GEORGIA INSTITUTE OF TECHNOLOGY | OFFICE OF CONTRACT ADMINISTRATION

PROJECT ADMINISTRATION DATA SHEET

[x] ORIGINAL [ ] REVISION NO. ______

Project No. A-3310 DATE 8/19/82

Project Director: John C. Mantovani CD ~~School~~/Lab ECSL/ECD

Sponsor: Bell Telephone Laboratories, Inc.

Type Agreement: Purchase Order Agreement No. 540621

Award Period: From 7/21/82 To ~~12/21/82~~ ~~12/31/82~~ ~~3/3/83~~ ~~5/16/83~~ 5-31-83 (Performance) ~~12/21/82~~ 5/16/83 (Reports)

Sponsor Amount: $36,630 Contracted through:

Cost Sharing: GTRI/~~GIT~~

Title: Spherical Dipole Emission Source

ADMINISTRATIVE DATA OCA Contact Faith G. Costello

1) Sponsor Technical Contact:

D. Heirman, A. Busala
BTL Technical Representative
Bell Laboratories
Crawford Corner Rd
Holmdel, NJ 07733

2) Sponsor Admin/Contractual Matters:

Mrs. S. H. Vogel, Buyer
Bell Laboratories
Crawfords Corner Rd.
Holmdel, NJ 07733

Ph: (201) 944-3051

Defense Priority Rating: NA

Security Classification: (Industrial - see below)

RESTRICTIONS

See Attached NA Supplemental Information Sheet for Additional Requirements.

Travel: Foreign travel must have prior approval — Contact OCA in each case. Domestic travel requires sponsor approval where total will exceed greater of $500 or 125% of approved proposal budget category.

Equipment: Title vests with sponsor

COMMENTS:

* Prior written consent required from sponsor for release of publication of any articles or advertising or publicity matter relating to work under this Agreement.

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FORM OCA 4:781

GEORGIA INSTITUTE OF TECHNOLOGY **OFFICE OF CONTRACT ADMINISTRATION**

SPONSORED PROJECT TERMINATION SHEET

Date 9/16/83

Project Title: Spherical Dipole Emission Source

Project No: A-3310

Project Director: John Mantovani

Sponsor: Bell Laboratories/American Bell, Inc.

Effective Termination Date: 5/31/83

Clearance of Accounting Charges: 8/31/83

Grant/Contract Closeout Actions Remaining:

- [X] Final Invoice ~~and Closing Documents~~
- [ ] Final Fiscal Report
- [ ] Final Report of Inventions
- [ ] Govt. Property Inventory & Related Certificate
- [ ] Classified Material Certificate
- [ ] Other ______________________

Assigned to: ECSL/ECD (~~School~~/Laboratory)

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FORM OCA 10:781

ENGINEERING EXPERIMENT STATION
Georgia Institute of Technology
A Unit of the University System of Georgia
Atlanta, Georgia 30332
1 September 1982

Bell Laboratories
Crawfords Corner Road
Holmdel, New Jersey 07733

Attention: Mr. Don Heirman

Subject: Monthly Progress and Financial Report No. 1, Project A-3310, Purchase Order No. 540621, "Spherical Dipole Emission Source," covering period 23 July 1982 to 30 August 1982

Gentlemen:

The objective of this program is to design, develop, and construct a spherical dipole emission source which radiates a known and repeatable field level at discrete frequencies from 30 MHz to 200 MHz. The specific tasks to be performed are:

I. Mechanical design and construction of the spherical dipole aperture,

II. Electrical design and construction of the circuitry required for the signal generation, and

III. Performance evaluation of the spherical dipole source.

During this initial month, Task I and II were initiated with primary emphasis being placed on Task I which is now 90% complete. A short description of the work performed and the status of these two tasks is as follows:

Task I: Major emphasis this month was devoted to the mechanical design and construction of the spherical dipole aperture. Detailed drawings of the spherical dipole aperture were completed and are given in Attachment I. Using the NBS prototype as a design guide, modifications were made to electrically feed the two hemispheres from rigidly soldered posts rather than the finger stock used in the NBS prototype. Also, a rotary switch was incorporated into the mechanical construction so that the radiator could be turned on and off without disasembling the sphere.

The materials required for the mechanical construction of the spherical dipole were purchased. The materials and the drawings were then sent to a shop for the machining of the two brass hemispheres, the four brass posts, and the two delrin rings. After the machining was completed, the spherical dipole was assembled with a blank PC board in order to assure proper alignment and verify mechanical rigidity and strength.

Task II: The electrical design of the signal generator (i.e., rf oscillator/rf amplifier/pulse generator) was initiated this month. A block diagram of the circuit was analyzed, and the major components of each block were identified. After a review of available parts was performed, those with minimum size and power consumption were chosen. The components were then immediately ordered so that delays due to delivery time could be minimized. Presently a detailed circuit is being designed and evaluated.

The power supply circuit (i.e., battery/battery monitor/voltage regulator/indicator light) was also initiated this month. Presently, tests are being performed on a variety of batteries to determine voltage drop with respect to time using a representative 25 mA initial load. Various types of batteries which are being tested include: alkaline, lithium, silver oxide, and mercury batteries. Preliminary results of these tests are given in Attachment II; these results show that for the batteries tested a standard 9V alkaline battery seems to be the best choice. A battery monitor circuit has been developed and tested which will shut off an indicator light when the voltage level of the battery drops below a set level. The level is adjusted to slightly higher than the minimum working voltage of the voltage regulator. In order to minimize power consumption, the battery indicator light is flashed on for approximately one second every five seconds.

During the next reporting period, it is anticipated that Task I will be completed and Task II will be continued. The financial report for this initial period is given in Attachment III.

Respectfully submitted,

J. C. Mantovani
Project Director, A-3310

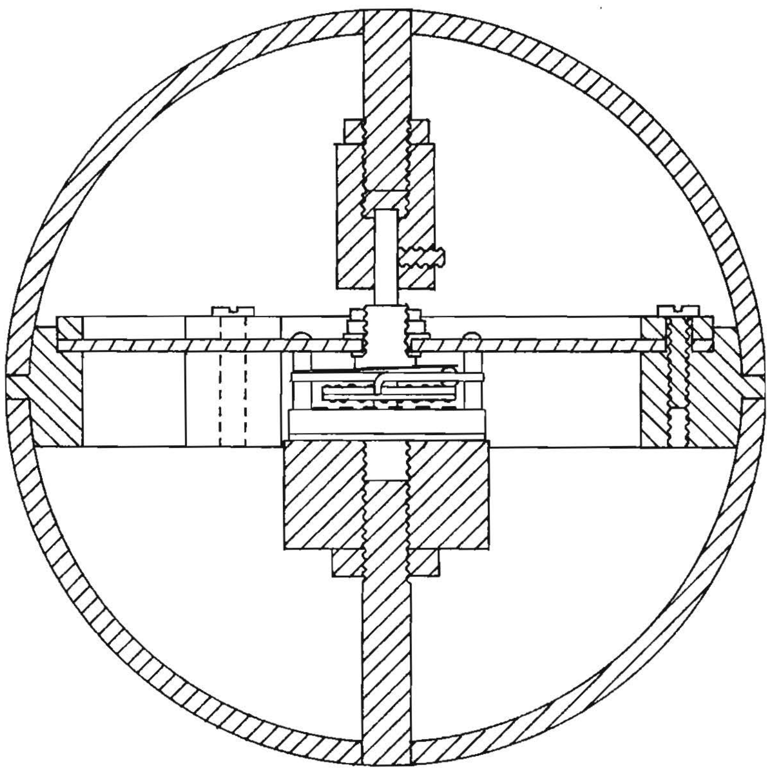
JCM:gh

Approved:

Hugh W. Denny, Chief
Electromagnetic Compatibility Division

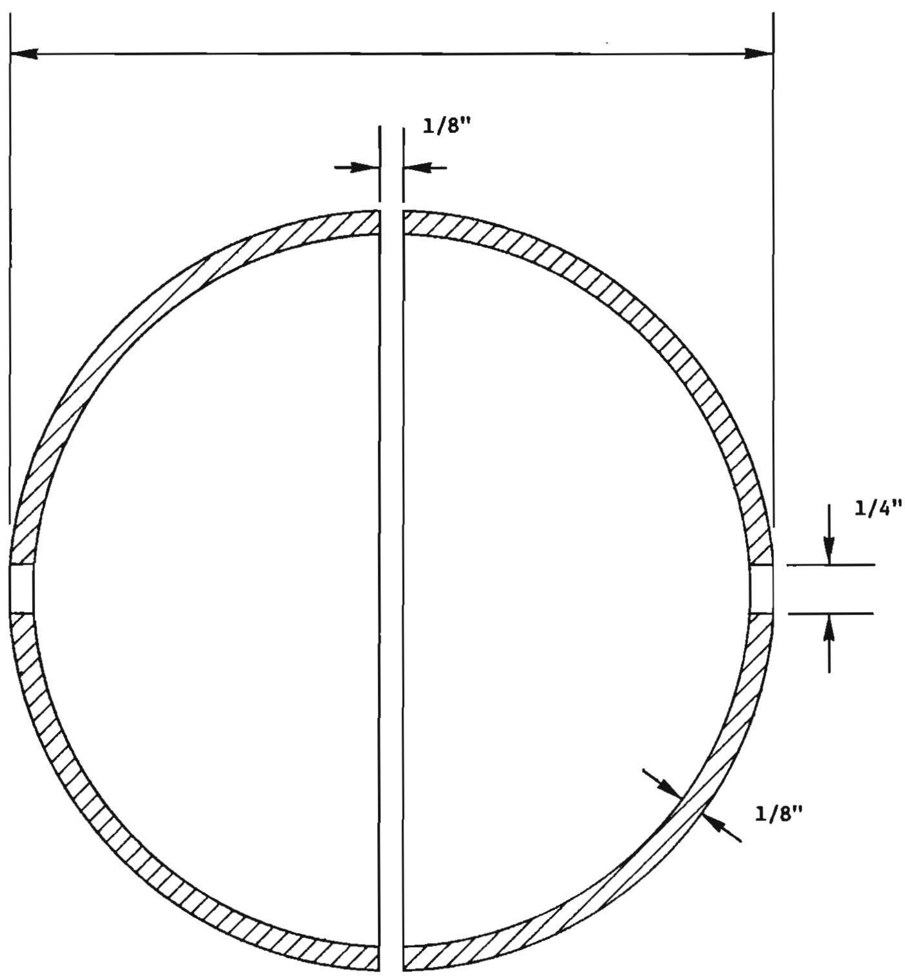
ATTACHMENT I

MECHANICAL DRAWINGS OF SPHERICAL DIPOLE APERTURE



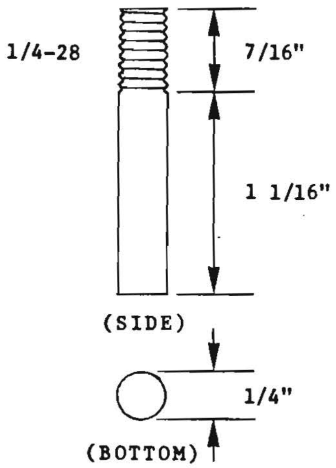
(HALF SECTION CUTAWAY)

TITLE	
SPHERICAL DIPOLE ANTENNA Assembled View	
ENG. J. Mantovani	SCALE 1" = 1"
DRAFT JGH	DATE 8/31/82

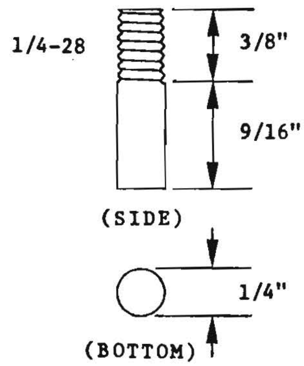


(HALF SECTION CUTAWAY)

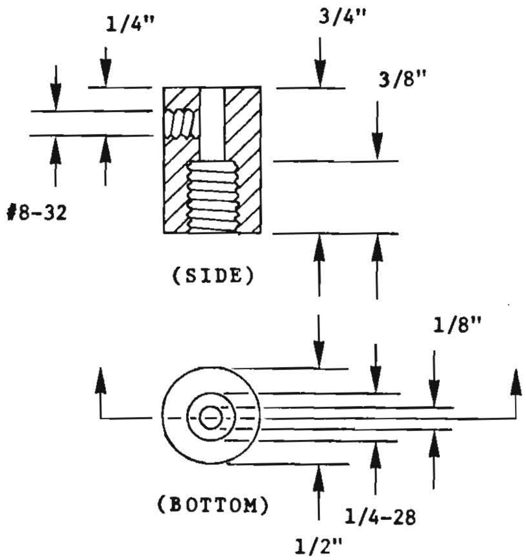
TITLE	
SPHERICAL DIPOLE ANTENNA Brass Sphere	
ENG. J. Mantovani	SCALE 1" = 1"
DRAFT JGH	DATE 8/4/82



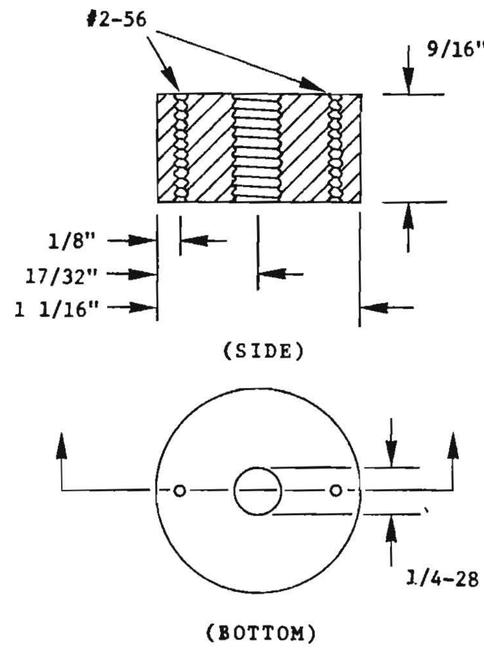
POST #1



POST #2

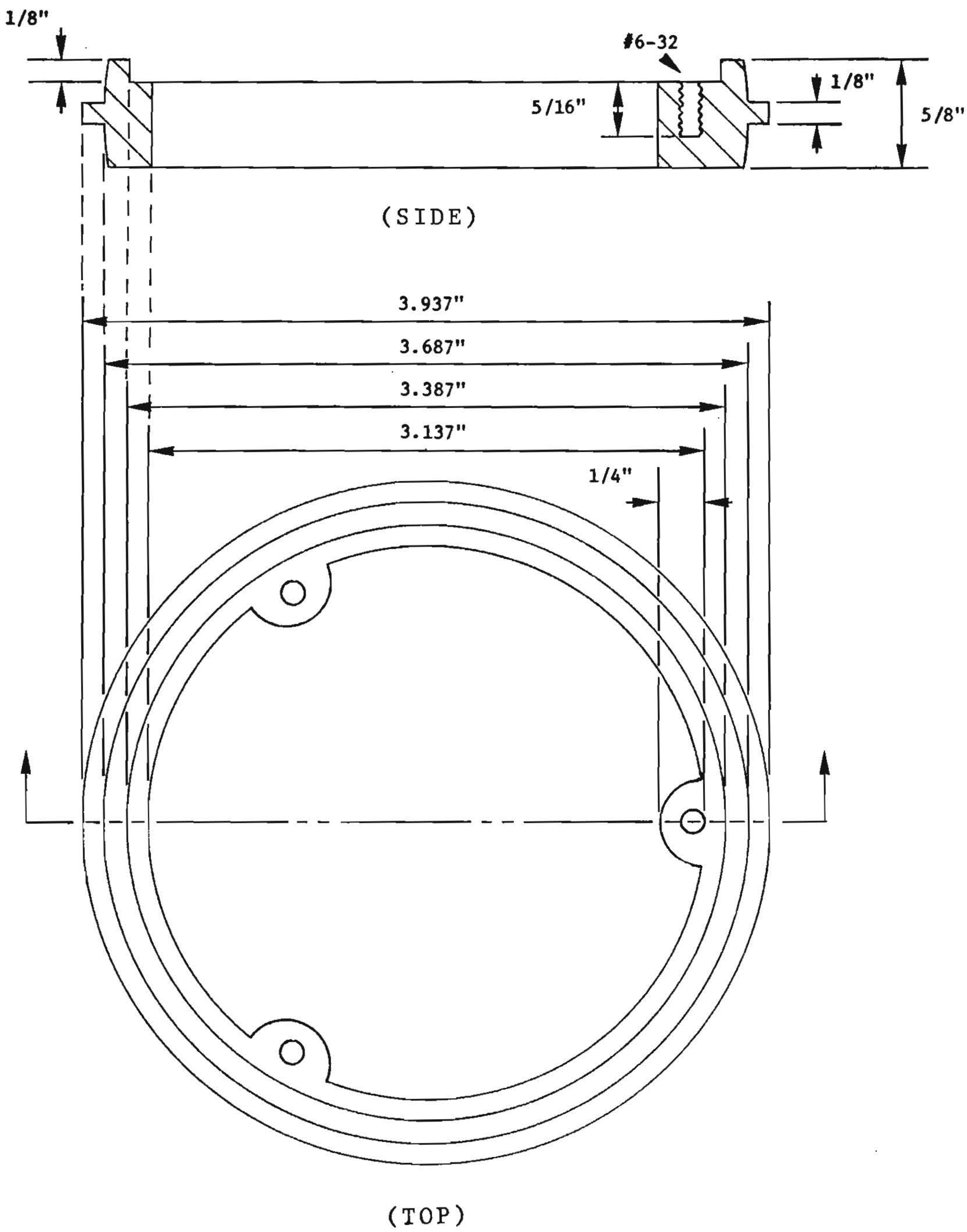


POST #3

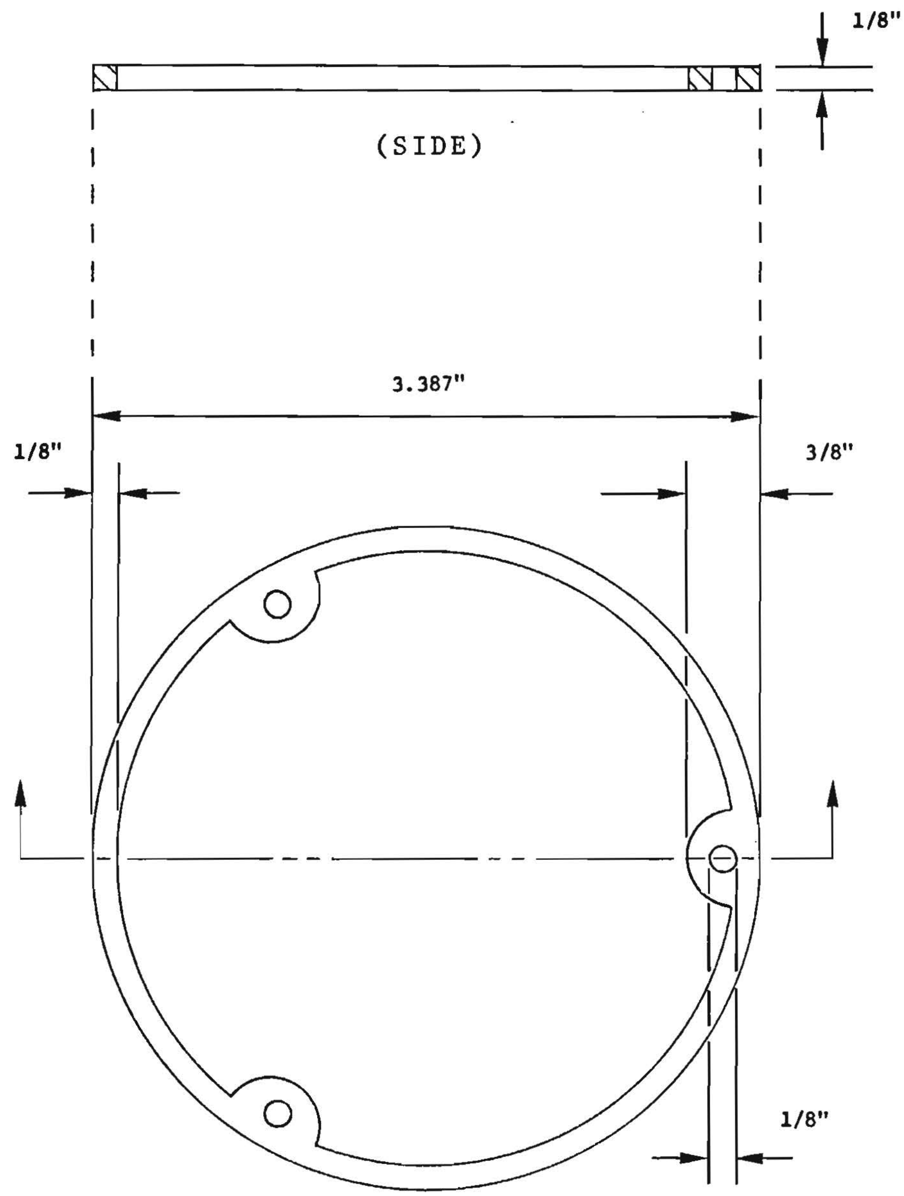


POST #4

TITLE SPHERICAL DIPOLE ANTENNA Brass Support Posts	
ENG. J. Mantovani	**SCALE** 1" = 1"
DRAFT JGH	**DATE** 8/4/82



TITLE	
SPHERICAL DIPOLE ANTENNA Dielectric Ring (Delrin)	
ENG. J. Mantovani	SCALE 1" = 1"
DRAFT JGH	DATE 8/4/82

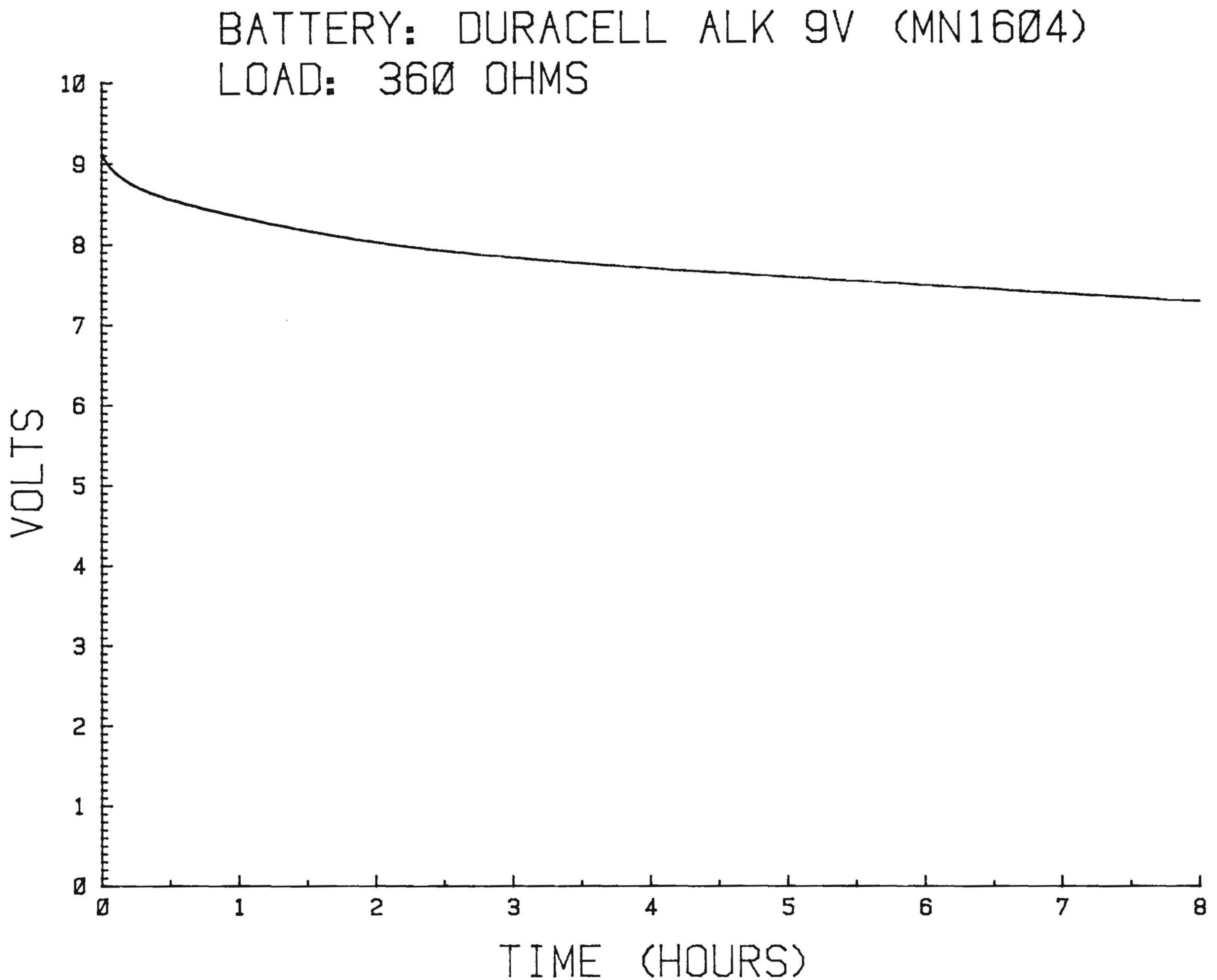


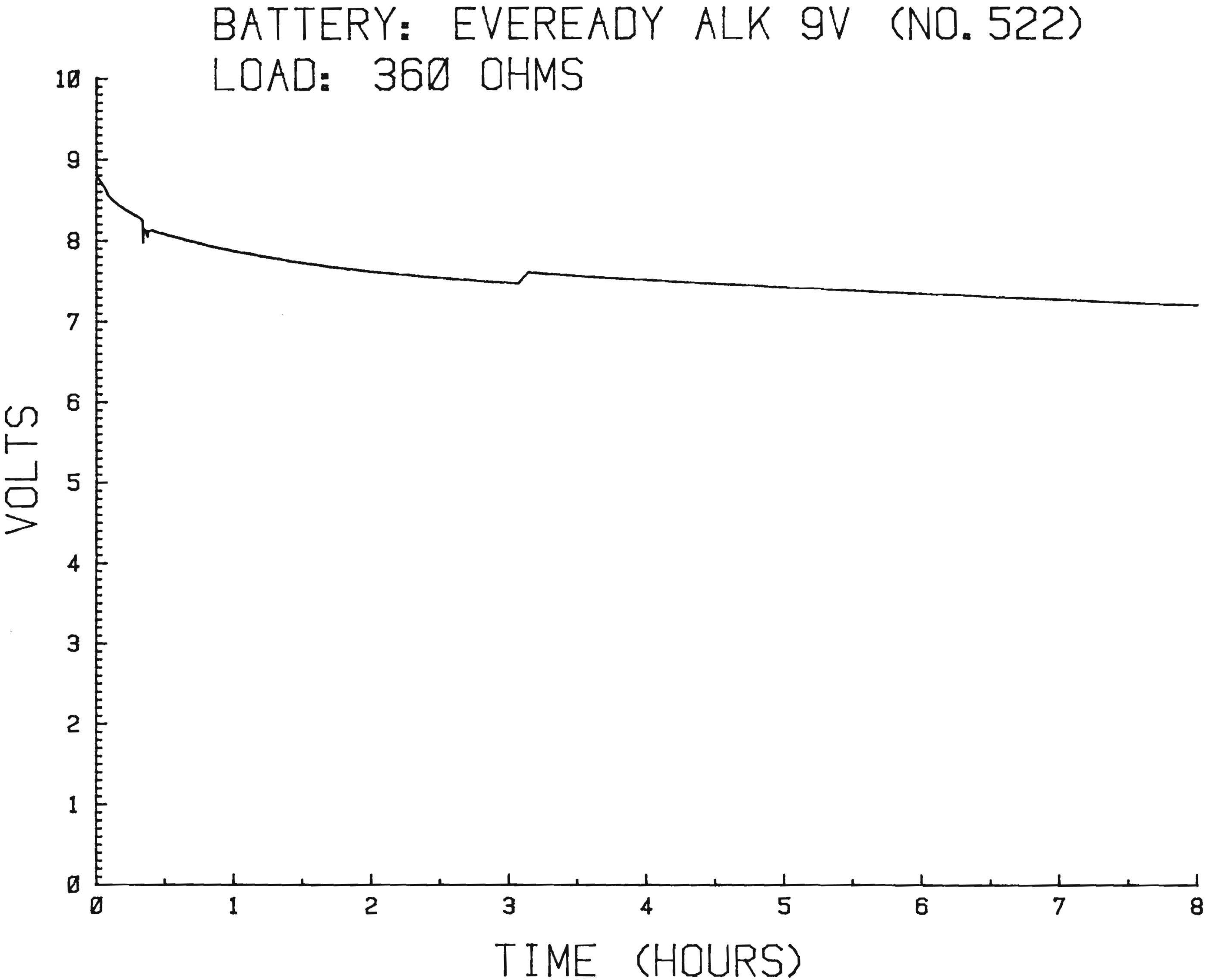
(TOP)

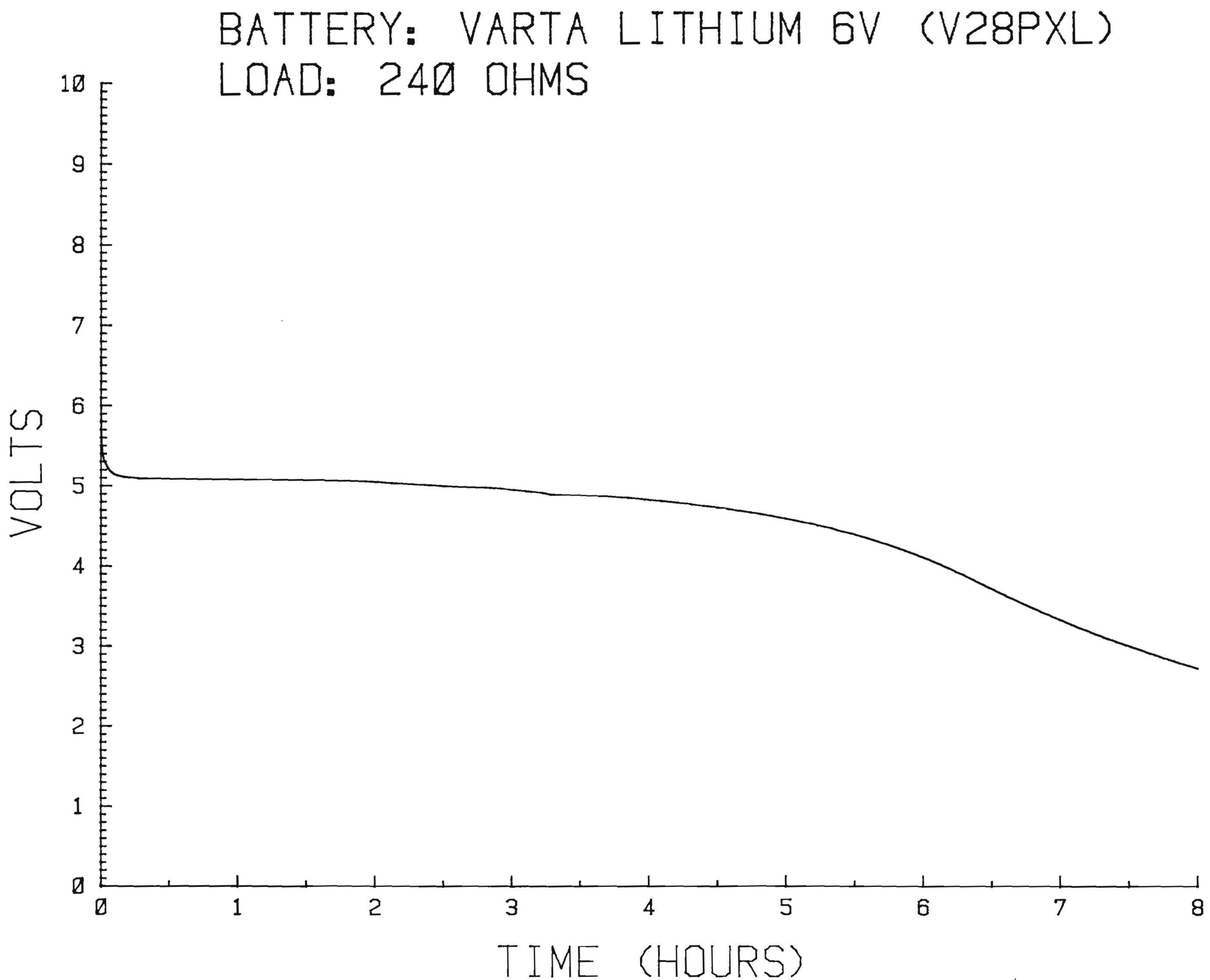
TITLE	
SPHERICAL DIPOLE ANTENNA PC Board Hold-down (Delrin)	
ENG. J. Mantovani	SCALE 1" = 1"
DRAFT JGH	DATE 8/4/82

ATTACHMENT II

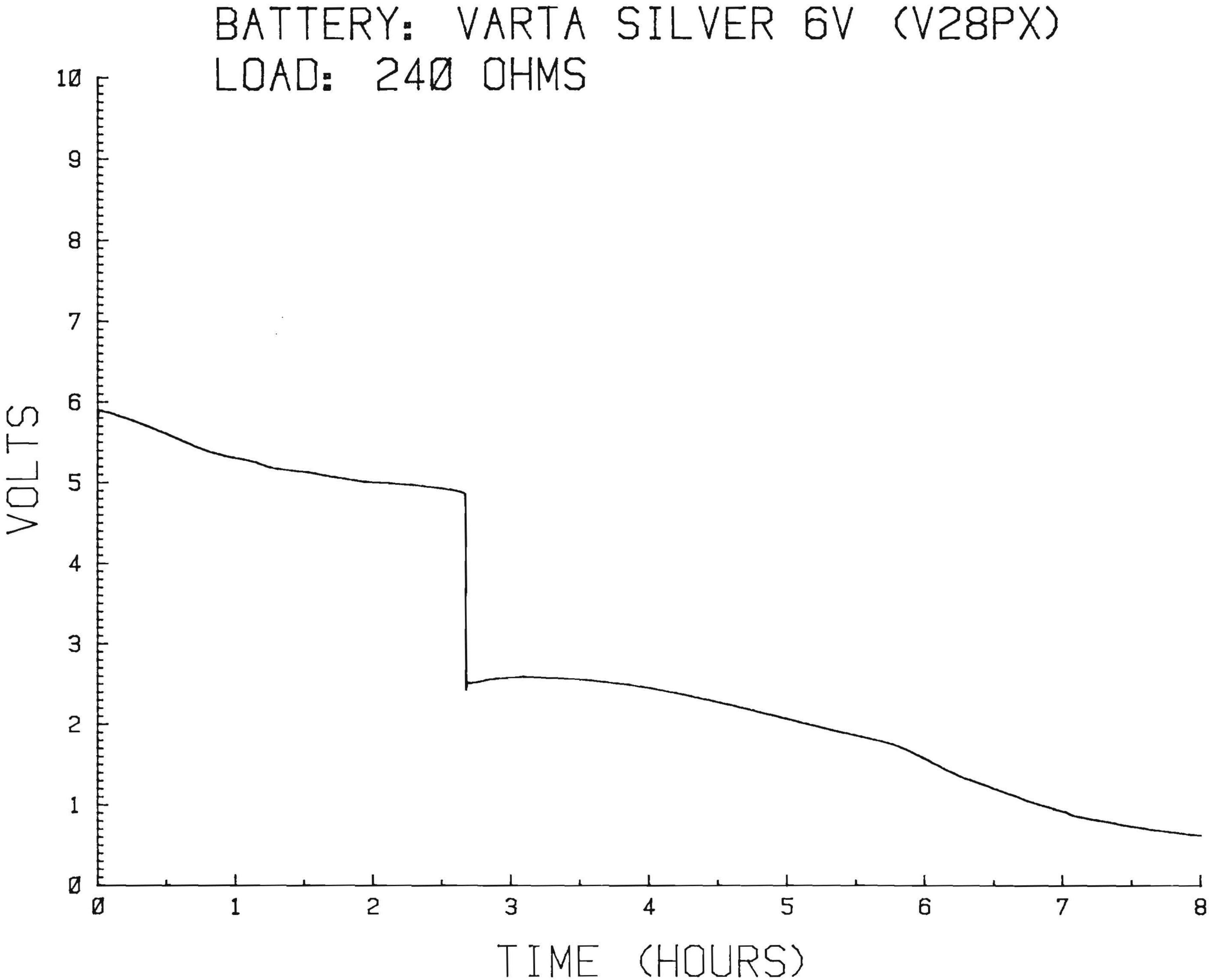
BATTERY VOLTAGE DROP WITH RESPECT TO TIME FOR A 25 mA INITIAL LOAD FOR VARIOUS TYPES OF BATTERIES

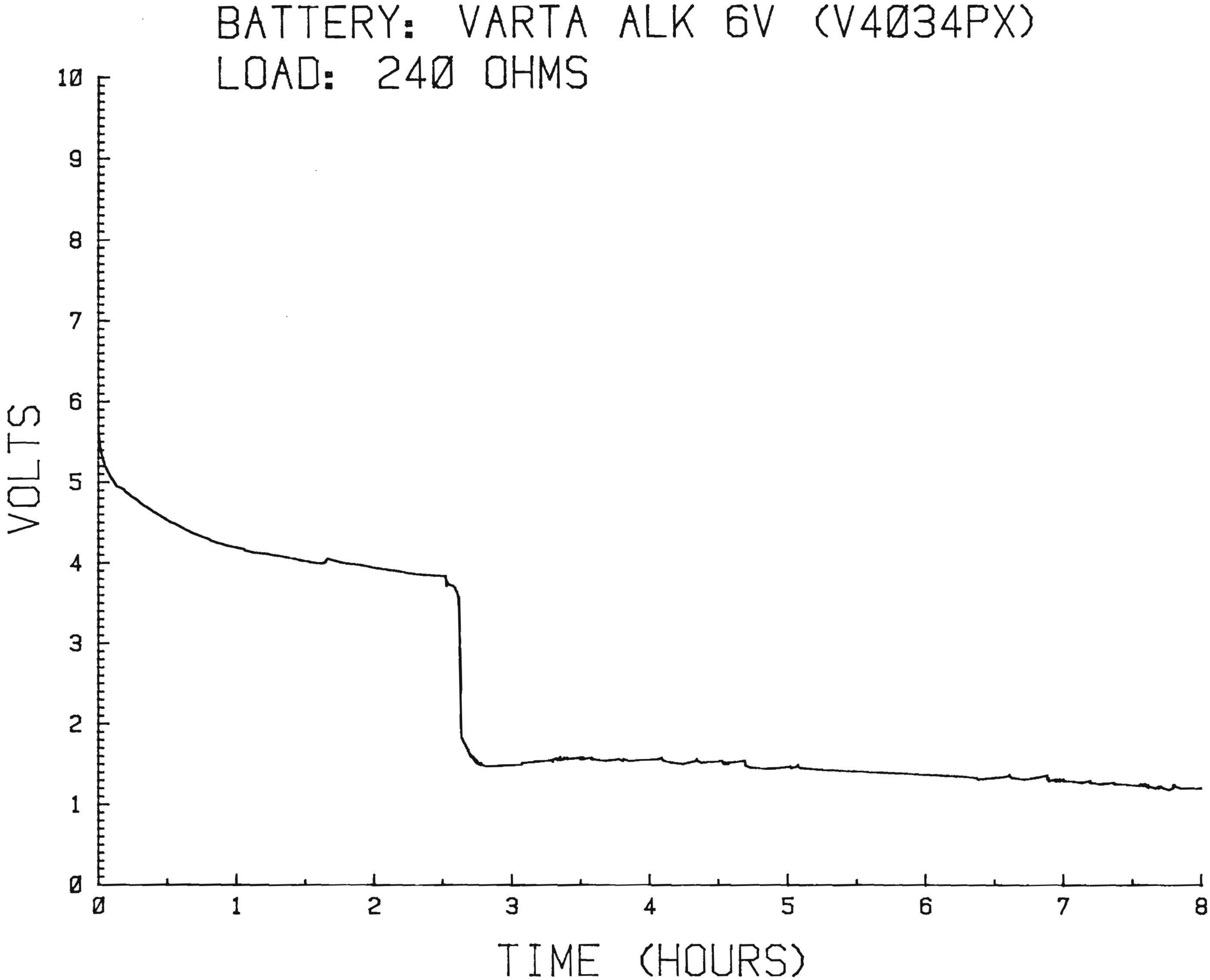

BATTERY: DURACELL ALK 9V (MN1604)
LOAD: 360 OHMS
VOLTS
TIME (HOURS)
10
9
8
7
6
5
4
3
2
1
0
0
1
2
3
4
5
6
7
8

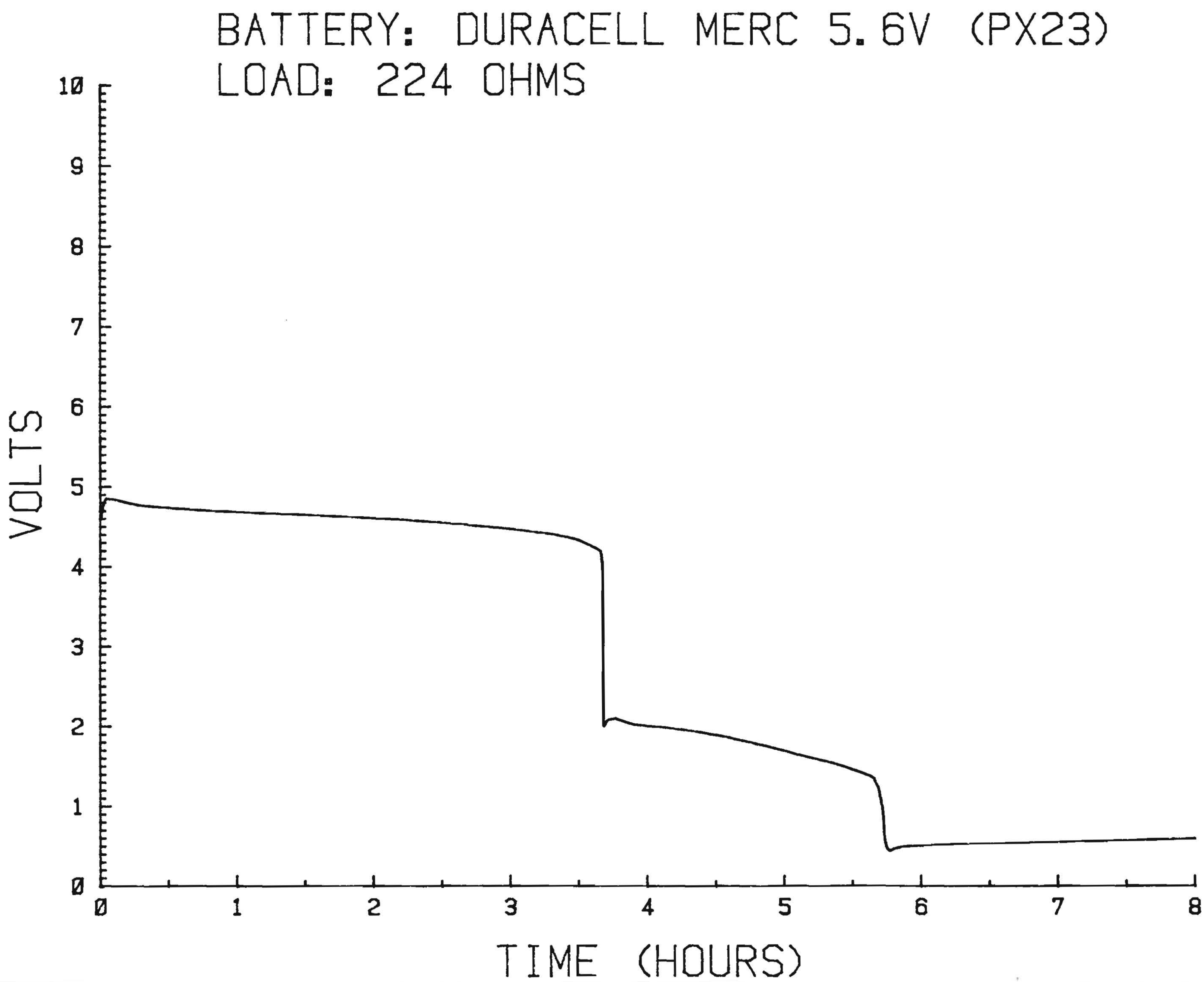

BATTERY: EVEREADY ALK 9V (NO. 522)
LOAD: 360 OHMS
VOLTS
TIME (HOURS)
10
9
8
7
6
5
4
3
2
1
0
0
1
2
3
4
5
6
7
8



BATTERY: VARTA LITHIUM 6V (V28PXL)
LOAD: 24Ø OHMS
VOLTS
1Ø
9
8
7
6
5
4
3
2
1
Ø
Ø
1
2
3
4
5
6
7
8
TIME (HOURS)


BATTERY: VARTA SILVER 6V (V28PX)
LOAD: 240 OHMS
VOLTS
10
9
8
7
6
5
4
3
2
1
Ø
Ø
1
2
3
4
5
6
7
8
TIME (HOURS)


BATTERY: VARTA ALK 6V (V4Ø34PX)
LOAD: 24Ø OHMS
VOLTS
TIME (HOURS)
10
9
8
7
6
5
4
3
2
1
Ø
Ø
1
2
3
4
5
6
7
8


BATTERY: DURACELL MERC 5.6V (PX23)
LOAD: 224 OHMS
VOLTS
TIME (HOURS)
0
1
2
3
4
5
6
7
8
9
10

ATTACHMENT III - FINANCIAL REPORT

23 July to 30 August 1982

Labor Categories	Contractual Man-Hours Proposed	Man-Hours Expended This Period	Cumulative Total of Expended Man-Hours
Principal Research Engineer	164	8.5	8.5
Research Engineer I	738	120	120
Machinist/Technician	72	57.5	57.5
Secretarial/Clerical/ Technical Assistant	480	170	170

A-3310

Georgia Institute of Technology
ENGINEERING EXPERIMENT STATION
ATLANTA, GEORGIA 30332

4 October 1982

Bell Laboratories
Crawfords Corner Road
Holmdel, New Jersey 07733

Attention: Mr. Don Heirman

Subject: Monthly Progress and Financial Report No. 2, Project A-3310, Purchase Order No. 540621, "Spherical Dipole Emission Source," covering period 1 September to 30 September 1982

Gentlemen:

The objective of this program is to design, develop, and construct a spherical dipole emission source which radiates a known and repeatable field level at discrete frequencies from 30 MHz to 200 MHz. The specific tasks to be performed are:

I. Mechanical design and construction of the spherical dipole aperture,

II. Electrical design and construction of the circuitry required for the signal generation, and

III. Performance evaluation of the spherical dipole source.

Efforts this month were directed primarily to Task II on the design of the signal generation circuitry. A short description of the worked performed is given in the following paragraphs.

A preliminary schematic of the signal generation circuitry is given in Figure 1. The component values given in Figure 1 are a result of a first cut design performed during this reporting period. The signal generator circuit consists of a Motorola K1152A CMOS crystal oscillator, which is used to generate the 5 MHz fundamental signal; an amplifier - driver, which delivers the required rf power to the diode; an input matching network, which matches the output impedance of the amplifier to the impedance of the diode; an impulse generator, which converts the input fundamental signal into a

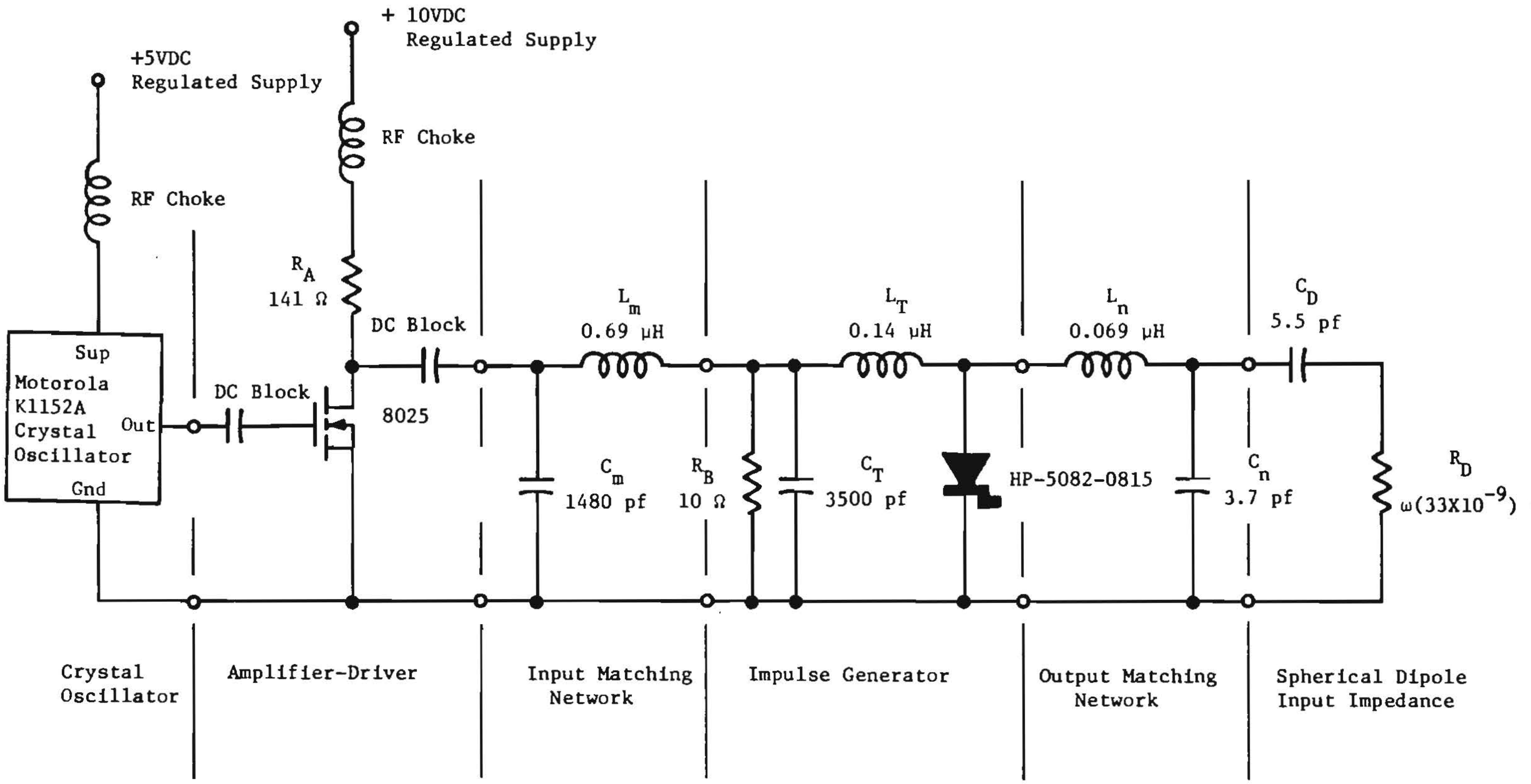


Figure 1. Schematic of Signal Generator Circuitry for Spherical Dipole Radiator.

periodic pulse; and an output matching network, which matches the low output impedance of the diode to the input impedance of the spherical dipole.

The heart of the circuit is the impulse generator section utilizing a HP 5082-0815 step recovery diode (SRD). The characteristically fast transition time of the diode ensures a rise time of the output pulse train which is fast enough to contain harmonics through 200 MHz. The drive inductor, L_T, in this section is used to store energy so that when the diode switches from its on to off state this energy is transferred to the spherical dipole in the form of a transient current. The shorting capacitor, C_T, is used to make the input impedance of the impulse generator purely resistive at 5 MHz by tuning out the drive inductance. The SRD is dc biased through the self biasing resistor, R_B.

In order to determine the performance of the SRD the impulse generator section of the circuit was tested in a 50 ohm system. An HP 651A test oscillator was used to drive the impulse generator. The values given in Figure 1 for the input matching network were changed in order to match the 50 ohm output impedance of the test oscillator. The impulse generator was then terminated into the 50 ohm input impedance of a Tektronics 492P spectrum analyzer; the values of the output matching network were also varied in order to match this load impedance. The results of these measurements, as depicted in Figure 2, show that for a 5 MHz input signal with an amplitude of 5 volts peak-to-peak, the output signal consists of harmonics from 30 MHz through 250 MHz whose amplitudes vary from -6 dBm to -20 dBm. Above 250 MHz the level of the harmonics start to roll off and various resonant frequencies can be seen. It is noted that the output levels of these signals should be of sufficient amplitude to generate the specified minimum field intensity; however, the circuit as tested is operating into a 50 ohm matched load. When the spherical dipole is used as the load it will not be possible to match the load at all frequencies and a loss of output power may be suffered. If such losses are too great it may require the use of two or three output matching networks for various frequency ranges; these networks can be switched in and out using a three pole rotary switch rather than the single pole rotary switch which is presently incorporated in the spherical dipole housing.

The 5 MHz crystal oscillator and VMOS amplifier - driver circuitry were then used to drive the impulse generator while still using the spectrum analyzer as the load. The value of the resistor, R_A, which sets the bias current through the VMOS driver was initially set to draw 25 mA bias current. This bias current however, was not sufficient to drive the impulse generator

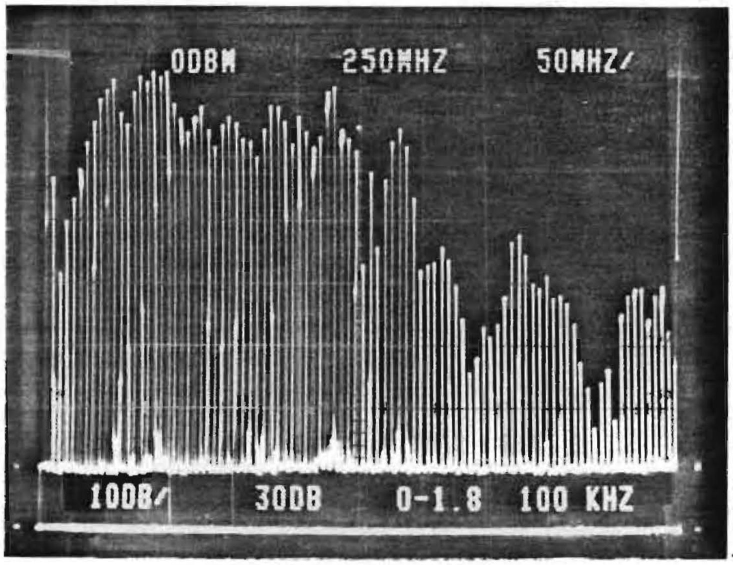


Figure 2. Output of Impulse Generator Circuit Driven with an HP651A Test Oscillator and Terminated with the 50 ohm Imput Impedance of a Tektronics 492P Spectrum Analyzer.

circuitry. The value of R_A was then changed so that the bias current was increased to 50 mA. The resulting output spectrum shown in Figure 3 was similar to the previous measurement utilizing the HP 651A test oscillator as the driver except that the output levels were decreased by approximately 10 dB. As the bias current was increased to 100 mA the output levels increased to values equivalent to the previous measurement using the test oscillator as the driver. Although the levels shown in Figure 3 for a 50 mA bias current should be of sufficient amplitude to radiate the minimum required field intensity, a 50 mA load may be excessive and battery life time may be reduced. Next month, tests will be performed to ensure that a 4 hour battery life time is possible for a 50 mA load. Also, other possible amplifier -driver configurations will be investigated to see if it is possible to drive the impulse generator with a lower level of dc bias current.

Tests were also performed this month to measure the output frequency drift versus time of two sample CMOS crystal oscillators. Results of this test are given in Figure 4 and show that for a constant supply voltage the maximum frequency change over an eight hour period is 4 Hz, which is much less than the specified 4 kHz drift. Since the crystal oscillator will be driven off a regulated supply, the frequency drift specification should be easily met.

During the next reporting period it is anticipated that Task I and Task II will be completed and that the signal generator circuitry will be incorporated into the spherical dipole aperture. A financial report for this reporting period is given in Attachment I.

Respectfully submitted,

J. C. Mantovani
Project Director, A-3310

Approved:

H. W. Denny, Chief
Electromagnetic Compatibility Division

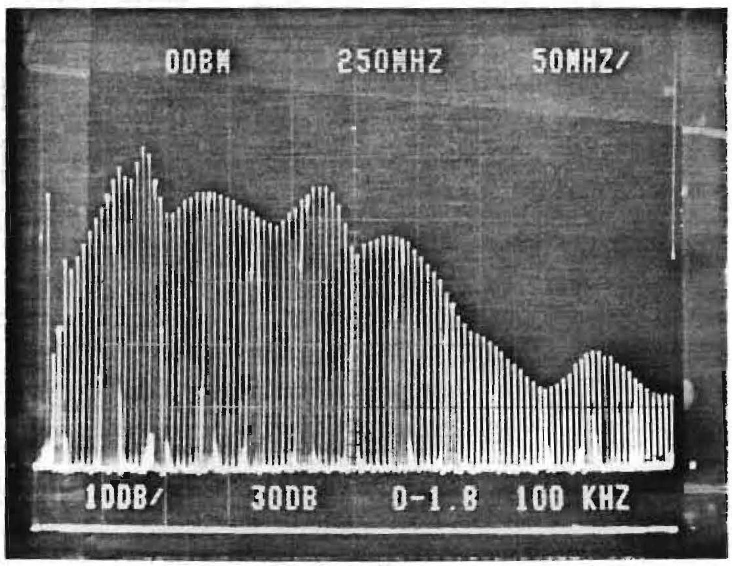


Figure 3. Output of Impulse Generator Circuit Driven with Crystal Oscillator/VMOS Driver Shown in Figure 1 and Terminated with the 50 ohm Input Impedance of a Tektronics 492P Spectrum Analyzer.

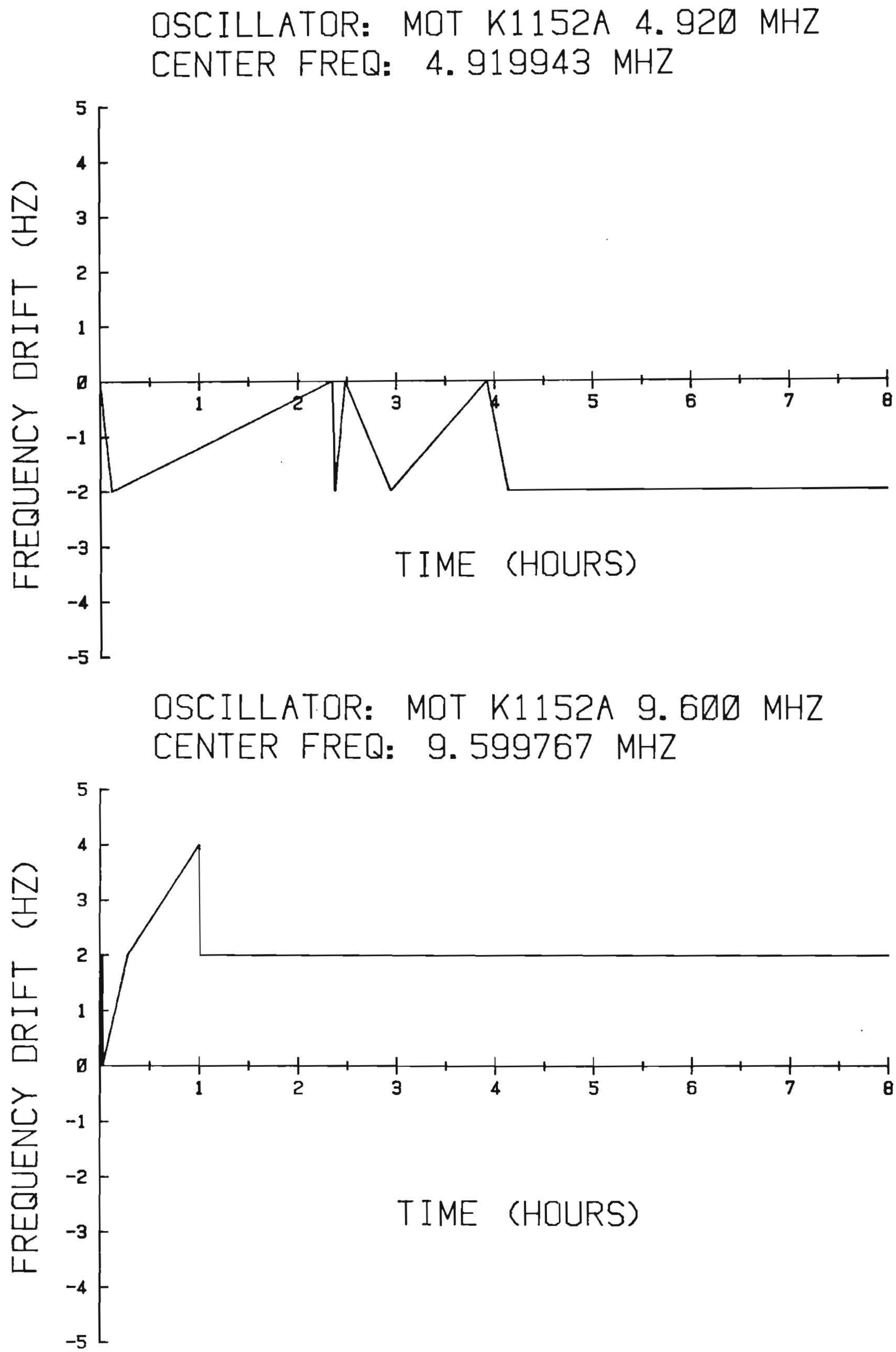


Figure 4. Frequency Drift of Two Motorola K1152A Crystal Oscillators Versus Time for Constant Supply Voltage.

ATTACHMENT I - FINANCIAL REPORT

1 September to 30 September 1982

Labor Categories	Contractual Man-Hours Proposed	Man-Hours Expended This Period	Cumulative Total of Expended Man-Hours
Principal Research Engineer	164	24.5	33
Research Engineer I	738	54	174
Machinist/Technician	72	57.5	57.5
Secretarial/Clerical/ Technical Assistant	480	123.5	293.5

A-3310

Georgia Institute of Technology

ENGINEERING EXPERIMENT STATION

ATLANTA, GEORGIA 30332

3 November 1982

Bell Laboratories
Crawfords Corner Road
Holmdel, New Jersey 07733

Attention: Mr. Don Heirman

Subject: Monthly Progress and Financial Report No. 3, Project A-3310, Purchase Order No. 540621, "Spherical Dipole Emission Source," covering period 1 October to 31 October 1982

Gentlemen:

The objective of this program is to design, develop, and construct a spherical dipole emission source which radiates a known and repeatable field level at discrete frequencies from 30 MHz to 200 MHz. The specific tasks to be performed are:

I. Mechanical design and construction of the spherical dipole aperture,

II. Electrical design and construction of the circuitry required for the signal generation, and

III. Performance evaluation of the spherical dipole source.

Efforts this month were directed toward the completion of Task I and Task II, and toward the incorporation of the signal generator into the spherical dipole aperture. Efforts were also begun in Task III on preliminary definitions of the measurement site and the measurement setup requirements for each of the various performance evaluation tests. A short description of the work performed in each task is given in the following paragraphs.

Task I. Measurements of the input impedance of the spherical dipole aperture were performed this month using a GR-1710 network analyzer. Results of these measurements are illustrated in Figure 1 showing both the magnitude and phase of input impedance over the frequency range of 15 MHz - 250 MHz. These results show that measured input impedance deviates significantly from the theoretical input impedance. In particular, note the resonance at 157.5

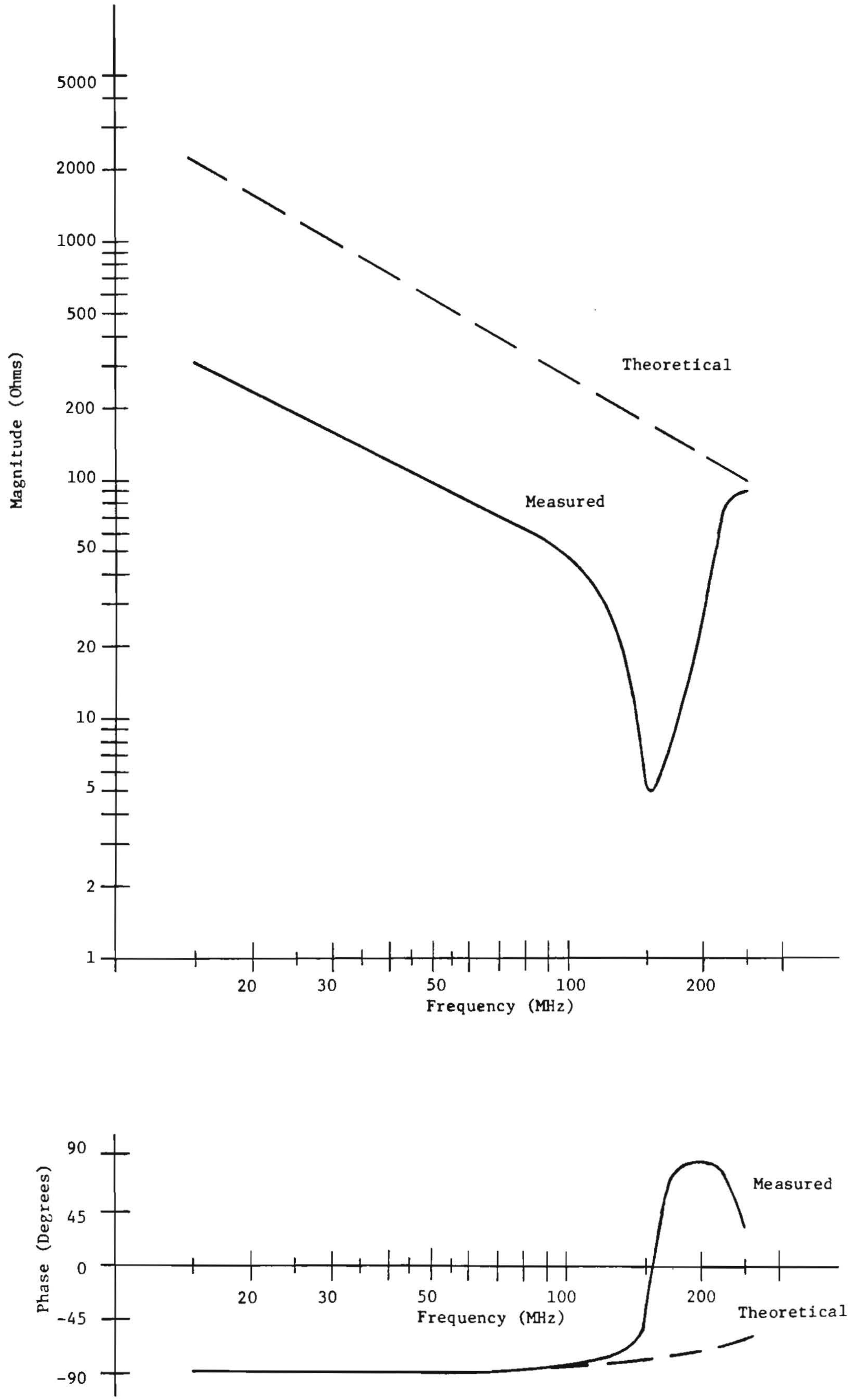


Figure 1. Measured and Theoretical Variation of the Magnitude and Phase of the Spherical Dipole Input Impedance as a Function of Frequency.

