NATIONAL RADIO ASTRONOMY OBSERVATORY
Green Bank, West Virginia

May 1, 1992

MEMORANDUM

To: Addressees

From: R. Lacasse, R. Norrod

Subj: RFI Tests on PowerTec Brushless Motor and Controller

On April 7/8 1992, preliminary tests were performed at Green Bank on a brushless motor and associated controller on loan from RSi/PCD. These motors have potential application on the GBT subreflector positioner and on the prime focus FRM. The preliminary tests indicated that, as delivered, the units could potentially produce harmful RFI. It was decided to do further tests and attempt to determine what steps would be required to eliminate the problem. This memo reports on that effort. A magnetostrictive position transducer and associated electronics were also tested and the results are reported separately.

Appended are diagrams of the test setups and test data obtained. The motor and controller are manufactured by PowerTec Industrial Corp. of Rock Hill, SC. The motor is a completely enclosed design. It requires two cables, one for power and the other for control signals. On the GBT, the motor would be part of an actuator that controls subreflector motion on the FRM. The controller would presumably be placed in an RFI shielded cabinet inside the receiver room. The controller appears to be the predominant source of RFI.

SUMMARY: Tests showed that detectable signals are radiated to at least 1500 MHz. The most obvious is a comb spaced at approximately 3.5MHz. The comb was detected in indoor tests in the 100-200 MHz range using a YAGI antenna, a transistor preamp, and a spectrum analyzer. It was also detected at 350-400MHz and 1300-1500 MHz using NRAO prime focus feeds and cooled receivers as preamps, and the spectrum analyzer.

The following steps were taken: The controller and associated operator interface were placed in a large metal box. The cover of this box is sealed with a conductive gasket and AC power into it goes through RFI filters. Cables with braided shields were used for both power and control signal cables. They were introduced into the large metal box and the motor housing through Crouse-Hinds cable-grip type feedthroughs. At each end the braided shield was folded back around the rubber grommet and forced into contact with the metal cable-grip shell. The goal was to provide a continuous metal shield around the electronics and the interconnecting wires.

These steps appeared to be successful. The test data shows that no signals could be detected from the motor or controller with the large metal box closed. It is hard to judge the absolute amount of shielding achieved because the "after" levels were below our setup's sensitivity, but it appears to be at least 30 db at 400 MHz. It appears that energy was being radiated predominantly by the controller - no RFI was detected when the controller was sealed within the metal box.

We feared that all the interconnecting leads would have to be filtered at each end, but it appears that this is probably not necessary if proper care is taken with the shielding of the electronics and the cable. The proper use of twisted pairs to transmit the differentially driven signal is important as well.

RECOMMENDATION: The motor controllers should be placed in RFI shielded cabinets. AC input power should be filtered. The interconnecting cables should be of the proper type and care should be taken when terminating the shield at both ends. It would also be good practice to use an RFI gasket in the motor's junction box, instead of the one provided. Although no RFI was detected, even with the junction cover off, other sources of RFI within the same cabinet could propagate down the motor leads and leak out around this gasket.

CONCLUSION: The steps taken are well known and widely recommended to fight RFI problems. A useful reference is Noise Reduction Techniques in Electronics Systems by H. W. Ott. These tests reinforce the effectiveness of, and need for, good grounding and shielding techniques when operating digital and power equipment near the GBT feeds and receivers. We conclude that, if similar techniques are used, RFI levels from the brushless motors and associated controllers will be acceptable. However, our test equipment is not as sensitive as the GBT data acquisition equipment, and shielding effectiveness is very implementation dependent. Therefore, we feel it would be prudent to leave some room in the PCD cabinet so that NRAO could add RFI filters to the cabling if it becomes necessary in the future. We would also be glad to review the details of the PCD design as it becomes available and make recommendations accordingly.

Distribution:

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Test Data Log

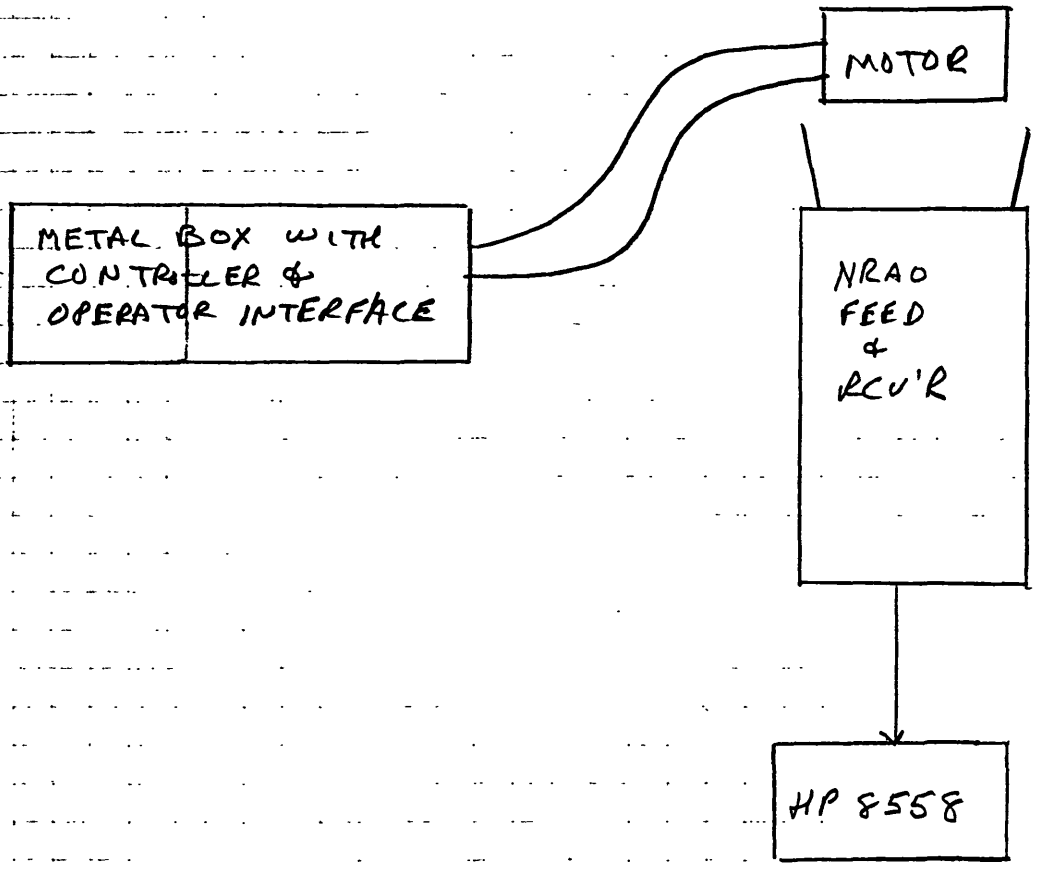
Plots generally show two traces. One is a reference trace. When not specified by "ON/OFF", the reference trace is with the power to the unit off. The other is with the conditions described below.

Center Freq.(MHz)	Controller Cover	Motor Cover	Motor Running	Notes	RFI Detected	Fig
144	OFF	ON	NO		Y	A
144	OFF	ON	NO	1	Y	B
144	ON/OFF	ON	NO		Y	C
144	ON/OFF	ON	YES		Y	D
400	ON/OFF	ON	YES	2,4	Y	E
400	ON/OFF	ON	NO	2,4	Y	F
400	ON/OFF	ON	YES	3,4	Y	G
400	ON/OFF	ON	YES	5	Y	H
1500	OFF	ON	?	9	Y	I
1500	ON	ON	YES	10	N	J
144	ON	ON/OFF	YES	6,7	N	K
144	ON	ON	YES/NO	8	N	L
144	ON	ON	YES		N	M
144	ON	ON	NO		N	N,O
400	ON	ON	YES		N	P

Notes:

1 - Max hold mode on spectrum analyzer.
2 - Motor over feed.
3 - Part of cable over feed.
4 - Controller located below feed.
5 - Controller located about 30 degrees off feed axis.
6 - Ground lead not connected to motor.
7 - Shield not connected to motor.
8 - Shield connected to motor.
9 - Controller in front of feed.
10 - Motor in front of feed.

