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FINAL REPORT

Project No. 330-011-03X

EVALUATION OF PROTOTYPE DOPPLER VOR SIDEBAND ANTENNA MONITOR

JUNE 1969

DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
National Aviation Facilities Experimental Center
Atlantic City, New Jersey 08405

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Prepared by:
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for

SYSTEMS RESEARCH AND DEVELOPMENT SERVICE

June 1969

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DEPARTMENT OF TRANSPORTATION
Federal Aviation Administration
National Aviation Facilities Experimental Center
Atlantic City, New Jersey 08405

ABSTRACT

This report presents the results of evaluation tests of a prototype Doppler VOR sideband antenna monitor. The monitor utilizes a bandpass spectrum analysis technique, as recommended in report No. RD-66-49, for the detection of a faulty sideband antenna. The ability to detect a sideband antenna fault deletes the requirement of two of the three VOR monitors presently used in the monitoring of a Doppler VOR navigational facility.

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INTRODUCTION

Purpose

The purpose of this project was to evaluate a prototype Doppler VOR sideband antenna monitor utilizing a spectrum analysis technique to determine whether this monitoring technique would meet the Doppler VOR system monitoring requirements of providing increased reliability and economics over the present method of monitoring the system signal performance along three selected radials.

Background

The conventional VOR monitor provides an alarm when:

1. the indicated bearing at the monitor position changes by a predetermined amount,

2. a change occurs in the modulation levels of the reference, variable or the 1020-cycle identification signals,

3. a change in the radiated carrier power level occurs, and

4. the monitor fails.

A Doppler VOR monitor must meet the above criteria plus the ability to monitor course-alignment as a function of the performance of each of the sideband antennas.

A failure of one sideband antenna affects only the course-alignment within a narrow sector. To provide monitoring of course-alignment for the 360° of azimuth it is necessary to use three monitors with their respective detectors placed 120° apart in azimuth. This is costly not only for the initial equipment, but also in the maintenance aspects. Installation and Material Services requested that a single monitor system be developed.

A Systems Research and Development Service (SRDS) contract was awarded for the development of a Doppler VOR system which included a single monitor requirement. The monitor, however, did not meet requirements because:

1. it was not fail-safe since some of the circuits of the monitor could develop faults without an alarm indication,

2. a shorted or open antenna did not always actuate the alarm, and

3. monitor adjustments were too critical for long-term unattended operation.

In-house efforts to complete the development of the contractor's feasibility monitor indicated that a new approach to the technique of detecting a faulty sideband antenna was necessary.

To provide the function of sideband antenna monitoring, without the use of two additional VOR monitors, sideband antenna fault detection capability could be added to the standard monitor. This capability could be in the form of an "add-on" unit to a standard VOR monitor. In-house effort to develop an add-on unit to the standard VOR monitor resulted in an ingenuous approach, completely new in concept, to the detecting of a faulty sideband antenna. This new concept of monitoring the sideband antenna is described in, "Experiment with Doppler VOR Monitors," report No. RD-66-49.[1]

Since this concept had not yet been proven, evaluation would be required before it could be installed in the Federal Airways System. Therefore, SRDS issued Engineering Requirement FAA-ER-330-004 for the production of a prototype sideband antenna monitor based on the circuit objectives and functions set forth in report No. RD-66-49. Contract FA-66-WA-1489 was awarded to Chain Lakes Research Associates, Incorporated, of Detroit, Michigan, for the production and delivery of two prototype units for evaluation.

The contractor, of its own volition, provided a separate circuit card for evaluation which would convert the delivered prototype unit to an alternate configuration. This alternate configuration utilized the same basic concept of the spectrum analysis technique for monitoring the sideband antennas. The only change in the alternate configuration was the method of generation of the signals for the "self-check" function. For the purpose of this report the configuration using this separate circuit card (1A) is referred to as the alternate configuration.

---

[1] Willey, V. E., "Experiment with Doppler VOR Monitors," Final Report, RD-66-49, Project No. 330-004-04X, dated October 1966. Available from Federal Clearinghouse for Scientific and Technical Information, AD-644962.

DISCUSSION

General

The Doppler VOR sideband antenna monitor requires 8-1/2 inches of vertical panel space in the standard 19-inch equipment rack.

The monitor requires for operation a power source of 60 Hz current (either 115 V or 230 V)connection to the normal course alarm circuitry of the conventional course deviation monitor, and auxiliary connections to the VOR monitor test generator. The RF source for the monitor, as delivered, is obtained from a separate antenna. Improvements to the monitor have been made which delete the antenna requirement and change the input circuitry. The details of these changes are given under Modifications, page 18.

An alarm bypass switch has been provided for use in the maintenance of the monitor. An alarm bypass indicator light will serve to remind the maintenance technician that the monitor alarm is not in normal monitoring function. Two complete monitor units are mounted in the panel. Either of which will provide full sideband antenna monitoring while the other unit is in a maintenance or standby status.

Solid-state circuitry is used throughout the monitor. This facilitates the use of plug-in circuit boards. With the exception of the power supplies, front panel controls, and circuitry, plug-in circuit boards are used. Figures 1 through 4 are photographic views of the monitor.

Basic Principles

The concept and basic theory of the spectrum analysis techniques of monitoring the sideband antenna are given in report No. RD-66-49. Briefly, a defective antenna produces a "notch" in the 9960 Hz radiation pattern. This notch represents an interruption or discontinuity of time; therefore, the signal is rich in harmonics. Thus, the function of the monitor must be to examine the 9960 Hz sideband energy for spectral purity.

In addition to sensing spectral impurity of the 9960 Hz energy, the monitor must generate a self-checking or "monitor-monitor"

FIG. 1 SIDEBAND MONITOR

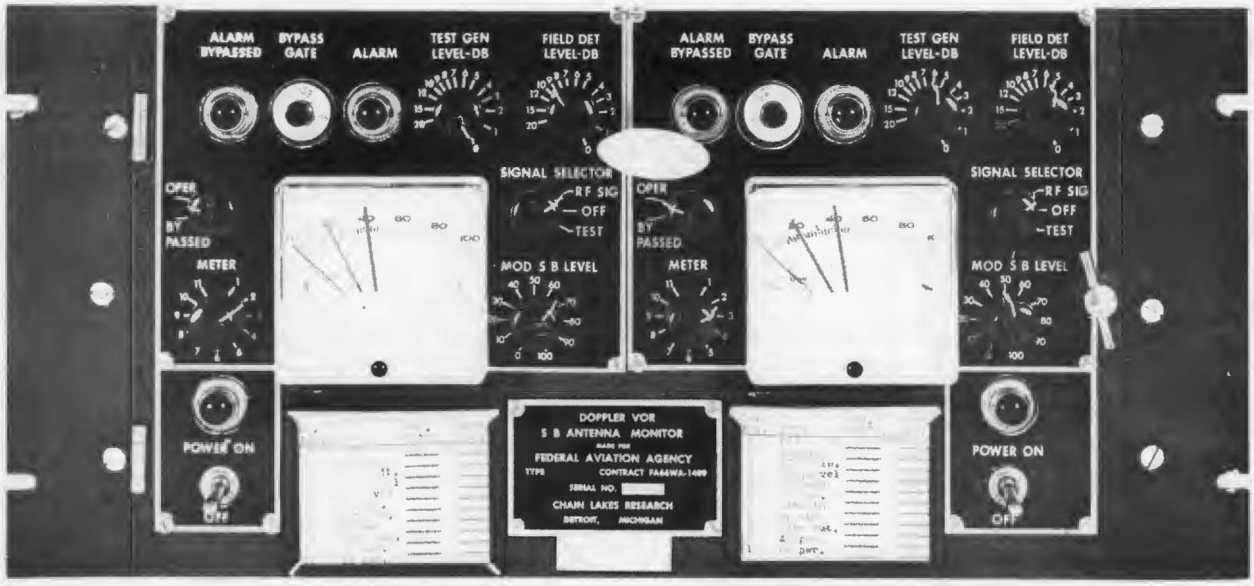


FIG. 2 SIDEBAND MONITOR FRONT PANEL VIEW

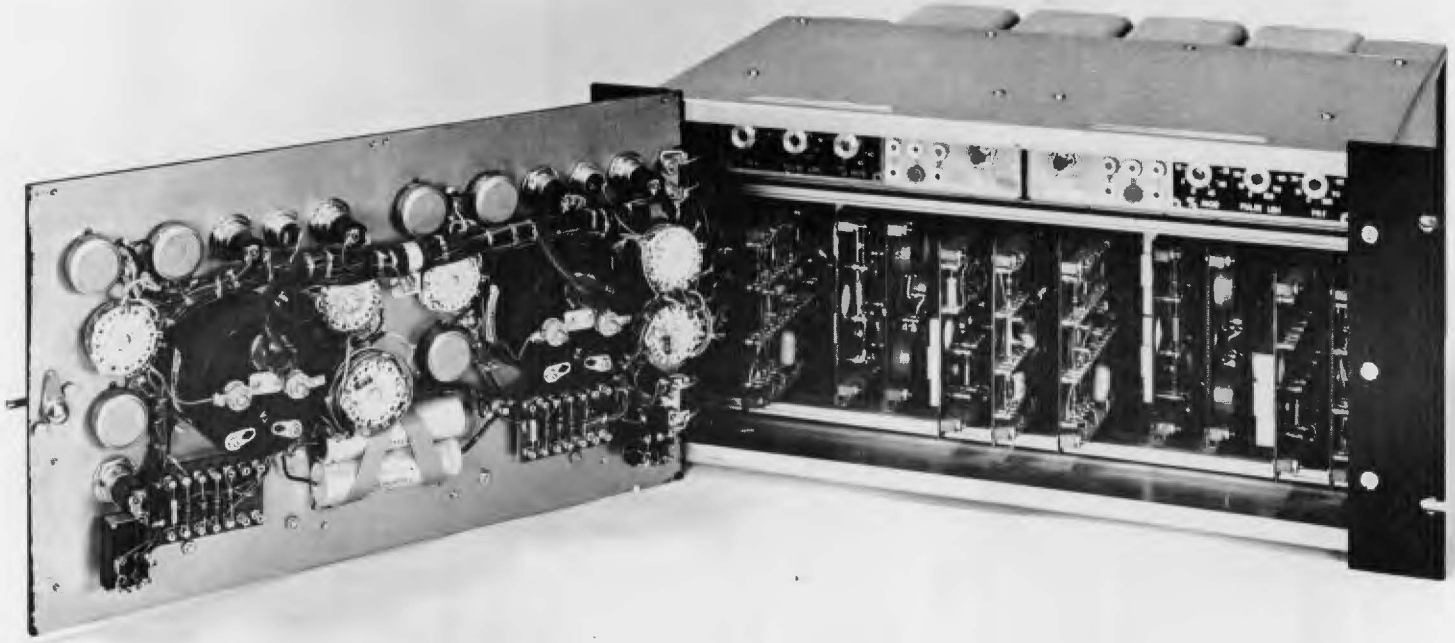
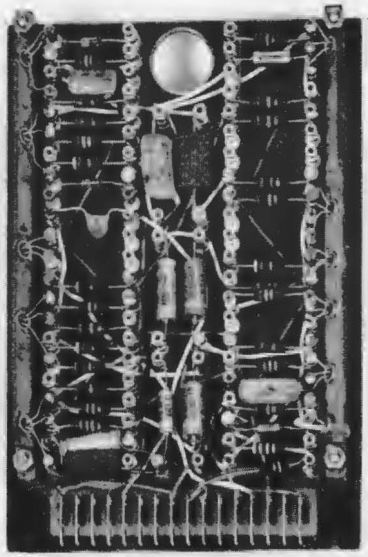
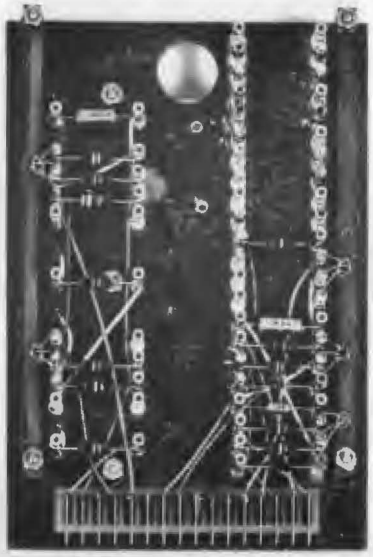


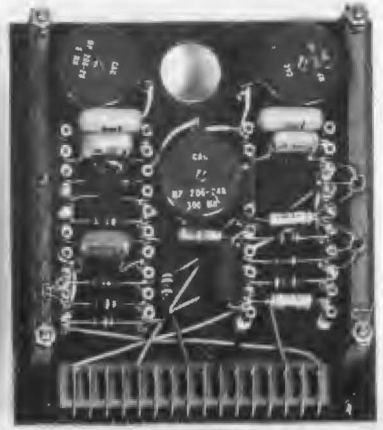
FIG. 3 SIDEBAND MONITOR INSIDE VIEW



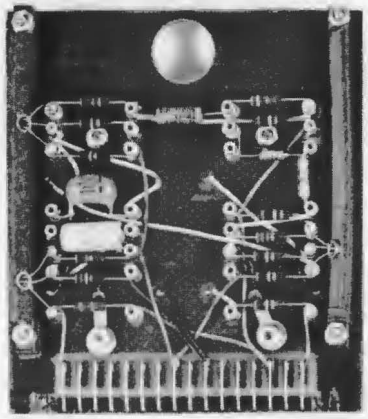
CIRCUIT BOARD #1



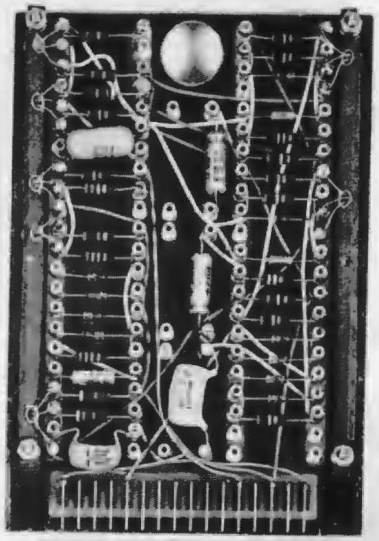
CIRCUIT BOARD #2



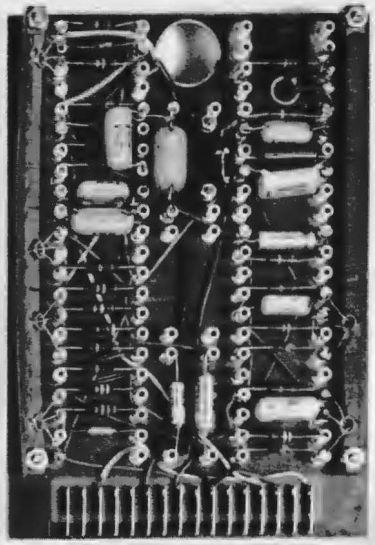
CIRCUIT BOARD #3



CIRCUIT BOARD #4



CIRCUIT BOARD #5



ALTERNATE 1A

FIG. 4 CIRCUIT BOARDS

function internally, will serve the purpose of qualifying the normal monitor signal channel by providing bias for the alarm output signal. Thus, the absence or significant reduction of the sideband signal will also produce an alarm, as would failure of the monitor circuitry. A functional block diagram is given in figure 5, the circuit details of which are given in the schematics of the monitor. In operation, the RF energy is obtained from a sampling antenna located above the carrier antenna of the Doppler VOR antenna array and is fed via a coaxial cable to the detector circuit of the monitor. The 9960 Hz sideband signal, obtained from the detector, is amplified and divided into three parallel signal paths which, when recombined, provide the monitor-monitor or self-check function in addition to passing the normal 9960 Hz signal.

Path No. 1 is a straight-through path from the output of the amplifier to the modulation percentage control.

Path No. 2 is from the output of the amplifier to a 30 Hz filter to recover the 30 Hz AM envelope which is used to drive a harmonic generator. The spectrum of the harmonic generator is filtered to derive a 200 to 600 Hz spectrum which is applied to the modulator stage to produce the signals for the "self-monitoring" function.

In path No. 3, the 9960 Hz signal is passed through a controllable gate to control the duty cycle of the self-monitoring function.

The gate signal (output of the RF detector) is modulated by the locally produced signals (200 to 600 Hz) in a modulator circuitry and applied to a 9960 Hz sideband filter to exclude all but the desired spectrum components. The filtered output is then detected and applied to a 200 to 600 Hz filter, the output of which is rectified and becomes the operating current of the optical meter/relay.

The optical meter/relay has adjustable high and low set points which will de-energize the alarm relay when the meter reading falls outside the value for which they are set. Fail-safe operation is obtained since the optical meter/relay is energized under normal operating conditions.

If a fault should occur in the sideband antenna system, the 200 to 600 Hz components generated will add to those produced by the

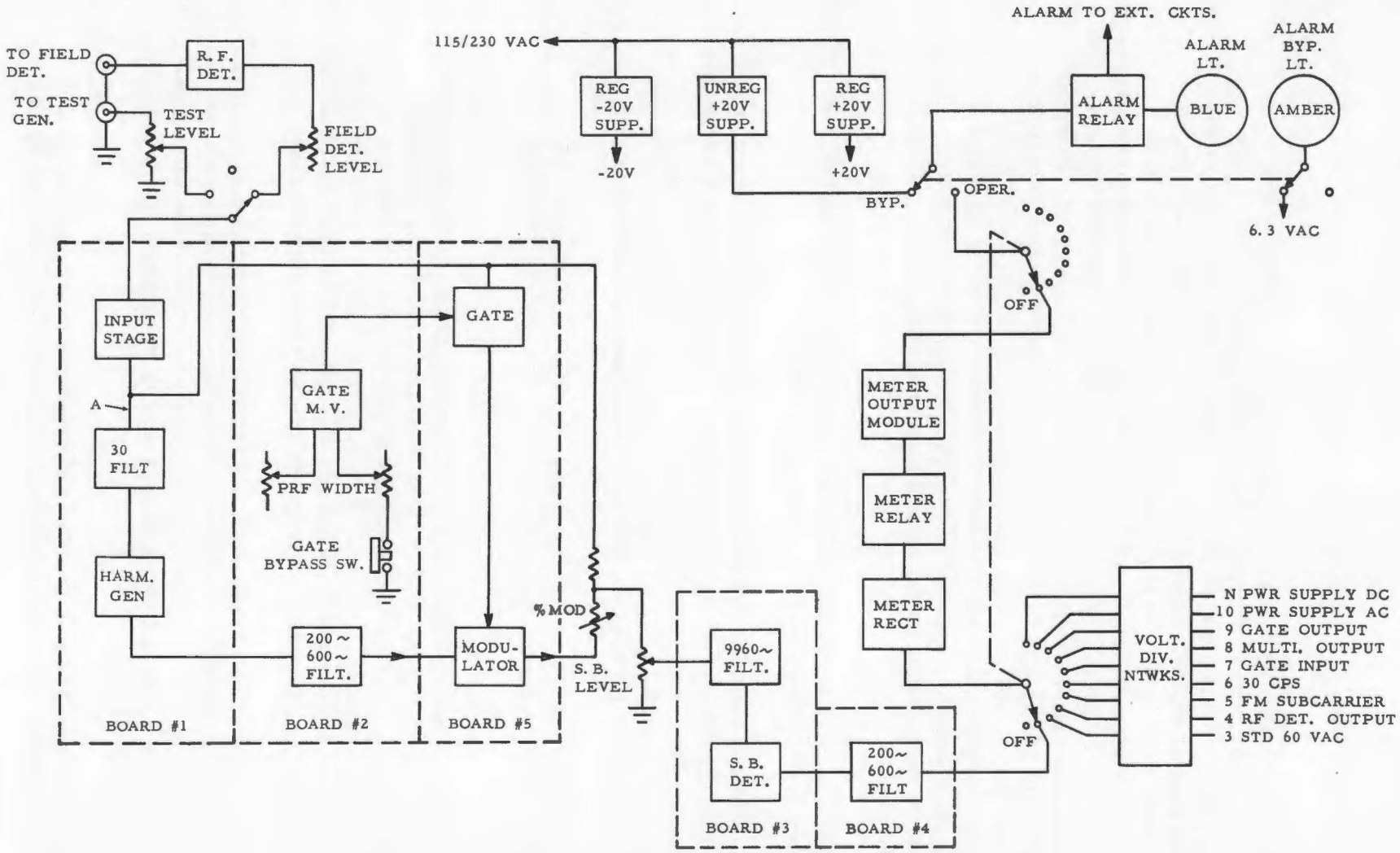


FIG. 5 BLOCK DIAGRAM OF MONITOR

self-monitoring circuitry, increasing the dc applied to the optical meter/relay, causing an increase in the meter indication above the pre-set value, resulting in an alarm. Should a fault occur in the monitor circuitry, there will be a decrease in the signal applied to the rectifier and dc through the optical meter/relay resulting in a decrease in the meter indication to a lower value then the pre-set low alarm value resulting in an alarm.

The Alternate Configuration

Figure 6 is a functional block diagram of the alternate configuration. The alternate configuration makes use of the same basic concept and principles specified in FAA-ER-330-004 and report No. RD-66-49, and for the most part, the same circuitry. The only change is the method of generating the signals for the self-monitoring function.

Instead of generating the harmonic signals and periodically modulating the normal 9960 Hz sideband signal from the RF detector, the alternate scheme simulates an antenna failure. This is accomplished by periodically chopping notches of decreased amplitude in the 9960 Hz sideband signal by interrupting a portion of the 9960 Hz signal with a diode gate controlled by a monostable multivibrator. This interruption of the 9960 Hz sideband signal produces the same harmonic spectrum as that produced by a faulty antenna and as specified in FAA-ER-330-004. The interrupted portion of the 9960 Hz signal, when summed with an appropriately weighed straight-through portion of the 9960 Hz sideband signal, and then detected, will produce a meter bias whose magnitude may be adjusted by varying the amplitude of the interrupted portion of the 9960 Hz sideband signal or varying the pulse repetition rate or the pulse-width of the gating multivibrator.

Referring to the block diagram in figure 6 and the schematic in figure 13, the incoming signal is amplified to the proper level, and a portion of the amplified signal is interrupted in the gate driven by the gating multivibrator at the frequency determined by the trigger generator which normally is set at approximately 30 pulses per second (pps). The chopped signal is adjusted by the percent modulation control and summed with the straight-through portion of the sideband signal at the input to the modulated sideband amplifier control. From this point, the configuration and operation are as specified in FAA-ER-330-004.

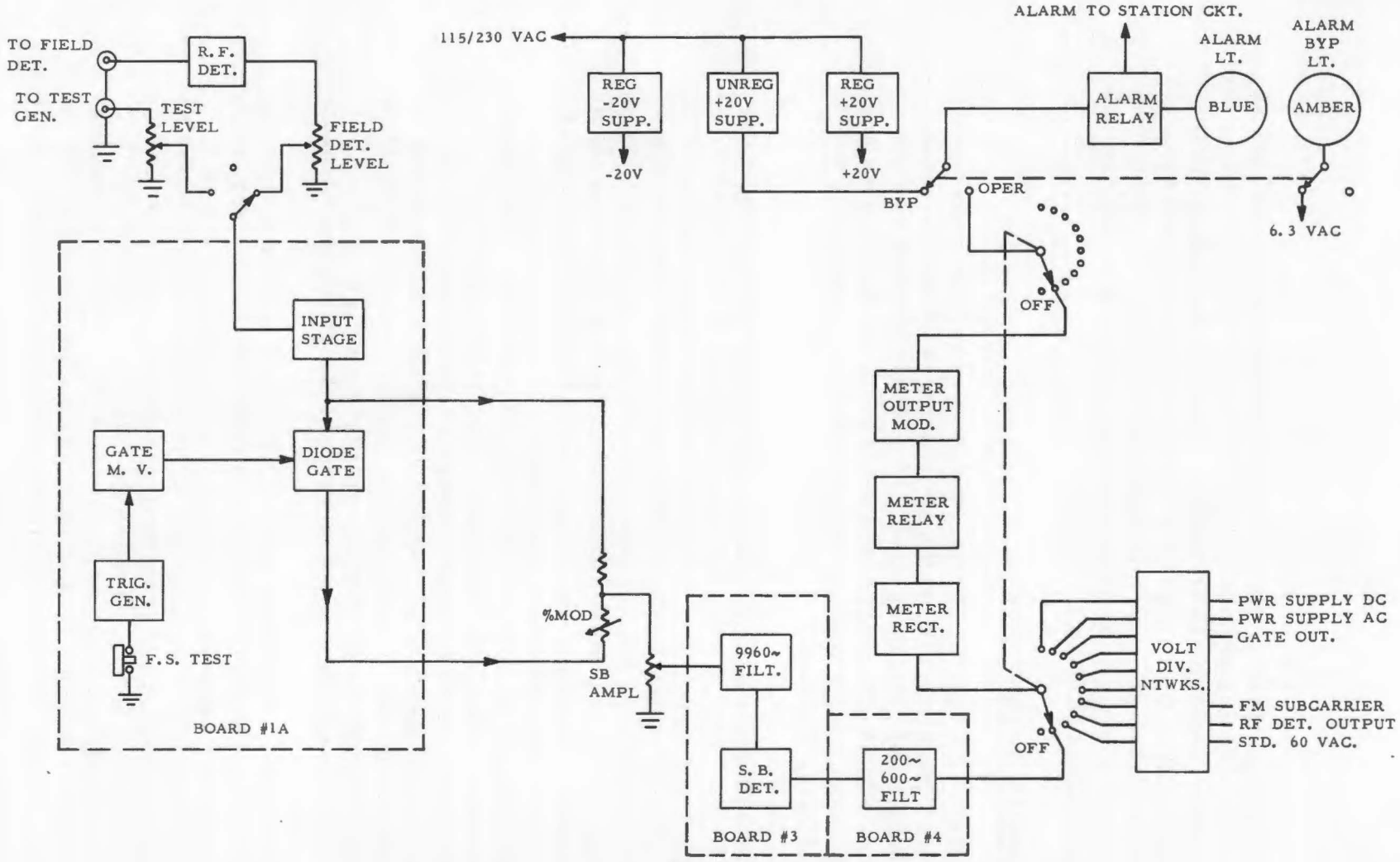


FIG. 6 BLOCK DIAGRAM OF MONITOR WITH ALTERNATE CONFIGURATION

Upon receipt of the prototype monitor, serial No. 1 was installed at the NAFEC Doppler VOR No. 1 (DVOR) facility for tests and evaluation of the monitor performance in the Doppler VOR System. The monitor, containing dual units, facilitated the installation of the alternate circuit board in one of the units, making possible direct comparison of the monitor performance with two methods of self-check circuitry. The conversion of the monitor to the alternate configuration was accomplished by replacing circuit board No. 1 with circuit board No. 1A and removal of circuit boards Nos. 2 and 5.

A standard VOR loop antenna was temporarily mounted above the Doppler VOR carrier antenna to sample the 9960 Hz sideband energy. It was mounted in a manner which would easily permit quick adjustment of its height above the carrier antenna, for determination of the proper spacing between the monitor antenna and carrier antenna for optimum monitor performance and the minimum effect to the 9960 Hz radiation pattern. It was anticipated that some degradation of the course-structure could possibly occur in using a standard VOR antenna for a monitor antenna, due to its large mass, creating reflections and re-radiation; however, the problem was not considered insurmountable.

The monitor antenna height was varied in 1-foot increments above the carrier antenna and the effect noted on the indicated azimuth of three conventional VOR course monitors with their respective detectors placed at different azimuths, one located at a distance of 500 feet and the other two at a distance of 200 feet from the facility.

Additional tests were made using 10 VOR navigation receivers located at a distance of approximately 200 feet from the facility. A common antenna with a height of 65 feet and a broadband amplifier with a distribution and matching pad was used to supply signals to the input of the 10 VOR receivers. The course deviation indicator (CDI) action was recorded as the monitor antenna height above the carrier antenna was varied. The results of the tests are tabulated in figures 7 and 8 for the 3 monitors, and in figures 9 and 10 for the 10 VOR receivers.

When the monitor antenna was placed at the height above the carrier antenna which would minimize the effects of the presence of the monitor antenna to the course alignment, there was insufficient energy to provide the detector of the prototype monitor with the proper signal level to function as designed. This problem was solved by modifying the detector circuit. The 50-ohm antenna load (input to the diode detector) was replaced with a tuned circuit.

SINGLE SIDEBAND DVOR SYSTEM
WITH 4-LOOP CARRIER ANTENNA

DETECTOR ANT. HEIGHT ABOVE CARRIER ARRAY IN FEET	MONITOR-INDICATED AZIMUTH CHANGE		
	200' DISTANCE 0° AZIMUTH	200' DISTANCE 120° AZIMUTH	500' DISTANCE 270° AZIMUTH
2'	+2.35	-0.05	-0.75
3'	+2.40	-0.03	-0.75
4'	+2.35	-0.45	-0.75
5'	+1.95	-0.4	-0.6
6'	+1.65	-0.55	-0.55
7'	+1.50	-0.65	-0.4
8'	+1.50	-0.75	-0.35
9'	+1.40	-0.5	-0.4
10'	+0.35	-0.5	-0.45
11'	0.0	-0.6	-0.4
WITH SINGLE-LOOP CARRIER ANTENNA			
2'	+0.25	+0.30	-1.4
3'	+0.35	+0.10	-1.7
4'	+0.45	+0.15	-1.6
5'	+0.25	0	-1.45
6'	+0.4	+0.05	-1.6
7'	+0.25	-0.10	-1.4
8'	+0.15	-0.10	-1.25
9'	+0.05	+0.03	-1.25
10'	+0.05	+0.05	-1.25
11'	+0.05	+0.05	-1.25

FIG. 7 MONITOR INDICATED AZIMUTH CHANGE VERSUS DETECTOR ANTENNA HEIGHT

DOUBLE SIDEBAND DVOR SYSTEM
WITH 4-LOOP CARRIER ANTENNA

DETECTOR ANT. HEIGHT ABOVE CARRIER ANT. IN FEET	200' DISTANCE 0° AZIMUTH	200' DISTANCE 120° AZIMUTH	500' DISTANCE 270° AZIMUTH
2	+0.2	+0.3	+0.05
3	+0.1	+0.3	0
4	+0.3	0	+0.05
5	+0.3	-0.05	+0.2
6	0	-0.05	+0.1
7	0	-0.02	+0.05
8	0	0	+0.05
9	0	-0.05	+0.05
10	0	-0.05	+0.05
11	0	-0.05	+0.05
	WITH SINGLE-LOOP CARRIER		
2	+0.45	+0.4	+0.1
3	+0.4	+0.05	-0.15
4	-0.25	0	-0.1
5	-0.35	-0.05	-0.1
6	-0.4	-0.05	-0.1
7	-0.38	0	-0.1
8	-0.05	-0.05	-0.1
9	-0.1	-0.1	-0.1
10	-0.1	-0.1	-0.1
11	0	-0.1	-0.1

FIG. 8 MONITOR INDICATED AZIMUTH CHANGE VERSUS DETECTOR ANTENNA HEIGHT

SINGLE SIDEBAND DVOR SYSTEM

DET. ANT. HEIGHT ABOVE CARRIER ANT. IN FEET	RECEIVER TYPE									
	A	B	C	D	E	F	G	H	I	J
WITH 4-LOOP CARRIER ANTENNA										
2	-.45	0	0	.05	0	-.1	-.2	-.1	-.1	0
3	-.35	0	.05	.08	0	-.1	-.15	-.1	-.1	0
4	-.3	-.05	0	.02	.09	-.2	-.1	-.1	-.1	0
5	-.3	-.1	0	0	0	-.2	-.1	-.1	-.1	0
6	-.25	0	.03	0	.05	-.1	-.05	-.05	-.05	0
7	0	0	.06	.25	.05	0	0	.06	0	0
8	0	0	0	.25	0	0	0	.05	-.2	0
9	-.15	-.1	0	.25	0	0	0	0	-.2	0
10	-.2	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0
WITH SINGLE-LOOP CARRIER										
2	.1	.25	-.1	.2	.3	.45	.3	.3	.45	.3
3	0	.1	.08	.45	0	.25	.07	.07	.15	.05
4	0	.13	.05	.4	0	.15	.06	.07	.1	.05
5	0	.1	0	.3	0	.25	.05	.06	.08	.05
6	.05	.08	0	.3	0	.2	.05	.05	.08	.05
7	.05	0	.05	.4	0	.0	.05	.05	.05	0
8	.08	.06	0	.08	0	.08	.05	0	.05	0
9	.05	.15	0	.05	0	.08	.05	0	.05	0
10	0	.2	0	0	0	.05	.05	0	0	0
11	0	0	0	0	0	0	0	0	0	0

FIG. 9 MONITOR HEIGHT VERSUS INDICATED COURSE DISPLACEMENT OF TEN RECEIVERS

DOUBLE SIDEBAND SYSTEM

DET. ANT. HEIGHT ABOVE CARRIER ANT. IN FEET	RECEIVER TYPE									
	A	B	C	D	E	F	G	H	I	J
WITH 4-LOOP CARRIER ANTENNA										
2	0	.05	0	0	.08	-.05	-.2	0	0	-.1
3	.1	0	.02	0	.05	0	-.15	0	.1	-.05
4	0	0	.02	0	0	0	-.2	0	.1	-.1
5	.15	-1	0	-.05	.05	0	-.2	-.05	.1	0
6	0	.05	0	0	0	0	-.2	-.05	0	-.1
7	0	.05	.1	.05	.05	0	.05	.05	0	0
8	0	.09	.1	.05	.05	0	.05	0	.1	0
9	0	.05	0	0	0	0	.05	0	.05	-.05
10	.05	0	0	0	0	0	0	0	0	-.05
11	0	0	0	0	0	0	0	0	0	0
WITH SINGLE-LOOP CARRIER										
2	.45	.45	.25		.15	.25	.45	.5	.4	.3
3	.05	.25	0		.05	.05	.2	.2	0	.05
4	.25	.25	.05		0	0	.2	.1	0	0
5	.15	.15	0		0	0	.2	.2	0	0
6	0	.08	.05		0	0	.2	.2	0	0
7	0	.05	0		0	0	.08	.06	0	0
8	0	0	0		0	0	.05	.05	0	0
9	0	0	0		0	0	0	.05	0	0
10	0	0	0		0	0	0	0	0	0
11	0	0	0		0	0	0	0	0	0

FIG. 10 MONITOR ANTENNA HEIGHT VERSUS INDICATED COURSE DISPLACEMENT OF TEN RECEIVERS

Observation of an oscilloscope display of the 9960 Hz pattern from the far field monitor disclosed some flattening of the forward "bump," and aberration in the pattern. This is illustrated in the photograph given in figure 11.

While the results of the monitor tests and the 10 receiver tests, described above, indicated only a small change in the course alignment at ground level due to the presence of the monitor antenna, experience with the Doppler VOR System has shown that the change would be somewhat greater at flight altitudes. The major effects of the aberration in the 9960 Hz pattern would be on the compatibility of the various types of navigational receivers. It appeared that a special monitor antenna, with less mass than the standard VOR loop antenna, would have to be developed.

In discussing these problems with Navigation Development Division (RD-300) personnel, it was suggested that the necessary signals for the sideband monitor could possibly be obtained from within the Doppler VOR System; i. e., at the input of the distributor. If this could be achieved, it would save

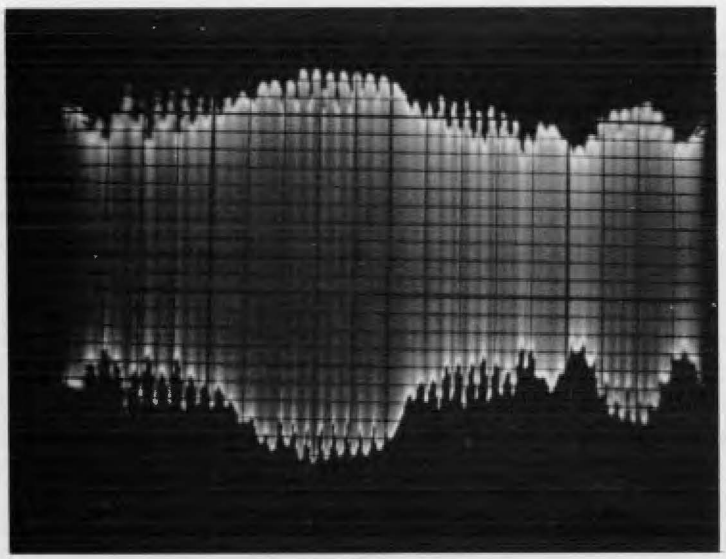
1. the cost of development of a special monitor antenna;

2. the NAFEC effort in working out necessary mounting and installation details of the monitor antenna for each of the Doppler VOR configurations, such as single carrier antenna, four-loop carrier system, the addition of DME to the system, and housing to provide weather protection;

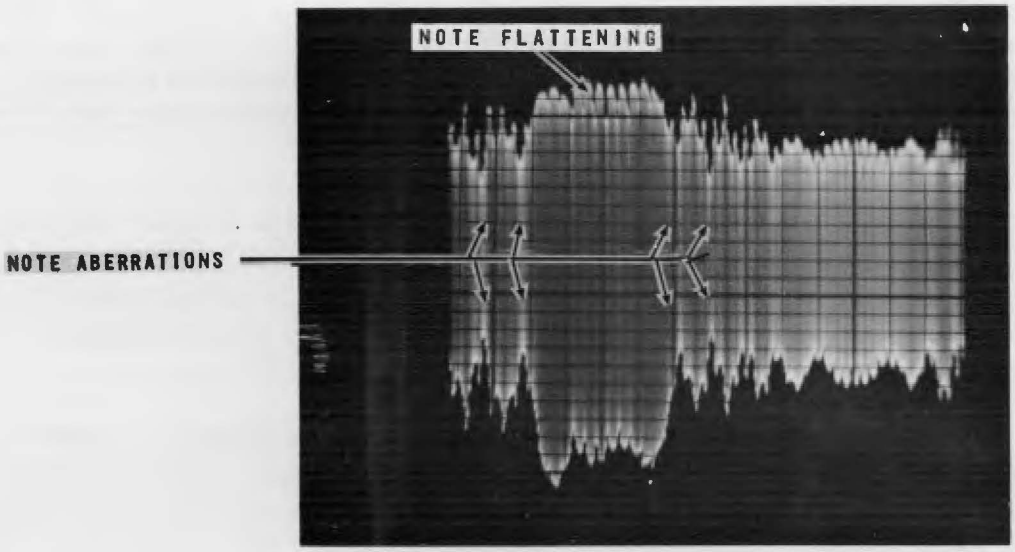
3. cost of tailoring, mounting, installation, and modification to existing structures, and future Doppler VOR facilities to accommodate the monitor antenna; and

4. reduction of the Doppler VOR outage time from an estimated minimum of 8 hours to 1 hour for installation of the monitor at existing facilities.