MHz where the phase angle of the input impedance passes through zero and the magnitude nulls to its lowest value of 5 ohms. The metal posts which feed the two hemispherical sections, add inductance to the input impedance and are probably the cause of the resonance. The theoretical analysis did not account for these posts. Also note that at frequencies below 100 MHz the input impedance is almost completely capacitive, as theoretically predicted. However, the value of the capacitance as calculated from the measured value is 36 pf which is much higher than the predicted 5.5 pf. The measured input impedance of the spherical dipole was modeled over the frequency range of interest (i.e. 30 MHz-200 MHz) as the series RLC network shown in Figure 2.

Task II. The signal generator circuitry shown in the previous monthly report was improved by changing the input impedance matching network thus reducing the required total average current pull of the circuit to 40 mA. Tests performed this month indicate that this amount of current drain can be sustained for at least a four hour interval with the 9V batteries previously chosen.

An output matching network was developed to match the theoretical input impedance of the spherical dipole to the pulse generator circuitry. Unfortunately, the input impedance measurements were performed after the output matching network was developed. The resonance in the input impedance of the spherical dipole at 157.5 MHz will have the effect of extremely complicating the development of the output matching network. Two possible solutions to this problem which will be investigated are: (1) the use of multiple matching networks which can be switched in and out for different frequency bands (i.e., possibly one frequency band below resonance, one band centered at resonance, and one band above resonance) or (2) shifting the resonance frequency of the dipole out beyond 200 MHz by increasing the gap separation, thus reducing the capacitance between the two hemispheres. The disadvantage of the later solution is that it will require additional milling work which will delay the completion of the construction phase of the program by possibly a week or more.

A preliminary printed circuit board was layed out and constructed so that the signal generator circuitry could be incorporated into the spherical dipole aperture, thus allowing tests of the signal generator circuitry when it is operating into the input impedance of the dipole. Figure 3 shows the completed pc boards with the electrical components, the switch, the

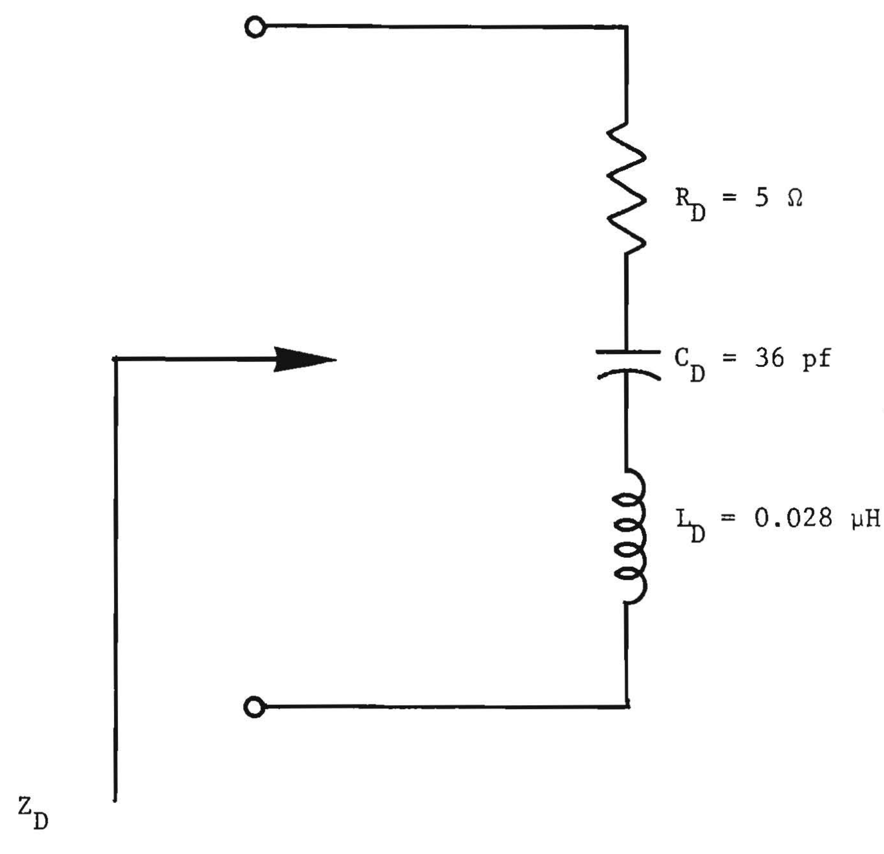


Figure 2. Equivalent Model of the Input Impedance to the Spherical Dipole Antenna.

batteries, and the connecting post all mounted to it. Figures 4 and 5 are a pictorial representation of the assembly of the complete spherical dipole.

As a first cut test, the matching network previously developed for the theoretical input impedance was used on the pc board and the spherical dipole emitter was assembled to determine if it would radiate a field using this simple output matching network. Results of this test were unsuccessful and indicate that this matching network will not work. It is believed that the input impedance of the spherical dipole loaded the output of the impulse generator circuit thus pulling the step recovery diode out of its switching state. Next month efforts will be continued to resolve this output matching problem so that the spherical dipole emitter will become operational. Note that preliminary tests performed on the circuit, in a conducted mode, indicate that the amplitude drift and frequency drift requirements should be easily met over a four hour interval.

Task III. Preliminary considerations were begun this month toward the determination of the requirements of the measurement sites and measurement setups used to perform the performance verification measurements for the spherical dipole emitter. A computer program was also developed and tested this month to be used with a HP-85 controller to perform the amplitude and frequency drift measurements using automated equipment. These measurements will be performed in an automated test setup due to the large number of points which must be taken.

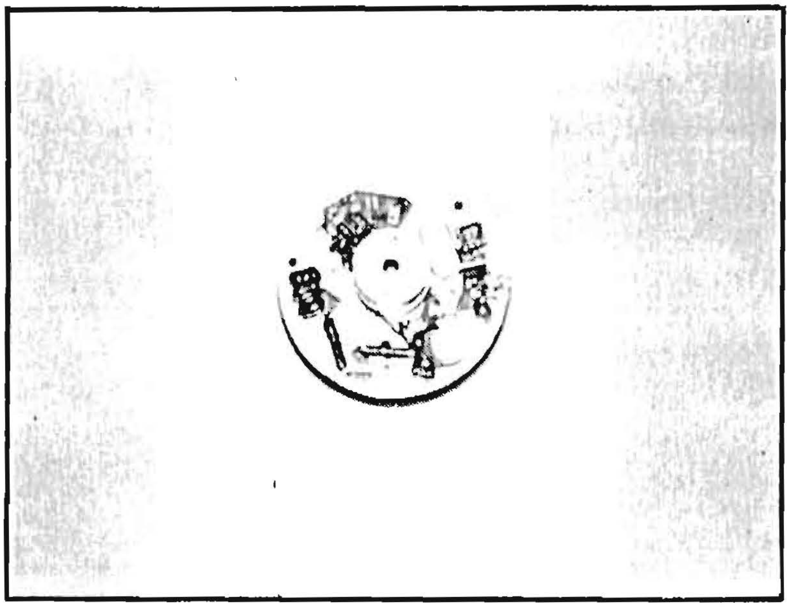
During the next reporting period it is anticipated that the output matching network problem will be resolved and that the performance evaluations tests in Task III will be initiated. A financial report for this reporting period is given in Attachment I.

Respectfully submitted,

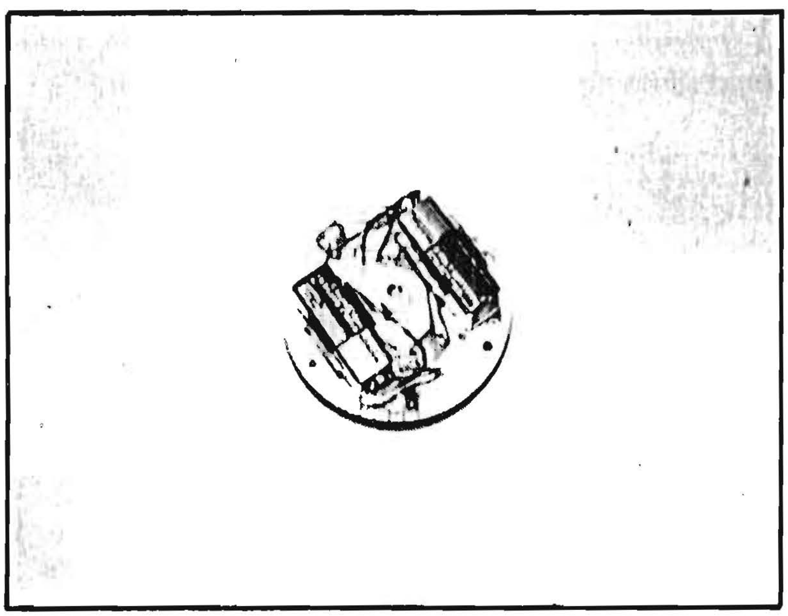
John C. Mantovani
Project Director

Approved:

H. W. Denny, Chief
Electromagnetic Compatibility Division

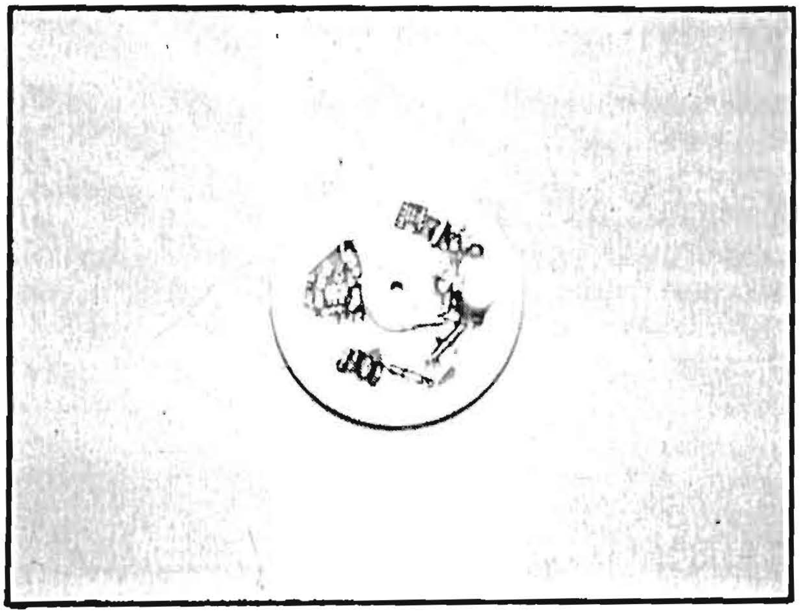


(a) Component Side of PC Board

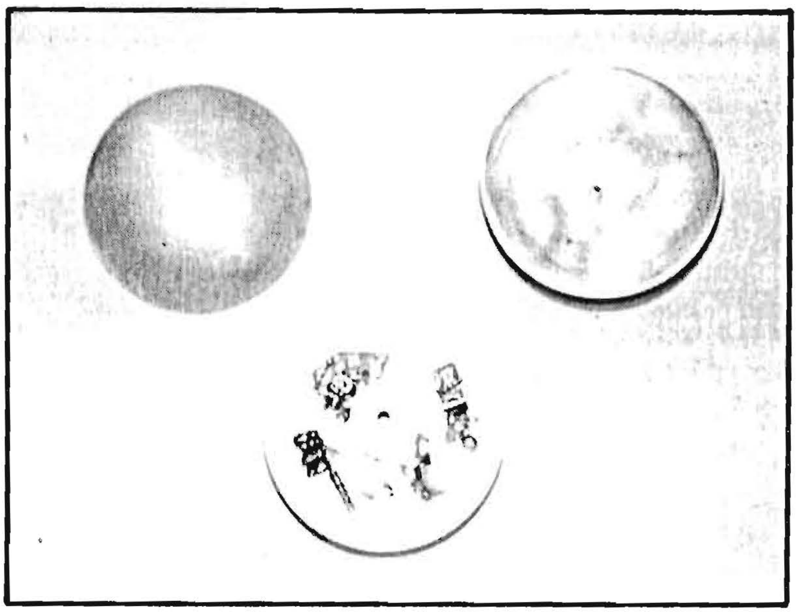


(b) Trace Side of PC Board

Figure 3. Assembled PC Board of the Spherical Dipole Circuitry Showing Placement of Electrical Components, Rotary Switch, Connecting Post, and Batteries

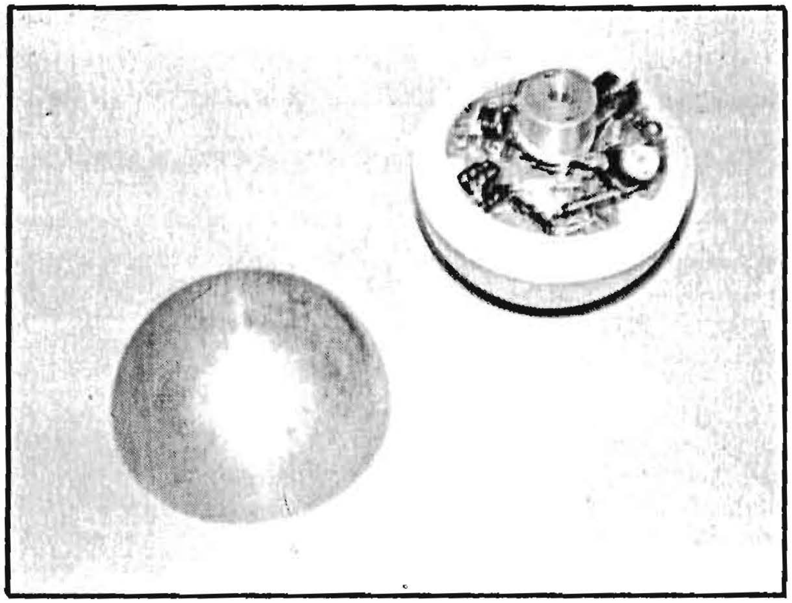


(a) PC Board Mounted in Delrin Ring Spacer

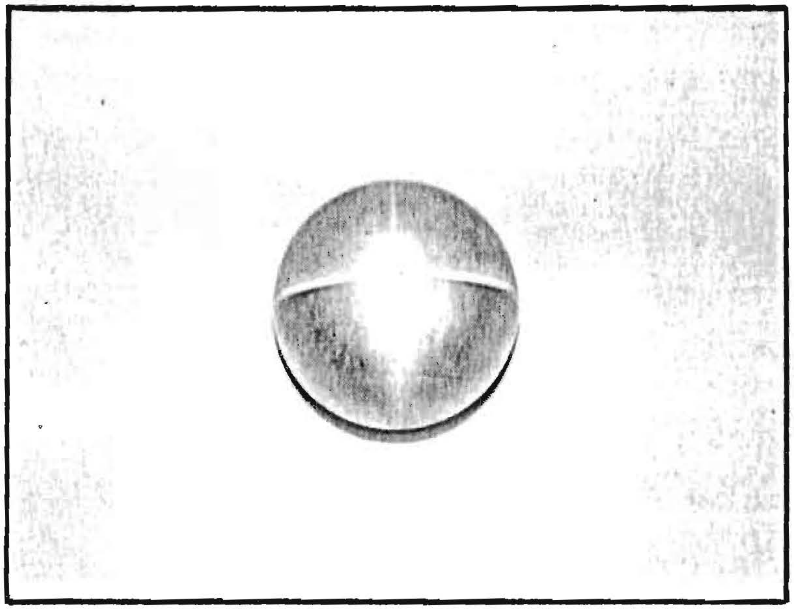


(b) Unassembled View

Figure 4. Unassembled Spherical Dipole Emitter Showing PC Board Mounted in Delrin Ring Spacer and the Two Brass Hemispherical Sections with Attached Feed Post.



(a) Half Assembled View



(b) Assembled View

Figure 5. Assembled Spherical Dipole Emitter Showing PC Board and Delrin Ring Attached to Lower Brass Hemispherical Section and Complete Assembled View.

ATTACHMENT I - FINANCIAL REPORT

1 October to 31 October 1982

Labor Categories	Contractual Man-Hours Proposed	Man-Hours Expended This Period	Cumulative Total of Expended Man-Hours
Principal Research Engineer	164	8	41
Research Engineer I	738	195	369
Machinist/Technician	72	57.5	57.5
Secretarial/Clerical/ Technical Assistant	480	43.5	337

A-3310

ENGINEERING EXPERIMENT STATION
Georgia Institute of Technology
A Unit of the University System of Georgia
Atlanta, Georgia 30332

1 December 1982

Bell Laboratories
Crawfords Corner Road
Holmdel, New Jersey 07733

Attention: Mr. Don Heirman

Subject: Monthly Progress and Financial Report No. 4, Project A-3310, Purchase Order No. 540621, "Spherical Dipole Emission Source," covering period 1 November to 30 November 1982

Gentlemen:

The objective of this program is to design, develop, and construct a spherical dipole emission source which radiates a known and repeatable field level at discrete frequencies from 30 MHz to 200 MHz. The specific tasks to be performed are:

I. Mechanical design and construction of the spherical dipole aperture,

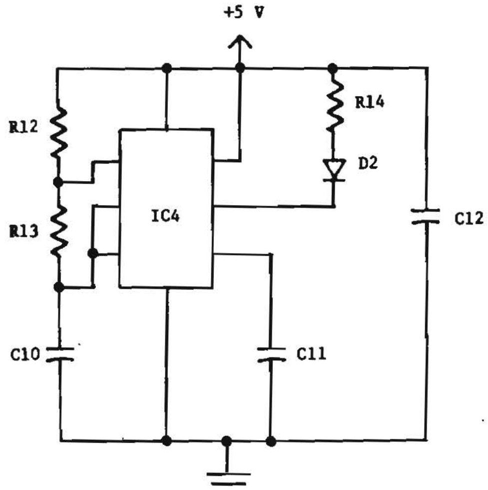
II. Electrical design and construction of the circuitry required for the signal generation, and

III. Performance evaluation of the spherical dipole source.

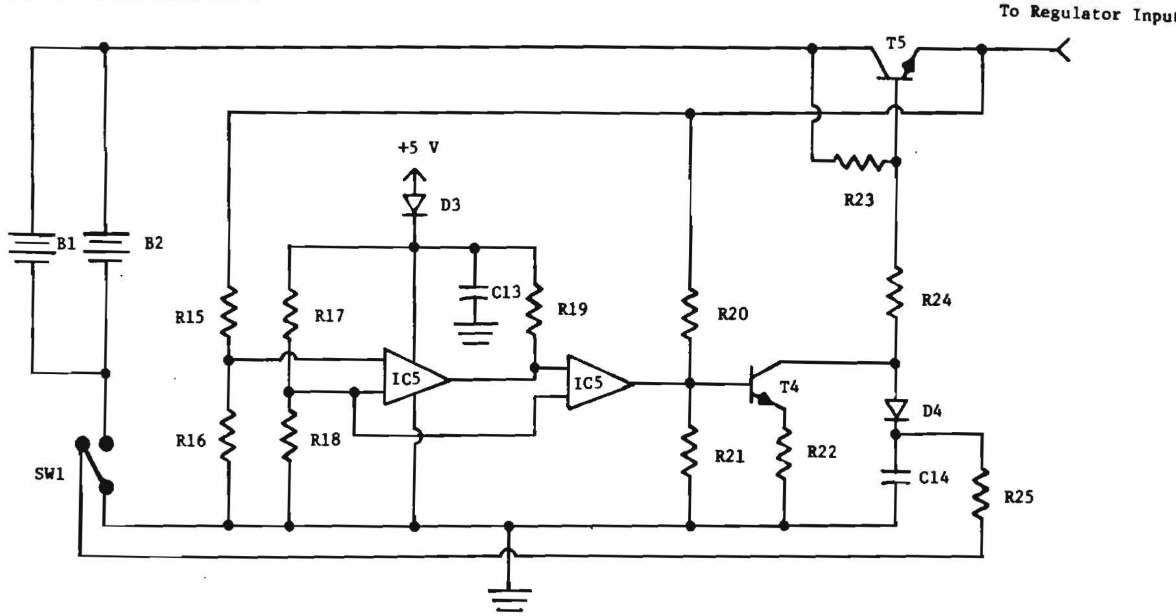
This month emphasis was placed in Task II on the finalization of the signal generation circuitry, and on the initiation of Task III in the performance evaluation of the spherical dipole source. A short description of the work performed is presented in the following paragraphs.

Task II

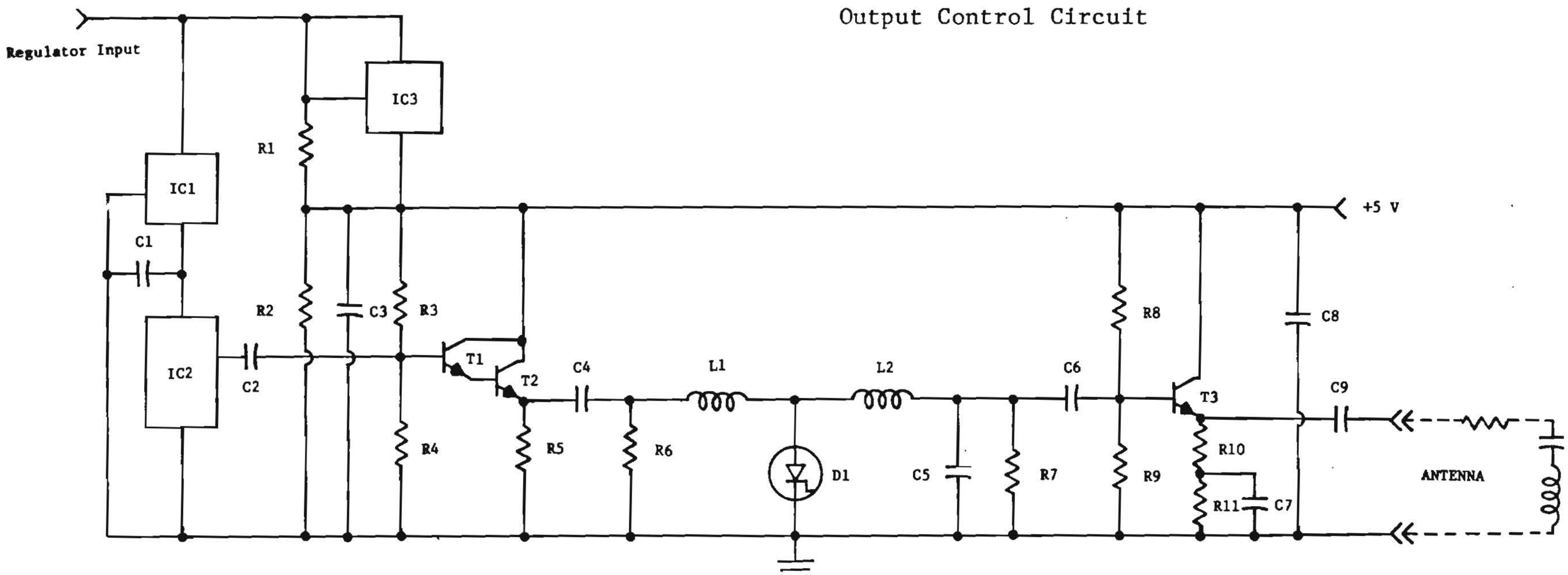
The complete schematic of the signal generation circuitry is shown in Figure 1. The component values and part numbers given in Table I are equivalent to those on the printed circuit board presently employed in the



Output Indicator Circuit



Output Control Circuit



RF Generator Circuit

Figure 1. Schematic Diagram of Signal Generator Circuitry for Spherical Dipole Emission Source.

TABLE I

PARTS LIST FOR SIGNAL GENERATOR CIRCUIT

Resistors	Capacitors	Transistors
R1 - 330Ω	C1 - 1 μf	T1 - 2N5828
R2 - 1.0 kΩ	C2 - 1 μf	T2 - 2N2222
R3 - 220 kΩ	C3 - 1 μf	T3 - ECG311
R4 - 220 kΩ	C4 - 1 μf	T4 - 2N3904
R5 - 150 Ω	C5 - 4 pf	T5 - 2N3906
R6 - 150 Ω	C6 - 1 μf	
R7 - 120 Ω	C7 - Open	**Batteries**
R8 - 1.0 kΩ	C8 - 1 μf	
R9 - 1.0 kΩ	C9 - 1 μf	B1 - 9V Alkaline
R10 - 100 Ω	C10 - 0.1 μf	B2 - 9V Alkaline
R11 - Short	C11 - 0.1 μf	
R12 - 3.6 MΩ	C12 - 1 μf	**Integrated Circuits**
R13 - 330 kΩ	C13 - 47 μf	
R14 - 1.0 kΩ	C14 - 10 μf	IC1 - PMI (REF-02)
R15 - 120 kΩ		IC2 - MOT. (K1152A-5.00)
R16 - 120 kΩ	**Inductors**	IC3 - LM317
R17 - 120 kΩ		IC4 - 7555N
R18 - 56 kΩ	L1 - 0.18 H	IC5 - LM2903N
R19 - 120 kΩ	L2 - 0.1 H	
R20 - 22 kΩ		**Switch**
R21 - 22 kΩ	**Diodes**	
R22 - 330 Ω		SW1 - Centralab (P-501)
R23 - 22 kΩ	D1 - HP-5082-0815	
R24 - 1.0 kΩ	D2 - Red Led	
R25 - 100 Ω	D3 - IN914	
	D4 - IN914	

spherical dipole housing. All of the performance data shown in this report are the results of measurements performed on this printed circuit. The signal generator circuitry is divided into three major sections: RF generator, output controller, and output indicator. The dc power for the spherical dipole is supplied by two standard 9 volt batteries. The batteries are connected in parallel in order to supply the required current drain at 50 mA for a least a 4-hour period.

The RF generator circuitry can be divided into the following stages: dc power regulator, 5 MHz signal source, 5 MHz amplifier, impulse generator, output matching network, and output driver. The dc regulator circuitry is composed of two individual components--a 5 V Precision Monolithic voltage reference (IC1) which is used to power the 5 MHz crystal oscillator, and a 5 V voltage regulator (IC3) which is used to power the remaining circuitry. The voltage reference is used to power the 5 MHz crystal oscillator since it only requires an input current of 1.1 mA. The voltage regulator powers the remaining circuitry since the voltage reference cannot supply the required current drain. This configuration otpimizes the stability of the output field levels since they are strongly dependent on changes in the output of the 5 MHz crystal oscillator, and since the voltage reference is more stable than the voltage regulator. A Motorola K1152A CMOS crystal oscillator (IC2) is used as the 5 MHz signal source offering the advantages of small size, low power consumption, precise frequency stability, and precise output level stability (with constant input voltage). The 5 MHz amplifier stage utilizes two bipolar transistors in a Darlington configuration (T1, T2) with the output transistor in a common collector stage, thus offering the advantages of a high input impedance, low output impedance, current amplification, and a low parts count. The impulse generator circuit utilizes a step recovery diode, SRD, (D1) with a characteristically fast transition time to ensure that the output of the pulse train has a rise time which is fast enough to contain harmonics through 200 MHz. The drive inductor (L1) in this section is used to store energy so that when the diode switches from its on to off state this energy is transferred to the spherical dipole in the form of a transient current. The SRD is dc biased through the self biasing resistor (R6). The output matching network (L2, C5, R7) is used to present the proper load impedance to the impulse generator circuit and is configured as a low-pass filter with a cutoff frequency of 250 MHz. The output driver circuit utilizes a high frequency BJT transistor configured in a common collector stage in order to present a low output impedance maximizing the input current to the antenna.

The output controller circuit consists of a manual on/off switch which is used to turn off the output field by removing the battery power from the signal generator circuit, and an automatic on/off switch which removes the battery power when the battery voltage drops below the voltage required to maintain regulation. The manual on/off switch (SW1) is a subminiature 2-position rotary switch which is mechanically attached to the two spherical dipole halves; thus, when the spherical dipole is assembled, the output field can be turned on and off, without disassembly, by rotating the two sphere halves in opposite directions. The automatic on/off switch utilizes a comparator (IC5) to monitor the battery dc voltage comparing it to the regulated +5 voltage. When the battery voltage drops below 7.0 volts, regulation can no longer be maintained. Thus, the comparator output is set to switch from its normally high state to a low state when the battery voltage equals 7.0 volts. When the comparators output drops to its low state, transistor T4 is shut off which in turn shuts transistor T5 off, thus removing the battery voltage from the complete signal generator circuit. The automatic on/off switch is initially allowed to turn on by the initial transient which is conducted through the initializing capacitor (C14). The resistor (R25) connected to the second position of the manual on/off switch is used to discharge the initializing capacitor (C14) when the circuit is turned off.

The output indicator circuit utilizes a flashing LED (D2) to visually indicate that the field is turned on. The LED is pulsed at approximately a one second repetition rate and a 10 percent duty cycle; thus, power consumption used in the output indicator circuit is reduced by approximately 90 percent from the power consumption required to have the LED on continuously. The pulse rate and duty cycle are controlled by the 7555 timer (IC4), resistors (R12 and R13), and capacitor (C10). The 7555 timer is a CMOS version of a 555 timer. The CMOS version is used since its power dissipation is much less than the 555 timer. The output indicator circuit is powered by the 5 volt regulator; thus, when the battery voltage drops below the required level to maintain regulation, the output controller circuit turns off the LED flasher as well as the radiated field.

Task III

Preliminary measurements were performed this month in order to verify that the spherical dipole source would meet the required performance specifications. In particular, measurements were made of the frequency and amplitude drift of the signal source as a function of time and of the relative radiated field levels. In addition, an outdoor open area test site was constructed and spot measurements of the site attenuation factor were performed.

The amplitude and frequency drift of the spherical dipole source was measured as a function of time utilizing a new set of Duracell alkaline 9 volt batteries. These measurements were performed in an automated measurement setup utilizing an HP-85 desktop computer as the controller, a Tektronics 492P spectrum analyzer as the receiver for the amplitude measurements, and an EIP 548A frequency counter to perform the frequency drift measurements. These measurements were performed in a conducted mode as shown in Figure 2 and are representative of the radiated field when the circuit is operating in the spherical dipole housing. Results of these measurements are given in Attachment I. Note from these plots that a 7.5 hour battery life time was realized before the output control circuit removed the battery voltage easily meeting the four-hour operating time requirement. From the plot of the frequency drift of the 35 harmonic (175 MHz) it is seen that a maximum frequency drift of only 120 Hz was measured during the entire battery life time. Thus, the frequency drift of the 40th harmonic (200 MHz signal) would be 137 Hz over the entire battery lifetime. Also note from the plots of the output levels at each frequency that ± 1 dB amplitude variation over a 4 hour interval is also easily met at each frequency.

The output levels of the signal source were measured at each frequency with the circuit operating in the following three configurations: (1) using the 50 ohm input impedance of the spectrum analyzer as the terminating impedance, (2) using the spherical dipole input impedance in parallel with the 50 ohm input impedance of the spectrum analyzer as the terminating impedance, and (3) radiating into a TEM chamber. Figures 3, 4,

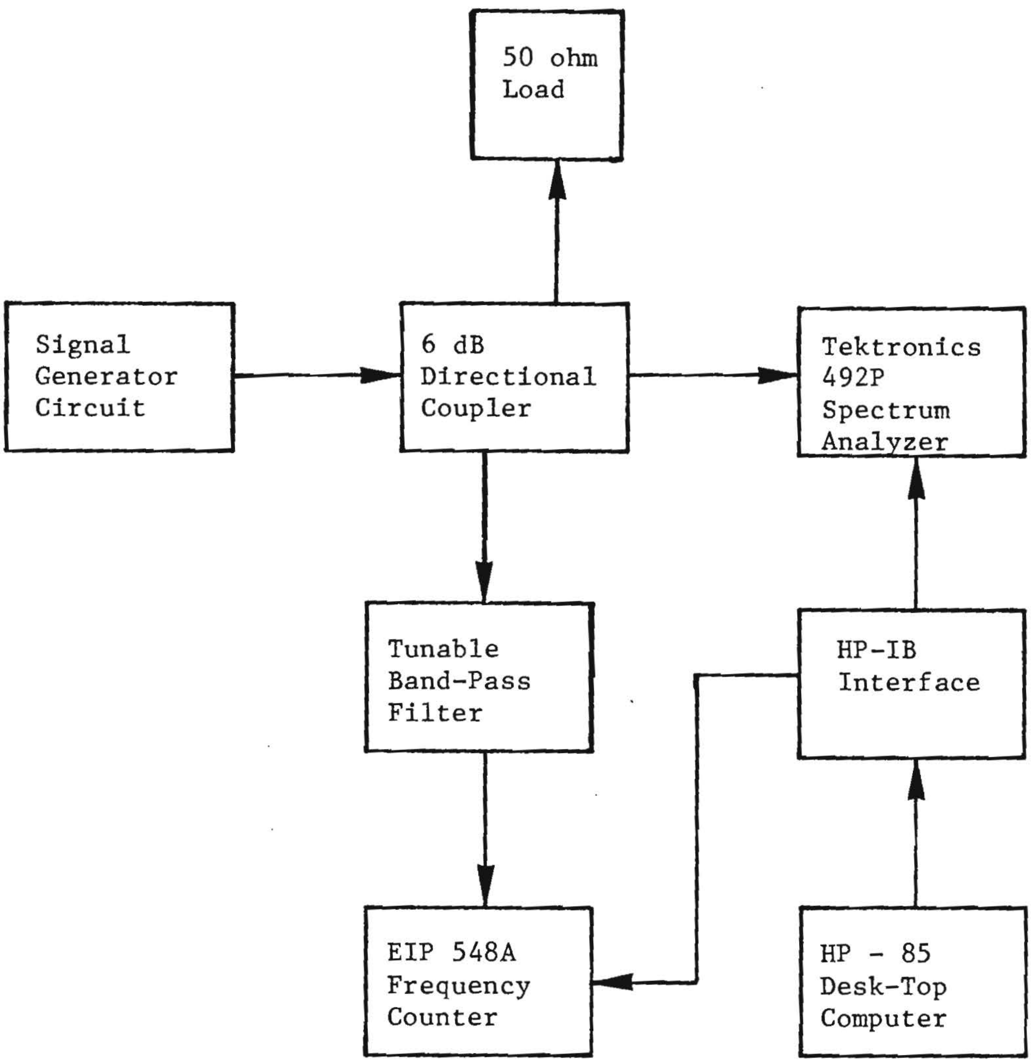
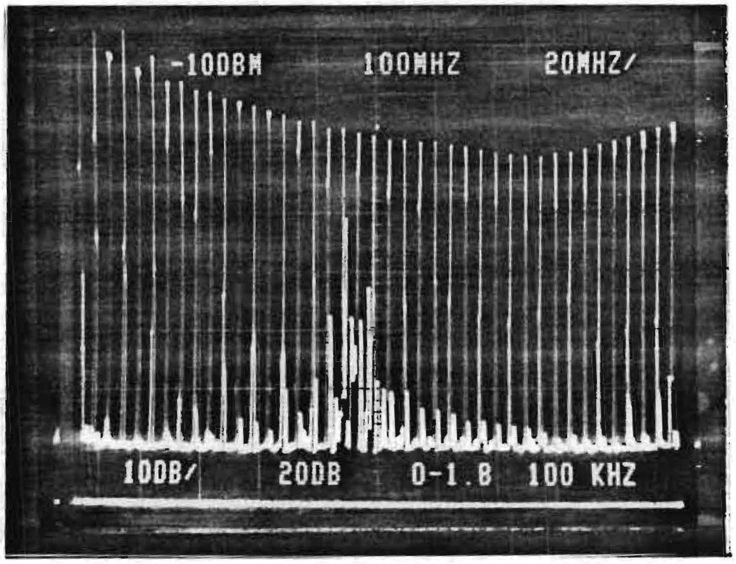


Figure 2. Block Diagram of Automated Measurement Setup Used to Perform Amplitude and Frequency Drift Measurements as a Function of Time.

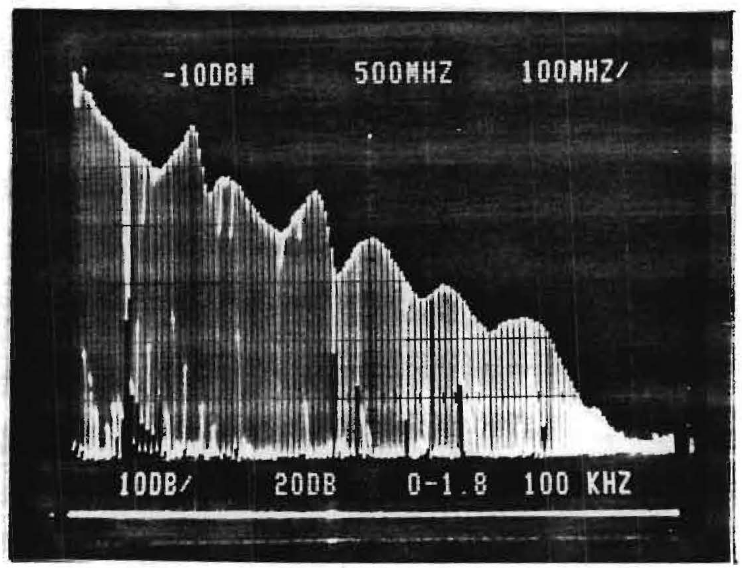
Reference Level	Center Frequency	Frequency Span/Division



Vertical Display	RF Atten	Frequency Band	Resolution Bandwidth

(a) Frequency Range 0 - 200 MHz

Reference Level	Center Frequency	Frequency Span/Division

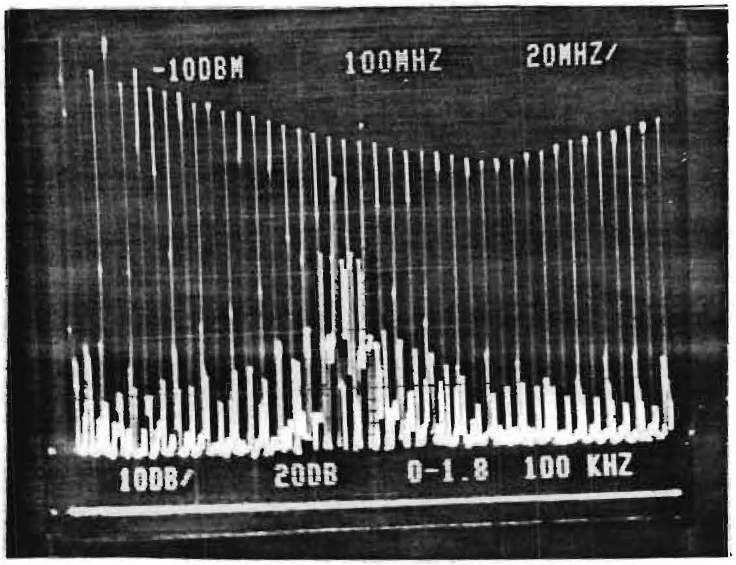


Vertical Display	RF Atten	Frequency Band	Resolution Bandwidth

(b) Frequency Range 0 - 1000 MHz

Figure 3. Output of the Signal Generator Circuitry Terminated with the 50 ohm Input Impedance of a Tektronics 492P Spectrum Analyzer.

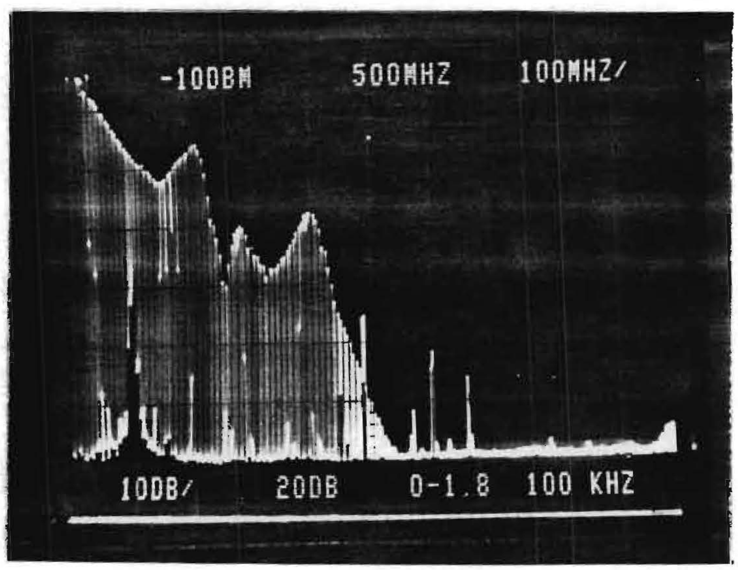
Reference Level | Center Frequency | Frequency Span/Division



Vertical Display | RF Atten | Frequency Band | Resolution Bandwidth

(a) Frequency Range 0 - 200 MHz

Reference Level | Center Frequency | Frequency Span/Division

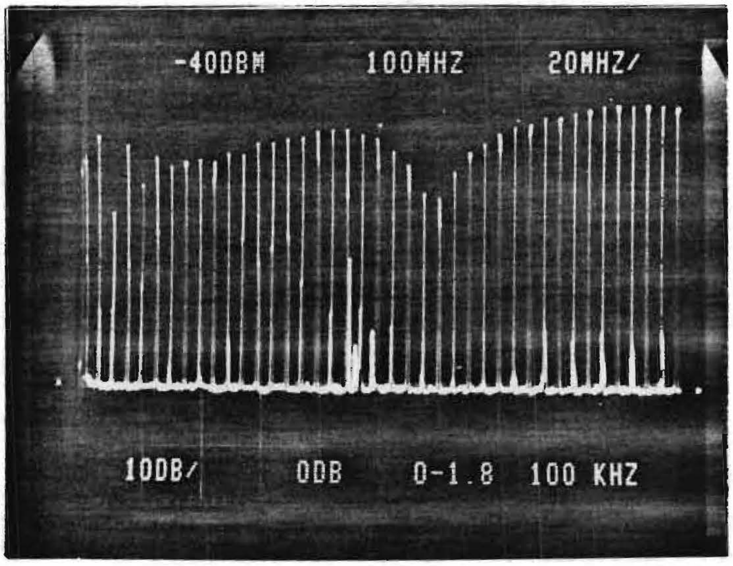


Vertical Display | RF Atten | Frequency Band | Resolution Bandwidth

(b) Frequency Range 0 - 1000 MHz

Figure 4. Output of the Signal Generator Circuitry Terminated with the Spherical Dipole Antenna in Parallel with the 50 ohm Input Impedance of a Tektronics 492P Spectrum Analyzer.

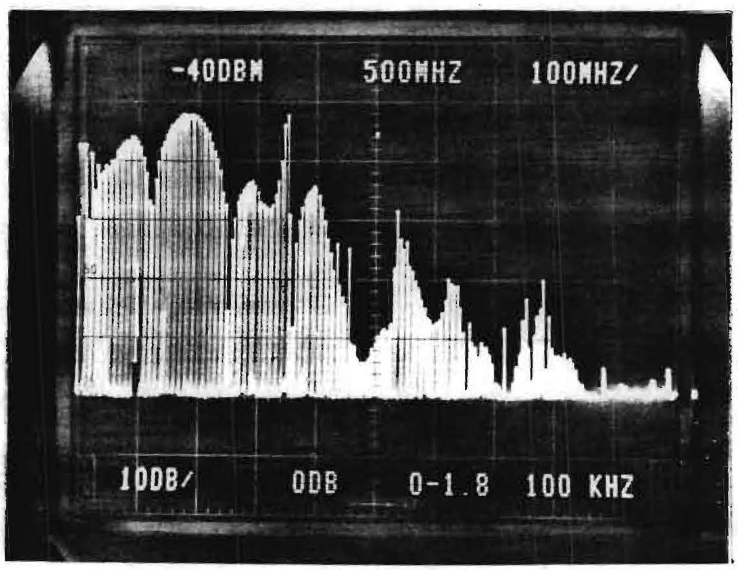
Reference Level | Center Frequency | Frequency Span/Division



Vertical Display | RF Atten | Frequency Band | Resolution Bandwidth

(a) Frequency Range 0 - 200 MHz

Reference Level | Center Frequency | Frequency Span/Division



Vertical Display | RF Atten | Frequency Band | Resolution Bandwidth

(b) Frequency Range 0 - 1000 MHz

Figure 5. Output of the Signal Generator Circuitry Terminated with the Spherical Dipole Antenna Radiating into a TEM Chamber.

and 5 show the results of these measurements, respectively. Each of these figures consist of two photographs of the spectrum analyzer display, one showing the frequency range of interest (0 to 200 MHz) and one showing the frequency range between 0 and 1000 MHz. Figure 3 shows that the conducted output levels between 30 MHz and 200 MHz vary approximately 18 dB and that output signals are present above the spectrum analyzer noise floor as far out as 900 MHz. Note, from Figure 4 that the impedance of the spherical dipole tends to attenuate the output levels of the higher harmonics while the output levels in the required frequency range are generally unaffected. Figure 5 shows the relative radiated field levels of the spherical dipole source operating in a TEM cell. Note, that resonance of the spherical dipole input impedance at approximately 120 MHz introduces a 12 to 14 dB null in the field level at this frequency. Also, note that the radiated field levels generally increase with increasing frequency over the 30 to 200 MHz frequency range, whereas the conducted levels shown in Figures 3 and 4 decreased with increasing frequency. This phenomena can be explained by the fact that the radiation efficiency of the spherical dipole tends to increase with incresing frequency since the aperture is a larger fraction of a wavelength.

One spot measurement of the field density in an anechoic chamber was made at 200 MHz for a 3 meter separation distance between the spherical dipole source and the receiving antenna. A tuned dipole was used for the receiving antenna and the field density was calculated from the received power level to be -60 dBm/m^2 (56 dBμV/m) which is 26 dB above the minimum required level. Thus, if it is assumed that the relative radiated field levels on the outdoor field site will be equivalent to those measured in the TEM cell, then the field intensities of all the signals in the 30 to 200 MHz frequency range should be above the minimum specified field level. In particular, note from Figure 5 that the lowest field component is at 120 MHz and it is approximately 14 dB below the level of the 200 MHz field component. Since the power received can be calculated from the equation

$$P_r = \frac{P_D G_R}{4 \pi \lambda^2} ,$$

the power density at 120 MHz can be approximated to be -70 dBm/m^2 (46 dBμV/m) which is still 16 dB above the minimum required level.

Efforts this month were also placed on the construction of an outdoor open area test site. A 9 meter by 6 meter ground plane was constructed out of a one-inch wire grid. All of the joints were tied together with 22 AWG solid tinned copper wire. Using a torch, these joints were then continuously soldered together. An antenna mount for the spherical dipole was constructed out of 2.5 inch OD plexiglass tubing. The mount was constructed so that it could either sit on a flat surface or be attached to a tripod utilizing a 1/4-20 screw-on. A polarization alignment jig was also fabricated so that the spherical dipole antenna could be easily aligned in both vertical and horizontal polarization. Initial spot measurements of the site attenuation factor indicate that the reflectivity of the area does meet the requirements set forth in the ANSI document C63.2.

During the next reporting period, it is anticipated that the absolute field level measurements will be performed on the open area test site and that the horizontal and vertical polarization azimuth radiation pattern measurements will be performed. In addition a second spherical dipole will be constructed identical to the first under P. O. No. 562,084. A shipment and storage container will also be constructed for both antennas and will accommodate both the spherical dipole antenna, the antenna mount, and the polarization alignment jig.

Respectfully submitted,

J. C.Mantovani
Project Director, A-3310

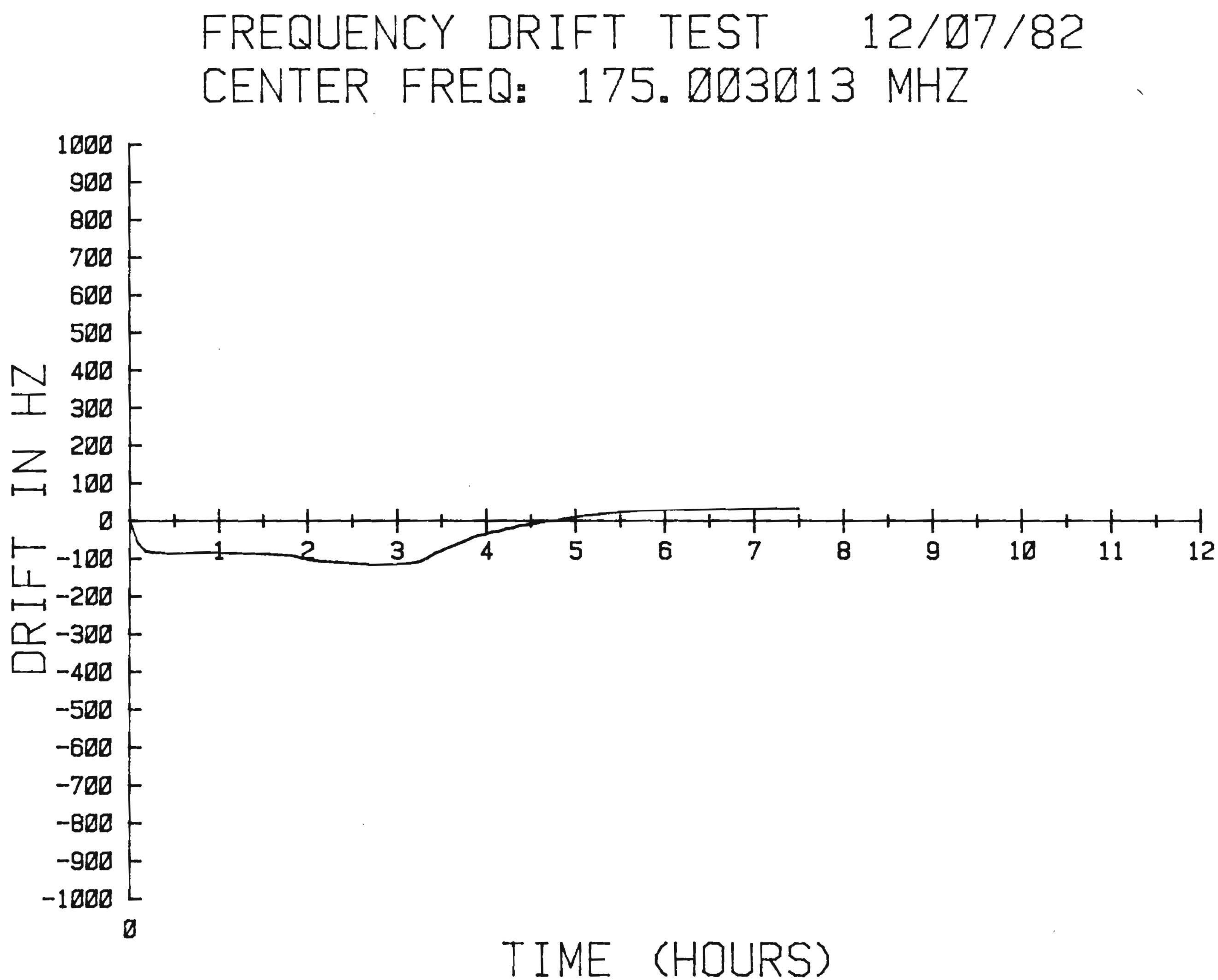
JCM:gh

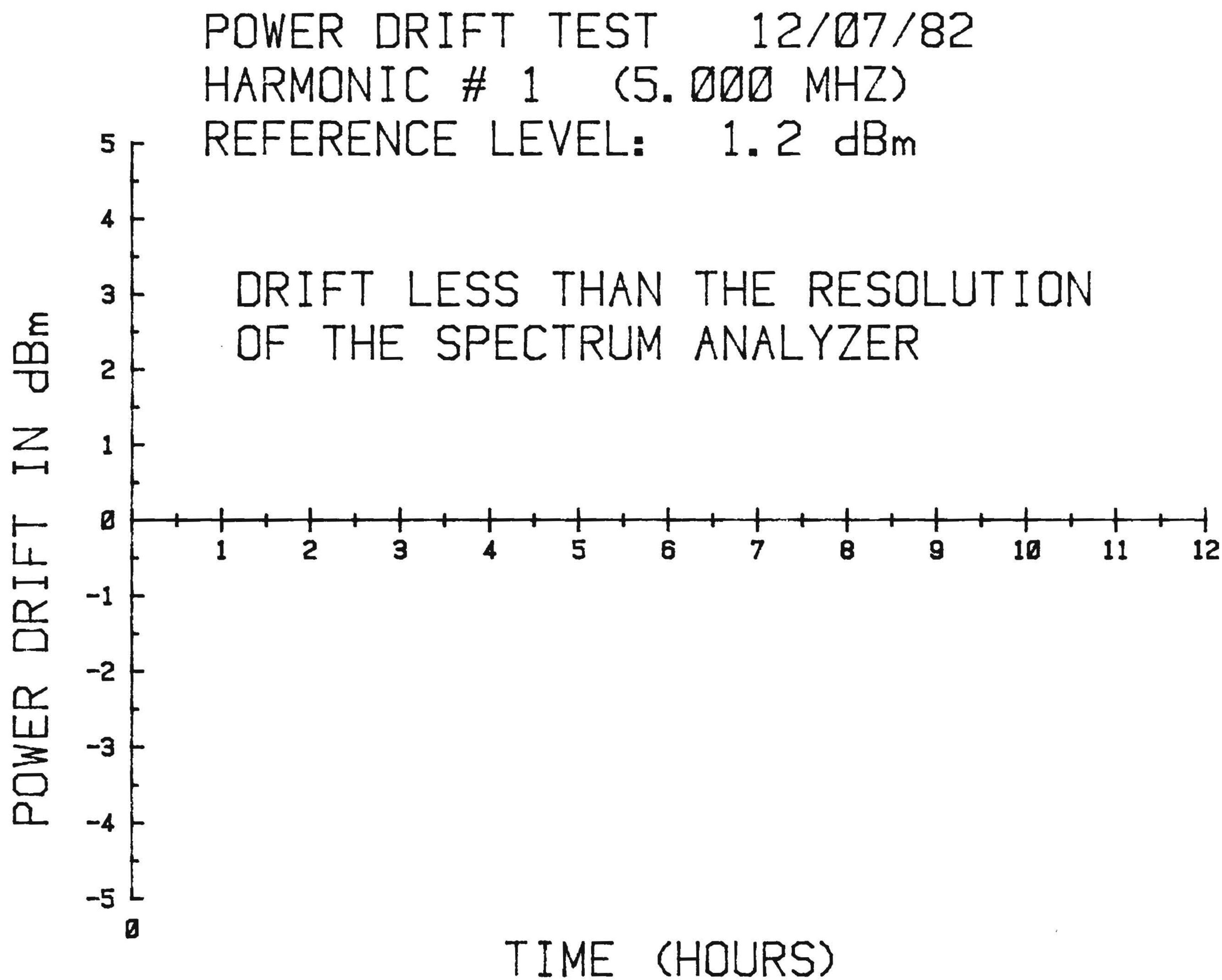
Approved:

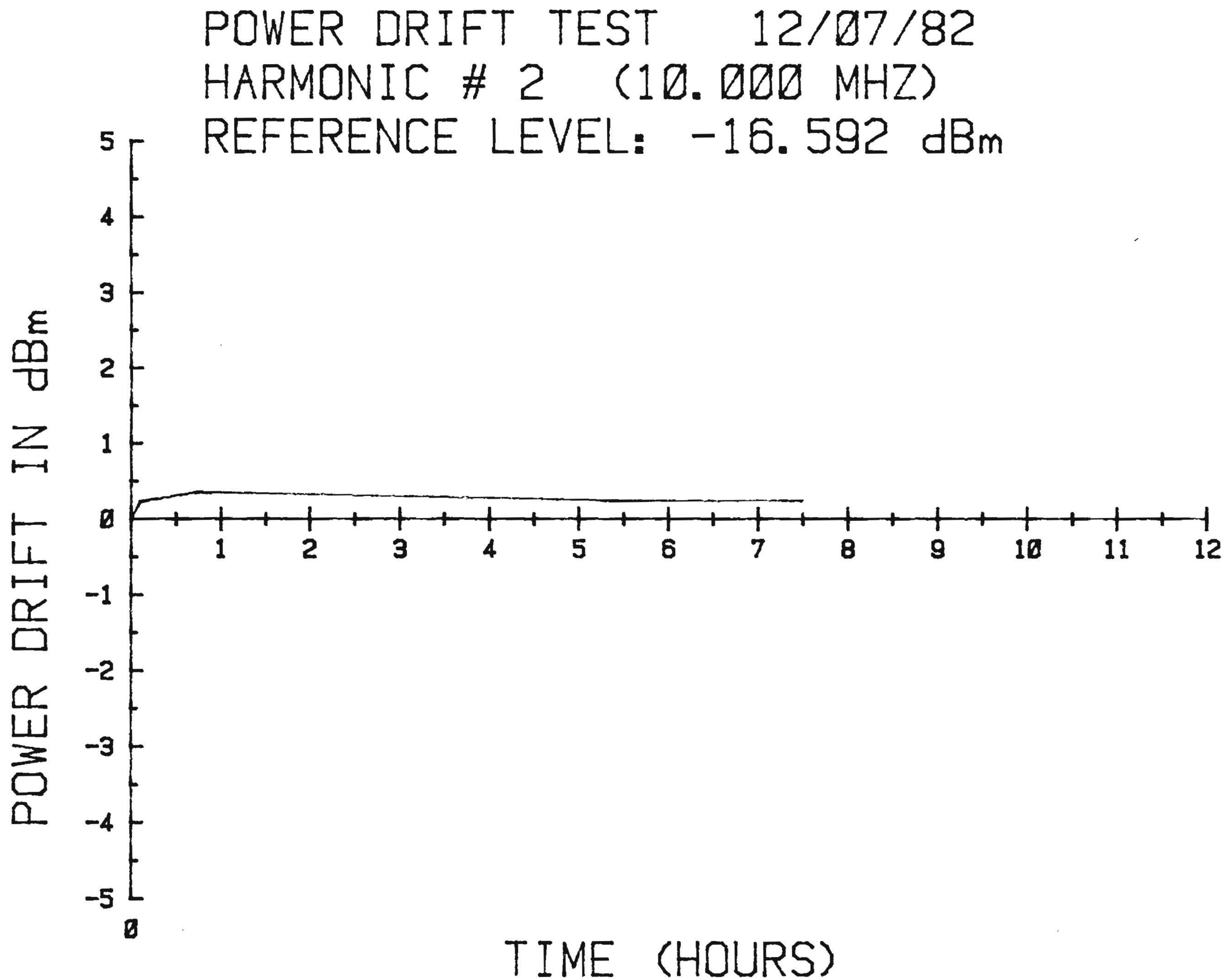
H. W. Denny, Chief
Electromagnetic Compatibility Division

ATTACHMENT I

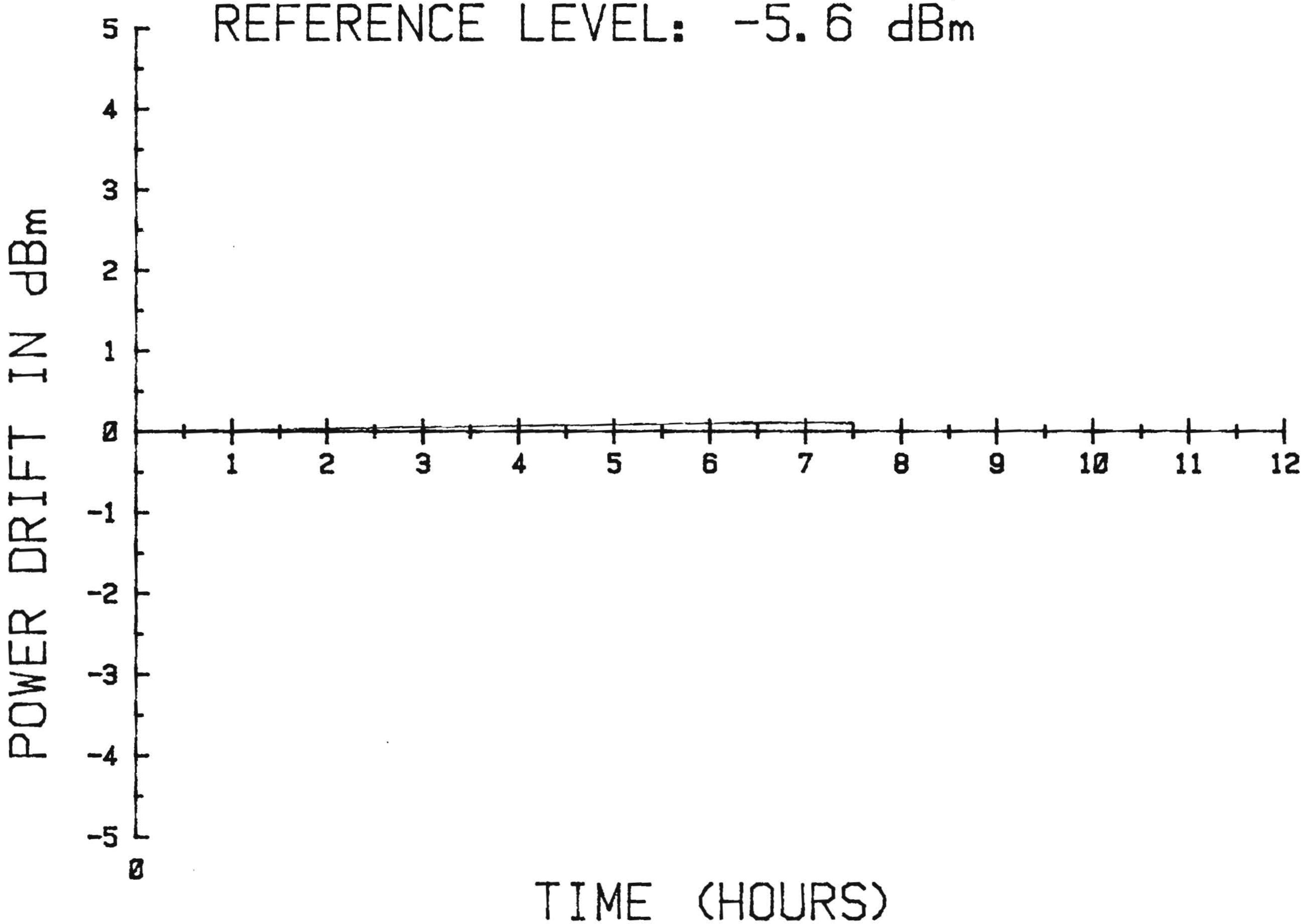
FREQUENCY AND AMPLITUDE DRIFT MEASUREMENT RESULTS

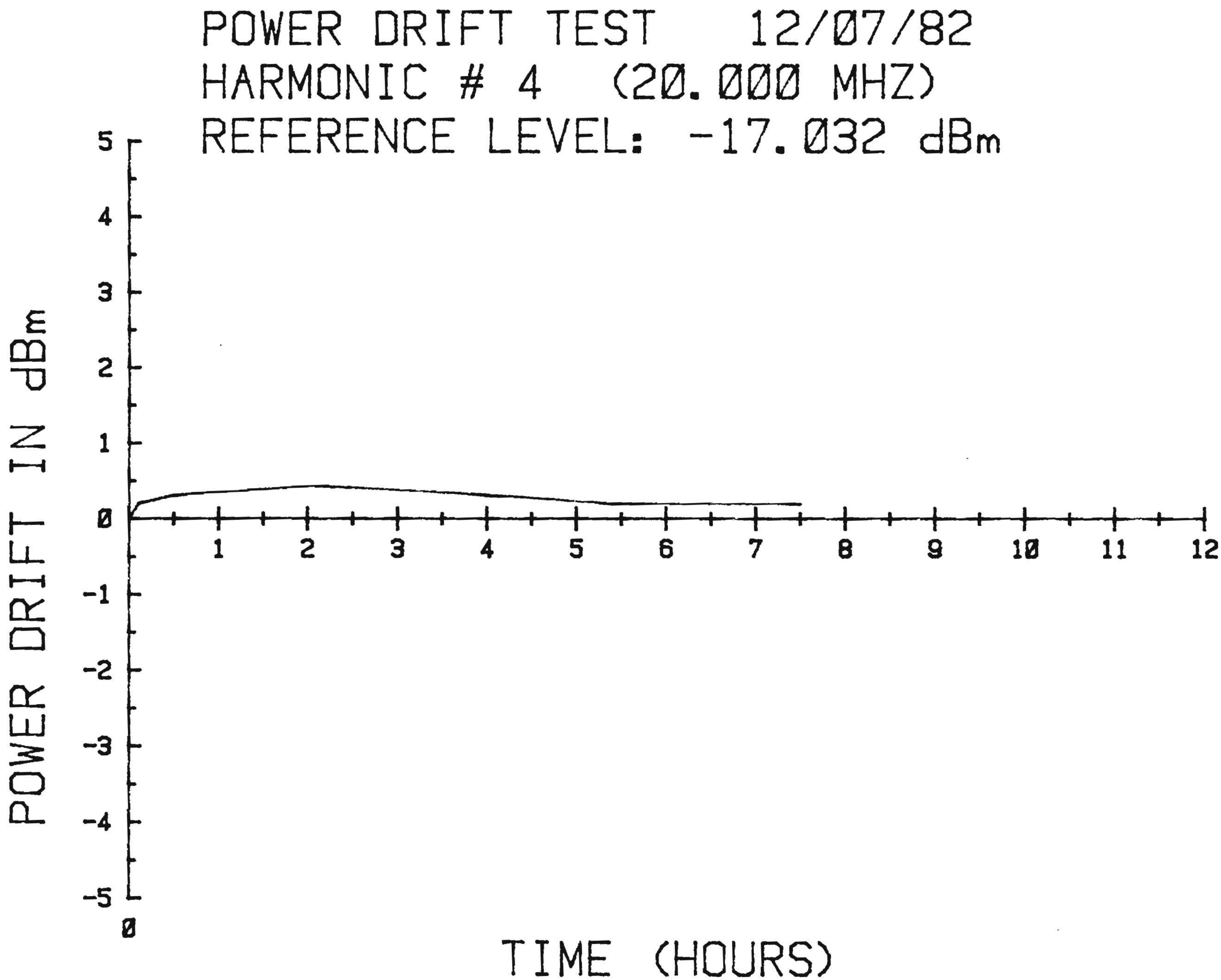

FREQUENCY DRIFT TEST 12/07/82
CENTER FREQ: 175.003013 MHZ
DRIFT IN HZ
1000
900
800
700
600
500
400
300
200
100
0
-100
-200
-300
-400
-500
-600
-700
-800
-900
-1000
0
1
2
3
4
5
6
7
8
9
10
11
12
TIME (HOURS)