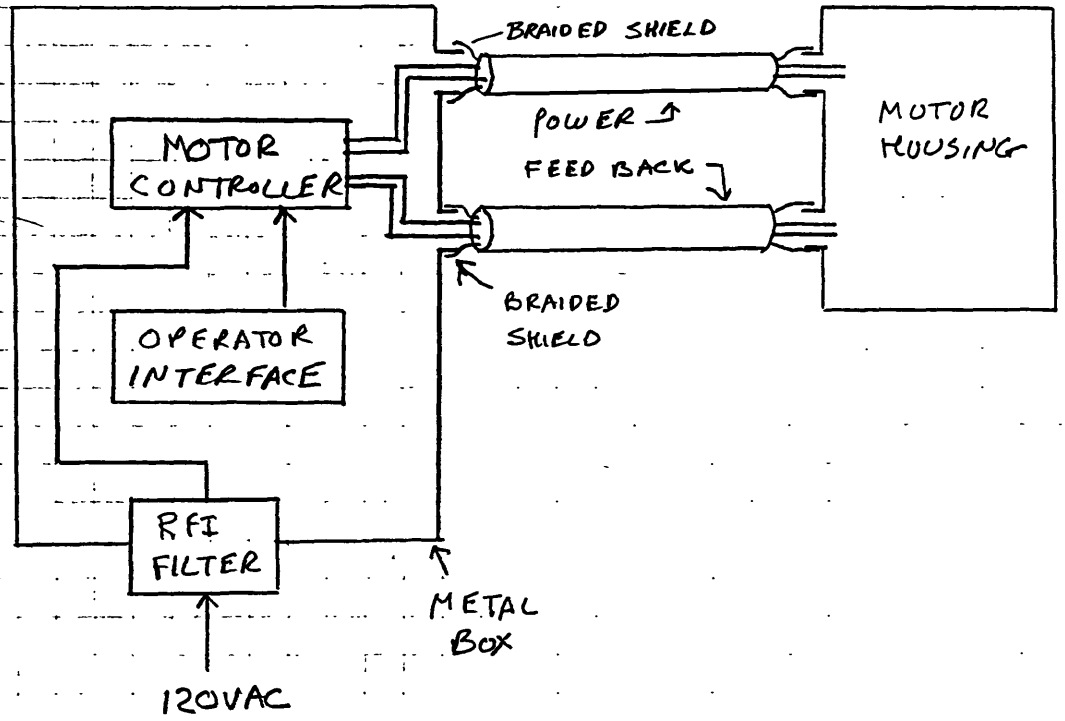
BRUSHLESS I MOTOR OUTDOOR TEST SET-UP 5-1-92



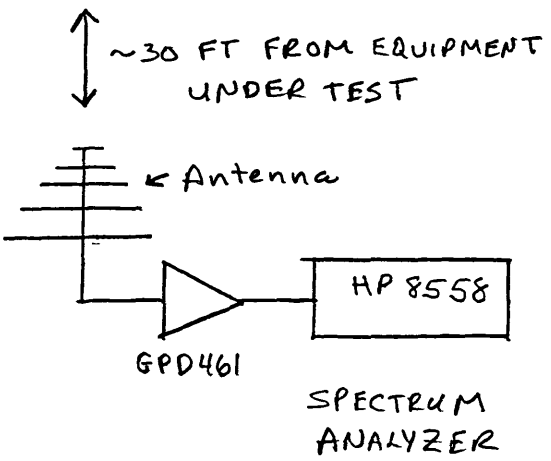
350-450 MHz
OR
1300-1500 MHz

FEED POINTED AT ZENITH FOR MOST TESTS. ALSO POINTED AT HORIZON FOR ONE CONTROLLER TEST.

