Space Division
North American Rockwell

SD72-SA-0100

WEST COAST RFI SURVEY

PREPARED BY: W.F. DEUTSCH
APPROVED BY: T.E. HILL

NORTH AMERICAN ROCKWELL CORPORATION
SPACE DIVISION
DOWNEY, CALIFORNIA

DECEMBER 21, 1972

FINAL REPORT

FOR PERIOD DECEMBER 7, 1971 - DECEMBER 15, 1972

PREPARED FOR

GODDARD SPACE FLIGHT CENTER

GREENBELT, MARYLAND 20771

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16. Abstract

The final report describes the activities and presents the data obtained under the subject contract. The topics covered are experiment design, mechanization on-board the aircraft, survey operations, quick look and automated data reduction and a qualitative comparison of survey data with ESL predicted values.

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ILLUSTRATIONS

INTRODUCTION AND SUMMARY

In order for the NASA to proceed with the evaluation of the various communication system concepts proposed for the TDRS system, it is essential that the characteristics and magnitude of the RFI problem be well defined.

The primary objective of the survey conducted and described herein is to accomplish the first step in this definition. This consisted of monitoring RF power levels in the frequency bands shown in Table I from a position that approximated the geometrical relationships of low orbiting spacecraft and terrestrial RF power sources.

Table I. Survey Bands

Band	Frequencies (MHz)
A	126-128
B	128-130
C	135-137
D	137-139
E	148-150
F	150-152
G	152-154

Major metropolitan areas on the West Coast of the United States were selected for the initial survey on the assumption that these geographical areas will provide representative information on worst case conditions.

These frequency bands and geographical areas were surveyed using sensing and recording equipment installed in an aircraft that maintained a relatively constant cruise altitude of 30,000 ft. For this purpose a North American Rockwell owned Sabreliner jet aircraft was used.

Although visual displays of the information obtained was provided in the aircraft to aid the principal investigator in the conduct of the survey, final data reduction and plotting of information was accomplished on the ground.

The data recorded during the flights has been reduced in the form of X-Y plots to illustrate the relationship of RF levels as a function frequency and time. Also, serial recordings of the oscillograph output were maintained, but due to the extensive amount of data on these recordings only representative outputs are included in this report. The X-Y plots are iterative tracings of each pass in the 2 MHz bands and provide insight into the density of transmission and frequency of occurrence, as well as indications of where clear segments exist. However, the amplitudes of the large emitter hits on these tracings are inaccurate due to the slow response times of the mechanical X-Y plotter. The amplitudes on the tape recordings are accurate and the optical tracings of the oscillograph outputs are accurate. However, the bulk of this data is so great that interpretation without further data reduction is impossible. For this reason only typical samples of the oscillograph traces are included.

Evaluation of the X-Y plots leads to the conclusion that the most promising portions of the VHF frequency spectrum are bands B, D and E. The traces of these frequency bands indicate the possible existence of clear sections and sections of low duty cycle. Evaluation of the X-Y plots in conjunction with the oscillograph traces indicate not only high density transmissions in the other bands but also very high power levels. The sample traces from the oscillograph output provided a measure of the background noise levels which can be seen to vary from nominal values of -120 dbm at the lower frequencies, to -140 dbm at the higher frequencies.

NR provided in excess of 60 flight hours of survey time. During the flight days the survey dwelled equally on each frequency band, except F and G which proved to be extremely congested early in the survey and not suitable for TDRS application. The surveys were conducted during the morning, afternoon, and evening hours of the day over the greater metropolitan areas of San Diego, Los Angeles, and San Francisco.

Reduction of the survey analog data was performed on a SDS 920 digital computer. The process involved A/D conversion, frequency bin occurrence and signal level sorting for each of the metropolitan areas. The frequency bin occurrence and signal levels were summed and converted to present the percentage of time the signal level exceeded a specified value between -70 and -140 dBm using a modified FR80 plot. Similarly, a California composite data set was generated by combining all of the data from the metropolitan areas surveyed. Data summaries of frequency or bin number as a function of percentage time of occurrence were generated for -115, -100, -85, and -70 dBm for each metropolitan area and the California composite. These summaries also were plotted using the modified FR80 program.

The results of the survey were compared qualitatively with the data presented in Electromagnetic Systems Laboratory (ESL) report ESL-TM215. A high degree of frequency correlation was observed; however, the amplitude and duty cycle varied widely. While duty cycle was anticipated to create the illusion of clear channels, the variance in signal magnitude was sufficient to conclude that the worst case treated in the ESL data consisted of maximum antenna gain responses from the terrestrial emitters. The geometry of the survey over flights would reflect that of a low orbit spacecraft; hence, the maximum field intensites of the terrestrial emitters would be experienced only near the radio horizon.

SURVEY DESIGN

The RF Survey was designed to enable measurement of amplitude, frequency and time of occurrence of terrestrial emissions in the VHF frequency band during overflights of heavily populated metropolitan areas located on the Pacific Coast of the Continental United States. These overflights were performed in Sabreliner N287NA, Figure 1, at a nominal altitude of 30,000 feet over Los Angeles, San Diego, and San Francisco. A total of 18 flights were made, involving a total of 65.25 flight hours, in performing the data acquisition. Measurements were performed in seven VHF frequency bands, Table I, with the equipment configuration shown in Figure 2.

Table I. Survey Bands

VHF Band Designation	Frequency, MHz
A	126.0 to 128.0
B	128.0 to 130.0
C	135.0 to 137.0
D	137.0 to 139.0
E	148.0 to 150.0
F	150.0 to 152.0
G	152.0 to 154.0

Sabreliner N287NA is normally used as an airborne test bed and is configured with 28 volt power and inverters that produce 115 volts AC, 60 and 400 Hz. The available aircraft power installation was adequate to furnish the requirements of the measurement system.

The ambient noise level created by the aircraft environment was of concern from the outset. The measurement system equipment was connected to the aircraft bus which was single-point grounded with a heavy copper strap.

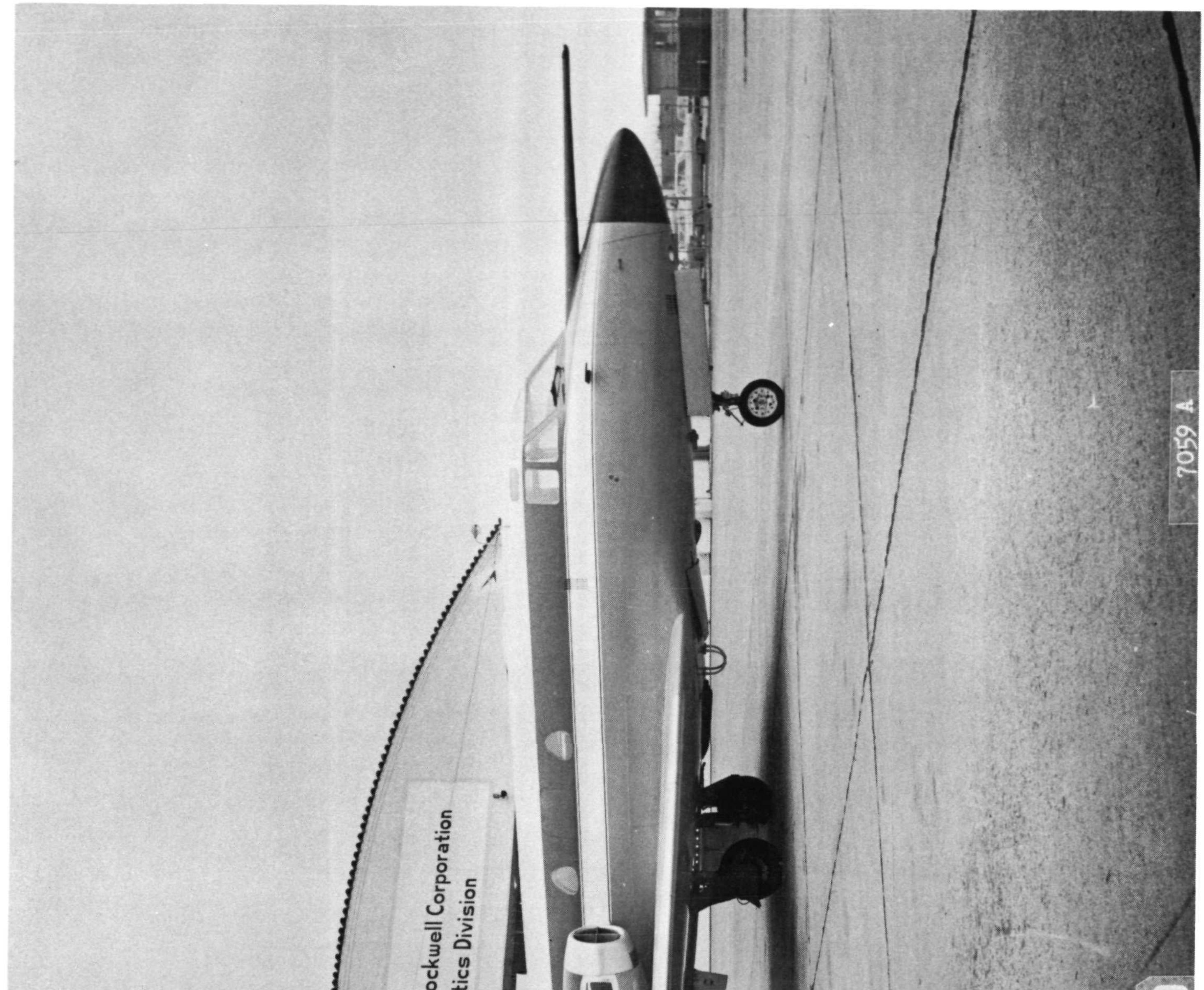


Figure 1. Sabreliner N287NA

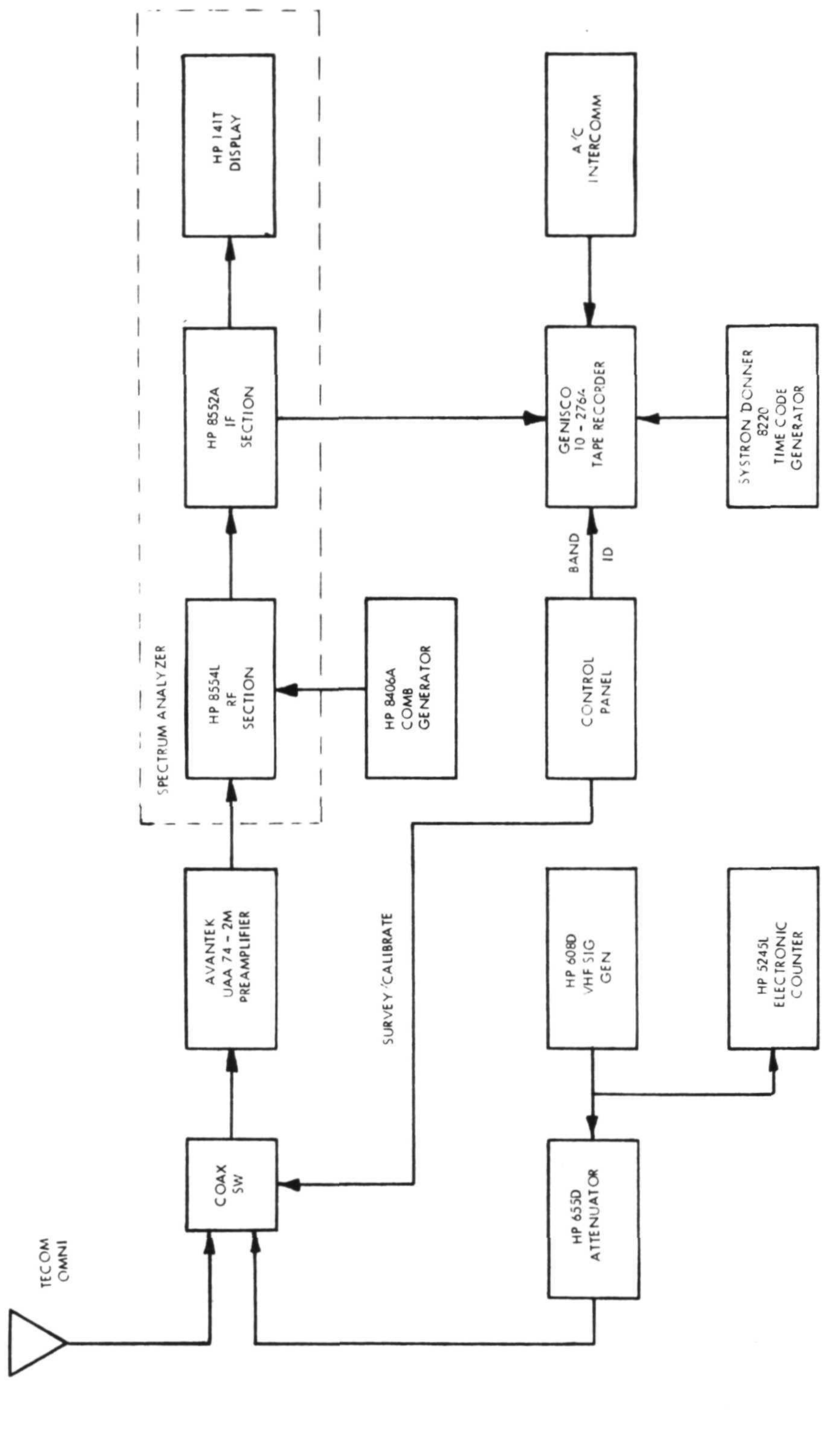


Figure 2 - FUNCTIONAL BLOCK DIAGRAM OF WEST COAST RFI SURVEY EQUIPMENT

During the ambient noise test, measurements indicated that the locally generated noise level was on the order of -140 dbm across the bands which was significantly lower than that measured during data acquisition.

The major elements of the measurement system installation include a special two-axis polarized data acquisition antenna system procured from TECOM Industries, Inc., an Avantek, Model UAA 742-M, preamplifier, a Hewlett-Packard, Model 8554L/8552A/141T, spectrum analyzer, Genisco, Model 10-276A, tape recorder, and a Systron/Donner, Model 8220, time code generator. The frequency and amplitude reference consisted of a Hewlett-Packard, Model 608D, VHF signal generator, a H-P, Model 5245L electronic counter with frequency conversion module, and an H-P Model 655D attenuator. An H-P, Model 8406A, comb generator was used to insert 1 megahertz crystal reference markers into the RF survey data to accomodate spectrum analyzer local oscillator frequency drift. The 1 megahertz markers identify the center frequency and edges of the frequency band being monitored.

The control panel provided for a remote mode select (survey/calibrate) control of the coaxial switch inserted between the antenna output and preamplifier input terminals. In the calibrate position, the frequency/amplitude reference was connected to the preamplifier during tuning and calibration procedures. In the survey mode, the system was configured to acquire data. The control panel also provided for identification of the frequency band being surveyed with a DC reference level corresponding to the selected band (switch position) and was recorded on tape recorder channel 7 as shown in Table II.

Each frequency band was assigned a separate tape recorder channel, Table II, to facilitate subsequent automated data reduction (which is beyond the scope of this activity) if desired. The amplitude of each emitter encounter

TABLE II

Tape Recorder Channel Assignments

Channel	
1	Frequency Sweep (Ramp Function)
2	Data Band A
3	Timing
4	Data Band B
5	Annotation
6	Data Band C
7	Data Band Identification
8	Data Band D
9	Unused
10	Data Band E
11	Unused
12	Data Band F
13	Unused
14	Data Band G

was recorded on one of these data channels along with the frequency correlation on channel 1 and the time of occurrence on channel 3. The annotation channel (5) was used to record aircraft data (position, heading and altitude, weather conditions), selected transmissions identified on the spectrum analyzer, and observations made during the acquisition of data.

Several changes to the proposed instrumentation were required to enable implementation of the survey measurement system. First, use of the HP-8406A comb generator as the frequency reference for turning the spectrum analyzer is quite satisfactory for laboratory conditions; however, a more positive method of marking center frequency was required for flight operations. In addition, the selected comb generator output level was uncalibrated and it was necessary that a calibrated reference level be available to verify system operation prior to each data acquisition period. The calibration system was changed to accomodate these operational requirements. Second, the Genisco tape recorder, Appendix A, was substituted for the Leach inflight recorder when it was observed that the shipment date of replacement electronics would not support the flight schedule. Third, the X-Y plotter was deleted from the flight inventory when it became obvious that in-flight recordings were unreliable due to pen jitter and ink flow problems. As a result, all X-Y recordings were prepared on the ground at the data reduction center.

Measurement System Calibration

Sabreliner N287NA is in the experimental category and is used extensively for operations requiring calibration at aircraft attitude; hence, instrument pitch and roll gyros, independent of the autopilot, are installed and were used in the verification of antenna pattern. A series of unrestricted flight profiles, Table III, were flown using test frequencies 123.35, 135.0 and 151.625 MHz to calibrate the antenna using a base station ground transmitter

TABLE III

Ambient Noise and Antenna Calibration Flight Plan

T.O. Wt. = 18,374# (For Flts above 18,275#)

Initial Pilot Anderson)
P. E. Deutsch)

S/L N287NA Flight 611 Date 29 Feb. 72

Base Communications 123.35 (VHF) (Autonetics Mobile)
Channel 5 USB (HF) (KNV8)

Test Freq. #1 = 123.35 MC
Test Freq. #2 - 135.0 MC
Test Freq. #3 - 151.625 MC (FM)

NO SPEED BRAKE - NO VHF DURING DATA

1. Loiter in "VHF Quiet" area

2. Over Water - 25 Mi. West of LAX - Alt 5000' ± 1000' (Gyro Calib)
   a) North Hdg - Test Freq #1 - Rt Wing up 90° & return to level
   b) Repeat 2a
   c) South Hdg - Test Freq #1 - Lt Wing up 90° & return to level
   d) Repeat 2c
   e) East Hdg - Test Freq #1 - 45° Climb Toward Base Station
   f) West Hdg - Test Freq #1 - 45° Dive Away From Base Station
   g) East Hdg - Test Freq #1 - 45° Climb Toward Base Station
   h) West Hdg - Test Freq #1 - 45° Dive Away From Base Station

3. a) North Hdg - Test Freq #2 - Rt Wing up 90° & return to level
   b) Repeat 3a (Gyro Calib)
   c) South Hdg - Test Freq #2 - Lt Wing up 90° & return to level
   d) Repeat 3c
   e) East Hdg - Test Freq #2 - 45° Climb Toward Base Station
   f) West Hdg - Test Freq #2 - 45° Dive Away From Base Station
   g) East Hdg - Test Freq #2 - 45° Climb Toward Base Station
   h) West Hdg - Test Freq #2 - 45° Dive Away From Base Station

4. a) North Hdg - Test Freq #3 - Rt Wing up 90° & return to level (Gyro Calib)
   b) Repeat 4a
   c) South Hdg - Test Freq #3 - Lt Wing up 90° & return to level
   d) Repeat 4c
   e) East Hdg - Test Freq #3 - 45° Climb Toward Base Station
   f) West Hdg - Test Freq #3 - 45° Dive Away From Base Station
   g) East Hdg - Test Freq #3 - 45° Climb Toward Base Station
   h) West Hdg - Test Freq #3 - 45° Dive Away From Base Station (Gyro Calib)

5. a) Fly over Base Sta - East Hdg - 7500' MSL - Test Freq #3
   b) Fly over Base Sta - East Hdg - 7500' MSL - Test Freq #2
   c) Fly over Base Sta - East Hdg - 7500' MSL - Test Freq #1

located at Los Angeles International Airport. Table III is a reproduction of the flight plan used for the calibration of the antenna at a distance of 25 miles on the Los Angeles VOR Station 248 degree radial. The principal objective of this flight was to determine if the installed antenna pattern deviated materially from the Free Space pattern, (Figure 3), under operational conditions. The data taken on this flight has been reduced revealing smooth, normal, variations in amplitude that are consistent with the free space patterns.

Monitoring and Recording Equipment

Photographs of the measurement system equipment installation along with element description and performance data are presented in this section. The RF sensor is a special antenna consisting of two half loops mounted orthoganally as shown in Figure 4. The speed brakes shown on the left side are normally retracted during flight. The aircraft skid is located immediately aft of the antenna and clears the escape hatch door on which the antenna has been mounted. This mounting configuration permitted easy access to the antenna terminals and close coupling of the coaxial switch and preamplifier as shown in Figure 5. The remainder of the measurement system is located behind the Flight Engineer Console (right side of Figure 6) to provide easy access by the equipment operator in the aft-right seat (left side of Figure 6). The contents of the aft-portside rack are shown in Figure 7 with the equipment operator's seat on the left. The equipment layout (clockwise) is:

HP Model 608D VHF Frequency Generator (second shelf right side)

Control Panel

HP Model 8406A Comb Generator

Genisco Model 10-276A Tape Recorder

HP 8554L/8552A/141T Spectrum Analyzer

PROJECT NO. C 50	FILE NO.
MODEL SCALE FULL	MODEL NO. TECOM Type 701001
MODEL FREQUENCY	ANTENNA TYPE Overflight Surveillance
FULL SCALE FREQUENCY 140 MHz	ANTENNA LOCATION
VEHICLE TYPE	NUMBER OF ANTENNAS ____ SHEET ____ OF ____