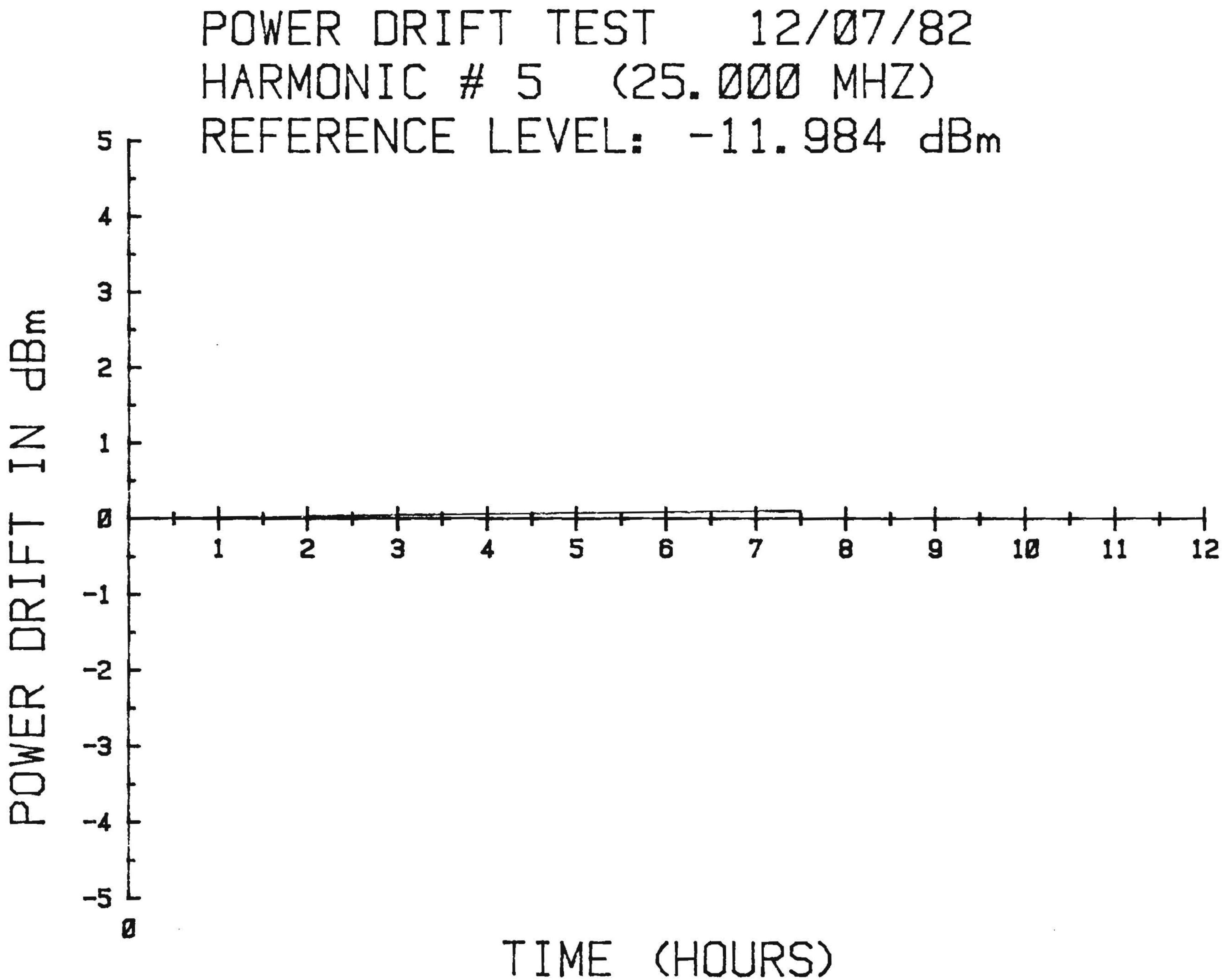

POWER DRIFT TEST 12/07/82
HARMONIC # 1 (5.000 MHZ)
REFERENCE LEVEL: 1.2 dBm
DRIFT LESS THAN THE RESOLUTION
OF THE SPECTRUM ANALYZER
POWER DRIFT IN dBm
5
4
3
2
1
0
-1
-2
-3
-4
-5
0
1
2
3
4
5
6
7
8
9
10
11
12
TIME (HOURS)

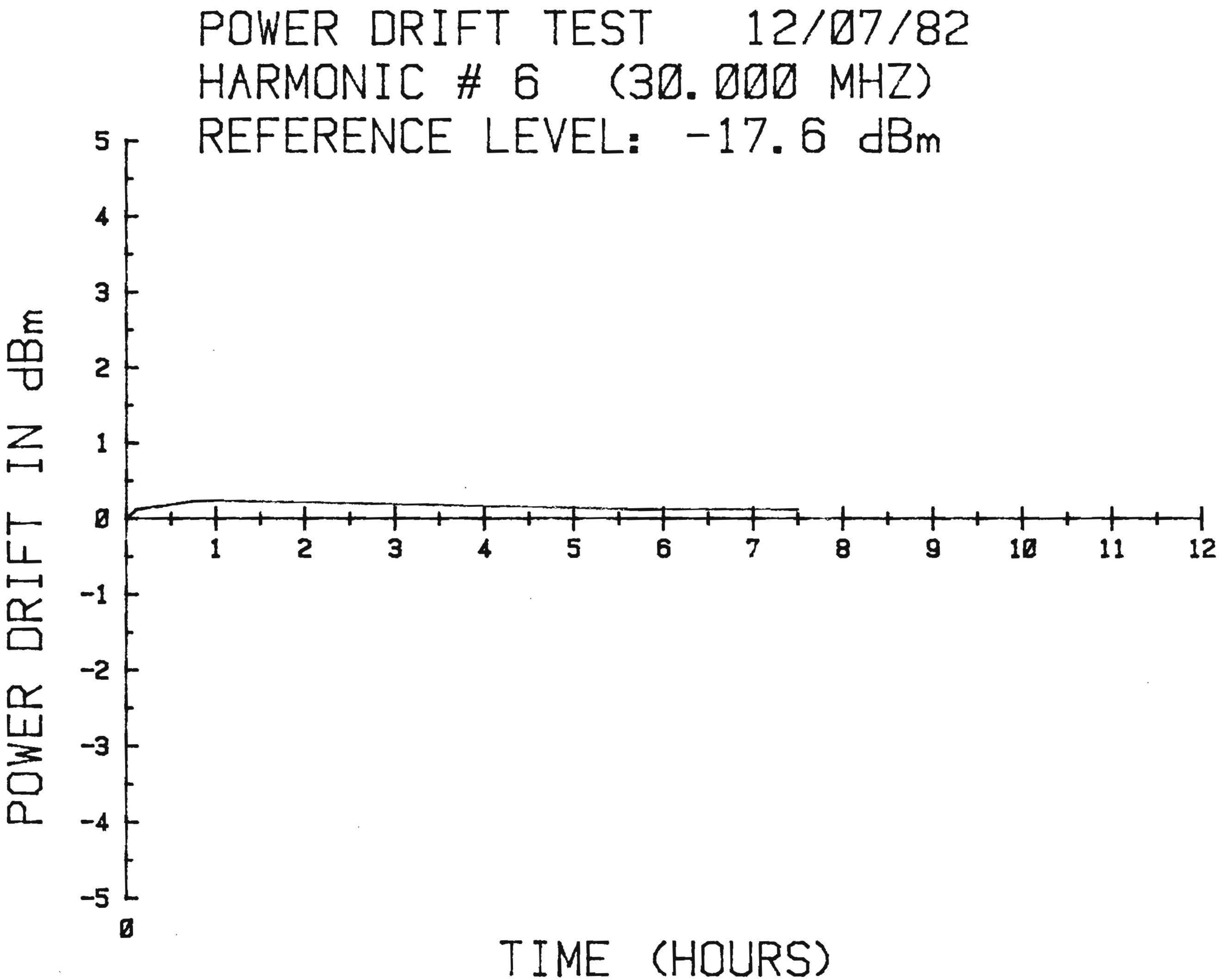

POWER DRIFT TEST 12/07/82
HARMONIC # 2 (10.000 MHZ)
REFERENCE LEVEL: -16.592 dBm
POWER DRIFT IN dBm
5
4
3
2
1
0
-1
-2
-3
-4
-5
0
1
2
3
4
5
6
7
8
9
10
11
12
TIME (HOURS)

POWER DRIFT TEST 12/07/82
HARMONIC # 3 (15.000 MHZ)
REFERENCE LEVEL: -5.6 dBm

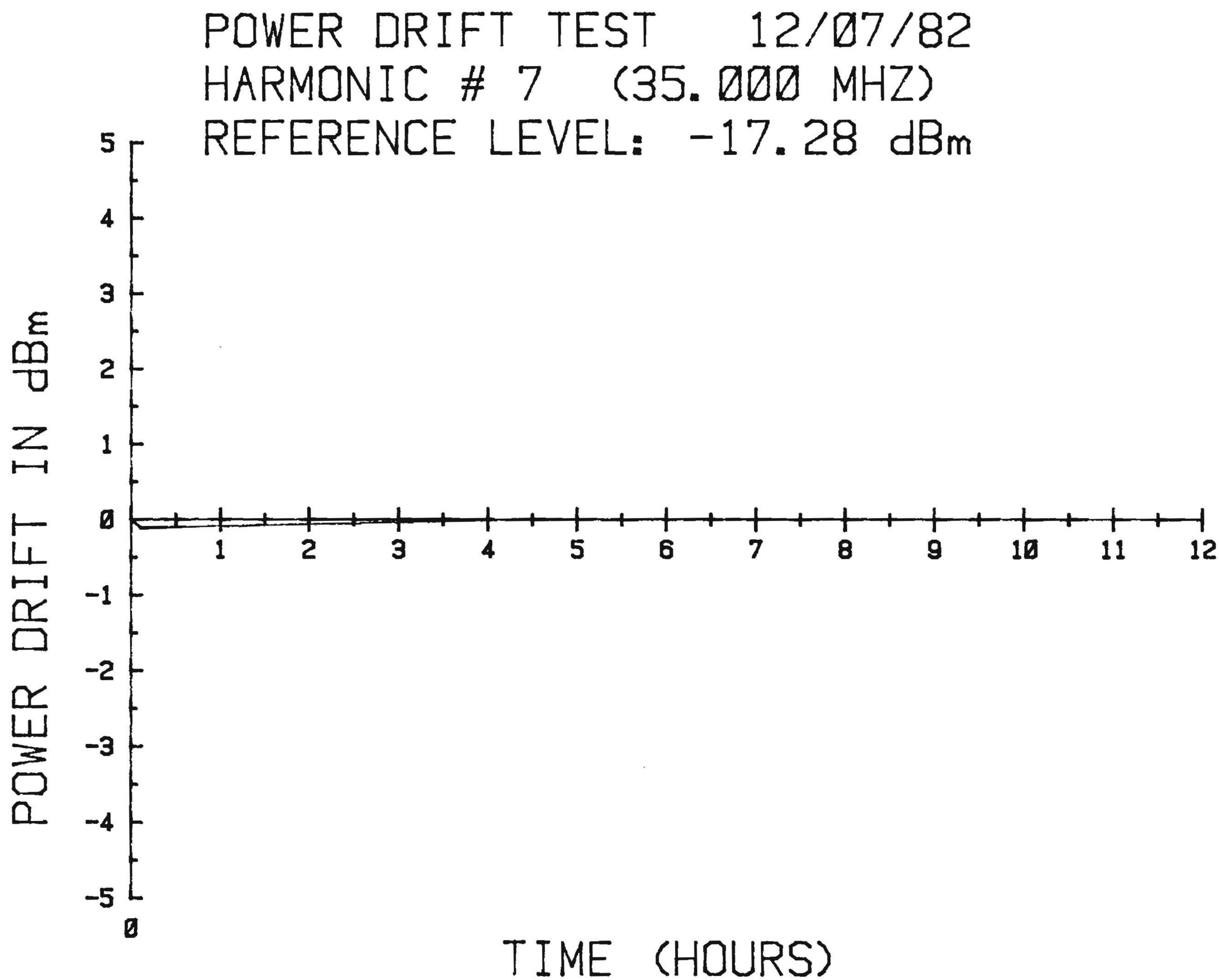


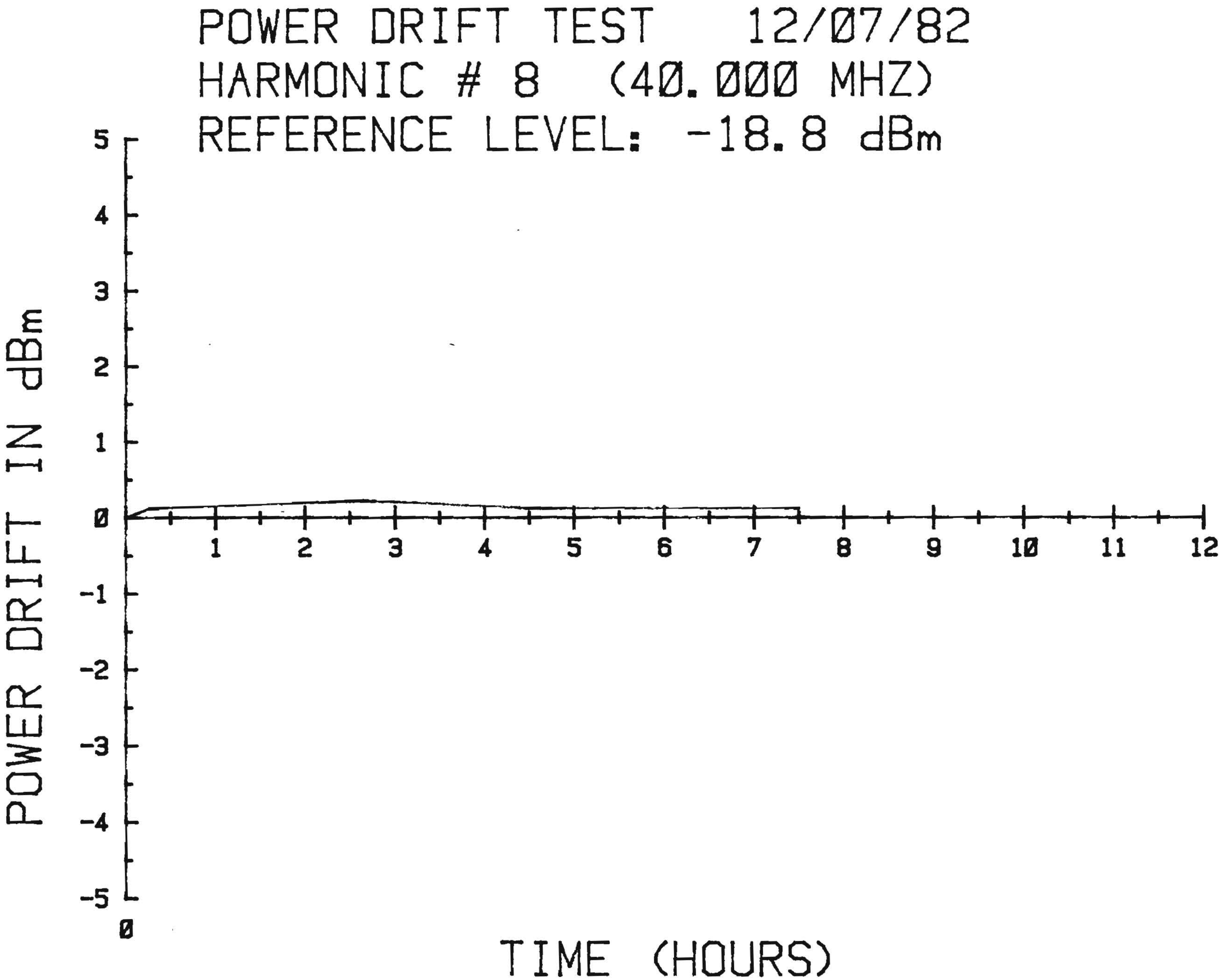

POWER DRIFT TEST 12/07/82
HARMONIC # 4 (20.000 MHZ)
REFERENCE LEVEL: -17.032 dBm
5
4
3
2
1
0
-1
-2
-3
-4
-5
0
1
2
3
4
5
6
7
8
9
10
11
12
POWER DRIFT IN dBm
TIME (HOURS)


POWER DRIFT TEST 12/07/82
HARMONIC # 5 (25.000 MHZ)
REFERENCE LEVEL: -11.984 dBm
POWER DRIFT IN dBm
5
4
3
2
1
0
-1
-2
-3
-4
-5
0
1 2 3 4 5 6 7 8 9 10 11 12
TIME (HOURS)

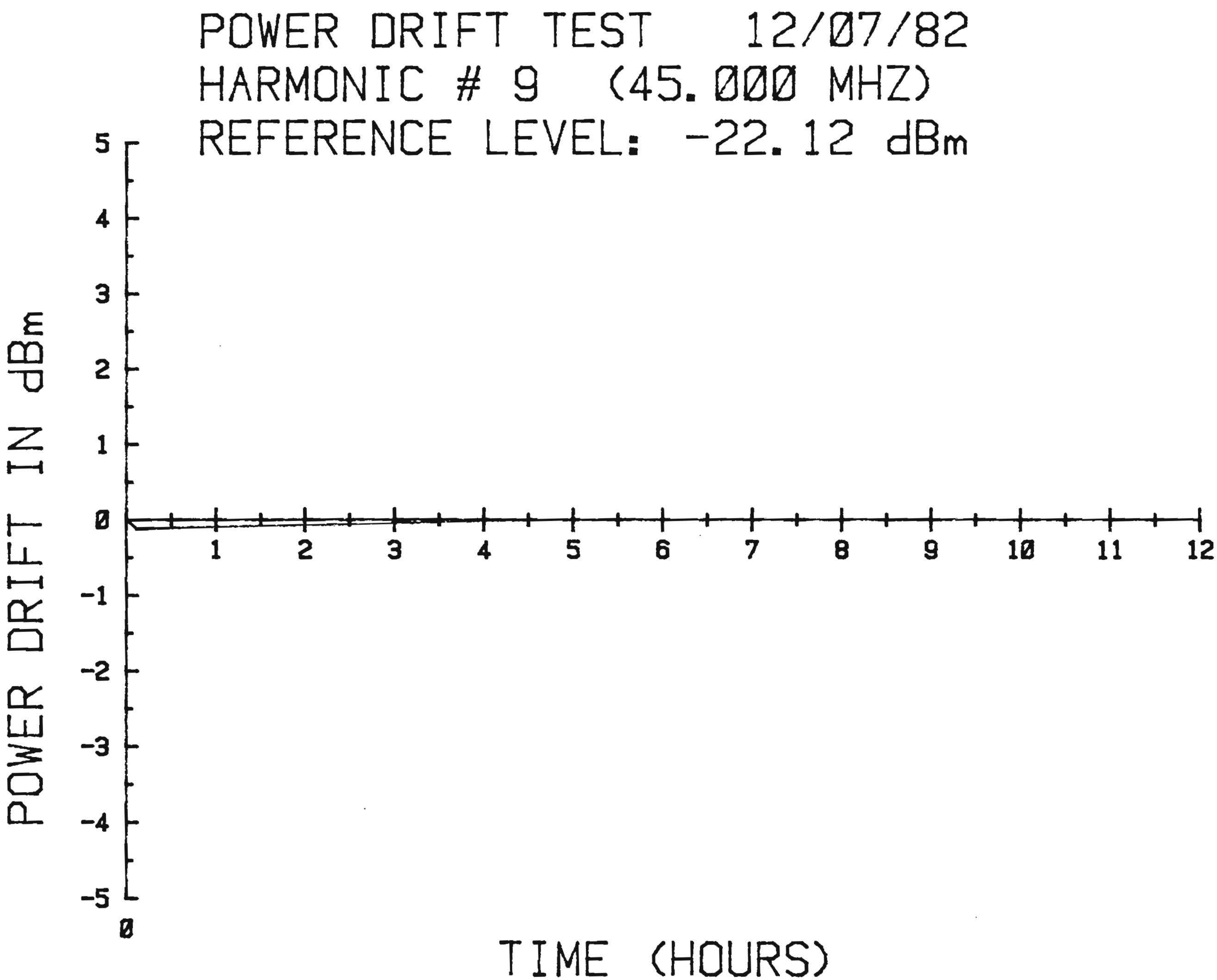


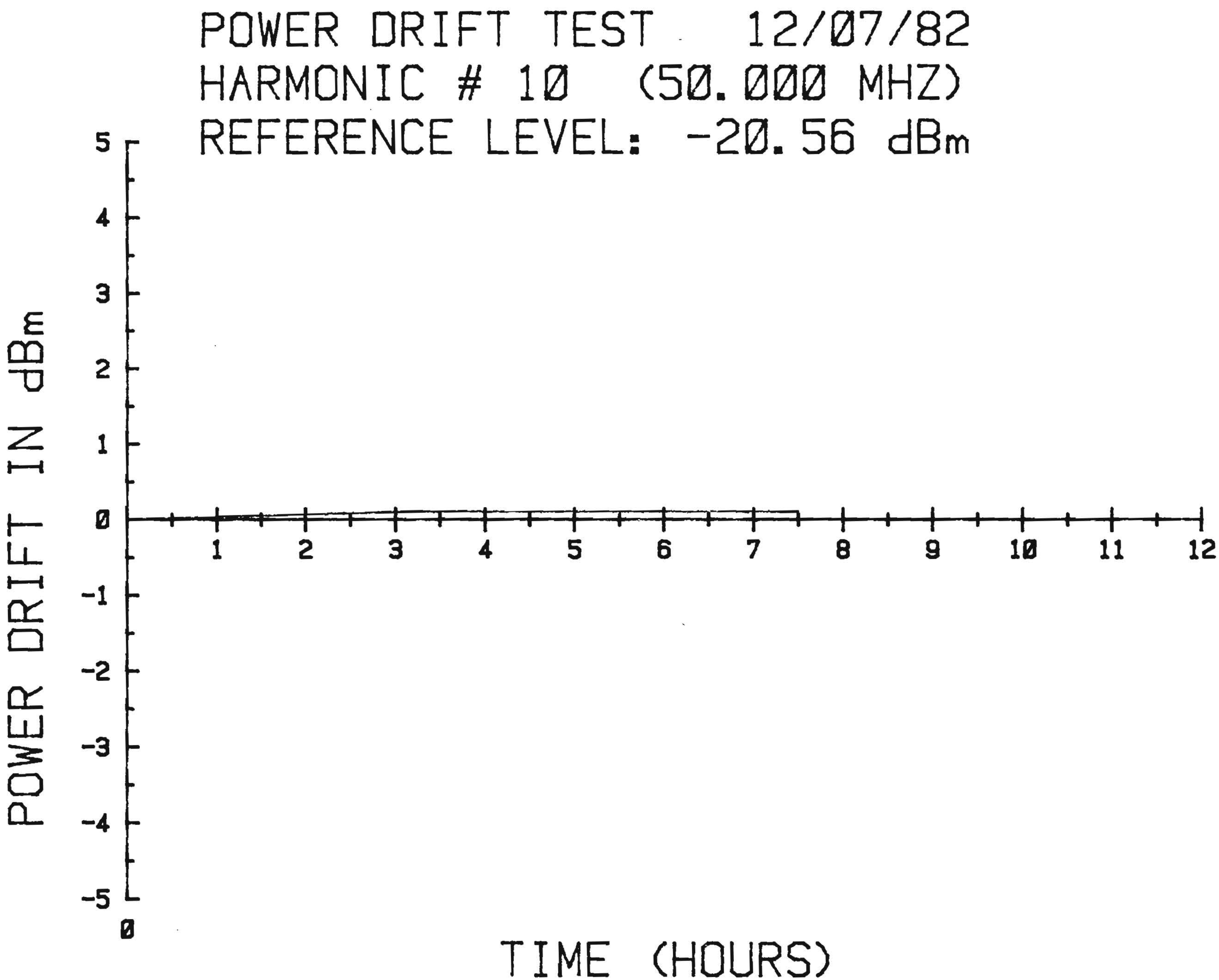
POWER DRIFT TEST 12/07/82
HARMONIC # 6 (30.000 MHZ)
REFERENCE LEVEL: -17.6 dBm
POWER DRIFT IN dBm
5
4
3
2
1
0
-1
-2
-3
-4
-5
0
1
2
3
4
5
6
7
8
9
10
11
12
TIME (HOURS)

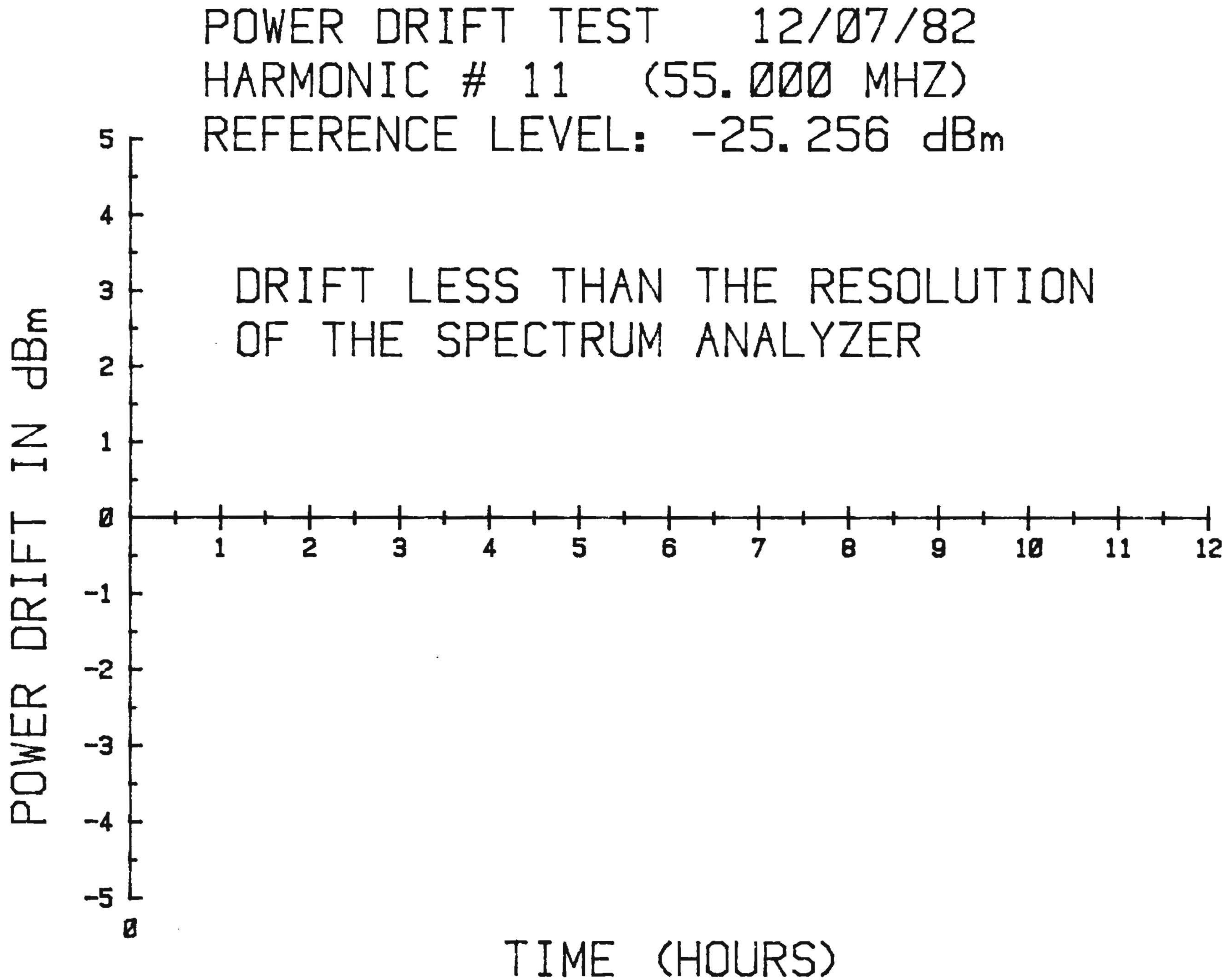

POWER DRIFT TEST 12/07/82
HARMONIC # 7 (35.000 MHZ)
REFERENCE LEVEL: -17.28 dBm
POWER DRIFT IN dBm
5
4
3
2
1
0
-1
-2
-3
-4
-5
0
1
2
3
4
5
6
7
8
9
10
11
12
TIME (HOURS)

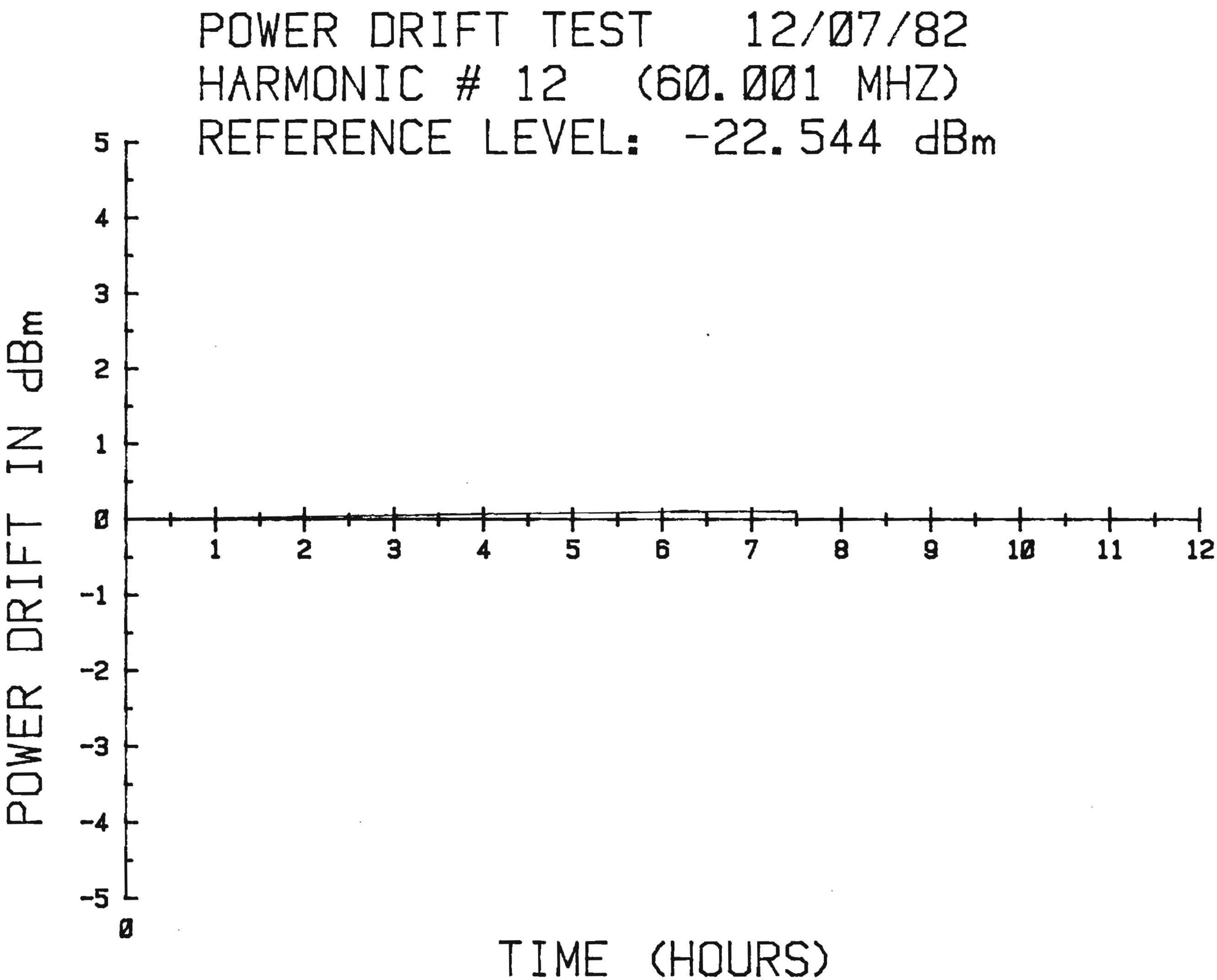


POWER DRIFT TEST 12/07/82
HARMONIC # 8 (40.000 MHZ)
REFERENCE LEVEL: -18.8 dBm
POWER DRIFT IN dBm
5
4
3
2
1
0
-1
-2
-3
-4
-5
0
1
2
3
4
5
6
7
8
9
10
11
12
TIME (HOURS)

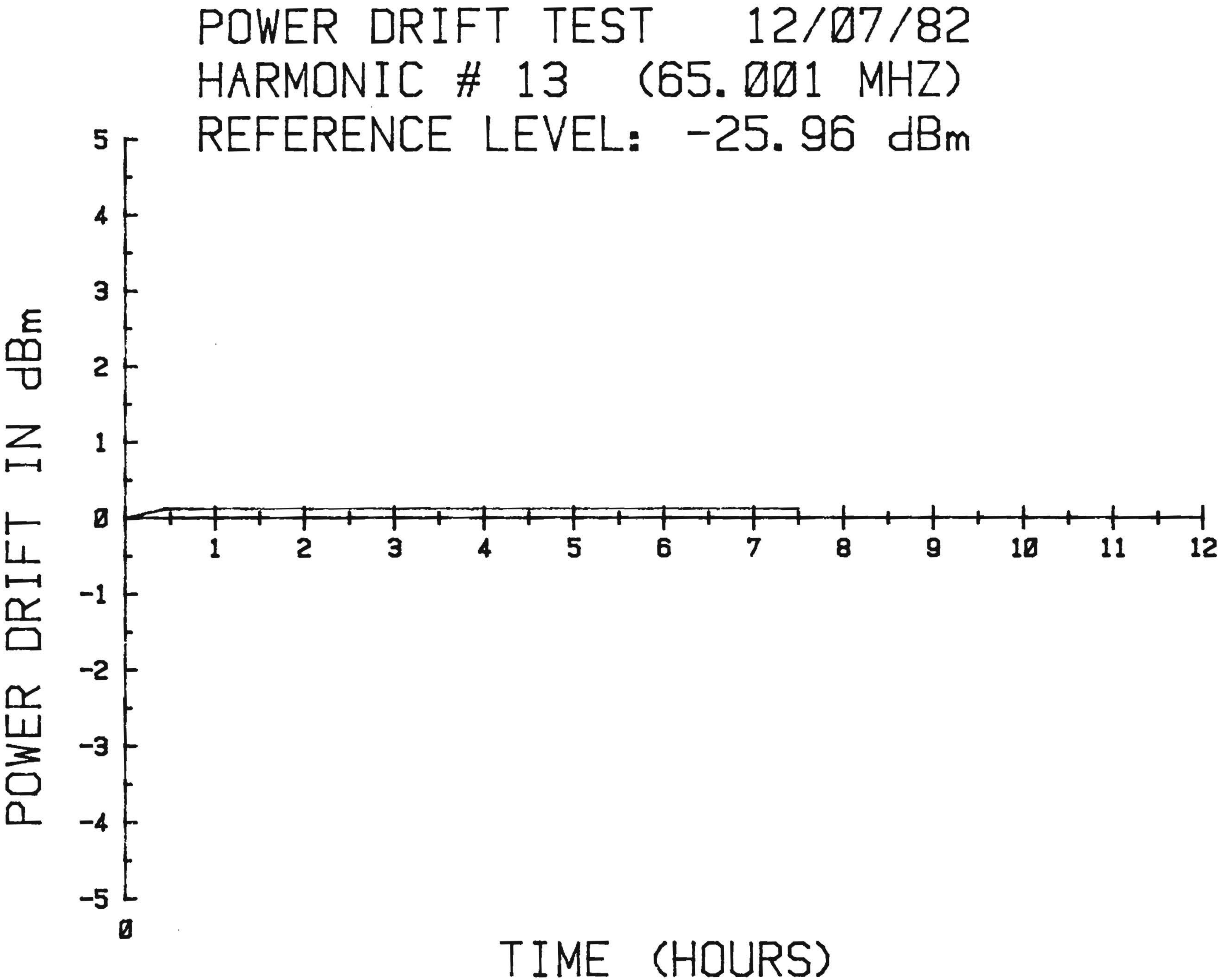

POWER DRIFT TEST 12/07/82
HARMONIC # 9 (45.000 MHZ)
REFERENCE LEVEL: -22.12 dBm
POWER DRIFT IN dBm
5
4
3
2
1
0
-1
-2
-3
-4
-5
0
1
2
3
4
5
6
7
8
9
10
11
12
TIME (HOURS)

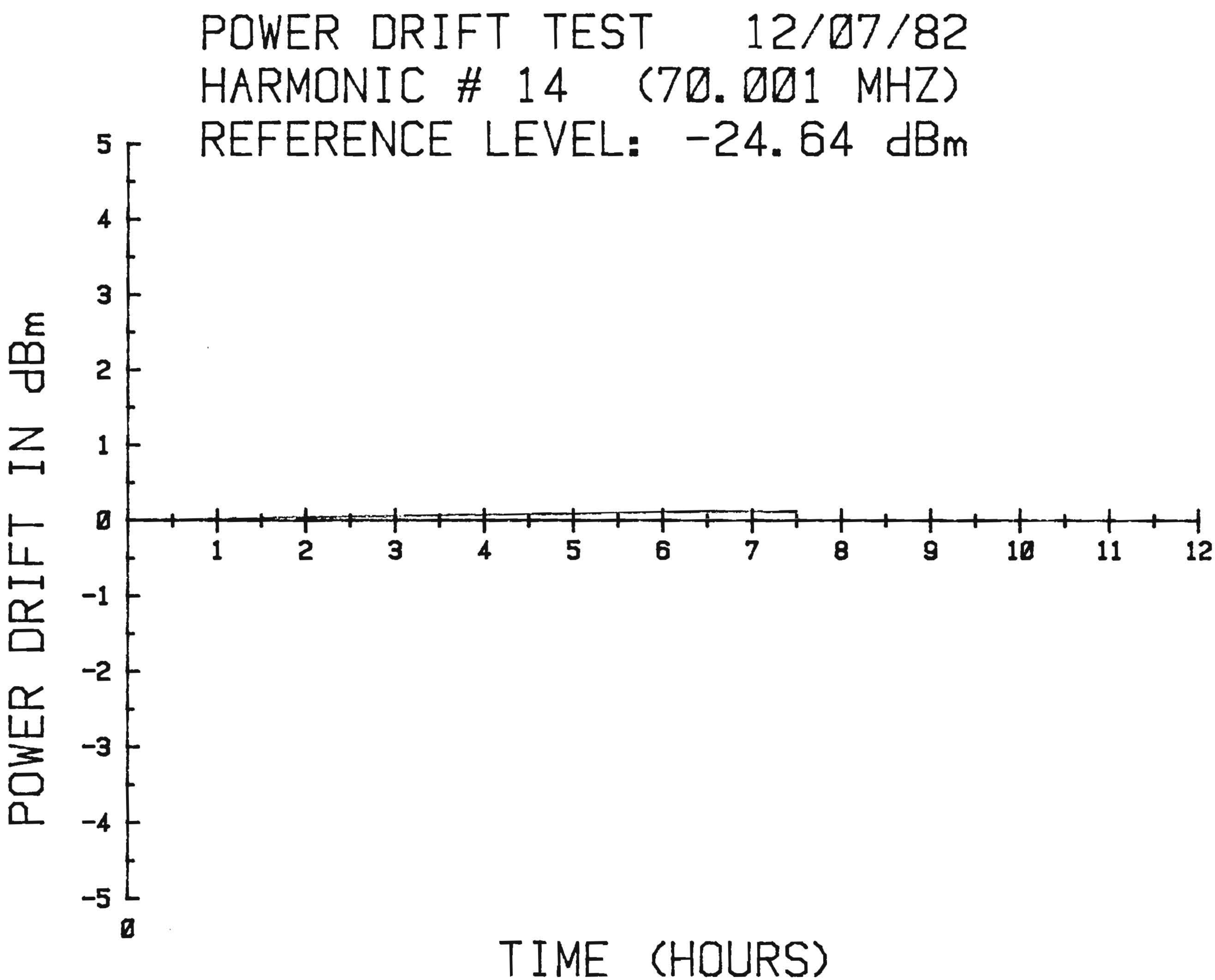

POWER DRIFT TEST 12/07/82
HARMONIC # 10 (50.000 MHZ)
REFERENCE LEVEL: -20.56 dBm
POWER DRIFT IN dBm
5
4
3
2
1
0
-1
-2
-3
-4
-5
0
1
2
3
4
5
6
7
8
9
10
11
12
TIME (HOURS)

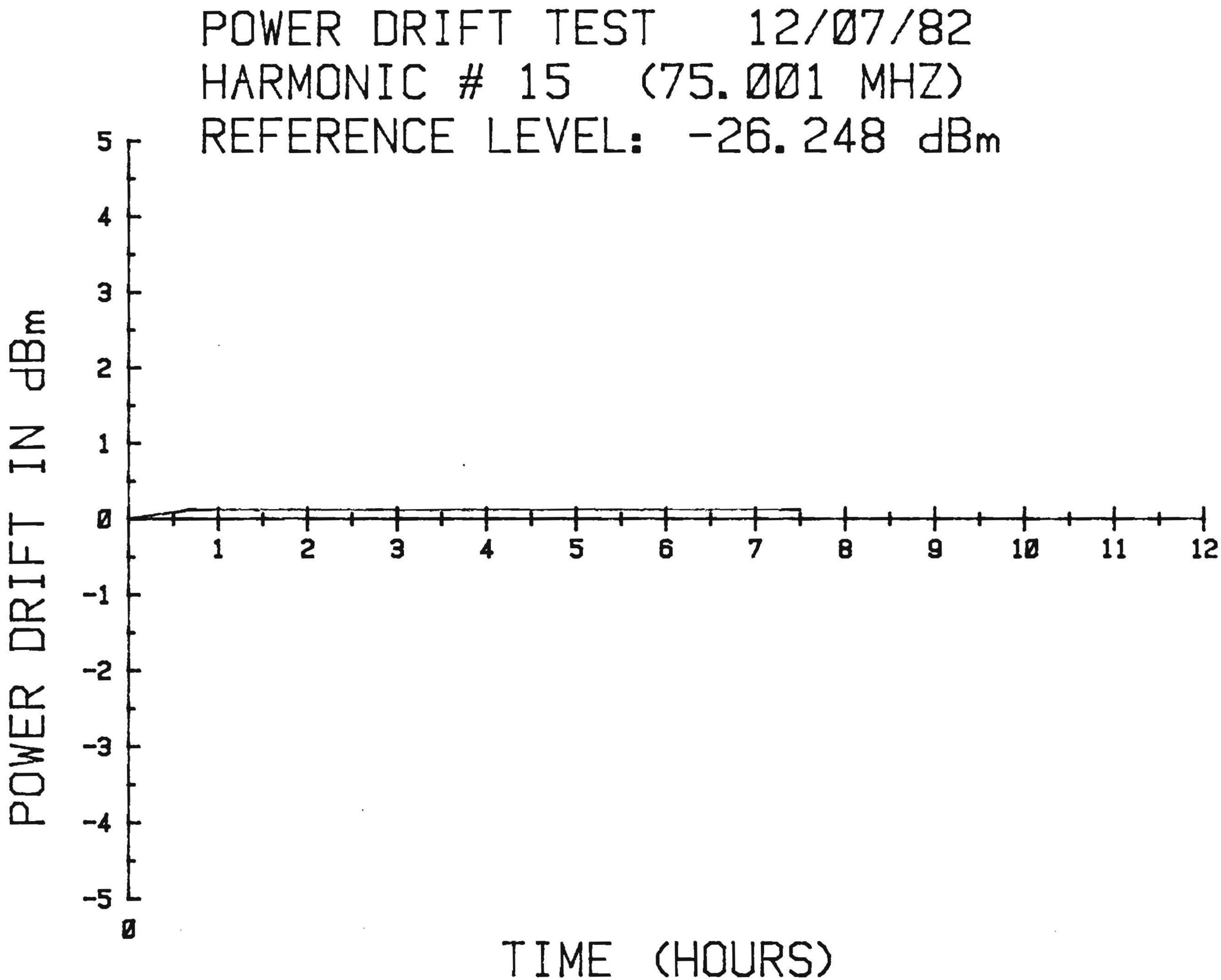

POWER DRIFT TEST 12/07/82
HARMONIC # 11 (55.000 MHZ)
REFERENCE LEVEL: -25.256 dBm
DRIFT LESS THAN THE RESOLUTION
OF THE SPECTRUM ANALYZER
POWER DRIFT IN dBm
5
4
3
2
1
0
-1
-2
-3
-4
-5
0
1
2
3
4
5
6
7
8
9
10
11
12
TIME (HOURS)



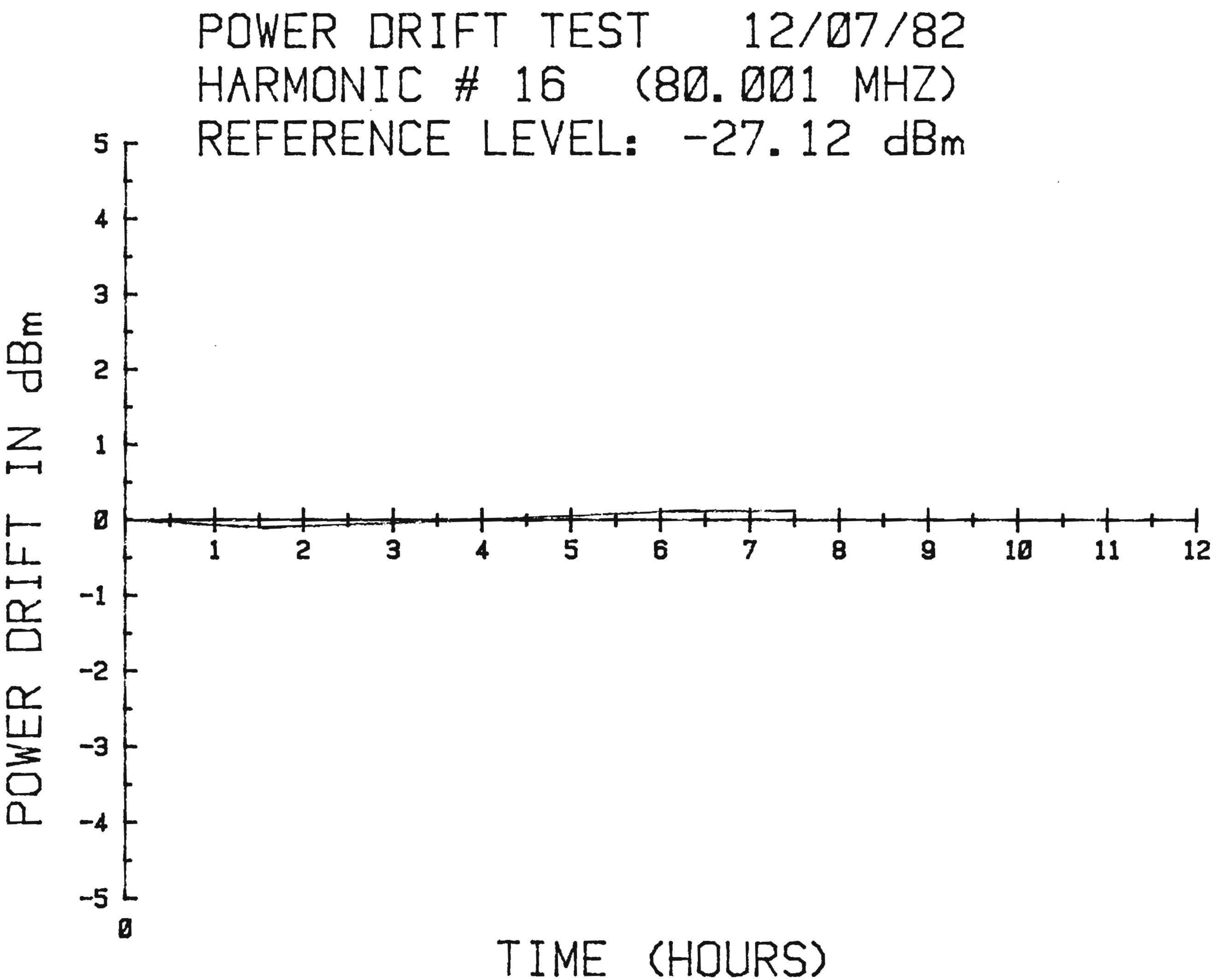
POWER DRIFT TEST 12/07/82
HARMONIC # 12 (60.001 MHZ)
REFERENCE LEVEL: -22.544 dBm
POWER DRIFT IN dBm
5
4
3
2
1
0
-1
-2
-3
-4
-5
0
1
2
3
4
5
6
7
8
9
10
11
12
TIME (HOURS)

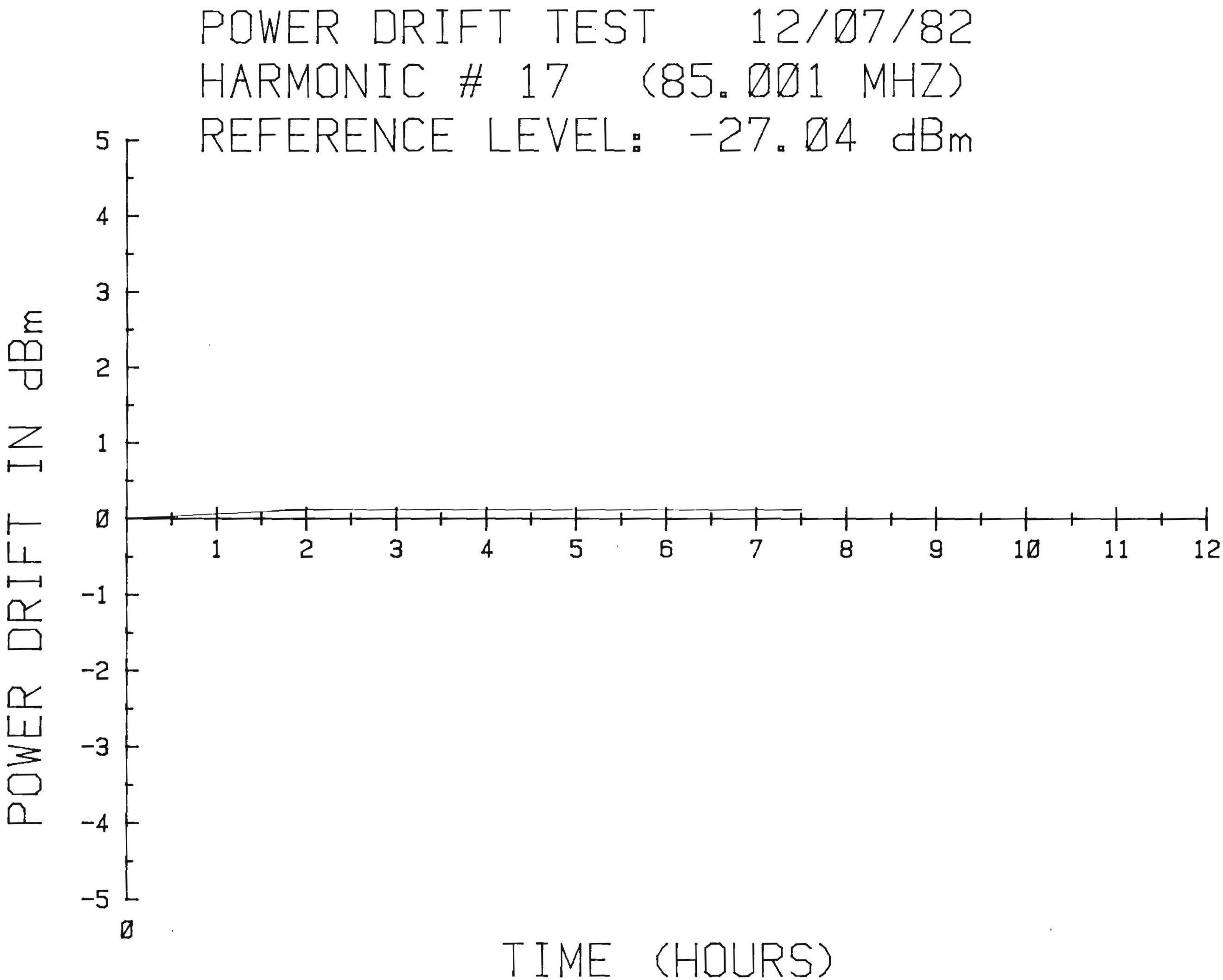

POWER DRIFT TEST 12/07/82
HARMONIC # 13 (65.001 MHZ)
REFERENCE LEVEL: -25.96 dBm
POWER DRIFT IN dBm
5
4
3
2
1
0
-1
-2
-3
-4
-5
0
1
2
3
4
5
6
7
8
9
10
11
12
TIME (HOURS)

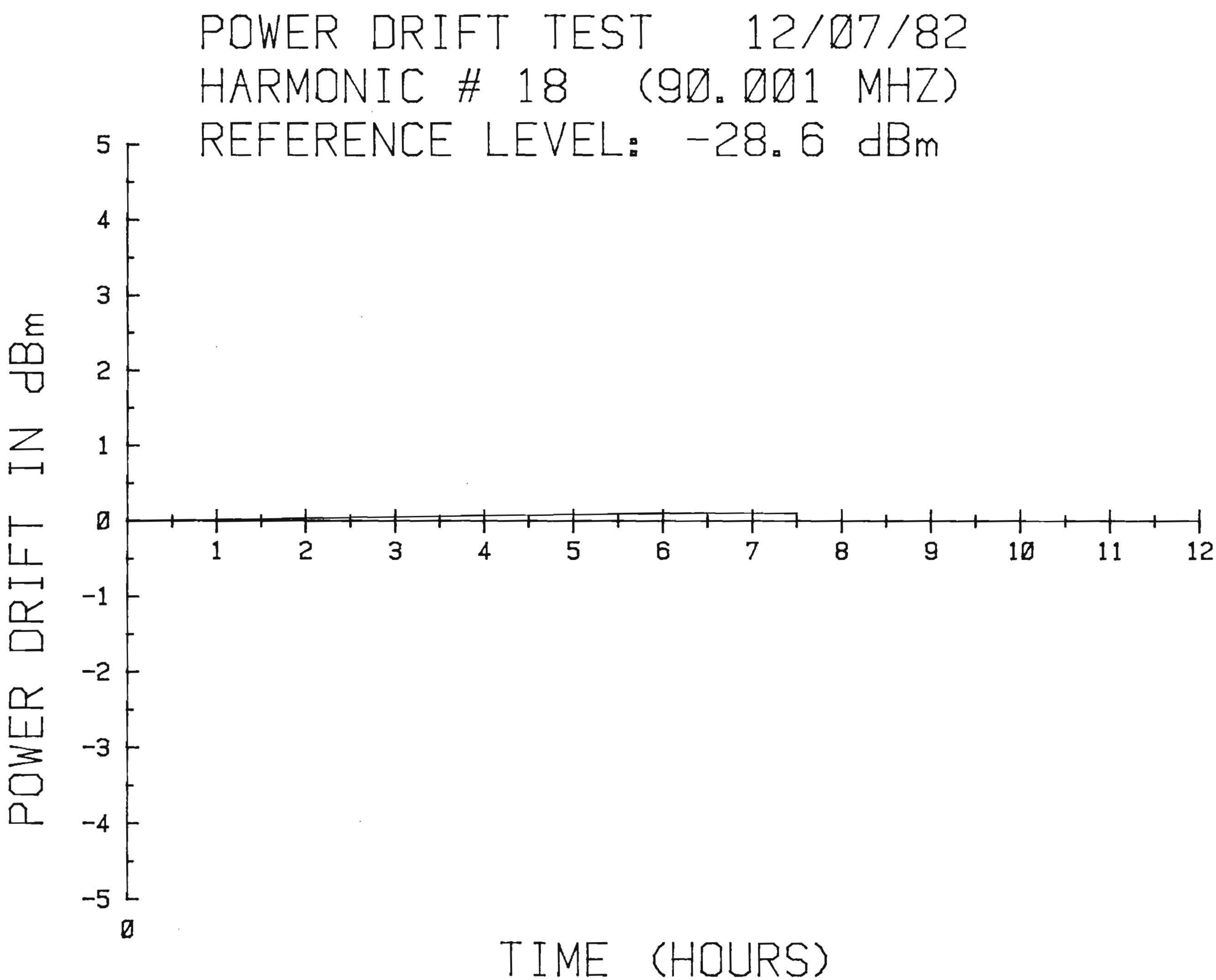

POWER DRIFT TEST 12/07/82
HARMONIC # 14 (70.001 MHZ)
REFERENCE LEVEL: -24.64 dBm
POWER DRIFT IN dBm
5
4
3
2
1
0
-1
-2
-3
-4
-5
0
1
2
3
4
5
6
7
8
9
10
11
12
TIME (HOURS)



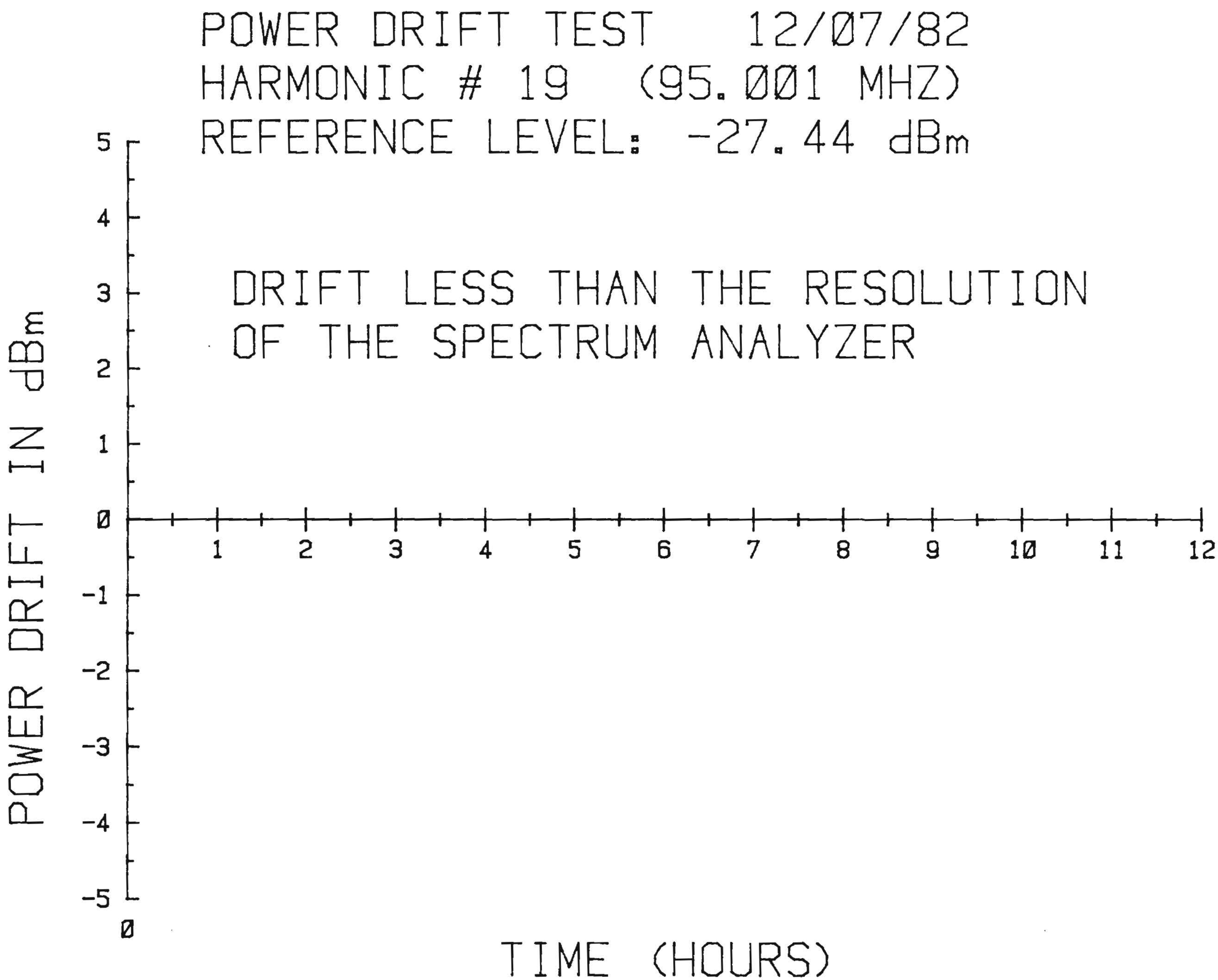
POWER DRIFT TEST 12/07/82
HARMONIC # 15 (75.001 MHZ)
REFERENCE LEVEL: -26.248 dBm
POWER DRIFT IN dBm
5
4
3
2
1
0
-1
-2
-3
-4
-5
0
1
2
3
4
5
6
7
8
9
10
11
12
TIME (HOURS)

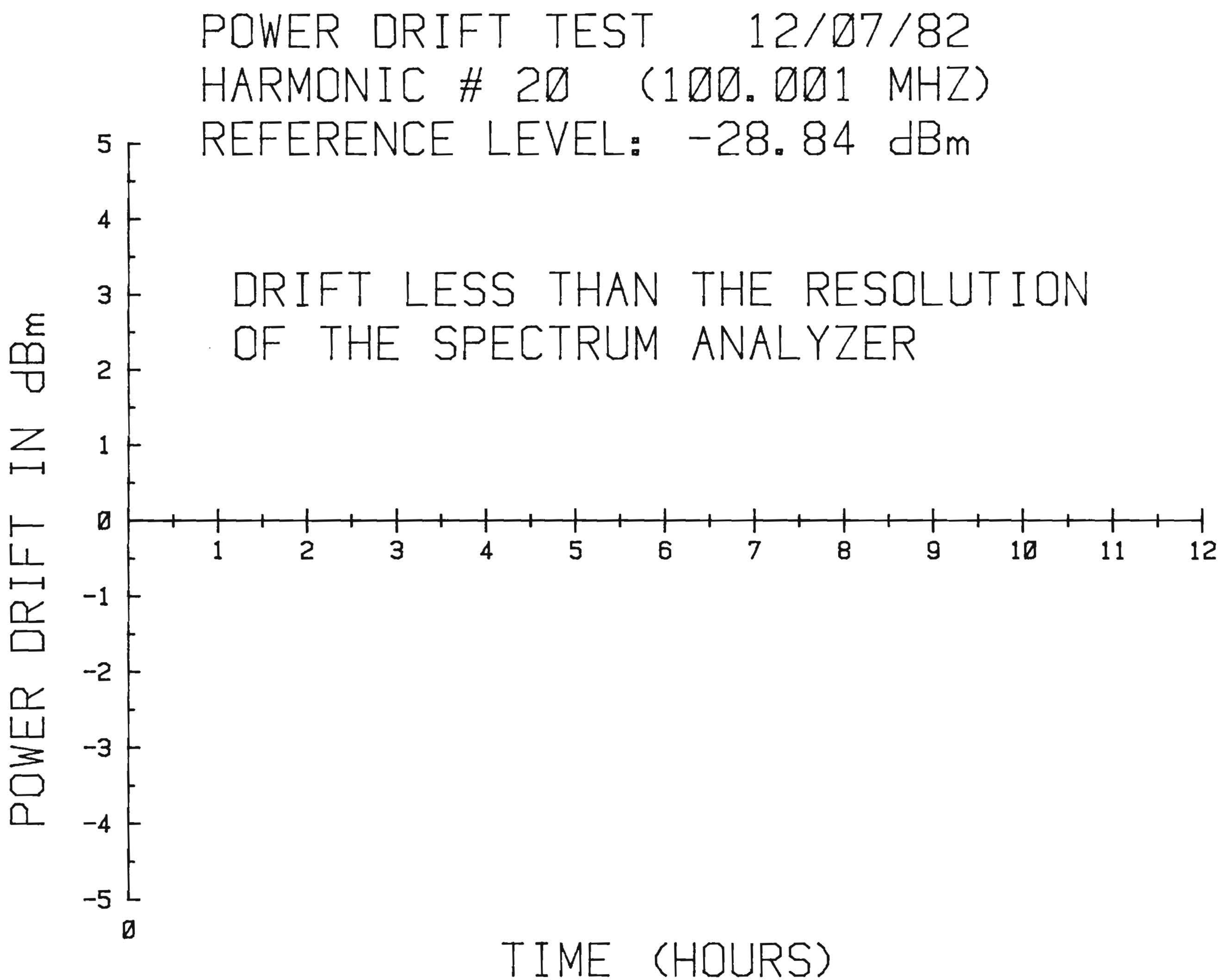

POWER DRIFT TEST 12/07/82
HARMONIC # 16 (80.001 MHZ)
REFERENCE LEVEL: -27.12 dBm
POWER DRIFT IN dBm
5
4
3
2
1
0
-1
-2
-3
-4
-5
0
1
2
3
4
5
6
7
8
9
10
11
12
TIME (HOURS)

