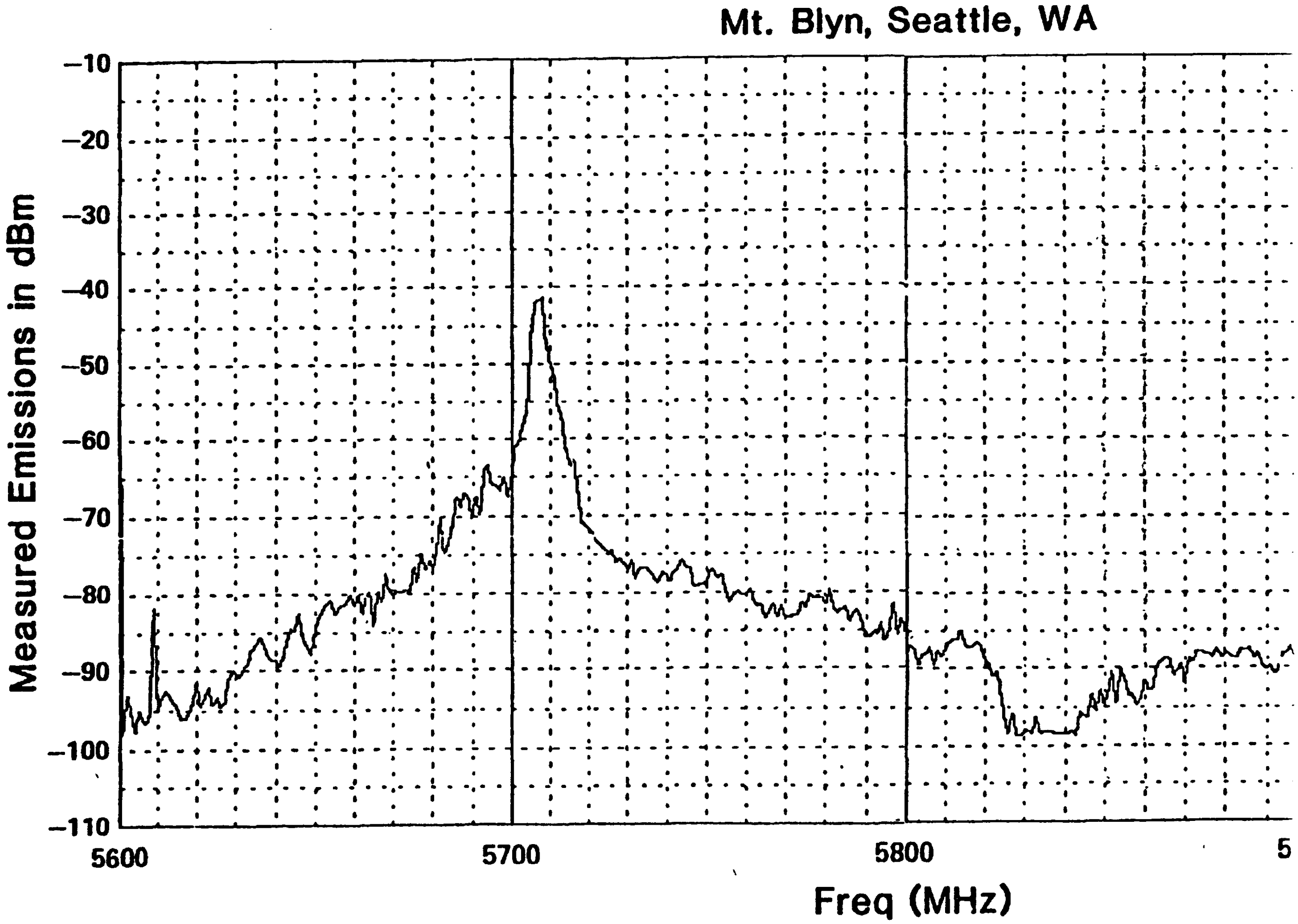

Figure 8. Spectrum Occupancy Measurements at Seattle, WA (June