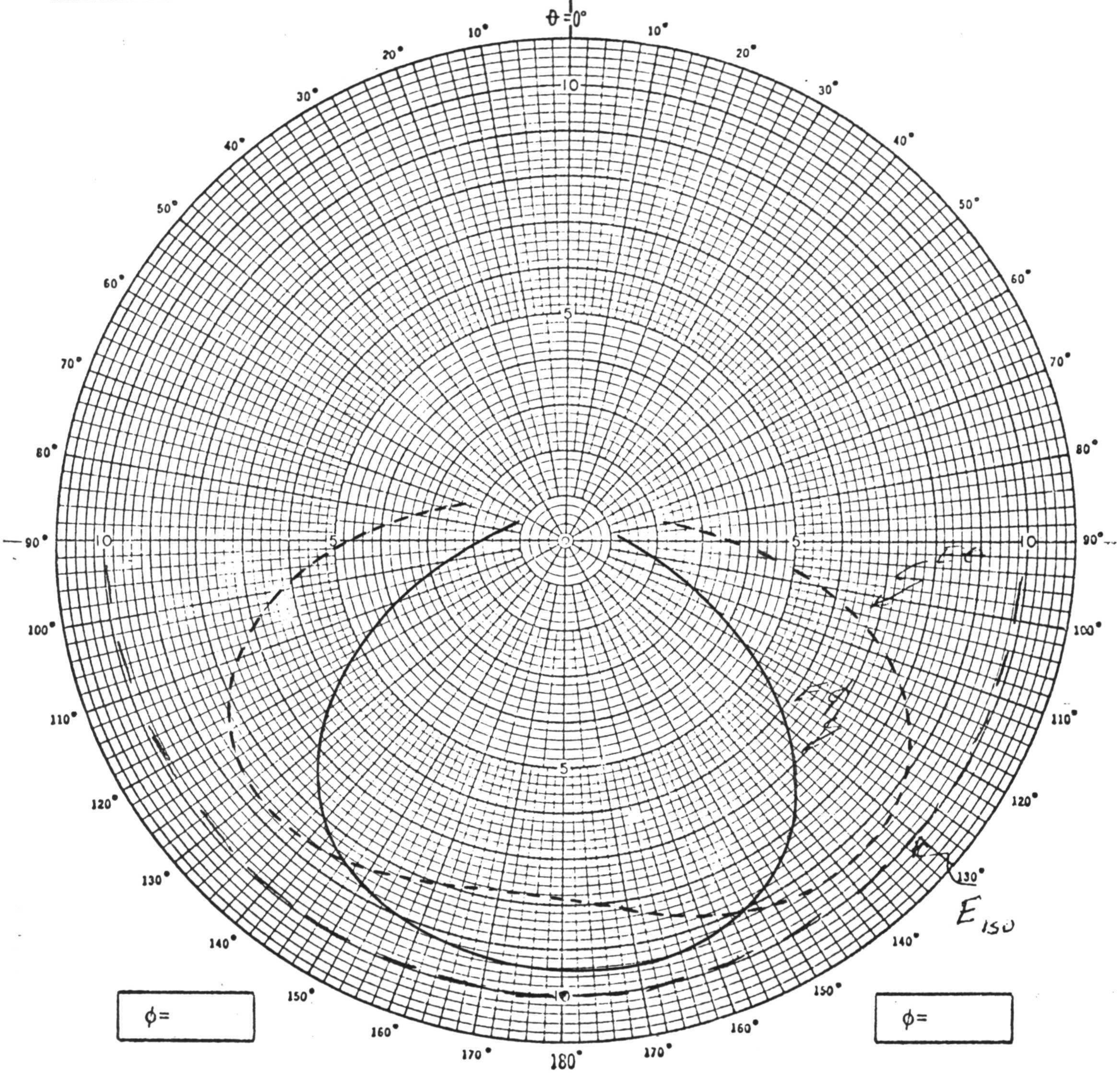


Figure 3. TECOM Type 701001 Overflight Surveillance Antenna

TECOM INDUSTRIES INC.
9000 OWENSMOUTH AVENUE
CANOGA PARK, CALIF. 91304

REMARKS

POLARIZATION: Eθ ✓ Eφ ✓ RC LC

CURVE PLOTTED IN VOLTAGE

INT. ____ M. ____ ISO. ____

OPER. ____ CHECKED ____ DATE 1/31/72

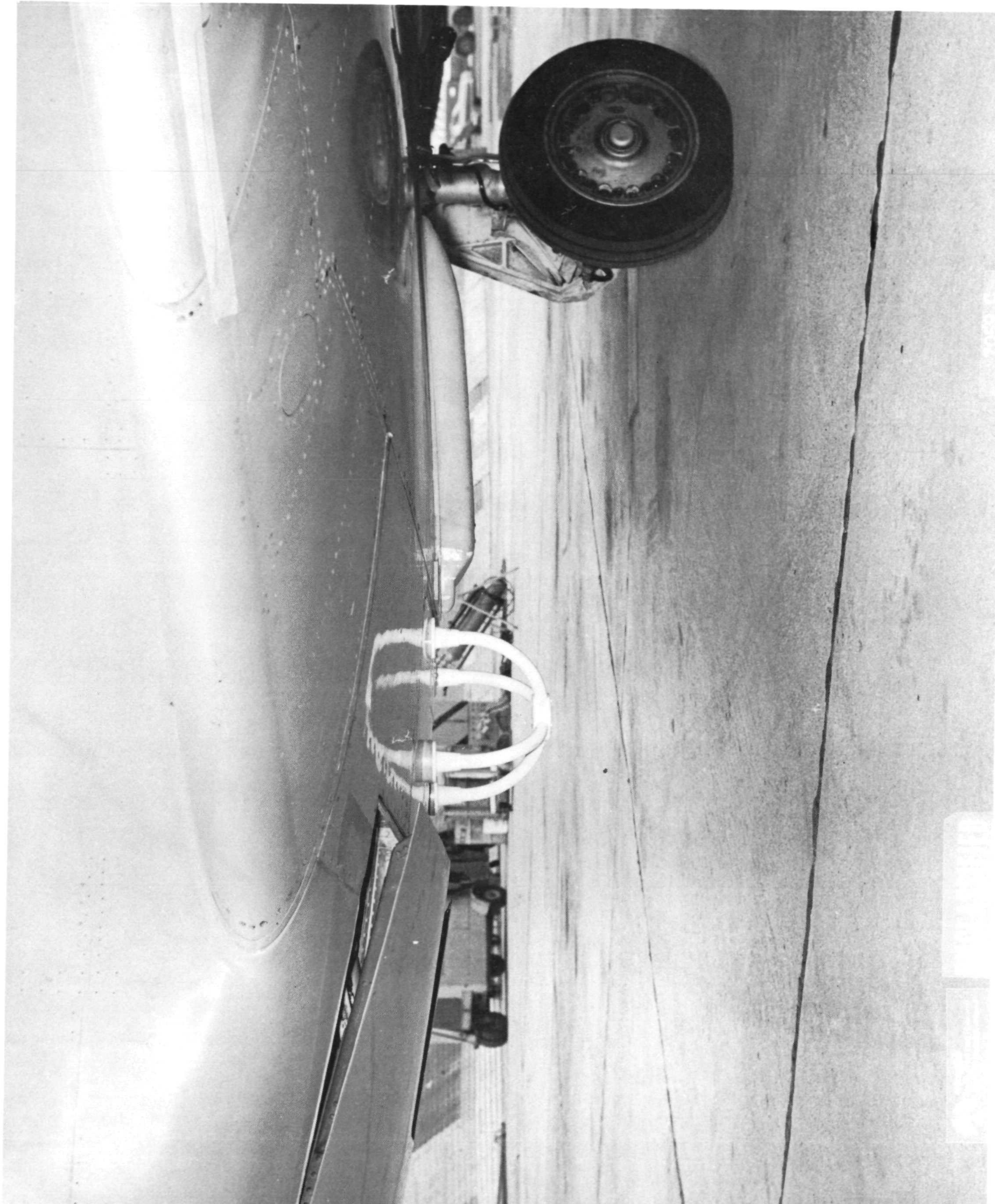


Figure 4. RF Sensor Installation

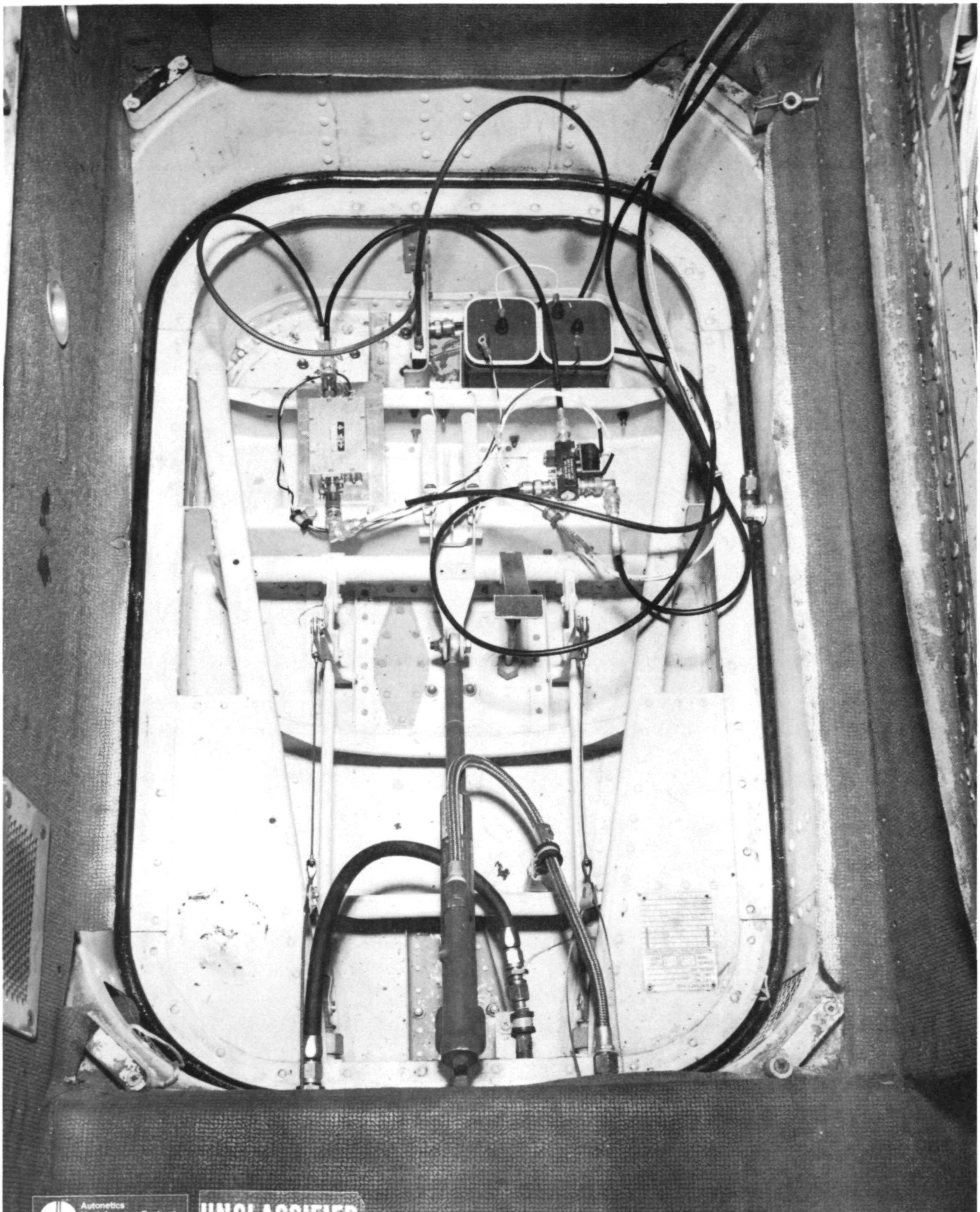


Figure 5. Emergency Hatch Installation of Preamplifier and Coaxial Switch

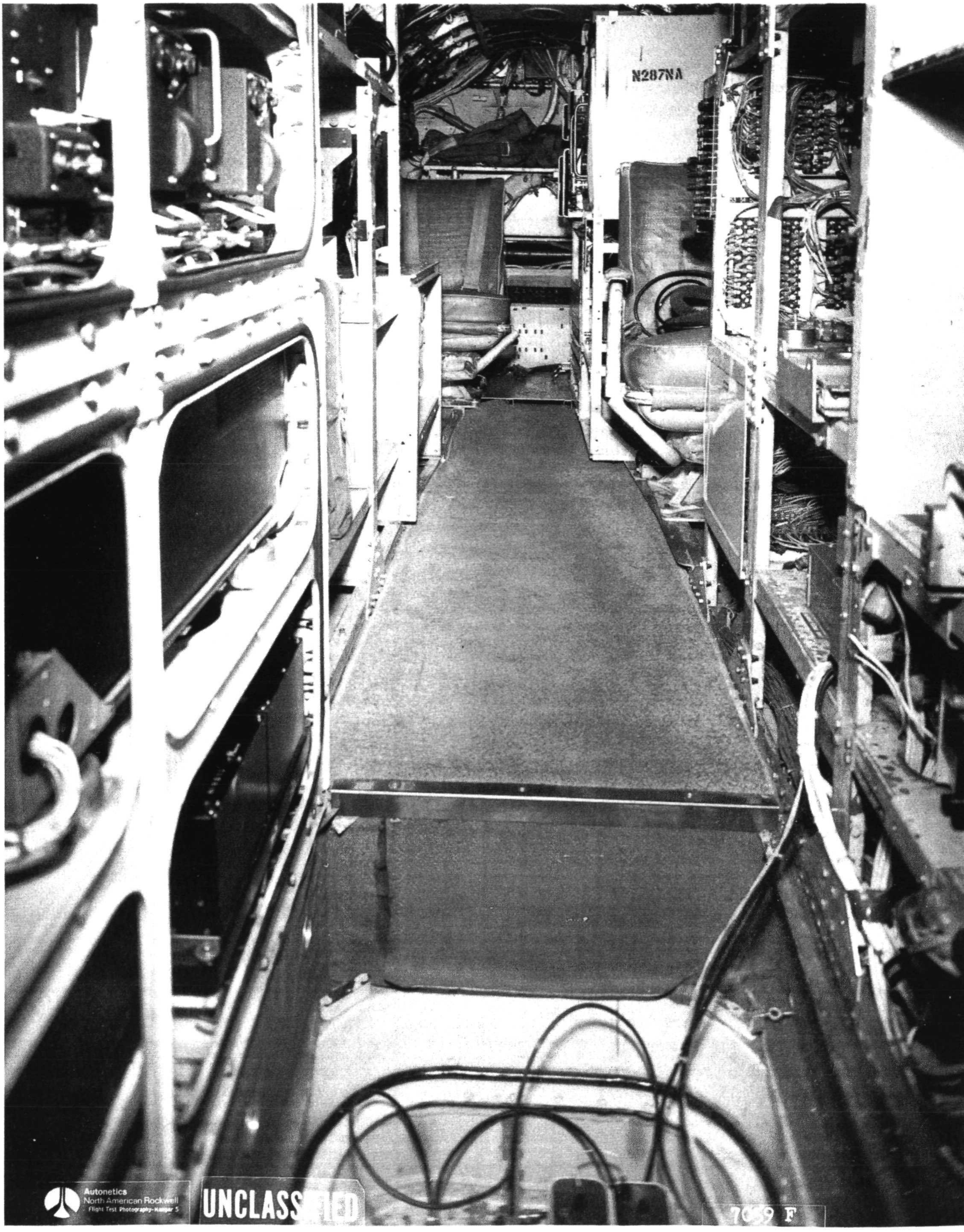


Figure 6. N287NA Interior - Aft View

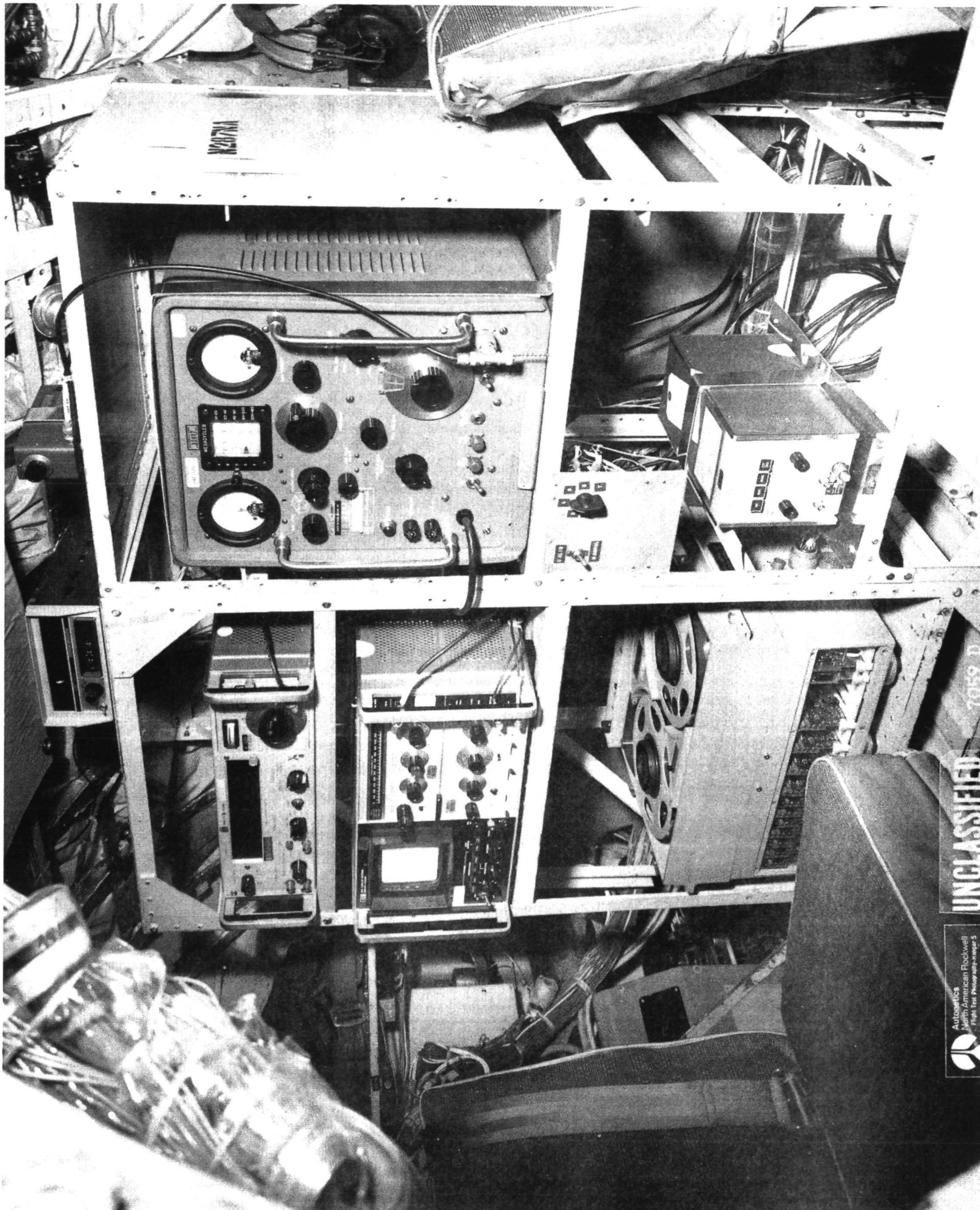


Figure 7. Aft - Portside Equipment Rack

HP 5245L/N520708 Electronic Counter with frequency converter

Systron/Donner Model 8220 Time Code Generator

HP Model 655D Attenuator

The equipment installation shown in the rack and hatch area were designed to permit both positive and negative G-loading during the maneuvers required to calibrate the antenna.

The Avantek Model UAA 742-M solid state preamplifier has a gain and noise figure of >26.7 db and <2.2 db, respectively, which exceed the supplier's specification. The supplier's data also specifies the input and output VSWR to be less than 1.5 and 1.2 db, respectively. The 1 db gain compression is greater than +4 dbm.

The preamplifier is powered by a 12 volt battery pack to eliminate noise originating from the aircraft electrical system. This power arrangement was selected after observing that the aircraft 28 volt bus would require substantial filtering to remove noise spikes. Therefore, since the preamplifer has a current drain of 28 milliamperes and the 28 volt filters were not readily available, the 12 volt battery pack approach was used to expedite the program.

The Hewlett-Packard, Model 8554L/8552A/141T, Spectrum Analyzer has a full 70 db of dynamic display range with a frequency response that is flat to ± 1 db over the entire sweep range. The specification for this equipment is in Appendix B.

A scan width of 200 KHz per division was selected to accomodate a 2.0 MHz band during each sampling period. A 1 KHz sweep or sampling bandwidth was used to enable discrimination of two closely spaced signals with large amplitude differential. The 1 KHz bandwidth permits identification of signal offsets of 3 and 20 KHz with amplitude differences of 20 and 60 db, respectively.

The automated features of the HP spectrum analyzer provide for flat response and optimum effective bandwidth by constraining the sampling times, instantaneous bandwidth, scan width and video filter settings that are compatible with the resolution capability of the analyzer. If any parameter was set improperly, a warning light cautioned the operator to recheck analyzer settings. Using a scan width of 200 KHz per division (2.0 MHz full scale), an instantaneous bandwidth of 1 KHz and a video filter bandwidth of 10 KHz, calibrated operation could only be maintained using a scanning rate of 1 second per division or 10 seconds per 2.0 MHz band. In contrast, a 0.5 second scan rate was possible when the video filter was bypassed with all other parameters unaltered. These two sweep rate conditions result in normalized sweeprate, values K, of 0.2 and 0.4 for 10 and 5 second sweep times, respectively. These normalized sweep rates correspond to no loss in amplitude, α, or degradation of effective bandwidth, $\Delta f_{eff}/\Delta f$, which are illustrated in Figure 8.

The slower sweep rates consistent with the identification of closely spaced emitters with large signal differences and accuracy of amplitude but could cause data loss of short duration transmissions. This data loss was evident from periodic monitoring of air traffic control and tower frequencies on the aircraft VHF receivers corresponding to the data acquisition band. Short duration ($<$ 1.5 seconds) bursts ("turn-off left," " Roger," "affirmative," etc.,) were frequently missed while long duration ($>$ 3 seconds) instructional transmissions were only occasionally missed. For this reason, data was obtained at sweep rates of 1.0, 0.5 and 0.05 seconds per division to provide a representative sampling of the emitter environment.

The calibration sequence given in Table IV is very time consuming and was performed immediately after each flight. A pre-flight calibration is performed only if the equipment has been on-line for a one hour warm-up. The spectrum analyzer is the most sensitive element of the measurement system and is subject to frequency drift which is compensated by injection of 1 MHz crystal markers.

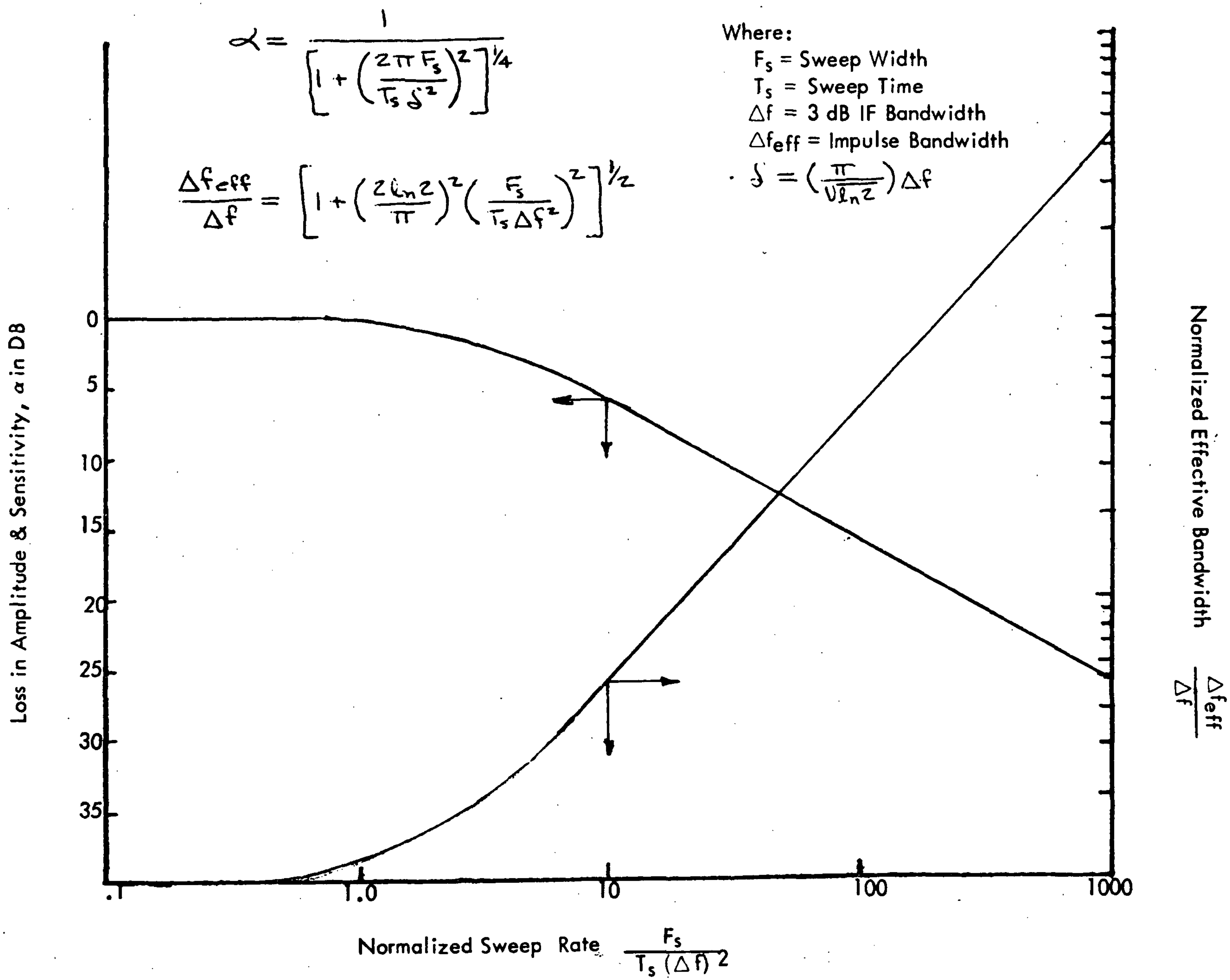


Figure 8 Effects of Sweep Rate

TABLE IV

Calibration Sequence

1. Turn on all equipment one hour before initiation of calibration to allow stabilization.

2. Set Spectrum Analyzer to the following:

   HP 8554L
   - A. Input attenuator - 0 dB
   - B. Sweep bandwidth - 200 KHz/division (2MHz)
   - C. Bandwidth - 1 KHz

   HP 8552
   - A. Scan time - 1.0 second/division (10 seconds)
   - B. Select log scale - Log reference level = -40 dB (Lighted)
   - C. Verify scale attenuator is 0 dB
   - D. Video Filter - 10 KHz
   - E. Scan Mode - Internal
   - F. Scan Trigger - Automatic

3. Select "Calibration" position on selector switch and verify tape recorder set on 7½ ips.

4. Set inline attenuator to 70 dB.

5. Adjust HP 608 Signal Generator to Band A center frequency and tune HP 8554L to center the calibration frequency on the HP 141T display. Verify HP 608 Signal Generator tuning with a peak response and a level set of + 4 dBm. Activate Recorder.

6. Disconnect input and connect out of HP 806A Comb Generator and verify 2 MHz bandwidth (200 MHz per division) by observing 3 marker signals displayed on HP 141T display. Restore input signal configuration.

7. Verify HP 855 attenuator setting is set at 70 dB and HP 608 level set adjusted to + 4 dBm. Adjust output level to +4, 0, -10, -20, -30, -40 and -50 dB at intervals of 10 seconds and record the IF output voltage on the tape recorder.

8. Without adjustment of HP 8554L tuning head, tune the HP 608 signal generator down in frequency 1 MHz, verifying frequency selection on HP 5245L, and repeat Step 7 using 10 second intervals after verifying tuning of HP 608 Signal Generator (as in Step 5).

9. Increase the frequency in 200 KHz steps, repeating Step 8, through the entire frequency band.

10. Select band B and repeat Steps 5 through 9.

11. Select band C and repeat Steps 5 through 9.

12. Select band D and repeat Steps 5 through 9.

13. Select band E and repeat Steps 5 through 9.

14. Select band F and repeat Steps 5 through 9.

15. Select band G and repeat Steps 5 through 9.

Preflight Calibration Complete -

Repeat for Postflight Calibration.

FLIGHT OPERATIONS

Data acquisition flight operations in N287NA were performed over Los Angeles, San Diego, San Francisco metropolitan areas and while enroute at a nominal altitude of 30, 000 feet. The basic flight plans (Appendix C) are plotted in Figures 9, 10, and 11 for the respective metropolitan areas. The Los Angeles flight path was approximately 126 N. Miles while the San Diego and San Francisco tracks were approximately 92 N. Miles. Using the maximum endurance airspeed (210 KI), average track times are 22 min: 04 sec. and 16 min: 09 sec. which correspond to a ground speed of 343-350 K. It should be noted that the FAA Air Traffic Control Centers were not always able to approve a block clearance for flight level 300 over metropolitan areas. Higher flight level blocks (340 and 370) were frequently used when F. L. 300 was unavailable. The time to altitude (30, 000 feet) after take-off was approximately 18 minutes while the descents were made quite rapidly (5 to 8 minutes)to maximize time at altitude. The flight time to San Diego averaged 17 minutes while the San Francisco enroute time averaged 35 minutes. Maximum endurance fuel consumption averaged 1575 pounds per hour which has enabled on-station operation for a period of approximately 3. 5 hours per flight. At least two flights are flown on each flight day netting a minimum of 7 hours on-station.

The equipment stabilizes in approximately one hour; therefore, ground power was applied to the aircraft prior to flight to expedite stabilization. During flight, amplitude remained essentially constant; however, the spectrum analyzer local oscillator frequency had a tendency to drift. As a result of the drift, 1 MHz crystal frequency markers were inserted during data runs to mark the center and edges of the band; thus, alleviating the need for extensive calibration before and after each data acquisition period. Tuning of the spectrum analyzer L.O. required more time than originally anticipated. Data acquisition periods averaged 5 minutes/band with occasional dwells on a band noted to be partially inactive. Equipment tuning has required approximately 1-1/2 minutes per band and resulted in a 77 percent efficiency. Based on the amplitude stability and the use of crystal frequency markers, the data acquisition period was increased, without incurring loss in accuracy, to approximately 15 minutes.

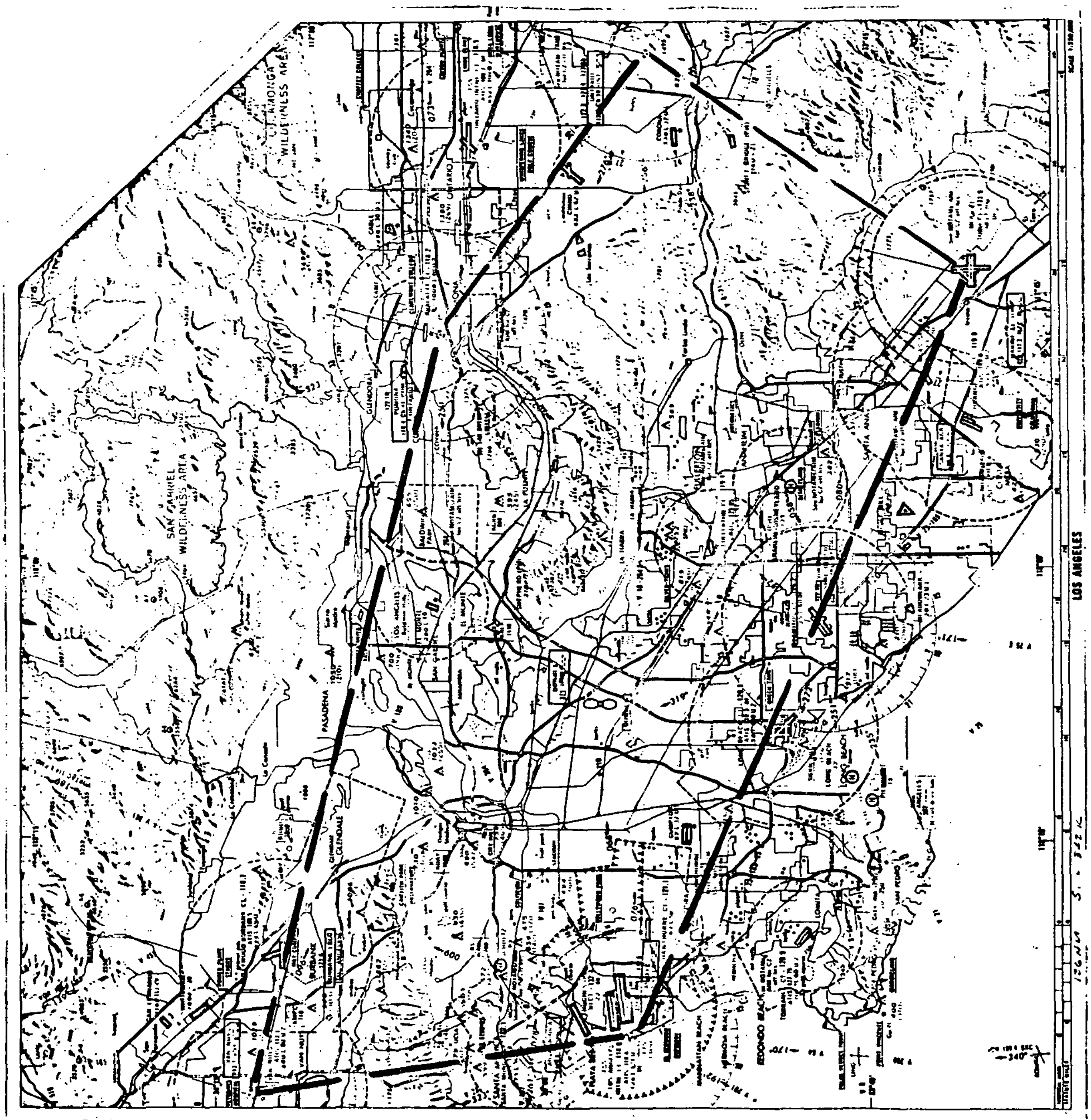


Figure 9 - Los Angeles Flight Path

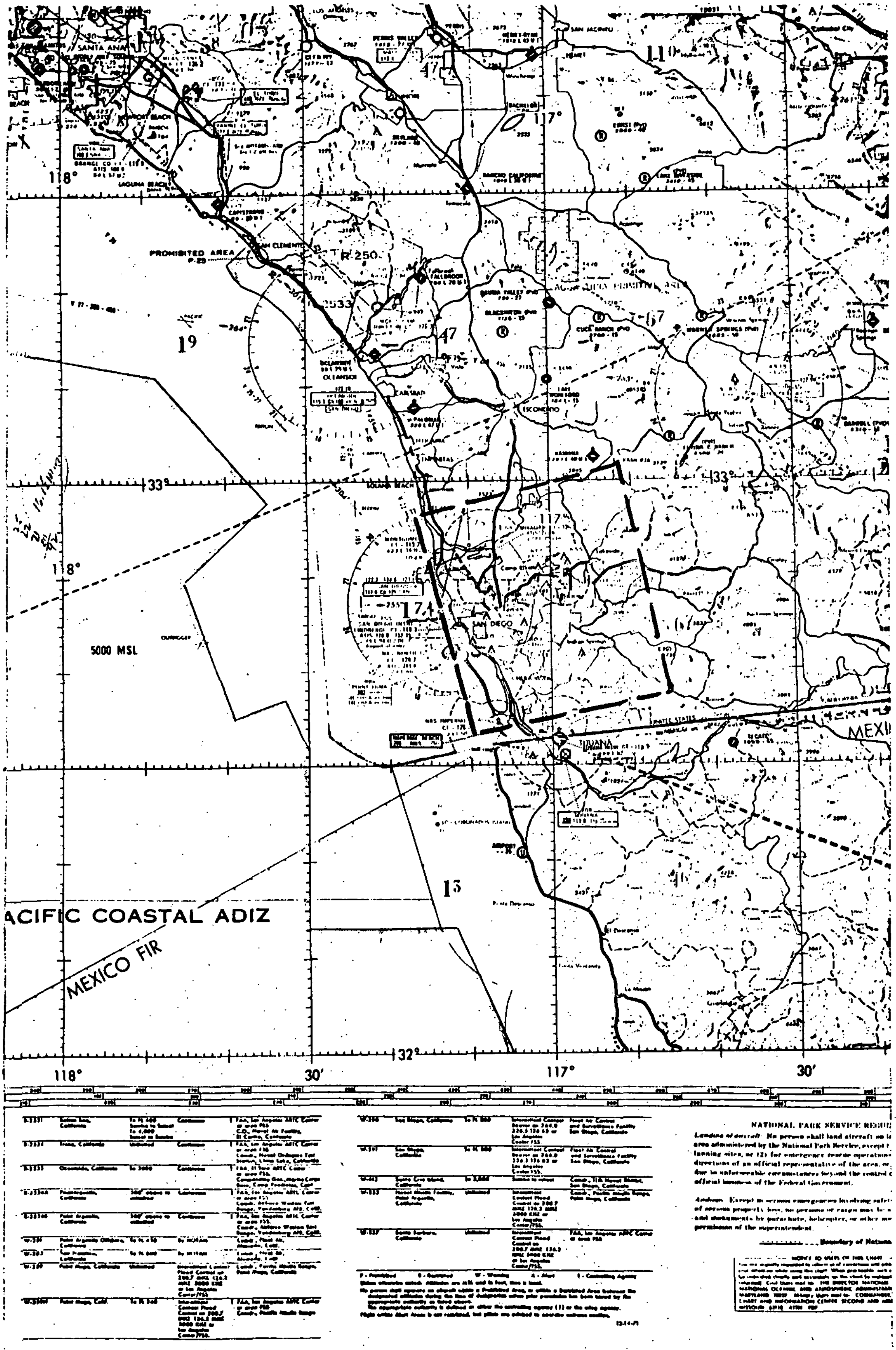


Figure 10 - San Diego Flight Path

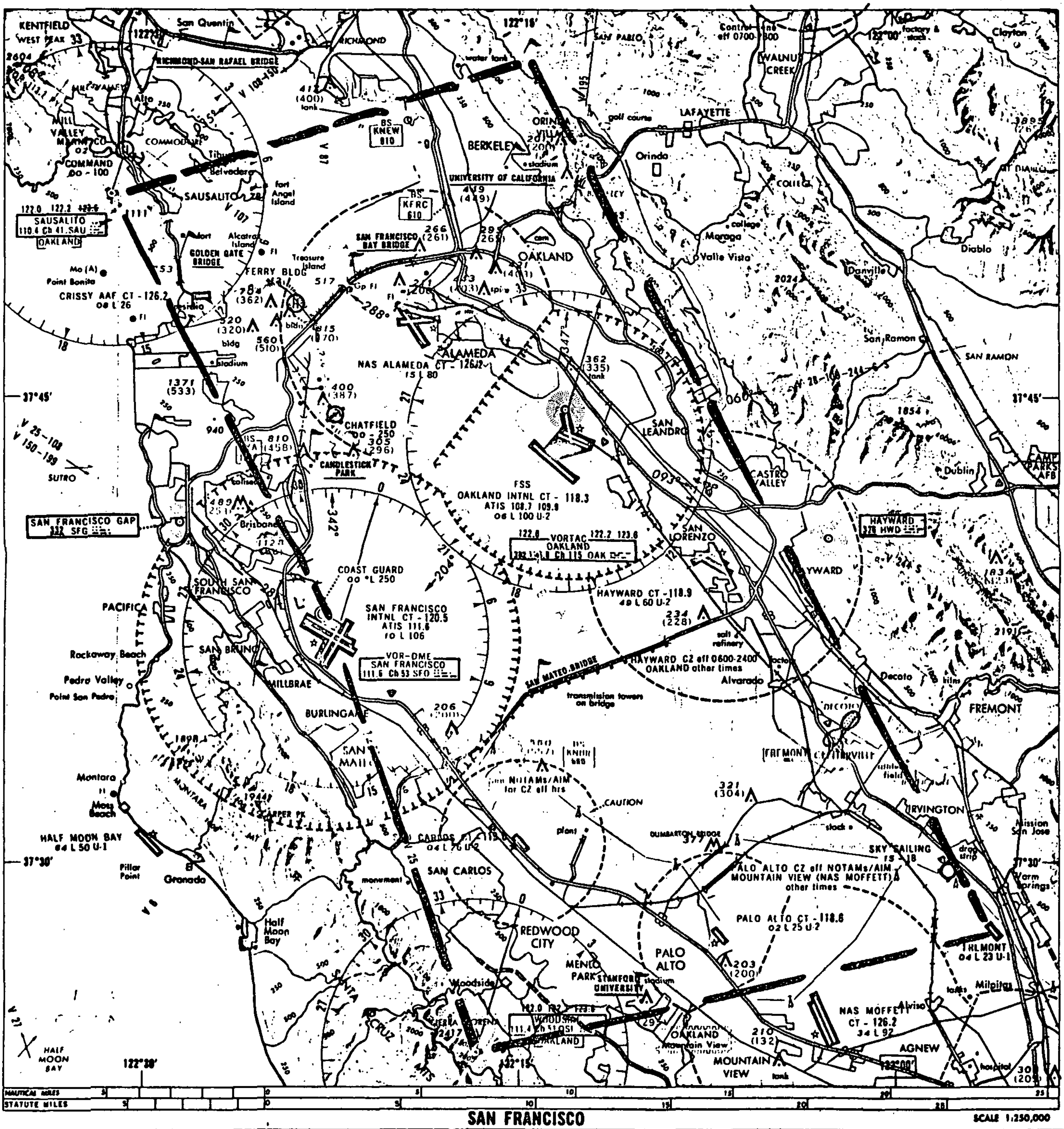


Figure 11 - San Francisco Flight Path

Data Acquisition Summary

The VHF spectrum data acquisition was performed during 17 flights on Sabreliner N287NA that were devoted exclusively to the monitoring task. The Measurement System described previously was configured to record the signal amplitude, frequency, and time of occurrence of terrestrial and airborne emitters along with descriptive annotation. Data was recorded only when the aircraft was above 20,000 feet in altitude during climb to (or descending from) a nominal flight level of 30, 000 feet. Data acquisition was initiated in each flight subsequent to at least one hour equipment warm-up and verification of normal measurement system operation.