BRUSHLESS MOTOR RFI INDOOR TEST SET-UP 5-1-92



CONTROLLER : POWERTEC, MODEL 500
MOTOR : POWERTEC, 1HP BRUSHLESS
MODEL 214ASA1000700000



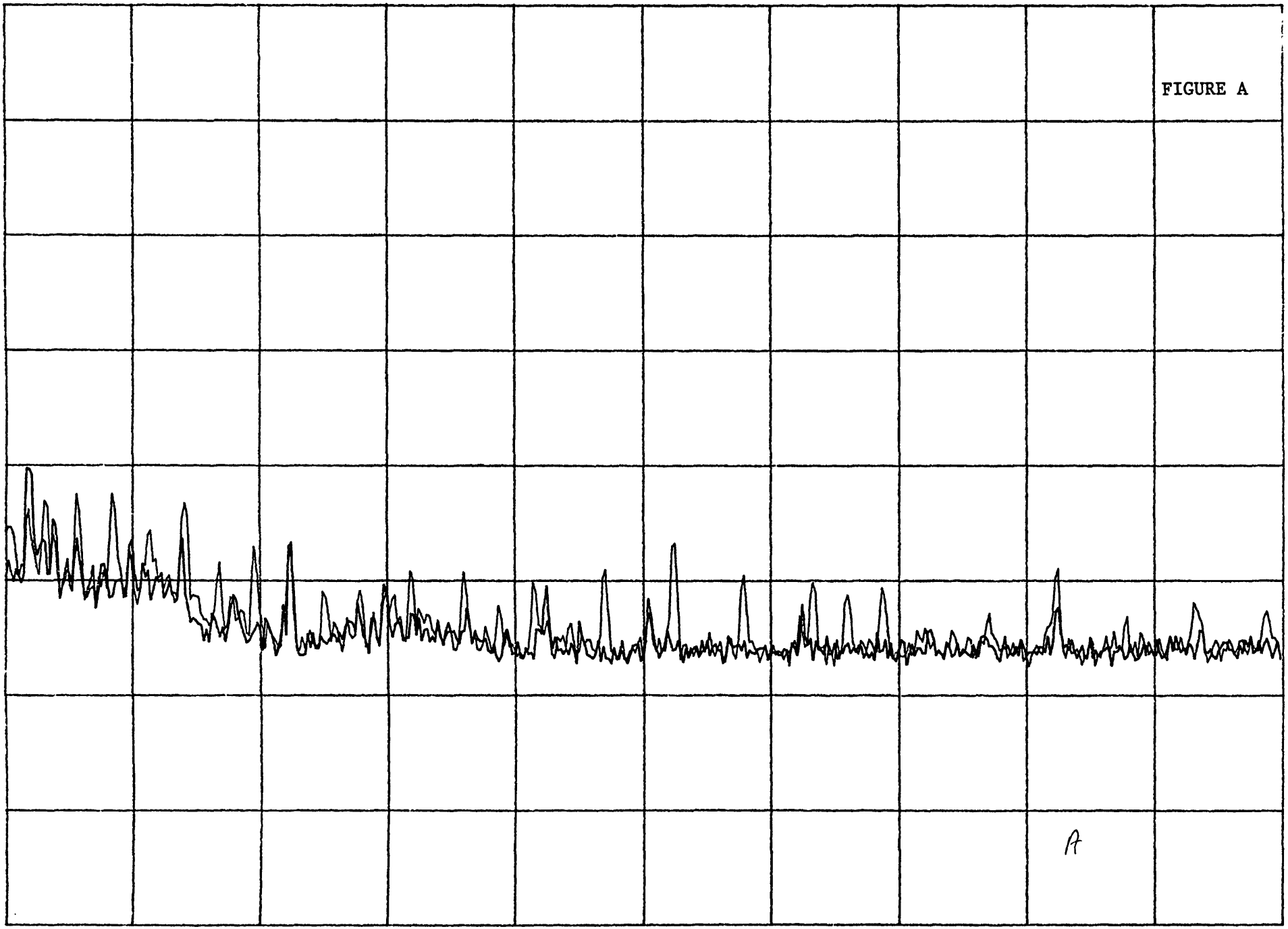


FIGURE A

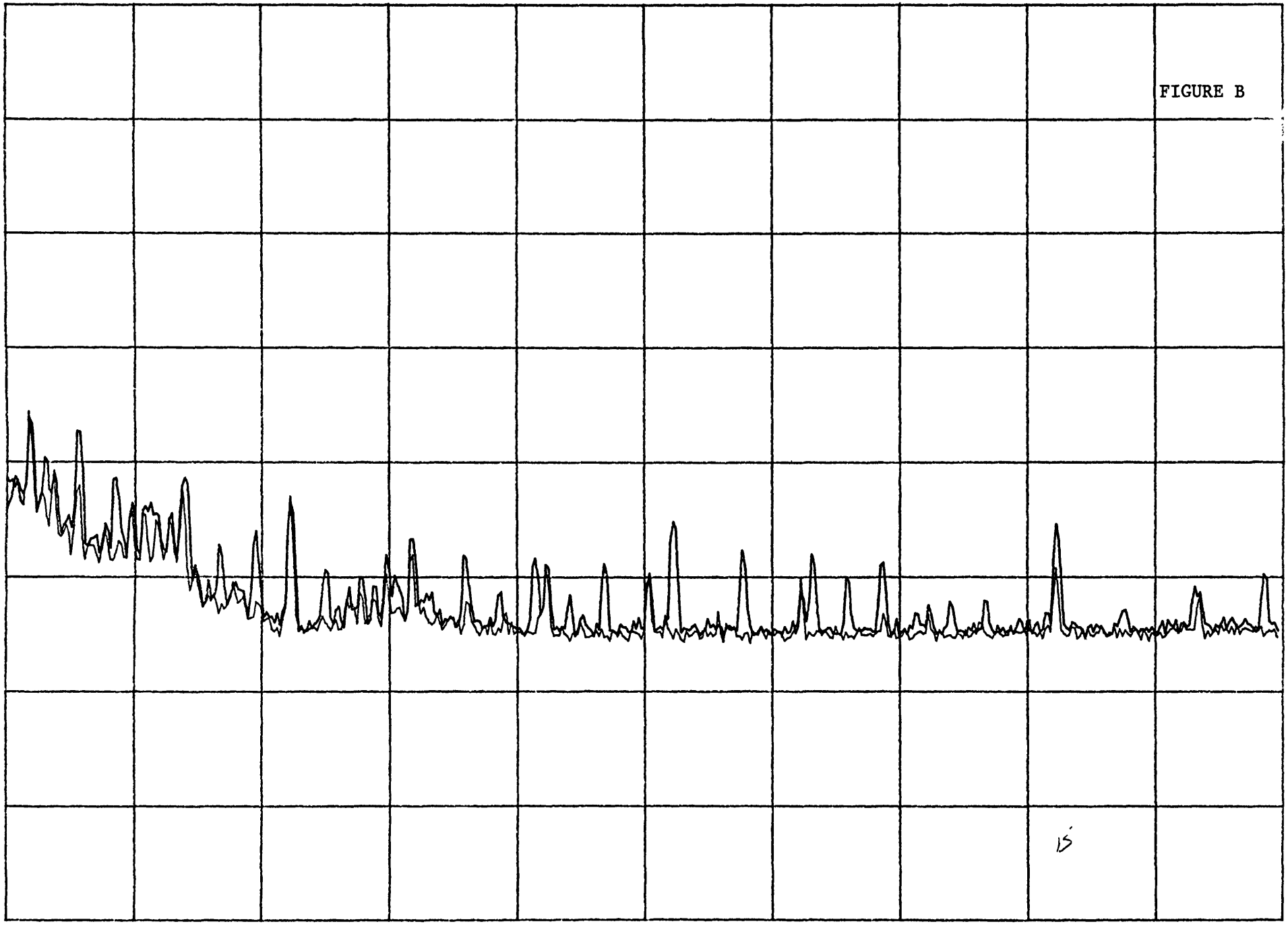