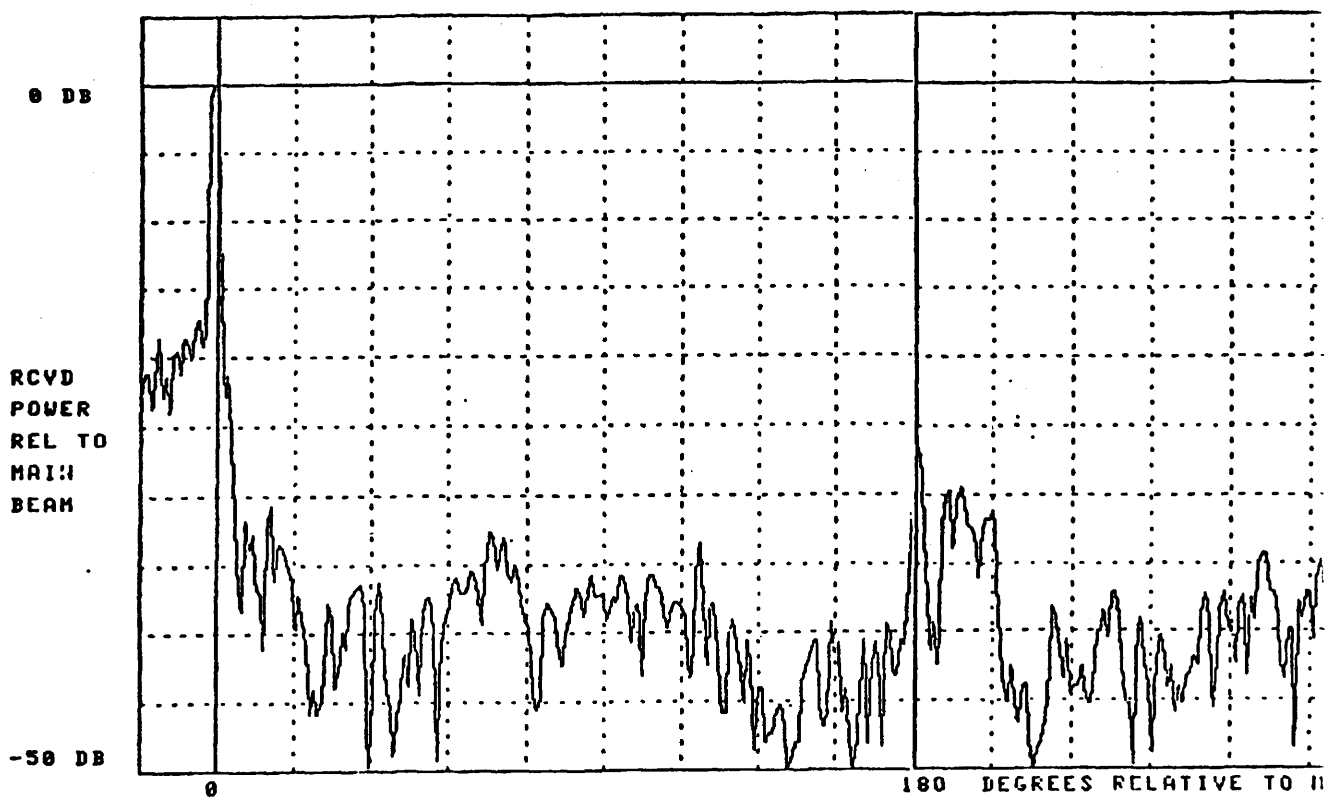

Figure 9. Measured AN/SPS-10 Antenna Pattern.

