FAA TECHNICAL CENTER LETTER REPORT

PERFORMANCE TESTS OF A VERY HIGH FREQUENCY (VHF) DIRECTIONAL POWER DETECTOR

by

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PREFACE

Acknowledgement is made to the following personnel for their contribution to this project: Mr. Adolph Cupp, Federal Aviation Administration Technical Center, for his help in equipment set up and transmitter adjustments; Mr. Hárry Brown, Technical Center, for his help in data collection on the slotted line; and Edward Marciano, Co-op, Drexel University, Technical Center, for his help in data collection on the detectors and slotted line.

INTRODUCTION

PURPOSE

The purpose of this activity was to evaluate the operating characteristics and parameters of a very high frequency (VHF) directional power detector (DPD) for use as a sensor in monitoring radio transmitting equipment. This work was performed under Task 9 of 9550-AAF-501-78-002.

BACKGROUND

The testing of this detector was performed to determine its possible use as an RF sensor in the Remote Maintenance Monitoring Sysytem (RMMS). Under Task 9 of 955-AFF-501-78-002, the functional and technical characteristics of sensors were investigated for possible use in monitoring facility equipment. Because of problems with existing RF sensors, the requirements of an RF sensor for RMMS were determined and presented to a vendor. In response, a VHF directional power detector (DPD) was designed and built by Coaxial Dynamics Inc. (CDI) under the direction of the FAA Technical Center. The CDI detector measures the forward and reflected power in the RF transmission line of a communications transmitter. The voltage standing wave ratio (VSWR) can then be calculated from the power measurements providing basic information on transmitter operation and antenna performance. The detector is inserted external to the transmitter in the transmission line and delivers DC voltages proportional to the forward and reflected power. The requirements of the detector, specified by the Technical Center, were based on the transmitter and expected antenna characteristics:

Forward power range: 5 to 15 watts
VSWR range: 1:1 to 2:1
Directivity: 40dB

DESCRIPTION OF DETECTOR

The VHF directional power detector was designed and built by Coaxial Dynamics Incorporated (CDI), Cleveland, Ohio. See Table 1 for manufacturer's specifications.

TABLE 1.

Maximum Power Handling:	Forward 60 Watts
	Reflected 15 Watts
Directivity:	>40 dB
Linearity Error:	<2%
Supply Voltage:	+18/-18 Volts
Dimensions:	Length 3.00 inches
	Width 1.75 inches
	Height 1.00 inch
Connectors:	Input TNC Female
	Output N Female

TESTS CONDUCTED

Tests were performed on the CDI detector to examine its response to various frequencies, VSWR's and input powers. The following test equipment was used in these tests.

Hewlett-Packard (HP) power meter, model 463A
HP power sensors, models 8481A and 8482H
HP audio gererator, model 200AB
HP SWR meter, model 415E
Alford slotted line assembly consisting of:
- Alford slotted line, type 1026C-6
- Alford taper reducers, types 1122C and 1122D
- Alford tuned probe, type 2162X

Systron Donner digital volt meter, model 7005A
Narda directional coupler, model 3020A
Bird terminator 50 ohms, model 81B
ITT VHF radio transmitter, model T1108/GRT21

TESTS 1 & 2

Test 1 and Test 2 were designed to define the output voltage of the CDI detector with respect to known input power and to verify the linearity of the detector output. For both tests the Narda coupler was used as a reference. Power measurements were taken from the Narda coupler at -24.42 dB (forward port) and -24.62 dB (reflected port) using the HP power meter and power sensor. Voltage measurements were taken from the CDI detector using the Systron Donner digital volt meter (DVM). The VSWR's were varied by inserting a tee and a range of stubs into the line at a point just before the termination. In both Test 1 and Test 2 the line was terminated with a Bird 50 Ohm load.