A quick test indicated that with some modifications to the monitor and to the Doppler VOR System, the monitor could be made to function with a signal source from within the Doppler VOR System.



NORMAL



ANTENNA MOUNTED ABOVE CARRIER ARRAY

FIG. 11 PHOTOGRAPHS OF THE 9960 Hz FROM THE COURSE MONITOR SHOWING THE EFFECTS OF THE MONITOR ANTENNA TO THE RADIATED SIGNAL

Modifications

The sideband monitor in its function examines the 9960 Hz sideband signal for spectral purity. Any disturbance in the 9960 Hz produces an alarm. When a sampling antenna is used as the signal source for the monitor it is necessary to provide a demodulator to obtain the 9960 Hz signal.

To obtain the 9960 Hz signals for the monitor from within the Doppler VOR System, it is necessary to replace the demodulator circuitry of the monitor with a mixer circuit (see figure 12). A sample of the carrier (Fc) and a sample of the sideband (Fc + 9960 Hz) energy is supplied to a mixer circuit to obtain the 9960 Hz signal for the monitor.

The point and method in the Doppler VOR System at which the sample of the sideband energy is obtained is most important. In both the single sideband and double sideband Doppler VOR System, the sample of the sideband energy for the mixer is obtained from a directional coupler installed immediately preceding the input matching network of the distributor as shown in figure 12. The directional coupler is installed in a manner which provides, at its output port, maximum attenuation to the forward energy being supplied to the distributor, and minimum attenuation to the reflected energy.

The sample of the carrier energy can be obtained from any convenient point in the Doppler VOR System. Preferably, the carrier energy should be free of modulation.

In the tests of the monitor performance in the single sideband Doppler VOR System, the carrier sample was obtained from the goniometer output of the modulation eliminator, making use of a quarter-wave power divider as an attenuator for proper signal level.

In the double sideband high level modulation Doppler VOR System, the carrier sample could not be obtained from the modulation eliminator of the automatic frequency control (AFC) circuitry because there was insufficient power available. The output of the driver stage of the carrier transmitter provided a convenient point to obtain a carrier sample for the mixer. This point in the system was used for the monitor tests in the double sideband system. Again, a quarter-wave power divider was used as an attenuator to obtain the proper signal level.

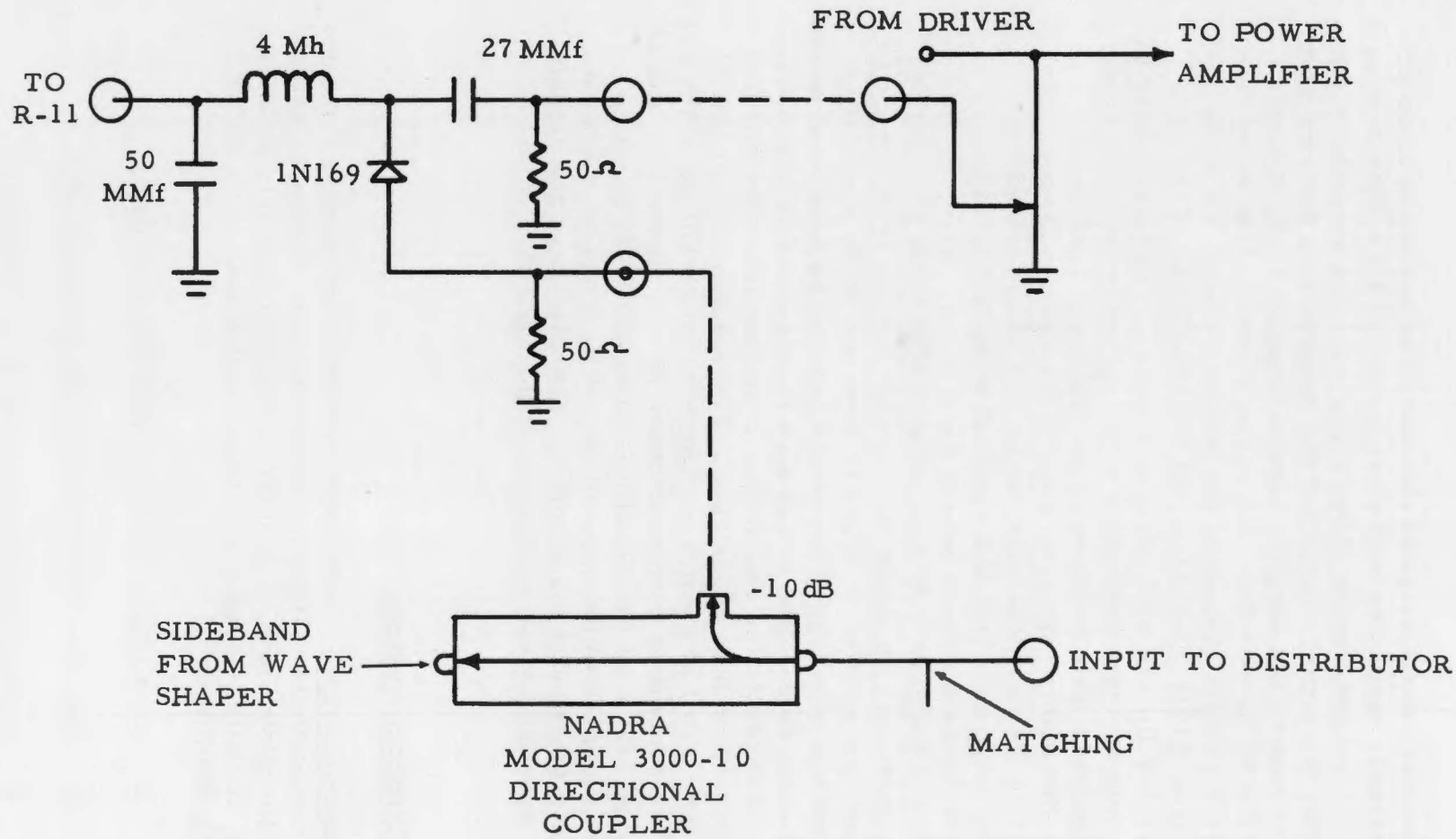


FIG. 12 MIXER CIRCUIT AND DIRECTIONAL COUPLER INSTALLATION DETAILS

The monitor, in its original circuitry and operating from a detector antenna, made use of the recovered 30 Hz modulation as a time-base for the generation of the signals for the self-check circuitry. When the signal source for the monitor was derived from within the system of the single sideband Doppler VOR, the only source for the 30 Hz was from the residual modulation appearing on the carrier sample applied to the mixer circuit. To make use of this residual 30 Hz modulation for the time-base of the harmonic generator for the self-check circuitry, it was necessary to use a minimum of approximately 2 watts of power from the modulation eliminator. This represents an additional load to the modulation eliminator, and also adds to the system losses. In addition, while the residual modulation was within tolerance, there was no assurance that the residual modulation for all Doppler VOR facilities would have a fixed value. Also, in the double sideband Doppler VOR System with high level modulation, it would be necessary to obtain the carrier sample from the output of the carrier transmitter in order to have the 30 Hz modulation necessary for the monitor. This would present an additional problem in that voice modulation would also be present at a high level. Therefore, to expedite the evaluation of the monitor, the monitor was modified rather than redesigned. The modification required opening of the circuit at point A in figure 5 (the details of which are covered in the schematic of circuit board No. 1, figure 13), and at point B (figure 13), a 30 Hz signal was provided from an audio oscillator and applied to the input of the 30 Hz filter to energize the self-check function of the monitor. Schematics of the circuit boards and panel are given in figures 13 through 19.

Tests

Single Sideband System:

Mixer Circuit - Tests were conducted by varying the ratio of the sideband sample voltage to carrier sample voltage to determine the ratio of sideband to carrier voltage which would produce the greatest dc voltage across the alarm meter terminals under the following conditions:

1. short placed across one of the antennas,
2. open feed line to one of the antennas, and
3. 50-ohm shunt across one of the antennas.

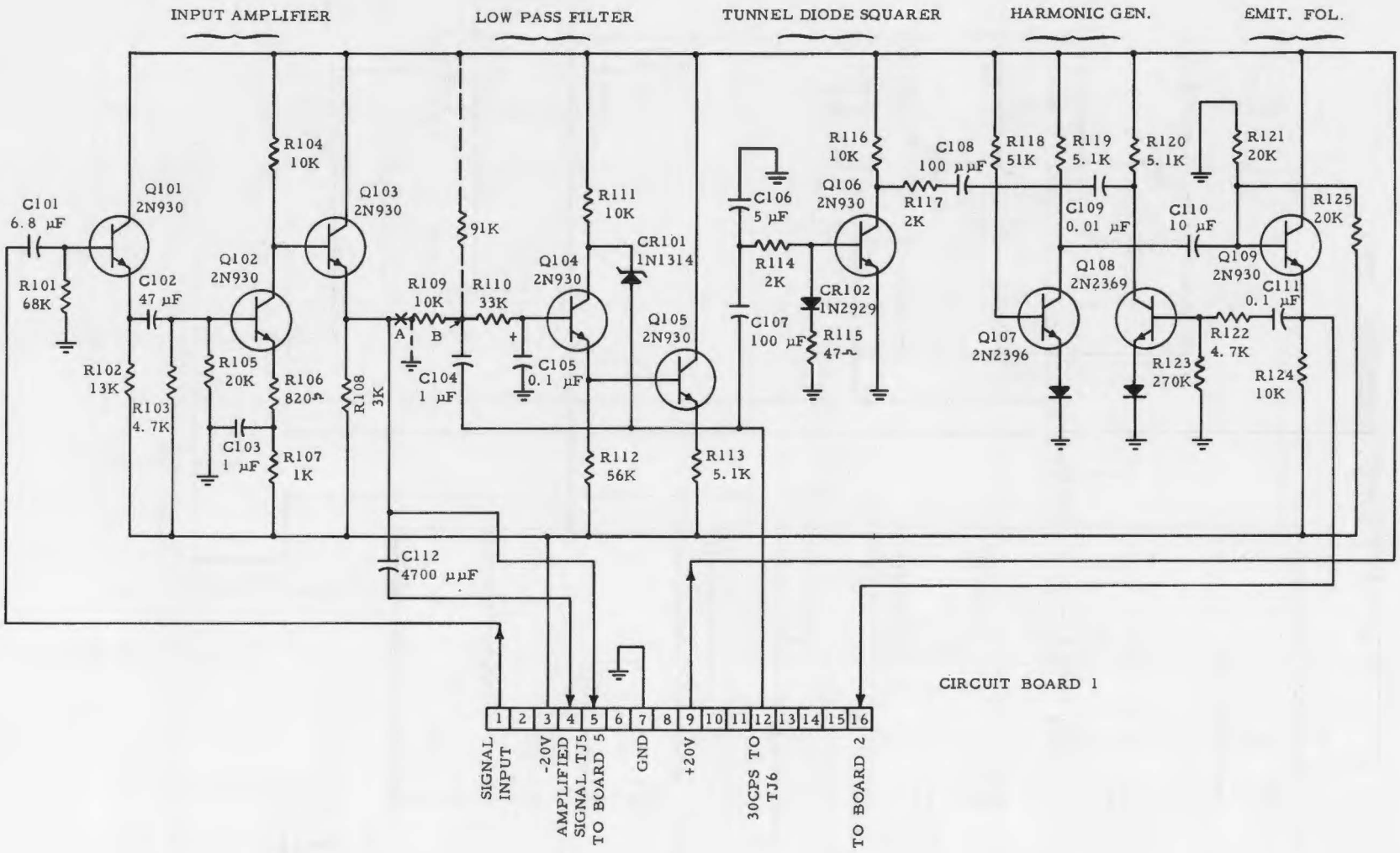


FIG. 13 SCHEMATIC OF CIRCUIT BOARD NO. 1

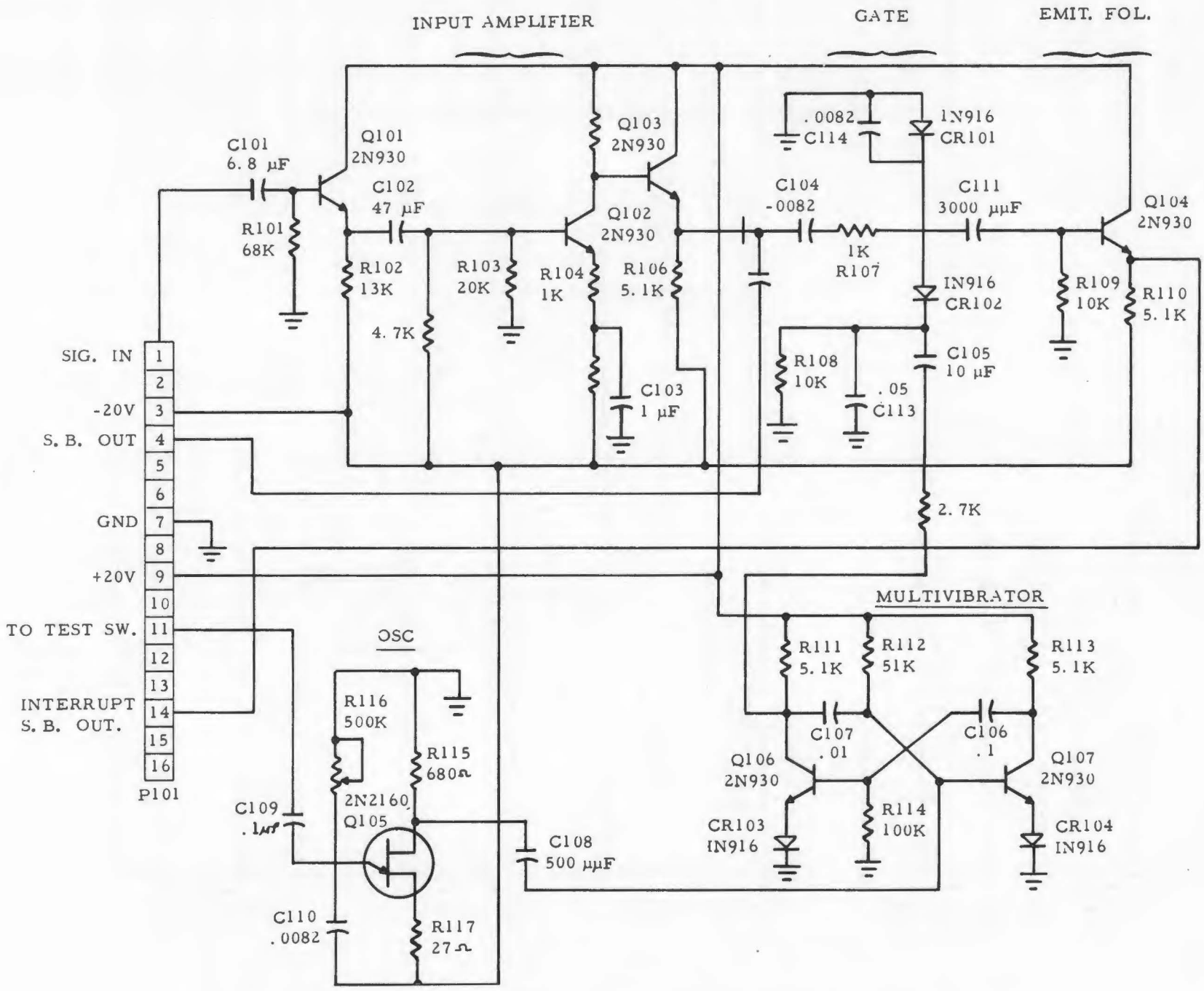


FIG. 14 SCHEMATIC OF ALTERNATE CIRCUIT BOARD NO. 1A

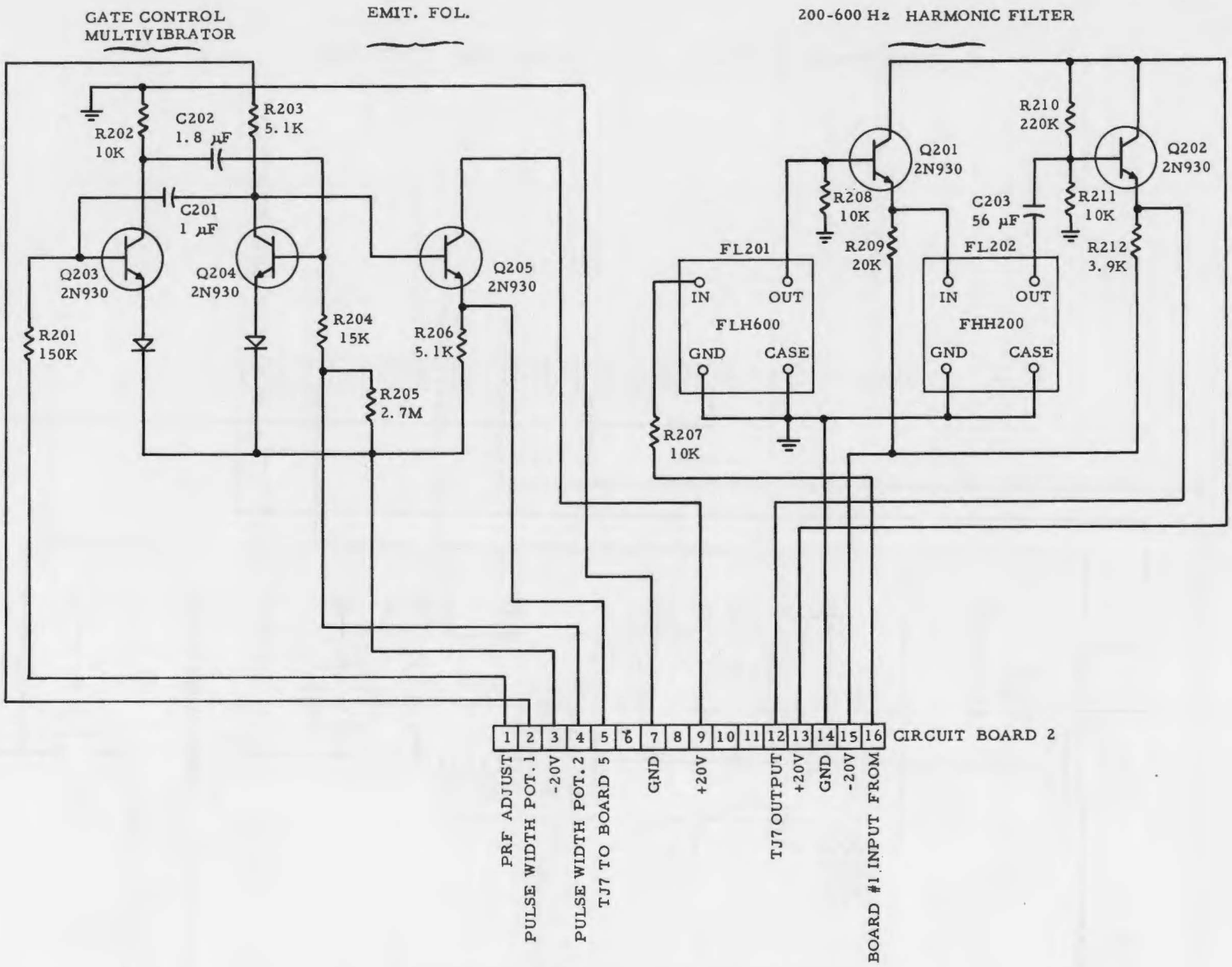


FIG. 15 SCHEMATIC OF CIRCUIT BOARD NO. 2

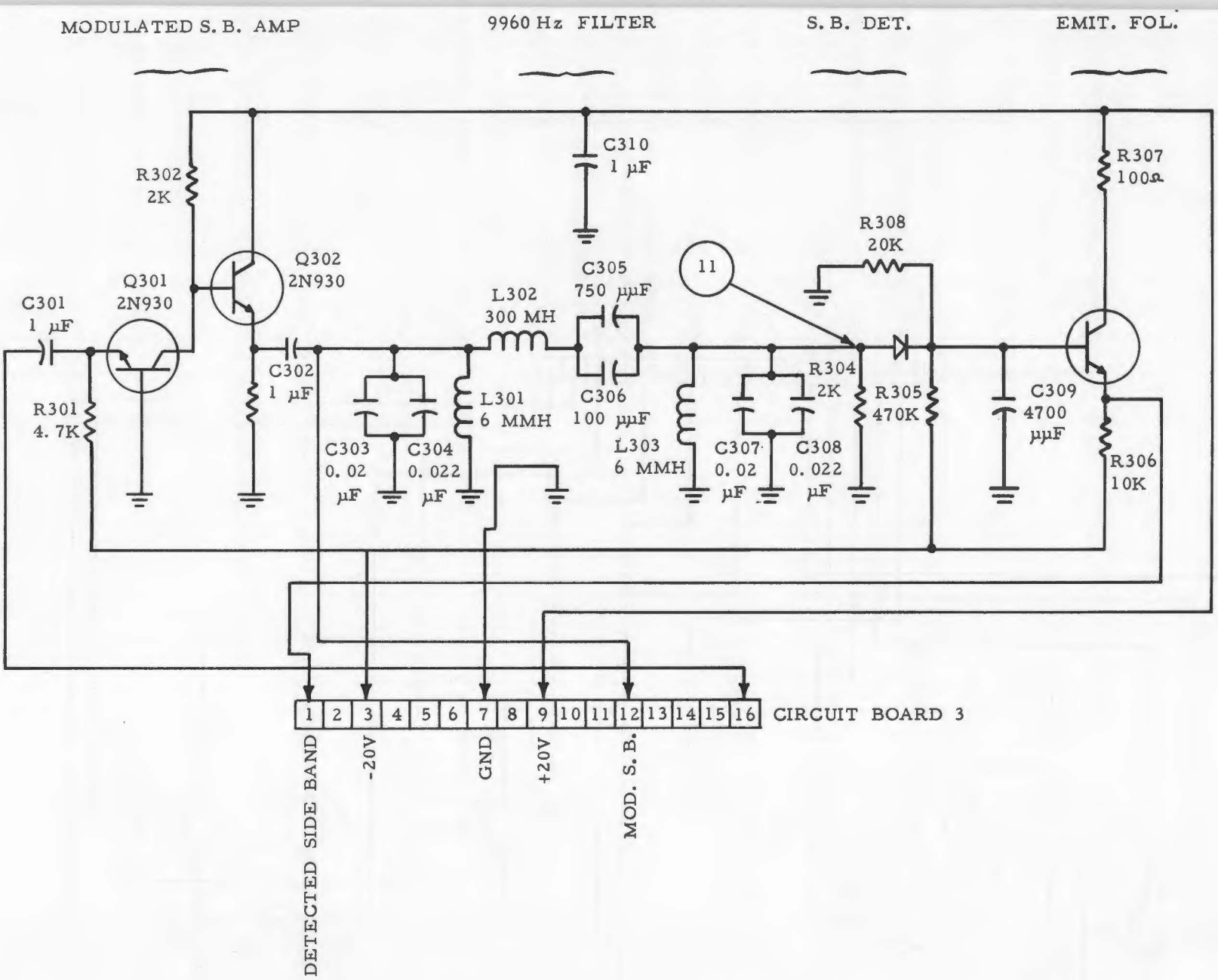


FIG. 16 SCHEMATIC OF CIRCUIT BOARD NO. 3

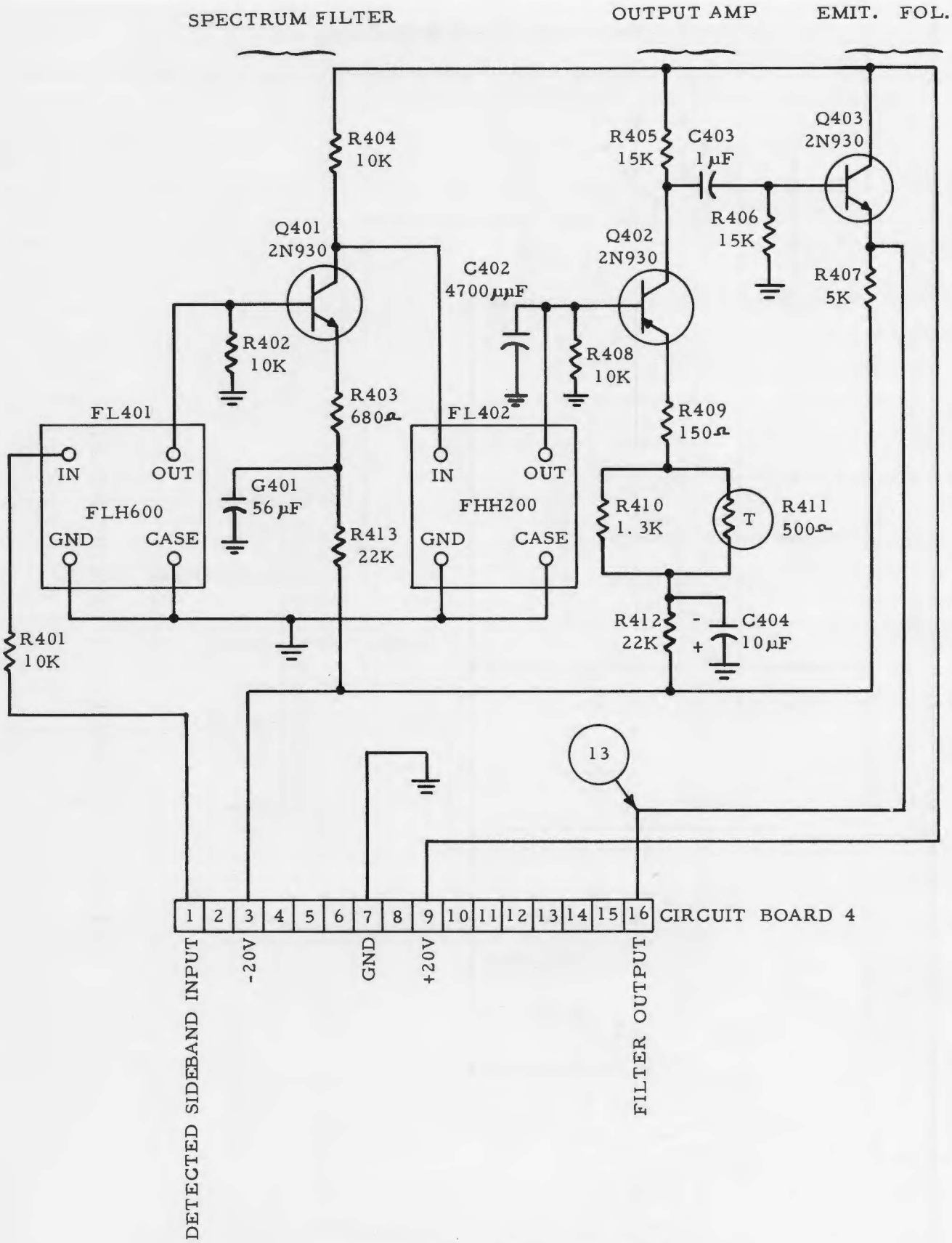


FIG. 17 SCHEMATIC OF CIRCUIT BOARD NO. 4

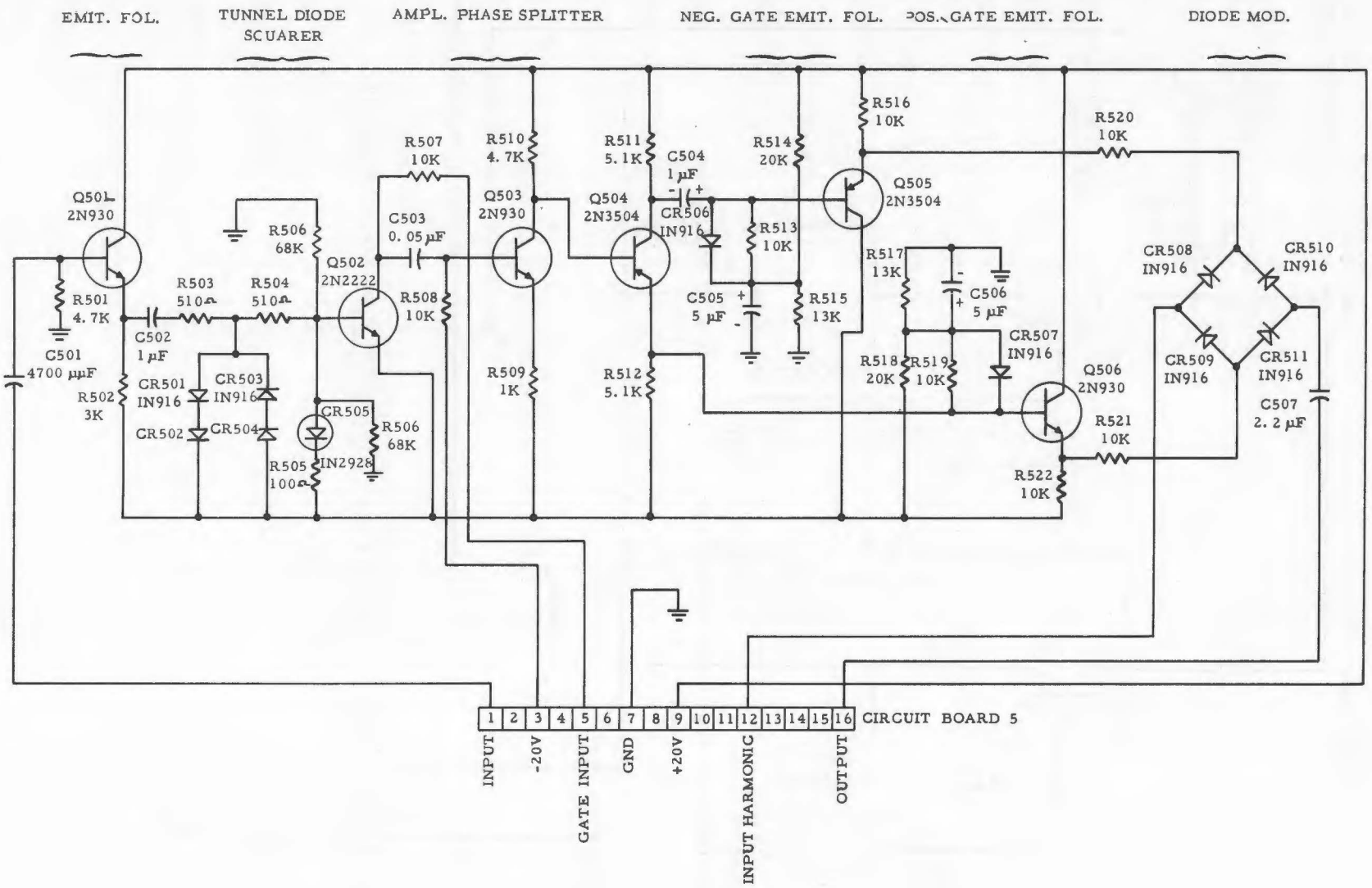


FIG. 18 SCHEMATIC OF CIRCUIT BOARD NO. 5

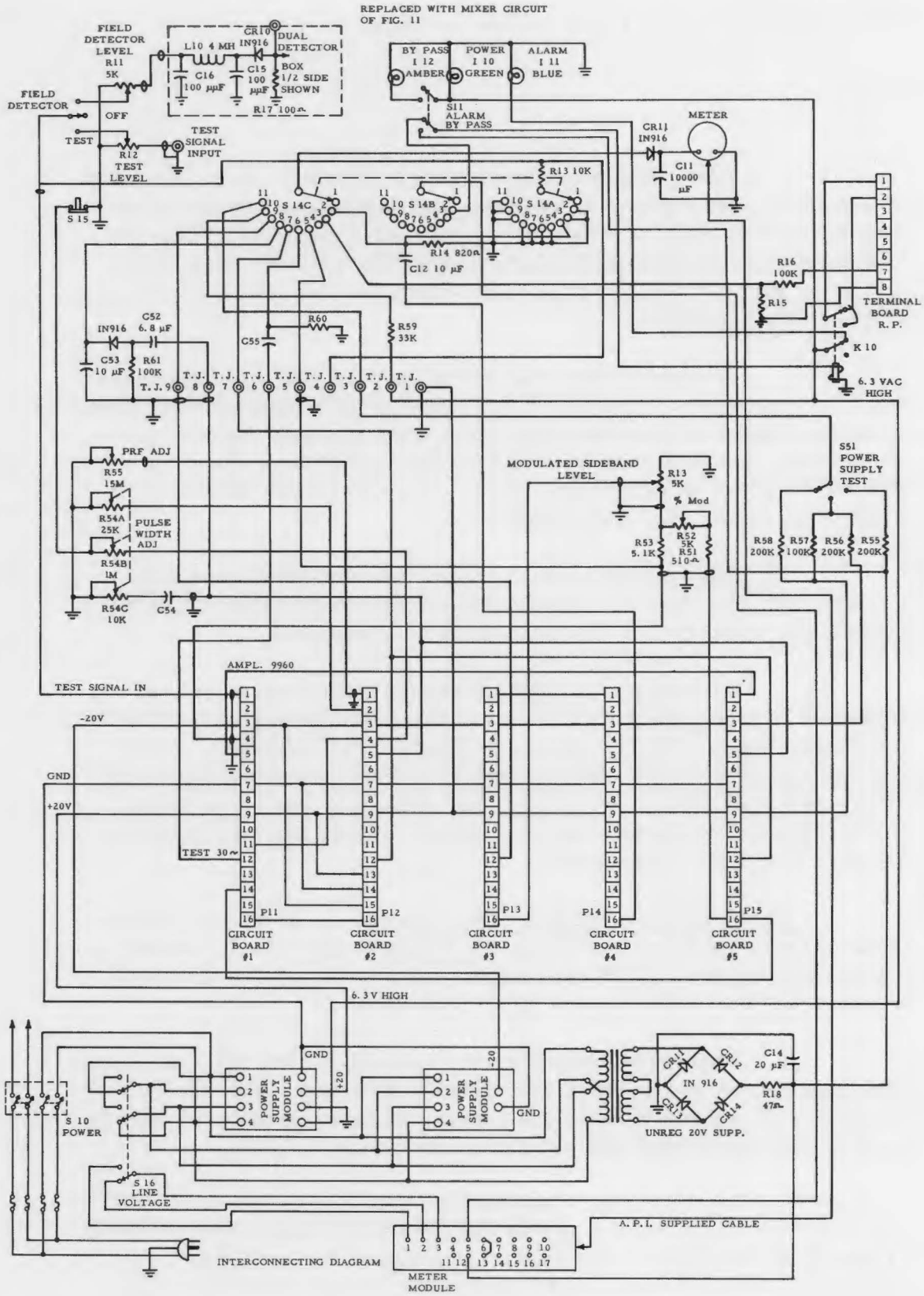


FIG. 19 PANEL AND INTERCONNECTING DIAGRAM

The results of these tests are tabulated in figure 20. From these test results it appears that the mixer circuit is not critical to the ratio of sideband to carrier sample voltages; the limitation being the effects of voice modulation, the gain of the monitor, and the RF power losses which can be tolerated in the Doppler VOR System.

Photographs of the 9960 Hz output of the mixer for the single sideband Doppler VOR System under several conditions of faulty sideband antenna operations, are given in figure 21. These may be compared with the photograph from report No. RD-66-49 given in figure 22, which shows the 9960 Hz output of a detector under the same condition.

Figures 23 to 26, inclusive, show the frequency spectrum of the 9960 Hz output of the mixer under the same simulated antenna faults for the photographs of figure 21.

An analysis of the frequency spectrum given in figures 23 to 26, and comparison of the photographs of the 9960 Hz signal obtained from within the Doppler VOR System, with the photographs of the 9960 Hz signal through external detection of the radiated signal, indicates that a faulty sideband antenna will produce a disruption of the 9960 Hz signal and will produce similar frequency spectrums.

Signal Processing Circuitry Tests - A frequency spectrum of the 9960 Hz detector output taken at pin No. 1, board No. 4 for normal Doppler VOR operation, and for simulated sideband antenna faults, are shown in figures 27 to 32.

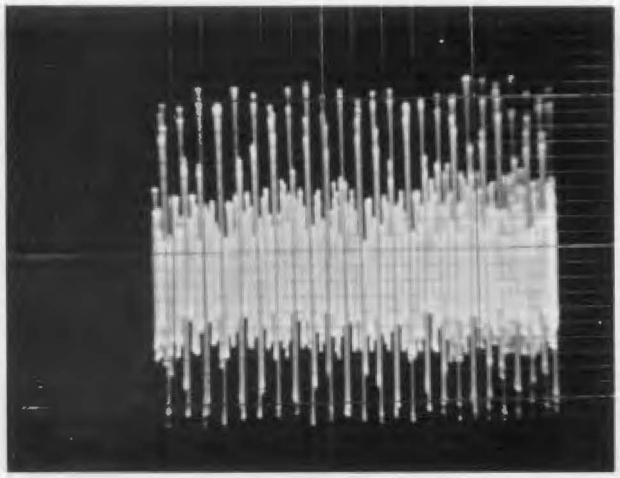
The self-check circuitry was disabled for these tests and for the frequency spectrum of the 200 to 600 Hz filter output at pin No. 16 of board No. 4, as shown in figures 33 to 35, for normal and simulated sideband antenna faults.