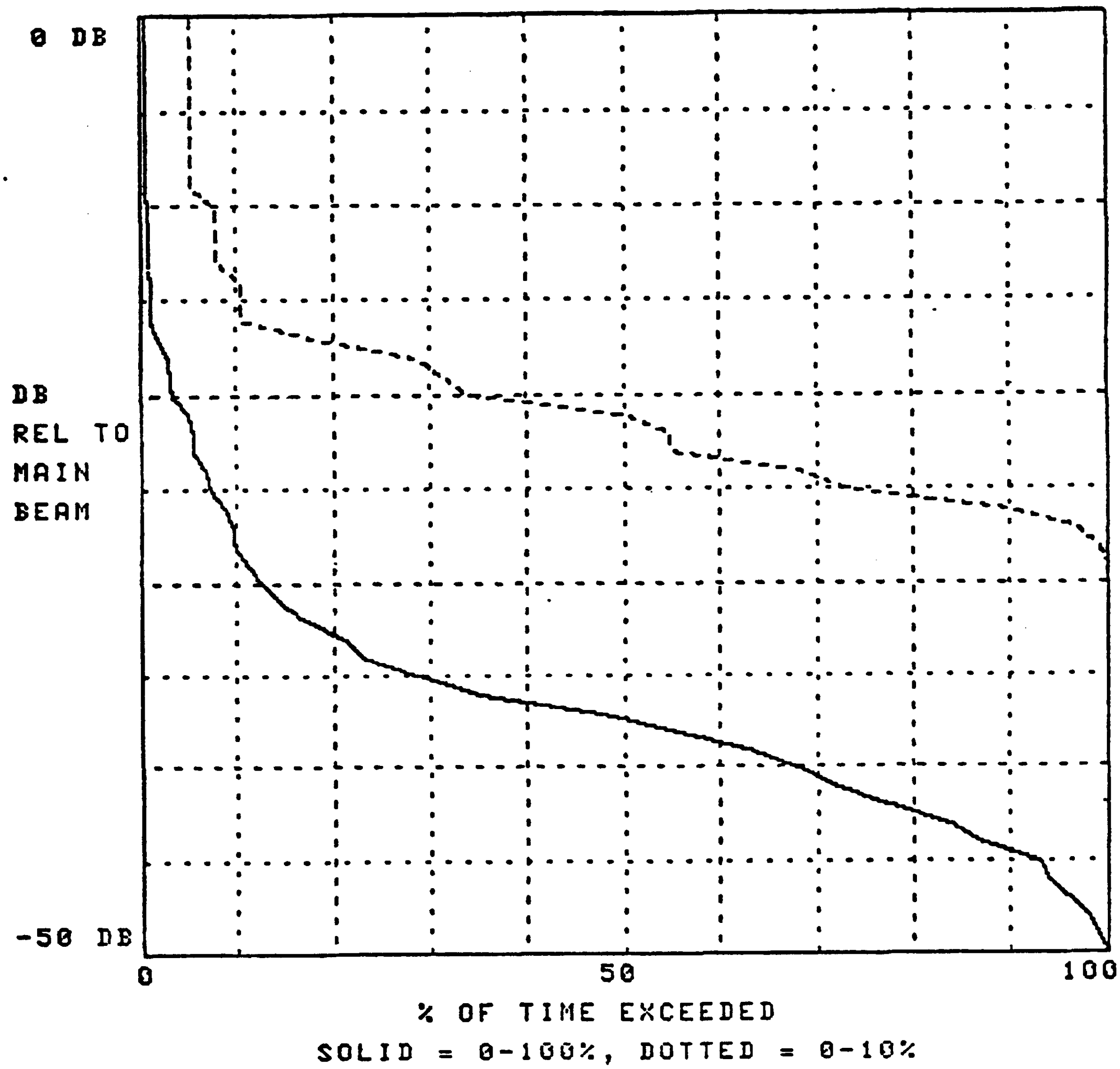

Figure 10. Statistical Antenna Pattern Distribution for AN/SPS-10.