The configuration of Test 1 was the insertion of the CDI detector closest to the transmitter, followed by the Narda coupler, then the tee and finally the 50 Ohm load (See Figure 1). The configuration of Test 2 was the insertion of the Narda coupler closest to the transmitter, followed by the CDI detector, then the tee and finally the 50 Ohm load (See Figure 2). The positions of the CDI and Narda couplers were switched from Test 1 to Test 2 so that an insertion loss by either could be detected. The tests were conducted at three different frequencies: 133.125, 127, and 118 MHz, representing the high end, center, and low end of the VHF band. Various VSWR's were attained by changing stubs. The VSWR's ranged from approximately 1.02 with no tee to 1.75 with stub number seven inserted in the line. For 133.125 MHz, the VSWR range was extended to 4.0 with the addition of one more stub. This was done to check the operation of the detector outside its expected VSWR range. Both of the tests were conducted at input powers from 5 to 15 watts in 1 watt increments as seen by the Narda coupler. For each set of tests, a DC offset voltage was recorded for the forward and reflected ports on the CDI detector when the transmitter was off. The offsets were recorded to assess their effects on VSWR calulations. A sample run of Test 1 was done with and without 5K Ohm loading resistors across the outputs of the CDI detector and it was determined that the absence of the loading resistors had no effect on the output voltages. This was expected due to the use of op-amps in the detector. Op-amps characteristically have a low output impedance and the presence of the loading resistors across the output of the detector was insignificant. (See Table 2)

TESTS 3 & 4

Test 3 and Test 4 were designed to compare the VSWR's calculated from the CDI detector voltages and the Narda coupler power readings with the VSWR's taken from the slotted line. The slotted line was used as the VSWR measurement standard.

The configuration of Test 3 was similar to the first two tests. The Narda coupler was inserted closest to the transmitter, followed by the slotted line, then the tee and finally the load. Test 4 was identical to Test 3 except that the CDI detector was used in place of the Narda coupler. (See Figures 3 and 4)

Both tests were conducted at the same three frequencies and the same range of VSWR's as in the first two tests. However, only input powers of five, ten, and fifteen watts were used. In Test 3, the power was adjusted to the proper level as seen by the Narda coupler. In Test 4, the input power was adjusted to a voltage level of a known power on the CDI detector. Powers and their corresponding votage levels were taken from Test 1 data.

TEST 5

Test 5 dealt with possible insertion losses in the line due to the presence of the Narda and CDI couplers. The results of this test were needed to validate the assignment of CDI detector voltages to power levels using the data from tests 1 and 2. This test was conducted in three parts; part A was the measurement of the VSWR of the line with just the slotted line, a connector, a tee with stubs, and the 50 Ohm load (See Figure 5). The connector was inserted to account for any insertion losses caused by the connectors in the detectors. The configuration of Part B, was the addition of the CDI detector into the line between the slotted line and the tee. The configuration of Part C was simply the replacement of the Narda for the CDI detector. All of the tests were done at approximately 10 watts input power. In part A, the VSWR's were recorded with the tee alone and then the tee with different stubs attached. These measurements were accepted as the reference for parts B and C. In part B with the CDI detector added, VSWR readings were taken with the detector supply voltage on and off so that any effects generated by the CDI in the line were noted. In part C, any effects of the Narda coupler on the VSWR's were noted.

TEST RESULTS

TESTS 1 & 2

The data from Test 1 and Test 2 related CDI detector voltages with transmission line power levels. However, when the CDI detector voltages were squared and then compared to the power levels, the relationship between them was found to be linear. Plots were generated on a Tektronix 4054 graphics terminal for forward CDI detector voltage squared vs. forward Narda coupler power and reflected CDI detector voltage squared vs. reflected Narda coupler power. Each plot shown, except for the ones with multiple traces, has a straight line superimposed over the line tracing the points. The straight line was calculated from the data points using linear regression. The linearity was consistant throughout the power range, the VSWR range and the frequency range (See Figures 6 through 21). The CDI detector voltage squared function remained linear even at a 4:1 VSWR, which is far outside the intended range of the detector (See Figures 22 through 25). Plots of this data were done with and without the subtraction of the offset voltage in the CDI detector. Linearity was slightly improved without the offset voltage correction (See Figures 26 and 27). Both graphs have a "best fit" line superimposed over the points.

TESTS 3 & 4

Tests 3 and 4 compared VSWR's calculated from the CDI and Narda Couplers with VSWR's measured on the slotted line. The VSWR from the Narda power readings was calculated using the following formula:

$$[1] \quad VSWR = \frac{1+\sqrt{Pr/Pf}}{1-\sqrt{Pr/Pf}}$$

Where: Pf=Forward Power
Pr=Reflected Power

The VSWR from the CDI voltages was calculated with this formula:

$$[2] \quad VSWR = \frac{1+(Vr/Vf)}{1-(Vr/Vf)}$$

Where: Vf=Forward CDI Voltage
Vr=Reflected CDI Voltage

See Appendix A for the derivation of Equation 2 from Equation 1.