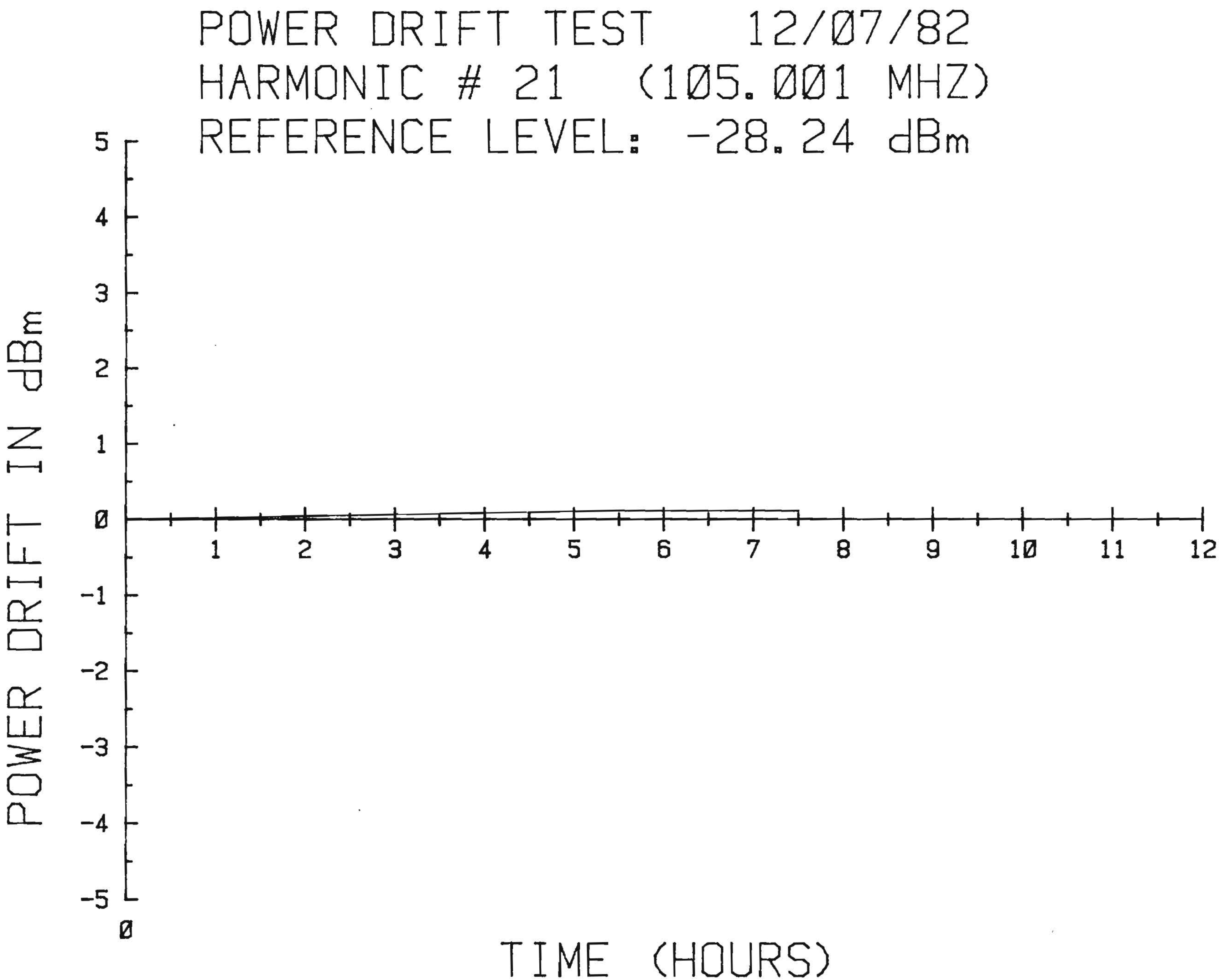

POWER DRIFT TEST 12/07/82
HARMONIC # 17 (85.001 MHZ)
REFERENCE LEVEL: -27.04 dBm
POWER DRIFT IN dBm
5
4
3
2
1
0
-1
-2
-3
-4
-5
0
1
2
3
4
5
6
7
8
9
10
11
12
TIME (HOURS)



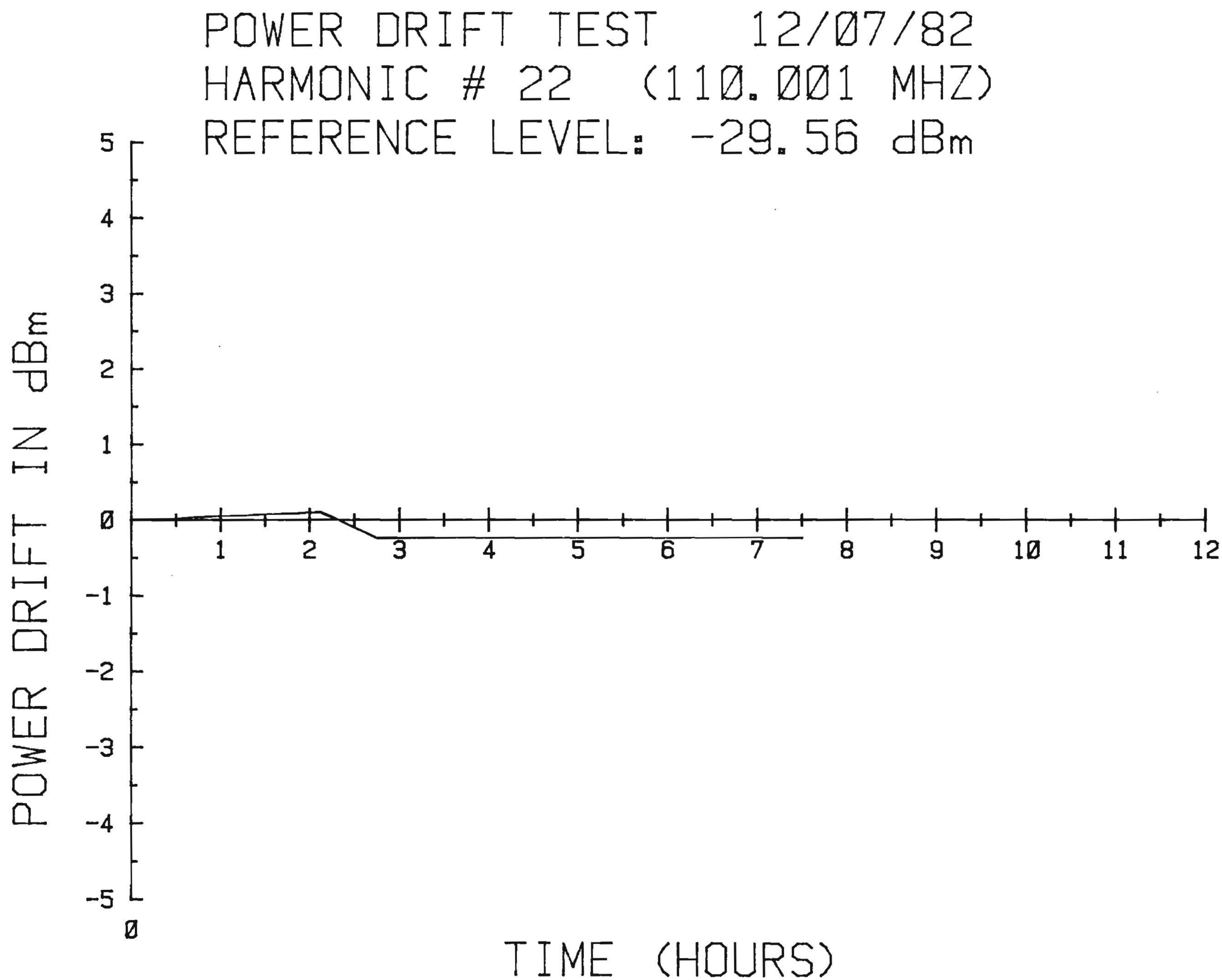
POWER DRIFT TEST 12/07/82
HARMONIC # 18 (90.001 MHZ)
REFERENCE LEVEL: -28.6 dBm
POWER DRIFT IN dBm
5
4
3
2
1
0
-1
-2
-3
-4
-5
0
1
2
3
4
5
6
7
8
9
10
11
12
TIME (HOURS)

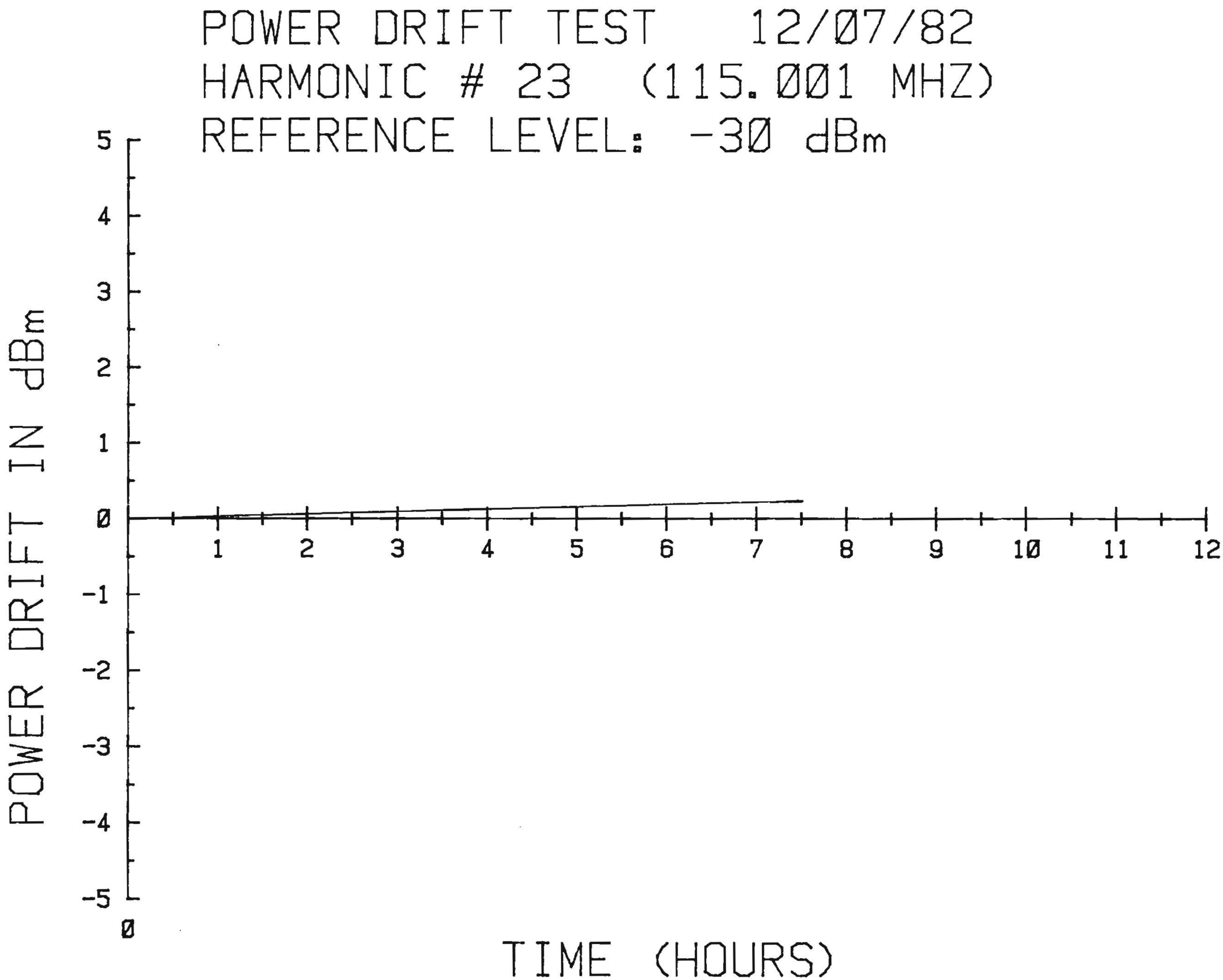

POWER DRIFT TEST 12/07/82
HARMONIC # 19 (95.001 MHZ)
REFERENCE LEVEL: -27.44 dBm
DRIFT LESS THAN THE RESOLUTION
OF THE SPECTRUM ANALYZER
POWER DRIFT IN dBm
5
4
3
2
1
0
-1
-2
-3
-4
-5
0
1
2
3
4
5
6
7
8
9
10
11
12
TIME (HOURS)


POWER DRIFT TEST 12/07/82
HARMONIC # 20 (100.001 MHZ)
REFERENCE LEVEL: -28.84 dBm
DRIFT LESS THAN THE RESOLUTION
OF THE SPECTRUM ANALYZER
POWER DRIFT IN dBm
5
4
3
2
1
0
-1
-2
-3
-4
-5
0
1
2
3
4
5
6
7
8
9
10
11
12
TIME (HOURS)

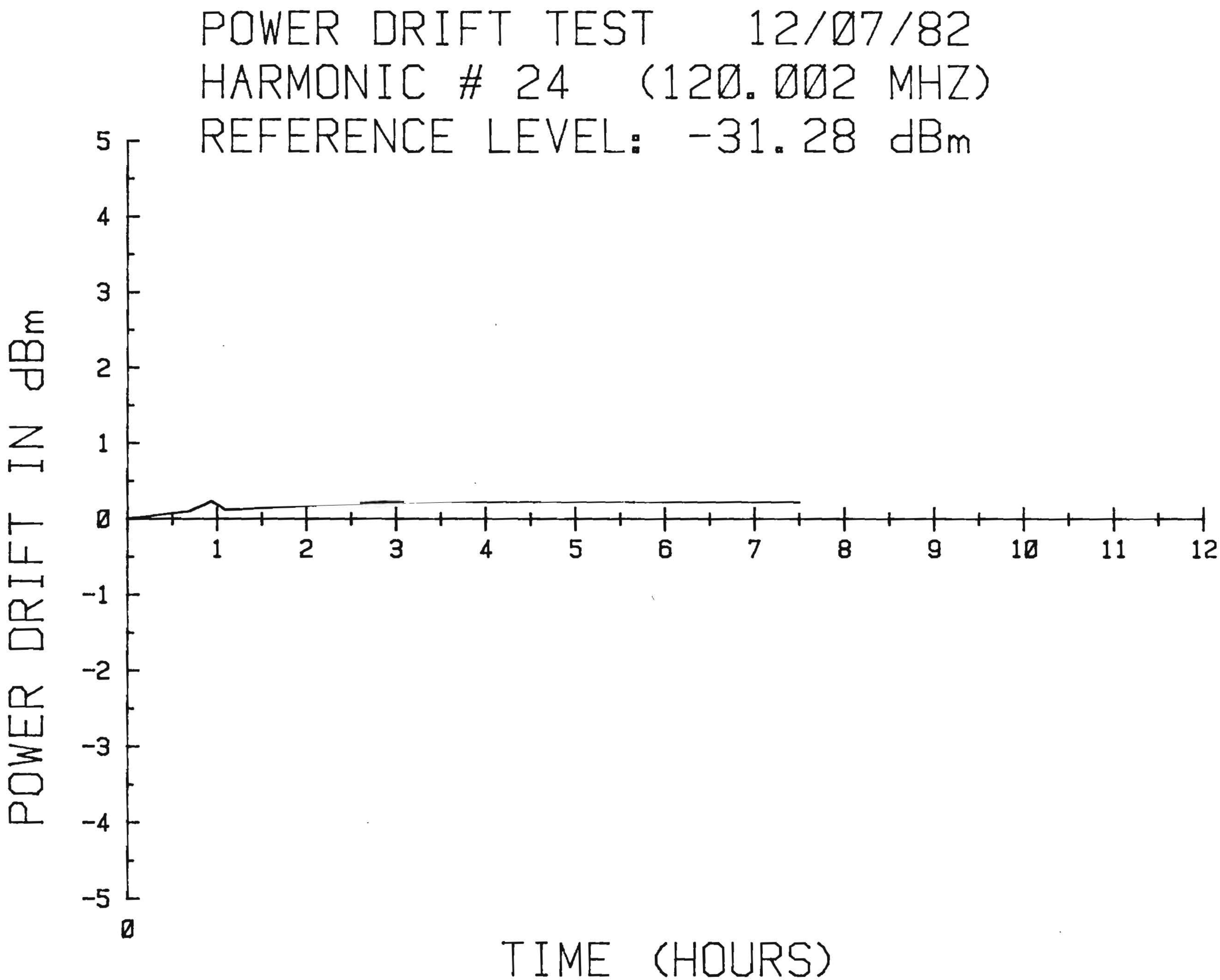


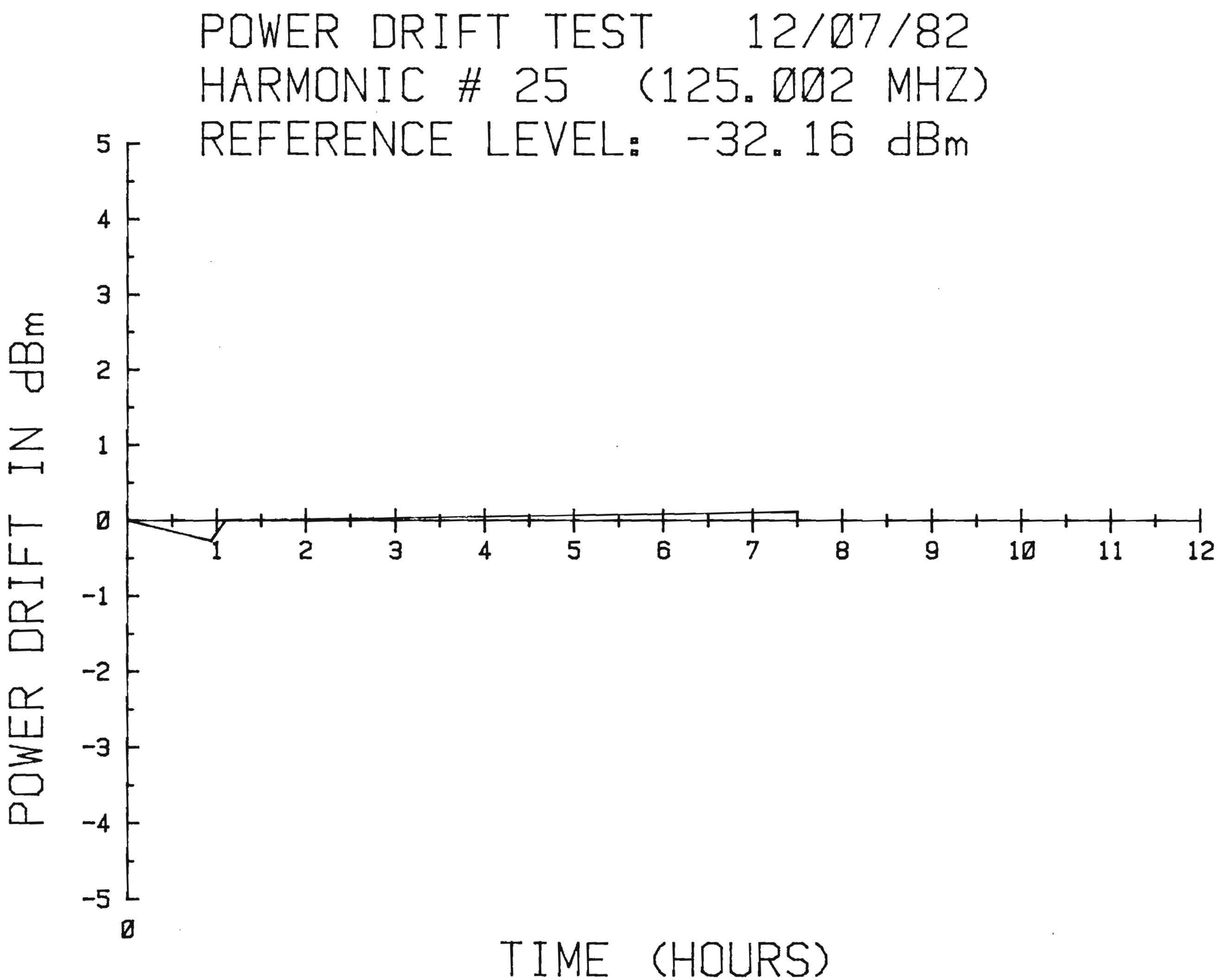
POWER DRIFT TEST 12/07/82
HARMONIC # 21 (105.001 MHZ)
REFERENCE LEVEL: -28.24 dBm
POWER DRIFT IN dBm
5
4
3
2
1
0
-1
-2
-3
-4
-5
0
1
2
3
4
5
6
7
8
9
10
11
12
TIME (HOURS)


POWER DRIFT TEST 12/07/82
HARMONIC # 22 (110.001 MHZ)
REFERENCE LEVEL: -29.56 dBm
POWER DRIFT IN dBm
5
4
3
2
1
0
-1
-2
-3
-4
-5
0
1
2
3
4
5
6
7
8
9
10
11
12
TIME (HOURS)

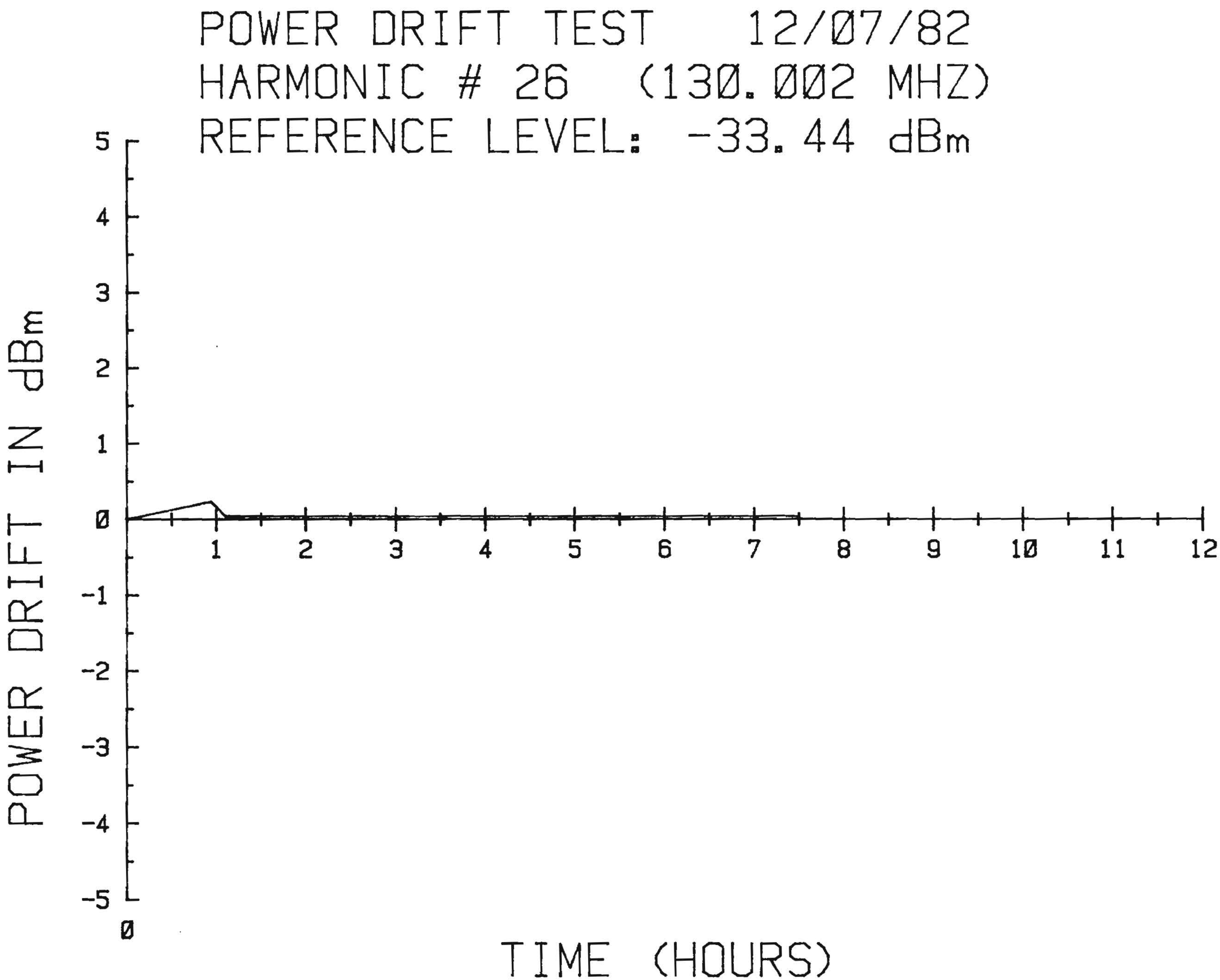


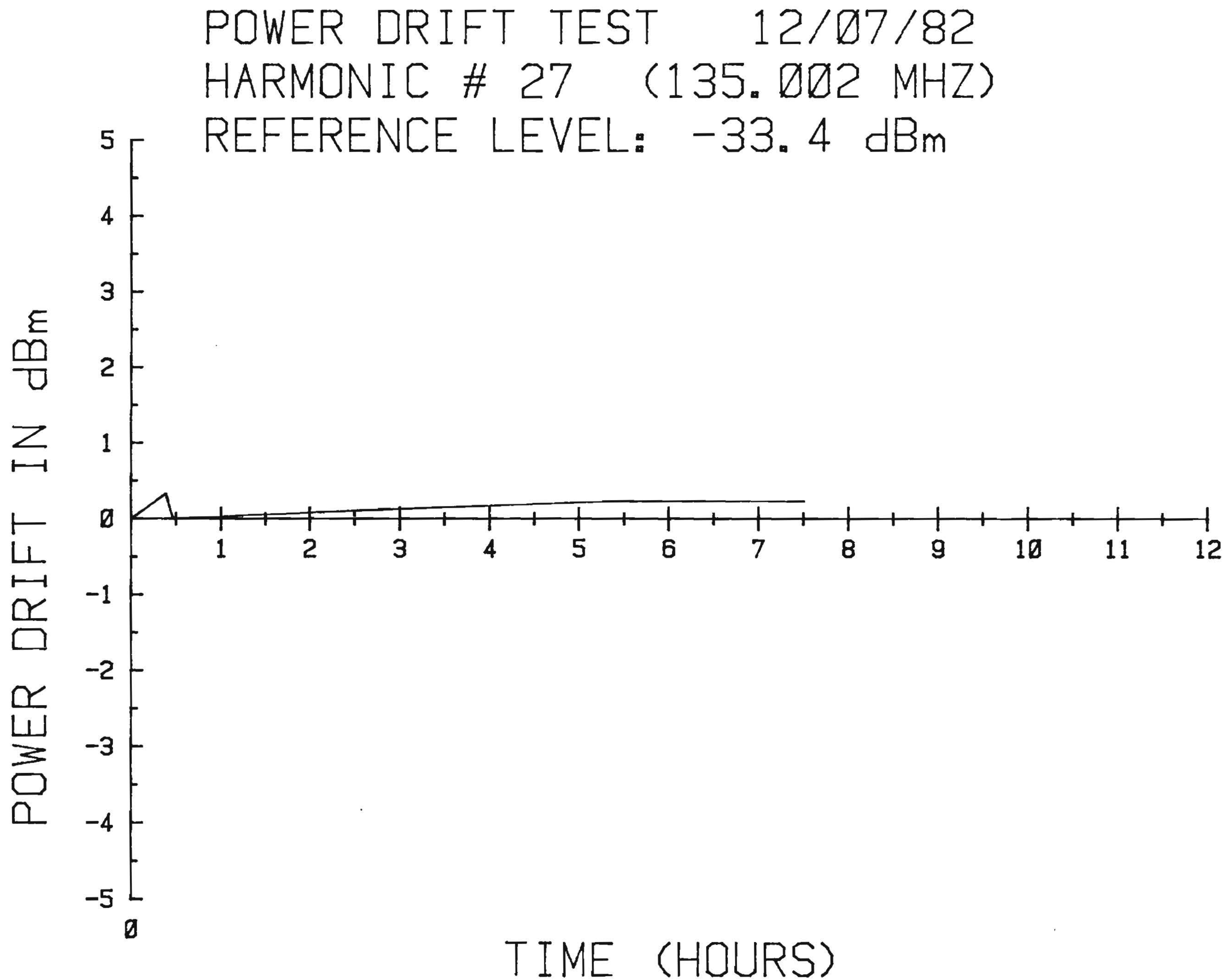
POWER DRIFT TEST 12/07/82
HARMONIC # 23 (115.001 MHZ)
REFERENCE LEVEL: -30 dBm
POWER DRIFT IN dBm
5
4
3
2
1
0
-1
-2
-3
-4
-5
0
1
2
3
4
5
6
7
8
9
10
11
12
TIME (HOURS)


POWER DRIFT TEST 12/07/82
HARMONIC # 24 (120.002 MHZ)
REFERENCE LEVEL: -31.28 dBm
POWER DRIFT IN dBm
5
4
3
2
1
0
-1
-2
-3
-4
-5
0
1
2
3
4
5
6
7
8
9
10
11
12
TIME (HOURS)

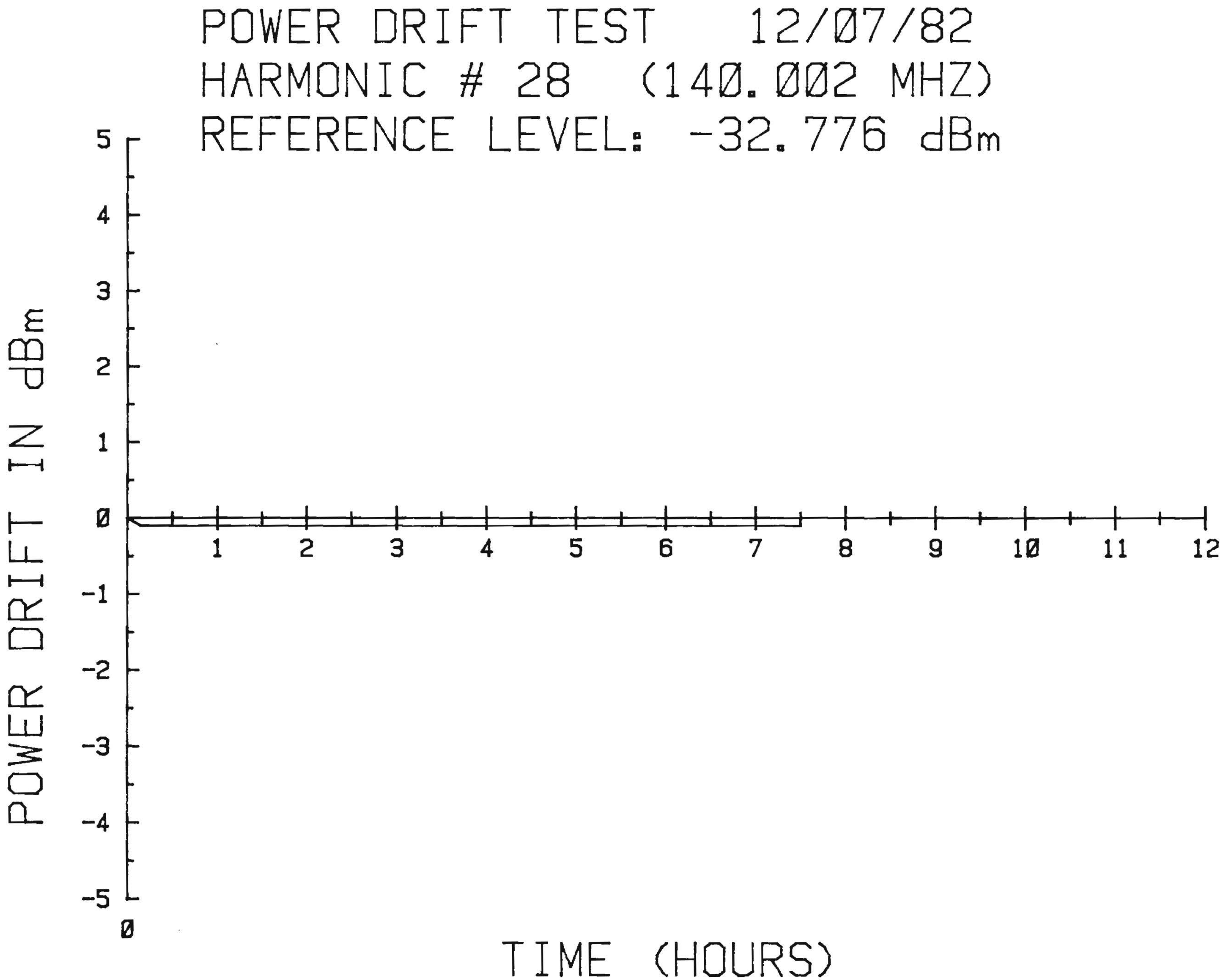


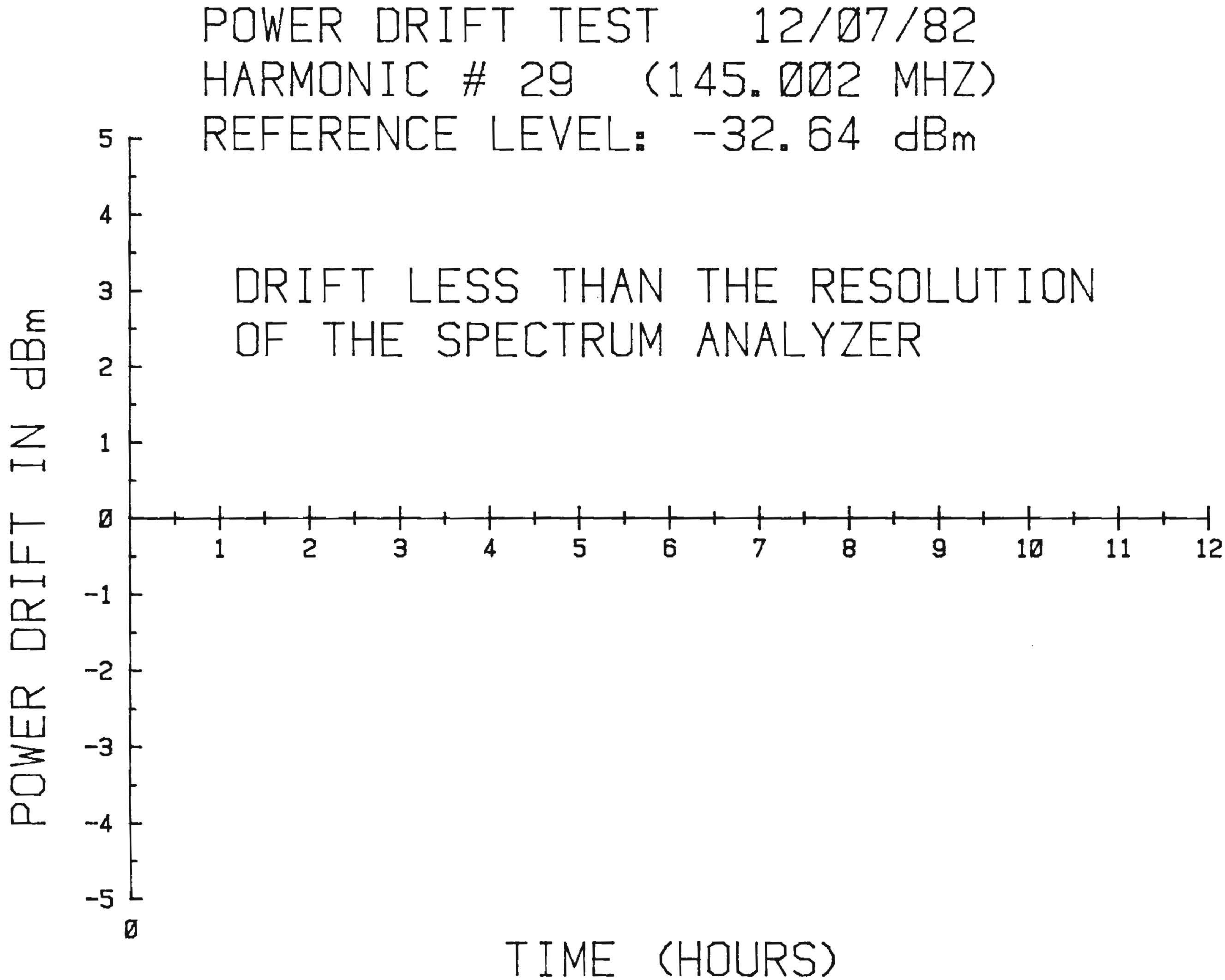
POWER DRIFT TEST 12/07/82
HARMONIC # 25 (125.002 MHZ)
REFERENCE LEVEL: -32.16 dBm
POWER DRIFT IN dBm
5
4
3
2
1
0
-1
-2
-3
-4
-5
0
1
2
3
4
5
6
7
8
9
10
11
12
TIME (HOURS)

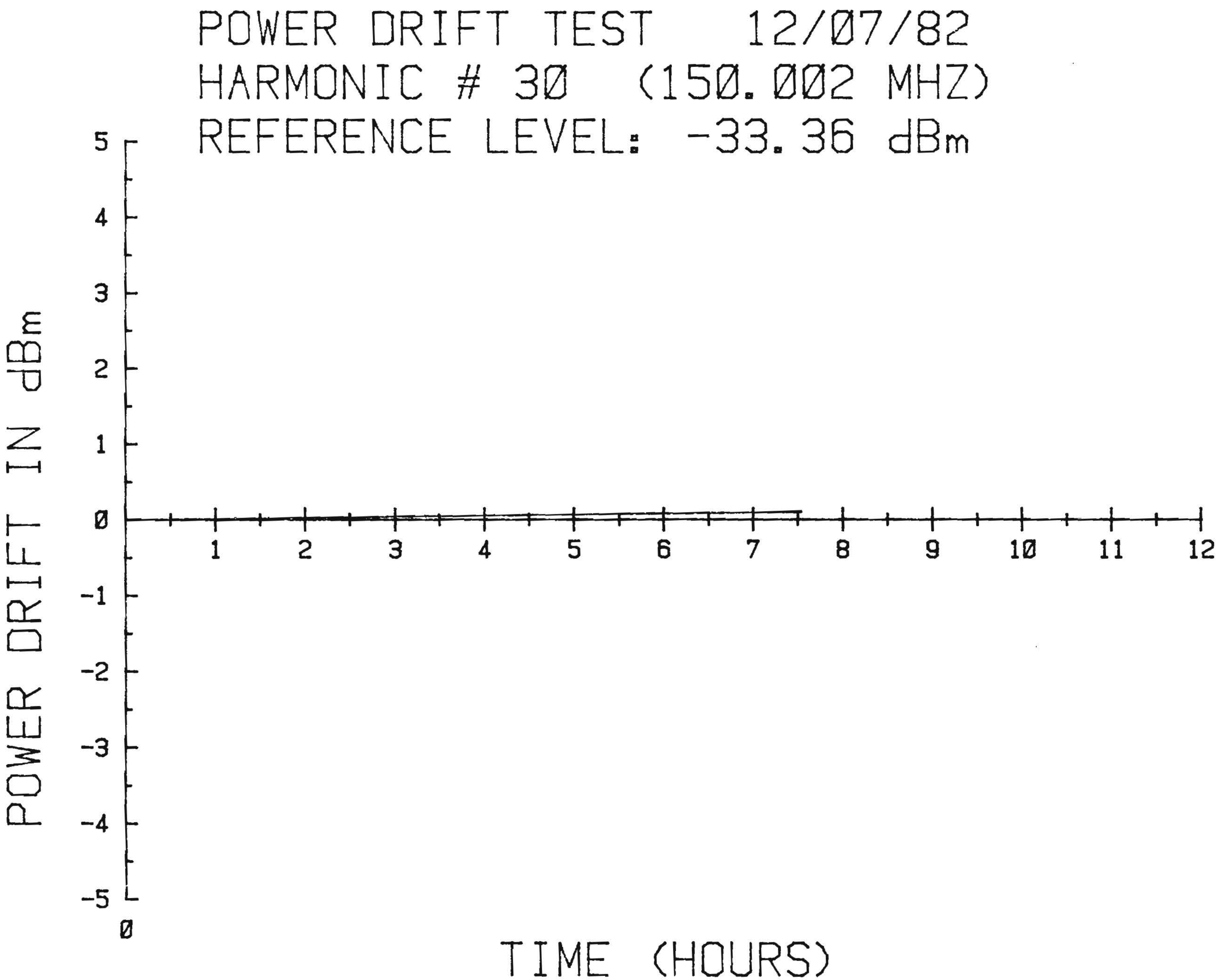

POWER DRIFT TEST 12/07/82
HARMONIC # 26 (130.002 MHZ)
REFERENCE LEVEL: -33.44 dBm
POWER DRIFT IN dBm
5
4
3
2
1
0
-1
-2
-3
-4
-5
0
1
2
3
4
5
6
7
8
9
10
11
12
TIME (HOURS)

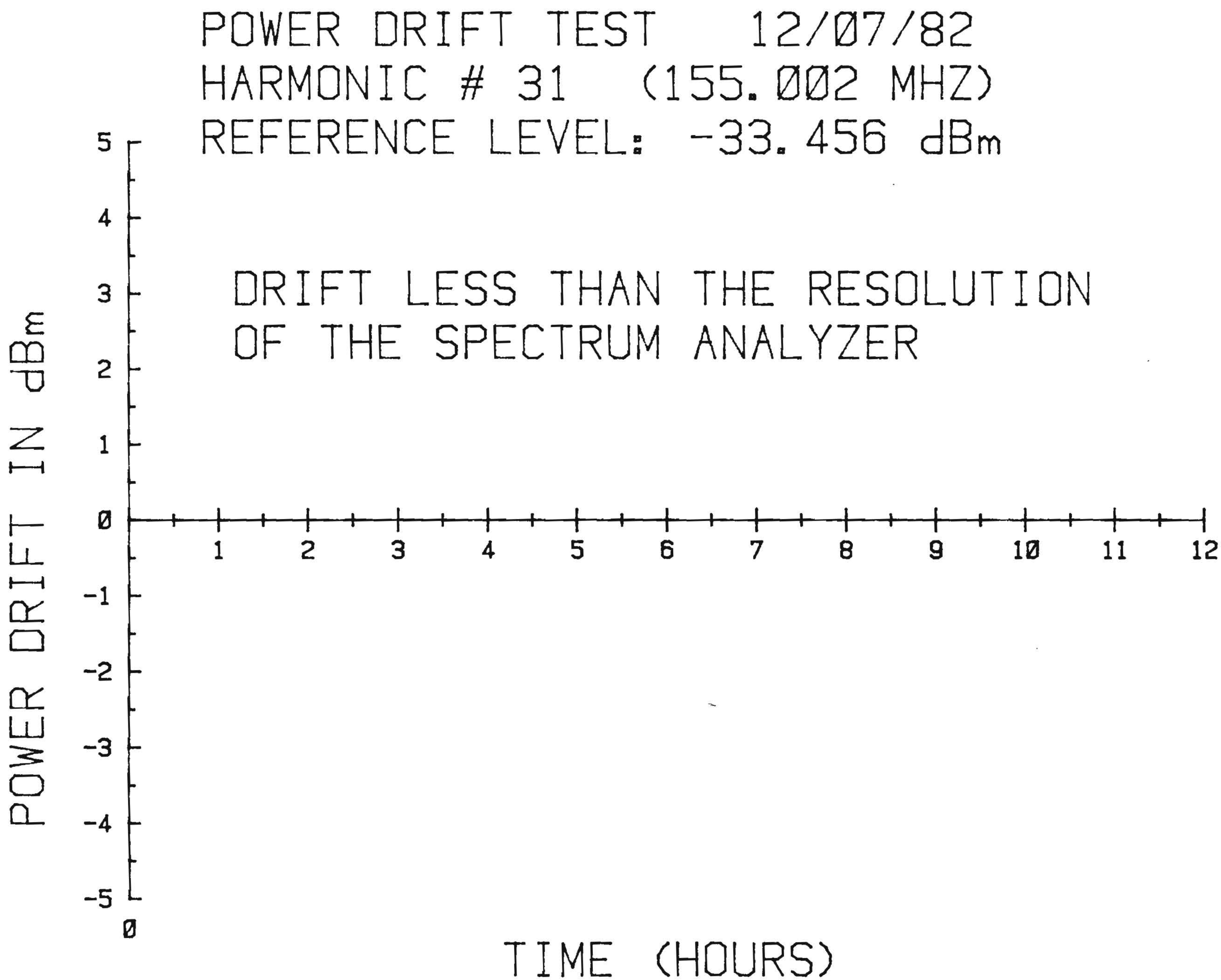


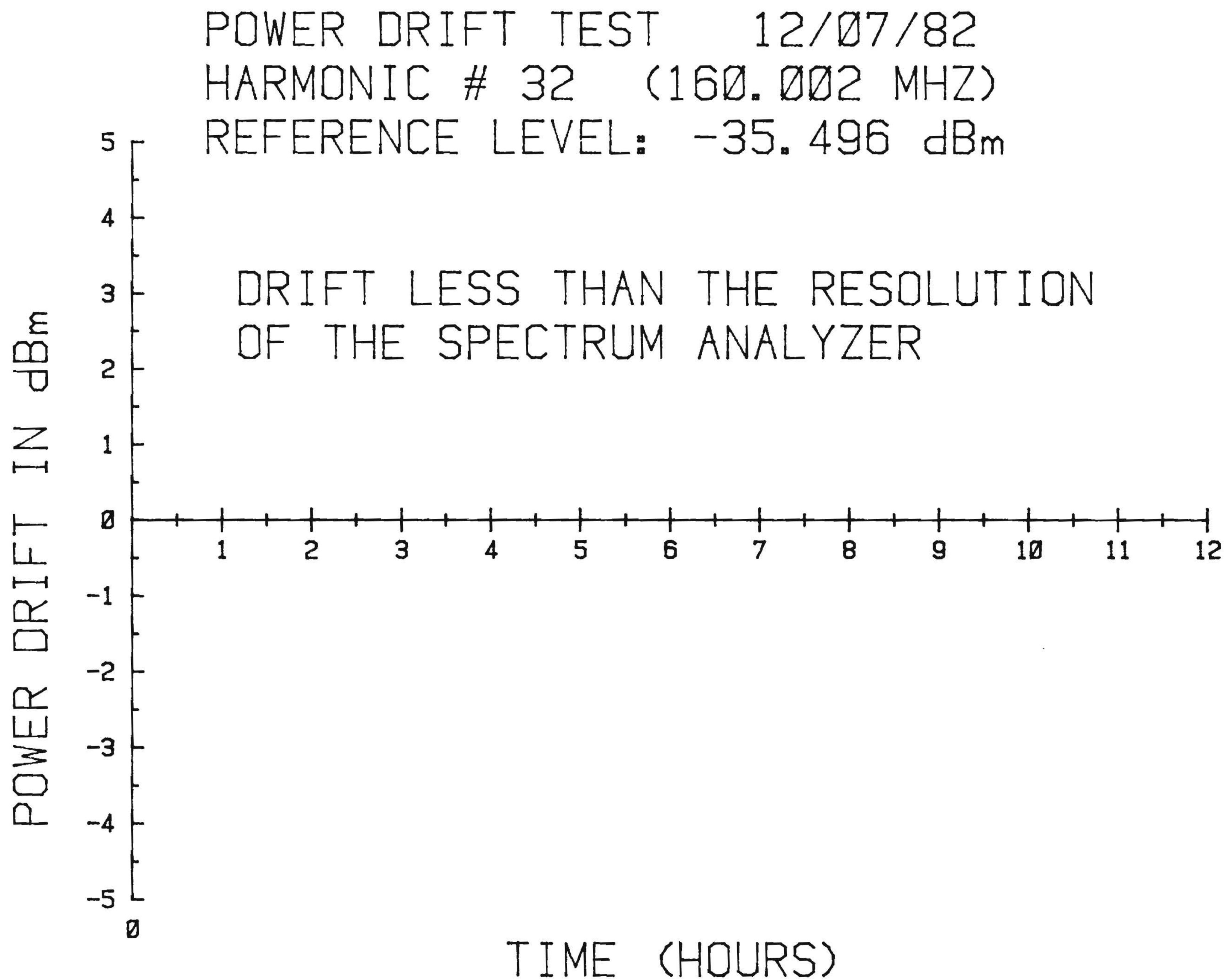
POWER DRIFT TEST 12/Ø7/82
HARMONIC # 27 (135.ØØ2 MHZ)
REFERENCE LEVEL: -33.4 dBm
POWER DRIFT IN dBm
5
4
3
2
1
Ø
-1
-2
-3
-4
-5
Ø
1
2
3
4
5
6
7
8
9
1Ø
11
12
TIME (HOURS)

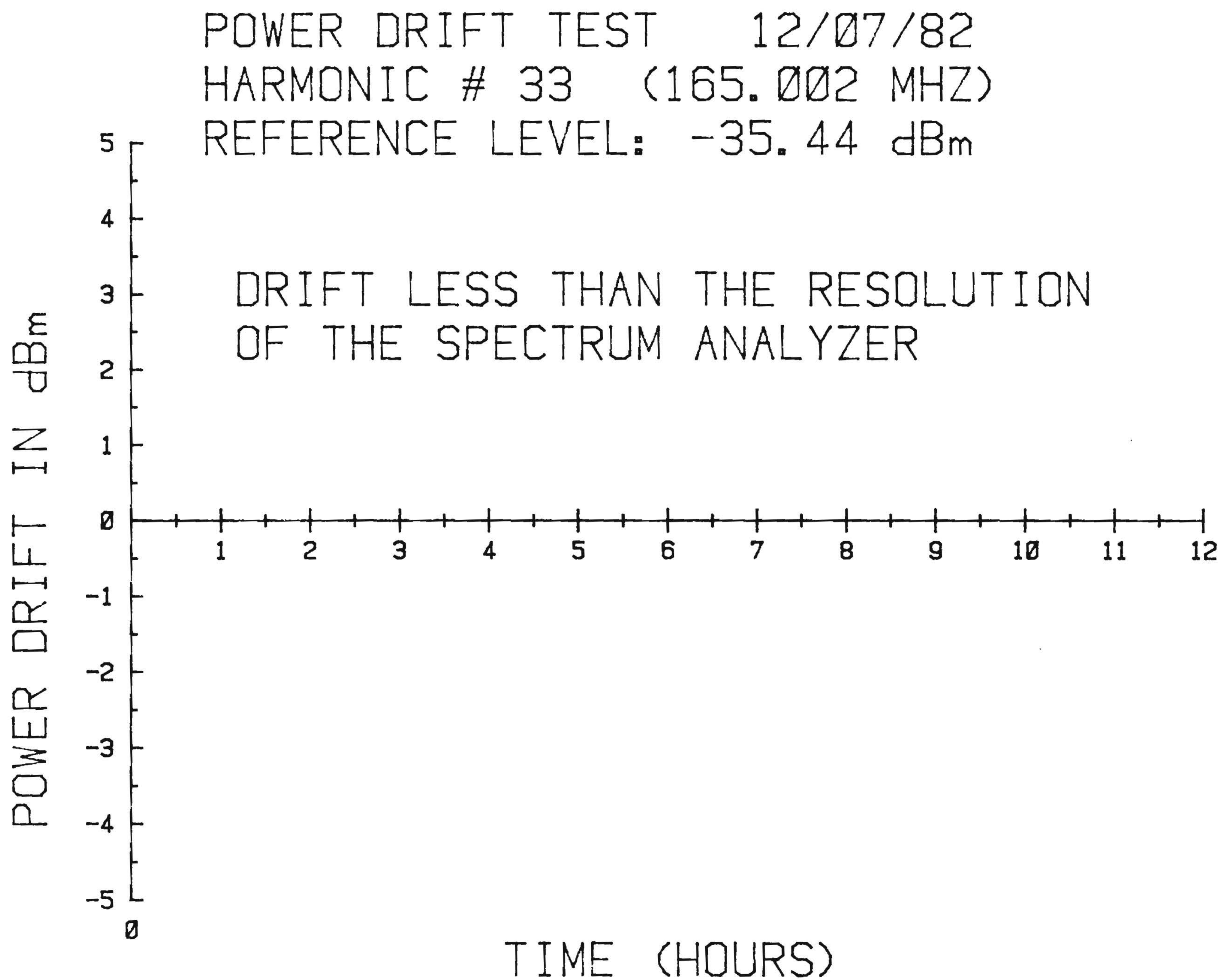

POWER DRIFT TEST 12/07/82
HARMONIC # 28 (140.002 MHZ)
REFERENCE LEVEL: -32.776 dBm
POWER DRIFT IN dBm
5
4
3
2
1
0
-1
-2
-3
-4
-5
0
1
2
3
4
5
6
7
8
9
10
11
12
TIME (HOURS)

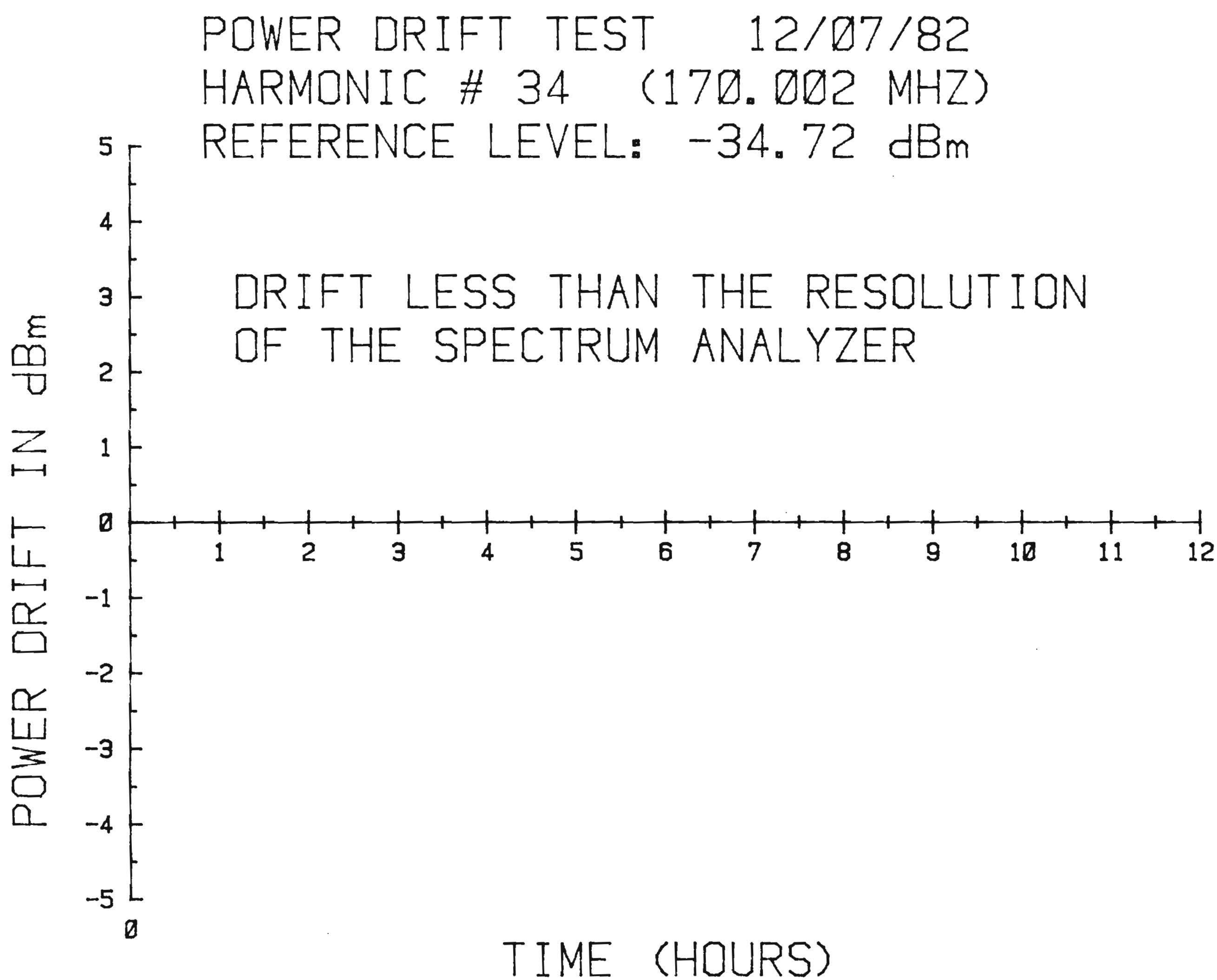

POWER DRIFT TEST 12/07/82
HARMONIC # 29 (145.002 MHZ)
REFERENCE LEVEL: -32.64 dBm
DRIFT LESS THAN THE RESOLUTION
OF THE SPECTRUM ANALYZER
POWER DRIFT IN dBm
5
4
3
2
1
0
-1
-2
-3
-4
-5
0
1
2
3
4
5
6
7
8
9
10
11
12
TIME (HOURS)

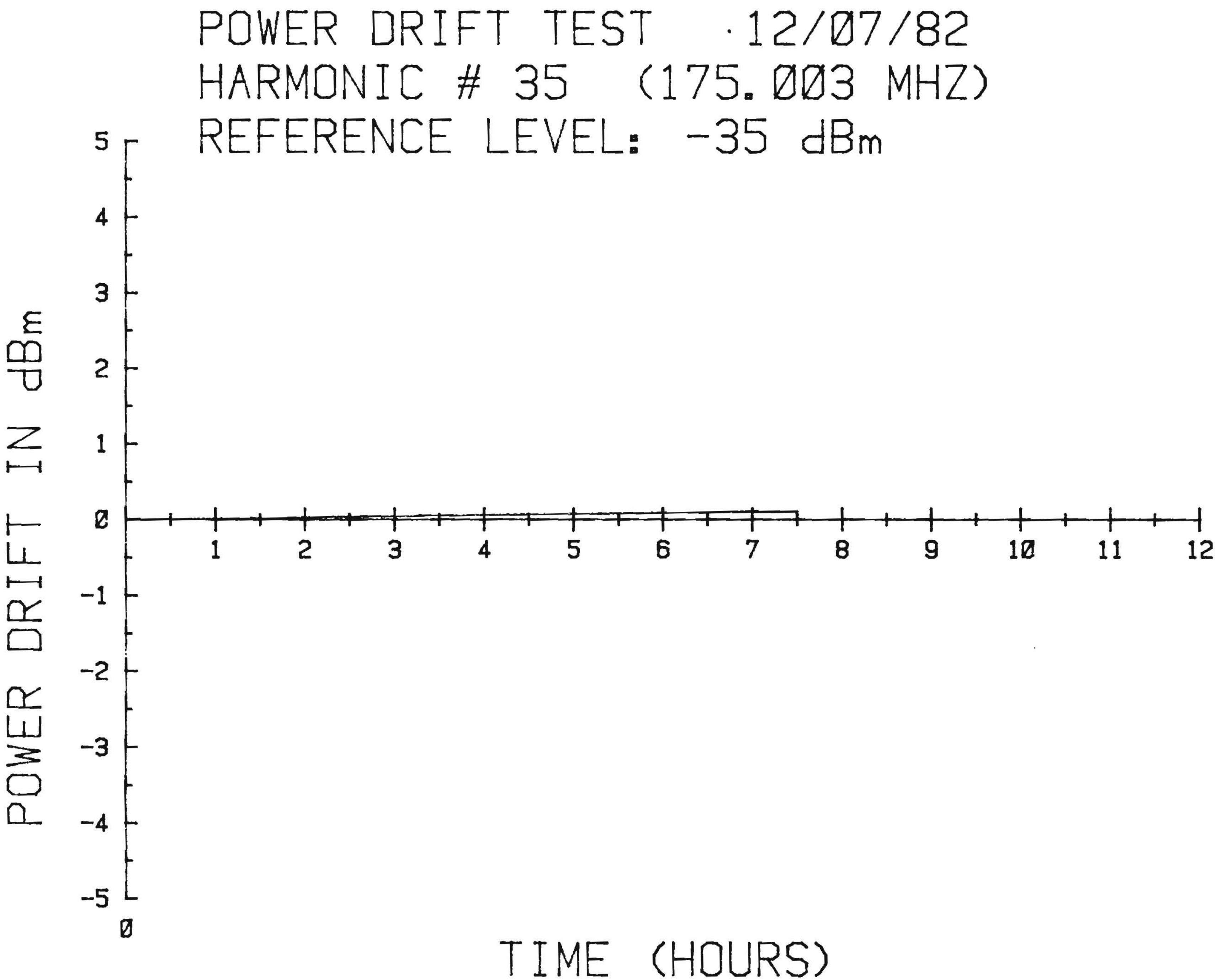

POWER DRIFT TEST 12/07/82
HARMONIC # 30 (150.002 MHZ)
REFERENCE LEVEL: -33.36 dBm
POWER DRIFT IN dBm
5
4
3
2
1
0
-1
-2
-3
-4
-5
0
1
2
3
4
5
6
7
8
9
10
11
12
TIME (HOURS)

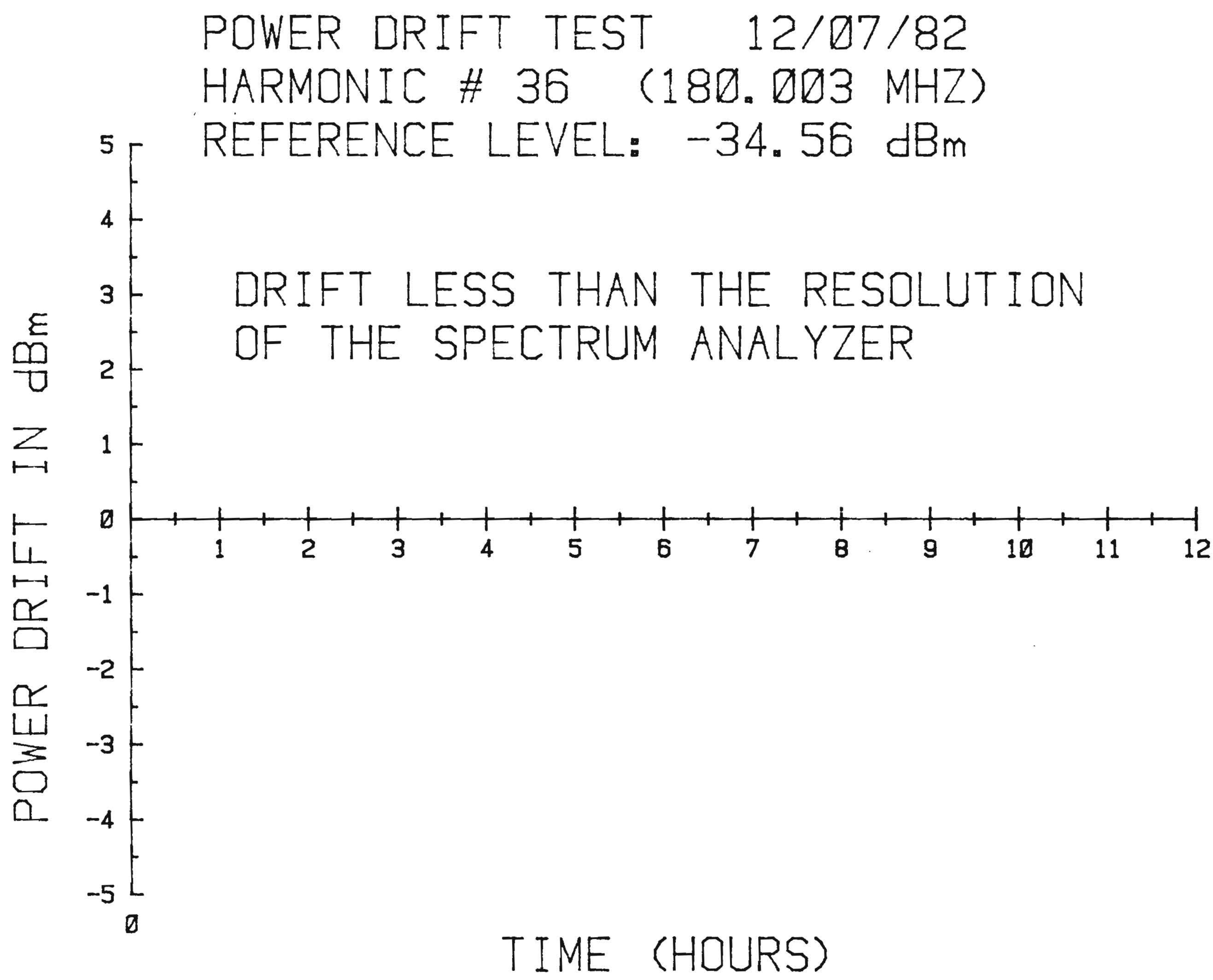

POWER DRIFT TEST 12/07/82
HARMONIC # 31 (155.002 MHZ)
REFERENCE LEVEL: -33.456 dBm
DRIFT LESS THAN THE RESOLUTION
OF THE SPECTRUM ANALYZER
POWER DRIFT IN dBm
5
4
3
2
1
0
-1
-2
-3
-4
-5
0
1
2
3
4
5
6
7
8
9
10
11
12
TIME (HOURS)