The Flight Summary given in Table V provides an overview of the RF Survey Logs tabulated in Appendix D. Flight operations were scheduled to provide data, with overlaps, throughout the work day in each of the seven survey bands. The data sampling consitutes a minimal base on which a statistical evaluation may be performed.

During preparation of typical X-Y plot data samples, it was determined that the mechanical response of the pen was not adequate to display high frequency/high amplitude data components viz noise and large emitters. The plotter effectively functioned as a low pass filter and, thereby, introduced amplitude error by the nonlinearity. This is readily observed by comparing any of the oscillograph recordings with the X-Y plots in the report and noting the dissimilar amplitude characteristics, Figure 12. Recordings were run at normal tape speed (7-1/2 ips) while the X-Y plots were prepared using a factor of two tape speed reduction. It is clear from the amplitude comparison of high frequency components that the usefulness of the X-Y plots are limited to locating unused frequency segments in the surveyed bands, defining occupied bands, and to providing insight into duty cycles.

TABLE V

FLIGHT SUMMARY

Flight No.	Date	Locale	Flight Period
611	2/29/72	Los Angeles*	
612	3/3/72	San Diego (enroute 17 min)	08:29 to 11:23
613	3/3/72	San Diego (enroute 17 min)	14:05 to 17:35
614	3/7/72	Los Angeles	08:30 to 12:35
615	3/7/72	Los Angeles	13:10 to 17:02
616	3/9/72	San Francisco (enroute 35 min)	07:50 to 11:55
617	3/9/72	San Francisco	12:50 to 16:45
618	3/9/72	San Francisco (enroute 35 min)	17:15 to 19:15
619	3/13/72	Los Angeles	11:08 to 15:11
620	3/13/72	Los Angeles	15:56 to 20:10
621	3/15/72	San Diego (enroute 17 min)	07:35 to 11:20
622	3/15/72	San Diego (enroute 17 min)	12:05 to 16:10
623	3/15/72	300 - 350 miles SW Los Angeles for ambient noise test	16:53 to 19:45
628	3/21/72	San Francisco (enroute 35 min)	08:15 to 20:00
629	3/21/72	San Francisco	13:05 to 17:10
630	3/21/72	San Francisco (enroute 35 min)	17:58 to 20:10
631	3/31/72	Los Angeles	08:05 to 12:00
632	3/31/72	San Diego (enroutes 17 min)	12:35 to 16:45

* Antenna Calibration

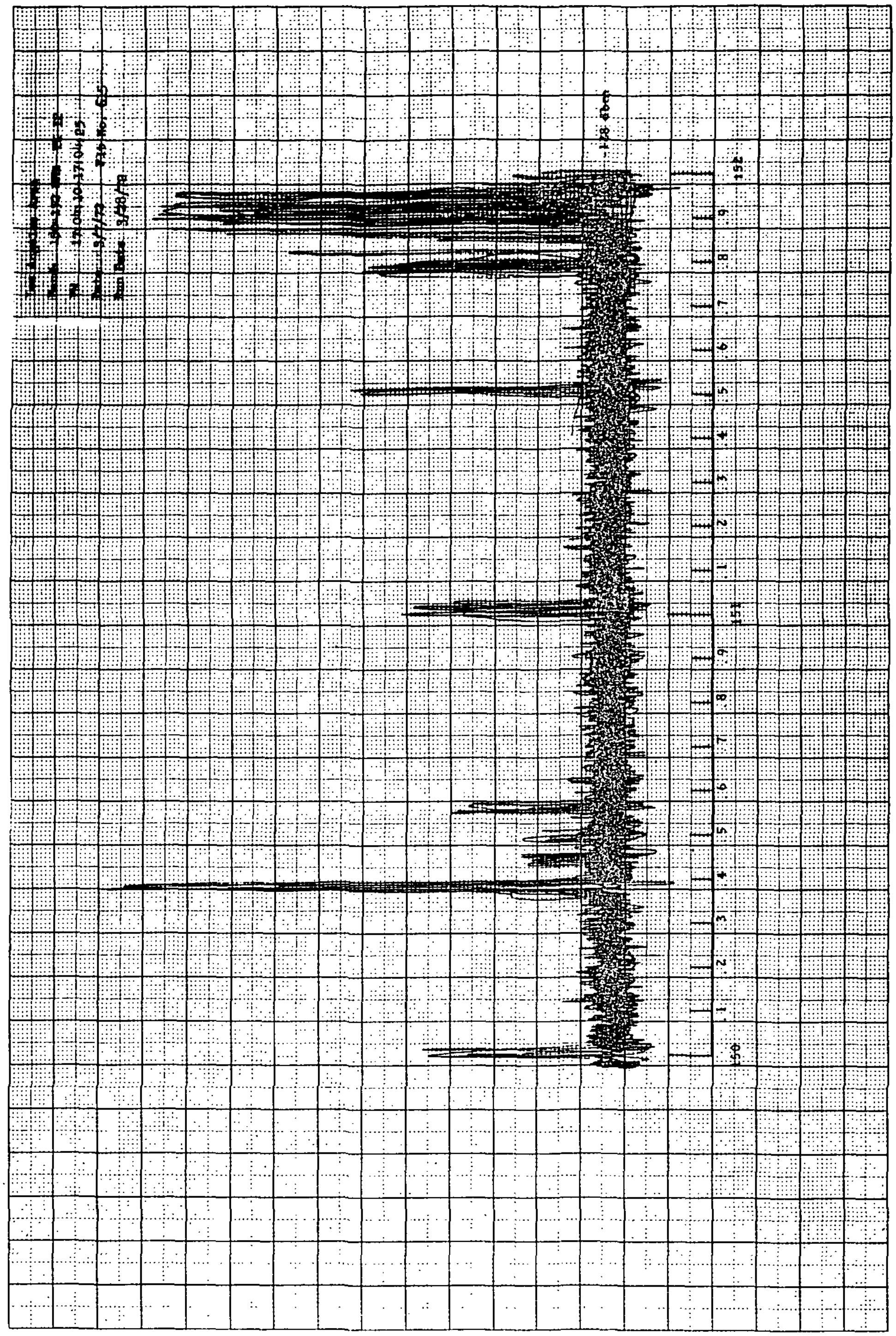


Figure 12A X-Y Plot
Oscillograph - X-Y Plot Amplitude Comparison

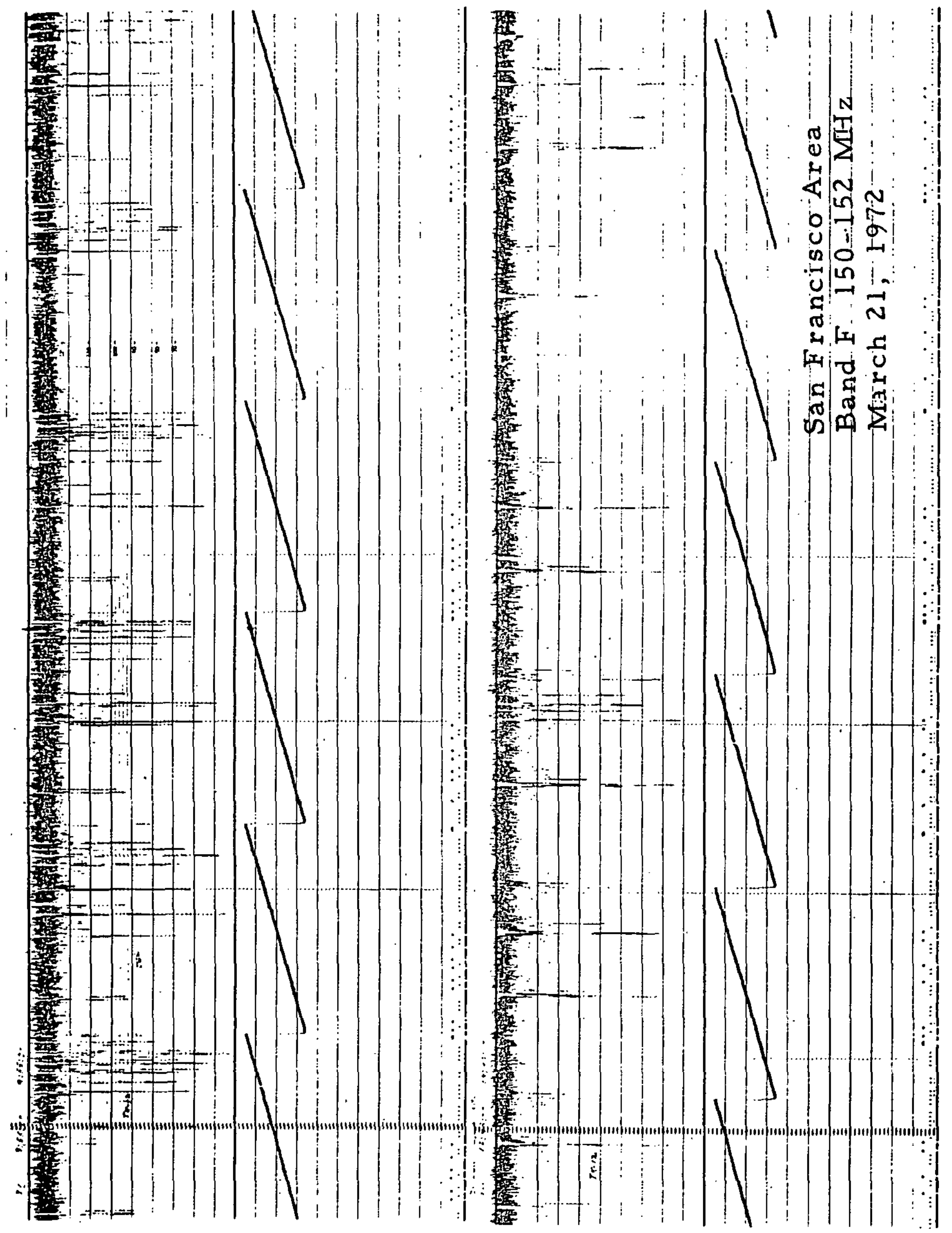


Figure 12B Oscillograph Reporting
Oscillograph - X-Y Plot Amplitude Comparison

Analysis of oscillograph recordings confirm the amplitude and frequency discrimination accuracy of the RF Survey measurement system. Amplitude is accurate to within ± 1 db and differentiation of adjacent emitters is readily accomplished regardless of signal level difference.

Quick look data were reviewed with three objectives:

1. Determine if clear channels are available in the RF Survey bands.
2. Eliminate from consideration the band(s), or segments thereof, that are congested with very active, high power emitters.
3. Determine the typical signal and noise level present at the terminals of the aircraft antenna.

Based on the X-Y plots, a summary of active emitters was tabulated by frequency, Table VI, to identify candidate segments that were unused. The frequency summaries were prepared for survey bands A through E only. Bands F and G (150 to 154 MHz) appears to be very congested with very active, high power emitters even though the ambient noise level proved to be less than the lower frequency bands. Morning and afternoon data samples from Los Angeles and San Diego were selected for preparation of the frequency utilization profile and are subsequently discussed.

Bands A and B (126 to 130 MHz) frequency utilization encompass virtually the entire spectrum segment; however, the duty cycle, in a majority of cases, was observed to be low. Only channels with 50 KHz bandwidths appeared to be available in Band B at center frequencies of 128.05, 128.25, 129.0, 129.25 and 129.45 MHz. It may be that these frequencies have been allocated by the FCC and were unused during the sampling periods. Band B appeared, for the most part, to be a low duty cycle portion of the spectrum. The emitters in Bands A and B are moderate and low power which is consistent

TABLE VI

BAND A FREQUENCY SUMMARY

Los Angeles 3/13/72
17:05:00 - 17:06:30

126.1
126.15
126.2
126.25
126.3
126.4
126.45
126.8
127.2
127.75

Los Angeles 3/13/72
11:25:00 - 11:36:30

126.2
126.65
127.2
127.5

San Diego 3/15/72
14:00:00 - 14:01:30

126.2
126.25
126.3
126.35
126.5
126.6
126.8
126.9
127.1
127.15
127.4
127.55
127.6
127.8
127.9

San Diego 3/15/72
08:23:00 - 08:24:30

126.0
126.1
126.2
126.3
126.5
126.55
126.9
127.0
127.1
127.2
127.25
127.45
127.5
127.8

TABLE VI

BAND B FREQUENCY SUMMARY

Los Angeles 3/13/72
17:21:00 - 17:22:30

128.0
128.1
128.2
128.3
128.35
128.45
128.5
128.55
128.6
128.65
128.7
128.75
128.8
129.5
129.6

Los Angeles 3/13/72
11:42:00 - 11:43:30

128.0
128.15
128.2
128.35
128.75
128.8
128.9
129.55
129.9

San Diego 3/15/72
09:18:00 - 09:19:30

128.1
128.2
128.6
128.65
128.8
128.85
129.05
129.1
129.15
129.2
129.3
129.35
129.55
129.6
129.65
129.7
129.75
129.9
129.95
130.0

San Diego 3/15/72
14:54:00 - 14:55:30

128.35
128.4
128.5
128.6
128.65
128.7
128.9
128.95
129.0
129.15
129.4
129.65
129.75
129.8
129.85

TABLE VI

BAND C FREQUENCY SUMMARY

135-137

135.1
135.15
135.25
135.4
135.45
135.65
135.75
135.875
135.9
135.95
136.075
136.125
136.575
136.875

Los Angeles
March 13, 1972
12:06 - 12:07:30

San Diego March 15, 1972
09:01:00 - 09:02:30

135.05
135.2
135.35
135.4
135.6
135.65
135.75
136.1
136.75
136.2
136.25
136.525
136.625
135.225
135.25

Los Angeles March 13, 1972
17:38:00 - 17:39:30

135.0
135.15
135.175
135.2
135.25
135.45
135.475
135.6
135.65
135.75
135.8
135.925
136.05
136.125
136.75
136.85
136.95

San Diego March 15, 1972
14:38:00 - 14:39:30

135.05
135.175
135.25
135.3
135.35
135.4
135.45
135.475
135.525
135.575
135.6
135.65
135.7
135.75
135.775
135.8
135.825
135.85
136.475
136.625

TABLE VI

BAND D FREQUENCY SUMMARY

Los Angeles 3/13/72
18:00:00 - 18:01:30

137.25
138.675
138.725
138.875
138.9
138.95

Los Angeles
12:34:00 - 12:35:30

137.0
138.15
138.45
138.475
138.55
138.675
138.75
138.85
138.9
138.975

San Diego 3/15/72
08:39:00 - 08:40:30

137.9
138.025
138.6
138.775
138.925

San Diego 3/15/72
14:22:00 - 14:23:30

137.95
138.55
138.85
138.90
138.95
138.975
139.0

TABLE VI

BAND E FREQUENCY SUMMARY

Los Angeles 3/13/72 18:15:00 - 18:16:30	Los Angeles 3/13/72 12:50:00 - 12:51:30
148.1	148.0
148.2	148.025
148.3	148.05
148.35	148.1
148.5	148.2
148.525	148.3
148.7	148.5
148.75	148.95
149.075	149.0
149.1	149.025
149.125	149.15
149.15	149.225
149.175	149.275
149.2	149.375
149.375	149.825
149.45	149.925

San Diego 3/15/72 14:00:00 - 14:01:30	San Diego 3/15/72 08:23:00 - 08:24:30
148.05	148.075
148.25	148.2
148.3	148.275
148.35	148.3
148.4	148.35
148.525	148.475
148.575	148.5
148.675	148.55
148.8	148.675
149.075	148.75
149.15	149.075
149.225	149.15
149.4	149.2
149.45	149.225
149.5	149.575
149.9	149.6
	149.925

with expectations for ground-air and air-ground communications. Band B is a very attractive companion spectra for the satellite communication band (136 - 138 MHz) in that antenna design would be simplified by their close proximity. Comprehensive data reduction of all RF survey recordings may confirm the unallocated or low duty cycle segments of Band B that could lead to clearing a 100 KHz channel for the exclusive use of the TDRS system.

The 135 - 136 MHz segment of Band C is occupied with a mixture of high and low power emitters and spread over the entire band. Occasional low power emitter activity was observed in isolated instances in the 136 to 137 MHz portion of Band C. Similarly, the 137 to 138 MHz segment of Band D revealed a few low power emitters. A 300 KHz gap appears in the 138 and 139 MHz band between 138.15 and 138.45 MHz. Comprehensive data reduction will be required to verify the gap noted in Band D. Band D would be even more attractive than Band B for the TDRSS application for the same reason cited above.

A gap was noted in the data between 149.6 and 149.825 MHz in Band E. This spectra gap may be a case of timing in that Band E activity was observed during the flight operations to be more intense than the lower bands (A, B, C, and D). It should be noted that extremely high and moderate magnitude emitters were observed in this band.

Survey Bands F and G (150 to 154 MHz) were essentially eliminated from further consideration based on emitter density and the consistently high magnitudes recorded throughout both bands. The duty cycle of these bands is very high and was observed to be quite active throughout the work day and diminished only during the lunch hour and later evening.

The San Francisco oscillograph data from Flight 628 on March 21, 1972, were reviewed to define typical signal level spreads at the aircraft antenna terminals. A summary of these data is given in Table VII. Levels greater than -66 dbm and as low as -118 dbm were observed from the data. These data are representative of the morning and afternoon samples given in San Francisco for burst durations of 1.5 minutes in each of the survey Bands A through D. These samples were obtained with a 5 second sweep rate of a 1 KHz instantaneous bandwidth over a 2 MHz bandwidth for each of the survey bands. Bay Approach Control (126.7 MHz) was monitored and recorded on tape to ascertain if the 5 second sampling rate was effective in capturing their emissions. The longer duration emissions originating in the ATC center were received; the short burst confirmations by user aircraft were seldom detected. The minimum level detected at 126.7 MHz was -78 dbm which is representative of 5 to 20 watt aircraft transmitter while the maximum level recorded exceeded the calibrated level of -66 dbm and is typical of FAA approach control radio equipment.

The unused frequencies noted in Band B with the exception of 129.25 MHz are also absent in the San Francisco data. The signal level at 129.25 MHz is quite low (-110 to -115 dbm) but was continuously present. This suggests the possibility that this frequency is used for ATIS (Airmans Traffic Information Service) at an airport in the bay area. Since this is a non-essential communication function, the service could be reallocated to another portion of the aircraft communications spectrum.

It is observed that a low level emitter (-110 to -117 dbm) was recorded in the Band D gap previously reported in the frequency sort.

TABLE VII. SOURCE FREQUENCY SUMMARY
SAN FRANCISCO - MARCH 21, 1972

BAND A		BAND B		BAND C		BAND D		BAND E	
Frequency MHz	Signal Level dbm	Frequency MHz	Signal Level dbm	Frequency MHz	Signal Level dbm	Frequency MHz	Signal Level dbm	Frequency MHz	Signal Level dbm
126.2	-73 to -89	128.0	-105	135.15	-101	137.25	<-120	148.175	-107
126.4	-67	128.1	-115	135.3	-107 to -112	137.425	<-120	148.225	-95
126.5	>-66 to -103	128.2	-84 to -118	135.45	-89 to -108	137.95	-110	148.35	-82
126.7	>-66 to -78	128.3	-115	135.5	-111	137.975	-110	148.45	-90
126.8	-75 to -82	128.35	-91 to -116	135.55	-105	138.15	-79 to -83	148.475	-98
127.5	-72 to -78	128.4	-117	135.8	-107 to -112	138.25	-110 to -117	149.0	-72
127.8	-69	128.45	-98	135.9	-105 to -111			149.2	>-66
128.0	-89			136.1	-113			149.4	-74
		128.7	-78 to -84	136.3	-107 to -112			149.975	-110
		128.8	-81 to -100	136.45	-113				
		129.1	-114	136.5	-109				
		129.2	-77 to -86	136.65	-107				
		129.25	-110 to -115	136.7	-111				
		129.3	-117						
		129.5	-69 to -74						
		129.7	-114						
		129.9	-109						

Measurement Technology

The measurement system used for the RF survey constitutes utilization of state-of-the-art devices and equipment for the purpose intended. The use of a low noise preamplifier significantly improved the performance (sensitivity) of the spectrum analyzer.

AUTOMATED DATA REDUCTION

The reduction of the West Coast RF Survey data on a digital computer and the preparation of statistical graphics corresponding to frequency, signal level, and percentage of channel or bin utilization necessitated a rather involved procedure of converting the analog data into digital formats. The complex data reduction task was further complicated by spectrum analyzer frequency drift which necessitated special software.

Initial data inspection of the analog data was accomplished by preparation and review of oscillographs of all data and annotation channels appearing on the acquisition flight tapes. Based upon the flight logs, band identifier, and IRIG time code, actual data segments were tabulated to enable programmed control of the subsequent A/D conversion. The IBM control cards provided the following:

1. Data start and stop times.
2. Frequency band.
3. Scan time (5 or 10 seconds).
4. Data/calibration identification.

Existing Saturn SII A/D conversion control software was rewritten to accommodate the West Coast RF Survey analog data. The modified A/D conversion has a full-scale resolution of 11 binary bits and a multi-channel input capability. To enable use of the maximum resolution of the A/D, each frequency band is maximum amplitude adjusted and offset to enable operation of separate multiplexer input channels. The frequency band identification signal, a stairstep, was digitized and stored to enable the computer to recognize the frequency band for each segment of data. Each data segment was tagged with the IRIG B time code which also provided the 1000 Hertz time base used for the sampling rate. This procedure ensured a uniform number of samples in each data frame regardless of any analog tape speed variations.

The form of the analog data is a series of recurrent frequency sweeps in a given frequency band. The beginning and end of each was detected by an analog circuit to provide an appropriate interrupt signal to the process controlling computer. Therefore, each occurrence of an interrupt signal would cause the PC computer to:

1. Call in an IRIG B time tag.
2. Switch the A/D to the Band Identification Signal.
3. Compare the Band ID with Active Search Band.
4. Switch A/D to appropriate peripheral corresponding to frequency band.
5. Write the last received frame and time tag on 1/2-inch computer tape.

These format A tapes provided a temporary storage of the frequency band sorted digitized data and annotation.

The next stage of activity involved stripping out frequency band by geographic locale and generating the format B tapes. In the process of generating these tapes, the data was reviewed to determine that complete frames contained either 10,000 or 5,000 samples depending on a sweep of 10 or 5 seconds, respectively. Incomplete data frames were discarded along with any calibration inserts. In the process of editing the data, calibrations were analyzed, amplitude shifts, if any, noted and stored. Again, these data were recorded on 7 different output tapes to correspond with the frequency bands.

The format B tapes consisted at this point of 7 frequency bands for each of the 3 geographic locations. At this point, the data was analyzed to sort prominent peaks and tabulate the amplitude and sample number. These data were used to perform a frequency drift analysis in that the data was known to be a problem. The correction for frequency drift was a primary consideration; hence, special software and check tape were produced to generate the quick look plots. Amplitude remained essentially invariant throughout the calibration sequence; however, frequency varied as much as 40 kilohertz. As a result of this analysis, frequency was calibrated through the format B tapes to enable registration. At this point, the data editing was completed and the frequency and amplitude magnitudes had been verified. The next step was the generation of the statistical graphics.

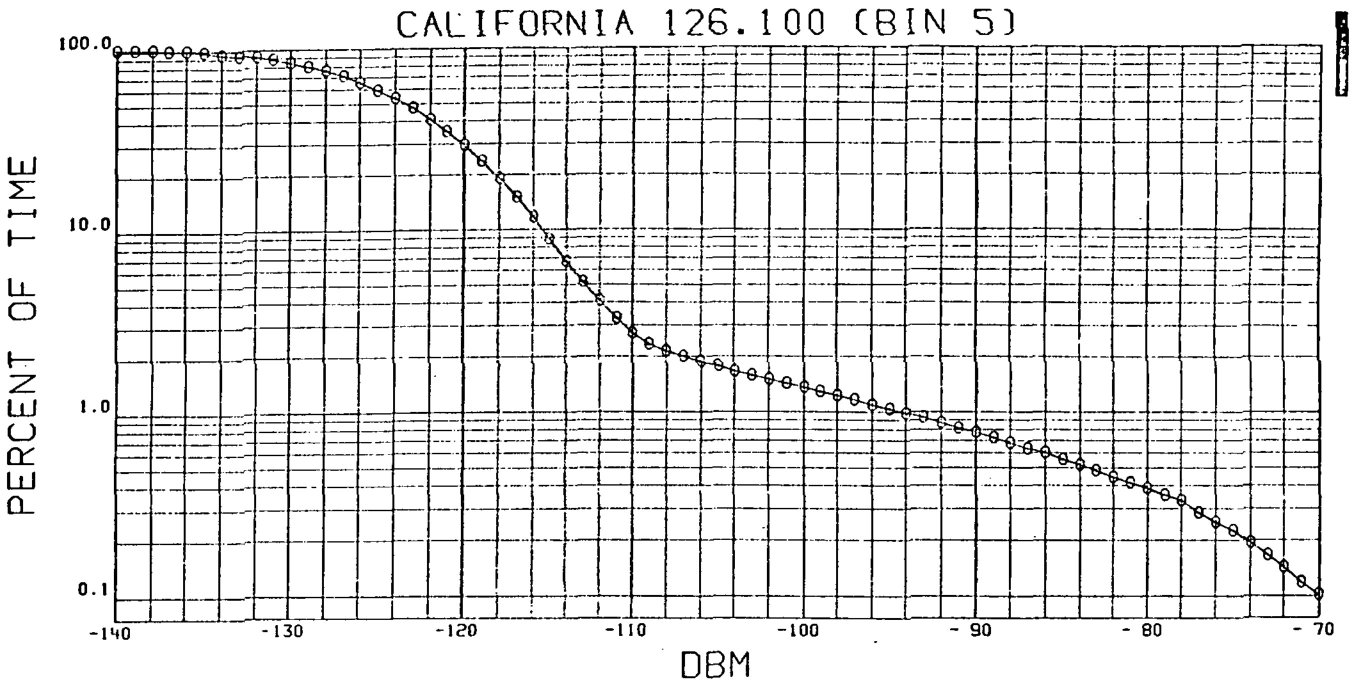
Software was prepared to enable processing of the format B tapes into Bin Plot Statistical tapes. This procedure consisted of designating 81 bins in computer memory. Since a total of 71 cells are required to store each bin, the memory requirement for each band is 71 x 81 = 5,751 memory cells. Prior to accumulation of bins for a given frequency band, the memory cells were all cleared to zero. The software provided for the reading of successive data frames from the format B tape and the bin sort. In the process of sorting, the frequency is correlated with the frequency bin, the amplitude count is converted to a corresponding RF signal level in dBm and stored in the appropriate memory position corresponding to the frequency and signal level. Each successive data frame in the frequency band enters data on the number of occurrences and level in each frequency bin. This procedure was used for all 7 bands for the 3 geographic locales. The data was summarily integrated to determine the percentage to time the signal level exceeded a given value in 1 dB steps over the dynamic range (70 dB) of the data.

The Bin Plot Statistical tapes for San Diego, Los Angeles, and San Francisco were combined to provide a composite California Bin Plot Statistical tape. This tape is indicative of the statistical emission characteristics that would be encountered by a low earth orbit spacecraft; however, the amplitude will require adjustment to compensate for the additional spreading loss.

The Bin Plot statistical tapes for San Diego, Los Angeles, San Francisco and the California composite were then scanned and sorted by frequency bin and percentage time of occurrence for four representative signal levels (-115, -100, -85 and -70 dBm). This procedure consisted of generating a new tape based on the data previously derived in a convenient format for CRT display.

A universal FR80 plot generation program was modified to accomodate the statistical tapes. The ordinate was converted from linear to logarthmic display and all labeling was generated. Subsequently, all of the reformatted data were transferred to FR80 Plot tapes to obtain a microfilm copy of the reduced data. Hard copy prints were prepared subsequently and appear in the appendices.