If the CDI offset voltages were taken into consideration, this formula was used:

$$[3] \quad VSWR = \frac{1+[(Vr-Or)/(Vf-Of)]}{1-[(Vr-Or)/(Vf-Of)]}$$

Where: Of=Forward Offset Voltage
Or=Reflected Offset Voltage

VSWR's and their percent deviation were calculated and compared (See Tables 3 to 11). The Narda coupler displayed a small, but consistent deviation from the slotted line. The CDI detector values without the offset correction were found to be very close to the slotted line values. When the offset correction was included, a shift in the values occurred, introducing a greater error.

TEST 5

As seen in the data, there was no significant change in the VSWR caused by the insertion of the Narda and CDI detectors. The little change shown is random and probably due to reading error on the slotted line.

CONCLUSIONS

Based on these tests, it is concluded that:

1. The directional power detector (DPD) tested is acceptable as a sensor for the RMMS project.

2. The DPD performed satisfactorily over the required power and frequency range.

3. The CDI detector voltage squared output is linear with respect to transmission line power.

4. The VSWR calculated from the output of the CDI detector without the offset correction is within +/- 3% when compared to slotted line values. With the offset correction included, the deviation is within +/- 6%.

RECOMMENDATIONS

It is recommended that:

1. A selection of the directional power detectors be obtained from a production run and that similar testing be conducted on them to verify that their characteristics are consistent.

2. An ultra high frequency (UHF) directional power detector (model 3183) made by CDI, with specifications similar to the VHF detector, should be tested to verify its characteristics.

3. Tests be conducted to determine if percent modulation may be accurately measured from the CDI detector output.

NARDA POWER		CDI WITH RESISTOR		CDI WITHOUT RESISTOR	
FORWARD (mw)	REFLECTED (mw)	FORWARD (volts)	REFLECTED (volts)	FORWARD (volts)	REFLECTED (volts)
54.2	5.30	4.895	1.532	4.893	1.530
50.6	4.94	4.742	1.490	4.737	1.489
46.9	4.58	4.566	1.469	4.560	1.466
43.3	4.22	4.384	1.420	4.387	1.419
39.7	3.88	4.200	1.373	4.198	1.373
36.1	3.53	4.009	1.323	4.010	1.323
32.5	3.17	3.802	1.284	3.798	1.285
28.9	2.82	3.590	1.239	3.607	1.239
25.3	2.47	3.364	1.195	3.359	1.195
21.7	2.14	3.150	1.146	3.148	1.142
18.1	1.77	3.094	1.090	3.090	1.093

TABLE 2. CDI Data With and Without Loading Resistors
(Data taken at 133.125 MHz. from Test 1 at 2:1 VSWR)

TABLE 3. VSWR PERCENT DEVIATION, NARDA VS. SLOTTED LINE AT 133.125 MHz (FROM TEST 3)

CDI 3182 133.125 MHz TEST 3 7/20/82

VSWR NARDA	VSWR SLOTTED LINE	% DEVIATION
NO TEE		
1.011	1.030	-1.848
1.010	1.029	-1.826
1.010	1.028	-1.760
TEE, NO STUB		
1.099	1.085	1.330
1.098	1.084	1.303
1.097	1.084	1.201
STUB #1		
1.474	1.460	0.959
1.475	1.460	1.030
1.472	1.460	0.848
STUB #2		
1.560	1.550	0.675
1.560	1.550	0.649
1.558	1.550	0.502
STUB #4		
1.616	1.610	0.372
1.614	1.610	0.221
1.614	1.610	0.257
STUB #7		
1.791	1.790	0.074
1.789	1.790	-0.046
1.788	1.790	-0.131
STUB #9		
1.958	1.950	0.416
1.951	1.960	-0.463
1.953	1.960	-0.363

TABLE 4. VSWR PERCENT DEVIATION, CDI VS. SLOTTED LINE AT 133.125 MHz (FROM TEST 4) WITHOUT OFFSET CORRECTION

CDI 3182 133.125 MHz TEST 4 7/20/82

VSWR CDI	VSWR SLOTTED LINE	% DEVIATION
NO TEE		
1.034	1.030	0.388
1.042	1.029	1.275
1.060	1.028	3.100
TEE, NO STUB		
1.083	1.085	-0.156
1.086	1.084	0.217
1.098	1.084	1.303
STUB #1		
1.444	1.460	-1.075
1.445	1.460	-1.036
1.451	1.460	-0.592
STUB #2		
1.532	1.550	-1.153
1.533	1.550	-1.076
1.541	1.550	-0.573
STUB #4		
1.588	1.610	-1.386
1.590	1.610	-1.253
1.599	1.610	-0.705
STUB #7		
1.767	1.790	-1.270
1.771	1.790	-1.054
1.784	1.790	-0.335
STUB #9		
1.939	1.950	-0.569
1.940	1.960	-1.020
1.960	1.960	-0.023