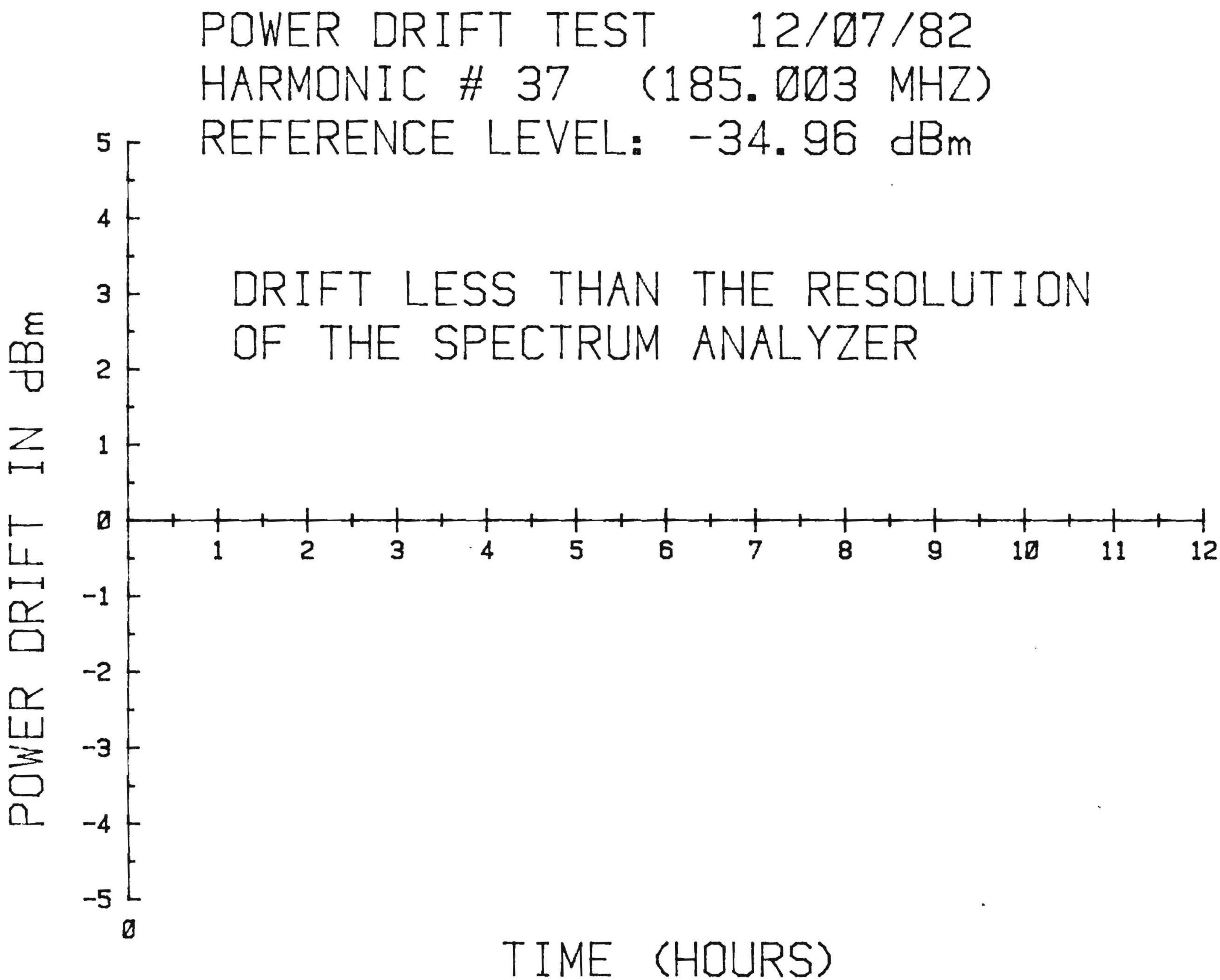

POWER DRIFT TEST 12/07/82
HARMONIC # 32 (160.002 MHZ)
REFERENCE LEVEL: -35.496 dBm
DRIFT LESS THAN THE RESOLUTION
OF THE SPECTRUM ANALYZER
POWER DRIFT IN dBm
TIME (HOURS)
5
4
3
2
1
0
-1
-2
-3
-4
-5
0
1
2
3
4
5
6
7
8
9
10
11
12

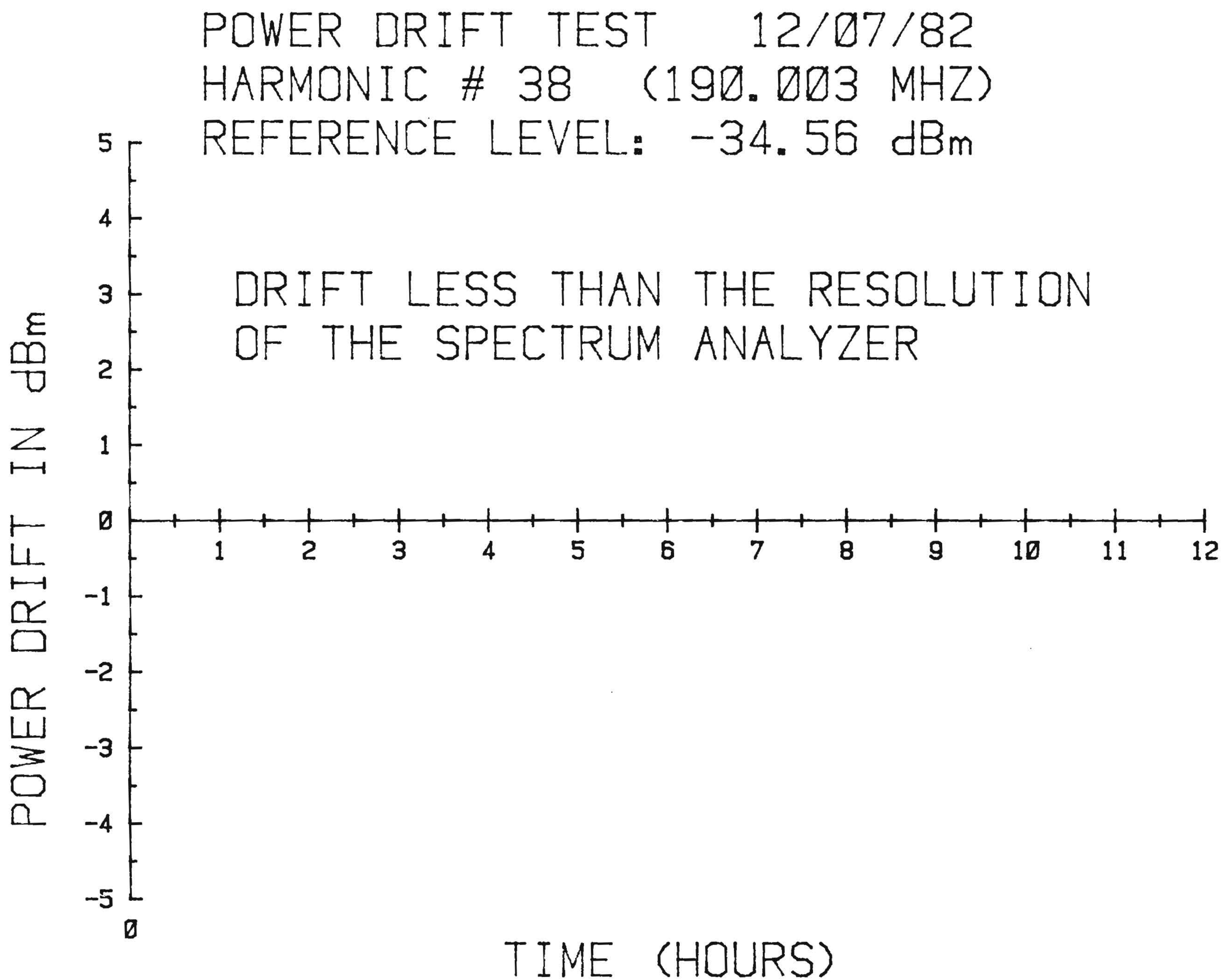

POWER DRIFT TEST 12/07/82
HARMONIC # 33 (165.002 MHZ)
REFERENCE LEVEL: -35.44 dBm
DRIFT LESS THAN THE RESOLUTION
OF THE SPECTRUM ANALYZER
POWER DRIFT IN dBm
5
4
3
2
1
0
-1
-2
-3
-4
-5
0
1
2
3
4
5
6
7
8
9
10
11
12
TIME (HOURS)

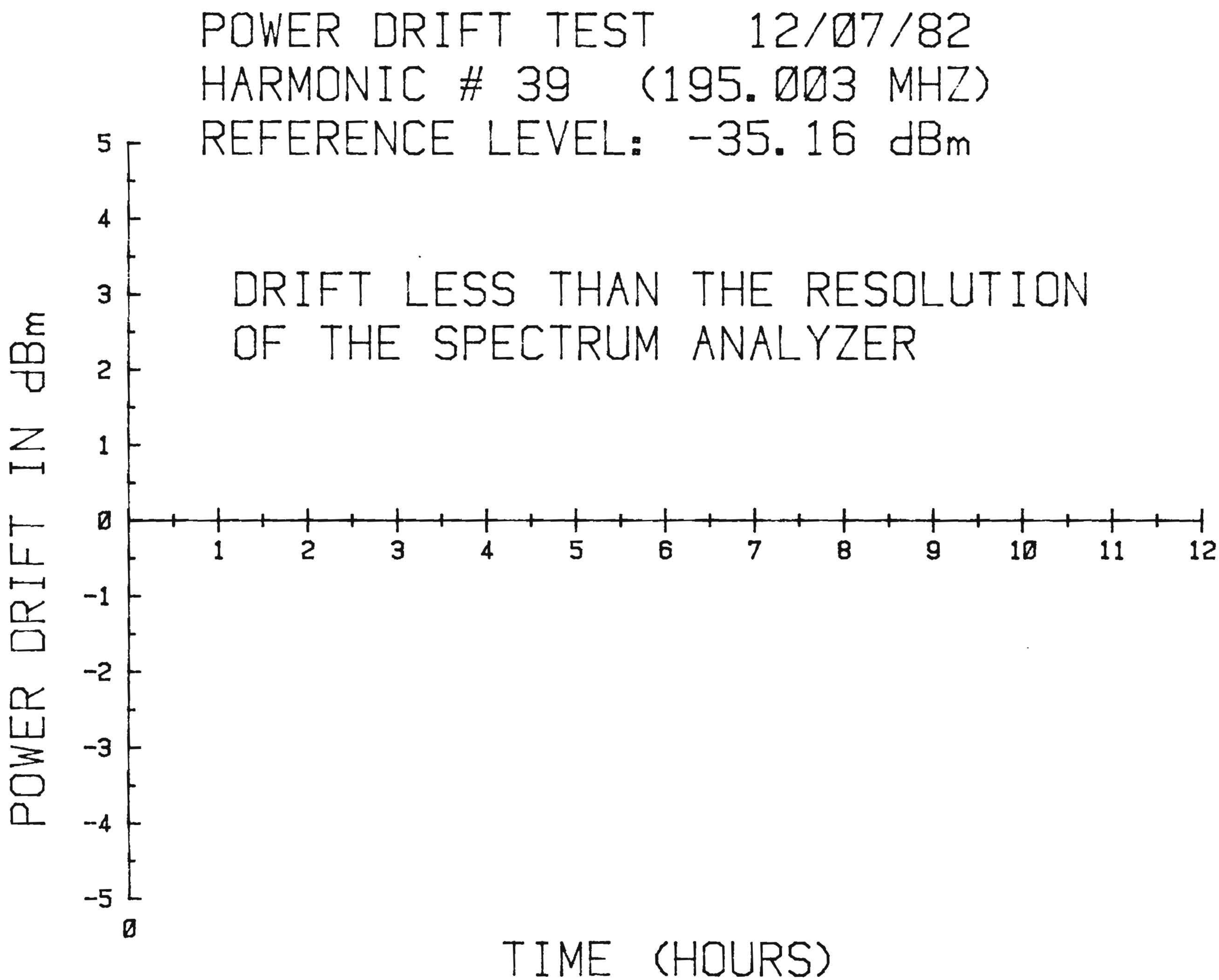

POWER DRIFT TEST 12/07/82
HARMONIC # 34 (170.002 MHZ)
REFERENCE LEVEL: -34.72 dBm
DRIFT LESS THAN THE RESOLUTION
OF THE SPECTRUM ANALYZER
POWER DRIFT IN dBm
5
4
3
2
1
0
-1
-2
-3
-4
-5
0
1
2
3
4
5
6
7
8
9
10
11
12
TIME (HOURS)

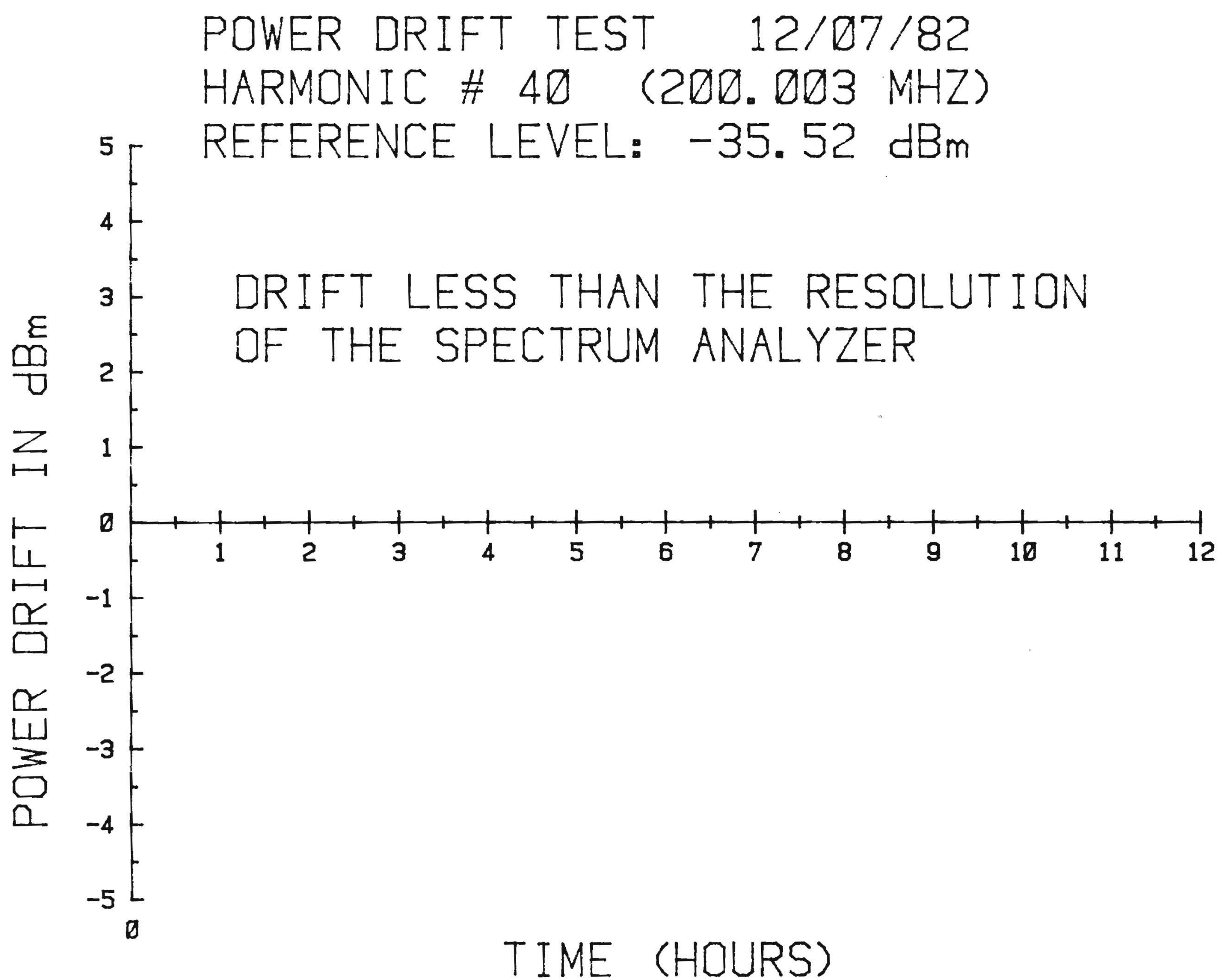

POWER DRIFT TEST 12/07/82
HARMONIC # 35 (175.003 MHZ)
REFERENCE LEVEL: -35 dBm
POWER DRIFT IN dBm
5
4
3
2
1
0
-1
-2
-3
-4
-5
0
1
2
3
4
5
6
7
8
9
10
11
12
TIME (HOURS)


POWER DRIFT TEST 12/07/82
HARMONIC # 36 (180.003 MHZ)
REFERENCE LEVEL: -34.56 dBm
DRIFT LESS THAN THE RESOLUTION
OF THE SPECTRUM ANALYZER
POWER DRIFT IN dBm
5
4
3
2
1
0
-1
-2
-3
-4
-5
0
1
2
3
4
5
6
7
8
9
10
11
12
TIME (HOURS)


POWER DRIFT TEST 12/07/82
HARMONIC # 37 (185.003 MHZ)
REFERENCE LEVEL: -34.96 dBm
DRIFT LESS THAN THE RESOLUTION
OF THE SPECTRUM ANALYZER
POWER DRIFT IN dBm
5
4
3
2
1
0
-1
-2
-3
-4
-5
0
1
2
3
4
5
6
7
8
9
10
11
12
TIME (HOURS)


POWER DRIFT TEST 12/07/82
HARMONIC # 38 (190.003 MHZ)
REFERENCE LEVEL: -34.56 dBm
DRIFT LESS THAN THE RESOLUTION
OF THE SPECTRUM ANALYZER
POWER DRIFT IN dBm
5
4
3
2
1
0
-1
-2
-3
-4
-5
0
1
2
3
4
5
6
7
8
9
10
11
12
TIME (HOURS)


POWER DRIFT TEST 12/07/82
HARMONIC # 39 (195.003 MHZ)
REFERENCE LEVEL: -35.16 dBm
DRIFT LESS THAN THE RESOLUTION
OF THE SPECTRUM ANALYZER
POWER DRIFT IN dBm
5
4
3
2
1
0
-1
-2
-3
-4
-5
0
1
2
3
4
5
6
7
8
9
10
11
12
TIME (HOURS)


POWER DRIFT TEST 12/07/82
HARMONIC # 40 (200.003 MHZ)
REFERENCE LEVEL: -35.52 dBm
DRIFT LESS THAN THE RESOLUTION
OF THE SPECTRUM ANALYZER
POWER DRIFT IN dBm
TIME (HOURS)
5
4
3
2
1
0
-1
-2
-3
-4
-5
0
1
2
3
4
5
6
7
8
9
10
11
12

ATTACHMENT II - FINANCIAL REPORT

1 November to 30 November 1982

Labor Categories	Contractual Man-Hours Proposed	Man-Hours Expended This Period	Cumulative Total of Expended Man-Hours
Principal Research Engineer	164	8	49
Research Engineer I	738	198	567
Machinist/Technician	72	57.5	57.5
Secretarial/Clerical/ Technical Assistant	480	42	379

A-3310

SPHERICAL DIPOLE EMISSION SOURCE

Final Report
Project A-3310
August 1983

By

J. C. Mantovani

Submitted to

BELL LABORATORIES
Crawford Corner Road
Holmdel, New Jersey 07733

Submitted by

ELECTROMAGNETIC COMPATIBILITY DIVISION
Electronics and Computer Systems Laboratory
Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

FOREWORD

This report was prepared by the Electronics and Computer Systems Laboratory of the Engineering Experiment Station (EES) of the Georgia Institute of Technology. The work was performed for Bell Laboratories/American Bell, Inc. under EES Project A-3310. The described work was conducted under the general supervision of Mr. F. L. Cain, Director of the Electronics and Computer Systems Laboratory; Mr. H. W. Denny, Chief of the Electromagnetics Compatibility Division; and Mr. J. C. Mantovani, Project Director. The report summarizes the design, construction, and calibration phases of a 5-month technical effort directed to developing a spherical dipole emission source for use as a standard radiating reference.

The author wishes to express his appreciation to Mr. W. B. Warren, Assistant Director of the Electronics and Computer Systems Laboratory, for his technical assistance in the design phase of the spherical dipole transmitter circuitry, and to Mr. J. P. Rohrbaugh and Mr. J. G. Hotchkiss for their overall assistance in the design, construction, and calibration phases of the program.

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1.0 INTRODUCTION

The Federal Communications Commission limits radiated RF emissions; most recently, emphasis has been placed on computing devices. A test site description and emission testing procedures for evaluating compliance with these emission requirements has recently been set forth in ANSI Standard C63.4 [1]. Because of variations between test sites such as ground plane conductivity and the presence of reflecting objects (cables, equipment, support structures, etc.), the levels of the radiated emissions measured from a particular device can vary from one test site to another. To minimize the site dependency of measured radiated emission levels, extreme care must be taken to assure that test sites are made as similar as possible in both the geometrical layout and the electrical characteristics.

One approach to achieving and assuring test site comparability is to utilize an emitting device having known and repeatable radiation properties as a transfer standard. By comparing the measured levels of the EM fields produced by this "standard radiating reference" at different test sites, test site variations can be defined.

1.1 Program Objective

This report summarizes the results of a program whose objective was the design, construction, and calibration of an emission source which could serve as such a "standard radiating reference". The source was required to operate over the frequency range from 30 MHz to 200 MHz, radiate an omnidirectional field in the plane normal to the axis of the source, and generate an electromagnetic field with a known and highly repeatable field strength level.

To satisfy the above objective, major efforts under the program were directed to: (1) developing a signal generation scheme which would cover the desired frequency range, maintain the desired stability, and produce the desired output power level; (2) constructing the source transmitter/antenna configuration; (3) verifying that the design goals were satisfied; and (4) calibrating the two sources which were constructed.

1.2 Performance Goals

The performance goals of the emission source are given in Table I. As seen from this table, the source was required to either be continuously

TABLE I
PERFORMANCE GOALS OF TRANSMITTING SYSTEM

Frequency Range	30 MHz - 200 MHz
Emission Characteristics	Continuous or Less Than 10 MHz Increments
Field Strength Level	A Minimum Level of 30 dBμV/m Measured at 3-meter Horizontal Separation, Over Entire Frequency Range
Battery Life	4 Hours Minimum
Frequency Stability	Less Than 4 kHz Drift Over a Four Hour Interval
Amplitude Stability	Less Than ± 1 dB Drift Over a Four Hour Interval
Amplitude Repeatability	Within ± 1 dB
Radiation Characteristics	Typical Dipole Donut Pattern Throughout Entire Frequency Range; Omnidirectional (Less Than ± 2 dB Variation For 360 Degree Rotation) In Plane Normal to the Axis of the Dipole, and Maximum Field in Plane Going Through Center of Dipole and Normal to It

tunable or generate discrete, evenly-spaced signals (maximum of 10 MHz between each signal) over the 30 MHz to 200 MHz frequency range, and provide a minimum field strength level of 30 dBμV/m over this frequency range, at a horizontal distance of 3 meters from the source. The frequency and amplitude drift of the radiated field at each frequency were specified to be less than 4 kHz and ± 1.0 dB, respectively. The radiation characteristics of the transmitting system over the entire frequency range were specified to be equivalent to the donut pattern associated with an electrically small antenna. Particularly, the characteristics of the field in the plane normal to the axis of the transmitting system were to be omnidirectional with less than ± 2 dB variation throughout the entire 360 degree rotation.

1.3 Design Approach

The radiated field generated by a conventional transmitting system is usually affected by the placement/position and electrical length of the coaxial cable connecting the transmitting antenna to the remotely located transmitter. Errors in the amplitude of the radiated field caused by cable placement and positioning require that the transmitting system must be completely self contained. The basic design concept was to place the transmitting circuitry and associated power supply physically inside the radiating aperture. In this manner the transmitting system could be placed in the test site and operated in the absence of any connecting cabling.

This design concept was based on the result of a fixed frequency 30 MHz spherical dipole radiator constructed at the National Bureau of Standards (NBS) and used in the evaluation of the receiving properties of TEM cells [2]. This basic design was used as a prototype for the design of broadband transmitting system meeting the design goals given above. The spherical dipole design offers the advantages of (1) being completely self-contained with no interconnecting cables, thus eliminating possible errors caused by cable placement and positioning; (2) providing the physical room necessary for housing the transmitter circuitry by forming the spherical dipole out of two hollow hemispherical sections; (3) having radiation characteristics which can be analytically determined, and which are consistent with the desired radiation characteristics of the transmitting system; and (4) minimizing interactions between the transmitting system and the receiving antennas since its size can be kept electrically small.

Although this approach eliminates problems caused by cable placement, it places several limitations on the design. Since it is desired to keep the spherical dipole electrically small such that it acts as a "point source radiator," the physical size of the spherical dipole is set by the operating frequency requirements. Thus, a limitation is placed on the physical size of the transmitter circuitry and on the batteries used to power the transmitter. Since the physical size of the batteries is limited the available power from the batteries is also limited. This, in turn, places a limit on the output field levels for a given battery life.

In order to simplify the transmitter circuitry and correspondingly minimize its physical space requirements, a transmitter which covers the desired frequency range with discrete, rather than continuous tuning, evenly-spaced signals, was used. This approach was chosen because it minimized space requirements and because the frequency stability of a discrete coherent frequency transmitter using frequency synthesis is much better than the frequency stability of a continuously tunable transmitter. The form of coherent frequency synthesis used involves the generation of a pulse train with a high harmonic content from a single CW signal source. Fourier analysis shows that the frequency spectrum of the pulse train contains the fundamental frequency plus all of its harmonics up to some frequency limit which is set by the rise and fall time of the pulse as well as by the pulse width. In this manner, the frequency stability of each signal component is harmonically related to the single fundamental source frequency which can be made highly stable through the use of crystal control.

2.0 DESIGN AND CONSTRUCTION

The design and construction of a spherical dipole source which radiates a known and repeatable signal at discrete frequencies from 30 MHz to 200 MHz can be categorized into two major subsections: (1) the mechanical design and construction of the spherical dipole antenna and mounting apparatus, and (2) the electrical design and construction of the transmitter circuitry.

2.1 Mechanical

The spherical dipole source development began with the mechanical design and construction of the spherical dipole antenna. The antenna was designed to serve the dual purpose of being the radiating aperture and housing the transmitter and power supply. A mount for the spherical dipole source and an associated polarization alignment tool were also included in the mechanical design and construction phase of the program.

2.1.1 Spherical Dipole Antenna

The overall design of the spherical dipole antenna was based on the National Bureau of Standard's 30 MHz, 10 cm diameter spherical dipole radiator (as requested in RFQ No. 82-42-PRG). Several modifications were made to improve the mechanical rigidity and assembly of the NBS prototype, although the overall dimensions (10 cm diameter and 1/8 inch gap spacing) were left unchanged.

A cross-sectional view of the spherical dipole antenna is illustrated in Figure 1. A complete set of mechanical drawings showing the dimensions and details of the various pieces of the antenna are given in Attachment I. The hemispherical sections, the feed posts, and the attachment posts of the antenna were all machined out of brass, while the spacer ring and the attachment ring were machined out of Delrin®, a dielectric material.

The transmitter circuitry is mounted on the printed circuit board, which is mounted securely in the spacer ring with the attachment ring and three teflon screws, as shown in Figure 1. A rotary switch is mounted at the center of the PC board so that the transmitter can be turned on and off without disassembling the sphere. The two feed posts, shown in Figure 1, are rigidly soldered to the two hemispherical sections. Assembly of the spherical dipole is accomplished through a clockwise rotation of the threaded feed posts into the attachment posts which are rigidly secured to the rotary switch. The stop

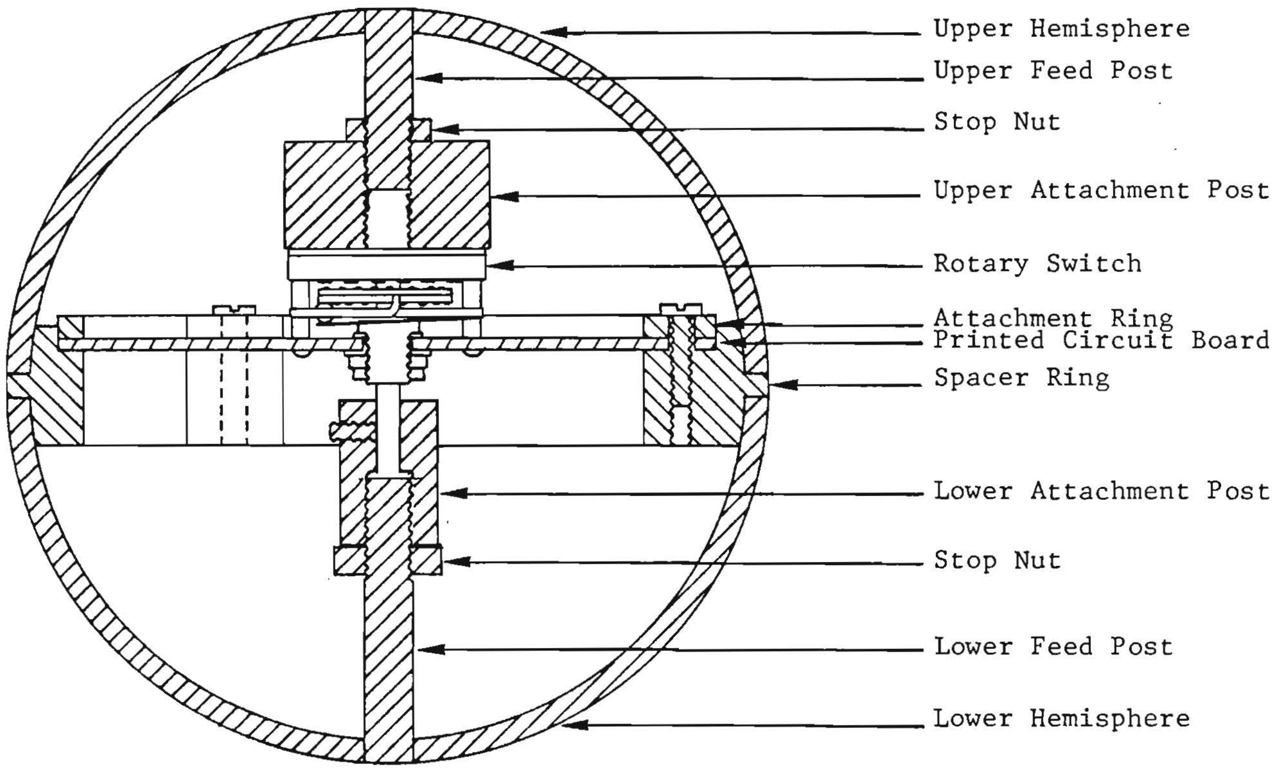


Figure 1. Cross Sectional View of Spherical Dipole Antenna.

nuts on the feed posts are set so that the feed post will stop threading into the attachment post when the hemispheres come into contact with the spacer ring. A further clockwise rotation of the lower hemisphere will thus cause the rotary switch to energize the transmitter, while a counter-clockwise rotation will turn it off.

2.1.2 Antenna Mount and Alignment Tool

An electrically transparent mount was designed and constructed to hold the spherical dipole when in use. The mount was designed such that it could either sit on a flat surface or be attached to a tripod which utilizes a 1/4-20 set screw (typically used on antenna tripods). The spherical dipole can be oriented on the mount to support either vertical or horizontal polarizations. Accurate and repeatable polarization alignment is accomplished through the use of the polarization alignment tool which is incorporated into the design of the antenna mount.

A perspective view of the spherical dipole and mount is illustrated in Figure 2. The mount is fabricated out of plexiglas using 2.5 inch (6.4 cm) outer-diameter tubing for the support cylinder and a 1/4 inch (0.64 cm) plexiglas sheet for the base plate. When the spherical dipole is placed in the cylindrical antenna mount, its center is 11-1/8 inches (28.3 cm) above the surface that the mount is placed upon. The horizontal distance from the center of the spherical dipole to the edge of the base of the mount is equal to 3 inches (7.6 cm). Horizontal separation between the spherical dipole and receiving antenna can then be measured by subtracting 3 inches (7.6 cm) from the desired separation and using the base of the mount as a reference point.

Figure 3 is an illustration of the alignment tool placed on the antenna mount. The top horizontal edge of the half cylinder and the rounded edge of the vertical blade are used as reference lines for proper polarization alignment. For vertical polarization, the top edge of the spacer ring on the spherical dipole is placed even with the top horizontal edge of the alignment tool, as seen in Figure 4. For horizontal polarization, the spacer ring is centered on the vertical edge of the center blade of the alignment tool, as seen in Figure 5. After the spherical dipole is placed on the antenna mount and aligned for the desired polarization, the alignment tool is carefully removed from the mount. The mechanical drawings of the antenna mount and alignment tool are given in Attachment II.

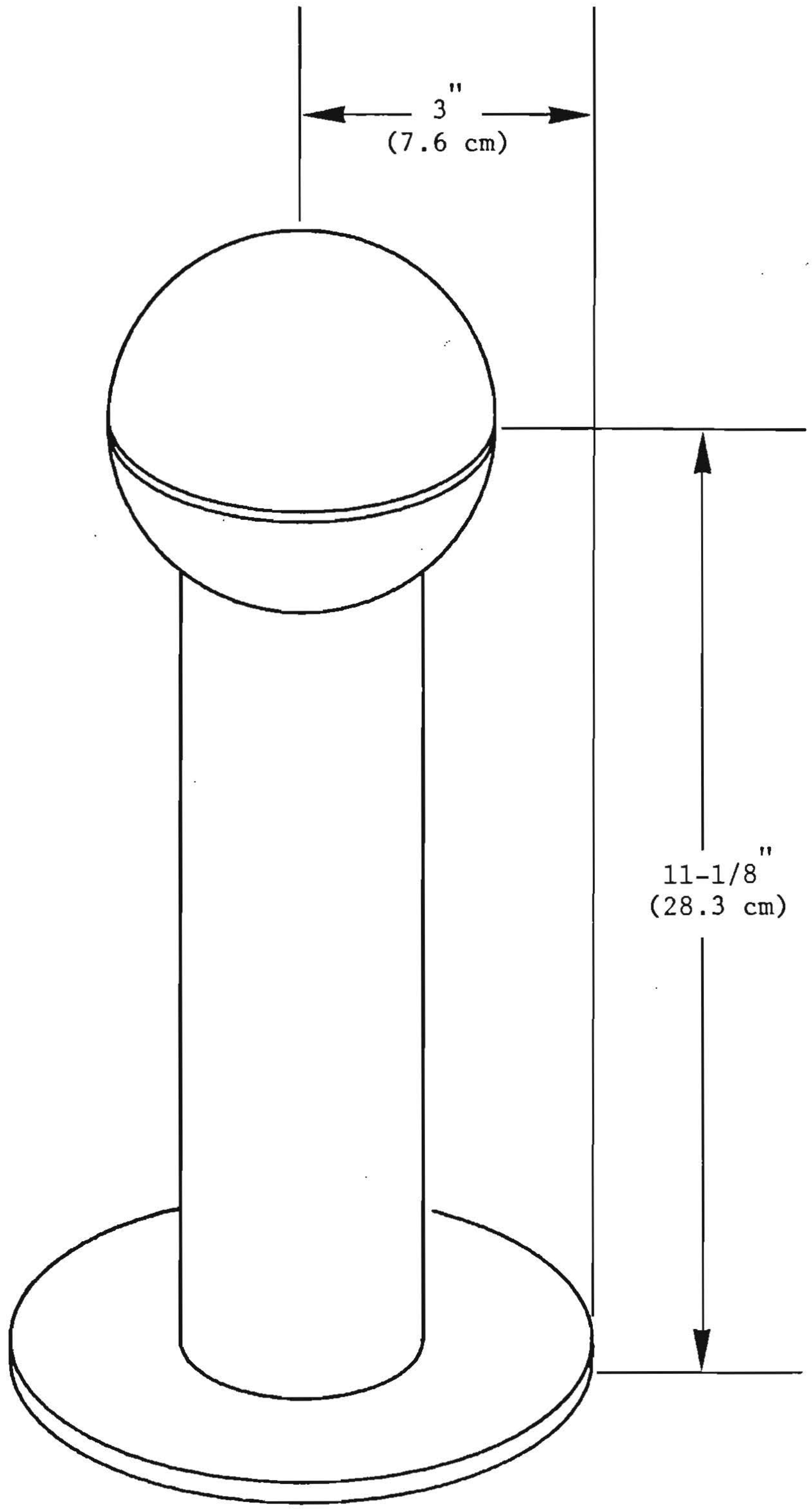


Figure 2. Perspective View of the Spherical Dipole Source Placed on its Cylindrical Mount

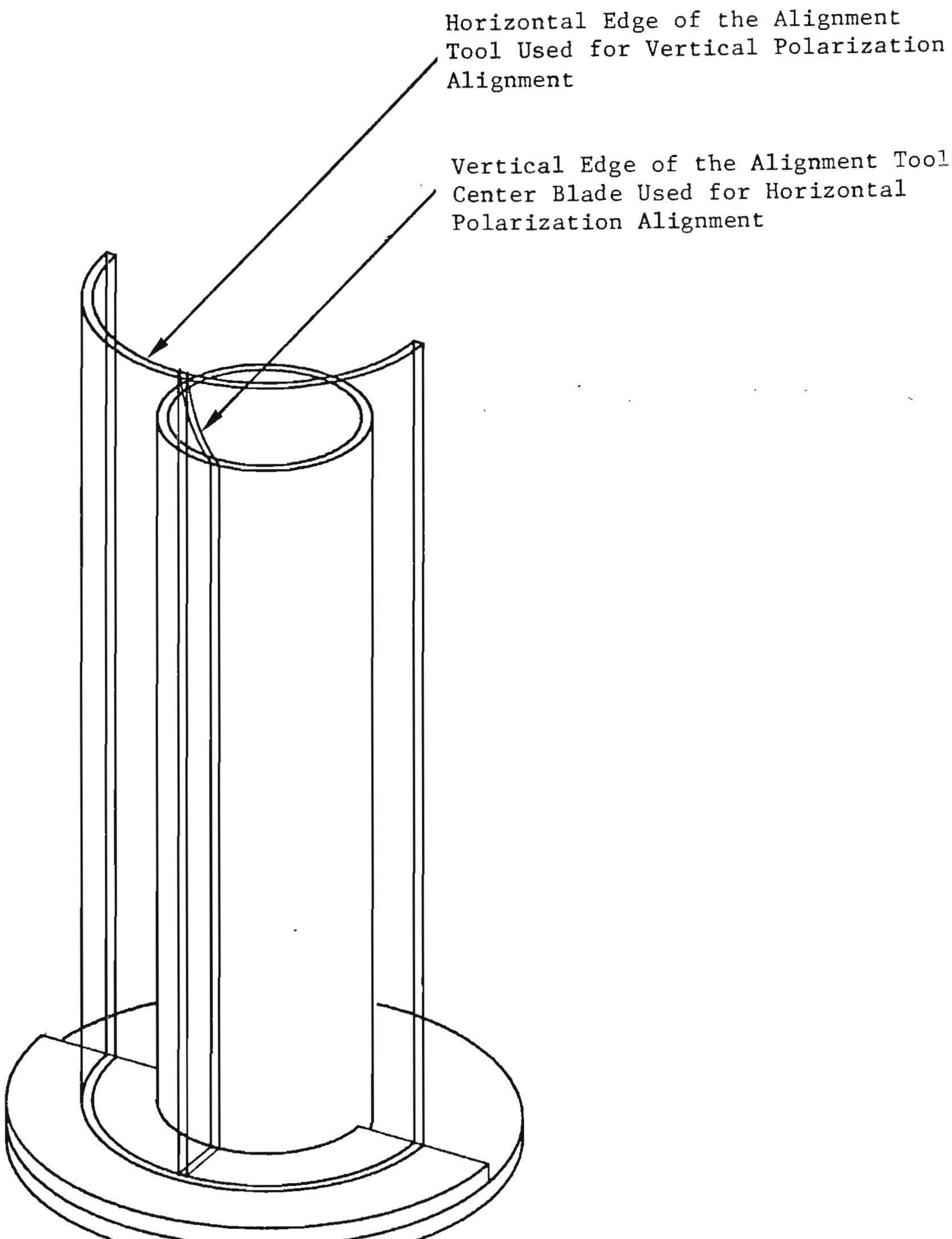


Figure 3. Alignment Tool and Mount for Spherical Dipole Source.

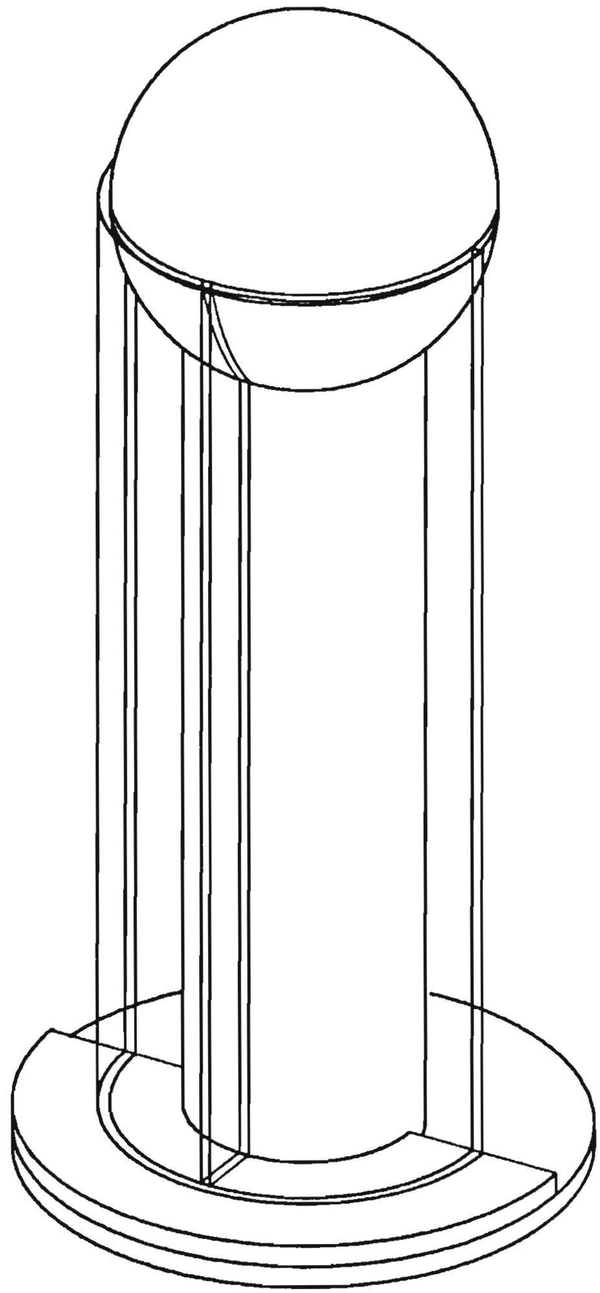


Figure 4. Spherical Dipole Mounted for Vertical Polarization Using the Top Horizontal Edge of the Alignment Tool

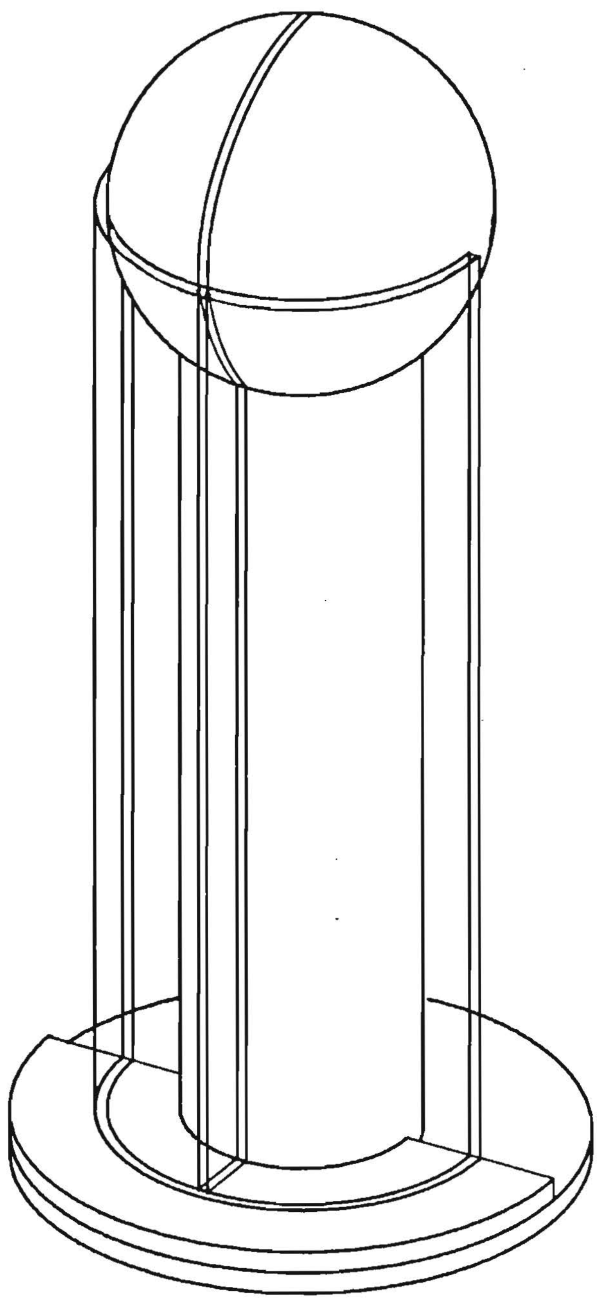


Figure 5. Spherical Dipole Mounted for Horizontal Polarization Using the Vertical Edge of the Center Blade of the Alignment Tool

2.2 Electrical

As previously discussed, the design of the transmitter involved the generation of multiple discrete frequency signals throughout the specified frequency range of 30 to 200 MHz. These signals were generated using a pulse train with a 5 MHz pulse repetition rate. Through Fourier analysis it can be shown that the frequency spectrum of the pulse train contains the 5 MHz fundamental signal and all of its harmonics up to a frequency limit which is set by the pulse rise and fall times and by the pulse width. This technique has the advantage of coherent synthesis in that the frequency stability of all of the signal components are dependent on a single signal source. In particular, if a crystal controlled frequency source is used to drive an impulse generator, then the frequency stability of each harmonic will be equal to the frequency stability of the crystal controlled source multiplied by its harmonic number. The amplitudes of the harmonics generated by the impulse generator are influenced by the load impedance presented to the impulse generator. Thus, through the proper design of an output matching network, a relatively uniform amplitude distribution can be obtained over the specified frequency band.

A complete block diagram of the transmitter is shown in Figure 6. The three major sections of the transmitter are (1) the RF generator, (2) the power supply, and (3) the output indicator. The RF generator is the heart of the transmitter circuitry since it delivers the RF signal to the antenna. The RF generator consists of a 5 MHz signal source, a 5 MHz amplifier, an impulse generator, a matching network, and an output driver circuit. The power supply serves the dual purpose of suppling power to the transmitter circuitry and controlling the radiated output by monitoring the power source life. The power supply includes a dc power source, an output controller, and a dc regulator. The output indicator visually indicates that the transmitting system is energized by flashing a light emitting diode (LED) at a periodic rate set by the timer circuitry.

The required electronic circuitry used to implement the block diagram shown in Figure 6 is discussed in the following three subsections. The component values and part numbers for the components shown in the schematic diagrams are presented in Attachment III.

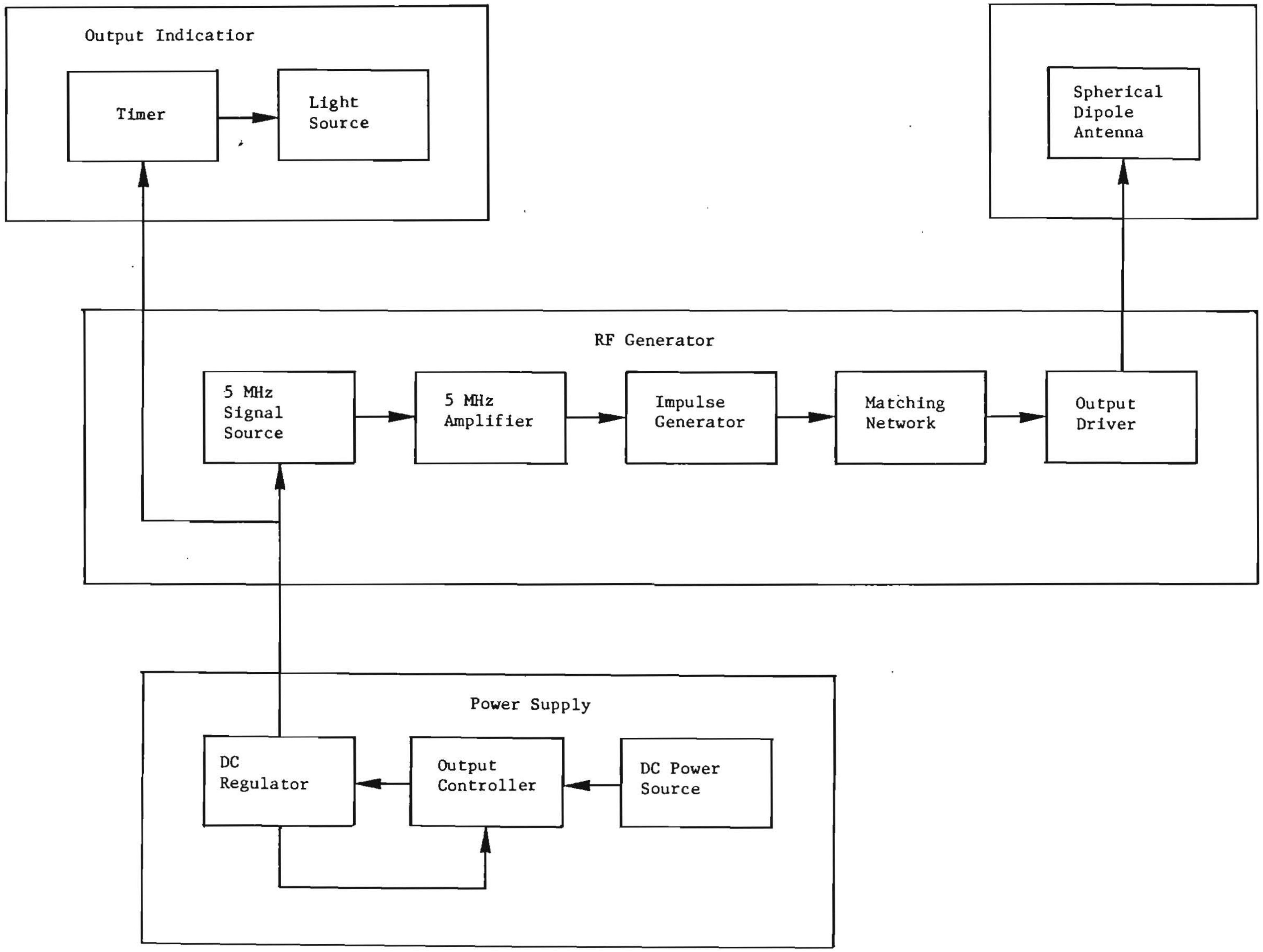


Figure 6. Block Diagram of the Transmitter for the Spherical Dipole Source.

2.2.1 RF Generator

The schematic diagram of the RF generator circuitry is shown in Figure 7. The CMOS crystal oscillator (IC1) used as the 5 MHz signal source offers the advantages of small size, low power consumption, precise frequency stability, and precise output level stability (with constant input dc supply voltage). The 5 MHz amplifier stage utilizes two bipolar transistors (T1, T2) in a Darlington configuration with the output configured as a common collector stage, thus offering the advantages of high input impedance, low output impedance, current amplification, and low parts count. The impulse generator circuit utilizes a step recovery diode (D1) with a characteristically fast transition time to ensure that the output of the pulse train has a rise time which is sufficient to generate harmonics through 200 MHz. The drive inductor (L1) in this section is used to store energy so that when the diode switches from its on to off state this energy is transferred to the spherical dipole antenna in the form of a transient current. The step recovery diode is dc biased through the self biasing resistor (R5). The output matching network (L2, C5, R6, C6, P1) is used to present the proper load impedance to the impulse generator circuit and is configured as a broadband matching network with a cutoff frequency of 250 MHz. The 3:1 transformer (P1) is used to step up the input pulse level driven into the bipolar transistor (T3) used in the output driver circuit. This circuit is configured as a class C amplifier with transistor (T3) biased off. When the input voltage applied to the base of the transmitter exceeds 0.7 volts the transistor is turned on and is quickly driven into saturation. Since the input signal to the transistor is a pulse train with a low duty cycle, a significant savings in battery current drain is obtained over a Class A amplifier. Also, since the supply current is fed through an inductor (L3), no dc voltage drop occurs and the output voltage can swing higher than the supply voltage, due to the stored energy in the magnetic field of the inductor. The result is an output waveform which is a pulse train with an amplitude of approximately 22 volts peak and a rise time which is fast enough to ensure output harmonics through 250 MHz.

Measurements of the input impedance of the spherical dipole antenna were performed using a GR-1710 network analyzer. The results of these measurements are illustrated in Figure 8 showing both the magnitude and phase of the input impedance over the frequency range from 15 MHz to 250 MHz. Note the resonance

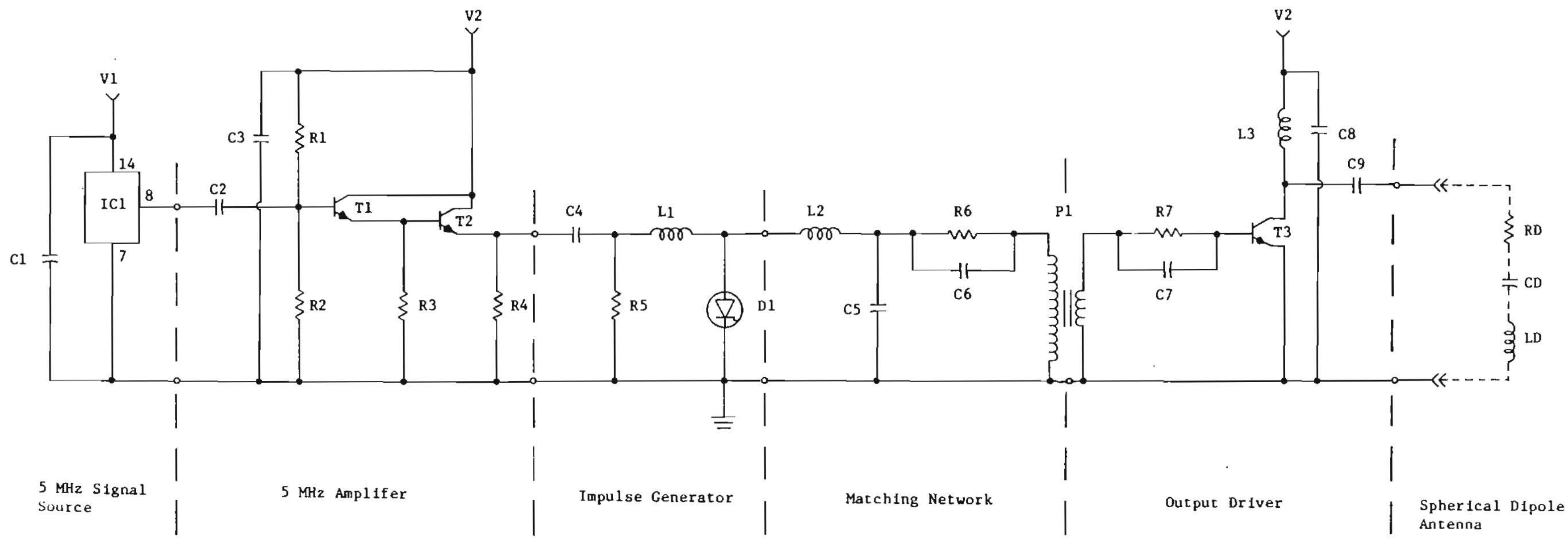


Figure 7. Schematic Diagram of the RF Generator Circuitry

at 157.5 MHz where the phase angle of the input impedance passes through zero and the magnitude nulls to its lowest value of 5 ohms. (It is believed that the inductance of the metal posts which feed the two hemispherical sections cause this resonance condition.) Also note that at frequencies below 100 MHz the input impedance is almost completely capacitive, as theoretically predicted [3]. The value of the capacitance as calculated from the measured impedance data is 36 pf, while the calculated inductance is 0.028 μH. The input impedance of the spherical dipole can be modeled from the measured data as the series RLC network shown in Figure 9.

The value of the radiation resistance of electrically small antennas is known to be proportional to frequency squared [4]. Thus, the value of the resistor R in the equivalent model is found by noting that at resonance (157.5 MHz) the input impedance is purely resistive and, from Figure 8, is equal to 5 ohms. From this measurement the proportionality constant is easily found to be 2.02×10^{-16} by dividing 5 ohms by the square of the frequency of resonance.

2.2.2 Power Supply

Figure 10 shows the schematic diagram of the power supply circuitry for the spherical dipole transmitter. The dc power is supplied by two standard 9 volt batteries connected in series. In order to maintain dc regulation, the battery voltage must be equal to or greater than 11.5 volts. Thus, the dc power supply life can be defined to be the time required to drain the battery voltage to 11.5 volts. Results of measurements performed indicate that a 9 volt alkaline battery will drain from 9 volts to 6.1 volts in 6 hours for an initial current drain of 55 mA, as seen in Figure 11. Since this is approximately equal to the total current drain of the transmitting circuitry, two 9V batteries in series will provide a dc power supply life of approximately 6 hours.

The output controller is used to manually turn the transmitter on and off and to automatically deenergize the transmitter when the battery life is exhausted. The manual on/off switch (SW1) is a subminiature 2-position rotary switch which is mechanically attached to the two spherical dipole halves. As previously discussed, this switch is used to manually energize/deenergize the transmitter by rotating the two brass hemispheres of the assembled spherical dipole in opposite directions. The automatic on/off switch utilizes a

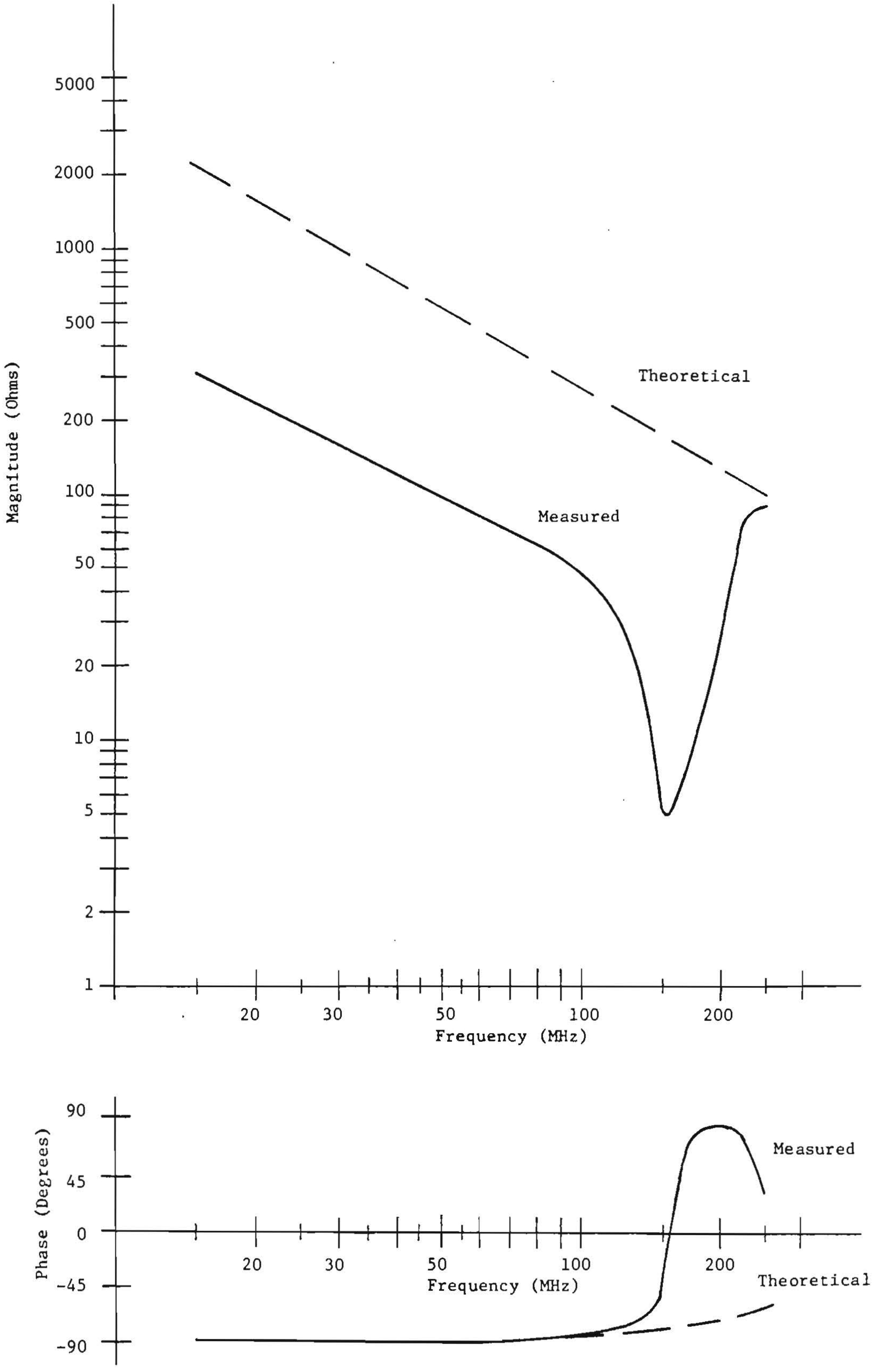


Figure 8. Measured Variation of the Magnitude and Phase of the Spherical Dipole Input Impedance as a Function of Frequency

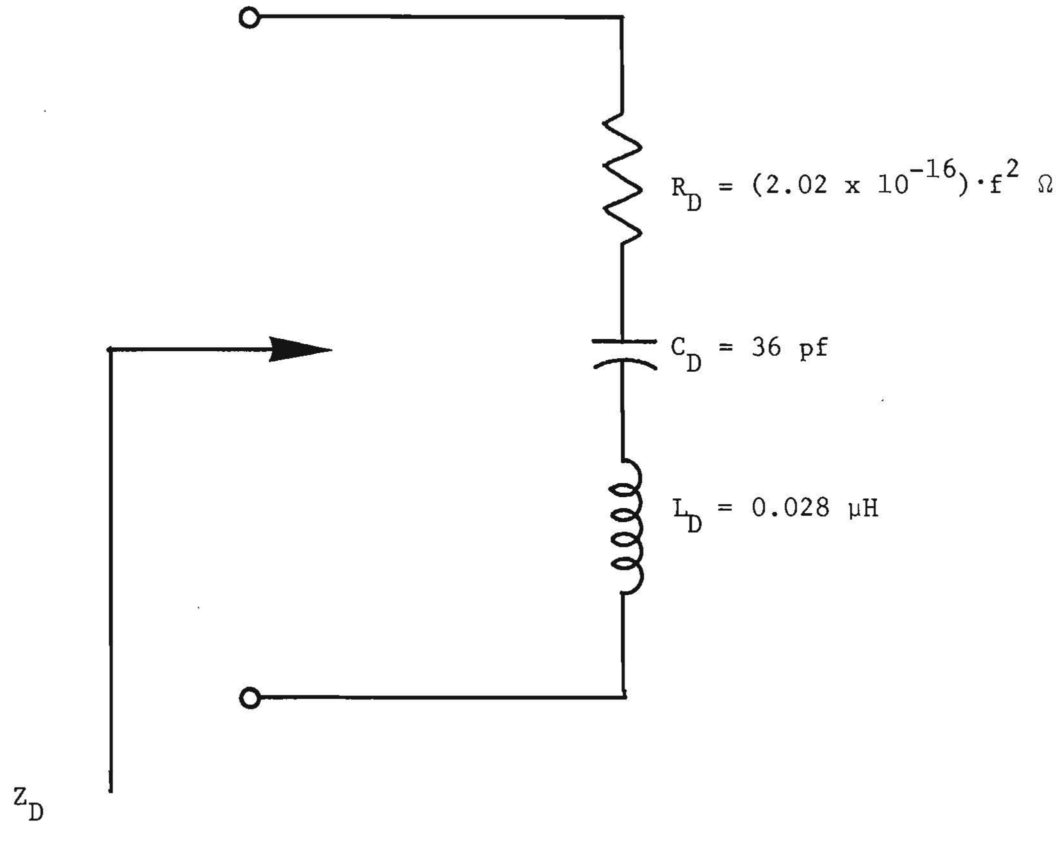


Figure 9. Equivalent Model of the Input Impedance to the Spherical Dipole Antenna.