The statistical bin plots are configured to provide a comprehensive evaluation of signal level as a function of percentage of time of occurrence, Figure 13. The abcissa provides for a signal level dynamic range of 70 db from a maximum level of -70 dBm. The printout features signal variations in 1 dB intervals which is extremely useful in detail analysis. The bin summaries shown in Figures 14 through 41 constitute a much more convenient presentation in that bin utilization of the entire frequency band is depicted in a single display. The four signal levels shown on each



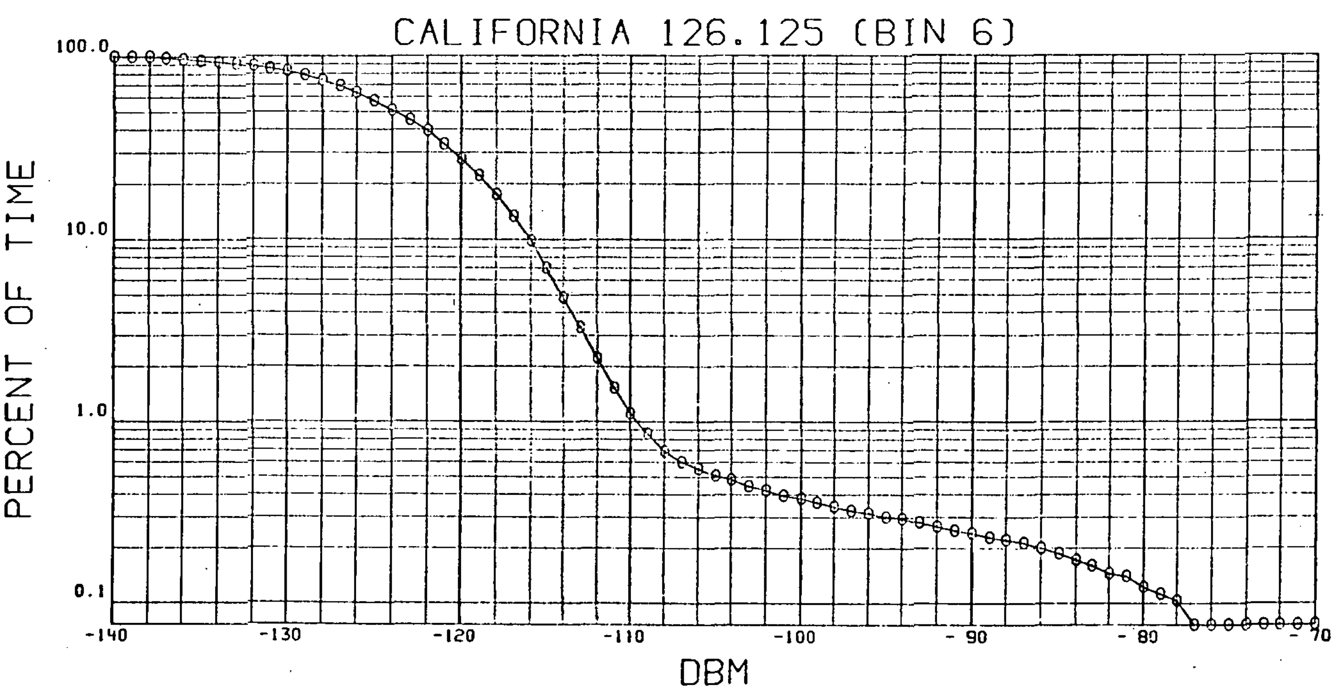


Figure 13. Typical Frequency Bin Data Presentation

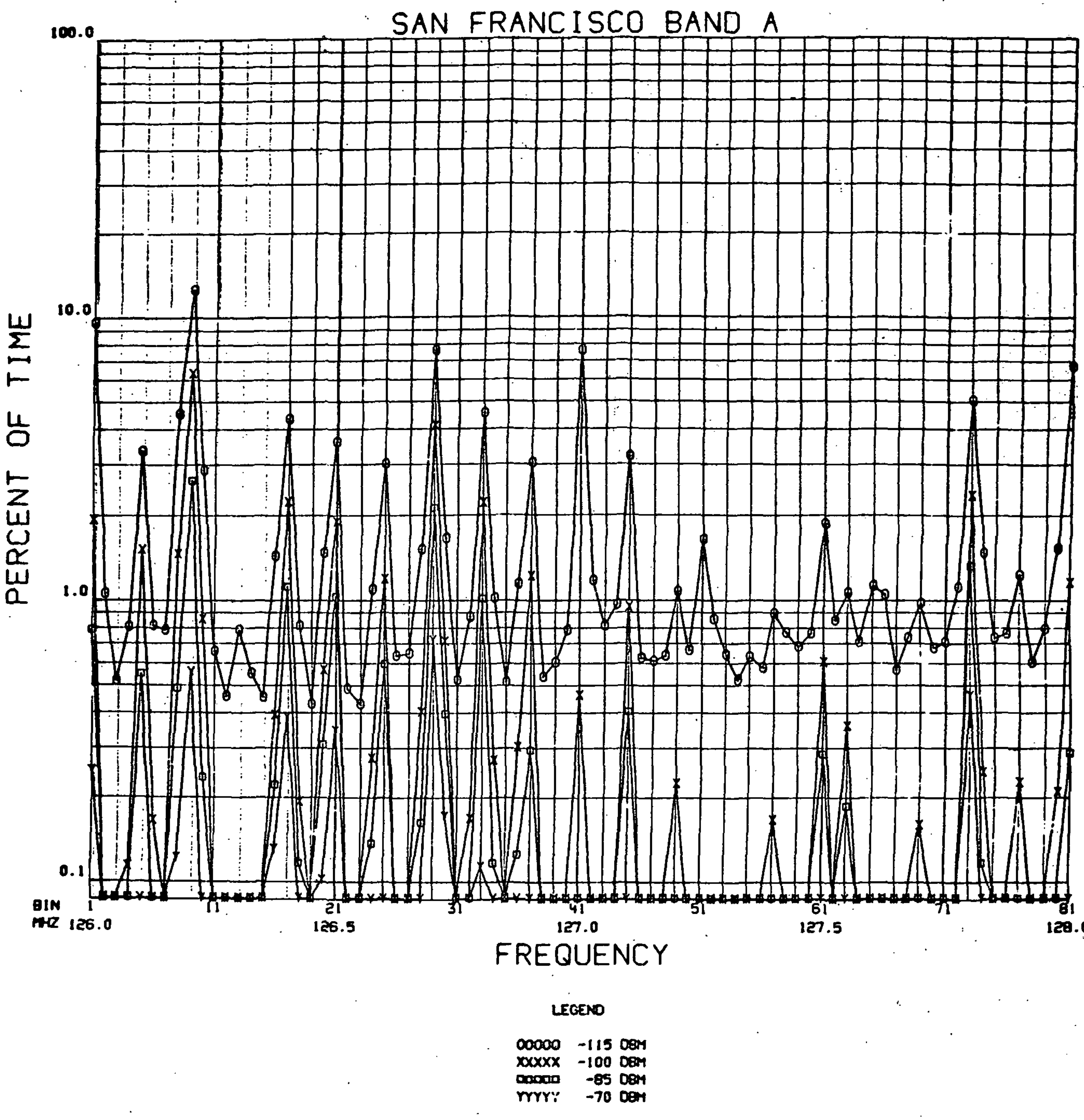


Figure 14. Frequency Summary - San Francisco Band A

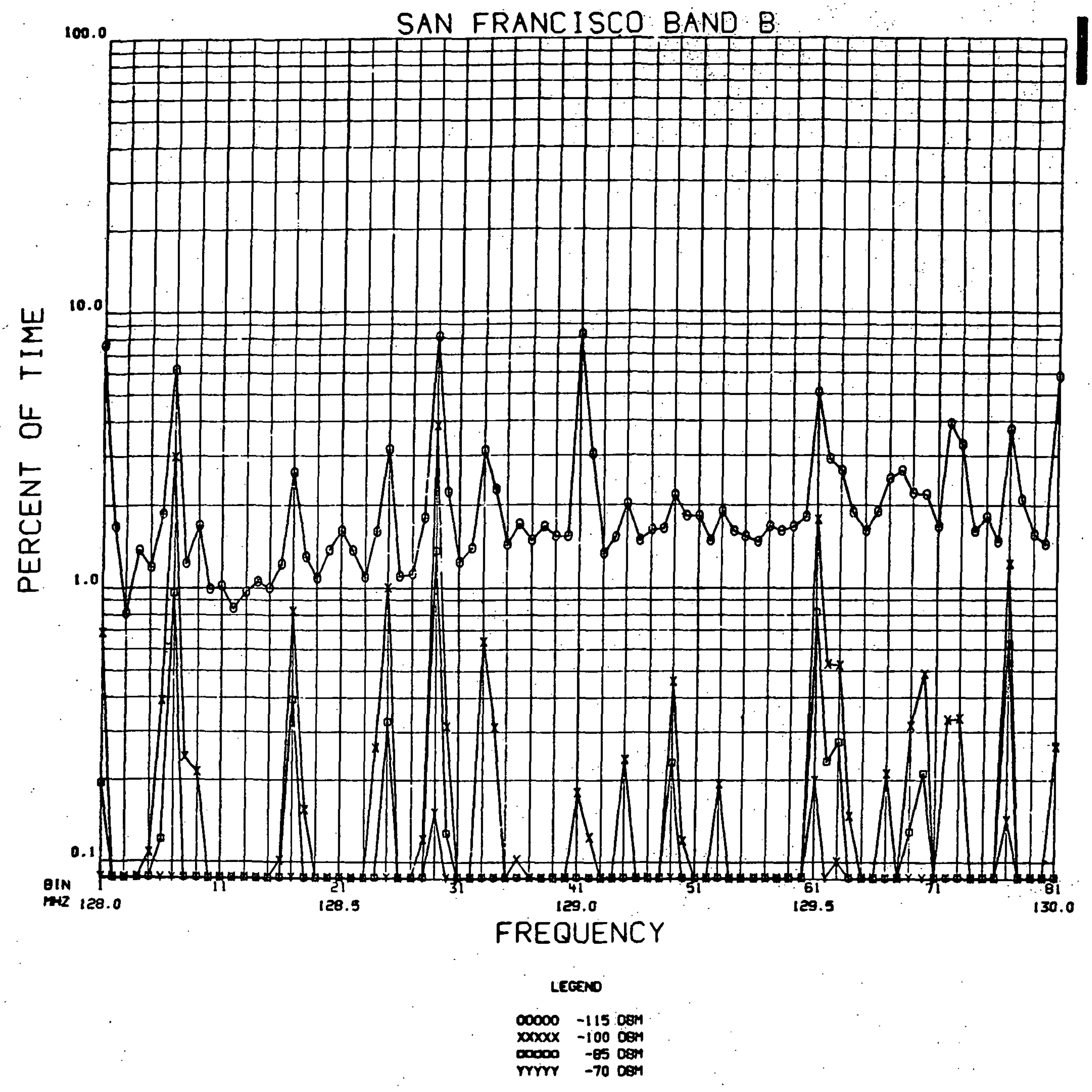


Figure 15. Frequency Summary -
San Francisco Band B

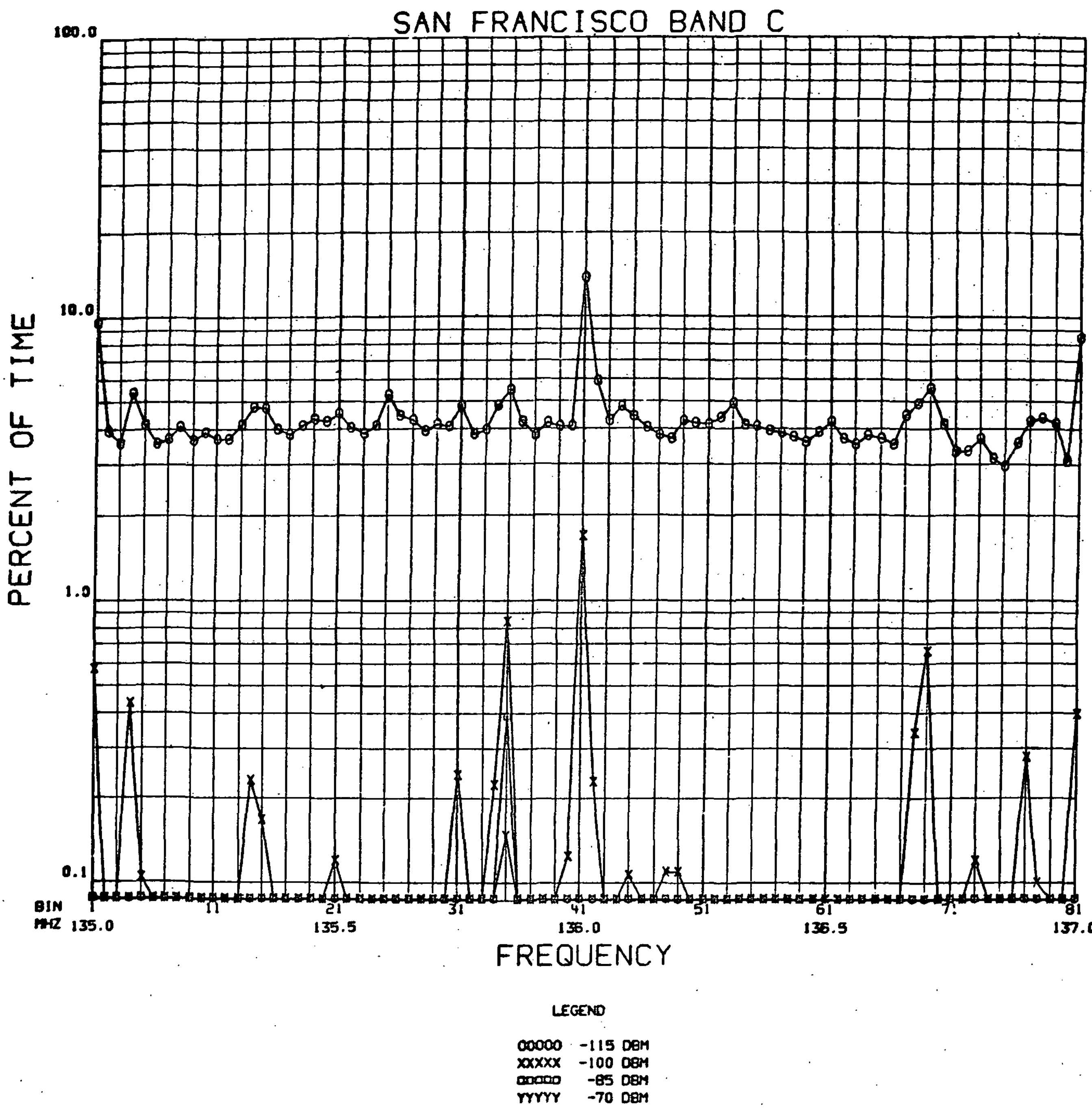


Figure 16. Frequency Summary - San Francisco Vand C

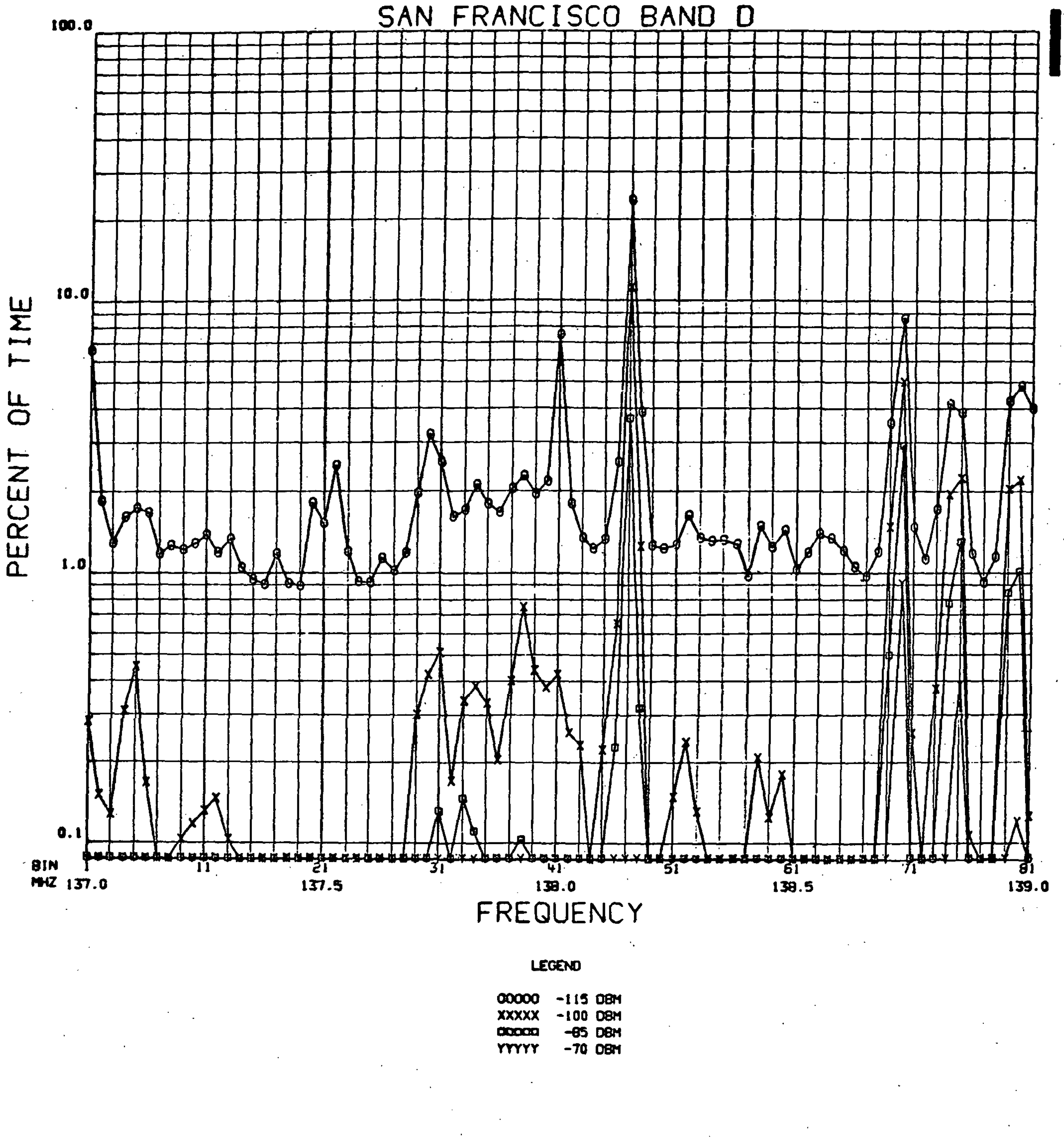


Figure 17. Frequency Summary - San Francisco Band D

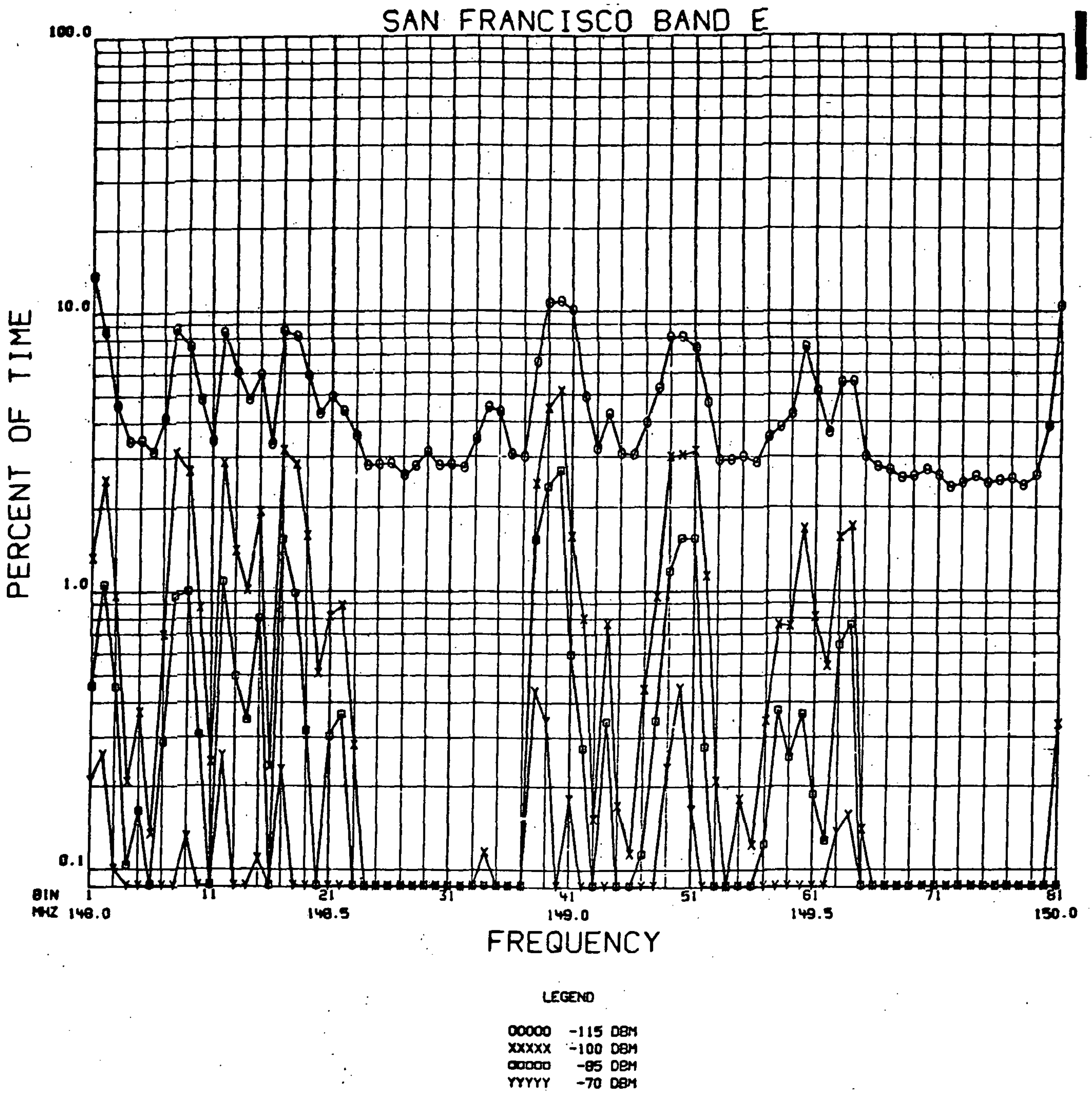


Figure 18. Frequency Summary - San Francisco Band E

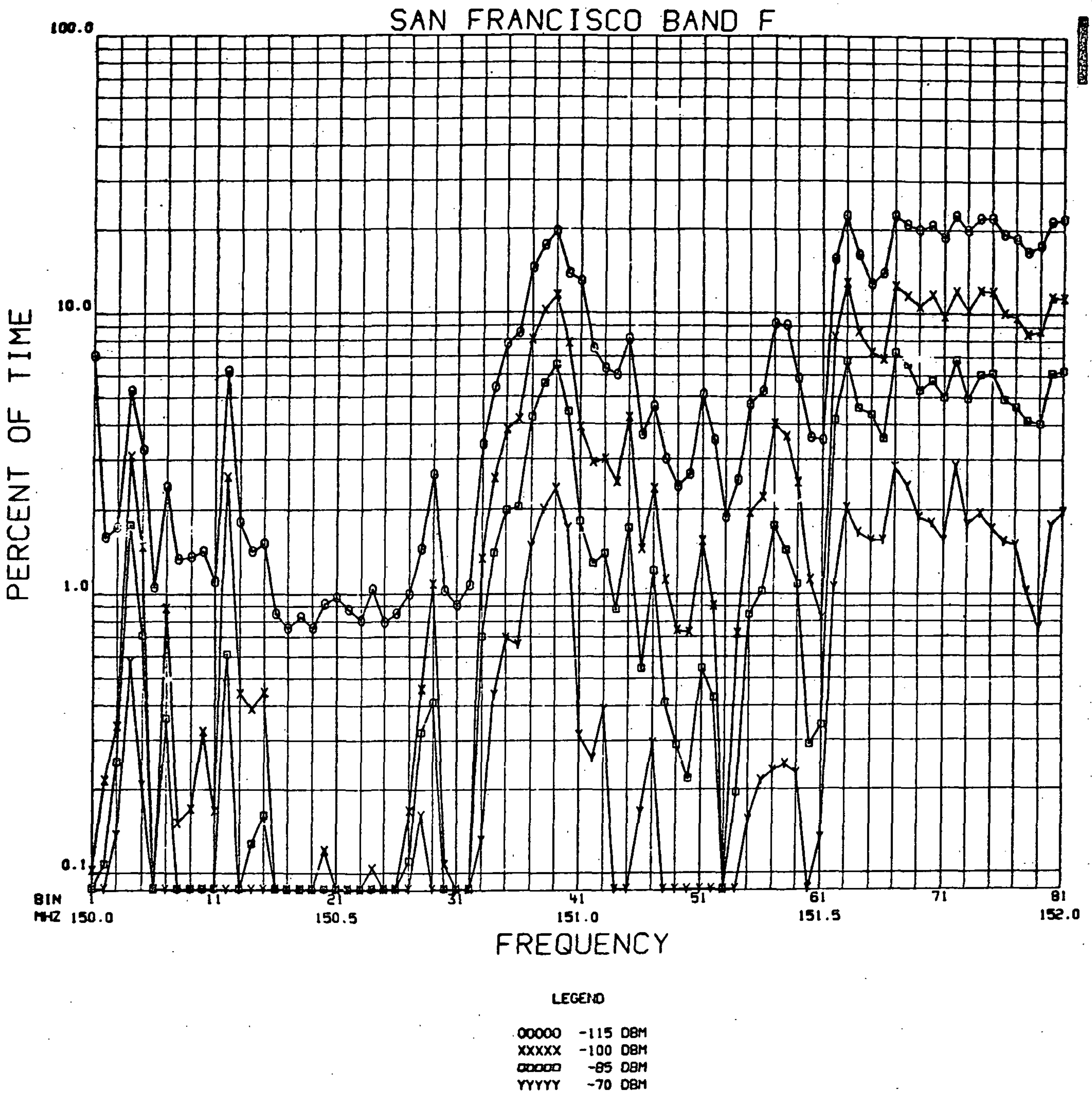


Figure 19. Frequency Summary - San Francisco Band F

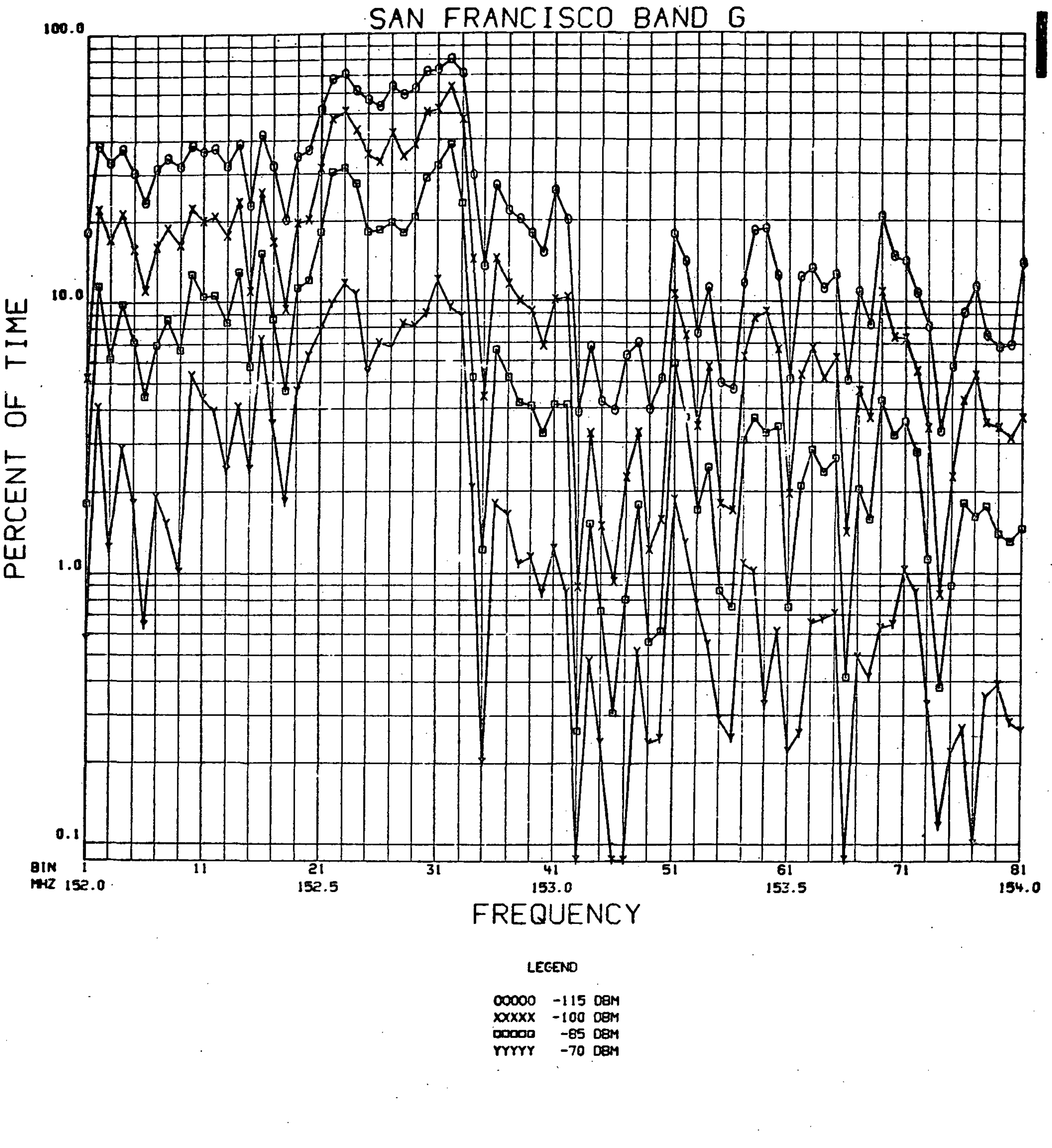


Figure 20. Frequency Summary - San Francisco Band G

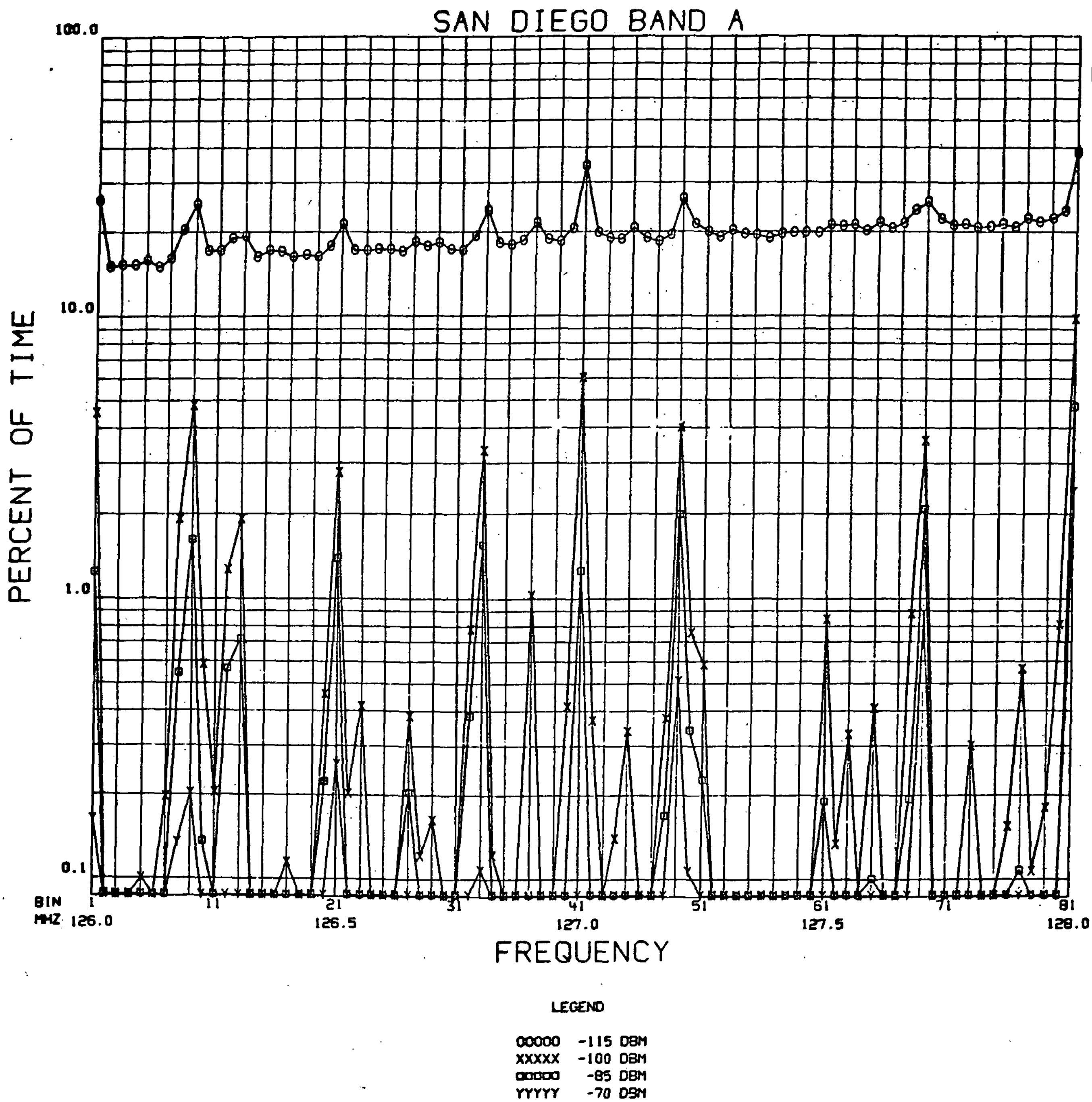


Figure 21. Frequency Summary - San Diego Band A

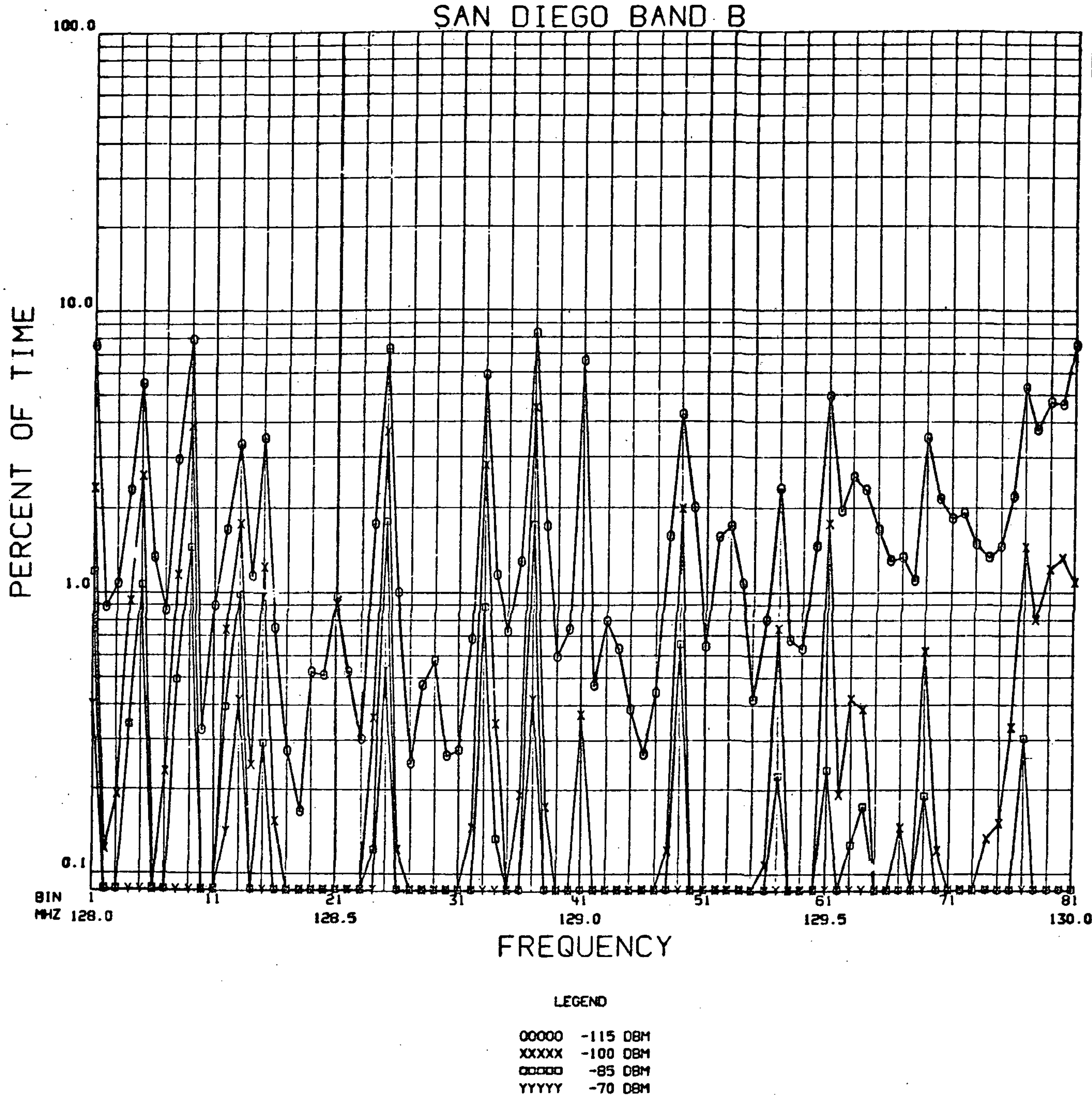


Figure 22. Frequency Summary - San Diego Band B

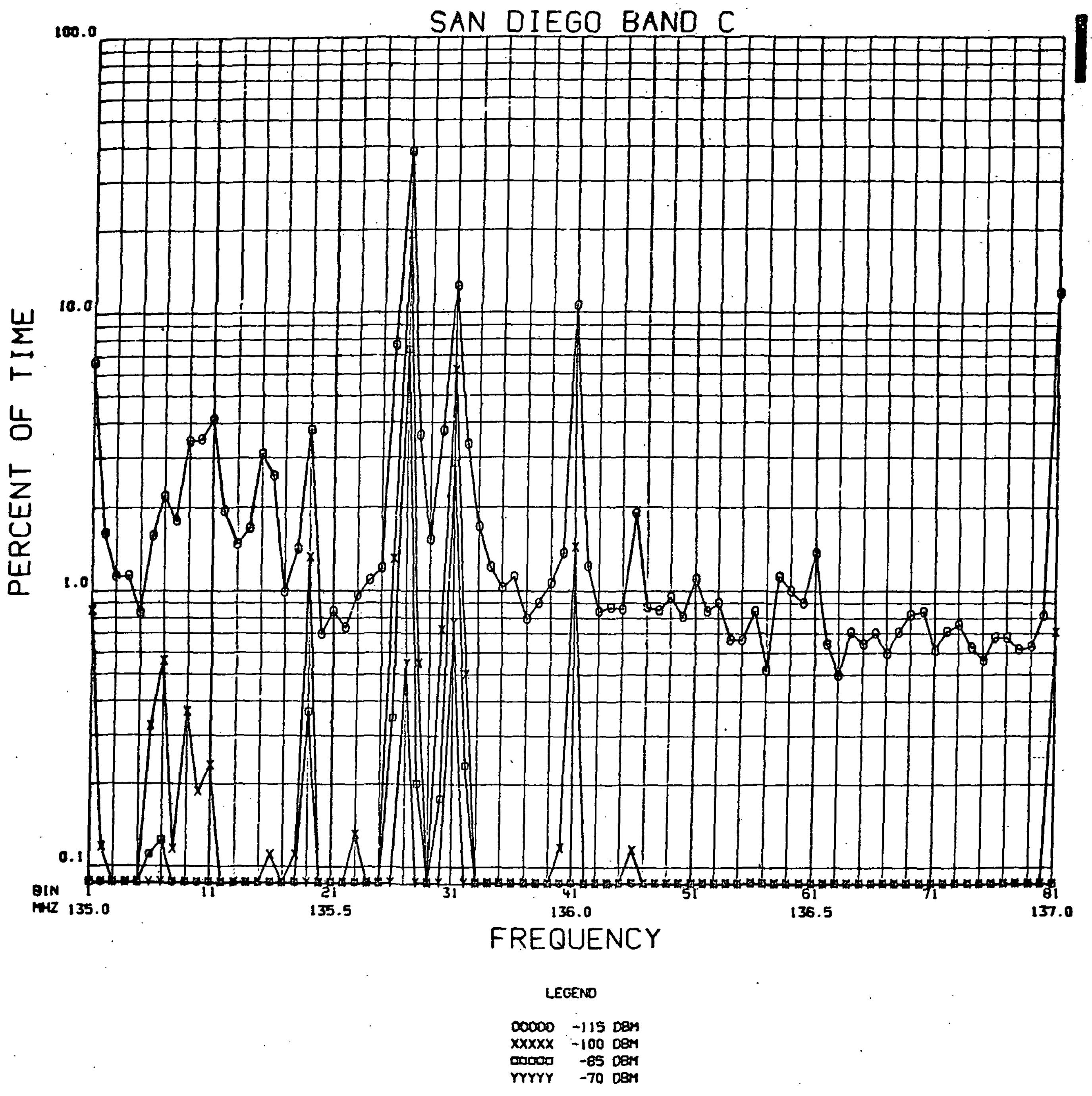


Figure 23. Frequency Summary - San Diego Band C

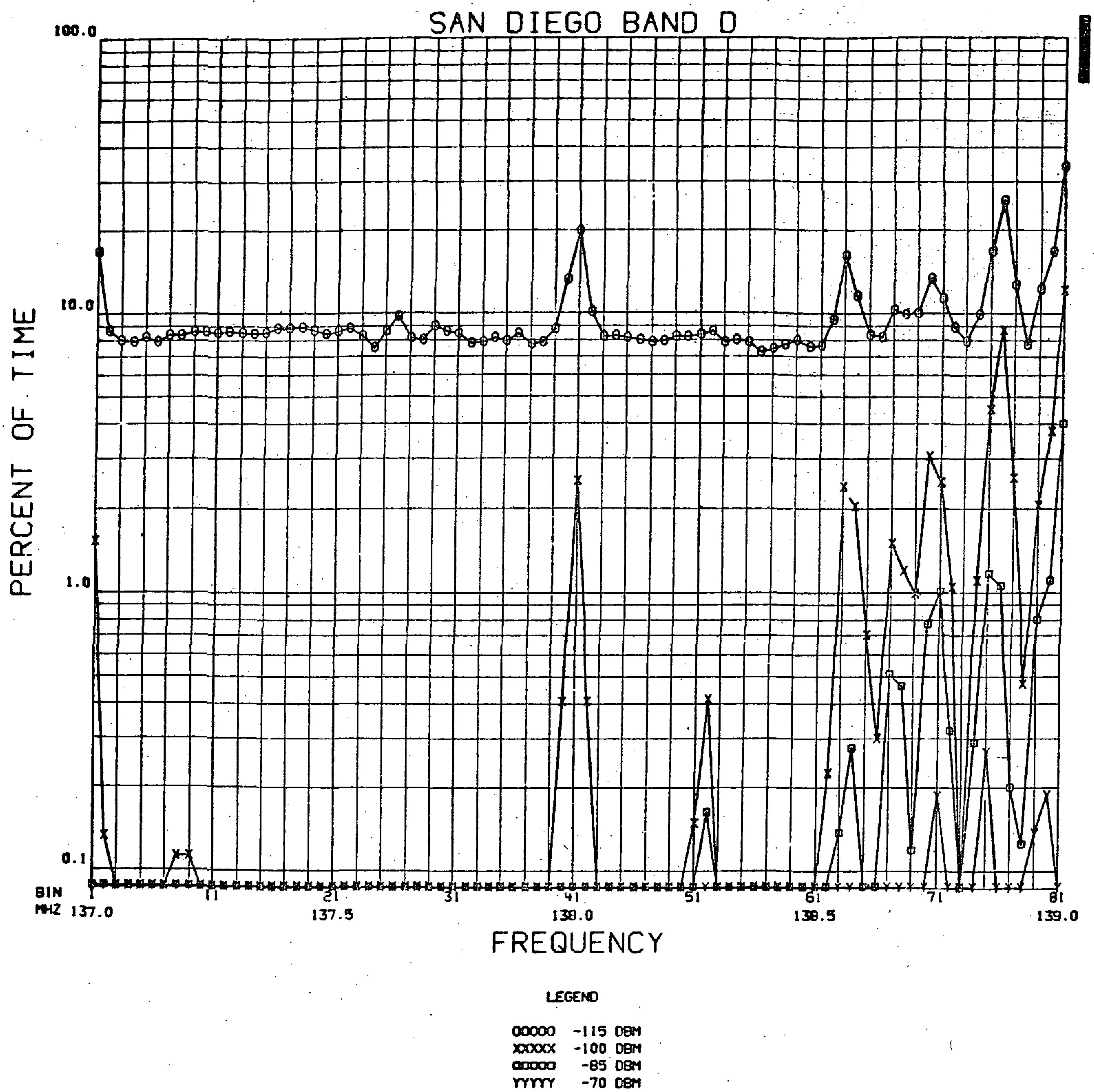


Figure 24. Frequency Summary - San Diego Band D

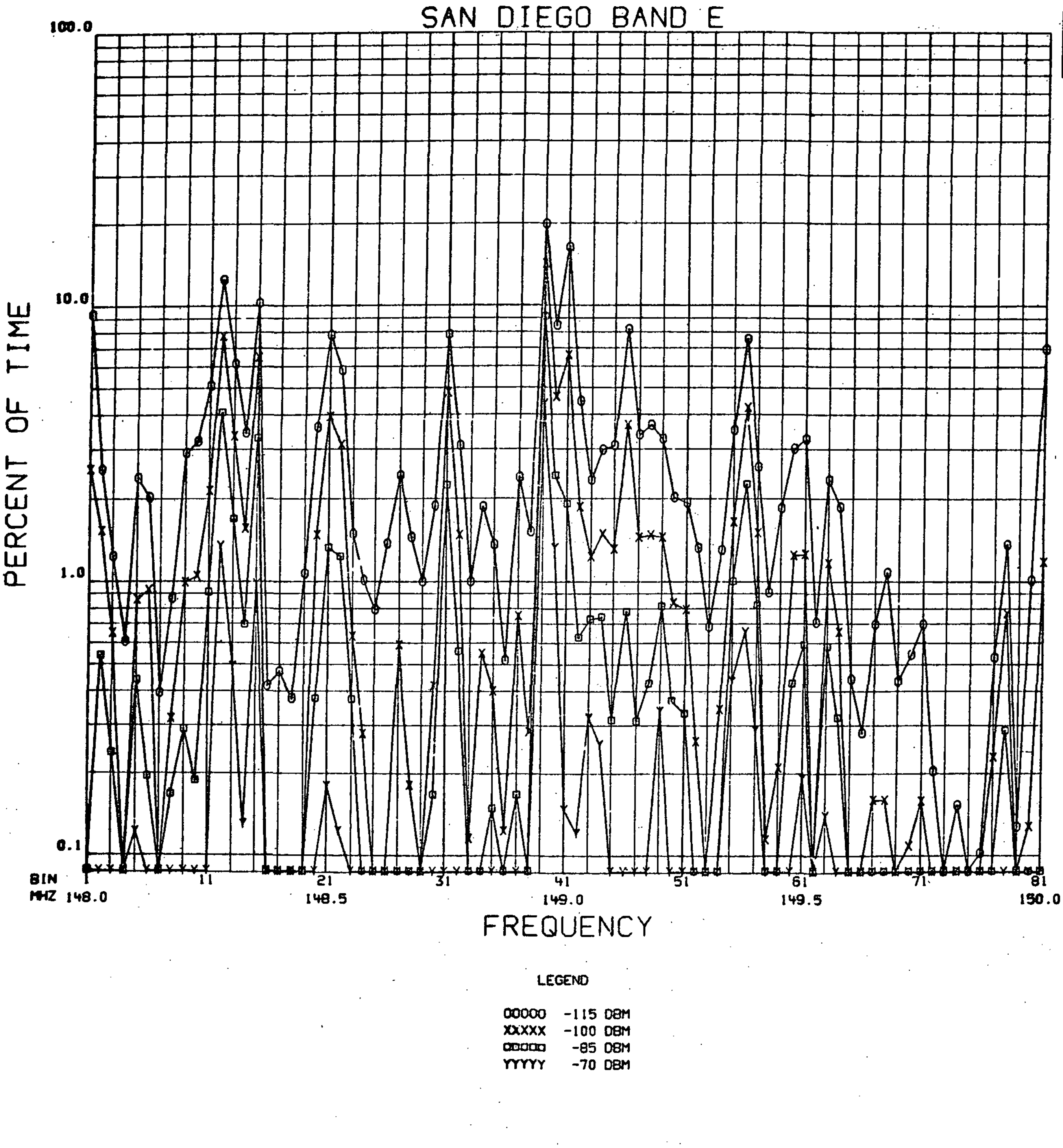


Figure 25. Frequency Summary - San Diego Band E

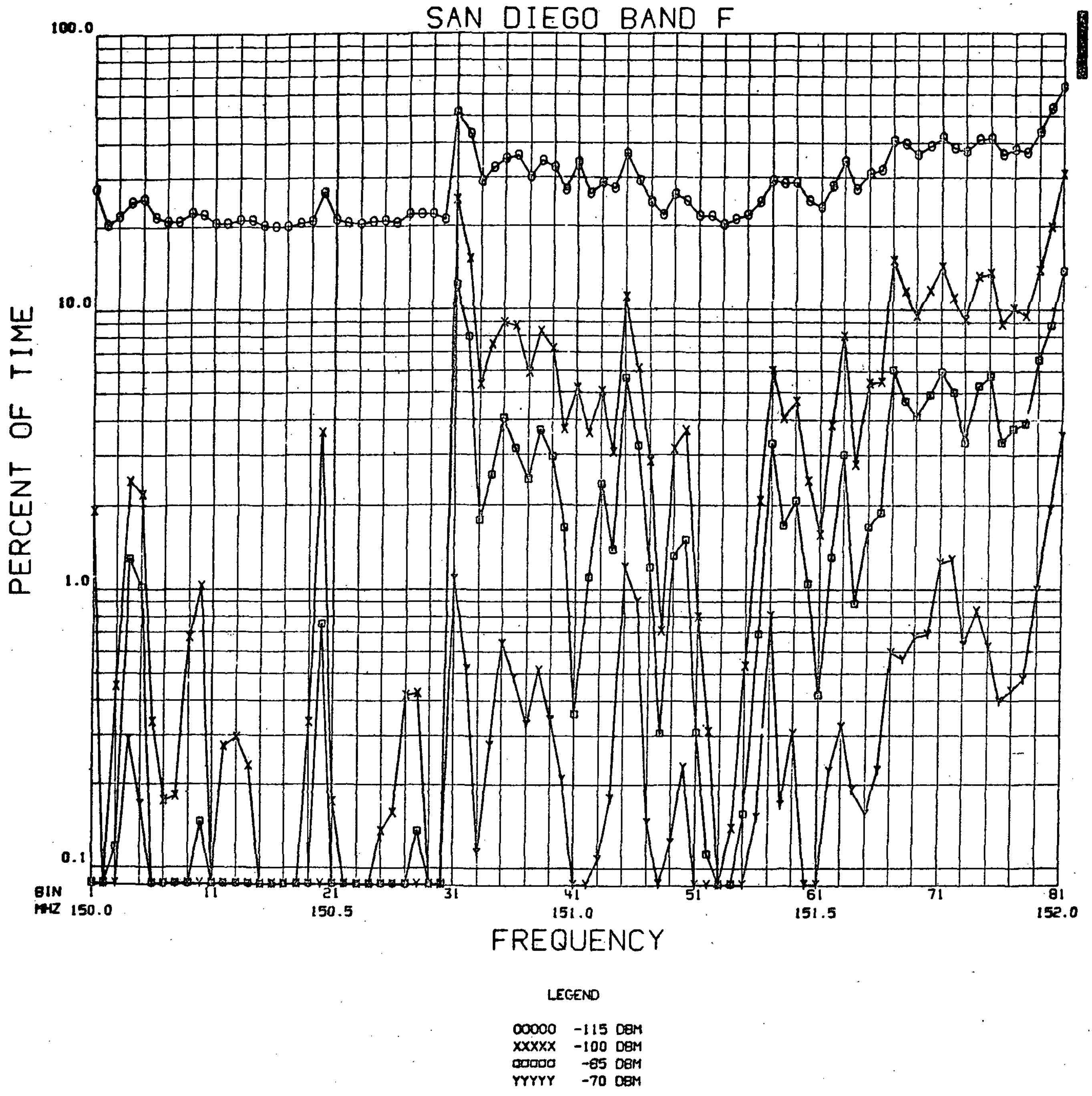


Figure 26. Frequency Summary - San Diego Band F

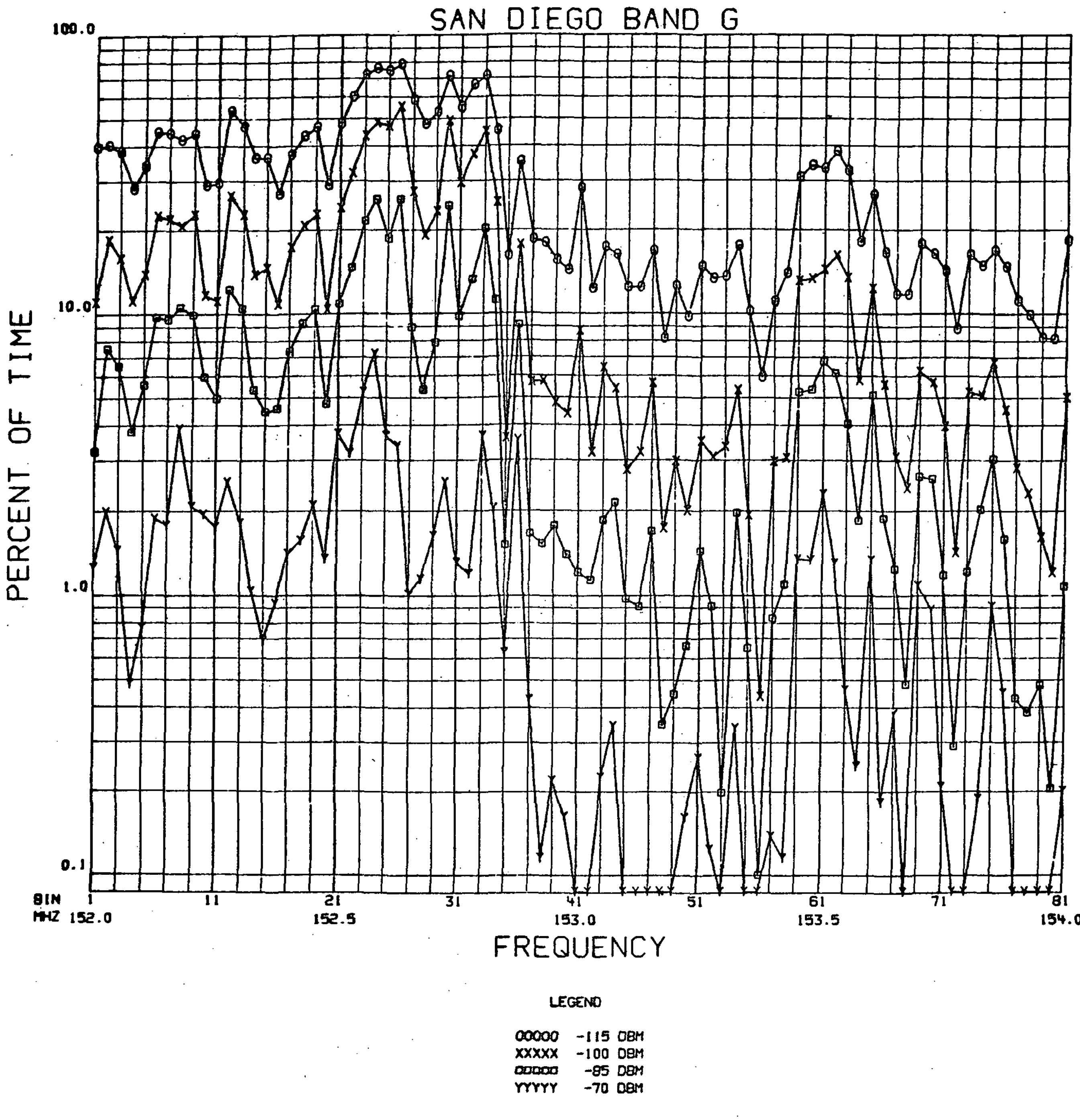


Figure 27. Frequency Summary - San Diego Band G

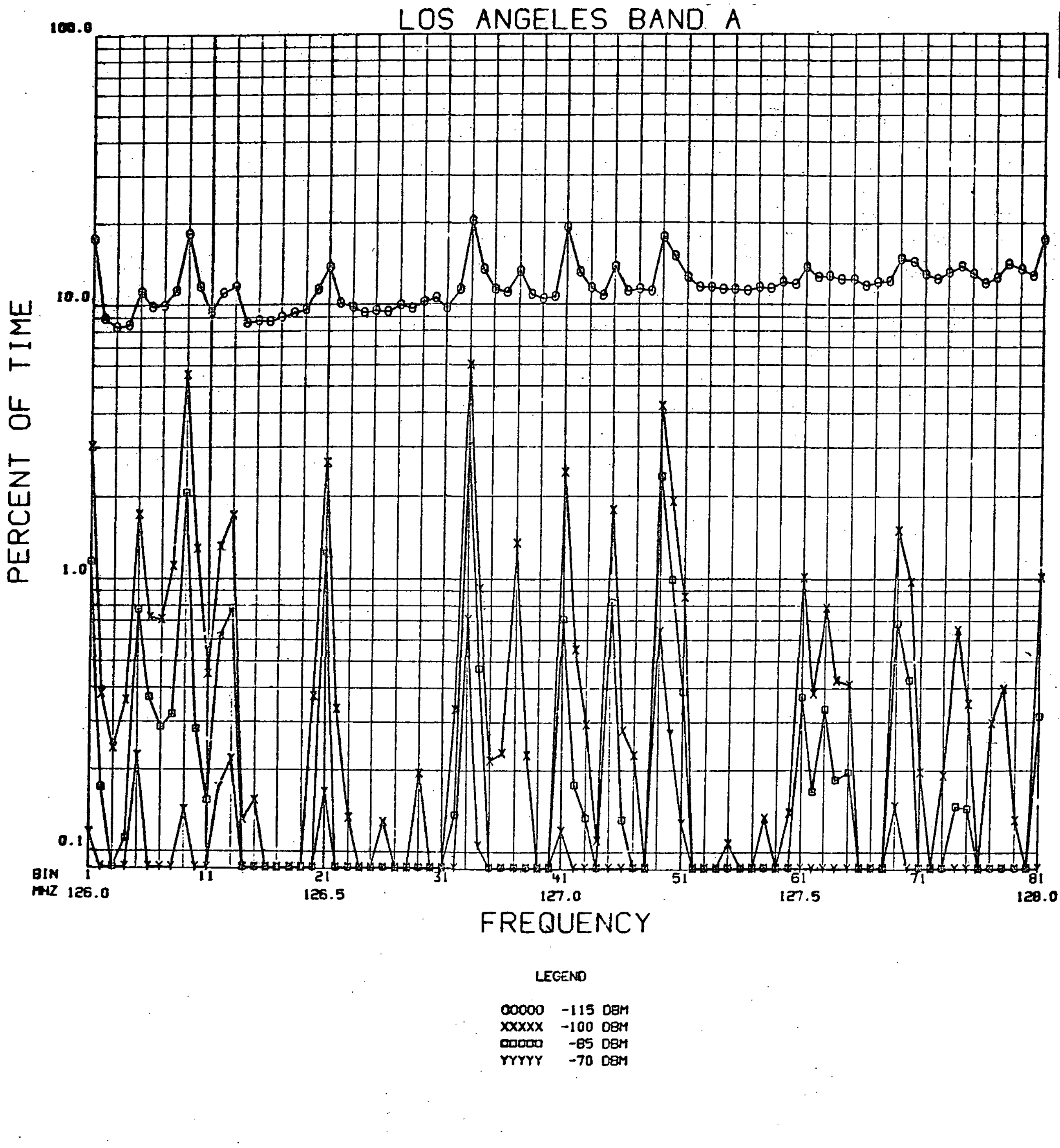


Figure 28. Frequency Summary - Los Angeles Band A

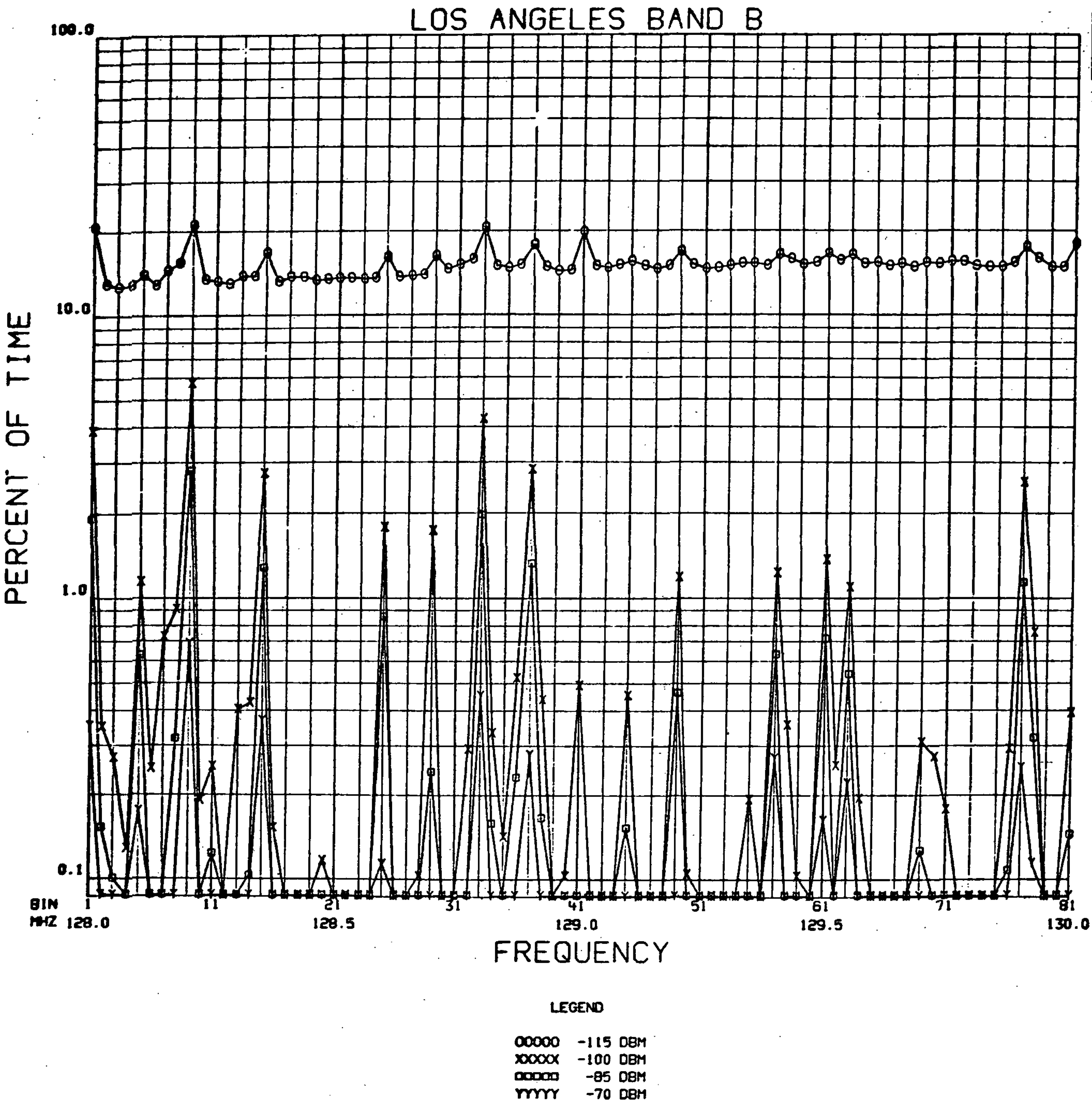


Figure 29. Frequency Summary - Los Angeles Band B

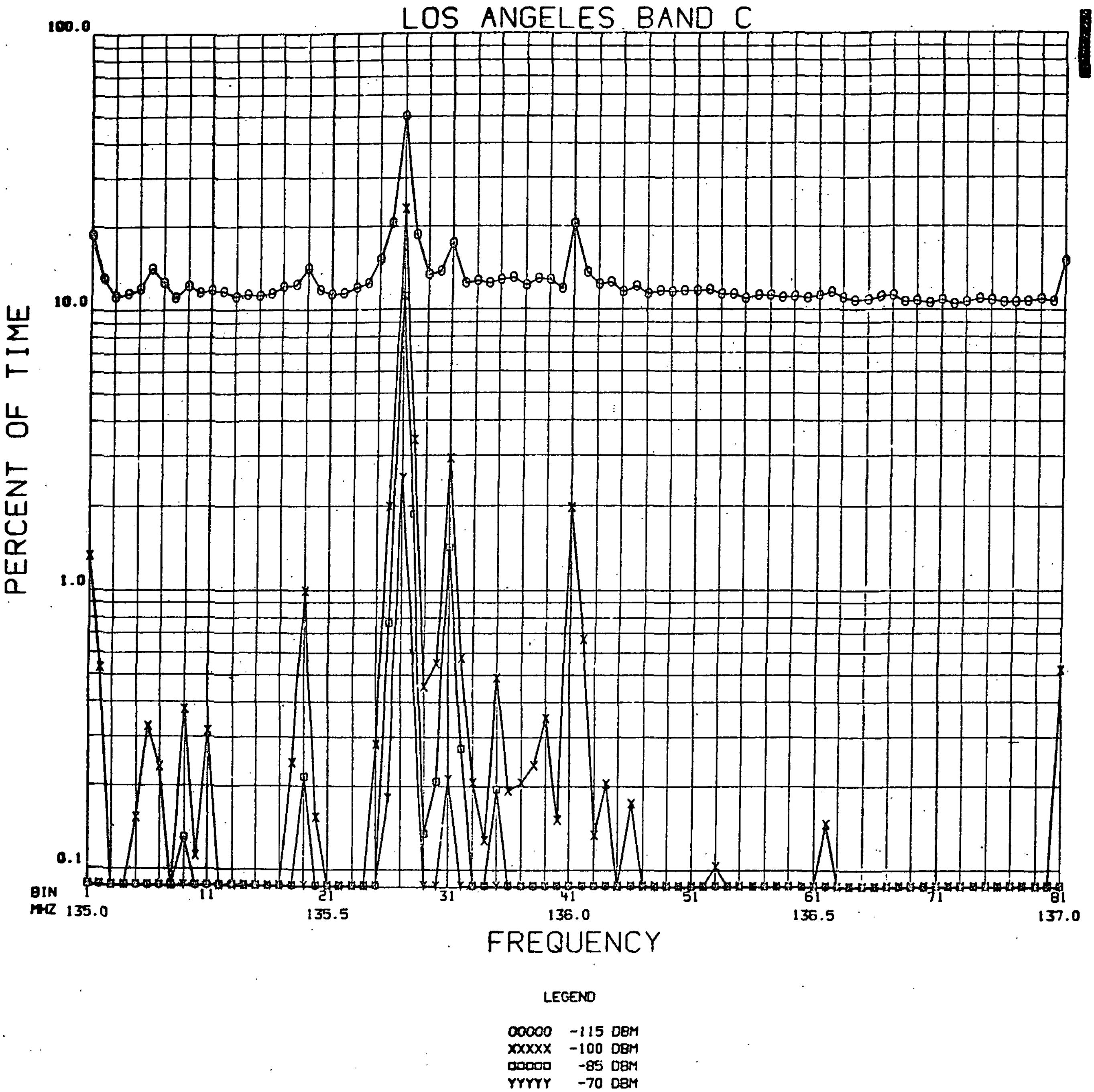


Figure 30. Frequency Summary - *Los Angeles Band C*

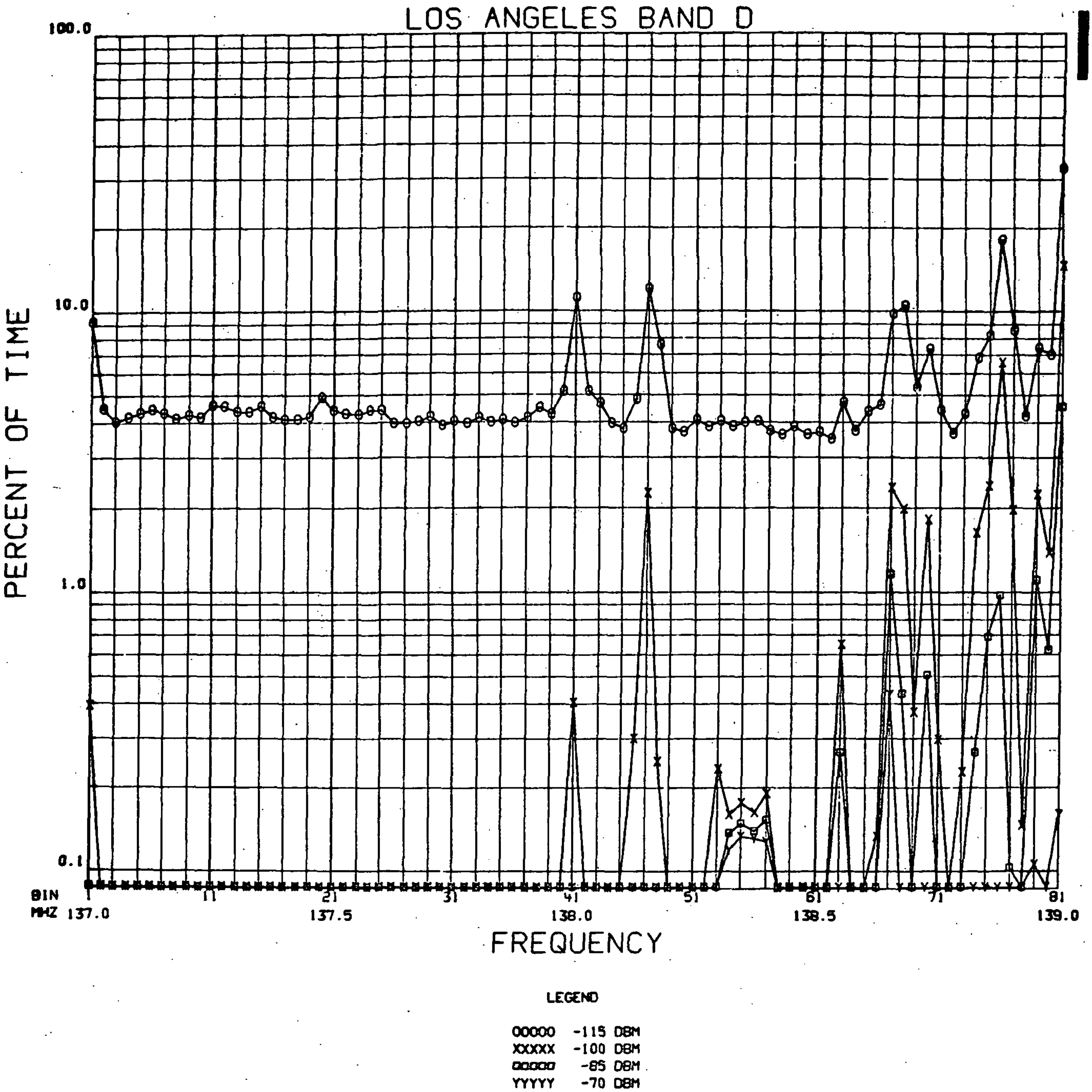


Figure 31. Frequency Summary - Los Angeles Band D

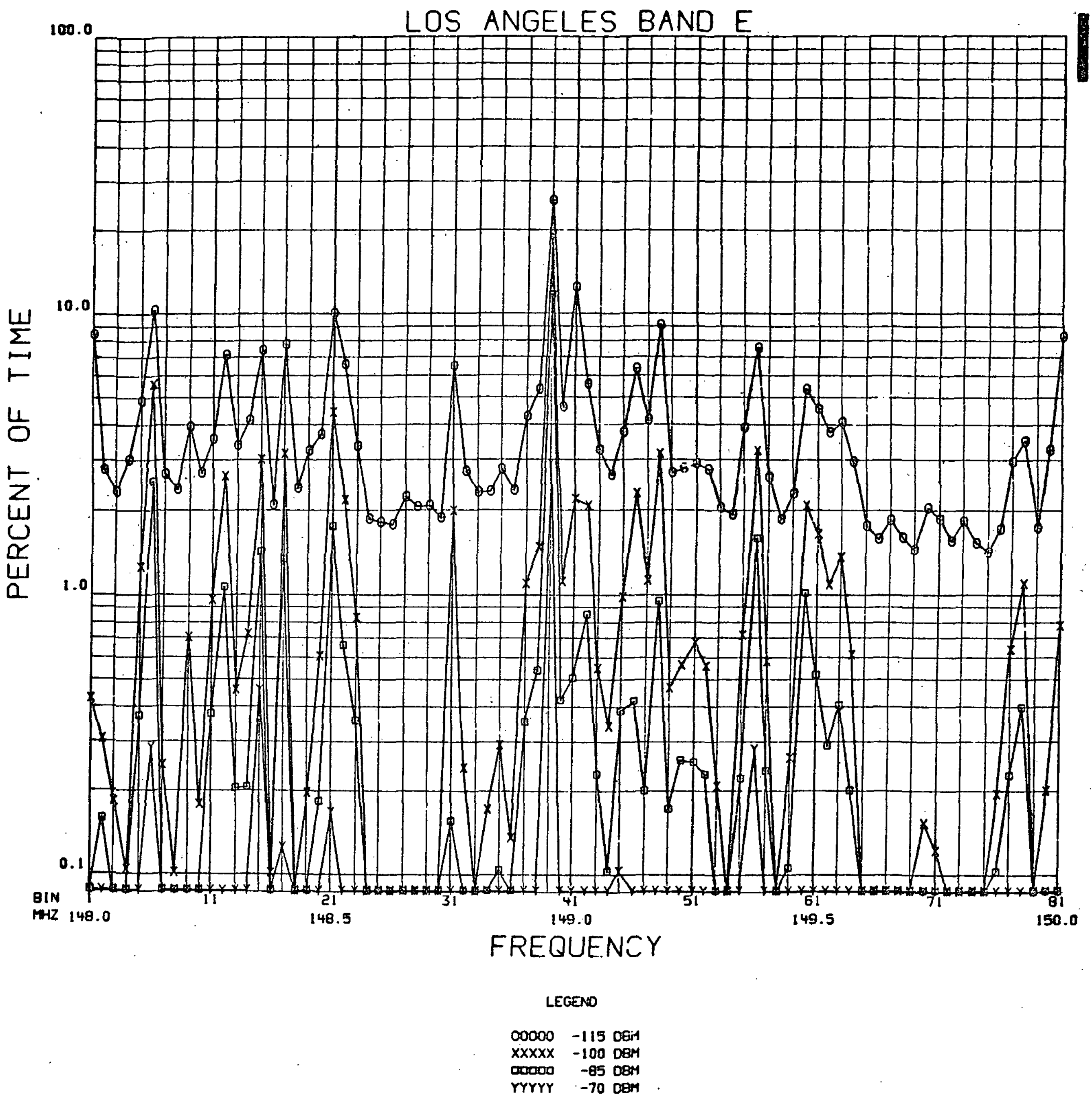


Figure 32. Frequency Summary - Los Angeles Band E

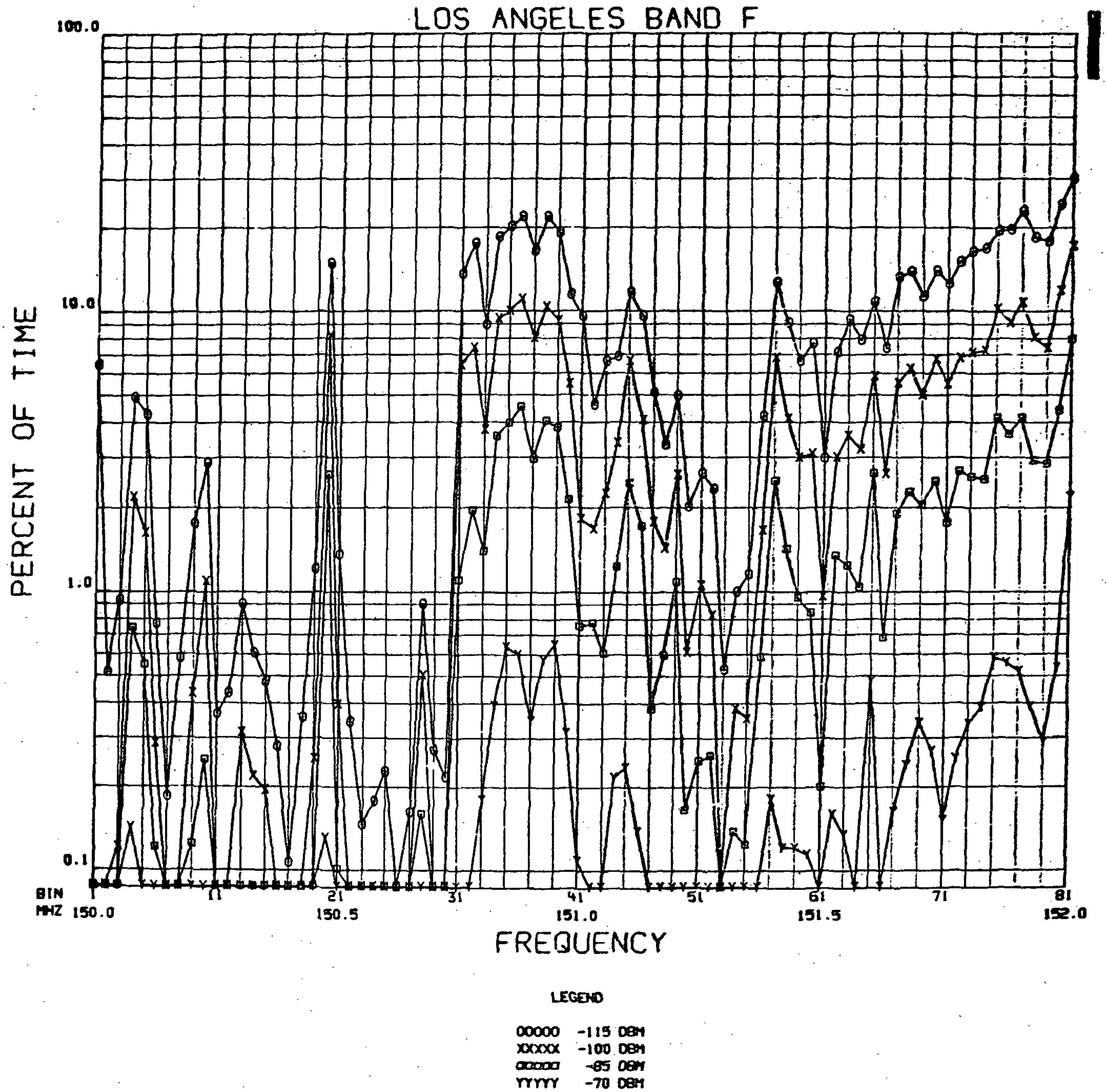


Figure 33. Frequency Summary
Los Angeles Band F

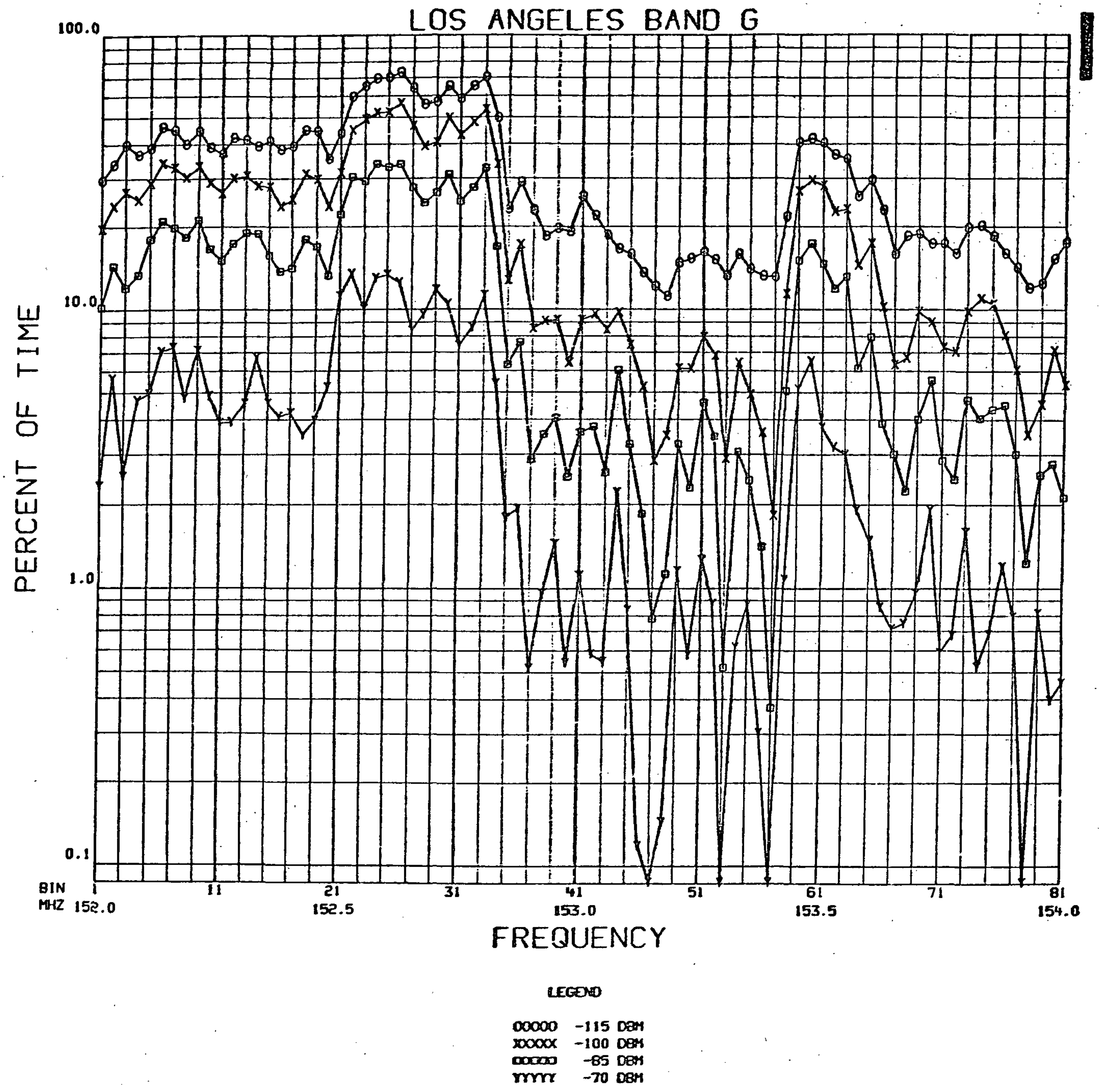


Figure 34. Frequency Summary
Los Angeles Band G

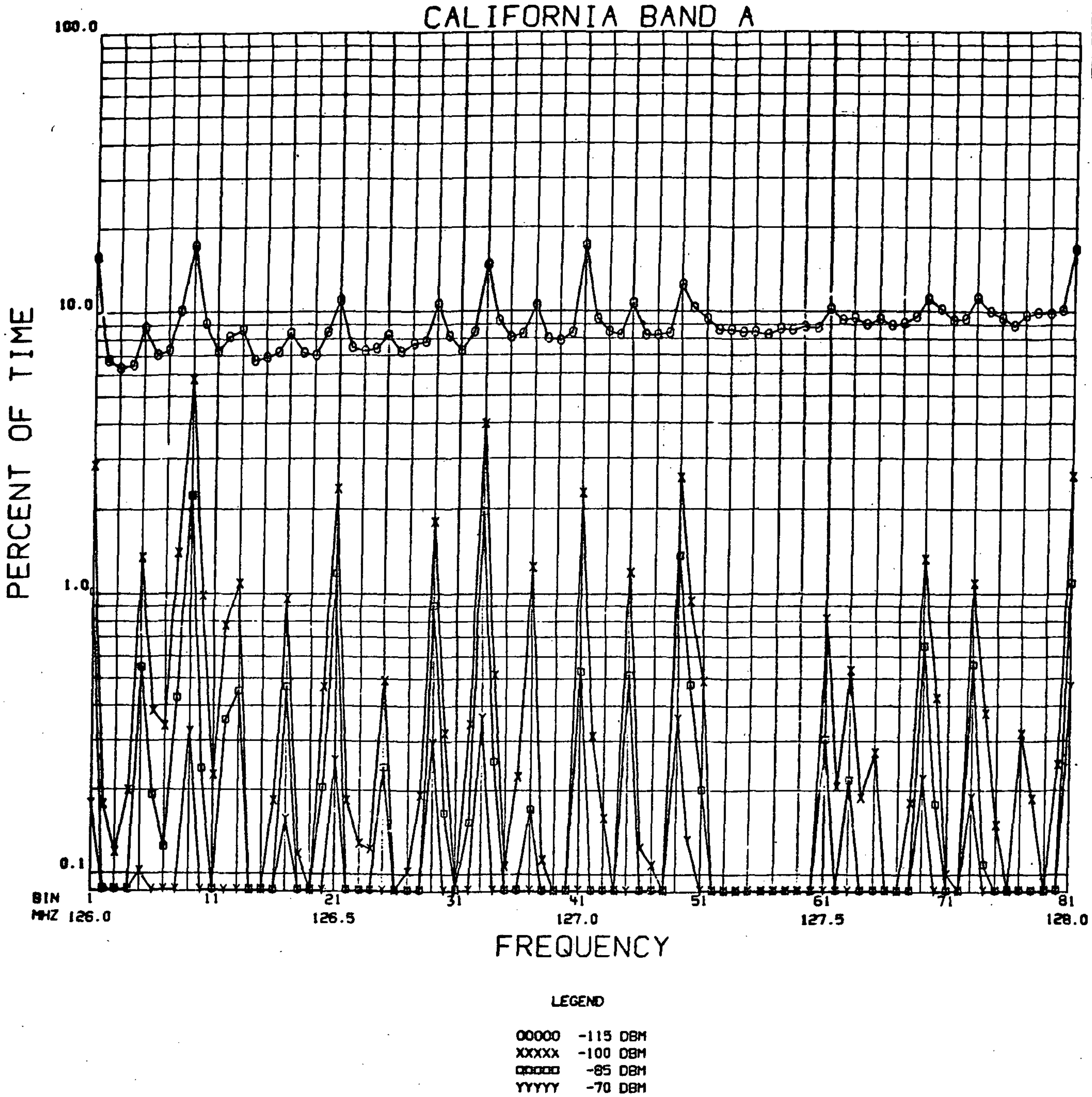


Figure 35. Frequency Summary - California Band A

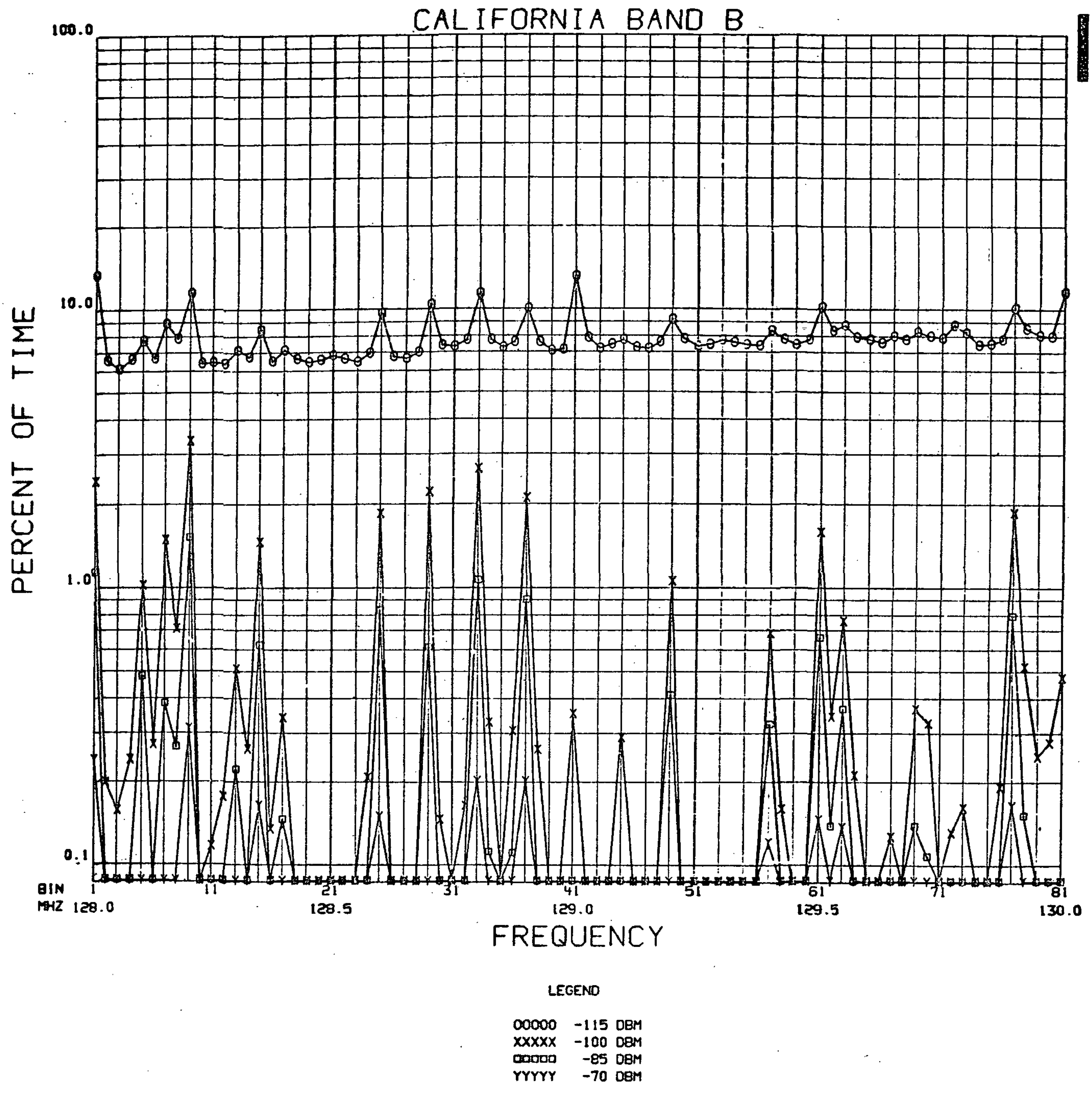


Figure 36. Frequency Summary - California Band B

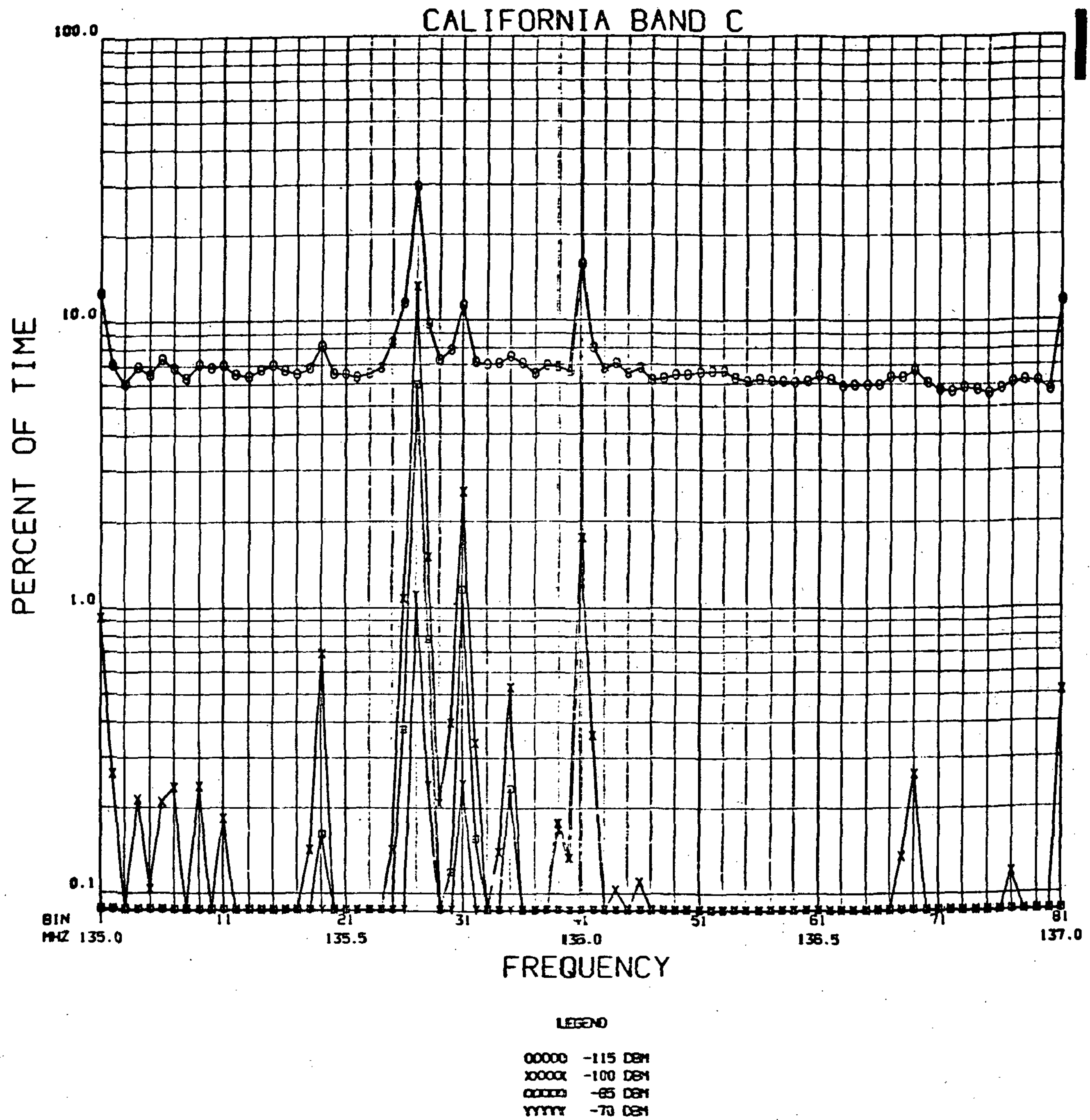


Figure 37. Frequency Summary - California Band C

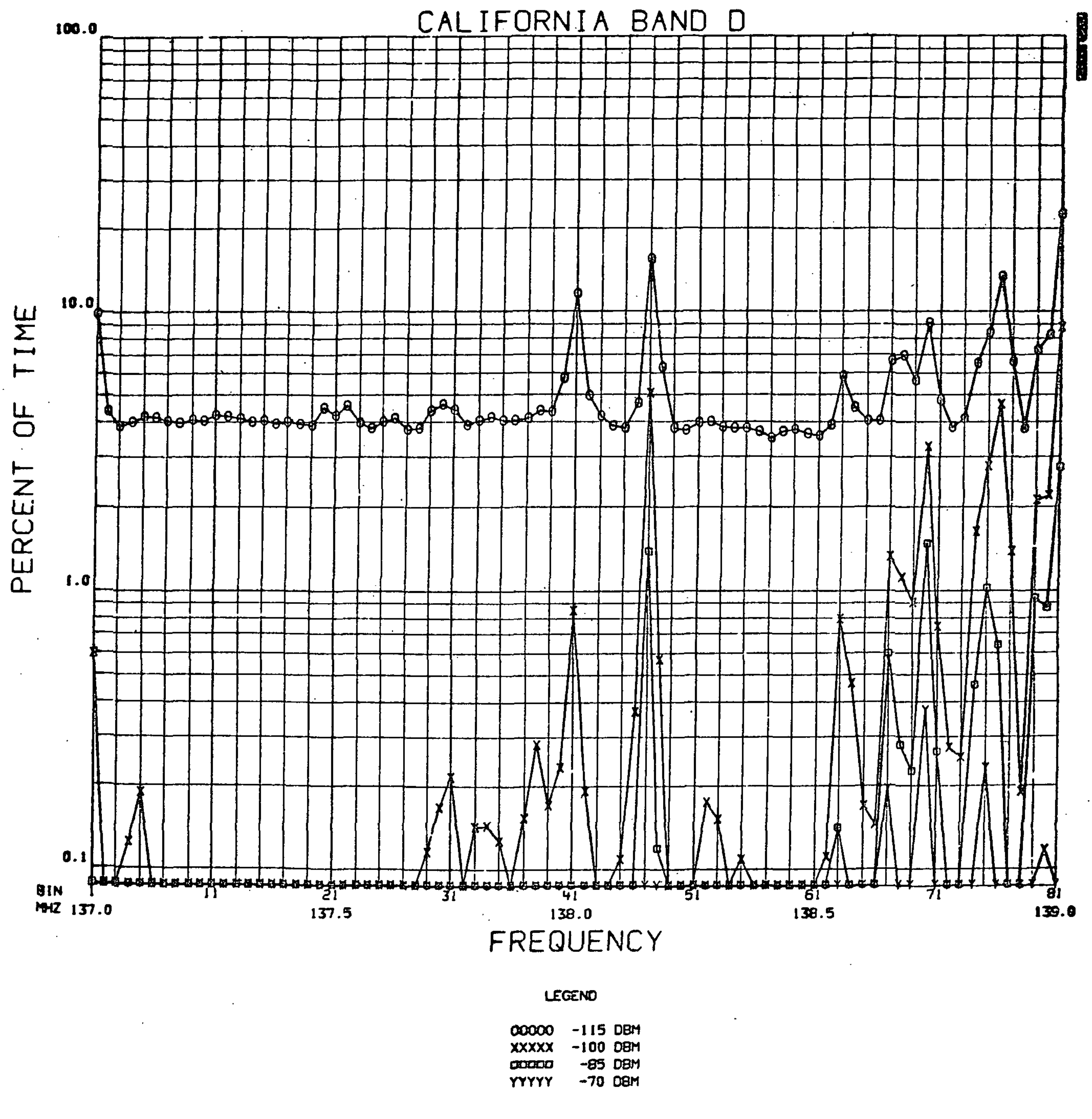


Figure 38. Frequency Summary - California Band D

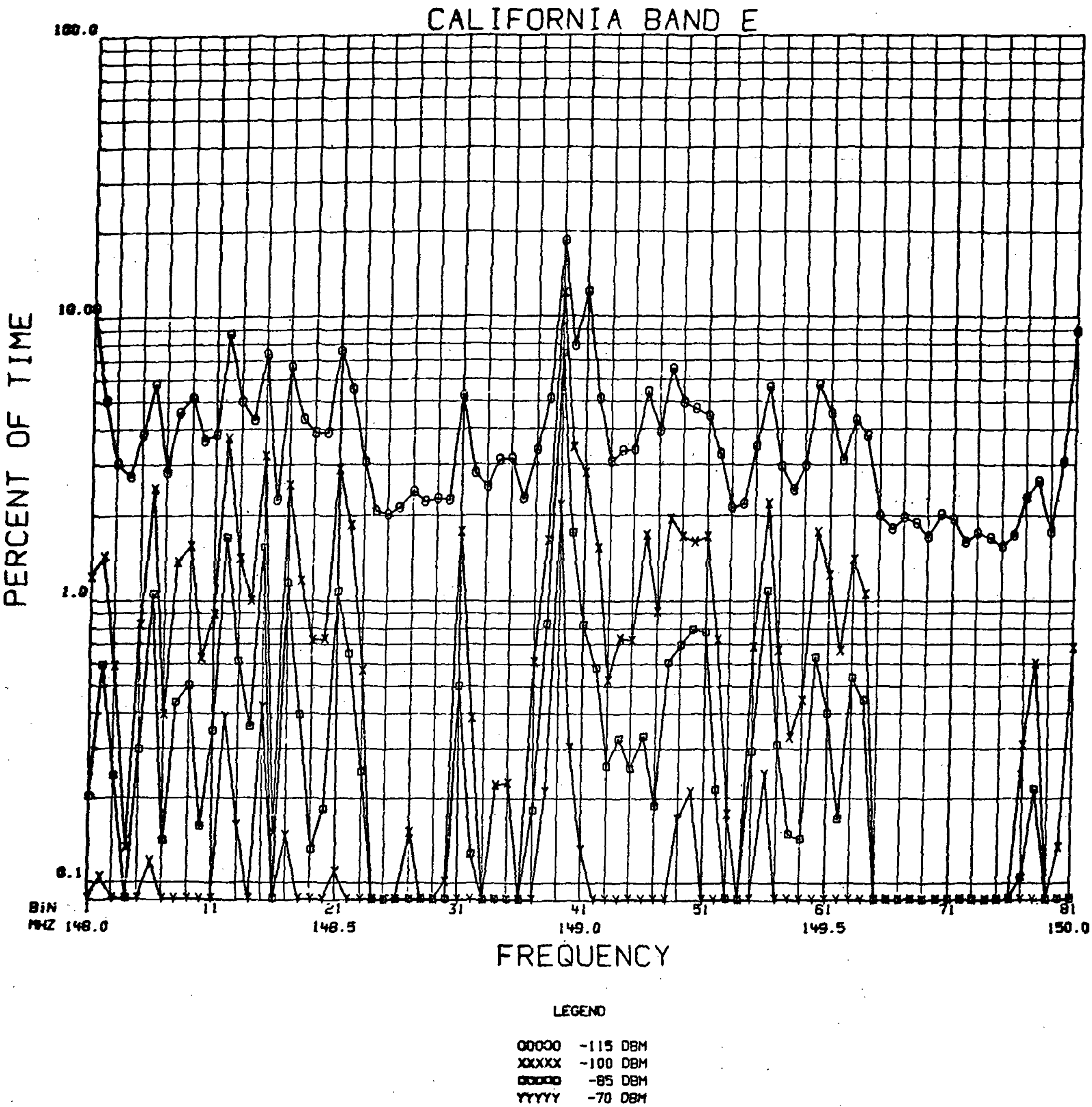


Figure 39. Frequency Summary - California Band E

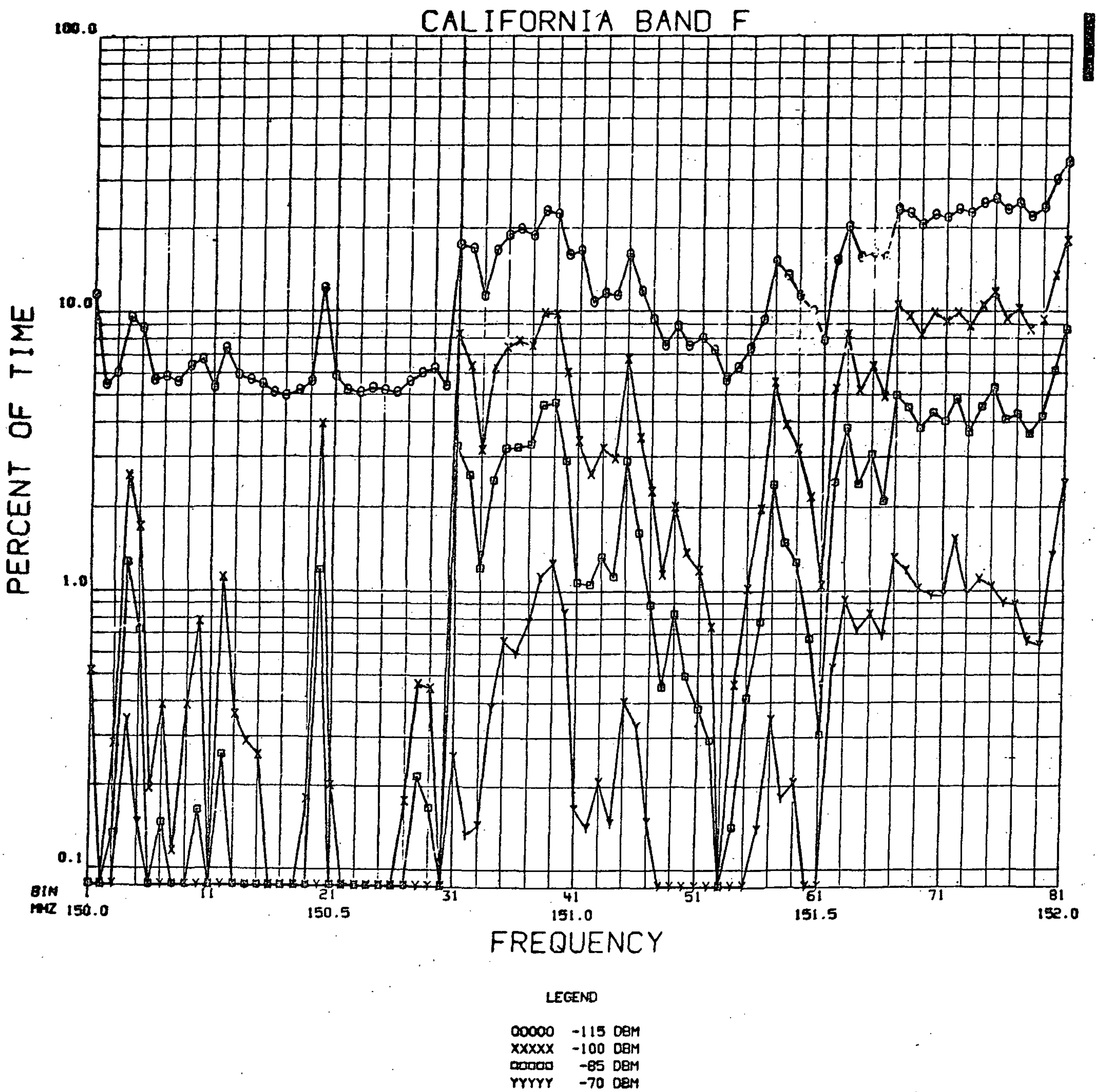


Figure 40. Frequency Summary - California Band F

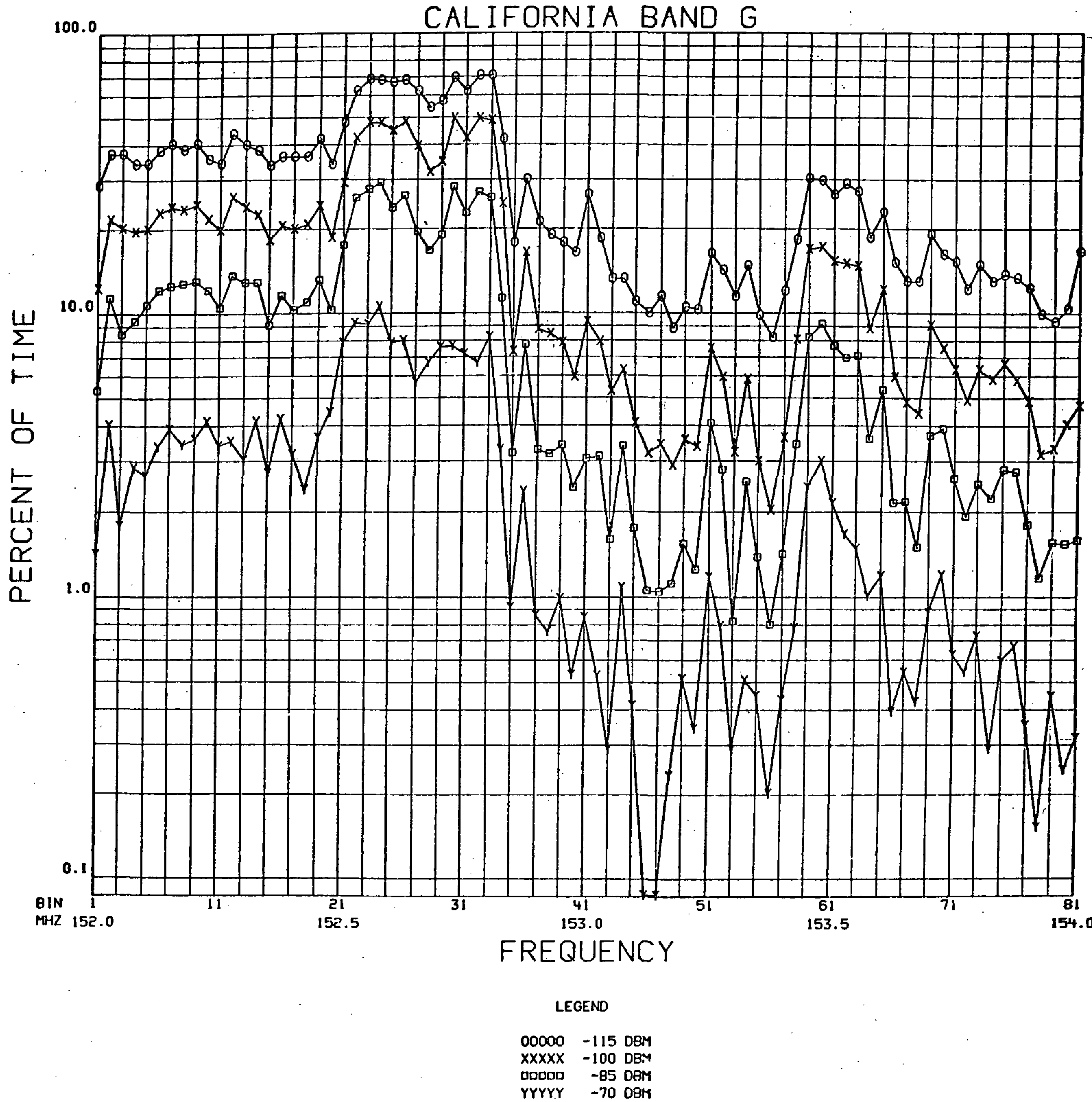


Figure 41. Frequency Summary
California Band G

chart use different symbols to provide a clear picture of the bin utilization; however, it is unfortunate that the FR80 program connected the points with straight lines. The signal levels plotted are representative of the bin center frequency and, as such, should be considered to occupy a line segment on plot.

The California composite band summary clearly supports the assumption that a major portion of the spectrum is used on a very low duty cycle. Several segments of the spectrum indicate little or no activity as follows:

Band	Frequency Range, MHz
A	127.275 - 127.475
B	128.425 - 128.525
B	128.625 - 128.675
B	128.950 - 129.175
B	129.225 - 129.375
B	129.600 - 129.850
C	135.050 - 135.600
C	136.025 - 137.000
D	137.000 - 138.125
D	138.200 - 138.525
E	149.600 - 150.000
F	150.300 - 150.450
F	150.525 - 150.700

ESL - WEST COAST RFI SURVEY DATA COMPARISON

The objective of this effort is to review the TDRS RF environment data prepared by Electromagnetic Systems Laboratories (ESL) and compare it with the results of the West Coast RF Survey. This correlation is made difficult by the ESL worst case analysis of all emitters active or powered up. The RF environment in Bands A, B, C, and D is largely composed of low-duty cycle ground to air and air to ground AM (A3) push to talk (PTT) emissions. The PTT and PTM emissions (A3 and F3) in Bands E, F, and G are of much higher density than the lower bands due to the nature (radio telephone and public safety) of the services.

The signal levels recorded during the survey are approximately 26 dB greater than those encountered by a spacecraft at an altitude of 100 nautical miles. Therefore, a signal level of -70 dBm is comparable to -96 dBm at altitude. In comparing the survey data with the ESL predicted values, an excellent correlation is observed at a level of -70 dBm in the 126 to 130 megaHertz frequency band. The 135 to 139 megaHertz frequency band (Bands C and D) are relatively inactive; however, the signal levels of the active transmitters closely approximate the ESL predicted values. The remainder of the survey data, with the exception of a large open band between 149.600 and 150.0 megaHertz, compares closely with the ESL values.