TABLE 5. VSWR PERCENT DEVIATION, CDI VS. SLOTTED LINE AT 133.125 MHz (FROM TEST 4) WITH OFFSET CORRECTION

CDI 3182 133.125 MHz TEST 4 7/20/82 (WITH OFFSET CORRECTION)

VSWR CDI	VSWR SLOTTED LINE	% DEVIATION
NO TEE		
1.003	1.030	-2.663
1.003	1.029	-2.567
1.002	1.028	-2.550
TEE, NO STUB		
1.051	1.085	-3.175
1.045	1.084	-3.557
1.038	1.084	-4.226
STUB #1		
1.402	1.460	-3.985
1.392	1.460	-4.664
1.374	1.460	-5.873
STUB #2		
1.487	1.550	-4.059
1.477	1.550	-4.701
1.459	1.550	-5.850
STUB #4		
1.541	1.610	-4.287
1.532	1.610	-4.870
1.514	1.610	-5.982
STUB #7		
1.715	1.790	-4.189
1.706	1.790	-4.694
1.689	1.790	-5.656
STUB #9		
1.881	1.950	-3.535
1.868	1.960	-4.695
1.854	1.960	-5.400

TABLE 6. VSWR PERCENT DEVIATION, NARDA VS. SLOTTED LINE AT 127 MHz (FROM TEST 3)

CDI 3:82 127 MHz TEST 3 8/11/82

VSWR NARDA	VSWR SLOTTED LINE	% DEVIATION
NO TEE		
1.038	1.020	1.786
1.038	1.020	1.783
1.039	1.020	1.828
TEE, NO STUB		
1.057	1.075	-1.719
1.057	1.075	-1.641
1.057	1.075	-1.669
STUB #1		
1.385	1.400	-1.057
1.385	1.420	-2.435
1.385	1.420	-2.480
STUB #2		
1.458	1.490	-2.117
1.459	1.500	-2.752
1.459	1.500	-2.742
STUB #4		
1.507	1.550	-2.744
1.507	1.550	-2.774
1.507	1.560	-3.425
STUB #7		
1.654	1.680	-1.573
1.653	1.700	-2.748
1.653	1.730	-4.480
STUB #9		
1.789	1.850	-3.315
1.789	1.850	-3.287
1.788	1.850	-3.370

TABLE 7. VSWR PERCENT DEVIATION, CDI VS. SLOTTED LINE AT 127 MHz (FROM TEST 4) WITHOUT OFFSET CORRECTION

CDI 3182 127 MHz TEST 4 8/11/82

VSWR CDI	VSWR SLOTTED LINE	% DEVIATION
NO TEE		
1.036	1.020	1.595
1.045	1.020	2.406
1.063	1.020	4.231
TEE, NO STUB		
1.079	1.075	0.337
1.082	1.075	0.657
1.095	1.075	1.856
STUB #1		
1.412	1.400	0.889
1.414	1.420	-0.394
1.421	1.420	0.038
STUB #2		
1.493	1.490	0.217
1.495	1.500	-0.337
1.502	1.500	0.114
STUB #4		
1.545	1.550	-0.338
1.547	1.550	-0.203
1.556	1.560	-0.285
STUB #7		
1.706	1.680	1.523
1.709	1.700	0.531
1.721	1.730	-0.495
STUB #9		
1.854	1.850	0.227
1.859	1.850	0.502
1.874	1.850	1.310

TABLE 8. VSWR PERCENT DEVIATION, CDI VS. SLOTTED LINE AT 127 MHz (FROM TEST 4) WITH OFFSET CORRECTION

CDI 3182 127 MHz TEST 4 8/11/82 (WITH OFFSET CORRECTION)