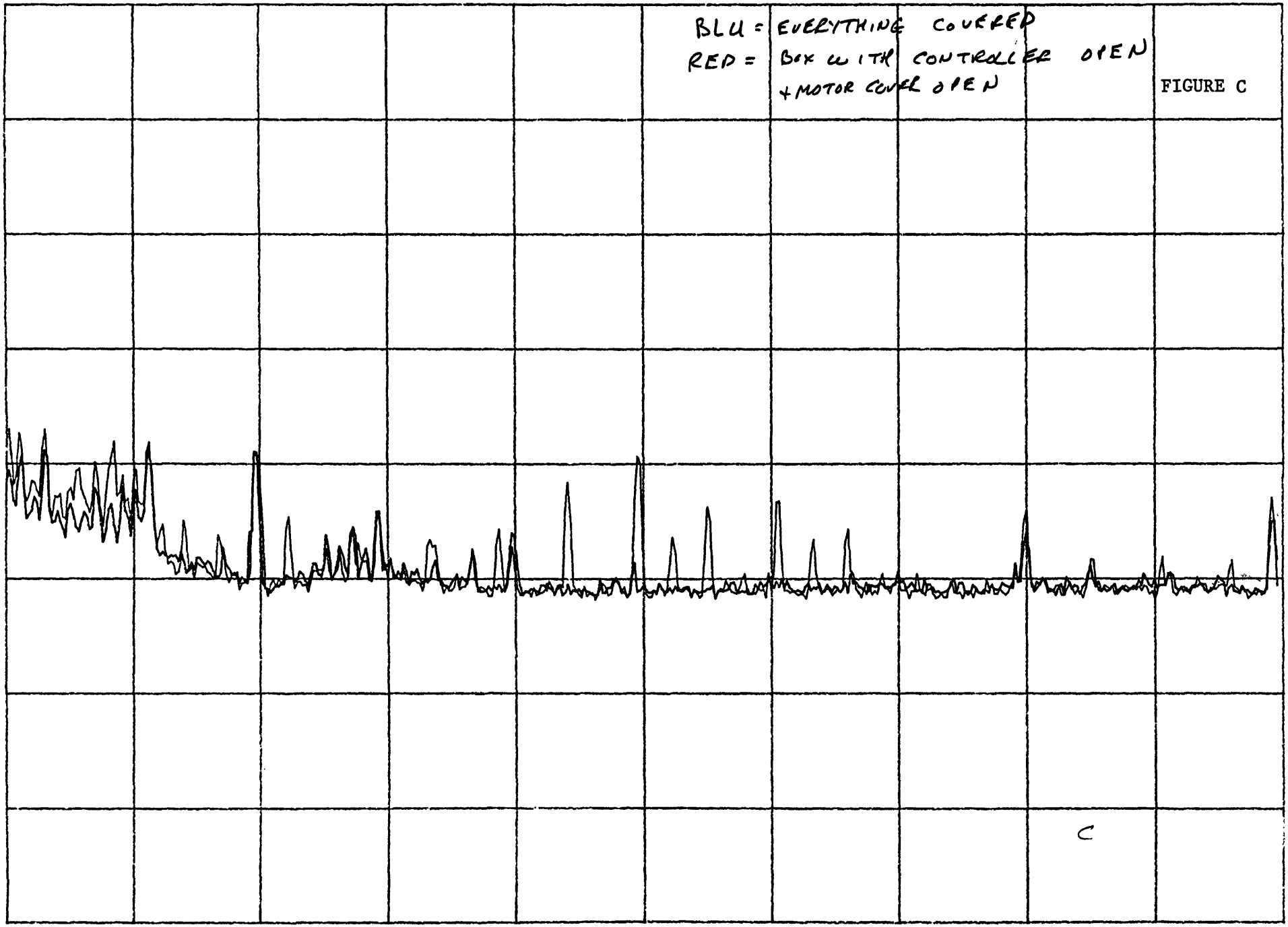


FIGURE B

BLU = EVERYTHING COVERED
RED = BOX WITH CONTROLLER OPEN + MOTOR COVER OPEN



C

FIGURE C

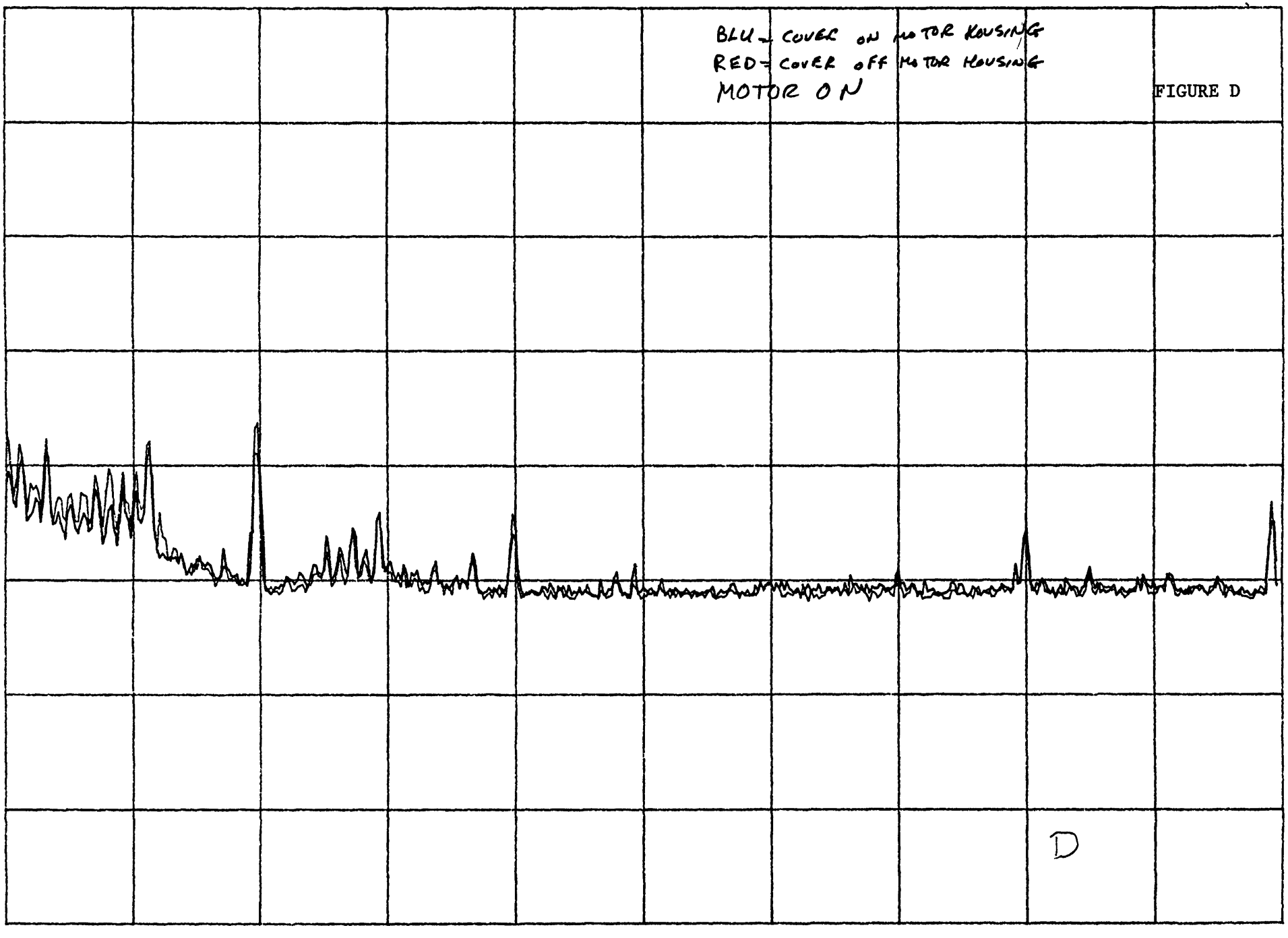
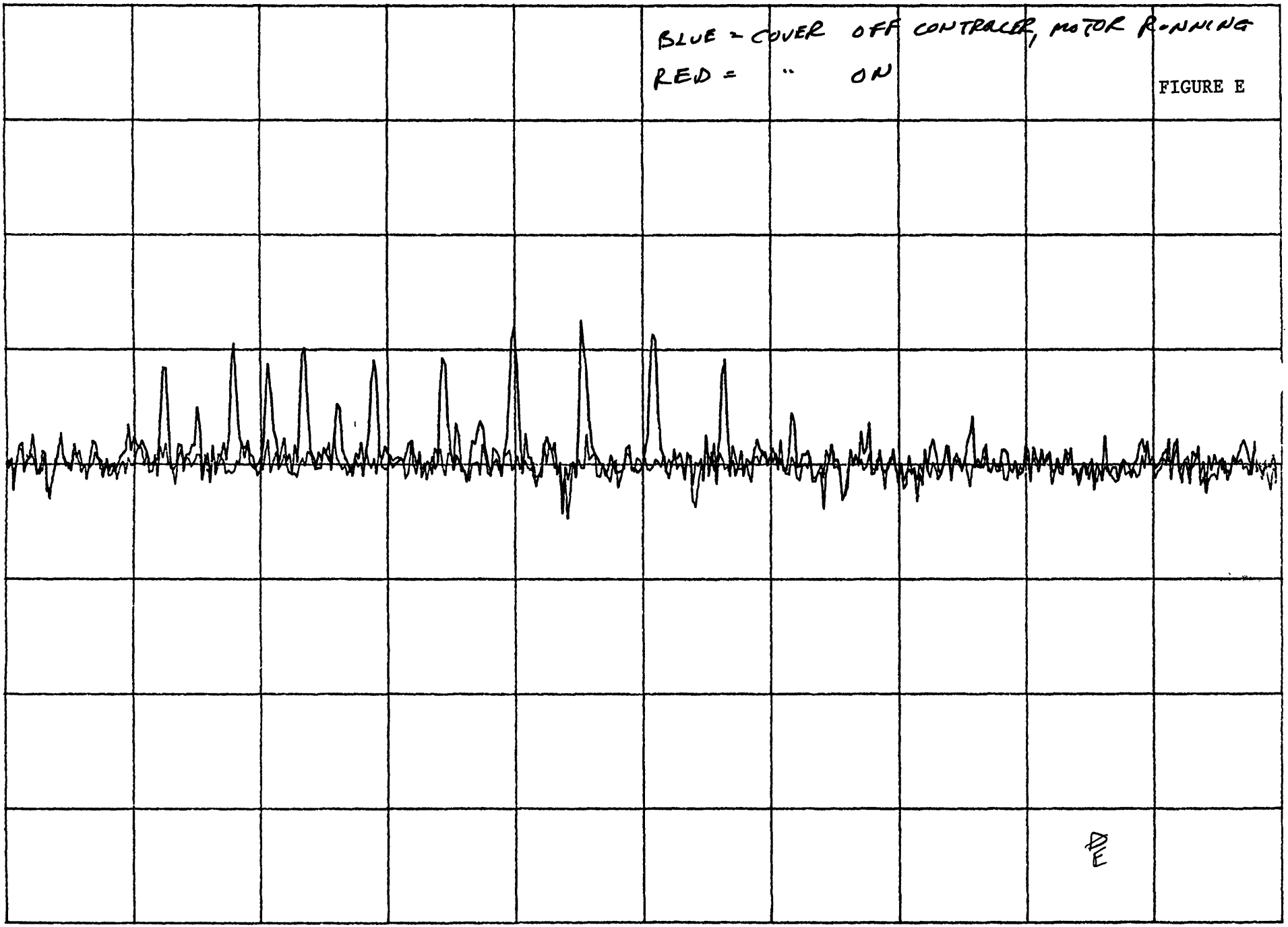

