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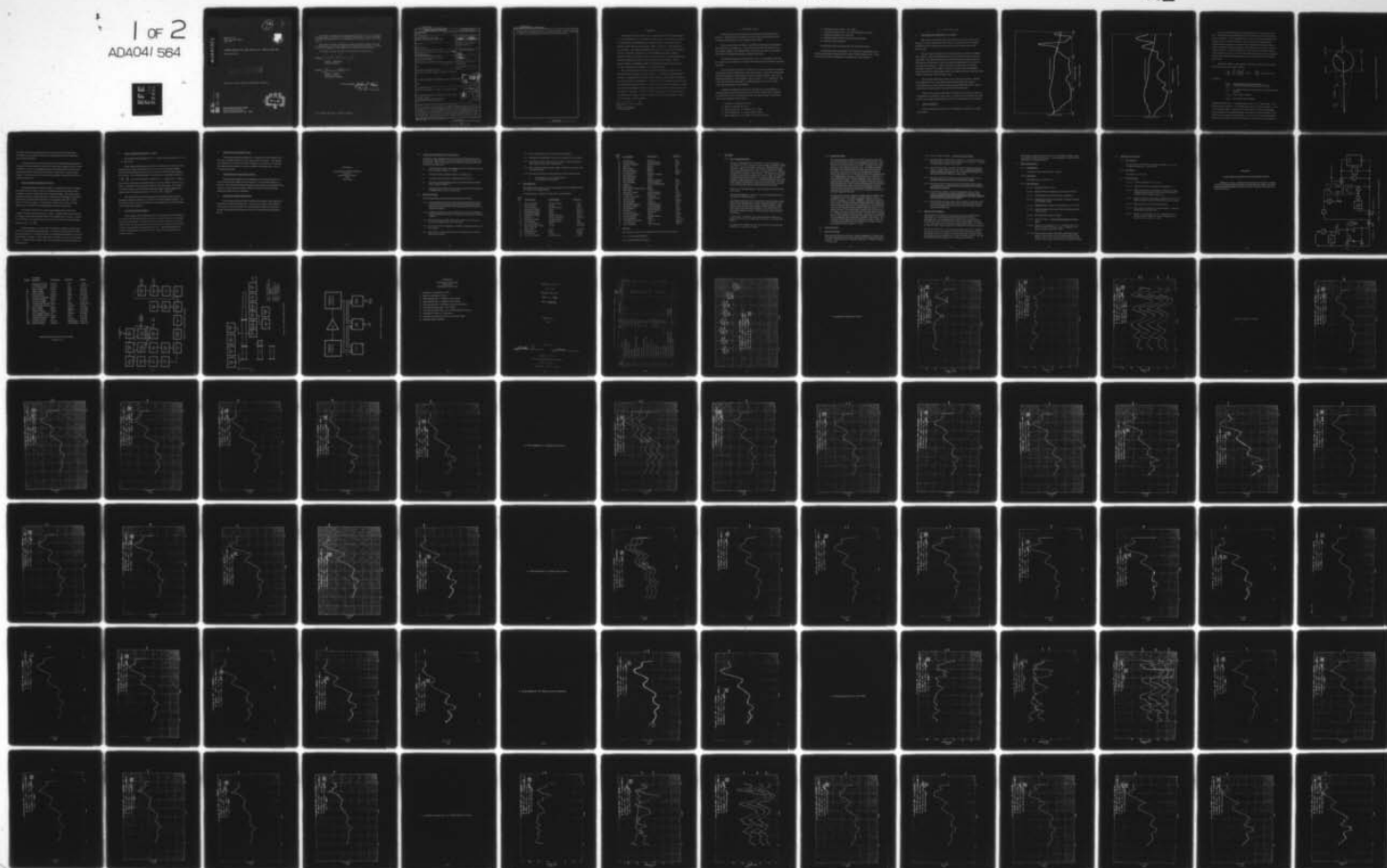
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RADC-TR-77-174
Final Technical Report
June 1977

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EXTENDED BANDWIDTH VTS-5753B1 COUPLED CAVITY TRAVELING WAVE TUBE

Varian Associates

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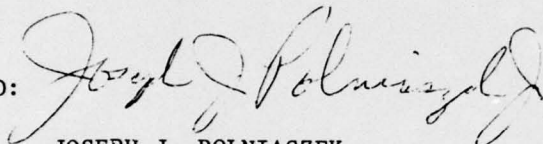
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This report contains some illustrations which may not be of the highest printing quality but because of economical consideration, it was determined to be in the best interest of the government that they be used in this publication.

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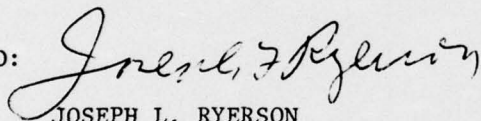
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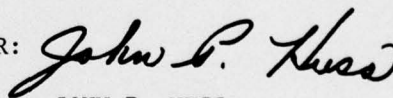
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) The objective of this effort was to establish sufficient data on the VTS-5753 family of coupled cavity traveling wave tubes to enable evaluation of the tube's capabilities in a tactical, ECCM environment. This was accomplished by the development of an extended bandwidth tube capable of transmitting sophisticated radar waveforms that have low ECM susceptibility and extensive testing of the resultant tube. This project was highly successful in both respects. A tube of the VTS5753 family was developed, the VTS5753B1, that has a 200 MHz wider		

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bandwidth than the previous version of the tube. Secondly, the testing program has supplied data invaluable to system designers/analysts that will allow them to incorporate tube nonlinearities into the overall system design.



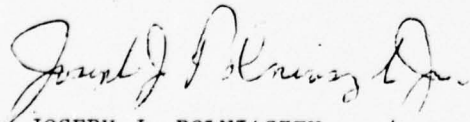
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EVALUATION

The Varian VTS-5753 coupled cavity traveling wave tube has been limited to a 12% bandwidth due to a narrowband window design. This effort was aimed at extending the tube bandwidth and tabulating data concerning the tube's operation under varying and sometimes adverse conditions. Both goals have been attained. The extended bandwidth tube has a useful electronic bandwidth of 18% and extensive evaluation over this bandwidth has been attained. Conditions such as beam supply pushing, long line effects and mismatched lines have been simulated and data has been collected and correlated. These results indicate a remarkable amount of amplitude and phase linearity over the band considering the absence of an input equalizer.

The conclusions and test results obtained through this effort will be incorporated into various Air Force projects. For example, system engineers now have a tabulated set of characteristics that will allow them to determine the radar amplifier's deviations from linear, and to determine the effects upon the sophisticated ECCM waveforms of today's "state of the art" systems. Further research and development can now be placed upon more refined tube characteristic measurements techniques. Finally, the data generated can be integrated into the RADSIM radar simulator software package to refine the transmitter complex for preliminary system evaluation.



JOSEPH J. POLNIASZEK
Project Engineer

I. INTRODUCTION

A general discussion of the program is presented in the Technical Report Summary. That document is considered to be part of this report and the data and comments presented therein are not repeated in this report.

The formal test data were taken in accordance with the approved Acceptance Test Procedure (see Appendix A). At the request of the RADC representative who witnessed the testing, some additional data were taken for the sake of completeness and in order to facilitate the computer simulation of the tube.

The official test data were limited to the 3.0 to 3.7 GHz frequency range due to a resonance in the collector at 2.950 GHz which interfered with the phase-measuring equipment.

Most of the data were taken at 4% duty factor in order to complete the required measurements without risking failure of the output window. The tube was subsequently tested to the required 8% duty near the end of the acceptance testing. There was no measurable difference in the amplitude or phase at either 4% or 8% duty factor. This is not surprising, since these tubes are routinely tested to 12 or even 15% duty factor without amplitude or phase changes.

Appendix B containing the test data is large because, in many instances, a separate graph was made for each drive level in order to simplify future computer processing of the data. It is organized into the following ten groups, each dealing with a major parameter and/or variable:

1. Amplitude as a function of rf drive
2. Phase as a function of rf drive
3. Phase pushing with $\pm 1\%$ change in beam voltage
4. Phase pushing with $\pm 3\%$ change in beam current
5. Phase pushing with ± 1 kV change in collector depression

6. Amplitude and phase with a 1.25:1 VSWR
7. Amplitude and phase with a 1.25:1 VSWR shifted by $\lambda/2$ phase
8. Amplitude and phase at 8% duty factor
9. Amplitude and phase at 300 microsecond pulse length
10. Intrapulse phase modulation

The test parameters are listed in the Test Performance Sheet.

A preliminary step in the testing is the calorimetric measurement of the efficiency-bandwidth with optimum drive at each 100 MHz frequency point. These data are given in the first graph and in replotted form in the summary.

II. TEST RESULTS

A. AMPLITUDE AS A FUNCTION OF RF DRIVE

The nominal rf drive selected for the testing was one watt, with two watts shown as +3 dB, one-half watt as minus 3 dB, etc. Optimum drive was actually between one and two watts and was used in the maximal flatness curves in the summary data.

The gain ripple is unusual for this tube type since it increased in amplitude with frequency. Several measurements were made to determine the origin of the gain ripple. The output hot match was measured by driving the output circuit from the output end with the beam on and observing the reflected power as compared to a short circuit (see Figure 1). This is a measure of regeneration in the output circuit due to internal mismatches. No direct correlation could be established between the output hot-match ripple and the small-signal gain ripple except that where the hot match is good, the least ripple occurs.

The hot match of the input circuit was also measured in order to establish the contribution, if any, of the input circuit to the gain ripple (see Figure 2). Comparison with the small-signal gain ripple again indicated that the gain ripple is least at the low end of the band, where the hot match is quite good.

Therefore, by process of elimination, the center drive circuit is suspected of being the main contributor to gain ripple. Measurement of hot match in the center circuit is not possible because the sever loads are an integral part of the assembly.

B. PHASE LINEARITY

The phase deviation from linear was investigated as a function of a variety of parameters.

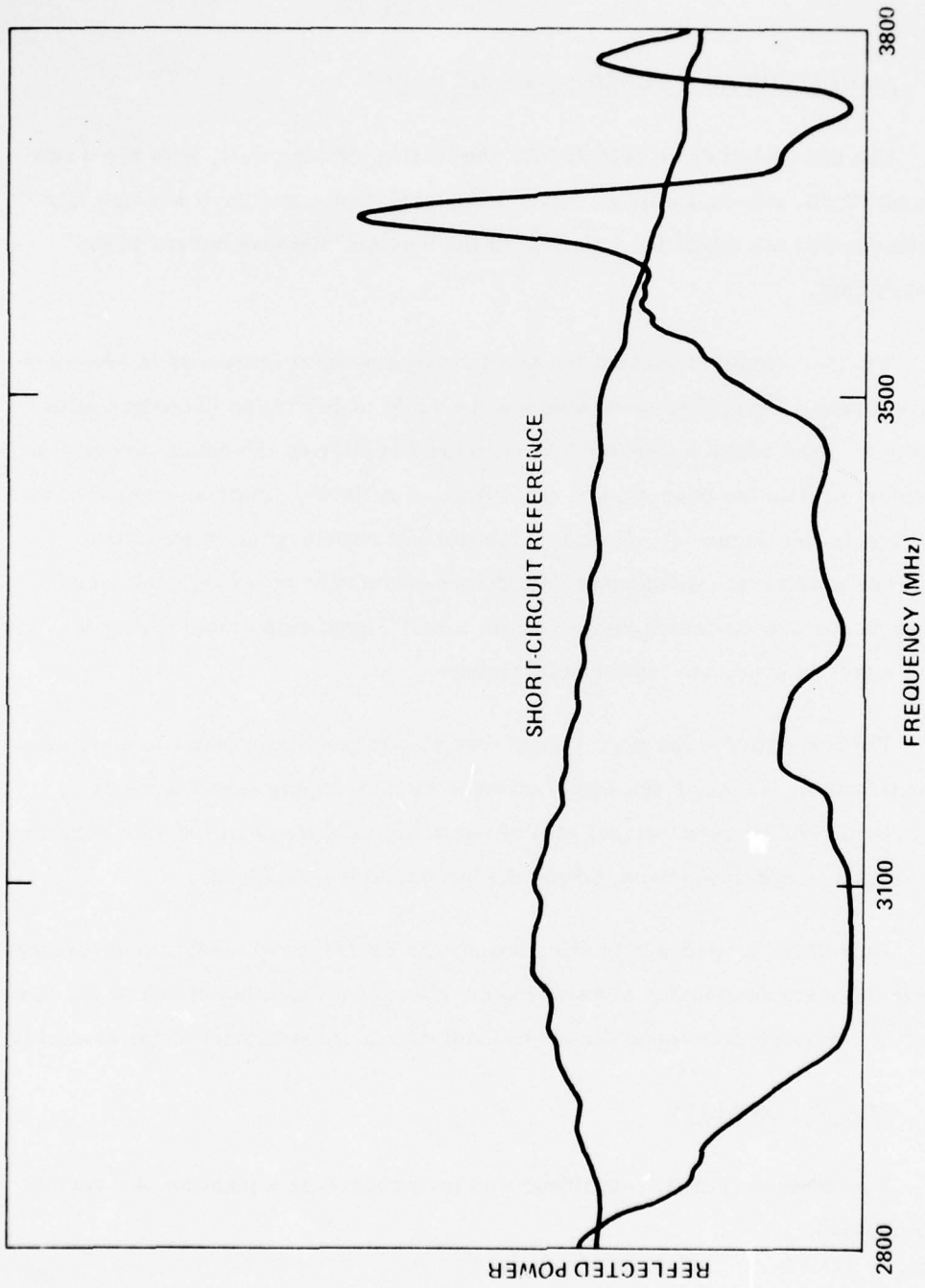


Figure 1. Hot Output VSWR

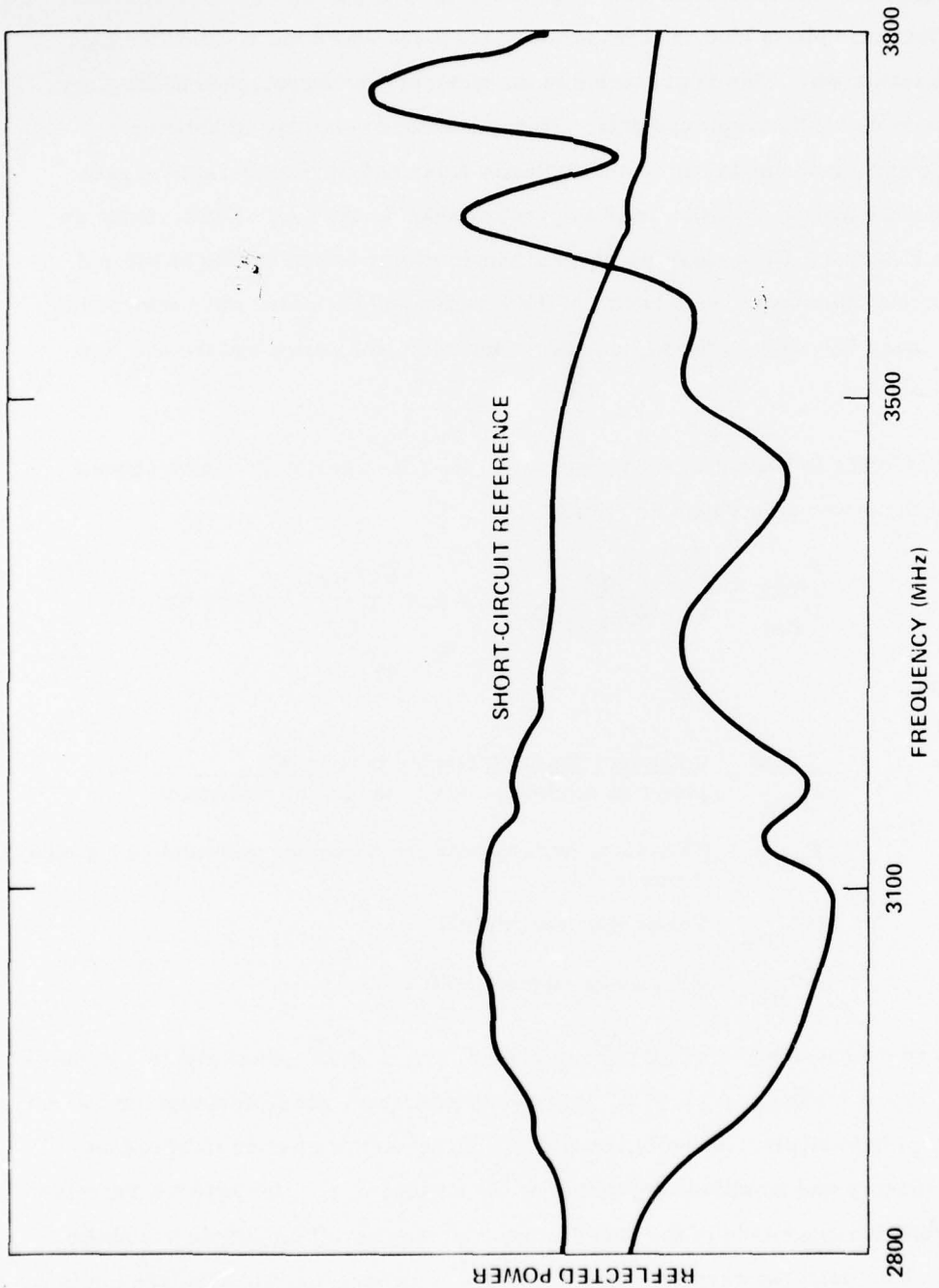


Figure 2. Hot Input VSWR

The correlation between phase ripple and gain ripple was evident from the data. The phase peaks (and valleys) occur at the point where the slope of the gain ripple is maximum. This is presented in the summary by superimposing the phase deviation on the -3 dB amplitude data. This quadrature relationship between amplitude and phase ripple can be theoretically explained by considering the gain ripple as a frequency-sensitive feedback vector added to the normal gain vector as shown in Figure 3. If we consider the gain ripple vector to be rotating at the end of the nominal gain vector as a result of the forward and backward wave interaction, then the phase deviation is the angle between the resultant vector and the average phase vector.

Referring to Figure 3, the magnitude of the phase deviation can be related to that of the power gain ripple as follows:

$$\frac{P_{\max}}{P_{\min}} = \left(\frac{1 + \Delta V_{RF}}{1 - \Delta V_{RF}} \right)^2 \quad \text{and} \quad \Delta \phi \approx \frac{\Delta V_{RF}}{V_{RF}} \quad \text{radians for small}$$

variations.

$$\frac{P_{\max}}{P_{\min}} = \frac{\text{maximum power in rippled response}}{\text{power at minimum next to the power maximum}}$$

$$V_{RF} = \text{RF voltage halfway between maximum and minimum peaks in power}$$

$$\Delta \phi_{\max} = \text{Phase ripple amplitude}$$

$$\Delta V_{RF} = \text{RF voltage ripple amplitude}$$

Using these expressions, a ± 1 dB gain ripple will give a $\pm 6.9^\circ$ phase ripple. From the tube data at midband, a ± 1.65 dB gain ripple yields $\pm 8^\circ$ phase deviation or $\pm 5^\circ$ for a 1 dB amplitude ripple. Actually, each of the three sections has an independent ripple frequency and amplitude depending on the number of cavities between the mismatches and the magnitude of the standing wave so the overall amplitude and phase ripple can be a complex waveform over the band. Compression and deceleration in

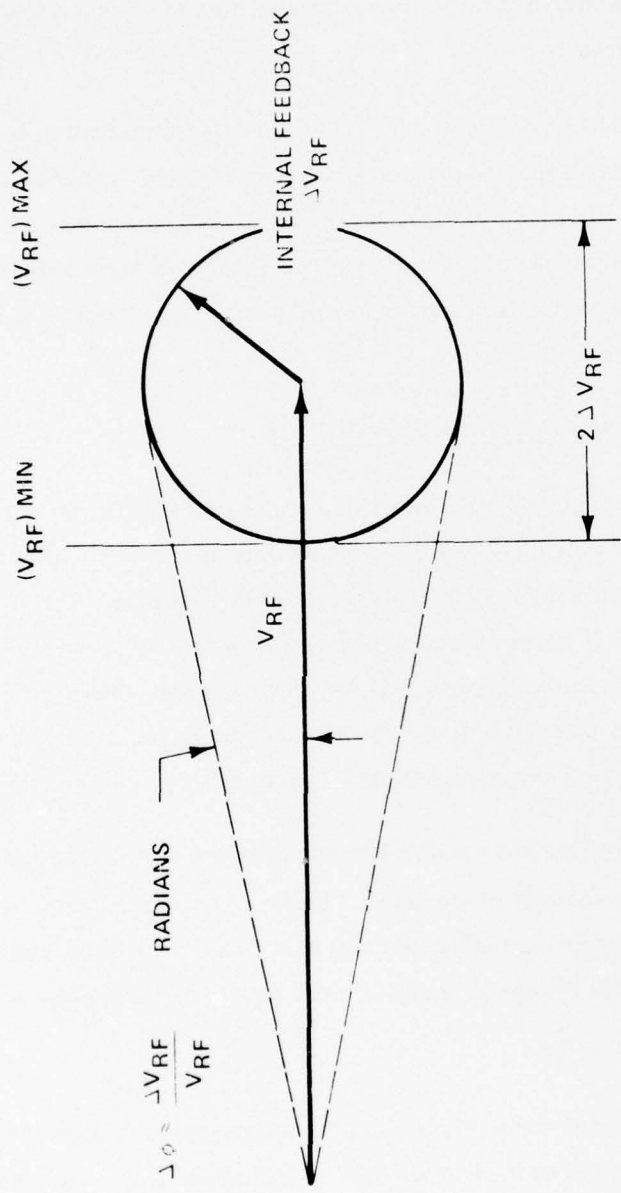


Figure 3. Vector Diagram, Gain-Phase Relationship

the output circuit also complicate the phase ripple to gain ripple relationship. Nevertheless, the simplified model gives reasonable agreement and explains the gain-to-phase quadrature.

The phase deviation can be greatly reduced by predistorting (equalizing) the amplitude of the drive signal to provide a flat small-signal response at the -3 dB and -6 dB level. In practice, the flattest phase is achieved by further trimming of the drive amplitude while observing the swept phase response from a dynamic phase analyzer. For this reason it is best to have the equalizer matched to each TWT by the tube manufacturer.

C. PHASE PUSHING WITH BEAM VOLTAGE

The phase pushing due to beam voltage was measured to be minus 28 degrees per percent of beam voltage. This is in reasonable agreement with theory based on change in the wave velocity due to the accelerating voltage. The voltage change represents a change in energy which bears a square root relationship to the electron velocity which is approximately one half for small changes, hence $\frac{\Delta v}{v} = \frac{1}{2} \frac{\Delta V}{V}$, where V is the beam voltage, v is the electron velocity, and ΔV and Δv are the changes in beam voltage and corresponding beam velocity, respectively.

The velocity of the hot wave is intermediate between the velocity of the circuit wave and the velocity of the beam. Hence, a change in beam velocity results in a change in phase approximately half that of the change in beam velocity. Actually, from TWT theory, the change in phase is more nearly 0.6 the beam velocity change.

Therefore, $\frac{\Delta \phi}{\phi} = 0.3 \frac{\Delta V}{V}$.

The phase change for a minus one percent change in voltage is approximately 0.003 times the total phase through the tube. At midband, the phase shift per cavity is approximately 270° ; and with 29 cavities, the phase change calculates to -23.5° per percent change in voltage. From the tube data at midband, a value of -25° is obtained with a +1% change in beam voltage. This is in good agreement with the approximate calculated value.

D. PHASE PUSHING WITH BEAM CURRENT

The measured phase change with a $\pm 3.3\%$ change in beam current was $\pm 16^\circ$, or $\approx 4.5^\circ$ per percent.

Phase change with beam current is due to the change in wave velocity, with a change in beam voltage at the center of the beam due to space-charge potential depression and the change of the slow space-charge wave velocity with a change in beam current. The relationship between microperveance and potential depression is $\frac{\Delta V}{V} = \frac{\mu K}{30}$, since microperveance is defined as $\mu K = \frac{I}{V^{3/2}}$; then, a change in beam current represents an equivalent change in perveance where V and ΔV are as before, I is the beam current, and μK is the beam microperveance. The change in slow space-charge wave velocity has approximately three times the effect as the change in the voltage depression value. Therefore, $\frac{\Delta \phi}{\Delta} \approx \left(\frac{0.3}{7.5}\right) \frac{\Delta I}{I}$.

This implies that the phase pushing per percent change in beam current (perveance) should be a factor of 7.5 less than the voltage pushing sensitivity. The data show the factor to be 6.2 less than the voltage pushing factor in percent change, which is quite good agreement.

E. COLLECTOR PHASE PUSHING

Phase pushing with collector depression is on the order of a few degrees per kV as long as the depression is not increased to the point that there is a substantial increase in body current. The body current is the result of slow electrons being reflected back down the beam tunnel and subsequently lowering the forward electron velocity by increasing the space-charge depression. The phase pushing due to collector voltage changes is therefore a result of this second-order effect of the returned electrons.

F. MISMATCH IN THE DUMMY LOAD

The amplitude and phase change due to a standing wave in the output load is due to the resultant standing wave in the output section of the tube. If the tube has well matched sever loads and no internal reflections as evidenced by a reasonable hot output match, the effect of a modest load VSWR will be quite small – as was measured for this tube.

G. INCREASED DUTY AND PULSE LENGTH

The phase and amplitude were investigated at an increased duty factor of 8% and an increased pulse length of 300 microseconds. No measurable change was observed. These tube types using the standard output window have subsequently been tested to 15% duty factor and at pulse lengths up to 1000 microseconds without significant change in phase or amplitude.

H. INTRAPULSE PHASE MODULATION

This measurement is primarily an addition of the quality of the regulation on the electrode voltages during the pulse. The data from the three pulse lengths of 50, 100 and 300 microseconds show very good intrapulse regulation and absence of any tube-contributed phase change due to thermal or space-charge neutralization effects.

APPENDIX A
ACCEPTANCE TEST PROCEDURE
FOR THE
125 kW PULSE S-BAND
TWT
VTS-5753B1

1.0 Calibration Measurement Accuracy Summary

Calibration of test equipment will be done by the Standards Laboratory of the Palo Alto Tube Division of Varian in conformance with QAOP and to the specification. These calibrations will be given below unless specified differently in individual tests.

- a. All directional couplers and attenuators used for measuring rf power will be calibrated within $\pm 1\%$ in dB.
- b. All meters will be calibrated within $\pm 2\%$ of full scale.
- c. All gauges and scopes will be calibrated within 1% to 3%.
- d. All current viewing transformers and associated viewing circuitry will be calibrated within 3%.
- e. The digital beam voltage meter and resistor chain will be calibrated on absolute basis to $\pm 0.2\%$ of full scale.

1.1 Safety Precautions

The following safety devices and procedures shall be provided:

- 1.1.1 All immediately involved personnel shall be informed of the nature and position of the test setup, specifically the high voltage hazard with the depressed collector mode of operation and the relevant precautions to be taken.
- 1.1.2 Applicable equipment will have shorting devices to insure discharge of high voltage storage capacitors when any terminal is in an exposed condition.
- 1.1.3 High-voltage-tested rubber mats will be utilized at the test set to decrease the chances of an electrical shock.
- 1.1.4 First Aid and medical supplies, to include a respiratory device, will be available.
- 1.1.5 Signs such as: Danger High Voltage, Emergency Off, etc. will be appropriately placed.

- 1.1.6 Extra safety glasses will be available when required.
- 1.1.7 Adequate fire extinguishers (CO₂ or dry chemical) will be available.
- 1.1.8 Two people will be present at all times when working on equipment which could present a high voltage hazard.
- 1.1.9 There will be a safety emergency light, to light the area in the event of a power failure.
- 1.1.10 The test set supervisor shall regularly check the following items:
 - 1. No HV leads are in an exposed position.
 - 2. HV interlocks are operational.

1.2 Instrumentation

The numbers in the blocks of the test setup diagrams refer to the block number column in the equipment list.

The following list of equipment will be used or its equivalent.

<u>Block No.</u>	<u>Nomenclature</u>	<u>Manufacturer</u>	<u>Model No.</u>
1	Sweep Oscillator	Hewlett Packard	692D
2	TWT Amplifier	Varian	1350G
3	Low Pass Filter	Hewlett Packard	360D
4	Directional Coupler	Narda	3043-30
5	Directional Coupler	Narda	3043-20
6	Directional Coupler	Narda	3043-10
7	Variable Attenuator	Hewlett Packard	S382B
8	Circulator	Western Microwave	CTS-2021
9	Thermistor Mount	Hewlett Packard	478A
10	Power Bridge	Hewlett Packard	431B
11	Arc Viewing Port	Varian	VES-8470
12	Dual Directional Coupler Nom. 50/50 dB	Varian	VA-136K
13	Water Load	Varian	L284DA2
14	Frequency Meter	FXR	N-410A
15	Arc Detector	Varian	V-9000
16	Coax to WG Adaptor	Hewlett Packard	S281B

<u>Block No.</u>	<u>Nomenclature</u>	<u>Manufacturer</u>	<u>Model No.</u>
17	Oscilloscope	Tektronix	545
18	Crystal Detector	Hewlett Packard	423A
19	Variable Attenuator	Hewlett Packard	S382B
20	Resolver	Wiltron	311
21	Pulse Adapter	Wiltron	306
22	Network Analyzer	Wiltron	310B
23	Dc Power Supply	Varian	Special
24	Dc Voltmeter	Sensitive Research	UEP
25	Blank Waveguide	Varian	
26	Phase Sampler	Varian	
27	Kilo Voltmeter	Sensitive Research	ESH
28	Coax Attenuator	Weinschel Engr.	210-10
29	Isolator	E and M Laboratories	519P
30	Beam Scale	Homs	105
31	Differential Pressure Gauge	Barton	227
32	Flow Meter	S and K	40J
34	Spectrum Analyzer	Hewlett Packard	8555A
35	Preselector	Hewlett Packard	8445A
36	50 Ohm Termination	Weinschel	535MN
40	X-Y Recorder	Hewlett Packard	7030
41	Reflectometer	Varian	Special
42	X-ray Monitor	Victoreen	440RF
43	RF Radiation Monitor	Hewlett Packard	8555
44	Microwave Switch	Hewlett Packard	3505
45	Pin Modulator	Hewlett Packard	8732B
46	Modulator	Hewlett Packard	8403A
47	Pulse Generator	Rutherford	B-14
48	50 Ohm Termination	Narda	369NM
49	Crystal Detector	Hewlett Packard	420A
50	Coax Attenuator	Narda	757C-20
51	Waveguide Termination	Americon	9099-5102
53	Coax DC Block	FXR	HR52N
54	Coax Attenuator	Weinschel Engr.	530A-20

1.3 Facilities

The facilities necessary for conducting tests in this procedure include:

1.3.1 Power Supply/Modulator

1.3.2 Recirculated Water System

1.4 Test Setup

1.4.1 Power Supply/Modulator

The power supply/modulator configuration is shown in Figure 2.1A. It consists of a 45 kV, 10 ampere, power supply, continuously variable from zero. Two series regulators drop and regulate the beam and collector voltages to the TWT. The collector regulator and supply has a rating of 20 amperes peak and is insulated for 50 kV. The beam regulator has a rating of 5 amperes peak. The metering is described in Figure 2.1B with the ranges and accuracies listed. The grid bias voltage and the grid pulse voltage are set using calibrated digital voltmeters with an accuracy of 1%. Additional monitoring is provided by pulse current transformers directly on the TWT leads. The peak body current is monitored by a pulse transformer that views the difference between the collector current and the beam current.

There are two filament supplies. The AC supply will be used for all of the tests.

The filament supplies are rated for 0 to 15 volts (minimum) and are floating at the cathode potential.

An electronic crowbar system is provided to remove the high voltage within 10 microseconds after a trigger input (waveguide arc, peak beam current, and peak body current). The beam supply is interlocked to remove and/or prevent application/re-application of the high voltage for the following conditions: external interlock open, electronic crowbar not ready, overcurrent relays not reset and low bias voltage.

A high voltage arc indicator is provided to indicate cathode arcs. Sensing is provided in the cathode lead by means of a current transformer.

All controls are insulated for safe, direct contact by personnel and included is an emergency off switch.

1.4.2 General RF Set-up

The equipment shown in Figures 2.2A and 2.2B is the general RF test set-up and will be used for the majority of the RF tests. When required, the general set-up will be modified by additions or deletions to perform specific tests on the TWT. Changes to the general set-up are shown under the specific tests. The changes describe the purpose of the modification and do not necessarily repeat the detail given in the general set-up. The equipment descriptions indicate the purpose of the component and equivalent components may be substituted unless it forms a functional part of a calibrated section. Substitutions of equivalent components will be noted and reported in the test report. The RF calibration will be contained in a calibration book and the equipment identified by calibration stickers. The calibrations and control of the test equipment will be performed by Instrument Services under the direction of Quality Assurance. Controls and procedures for calibration are specified in Quality Assurance Operating Procedure 87-800-154 and Instrument Services Operation Manual 87-800-153.

The general RF set-up consists of a sweeper and RF amplifier with a feedback loop via coax coupler and power bridge to provide a leveled RF source. A precision attenuator is used to set the drive level as monitored by a coupler, attenuator, thermistor mount, and power meter. The input waveguide section that forms the functional part of measuring drive power is calibrated intact. The output line consists of a waveguide dual directional coupler followed by a 1.05:1 (max) waterload. The output coupler provides two samples of the RF output. One arm is terminated in a thermistor and power bridge for a relative indication of power output. The other arm is terminated in a crystal detector which allows the output pulse to be observed on an oscilloscope and the frequency checked by a wavemeter. The mismatch and the output line are calibrated for VSWR. Power out is measured calorimetrically and all other power output indicators are referenced to the calorimetric value.

2.0 Test Procedures

2.1 Turn-on Procedure

Insure that coolant flow connections, cathode, heater grid, collector, solenoid and body electrical connections and the VacIon^(R) pump connection are all made. Connect the basic rf input and output lines as shown by Figures 2.2A and 2.2B.

- 2.1.1 Check coolant resistivity. RECORD ON DATA SHEET.
- 2.1.2 Set liquid and air coolant flow to rated flow. Check inlet liquid coolant temperature to insure that it is between 15° and 40° C. RECORD FLOW RATES ON TEST DATA SHEET.
- 2.1.3 Turn on VacIon pump, solenoid, and heater voltages to nameplate values. Set bias voltage to -500V to -700V. RECORD BIAS VOLTAGE ON TEST DATA SHEET. Observe that the VacIon pump voltage and current are within the normal range.
- 2.1.4 Set beam and collector voltages to previously determined values. RECORD THESE VALUES ON THE TEST DATA SHEET.
- 2.1.5 After five minutes of heater operation, final adjust heater voltage to nameplate value. RECORD HEATER VOLTAGE AND CURRENT ON TEST DATA SHEET.
- 2.1.6 Set grid drive voltage to previously determined value and start pulsing. RECORD GRID PULSE CURRENT, VOLTAGE, PEAK CATHODE, BODY, COLLECTOR CURRENTS, SOLENOID CURRENT AND VOLTAGE ON TEST DATA SHEET.
- 2.1.7 Verify that the operating voltages and currents are within the limits as given in the Test Data Sheet. These values define the standard operating conditions of the tube and are set for all tests except as noted in individual tests.

2.2 Standard Test Conditions

The standard test voltages and currents are as determined (defined) in Paragraph 2.1. The normal video pulse length is 15 to 310 μ sec measured at the 70% amplitude points and the normal rf pulse length is 10 to 300 μ sec. The rise and fall times of the rf pulse shall be less than 2 μ sec. The flatness of the grid pulse voltage shall be within ± 2 V across the specified pulse length except for the leading and trailing edge transients.

Normal video duty cycle is 9% and normal rf duty cycle is 8%*. Optimum drive power is set to a constant level between the limits of 0 and 12.5 W. The optimum drive power shall be determined prior to acceptance testing and shall become the nameplate value. The load VSWR is 1.05:1. The output waveguide shall be pressurized at 5 psig with dry nitrogen.

*Preliminary testing will be performed at 5% video and 4% rf duty to minimize window - failure during testing. Limited testing at 8% duty will follow completion of the required testing.

3.1 Phase Linearity Test

3.1.1 Test Objective

To measure swept frequency phase response.

3.1.2 Test Set-up

Per Figure 2.2A, 2.2B and 2.2C.

3.1.3 Test Procedure

3.1.3.1 Maximum VSWR of 1.05:1.

3.1.3.2 Operate TWT per Paragraph 2.1 except use CW drive.

3.1.3.3 Calibrate phase detection system per Appendix A,

3.1.3.4 Adjust phase detector and recorder for nominal response over frequency range.

3.1.3.5 Adjust RF drive frequency to sweep from 2.9 to 3.7 GHz.

3.1.3.6 Adjust recorder axis to achieve full scale deflection from 2.9 to 3.7 GHz.

3.1.3.7 Set sweep time to 100-10 seconds.

3.1.3.8 Activate recorder. Label and attach graph to test data sheet.

3.1.3.9 Repeat 3.1.4.5 through 3.1.4.8. Adjust RF drive to +3 dB and -12 dB in 3 dB steps. Note: Limitations in RF drive may limit overdrive to +3 dB.

3.1.3.10 Phase measurements at short pulse length approaching 10 μ sec will be a goal, because of phase equipment limitations. Phase is normally measured with rf pulse width of 50 μ sec and a phase sample of 25 μ sec within the rf pulse.

4.1 Amplitude Linearity Test

4.1.1 Test Objective

To measure the swept frequency amplitude response of the tube RF output operating into a matched load.

4.1.3 Test Set-up

Per Figure 2.2A and 2.2B.

4.1.4 Test Procedure

- 4.1.4.1 Maximum VSWR of 1.05:1 or less.
- 4.1.4.2 Operate the TWT per conditions of Paragraph 2.1.
- 4.1.4.3 Adjust rf attenuators preceding the rf input and rf output monitoring thermistors, to achieve on scale deflection on power meters throughout sweep F_B .
- 4.1.4.4 Adjust rf frequency sweep interval starting at 2.9 GHz and adjust recorder X-axis for full deflection over this range.
- 4.1.4.5 Step sweep time to 100-10 seconds nominal.
- 4.1.4.6 Plot a graph of output power versus frequency. Label and attach graph to test data sheet.
- 4.1.4.7 Repeat 4.1.4.2 through 4.1.4.6. Adjust rf drive to +3 dB and -12 dB in 3 dB steps. Note: Limitations in rf drive may limit overdrive to +3 dB.

APPENDIX A

CALIBRATION OF WILTRON PHASE MEASURING SYSTEM

Methods for set-up, calibration and operation of the system is contained in Wiltron Company Instruction Manual for Model 306 pulse adapter and Wiltron Company Instruction Manual for Model 310B network analyzer with Model 311 series rf resolvers.