The frequency spectrum tests of the detected 9960 Hz sideband and of the output of the 200 to 600 Hz filter were repeated using the alternate circuit board 1A because the circuitry preceding the 9960 Hz filter was different due to the method of providing the self-check function of the monitor.

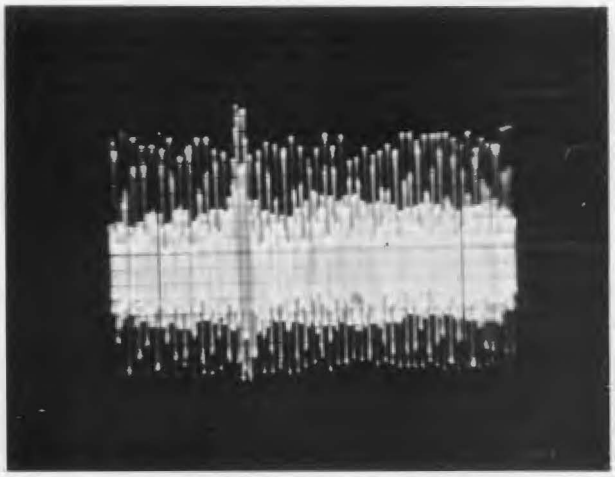
				MONITOR AS PER SPECIFICATIONS							MONITOR WITH ALTERNATE CIRCUIT BOARD 1A						
VOLTS RF AT INPUT OF MIXER		RATIO	MIXER OUTPUT	DC VOLTAGE ACROSS METER TERMINALS				RATIO			DV VOLTAGE ACROSS METER TERMINALS				RATIO		
SB	Fc	SB-Fc	VOLTS	N	S	O	Sh.	N-S	N-O	N-Sh.	N	S	O	Sh.	N-S	N-O	N-Sh.
1.9	10.5	1-5.5	.90	.135	.65	.5	.26	1-4.8	1-3.7	1-1.9	.145	.6	.5	.24	1-4.1	1-3.4	1-1.6
1.45	10.5	1-7.2	.66	.17	.6	.41	.235	1-3.5	1-2.4	1-1.4	.17	.55	.41	.25	1-3.2	1-2.4	1-1.5
1.1	10.5	1-9.5	.50	.085	.5	.4	.145	1-5.9	1-4.7	1-1.7	.095	.5	.4	.18	1-5.3	1-4.2	1-1.9
0.81	10.5	1-13.0	.42	.05	.4	.4	.12	1-8.0	1-8.0	1-2.4	.06	.4	.4	.15	1-6.7	1-6.7	1-2.5
1.9	5.3	1-2.8	.65	.135	.6	.4	.165	1-4.4	1-3.0	1-1.2	.13	.55	.45	.18	1-4.2	1-3.4	1-1.4
1.45	5.3	1-3.6	.51	.13	.6	.4	.17	1-4.6	1-3.1	1-1.3	.135	.6	.4	.19	1-4.4	1-2.9	1-1.4
1.1	5.3	1-4.8	.36	.055	.45	.4	.693	1-8.2	1-7.3	1-1.7	.07	.5	.4	.12	1-7.1	1-5.7	1-1.7
0.81	5.3	1-6.5	.34	.02	.4	.4	.065	1-20	1-20	1-3.2	.035	.4	.4	.09	1-11.0	1-11.0	1-2.6
1.9	3.2	1-1.7	.48	.09	.55	.4	.125	1-6.1	1-4.4	1-1.4	.10	.55	.4	.14	1-5.5	1-4.0	1-1.4
1.45	3.2	1-2.2	.40	.065	.5	.4	.10	1-7.7	1-6.2	1-1.6	.08	.5	.4	.12	1-6.2	1-5.0	1-1.5
1.1	3.2	1-2.9	.30	.03	.42	.4	.06	1-14	1-13	1-2.0	.045	.45	.4	.08	1-10	1-8.9	1-1.8
0.81	3.2	1-4	.24	.01	.4	.4	.03	1-40	1-40	1-3.0	.02	.4	.4	.045	1-20	1-20	1-2.2

SB - SIDEBAND (Fc + 9960 Hz)
Fc - CARRIER FREQUENCY
N - NORMAL DVOR SYSTEM
S - SHORTED ANTENNA
O - OPEN ANTENNA
Sh - 50 OHM SHUNT ACROSS ANTENNA

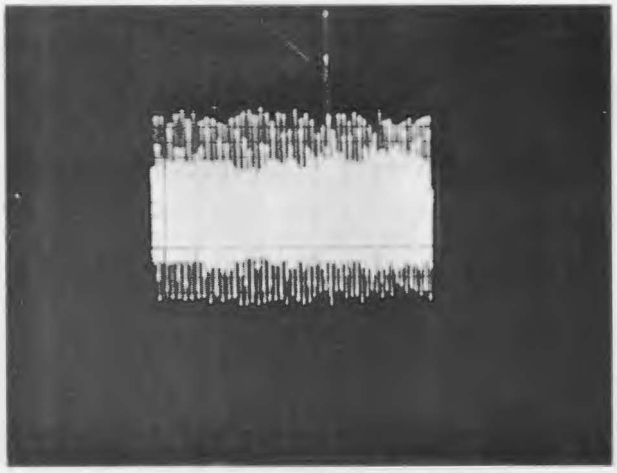
FIG. 20 MONITOR SENSITIVITY VERSUS RF INPUT



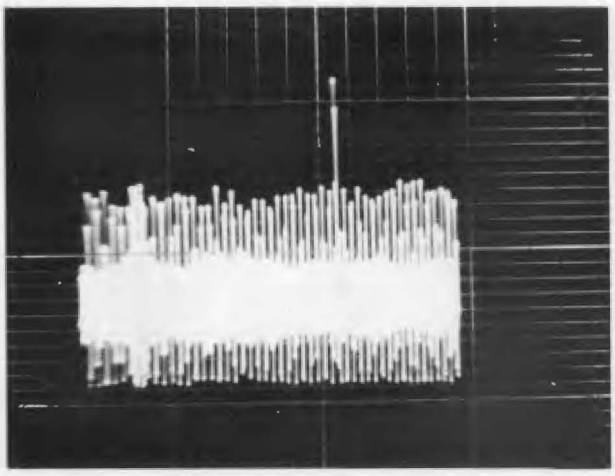
NORMAL



ANTENNA NO. 50 SHORTED

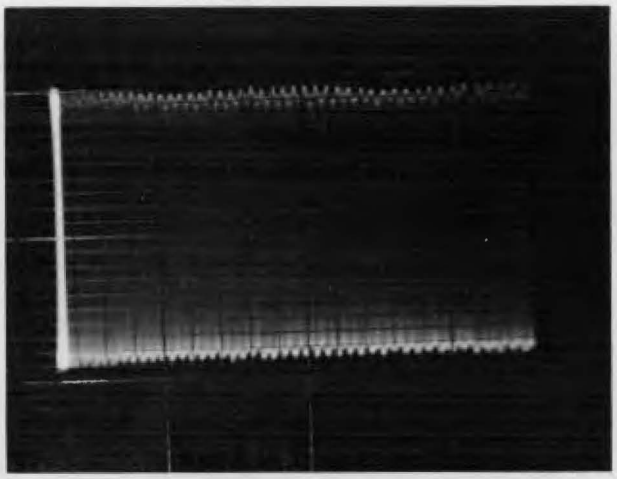


ANTENNA NO. 50 OPEN

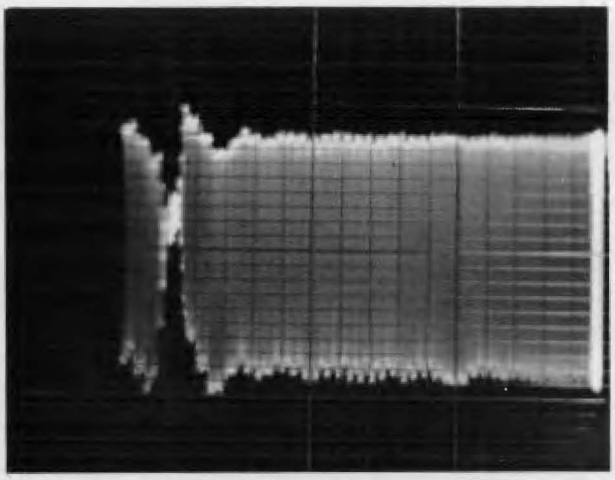


ANTENNA NO. 26 OPEN AND
ANTENNA NO. 50 SHORTED

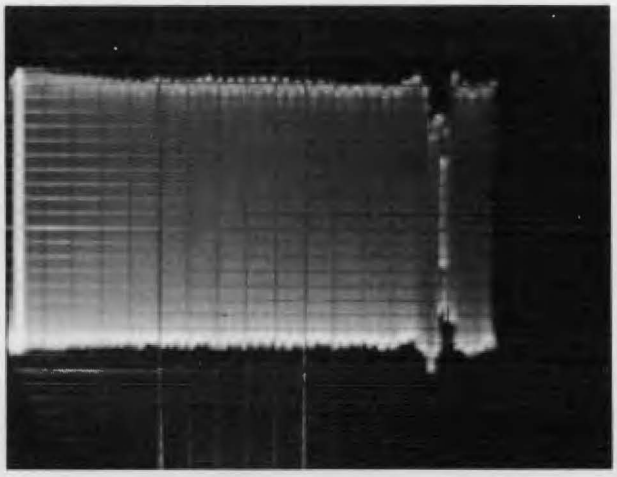
FIG. 21 PHOTOGRAPH OF 9960 Hz OUTPUT OF MIXER



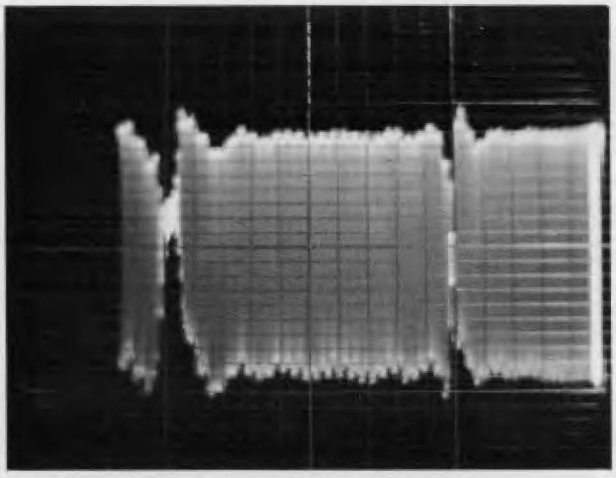
NORMAL



ANTENNA NO. 50 SHORTED



ANTENNA NO. 50 OPEN



ANTENNA NO. 50 SHORTED AND
ANTENNA NO. 26 OPEN

FIG. 22 PHOTOGRAPHS OF THE DETECTED 9960 Hz OF THE RADIATED SIGNAL (FROM REPORT RD-66-49)