BLU = COVER ON MOTOR HOUSING
RED = COVER OFF MOTOR HOUSING
MOTOR ON
D

FIGURE D


BLUE = COVER OFF CONTRACER, MOTOR RUNNING
RED = " ON
FIGURE E
E

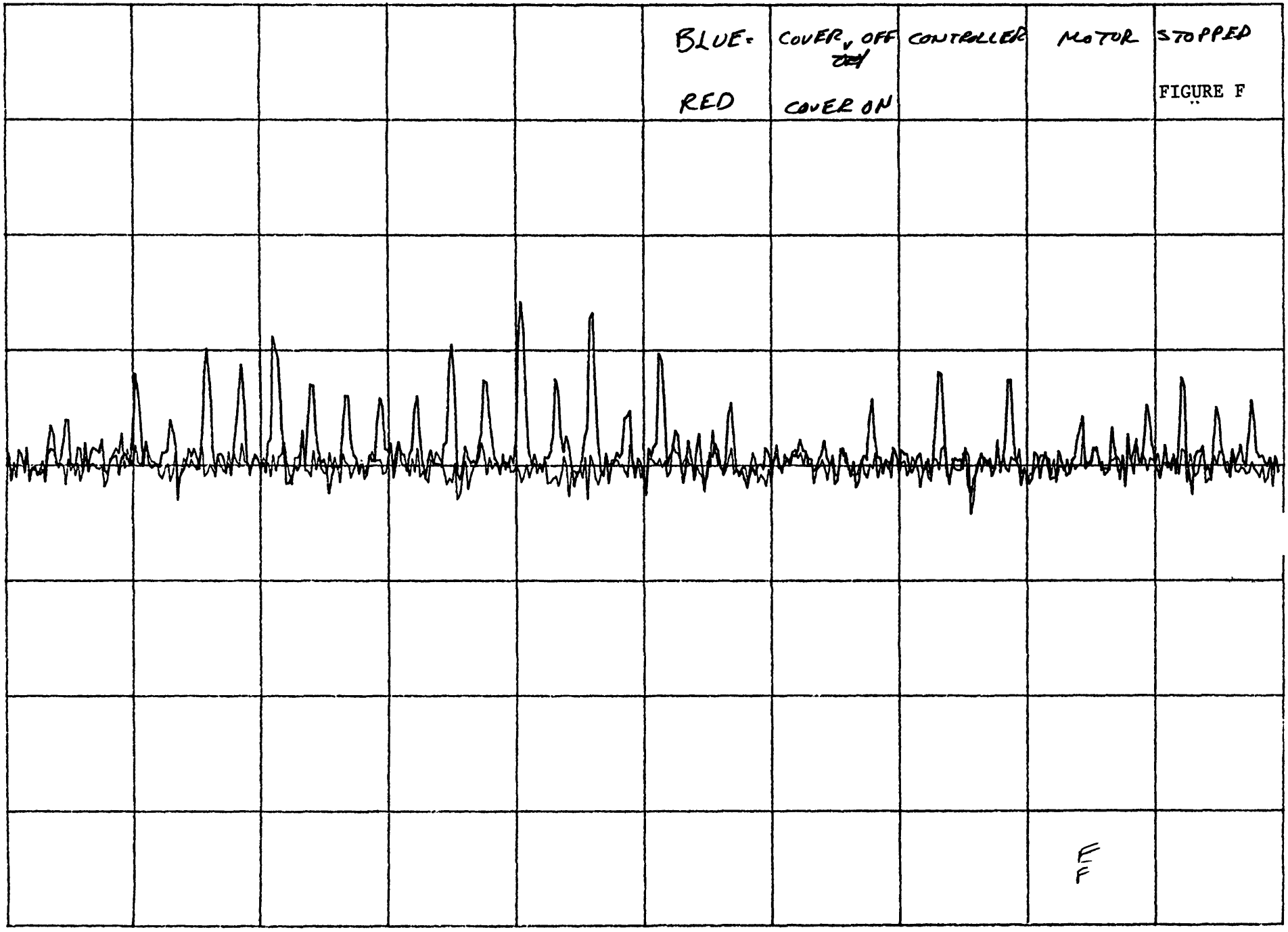


FIGURE F

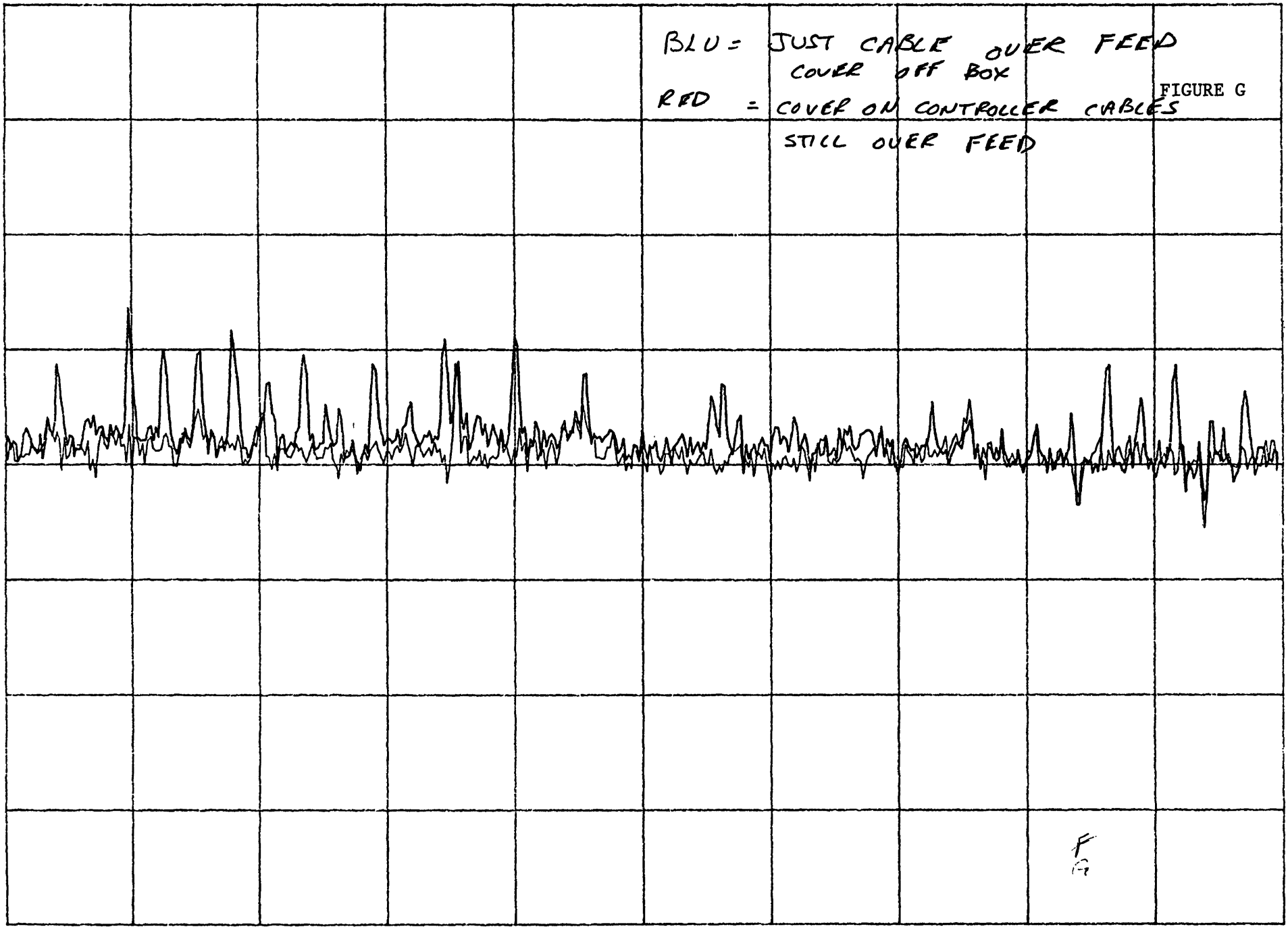
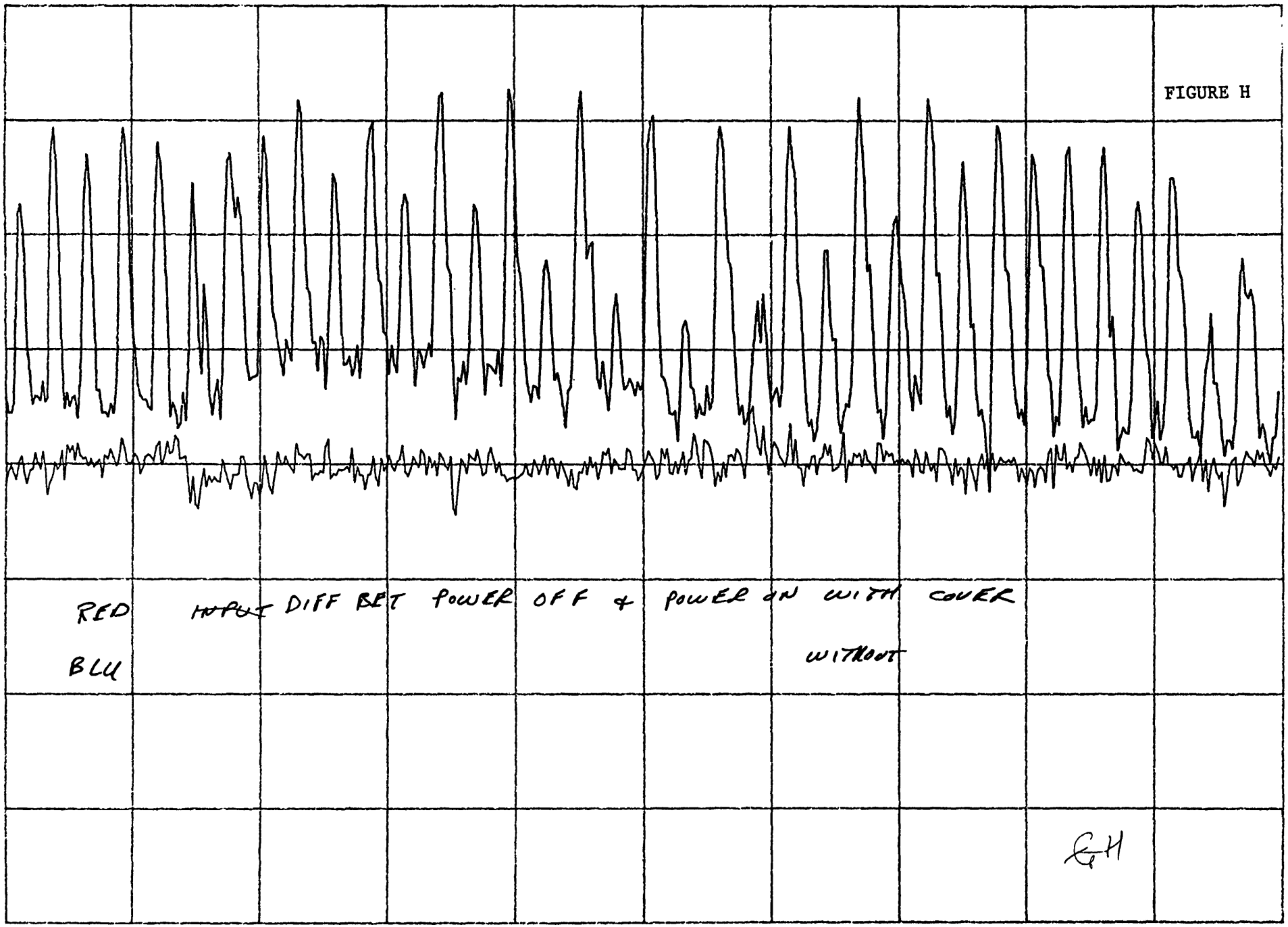