The fundamental problem encountered in a qualitative comparison of measured data with frequency/EIRP allocations is the utilization factor of each emitter in the band. The survey data clearly demonstrates that duty cycle is a parametric that should not be ignored in analyzing the severity of RFI. The worst case presentations by ESL is contrary to the nature of PTT and PTM systems with their extreme variations in duty factor. In contrast, the survey data shows many emitters inactive or used very sparingly in many of the frequency bands.

The survey data acquisition was performed in an aircraft at an altitude greater than 30,000 feet above the aforementioned metropolitan areas; hence, the aircraft is observing essentially the same RFI that a low orbit spacecraft encounters at a higher signal intensity. This overview of a metropolitan area by the aircraft closely simulates the low orbit spacecraft geometry but the terrestrial emitter maximum field intensities are unobserved. This situation is created by the shaping of terrestrial emitter antenna patterns to maximize performance near the horizon with little energy radiation upward. A majority of the terrestrial emitters use vertical linear polarization and monopole antennas.

The major lobes of these smaller emitters are also in the horizon plane; hence, the received field intensity is a function of the cosine of the angle between the respective emitters and the aircraft. Therefore, as a low orbit spacecraft passes over a metropolitan area, the greatest flux densities be observed near the radio horizon and should diminish in magnitude as the spacecraft viewing angle increases.

Conclusions

Based on a review of quick-look data, operator tape annotations, and computer processed data, it is concluded that several segments of the frequency bands monitored during the RF survey show promise as candidates for TDRSS communication. Bands B, C, D, and E show the highest probability of unused or low duty cycle channels.

Oscillograph recordings taken from the analog magnetic data tapes confirm that the frequency response of the recorder was more than adequate to preserve the detailed video and sweep outputs of the HP spectrum analyzer. The oscillographs also amplify the fact that reiterative X-Y plots are useful only to determine frequency occurrence, identification of potentially clear channels and an indication of duty cycle.

Finally, the volume of data can only be accommodated through the use of automated reduction procedures as demonstrated by the reduced data in the appendixes which will facilitate timely availability of survey results to support the Phase C/D TDRSS studies.

A perusal of the reduced data result in support on the conclusion that the low duty cycle communication traffic segment of the spectrum (Bands B, C, D and E) will accommodate TDRSS. It is clear that spread spectrum modulation techniques, either 1 or 2 MHz, are potentially available in Bands B, C, and D, while a clear channel appears to be available in Band E.

Recommendations

The West Coast RFI Survey has resulted in the developing of both airborne data acquisition techniques and automated data processing capabilities to investigate any portion of the radio frequency spectrum in detail.

This survey has produced statistical data in several VHF frequency bands and should be considered a minimum base on which tentative frequency selections can be designated for more detailed investigation. These data should, therefore, be carefully analyzed to enable planning of similar, discrete frequency studies in the same geographic locales and other regions to develop a comprehensive test verification of the TDRSS RFI environment.

The software provides for frequency search routines to determine the number of occurrences of a given frequency, duty cycle or rate of utilization, and diurnal and weekly variations in duty cycle. Additionally, subroutines were developed to enable amplitude or signal level searches to be performed to conform with a number of formats. In short, a very powerful tool has been developed to support the survey data processing. The present study results uses only a portion of the presentation options available; hence, the follow-on effort recommended above can be accommodated with no modification of software.

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TABLE 1-1

SPECIFICATIONS
OF
MODEL 10-276
INSTRUMENTATION TAPE RECORDER

GENERAL

Power Requirements:	Transport: 28±4 VDC (MIL-STD-704), 80 watts
	Record: 17 watts for 14 channels
	Reproduce: 12 watts for 14 channels
	With external power supply: 105 to 125 V AC, 48 to 420 Hz
Weight:	With 14 channels record/reproduce: 65 lbs
Size:	Refer to Fig. 2-1
Connectors:	MS 3114E type, or equivalent

ENVIRONMENTAL

Temperature:	Non-operating, with tape: -80° to +183°F (-62 to +85°F)
	Non-operating, with tape: -80°F to +183°F (-62 to +71°C)
	Operating: -4°F to 160°F (-20 to +71°C)
Humidity:	95% max, relative, without condensation

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Altitude:	Per MIL-E-5400 Class 1 Equipment: sea level to 50,000 feet
Vibration:	Per MIL-E-5400 Curve IV, Helicopter and Aircraft: ±10 g, with isolators
Shock:	Per MIL-E-5400: Operate, 15 g for 11 ± 1 milliseconds
	Crash safety, 30 g for 11±1 milliseconds
Acceleration:	25 g sustained

PERFORMANCE:

Tape Speeds:	120, 60, 30, 15, 7-1/2, 3-3/4, and 1-7/8IPS (Inches Per Second)
Speed Accuracy:	Within ±0.25% of selected speed, with phase-lock servo