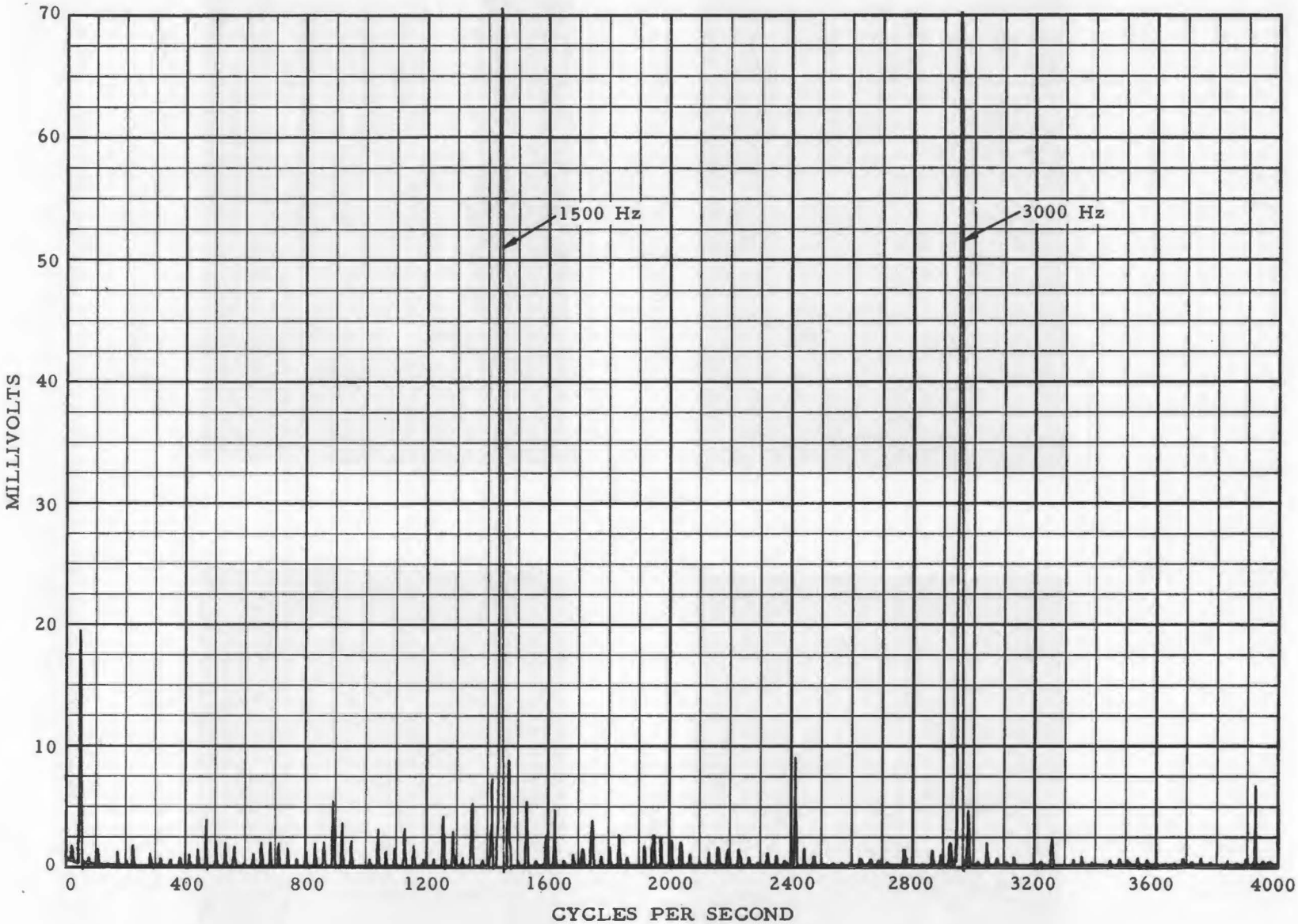


FIG. 23 FREQUENCY SPECTRUM OF MIXER OUTPUT NORMAL SINGLE SIDEBAND DOPPLER VOR

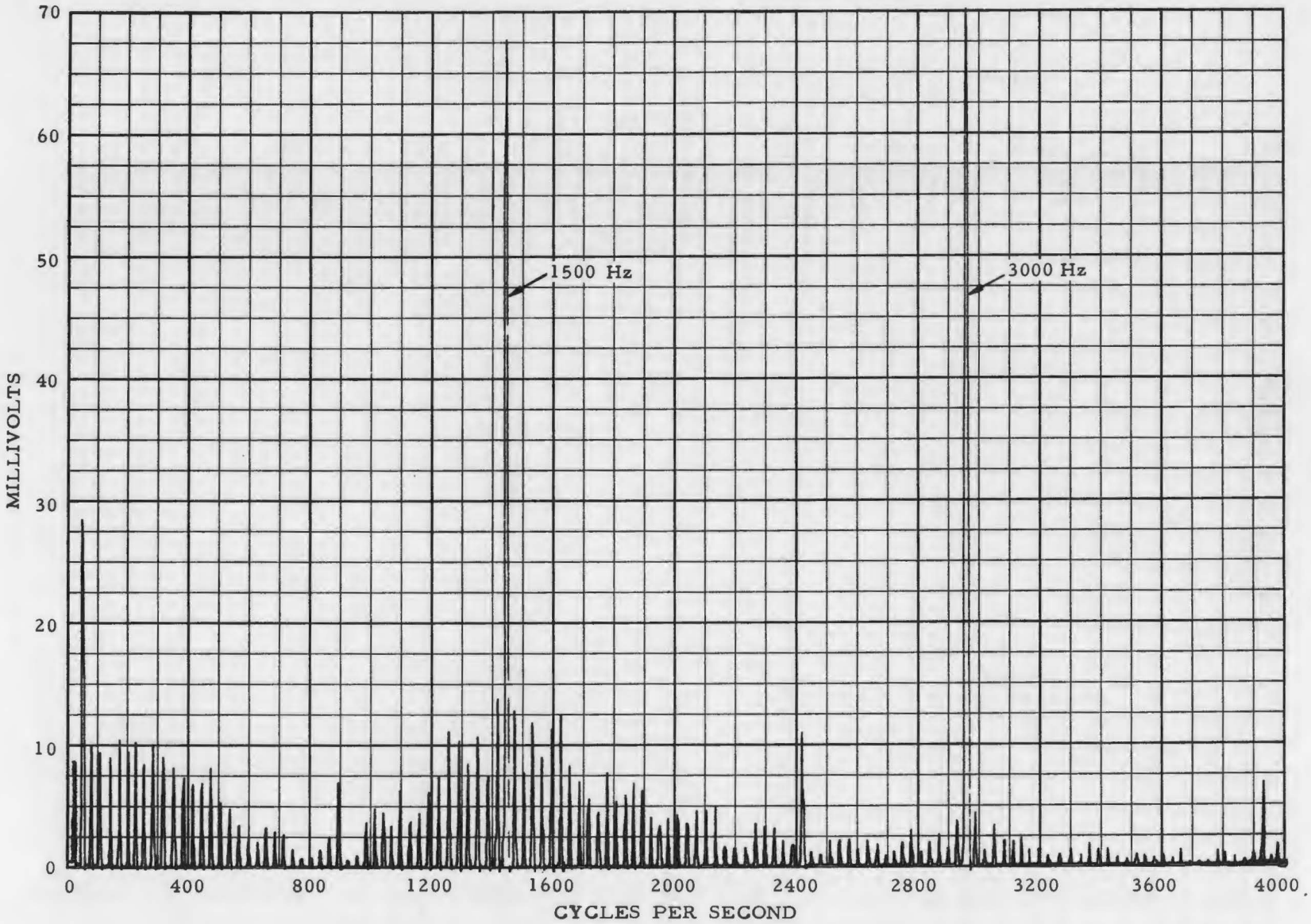


FIG. 24 FREQUENCY SPECTRUM OF MIXER OUTPUT WITH ANTENNA NO. 50 SHORTED

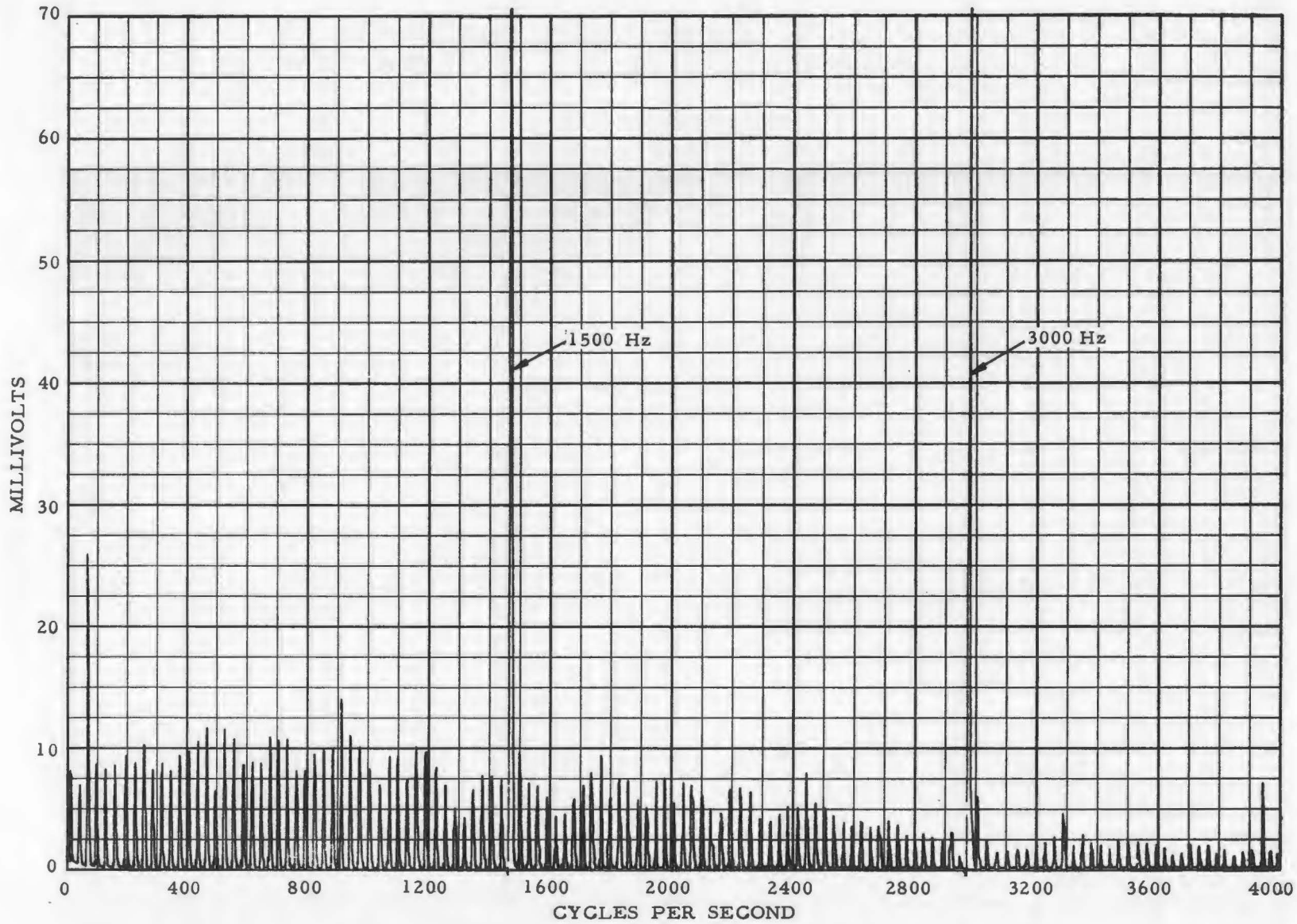


FIG. 25 FREQUENCY SPECTRUM OF MIXER OUTPUT WITH ANTENNA NO. 50 OPEN
SINGLE SIDEBAND DOPPLER VOR

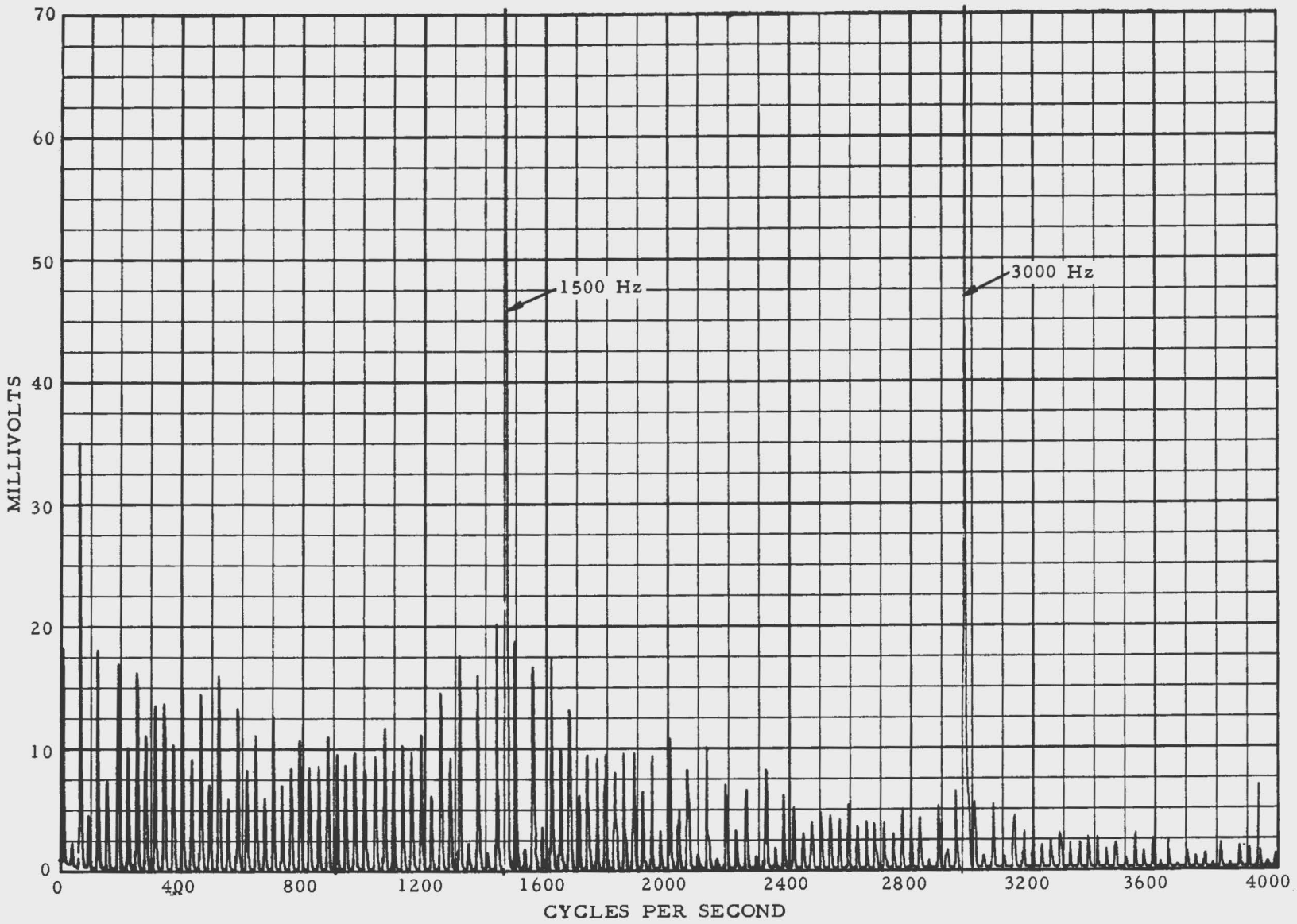


FIG. 26 FREQUENCY SPECTRUM OF MIXER OUTPUT WITH ANTENNA NOS. 26 OPEN AND 50 SHORTED

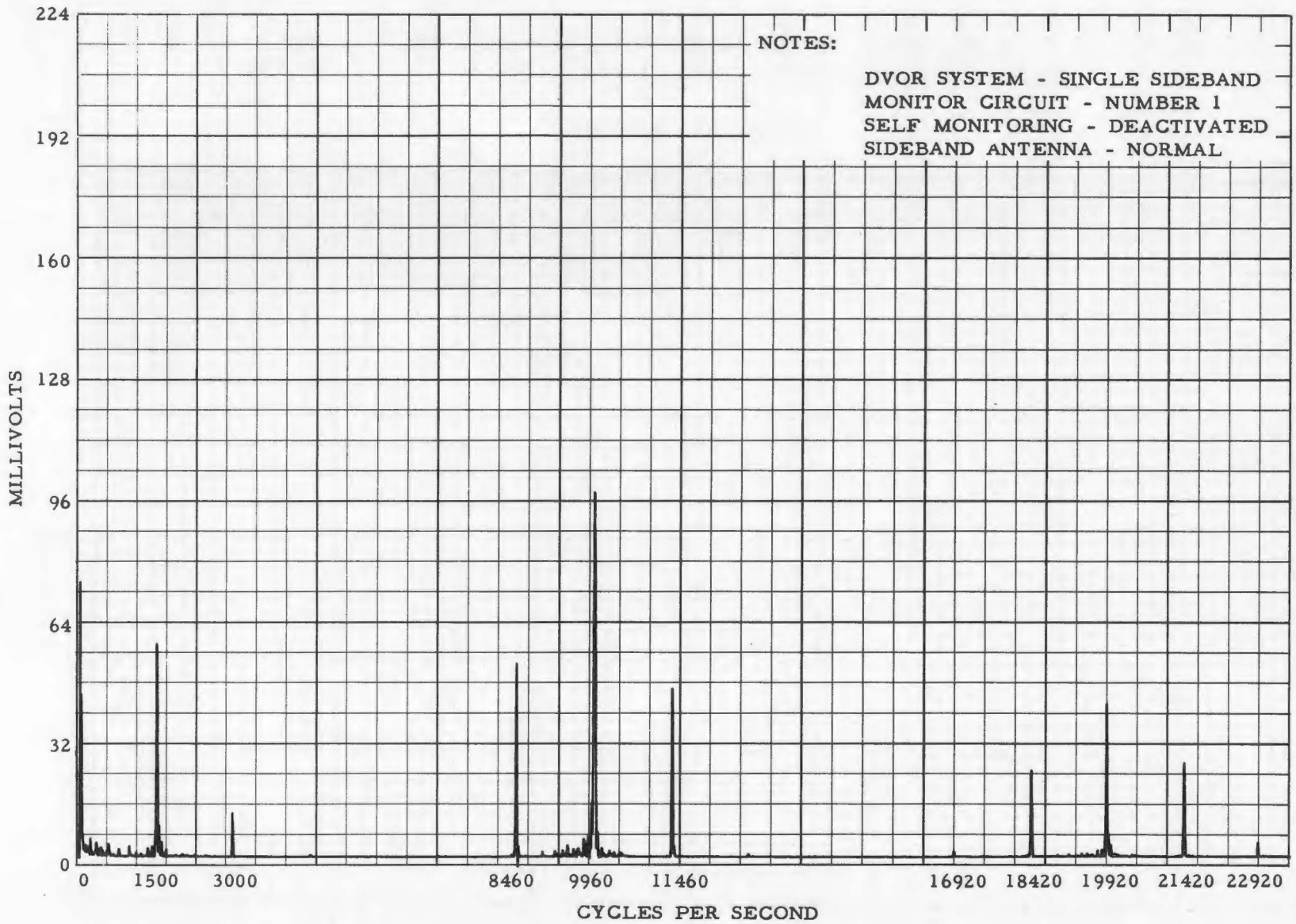


FIG. 27 BROAD FREQUENCY SPECTRUM OF THE 9960 Hz SIDEBAND DETECTOR OUTPUT AT PIN NO. 1 OF BOARD NO. 4

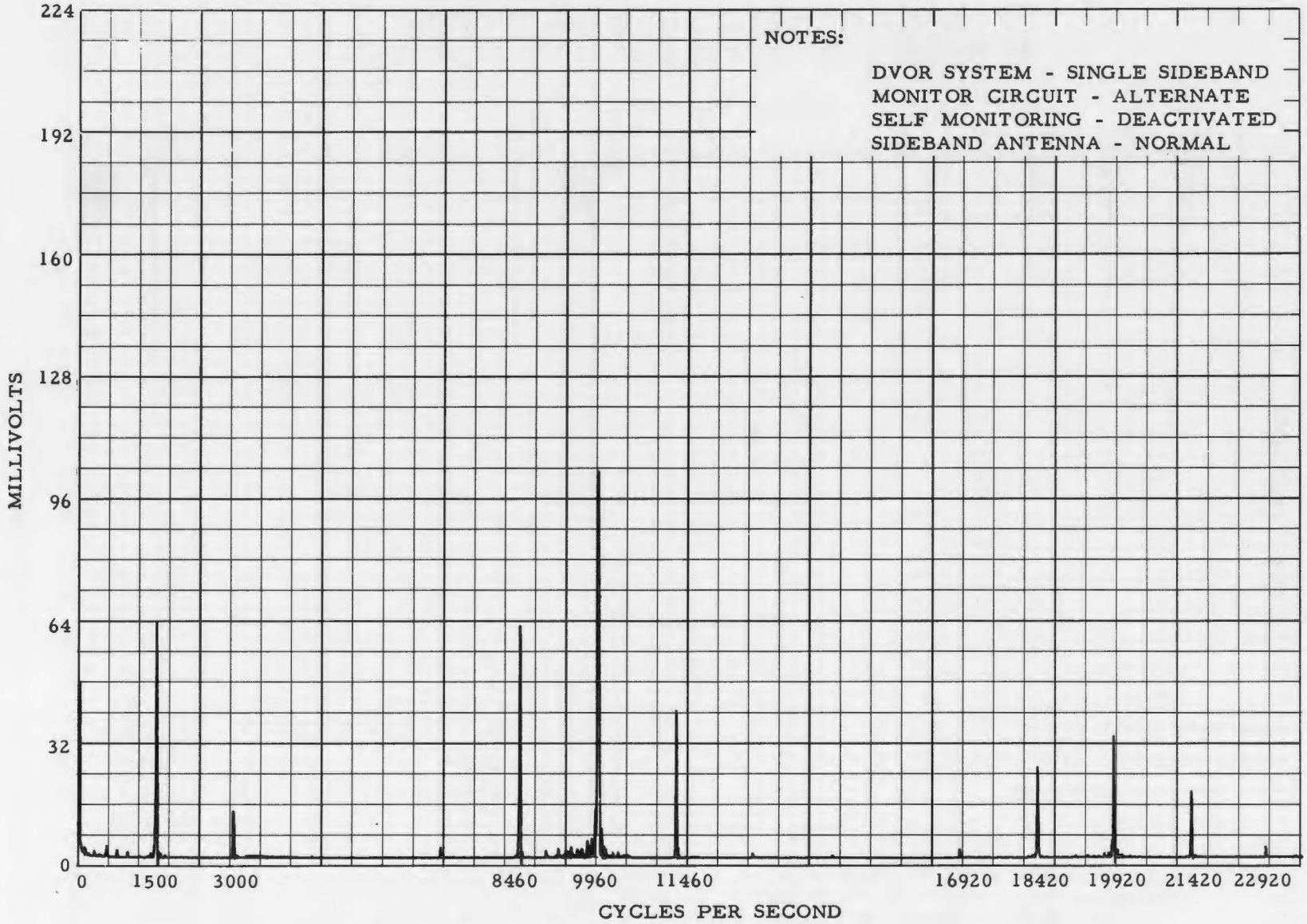


FIG. 27A BROAD FREQUENCY SPECTRUM OF THE 9960 Hz SIDEBAND DETECTOR OUTPUT AT PIN NO. 1 OF BOARD NO. 4

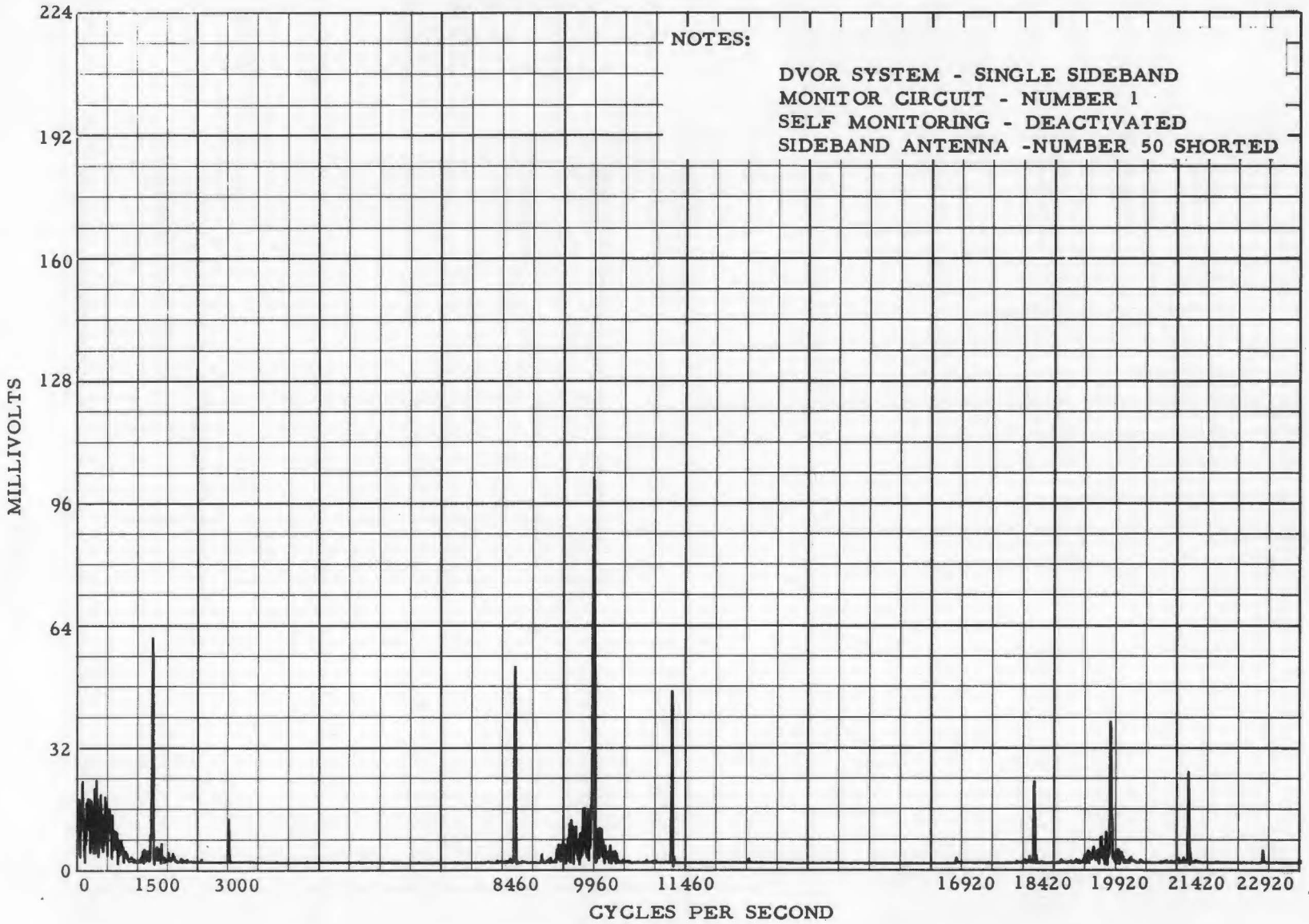


FIG. 28 BROAD FREQUENCY SPECTRUM OF THE 9960 Hz SIDEBAND DETECTOR OUTPUT AT PIN NO. 1 OF BOARD NO. 4

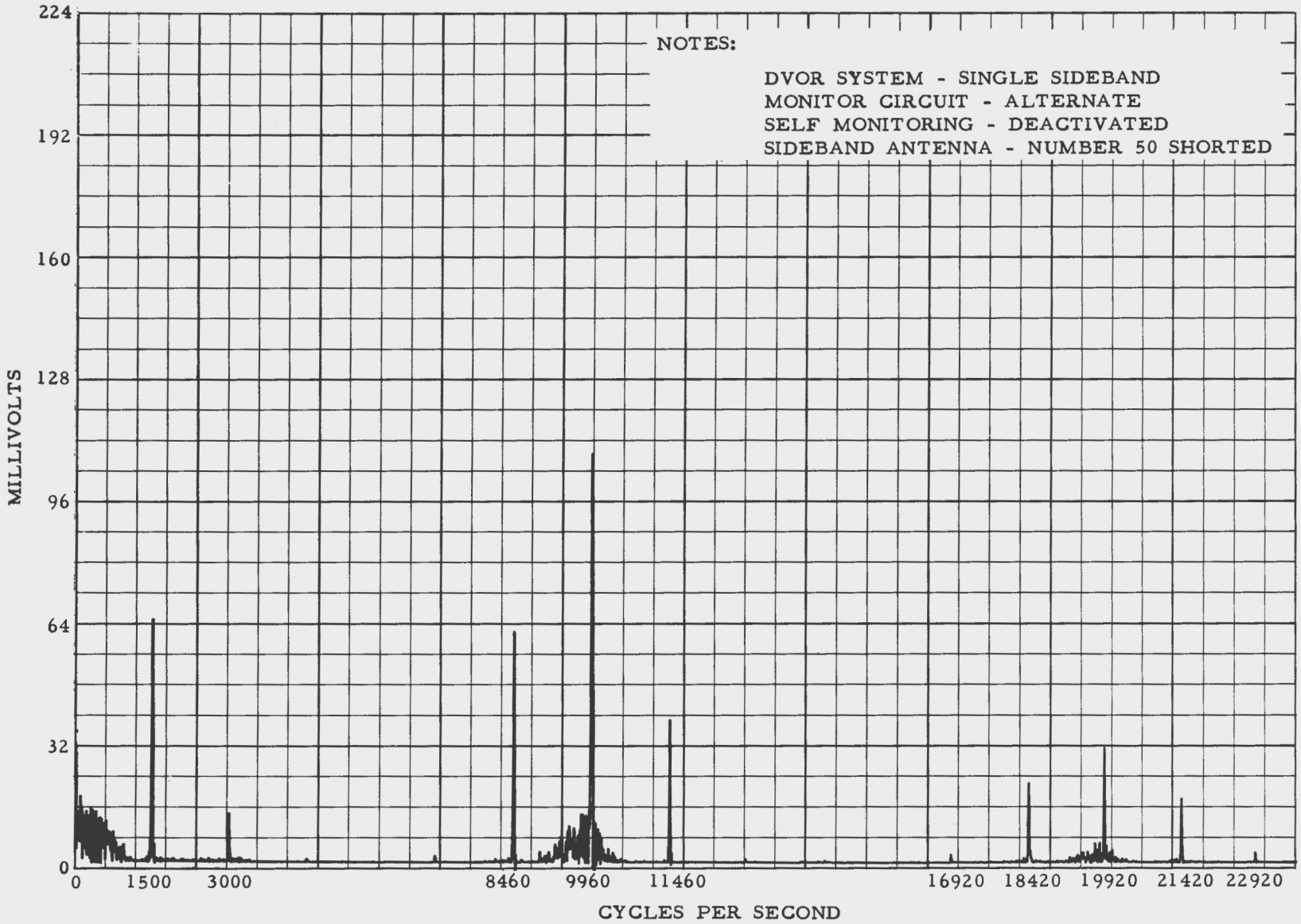


FIG. 28A BROAD FREQUENCY SPECTRUM OF THE 9960 Hz SIDEBAND DETECTOR OUTPUT AT PIN NO. 1 OF BOARD NO. 4

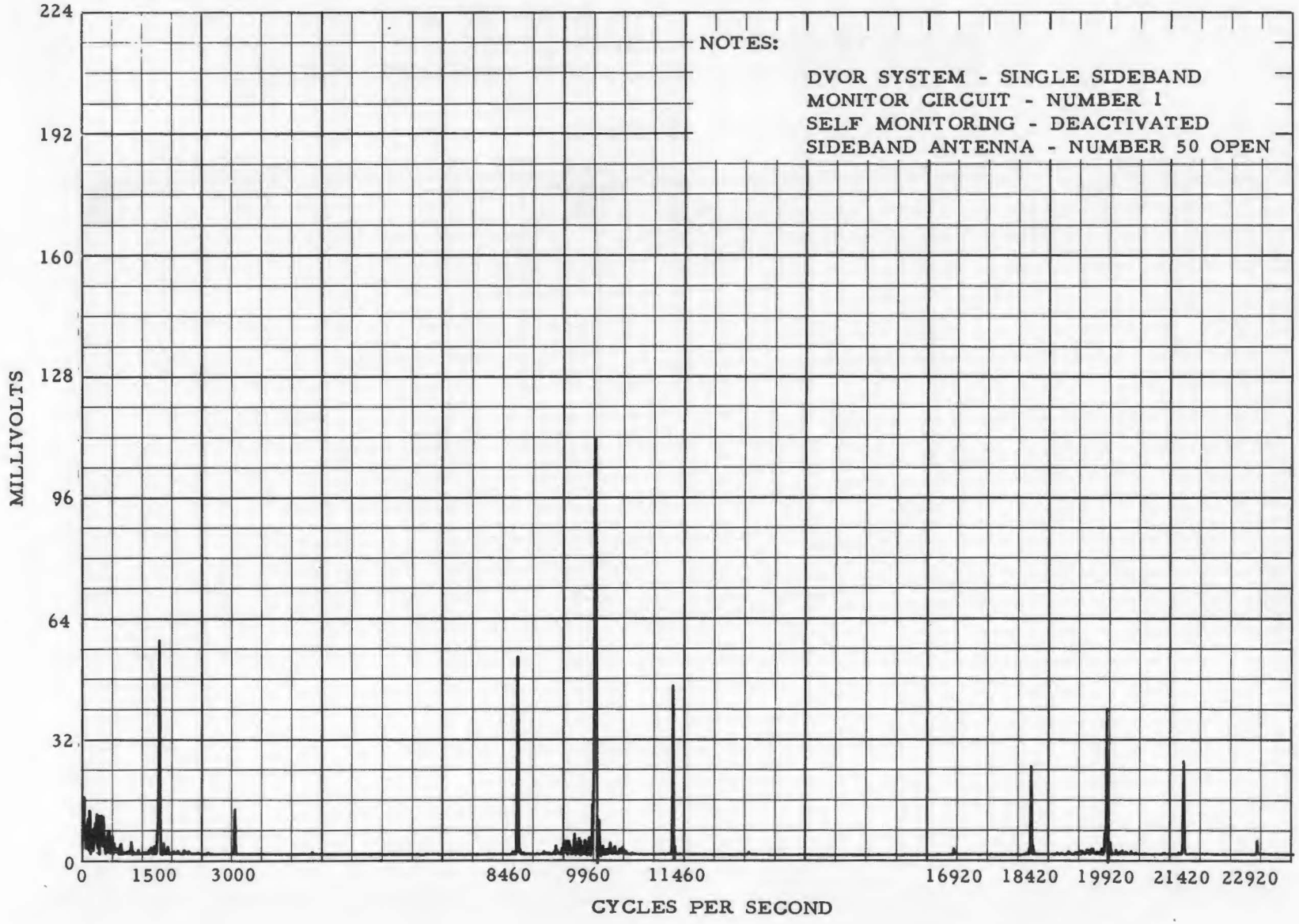


FIG. 29 BROAD FREQUENCY SPECTRUM OF THE 9960 Hz SIDEBAND DETECTOR OUTPUT AT PIN NO. 1 OF BOARD NO. 4

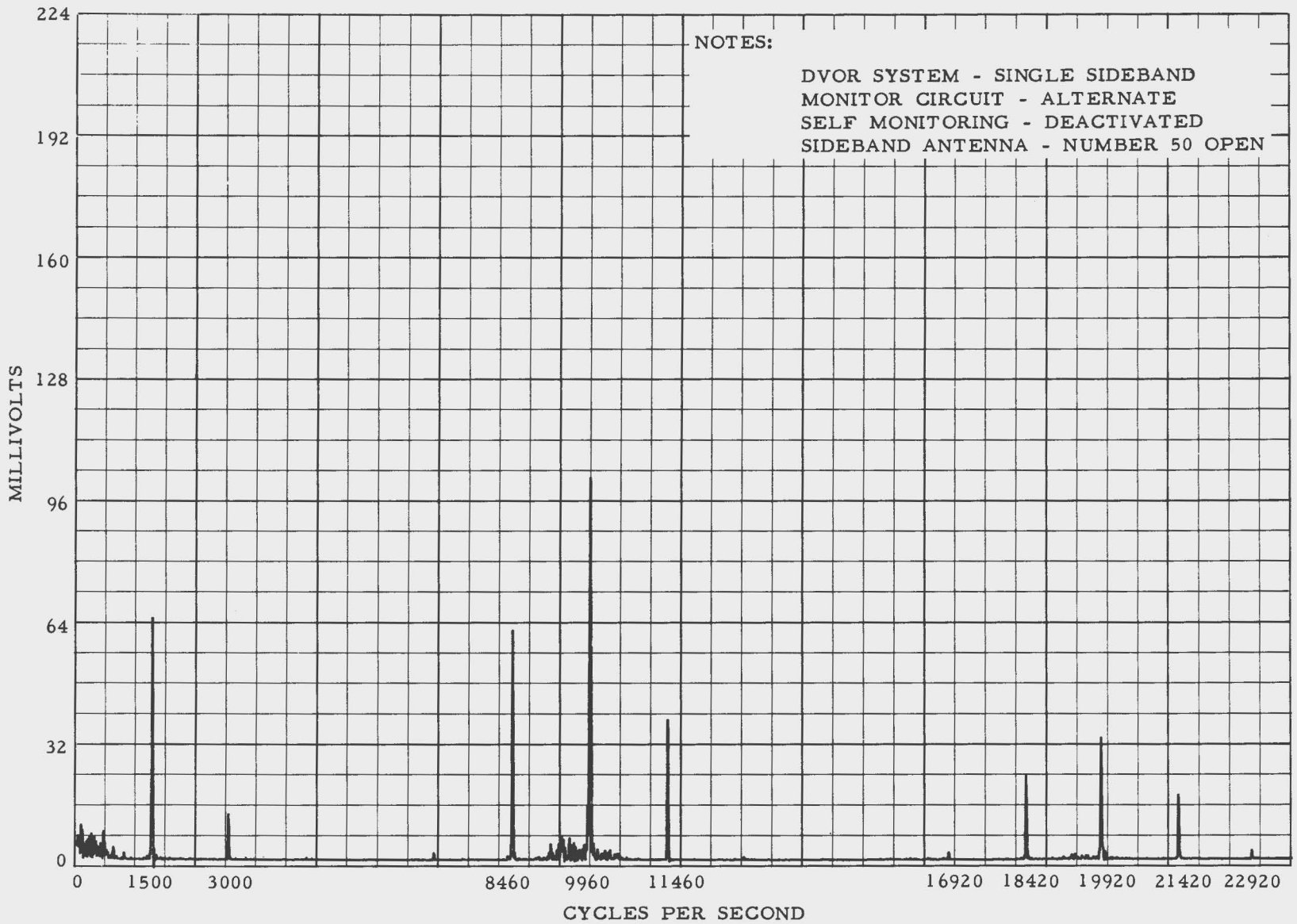


FIG. 29A BROAD FREQUENCY SPECTRUM OF THE 9960 Hz SIDEBAND DETECTOR OUTPUT AT PIN NO. 1 OF BOARD NO. 4

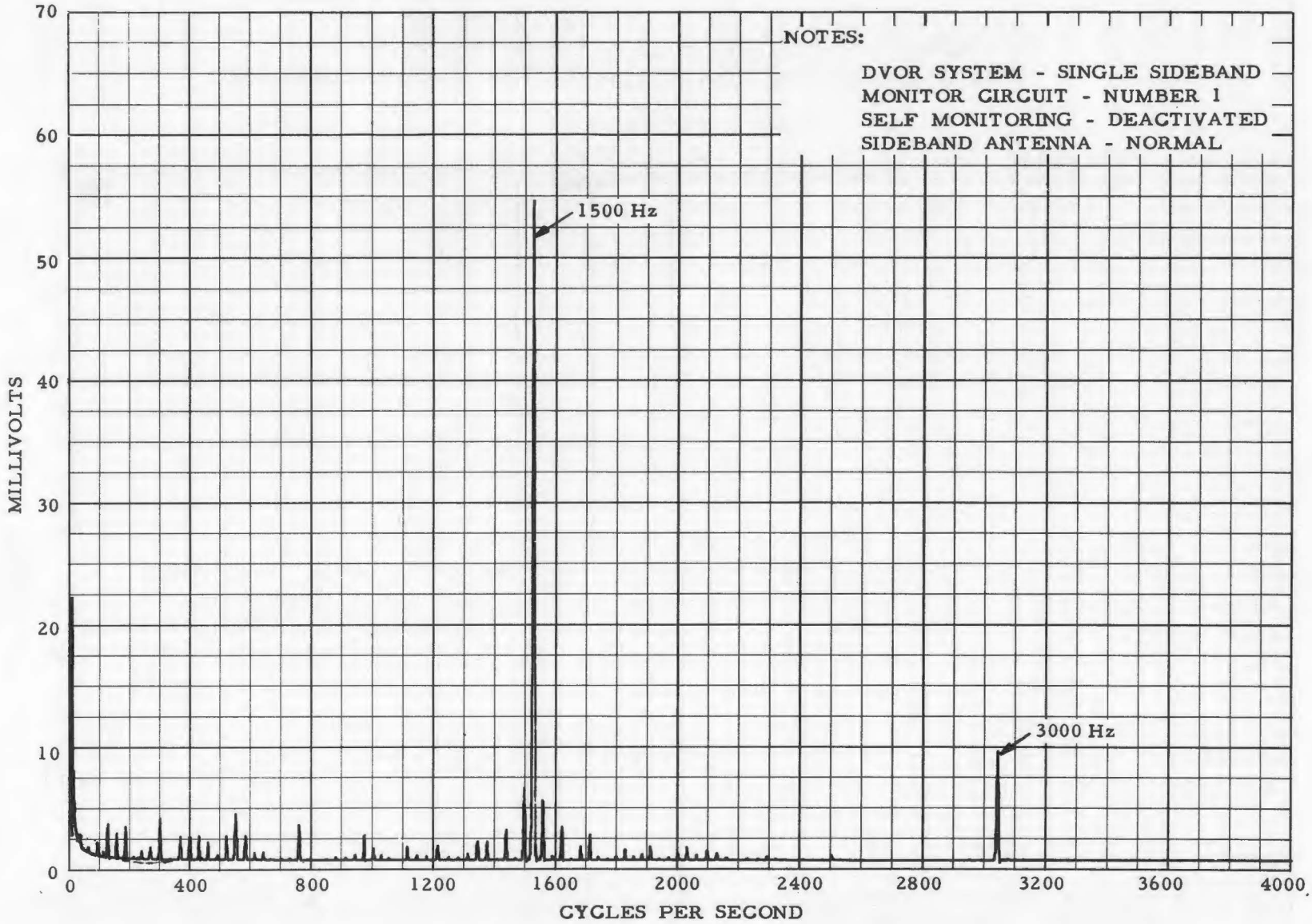


FIG. 30 NARROW FREQUENCY SPECTRUM OF THE 9960 Hz SIDEBAND DETECTOR OUTPUT AT PIN NO. 1 OF BOARD NO. 4

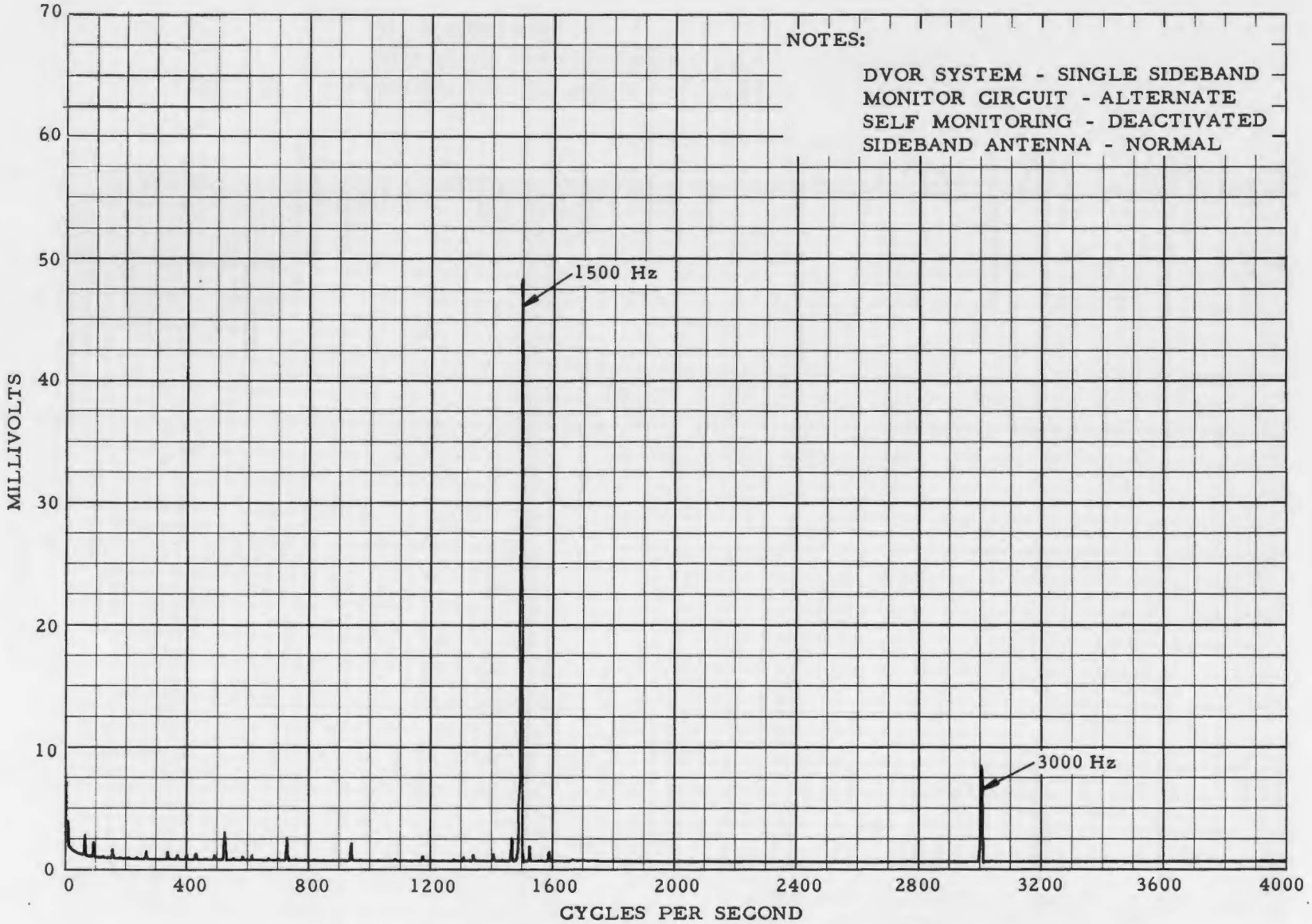


FIG. 30A NARROW FREQUENCY SPECTRUM OF THE 9960 Hz SIDEBAND DETECTOR OUTPUT AT PIN NO. 1 OF BOARD NO. 4

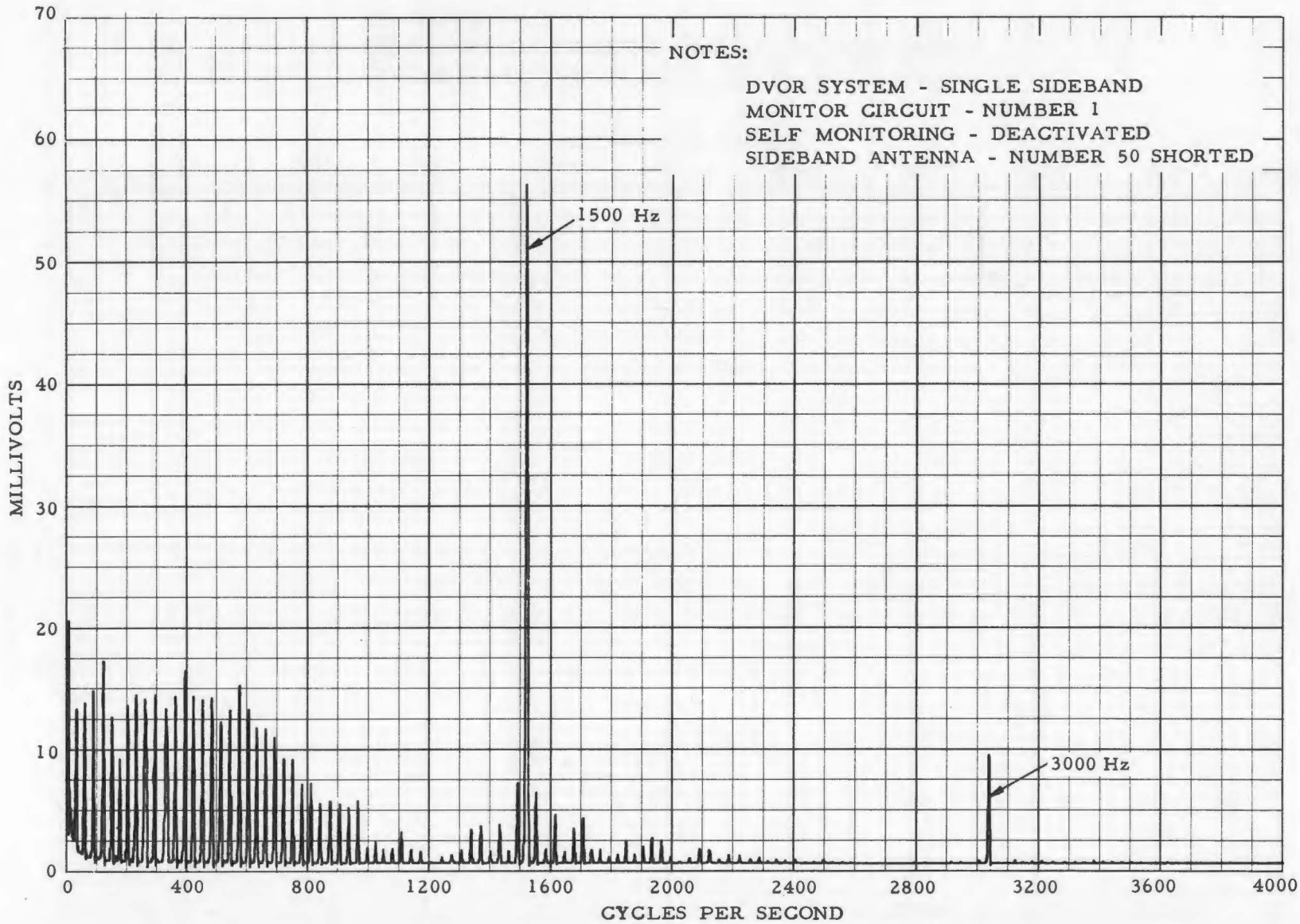


FIG. 31 NARROW FREQUENCY SPECTRUM OF THE 9960 Hz SIDEBAND DETECTOR OUTPUT AT PIN NO. 1 OF BOARD NO. 4

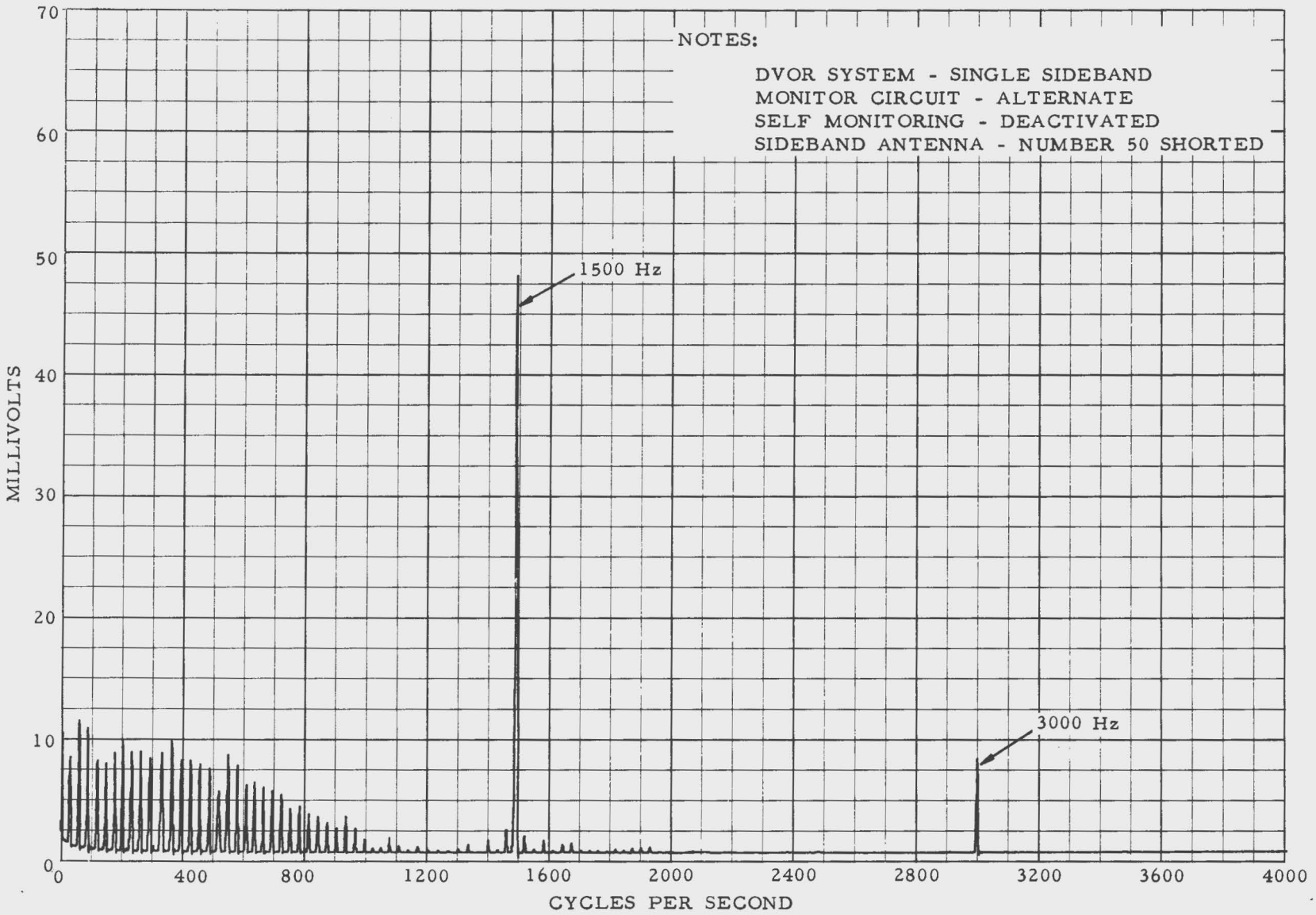


FIG. 31A NARROW FREQUENCY SPECTRUM OF THE 9960 Hz SIDEBAND DETECTOR OUTPUT AT PIN NO. 1 OF BOARD NO. 4

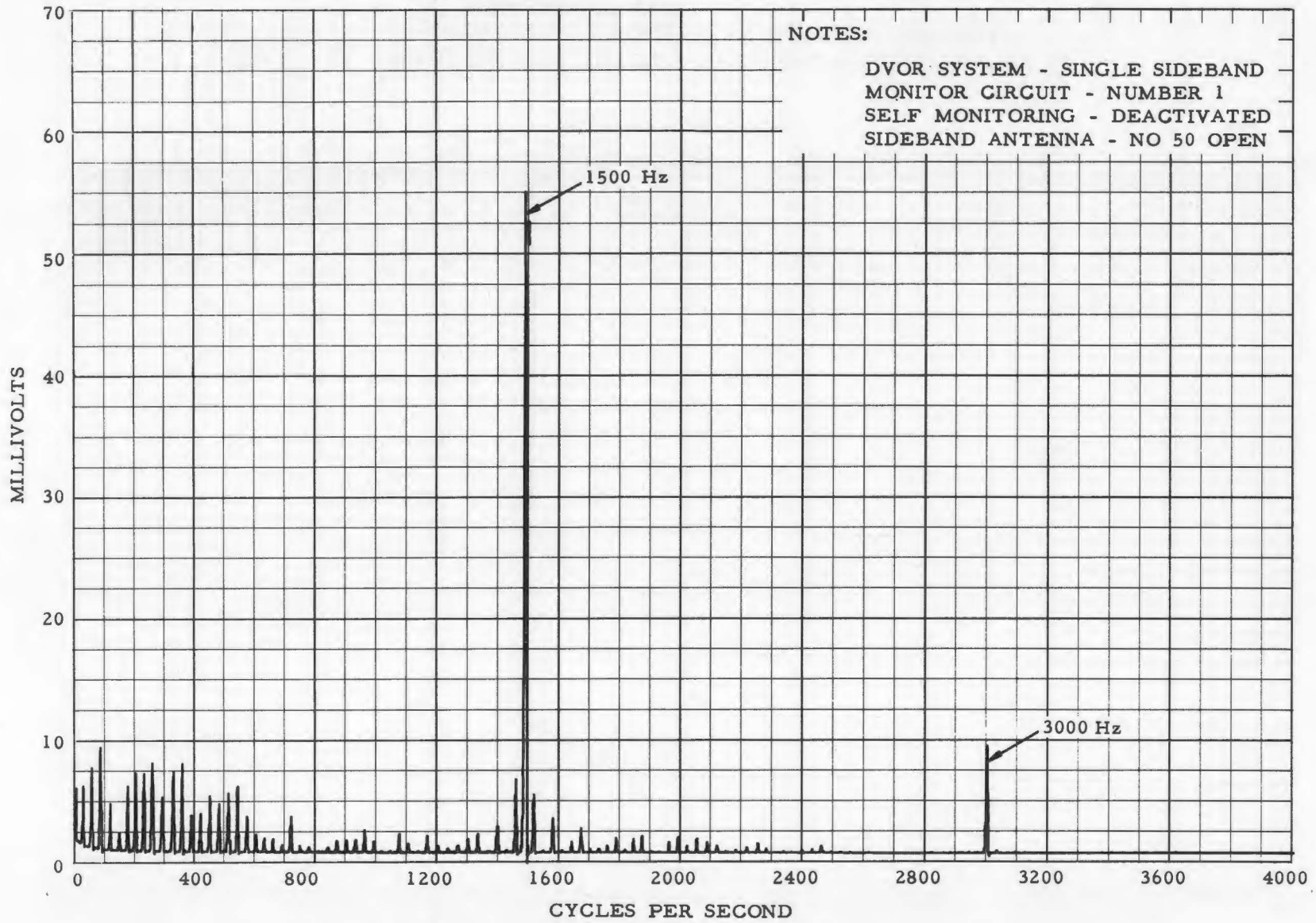


FIG. 32 NARROW FREQUENCY SPECTRUM OF THE 9960 Hz SIDEBAND DETECTOR OUTPUT AT PIN NO. 1 OF BOARD NO. 4

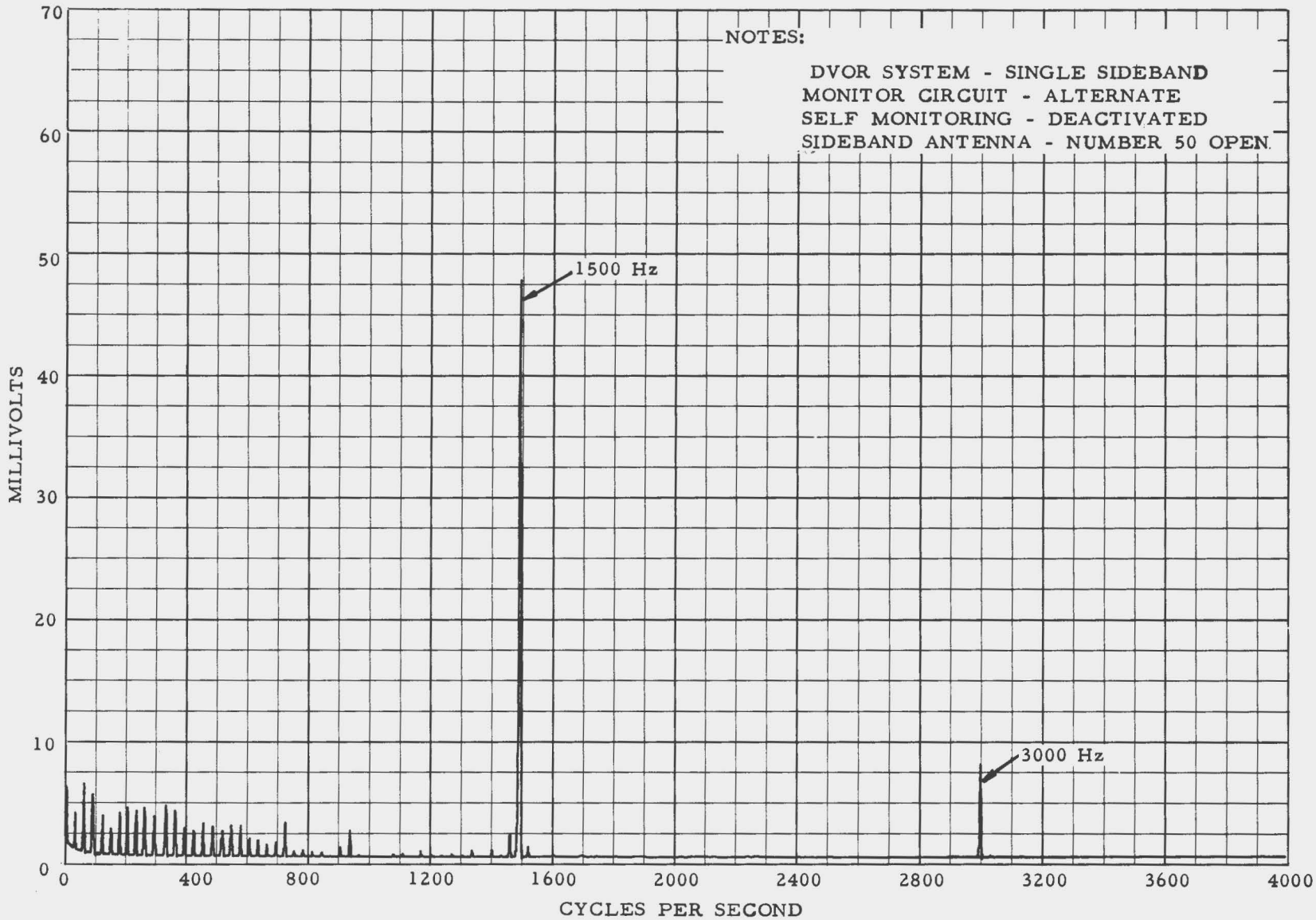


FIG. 32A NARROW FREQUENCY SPECTRUM OF THE 9960 Hz SIDEBAND DETECTOR OUTPUT AT PIN NO. 1 OF BOARD NO. 4

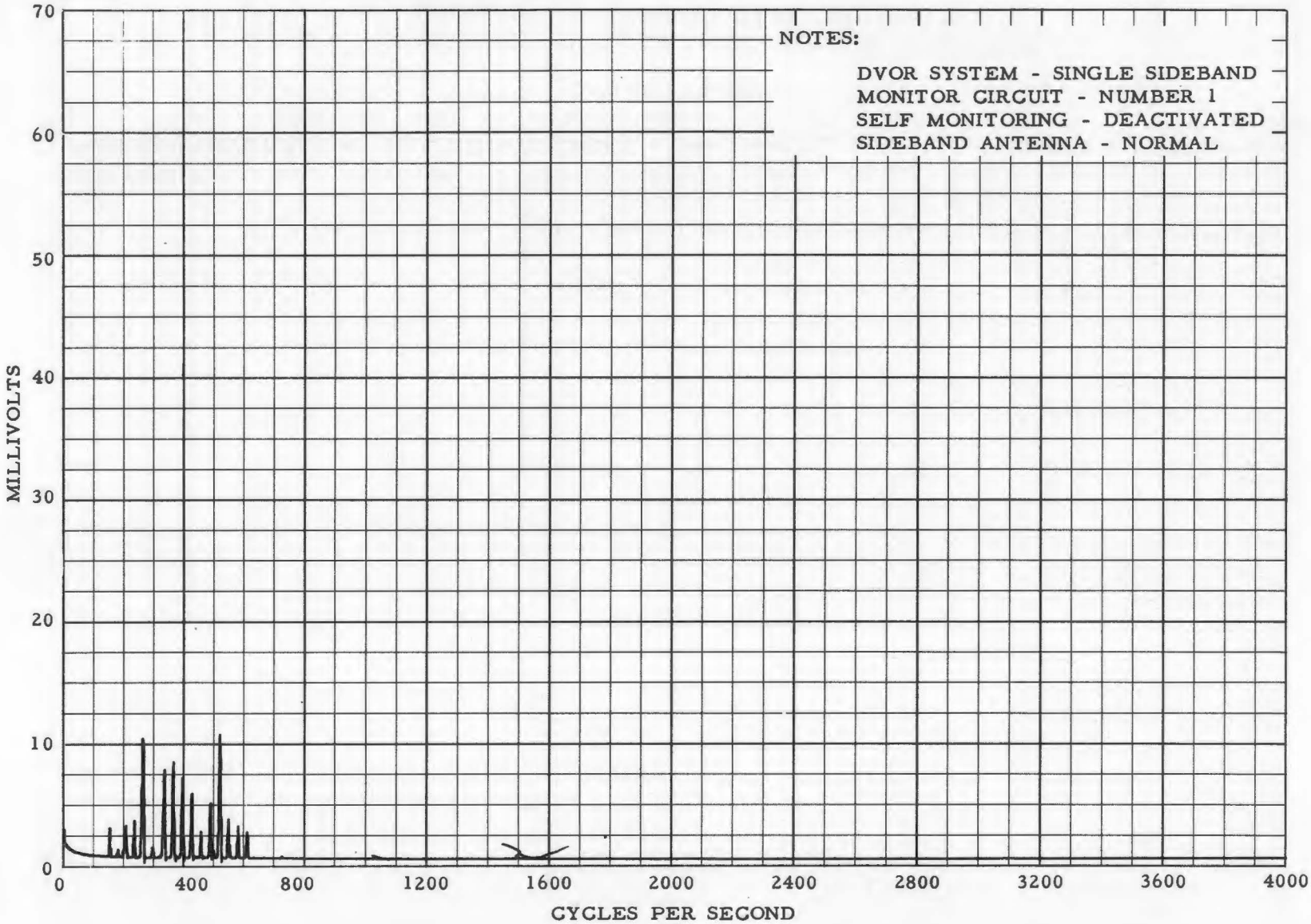


FIG. 33 FREQUENCY SPECTRUM OF THE 200 TO 600 Hz FILTER OUTPUT AT PIN NO. 16 OF BOARD NO. 4

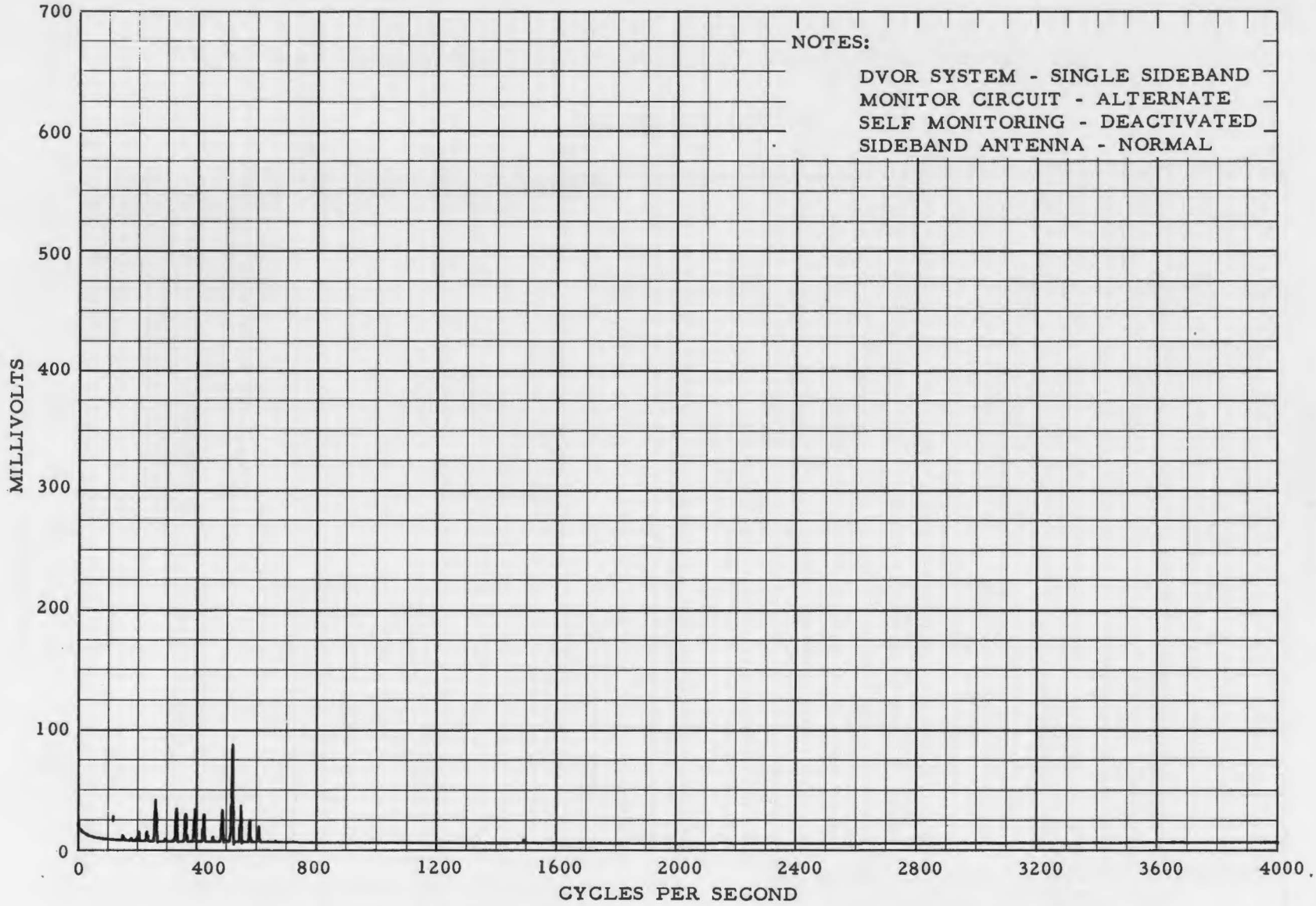


FIG. 33A FREQUENCY SPECTRUM OF THE 200 TO 600 HZ FILTER OUTPUT AT PIN NO. 16 OF BOARD NO. 4

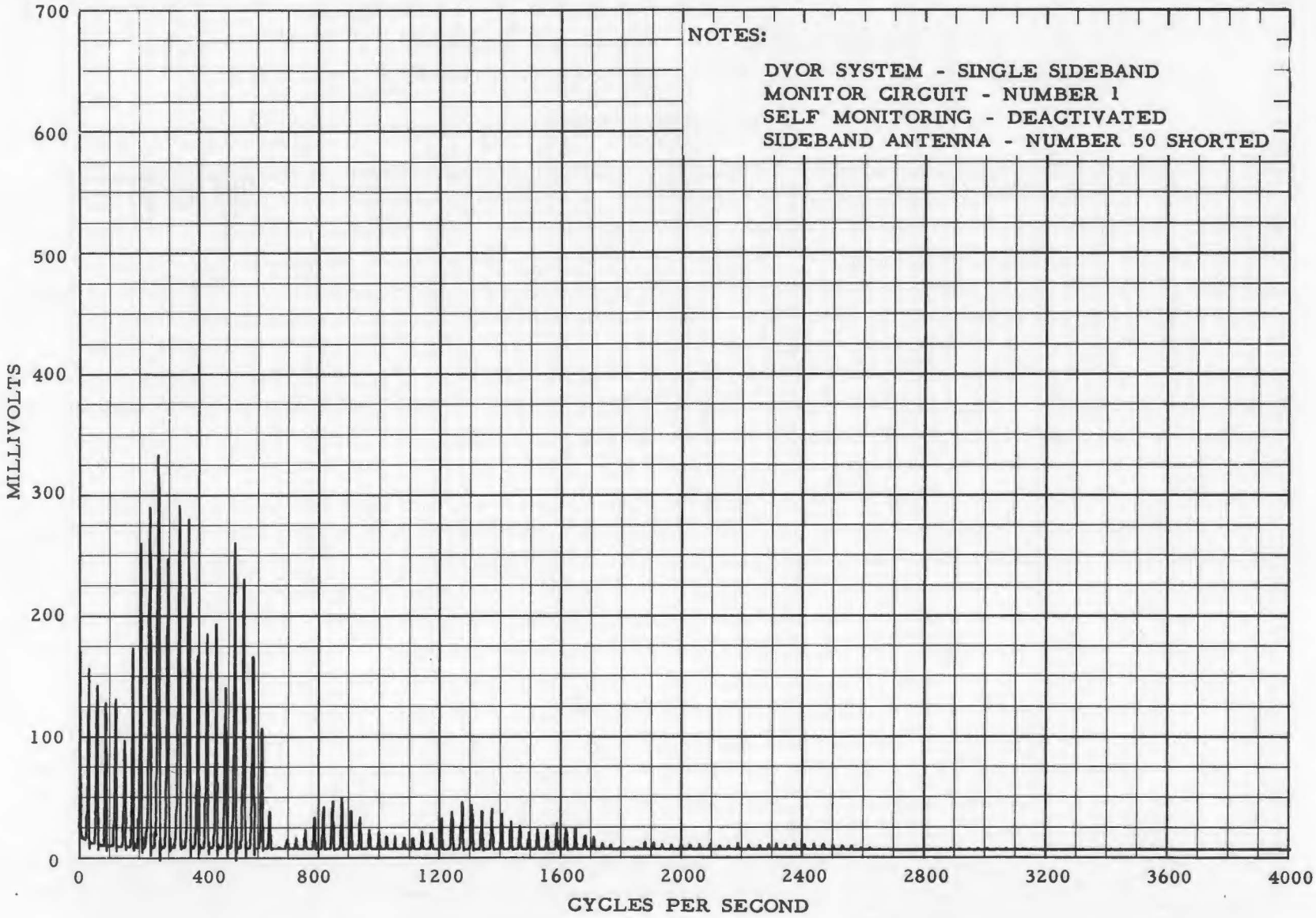


FIG. 34 FREQUENCY SPECTRUM OF THE 200 TO 600 Hz FILTER OUTPUT AT PIN NO. 16 OF BOARD NO. 4

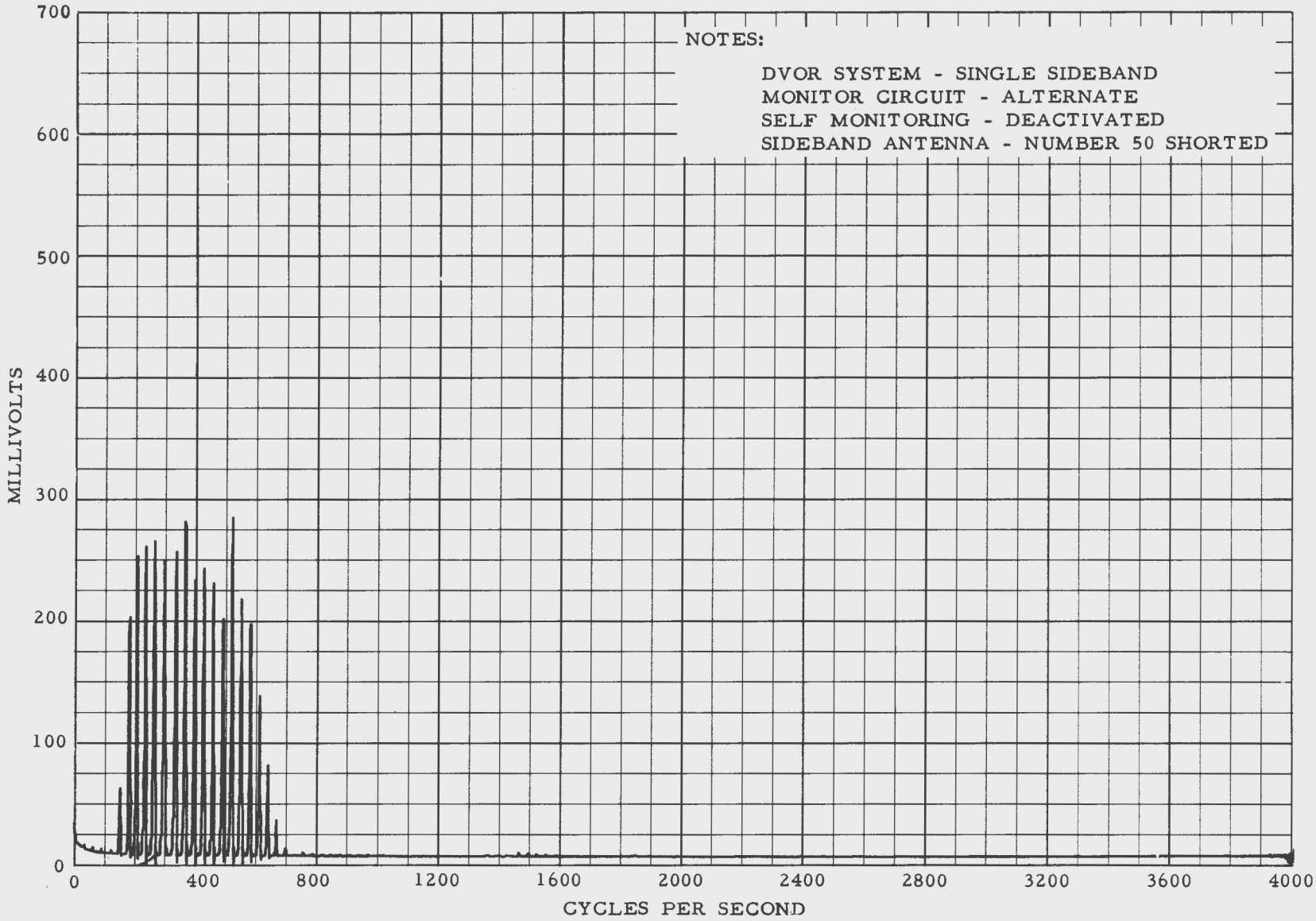


FIG. 34A FREQUENCY SPECTRUM OF THE 200 TO 600 Hz FILTER OUTPUT AT PIN NO. 16 OF BOARD NO. 4

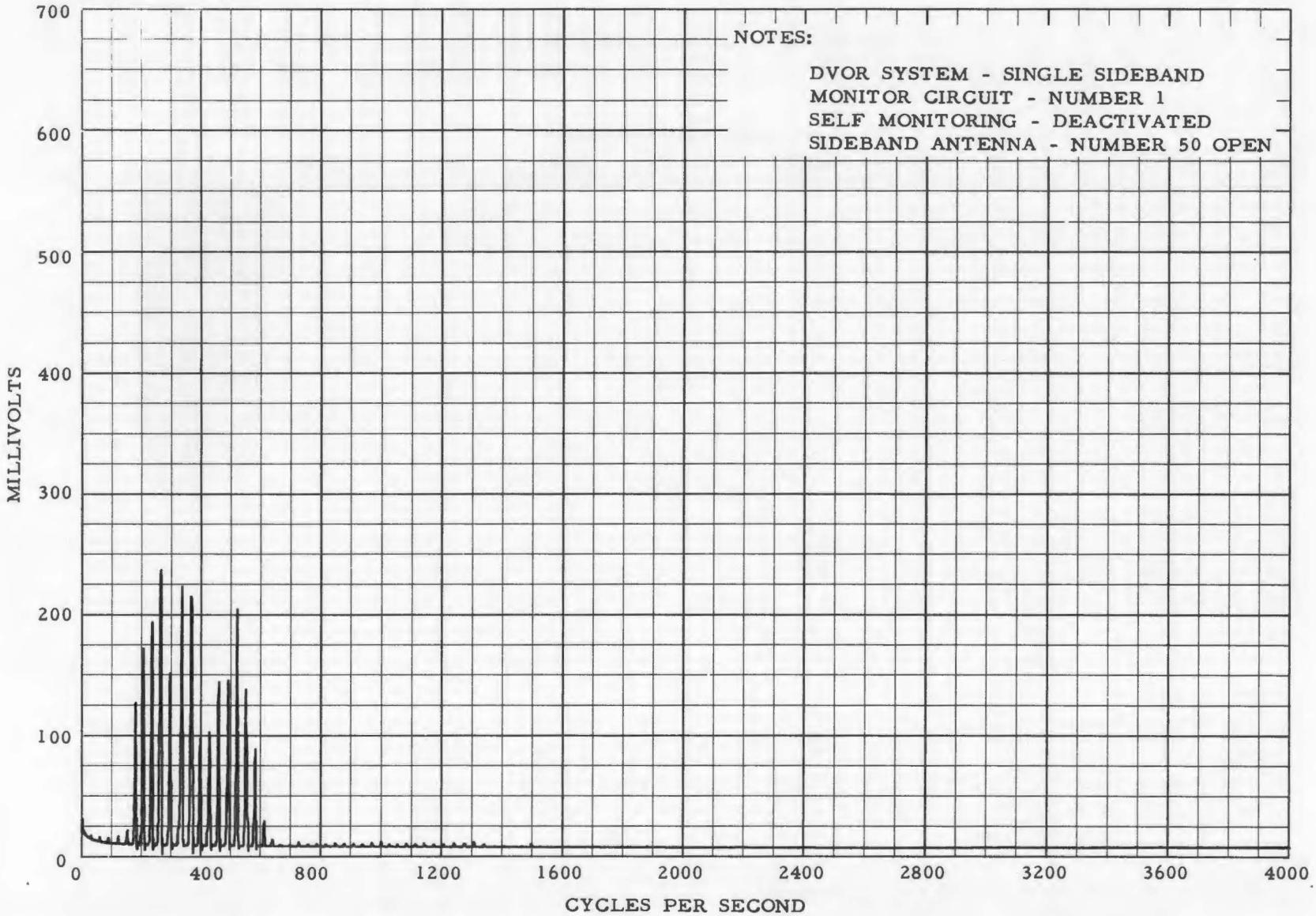


FIG. 35 FREQUENCY SPECTRUM OF THE 200 TO 600 Hz FILTER OUTPUT AT PIN NO. 16 OF BOARD NO. 4

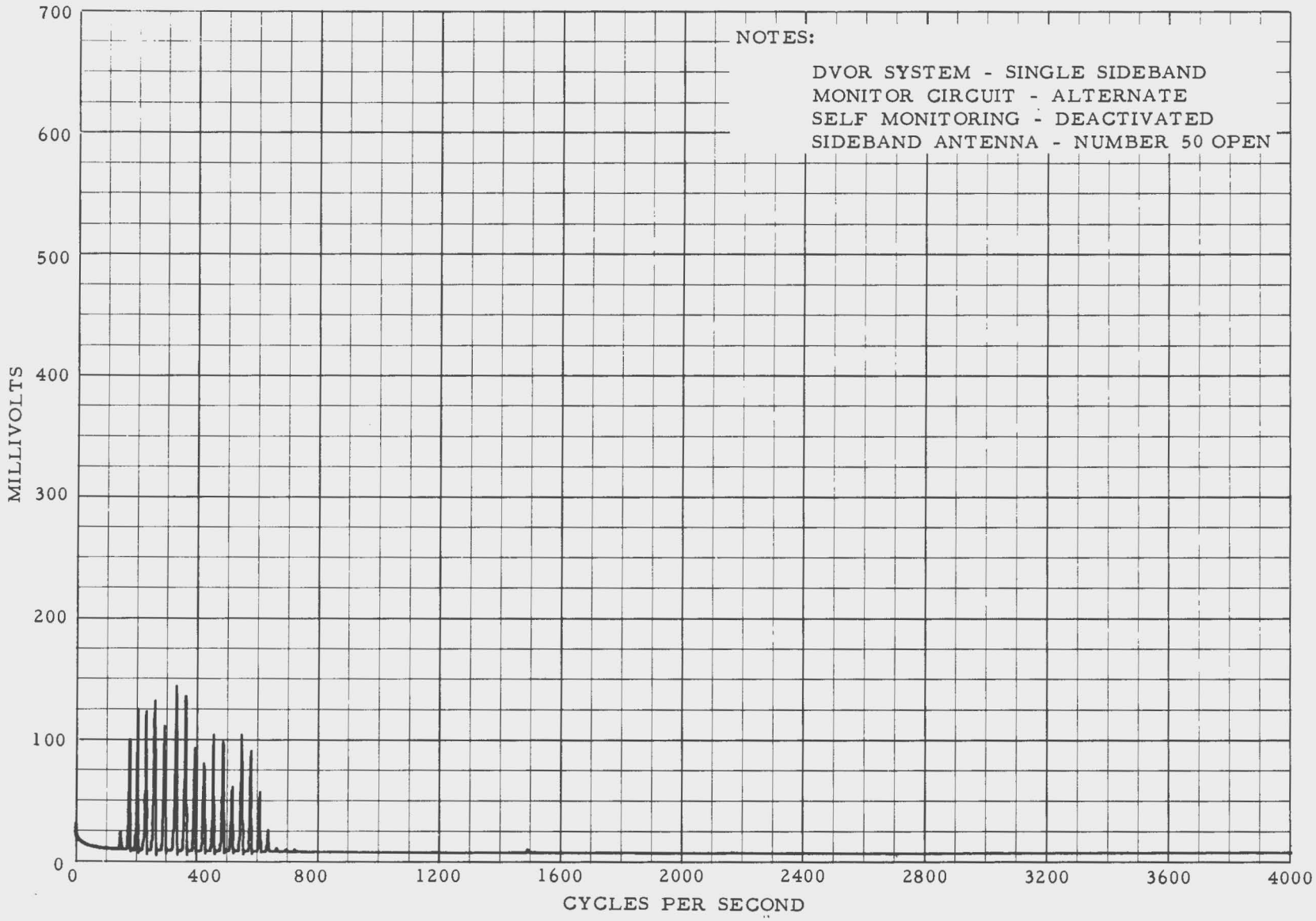


FIG. 35A FREQUENCY SPECTRUM OF THE 200 TO 600 Hz FILTER OUTPUT AT PIN NO. 16 OF BOARD NO. 4