VSWR CDI	VSWR SLOTTED LINE	% DEVIATION
NO TEE		
1.003	1.020	-1.638
1.003	1.020	-1.648
1.002	1.020	-1.719
TEE, NO STUB		
1.045	1.075	-2.826
1.040	1.075	-3.299
1.033	1.075	-3.932
STUB #1		
1.370	1.400	-2.166
1.361	1.420	-4.158
1.343	1.420	-5.427
STUB #2		
1.448	1.490	-2.805
1.439	1.500	-4.086
1.420	1.500	-5.332
STUB #4		
1.498	1.550	-3.337
1.489	1.550	-3.949
1.471	1.560	-5.700
STUB #7		
1.654	1.680	-1.528
1.645	1.700	-3.234
1.628	1.730	-5.883
STUB #9		
1.798	1.850	-2.790
1.790	1.850	-3.265
1.773	1.850	-4.180

TABLE 9. VSWR PERCENT DEVIATION, NARDA VS. SLOTTED LINE AT 118 MHz (FROM TEST 3).

CDI 3:82 118 MHz TEST 3 8/16/82

VSWR NARDA	VSWR SLOTTED LINE	% DEVIATION
NO TEE		
1.014	1.025	-1.113
1.014	1.020	-0.612
1.014	1.022	-0.829
TEE, NO STUB		
1.020	1.070	-4.702
1.019	1.075	-5.164
1.019	1.080	-5.631
STUB #1		
1.359	1.400	-2.913
1.359	1.400	-2.918
1.35[illegible]	1.400	-3.473
STUB #2		
1.427	1.455	-1.949
1.426	1.460	-2.329
1.417	1.460	-2.929
STUB #4		
1.468	1.500	-2.146
1.466	1.500	-2.284
1.459	1.500	-2.742
STUB #7		
1.596	1.630	-2.071
1.594	1.630	-2.179
1.585	1.630	-2.741
STUB #9		
[illegible]4	1.750	-2.076
1.699	1.750	-2.942
1.698	1.750	-2.946

TABLE 10. VSWR PERCENT DEVIATION, CDI VS. SLOTTED LINE AT 118 MHz (FROM TEST 4) WITHOUT OFFSET CORRECTION

CDI 3182 118 MHz TEST 4 8/16/82

VSWR CDI	VSWR SLOTTED LINE	% DEVIATION
NO TEE		
1.037	1.025	1.198
1.244	1.025	1.901
1.263	1.025	3.684
TEE, NO STUB		
1.068	1.077	-0.882
1.072	1.077	-0.501
1.085	1.077	0.755
STUB #1		
1.361	1.400	-2.814
1.362	1.400	-2.708
1.369	1.400	-2.183
STUB #2		
1.430	1.460	-2.070
1.432	1.460	-1.945
1.438	1.460	-1.499
STUB #4		
1.473	1.500	-1.782
1.475	1.500	-1.654
1.484	1.500	-1.097
STUB #7		
1.609	1.630	-1.268
1.611	1.630	-1.152
1.621	1.630	-0.571
STUB #9		
1.735	1.750	-0.854
1.740	1.750	-0.597
1.753	1.750	0.144

TABLE 11. VSWR PERCENT DEVIATION, CDI VS. SLOTTED LINE AT 118 MHz (FROM TEST 4) WITH OFFSET CORRECTION

CDI 3182 118 MHz TEST 4 8/16/82 (WITH OFFSET CORRECTION)

VSWR CDI	VSWR SLOTTED LINE	% DEVIATION
NO TEE		
1.005	1.025	-1.942
1.004	1.025	-2.021
1.004	1.025	-2.092
TEE, NO STUB		
1.035	1.077	-3.938
1.031	1.077	-4.310
1.025	1.077	-4.840
STUB #1		
1.320	1.400	-5.703
1.312	1.400	-6.297
1.296	1.400	-7.429
STUB #2		
1.387	1.460	-4.968
1.379	1.460	-5.547
1.361	1.460	-6.757
STUB #4		
1.430	1.500	-4.685
1.421	1.500	-5.258
1.404	1.500	-6.371
STUB #7		
1.562	1.630	-4.176
1.552	1.630	-4.765
1.535	1.630	-5.852
STUB #9		
1.684	1.750	-3.774
1.676	1.750	-4.229
1.659	1.750	-5.180