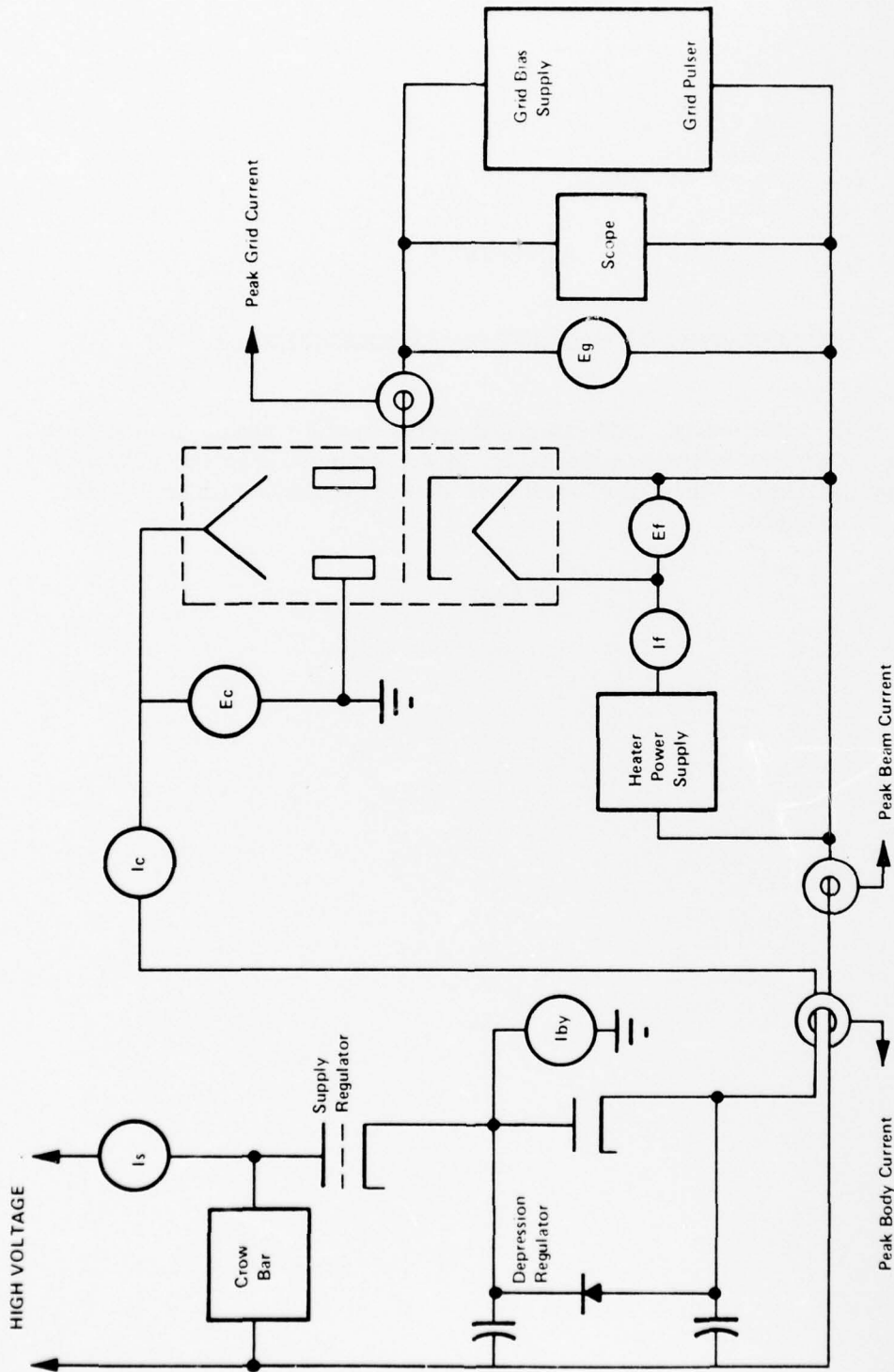
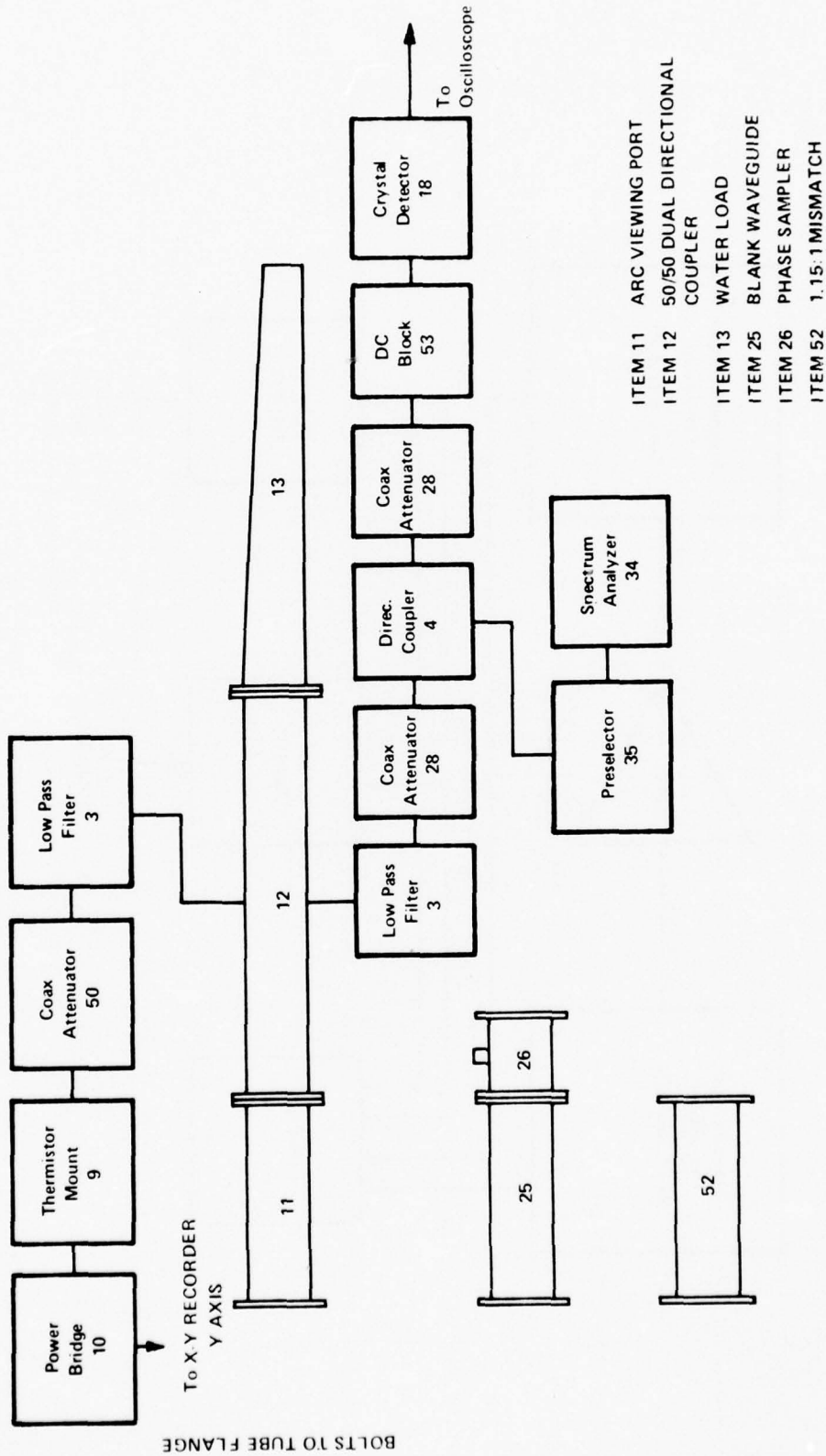


Figure 2.1A. Power Supply/Modulator Configuration

<u>Symbol</u>	<u>Parameter Measured</u>	<u>Manufacturer</u>	<u>Model No.</u>	<u>Range</u>
	Peak Body Current	Pearson	2100	1 V/1A
	Peak Beam Current	Pearson	325	0.25 V/1 A
	Peak Grid Current	Pearson	2100	1 V/1 A
Ef	Heater Voltage	Weston	1941T	0-30 Vdc
Ef	Heater Voltage	Weston	1944	0-15 Vac
If	Heater Current	Weston	1944	0-30 Aac
If	Heater Current	Weston	1941T	0-20 Adc
Eg	Grid Pulse Amplitude	Weston	1294	0-1.99 kV
Eg	Grid Bias Voltage	Weston	1294	0-1.99 kV
Eg	Grid Bias Voltage	API	461	0-1.5 kV
Iby	Average Body Current	Weston	1951T	0-300 mAdc
Iby	Average Body Current	API	428-1223	0-1 Adc
Ek	Beam Voltage	Weston	1941T	0-50 kVdc
Ek	Beam Voltage	Beede	MR24-05	0-50 kVdc
Ec	Collector Voltage	Weston	1941T	0-25 kVdc
Is	Power Supply Current	API	428-1223	0-10 Adc
Is	Power Supply Current	Weston	1941T	0-10 Adc
Ic	Collector Current	Weston	1941T	0-10 Adc
Ic	Collector Current	API	428-1223	0-10 Adc
Isol	Solenoid Current	Sorensen	Power Supply	0-50 Adc
Esol	Solenoid Voltage	Sorensen	Power Supply	0-200 Vdc

POWER SUPPLY/MODULATOR METERING

FIGURE 2.1B



- ITEM 11 ARC VIEWING PORT
- ITEM 12 50/50 DUAL DIRECTIONAL COUPLER
- ITEM 13 WATER LOAD
- ITEM 25 BLANK WAVEGUIDE
- ITEM 26 PHASE SAMPLER
- ITEM 52 1.15:1 MISMATCH

Figure 2.2B. Standard Output Test Setup

BOLTS TO TUBE FLANGE

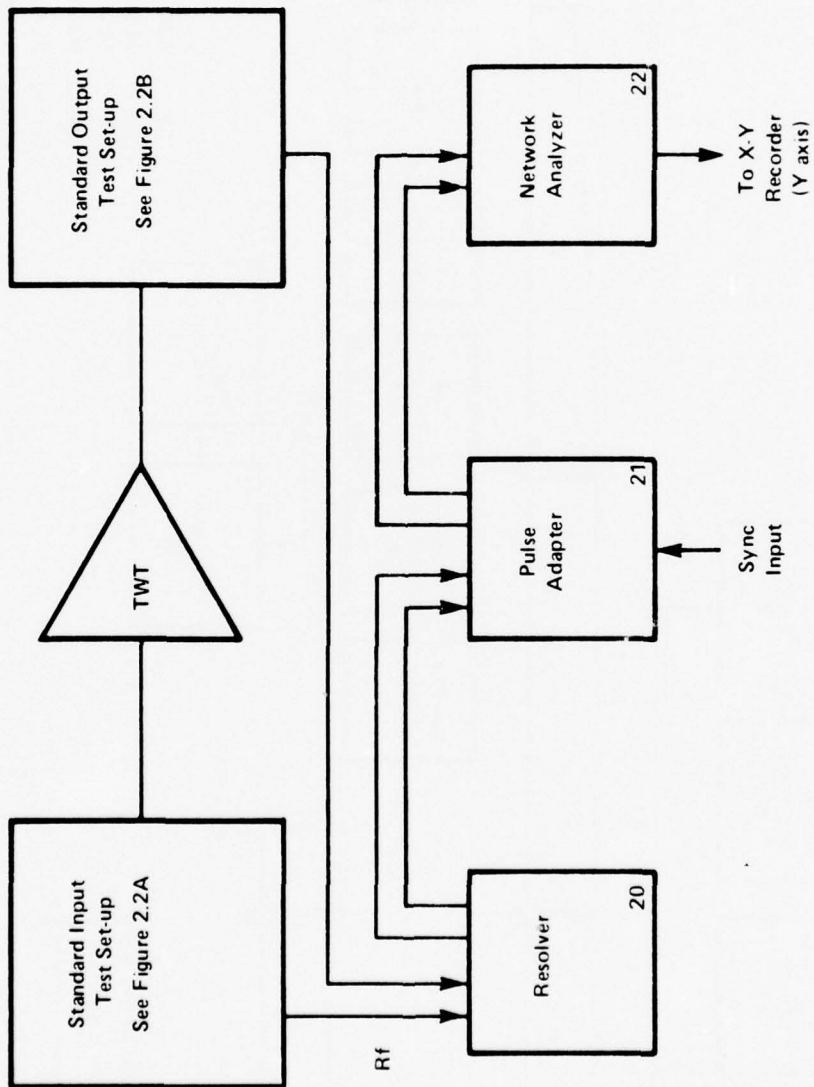


Figure 2.2C. Phase Linearity Test Setup

APPENDIX B
ACCEPTANCE TEST DATA
VTS-5753B1
TRAVELING WAVE TUBE

1. Amplitude as a function of rf drive
2. Phase as a function of rf drive
3. Phase pushing with $\pm 1\%$ change in beam voltage
4. Phase pushing with $\pm 3\%$ change in beam current
5. Phase pushing with ± 1 kV change in collector depression
6. Amplitude and phase with a 1.25:1 VSWR
7. Amplitude and phase with a 1.25:1 VSWR shifted by $\lambda/2$ phase
8. Amplitude and phase at 8% duty factor
9. Amplitude and phase at 300 microsecond pulse length
10. Intrapulse phase modulation

ACCEPTANCE TEST DATA

VTS 5753B1

TRAVELING WAVE TUBE

SERIAL NO. 106

DATE 12/8/76

Prepared For:

RADC

Tested By:


VARIAN



12/9/76
DATE

VARIAN ASSOCIATES

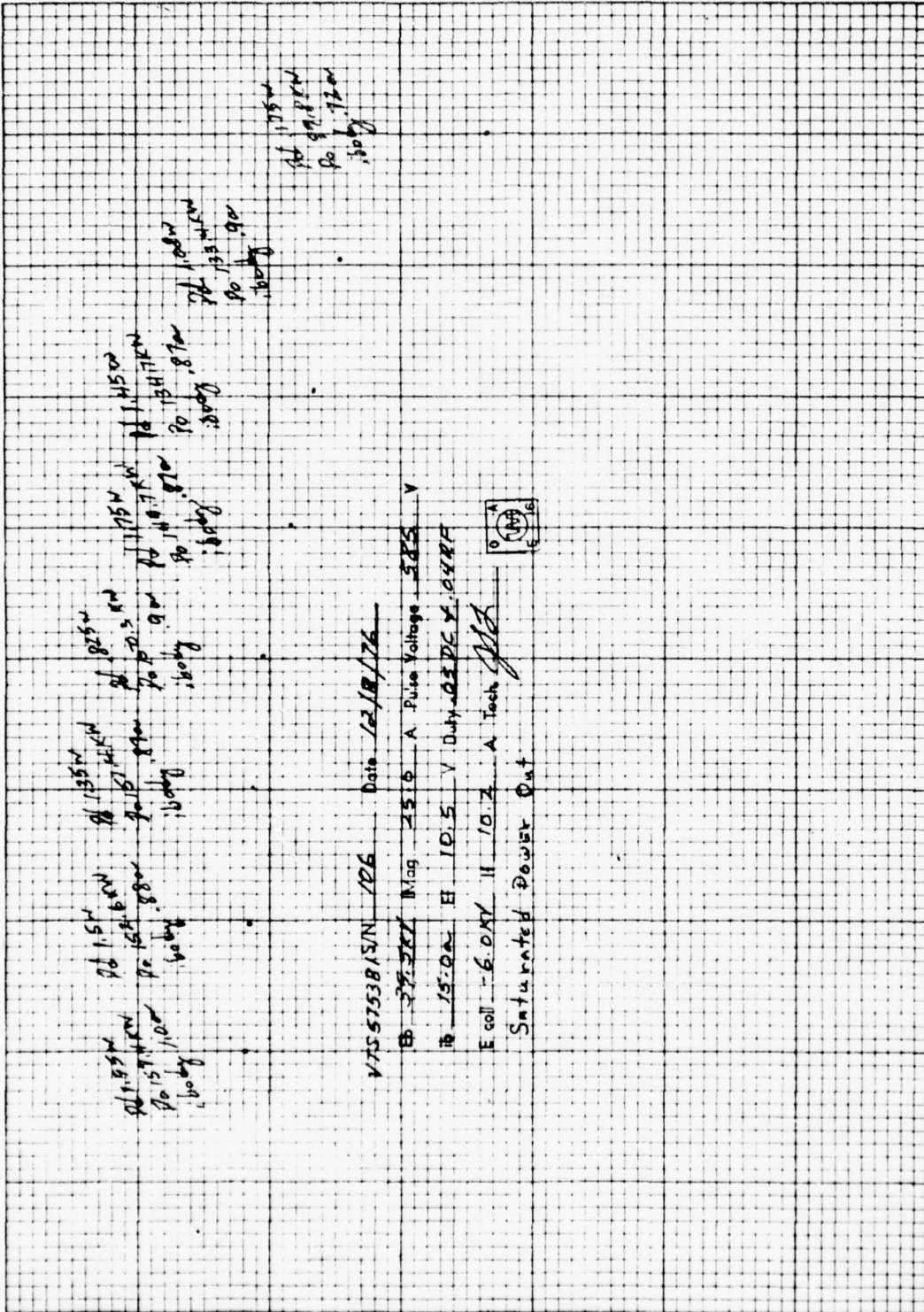
Palo Alto Microwave Tube Division

611 Hansen Way

Palo Alto, California 94303



ATP Paragraph	Test Title	Min. Spec.	Not Freq. Rel.	Measured Value	Maximum Specification	Units
2.1.0	Liquid Coolant Resistivity	0.5	1.0			MΩ
2.1.1	Liquid Coolant Flow Rate	16	16.3		21	GPM
2.1.1	Air Coolant Flow Rate	30	>30			CFM
2.1.2	Bias Voltage	-500	-600		-700	V
2.1.3	Beam Voltage		39.5		44.0	kV
2.1.3	Collector Voltage w.r.t. Body	-1.5	-6.0		-6.0	kV
2.1.4	Heater Voltage	9.5	10.5		11.0	V
2.1.4	Heater Current	9.0	10.2		11.0	A
2.1.5	Peak Grid Current (Ik=NPV)		22		50	ma
2.1.5	Grid Pulse Voltage (Ik = NPV)	400	585		900	V
2.1.5	Peak Cathode Current		15.0		17	a
2.1.5	Peak Body Current (Pd = 0)		0.175		0.05 ik	a
2.1.5	Peak Collector Current	.95ik	14.825			a
2.1.5	Solenoid Current	22	25.0		26	A
2.1.5	Solenoid Voltage	125	141		200	V
2.1	RF Drive Level		0.96		12.5	w
2.2.1	Ion Pump Voltage		3.5		3.5	kV
2.2.1	Ion Pump Current		0.4		20	μA
3.1	Phase Linearity Test (Matched Output)			See Graph		
4.1	Amplitude Linearity (Matched Output)			See Graphs		
4.1.4.7	Peak Body Current (Pd = NP)		1.0		1.5	a

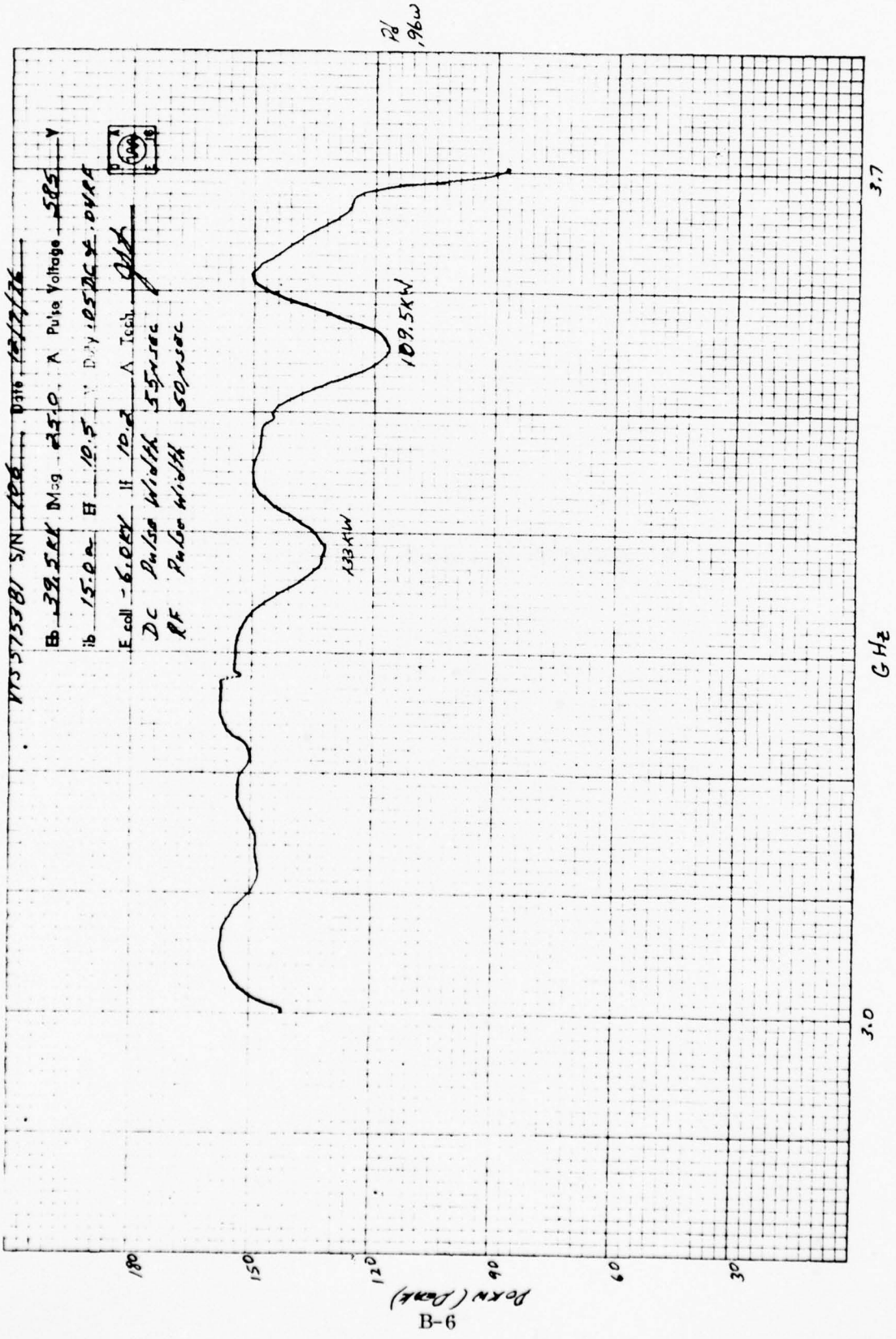


3.7

6 Hz

3.0

1. Amplitude as a function of rf drive



796'
 PA

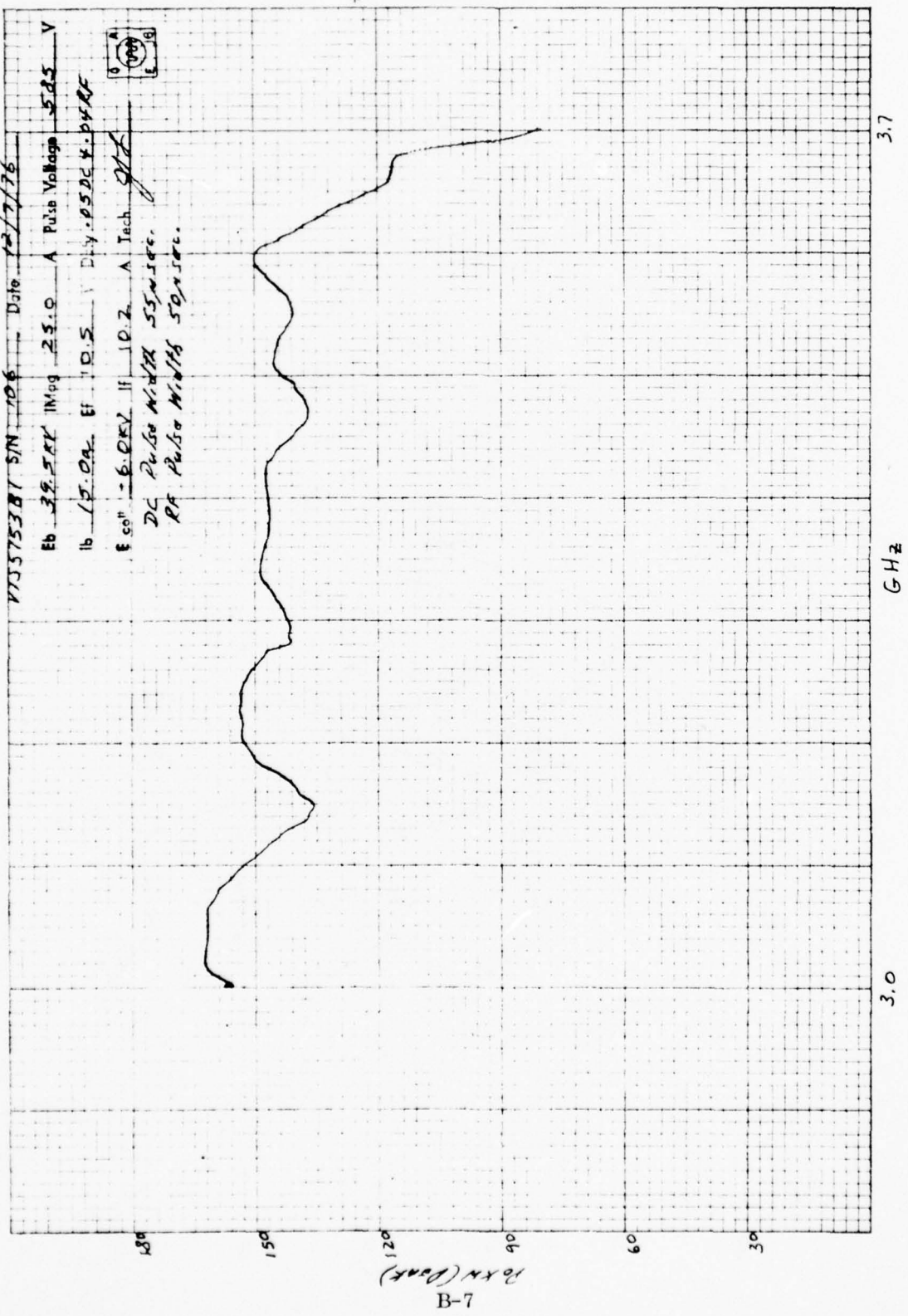
VIS575387 SIN 106 Date 12/7/76

Eb 39.5K IMag 25.0 A Pulse Voltage 58.5 V
Ib 15.0A Ef 10.5 Div. 0.5DEK. 44RF

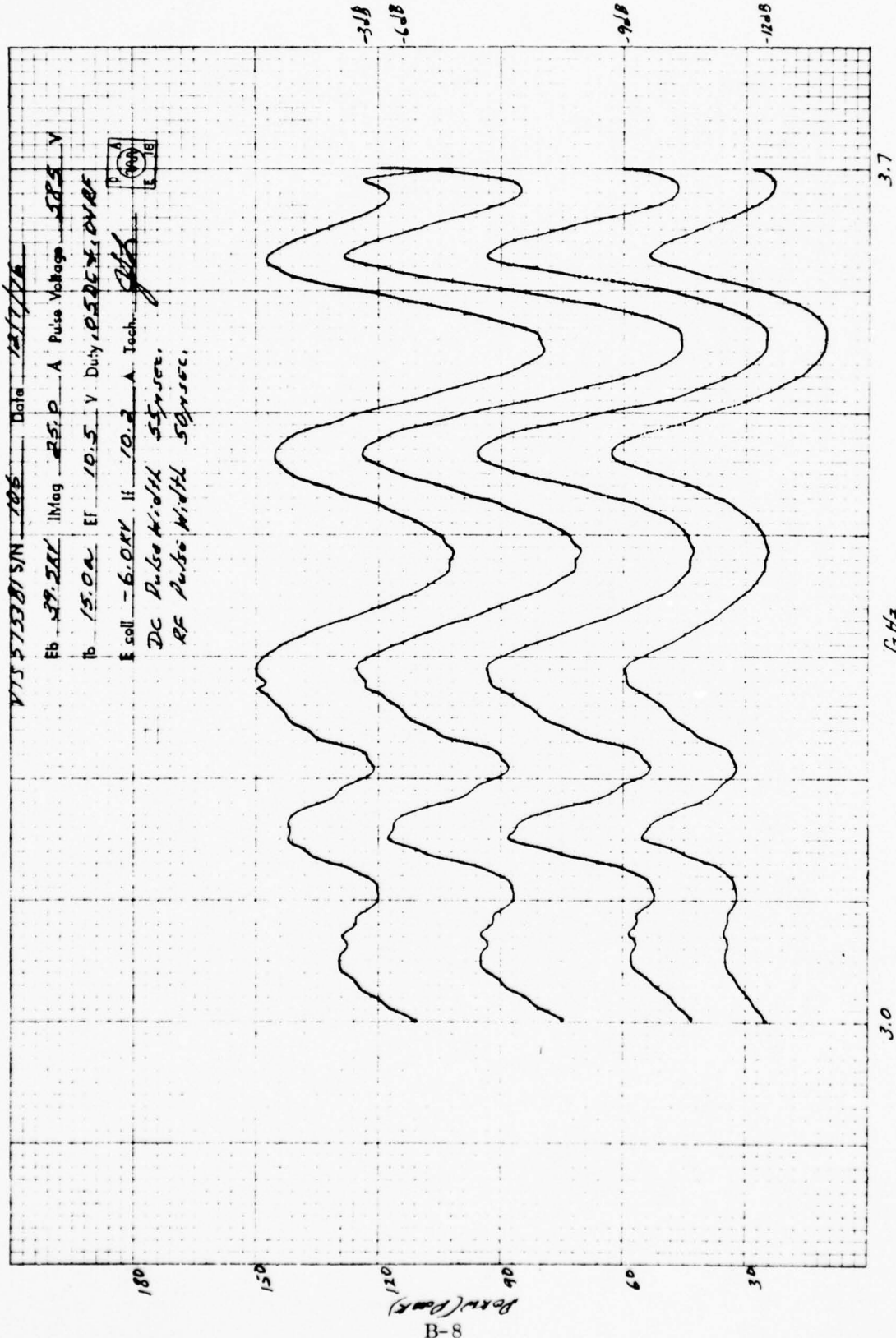
E corr -6.0KV If 10.2 A Tech 911
DC Pulse Width 55µsec.
RF Pulse Width 50µsec.



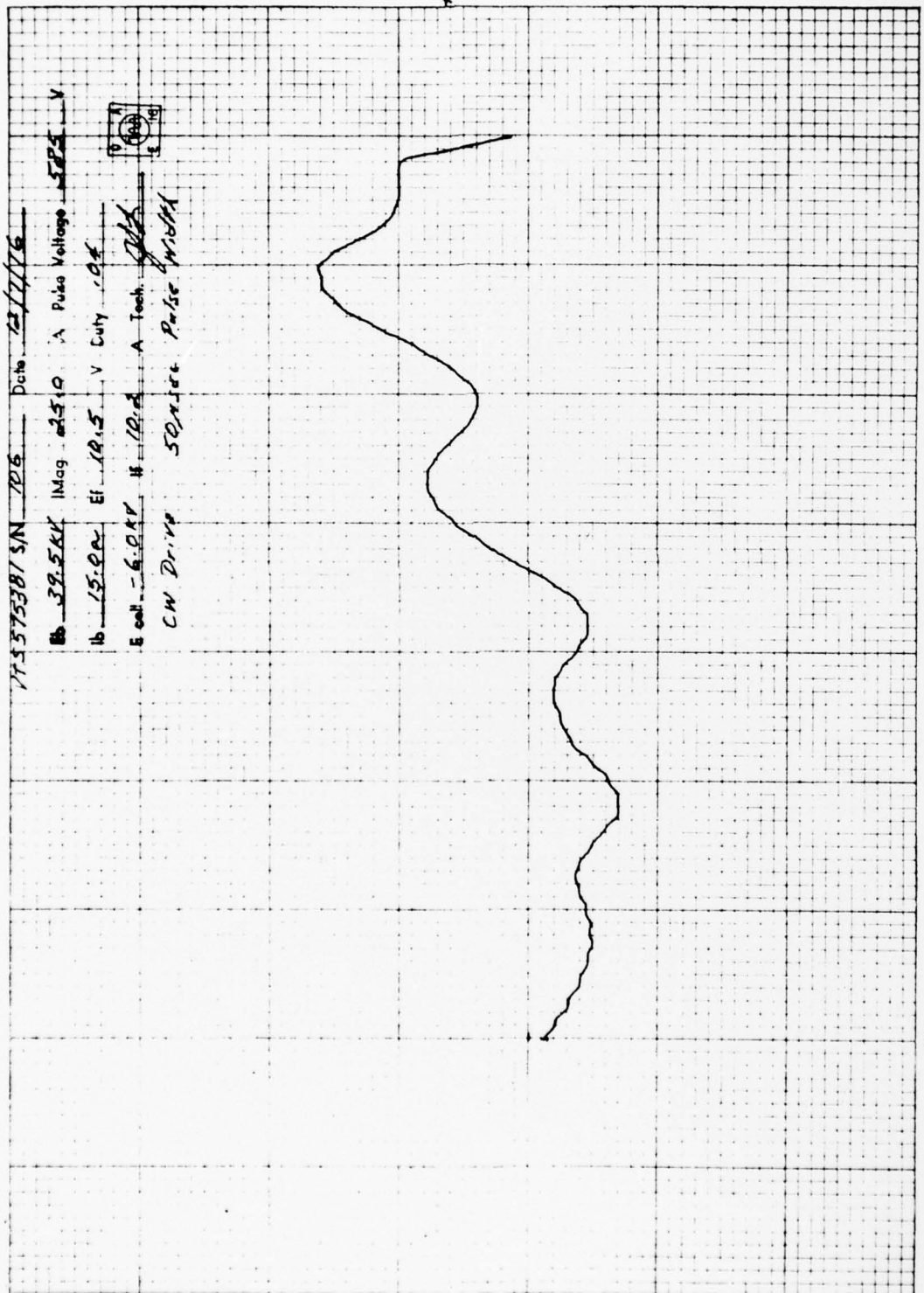
+3dB



B-7



2. Phase as a function of rf drive



11-575381 SN 706 Date 12/1/66
 IMag 2510 A Pulse Voltage 50V V
 EI 18.5 V Duty 10%
 E cal -6.0KV H 10.2 A Tech. JKL
 CW Drive 50% det. Pulse Width

40°/INCH

B-10

+360

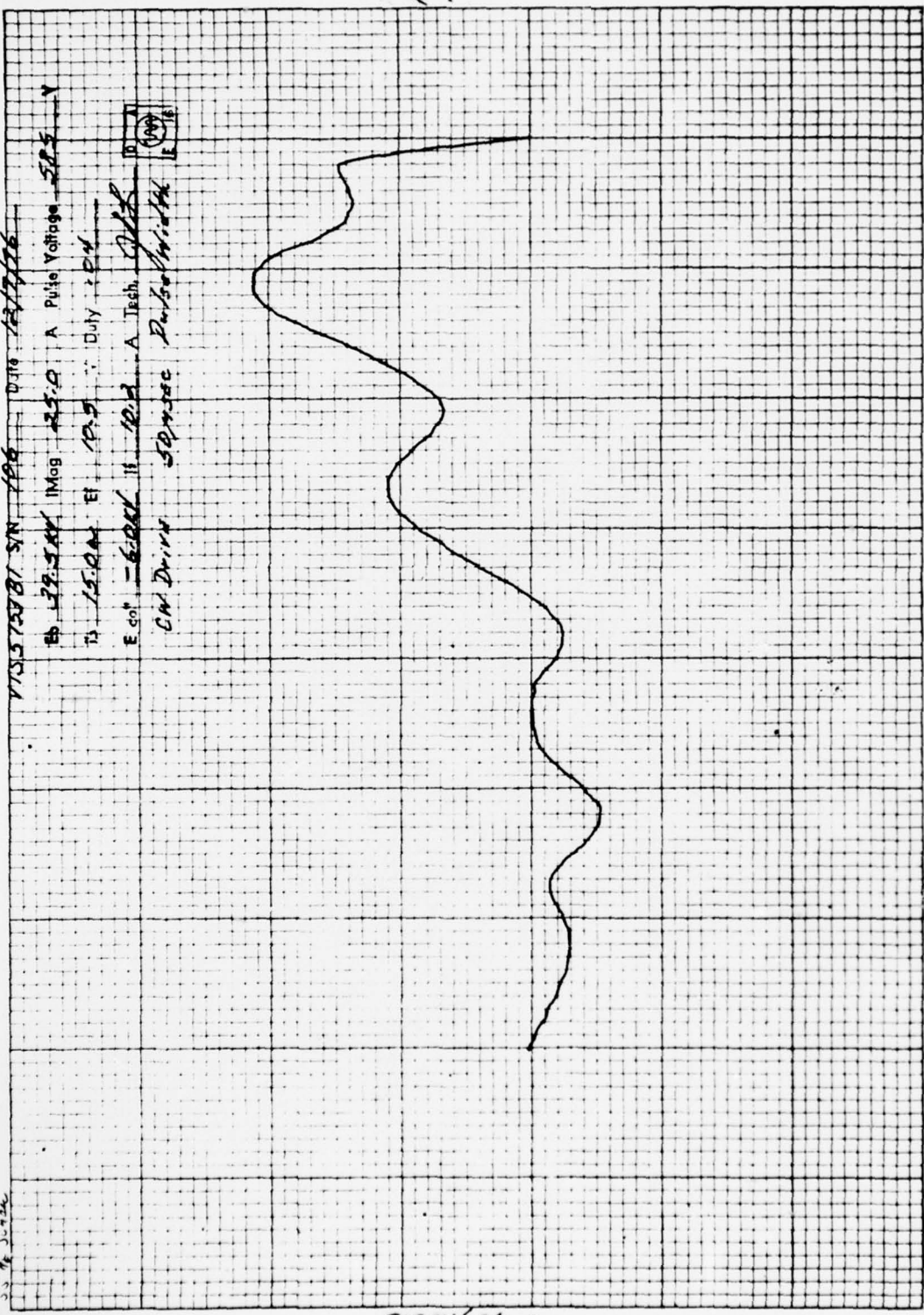
3.7

G.H.Z

3.0

55 16 June 66

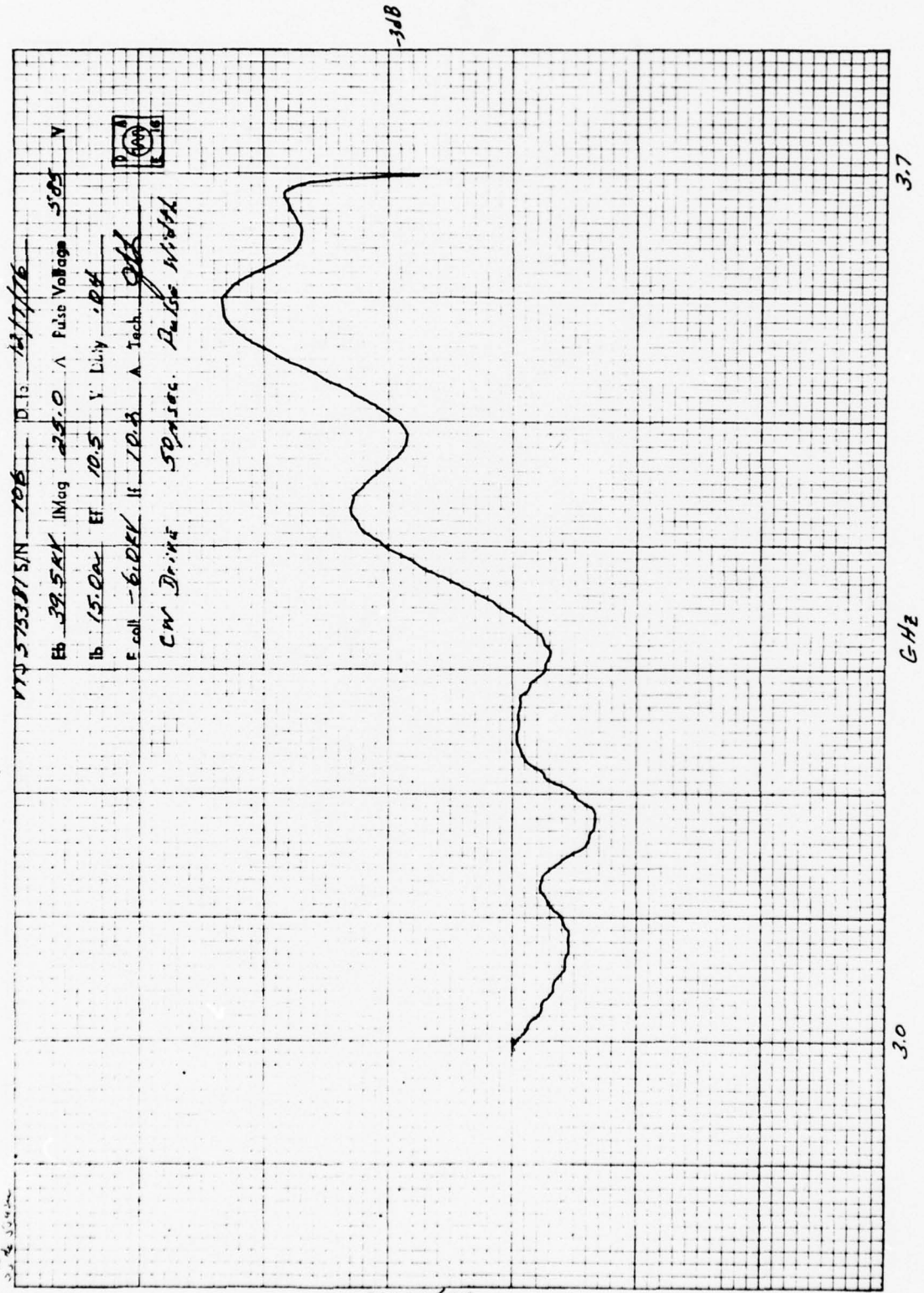
VTS 5750 BT SIN 196 DTG 121706
 EQ 139.5 AM IMAG 135.0 A Pulse Voltage 50.5 V
 TA 15.0 AM ET 17.5 DUTY 2 PM
 E 001 - 6000 11 10.0 A Tech. CH
 CW Drive 50 msec Pulse Width 100