Start/Stop Time:	2 sec. for stable motion to or from 60IPS
Fast Wind/Rewind Time:	4 min. for 2400 ft. of tape at 120IPS.
End and Beginning-Of-Tape Sense:	Automatic stop at end or beginning of tape in any mode of operation
Tape Reels:	Standard NAB 8-in. flanged, IBM 8-1/2 in., or special NAB 8-1/2 in.
Tape Capacity:	2400 ft., 1.0-mil-base tape, 8-in. reel

Tape Width:	1 or 1-1/2 in.
Local Controls:	Back-lit pushbuttons control on-off, record, stop, play, fast rewind, and fast wind functions; 7-position rotary switch selects tape speed
Tape Footage Indicator:	4-digit indicator, with reset
Remote Controls: (Remote Control Box is optional at extra cost; connection provisions on local unit are standard)	All functions except speed selection may be controlled by pushbuttons on remote control box
Remote Tape Footage Indicator: (optional at extra cost)	4-digit indicator, with reset, on remote control box
Test Connector: (optional at extra cost)	Used to connect external equipment for measuring record head currents, power supply outputs, and servo output
Tape Servo Reference Oscillator Frequency:	Seven (7) electrically switchable frequencies form 200 KHz to 6.25 Kha or from 100 KHz to 3.375 KHz; selected frequencies accurate to within $\pm 0.01\%$

Flutter, Cumulative:

Tape Speed (IPS)	Bandwidth	Flutter, % Peak-To-Peak
120	0.2Hz to 10 KHz	0.35
60	0.2Hz to 10 KHz	0.35
30	0.2Hz to 5 KHz	0.35
15	0.2Hz to 2.5 KHz	0.40
7-1/2	0.2Hz to 1.25 KHz	0.60
3-3/4	0.2Hz to 625 Hz	0.80
1-7/8	0.2Hz to 312 Hz	1.00

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Dynamic Skew:	Less than 0.27 microseconds, zero to peak, at 120IPS on adjacent tracks; increases in approximate proportion at slower tape speeds
Heads:	All metal-face construction; provisions for 4 head stacks
Number of Tracks:	14 on 1-in. tape or 7 on 1/2-in. tape, interleaved per IRIG standards; 7 or 9 tracks in line per IBM standards, up to 32 tracks on 1-in. tape
Head Construction:	Equal or better than specifications as set forth by IRIG or IBM standards
Voice Track: (optional at extra cost)	Separate edge track with IRIG configuration for 1/2- or 1-in. tape
Reproduce Monitor: (optional at extra cost)	Any 2 channels, selectable

System Performance:

Tape Speed IPS	Record Time	Direct Bandwidth 3.0 db	S/N (db) Ratio RMS
120	4 min.	*	*
60	8 min.	300Hz-250KHz	35
30	16 min.	200Hz-125KHz	34
15	32 min.	100Hz- 60KHz	32
71/2	1 hr/ 4 min.	100Hz- 30KHz	32
33/4	2 hr/ 8 min.	100Hz- 15KHz	30
17/8	4 hr/16 min.	100Hz-7.5KHz	28

* Not used in 10-276A Model, affords future up-dating.

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Tape Speed IPS	FM Bandwidth 1.0 db	S/N (db) Ratio RMS	Digital Bits/Sec Track 800 BPI	556BPI
120	DC- 40KHz	45	96K	66.7K
60	DC- 20KHz	44	48K	33.4K
30	DC- 10KHz	44	24K	16.7K
15	DC- 5KHz	42	12K	8.4K
71/2	DC- 2.5KHz	42	6K	4.2K
33/4	DC-1.25KHz	40	3K	2.1K
17/8	DC- 625Hz	38	1.5K	1.05K

Tape Speed IPS	PDM Duration Microseconds
120	15 to 10,000
60	20 to 10,000
30	30 to 10,000
15	60 to 10,000
71/2	100 to 10,000
33/4	175 to 10,000
17/8	350 to 10,000

Modes of Operation:

1. Direct record/reproduce
2. FM record/reproduce
3. Digital record/reproduce
4. PDM record/reproduce

Direct Record/Reproduce Specifications

Input Level: Adjustable with potentiometer from 0.1 to 5.0 V rms for full-scale recording

Input Impedance: 100 ohms, unbalanced to ground

Output Level: 1.0 V rms nominal across not less than 600 ohms

Output Impedance: Less than 50 ohms, unbalanced to ground

Harmonic Distortion: 1% third harmonic of 1 KHz recording at normal level

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FM Record/Reproduce Specifications Input Level:	Continuously adjustable from ±0.25 to 2.5 V peak-to-peak or from ±0.5 to 5.0 V peak-to-peak for fullscale recording
Input Impedance:	100 ohms, unbalanced to ground
Record Center Frequency Offset:	Continuously adjustable from -40% to +10% departure from center to permit recording bi-directional or unidirectional input signal
Record Linearity:	±0.5% of full band, best straight line
Record DC Drift:	Less than ±0.5% of full band, in 8 hours, after 5-minute warmup in -40° to +160° F (-40 to +71°C) ambient temperature range
Output Level:	Continuously adjustable from ±0.25 to 2.5 V peak-to-peak across not less than 600 ohms
Output Impedance:	Less than 50 ohms, unbalanced to ground
Reproduce Linearity:	±0.5% of full band, best straight line
Reproduce DC Drift:	Less than ±0.5% of full band, 8 hours, after 5-minute warm-up in -40° to +160° F (-40 to +71°C) ambient temperature range
Harmonic Distortion:	60 to 1-1/2 ips: 1% total harmonic distortion; 3-3/4 to 1-7/8 ips: 1.5% total harmonic distortion; both figures apply under conditions of 0.1 of maximum bandwidth

Digital Write/Read Specifications

Input Format:	Accepts NRZI (Mark), NRZ (Change), or Manchester, with same record amplifier
Input Level:	"0" = 0 - 0.5 VDC "1" = 4.5 to 10 VDC
Input Impedance:	20 ohms, unbalanced to ground
Output Level:	"0" = 0 - 0.5VDC "1" = 10.0 ± 0.5VDC across not less than 1,000 ohms
Output Rise/Fall Times: (Between 10% and 90%)	Rise 1.5 usec, max. Fall 2.0 usec, max.
Output Impedance:	Less than 100 ohms, unbalanced to ground
Packing Density:	800 bits per inch, max. error 1 part in 10^5
PDM Record/Reproduce Specifications Input Level:	1.0 V to 20 V peak-to-peak, rectangular waveform
Input Impedance:	20 K ohms, unbalanced to ground
Output Impedance:	Less than 100 ohms, unbalanced to ground