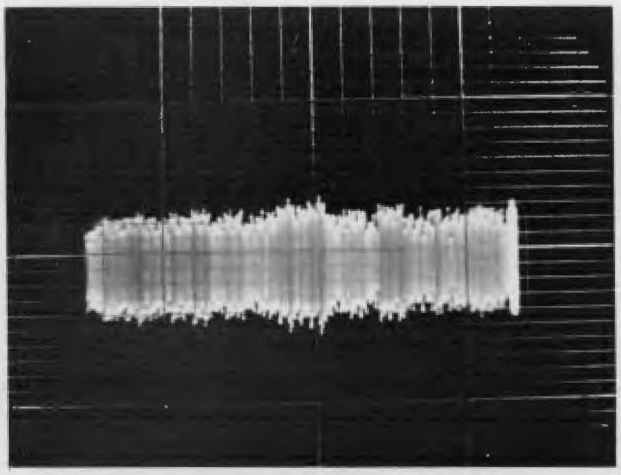
The frequency spectrum using the alternate circuit board are given in figures 27A to 32A for the 9960 Hz detector output, and figures 33A to 35A for the output of the 200 to 600 Hz filter. Photographs of the 9960 Hz detected output, using circuit board No. 1 and the alternate circuit board 1A, with antenna No. 50 shorted and antenna No. 26 open, are given in figure 36 for comparison of the effects to the 9960 Hz signal resulting from an open or shorted antenna.

Self-Check Tests - With the RF inputs to the mixer circuit disconnected and a 30 Hz signal injected at point B (see figure 13) to trigger the harmonic generator, a frequency spectrum of the self-check function using circuit board No. 1, was made of the output of the 200 to 600 Hz harmonic filter (pin No. 12 of board No. 2), and of the output of the 200 to 600 Hz detected spectrum filter at pin No. 16 of board No. 4. These are given in figures 37 and 38, respectively.

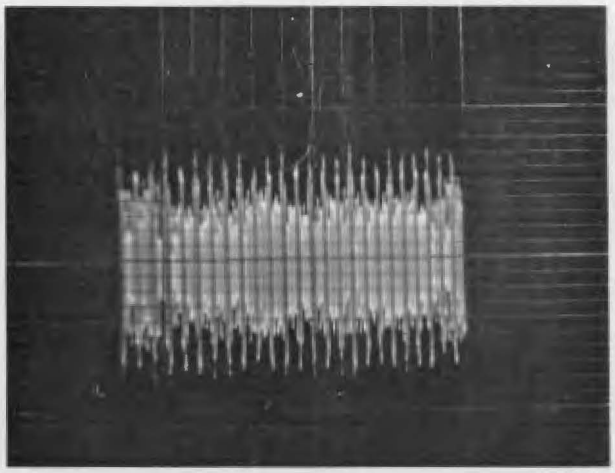
A similar frequency spectrum was made with the alternate circuit board 1A. As this system of self-check function makes use of the 9960 Hz signal from the mixer, the monitor was restored to normal operation by replacing the RF inputs to the mixer circuit. The frequency spectrum of the self-check function as it appears at the output of the 200 to 600 Hz detected spectrum filter pin No. 16 of board No. 4, is given in figure 38A. Photographs of the 9960 Hz filter output with the self-check signal present is given in figure 39.

Alarm Circuitry Tests - Two alarm circuitry tests were conducted to determine the dc voltage developed across the meter relay terminals with two modes of monitor operation. The first test was to determine the maximum value of the dc voltage which the monitors would produce under simulated antenna faults. To accomplish this the self-check function of the monitor was disabled and the gain controls set for maximum. The value of dc voltage across the meter relay terminal was measured and recorded as each of the antenna feed lines were opened, shorted, and with a 50-ohm shunt, placed across each feed line. The results of these tests are given in figures 40 to 42.

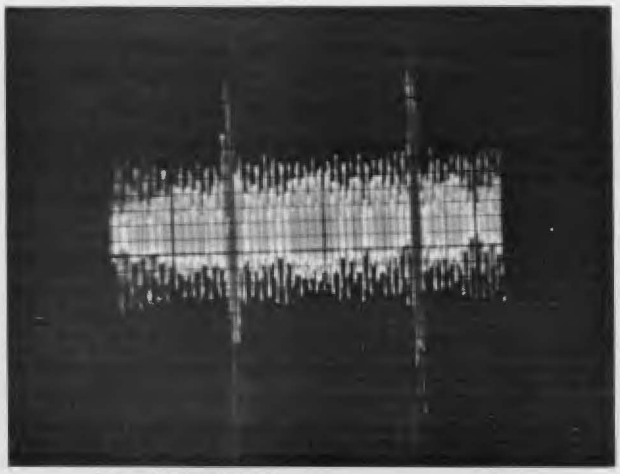
The second test was to determine the value of the dc voltage developed across the meter relay terminals for the same simulated antenna faults with the monitor in normal operating status.



NORMAL

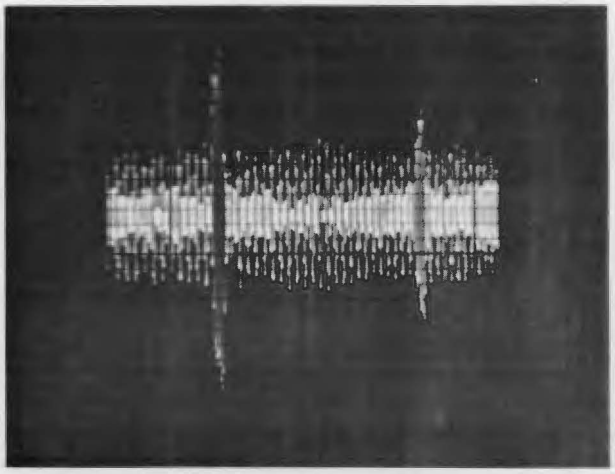


NORMAL



ANTENNA NO. 26 OPEN AND
ANTENNA NO. 50 SHORTED

WITH CIRCUIT BOARD 1



ANTENNA NO. 26 OPEN AND
ANTENNA NO. 50 SHORTED

WITH ALTERNATE CIRCUIT BOARD 1A

FIG. 36 PHOTOGRAPH OF THE OUTPUT OF THE 9960 Hz FILTER AT PIN NO. 1 OF BOARD NO. 4

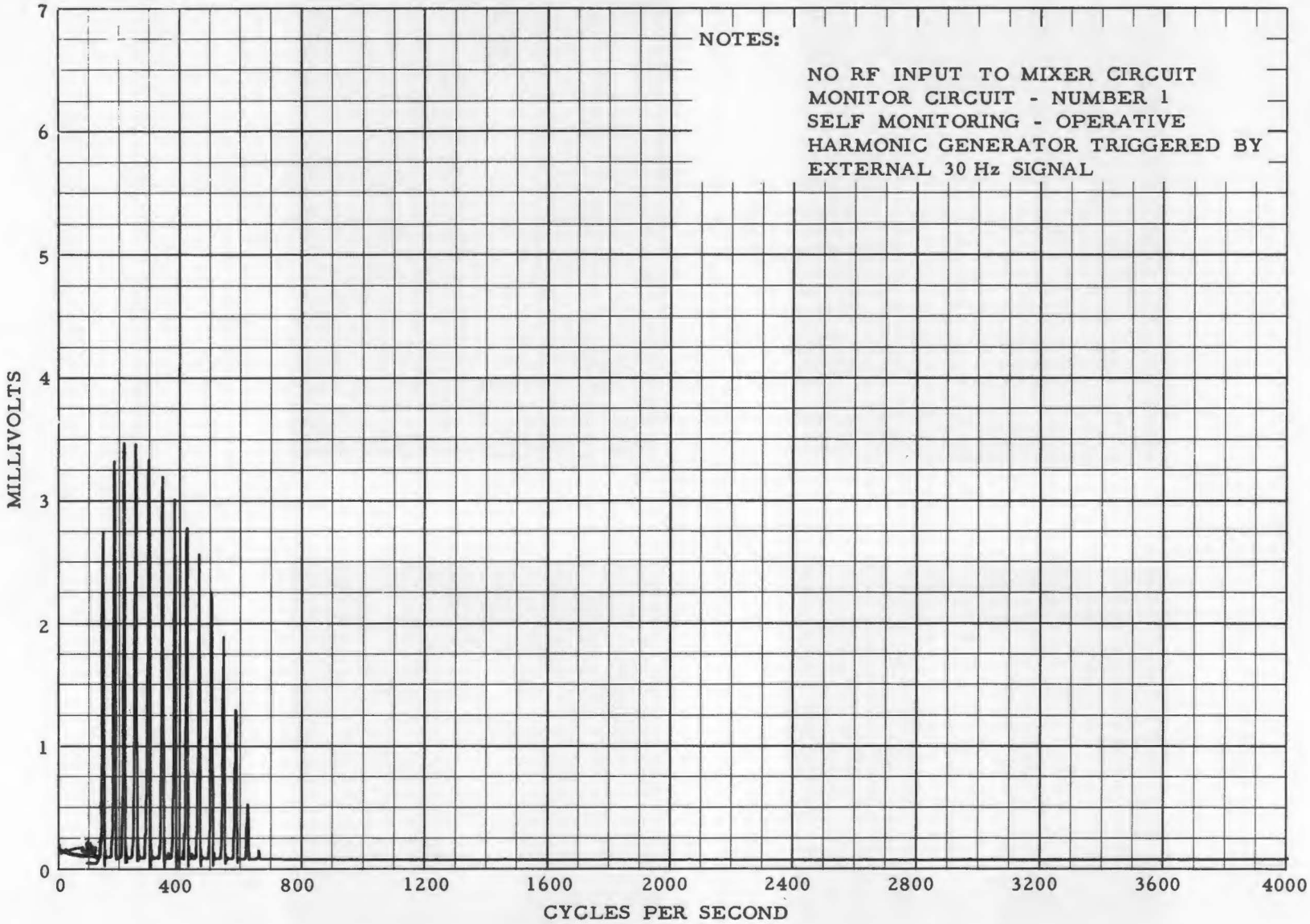


FIG. 37 FREQUENCY SPECTRUM OF THE HARMONIC GENERATOR AT THE OUTPUT OF THE 200 TO 600 Hz HARMONIC FILTER AT PIN NO. 12 OF BOARD NO. 2

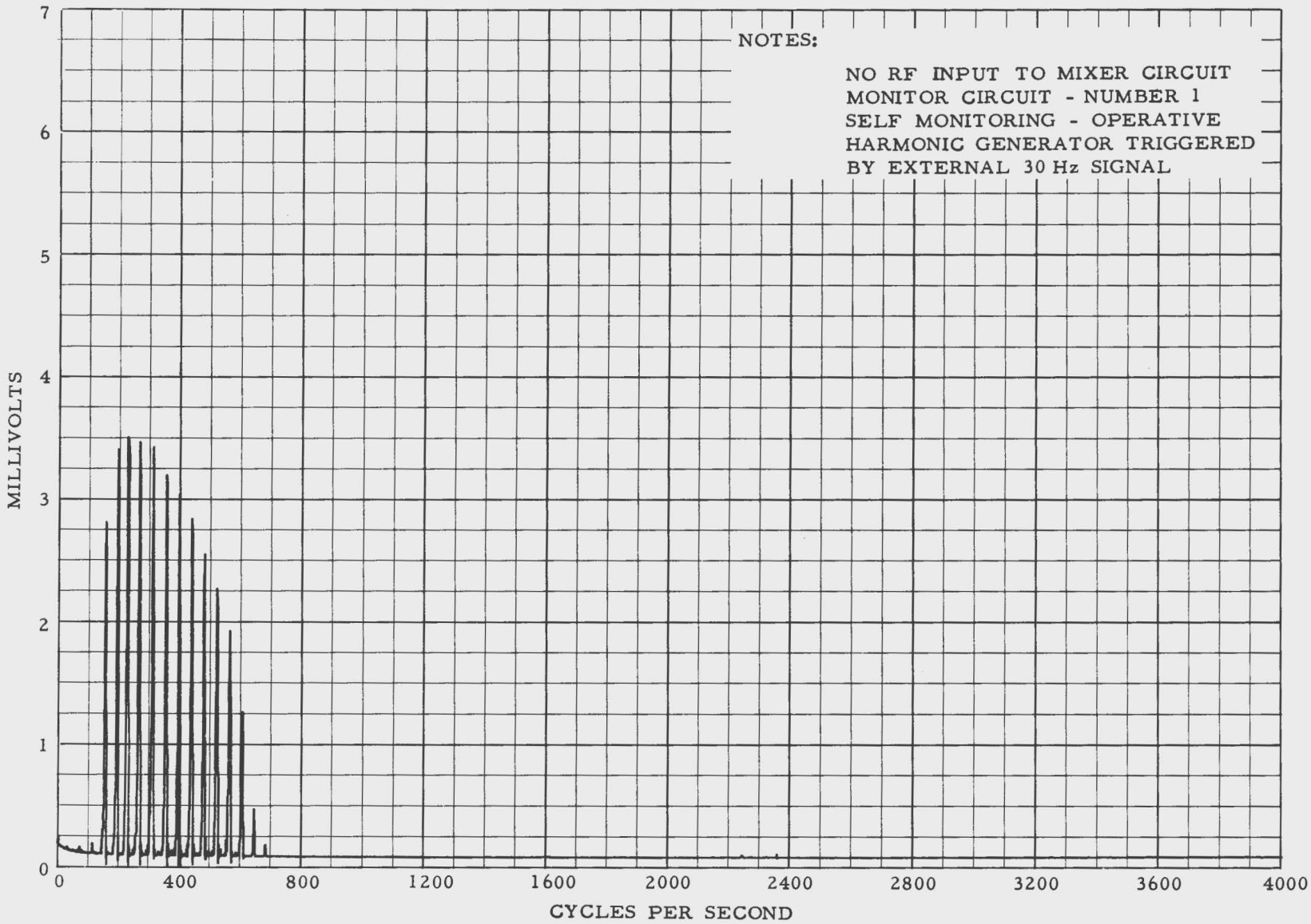


FIG. 38 FREQUENCY SPECTRUM OF THE HARMONIC GENERATOR AT THE OUTPUT OF THE 200 TO 600 Hz DETECTOR FILTER AT PIN NO. 16 OF BOARD NO. 4