40 inch
 B-11

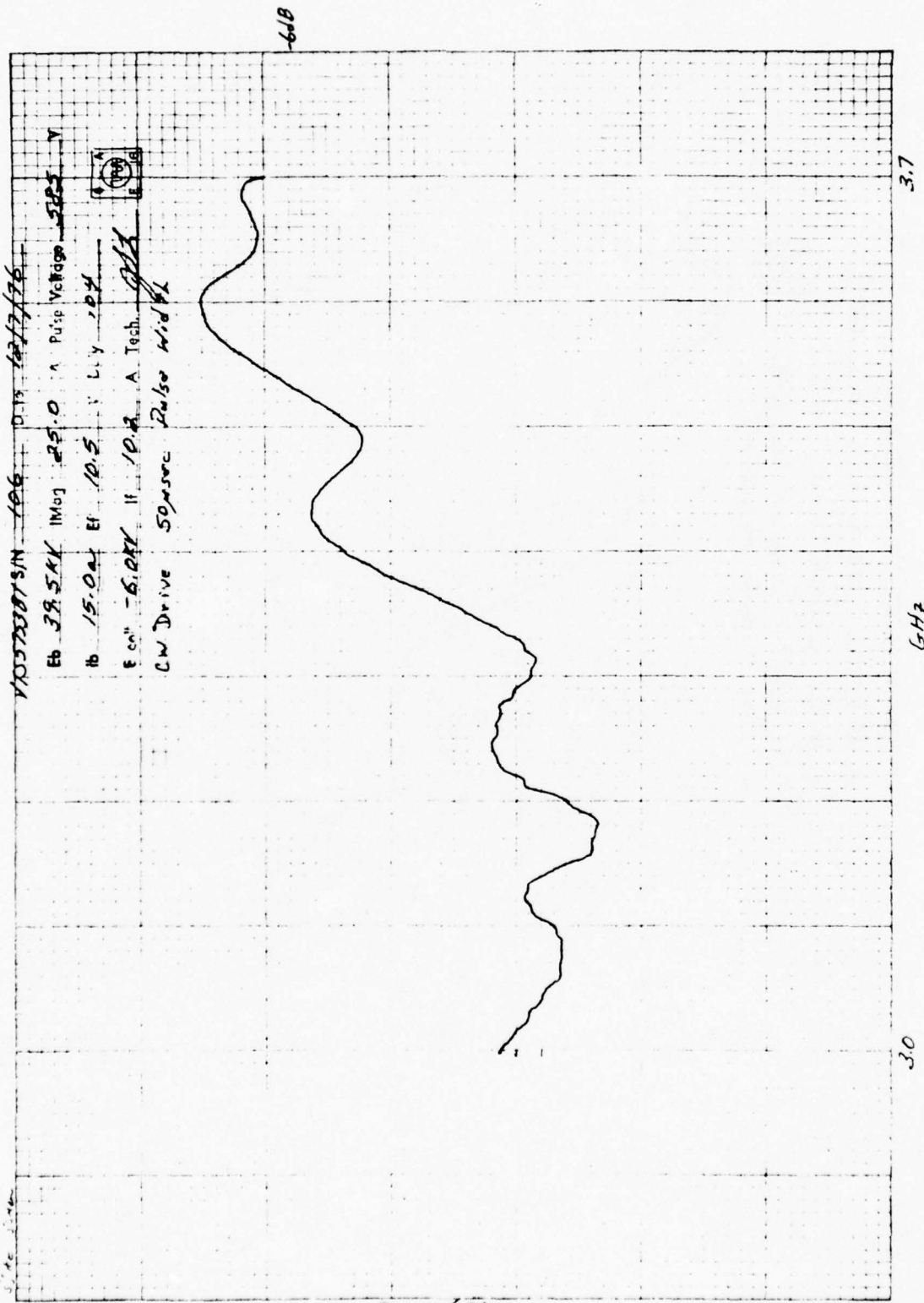
R
 .96w

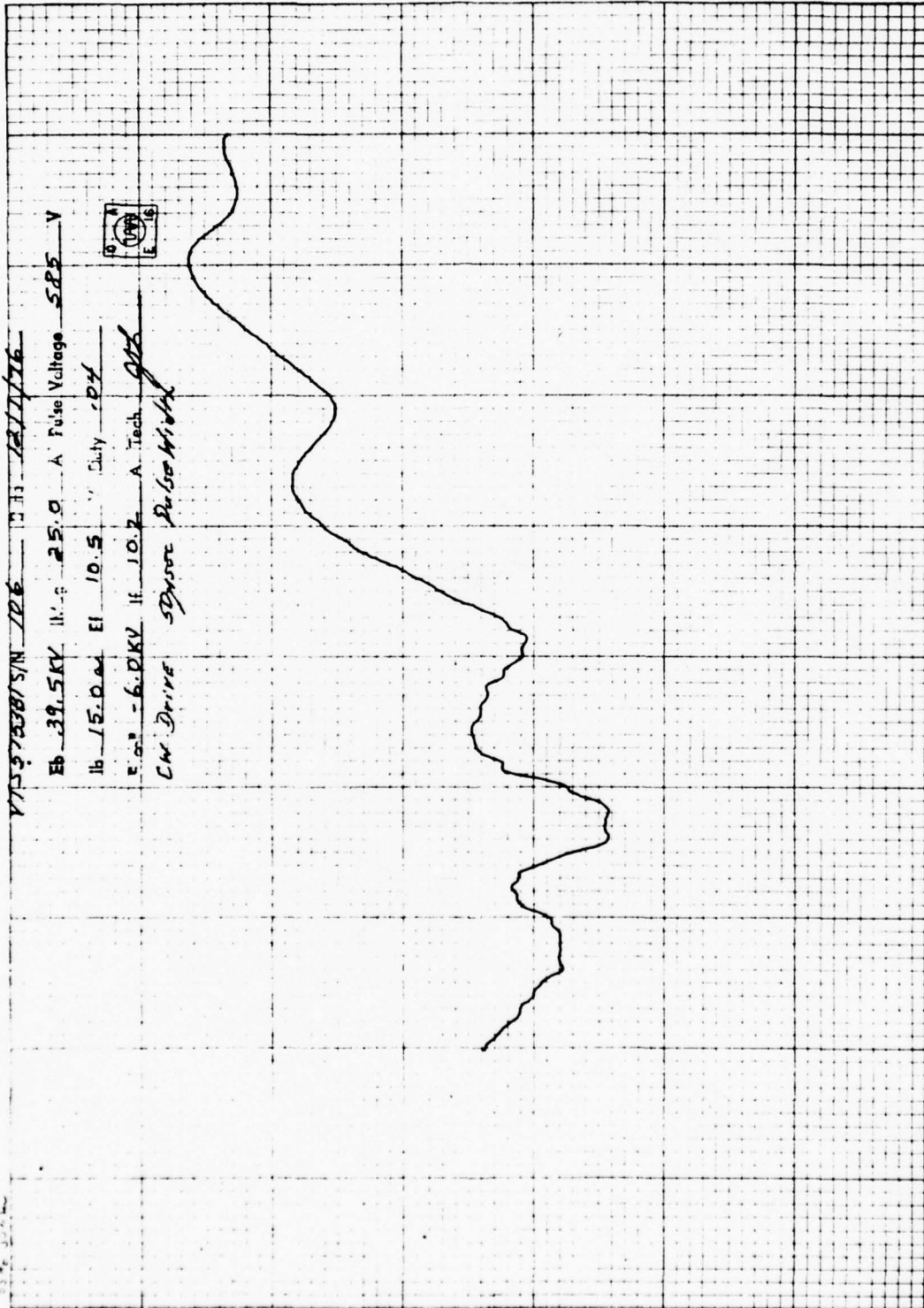
3.0 GHz 3.7



-31B

400/mick
B-12



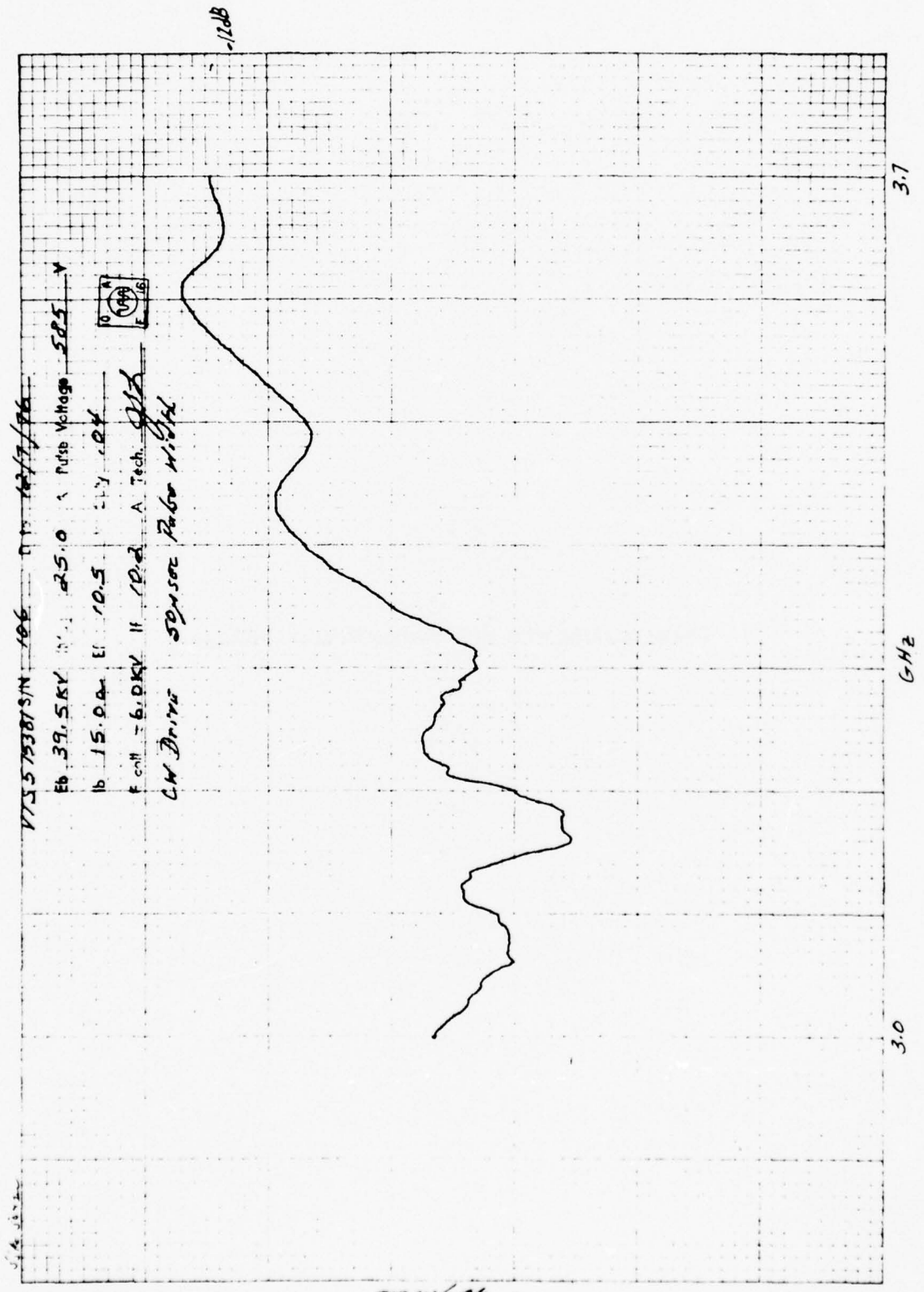


VT59700815/N 206 10 H3 12/1/76
 Eb 39.5KV 11.5 25.0 A Pulse Voltage 585 V
 Ib 15.0mA EI 10.5 Duty 24
 Freq 6.0KV If 10.7 A Tech 918
 CW Drive 50000 Pulses/Min



-918

40/mvch
B-14



40°/in
B-15

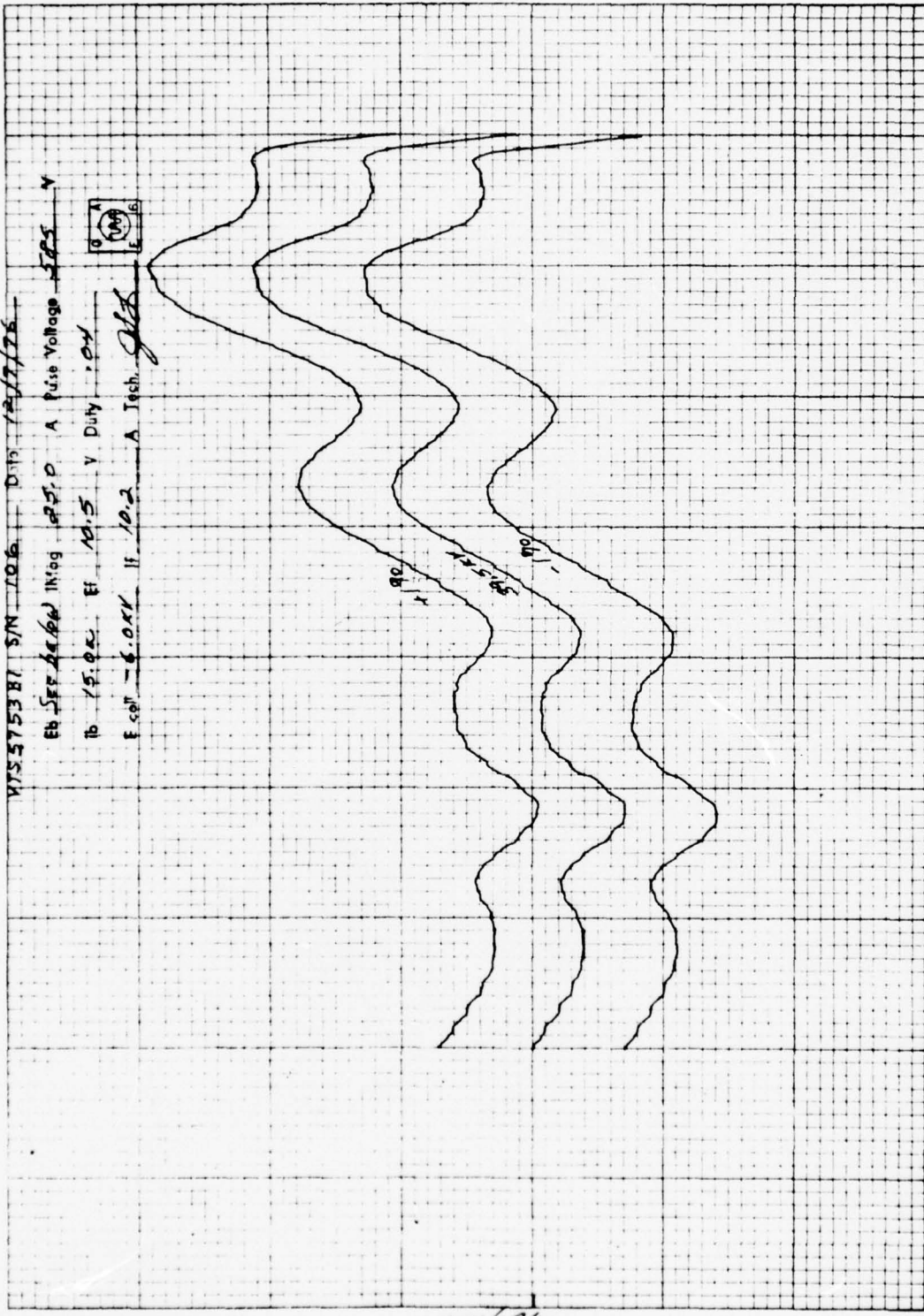
3. Phase pushing with $\pm 1\%$ change in beam voltage

NY 5575381 S/N 706 Date 12/7/76

EB SES 46.6W IN 10g 20.5.0 A Pulse Voltage 5.75 V

IB 15.0c EI 10.5 V Duty 1.0M

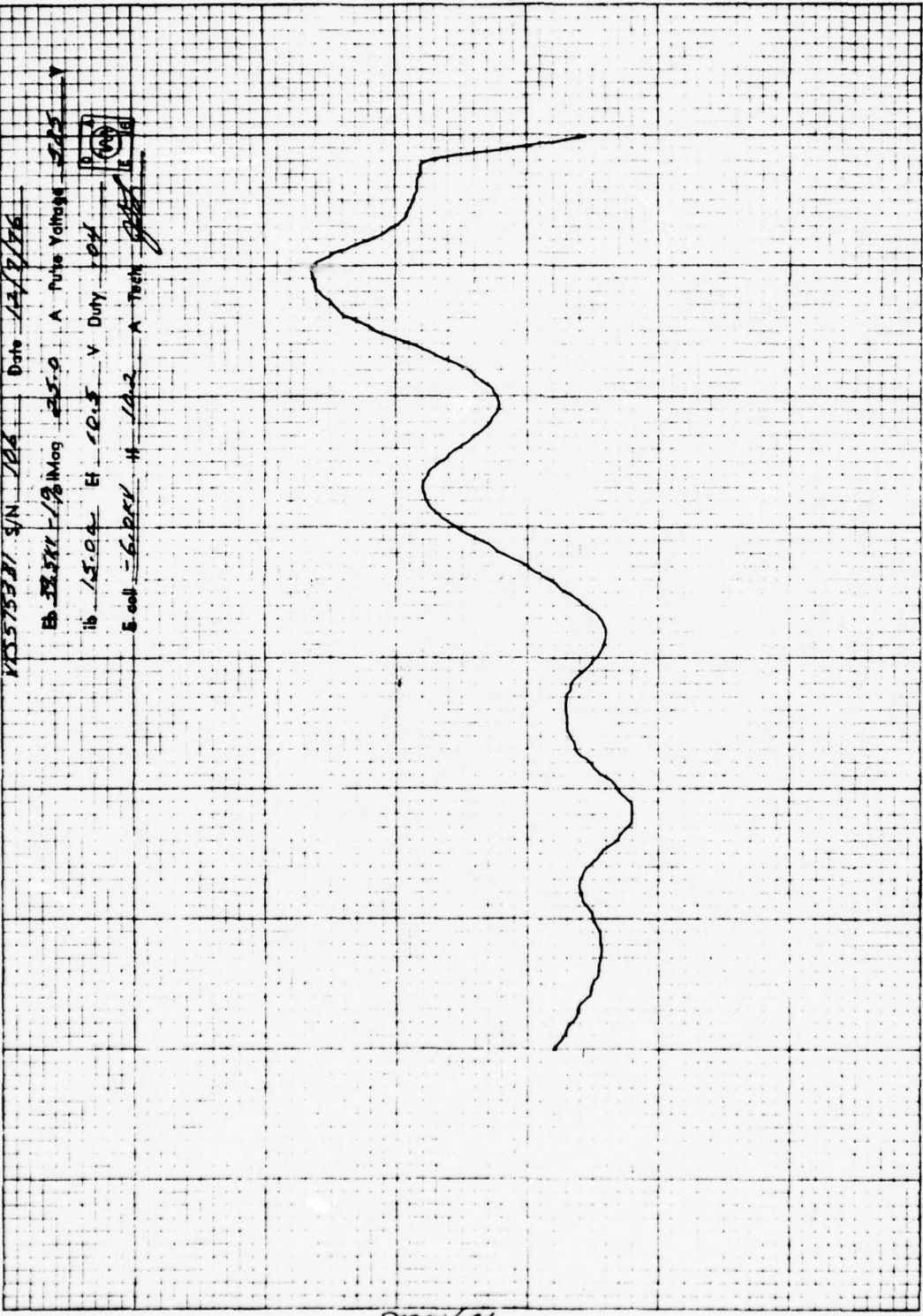
F. cell - 6.0KV II 10.2 A Tech. J.H.



Ad 960

40°/in x
B-17

3.7
GHz
3.0



134B

40°/mV

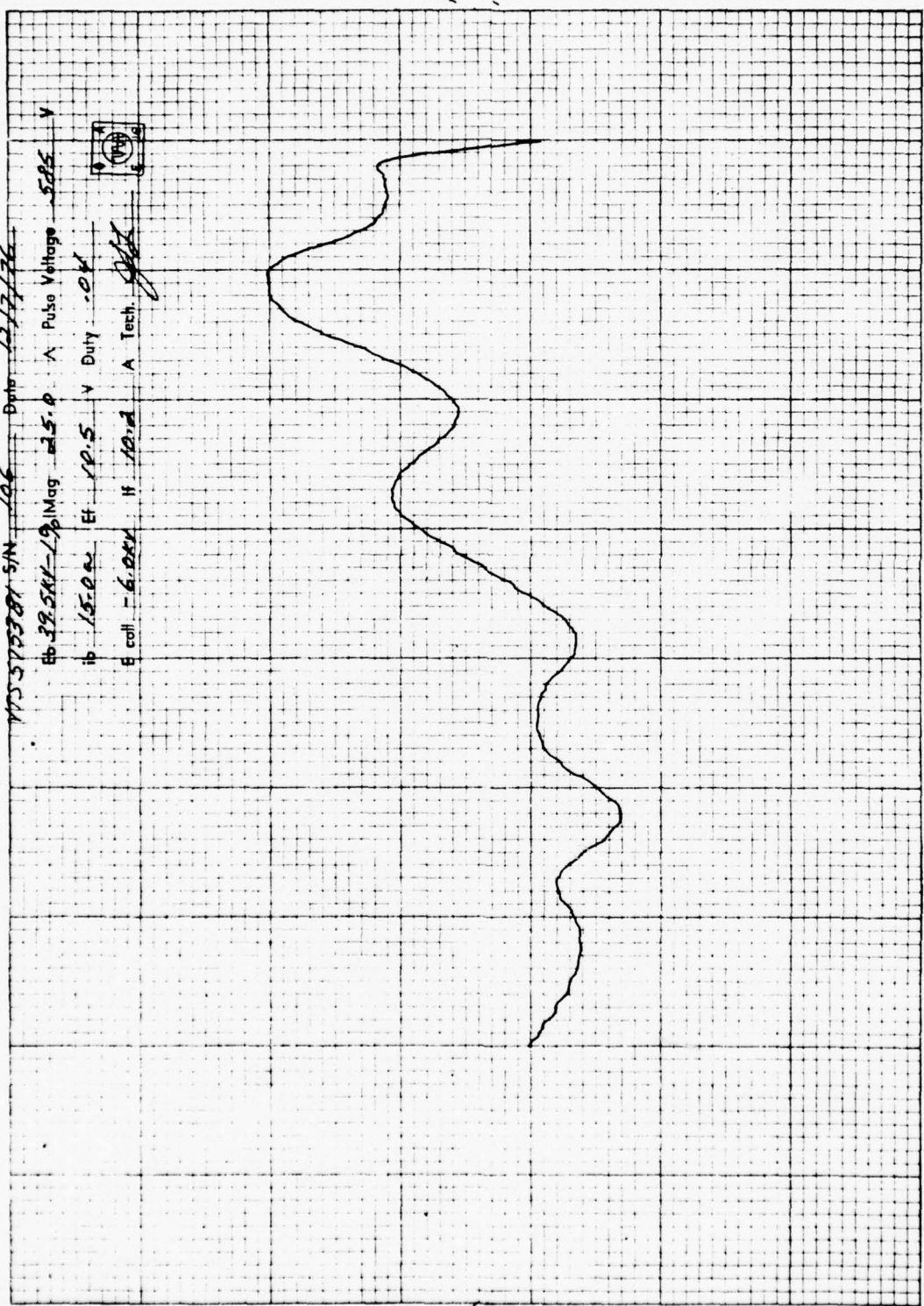
3.7

6mV

3.0

MS 575381 SN 106 Date 12/27/76

EB 32.5KV-19 Mag 25.0 A Pulse Voltage 5PS V
Ib 15.0V Ef 10.5 V Duty .04
E coll -6.0KV If 10.0 A Tech. *[Signature]*



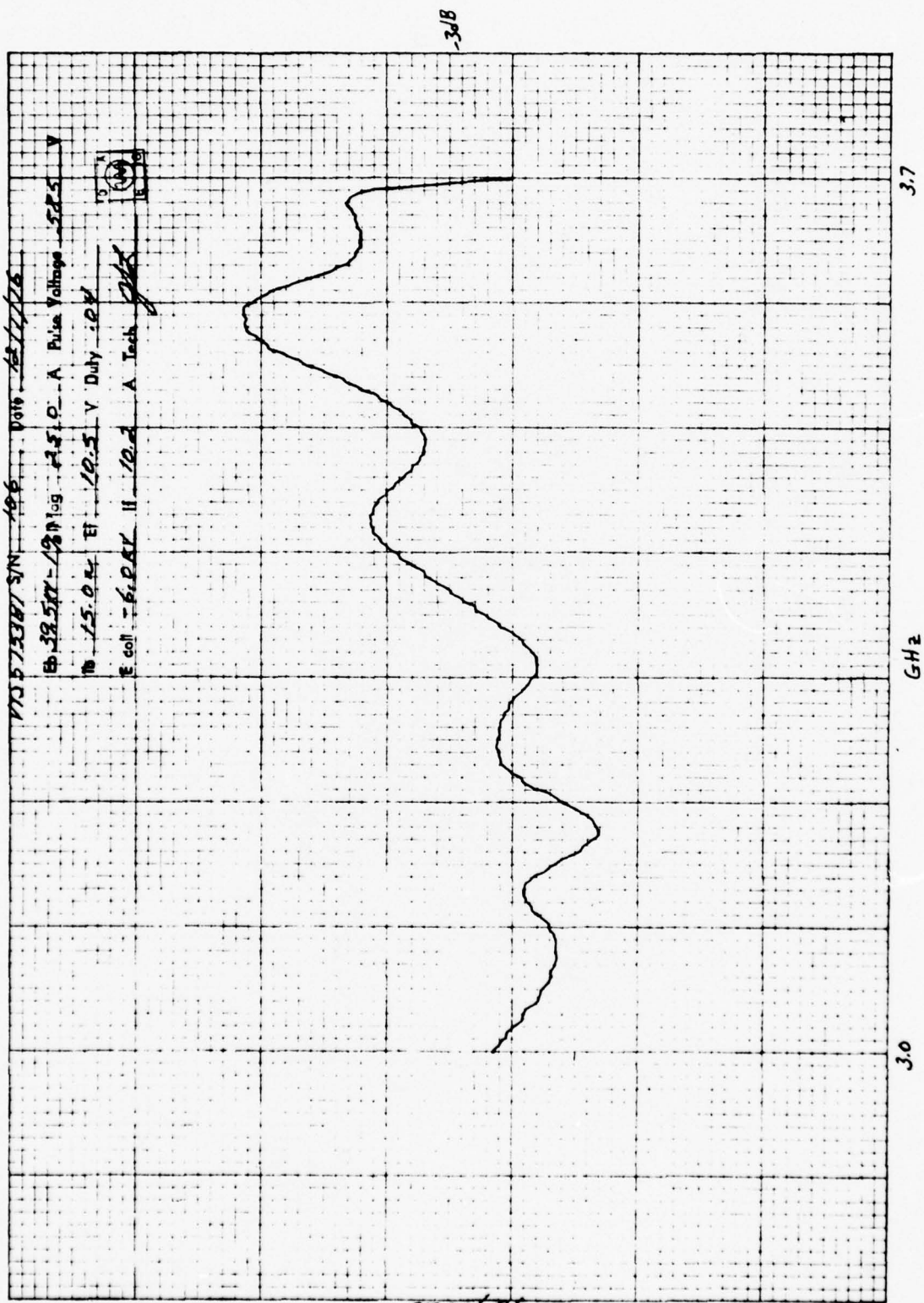
400/mv

pd
1.76u

3.7

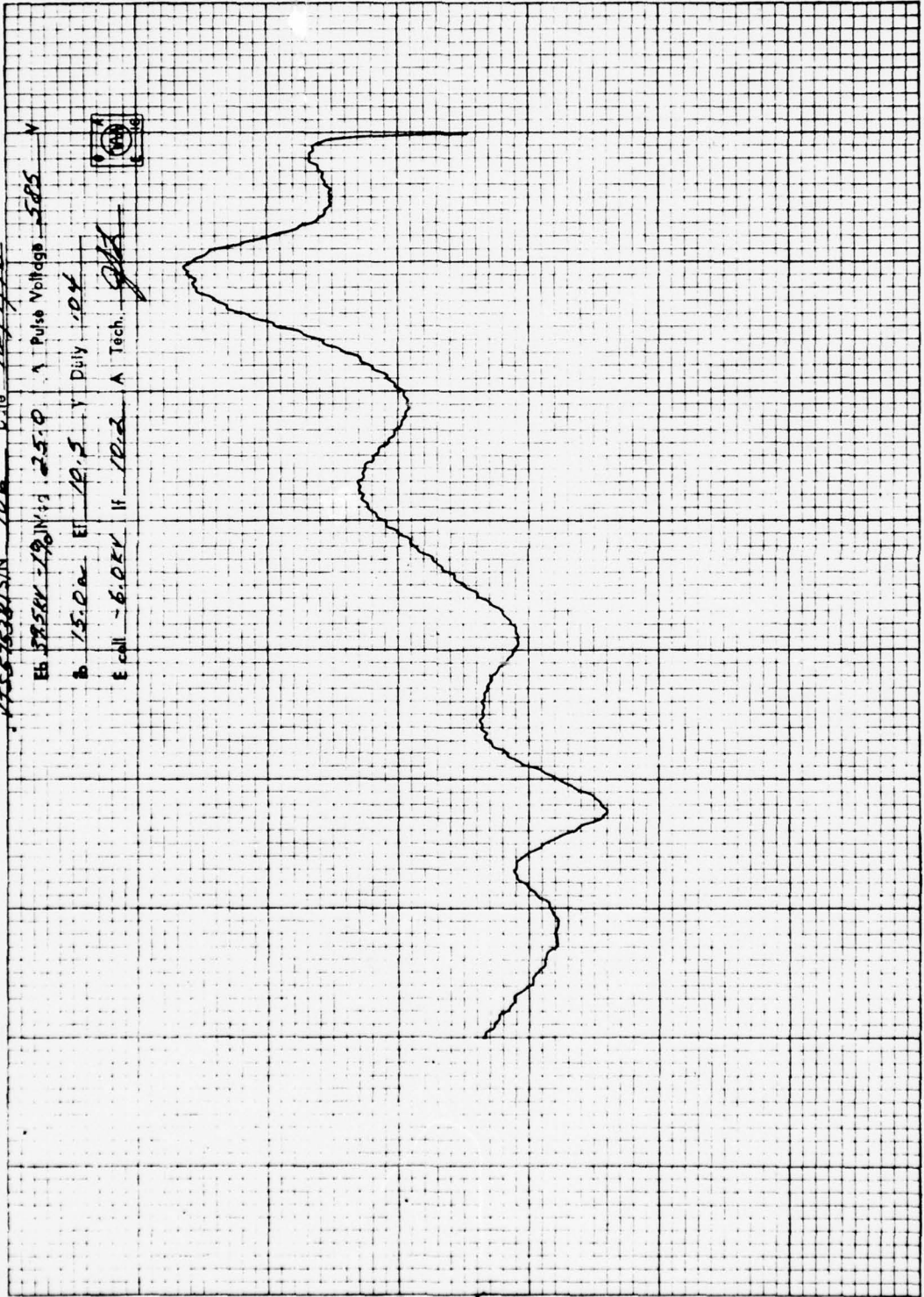
6 Hz

3.0



VT55753815IN 106 Date 12/7/76

EB 575KV 19.1N:1 25.0 1 Pulse Voltage 585 V
b 15.0 sec ET 10.5 Y Duty 104
E cell -6.0KV H 10.2 A Tech. *[Signature]*