Output Rise/Fall Times: (Between 10% and 90%)	Rise 1.0 usec, max. Fall 1.0 usec, max.
Pulse Width Accuracy:	Within ±2.0 usec at 60 ips over pulse width range of 30 to 90 usec

HEWLETT-PACKARD SPECTRUM ANALYZER

SECTION I

GENERAL INFORMATION

1-1. INTRODUCTION.

1-2. The HP 8554L 8552A Spectrum Analyzer provides a visual display of the frequency domain from 500 kHz to 1250 MHz. The analyzer is absolutely calibrated along the horizontal (frequency) axis and the vertical (amplitude) axis; both input signal level and input signal frequency may be read from the display CRT. Controls of the instrument are grouped so that amplitude and frequency measurements are easy to make. There are no complicated procedures involved in making measurements; interpretation of the display as related to the control settings is not complex. See Figure 1-1 for a graphic illustration of control functions.

1-3. Typically, the Spectrum Analyzer is used to measure absolute frequency and amplitude, frequency response, harmonic and intermodulation distortion, gain, attenuation, modulation index, spectral purity, noise density, and other operational parameters. These measurements may be made on amplifiers, oscillators, mixers, modulators, etc., to determine that they are (or are not) performing within their design specifications.

1-4. MANUAL CONTENT.

1-5. This manual is intended as a source of operator information only. Calibration and adjustment procedures are covered in the Calibration and Adjustment Manual. Maintenance and Parts information is contained in the Service Manual.

1-6. The inside front cover of this manual illustrates front and rear views of the Spectrum Analyzer and initial control settings. Test and adjustments prescribed in this manual all begin with the controls set as in this illustration.

1-7. A control-indicator dictionary is included at the rear of this manual as a fold out page. It may be extended for ready reference when other parts of the manual are being used.

1-8. Specifications, performance characteristics, and accessory information for the instrument are included in this section. Preparation for use is covered in Section II. Operation and theory of operation is covered in Sections III and IV. Operator maintenance is covered in Section V.

1-9. SPECIFICATIONS. See Table 1-1.

Table 1-1. Specifications

FREQUENCY CHARACTERISTICS:
- FREQUENCY RANGE: 500 kHz - 1250 MHz.
- Scan Width: (on 10 division CRT horizontal axis).
  - Per Division: 15 calibrated scan widths from 100 MHz/div to 2 kHz/div in a 1, 2, 5 sequence.
  - Preset: 0 - 1250 MHz.
  - Zero: Analyzer is fixed tuned receiver.

FREQUENCY ACCURACY:
- Center Frequency Accuracy: The dial indicates the display center frequency within 10 MHz.
- Scan Linearity: Frequency error between two points on the display is less than 10% of the indicated separation.

RESOLUTION:
- Bandwidth: IF bandwidths of 0.3 to 300 kHz provided in a 1, 3 sequence.
- Bandwidth Accuracy: Individual IF bandwidths 3 dB points calibrated to ±20%. (10 kHz bandwidth ±5%.)
- Bandwidth Selectivity: 60 dB/3 dB IF bandwidth ratio <20:1 for IF bandwidths from 1 kHz to 300 kHz. 60 dB/3 dB bandwidth ratio <25:1 for 300 Hz IF bandwidth.

STABILITY:
- Residual FM:
  - Stabilized: <300 Hz peak-to-peak.
  - Unstabilized: <10 kHz peak-to-peak.
  - Noise Sidebands: More than 60 dB below CW signal, 20 kHz or more away from signal, with 1 kHz IF bandwidth.

AMPLITUDE SPECIFICATIONS.

ABSOLUTE AMPLITUDE CALIBRATION RANGE:
- Log: From -120 to +10 dBm, 10 dB/div on a 70 dB display.
- Linear: From 0.1 μV/div to 100 mV/div in a 1, 2 sequence on an 8-division display.

DYNAMIC RANGE:
- Average Noise Level: < -102 dBm with 10 kHz IF bandwidth.
- Spurious Responses: For -40 dBm signal level to the input mixer*: image responses, out-of-band mixing responses, harmonic and intermodulation distortion are all more than 60 dB below the input signal level.
- Residual Responses: Referred to signal level at input mixer*: < -100 dBm.

*Signal level at input mixer = (signal level at input) - (input RF attenuation).

Table 1-1. Specifications (Cont'd)

AMPLITUDE ACCURACY

	Log	Linear
Frequency Response (Flatness):		
(1 MHz - 1.0 GHz)	±1 dB	±12%
(500 kHz - 1.25 GHz)	±2 dB	±25%
Switching Between Bandwidths: (At 20°C)	±0.5 dB	±5.8%
Amplitude Display:	±0.25 dB/dB but not more than ±1.5 dB over the full 70 dB display range	2.8% of full 8 div deflection

CALIBRATOR OUTPUT:
Amplitude: -30 dBm, ±0.3 dB.
Frequency: 30 MHz, ±0.3 MHz.

INPUT SPECIFICATIONS.

Input Impedance: 50 Ω nominal. Reflection coefficient < 0.30 (1.85 SWR).
Maximum Input Level: Peak or average power +10 dBm (1.0 Vac peak), ±50 Vdc.

SCAN TIME SPECIFICATIONS.

Scan Time: 16 internal scan rates from 0.1 ms/div to 10 sec/div in a 1, 2, 5 sequence.
Scan Time Accuracy:
0.1 ms/div to 20 ms/div: ±10%.
50 ms/div to 10 s/div: ±20%.

GENERAL SPECIFICATIONS.

Power Requirements: 115 or 230 volts ±10%, 50 to 60 Hz, normally less than 225 watts (varies with plug-in units used).
Dimensions: Model 140S or 141S Display Section: 9-1/16 in. high (including height of feet) x 16-3/4 in. wide x 18-3/8 in. deep (229 x 425 x 467 mm).
Weight:
Model 8554L RF Section: Net, 10 lb 4 oz (4,7 kg). Shipping, 17 lb (7,8 kg).
Model 8552A IF Section: Net, 9 lb (4,1 kg). Shipping, 14 lb (6,4 kg).
Model 140S Display Section: Net, 37 lb (16,8 kg). Shipping, 45 lb (20 kg).
Model 141S Display Section: Net, 40 lb (18 kg). Shipping, 51 lb (23 kg).

1-10. SUPPLEMENTAL PERFORMANCE CHARACTERISTICS. (See Table 1-2.)