BLU = JUST CABLE OVER FEED
COVER OFF BOX
RED = COVER ON CONTROLLER CABLES
STILL OVER FEED
F
G

FIGURE G

FIGURE H


RED
BLU
INPUT DIFF BET POWER OFF & POWER ON WITH COVER
WITHOUT
G-H

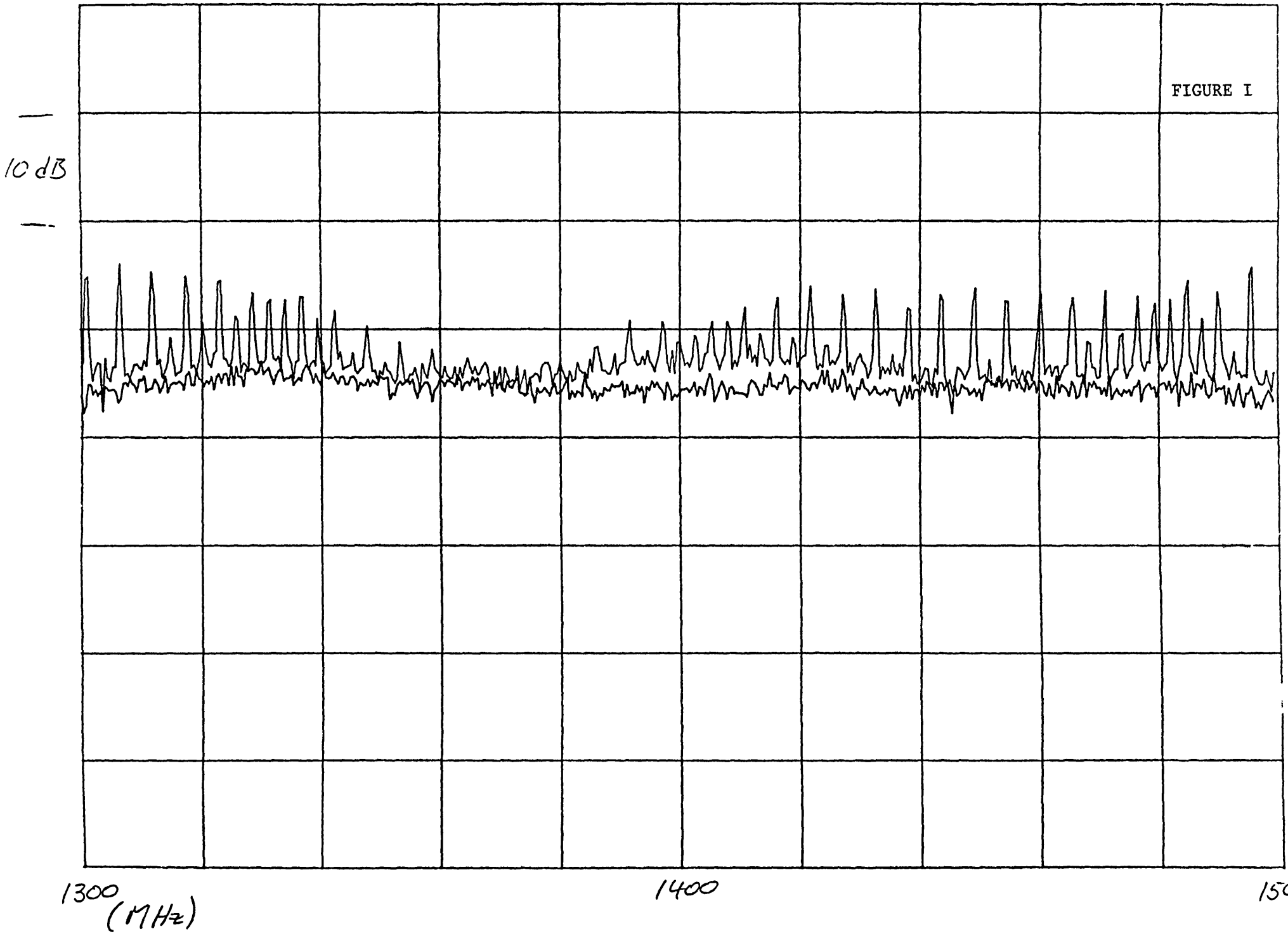
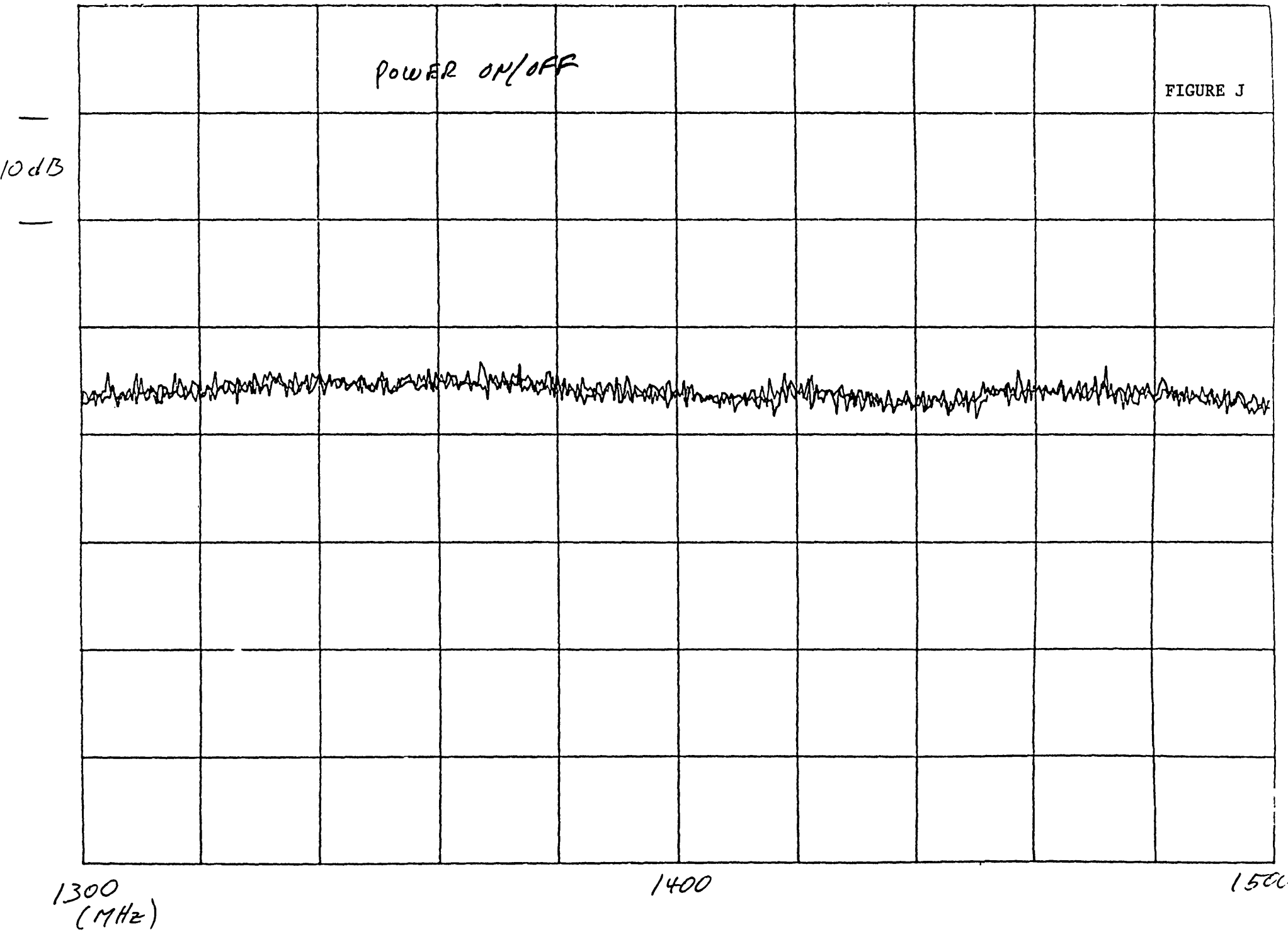
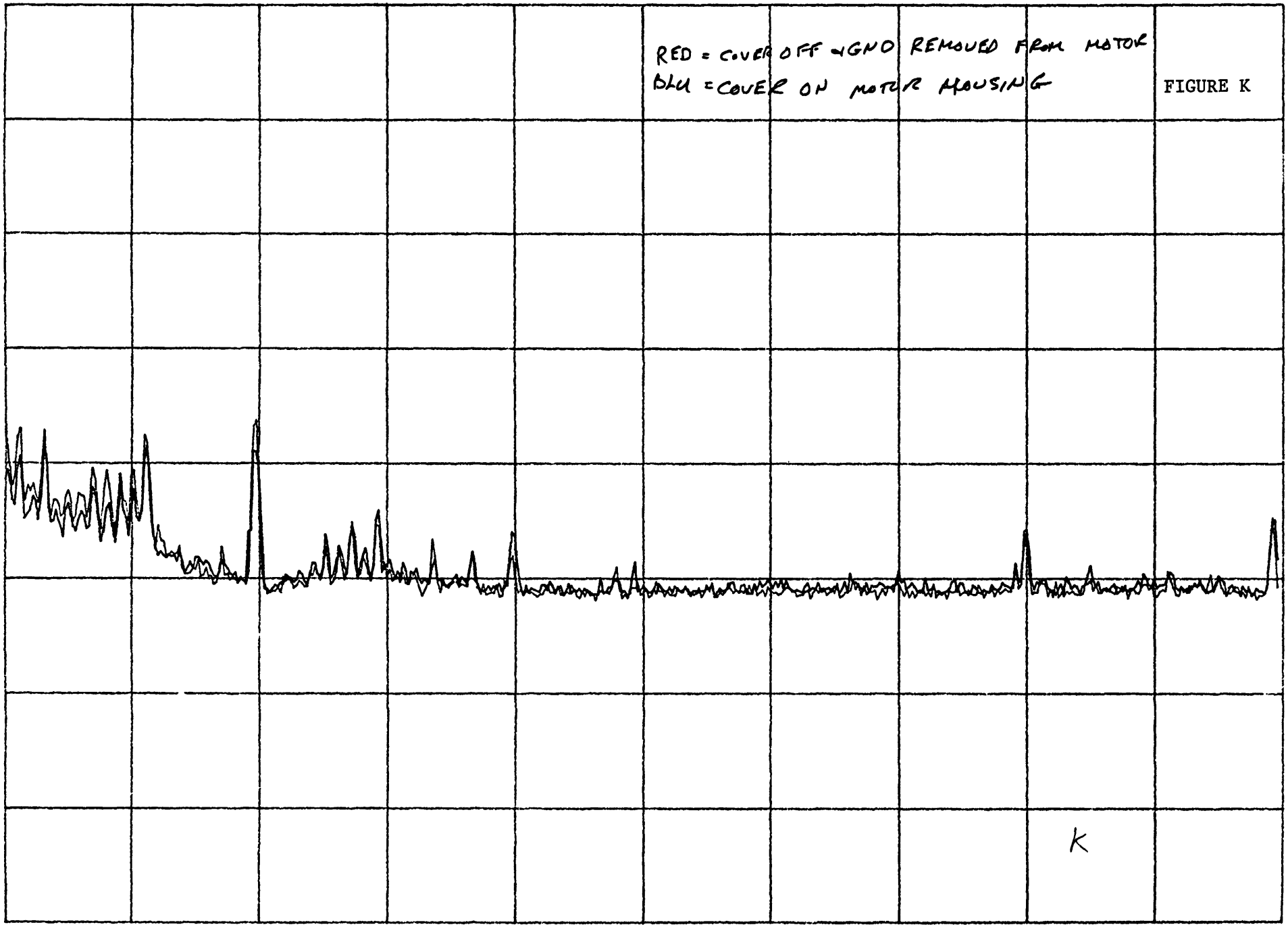