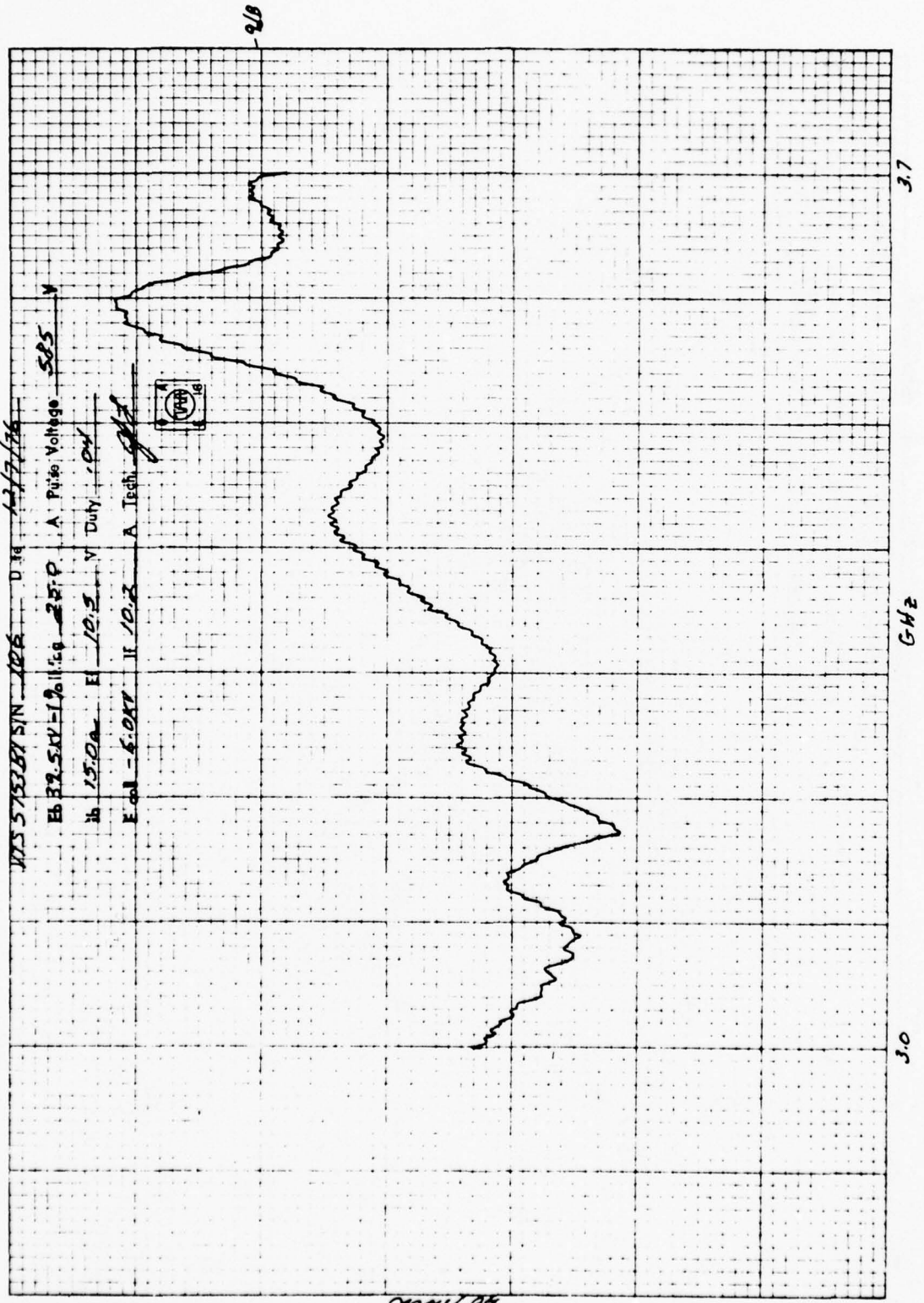
400/mvch
B-21

-6dB

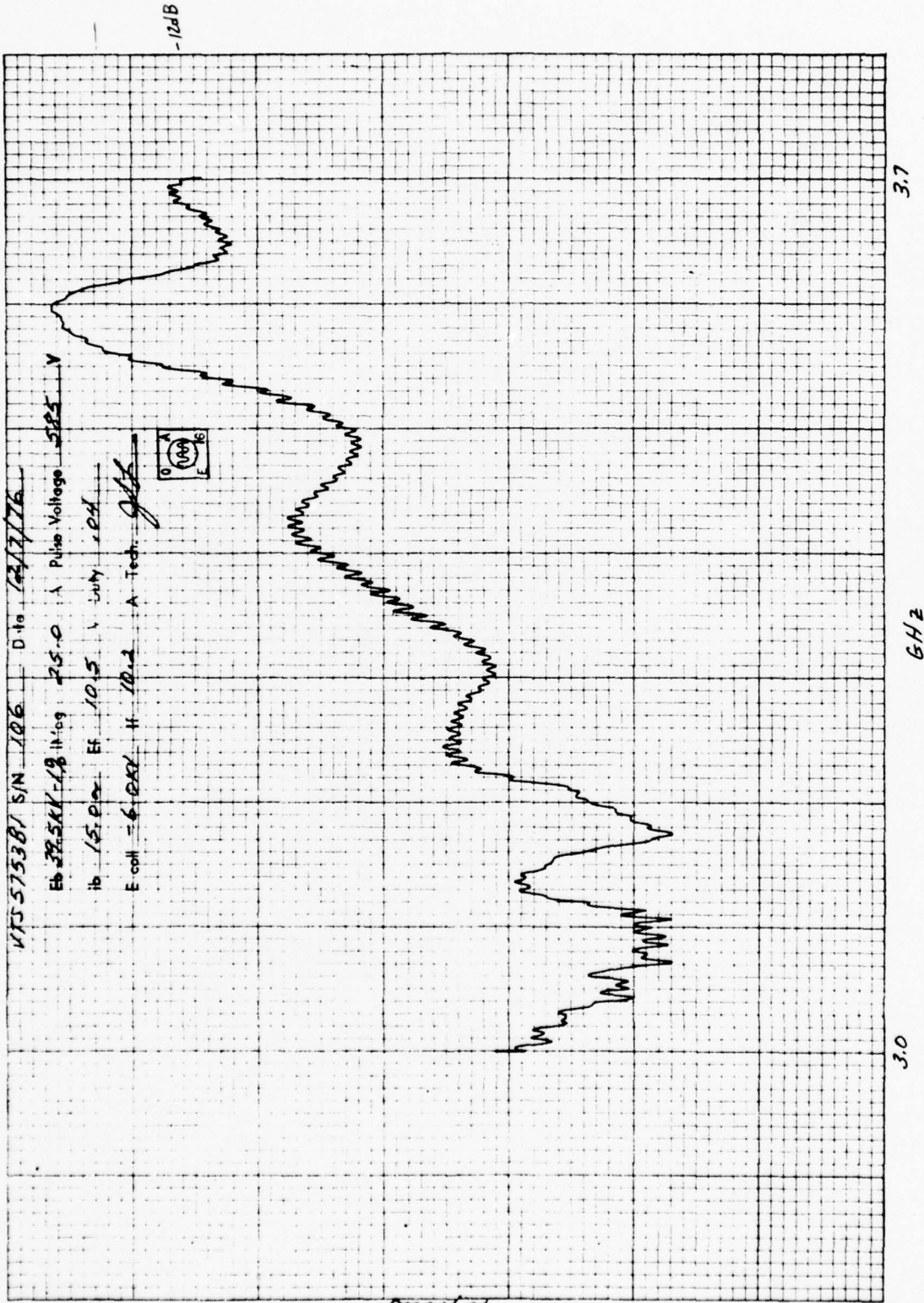
3.7

GHz

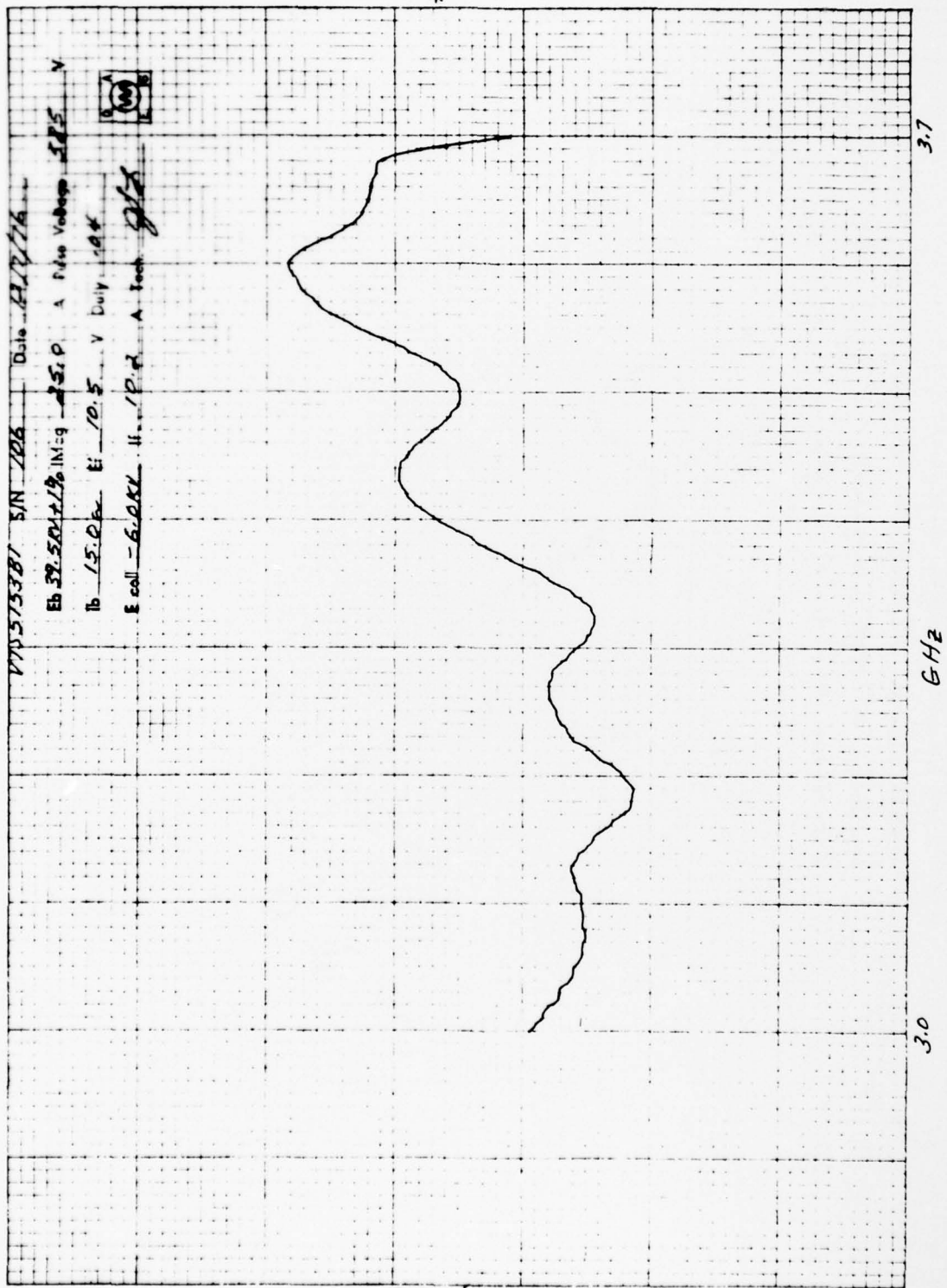
3.0



10°/inch
B-22

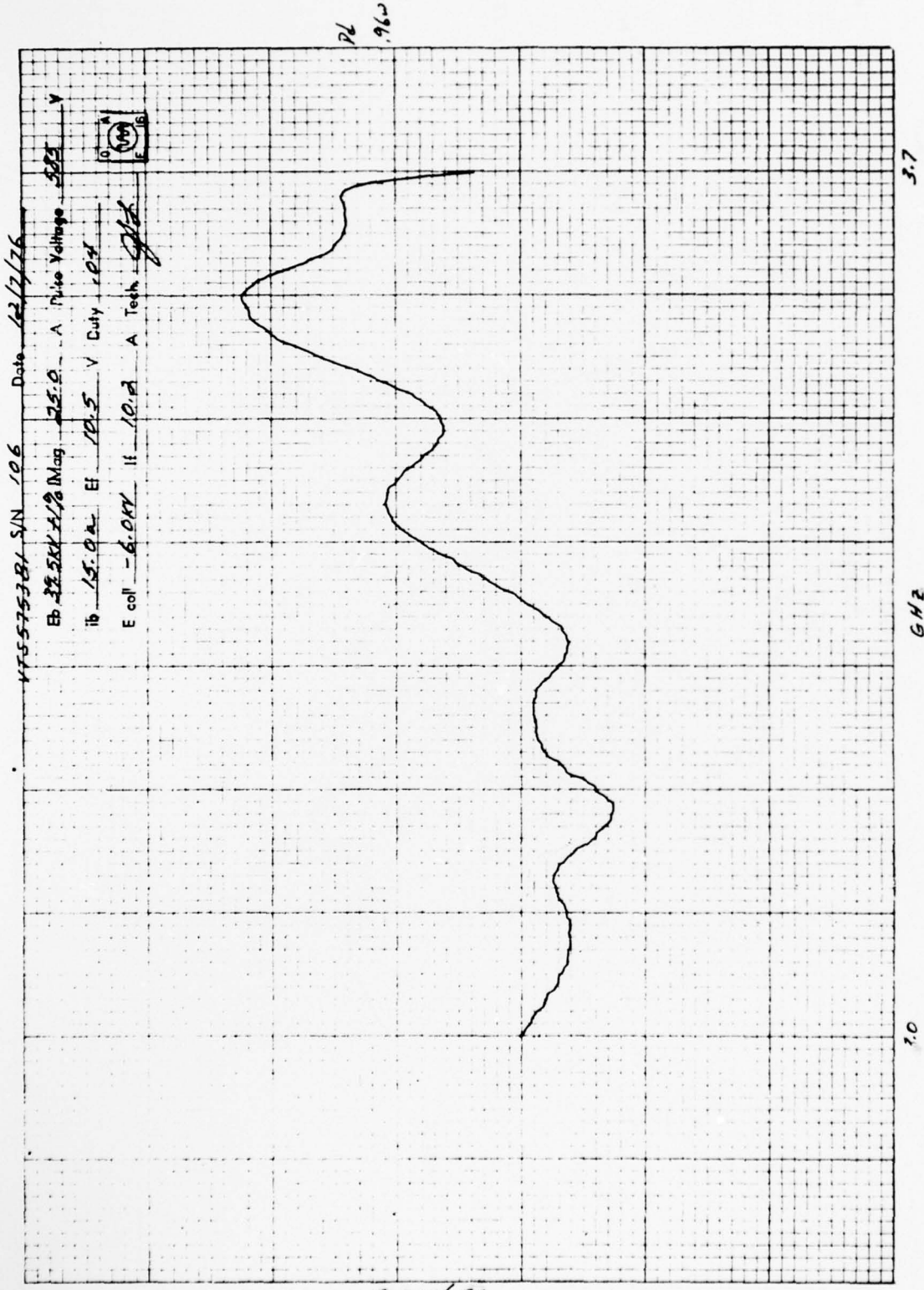


10/10/04
 B-23



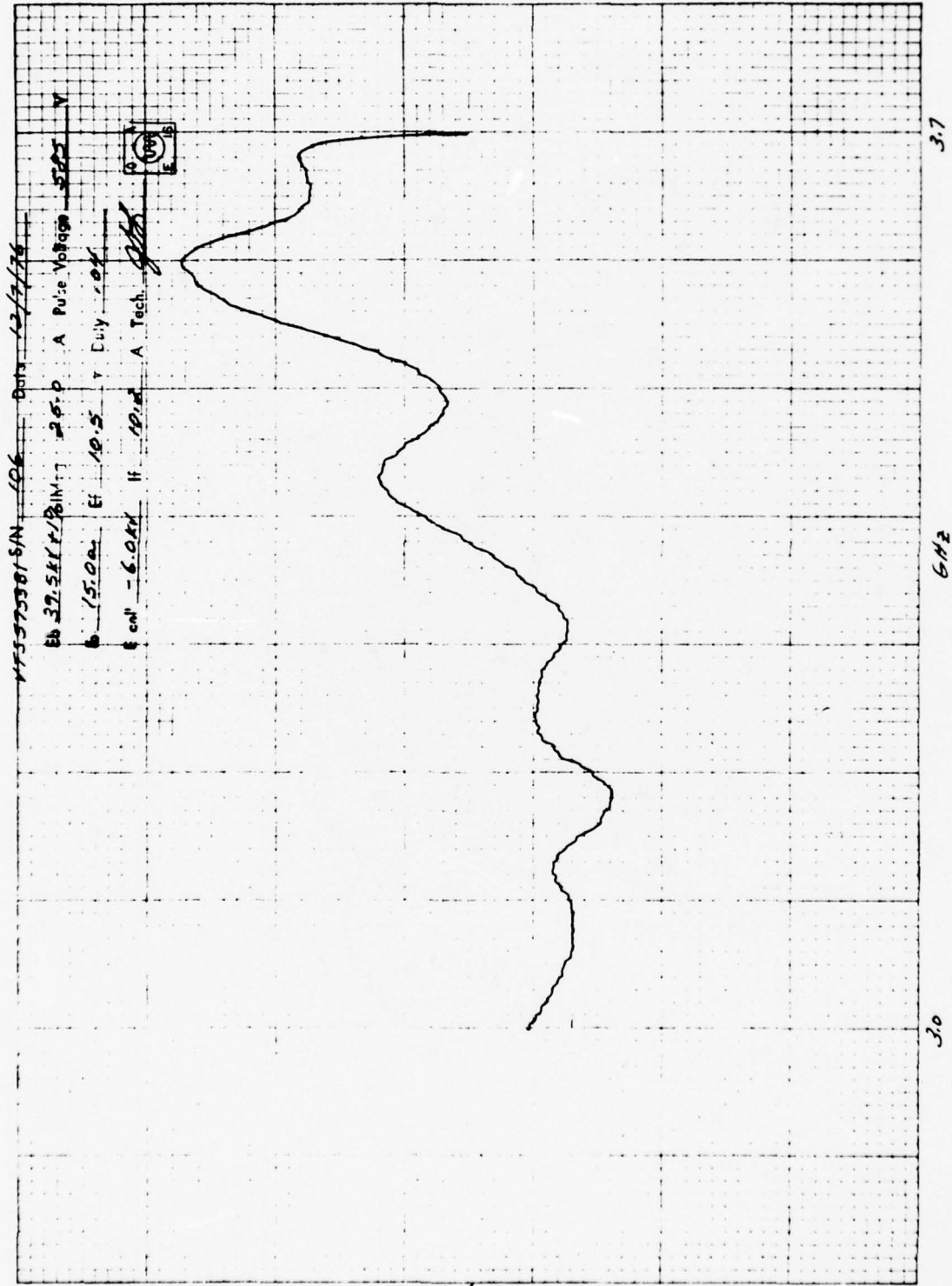
400/wch
B-24

+3dB



PL
960

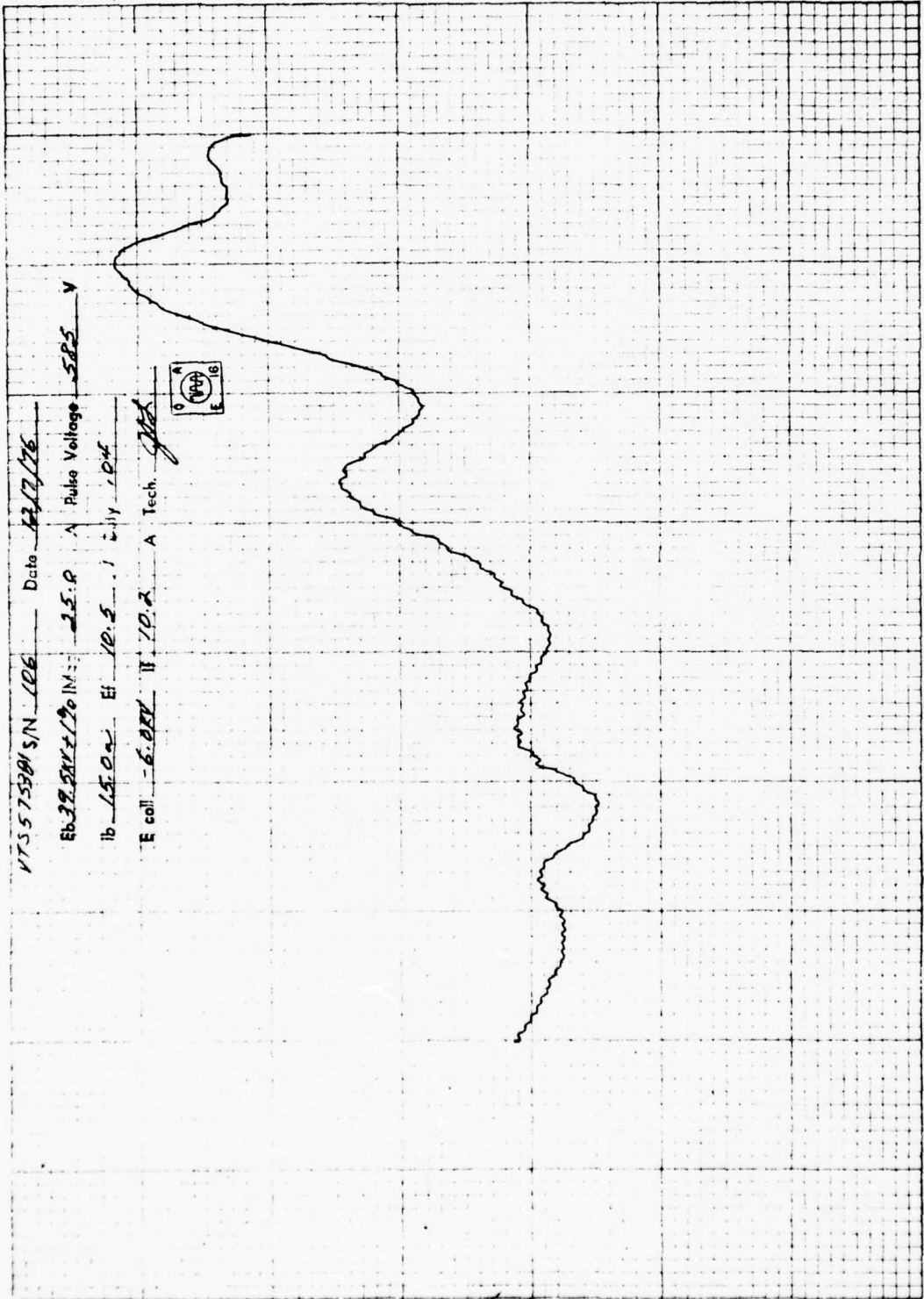
40°/inch



-3dB

40°/in

VT-57590 S/N 1006 Date 12/7/76
 Eb 32.0V ± 10 IN 25.0 A Pulse Voltage 585 V
 Ib 15.0 A Ef 10.5 A Iy 1.0 A
 E coll -6.00V If 10.2 A Tech. JMA



400/mvch

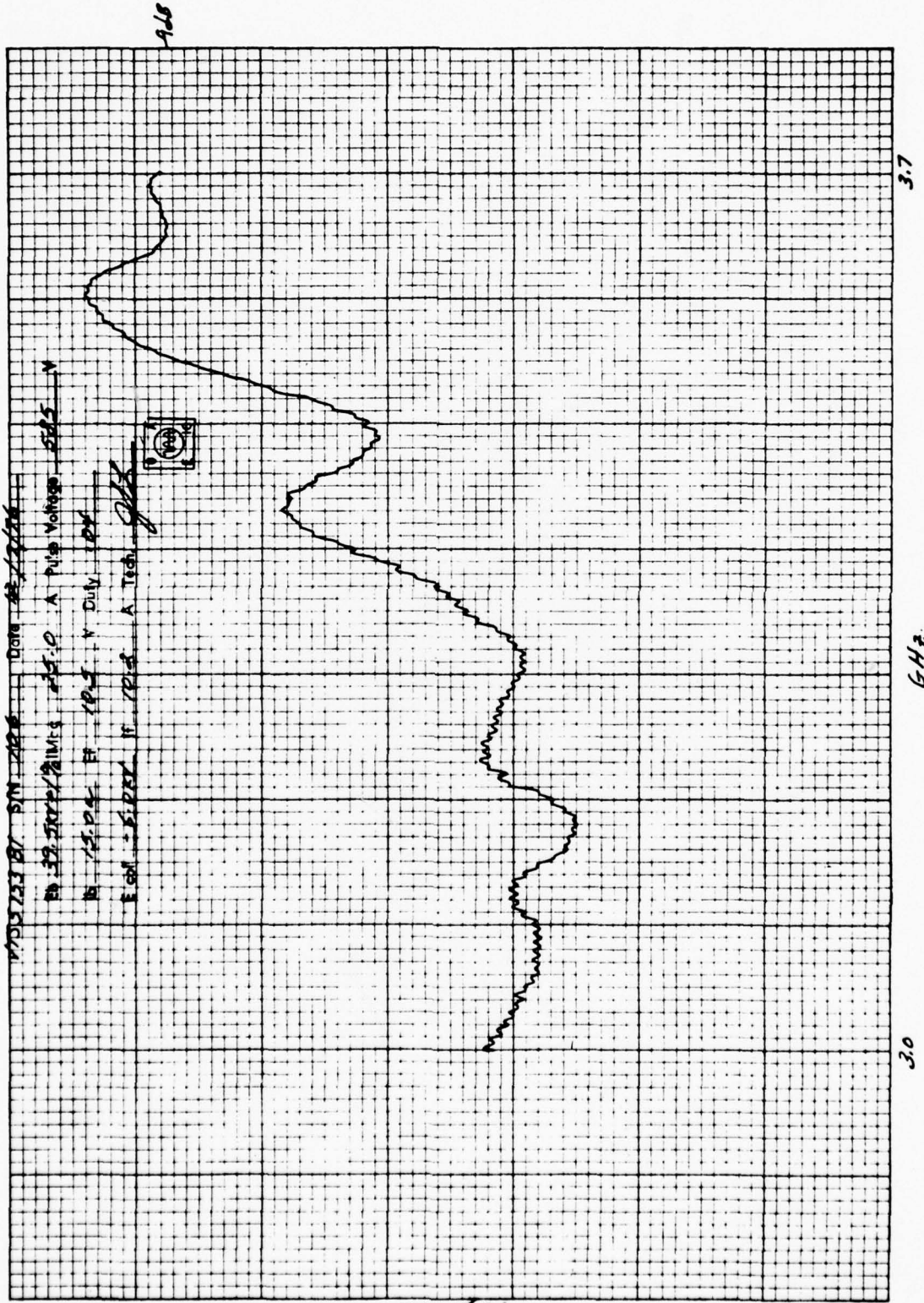
B-27

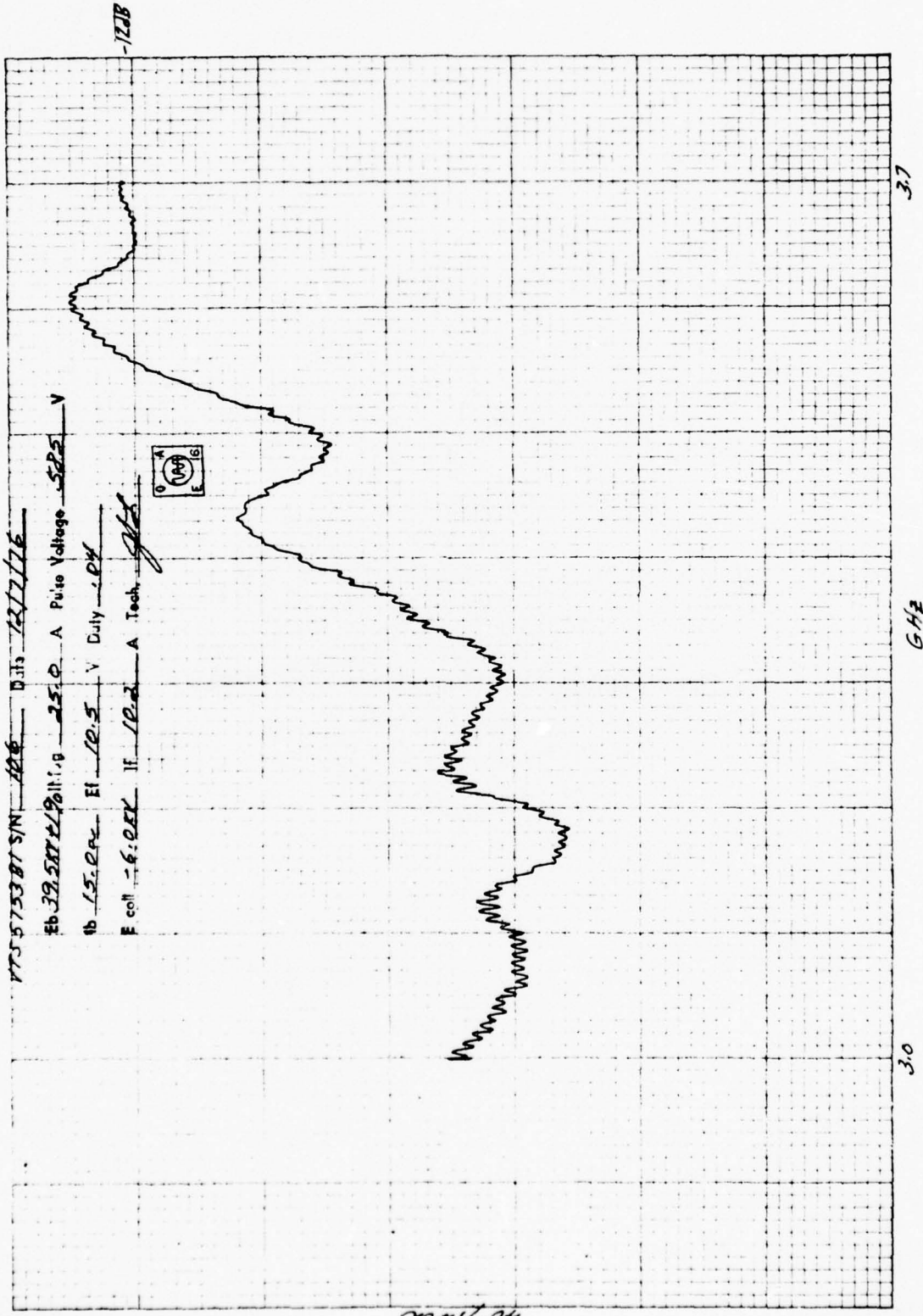
-60B

3.7

G-43

3.0





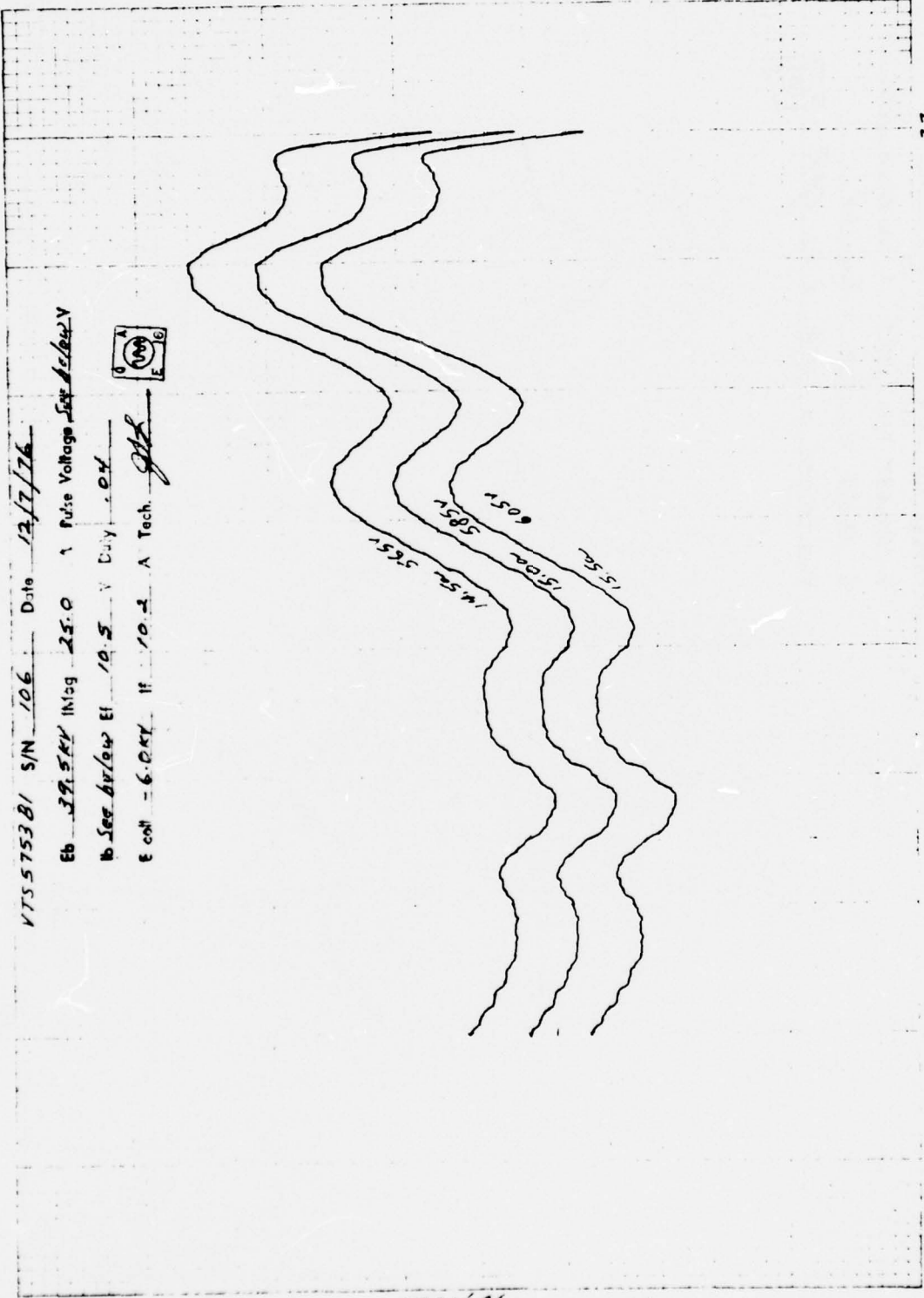
4. Phase pushing with $\pm 3\%$ change in beam current

VTS575381 SN 106 Date 12/7/76

Eb 39.5KV IMag 25.0 Pulse Voltage 50V/100V

W See below EI 10.5 V Duty .04

E coil - 6.0KV IF 10.2 A Tech JH



96
R

3.7

GHz

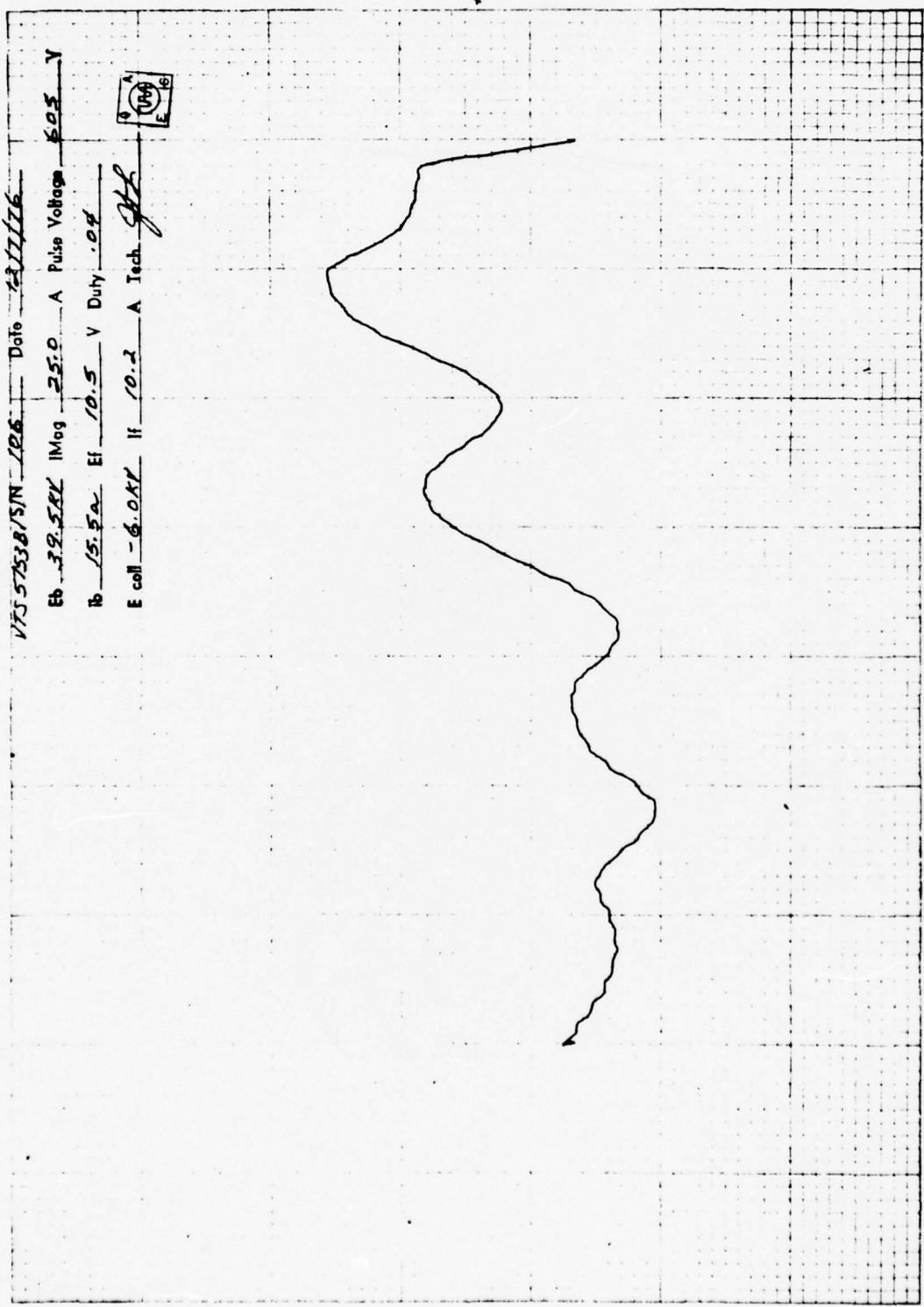
3.0

V7557338/S/N 106 Date 12/11/16

Eb 39.5KV IMag 25.0 A Pulse Voltage 605 V

R 15.5a Ef 10.5 V Duty .04

E coll -6.0KV If 10.2 A Tech JHL



400/mvch
B-32

VTS 575381 S/N 106 D. to ~~137776~~
 Eb 39.5KV IMug 25.0 A Pulse Voltage 405 V
 Ib 15.5u EI 10.5 Duty .04
 E out -6.0KV IF 10.2 A Tech. *gls*



40/mv
 B-33

R
 96w

3.7

GHz

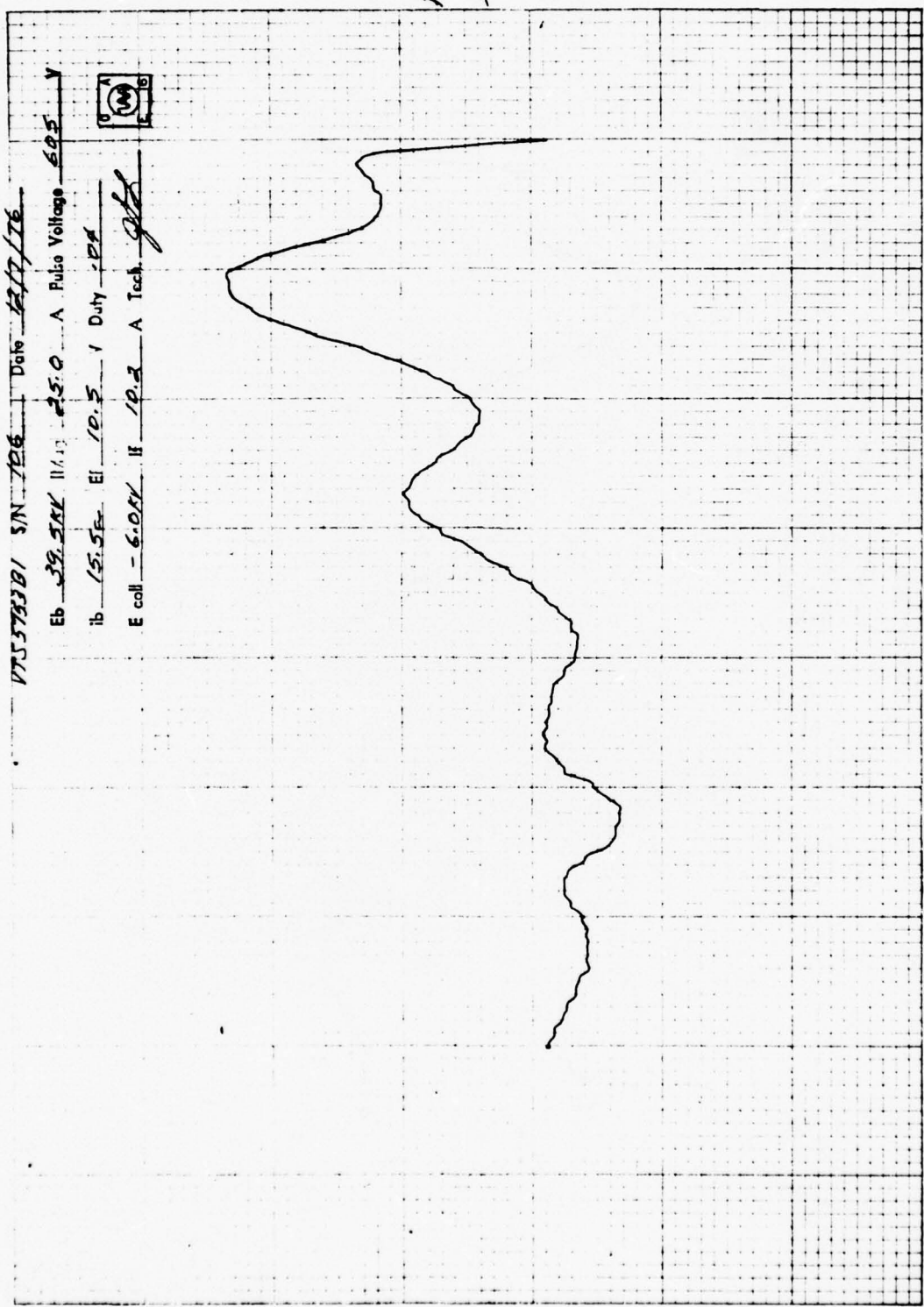
3.0

V755733B1 SIN 126 Date 12/7/76

Eb 39.5KV 11.43 25.0 A Pulse Voltage 605 V

ib 15.55e EI 10.5 1 Duty 20%

E coll - 6.0KV II 10.3 A Tech. gfb



40/inch

B-34

R
-3dB

37

GH2

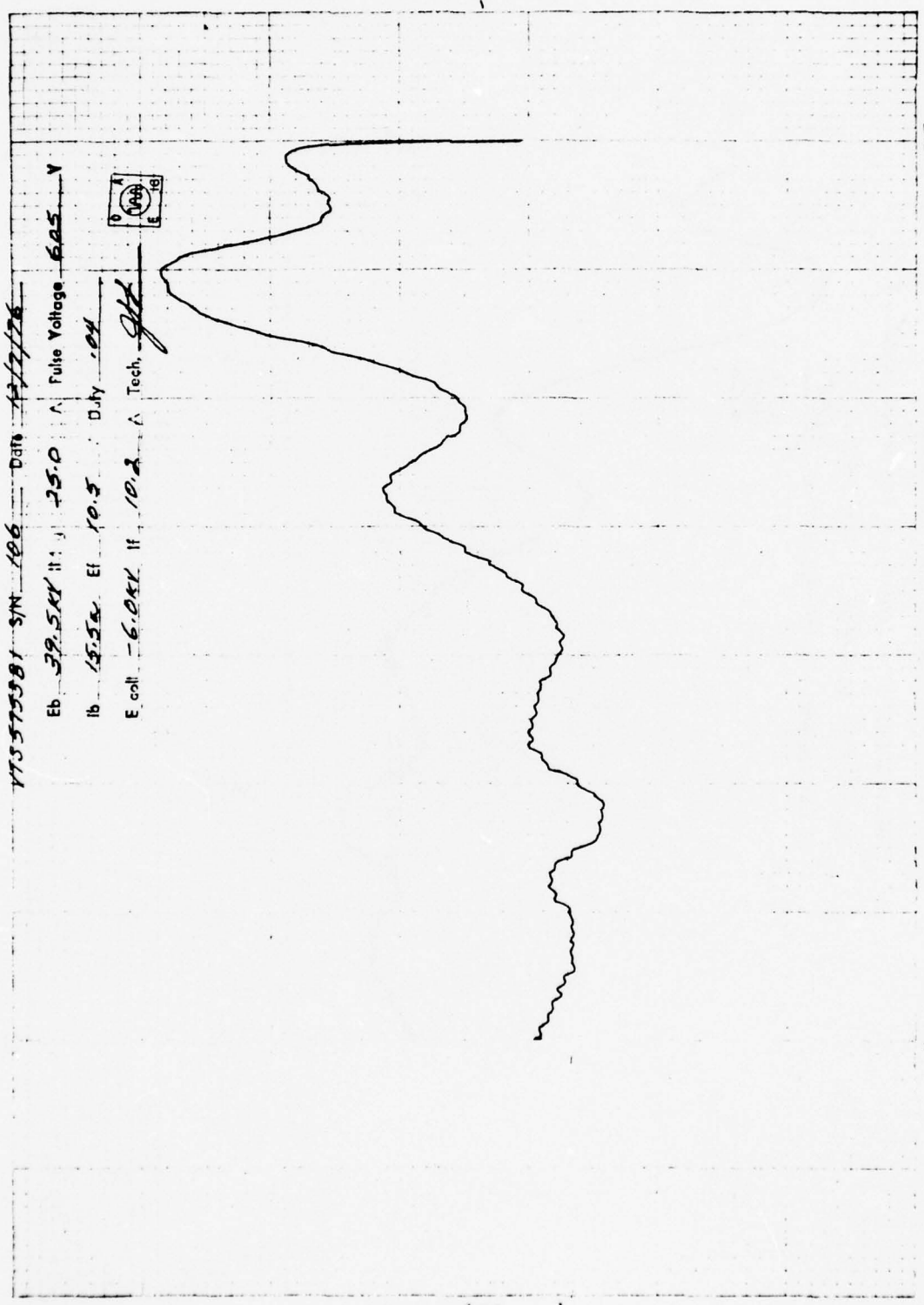
30

MTS 575381 SM 106 DATE 12/2/76

Eb 39.5KV II 25.0 Pulse Voltage 605 V

Ib 15.5x EI 10.5 Duty .04

E coll -6.0KV II 10.2 Tech. *SPH*



40°/inch
B-35

-608

37

6H2

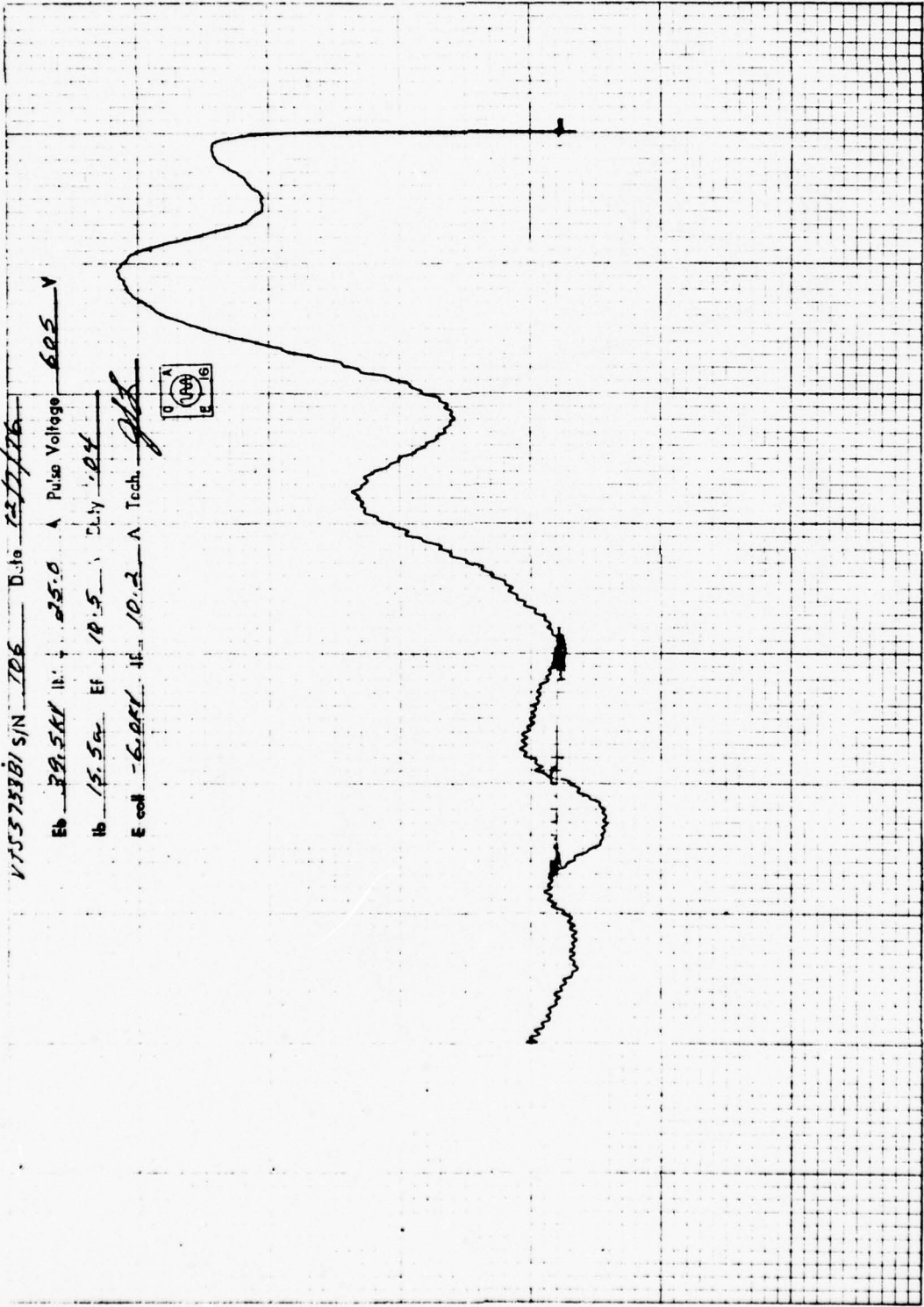
30

VTS573381 SIN 106 Date 12/17/76

Eb 29.5KV Ib 25.0 A Pulse Voltage 605 V

Ib 15.5a Ef 10.5 Slly .024

E coil -6.0KV if 10.2 A Tech JLB



918

3.7

GHz

3.0

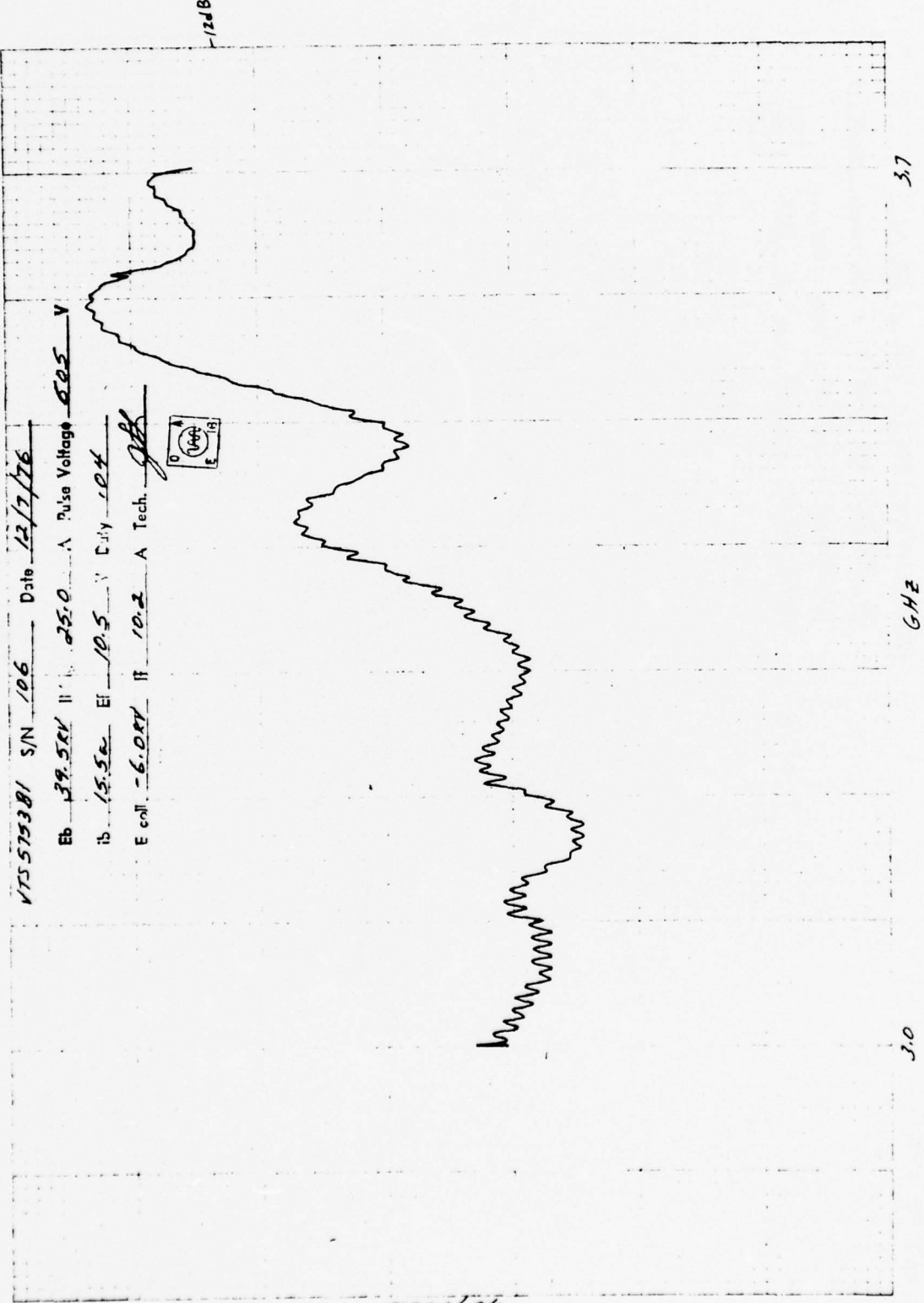
40°/in ch
B-36

VTS 579381 SN 106 Date 12/7/76

Eb 39.5KV II 25.0 A Pulse Voltage 605 V

Ib 15.5e Ef 10.5 V Duty 10%

E coll. -6.0KV IF 10.2 A Tech. JEB



40°/inch
B-37

50 Hz CURVE

175575381 S/N 106 Date 12/18/76

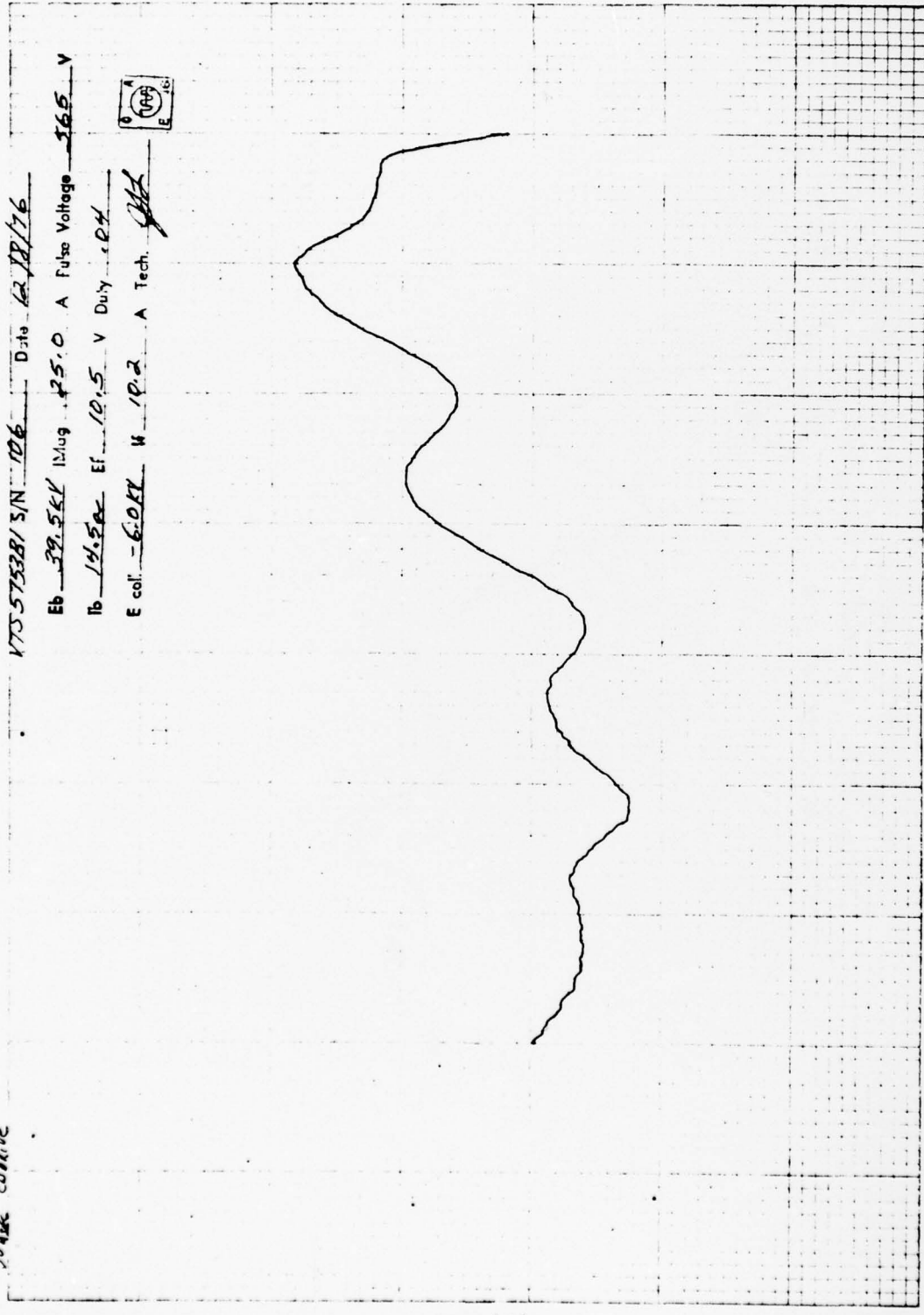
Eb 39.5KV IMug 25.0 A Pulse Voltage 165 V