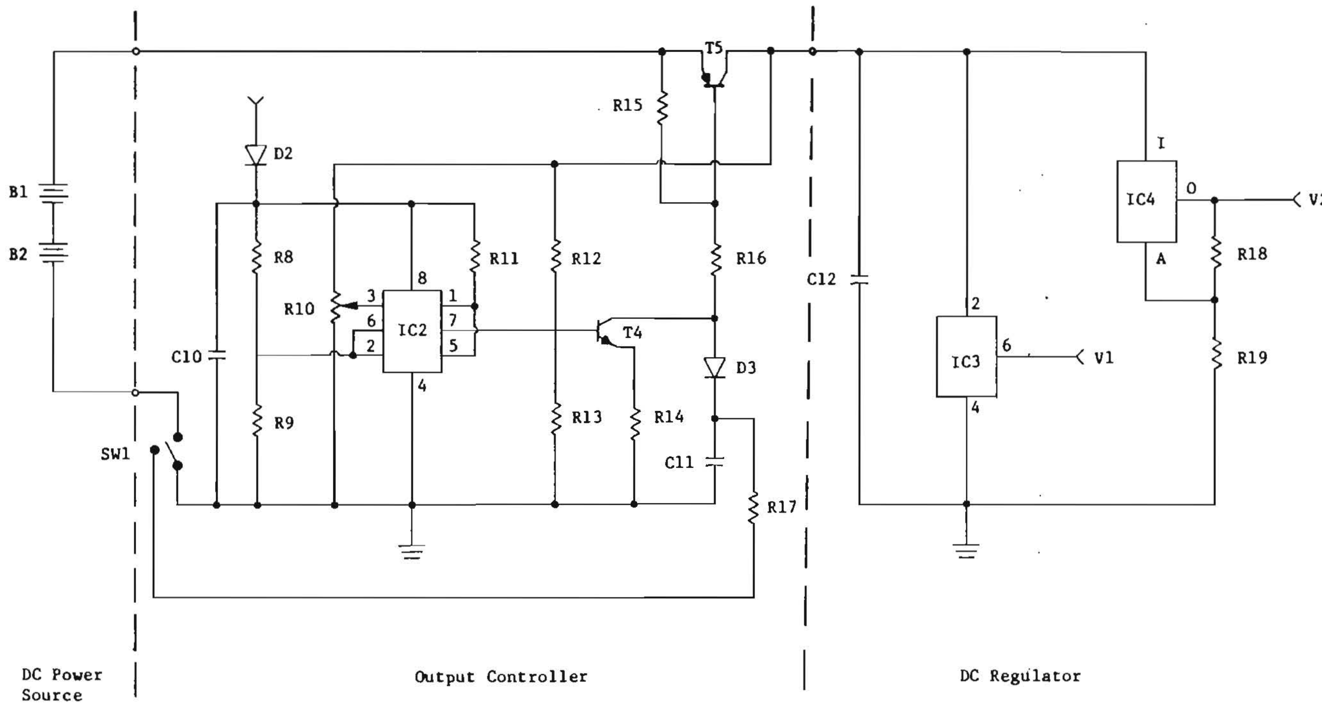


Figure 10. Schematic Diagram of the Power Supply Circuitry

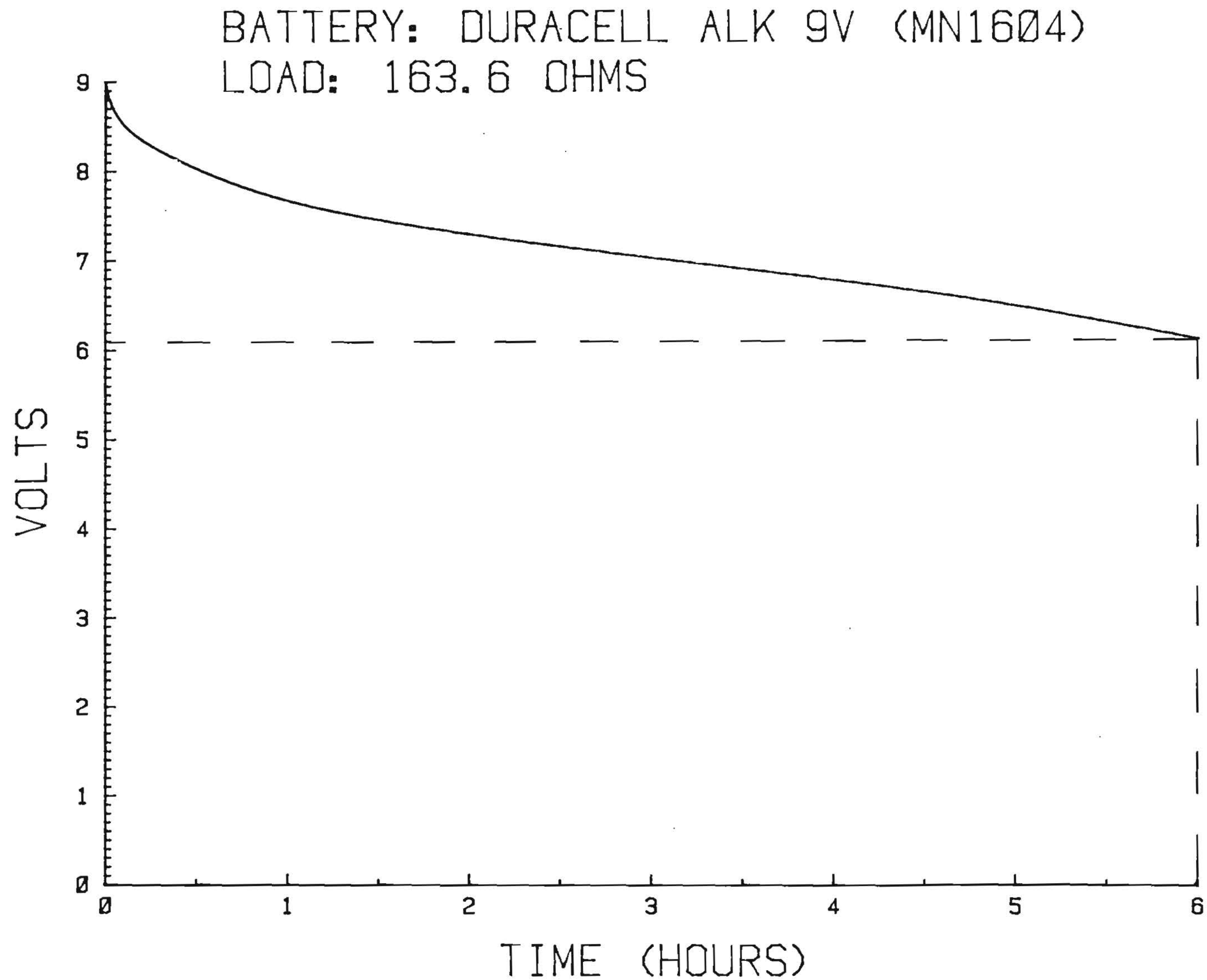


Figure 11. Battery Voltage Drain with Respect to Time for a 55mA Initial Load.

comparator (IC2) to compare the battery dc voltage to the regulated supply voltage. The comparator output is set through resistors R8, R9, and R10 to switch from its normally high state to a low state when the battery voltage falls to 12.0 volts. When the comparator output drops to its low state, transistor T4 is shut off which in turn shuts transistor T5 off. When transistor T5 is turned off the battery voltage is removed from the dc regulator input, which turns off the transmitter and the output indicator light. The automatic on/off switch is initially allowed to turn on by the initial transient which is conducted through the initializing capacitor (C11). The resistor (R17) connected to the second position of the manual on/off switch is used to discharge the initializing capacitor (C11) when the circuit is turned off.

The dc regulator circuitry utilizes two independent regulators -- a 5 V Precision Monolitic voltage reference (IC3) which is used to power the 5 MHz crystal oscillator, and an adjustable voltage regulator (IC4) which is set to 9.5 volts through resistors (R18 and R19) and is used to power the remaining circuitry. The voltage reference (IC3) output voltage stability is temperature compensated and its longterm stability is specified to be more accurate than the voltage regulator (IC4); however, the voltage regulator has higher output current capacity. Thus, the voltage reference is used to power the 5 MHz crystal oscillator since the oscillator only requires an input current of 1.1 mA, and since the output level of the oscillator is highly dependent on the input dc voltage. The voltage regulator powers the remaining circuitry supplying the required current. This configuration optimizes the stability of the output field levels.

2.2.3 Output Indicator

The output indicator circuitry, shown in Figure 12, utilizes a flashing LED (D4) to visually indicate that the transmitter is energized. The LED is pulsed at approximately a one second repetition rate and a 10 percent duty cycle; thus, power consumption used in the output indicator circuit is reduced by approximately 90 percent from the power consumption required to have the LED on continuously. The pulse rate and duty cycle are controlled by the 7555 timer (IC5), resistors (R20 and R21), and capacitor (C13). The 7555 timer is a CMOS version of a 555 timer. The output indicator circuit is

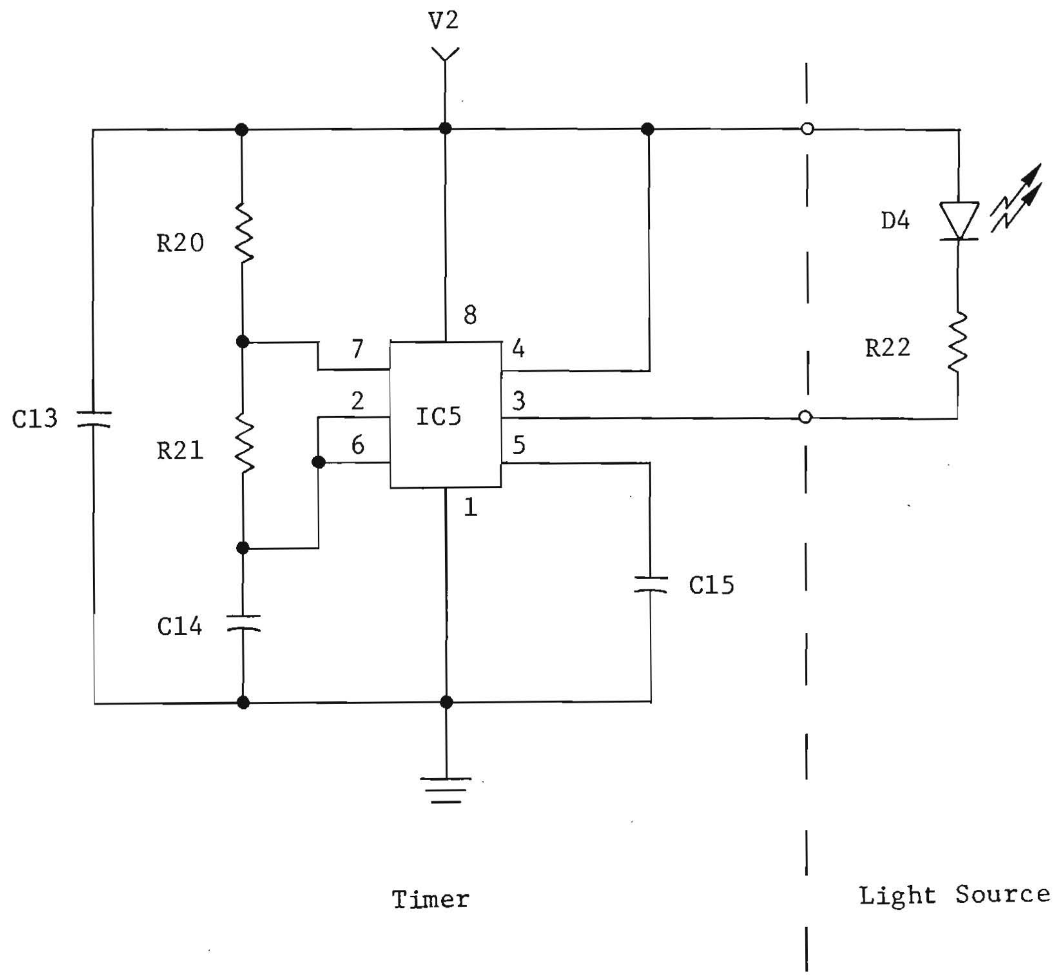


Figure 12. Schematic Diagram of the Output Indicator Circuitry

powered by the 9.5 volt regulator (IC4); thus, when the battery voltage drops below the required level to maintain regulation, the output controller circuit turns off the LED flasher as well as the radiated field. In this manner, the output indicator light provides a visual indication that the battery voltage is sufficient to maintain regulation of the transmitter output level.

3.0 CALIBRATION MEASUREMENTS

Calibration measurements were performed to define the performance characteristics of the spherical dipole source. Individual tests include spectrum content measurements, amplitude and frequency drift measurements, radiation pattern measurements, 3-meter field strength measurements, and repeatability measurements. The measurement procedures and technique for each of the various performance tests are described below and the results of the performance tests are presented in summary form. The complete set of performance data for each of the two individual spherical dipole sources constructed are given under separate cover entitled "Performance Data, Spherical Dipole Source, Serial No. 005 or 006" [5-6].

3.1 Spectrum Content Measurements

The spectrum content measurements involved the determination of the power output/field strength versus frequency characteristics of the spherical dipole source. Thus, the spectrum content measurements include the definition of both desired and undesired emissions. The desired emissions are comprised of the 5 MHz fundamental signal and all of its associated harmonics up to and beyond 200 MHz. Undesired emissions would include signals at frequencies which are not a harmonic multiple of the 5 MHz fundamental but may be a result of intermodulation products or modulation components.

The spectrum content measurements were performed in both a conducted and radiated mode. The conducted measurements were performed in a shielded room in order to eliminate interference caused by signals in the external environment which might couple into the test setup. The radiated measurements were performed in a TEM cell which served the dual purpose of isolating the radiated field from the environment and providing a receiving aperture for the radiated field which has a relatively uniform response for frequencies from dc up to its cutoff frequency of 200 MHz. Above 200 MHz, high-frequency resonances and multimoding occur within the cell and distort the uniform characteristics of the cell's TEM mode.

Figures 13 and 14 illustrate the spectrum content conducted measurement set up and the instrumentation interconnection, respectively. A conducted measurement attachment fixture was used to connect the spherical dipole to the receiver. Its assembly is illustrated in Figure 15. After the two hemispheres

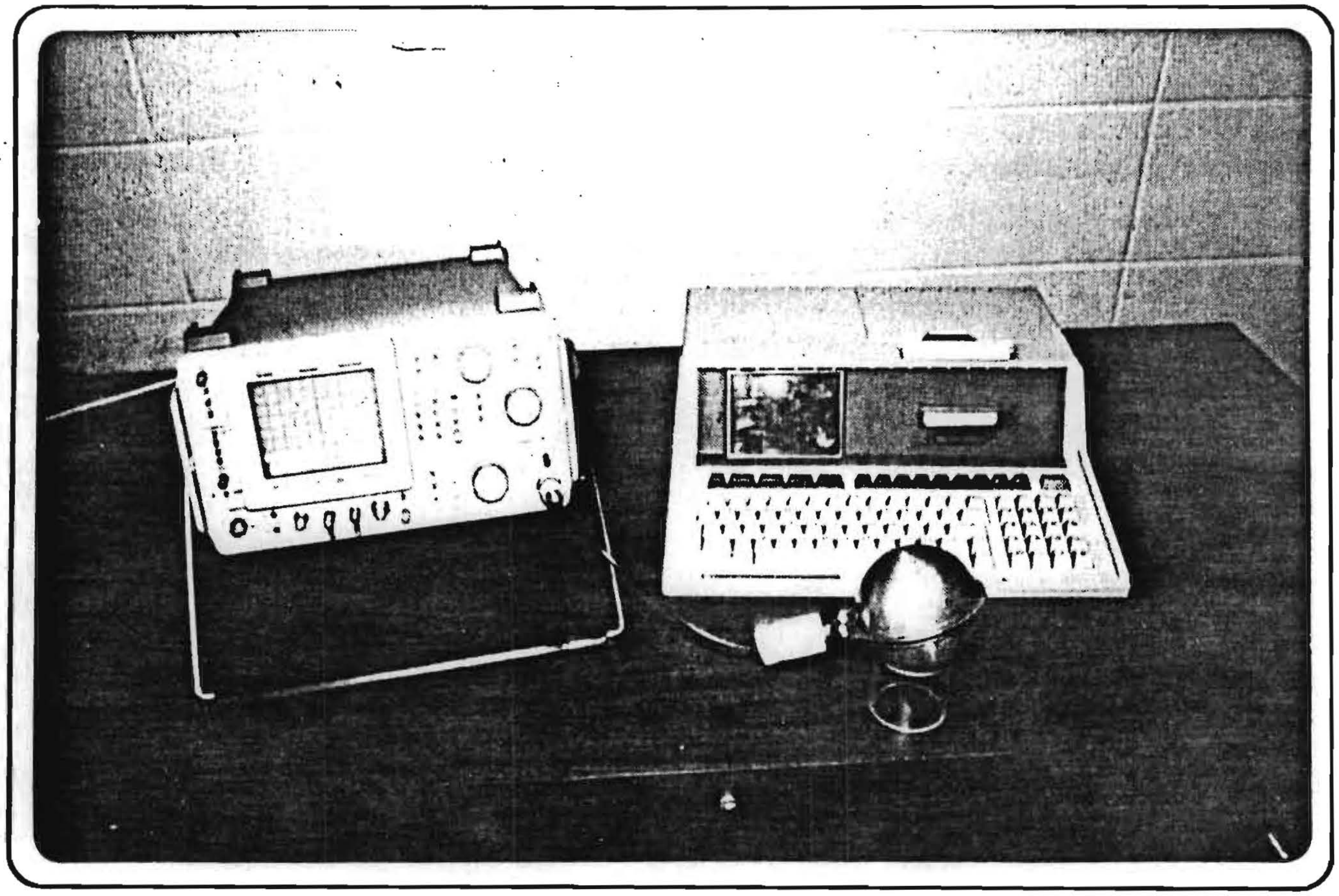


Figure 13. Pictorial View of Spectrum Content Conducted Measurement Set Up.

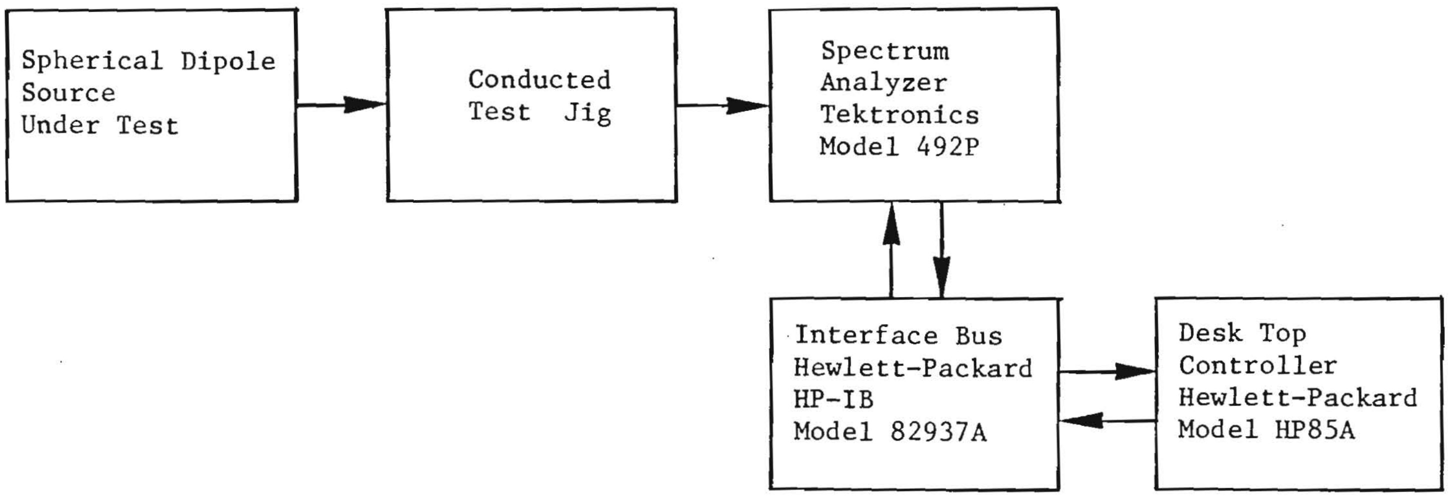


Figure 14. Block Diagram Identifying Instrumentation Interconnection for the Spectrum Content Conducted Measurement Set Up

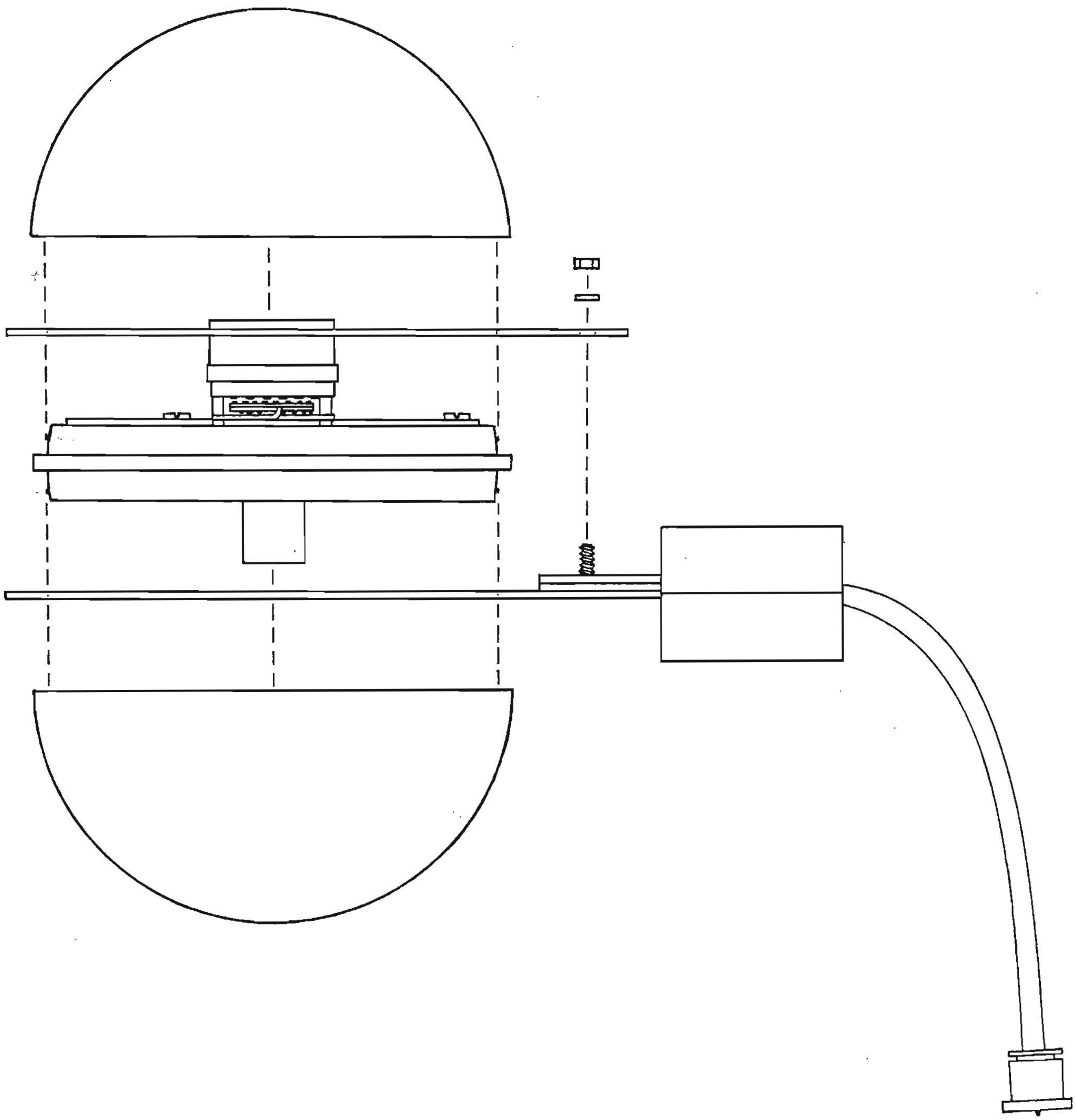


Figure 15. Exploded View Showing Assembly of Spherical Dipole onto the Conducted Measurement Setup Attachment Fixture.

are disconnected from the attachment posts and the attachment fixture is assembled onto the Delrin ring, the rotary switch is rotated clockwise to turn the transmitter on. The hemispheres are then screwed onto the attachment posts until they come into firm contact with the attachment fixture.

A Tektronics 492P spectrum analyzer was used as the receiver. Using a 100 kHz resolution bandwidth the spectrum analyzer was initially set to have a 20 MHz span/division scale on the horizontal axis and a 10 dB/division scale on the vertical axis. With the center frequency set to 100 MHz, the spectrum content from 0-200 MHz could be viewed on the spectrum analyzer display. Changing the frequency span/division to 50 MHz and center frequency to 250 MHz allowed the spectrum from 0-500 MHz to be viewed. Results of these measurements on spherical dipole Serial Number 006 are shown in Figure 16. Note that all of the conducted signals measured are desired signals (harmonics of the 5 MHz fundamental) and that their levels varied approximately 30 dB over the 30-200 MHz frequency band.

In order to get an accurate reading of the level of each signal component, the spectrum analyzer's vertical display setting was changed to 1 dB/division and its frequency span to 500 kHz/division. The center frequency was then tuned to each harmonic frequency from 30 MHz to 200 MHz and the level of each signal measured in an automated mode using the HP-85 desktop computer as the controller. These results are tabulated in the "Performance Data" documents [5-6].

The spectrum content measurements were then repeated in a radiated mode using a TEM cell as depicted in Figure 17. A block diagram of the instrumentation setup is shown in Figure 18. The measurements and measurement procedures were identical to those described above for the conducted measurements. The radiated spectrum for spherical dipole Serial Number 006 as measured in the TEM cell is shown in Figure 19. Note that the measured field levels varied approximately 18 dB over the 30-200 MHz band. Also note the resonance of the radiated spectrum at approximately 150 MHz which can be associated with the measured resonance of the impedance of the spherical dipole antenna. The radiated spectrum above 200 MHz could not be measured in the TEM cell due to resonance and multimoding problems associated with the TEM cell above this frequency. The results of the amplitude measurements between

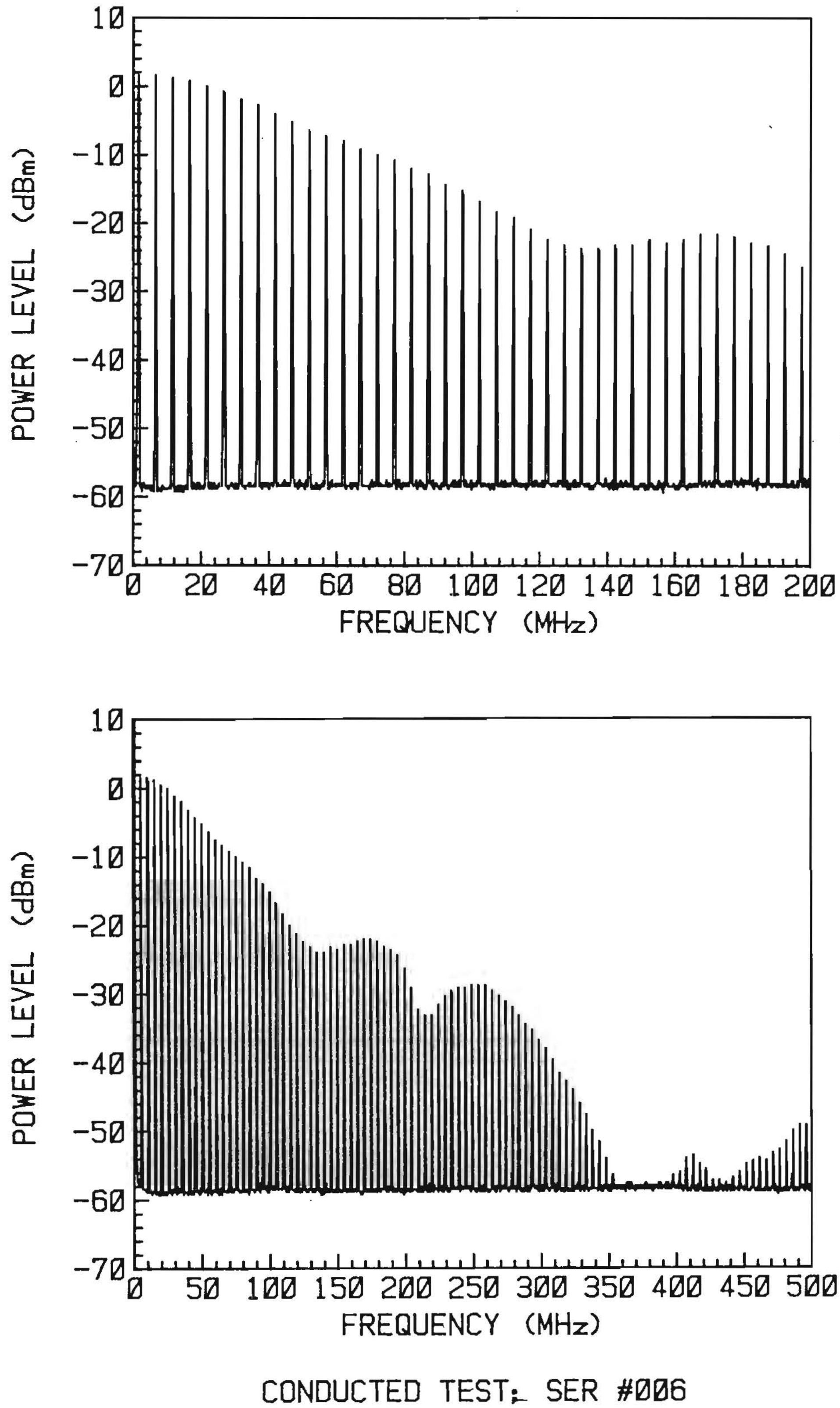


Figure 16. Spectrum Content of the Conducted Signal Levels Onto the Spherical Dipole Antenna Terminated Into the 50 ohm Input Impedance of the Spectrum Analyzer.

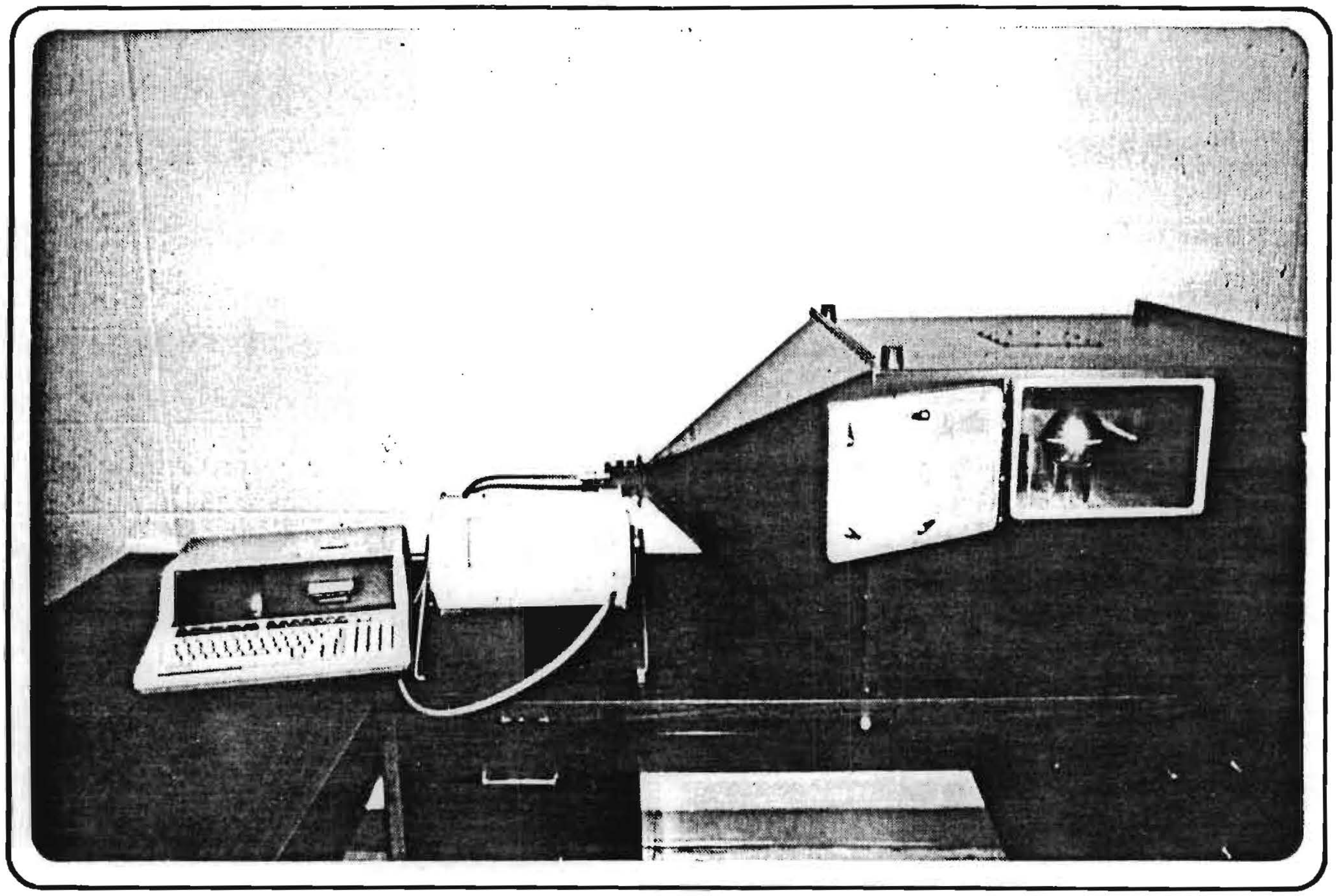


Figure 17. Pictorial View of Spectrum Content Radiated Measurement Set Up.

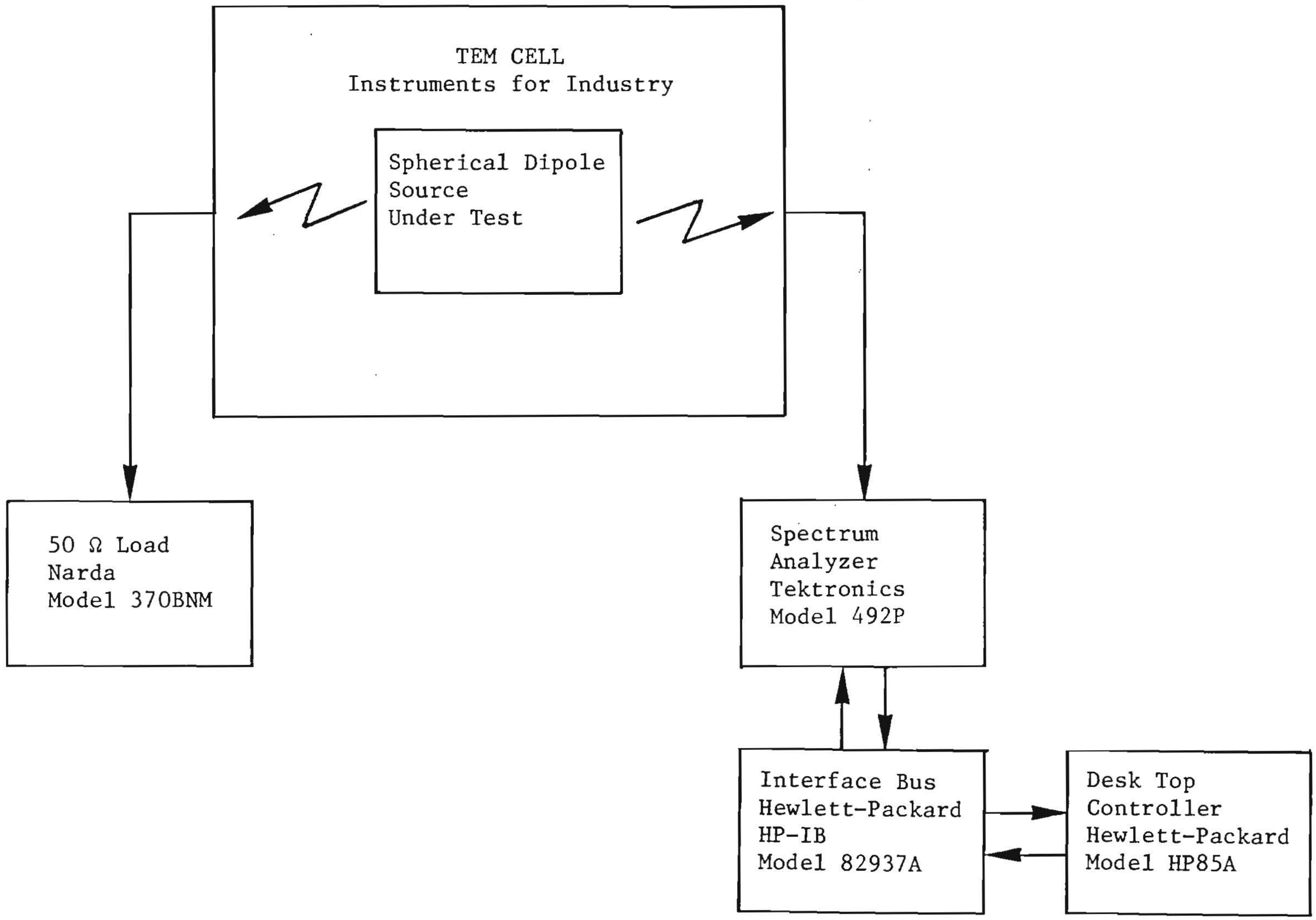


Figure 18. Block Diagram Identifying Instrumentation Interconnection for the Spectrum Content Radiated Measurement Set Up.

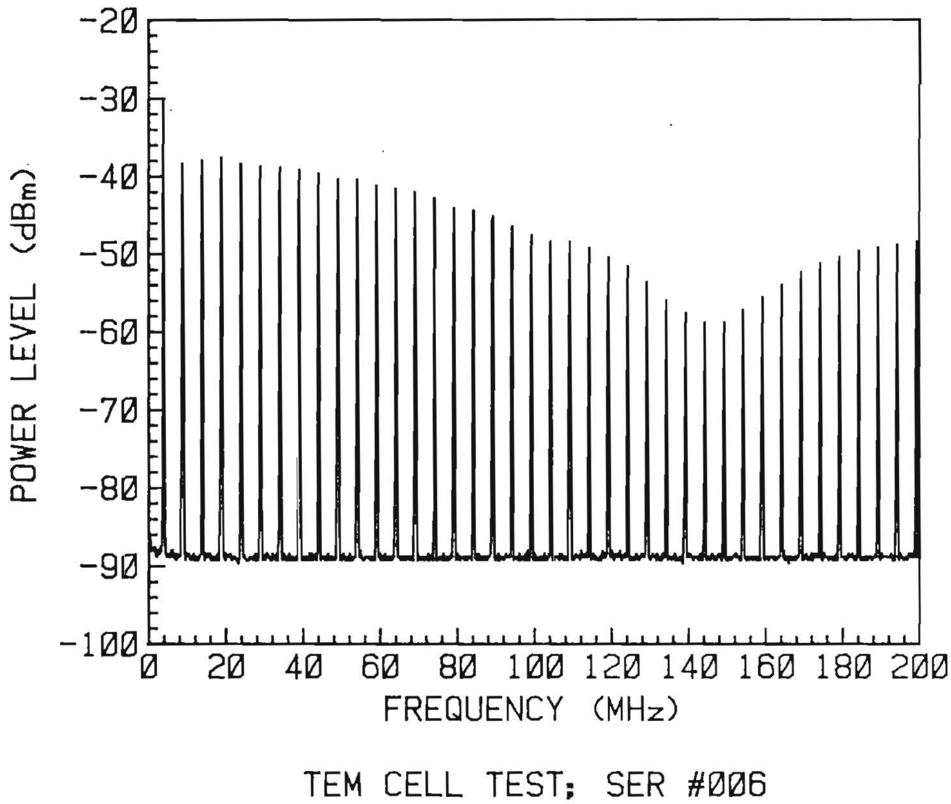


Figure 19. Spectrum Content of the Radiated Field From the Spherical Dipole Transmitting Anetnna System as Received Through a TEM Cell.

30 and 200 MHz for the two spherical dipole transmitters are also given in the "Performance Data" documents [5-6].

3.2 Frequency and Amplitude Drift Measurements

This section describes the measurements performed to determine the frequency and amplitude drift versus time of the radiated signals. These measurements are also indirectly a measure of the battery life, since as previously stated, the transmitter automatically turns itself off when the battery voltage is drained below 12.0 volts. A new set of batteries was used at the start of the test and the battery life determined by noting the time at which all the field components went to zero.

The measurements were performed in a radiated mode using the TEM cell as the receiving aperture. Since the frequency drift of each of the radiated signal components are all harmonically related to the frequency drift of the fundamental oscillator (5 MHz), frequency drift measurements on all the radiated signal components were not required. Through the use of appropriate multipliers, the measured value of frequency drift for one frequency component can be used to calculate the frequency drift of all other frequency components. The 40th harmonic of the fundamental oscillator frequency (200 MHz) was selected for measurement since it will exhibit the largest frequency drift of those signals in the 30-200 MHz frequency band, thus offering the maximum measurement sensitivity. The frequency drift of all other frequency components can then be calculated by multiplying the measured drift of the 40th harmonic frequency by X/40, where X equals the harmonic number of the signal for which the drift is being calculated. The amplitudes of the harmonic signals are not harmonically related, however, and may vary independently; thus the amplitude drift measurements were performed on each of the signal components in the 30 to 200 MHz frequency range.

Due to the large number of points required for these tests, the measurements were performed in an automated measurement setup utilizing an HP-85 desktop computer as the controller, a Tektronics 492P spectrum analyzer as the receiver for the amplitude measurements, and an EIP 548A frequency counter to perform the frequency drift measurements. Figure 20 is a photograph showing the measurement set up while Figure 21 shows the instrumentation interconnection for the frequency drift measurements. The measurement setup

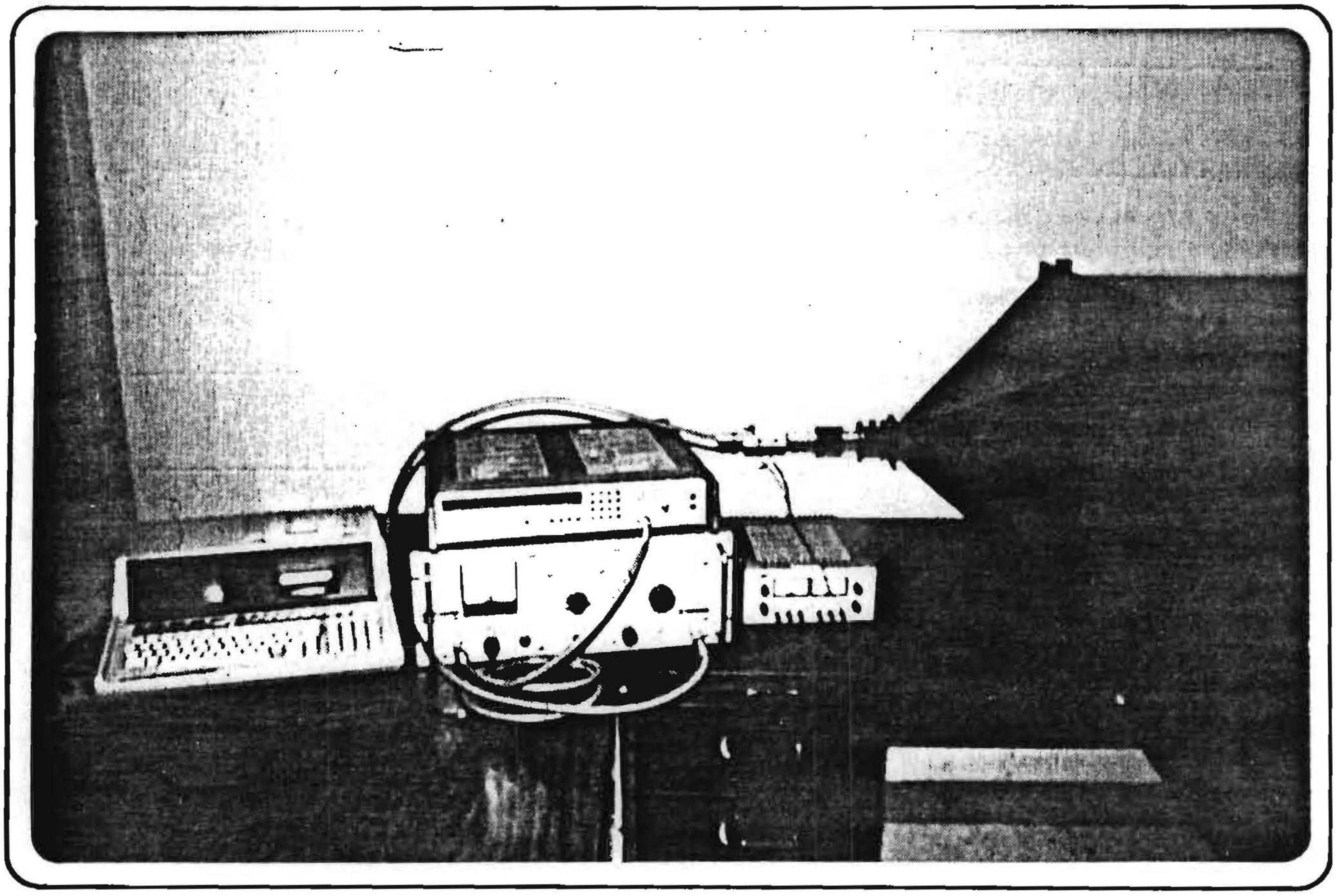


Figure 20. Pictorial View of Frequency Drift Measurement Set Up

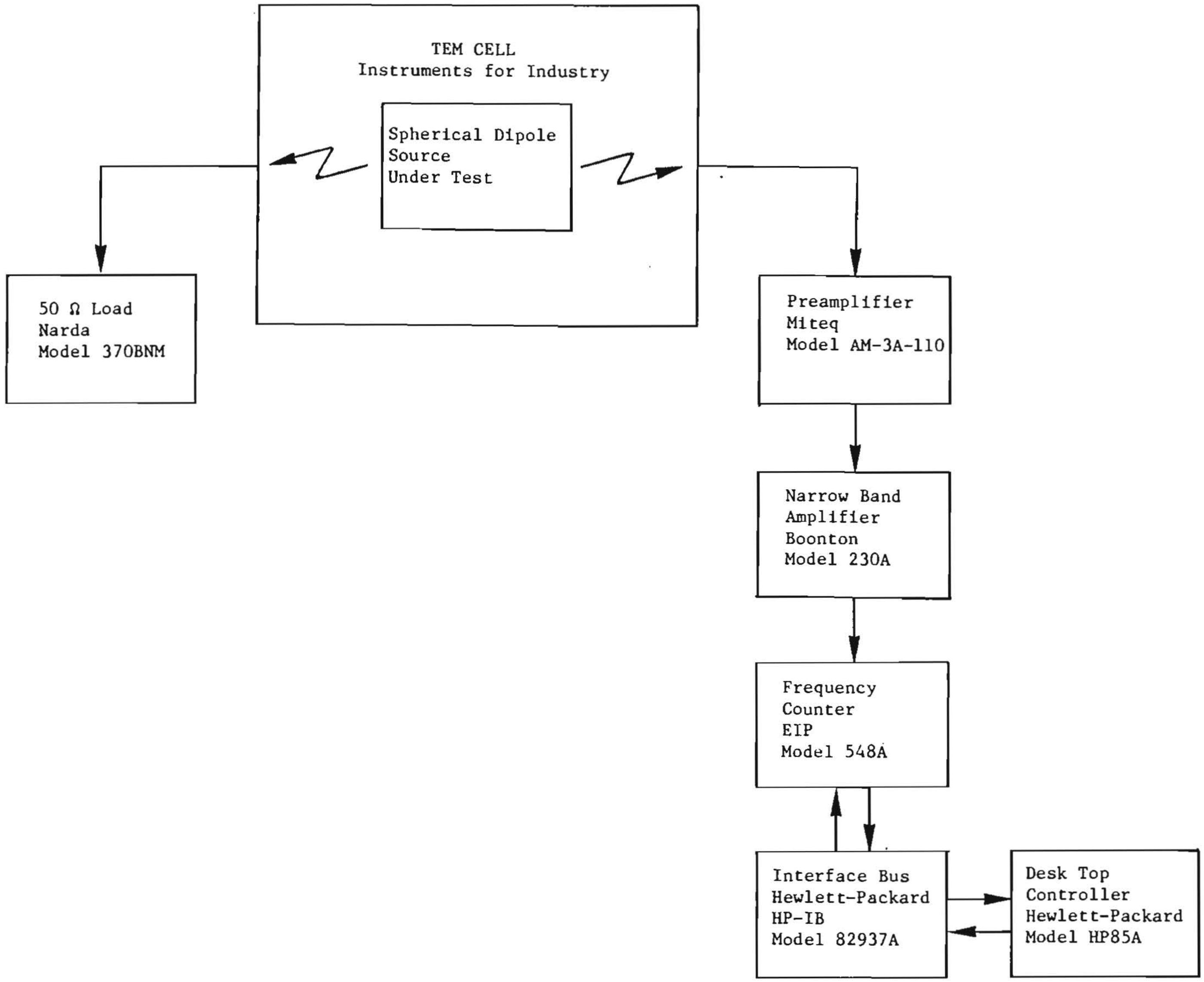


Figure 21. Block Diagram Identifying Instrumentation Interconnection for the Frequency Drift Measurement Set Up

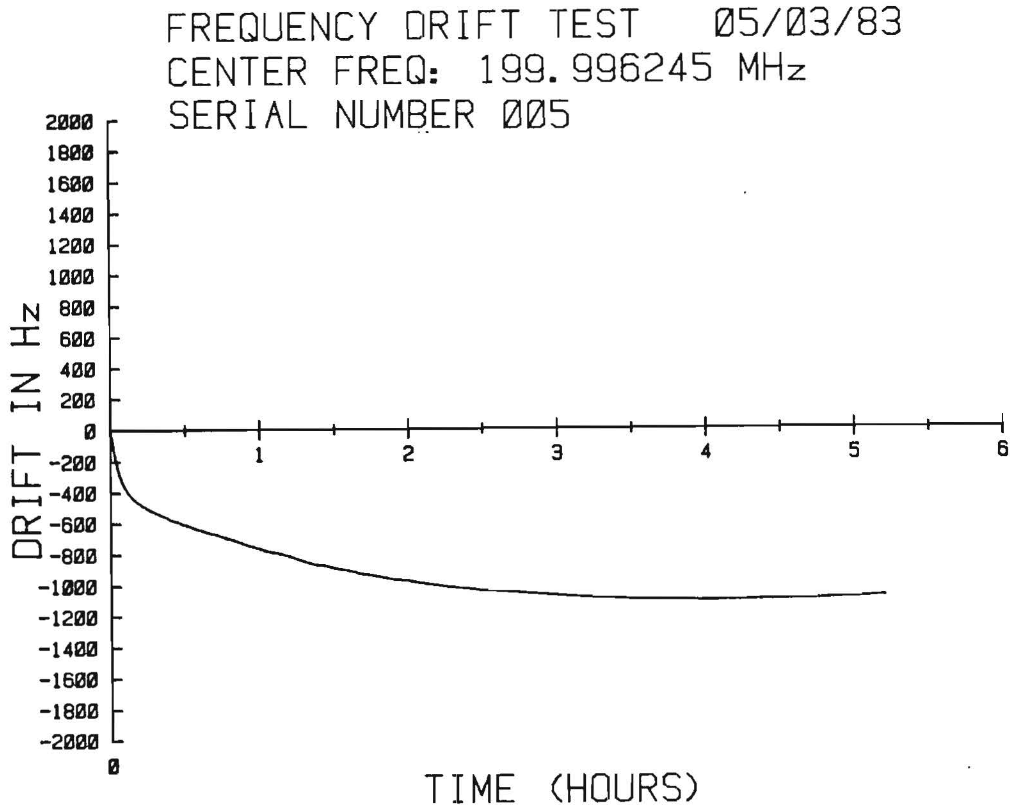
used for the power drift measurement was identical to that used in the spectrum content measurements shown in Figures 17 and 18.

The computer programs used to automate the frequency and amplitude drift tests and plot the meaured results were written in HP-85 Basic. A copy of the machine codes are given in Attachment IV. "FRQTST" is the program used for the frequency drift tests, "PWRTST" is the name of the program used for the power drift tests, and "PLTF/P" is used to plot the measured results from both the frequency and power drift tests.

Both the frequency and power drift tests were performed by first storing an initial value for the frequency or power level measured at the start of the test. These measurements were then continuously repeated noting any deviations from the initial value. Measurements were repeated in 5 second intervals for the frequency drift measurements. The power drift measurements were made at each harmonic by using the controller to tune the spectrum analyzer from 5 to 200 MHz stopping at each harmonic for the amplitude measurement. An entire scan from 5 to 200 MHz took approximately 6 minutes, thus setting the sample rate for the power drift measurements at each frequency. The minimum length of the drift measurements is set at the beginning of the test; however, the controller automatically stopped the test when the transmitter turned itself off due to low battery voltage (the time of drop out was recorded).

Figure 22 shows the results of the frequency drift measurement performed on spherical dipoles serial number 005 and 006. Note that the maximum frequency drift measured was slightly over 1 kHz which is well within the desired goal since a 4 kHz drift in 4 hours was desired. Also note that a battery life greater than 5 hours was realized which is also greater than the 4 hour performance goal.

A representative graph of the results of the amplitude drift measurements is shown in Figure 23, which shows the results of the amplitude drift measurements of the 6th harmonic (30 MHz) for spherical dipole serial number 006. The complete set of all the harmonics (30 - 200 MHz) is given in the "Performance Data" documents [5-6] for each of the spherical dipole transmitters. The maximum drift of any of the harmonic signals for spherical dipole serial number 005 is 0.25 dB and the maximum drift of any of the harmonics for serial number 006 is 0.75 dB. Note that these drift measurements are within the specified $\pm$ 1.0 dB performance goal.



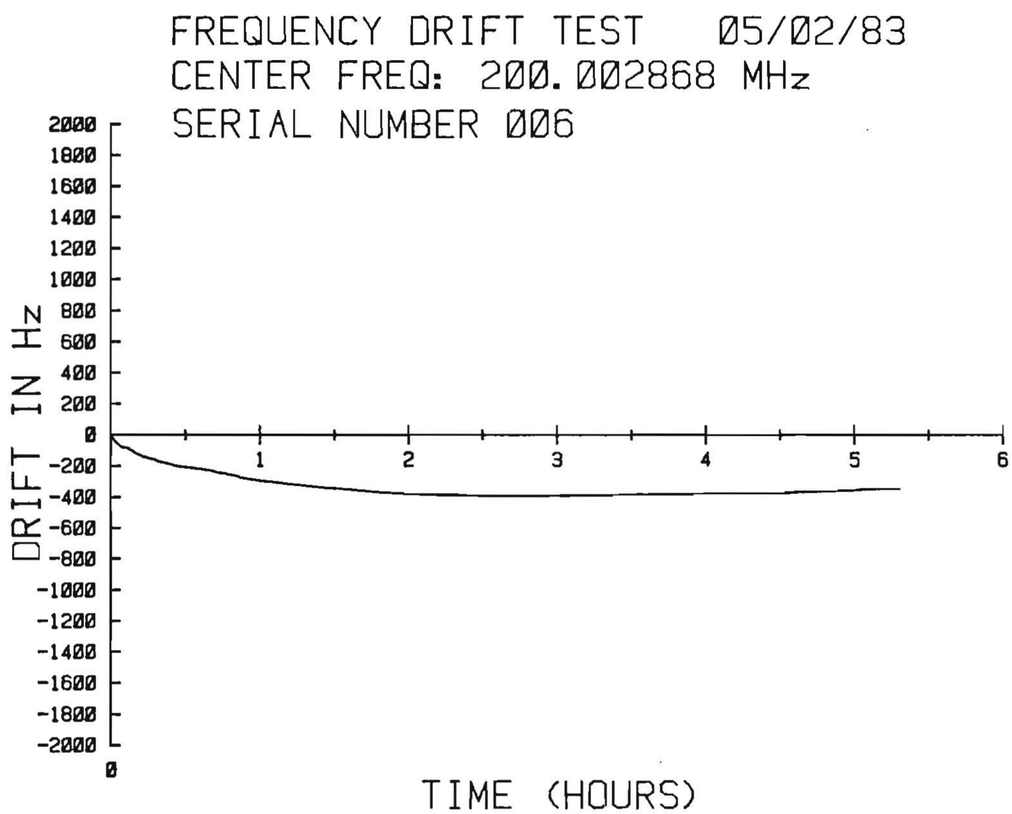


Figure 22. Frequency Drift of the 40th Harmonic Component of Spherical Dipole Serial Number 005 and 006 During Entire Battery Life

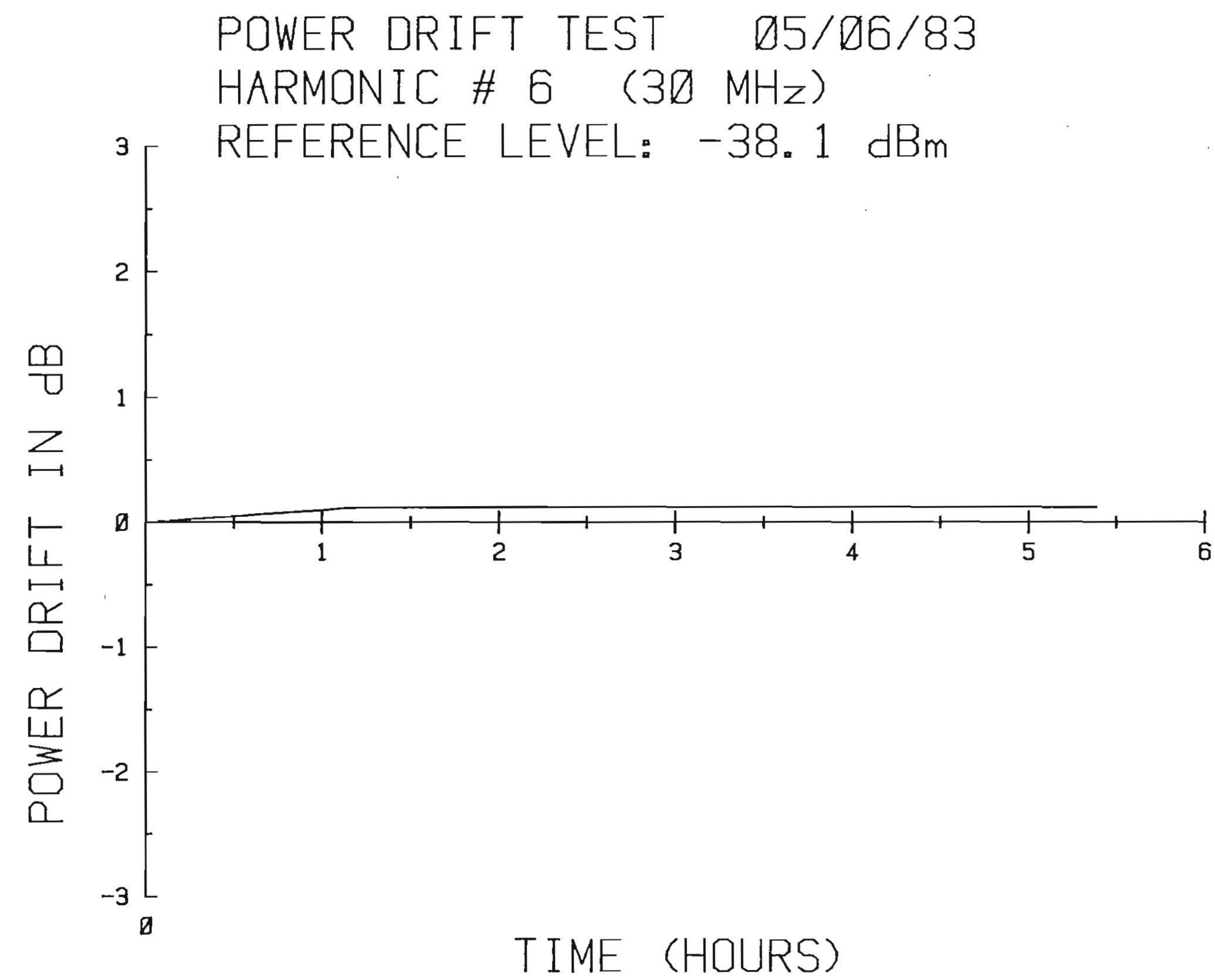


Figure 23. Amplitude Drift of the 6th Harmonic Component of Spherical Dipole Serial Number 006 During Entire Battery Life.

3.3 Radiation Pattern Measurements

The radiation characteristics of the spherical dipole source was specified to be equivalent to the donut pattern associated with an electrically small antenna. Specifically, the radiation pattern is to be omnidirectional in the plane normal to the axis of the dipole with less than ± 2 dB variation throughout an entire 360 degree rotation. The pattern is also specified to be a maximum in the plane going through the center of the dipole and normal to it.

The radiation pattern measurements were performed on an outdoor field site utilizing a 9m by 6m wire screen ground plane. A biconical antenna was used as the receiving antenna since its bandwidth covered the entire 30 to 200 MHz frequency range over which the radiation pattern measurements were to be performed. Figure 24 is a photograph depicting the outdoor field site, antenna placement, and antenna mounting apparatus. Note that the spherical dipole is mounted on its associated plexiglas mount, which is placed on top of a styrofoam pedestal. The styrofoam pedestal is secured to the turntable platform used to rotate the spherical dipole for the radiation pattern measurements. The height of the spherical dipole center is approximately 1 meter (within ± 1 cm) above the ground plane. The biconical antenna is mounted on a wooden tripod approximately 1.5 meters (within ± 1 cm) above the ground plane.

A block diagram showing the instrumentation interconnection is given in Figure 25. The Miteq low noise, high gain preamplifier is used to set the receiving system sensitivity/noise figure. The Boonton narrowband amplifier is used to selectively amplify the harmonic at which the pattern measurement is to be performed while attenuating the relative amplitude of all the other harmonic signals and all the ambient signals which are outside its bandwidth. The Ailtech amplifier is then used to supply additional amplification to the signal. The Scientific Atlanta receiver measures the relative amplitude of the received signal and sends an output signal which is proportional to the received signal level to the Scientific Atlanta pattern recorder. The Scientific Atlanta positioner control unit is used to rotate the Scientific Atlanta turntable. The Hewlett Packard signal source is used to tune the Scientific Atlanta receiver and to verify the linearity of the receiving

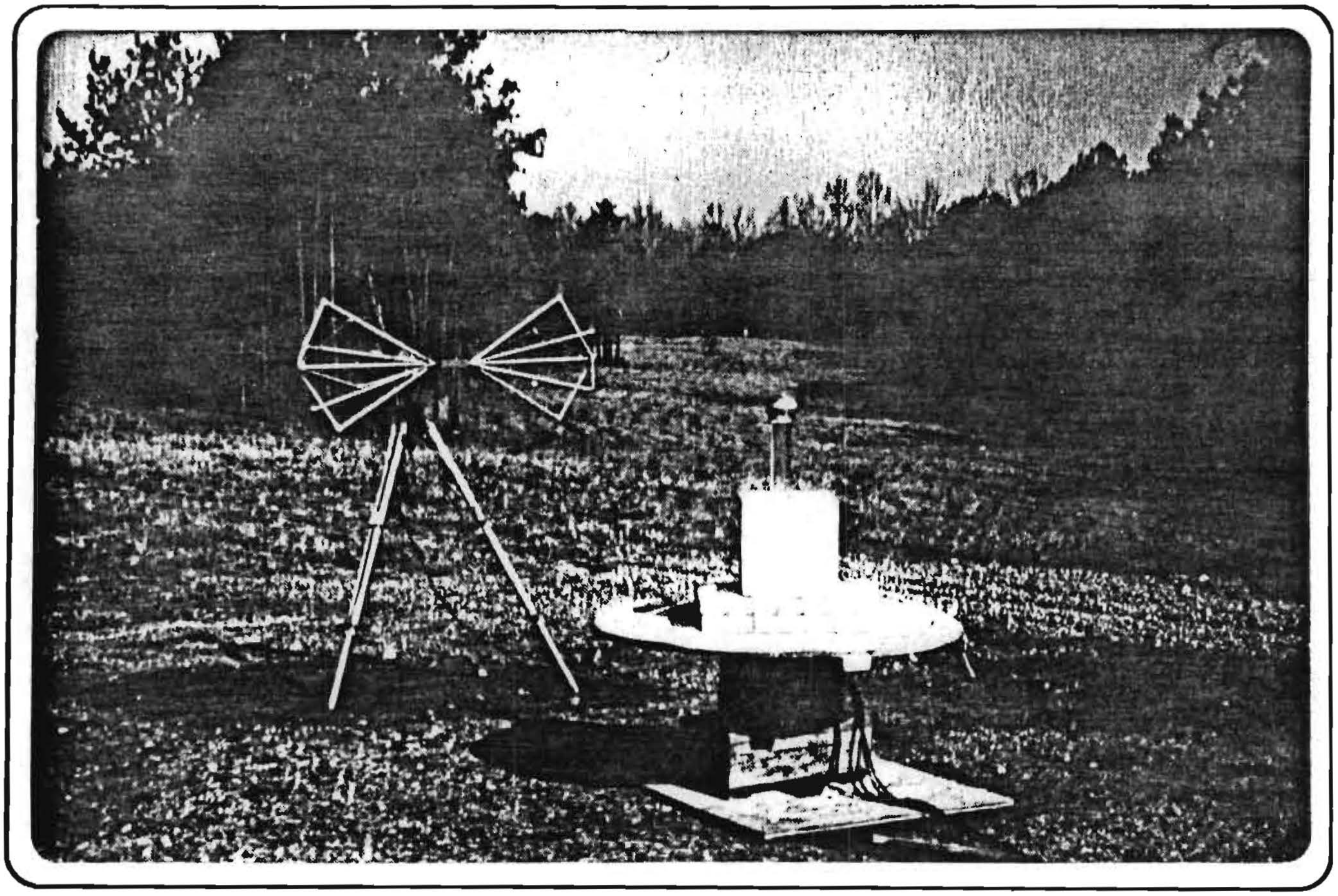


Figure 24. Pictorial View of the Outdoor Field Site Antenna Set Up for the Radiation Pattern Measurements.

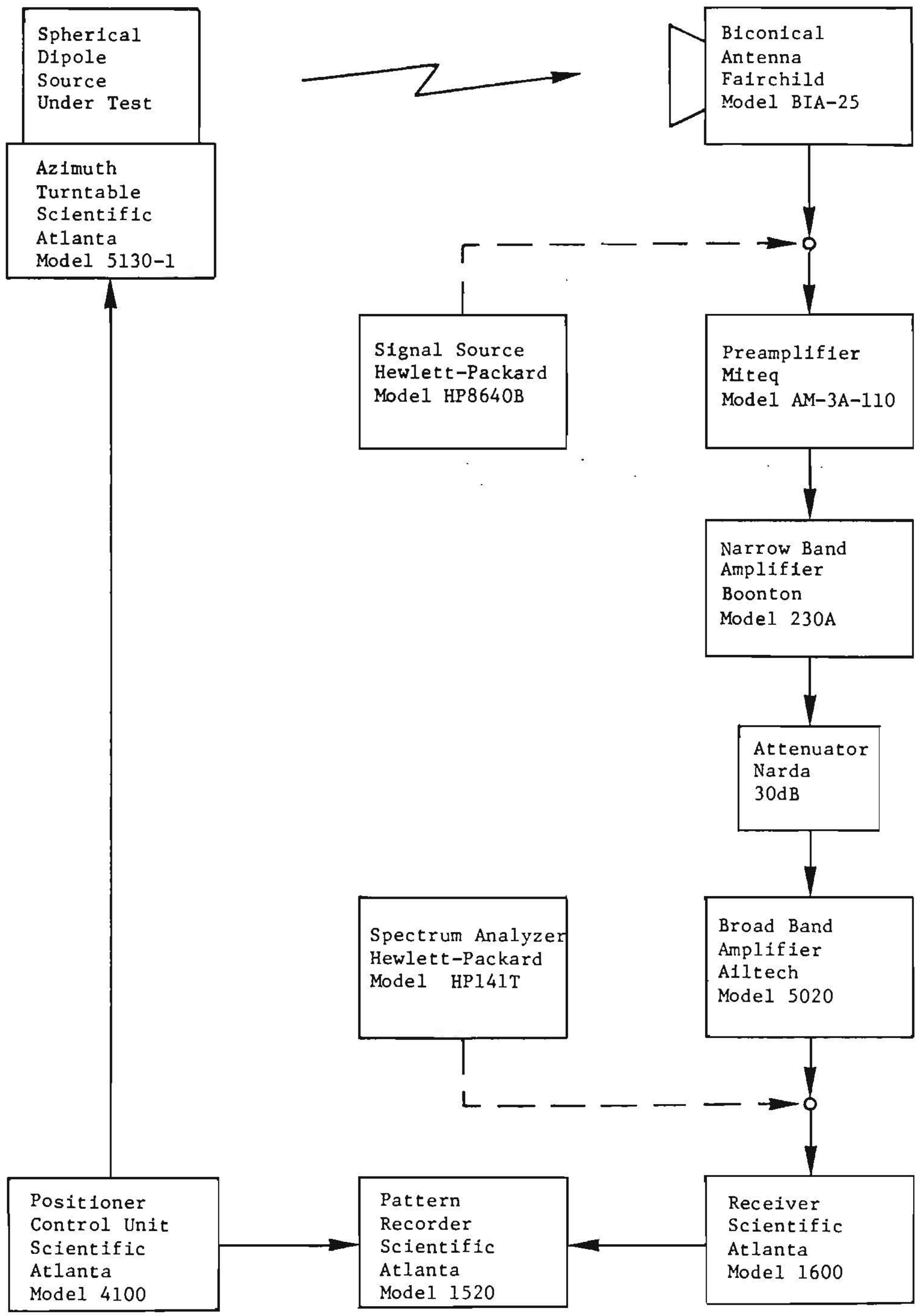


Figure 25. Block Diagram Identifying Instrumentation Interconnection for the Radiation Pattern Measurement Set Up.

system. The spectrum analyzer is used to tune the Boonton amplifier, check the received signal level, and verify that no interfering ambient signals are within the receiving system bandwidth.