FIGURE I
10 dB
1300
(MHz)
1400
1500


POWER ON/OFF
FIGURE J
10 dB
1300
(MHz)
1400
1500


RED = COVER OFF + GND REMOVED FROM MOTOR
BLU = COVER ON MOTOR HOUSING
FIGURE K
K

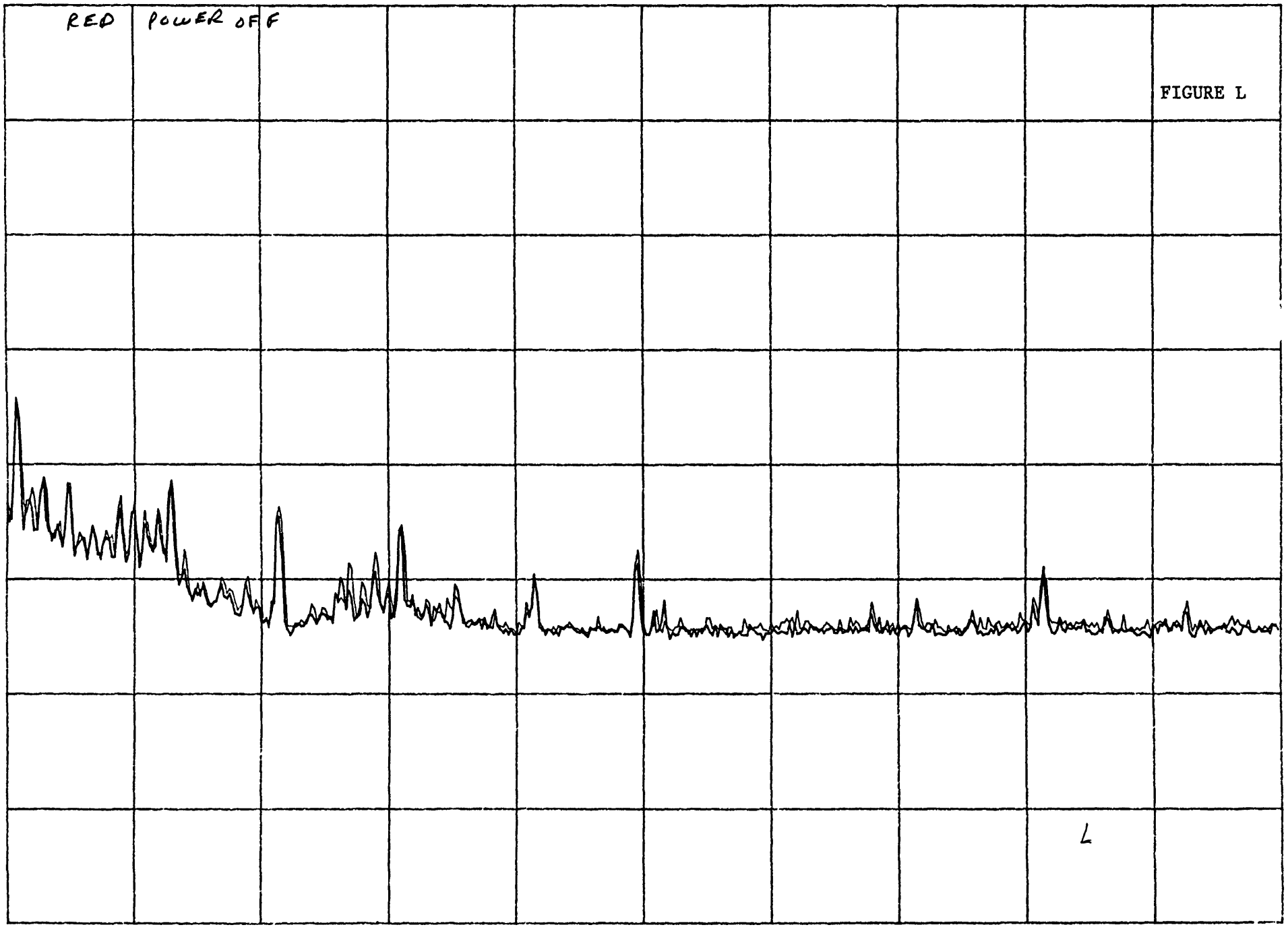