Ib 14.5A Ef 10.5 V Duty 24

E coll. 6.0KV W 10.2 A Tech. JH



+3dB



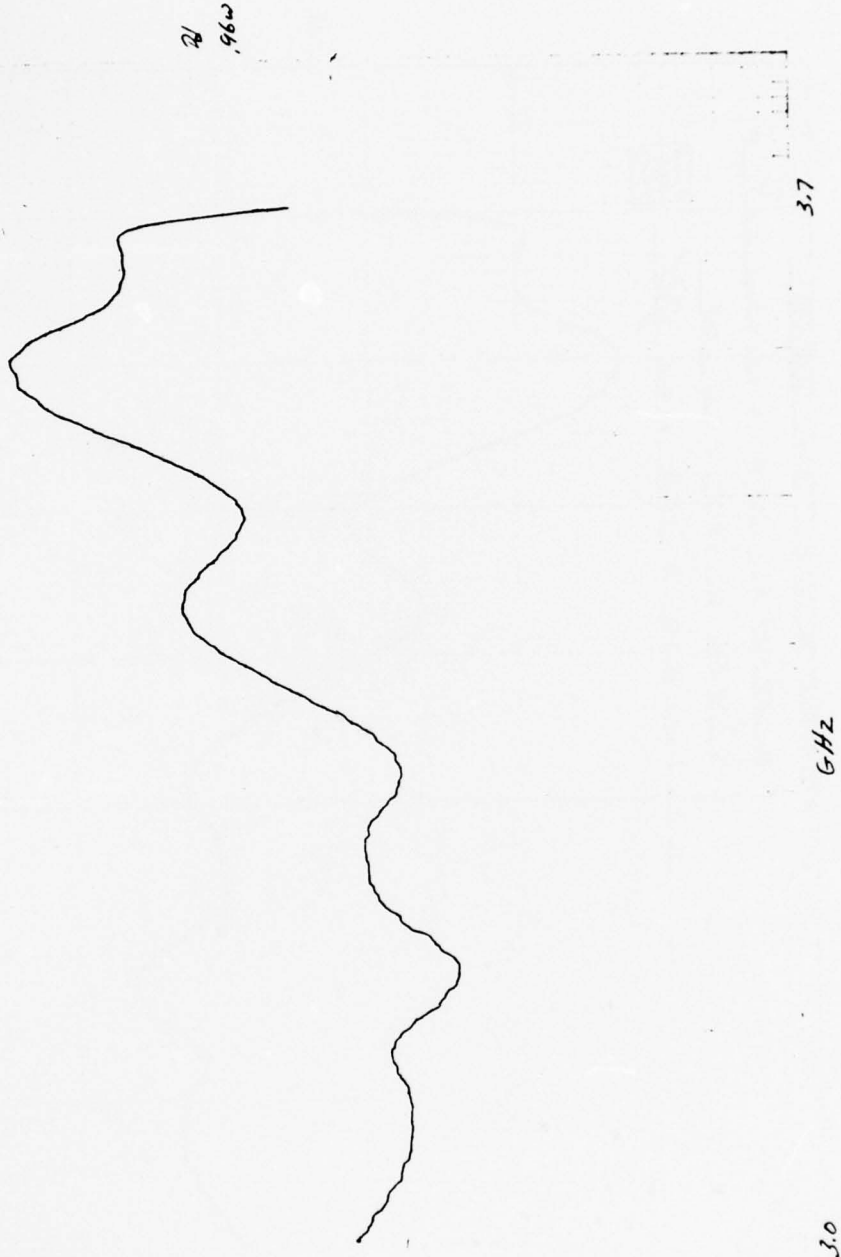
40 dB/INCH
B-38

3.7

GHz

3.0

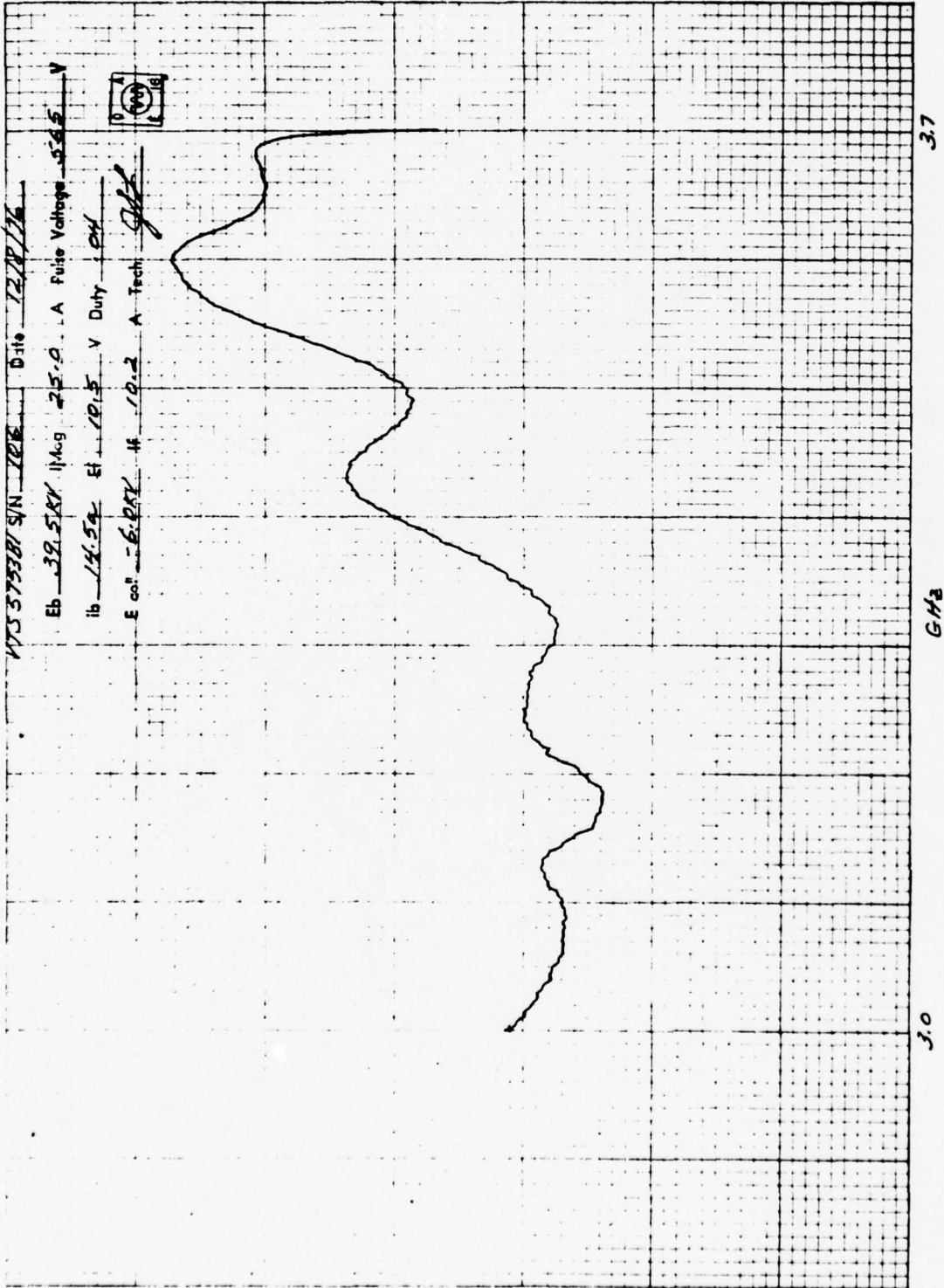
VTS575381 SIN 106 Date 12/18/76
 Eb 38.5KV Mag 25.0 A Pulse Voltage 565 V
 Ib 14.5a Ef 10.5 V Duty .04
 E enll -6.0KV if 10.2 A Tech. *gfa*



21
 996

400/mil
 B-39

-3PB



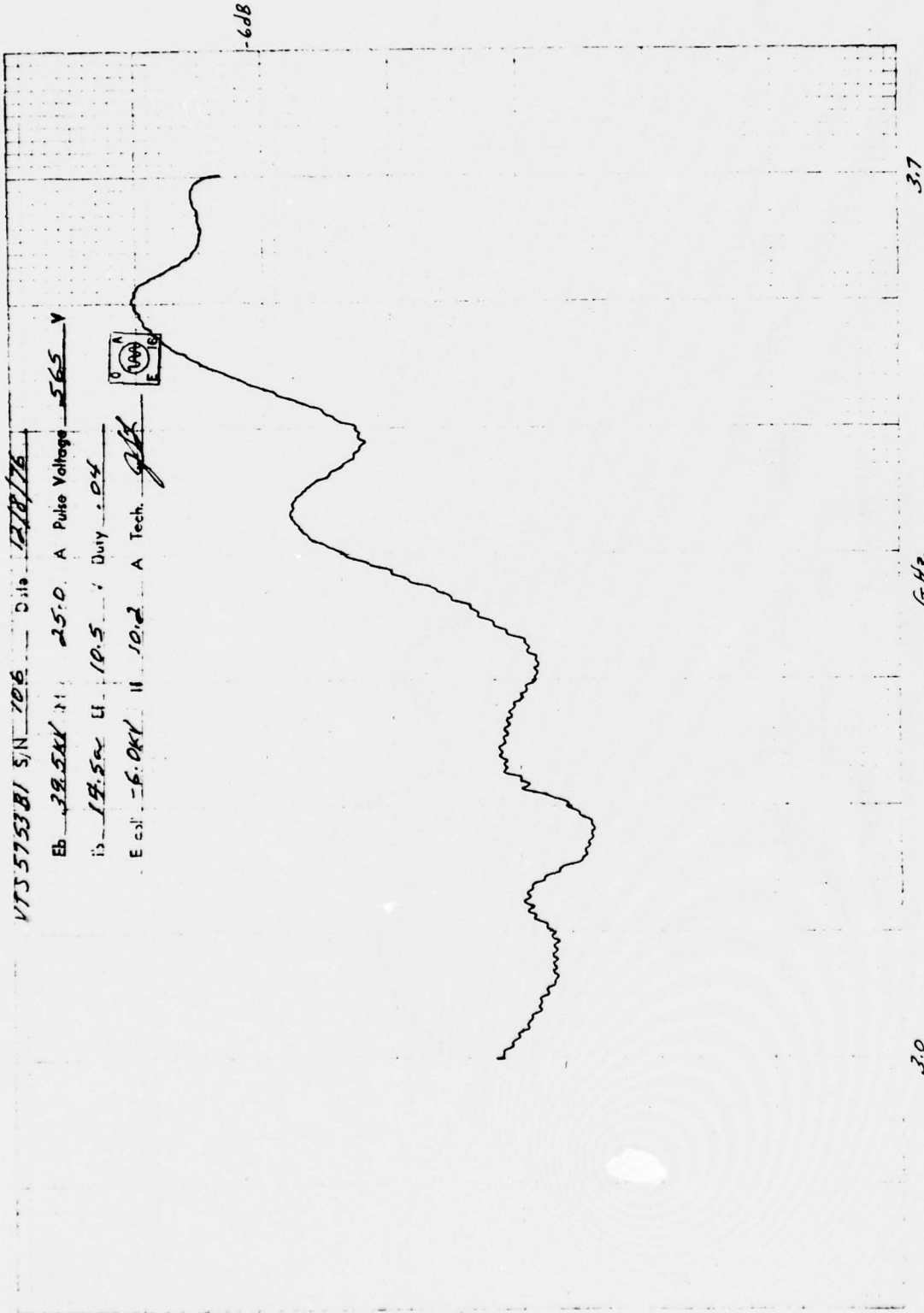
40/inch
B-40

VTS 575381 S/N 706 Dils 12/18/76

Eb 28.5KV M 25.0 A Pulse Voltage 565 V

Is 19.5KV U 10.5 V Duty .04

E cal -6.0KV II 10.2 A Tech. *grr*



40/100
B-41

VOS75381 SN 2026 Date 12/18/76

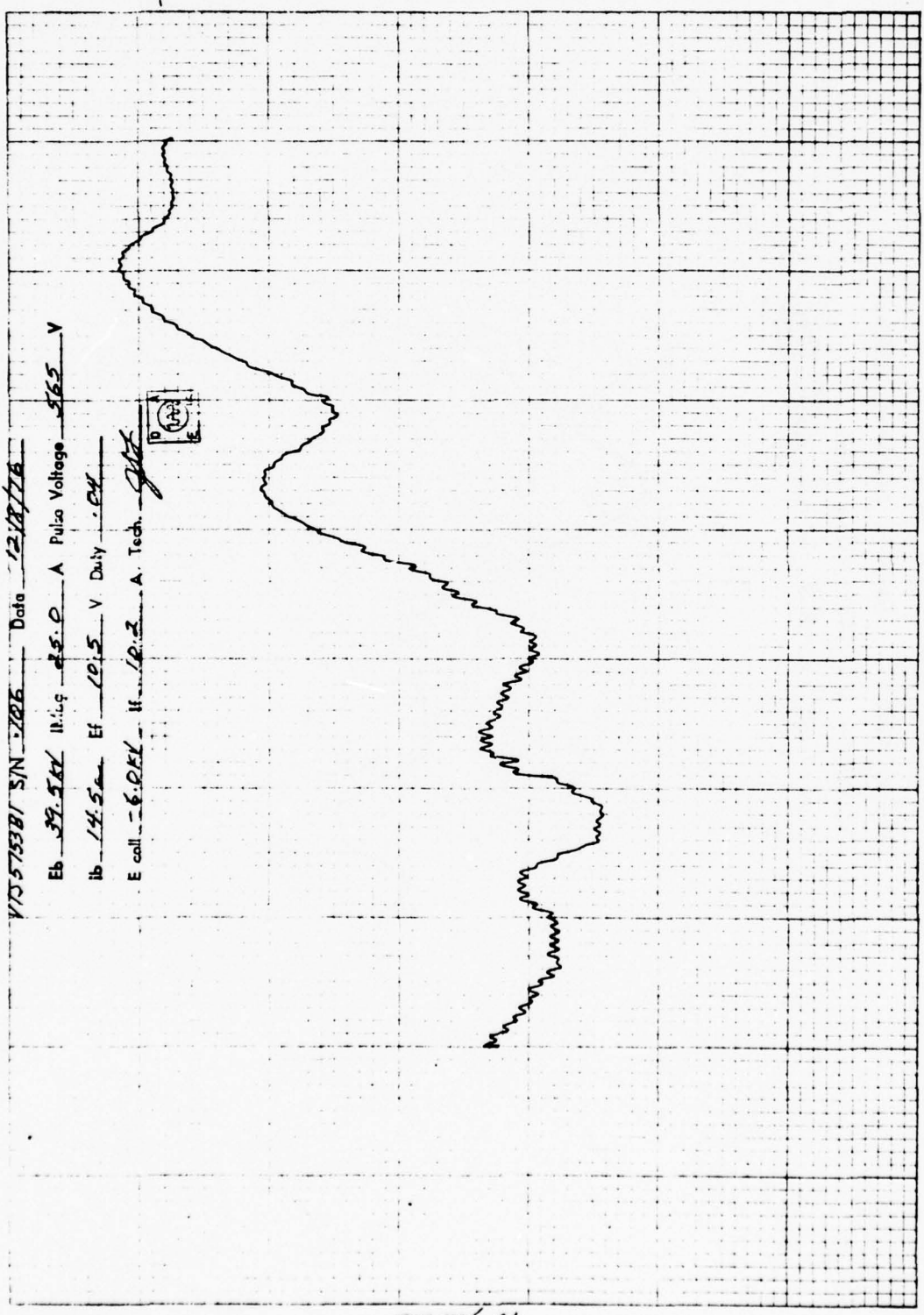
Eb 39.5KV Il. 10.5 A Pulse Voltage 565 V

Ib 14.5 A Ef 10.5 V Duty .64

E coll -6.0KV H 10.2 A Tech. JHE



-9dB



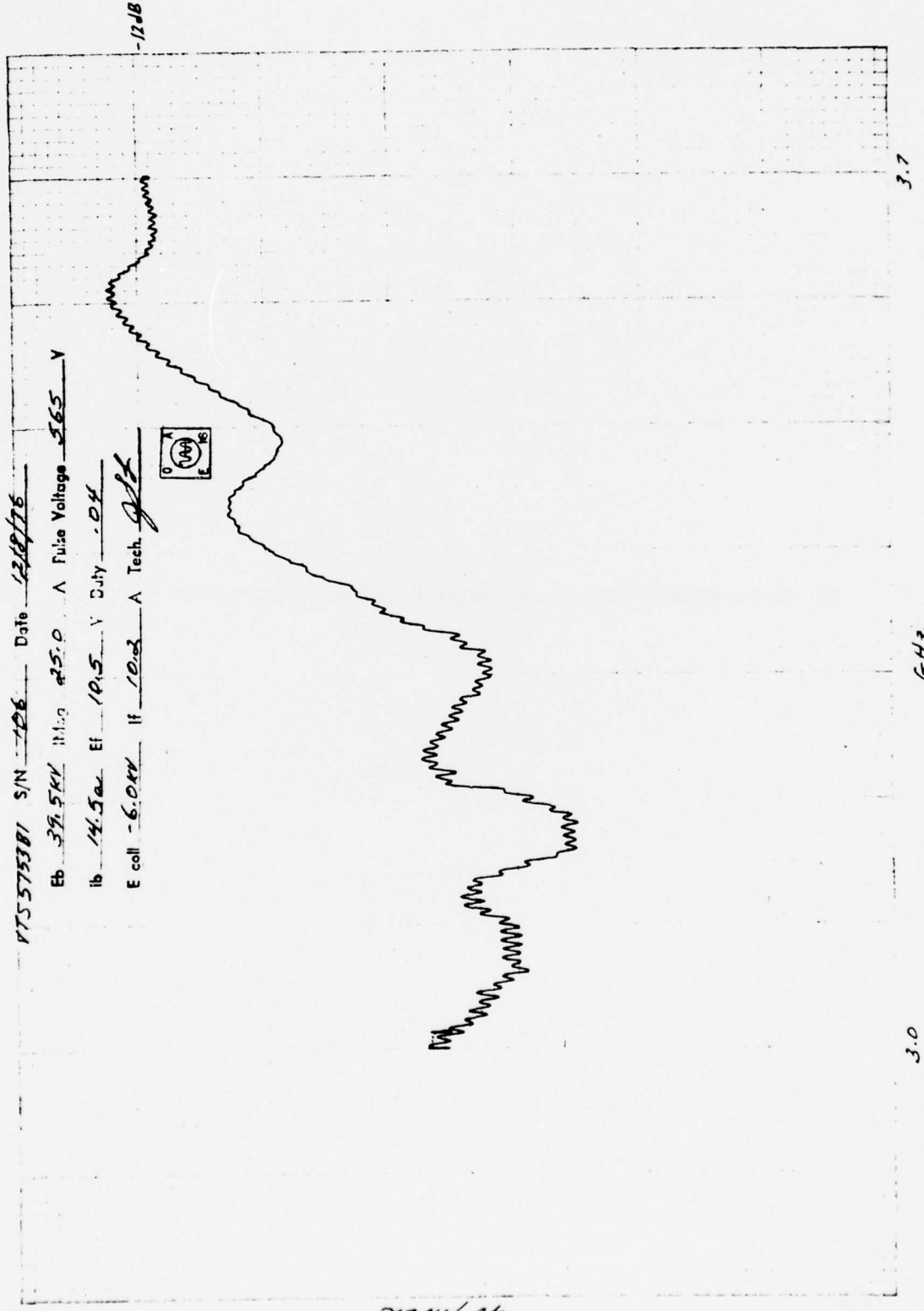
40°/inch
B-42

PT5575381 S/N 726 Date 12/18/76

Eb 39.5KV I1:100 I2:50 A Pulse Voltage 565 V

Ib 14.5a Ef 10.5 V Duty .04

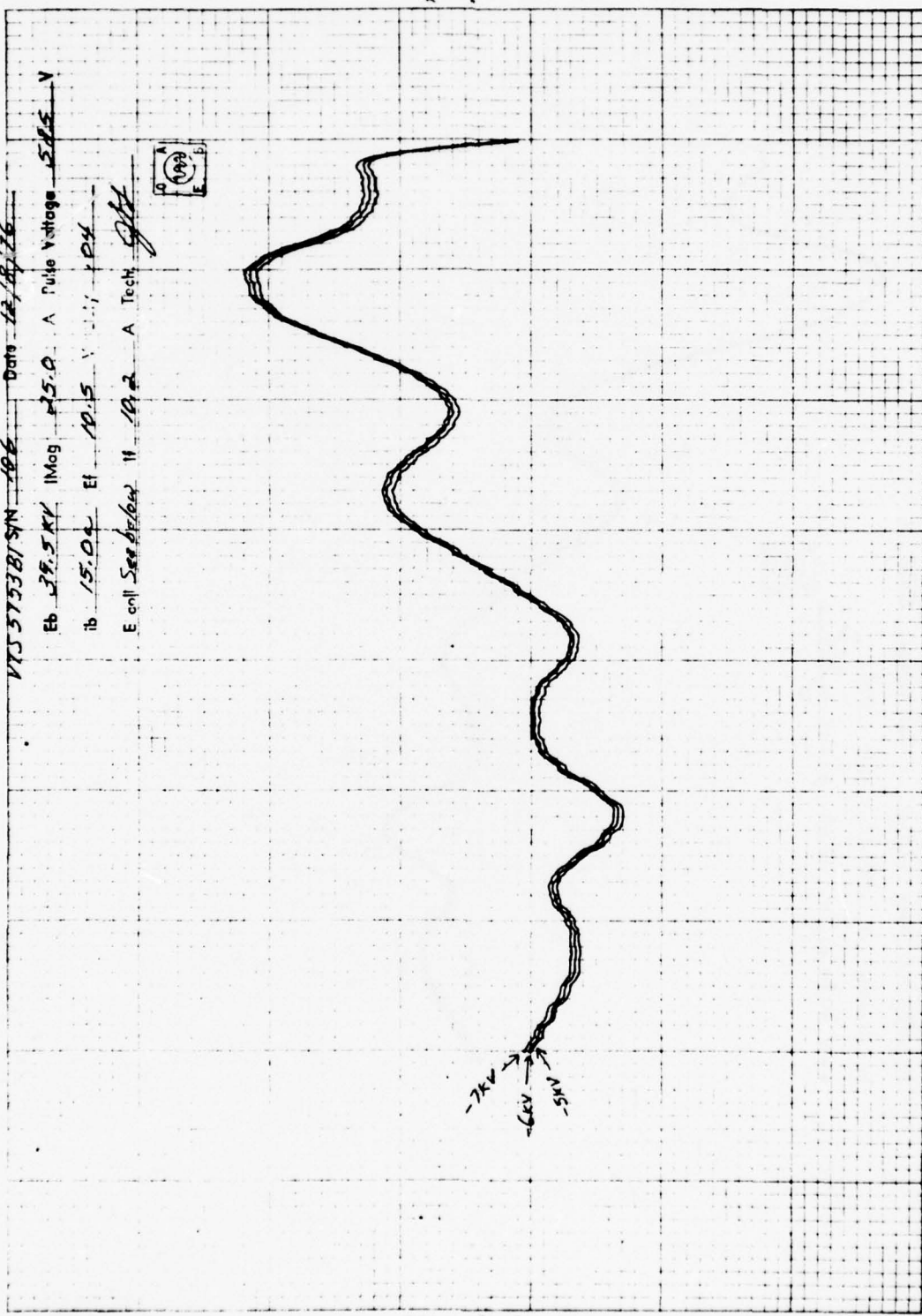
E coll -6.0KV If 10.2 A Tech. JLT



40°/inck
B-43

5. Phase pushing with ± 1 kV change in collector depression

VTS 575381 SYN 186 Date 12/17/26
 Eb 39.5KV IMag 45.0 A Pulse Voltage 585 V
 Ib 15.04 EI 10.5 V ... 104
 E coll See below 11 1012 A Tech *gjh*



P/ .96w

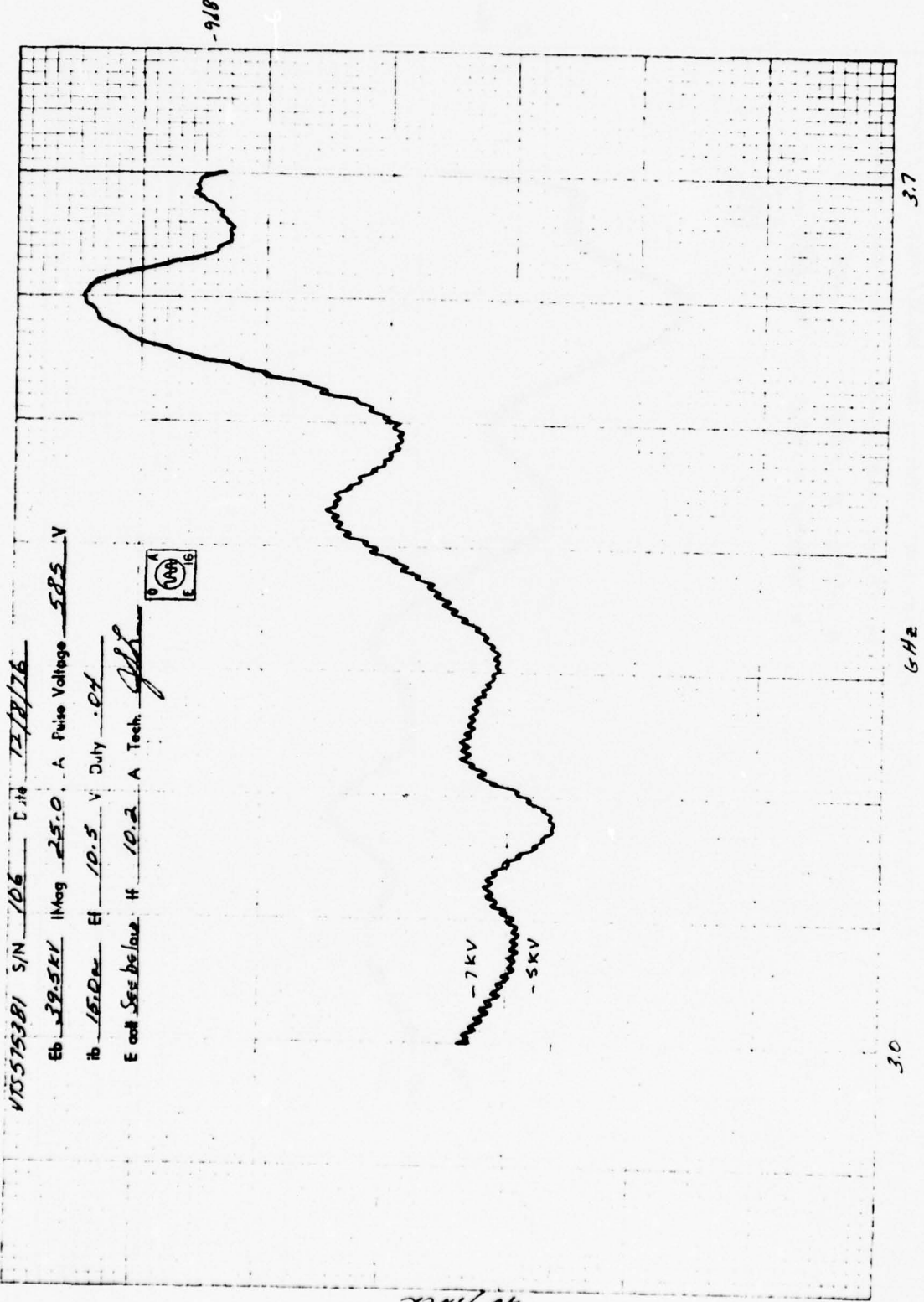
40°/inch

VTS575381 S/N 106 D. No. 12/17/76

Eh 39.5KV IMag 25.0 A Pulse Voltage 585 V

ib 15.0KV EI 10.5 V Duty .04

E cell See below H 10.2 A Tech. JLL



400/inch
B-46

6. Amplitude and phase with a 1.25:1 VSWR

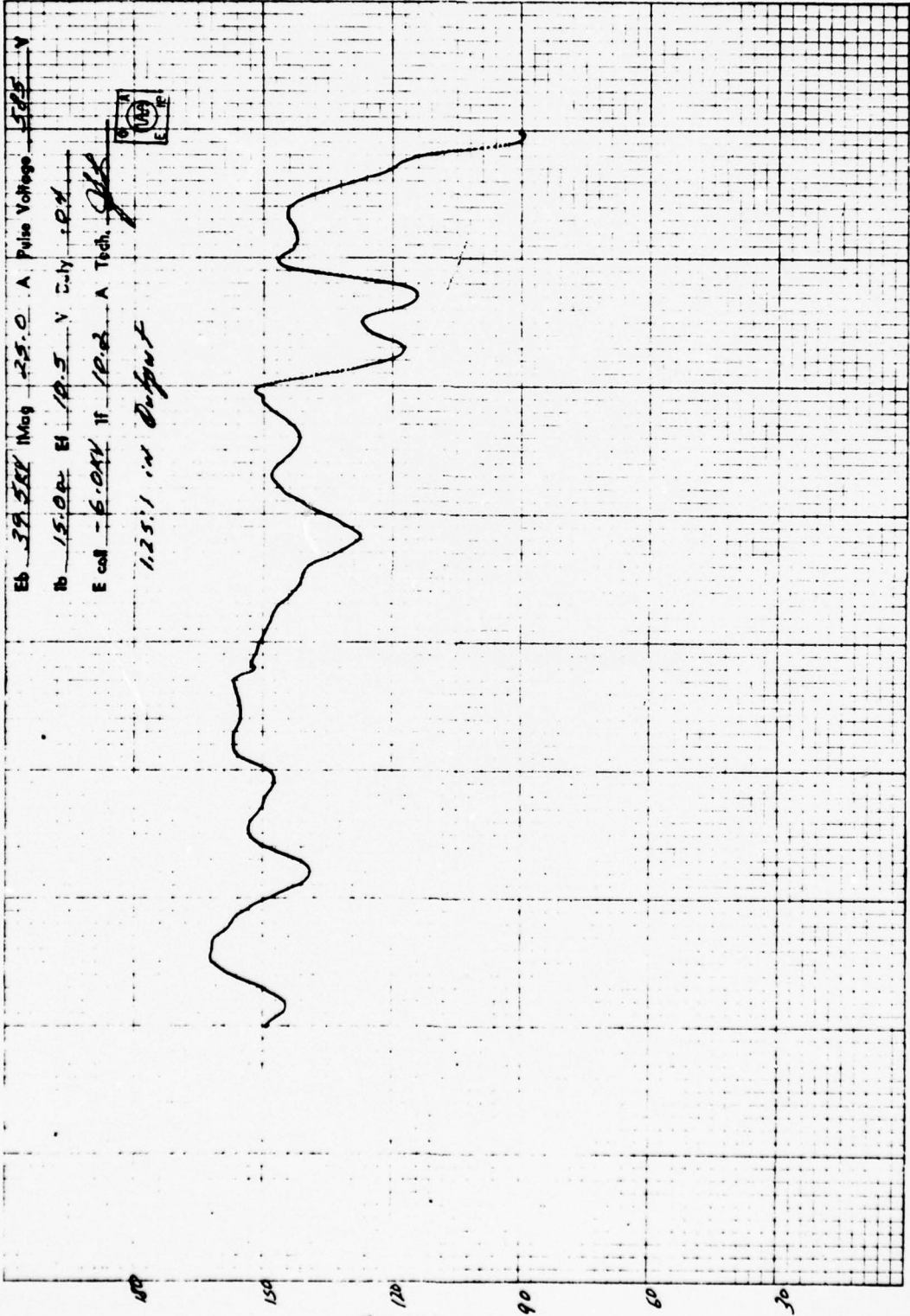
VTS 575381/SIN 06 Date 12/18/76

Eb 39.55K Mag 25.0 A Pulse Voltage 500V V

Mo 15.00E H 12.3 V Duty 0.2

E coil - 6.00V If 12.03 A Tech. JLS

125.1 in Output



B-48
PKN (Peak)

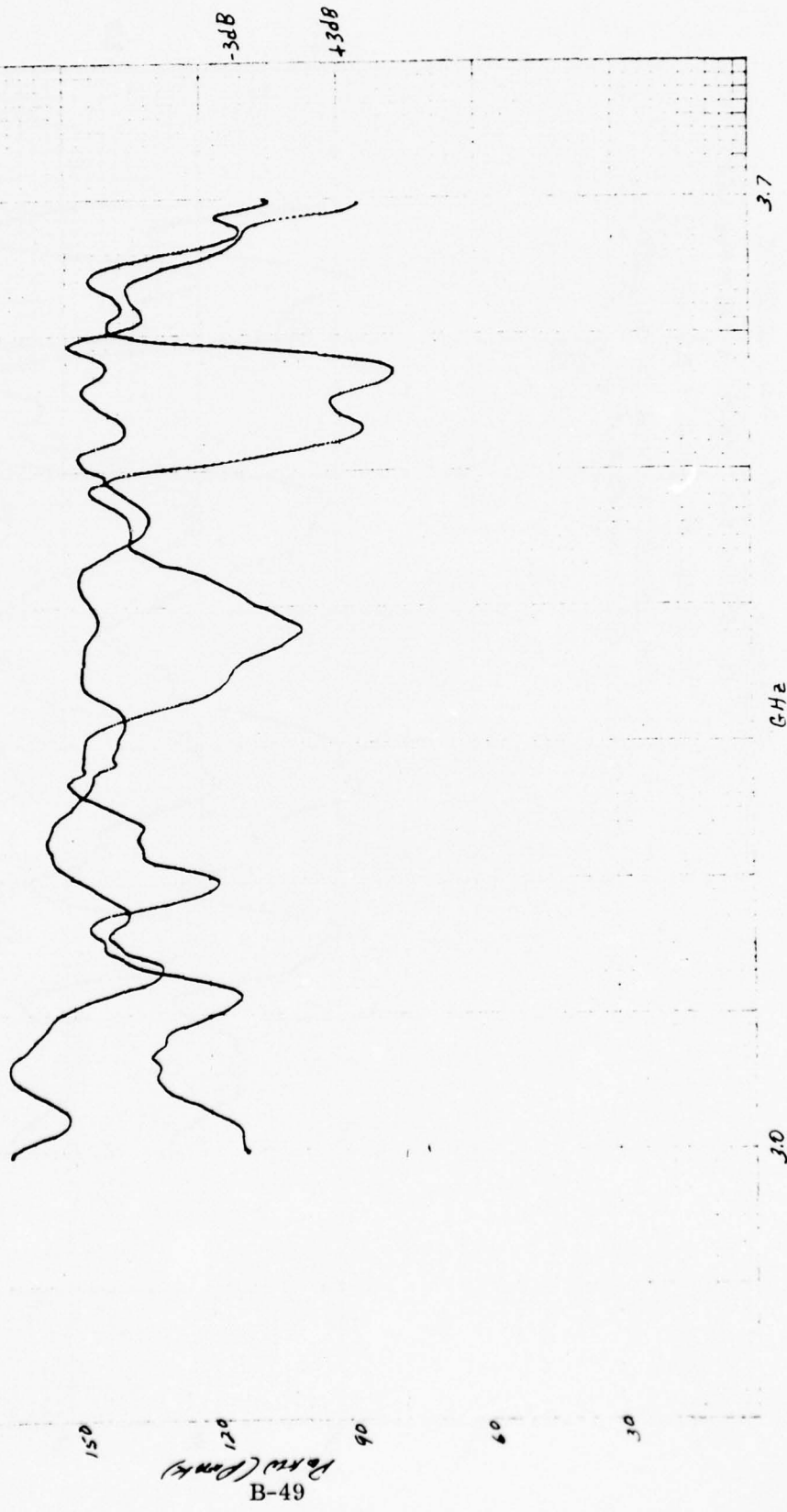
RI 960

ITS 5753B1 SIN 106 Date 12/18/76

Eb 39.54K IMag 25.0 A Pulse Voltage 525 V

Hb 15.02c Ef 10.5 V Duty .04

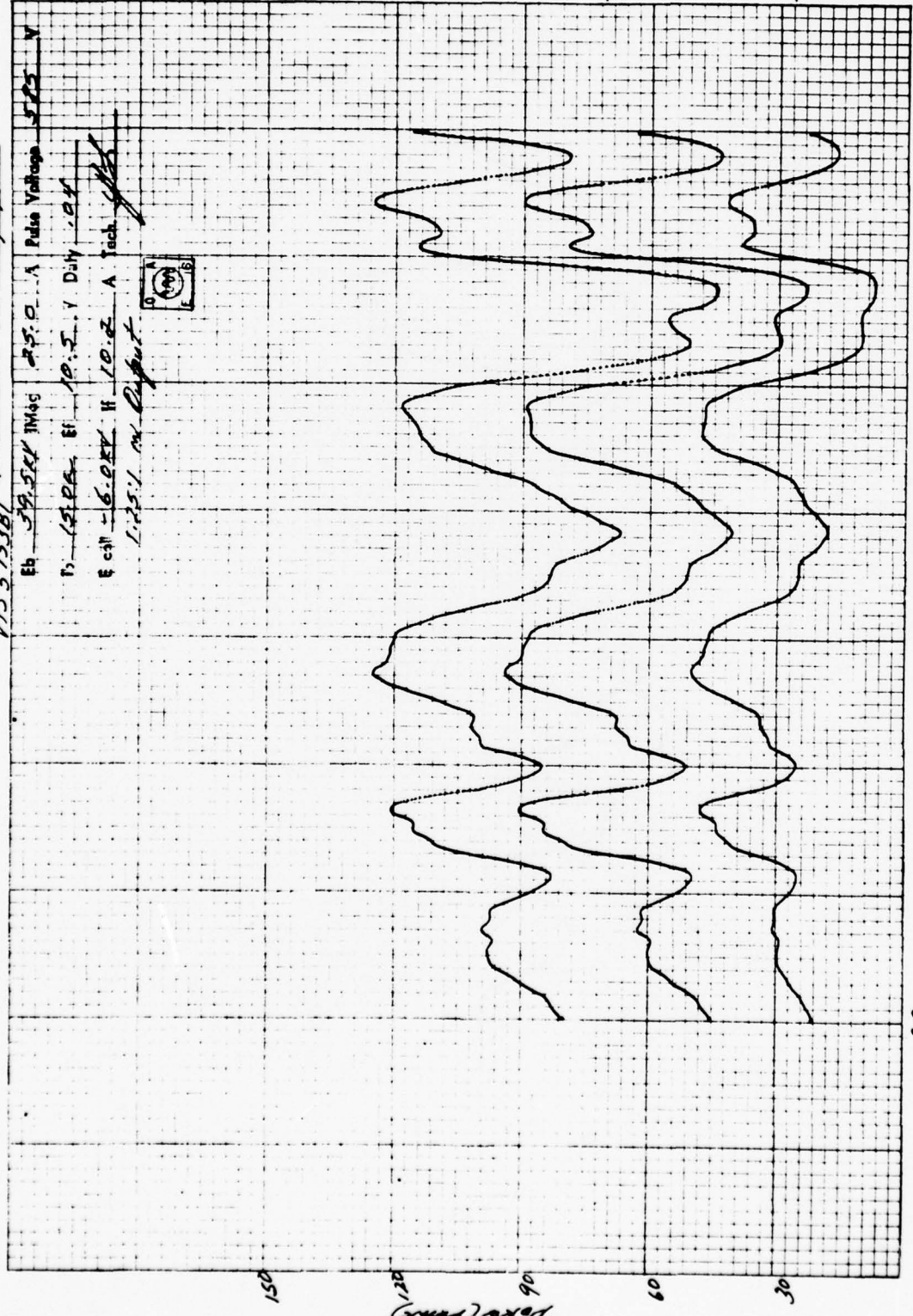
E coil = 5.04K H 10.2 A Tech. *JH*
1.25:1 in Output



B-49

VTS 57538/ SN 106 Date 12/18/76

Ex 59.5KV IM45 25.0 A Pulse Voltage 5.15 V
T1 15.05V E1 10.5 V Duty .04
E cell = 6.0KV H 10.0 A Tach ~~1.25/1~~