TEST 1

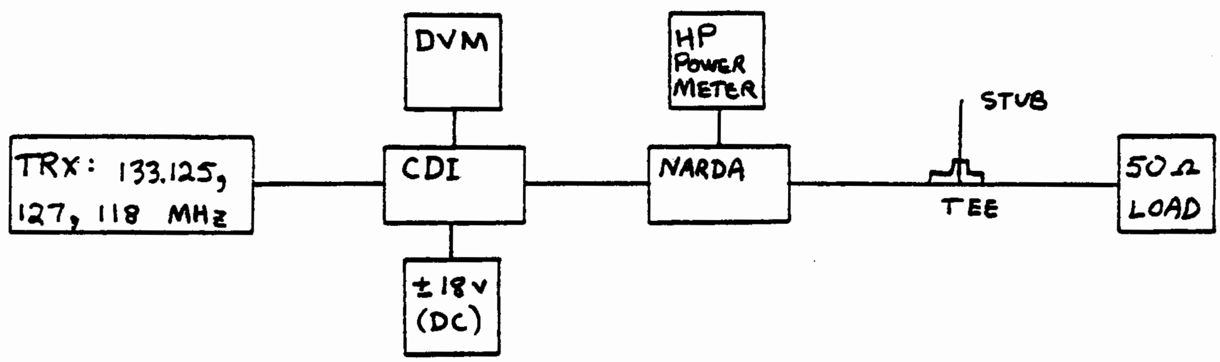


FIGURE 1. TEST 1 CONFIGURATION

TEST 2

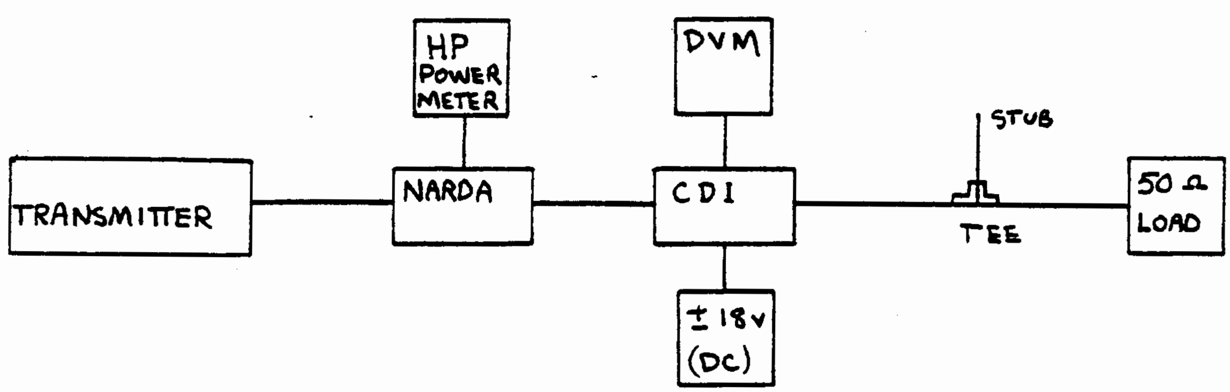


FIGURE 2. TEST 2 CONFIGURATION

TEST 3

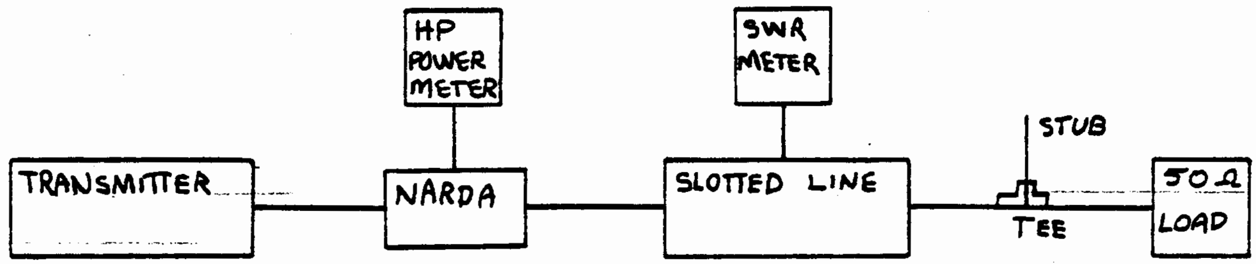


FIGURE 3. TEST 3 CONFIGURATION

TEST 4

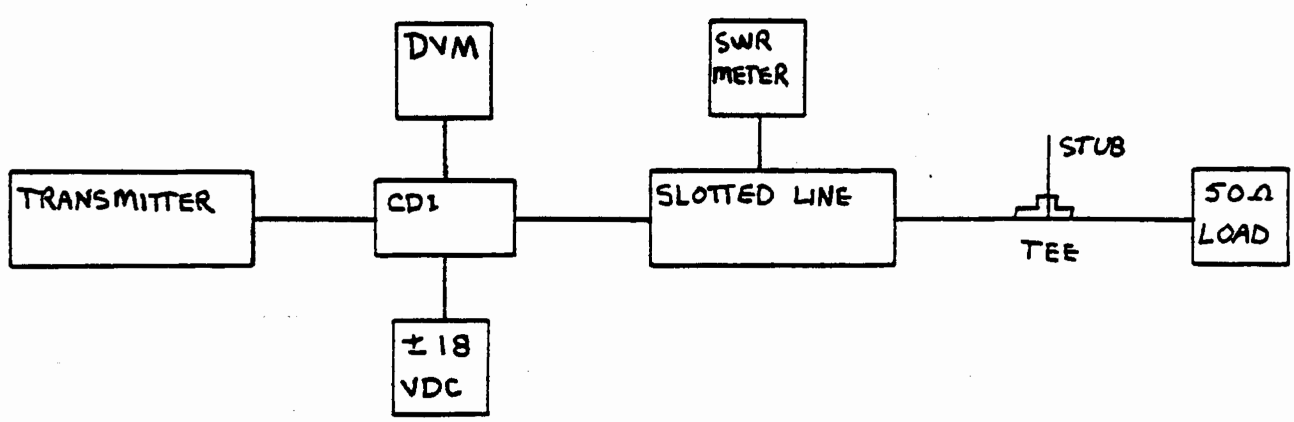
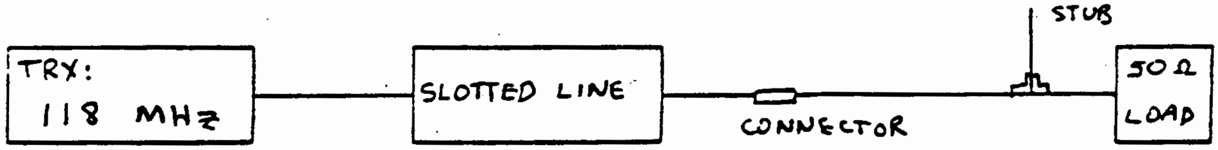


FIGURE 4. TEST 4 CONFIGURATION

8/11/[illegible]