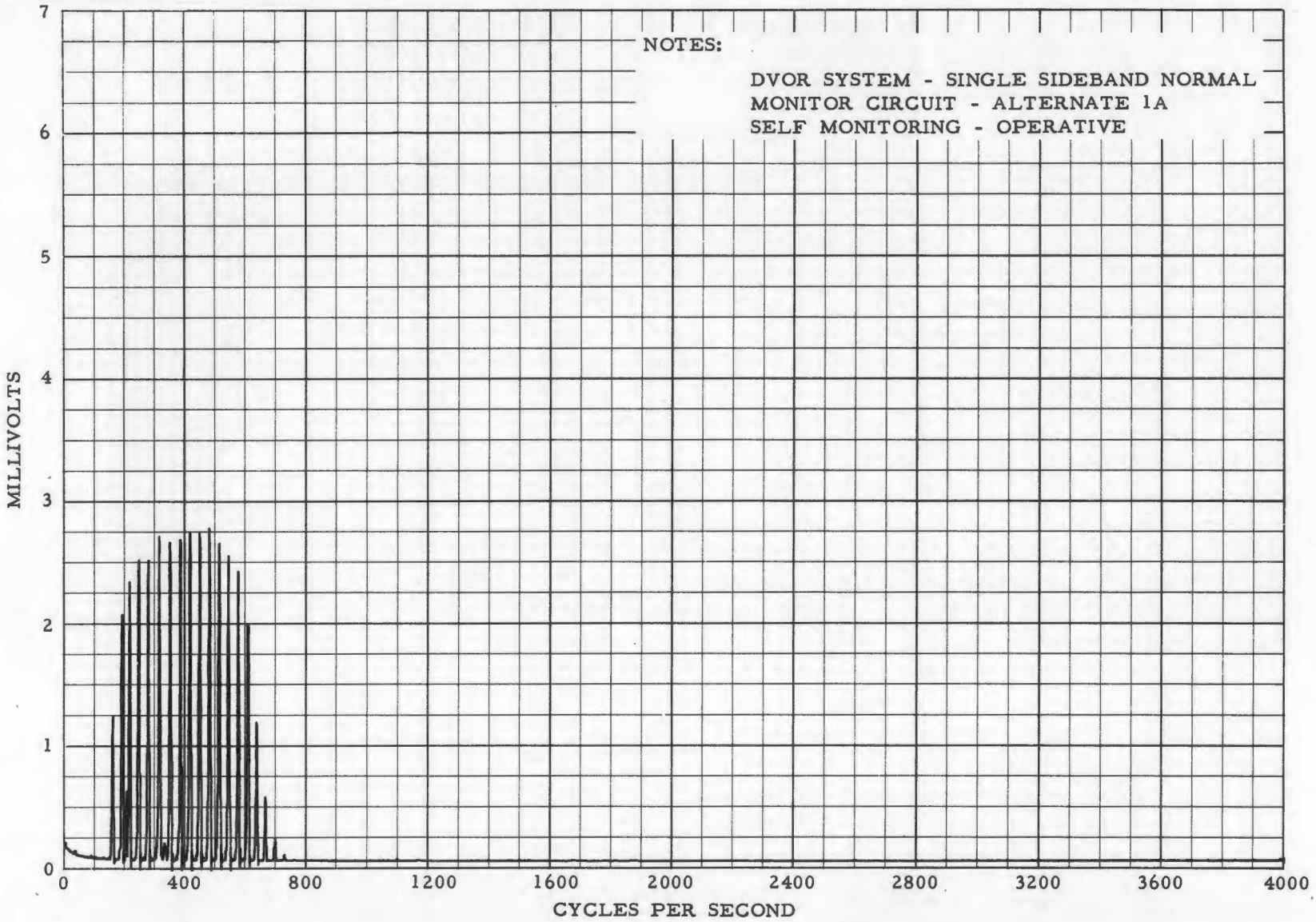
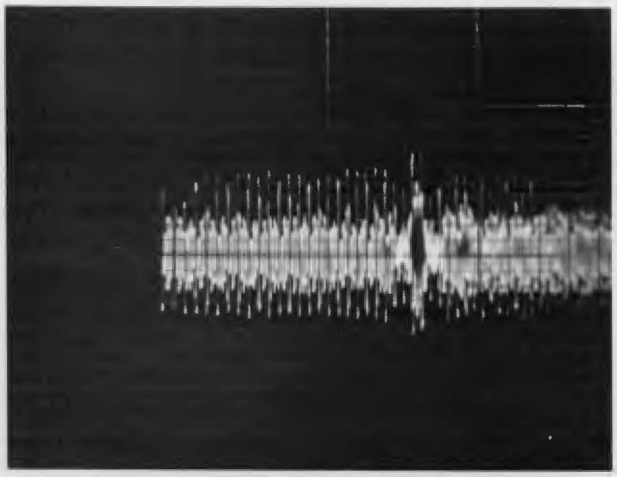
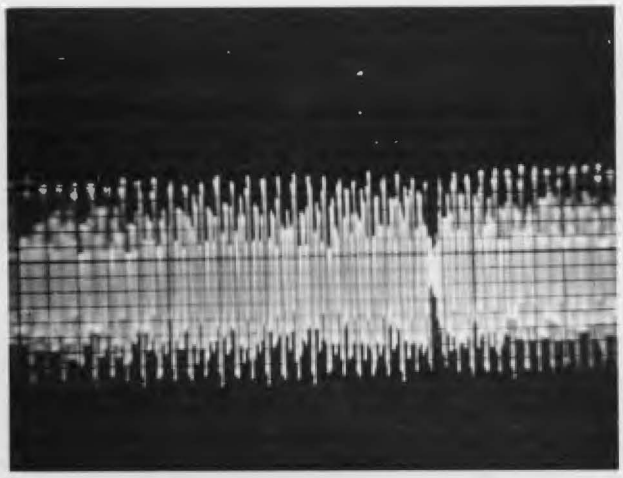


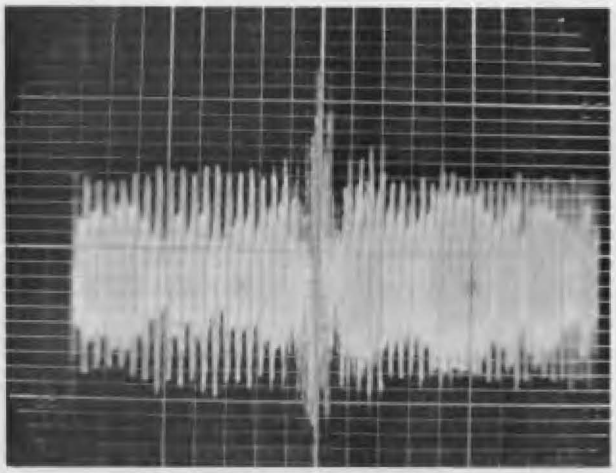
FIG. 38A FREQUENCY SPECTRUM OF THE HARMONIC GENERATOR AT THE OUTPUT OF THE 200 TO 600 Hz DETECTOR FILTER AT PIN NO. 16 OF BOARD NO. 4



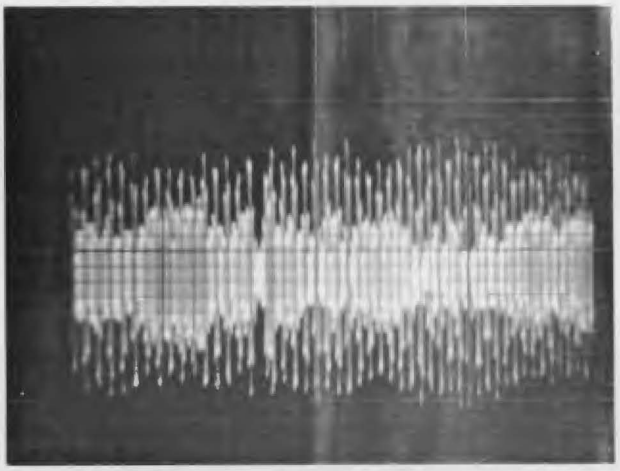
AT TEST JACK NO. 19



AT TEST JACK NO. 19



AT THE OUTPUT OF THE 9960 Hz FILTER



AT THE OUTPUT OF THE 9960 Hz FILTER

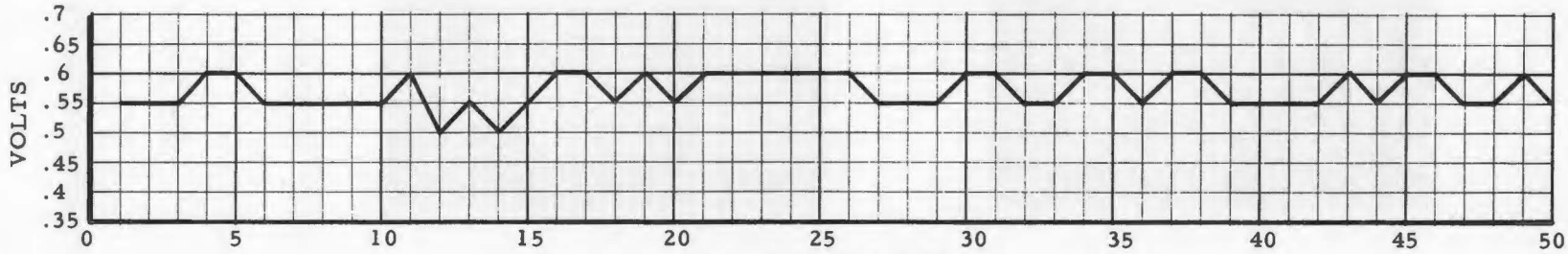
CIRCUIT BOARD 1

ALTERNATE CIRCUIT BOARD 1A

FIG. 39 EFFECTS OF THE SELF-CHECK FUNCTION TO THE 9960 Hz SIGNAL

NOTES:

DVOR SYSTEM - SINGLE SIDEBAND
SELF MONITORING - DEACTIVATED
GAIN SET FOR MAXIMUM OUTPUT
CONDITION - OPEN ON EACH ANTENNA



ANTENNA NUMBER

MONITOR WITH CIRCUIT BOARD 1

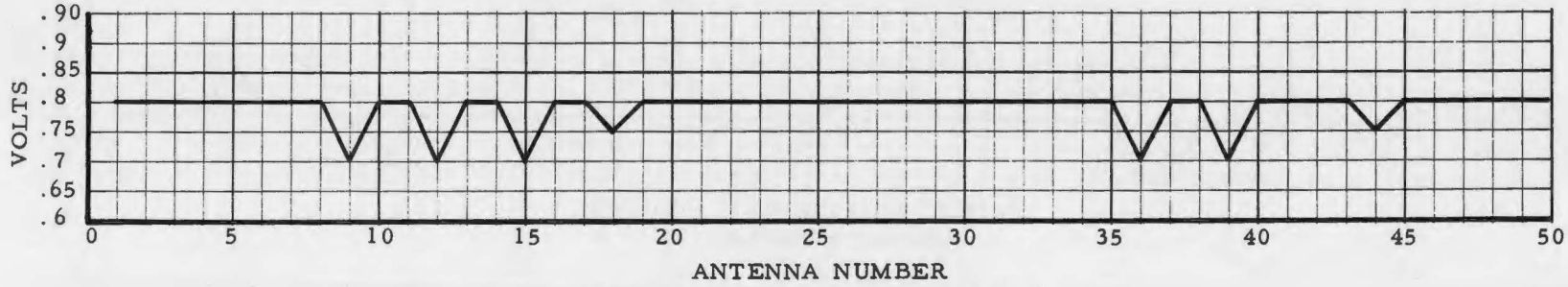
ANTENNA NUMBER

MONITOR WITH ALTERNATE CIRCUIT BOARD 1A

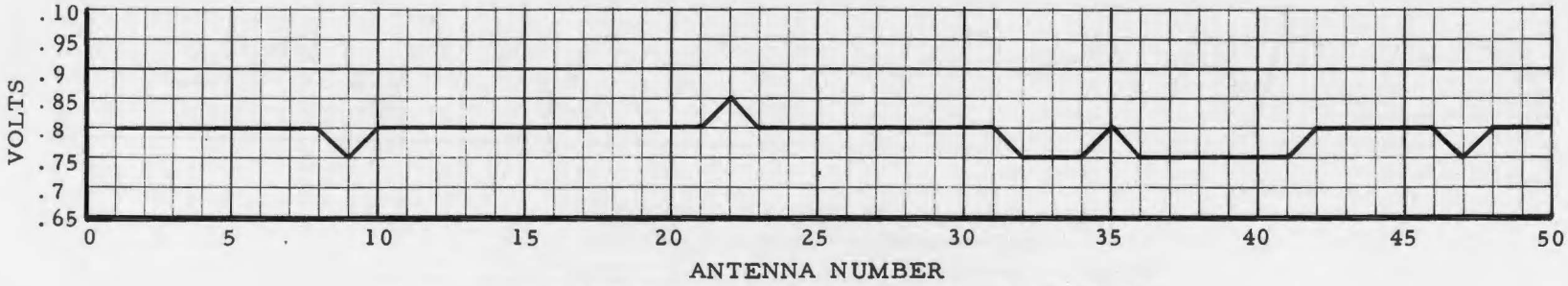
FIG. 40 DC VOLTAGE DEVELOPED ACROSS METER/RELAY TERMINALS

NOTES:

DVOR SYSTEM - SINGLE SIDEBAND
SELF MONITORING - DEACTIVATED
GAIN SET FOR MAXIMUM OUTPUT
CONDITION - SHORT ON EACH ANTENNA



MONITOR WITH CIRCUIT BOARD 1

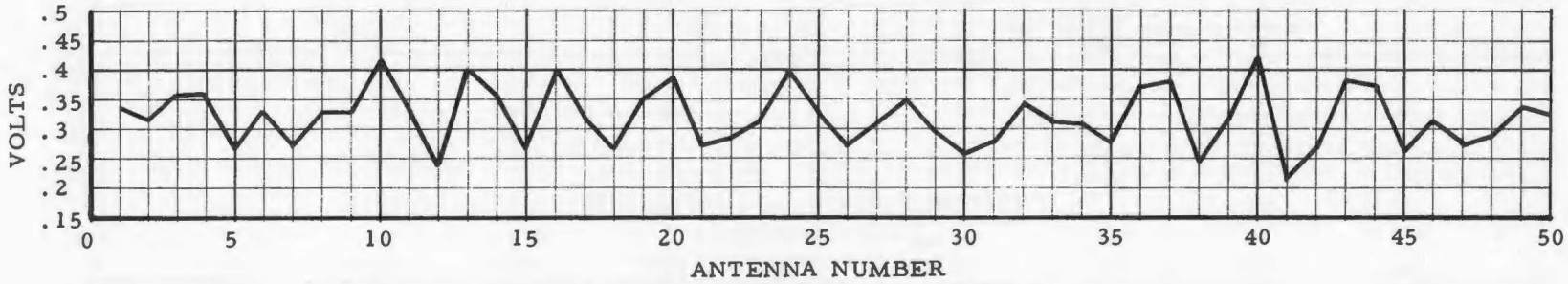


MONITOR WITH ALTERNATE CIRCUIT BOARD 1A

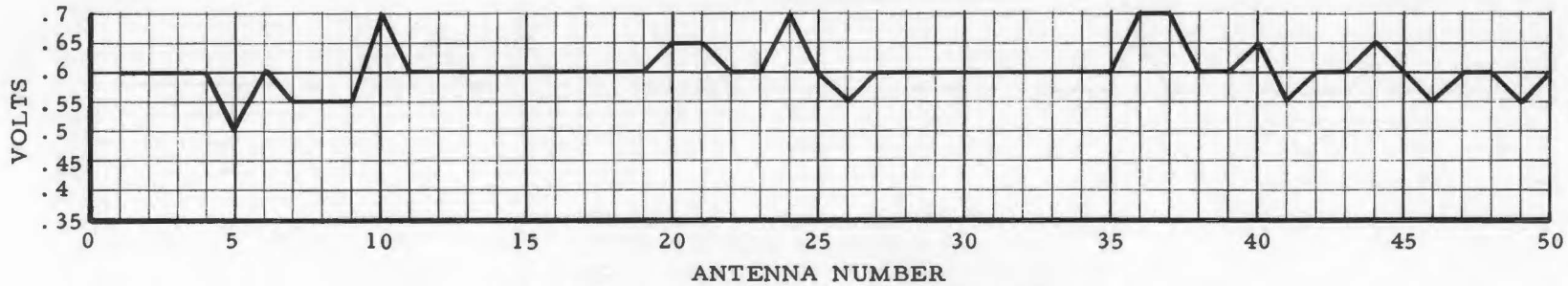
FIG. 41 DC VOLTAGE DEVELOPED ACROSS METER/RELAY TERMINALS

NOTES:

DVOR SYSTEM - SINGLE SIDEBAND SYSTEM
SELF MONITORING - DEACTIVATED
CONDITION - 50 OHM SHUNT EACH ANTENNA



MONITOR WITH CIRCUIT BOARD 1



MONITOR WITH ALTERNATE CIRCUIT BOARD 1A

FIG. 42 MAXIMUM DC VOLTAGE DEVELOPED ACROSS METER/RELAY TERMINALS

The self-check function was restored. The alarm points were set for a meter indication of 30 (.03V) for normal Doppler VOR operation, a meter indication of 40 (.04V) for a sideband antenna fault alarm, and an indication of 20 (.02V) for the monitor self-check alarm function.

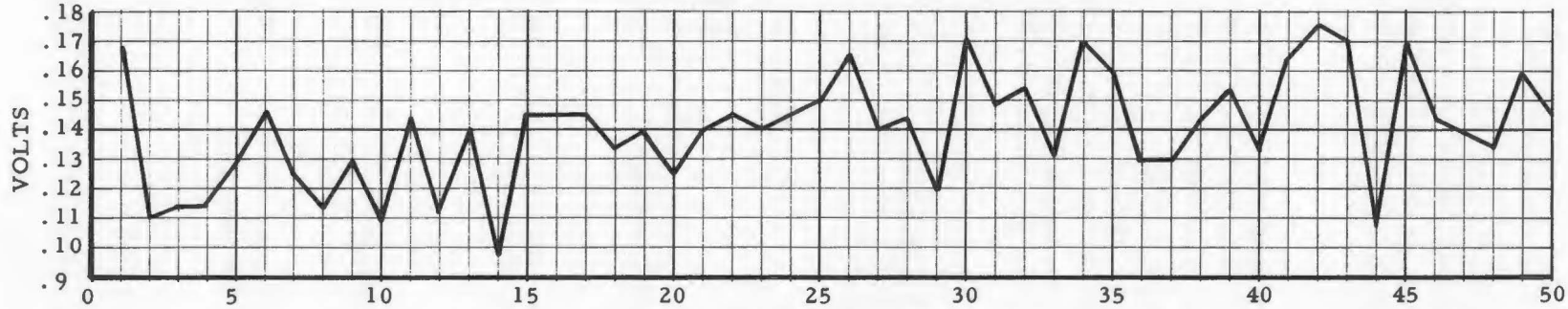
These alarm tolerances were arbitrarily chosen for normal monitor operation. In field operations it may be necessary to change the value of the alarm points due to operational environment and due to changes from a prototype model to production model. However, for the purpose of this report these tolerances will be considered as normal operation values. With the monitor adjusted to these tolerances the simulated sideband antenna faults used in the first test were repeated and the results given in figures 43 to 45.

Tests of the Self-Check Operation - With the Doppler VOR and monitor operating in a normal status the following tests were made with the results indicated:

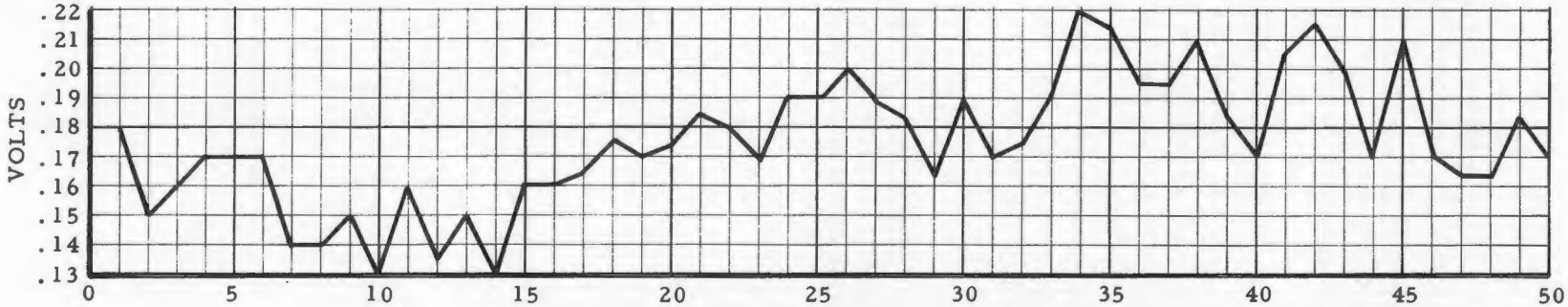
	Monitor with Circuit Board 1 Alarm	1A Alarm
1. Loss of sideband energy to mixer	Yes	Yes
2. Loss of carrier energy to mixer	Yes	Yes
3. Loss of mixer output	Yes	Yes
4. Loss of self-check trigger	Yes	Yes
5. Removal of any one of the five circuit boards	Yes	Yes
6. Loss of 110 v, 60 Hz power to monitor	Yes	Yes
7. Loss of either of the 20 v dc power supply	Yes	Yes

NOTES:

DVOR SYSTEM - SINGLE SIDEBAND
SELF MONITORING - OPERATIVE
NORMAL OPERATION
ALARM VOLTAGE .04 VOLTS
CONDITION - OPEN ON EACH ANTENNA



ANTENNA NUMBER
MONITOR WITH CIRCUIT BOARD 1

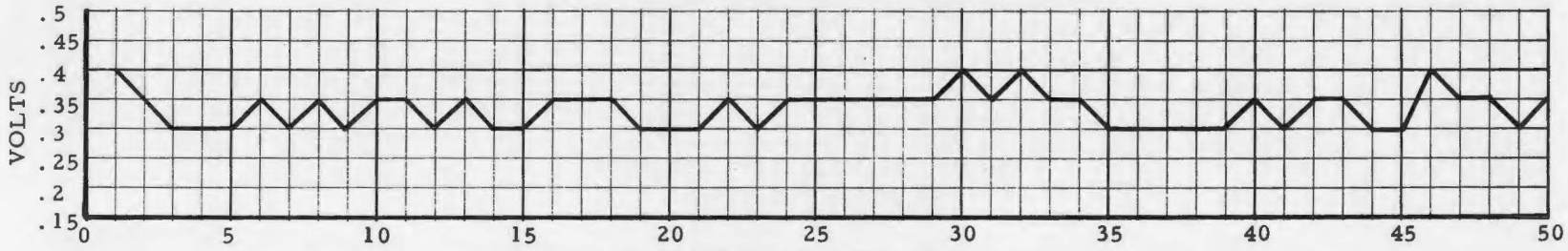


ANTENNA NUMBER
MONITOR WITH ALTERNATE CIRCUIT BOARD 1A

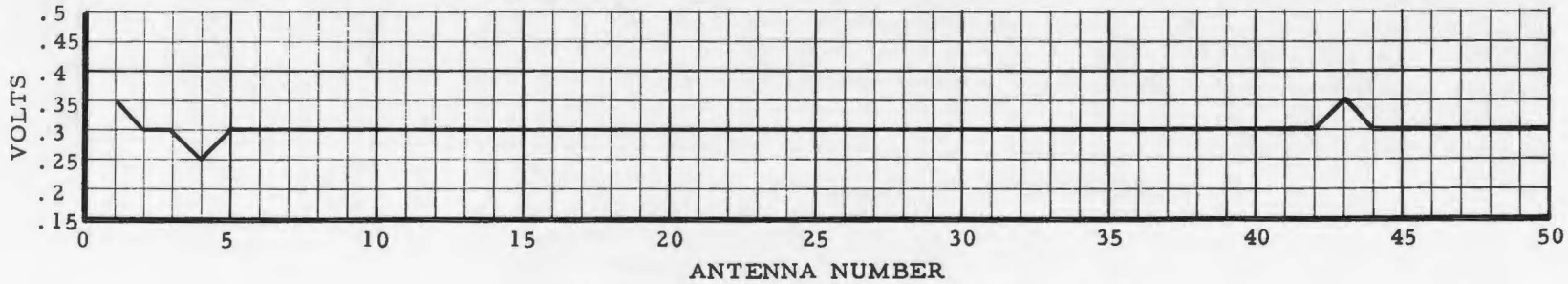
FIG. 43 DC VOLTAGE ACROSS METER/RELAY TERMINALS

NOTES:

DVOR SYSTEM - SINGLE SIDEBAND
SELF MONITORING - OPERATIVE
NORMAL OPERATION
ALARM VOLTAGE .04 VOLTS
CONDITION - SHORT ON EACH ANTENNA



MONITOR WITH CIRCUIT BOARD 1

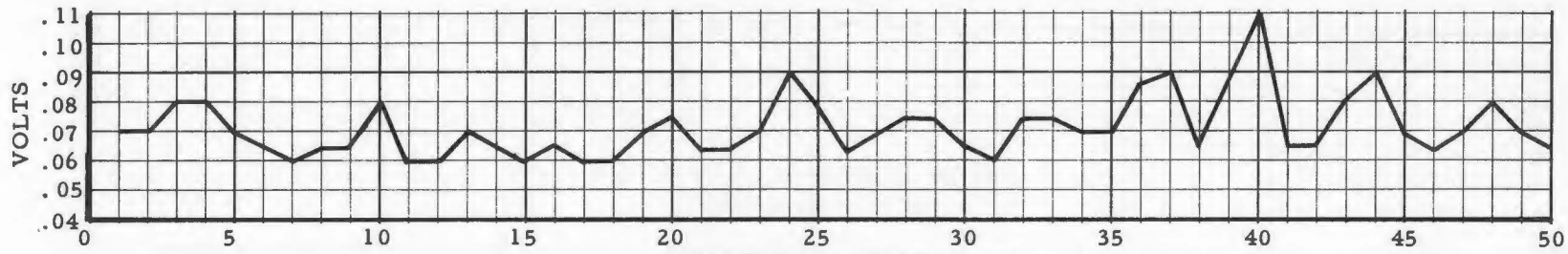


MONITOR WITH ALTERNATE CIRCUIT BOARD 1A

FIG. 44 DC VOLTAGE ACROSS METER/RELAY TERMINALS

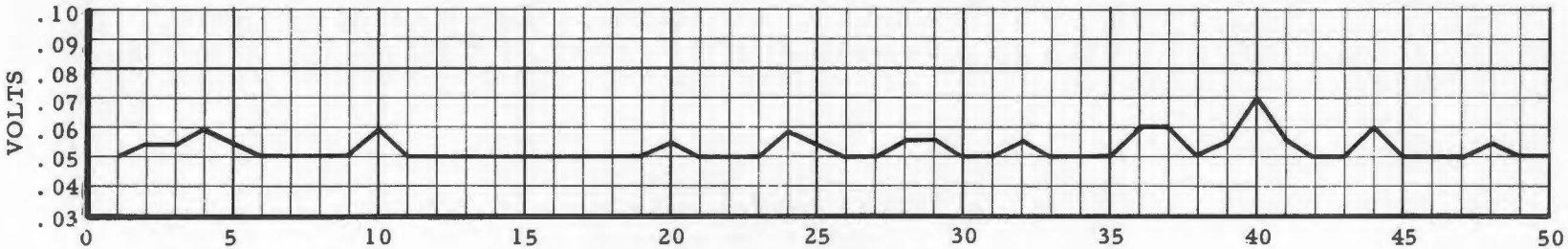
NOTES:

DVOR SYSTEM - SINGLE SIDEBAND
SELF MONITORING - OPERATIVE
NORMAL OPERATION
ALARM VOLTAGE .04 VOLTS
CONDITION - 50 OHM SHUNT ON EACH ANTENNA



ANTENNA NUMBER

MONITOR WITH CIRCUIT BOARD 1



ANTENNA NUMBER

MONITOR WITH ALTERNATE CIRCUIT BOARD 1A

FIG. 45 DC VOLTAGE ACROSS METER/RELAY TERMINALS

There were two transistor failures, both of which produced an alarm. These were reference No. Q101, type 2N930 input amplifier of circuit board No. 1, and reference No. Q103, type 2N930 of circuit board 1A. In addition, one of the Technipower 20 V dc power supplies developed a defect resulting in spikes appearing on the dc output. This also produced an alarm.

Stability Tests - The monitor underwent stability tests during the acceptance test; therefore, stability tests were limited to determining the effects that changes in the sideband antenna transmission line electrical length due to temperature variation would have in the monitoring function. Based on data obtained during previous tests made to determine the effect of temperature on the electrical length of RG-8/u transmission line,[2] a temperature change of 11° F will produce a change of 1° (electrical) in a 35-foot length of line, approximately the length of each of the sideband antenna's transmission lines.

With the DVOR facility and the monitor in normal operation, simulated temperature changes were made by varying the sideband antenna transmission line lengths in steps of 5° (electrical) until the monitor indicated an alarm. The results are tabulated in figure 46. The matching stub length was decreased to the point at which the monitor alarmed and was found to change from 1.95 VSWR for normal condition to 2.1 VSWR at the alarm point. A change in the electrical length of the feed lines or of the distributor input matching network will be reflected as a change in the VSWR. However, the sensitivity setting of the monitor will determine the point of alarm for a change in the VSWR at the input of the distributor. It is interesting to note that the monitor will tolerate a greater change in electrical line length as long as all lines change equally, yet will alarm when only one line changes a small amount.

Carrier Modulation Effects - The monitor was adjusted for normal operation and the carrier transmitter modulated by voice from a continuous loop tape recording. The modulation of the carrier transmitter was adjusted for 28 percent on voice peaks and the effects noted on the meter/relay of the monitor. The voice modulation of the carrier increased the meter/relay reading, varying from its normal value of 30 to 36. Increasing

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[2] Taggart, S. E., DeZoute, O. J., and Ehler, W. M., "The CAA Directional Localizer," Technical Development Report No. 367, dated August 1958.

FEED LINE TO ANTENNA NUMBER	DIRECTION OF CHANGE	AMOUNT OF CHANGE	MONITOR ALARM	
			1	1A
#50	INCREASED	5°	NO	NO
#50	INCREASED	10°	YES	YES
#13	INCREASED	5°	NO	NO
#13	INCREASED	10°	YES	YES
#50	DECREASED	5°	YES	YES
#13	DECREASED	5°	YES	YES
ALL FEED LINE	INCREASED	5°	NO	NO
ALL FEED LINE	INCREASED	10°	NO	NO
ALL FEED LINE	INCREASED	15°	NO	NO
ALL FEED LINE	INCREASED	20°	YES	YES
ALL FEED LINE	DECREASED	5°	NO	NO
ALL FEED LINE	DECREASED	10°	YES	YES
#49 } #50 }	INTERCHANGE		YES	YES

FIG. 46 TABULATION OF CHANGES IN THE ANTENNA FEED LINE ELECTRICAL LENGTH TO PRODUCE AN ALARM

the modulation percentage from 28 on peaks to 33 caused an intermittent alarm. The alarm value was set for a meter reading of 40. A further increase in the modulation percentage caused a steady alarm; the normal course alignment monitor was also affected.

An audio oscillator signal was substituted for the voice signal and the frequency of the audio oscillator varied from 100 Hz to 800 Hz, holding the output constant to determine the frequency which would produce the greatest effect to the monitor. There was no effect below 200 Hz as this was below the lower limit of the 200 to 600 Hz filter. There was a peak around 500 Hz and a downward trend from 500 Hz to 650 Hz. The upper frequency limit of the 200 to 600 Hz filter is 600 Hz. The voice modulation characteristics of the carrier transmitter attenuates frequencies below 300 Hz and is flat, within 6 dB, from 300 Hz to 2,500 Hz. The combination of modulation characteristics and filter characteristics would result in the above frequency response of the monitor. Taking into consideration the spectrum of frequencies produced at the output of the 200 to 600 Hz filter due to a faulty antenna (see figures 33 to 35, and 53 to 55) and the modulation characteristics of the carrier transmitter, it appears that the specification for the 200 to 600 Hz filter could be changed. The low frequency "cut-off" could be lowered from 200 Hz to approximately 150 Hz to take advantage of the energy contained in those frequencies generated below 200 Hz by a faulty antenna. The low frequency limit of 150 Hz will still provide rejection of the 30 Hz main modulation component of the carrier energy and any 60 Hz residual hum of the carrier. This change would also take advantage of the low modulation response of the transmitter for those frequencies below 300 Hz. The upper cut-off frequency of the filter could be lowered from 600 Hz to 550 Hz or 500 Hz to reduce the effects of voice modulation to the monitor. The loss of spectrum energy resulting from lowering the high frequency cut-off will be more than offset by the change of the low frequency cut-off point of the filter.

Double Sideband System: Tests of the monitor performance in the double sideband Doppler VOR System were limited to determining the frequency spectrum of the output of the mixer, the 9960 Hz filter, 200 to 600 detector filter, and the dc voltage levels developed across the meter/relay terminals.

The double sideband Doppler VOR System, used for the monitor performance tests, consisted of 52 sideband antennas and a high level modulation system for the 30 Hz am signal.

The sideband energy for the mixer circuit was obtained from a directional coupler installed in the upper sideband input to

the distributor in the same manner as was done in the single sideband tests. The carrier energy was obtained from the driver stage for the power amplifier of the carrier transmitter making use of a quarter-wave power divider to obtain the proper level of carrier energy.

The frequency spectrum of the output of the mixer under normal Doppler VOR operation, and with simulated sideband antenna faults, are given in figures 47 to 49.

With the self-check function of the monitor deactivated, the frequency spectrum of the 9960 Hz filter output for normal operation and for simulated sideband antenna faults are given in figures 50 to 52, for the monitor using circuit board No. 1; and figures 50A, 51A, and 52A using the alternate circuit board No. 1A. The frequency spectrum of the 200 to 600 Hz detector filter output are given in figures 53 to 55 for circuit board No. 1, and 53A, 54A, and 55A for the alternate circuit board No. 1A. The maximum dc voltages developed across the meter/relay terminals are given in figures 56 and 57. The dc voltages developed across the meter/relay terminals with simulated antenna faults for normal monitor operation are given in figures 58 and 59.

Functional Test Circuit for Sideband Monitor

A simulated antenna fault, to be used for testing of the monitor, can be obtained by modification to the standard VOR test generator type FA-5628. The modification consists of adding a capacitor of .033 uF value to capacitor C7, and supplying a 70 V 300 us pulse, PRF-30 Hz, from a Hewlett Packard model 214 through a 5 kilohm resistor to terminals 9 and 10 of the VOR test generator. This will produce a distortion in the 9960 Hz signal similar to the distortion produced by the self-check function of the alternate circuit board No. 1A.