-61B

-218

-1121B

Pulse (Peak)
150
120
90
60
30

3.0 6.12 3.7

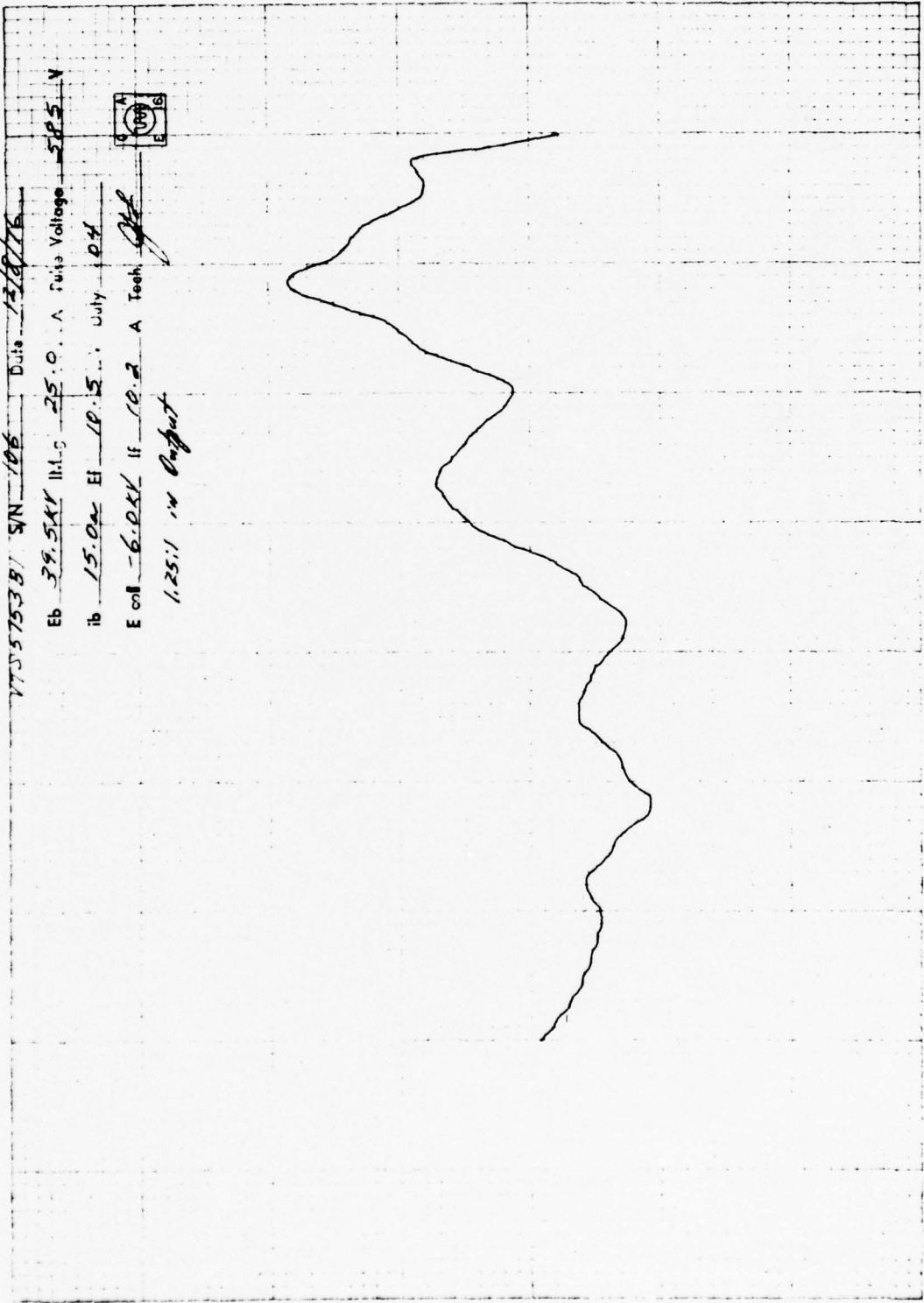
B-50

775575381 SIN 106 Date 12/18/76

Eb 39.5KV IM.G 25.0... A Tube Voltage 505 V

ib 15.0u EI 10.5... July 04

E coil - 6.0KV If 10.2 A Tech. *[Signature]*
1.25:1 in Output



40°/inch
B-51

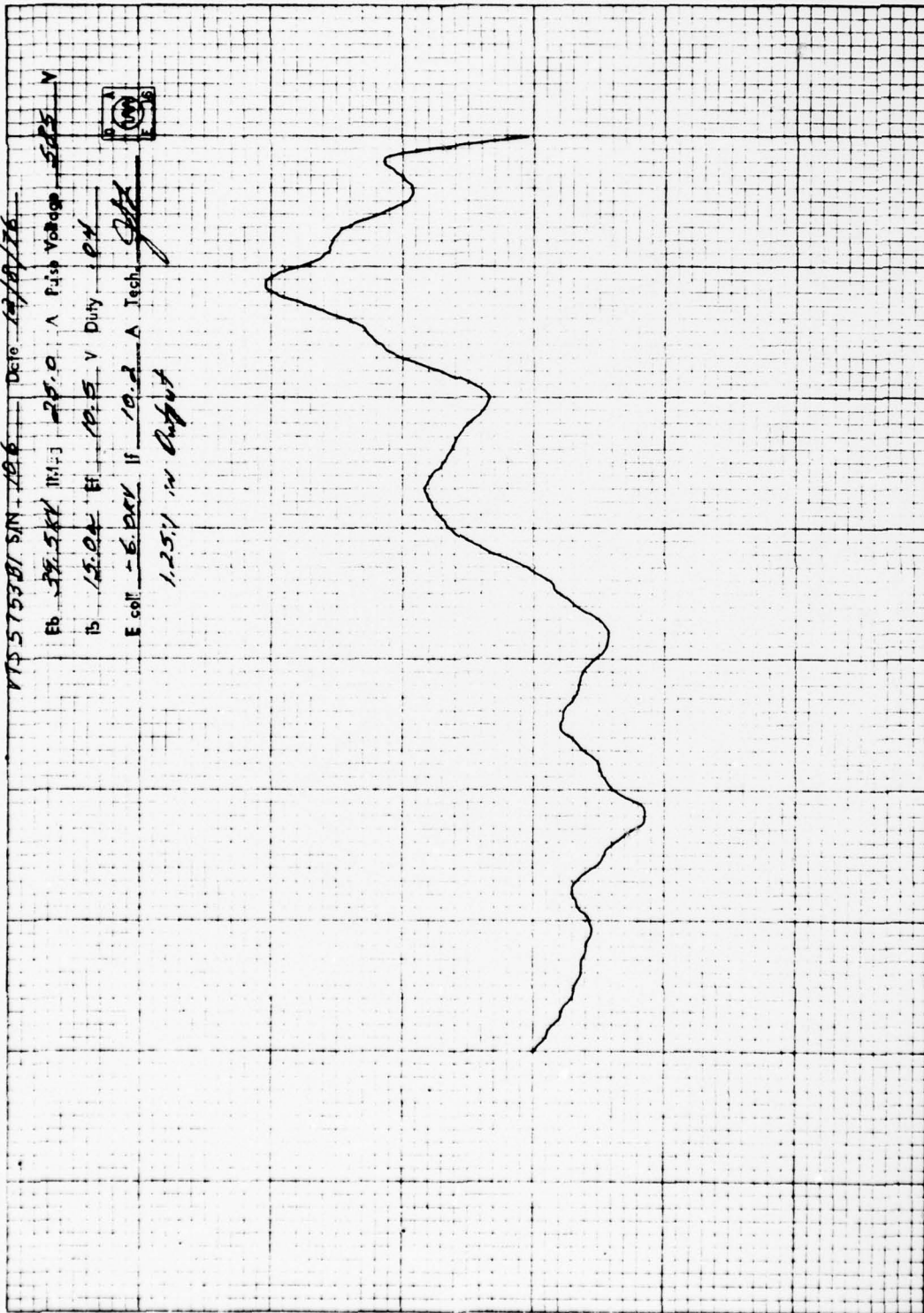
1318

3.7

MHz

3.0

VT 575381 SIN + 10.6 DEIC 10/10/76
 Eb 37.5KV 11.3 20.0 A Pulse Voltage 5.15 V
 Is 12.04 Ef 10.5 V Duty 0.4
 E coll + 6.0KV If 10.2 A Tech. *[Signature]*
 1.25% in Output



40°/inch
 B-52

960

3.7

GHz

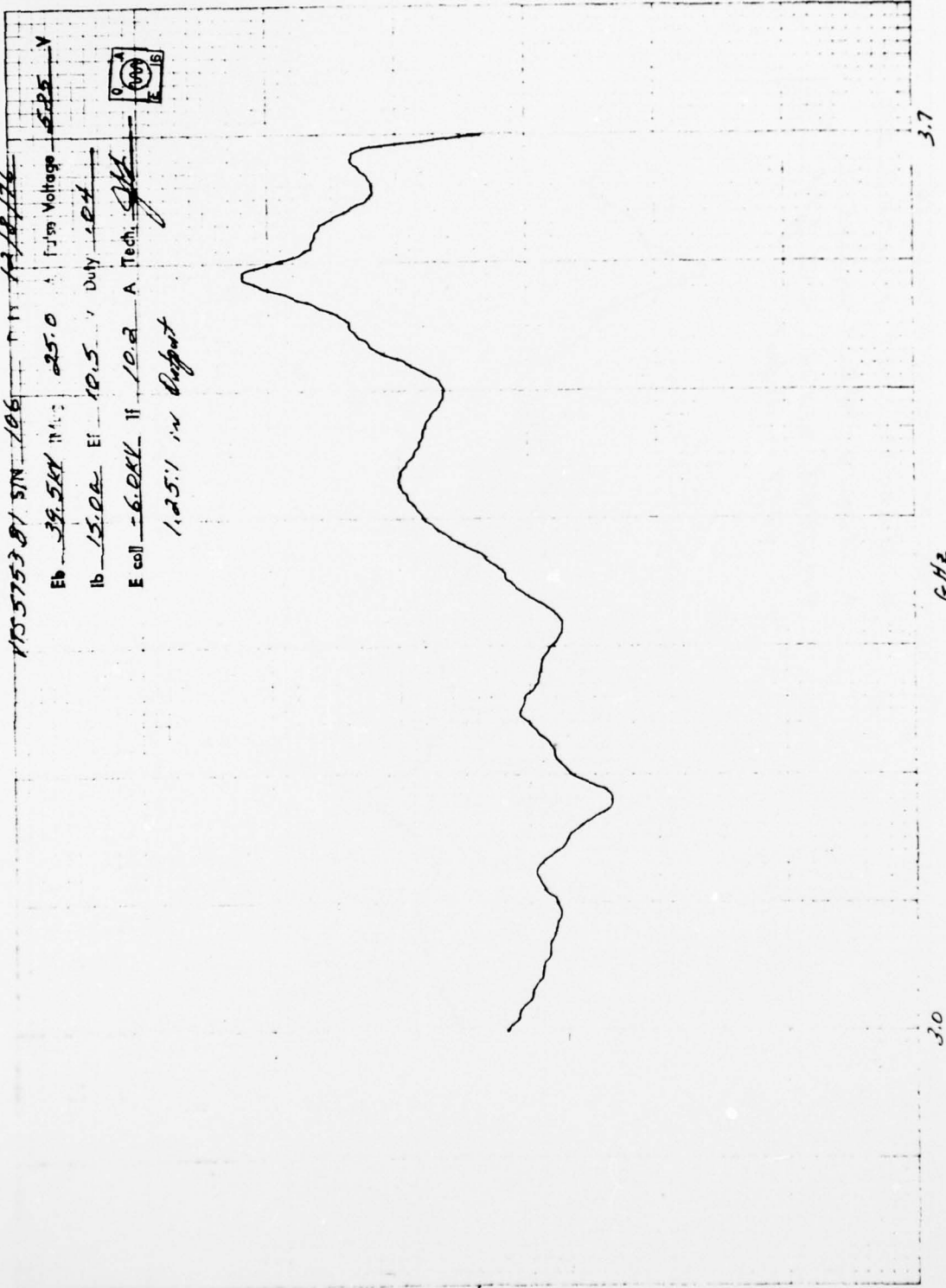
3.0

105-5753-81 SN 106 T 11 12/8/76

Fb 39.5KV M.I. 25.0 A. Prim Voltage 5.25 V

Ib 15.0A EI 10.5 V Duly 1.04

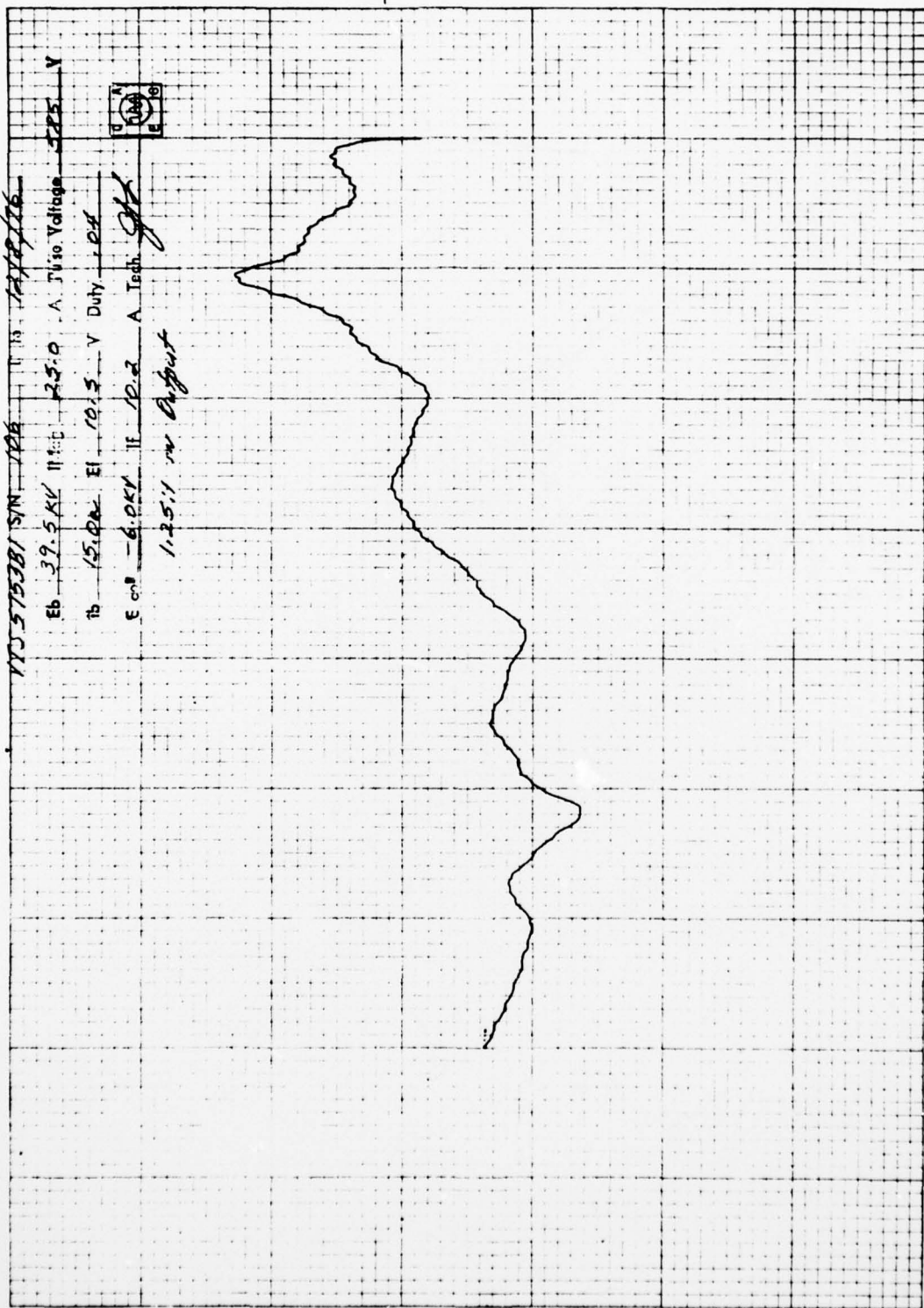
E coll -6.0KV If 10.2 A Tech. *[Signature]*
1.25" in Diameter



-3dB

40°/inch
B-53

-6dB



175 575381 SIN 126 11.13 1412.16
 Eb 39.5 KV 11.00 25.0 A J to Voltage 585 V
 Ib 15.0 A EI 10.5 V Duty 1.04
 E con -6.0KV IF 10.2 A Test. *GH*
 1.25:1 in Output

40/104
 B-54

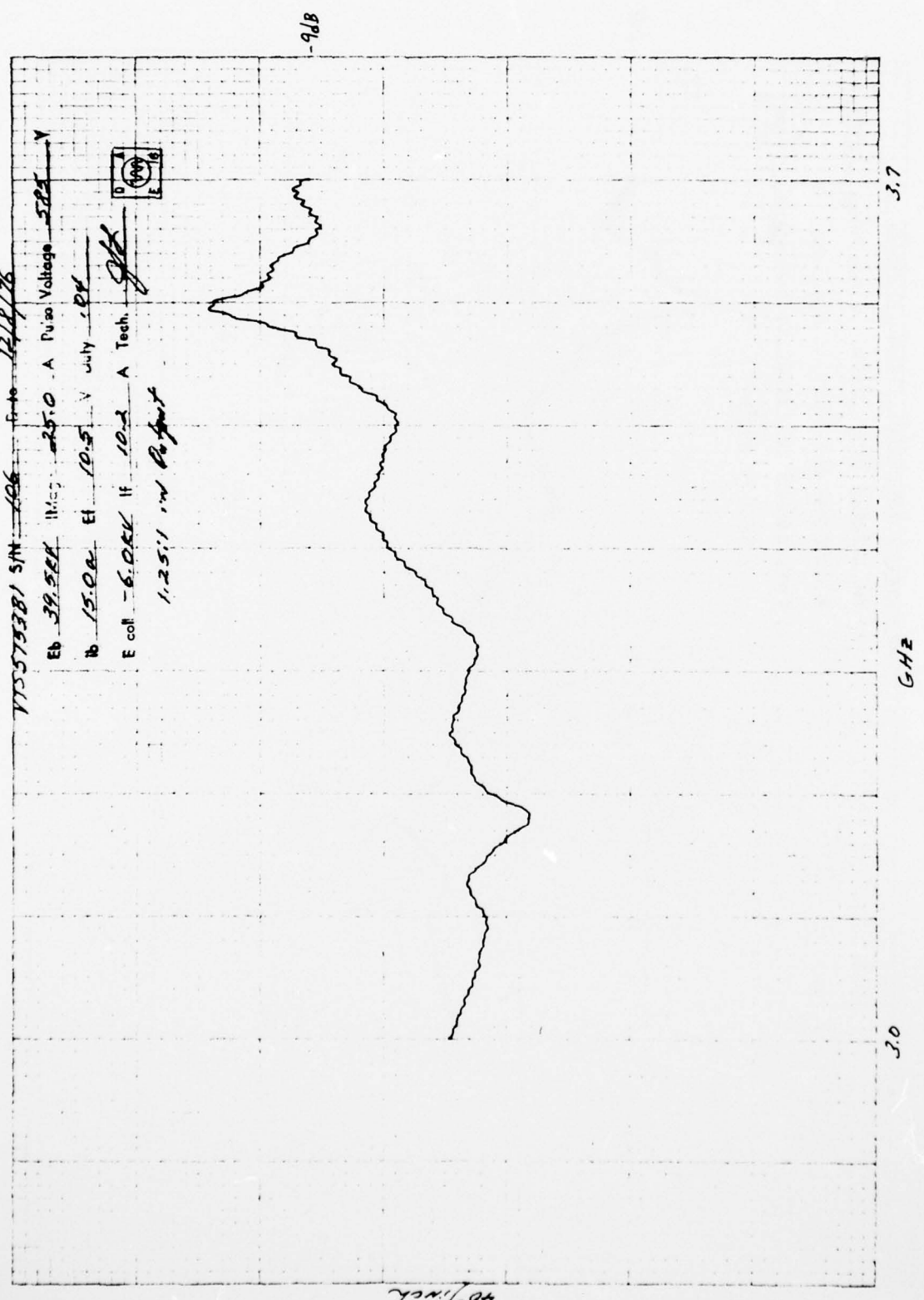
3.7

GHz

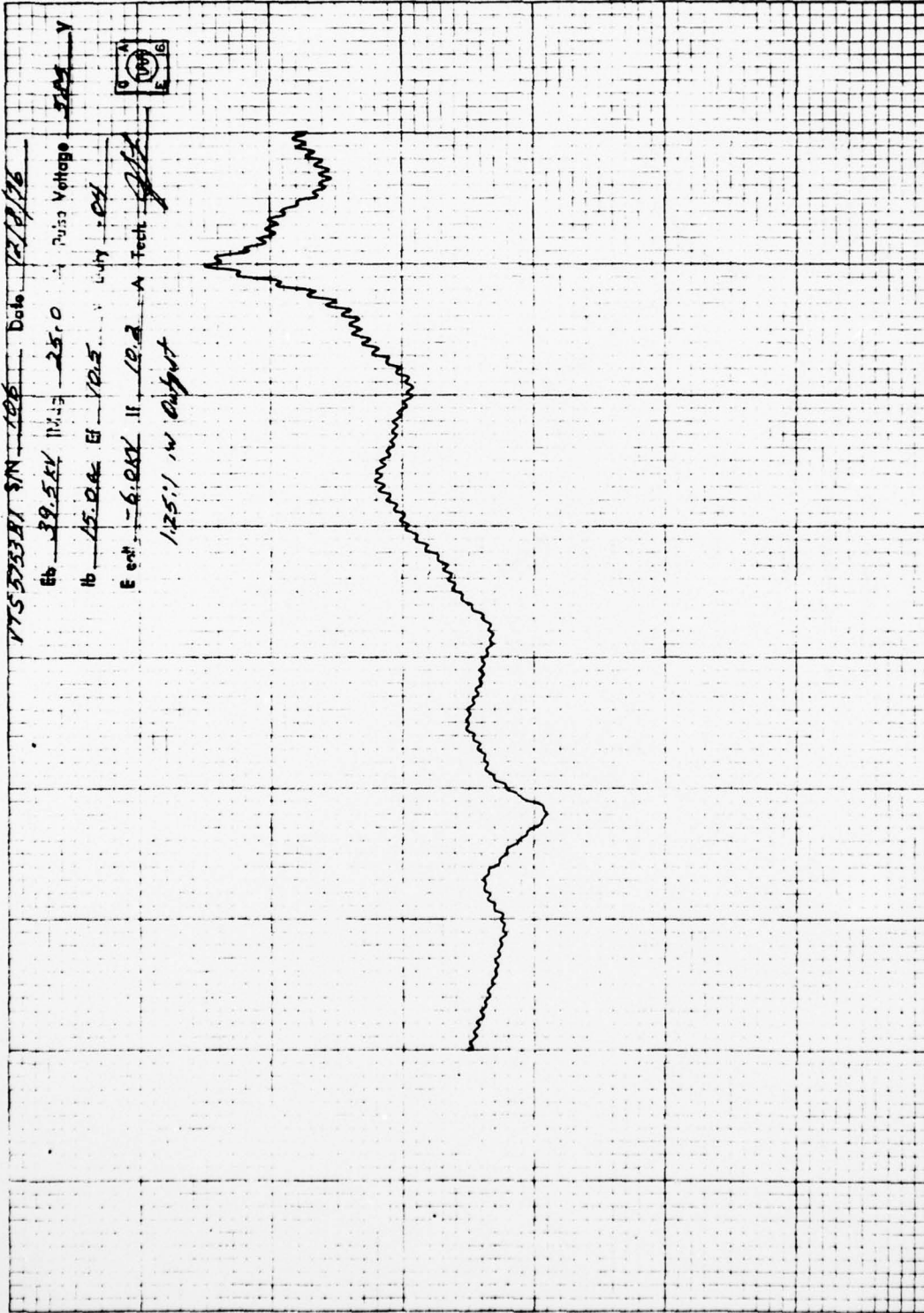
3.0

Y15579381 SM 106 Date 12/19/76

EB 39.50K 11Mag 25.0 A Puro Voltage 500 V
 10 15.00E 10.5 V July 1976
 E coll - 6.0KV IF 10.2 A Tech. JHT
 1.25" in Refpoint



400/mch
B-55



175575371 91N 106 Date 12/17/76
 fb 39.5KV 11.43 Pulse Voltage 310V
 lb 15.04E 10.5 LHM 04
 E est -6.0KV II 10.3 A Test ~~91N~~
 1.25:1 W Output

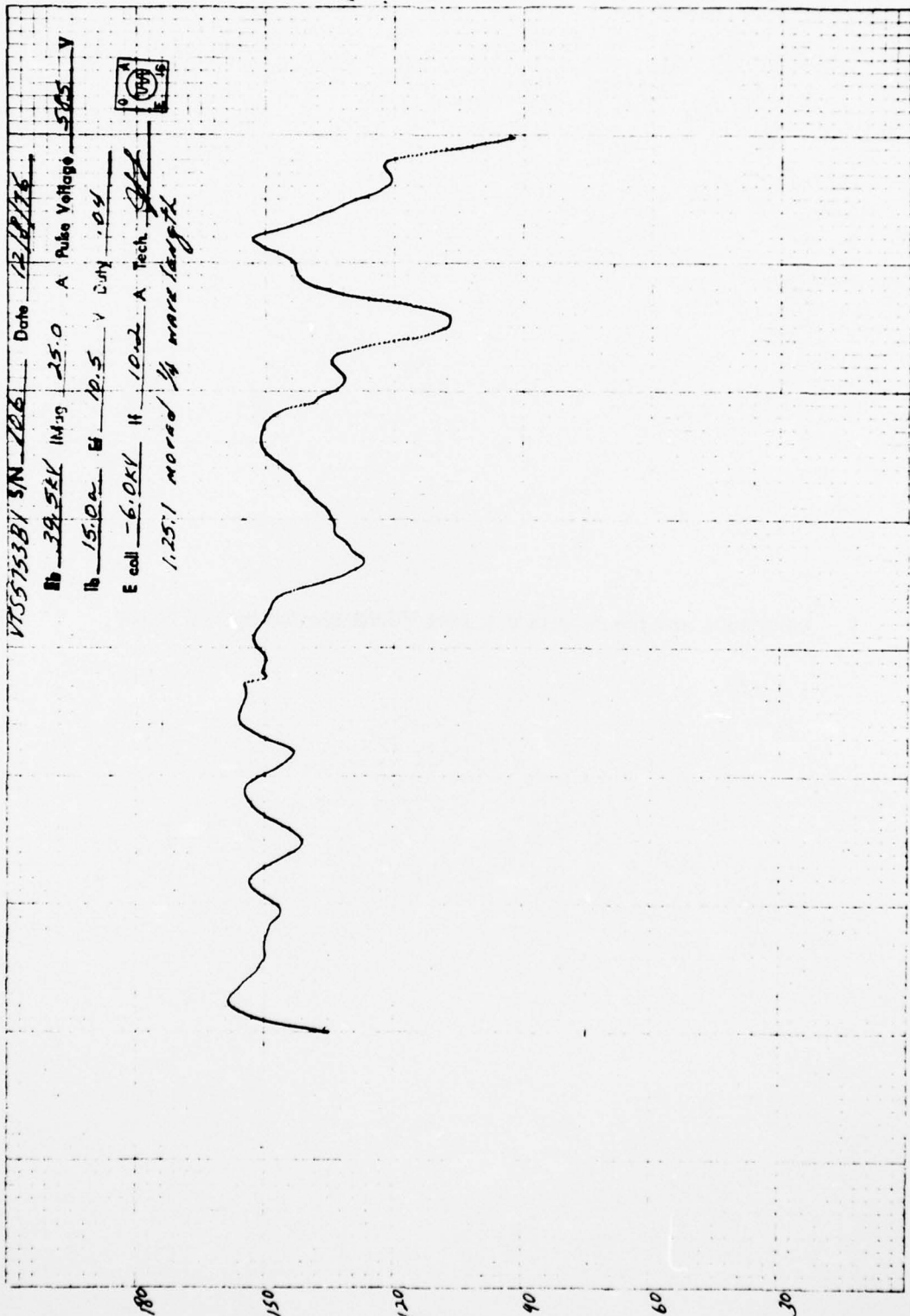
37

GHz

3.0

7. Amplitude and phase with a 1.25:1 VSWR shifted by $\lambda/2$ phase

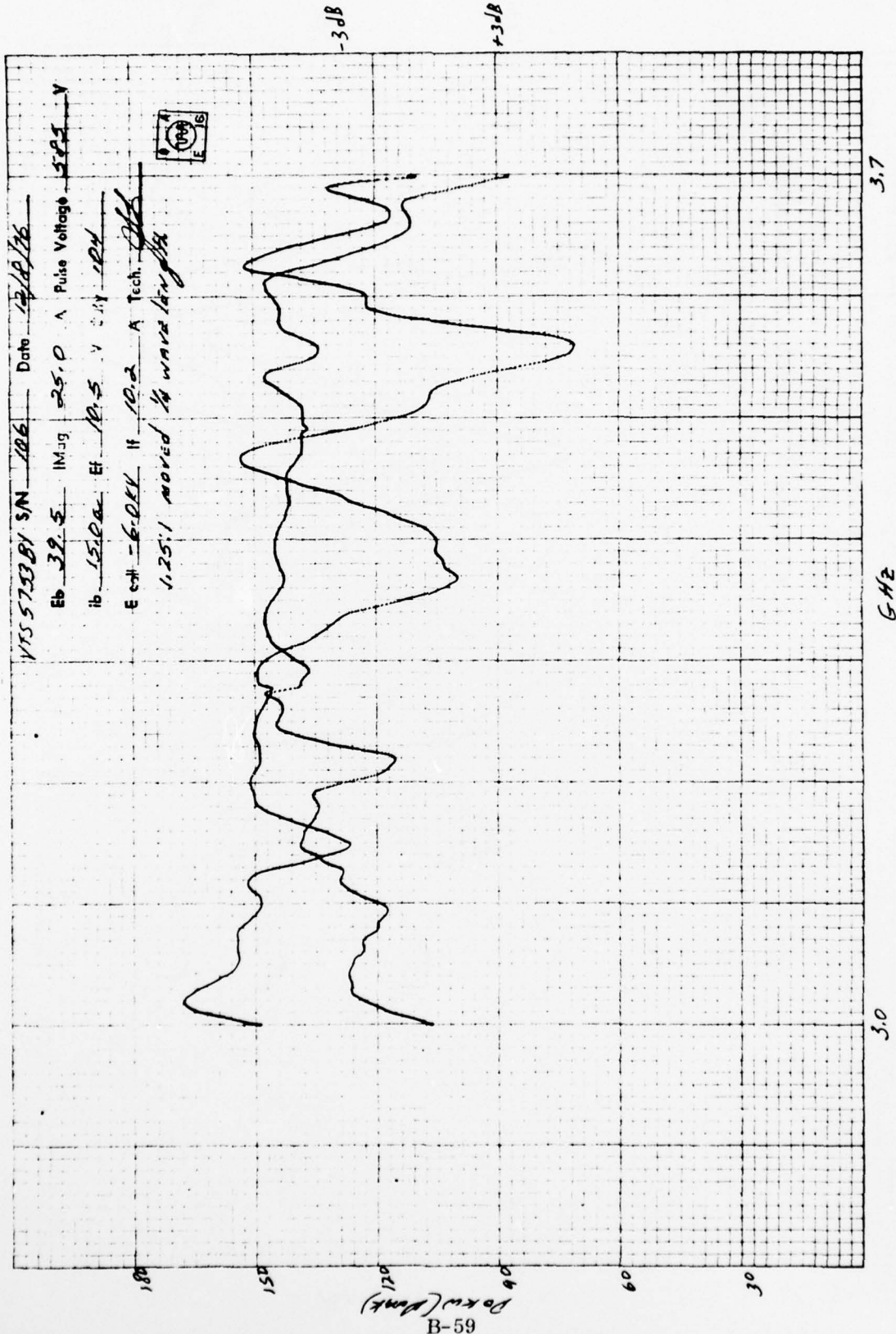
VT55753BY SN 206 Date 12/12/76
 Rb 39.5KV IMag 25.0 A Tube Voltage 575 V
 Rb 15.0A W 10.5 V Duty .04
 E coll -6.0KV H 10.2 A Tech. ~~SA~~
 1.25.1 moved 1/4 wave length

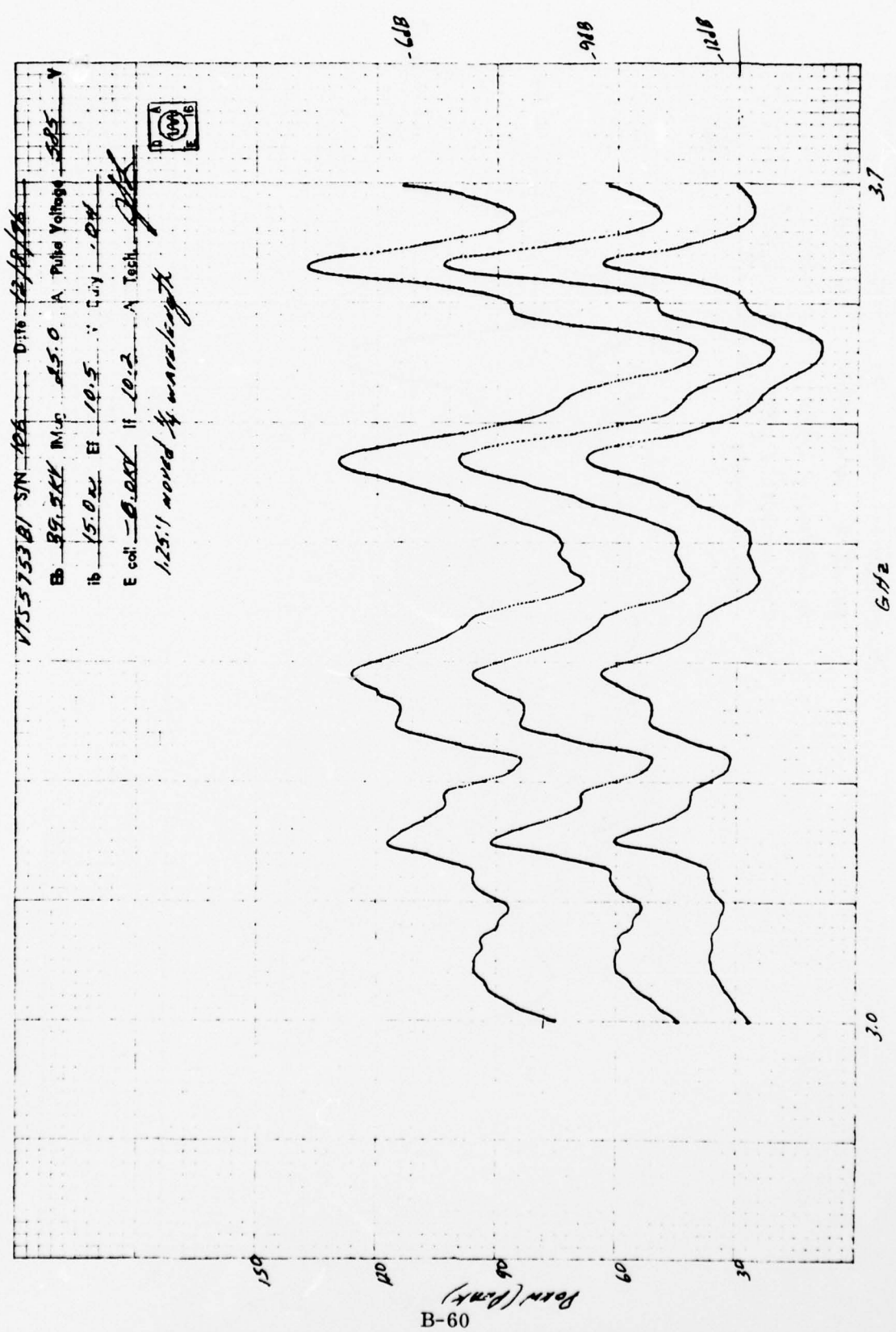


24
 960

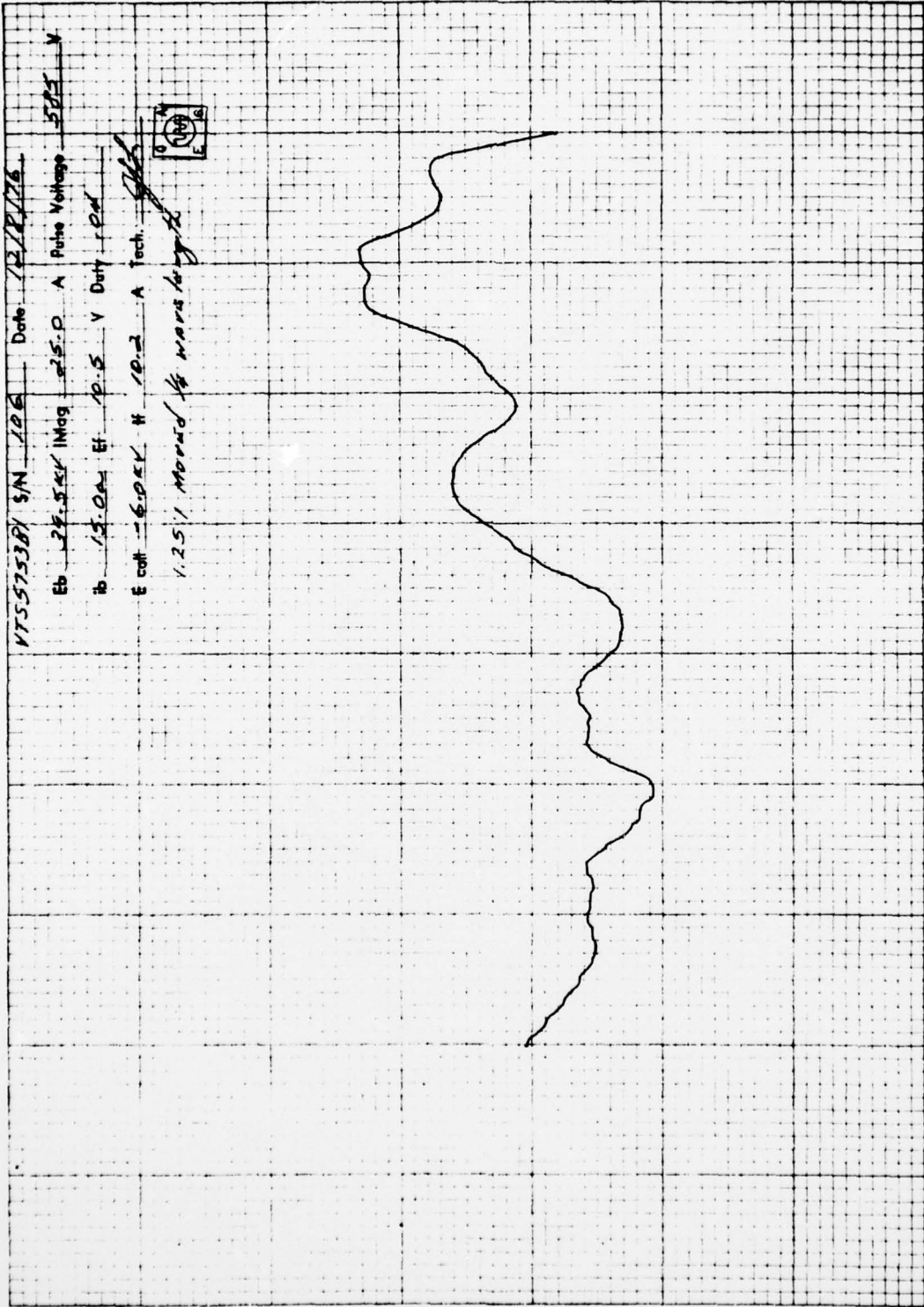
Peak (Peak)
 B-58

3.0 GHz 3.7





B-60



NT55753B1 SN 106 Date 12/2/76
 Eb 24.5KV IMag 25.0 A Pulse Voltage 50V
 Ib 13.0A Et 10.5 V Duty 100
 E coll -6.0KV H 10.2 A Tech. *[Signature]*



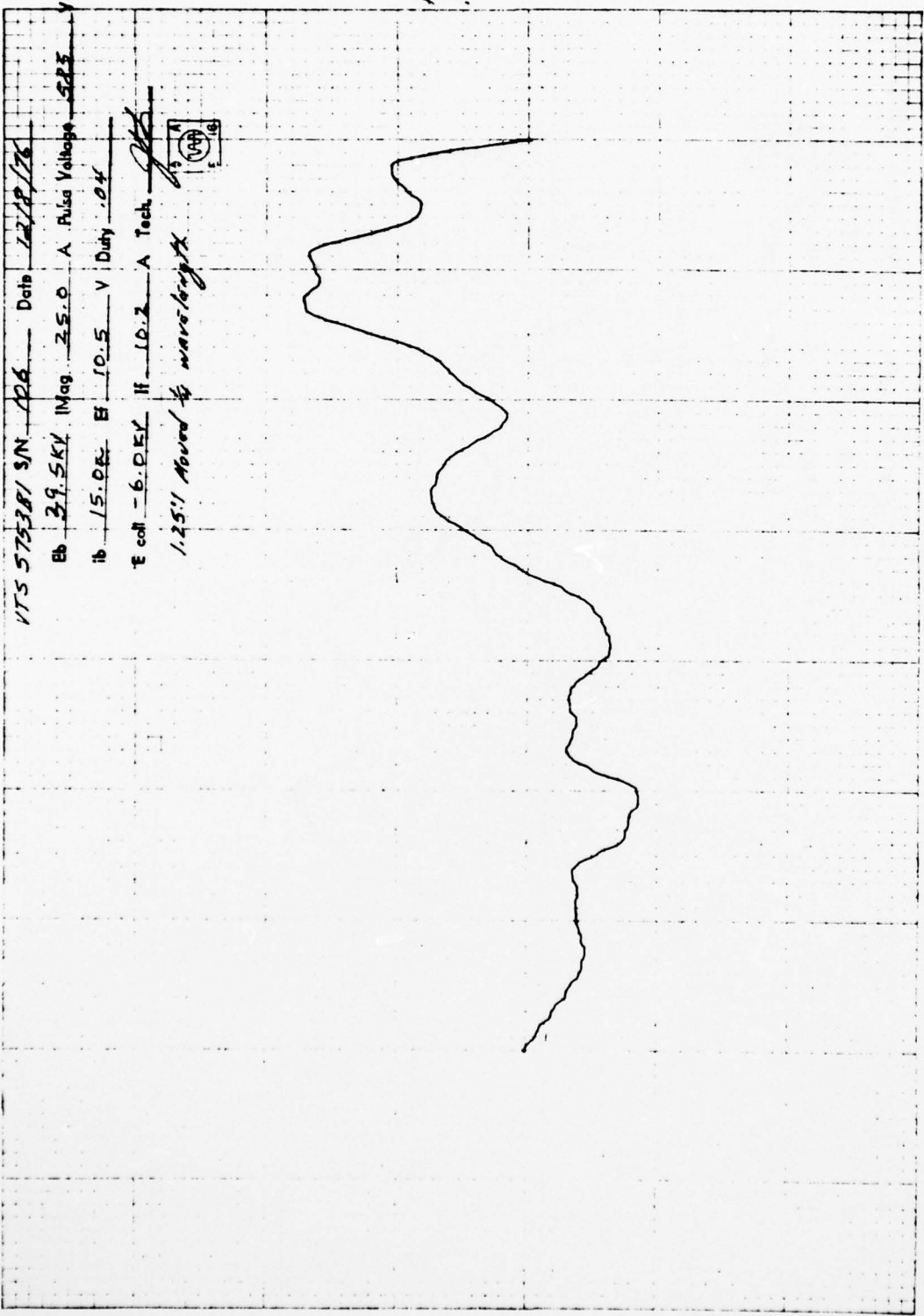
1.25 / Moved to Marsburg

+30dB

3.7

6.13

3.0



VTS 575381 SN 126 Date 12/18/76
 Eb 29.5KV Mag. 25.0 A Pulse Voltage 525
 Ib 15.0KV Ef 10.5 V Duty .04
 E coil - 6.0KV If 10.2 A Tech [Signature]
 1.25" Moved to wavelength [Signature]