FIGURE L

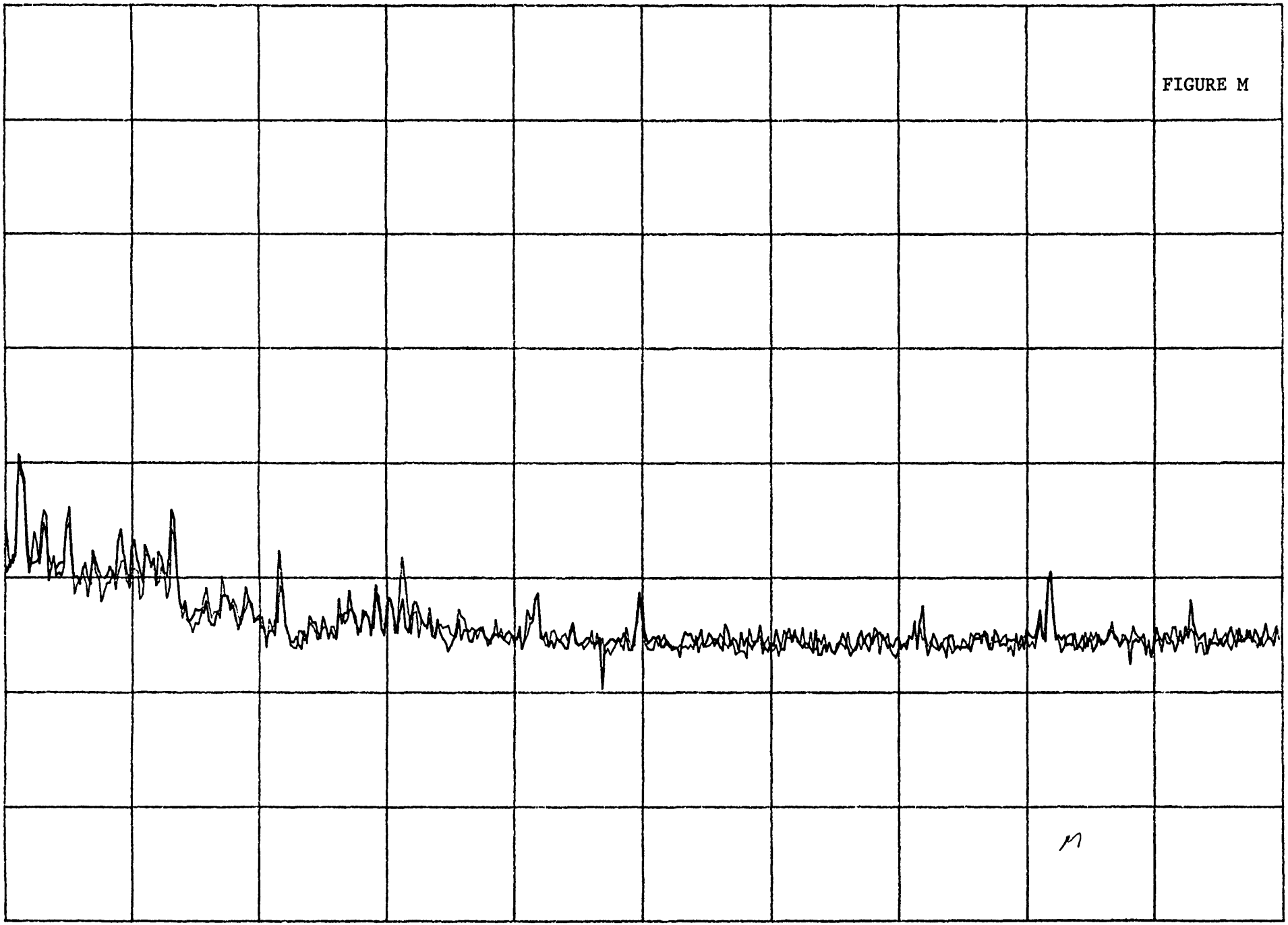


FIGURE M

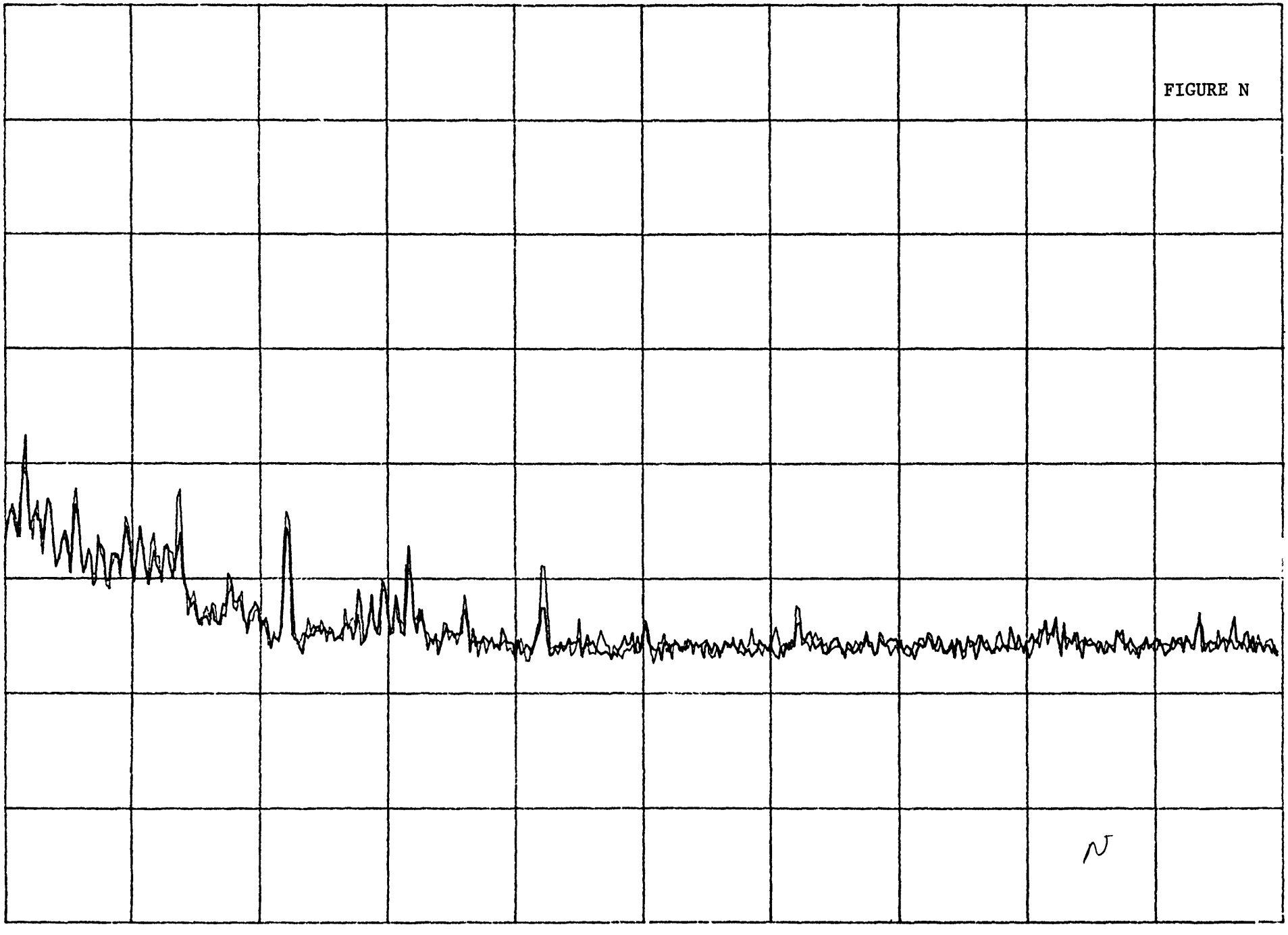


FIGURE N

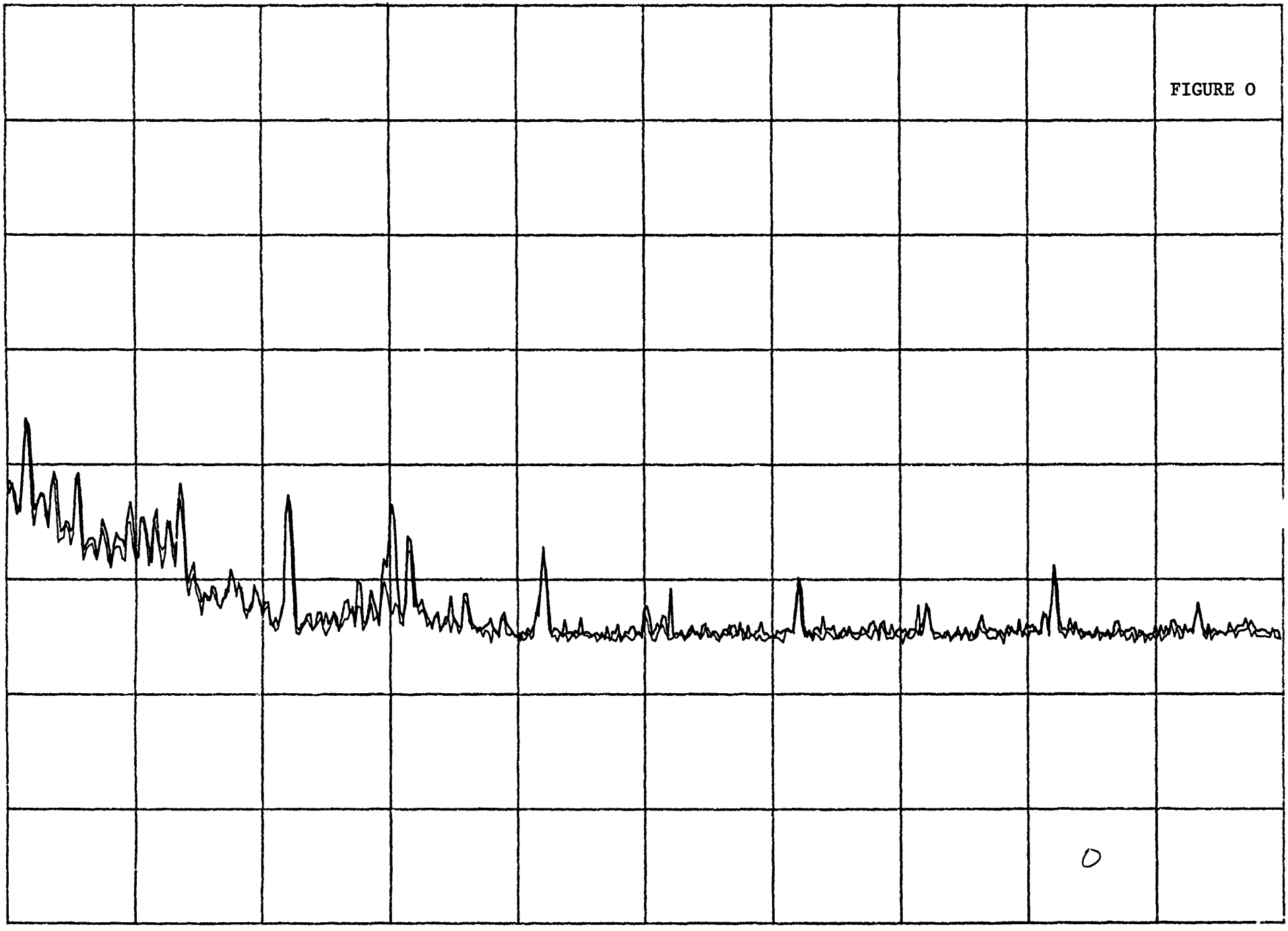


FIGURE 0
0

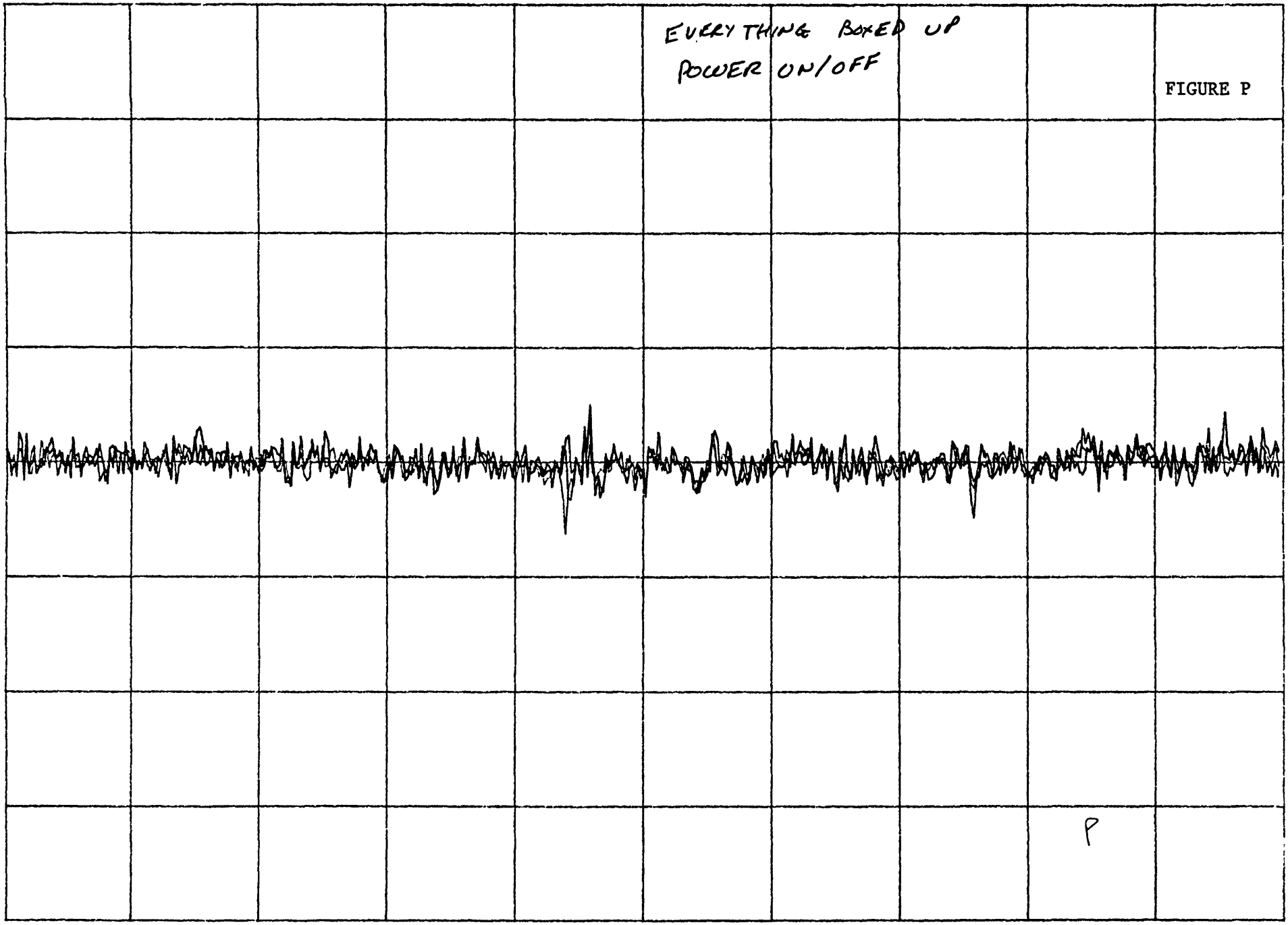


FIGURE P