1-11. ACCESSORY EQUIPMENT FURNISHED. Rack Mounting Kit, part number 5060-0777 is shipped with the Spectrum Analyzer Display Section.

1-12. ACCESSORIES AVAILABLE.

1-13. Model 8405A Frequency Comb Generator; provides frequency markers spaced 1, 10 and 100 MHz apart for precise frequency calibration of the analyzer. Frequency accuracy is ±0.01%.

1-14. Model 8553L 1 kHz to 110 MHz Spectrum Analyzer RF Section. Used in place of the 8554L, it provides swept coverage from 1 kHz to 110 MHz. Absolute calibration extends to -130 dBm and minimum bandwidth (3 dB) is 50 Hz. Operating characteristics are similar to the 8554L.

1-15. Model 11592A Service Kit: provides extender cables, connectors and adapters which are required to service the analyzer.

1-16. MODIFICATION REQUIRED.

1-17. IF Sections (HP 8552A) with a serial number prefix lower than 851- should be modified to ensure compatibility with the 8554L. This modification can be made with HP Part Number 08552-6048 which is available on request at no cost.

1-18. INSTRUMENT AND MANUAL IDENTIFICATION.

1-19. Hewlett-Packard uses a two-section, eight-digit serial number (000-00000) on all instruments. This manual applies directly to all instruments bearing the serial prefixes shown on the inside title page of this manual.

Table 1-2. Supplemental Performance Characteristics

These Supplemental Performance Characteristics expand the 8554L/8552A specifications, indicate the instrument's performance at other than normal operating conditions, describe the instrument's unique features and characteristics, and provide other information useful in applying the instrument.

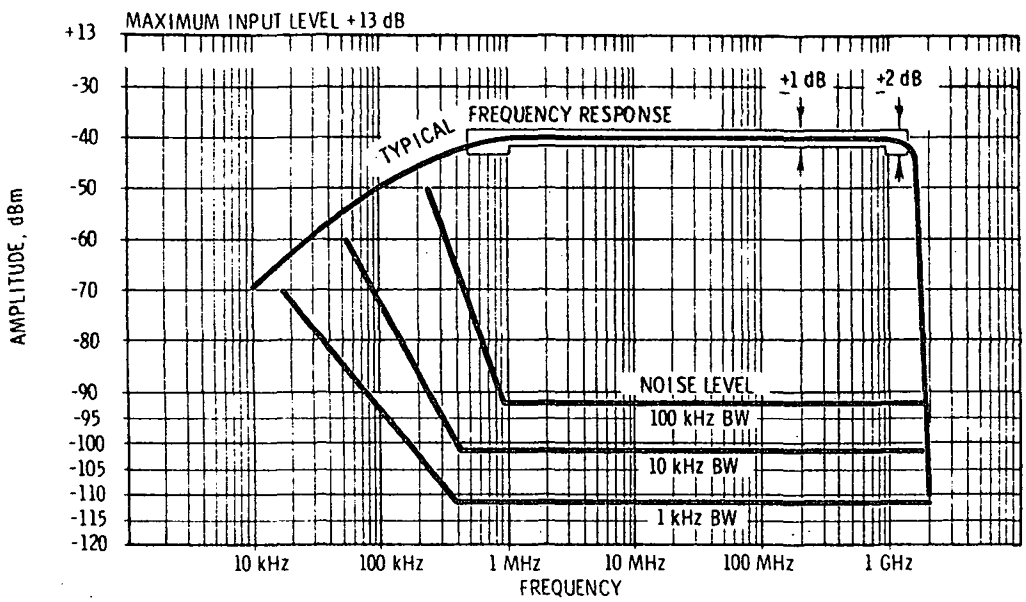


Figure 1

FREQUENCY CHARACTERISTICS

Frequency Range: For operation of the analyzer outside the 500 kHz to 1250 MHz range, see Figure 1, Frequency Response Curve.

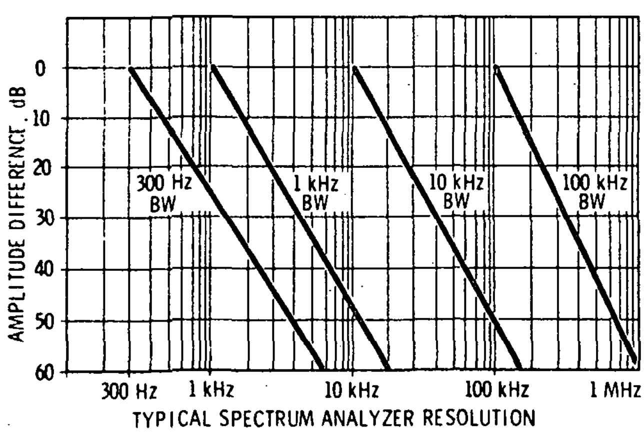


Figure 2

Scan Width:

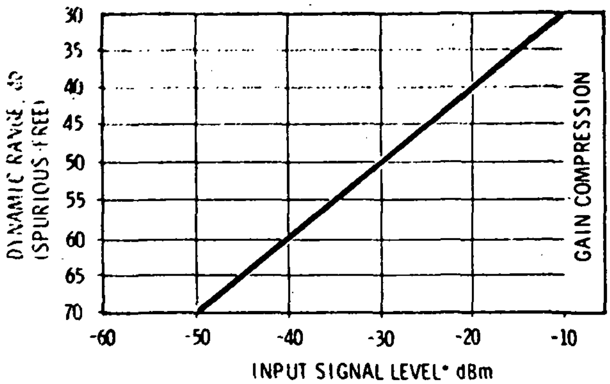
Preset 0 - 1250 MHz: Inverted marker identifies the frequency that becomes the center frequency for scan width per division and zero scan modes.

Zero: Analyzer becomes fixed-tuned receiver with frequency set by frequency and fine tune controls and selectable bandwidths set by BANDWIDTH control. Amplitude variations are displayed versus time on the CRT.

Resolution: See Figure 2 for curves of typical 8554L/8522A Spectrum Analyzer resolution using different IF bandwidths.

Stability: First local oscillator can be automatically stabilized (phase-locked) to internal reference for scan widths of 200 kHz/div or less. Signal display shift with stabilization <50 kHz.
Long Term Drift: (At fixed center frequency, after 2-hour warm-up).
Stabilized: ±10 kHz/10 min.
Unstabilized: ±50 kHz/10 min.
Temperature Drift:
Stabilized: 100 kHz/°C
Unstabilized: 200 kHz/°C.

Table 1-2. Supplemental Performance Characteristics (Cont'd)



*o dB Input attenuation (input signal level = RF input level - input atten.)

Signal Level to Input Mixer*

Figure 3

AMPLITUDE CHARACTERISTICS

Noise Level:

IF Bandwidth	Average Noise Level
1 kHz	<-112 dBm
10 kHz	<-102 dBm
100 kHz	<-92 dBm

The average noise level indicates the maximum sensitivity of the analyzer. For typical noise level versus input frequency curves from 1 kHz to 1250 MHz, see Figure 1.

Dynamic Range: For dynamic range with other than -40 dBm input level, see Figure 3.

Gain Compression: For <-10 dBm signal level to the input mixer* gain compression <1 dB.

Amplitude Accuracy:

Measurement Accuracy: Largely determined by frequency response (±1 dB) and display accuracy (±1.5 dB) for general use. This ±2.5 dB can be improved using IF substitution techniques.

Frequency Response (flatness): For typical response characteristics, see Figure 1.

Input Attenuation: Included as convenient level set. 0, 10 and 20 dB positions accurate to ±0.3 dB, useful when checking for input mixer overload.

Log Reference Level: Accurate to ±0.2 dB (±2.3%, linear sensitivity).

Log Reference Level vernier: Accurate to ±0.1 dB (±1.2%) in 0, 6 and -12 dB positions; otherwise, ±0.25 dB (±2.8%).

Amplitude Stability: ±0.07 dB/°C in LOG, ±0.6%/°C in LINEAR.

*Signal level to input mixer = (Signal level at input) - (Input RF attenuator).

Display Uncalibrated Light: Panel light warns operator of uncalibrated amplitude display if selected IF or video bandwidth is too narrow for combination of scan width per division and scan time selected.

Video Filter: Post-detection filter used to average displayed noise. Nominal bandwidths: 10 kHz and 100 Hz.

RF INPUT CHARACTERISTICS

Impedance: 50Ω nominal.

Reflection Coefficient: For 0 dB input attenuation when analyzer is tuned to input signal: <0.4 (2.33 SWR).

Attenuator: 0, 10 and 20 dB positions coupled to log reference level indicator to automatically maintain absolute amplitude calibration.

Connector: BNC.

SCAN CHARACTERISTICS

Scan Mode:

Int: Analyzer repetitively scanned by internally generated ramp; synchronization selected by SCAN TRIGGER.

Single: Single scan actuated by front panel pushbutton.

Ext: Scan determined by 0 to +8 volt external signal; scan input impedance >10 kΩ.

Blanking: 1.5 V external blanking signal required.

Scan Trigger: For Int scan mode, select between:

Auto: Scan free runs.

Line: Scan synchronized with power line frequency.

Ext: Scan synchronized with >2 volt (20 volt max.) trigger signal (polarity selected by internally located switch in Model 8552A IF Section).

Video: Scan internally synchronized to envelope of RF input signal (signal amplitude of 1.5 major divisions peak-to-peak required on display section CRT).

DISPLAY CHARACTERISTICS

Normal Persistence (Model 140S):

Plug-ins: Accepts Model 8550-series Spectrum Analyzer plug-ins and Model 1400-series time domain plug-ins.

Cathode-ray Tube:

Type: Post-accelerator, 7300 volt potential medium-short persistence (P7) phosphor, light blue filter supplied, etched safety glass face plate reduces glare.

Graticule: 8 x 10 divisions (approximately 7.2 x 9.0 cm) parallex-free internal graticule; five subdivisions per major division on horizontal and vertical axes.

Table 1-2. Supplemental Performance Characteristics (Cont'd)

Functions Used with Time Domain Plug-ins Only: Intensity modulation, calibrator, beam finder.

Special Order: Chassis sides and adapter kit: Fixed sides, order HP Part Number 1490-0714; pivot sides, order HP Part Number 1490-0718; slide adapter kit for mounting slides on scope, order HP Part Number 1490-0721.

Variable Persistence Storage (Model 141S).

Plug-ins: Same as 140S.

Cathode-ray Tube:

Type: Post-accelerator storage tube, 7300 volt accelerating potential; aluminized P31 phosphor; etched safety glass face plate reduces glare.

Graticule: 8 x 10 divisions (approximately 6.6 x 8.2 cm) parallax-free internal graticule; five subdivisions per major division on horizontal and vertical axes.

Persistence:

Normal: Natural persistence of P31 phosphor (approximately 0.1 second).

Variable:

Normal Writing Rate Mode: Continuously variable from less than 0.2 second to more than one minute (typically to two or three minutes).

Maximum Writing Rate Mode: Typically from 0.2 second to 15 seconds.

Erase: Manually: erasure takes approximately 100 ms: CRT ready to record immediately after erasure.

Storage Time:

	NORMAL WRITING RATE Mode	MAX WRITING RATE MODE
STORE Mode (dim display)	Longer than 1 hour	Typically 15 minutes
VIEW Mode (brigh display)	Longer than 1 minute (typically 2 or 3 minutes)	Typically 15 seconds

Functions Used with Time Domain Plug-ins Only: Same as 140S. Special Order: Same as 140S.

GENERAL CHARACTERISTICS

Auxiliary Outputs:

Vertical Output: Approximately 0 to -0.8 V for 8 division deflection on CRT display: 1 kΩ output impedance

CRT Baseline Clipper: Front panel control adjusts blanking of CRT trace baseline to allow more detailed analysis of low-repetition-rate signals and improved photographic records to be made.

EMI: Conducted and radiated interference is within requirements of MIL-I-16910C and MIL-I-6181D and methods CE03 and RE02 of MIL-STD-461 (except 35 to 40 kHz) when 8554L and 8522A are combined in a 140S or 141S Display Section.

Temperature Range: Operating, 0° to +55°C: storage, -40° to +75°C.

FLIGHT PLAN

T. O. WT = 19,115# (FOR FLIGHTS ABOVE 18,265#):

INITIAL PILOT ________________

INITIAL P. E. ________________

T. O. ____________ T. D. ____________ DUR ____________

S/L N287NA FLTS ____________ DATE ____________

BASE COMMUNICATIONS 123.35 (VHF) (AUTONETICS L. A.)

NO SPEED BRAKES - NO VHF - DURING DATA

---

1. Los Angeles primary data area - approximately 30K' MSL - speed approximately 200 KIAS.

   a) Orbit Los Angeles primary data area beginning at LAX VOR, then 38 miles to El Toro VOR, then 18 miles to Ontario VOR, then 16 miles to Pomona VOR, then 36 miles to Van Nuys VOR, and finally 18 miles to LAX VOR (approximate total orbit 126 NM).

   (Orbit primary data area as required)

FLIGHT PLAN

T.O. WT = 19,115# (FOR FLIGHTS ABOVE 18,265#):

INITIAL PILOT ________________

INITIAL P.E. ________________

T.O. ____________ T.D. ______________ DUR ________________

S/L N287NA FLTS ______________ DATE ______________

BASE COMMUNICATIONS 123.35 (VHF) (AUTONETICS L.A.)
CHANNEL 5 USB (HF) (KNV8)

NO SPEED BRAKES - NO VHF - DURING DATA

---

1. LAX south to San Diego along airway V25 (nominal 30,000' MSL altitude; speed approx. 200 KIAS). (System calibration enroute).

2. Orbit San Diego primary data area: an approx. 20 x 25 mile rectangular course beginning at San Diego VOR, then 150° radial for 15 DME miles SE to a point near Imperial Beach; then MH 060° to a point on 098° radial and 25 DME miles from VOR; then MH 330° to a point near Ramona airport on 037° radial and 23 DME miles from VOR; then MH 240° to a point near Del Mar on 330° radial and 10 DME miles from VOR; and finally MH 150° on 330° radial to VOR (approximate total orbit 90 NM).
(Orbit primary data area as required)

3. San Diego north to LAX along airway V23 (approx. 30,000' MSL, approx. 200 KIAS) (Data enroute)

FLIGHT PLAN

T.O. WT = 19115# (FOR FLIGHTS ABOVE 18265#):

INITIAL PILOT ________________

INITIAL P.E. ________________

T.O. ____________ T.D. ____________ DUR ____________

S/L N287NA FLT ________________ DATE ____________

BASE COMMUNICATIONS 123.35 (VHF) (AUTONETICS L.A.)
CHANNEL 5 USB (HF) (KNV8)

NO SPEED BRAKES - NO VHF - DURING DATA

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1. LAX north to San Francisco via airway V27 (nominal 30,000' MSL altitude; speed approx. 200 KIAS) (system calibration & data enroute). (Annotations required)

2. Orbit San Francisco primary data area: begin at Woodside VOR, then 13-1/2 miles to San Francisco VOR, then 16-1/2 miles to Sausalito VOR; then MH 054° to a point 14 DME miles near San Pablo Reservoir on 054° radial from Sausalito VOR; then MH 136° to a point near Fremont Airport on 060° Woodside VOR radial and 17 DME miles from Woodside VOR, and finally MH 240° on 060° radial and 17 DME miles to Woodside VOR. (Approximate total orbit 92 NM). (Annotations required).

   (Orbit primary data area as required).

3. San Francisco south to LAX via airway V27 (approx. 30K' MSL alt.; speed approx. 200 KIAS) (System calibration & data enroute). (Annotations required)

March 3, 1972
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San Diego

RFI SURVEY LOG

TIME						FREQUENCY BAND								
BEGIN			END											
HRS.	MIN.	SEC.	HRS.	MIN.	SEC.	A	B	C	D	E	F	G	CAL	Tape No.
08	29	T/O	Flight 612											1
09	06	54	09	12	58	X								
09	14	40	09	19	40		X							
09	22	13	09	27	00			X						1
09	35	55	09						X					2
09	42	27	09	47	13				X					
09	50	09	09	55	10					X				
09	57	06	10	03	07						X			
10	05	14	10	09	15							X		
10	12	20	10	17	20	X								
10	19	15	10	24	19		X							2
10	32	44	10	37	44			X						3
10	39	44	10	44	44				X					
10	47	25	10	52	25					X				
10	55	29	11	00	29						X			
11	02	57	11	07	57							X		
11	12	15	11	17	15	X								
11	20	57					X							3
11	26	44	11	32	00		X							4
11	34	26	11	39	26			X						
11	41	44	11	46	44				X					4

March 3, 1972
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RFI SURVEY LOG

San Diego

TIME													
BEGIN			END			FREQUENCY BAND							
HRS.	MIN.	SEC.	HRS.	MIN.	SEC.	A	B	C	D	E	F	G	CAL
11	50	33	11	56	35					X			4
11	59	30	12	05	30						X		
12	07	50	12	11	50							X	4
12	23	Landing											
14	05	T/O	Flight 613										
14	21	09	14	26	54							X	5
14	30	04	14	36	04	X							
14	39	28		42			X						5
14	48	40	14	50	40		X						6
14	52	52	14	57	52			X					
14	59	18	15	04	18				X				
15	07	06	15	15	06					X			
15	15	52	15	20	52						X		
15	22	50	15	27	50							X	
15	31	27	15	36	36	X							
15	39	05	15	44	04		X						6
15	52	25	15	57	25			X					7
15	59	45	16	04	45				X				
16	07	47	16	12	16					X			
16	14	10	16	20	10						X		
16	22	16	16	27	16							X	7

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San Diego

RFI SURVEY LOG

TIME BEGIN HRS.	MIN.	SEC.	END HRS.	MIN.	SEC.	FREQUENCY BAND A	B	C	D	E	F	G	CAL
16	30	36	16	35	32	X							7
16	38	32	16	43	32		X						↕
16	46	09	16	51	09			X					7
17	00	18	17	05	38				X				8
17	08	10	17	13	12					X			↕
17	15	00	17	21	00						X		8
17	35	Landing											

March 7, 1972
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Los Angeles

RFI SURVEY LOG

TIME						FREQUENCY BAND								
BEGIN			END											
HRS.	MIN.	SEC.	HRS.	MIN.	SEC.	A	B	C	D	E	F	G	CAL	Tape No.
8	30		Flight 614											
8	39	53	8	44	53	X								1
8	46	30	8	51	30		X							
8	52	32	8	57	32			X						
8	59	33	9	04	33				X					
9	05	32	9	09	32					X				
9	09	59	9	14	59						X			
9	15	45	9	20	45							X		
9	22	25	9	27	27	X								1
9	33	26	9	38	26		X							2
9	39	07	Tape Jam											
9	50	47	9	55	47			X						
9	57	26	10	02	26					X				
10	03	02	10	08	18						X			
10	09	02	10	14	02							X		
10	14	40	10	19	40	X								
10	20	40	10	25	40		X							
10	26	43	10	31	45			X						2
10	37	50	10	42	50				X					3
10	45	06	10	49	18					X				
10	50	12	10	55	14						X			
10	56	04	11	01	04							X		3

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Los Angeles

RFI SURVEY LOG

TIME BEGIN			TIME END			FREQUENCY BAND								
HRS.	MIN.	SEC.	HRS.	MIN.	SEC.	A	B	C	D	E	F	G	CAL	Tape No.
11	02	12	11	17	12	X								3
11	18	08	11	27	35		X							3
11	38	15	11	53	15			X						4
11	53	52	12	09	00				X					
12	9	42	12	16						X				
12	35		Landing											
13	10	T/O	Flight 615											
13	20	18	13	38	35						X			4
13	44	18	13	49	37							X		5
13	50	29	14	05		X								
14	06	25	14	21	25		X							
14	22	25	14	32	40			X						
14	33	26	14	40	00				X					5
14	46	30	14	51	30					X				6
14	52	14	14	59	55						X			
15	01	12	15	06	12							X		
15	09	57	15	14	57	X								
15	16	38	15	21	38		X							
15	22	34	15	27	34			X						
15	28	14	15	33	30				X					
15	34	14	15	38	30					X				6

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Los Angeles

RFI SURVEY LOG

TIME BEGIN HRS.	MIN.	SEC.	END HRS.	MIN.	SEC.	FREQUENCY BAND A	B	C	D	E	F	G	CAL	Tape No.
15	47	30	16	02	30						X			7
16	03	20	16	18	32						X			
16	19	57	16	26	27							X		
16	27	31	16	32	31	X								
16	33	07	16	38	07		X							
16	38	53	16	42	05			X						7
16	50	18	16	55	20				X					8
16	56	15	17	01	17					X				
17	02	15	Landing											8

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San Francisco

RFI SURVEY LOG

TIME						FREQUENCY BAND								
BEGIN			END											
HRS.	MIN.	SEC.	HRS.	MIN.	SEC.	A	B	C	D	E	F	G	CAL	Tape No.
07	50	T/O	Flight 616											
08	25	02	08	32	01	X								1
08	35	03	08	40	09		X							
08	41	09	08	46	50			X						
08	48	42	08	54	42				X					
08	56	40	09	01	40					X				
09	03	24	09	08	24						X			
09	10	04	09	15	04							X		
09	17	18	09	22	18	X								
09	23	40	09	26	40		X							1
09	37	30	09	40	30		X							2
09	42	04	09	48	04			X						
09	49	36	09	54	36				X					
09	56	05	10	04	30					X				
10	05	50	10	10	50						X			
10	12	40	10	17	40							X		
10	19	21	10	24	21	X								
10	25	46					X							2
10	43	30	10	48	30			X						3
10	50	54	10	55	54				X					
10	57	24	11	02	27					X				3

San Francisco

RFI SURVEY LOG

TIME BEGIN HRS.	MIN.	SEC.	END HRS.	MIN.	SEC.	FREQUENCY BAND A	B	C	D	E	F	G	CAL	Tape No.
11	03	47	11	09	10						X			3
11	10	25	11	15	25							X		
11	16	30	11	22	30	X								
11	23	42	11	29	55		X							
11	55	Landing												
12	50	T/O	Flight 617											
13	02	45	13	08	45			X						
13	09	47	13	15	15				X					3
13	22	40	13	28	00					X				4
13	28	53	13	33	53						X			
13	35	04	13	40	04							X		
13	42	34	13	47	35	X								
13	49	13	13	54	13		X							
13	55	47	14	00	47			X						
14	01	33	14	06	33				X					
14	07	56	14	12	56					X				
14	14	10	14	19	10						X			
14	21	12	14	24	30							X		4
14	31	29	14	37	00	X								5
14	38	14	14	43	14		X							
14	44	35	14	49	35			X						5

San Francisco

RFI SURVEY LOG

TIME BEGIN			TIME END			FREQUENCY BAND								
HRS.	MIN.	SEC.	HRS.	MIN.	SEC.	A	B	C	D	E	F	G	CAL	Tape No.
14	50	55	14	57	38				X					5
14	59	40	15	06	15					X				
15	08	48	15	14	15						X			
15	15	26	15	20	26							X		
15	22	02	15	27	01	X								
15	28	24	15	31	24		X							5
15	39	15	15	42	15		X							6
15	43	35	15	48	35			X						
15	49	42	15	54	42				X					
15	55	51	16	00	53					X				
16	03	16	16	08	16						X			
16	10	20	16	15	37							X		
16	17	11	16	22	11	X								
16	23	29	16	28	29		X							
16	29	50	16	34	50			X						6
16	45	Landing												
17	15	T/O	Flight 618											
17	29	08	17	34	40			X						7
17	36	25	17	42	35				X					
17	44	00	17	52	37					X				
17	54	07	17	59	07						X			7

San Francisco

RFI SURVEY LOG

TIME															
BEGIN			END			FREQUENCY BAND									
HRS.	MIN.	SEC.	HRS.	MIN.	SEC.	A	B	C	D	E	F	G	CAL	Tape No.
18	00	55	18	05	55							X		7
18	07	32	18	11	34	X								
18	12	51	18	17	29		X							
18	21	25				X								7
19	15													

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Los Angeles

RFI SURVEY LOG

TIME														
BEGIN			END			FREQUENCY BAND								
HRS.	MIN.	SEC.	HRS.	MIN.	SEC.	A	B	C	D	E	F	G	CAL	Tape No.
11	08	00	T/O	Flight 619										1
11	28	00	11	43	04	X								
11	46	03	12	01	04		X							
12	05	12	12	11	30			X						1
12	21	37	12	30	45			X						2
12	31	38	12	46	38				X					
12	47	51	12	02	55					X				
13	04	26	13	19	26						X			2
13	26	32	13	41	32							X		3
13	44	00	13	59	00	X								
14	00	26	14	15	05		X							
14	16	43	14	28	40			X						3
14	34	41	14	49	41				X					4
15	11	00	Landing											
15	56	00	T/P	Flight 620										
16	08	18	16	23	45					X				
16	26	26	16	41	26						X			
16	44	12										X		4
16	50	52	17	02	07							X		5
16	04	00	17	19	00	X								
17	20	00	17	35	00		X							5

RFI SURVEY LOG

Los Angeles

TIME BEGIN HRS.	MIN.	SEC.	END HRS.	MIN.	SEC.	FREQUENCY BAND A	B	C	D	E	F	G	CAL	Tape No.
17	36	27	17	51	18			X						5
17	57	-	18	12	11				X					6
18	13	30	18	28	38					X				
18	30	43	18	45	44						X			
18	47	47	18	59	27							X		6
19	07	47	19	17	50	X								7
19	19	13	19	26	09		X							7
20	10													

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San Diego

RFI SURVEY LOG

TIME															
BEGIN			END			FREQUENCY BAND									
HRS.	MIN.	SEC.	HRS.	MIN.	SEC.	A	B	C	D	E	F	G	CAL	Tape No.
07	34	36	T/O	Flight 621										1
07	46	00	08	01	48							X		
08	04	14	08	19	30						X			
08	21	51	08	36	29					X				
08	37	55	08	44	30				X					1
08	51	25	08	58	29				X					2
09	00	02	09	15	01			X						
09	16	22	09	31	20		X							
09	32	28	09	49	25	X								2
09	57	02	10	12	02							X		3
10	13	51	10	33	56						X			
10	34	47	10	50	45					X				
10	52								X					3
11	20		Landing											
12	05	T/O	Flight 622											
			12	31	13				X					4
12	32	50	12	47	50			X						
12	49	10	12	04	16		X							
13	05	30	13	17	15	X								4

San Diego

RFI SURVEY LOG

TIME						FREQUENCY BAND							
BEGIN			END										
HRS.	MIN.	SEC.	HRS.	MIN.	SEC.	A	B	C	D	E	F	G	CAL
13	25	01	13	41	09							X	5
13	42	28	13	57	28						X		
13	58	37	14	12	17					X			5
14	20	20	14	35	20				X				6
14	36	50	14	51	50			X					
14	53	07	15	08	07		X						
15	09	12	15	17	36	X							6
15	23	50	15	29	50	X							7
15	31	48	15	46	50							X	
16	10		Land										7
16	55	T/O	Flight 623										
		Ambient Noise and Post Flight Calibration											
16	52	58	T/O										
	Cal.	A	127.0			X							
			126.2			X							
			127.8			X							
	Cal.	B	129.0				X						
			128.2				X						
			129.8				X						

RFI SURVEY LOG

San Diego

TIME						FREQUENCY BAND							
BEGIN			END										
HRS.	MIN.	SEC.	HRS.	MIN.	SEC.	A	B	C	D	E	F	G	CAL
	Cal.	C	136.0					X					
			135.2					X					
			136.8					X					
	Cal.	D	138.0						X				
			137.2						X				
			138.8						X				
	Low Noise Test												
						X							
							X						
								X					
									X				
										X			
											X		
												X	
	Cal.	E	149.0							X			
			148.2							X			
			149.8							X			
	Cal.	F	151.0								X		
			150.2								X		
			151.8								X		

San Diego

RFI SURVEY LOG

TIME BEGIN HRS.	MIN.	SEC.	END HRS.	MIN.	SEC.	FREQUENCY BAND A	B	C	D	E	F	G	CAL
	Cal.	G	153.0									X	
			152.2									X	
			153.8									X	
	End of tape 8												
19	45												

March 21, 1972

RFI SURVEY LOG

SAN FRANCISCO

TIME						FREQUENCY BAND								
BEGIN			END											
HRS.	MIN.	SEC.	HRS.	MIN.	SEC.	A	B	C	D	E	F	G	CAL	Tape No.
8	15	07	Take Off - Flight 628											1
			08	41	37	X								
08	43	13	08	53	13		X							
08	54	54	09	09	18			X						
09	11	00	09	29	00				X					1
09	37	00	09	52	00					X				2
09	53	29	10	12	30						X			
10	14	47	10	28	30							X		2
10	34	38	10	53	06	X								3
10	55	14	11	10	16		X							
11	11	36	11	29	55			X						3
11	35	45	11	52	01				X					4
12	06		Landing - Monterey											
13	05		Take-off - Flight 629											
13	13	13	13	28	26					X				
13	29	48	13	44	51						X			
13	45	56										X		4
14	04	54	14	20	54	X								5
14	22	46	14	38	01		X							
14	39	15	14	55	35			X						
14	57	33	15	05	03				X					5

March 21, 1972

RFI SURVEY LOG

SAN FRANCISCO

TIME BEGIN HRS.	MIN.	SEC.	END HRS.	MIN.	SEC.	FREQUENCY BAND A	B	C	D	E	F	G	CAL	Tape No.
15	10	52	15	25	51					X				6
15	27	16	15	42	06						X			
15	43	32	15	58	32							X		
16	00	24				X								6
16	20	20	16	25	18	X								7
16	26	36	16	41	36		X							
16	42	55						X						
17	10		Landing - Monterey - Refuel											
17	58		Take Off - Flight 630											
18	09	00	18	23	14				X					
18	24	28	18	28	00					X				7
18	34	32	18	44	37					X				8
18	46	28	18	56	29						X			
18	57	40	19	04	42							X		
	Calibration											X		
19	48	12				X								
20	10		Landing											

March 31, 1972

RFI SURVEY LOG

Los Angeles

TIME						FREQUENCY BAND								
BEGIN			END											
HRS.	MIN.	SEC.	HRS.	MIN.	SEC.	A	B	C	D	E	F	G	CAL	Tape No.
08	05		Take Off - Flight 631											1
08	14	45	08	29	58	X								
08	30	56	08	45	55		X							
08	47	22	09	05	24			X						
09	07	56	09	17	08				X					1
09	22	52	09	28	56				X					2
09	30	36	09	45	37					X				
09	46	50	10	02	12						X			
10	03	41	10	18	42							X		
10	20	59	10	25	37	X								2
10	31	05	10	41	29	X								3
10	42	29	10	57	30		X							
11	00	03	11	17	15			X						
11	18	26	11	31	31				X					3
11	37	58	11	53	05					X				4
			Landing											

RFI SURVEY LOG

San Diego

TIME														
BEGIN			END			FREQUENCY BAND								
HRS.	MIN.	SEC.	HRS.	MIN.	SEC.	A	B	C	D	E	F	G	CAL	Tape No.
12	35		Take Off Flight 632											4
12	47	45	13	05	09						X			
13	06	10	13	21	09							X		
13	23	34	13	31	31	X								4
13	37	13	13	42	11	X								5
13	43	29	14	00	10		X							
14	02	05	14	16	00			X						
14	17	00	14	32	00				X					
14	33	17	14	41	32					X				5
14	48	32	14	54	50					X				6
14	55	55	15	05	52						X			
15	06	51	15	21	51							X		
15	23	30	15	38	31	X								
15	40	39	15	50	40		X							6
15	56	28	16	01	28		X							7
16	02	34	16	12	31			X						
16	14	09	16	23	14				X					
16	25	54	16	29	47					X				
16	45		Landing											7