.96
 .96

3.7

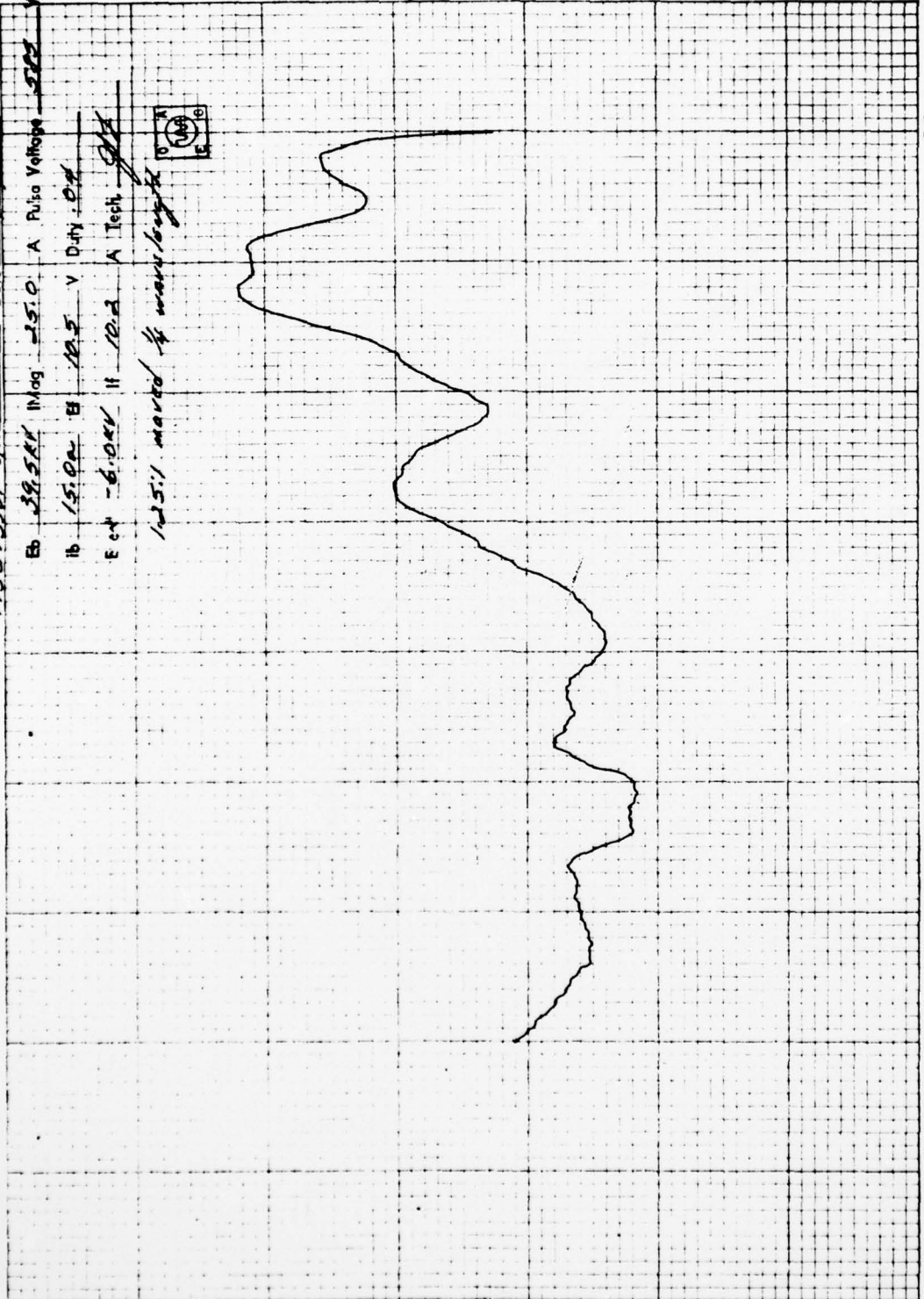
GHz

3.0

VT5-5753B1 SIN 106 Date 12/18/76

Eb 39.5KV IMag -25.0 A Pulse Voltage 575
Ib 15.0u B 10.5 V Duty 0.4
Ech -6.0KV H 10.2 A Test 0.4

125:1 moved to main length



-3dB

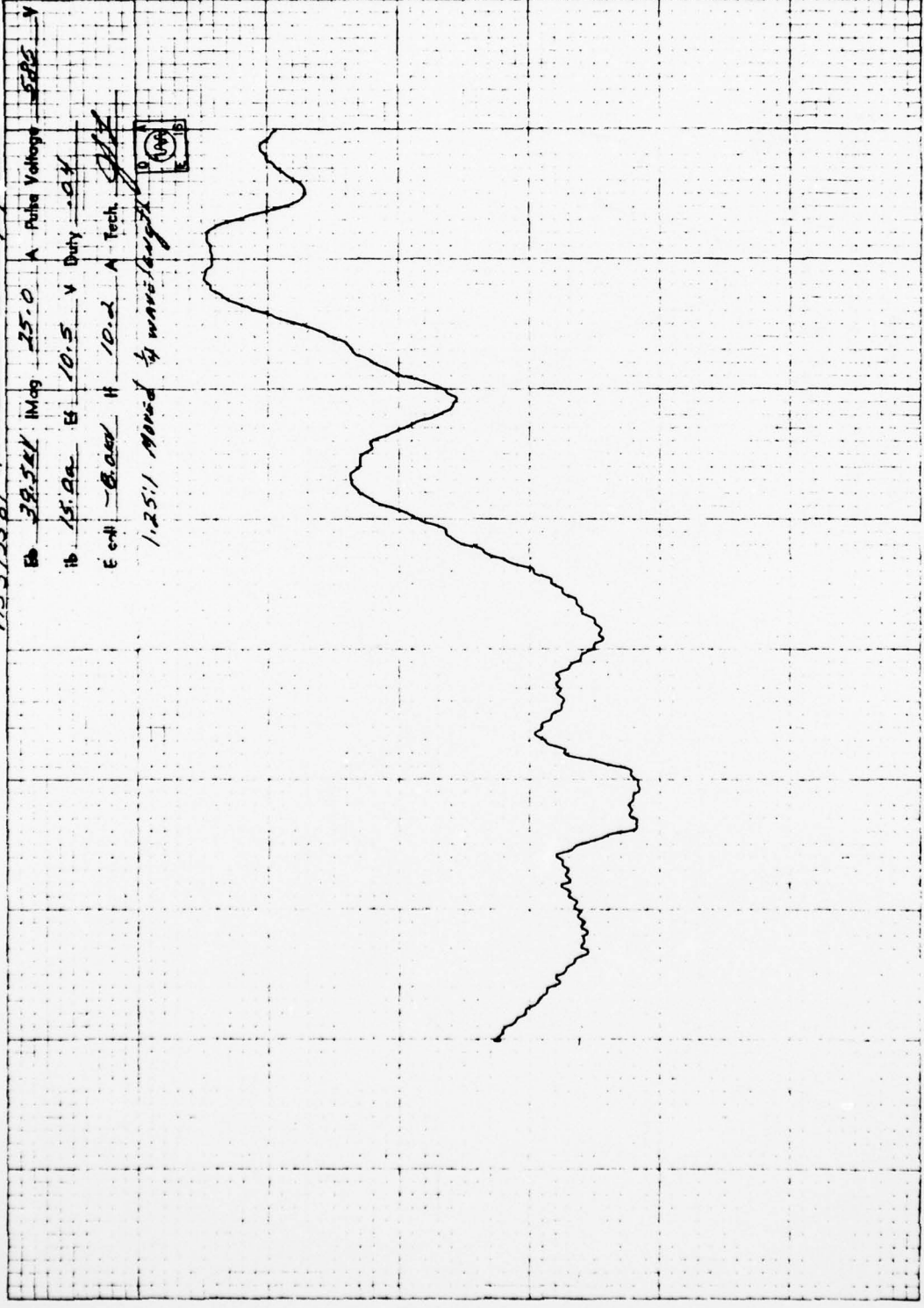
40/div
B-63

37

GHz

3.0

VTS 57538 / S/N 106 Date 12/29/76



Bb 39.5K IMdg 25.0 A Pulse Voltage 500 V
 H 15.0a B 10.5 V Duty 0.4
 E ch - B load H 10.2 A Tech. *[Signature]*
 1.25:1. Moved to wave length *[Signature]*



666

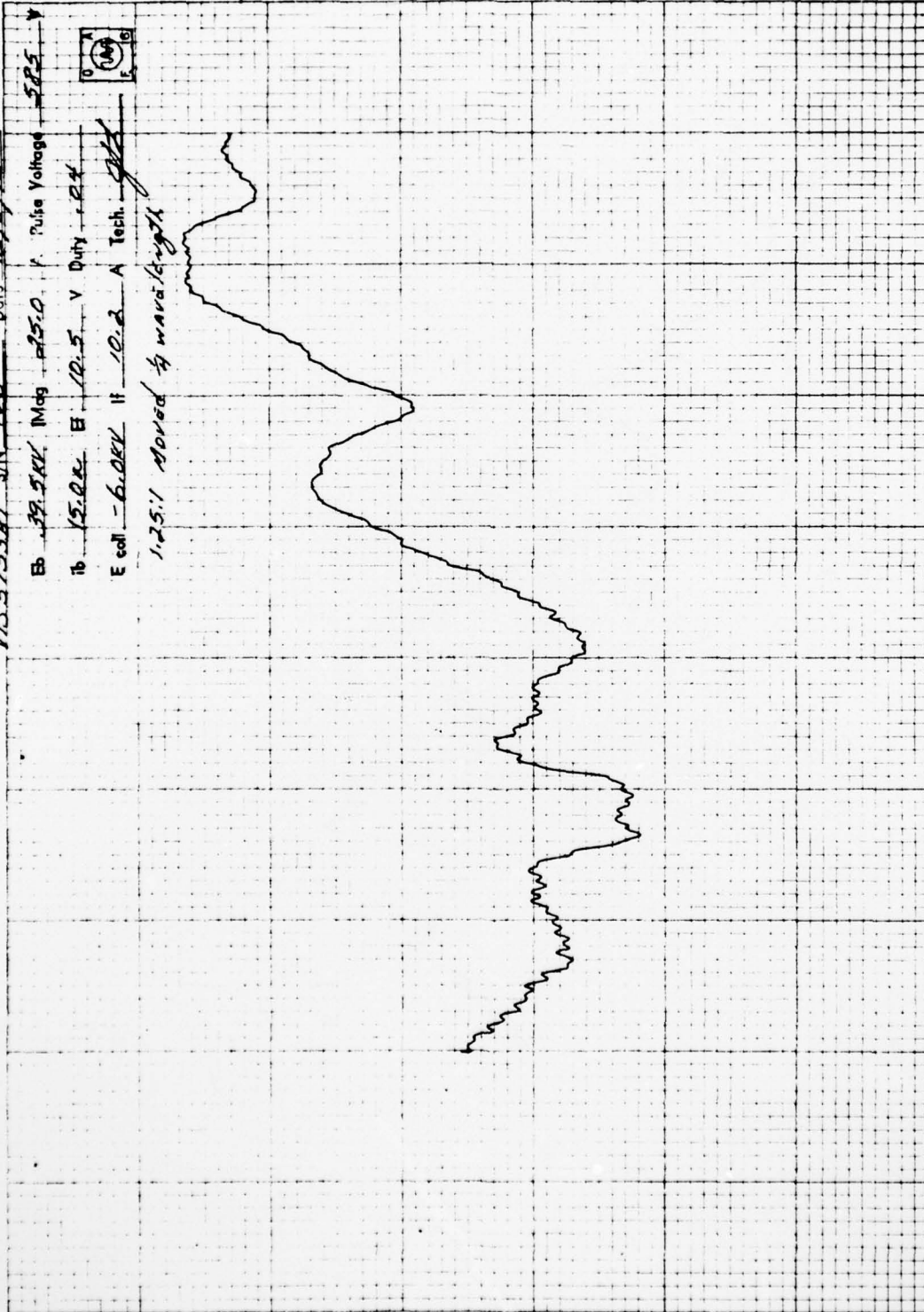
40''/in/k
B-64

3.7
4.0
5.7

MS 575381 SN 106 Date 12/2/76

EB 39.5KV Mag 25.0 V Pulse Voltage 50E V
IB 15.0KV E 10.5 V Duty 1.24
E cell -6.0KV IF 10.2 A Tech. ~~JK~~

1.25:1 Moved by wave length



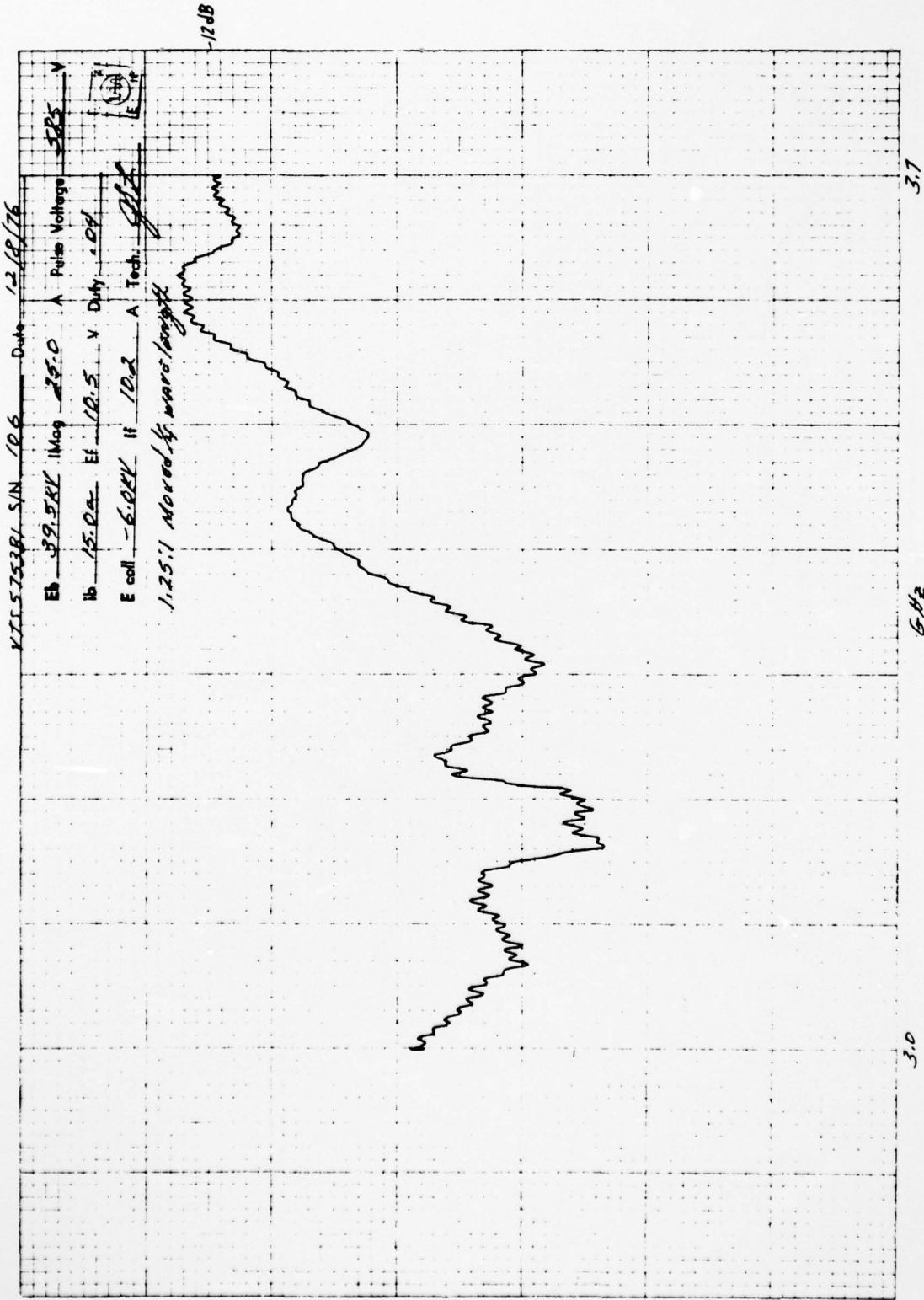
-9dB

3.7

GHz

3.0

40 lines
B-65



AD-A041 564

VARIAN ASSOCIATES PALO ALTO CALIF PALO ALTO MICROWAV--ETC F/G 9/5
EXTENDED BANDWIDTH VTS-5753B1 COUPLED CAVITY TRAVELING WAVE TUB--ETC(U)
JUN 77 R GIEBLER F30602-76-C-0232

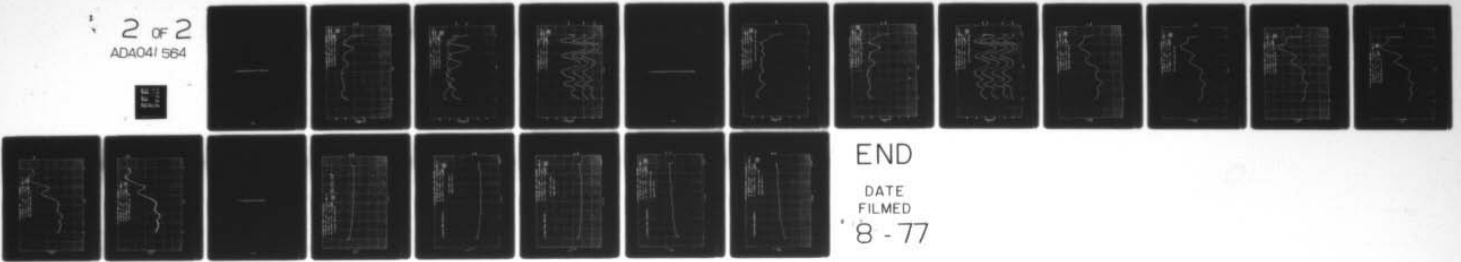
UNCLASSIFIED

RADC-TR-77-174

NL

2 OF 2

AD4041 564

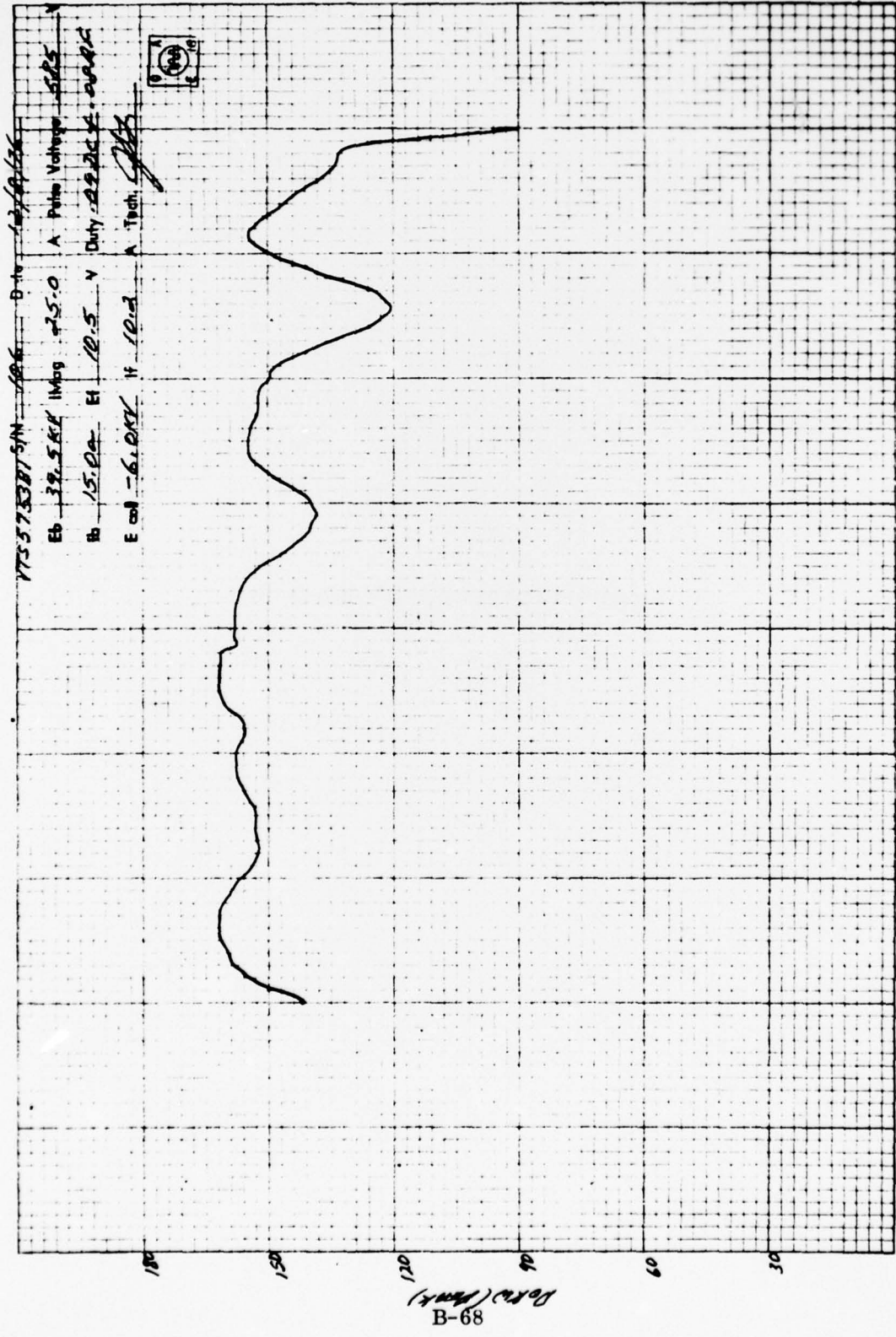


END

DATE
FILMED

8 - 77

8. Amplitude and phase at 8% duty factor



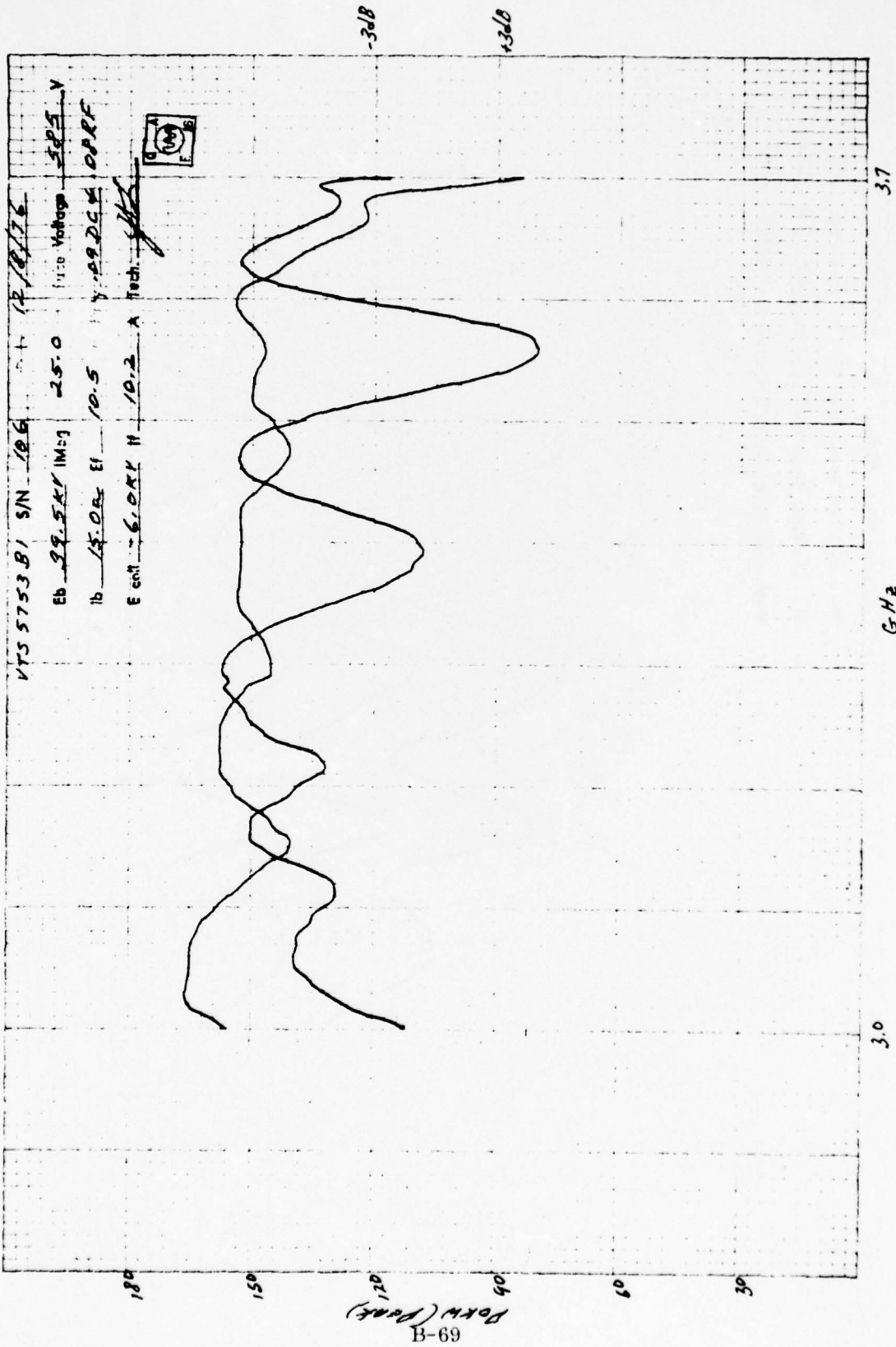
Pd
.96w

89-B-68
Volts (Peak)

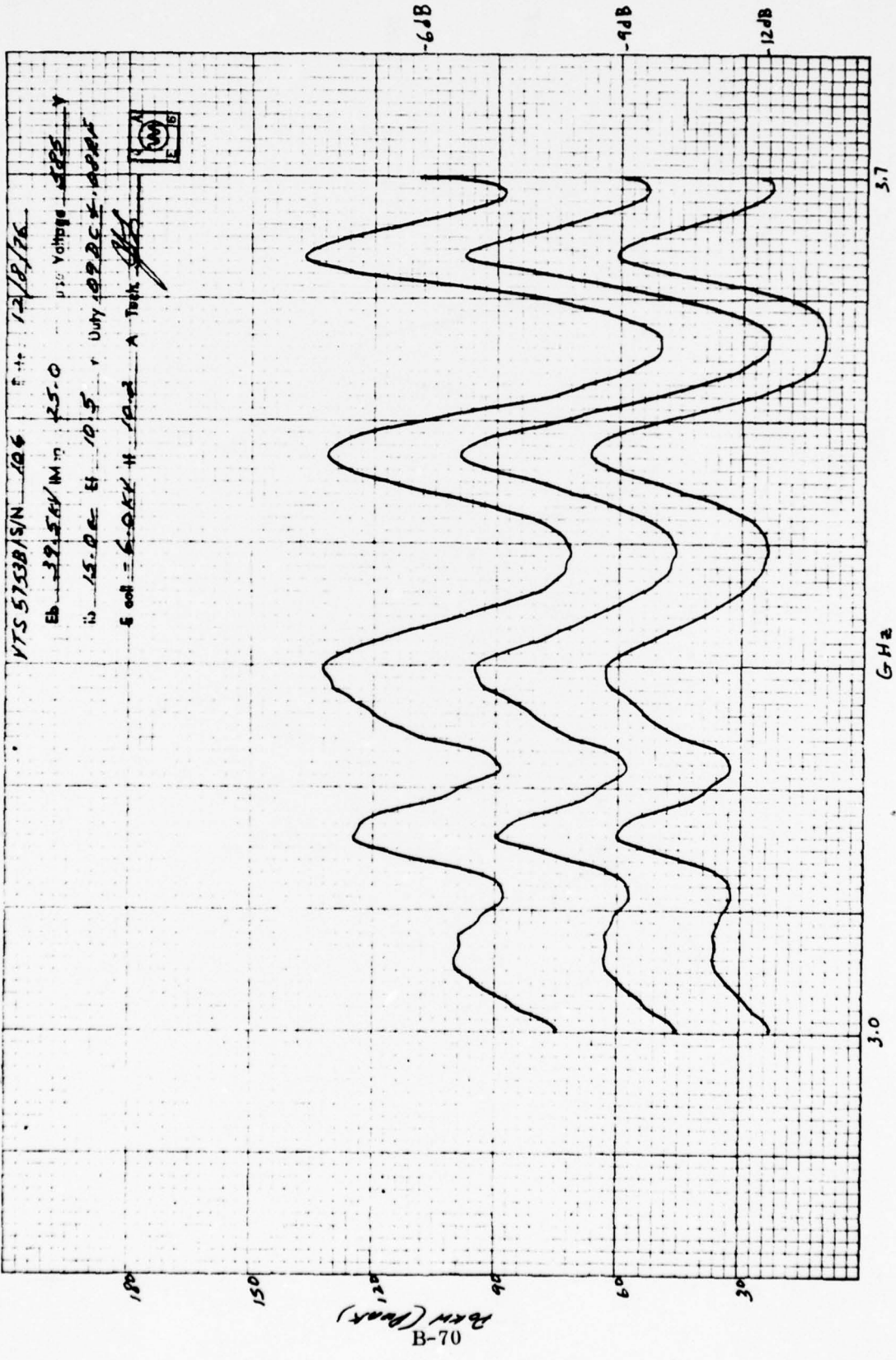
3.7

GM2

3.0



B-69



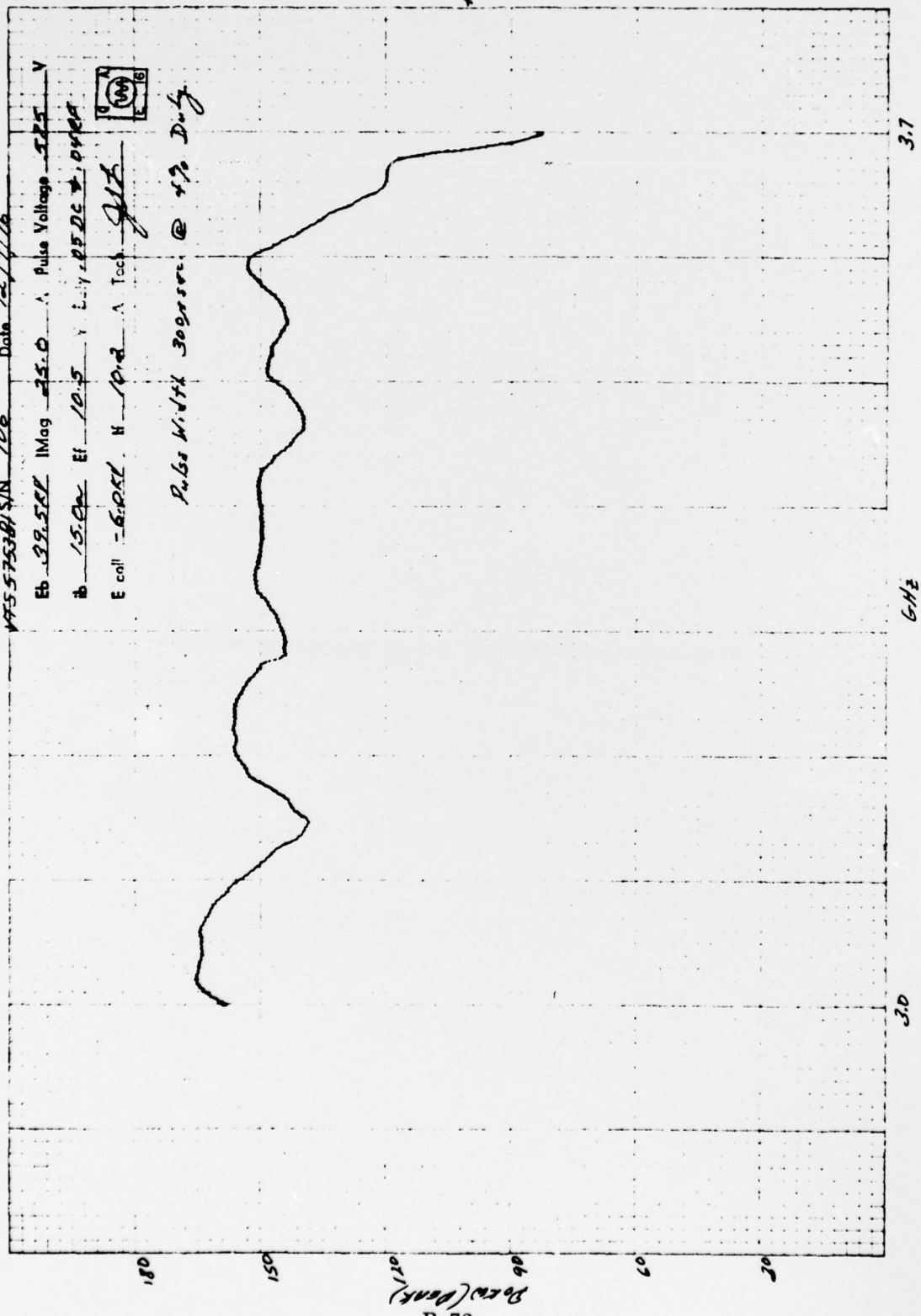
9. Amplitude and phase at 300 microsecond pulse length

445 575381 SN 106 Date 12/7/76

Eh 32.5ER IMag 25.0 A Pulse Voltage 525 V
R 15.0m EI 10.5 V L 1.05DC 0.444
E coll -6.051 H 10.2 A Toss 912

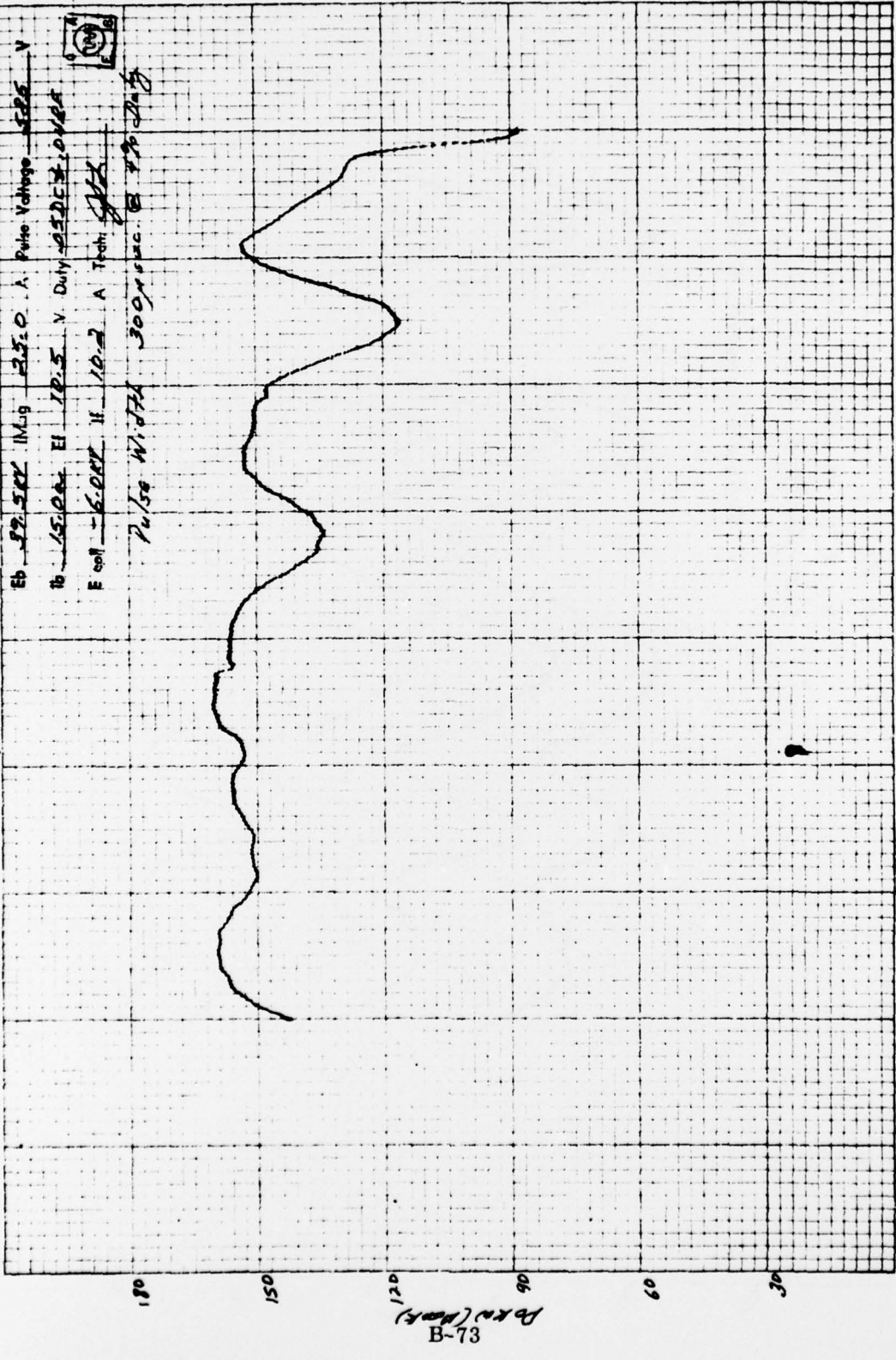


Pulse Width 309ns @ 4% Duty



Dc (Peak)
B-72

175 575381 S/N 106 Date 12/7/76



Eb 52.5KHz IM Lig 25.0 A. Pulse Voltage 525 V
 T_b 15.0 Hz EI 10.5 V Duty 0.500 1.0VRA
 F_{coil} 6.0MHz II 10.2 A Tech. *[Signature]*
 Pulse Width 300µsec B 7.0 A *[Signature]*

Pd .96w

B-73 Pk (dB)

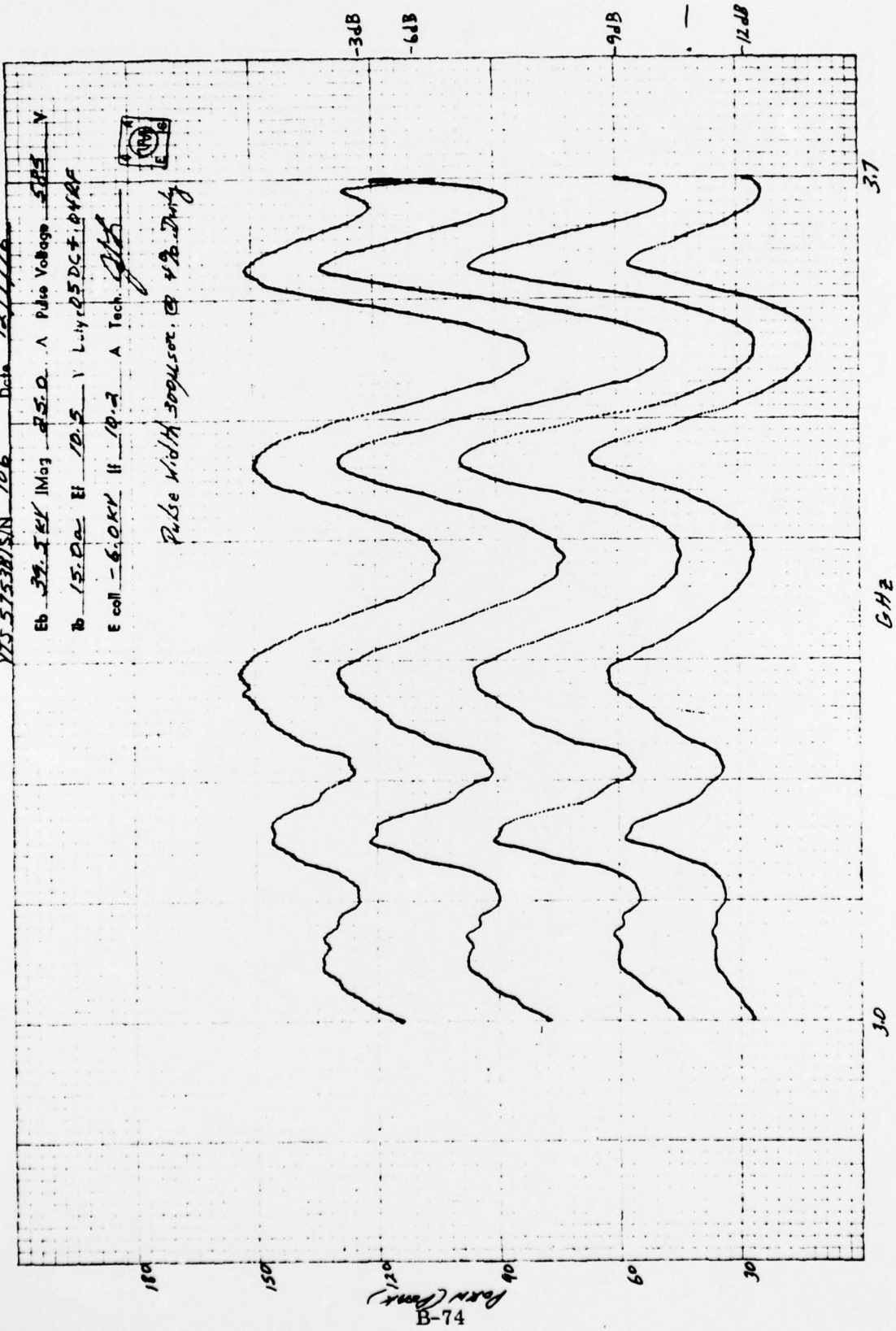
GHz 3.0 3.7

YIS 5753815N 106 Date 12/7/76

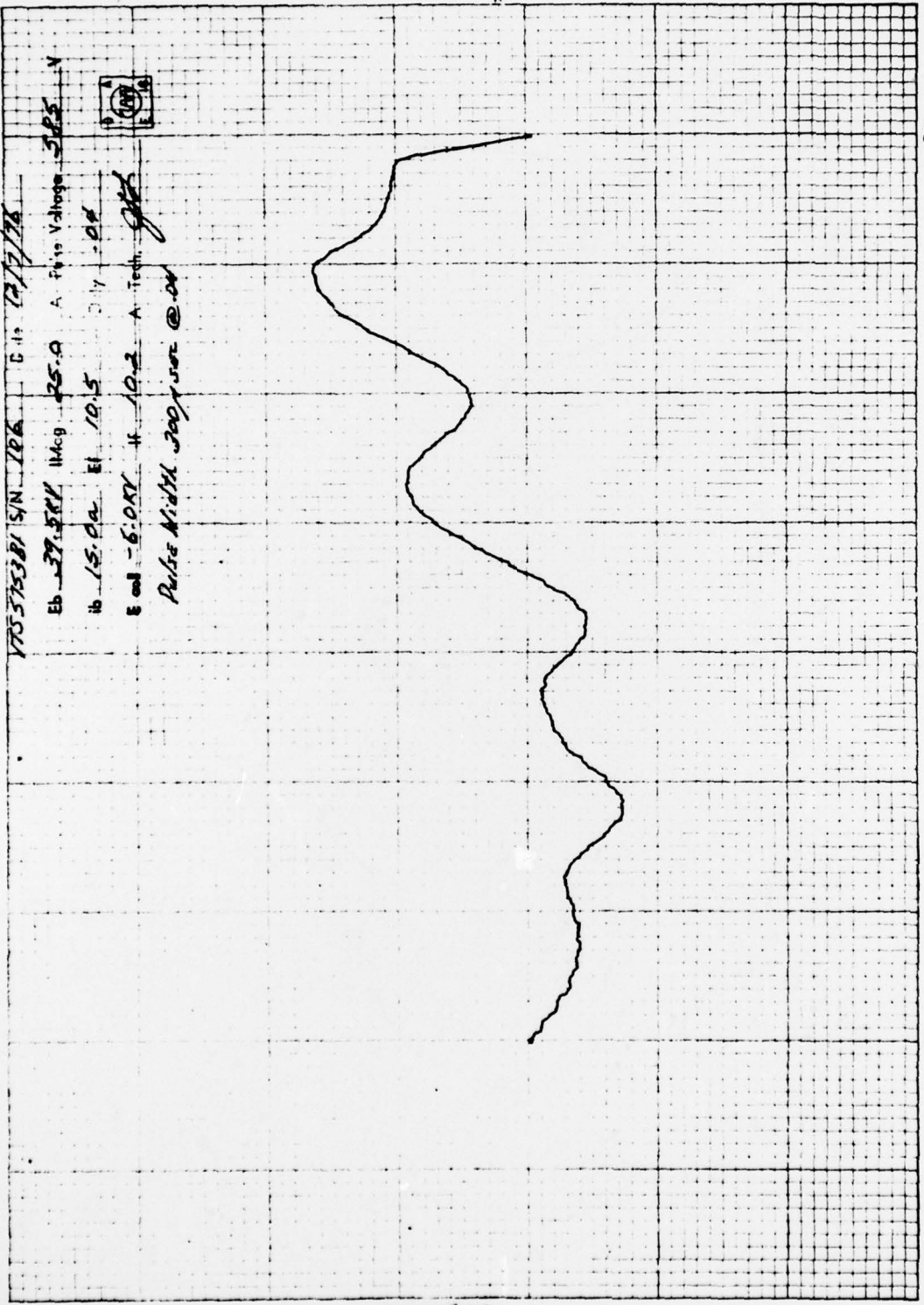
Eb 39.1 K IMag 25.0 A Pulse Voltage 5.15 V
To 15.0a E1 10.5 V L14.05 DCF. 0.4KAF
E coll -6.0KV II 10.3 A Tech. *[Signature]*