SUMMARY

Self-Check Function

Comparison of frequency spectrum of figure 38, with figure 38A, indicates that the two methods of generating the spectrum of harmonics for the self-check function will produce approximately the same spectrum of frequencies. It will be noted in figure 38

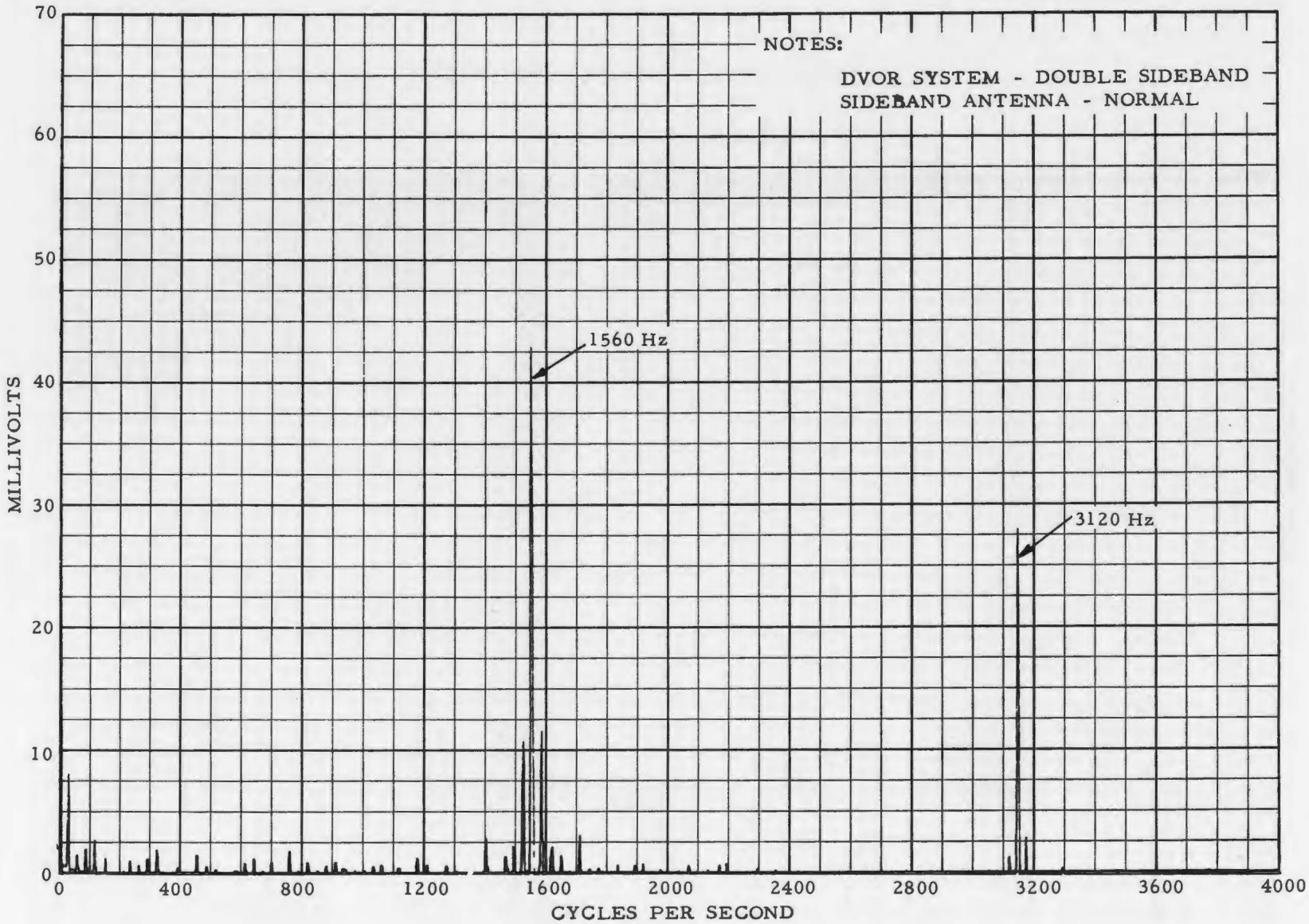


FIG. 47 FREQUENCY SPECTRUM OF MIXER OUTPUT

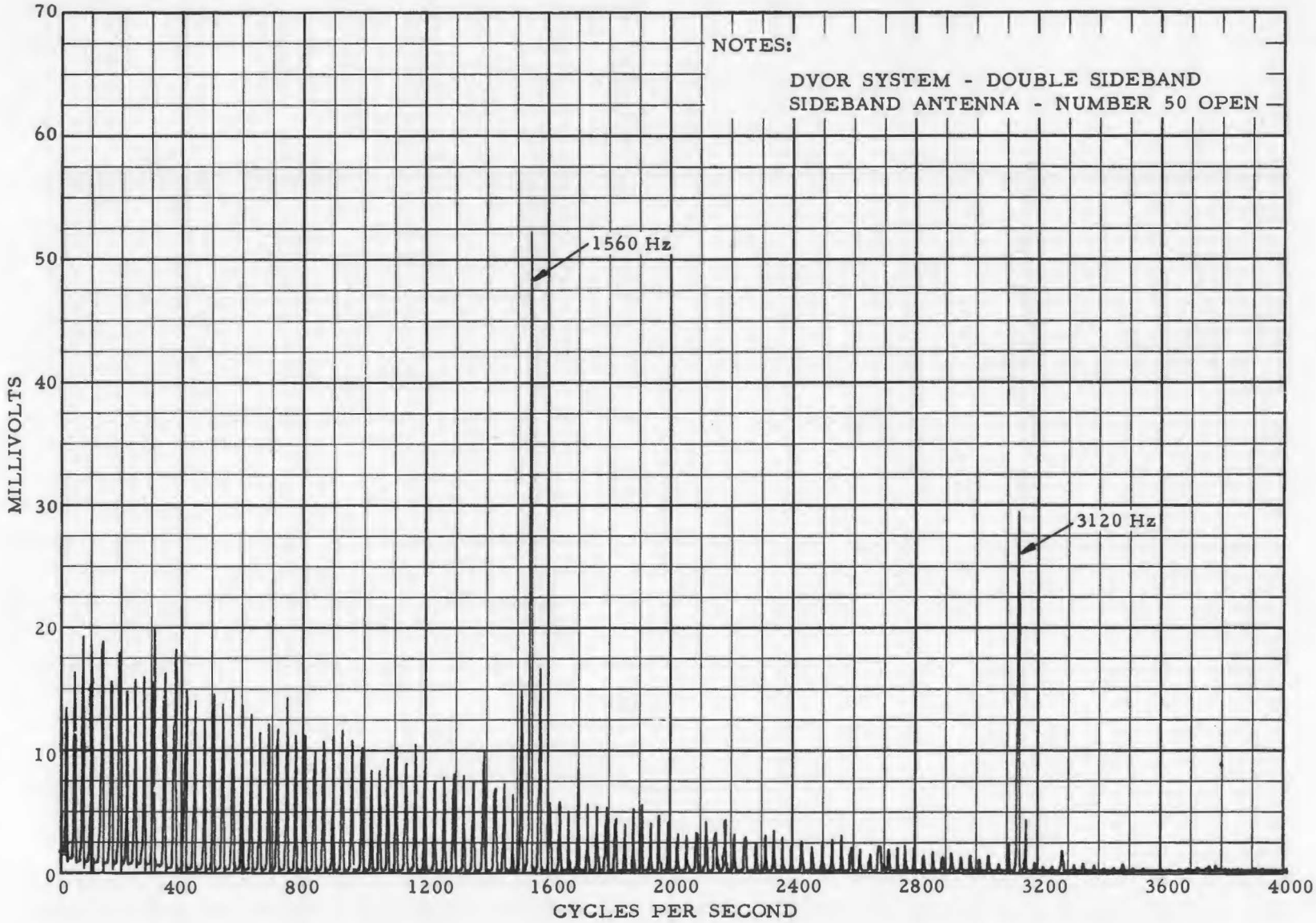


FIG. 48 FREQUENCY SPECTRUM OF MIXER OUTPUT

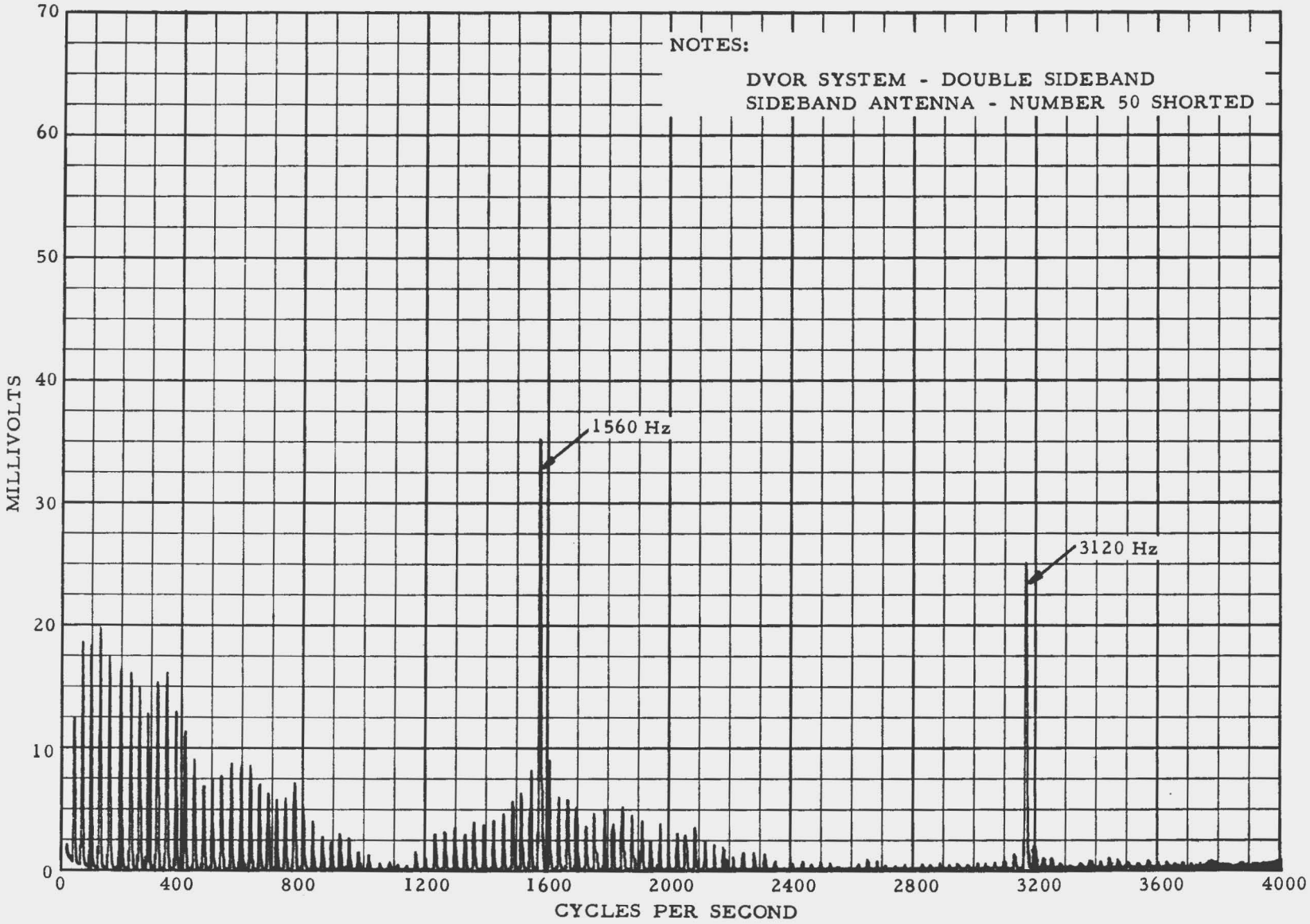


FIG. 49 FREQUENCY SPECTRUM OF MIXER OUTPUT

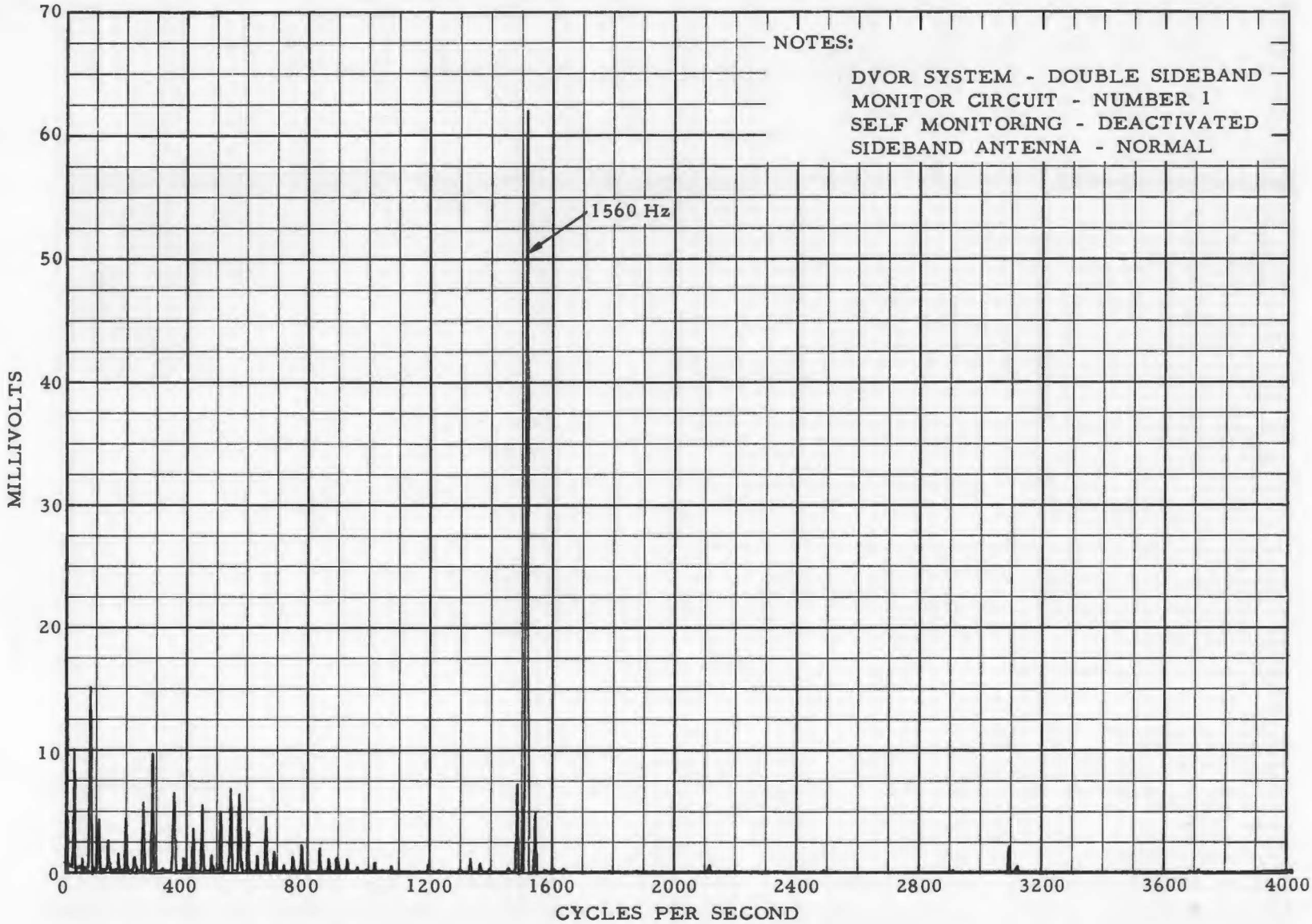


FIG. 50 FREQUENCY SPECTRUM OF THE 9960 Hz SIDEBAND DETECTOR OUTPUT AT PIN NO. 1 OF BOARD NO. 4

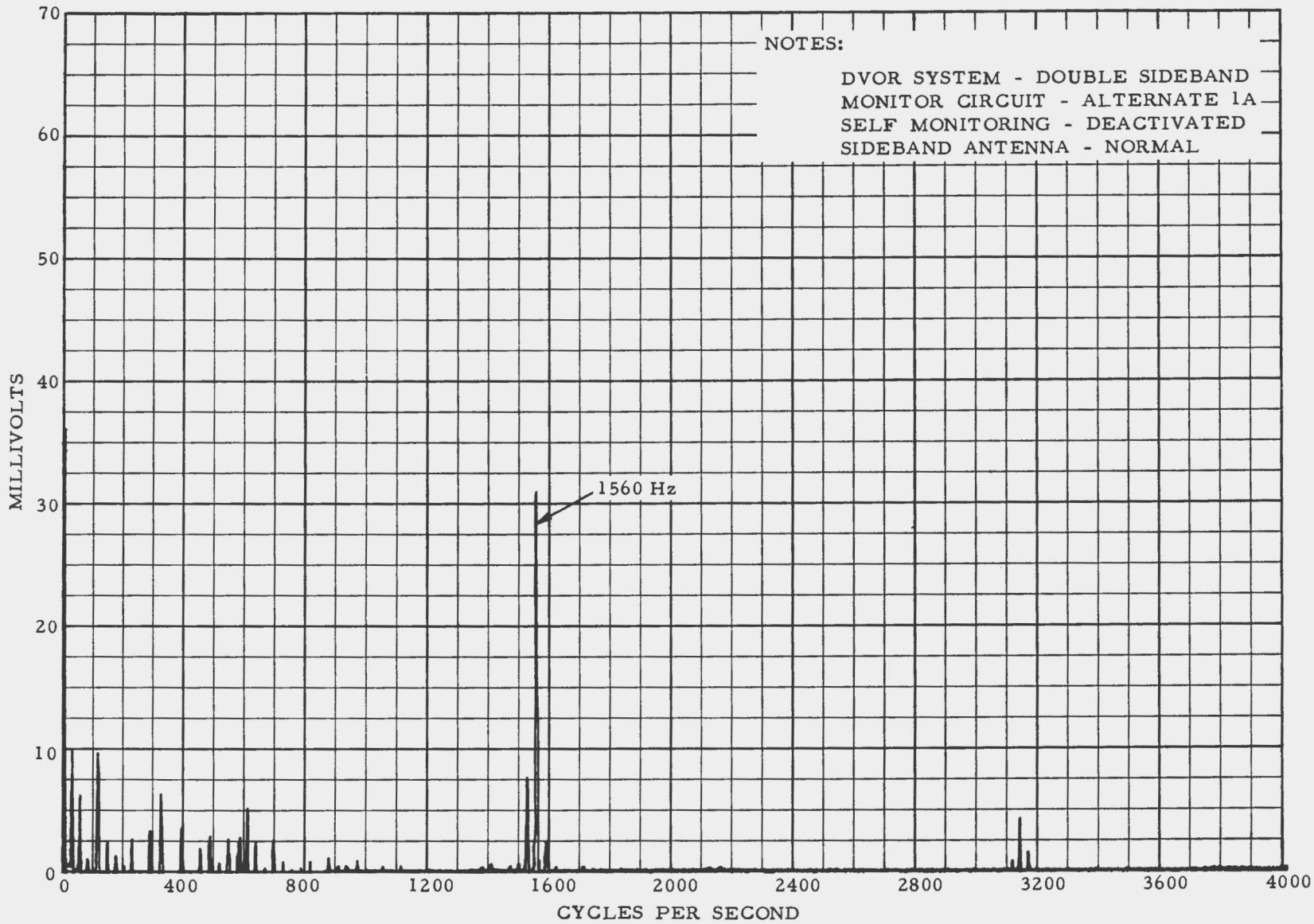


FIG. 50A FREQUENCY SPECTRUM OF THE 9960 Hz SIDEBAND DETECTOR OUTPUT AT PIN NO. 1 OF BOARD NO. 4

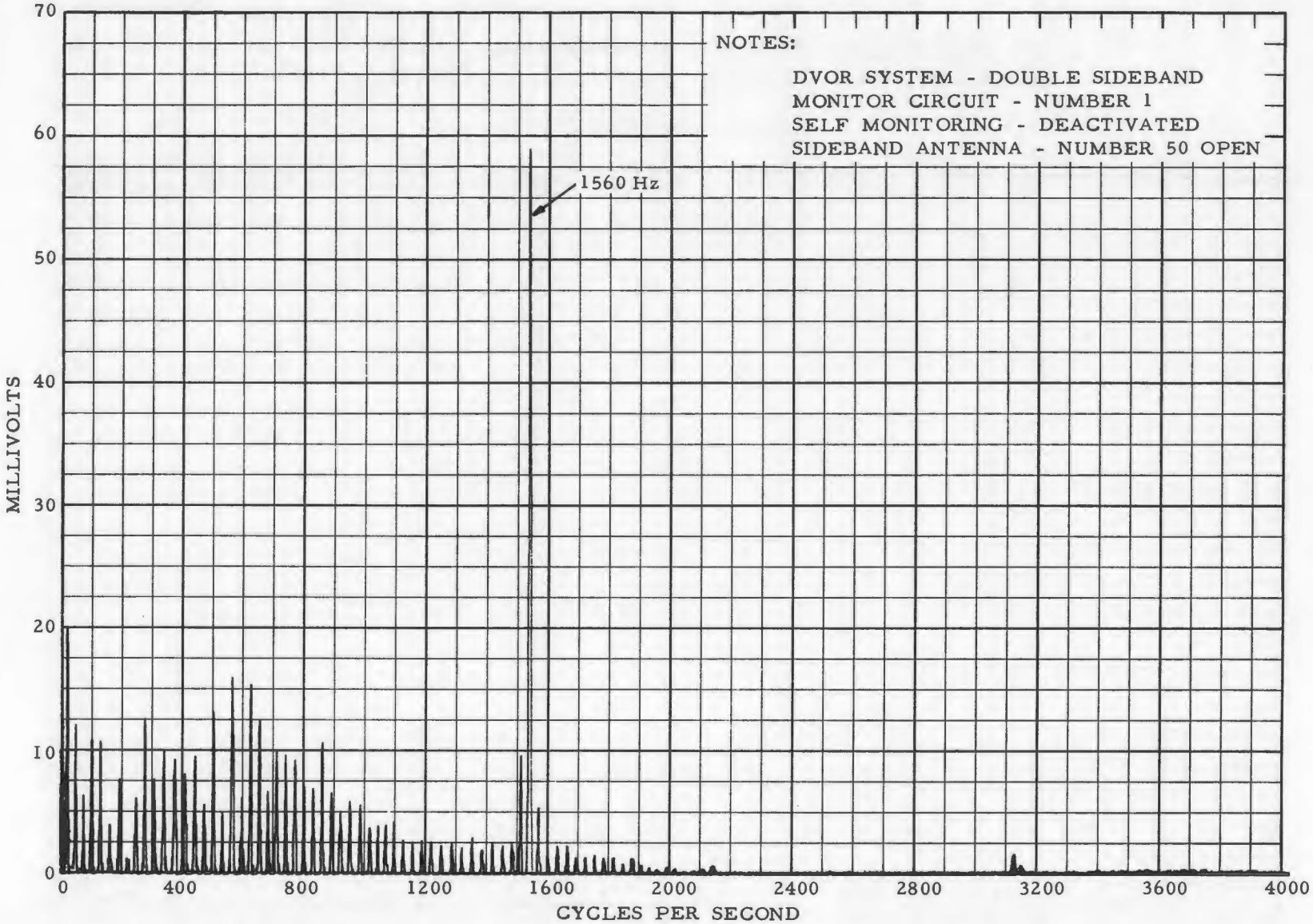


FIG. 51 FREQUENCY SPECTRUM OF THE 9960 Hz SIDEBAND DETECTOR OUTPUT AT PIN NO. 1 OF BOARD NO. 4

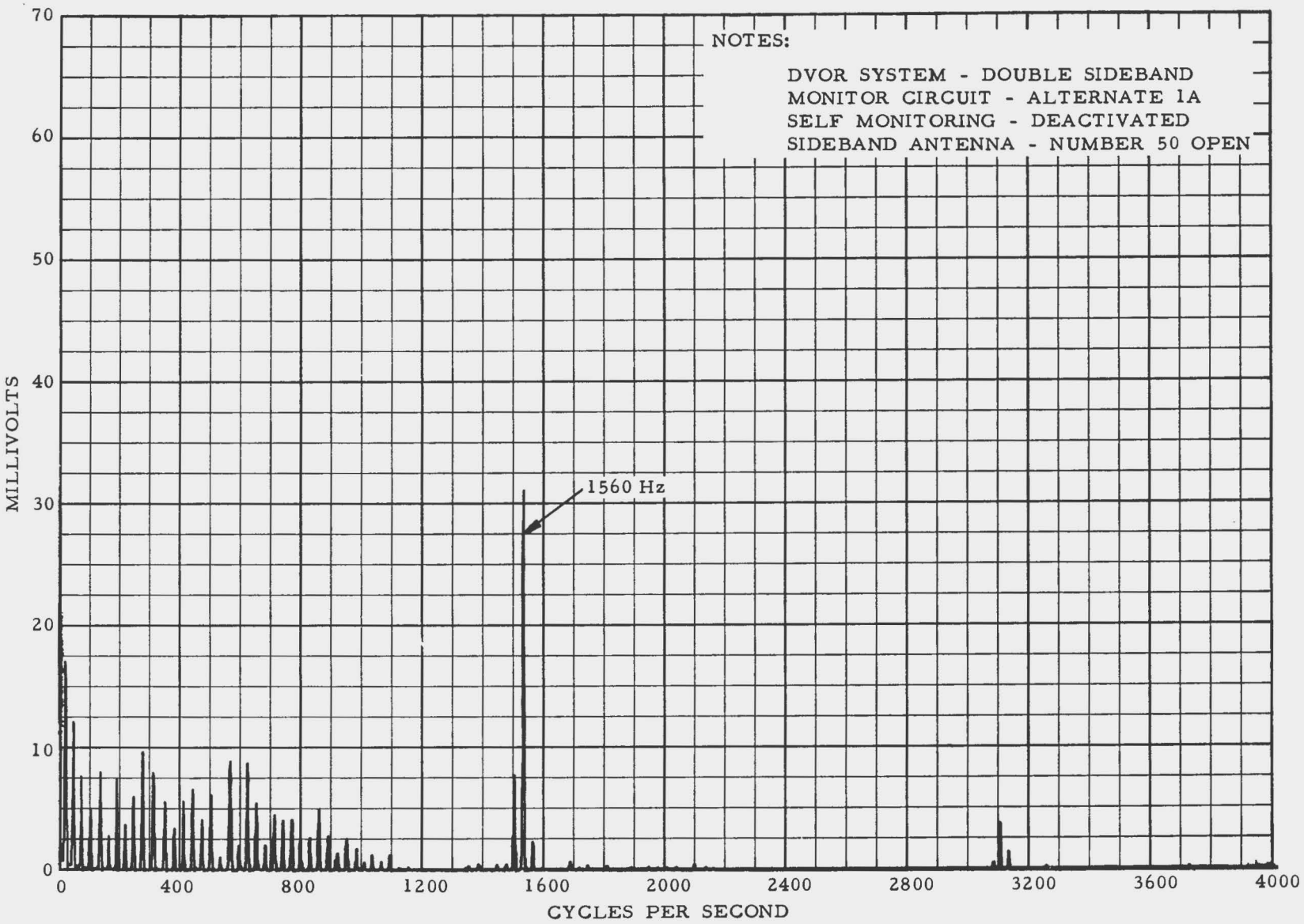


FIG. 51A FREQUENCY SPECTRUM OF THE 9960 Hz SIDEBAND DETECTOR OUTPUT AT PIN NO. 1 OF BOARD NO. 4

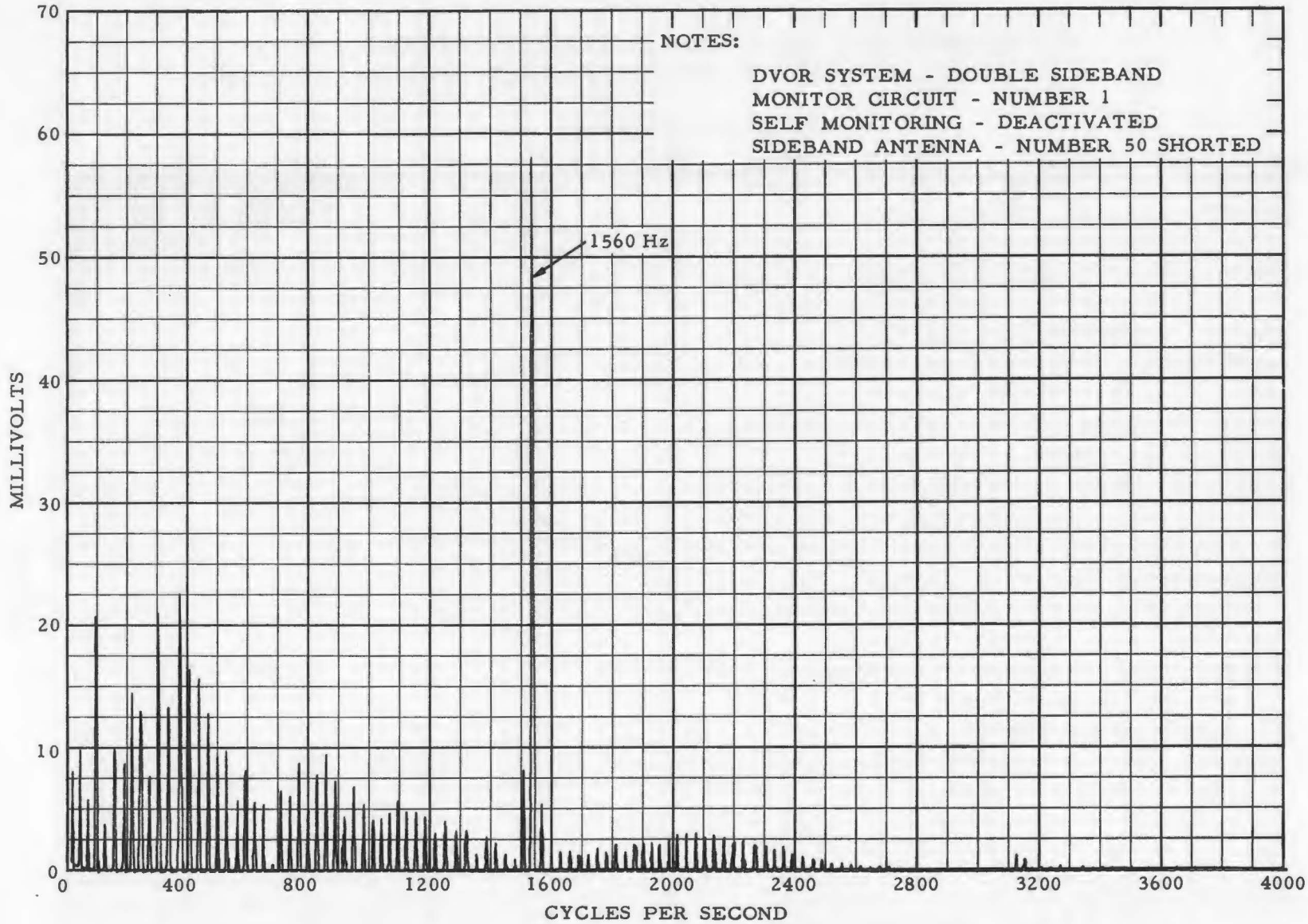


FIG. 52 FREQUENCY SPECTRUM OF THE 9960 Hz SIDEBAND CYCLES PER SECOND DETECTOR OUTPUT AT PIN NO. 1 OF BOARD NO. 4

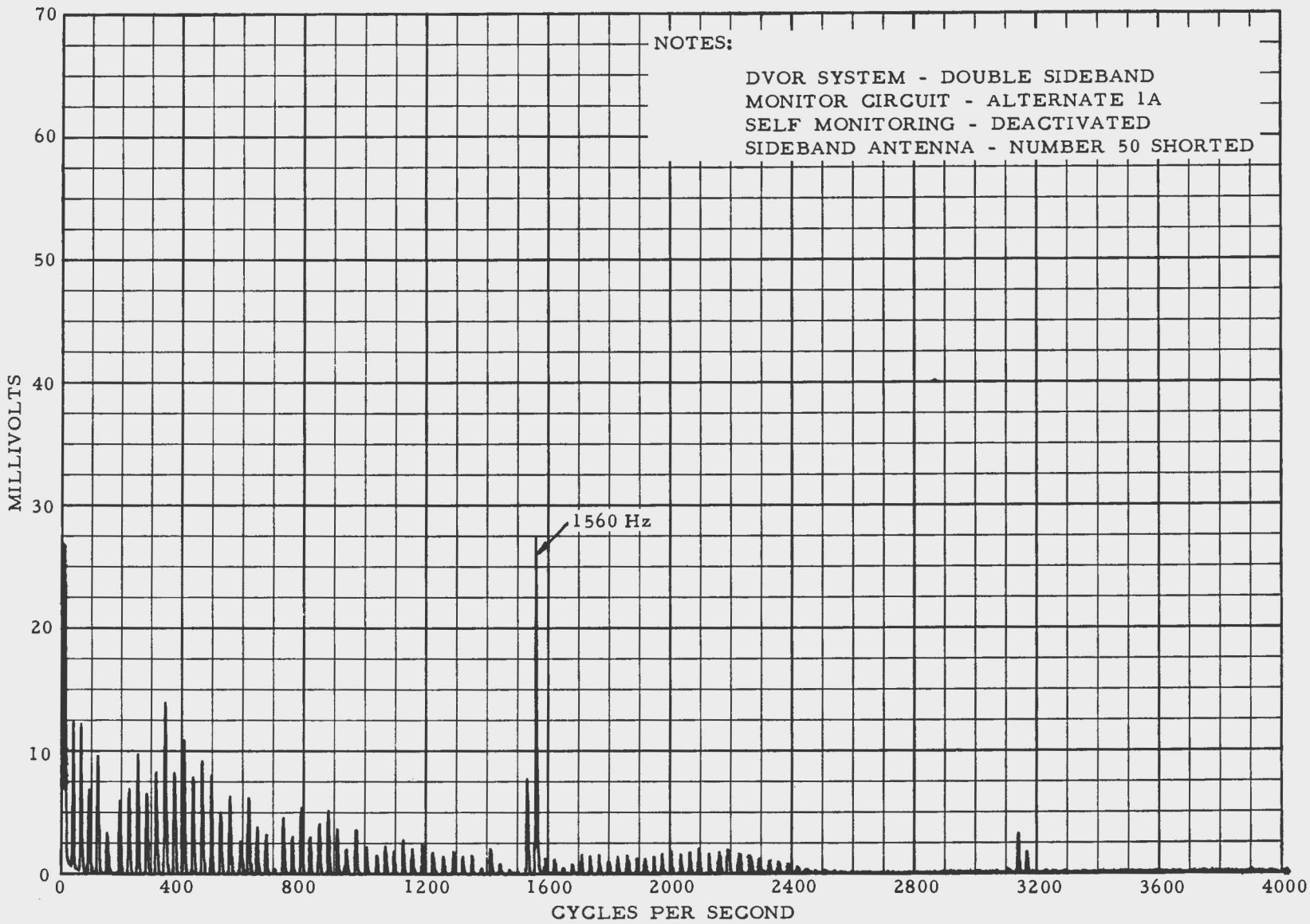


FIG. 52A FREQUENCY SPECTRUM OF THE 9960 Hz SIDEBAND DETECTOR OUTPUT AT PIN NO. 1 OF BOARD NO. 4

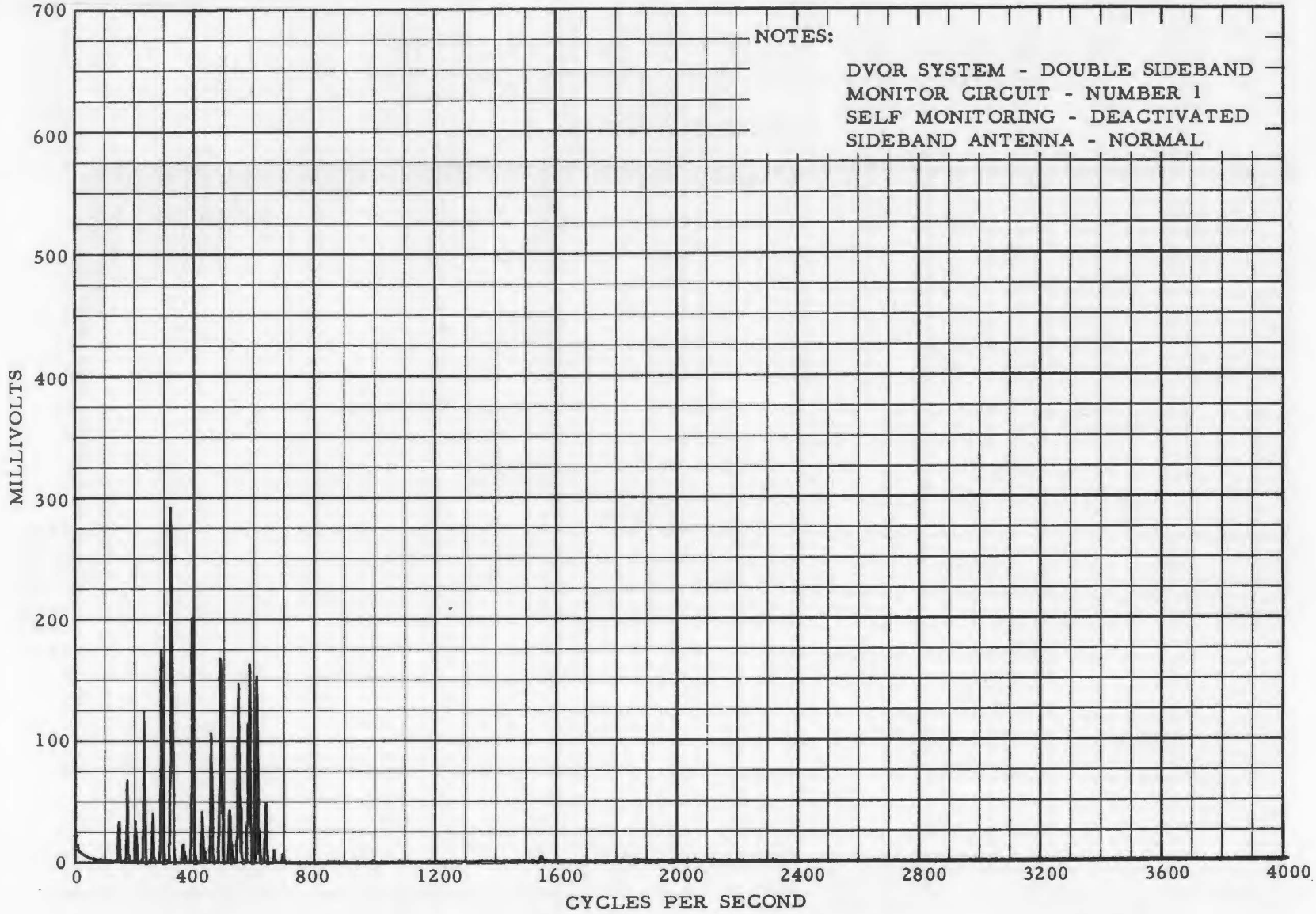


FIG. 53 FREQUENCY SPECTRUM OF THE 200 TO 600 Hz FILTER OUTPUT AT PIN NO. 16 OF BOARD NO. 4

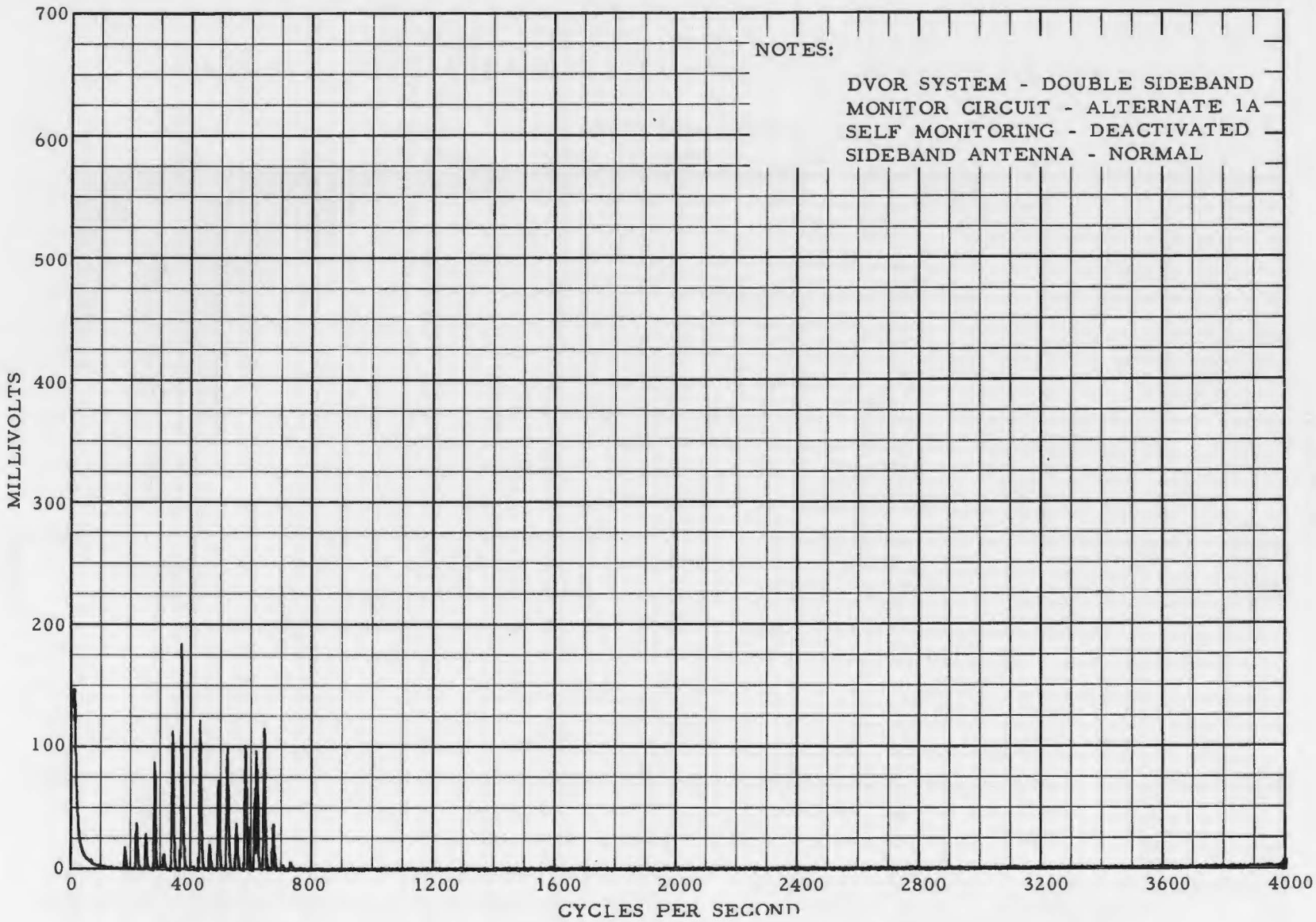


FIG. 53A FREQUENCY SPECTRUM OF THE 200 TO 600 Hz FILTER OUTPUT AT PIN NO. 16 OF BOARD NO. 4

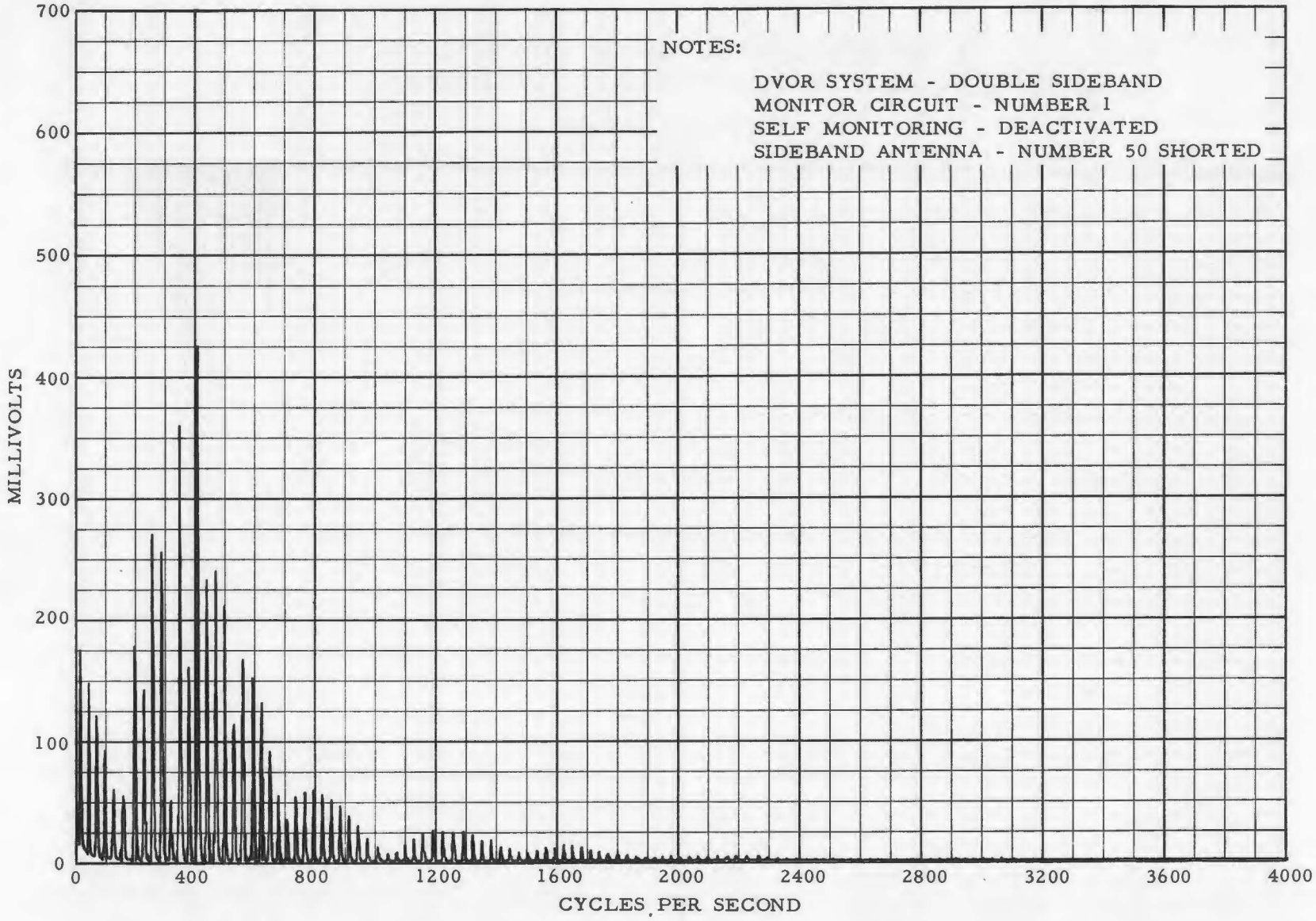


FIG. 54 FREQUENCY SPECTRUM OF THE 200 TO 600 Hz FILTER OUTPUT AT PIN NO. 16 OF BOARD NO. 4

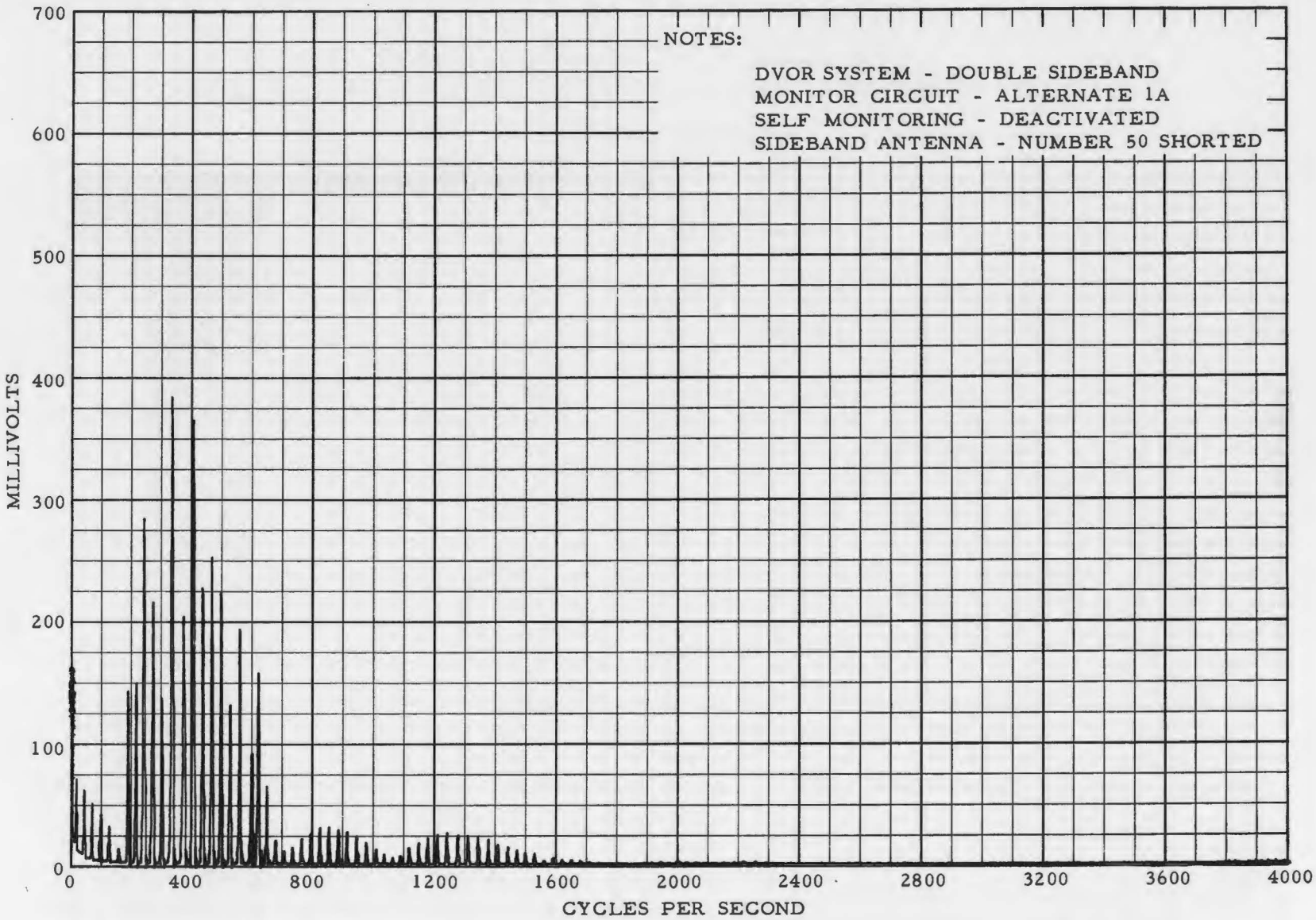


FIG. 54A FREQUENCY SPECTRUM OF THE 200 TO 600 Hz FILTER OUTPUT AT PIN NO. 16 OF BOARD NO. 4

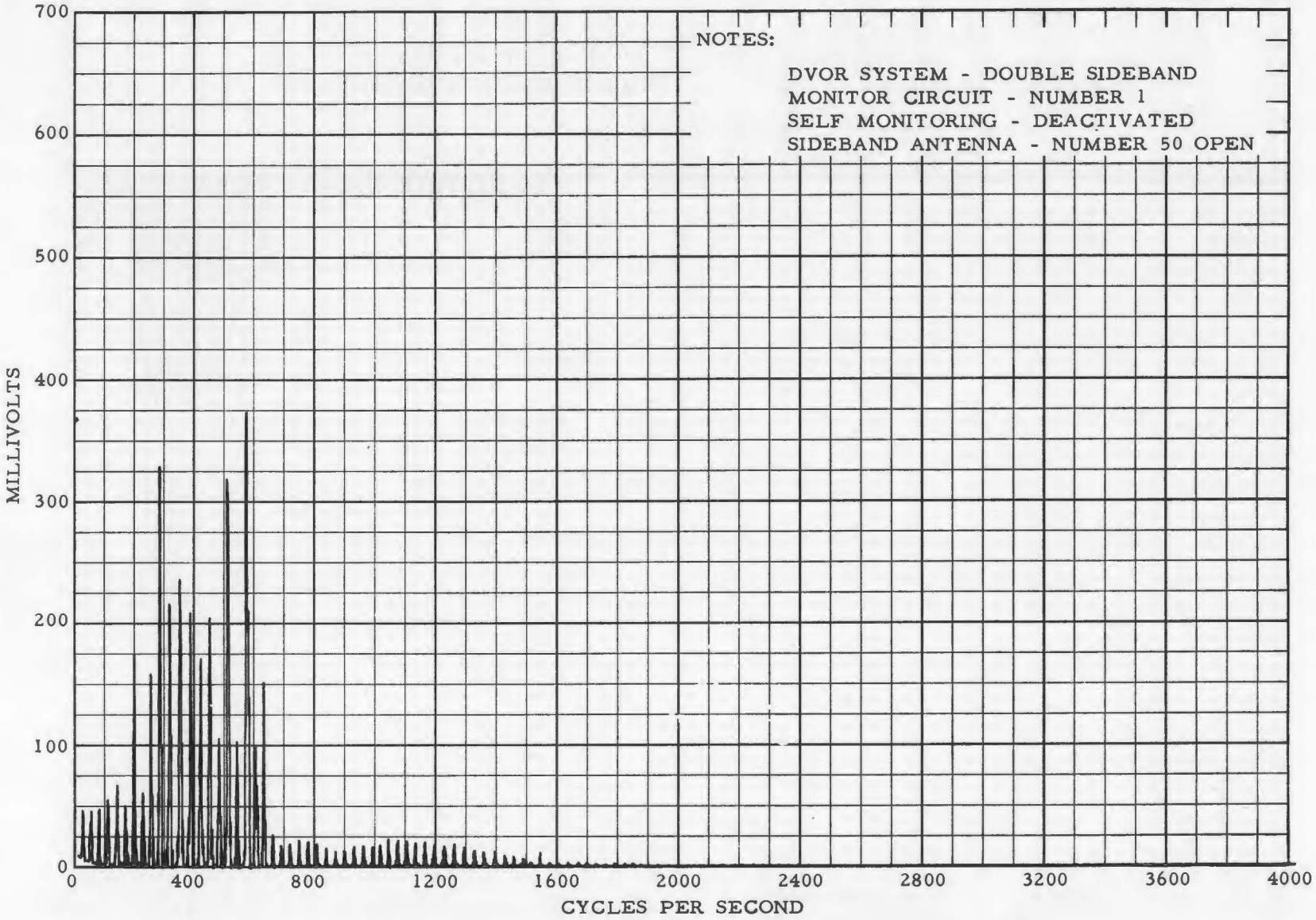


FIG. 55 FREQUENCY SPECTRUM OF THE 200 TO 600 Hz FILTER OUTPUT AT PIN NO. 16 OF BOARD NO. 4

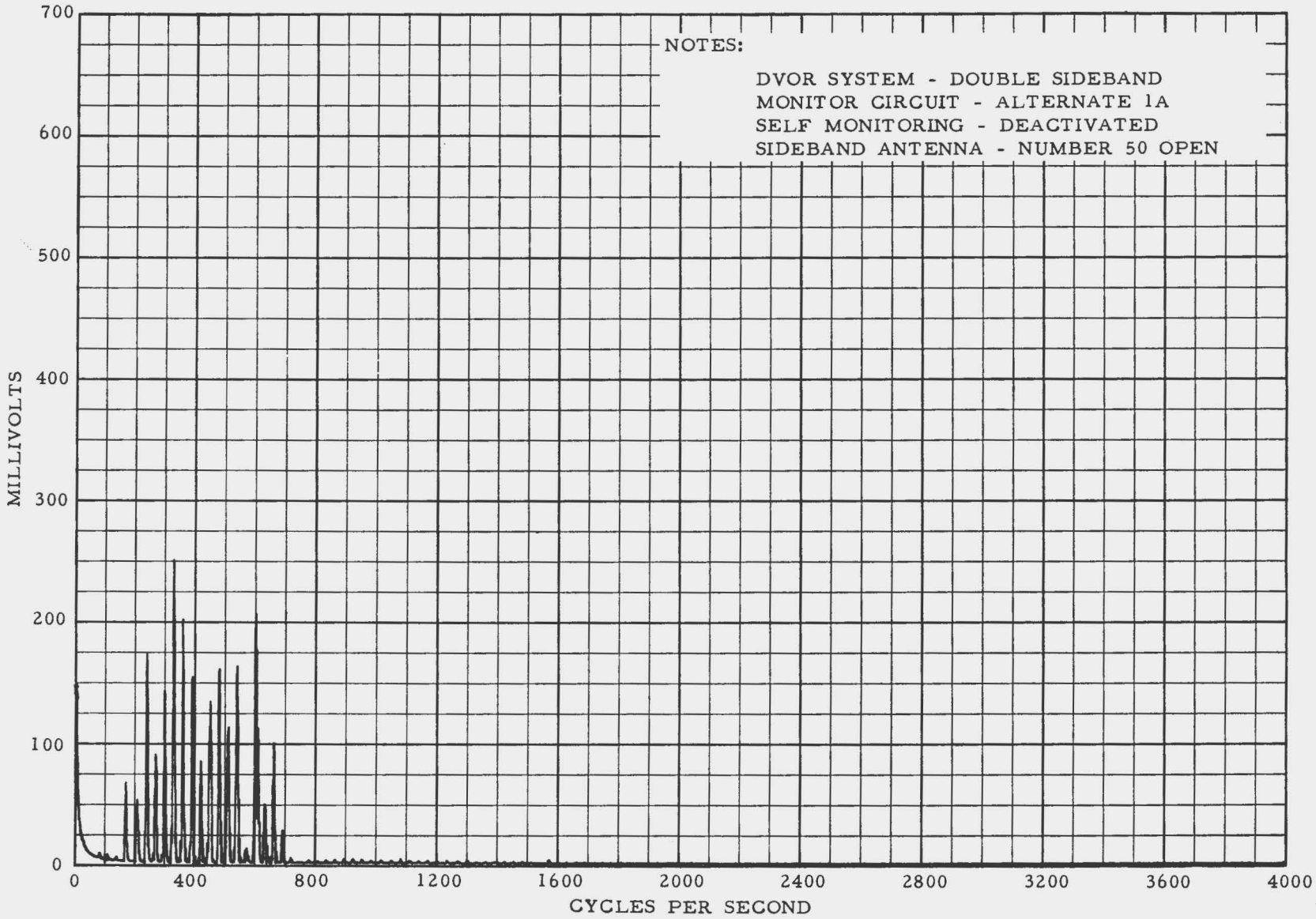
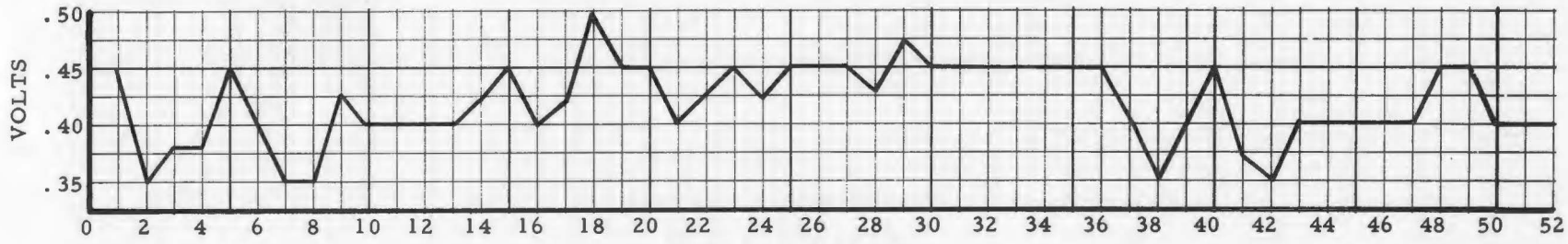


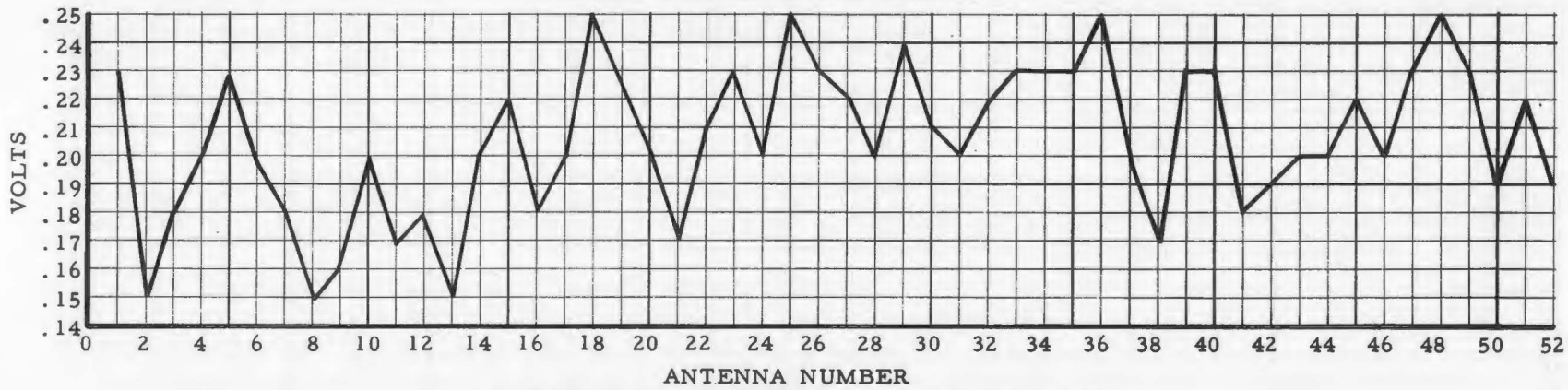
FIG. 55A FREQUENCY SPECTRUM OF THE 200 TO 600 Hz FILTER OUTPUT AT PIN NO. 16 OF BOARD NO. 4

NOTES:

DVOR SYSTEM - DOUBLE SIDEBAND
SELF MONITORING - DEACTIVATED
GAIN SET FOR MAX. OUTPUT
CONDITION - OPEN EACH ANTENNA



MONITOR WITH CIRCUIT BOARD 1

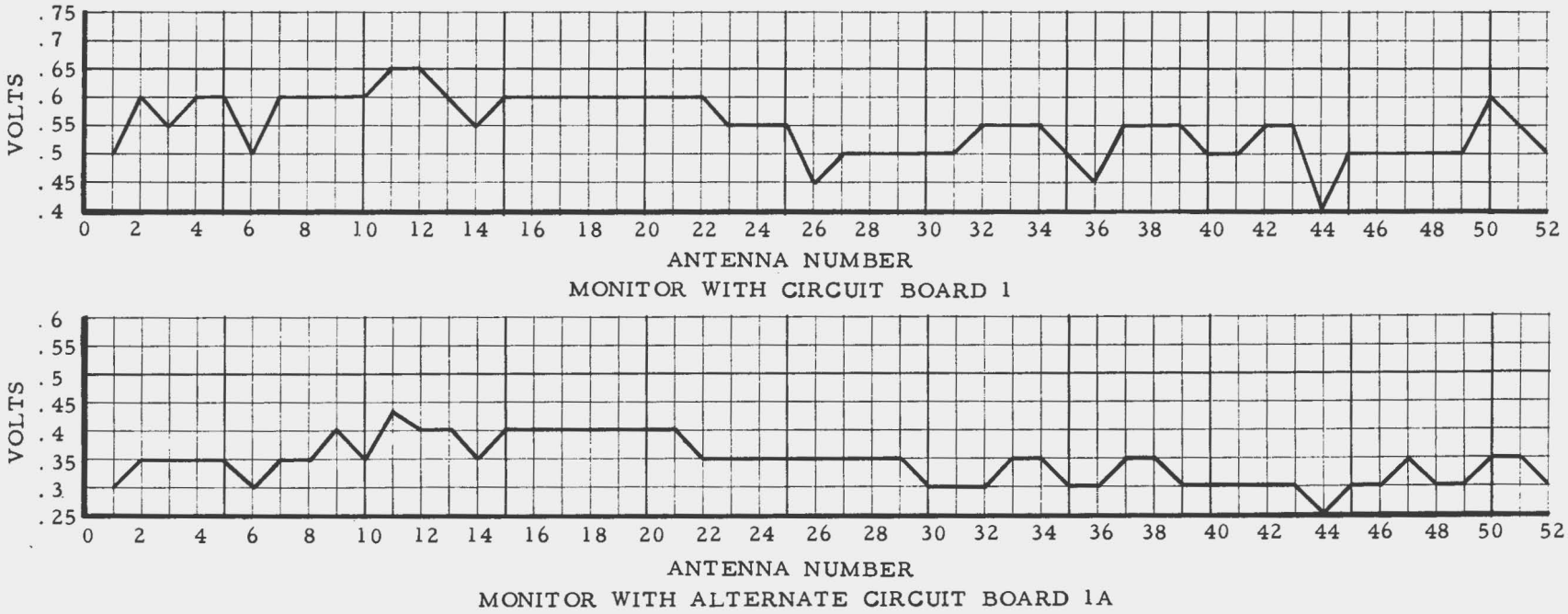


MONITOR WITH ALTERNATE CIRCUIT BOARD 1A

FIG. 56 DC VOLTAGE ACROSS METER/RELAY TERMINALS

NOTES:

DVOR SYSTEM - DOUBLE SIDEBAND
SELF MONITORING - DEACTIVATED
GAIN SET FOR MAX. OUTPUT
CONDITION - SHORT ON EACH ANTENNA



MONITOR WITH CIRCUIT BOARD 1

MONITOR WITH ALTERNATE CIRCUIT BOARD 1A

FIG. 57 DC VOLTAGE ACROSS METER/RELAY TERMINALS

NOTES:

DVOR SYSTEM - DOUBLE SIDEBAND
SELF MONITORING - DEACTIVATED
GAIN SET FOR NORMAL OPERATION
CONDITION - OPEN EACH ANTENNA
ALARM VOLTAGE .04 VOLTS

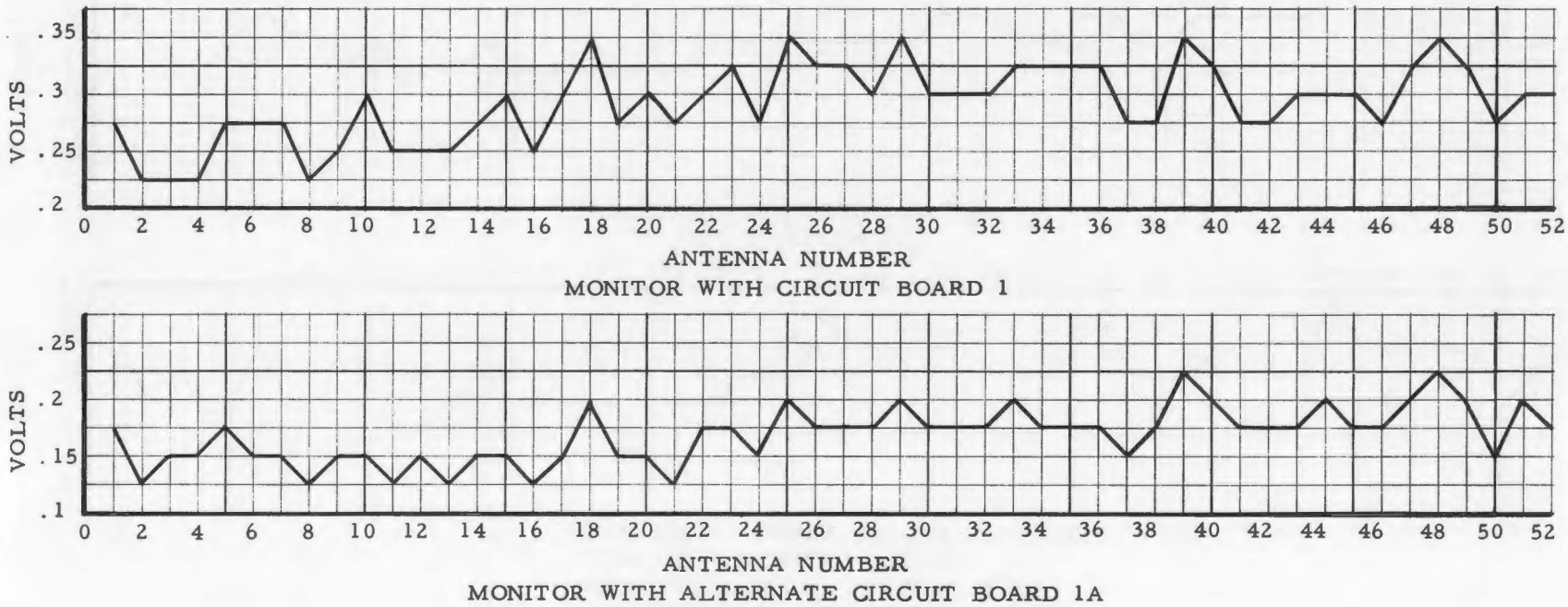
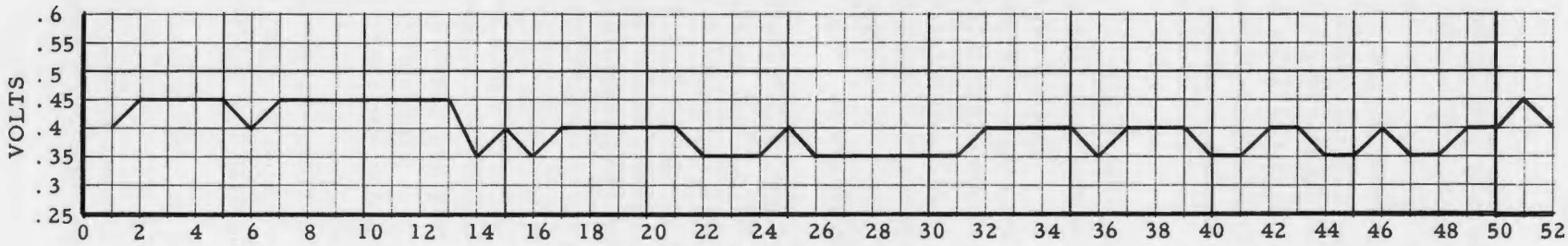


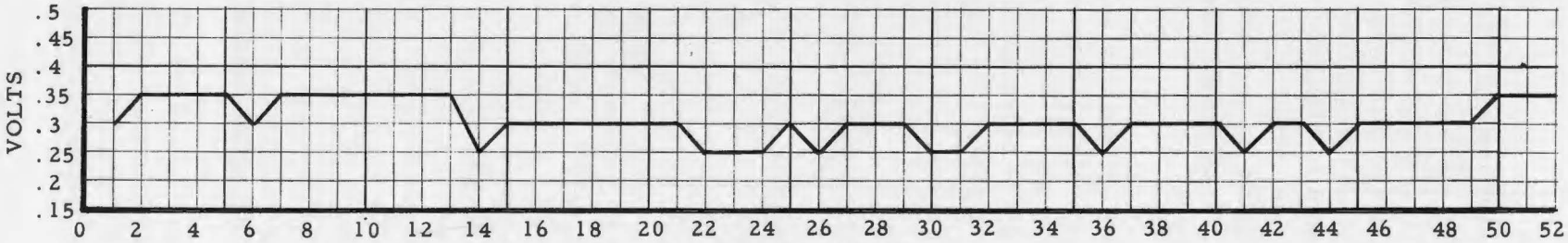
FIG. 58 DC VOLTAGE ACROSS METER/RELAY TERMINALS

NOTES:

DVOR SYSTEM - DOUBLE SIDEBAND
SELF MONITORING DEACTIVATED
GAIN SET FOR NORMAL OPERATION
CONDITION SHORT ON EACH ANTENNA
ALARM VOLTAGE .04 VOLTS



ANTENNA NUMBER
MONITOR WITH CIRCUIT BOARD 1



ANTENNA NUMBER
MONITOR WITH ALTERNATE CIRCUIT BOARD 1A

FIG. 59 DC VOLTAGE ACROSS METER/RELAY TERMINALS

(original No. 1 method) that the maximum amplitude was reached at approximately 300 Hz and decreased to approximately one-half of the maximum value at approximately 500 Hz. However, in the alternate (1A) method of configuration (see figure 38A) the maximum amplitude is reached at approximately 450 Hz with little change in amplitude from 200 to 600 Hz. This is to the advantage of method No. 1, as the voice modulation of the Doppler VOR has the greatest effect on the monitor at approximately 500 Hz. However, this can be corrected in the alternate method by redesign of the 200 to 600 Hz detector filter.

With the monitor signals derived from within the Doppler VOR System, the effects of a faulty sideband antenna did not produce a notch in the observed 9960 Hz signal as occurred when the signals for the monitor were obtained from the radiated energy. This is illustrated by comparison of figure 21 with figure 22. Although this difference exists, the spectrum of harmonics remain essentially the same. The method of generating the self-check signal used in monitor No. 1, produced the same effects to the 9960 Hz from the mixer circuit as did a faulty antenna.

The 1A method of generating the self-check signal did not produce the same effects to the 9960 Hz as are produced in method No. 1. The 1A method produced a notch in the 9960 Hz signal from the mixer, similar to the notch produced by a faulty sideband antenna when the monitor signal source was from the radiated energy. With the change in the source of the monitor signal from radiated energy to within the system, a notch was no longer produced by a faulty sideband antenna. A comparison of the two methods of self-check generation can be made by referring to the photographs of the 9960 Hz given in figure 39. Although the resulting frequency spectra were similar, ideally the preference would be a self-check signal which would produce the same distortion of the 9960 Hz signal as would a faulty sideband antenna. This would forestall the remote possibility of a faulty sideband antenna and the self-check signal occurring at the same instance of time resulting in a very slow rate of alarm voltage increase, and of a magnitude which would barely trip the alarm.

In method No. 1, the 30 Hz filter of circuit board No. 1 is not required when the monitor signal source is derived from within the Doppler VOR System. In production models the 30 Hz filter would be replaced with a free running multivibrator to produce

the self-check signal in lieu of the external 30 Hz source used in the evaluation tests. With these changes in circuit board No. 1, the cost advantage of the alternate circuit board No. 1A is reduced.

From an analysis of the test data, either method of generation of the self-check signals will function. The most important considerations are

1. that the modulation of the 9960 Hz monitor signal be held constant both in amplitude and width to provide stability of the self-check function, and