The vertical and horizontal polarization patterns were measured for both spherical dipole sources at each harmonic in the 30 to 200 MHz frequency region. However, several frequencies had to be skipped due to the presence of ambient signals in the environment which were at or near (within 1 MHz) the harmonic frquency to be measured and which were of sufficient amplitude to cause significant interference in the pattern measurements. The measurement procedure began by connecting the signal source to the Miteq preamplifier input and the output of the Ailtech amplifier to the spectrum analyzer. The output frequency of the Hewlett Packard signal generator was set to the desired harmonic frequency to be measured and the Boonton amplifier was tuned by maximizing the signal displayed on the spectrum analyzer. The output of the Ailtech amplifier was then connected to the input of the Scientific Atlanta receiver in order to tune it to the appropriate frequency. The linearity of the receiving system was then checked by decreasing the output of the signal source in 10 dB steps and noting that the pen on the chart recorder also decreased by 10 dB. After the linearity was checked the biconical antenna output was connected to the input of the Boonton amplifier and the output of Ailtech amplifier was reconnected to the spectrum analyzer in order to determine if any ambient signals were present which would interfere with the radiation pattern measurements. Finally, the output of the Ailtech amplifier was connected to the Scientific Atlanta receiver, the antennas were mechanically boresighted so that the pattern would be properly positioned on the chart paper, and a 360° azimuth pattern was plotted. This procedure was repeated at each frequency and for both polarizations.

Figures 26 and 27 show representative radiation patterns of the spherical dipole sources for vertical and horizontal polarizations, respectively. These patterns were recorded on spherical dipole Serial Number 005 at 195 MHz. The vertical polarization pattern, Figure 26, shows that the maximum deviation in the plane normal to the axis of the dipole is ± 0.25 dB at 195 MHz. The horizontal polarization pattern, Figure 27, is a typical pattern for an electrically small antenna (note the 90 degree, 3 dB beamwidth). The

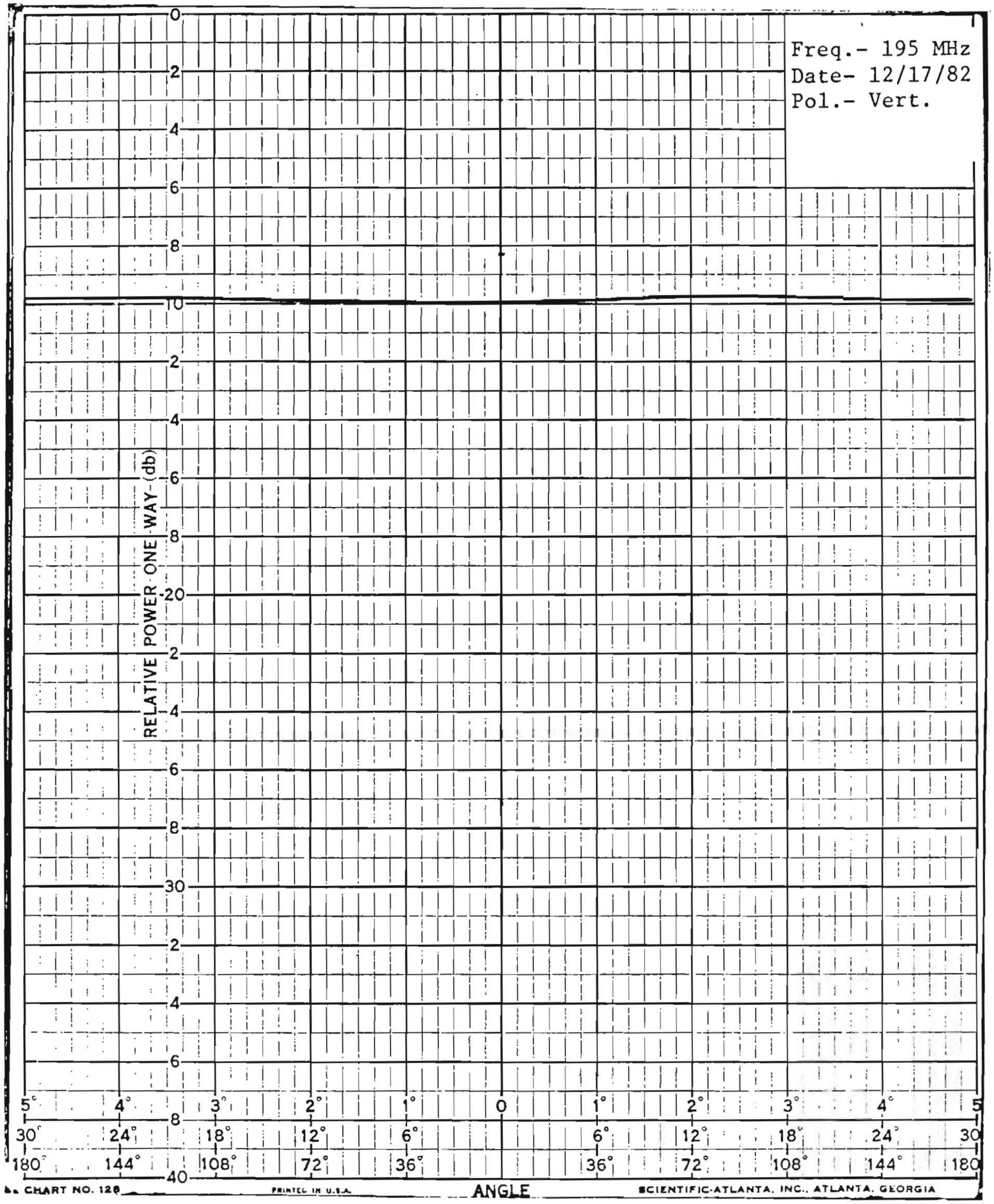


Figure 26. Radiation Pattern for 360° Azimuth Rotation of Spherical Dipole Transmitter Aligned for Vertical Polarization.

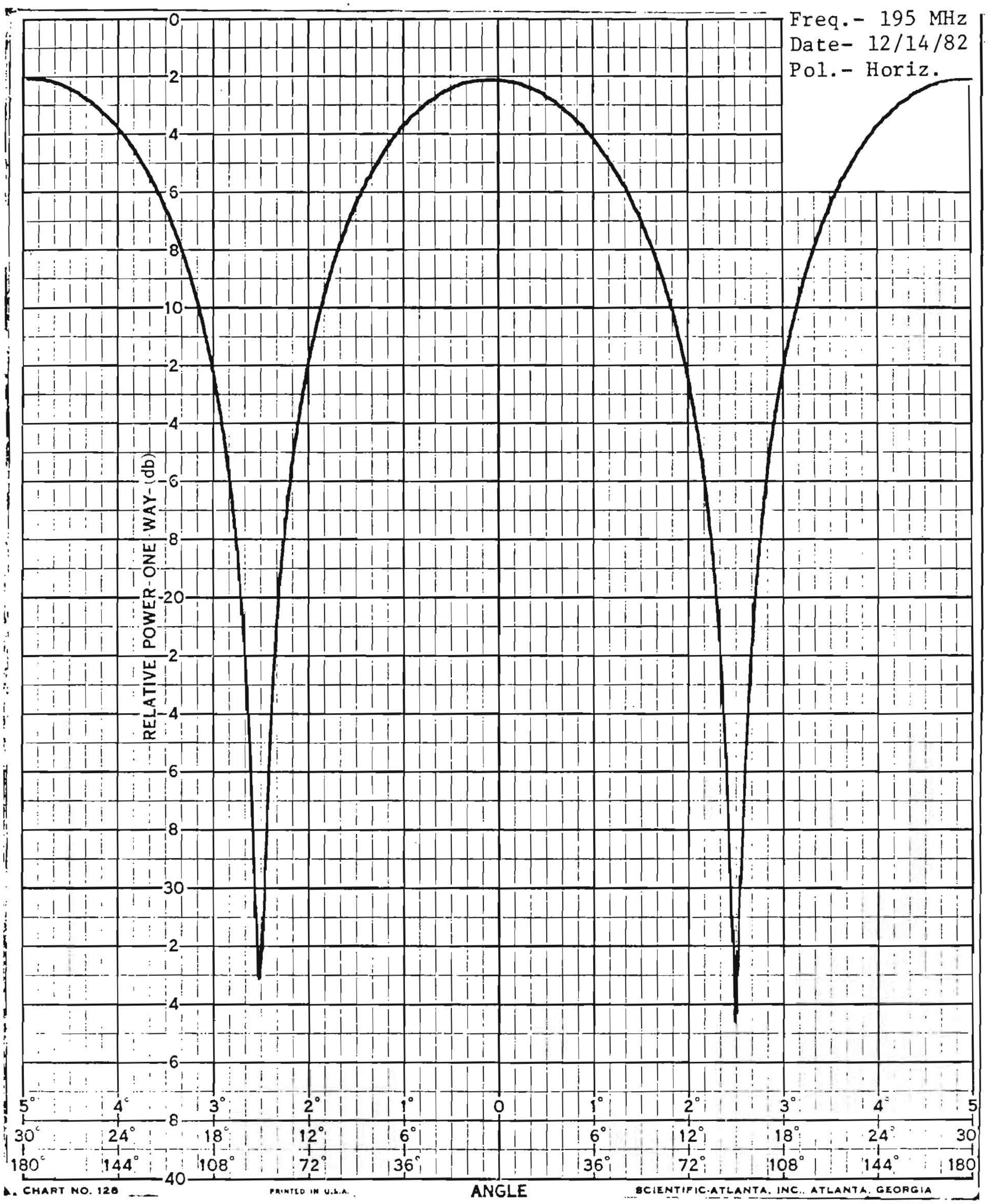


Figure 27. Radiation Pattern for 360° Azimuth Rotation of Spherical Dipole Transmitter Aligned for Horizontal Polarization.

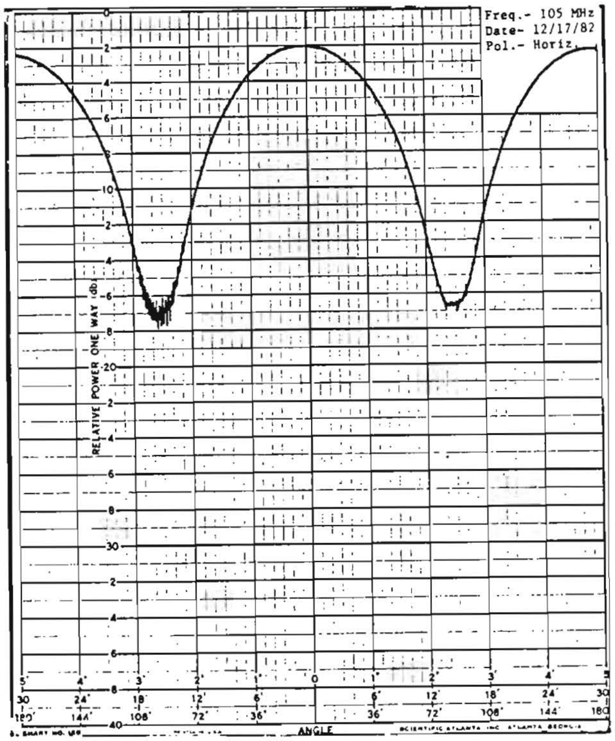
complete set of vertical and horizontal polarization patterns are given in the "Performance Data" documents for each dipole [5-6]. The maximum deviation of the vertical polarization patterns for either of the two dipoles is ± 1 dB, which is within the performance goal of ± 2 dB. The horizontal polarization patterns show that the specification requiring that the maximum energy be emitted in the plane going through the center of the dipole and normal to its axis is also met at every frequency.

The output of the Scientific Atlanta receiver is proportional to the vector sum of all signals presented to its input that are within its bandwidth. Thus many of the radiation pattern measurements given in the "Performance Data" documents show the results of interference caused by ambient signals present in the environment. For example, Figure 28(a) shows the null filling which results from an ambient signal in the environment which is within the tuned frequency bandwidth of the receiver. Figure 28(b) shows the results of an ambient signal which is at the same frequency as the received harmonic signal, but has an amplitude which is much smaller than the harmonic signal and a phase angle which is between +90 and +270 degrees relative to the harmonic signal. The noisy signal shown in Figure 28(c) was not specifically identified, but could be the result of an amplitude modulated signal which is in the receiver bandwidth and has an amplitude approximately equal to or greater than the received harmonic signal. Also, a signal in the environment which is keyed on and off and is in the passband of the receiver will cause discontinuities in the pattern measurement as shown in Figure 28(d).

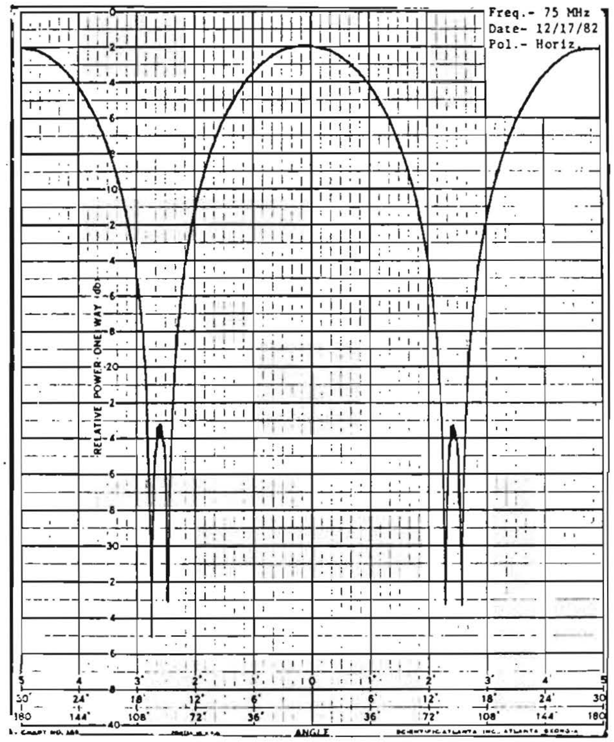
3.4 3-Meter Field Strength Measurements

The 3-meter field strength measurements involves the calibration of the radiated field amplitude at a distance of 3-meters from the spherical dipole transmitter. Thus, these measurements must be performed on a test site which does not itself introduce errors into the measurements. Since an "ideal site" is not physically realizable, the measurements must be performed on a site which approaches an ideal site and which has been tested to show its suitability.

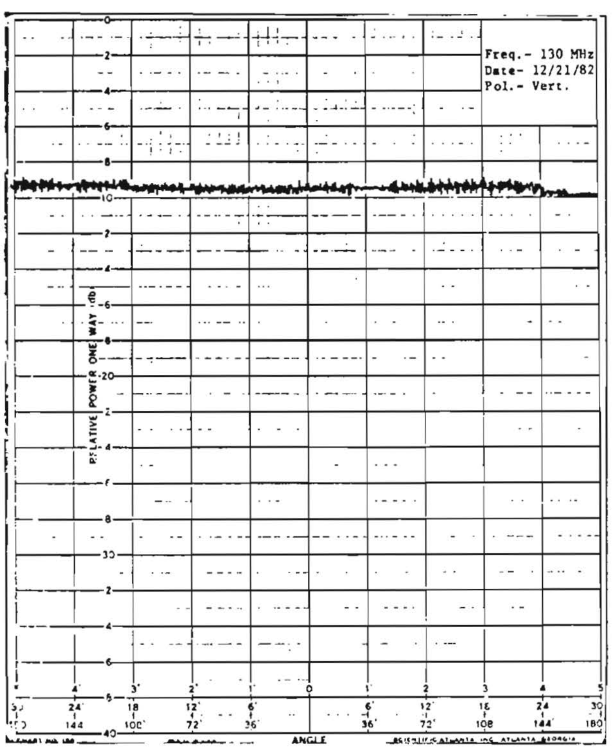
The 3-meter field strength measurements were performed on the two spherical dipole emission sources at American Bell's open field 3-meter site



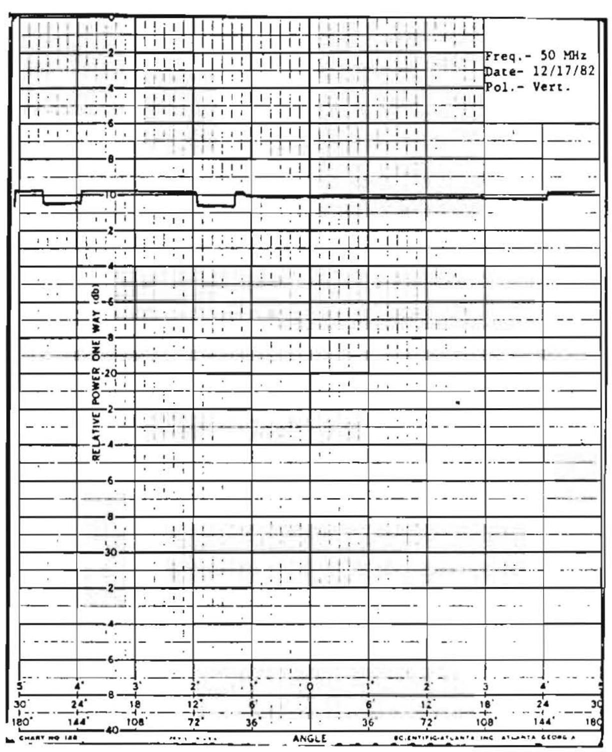
(a) Null Filling



(b) Pseudo-Sidelobe



(c) Noise



(d) Keying

Figure 28. Examples of Interference in the Measured Radiation Pattern Caused by Signals Present in the Ambient Environment

in Chester, New Jersey. This field site was built in accordance with FCC Bulletin OST55 7 , is enclosed in a completely nonmetallic tent structure to protect it from weather conditions, and utilizes an instrumentation area which is below the ground plane level. The suitability of this site has been determined by performing site attenuation measurements as detailed in 1 . The results of these measurements were then compared to the calculated site attenuation for an "ideal site." The results of these measurements are shown in Figure 29, along with the calculated results for an ideal site. As seen in Figure 29, the theoretical and measured values are within 3 dB, throughout the 30 to 1000 MHz frequency range.

Figures 30 and 31 are photographs of the open field 3-meter site showing an outside view of the all-weather tent structure and an interior view depicting the antenna placement and mounting apparatus for the field strength measurements. The spherical dipole is mounted 1 meter above the ground plane on its associated plexiglas mount, which is threaded onto an adjustable tripod. Tunable dipole antennas were used for the receiving antenna, and were mounted on a nonmetallic mount which allowed the dipole antenna's height above the ground plane to be remotely positioned to any height between 1 and 4 meters. A block diagram of the instrumentation interconnection for the 3-meter field strength measurements is shown in Figure 32. Note that an Electrometric Interference Analyzer, Model EMC 25, is used as the field strength receiver. The audio speaker was used to detect interference caused by ambient signals in the electromagnetic environment.

The field strength measurements were performed for both vertical and horizontal polarizations at each harmonic frequency starting at 30 MHz and ending at the harmonic frequency at which the field strength amplitude had decreased to a value which was less than the performance goal of 30 dBμ V/m. The measurement procedure began by manually adjusting the receiving dipole antenna to the proper length for the test frequency. After the receiver was tuned and calibrated at the test frequency, the receiving antenna's height above the ground plane was remotely scanned between 1 and 4 meters in order to find the maximum field strength level. If there were no ambient signals detectable through the tone emanating from the audio speaker which could cause interference in the measured field strength value, the received voltage level

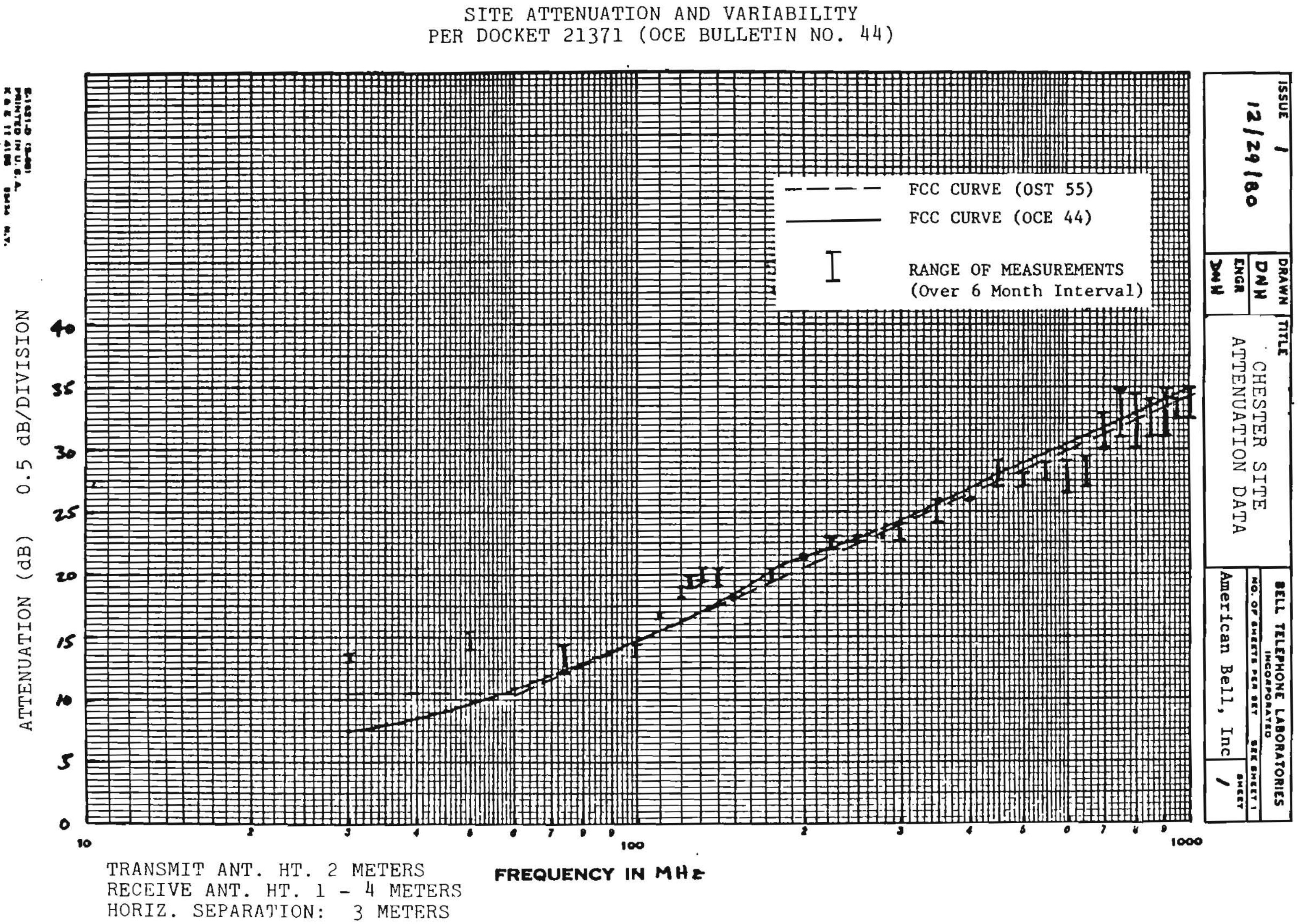


Figure 29. Measured Site Attenuation Results for the Open Field 3-meter Site in Chester, New Jersey as Compared with the Calculated Results for an "Ideal Site".

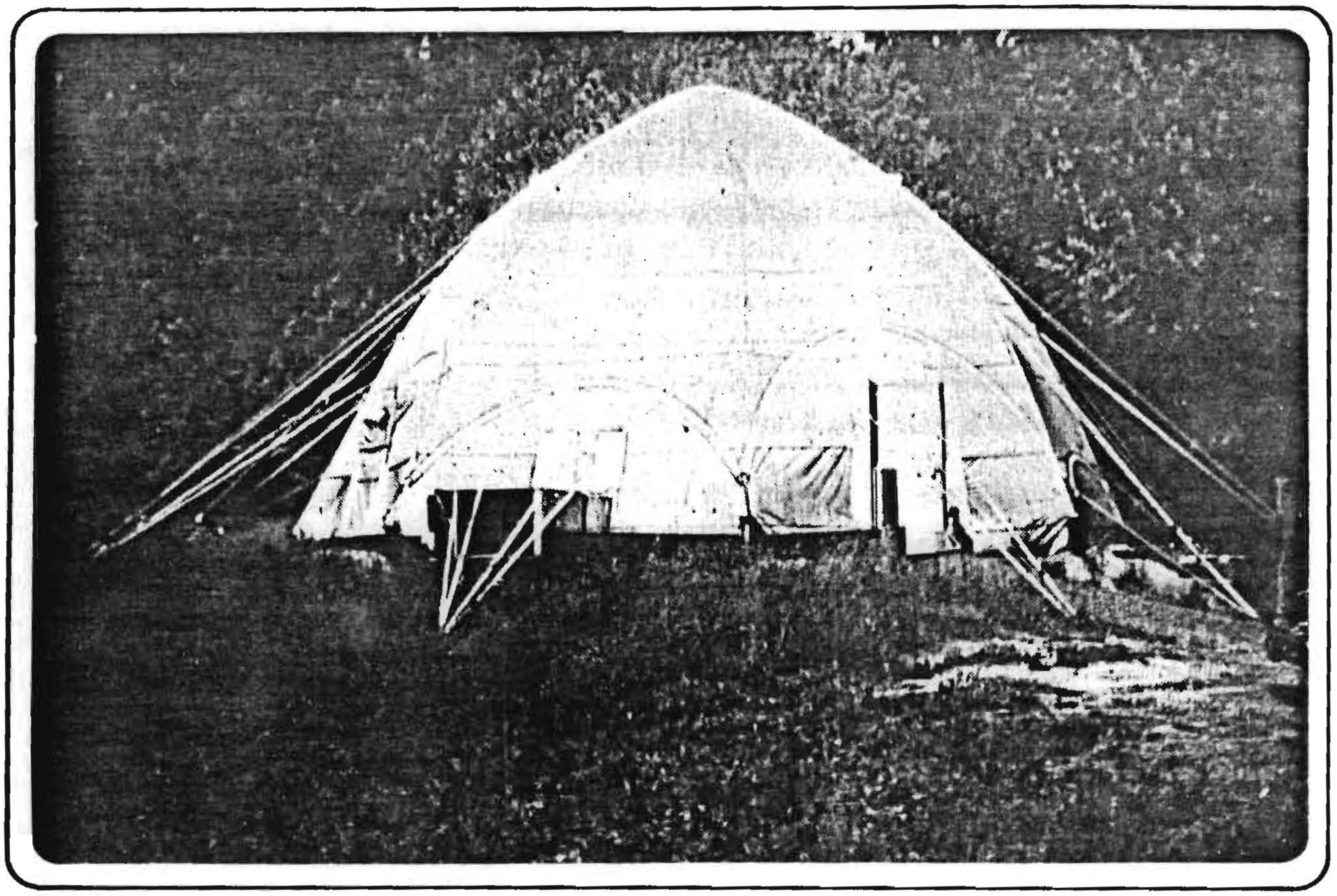


Figure 30. Photograph of the All-Weather Tent Structure Used in the Chester, New Jersey 3-meter Open Field Site

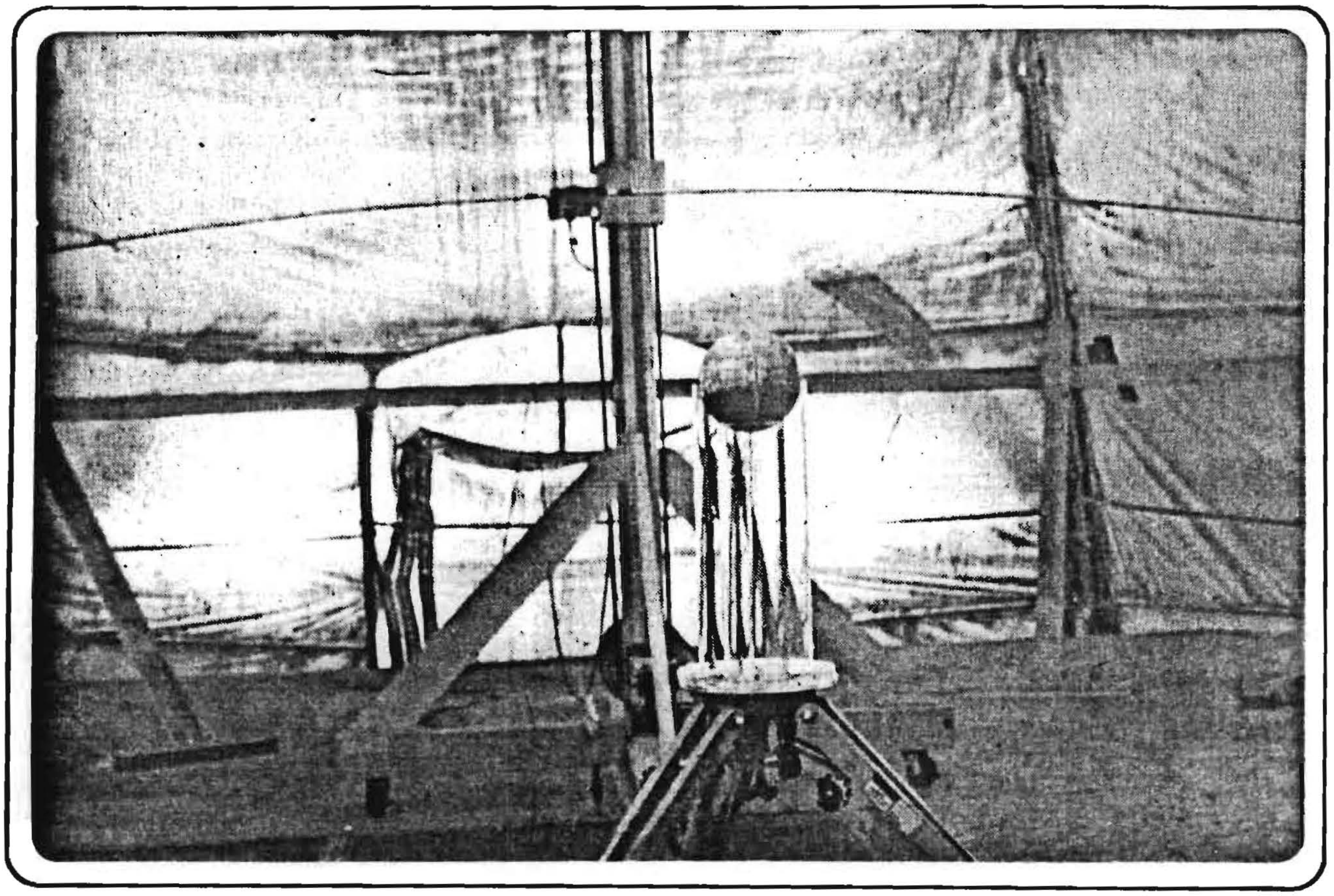


Figure 31. Pictorial View of the Antenna Set Up Used for the Field Strength Measurements Performed at the Open Field 3-meter Site in Chester, New Jersey

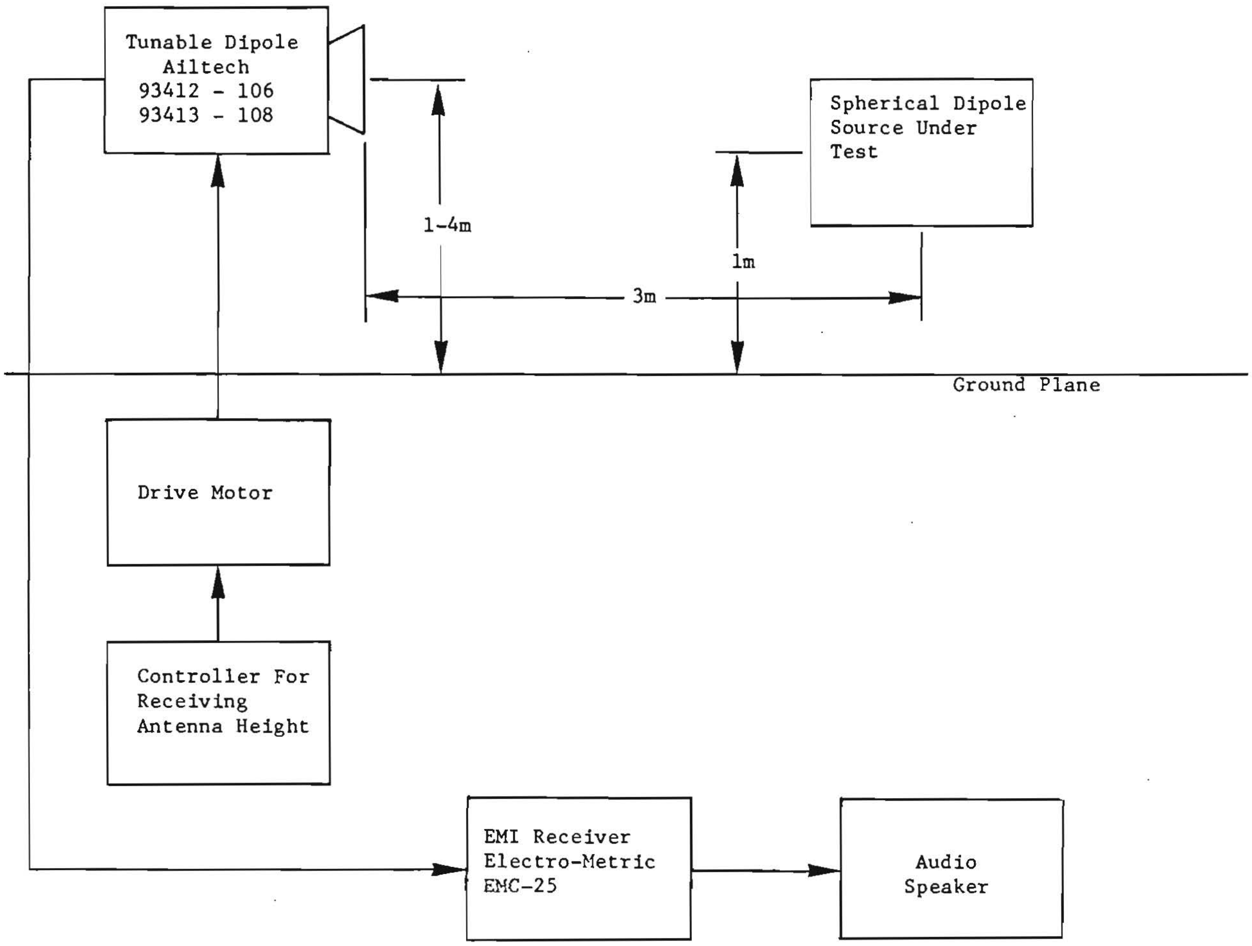


Figure 32. Block Diagram Identifying Instrumentation Interconnection for the 3-meter Open Field Strength Measurements

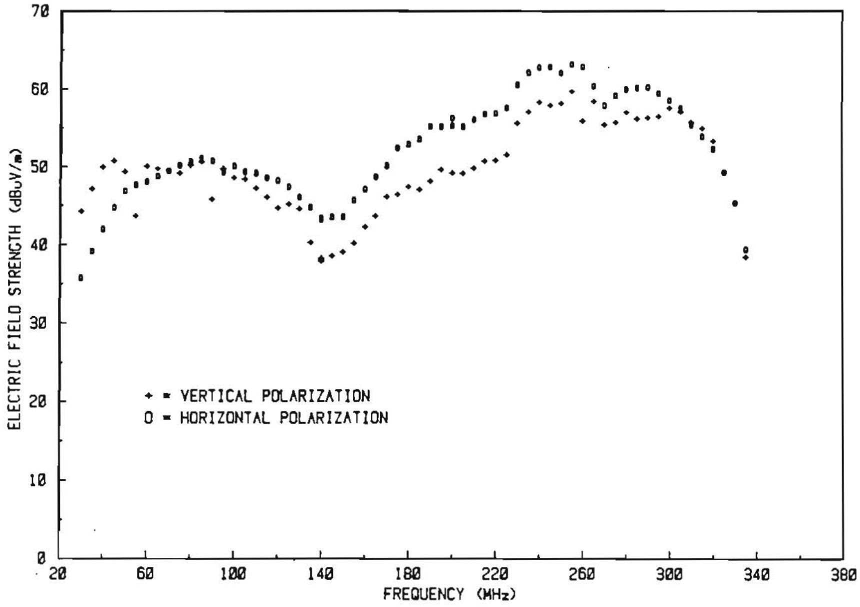
at the receiver (attenuator plus meter reading), in dBμV, was recorded. The 3-meter field strength level, in dBμV/m, was then determined by adding the antenna factor for the receiving antenna, in dB/m, and the cable loss between the receiver and the antenna, in dB, to the received voltage level.

Figure 33 illustrates the results of the 3-meter field strength measurements for serial numbers 005 and 006. Measurements were made for both vertical and horizontal polarizations. Note that the 3-meter field strength levels for both sources are above the 30 dBμV/m desired field level from 30 MHz through 335 MHz, which is well past the desired goal of 200 MHz. The specific field strength levels are tabluated in the "Performance Data" documents [5-6] for the two spherical dipole sources.

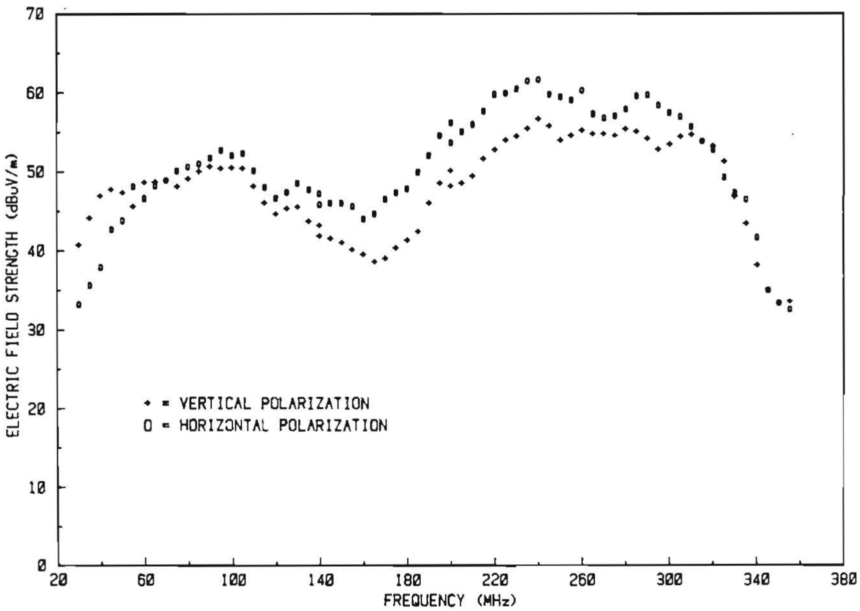
3.5 Repeatability Measurements

This section describes the measurements performed to determine the repeatability of the amplitude levels of the radiated field components. Various tests which were performed include amplitude changes as a result of power up/down, insertion of new batteries, and reassembling dipole halves after disassembly, temperature variations, and day-to-day performance. The repeatability measurements were performed in the radiated mode using the TEM chamber. The measurement setups used for these measurements are equivalent to those used in the spectrum content measurements and are illustrated in Figures 12, 13, 16, and 17. In the radiated measurements care was taken to repeatably align the spherical dipole in a fixed position in the TEM cell for each of the repeatability tests.

The radiated measurement results include the variations of the amplitude levels at each harmonic frequency between 5 and 200 MHz as a result of the following: (1) removing spherical dipole from TEM cell and realignment without turning transmitter off, (2) turning transmitter off and back on without removing dipole from chamber, (3) assembly of spherical dipole after disassembly of the two hemispherical halves, (4) replacement of battery sets with both new and used batteries, and (5) day-to-day variations. The measurements were repeated two times for the first four categories given above, and over a 14 day period. Figure 34 shows the results of these measurements for both spherical dipoles. Note that the measured variations are within the desired performance goals of $\pm$ 1 dB.

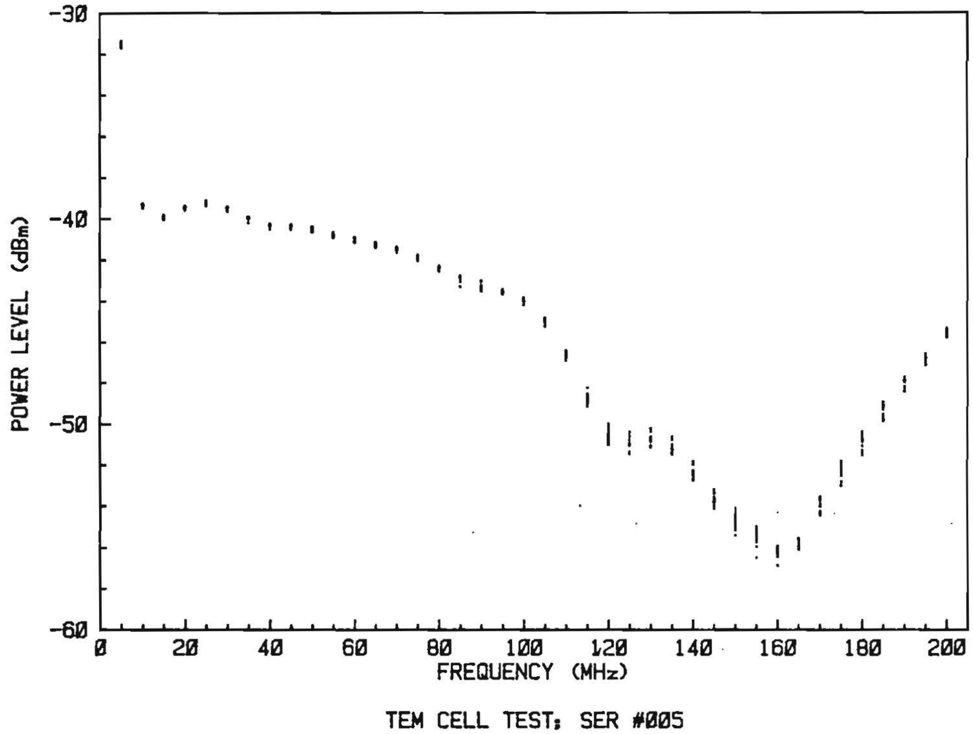


THREE-METER RADIATED FIELD STRENGTH: SERIAL # 005



THREE-METER RADIATED FIELD STRENGTH: SERIAL # 006

Figure 33. Results of the 3-meter Open Field Strength Measurements Performed on Spherical Dipole Serial Number 005 and 006



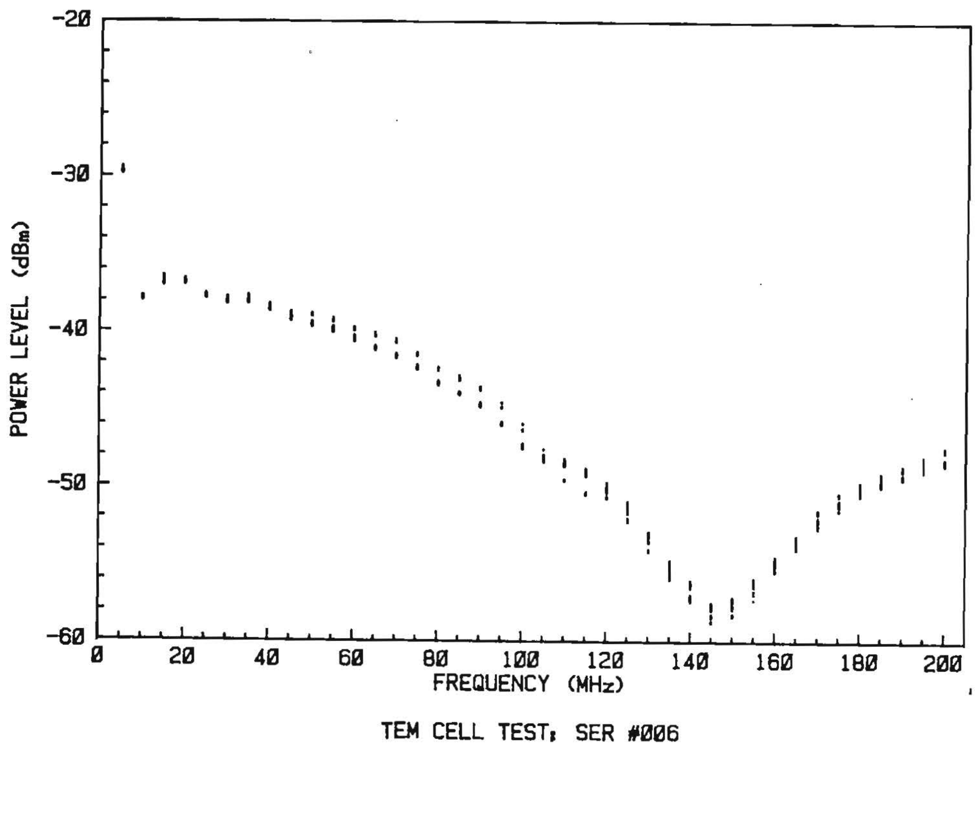


Figure 34. Results of Radiated Repeatability Measurements for Spherical Dipoles Serial Numbers 005 and 006

The variations of the output field levels as a function of the ambient temperature were performed in a conducted mode in a environmental control chamber. Measurements were made at room temperature ($25^{o}C$) and at the upper ($39^{o}C$) and lower ($15^{o}C$) tempeartures of the desired performance goal temperature range. These results are presented in Figure 35 for both spherical dipoles, and show that the desired goal of less than $\pm$ 1 dB is achieved for both units at each frequency.

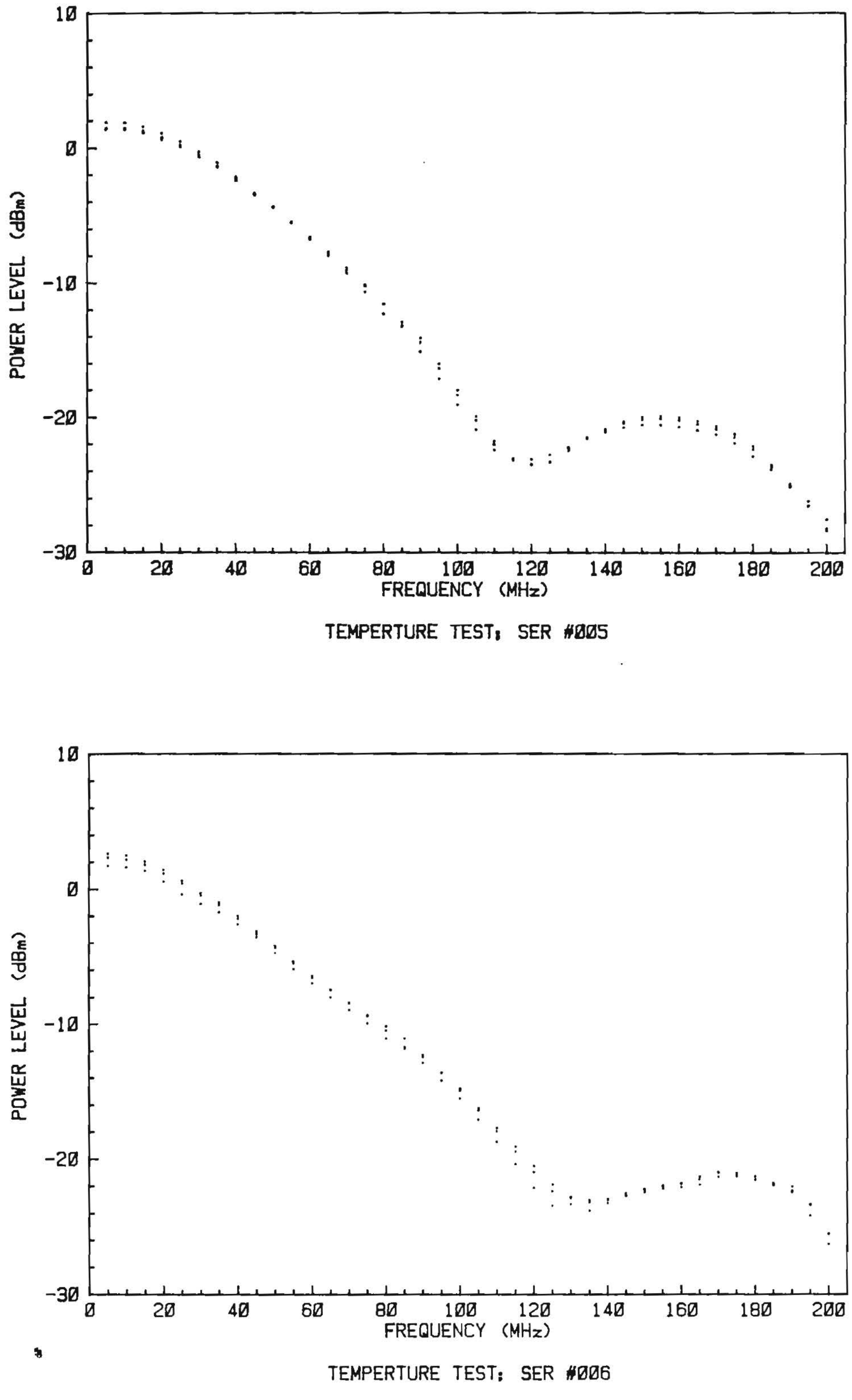


Figure 35. Results of Conducted Repeatability Measurements as a Function of Temperature Variations for Spherical Dipoles Serial Numbers 005 and 006

4.0 CONCLUSIONS

A spherical dipole source was developed which could be used as a "standard radiating reference". Two identical prototypes have been constructed and calibrated. The dipoles are completely self-contained with no interconnecting cabling, thus eliminating variations in the radiated fields levels caused by cable placement and positioning. Figure 36 depicts one of the spherical dipoles mounted on its associated plexiglass mount, and Figure 37 is a view of the disassembled spherical dipole showing the transmitter circuitry and the feed posts.

The performance results of the two sources are given in Table II. The two dipoles radiate a spectrum which consists of a comb of frequencies spaced in 5 MHz increments. Over the frequency range of 30 to 335 MHz the field strength level is greater than or equal to 30 dBμV/m, measured at 3m horizontal separation.

The amplitude of each signal component is repeatable within ±1.0 dB, and the amplitude drift as a result of battery drain and thermal equilibrium is less than ± 0.8 dB throughout the entire battery life of 5 - 5.5 hours. Also, the maximum frequency drift is less than 1100 Hz (for the 40th harmonic) during the battery lifetime. The radiation characteristics of the two tested spherical dipole sources are consistent with the radiation characteristics of an electrically small antenna. The measured omnidirectionality of the field in the plane normal to the axis of the dipole is within ±1 dB for a complete 360^o rotation.

If performance results for the two spherical dipoles (Table II) are compared to the desired performance goals (Table I) for the emission source, it is seen that the two working models meet or surpass all of the performance requirements of a "standard radiating reference". As a result, they can be used to compare and define variation in test sites used for radiated emission measurements.

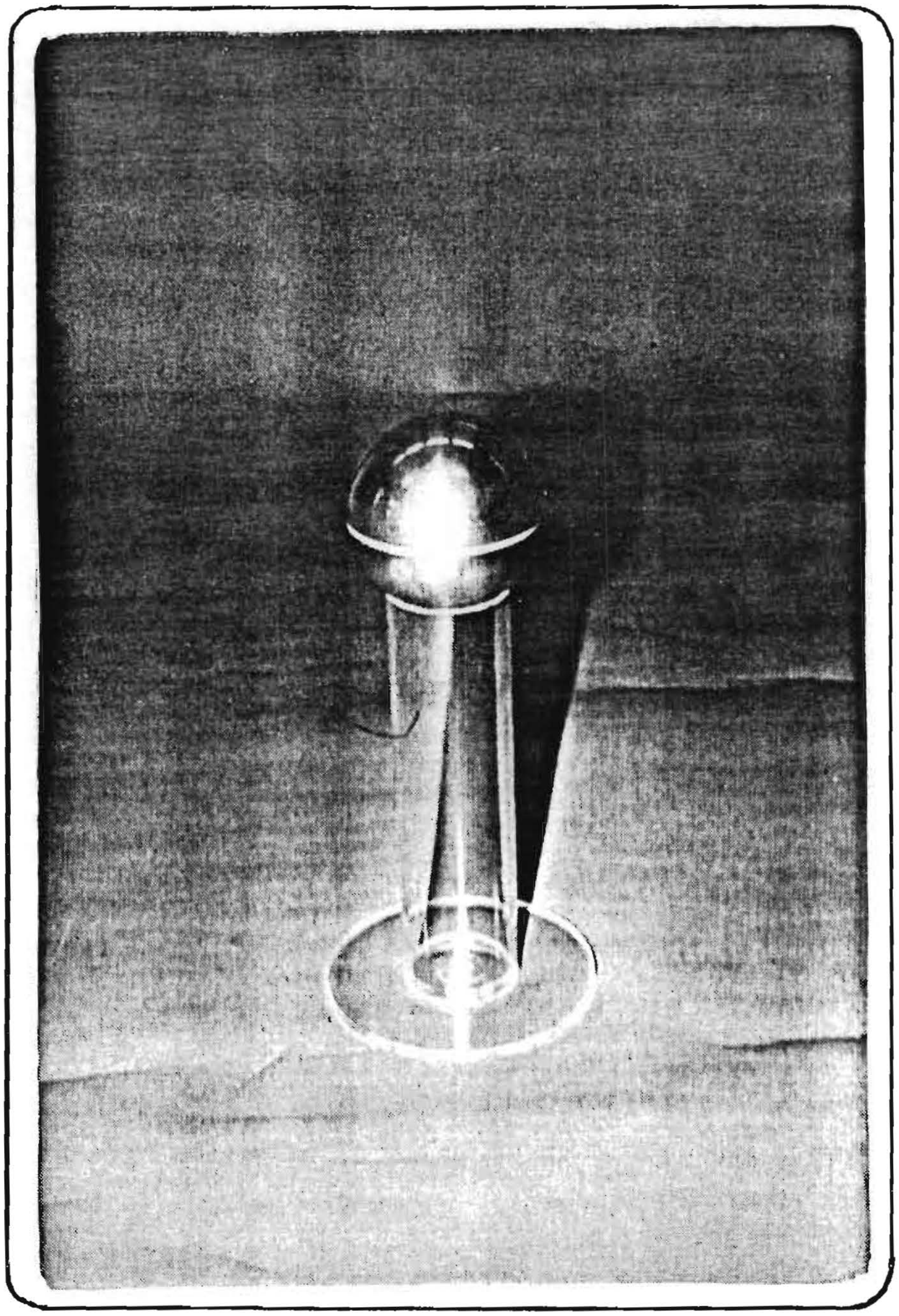


Figure 36. Spherical Dipole Source Placed on its Associated Mount

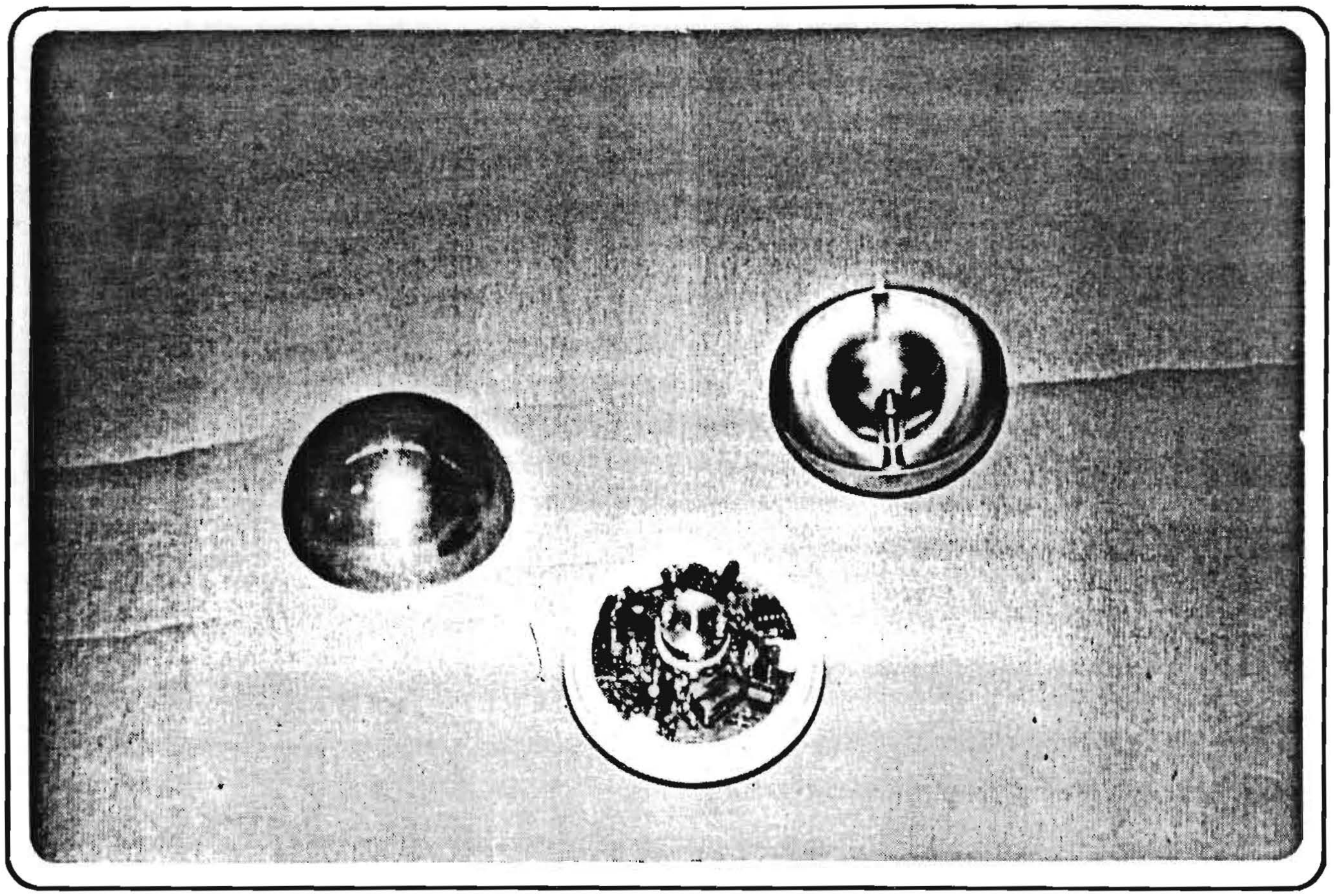


Figure 37. Disassembled View of Spherical Dipole Source

TABLE II

PERFORMANCE RESULTS OF THE TWO SPHERICAL DIPOLE SOURCES

	PERFORMANCE GOALS	PERFORMANCE RESULTS
Frequency Range	30 MHz - 200 MHz	30 MHz - 335 MHz
Emission Characteristics	Continuous or Less Than 10 MHz Increments	5 MHz Increments
Field Strength Level	A Minimum Level of 30 dBμV/m Measured at 3-meter Horizontal Separation, Over Entire Frequency Range	Minimum Level of 30 dBμV/m Measured at 3-meter Horizontal Separation, Throughout Entire Frequency Range
Battery Life	4 Hours Minimum	Greater Than 5 Hours for Two 9 Volt Alkaline Batteries
Frequency Stability	Less Than 4 kHz Drift Over a Four Hour Interval	Less Than 1100 Hz Drift at 200 MHz During Entire Battery Life
Amplitude Stability	Less Than $\pm$ 1 dB Drift Over a Four Hour Interval	Less Than $\pm$0.8 dB Drift During Entire Battery Life
Amplitude Repeatibility	Within $\pm$ 1 dB	Within $\pm$ 1.0 dB
Radiation Characteristics	Typical Dipole Donut Pattern Throughout Entire Frequency Range; Omnidirectional (Less Than $\pm$ 2 dB Variation For 360 Degree Rotation) In Plane Normal to the Axis of the Dipole, and Maximum Field in Plane Going Through the Center of Dipole and Normal to It.	Typical Dipole Donut Pattern; Omnidirectional (Less Than $\pm$ 1 dB Variation For 360 Degree Rotation) In Plane Normal to the Axis of the Dipole, and a Maximum Field in Plane Going Through the Center of Dipole and Normal to It.

REFERENCES

1. Draft Addition to American National Standard C63.4, Draft 9, "Open Area Test Sites", February, 1983.

2. Crawford, M. L. and Workman, J. L., "Predicting Free-Space Radiated Emissions From Electronic Equipment Using TEM cell and Open-Field Site Measurements", 1980 IEEE International Symposium on Electromagnetic Compatibility, 1980.

3. Ramo, Simon, and Whinnery, John R., Fields and Waves in Modern Radio, John Wiley and Sons, Inc., New York, Chapman and Hall, LTD, London, 1953.

4. Weeks, W. L., Antenna Engineering, McGraw-Hill Book Co., New York, 1968.

5. Mantovani, J. C., "Performance Data Spherical Dipole Emission Source, Serial Number 005", May 1983.

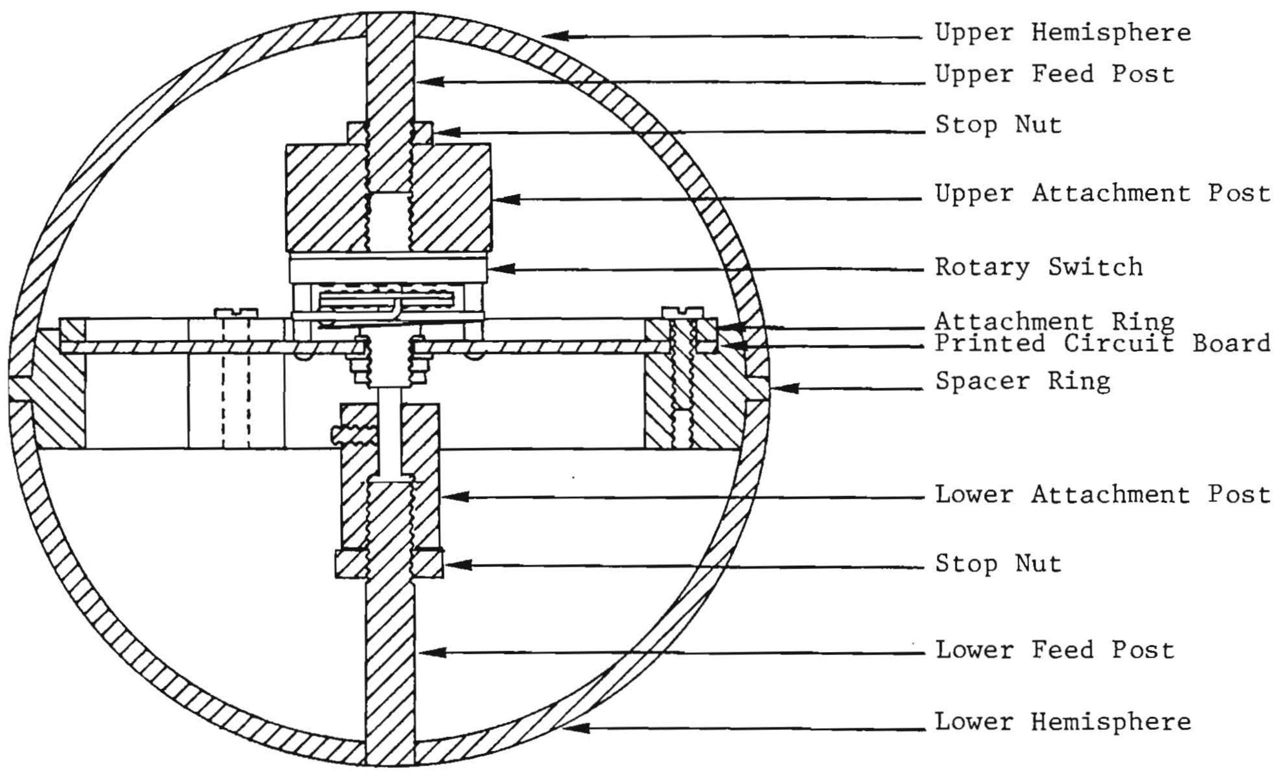
6. Mantovani, J. C., "Performance Spherical Dipole Emission Source, Serial Number 006", May 1983.

7. Federal Communications Bulletin OST55.

ATTACHMENT I

MECHANICAL DRAWINGS FOR THE SPHERICAL DIPOLE

The mechanical drawings for various pieces of the spherical dipole are given in this attachment and include the following: the two brass hemispherical sections, the two brass feed posts, the two brass attachment posts, the Delrin spacer ring, and the Delrin attachment ring. The assembly of the spherical dipole housing is given through a half-section cross-sectional view.