Pulse Width 300µsec. @ 48.2MHz



1755381 SIN 126 C 11 12/7/76
 Eb 27.5KV 11Mcg 25.0 A. F. is Voltage 3.85 V
 Ib 15.0a Et 10.5 0.17 -0.4
 E and -6.0KV H 10.2 A. Term. *gpc*
 Pulse Width 200 μ sec @ 0.1V



37

30

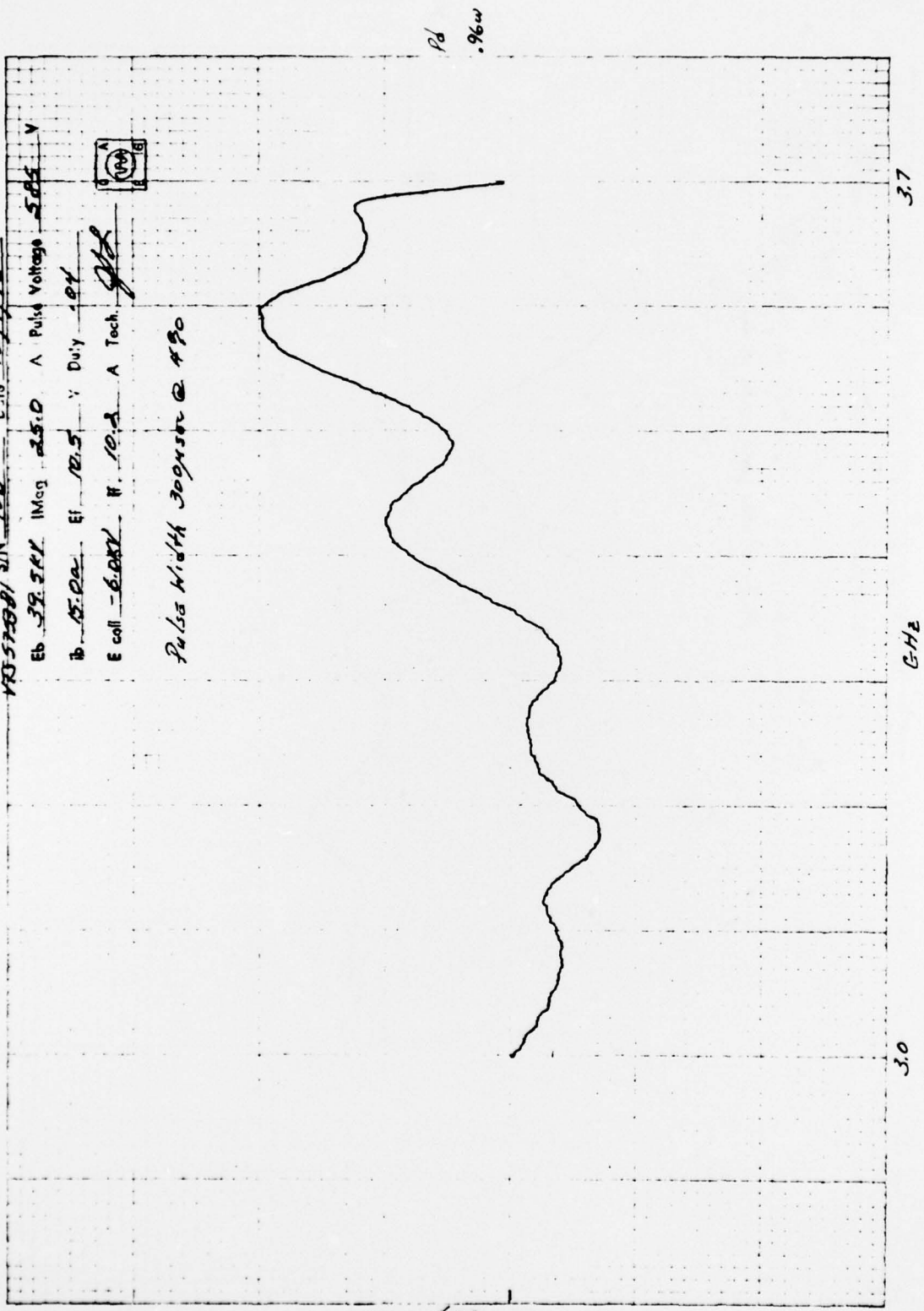
96
+3.68

YR-57581 SN 106 D.to 12/7/76

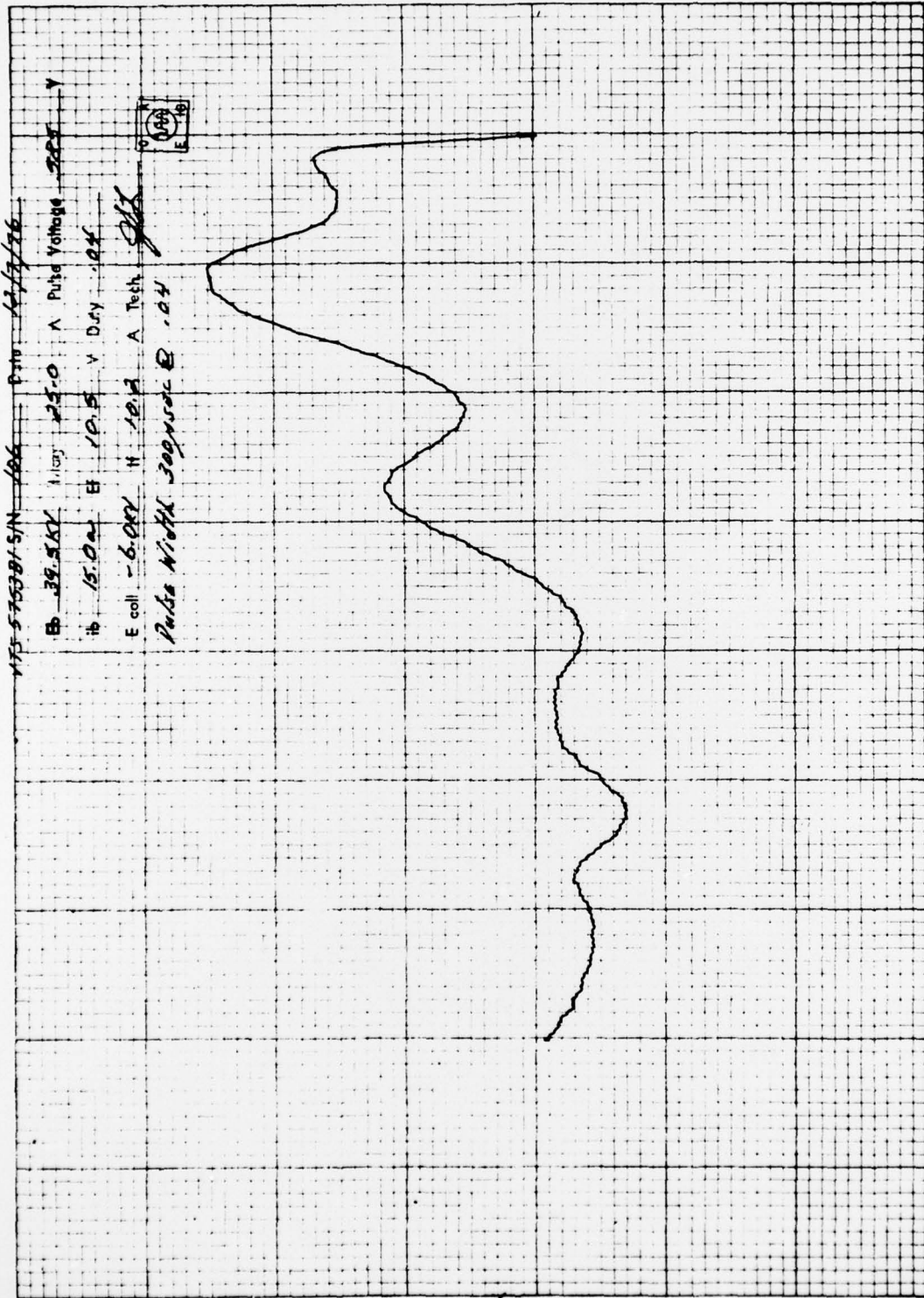
Eb 32.5K IMag 25.0 A Pulse Voltage 585 V
Ib 15.0A Ei 10.5 V Duty 04
E call - 6.0KV W. 10.3 A Tech. *[Signature]*



Pulse Width 300µs @ 490



40/inch
B-76



175-575381 SIN 106
 P. 110 12/13/76
 Bb 39.5KV
 1.10V 25.0 A Pulse Voltage 200
 1b 15.0u Bf 10.5 V DAY .04
 E coll. -6.0KV H 10.2 A Tech. *SPK*
 Pulse Width 300ns @ E .04

40°/inch
 B-77

-3dB

3.7

GHz

3.0

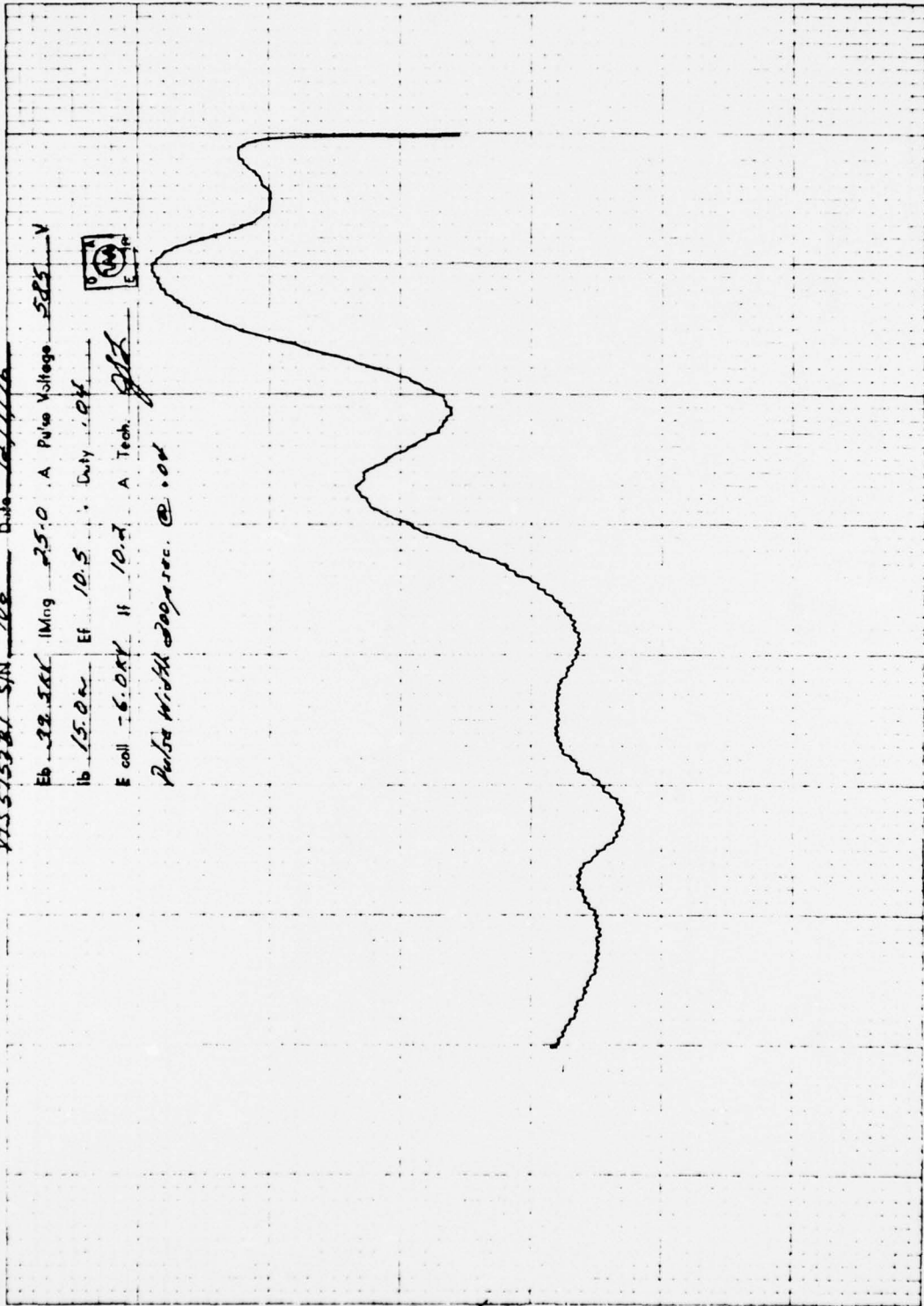
YIS 575381 SN 106 Date 12/7/76

Fb 32.5K IMing 25.0 A Pulse Voltage 585 V

Ib 15.0k Ef 10.5 Duty .04

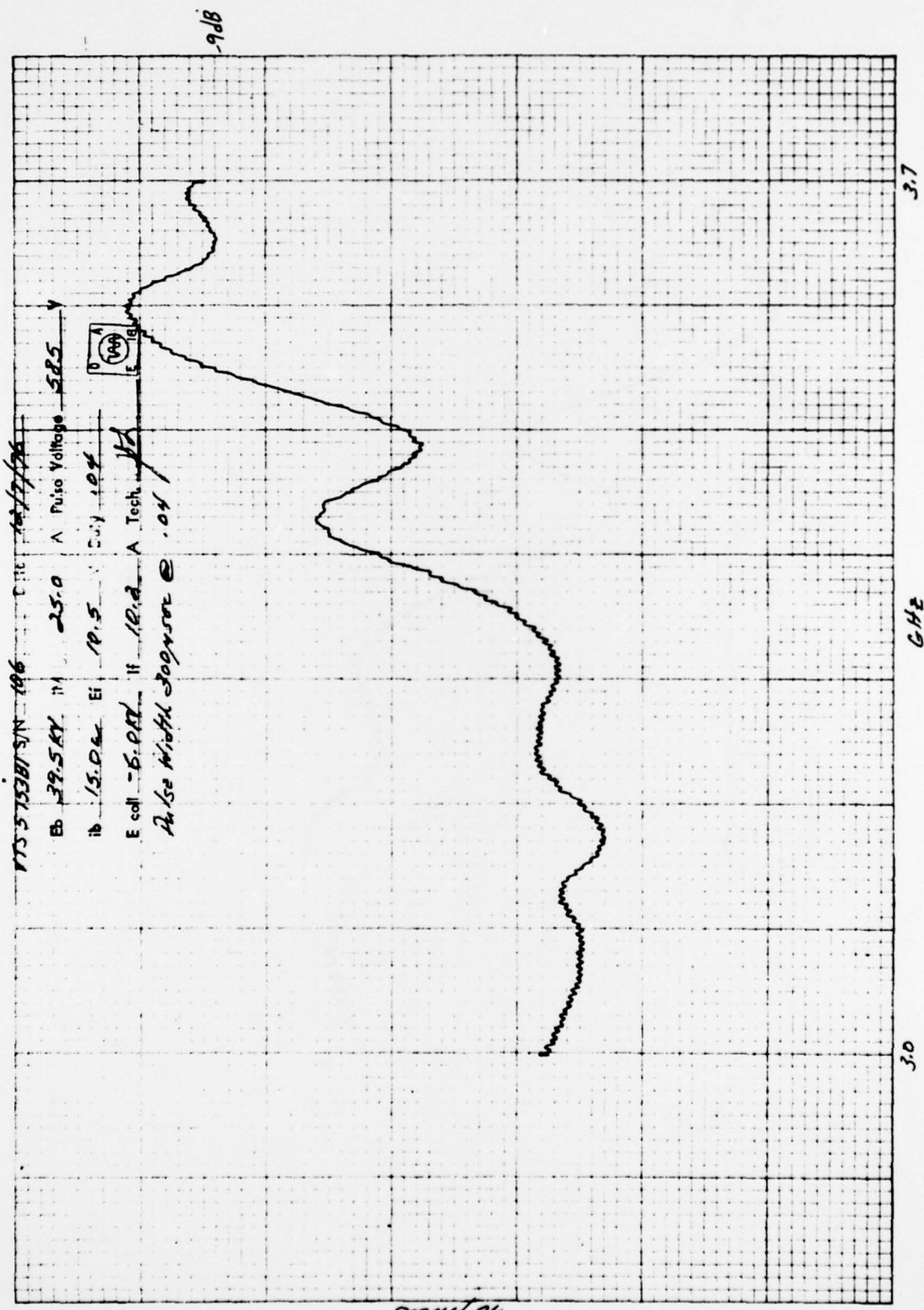
E coll -6.0KV II 10.7 A Tech. JH

Pulse Width 200 nsec. @ 1.0V



40°/inch
B-78

PL
-61B



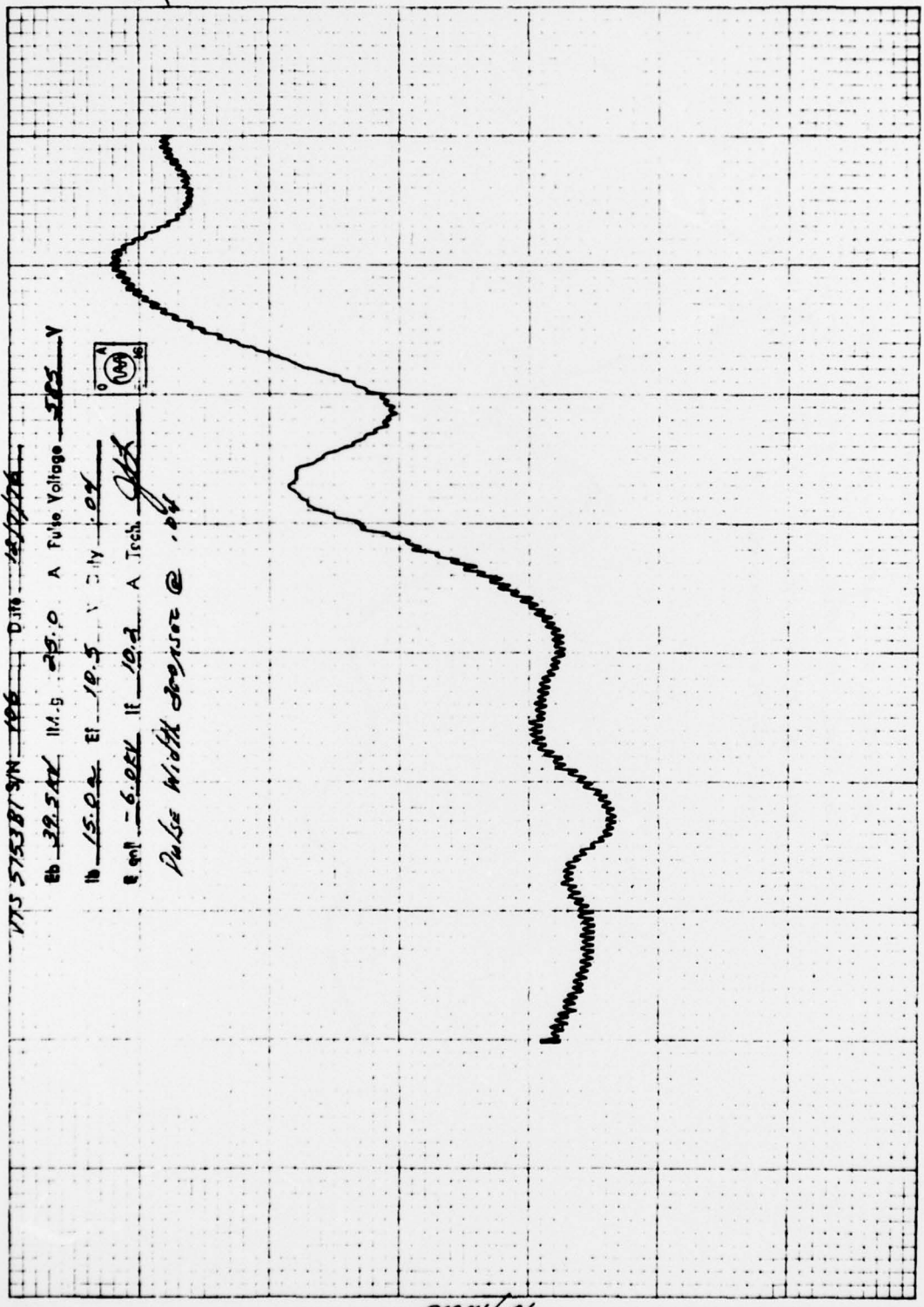
40/mv

B-79

175 5753819N 106 D.116 ~~12/17/76~~
 Eb 32.54K 114.5 29.0 A Pulse Voltage 5PS V
 10 15.02 EI 10.5 V 0.14 0.2
 8.01 -6.05V 11 10.2 A Tech JKH
 Pulse Width 200ns @ 10V



PL
 -12dB



40/mv
 B-80

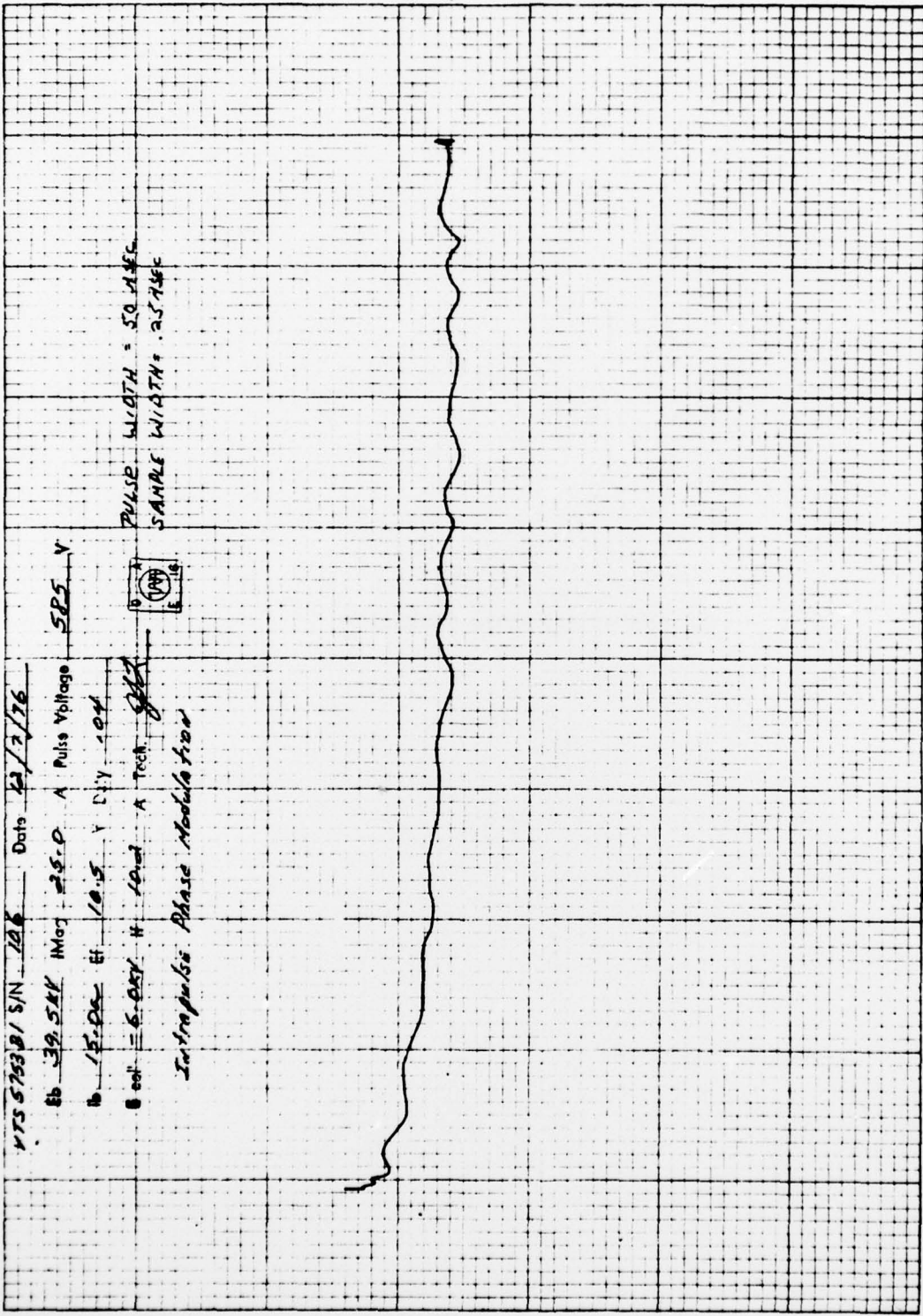
3.7
 6Hz
 3.0

10. Intrapulse phase modulation

WTS 5763B1 S/N 106 Date 4/2/76
 Eb 39.5KV IMag 25.0 A Pulse Voltage 585 V
 Ib 15.0KV Et 10.5 V Div 104
 B cool 6.05V H 10.0 A Tech ~~SP~~

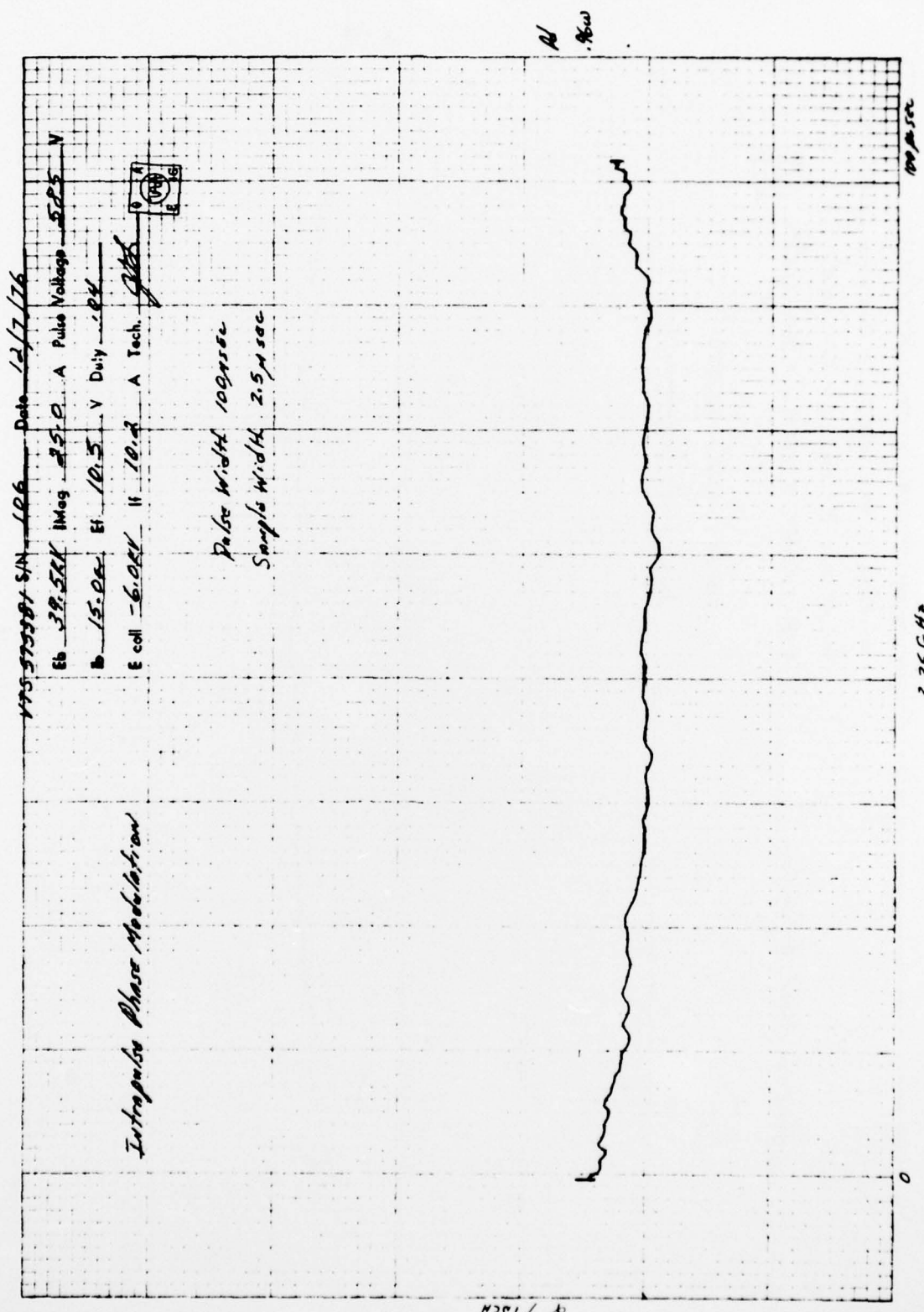
Interpulse Phase Modulation

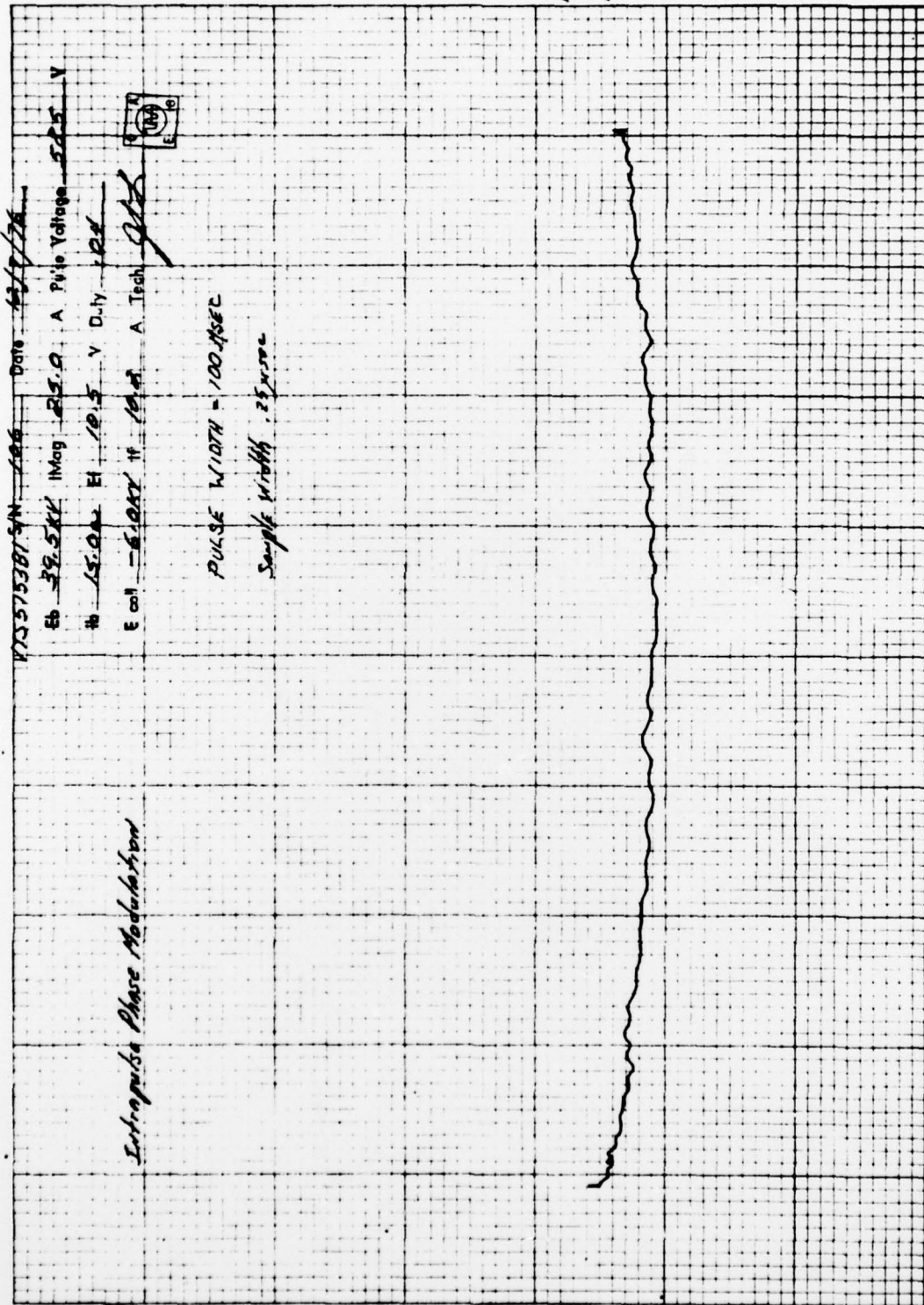
PULSE WIDTH = 50 μ SEC
 SAMPLE WIDTH = 2.5 μ SEC



21
 96

3.35GHz





VTS 575387-5N 1.06 Date 12/17/76
 Eb 39.5KV IMag 25.0 A Pile Voltage 525 V
 H 15.02 H 10.5 V Duty 100
 E col - 6.02V H 10.4 A Tech JKS

Intra-pulse Phase Modulation

PULSE WIDTH = 100 nSEC
 Sample Width = 25 nSEC



Pd
 .96w

100 nSEC

3.35 GHz

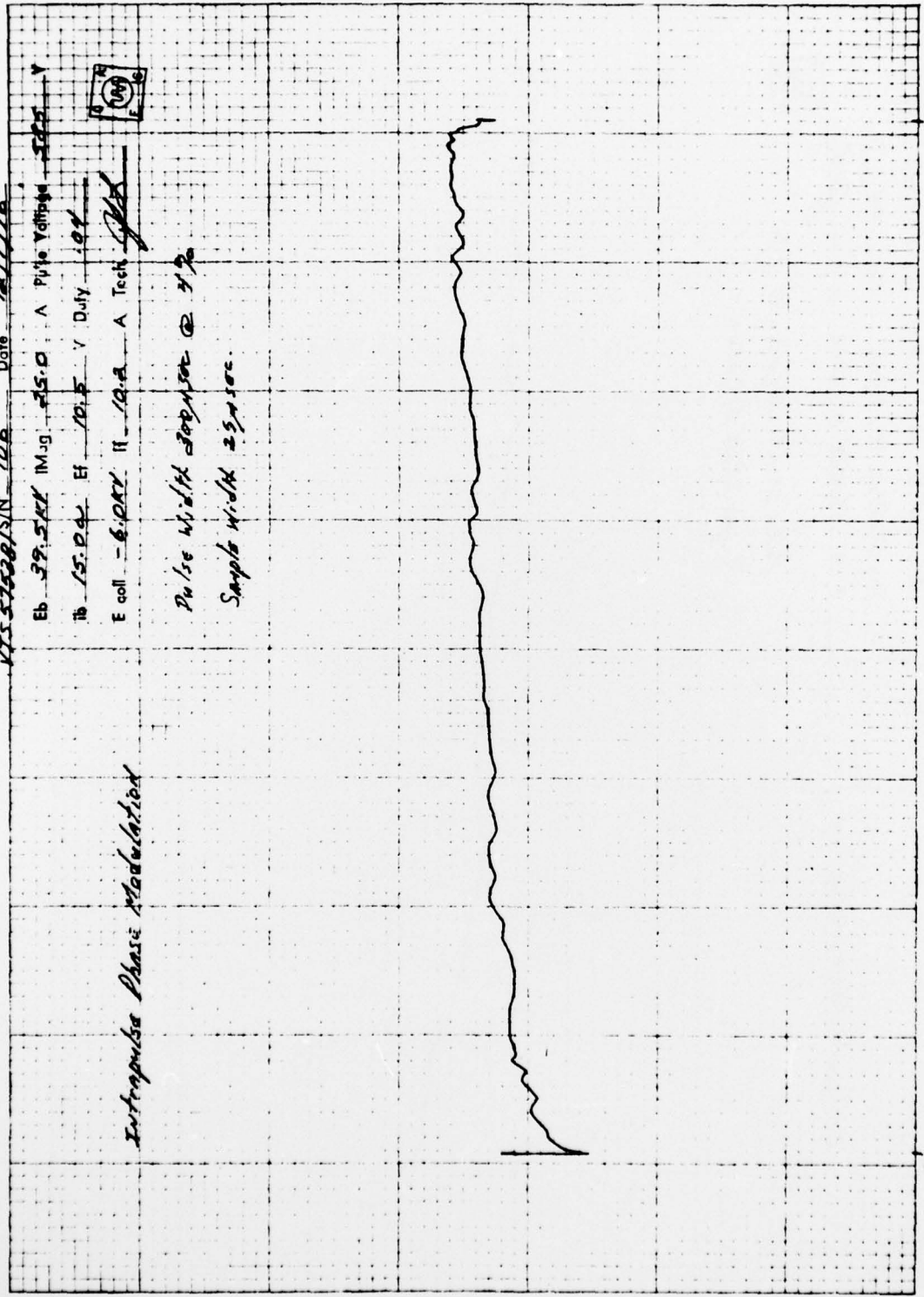
KT5-57508/SIN 106 Date 12/17/76

Eb 39.5KV IMJg 25.0 A Pk-to-Pk Voltage 500 V
Ib 15.0A Ef 10.5 V Duty 10%
E coll -6.0KV II 10.2 A Tech GJK



Intrapulse Phase Modulation

Pulse Width 300ns @ 5%
Sample Width 2.5ns

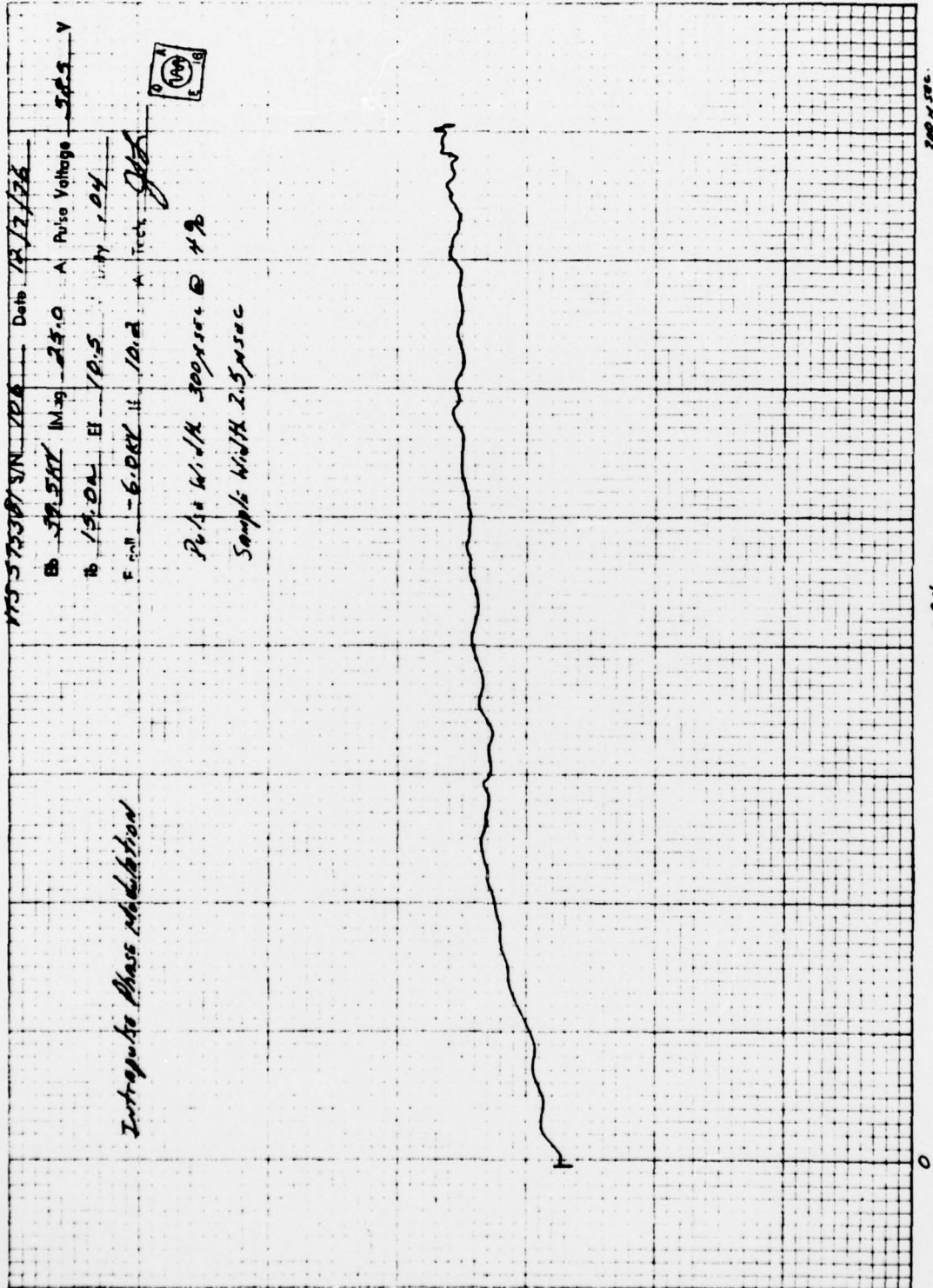


2°/inch
B-85

96
96

300 nSEC

3.35 GHz



MS 573381 SIN 206 Date 12/17/76
 Bb 70.5KV Mag 25.0 A Pulse Voltage 30.5 V
 Bb 15.0A EI 10.5 V 1.04
 F 0.01 -6.0KV II 10.2 A Tech JGH

Integrate Phase Modulation

Pulse Width 300 nsec @ 4%
 Sample Width 2.5 nsec

12
 .86

20/inch
 B-86

300 nsec
 1.35 GHz