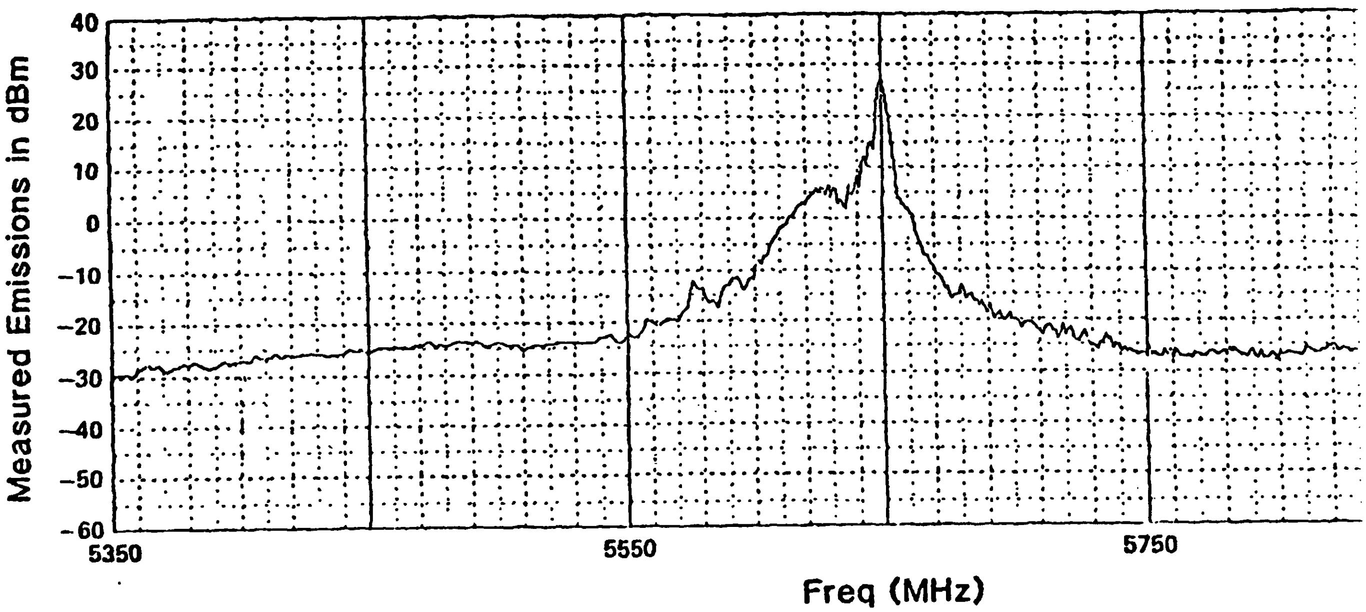

Figure 11. Measured AN/SPS-10 Emission Spectrum (Short Pulse Mode).

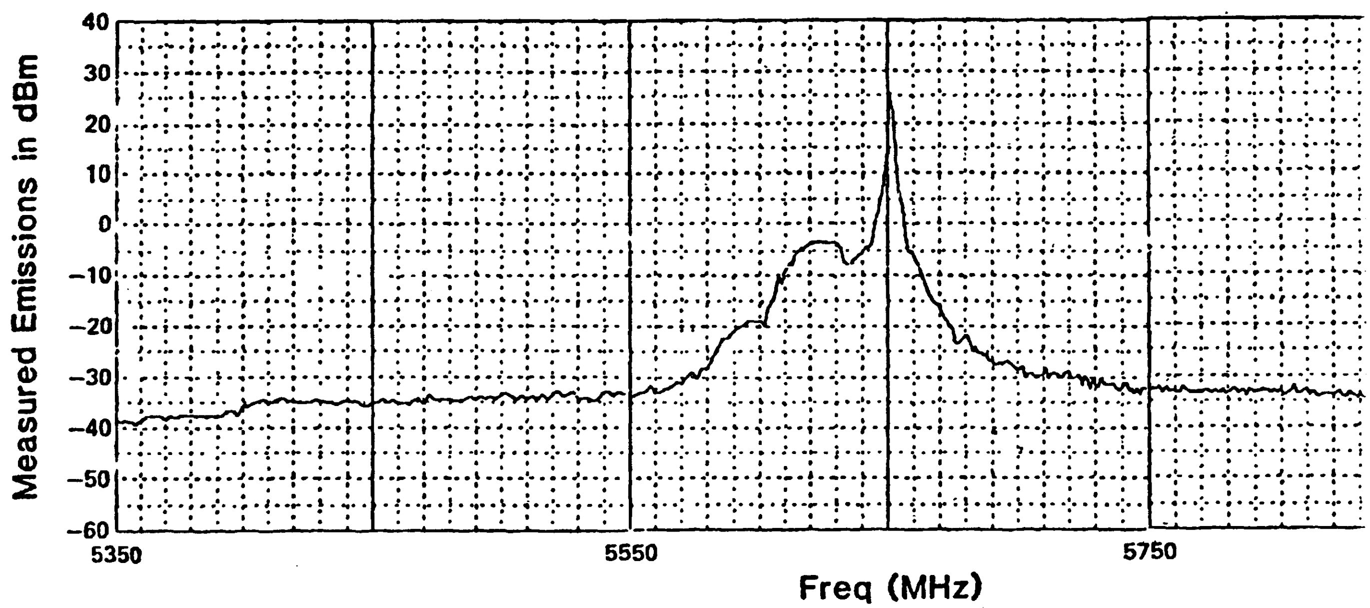

Figure 12. Measured AN/SPS-10 Emission Spectrum (Long Pulse Mode).