(Cross-Sectional View)

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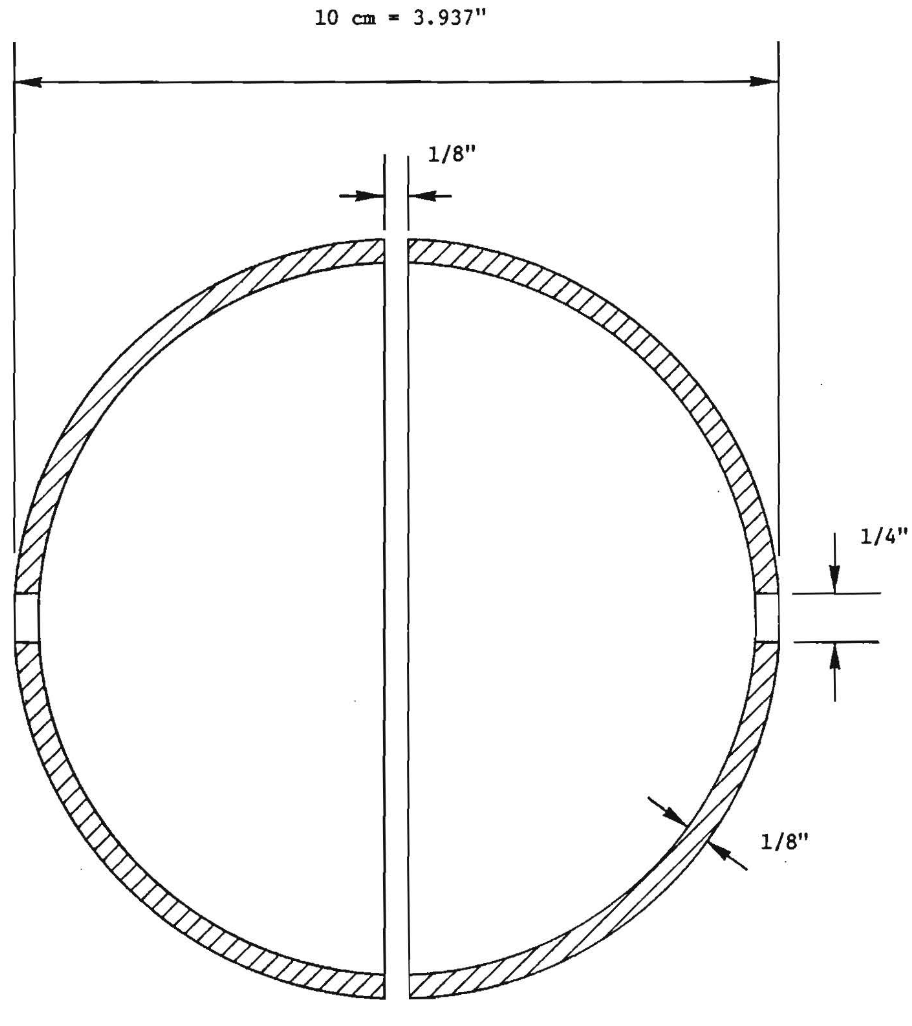
ENG. J. Mantovani	**SCALE** 1" = 1"
DRAFT JGH	**DATE** 8/31/82



(HALF SECTION CUTAWAY)

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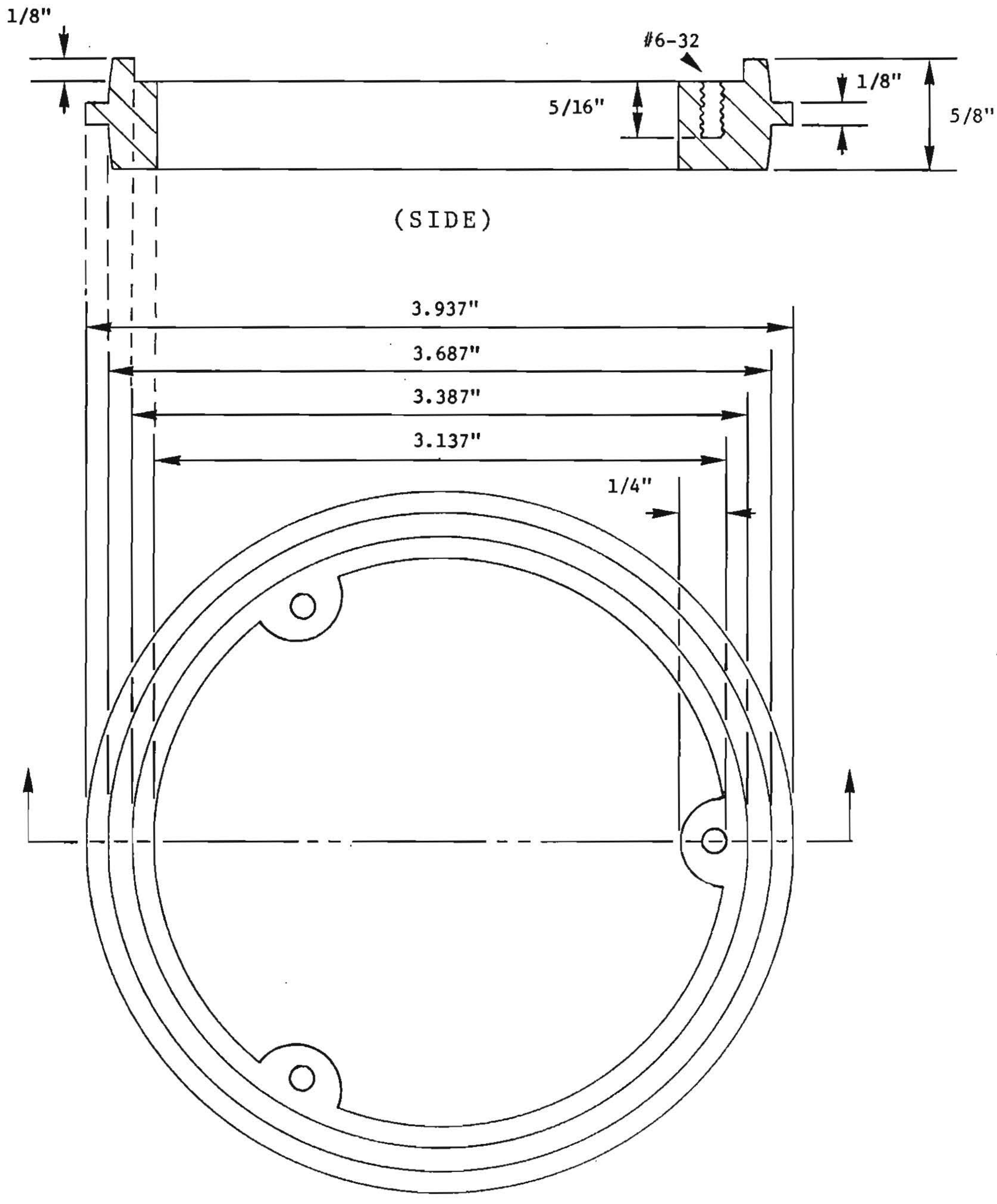
ENG. J. Mantovani	SCALE 1" = 1"
DRAFT JGH	DATE 8/4/82



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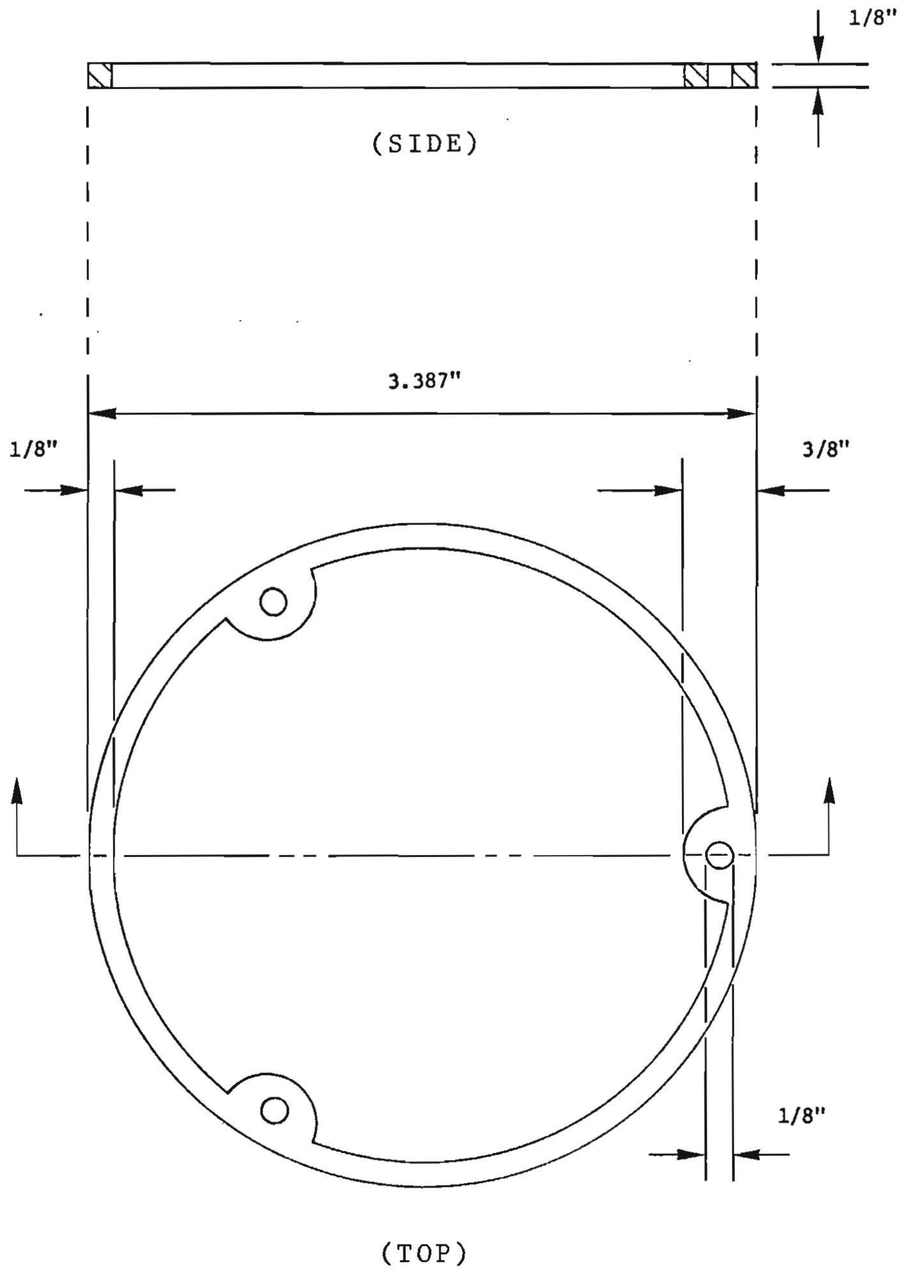
ENG. J. Mantovani	**SCALE** 1" = 1"
DRAFT JGH	**DATE** 8/4/82



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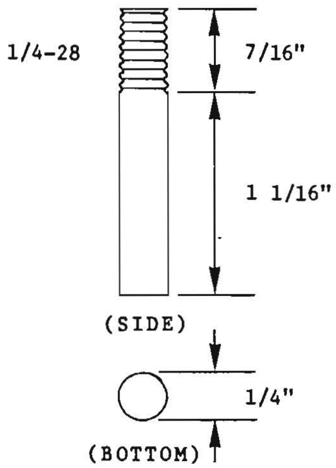
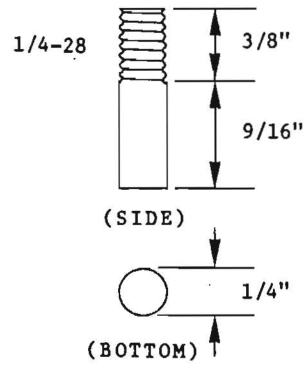
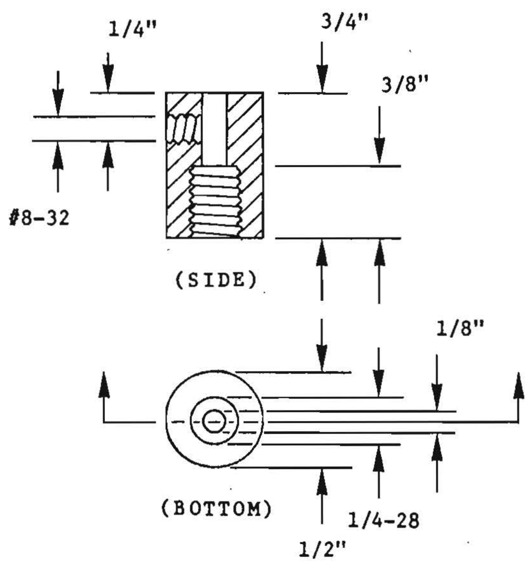


Lower Feed Post



Upper Feed Post



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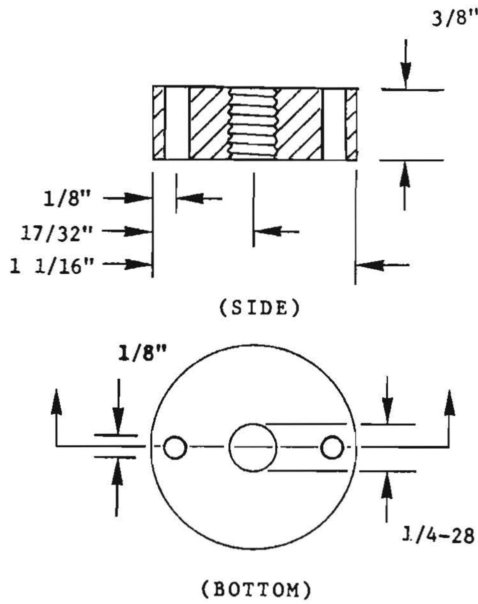

Upper Attachment Post

TITLE	
SPHERICAL DIPOLE ANTENNA Brass Support Posts	
ENG. J. Mantovani	SCALE 1" = 1"
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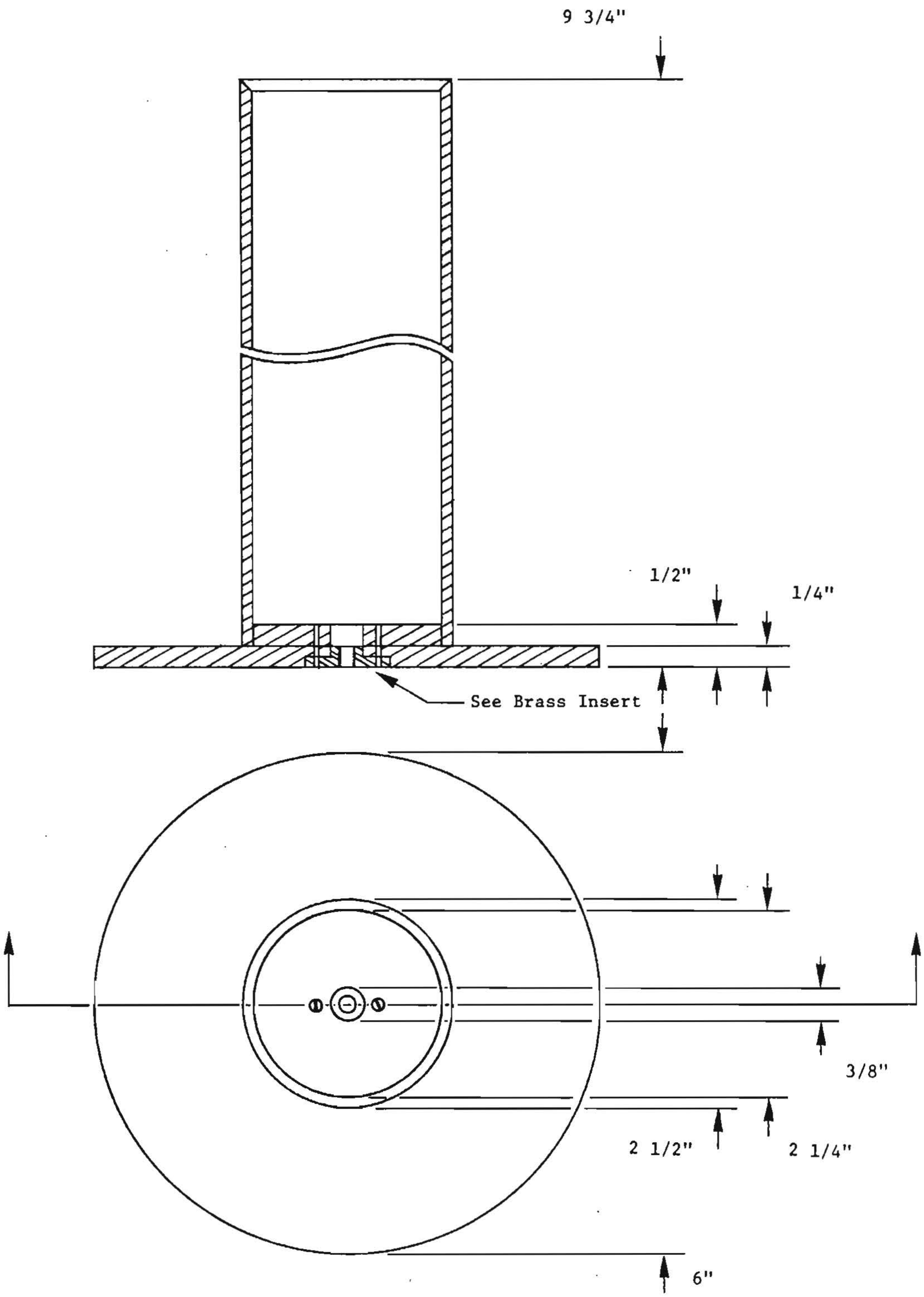
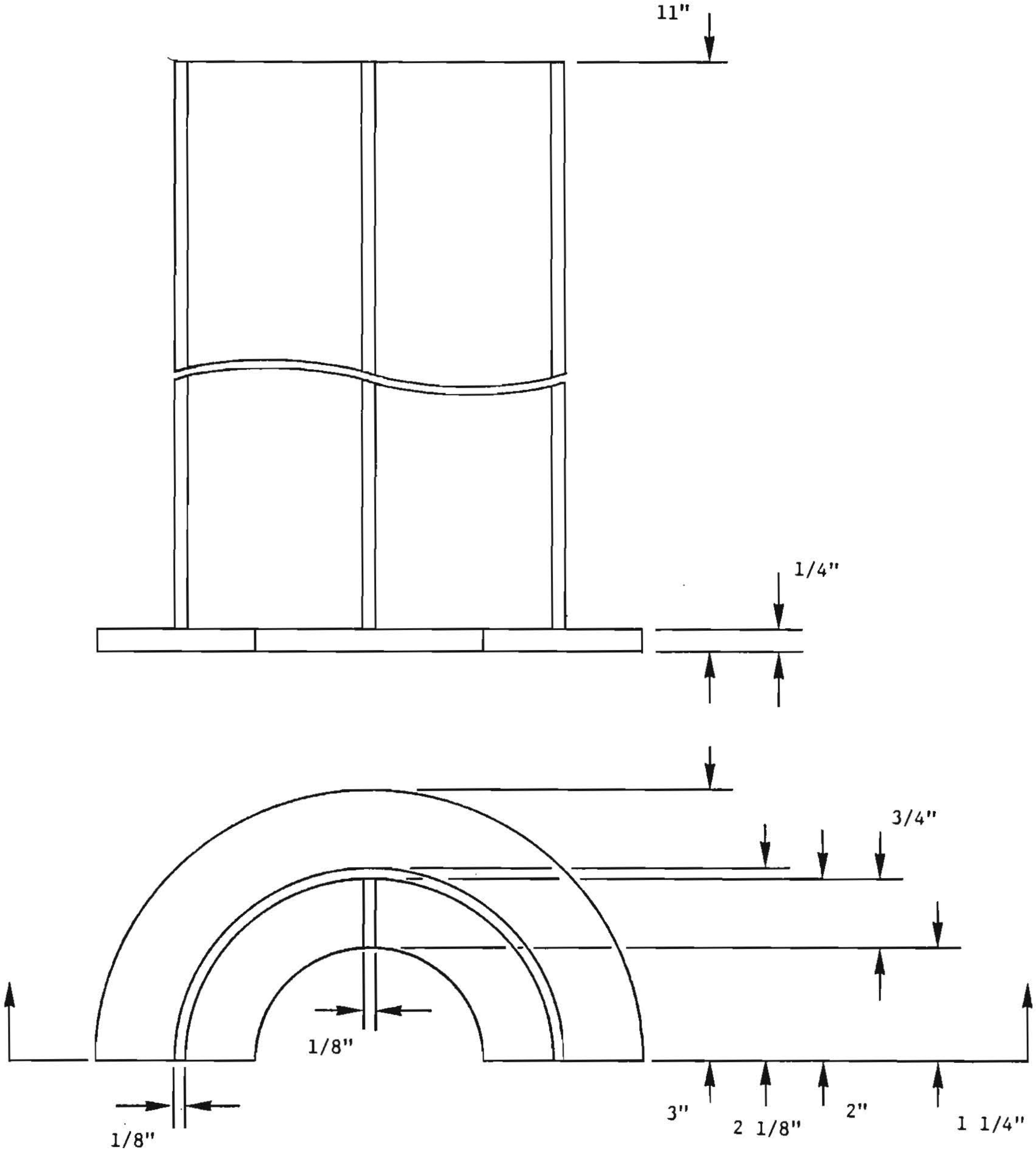
ATTACHMENT II

MECHANICAL DRAWINGS FOR THE SPHERICAL DIPOLE MOUNT AND ALIGNMENT TOOL

The mechanical drawings for the spherical dipole mount and alignment jig are given in this attachment. The mechanical drawings include the cylindrical plexiglas mount, the half-cylinder plexiglas alignment tool, and the brass tripod attachment bolt.



TITLE	
SPHERICAL DIPOLE ANTENNA Plexiglass Antenna Mount	
ENG. J. Mantovani	SCALE 1" = 2"
DRAFT JGH	DATE 1/19/83

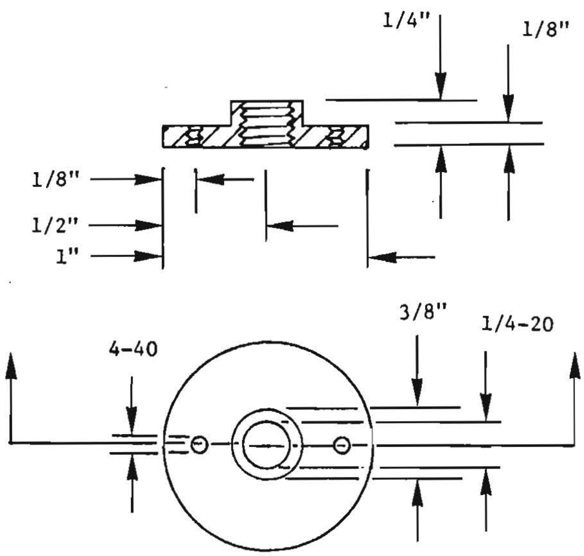


TITLE

SPHERICAL DIPOLE ANTENNA

Plexiglass Polarization Tool

ENG.	SCALE
J. Mantovani	1" = 2"
DRAFT	**DATE**
JGH	1/19/83



TITLE	
SPHERICAL DIPOLE ANTENNA Brass Insert to Plexiglass Antenna Mount	
ENG. J. Mantovani	SCALE 1" = 1"
DRAFT JGH	DATE 1/19/83

ATTACHMENT III

PARTS LIST OF THE TRANSMITTER CIRCUITRY FOR THE SPHERICAL DIPOLE

The component values and model numbers are tabulated and given in this attachment for the transmitter circuitry of the spherical dipole source. The part number for each component listed correspond to the schematic diagrams given in Section 2.2 for the RF generator circuitry (Figure 7), the power supply circuitry (Figure 10), and the output indicator circuitry (Figure 12).

PARTS LIST FOR SIGNAL GENERATOR CIRCUIT

Resistors[1]

R1 - 220 KΩ
R2 - 220 KΩ
R3 - 56 KΩ
R4 - 150 Ω
R5 - 150 Ω
R6 - 120 Ω
R7 - 1.0 KΩ
R8 - 120 KΩ
R9 - 120 KΩ
R10 - 200 KΩ
R11 - 120 KΩ
R12 - 22 KΩ
R13 - 22 KΩ
R14 - 330 Ω
R15 - 22 KΩ
R16 - 1.0 KΩ
R17 - 100 Ω
R18 - 120 Ω
R19 - 820 Ω
R20 - 3.6 MΩ
R21 - 330 KΩ
R22 - 1.0 KΩ

Capacitors[2]

C1 - 1.5 μf
C2 - 1.5 μf
C3 - 1.5 μf
C4 - 1.5 μf
C5 - 4 pf
C6 - 110 pf
C7 - 180 pf
C8 - 1.5 μf
C9 - 1.5 μf
C10 - 47 μf
C11 - 10 μf
C12 - 1.5 μf
C13 - 1.5 μf
C14 - 1.5 μf
C15 - 1.5 μf

Inductors

L1 - 0.18 μH
L2 - 0.1 μH
L3 - 33μH

Transformers

P - 3:1 Turns Ratio

Diodes

D1 - HP-5082-0815
D2 - IN914
D3 - IN914
D4 - Red Led

Transistors

T1 - 2N5828
T2 - 2N2222
T3 - 2N3866
T4 - 2N3904
T5 - 2N3906

Batteries

B1 - 9V Alkaline
B2 - 9V Alkaline

Integrated Circuits

IC1 - MOT. (K1152A-5.00)
IC2 - LM2903N
IC3 - PMI (REF-02)
IC4 - LM317
IC5 - 7555N

Switch

SW1 - Centralab (P-501)

---

1. All resistors values are 10% tolerance except for R10 which is set for proper turn-off voltage (i.e., 12 V).

2. All capacitors values are 10% tolerance.

3. All inductors values are 10% tolerance.

ATTACHMENT IV

FREQUENCY AND AMPLITUDE AUTOMATED TEST

COMPUTER CODE DOCUMENTATION

The software used to perform the automated frequency and amplitude drift measurements is documented in this attachment. The program entitled "FRQTST" performs the frequency drift measurements controlling the frequency counter, running the test, and storing the measured data on a magnetic tape. The programs entitled "PWRTST" performs the power drift test controlling the spectrum analyzer, running the test, and storing the measured data on a magnetic tape. The companion program entitled "PLTF/P" reads the data off the magnetic tape, lists the test parameters specified, and plots the frequency and amplitude drifts measured. The computer codes are written HP-85 basic for a HP-85 desk top controller.

```
10 ! FREQUENCY DRIFT TEST
15 ! PROGRAM "FRQTST"
20 ! WRITTEN BY JOHN HOTCHKISS
30 ! DATE WRITTEN: 03/17/83
40 ! LAST UPDATE: 03/17/83
60 !  INITIAL SETUP STUFF
70 :
80 ON ERROR GOSUB 6000
83 SET TIMEOUT 7;1000
85 ON TIMEOUT 7 GOSUB 5000
90 CLEAR
110 OPTION BASE 1
120 REAL D(50),S(50,2),C(5)
130 REAL C,C7,C8,D,D9,E7,F1,F3,H,H1,H3,H8,H9
140 REAL L,M1,M2,N4,N5,R,R1,R2,S,T6,T8,T9,Z
170 DIM C$[100],D$[18],F1$[18],F2$[18],N$[18],P$[18],Q$[18],Z$[30]
180 M1=100000 @ L=0 @ T6=3600
185 M2=0 @ H1=0 @ H9=0 @ R2=0 ! SET UNUSED (BUT STORED) VARIABLES TO ZER
O
190 DISP "INITIALIZING"
200 ! PROGRAM TEST SECTION
210 ! PROGRAM WILL GO INTO TEST MODE IF FUNCTION KEY #1 IS
220 ! PRESSED IMMEDIATELY AFTER 'INITIALIZING' IS DISPLAYED
230 ON KEY# 1 GOTO 240
235 WAIT 1000 @ GOTO 245
240 DISP "NUMBER OF SECONDS IN AN HOUR";@ INPUT T6
245 OFF KEY# 1
250 FOR Z=1 TO 50
255 S(Z,1)=0 @ S(Z,2)=0 @ D(Z)=0
260 NEXT Z
265 CLEAR @ BEEP
270 DISP "SERIAL# OF ANTENNA TO TEST";@ INPUT N$
280 DISP "TEST LENGTH IN HOURS";@ INPUT T9
290 T8=T9*T6
300 DISP "DATE IN FORM MM/DD/YY?" @ DISP "INCLUDE LEADING ZEROS" @ INPUT
 D$
430 DISP "HARMONIC TO BE LOGGED FOR" @ DISP "FREQUENCY DRIFT";@ INPUT H3
440 DISP "FREQ RESOLUTION IN HZ?" @ DISP "MIN= 2 HZ" @ INPUT R1
450 IF R1<2 THEN R1=2
470 DISP "COMMENTS TO BE KEPT ON RECORD   (MAX 100 CHAR)" @ INPUT C$
480 DISP "" @ DISP "INSERT DATA TAPE AND THEN PRESS CONTINUE" @ PAUSE
490 DISP "" @ DISP "TAKING INITIAL DATA"
500 ! SET UP FREQ COUNTER
520 ABORTIO 7 @ RESET 7
530 LOCAL LOCKOUT 7
550 OUTPUT 719 ;"HPDAB2R0FA0P"
560 OUTPUT 719 ;"PPTPESRPTN"
681 SETTIME 0,0 ! START HERE SINCE INITIAL READINGS ARE DATA TOO
682 ! GET INITIAL FREQ, CALCULATE BASE FREQ
684 ENTER 719 ; Z$@ F3=VAL(Z$)
686 F1=IP(F3/H3+.5)
690 DISP USING 692 ; F1/1000000
692 IMAGE "BASE FREQ IS ",DD.DDDDDD," MHZ"
1000 ! STORE SETUP INFO AND INITIAL DATA ON TAPE
```

```
1005 DISP "" @ DISP "STORING INITIAL DATA" @ BEEP
1006 WAIT 1000
1010 F1$=D$[1,2] @ F1$[3,4]=D$[4,5] @ F1$[5]="8U"
1030 CREATE F1$,5
1040 ASSIGN# 1 TO F1$
1050 PRINT# 1 ; N$,D$,C$,T9,T6,F1,H1,H3,H9,R1,R2,M1,M2
1060 PRINT# 1 ; S(,),F3
1070 ! ALL DONE STORING--CLOSE FILE
1080 ASSIGN# 1 TO *
2000 ! MAIN DATA LOGGING LOOP
2010 ! SET UP FILE STUFF
2020 N5=1 @ N4=0
2022 ! CREATE FIRST FILE
2025 F2$=F1$ @ F2$[5]="01"
2030 CREATE F2$,8
2035 ASSIGN# 2 TO F2$
2040 ! SET UP DATA LOGGING STUFF
2060 D9=0
2100 ! HERE WE GO !
2102 DISP "" @ DISP "HERE WE GO!" @ BEEP
2105 IF TIME>T8 THEN 7000
2106 IF RMD(TIME,T6/12)<T6/12 THEN 2110
2107 DISP USING 2108 ; TIME/T6
2108 IMAGE "TIME IS ",DD.DD," HOURS INTO TEST"
2110 ENTER 719 ; Z$
2120 D=VAL(Z$)-F3
2130 IF ABS(D-D9)<R1 THEN 2320
2140 IF ABS(D)>M1 THEN 2165
2145 D9=D
2150 PRINT# 2 ; "F",H3,D,TIME
2155 DISP USING 2156 ; H3,D,TIME/T6
2156 IMAGE "F-H=",DD," D=",SDDDDD," T=",DD.DD
2160 GOTO 2180
2165 GOSUB 4560 ! CHECK FOR DEAD BATTERY
2170 PRINT# 2 ; "E",H3,D,TIME
2175 DISP USING 2176 ; H3,D,TIME/T6
2176 IMAGE "E-H=",DD," D=",SD.DDDE," T=",DD.DD
2180 N4=N4+1
2190 IF N4>=72 THEN GOSUB 3520
2320 WAIT 1000
2330 GOTO 2105
3000 ! SUBROUTINES
3010 !
3500 ! NEW FILE GENERATION
3510 ! N5=PRESENT FILE
3520 ASSIGN# 2 TO *
3530 N5=N5+1 @ N4=0
3540 IF N5<10 THEN 3590
3550 IF N5<99 THEN 3570
3560 DISP "FILE ERROR--TOO MANY FILES--PROGRAM PAUSED" @ BEEP @ PAUSE
3570 F2$[5]=VAL$(N5)
3580 GOTO 3600
3590 F2$[5]="0" @ F2$[6]=VAL$(N5)
3600 CREATE F2$,8
```

```
3610 ASSIGN# 2 TO F2$
3620 RETURN
4500 ! DEAD BATTERY CHECK
4510 ! CRITERION IS 5 MEASUREMENTS
4520 ! IN A ROW WITH DRIFT > M1
4540 !
4560 FOR C7=1 TO 5
4570 WAIT 1000
4580 ENTER 719 ; Z$
4600 IF ABS(VAL(Z$)-F3)<M1 THEN 4660
4610 NEXT C7
4620 ! BATTERY IS DEAD- PUT DELIMITER ON END OF FILE
4630 PRINT# 2 ; "T",H3,-99,TIME
4640 DISP USING 4645 ; TIME/3600
4645 IMAGE "BATTERY IS DEAD @ ",DD.DD," HOURS"
4650 GOTO 7000 ! END OF TEST
4660 ! NO DEAD BATTERY- REPORT AS ERROR
4680 RETURN
5000 ! I/O ERRORS
5010 ABORTIO 7 @ RESET 7
5020 ON TIMEOUT 7 GOTO 5050
5030 E7=SPOLL(719)
5040 GOTO 5140
5050 PRINT "FREQUENCY COUNTER I/O ERROR"
5060 DISP "FREQUENCY COUNTER I/O ERROR"
5070 L=L+1
5140 IF L>100 THEN 7000
5150 ABORTIO 7 @ RESET 7
5160 ON TIMEOUT 7 GOSUB 5000
5170 RETURN
6000 ! COMPUTER ERRORS
6005 IF ERRN<100 THEN 6010
6007 IF ERRN<123 THEN 6040
6010 PRINT USING 6020 ; ERRL,ERRN
6015 DISP USING 6020 ; ERRL,ERRN
6020 IMAGE "E, ERRL=",DDDD," ERRN=",DDD
6030 GOTO 6060
6040 PRINT USING 6050 ; ERRL,ERRN,ERRSC
6045 DISP USING 6050 ; ERRL,ERRN,ERRSC
6050 IMAGE "E, ERRL=",DDDD," ERRN=",DDD," ERRSC=",DDD
6060 L=L+1
6070 IF L<100 THEN RETURN ELSE GOTO 7000
7000 ! END OF TEST SEQUENCE
7010 ASSIGN# 2 TO * ! CLOSE LAST DATA FILE
7040 DISP "TEST OVER-LOAD DATA PLOTTING" @ DISP "PROGRAM 'PLTF/P'" @ BEE
P @ BEEP
9999 END
```

```
10 ! POWER DRIFT TEST
15 ! PROGRAM "PWRTST"
20 ! WRITTEN BY JOHN HOTCHKISS
30 ! DATE WRITTEN: 03/17/83
40 ! LAST UPDATE: 04/18/83
60 !  INITIAL SETUP STUFF
70 !
80 ON ERROR GOSUB 6000
83 SET TIMEOUT 7;1000
85 ON TIMEOUT 7 GOSUB 5000
90 CLEAR
110 OPTION BASE 1
120 REAL D(50),S(50,2),C(5)
130 REAL C,C7,C8,D,D9,E7,F1,F3,H,H1,H3,H8,H9
140 REAL L,M1,M2,N4,N5,P5,R,R1,R2,S,T6,T8,T9,Z
170 DIM C$[100],D$[18],F1$[18],F2$[18],N$[18],P$[18],Q$[18],Z$[30]
180 M2=2.5 @ L=0 @ T6=3600
185 M1=0 @ R1=0 @ H3=0 ! SET UNUSED (BUT STORED) VARIABLES TO ZERO
190 DISP "INITIALIZING"
200 ! PROGRAM TEST SECTION
210 ! PROGRAM WILL GO INTO TEST MODE IF FUNCTION KEY #1 IS
220 ! PRESSED IMMEDIATELY AFTER "INITIALIZING" IS DISPLAYED
230 ON KEY# 1 GOTO 240
235 WAIT 1000 @ GOTO 245
240 DISP "NUMBER OF SECONDS IN AN HOUR";@ INPUT T6
245 OFF KEY# 1
250 FOR Z=1 TO 50
255 S(Z,1)=0 @ S(Z,2)=0 @ D(Z)=0
260 NEXT Z
265 CLEAR @ BEEP
270 DISP "SERIAL# OF ANTENNA TO TEST";@ INPUT N$
280 DISP "TEST LENGTH IN HOURS";@ INPUT T9
290 T8=T9*T6
300 DISP "DATE IN FORM MM/DD/YY?" @ DISP "INCLUDE LEADING ZEROS" @ INPUT
 D$
310 DISP "BASE FREQ IN MHZ";@ INPUT F1@ F1=F1*1000000 @ F3=F1
320 DISP "POWER RESOLUTION IN dB?" @ DISP "MIN= .1 dB" @ INPUT R2
330 IF R2<.1 THEN R2=.1
400 DISP "NUMBER OF FIRST HARMONIC OF BASEFREQ TO RECORD";@ INPUT H1
410 DISP "NUMBER OF LAST HARMONIC OF BASE FREQ TO RECORD";@ INPUT H9
440 DISP "ENTER 5 HARMONICS TO BE USED TO CHECK FOR A DEAD BATTERY."
450 DISP "THEY SHOULD BE HARMONICS WHICH  DO NOT HAVE ANY AMBIENT SIGNAL
S NEAR THEM."
455 DISP "ENTER IN FORM H#,H#,H#,H#,H#"
460 INPUT C(1),C(2),C(3),C(4),C(5)
470 DISP "COMMENTS TO BE KEPT ON RECORD   (MAX 100 CHAR)" @ INPUT C$
475 DISP "DO YOU WANT INITIAL POWER" @ DISP "LEVELS PRINTED";@ INPUT G$
476 IF G$[1,1]="Y" THEN P5=1 ELSE P5=0
480 DISP "" @ DISP "INSERT DATA TAPE AND THEN PRESS CONTINUE" @ PAUSE
490 DISP "" @ DISP "TAKING INITIAL DATA"
500 ! SET UP SPECTRUM ANALYZER
510 ABORTIO 7 @ RESET 7
520 LOCAL LOCKOUT 7
530 OUTPUT 701 ;"INIT"
```

```
580 WAIT 3000
590 ! PERFORM INITIAL ALIGNMENT
600 OUTPUT 701 ;"SPA 1E7;RES 1E6"
605 WAIT 2000
610 OUTPUT 701 ;"FMA;CEN"
620 ! NOW SET IN RUNNING SHAPE
640 OUTPUT 701 ;"SPA 5E5;RES 1E5;REF 20;CLI ON;VID NAR;CRS PEA"
650 WAIT 1000
660 OUTPUT 701 ;"FMA;CEN"
670 OUTPUT 701 ;"FRD 0"
680 WAIT 1000
681 SETTIME 0,0 ! START HERE SINCE INITIAL READINGS ARE DATA TOO
690 DISP USING 692 ; F1/1000000
692 IMAGE "BASE FREQ IS ",DD.DDDDDD," MHZ"
700 ! GET INITIAL READINGS
710 !  HARMONIC IS ZERO
720 H8=0
730 ! GET HARMONICS DATA
740 OUTPUT 701 ;"VRT LOG;1"
750 ! GET FIRST HARMONIC
760 H=H1 @ GOSUB 3120
770 FOR R=15 TO -99 STEP -1
780 Z$="REF " @ Z$[5]=VAL$(R)
790 OUTPUT 701 ;Z$
800 WAIT 1000
810 OUTPUT 701 ;"FMA;POINT?"
820 ENTER 701 ; P$
830 IF FNY(P$)<=0 THEN 850
840 IF FNY(P$)>110 THEN 880
850 NEXT R
860 DISP "COULD NOT FIND FIRST HARMONIC"
870 GOTO 9999
880 S(H,1)=R
890 S(H,2)=FNF
900 ! NOW GET OTHER HARMONICS-- REF (R) AT LEVEL OF FIRST HARMONIC
910 FOR H=H1+1 TO H9
920 GOSUB 3120 ! TUNE TO NEXT HARMONIC
930 WAIT 1000
940 OUTPUT 701 ;"FMA;POINT?"
950 ENTER 701 ; P$
952 IF FNY(P$)<110 THEN 958
954 IF FNY(P$)>140 THEN 970
956 GOTO 980
958 OUTPUT 701 ;"REF DEC" @ R=R-1
960 WAIT 1000
962 OUTPUT 701 ;"FMA;POINT?"
964 ENTER 701 ; P$
966 IF FNY(P$)<110 THEN 958
968 GOTO 980
970 OUTPUT 701 ;"REF INC" @ R=R+1
972 WAIT 1000
974 OUTPUT 701 ;"FMA;POINT?"
976 ENTER 701 ; P$
978 IF FNY(P$)>140 THEN 970
```

```
980 S(H,1)=F
990 S(H,2)=FNP
991 OUTPUT 701 ;"CEN" ! CENTER THINGS UP
995 NEXT H
1000 ! PRINTING INITIAL VALUES SECTION
1010 IF P0=0 THEN 1100
1020 PRINT USING "3/"
1022 PRINT "DATE: ";D$
1023 PRINT
1024 PRINT "SERIAL NUMBER: ";N$
1025 PRINT
1026 PRINT C$
1027 PRINT USING "2/"
1030 PRINT "  FREQ (MHz)  POWER LEVEL (dBm)"
1040 FOR H=H1 TO H9
1050 PRINT USING 1060 ; IP(F1*H/1000000+.5),S(H,2)
1060 IMAGE 5X,DDD,11X,SDD.DDD
1070 NEXT H
1080 PRINT USING "2/"
1100 ! STORE SETUP INFO AND INITIAL DATA ON TAPE
1105 DISP "" @ DISP "STORING INITIAL DATA" @ BEEP
1106 WAIT 1000
1110 F1$=D$[1,2] @ F1$[3,4]=D$[4,5] @ F1$[5]="SU"
1120 PRINT USING "3/"
1130 CREATE F1$,5
1140 ASSIGN# 1 TO F1$
1150 PRINT# 1 ; N$,D$,C$,T9,T6,F1,H1,H3,H9,R1,R2,M1,M2
1160 PRINT# 1 ; S(,),F3
1170 ! ALL DONE STORING--CLOSE FILE
1180 ASSIGN# 1 TO *
2000 ! MAIN DATA LOGGING LOOP
2010 ! SET UP FILE STUFF
2020 N5=1 @ N4=0
2022 ! CREATE FIRST FILE
2025 F2$=F1$ @ F2$[3]="01"
2030 CREATE F2$,8
2035 ASSIGN# 2 TO F2$
2040 ! SET UP DATA LOGGING STUFF
2050 FOR H=1 TO 50
2060 D(H)=0
2070 NEXT H
2085 OUTPUT 701 ;"VRT LOG:1"
2100 ! HERE WE GO !
2102 DISP "" @ DISP "HERE WE GO!" @ BEEP
2105 IF TIME>T8 THEN 7000
2107 DISP USING 2108 ; TIME/T6
2108 IMAGE "TIME IS ",DD.DD," HOURS INTO TEST"
2200 ! GET POWER DATA
2220 FOR H=H1 TO H9
2223 IF H<>H1 THEN 2230
2225 GOSUB 3410 ! TUNE TO FIRST HARM ROUTINE
2227 GOTO 2240
2230 GOSUB 3220 ! TUNE TO HARM
2240 D=FNP-S(H,2)
```

```
2250 IF ABS(D-D(H))<R2 THEN 2320
2260 IF ABS(D)>M2 THEN 2285
2265 D(H)=D
2270 PRINT# 2 ; "P",H,D,TIME
2275 DISP USING 2276 ; H,D,TIME/T6
2276 IMAGE "P-H=",DD," D=",SD.DD," T=",DD.DD
2280 GOTO 2300
2285 GOSUB 4550 ! CHECK FOR DEAD BATTERY
2290 PRINT# 2 ; "G",H,D,TIME
2295 DISP USING 2296 ; H,D,TIME/T6
2296 IMAGE "G-H=",DD," D=",SDD.DD," T=",DD.DD
2300 N4=N4+1
2310 IF N4>=72 THEN GOSUB 3520
2320 NEXT H
2330 GOTO 2105
3000 ! SUBROUTINES
3010 !
3100 ! TUNE W/O REGARD TO INITIAL DATA
3110 ! H=HARM TO GO TO;H8=PRESENT HARM TUNED TO
3120 Z$="TUN " @ Z$[5]=VAL$(FNR(F1*(H-H8)))
3125 WAIT 500
3130 OUTPUT 701 ;Z$
3140 H8=H
3150 RETURN
3200 ! TUNE W/ REGARD TO INITIAL DATA
3210 ! H=HARM TO GOTO; H8=PRESENT HARM
3220 WAIT 500
3230 Z$="TUN " @ Z$[5]=VAL$(FNR(F1*(H-H8)))
3240 OUTPUT 701 ;Z$
3250 H8=H
3260 WAIT 500
3270 Z$="REF " @ Z$[5]=VAL$(S(H,1))
3280 OUTPUT 701 ;Z$
3290 WAIT 2000
3300 OUTPUT 701 ;"FMA;POINT?"
3302 ENTER 701 ; Z$
3305 IF FNY(Z$)<125-(M2+.5)*25 THEN 3340 ! IF LEVEL IS M2+.5 dB DOWN FRO
M CENTER DON'T FRC
3310 OUTPUT 701 ;"CEN"
3315 WAIT 500
3320 Z$="FRC " @ Z$[5]=VAL$(FNR(F1*H))
3330 OUTPUT 701 ;Z$
3340 WAIT 500
3350 RETURN
3400 ! TUNE TO FIRST HARM (FROM LAST HARM)
3410 OUTPUT 701 ;"FRE 0;REF -10;SPA 1E6"
3420 WAIT 4000
3430 OUTPUT 701 ;"FMA;CEN;FRC 0"
3440 WAIT 1000
3445 OUTPUT 701 ;"SPA 5E5"
3450 WAIT 3000
3455 OUTPUT 701 ;"FMA;CEN;FRC 0"
3460 WAIT 1000
3470 H8=0
```

```
3480 GOSUB 3250 ! TUNE TO H HARMONIC
3490 RETURN
3500 ! NEW FILE GENERATION
3510 ! N5=PRESENT FILE
3520 ASSIGN# 2 TO *
3530 N5=N5+1 @ N4=0
3540 IF N5<10 THEN 3590
3550 IF N5<99 THEN 3570
3560 DISP "FILE ERROR--TOO MANY FILES--PROGRAM PAUSED" @ BEEP @ PAUSE
3570 F2$[5]=VAL$(N5)
3580 GOTO 3600
3590 F2$[5]="0" @ F2$[6]=VAL$(N5)
3600 CREATE F2$,8
3610 ASSIGN# 2 TO F2$
3620 RETURN
4000 ! FUNCTIONS
4005 ! FNY-GET NUMBER FROM POINT STRING
4010 DEF FNY(P$) = VAL(P$[POS(P$,",")+1])
4020 ! FNR-ROUND NUMBERS IN THE MILLIONS (FREQ)
4030 DEF FNR(Z) = SGN(Z)*IP(ABS(Z)/1000000+.5)*1000000
4100 ! FNP- AVERAGED POWER OVER 5 READINGS
4105 ! H MUST BE CURRENT HARMONIC TUNED TO, Z MUST NOT BE USED
4110 DEF FNP
4120 S=0
4130 FOR Z=1 TO 5
4140 WAIT 500
4150 OUTPUT 701 ;"FMA;POINT?"
4160 ENTER 701 ; P$@ S=S+FNY(P$)
4170 NEXT Z
4180 S=S/5
4190 FNP=S(H,1)-8+(S-25)/25
4200 FN END
4500 ! DEAD BATTERY CHECK
4510 ! CRITERION IS 5 PRESELECTED HARMONICS HAVE LEVELS
4520 ! M2 dB OR MORE DOWN
4530 ! CHECK HARMONICS IN C(5)
4540 !
4550 C8=H ! KEEP CURRENT H IF NOT DEAD BATTERY
4560 FOR C7=1 TO 5
4570 H=C(C7)
4580 GOSUB 3220 ! TUNE TO HARM TO CHECK
4590 C=FNP-S(H,2)
4600 IF ABS(C)<M2 THEN 4660
4610 NEXT C7
4620 ! BATTERY IS DEAD- PUT DELIMITER ON END OF FILE
4630 PRINT# 2 ; "T",C8,-99,TIME
4640 DISP USING 4645 ; TIME/3600
4645 IMAGE "BATTERY IS DEAD @ ",DD.DD," HOURS"
4650 GOTO 7000 ! END OF TEST
4660 ! NO DEAD BATTERY- REPORT AS ERROR
4670 H=C8 ! RESTORE H COUNTER
4680 RETURN
5000 ! I/O ERRORS
5010 ABORTIO 7 @ RESET 7
```

```
5080 ON TIMEOUT 7 GOTO 5110
5090 E7=SPOLL(701)
5100 GOTO 5140
5110 PRINT "SPECTRUM ANALYZER I/O ERROR"
5120 DISP "SPECTRUM ANALYZER I/O ERROR"
5130 L=L+1
5140 IF L>100 THEN 7000
5150 ABORTIO 7 @ RESET 7
5160 ON TIMEOUT 7 GOSUB 5000
5170 RETURN
6000 ! COMPUTER ERRORS
6005 IF ERRN<100 THEN 6010
6007 IF ERRN<123 THEN 6040
6010 PRINT USING 6020 ; ERRL,ERRN
6015 DISP USING 6020 ; ERRL,ERRN
6020 IMAGE "E, ERRL=",DDDD," ERRN=",DDD
6030 GOTO 6060
6040 PRINT USING 6050 ; ERRL,ERRN,ERRSC
6045 DISP USING 6050 ; ERRL,ERRN,ERRSC
6050 IMAGE "E, ERRL=",DDDD," ERRN=",DDD," ERRSC=",DDD
6060 L=L+1
6070 IF L<100 THEN RETURN ELSE GOTO 7000
7000 ! END OF TEST SEQUENCE
7010 ASSIGN# 2 TO * ! CLOSE LAST DATA FILE
7040 DISP "TEST OVER-LOAD DATA PLOTTING" @ DISP "PROGRAM 'PLTF/P'" @ BEE
P @ BEEP
9999 END
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10 ! PLOTTING AND DATA MANIPULATION PROGRAM FOR DRIFT DATA
15 ! PROGRAM 'PLTF/P'
20 ! USE WITH PROGRAMS 'PWRTST', 'FRQTST', AND 'F/PTST'
30 ! WRITTEN BY JOHN HOTCHKISS
40 ! DATE 10/13/82
50 ! LAST UPDATE 3/17/83
60 ! INITIAL SETUP STUFF
70 ON ERROR GOSUB 6000
75 SET TIMEOUT 7;25000
78 ON TIMEOUT 7 GOSUB 7000
80 CLEAR
90 DISP 'INITIALIZING'
100 OPTION BASE 1
110 REAL D(200),T(200),S(50,2),E(50),T3(50)
120 REAL D,D9,F1,F3,H,H1,H3,H5,H6,H7,H9,L
130 REAL M1,M2,N,N1,N4,N5,P,P1,P9,R1,R2,R5,S,T,T6,T7,T8,T9,X,Y,Z
140 DIM C$[100],C1$[18],C2$[18],D$[18],F1$[18],F2$[18],N$[18]
150 DIM Q$[18],Q1$[18],T$[18],Z$[18],Z1$[18],Z2$[18]
200 CLEAR @ BEEP
210 DISP 'DATE OF TEST IN FORM MM/DD/YY ?' @ DISP 'INCLUDE LEADING ZEROS
' @ INPUT D$
220 F1$=D$[1,2] @ F1$[3,4]=D$[4,5] @ F1$[5]='SU'
225 DISP 'INSERT DATA TAPE INTO TAPE' @ DISP 'READER AND THEN PRESS CONT
INUE" @ BEEP @ PAUSE
230 DISP 'LOADING SETUP INFORMATION' @ WAIT 1000
240 ASSIGN# 1 TO F1$
250 READ# 1 ; N$,D$,C$,T9,T6,F1,H1,H3,H9,R1,R2,M1,M2
260 READ# 1 ; S(,),F3
265 ASSIGN# 1 TO *
270 DISP 'SETUP INFO READ INTO HP85' @ BEEP
280 DISP 'DO YOU WANT HARD COPY';@ INPUT Q$
290 IF Q$[1,1]='Y' THEN PRINTER IS 2 ELSE PRINTER IS 1
295 PRINT USING '2/'
300 PRINT 'HARMONIC POWER TEST'
305 PRINT USING '/"
310 PRINT 'DATE: ';D$
320 PRINT 'SERIAL# OF ANTENNA: ';N$
330 PRINT USING 340 ; T9
340 IMAGE 'DURATION OF TEST: ',DD,' HOURS'
350 PRINT USING 360 ; F1/1000000
360 IMAGE 'BASE FREQUENCY: ',DDD.DDD,'MHZ'
370 PRINT USING 380 ; H1
380 IMAGE 'FIRST HARMONIC RECORDED: ',DD
390 PRINT USING 400 ; H9
400 IMAGE 'LAST HARMONIC RECORDED: ',DD
430 PRINT USING 440 ; R1
440 IMAGE 'FREQUENCY RESOLUTION: ',DDD,' HZ'
450 PRINT USING 460 ; R2
460 IMAGE 'POWER RESOLUTION: 'D.DD,' dB'
462 PRINT 'COMMENTS:'
464 PRINT C$
466 DISP USING '/'
468 DISP 'HIT CONT WHEN DONE READING DATA' @ BEEP @ PAUSE
470 DISP 'DO YOU WANT INITIAL VALUES PRINTED';@ INPUT Q$
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472 IF Q$[1,1]="N" THEN 484
473 PRINT USING "3/"
474 PRINT "  FREQ(MHZ)      INITIAL VALUE"
476 FOR H=H1 TO H9
478 PRINT USING 480 ; IP(F1*H/1000000+.5),S(H,2)
480 IMAGE 5X,DDD,11X,SDD.DDD
482 NEXT H
484 DISP USING "/"
486 DISP "WHEN PLOTTING POWER DRIFT DATA," @ DISP "DO YOU WANT TO ENTER
VALUES OR"
487 DISP "SHOULD THE COMPUTER USE STORED" @ DISP "VALUES"
488 DISP "E=YOUR OWN,C=COMPUTER" @ BEEP
489 INPUT Q1$@ Q1$=Q1$[1,1]
490 DISP USING "3/"
500 ! TAPE OPERATION
510 ! FIND NUMBER OF FILES-N5
520 ! AND LAST RECORD NUMBER-N4
525 ! ALSO FIND LAST TIME T8
527 DISP "SEARCHING DATA FOR LAST FILE" @ WAIT 1000
530 ON ERROR GOTO 620
540 F2$=F1$[1,4] @ T8=T6*T9
550 FOR N5=1 TO 99
560 IF N5<10 THEN 580
570 F2$[5]=VAL$(N5) @ GOTO 590
580 F2$[5]="0" @ F2$[6]=VAL$(N5)
590 ASSIGN# 2 TO F2$
600 ASSIGN# 2 TO *
610 NEXT N5
620 ! N5 NOW HAS NUMBER OF LAST FILE +1
630 N5=N5-1
640 IF N5<10 THEN 660
650 F2$[5]=VAL$(N5) @ GOTO 670
660 F2$[5]="0" @ F2$[6]=VAL$(N5)
670 ASSIGN# 2 TO F2$
680 ! NOW FIND LAST RECORD N4 + LAST TIME T8
690 ON ERROR GOTO 750
700 FOR N4=1 TO 72
710 READ# 2 ; T$,H,D,T
715 IF T$="T" THEN T8=T
720 NEXT N4
740 ! N4 NOW HAS LAST RECORD NUMBER + 1
750 N4=N4-1
760 ASSIGN# 2 TO *
770 ON ERROR GOSUB 6000 ! RETURN TO NORMAL ERROR HANDLER
780 ! ADJUST LENGTH OF TEST T9 FOR PLOTS TO NEXT EVEN HOUR AFTER BATTERY
 DEAD
790 T7=IP(T8/T6+.9999)
800 IF RMD(T7,2)=0 THEN 820
810 T9=T7+1 @ GOTO 830 ! HRS ODD
820 T9=T7 ! HRS EVEN
830 ! ALL DONE DOING TAPE FILE STUFF
1000 ! READ IN AND ANALYZE DATA SECTION
1010 !
1020 GOSUB 1500 ! ASSIGN KEYS AND FUNCTIONS,ETC
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1030 GOTO 1030 ! KEEP ITSELF BUSY!
1100 ! PLOT FREQUENCY DATA
1105 GOSUB 1700 ! CLEAR EVERYTHING, UNASSIGN KEYS
1110 DISP 'FREQUECY DRIFT PLOTTING'
1120 DISP 'LOADING FREQUENCY DRIFT DATA'
1130 C1$='F' @ C2$='E' @ H7=H3
1140 GOSUB 2000 ! GET DATA
1150 GOSUB 3000 ! PLOT IT
1160 GOSUB 1500 ! REASSIGN FUNCTION KEYS,ETC
1170 RETURN
1200 ! SINGLE POWER PLOT SECTION
1205 GOSUB 1700 ! UNASSIGN FUNCTION KEYS,ETC
1210 DISP 'SINGLE HARMONIC POWER DRIFT' @ DISP 'PLOTTING SECTION'
1220 DISP 'WHICH HARMONIC TO PLOT'
1230 INPUT H7
1240 DISP 'LOADING POWER DRIFT DATA FOR' @ DISP 'HARMONIC #';H7
1250 C1$='P' @ C2$='G'
1260 GOSUB 2000 ! GET DATA
1270 GOSUB 5000 ! PLOT IT
1280 GOSUB 1500 ! REASSIGN FUNCTION KEYS
1290 RETURN
1300 ! MULTIPLE POWER PLOT SECTION
1305 GOSUB 1700
1310 DISP 'MULTIPLE HARMONIC POWER DRIFT' @ DISP 'PLOTTING SECTION'
1320 DISP 'FIRST HARMONIC TO BE PLOTTED' @ INPUT H5
1330 DISP 'LAST HARMONIC TO BE PLOTTED' @ INPUT H6
1340 C1$='P' @ C2$='G'
1350 FOR H7=H5 TO H6
1360 DISP 'LOADING POWER DRIFT DATA FOR' @ DISP 'HARMONIC #';H7
1370 GOSUB 2000 ! GET DATA
1380 GOSUB 5000 ! PLOT IT
1390 NEXT H7
1400 GOSUB 1500 ! REASSIGN FUNCTION KEYS
1410 RETURN
1500 ! SUBROUTINE TO ASSIGN FUNCTION KEYS AND  ISP MENU
1510 ON KEY# 5,' FREQ' GOSUB 1100
1520 ON KEY# 1,' PLOT' GOSUB 1100
1530 ON KEY# 6,'SINGLE' GOSUB 1200
1540 ON KEY# 2,'PWR PLT' GOSUB 1200
1550 ON KEY# 7,'MULTIPLE' GOSUB 1300
1560 ON KEY# 3,'PWR PLT' GOSUB 1300
1570 ON KEY# 8,'  END' GOTO 9000
1580 ON KEY# 4 GOTO 9000
1590 CLEAR @ KEY LABEL
1600 DISP 'PRESS KEY FOR FUNCTION DESIRED'
1610 RETURN
1700 ! UNASSIGN ALL KEYS, ETC
1710 OFF KEY# 1 @ OFF KEY# 2
1720 OFF KEY# 3 @ OFF KEY# 4
1730 OFF KEY# 5 @ OFF KEY# 6
1740 OFF KEY# 7 @ OFF KEY# 8
1750 CLEAR
1760 RETURN
2000 ! SUBROUTINE TO READ IN DATA ARRAY FROM TAPE FILES
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2010 ! C1$=GOOD DATA,C2$=BAD
2020 ! SEARCH THROUGH ALL FILES
2025 ! BUFFER #2 MUST BE CLOSED
2030 ! ZERO ARRAYS
2040 FOR Z=1 TO 200
2050 D(Z)=0 @ T(Z)=0
2060 NEXT Z
2070 FOR Z=1 TO 50
2080 E(Z)=0 @ T3(Z)=0
2090 NEXT Z
2100 P=1 @ P1=1
2110 FOR N=1 TO N5
2130 IF N<10 THEN 2150
2140 F2$[5]=VAL$(N) @ GOTO 2160
2150 F2$[5]="0" @ F2$[6]=VAL$(N)
2160 ASSIGN# 2 TO F2$
2170 IF N=N5 THEN N3=N4 ELSE N3=72
2180 FOR N1=1 TO N3
2190 READ# 2 ; T$,H,D,T
2195 IF H<>H7 THEN 2250
2200 IF T$=C1$ THEN 2230
2210 IF T$=C2$ THEN 2240
2220 GOTO 2250 ! GOOF OR 'T' RECORD
2230 D(P)=D @ T(P)=T @ P=P+1 @ GOTO 2250
2240 E(P1)=D @ T3(P1)=T @ P1=P1+1
2250 NEXT N1
2260 NEXT N
2265 ASSIGN# 2 TO *
2270 ! ADJUST ENDPOINT OF ARRAY
2280 IF P=1 THEN T(2)=T8 @ P9=2 @ GOTO 2300
2290 IF T(P-1)<T8 THEN T(P)=T8 @ D(P)=D(P-1) @ P9=P ELSE P9=P-1
2300 P8=P1-1
2310 ! FIND MAX DEVIATION D9
2320 D9=0
2330 FOR Z=1 TO P9
2340 IF D9<ABS(D(Z)) THEN D9=ABS(D(Z))
2350 NEXT Z
2360 RETURN
3000 ! PLOT FREQ DATA
3010 DISP "" @ DISP "SET UP PLOTTER AND HIT CONTINUE" @ BEEP
3020 PAUSE
3030 ABORTIO 7 @ RESET 7
3040 S=SPOLL(706) ! SEE IF PLOTTER IS THERE
3050 PLOTTER IS 706
3060 LIMIT 0,260,0,200
3070 CSIZE 6 @ LORG 1 @ LDIR 1,0
3075 OUTPUT 706 ;"VS 5"
3076 MOVE 55,8 @ LABEL "T"
3080 MOVE 55,8 @ LABEL "TIME (HOURS)"
3090 MOVE 27,94 @ LABEL "FREQUENCY DRIFT TEST   ";D$
3100 Z$=VAL$(F3) @ L=LEN(Z$)
3110 Z1$=VAL$(IP(F3/1000000))
3120 Z2$=Z$[L-5,L]
3130 MOVE 27,89 @ LABEL "CENTER FREQ: ";Z1$;".";Z2$;" MHz"
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3230 LDIR 0,1
3240 MOVE 12,36 @ LABEL "DRIFT IN Hz"
3250 CSIZE 3 @ LDIR 1,0 @ LORG 6
3260 MOVE 20,13 @ LABEL "0"
3270 LOCATE 20,120,15,85
3280 SCALE 0,T9,-10,10
3300 AXES -.5,1,0,0,2,1
3310 LORG 8 @ LDIR 1,0
3320 SCALE 20,120,-1000,1000
3330 FOR P=-1000 TO 1000 STEP 100
3340 MOVE 19.5,P @ LABEL P
3350 NEXT P
3360 LORG 6
3370 SCALE 0,T9,15,85
3380 FOR P=1 TO T9
3390 MOVE P,48 @ LABEL P
3400 NEXT P
3410 SCALE 0,T9,-1000,1000
3420 MOVE 0,0
3430 ! DRAW DATA
3440 FOR P=1 TO P9
3450 X=T(P)/T6 @ Y=D(P)
3460 DRAW X,Y
3470 NEXT P
3480 PENUP
3490 OUTPUT 706 ;"IN"
3495 BEEP
3500 DISP "DO YOU WISH TO MAKE ANOTHER" @ DISP "PLOT OF THE SAME DATA";@
 INPUT Q$
3510 IF Q$[1,1]="Y" THEN 3010
3520 RETURN
5000 ! PLOT POWER DATA
5003 IF Q1$="E" THEN 5007
5005 R5=S(H7,2) @ GOTO 5010
5007 DISP "ENTER ABSOLUTE POWER LEVEL FOR  PLOT" @ BEEP @ INPUT R5
5010 DISP "" @ DISP "SET UP PLOTTER AND HIT CONTINUE" @ BEEP
5020 PAUSE
5030 ABORTIO 7 @ RESET 7
5040 S=SPOLL(706) ! SEE IF PLOTTER IS THERE
5050 PLOTTER IS 706
5060 LIMIT 0,260,0,200
5070 CSIZE 6 @ LORG 1 @ LDIR 1,0
5075 OUTPUT 706 ;"VS 5"
5078 MOVE 55,8 @ LABEL "T"
5080 MOVE 55,8 @ LABEL "TIME (HOURS)"
5090 MOVE 27,94 @ LABEL "POWER DRIFT TEST    ";D$
5100 Z$=VAL$(IP(F1*H7/1000000+.5))
5130 MOVE 27,89 @ LABEL "HARMONIC #";H7;" (";Z$;" MHz)"
5132 R5=SGN(R5)*(IP(ABS(R5))+IP(FP(ABS(R5))*10+.5)/10)
5134 Z$=VAL$(IP(R5*10)) @ L=LEN(Z$)
5136 Z1$=Z$[1,L-1] @ Z2$=Z$[L]
5140 MOVE 27,84 @ LABEL "REFERENCE LEVEL: ";Z1$;".";Z2$;" dBm"
5150 IF D9<>0 THEN 5230
5160 MOVE 30,70 @ LABEL "DRIFT LESS THAN THE RESOLUTION"
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5170 MOVE 30,65 @ LABEL "OF THE SPECTRUM ANALYZER"
5230 LDIR 0,1
5240 MOVE 12,22 @ LABEL "POWER DRIFT IN dB"
5250 CSIZE 3 @ LDIR 1,0 @ LORG 6
5260 MOVE 20,13 @ LABEL "0"
5270 LOCATE 20,120,15,85
5280 SCALE 0,T9,-3,3
5290 AXES -.5,.5,0,0,2,2
5310 LORG 8 @ LDIR 1,0
5320 SCALE 20,120,-3,3
5330 FOR P=-3 TO 3 STEP 1
5340 MOVE 19.5,P @ LABEL P
5350 NEXT P
5360 LORG 6
5370 SCALE 0,T9,15,85
5380 FOR P=1 TO T9
5390 MOVE P,48 @ LABEL P
5400 NEXT P
5410 SCALE 0,T9,-3,3
5420 MOVE 0,0
5430 ! DRAW DATA
5440 FOR P=1 TO P9
5450 X=T(P)/T6 @ Y=D(P)
5460 DRAW X,Y
5470 NEXT P
5480 PENUP
5490 OUTPUT 706 ;"IN"
5495 BEEP
5500 DISP "DO YOU WISH TO MAKE ANOTHER" @ DISP "PLOT OF THE SAME DATA";@
 INPUT Q$
5510 IF Q$[1,1]="Y" THEN 5010
5520 RETURN
6000 DISP "COMPUTER ERROR!"
6005 DISP "ERRL=";ERRL;"  ERRN=";ERRN
6010 PAUSE
6020 RETURN
7000 DISP "I/O ERROR!"
7005 DISP "ERRL=";ERRL;"  ERRN=";ERRN
7010 PAUSE
7020 RETURN
9000 CLEAR
9010 END
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