2. the rate at which the self-check signals are injected into the monitor circuitry. If the rate of injection is synchronous with the rate at which each of the sideband antennas are energized, the possibility exists of having the effects of a faulty sideband antenna occurring at the same instant of time as the injection of the self-check signal. When this occurs, although an alarm is produced, under certain conditions of harmonics and phase relation, the dc voltage generated across the meter/relay terminals is lower in value than otherwise would be if the self-check signal was non-synchronous with antenna excitation rate. From observation of this phenomena, the best monitoring action is obtained when the rate of injection of the self-check signal is very slightly above the 30 Hz rate at which the sideband antennas are energized. This scanning or sweep action of the self-check signal prevents the possibility of the synchronization discussed above.

The 200 to 600 Hz Filter

The effect of voice modulation of the carrier can be reduced by

1. changing the upper alarm limit to a higher value, and

2. a change in the specifications of the 200 to 600 Hz filter.

From an analysis of the frequency spectrum for the normal Doppler VOR operation there appears to be little, if any, 60 Hz or 120 Hz present. Taking this into consideration, it appears that

the lower limit could be safely set at 150 Hz and the upper limit at approximately 500 Hz. Inasmuch as the modulation characteristics of the carrier transmitter are such that for a given input a higher modulation results at 500 Hz than at 200 Hz, then the characteristics of the filter and amplifier could be designed to give a 2:1 gain at 200 Hz above the gain at 500 Hz.

Time Delay

A push-button switch to reduce the amount of time delay across the meter/relay, would be advantageous to the maintenance personnel in making adjustment to the monitor.

Functional Metering and Test Points

The use of test points and switched functional meter circuit provides a quick method of analysis of the operational functions of the circuit parameters for maintenance of the monitor and should be included in the production models.

Dual Units

Considering the high reliability of solid-state devices, the use of a dual unit monitor appears to be unnecessary. A single unit monitor, with a set of spare circuit boards in lieu of a dual unit, should suffice, resulting in lower initial cost and a saving in panel space in the VOR monitor equipment rack.

CONCLUSIONS

Based on the test results, it is concluded that:

1. The prototype Doppler VOR sideband monitor recommended in report No. RD-66-49 will meet the Doppler VOR System requirements when the necessary circuit redesigns and signal pick-up changes, as given in this report, are incorporated.

2. The method of obtaining the sample of sideband energy for monitor input from a directional coupler installed preceding the matching network of the distributor in place of the originally intended sampling antenna method provides a more practical design for field installation. The circuit design changes incorporated into the prototype monitor performed well.

3. The monitor will satisfactorily provide more complete monitoring throughout 360° azimuth of the Doppler VOR ground station than at present, and thereby provide more reliable omni-directional service to the National Airspace System. This is considered important particularly when utilizing the station in an area navigation system.

4. The "passband" of the 200 to 600 Hz filter could be changed to 150 to 500 Hz and thereby provide increased protection from the effects of voice modulation on the carrier frequency.

5. The monitor will function on either the single sideband or the double sideband Doppler VOR System.

6. The alternate method of generation of the self-check signals will function satisfactorily when made non-synchronous with the antenna excitation rate.

7. This monitor will be an economical replacement for two of the three conventional VOR monitors presently used for monitoring the Doppler VOR System. The maintenance cost for the monitor system would also be reduced.

8. The significant reduction in the number of active devices will increase the reliability and availability of the ground station to the National Airspace System.

RECOMMENDATIONS

Based on the test results, it is recommended that:

1. A monitor making use of the spectrum analysis technique of detecting a faulty sideband antenna be included in the monitoring system of the Doppler VOR facilities to replace the two conventional VOR monitors presently used for sideband antenna monitoring.

2. The directional coupler signal sample method and related modifications incorporated into the prototype monitor during evaluation be adopted for use in Doppler VOR field installations.

3. Specifications for production units be based on the prototype design except that they be of single unit construction and the 200 - 600 Hz spectrum filter be changed to 150 - 500 Hz.

4. The alternate self-check technique be used in the production units.

ACKNOWLEDGMENT

Credit is given to Robert B. Flint, RD-330, for the suggestion of obtaining the monitor signals from within the Doppler VOR System in lieu of a monitor antenna. This suggestion not only expedited the project, but also saved the cost of development and evaluation of a special monitor antenna, cost of tailoring, installation and modification to existing and future Doppler VOR facilities to accommodate the monitor antenna, and reduction of the Doppler VOR outage time from an estimated minimum of 8 hours to 1 hour for installation of the monitor at existing facilities.

Department of Transportation, Federal Aviation Administration, National Aviation Facilities Experimental Center, Atlantic City, New Jersey 08405
EVALUATION OF PROTOTYPE DOPPLER VOR SIDEBAND ANTENNA MONITOR by Virgil E. Willey, Final Report, June 1969, 99 pp., incl. 75 illus.
(Project No. 330-011-03X, Report No. NA-69-19)
(RD-69-27)
Unclassified Report

This report presents the results of evaluation tests of a prototype Doppler VOR sideband antenna monitor. The monitor utilizes a bandpass spectrum analysis technique, as recommended in report No. RD-66-49, for the detection of a faulty sideband antenna. The ability to detect a sideband antenna fault deletes the requirement of two of the three VOR monitors presently used in the monitoring of a Doppler VOR navigational facility.

UNCLASSIFIED

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II. Project No. 330-011-03X
III. Report No. NA-69-19
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Descriptors

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Sideband Antenna Fault Detector

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