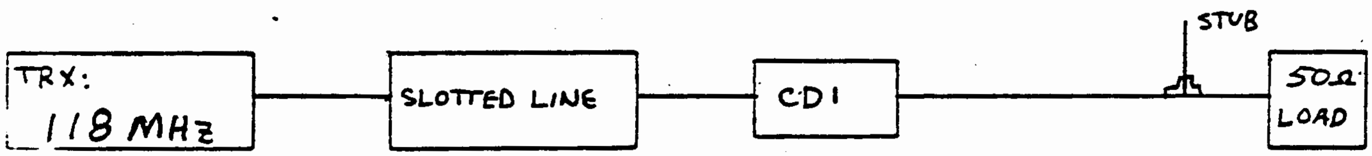
TEST 5 118 MHz TRx POWER ≈ 10 WATTS

a)



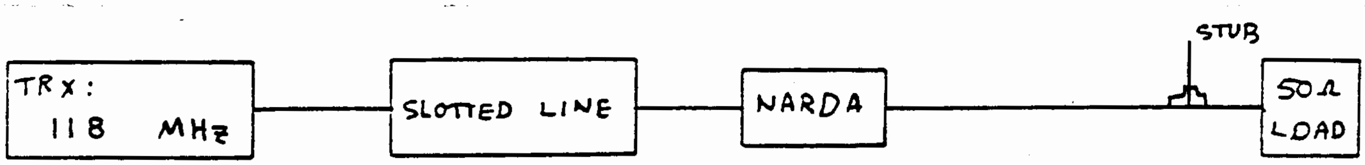
STUB #	VSWR
WITH TEE	1.065
# 1	1.321
# 2	1.375

b)



	VSWR	
STUB #	CDI ON	CDI OFF
WITH TEE	1.065	1.065
# 1	1.325	1.325
# 2	1.38	1.38

c)



STUB #	VSWR
WITH TEE	1.065
# 1	1.330
# 2	1.375

FIGURE 5. TEST 5 CONFIGURATIONS (TESTS CONDUCTED AT APPROXIMATELY 10 WATTS)

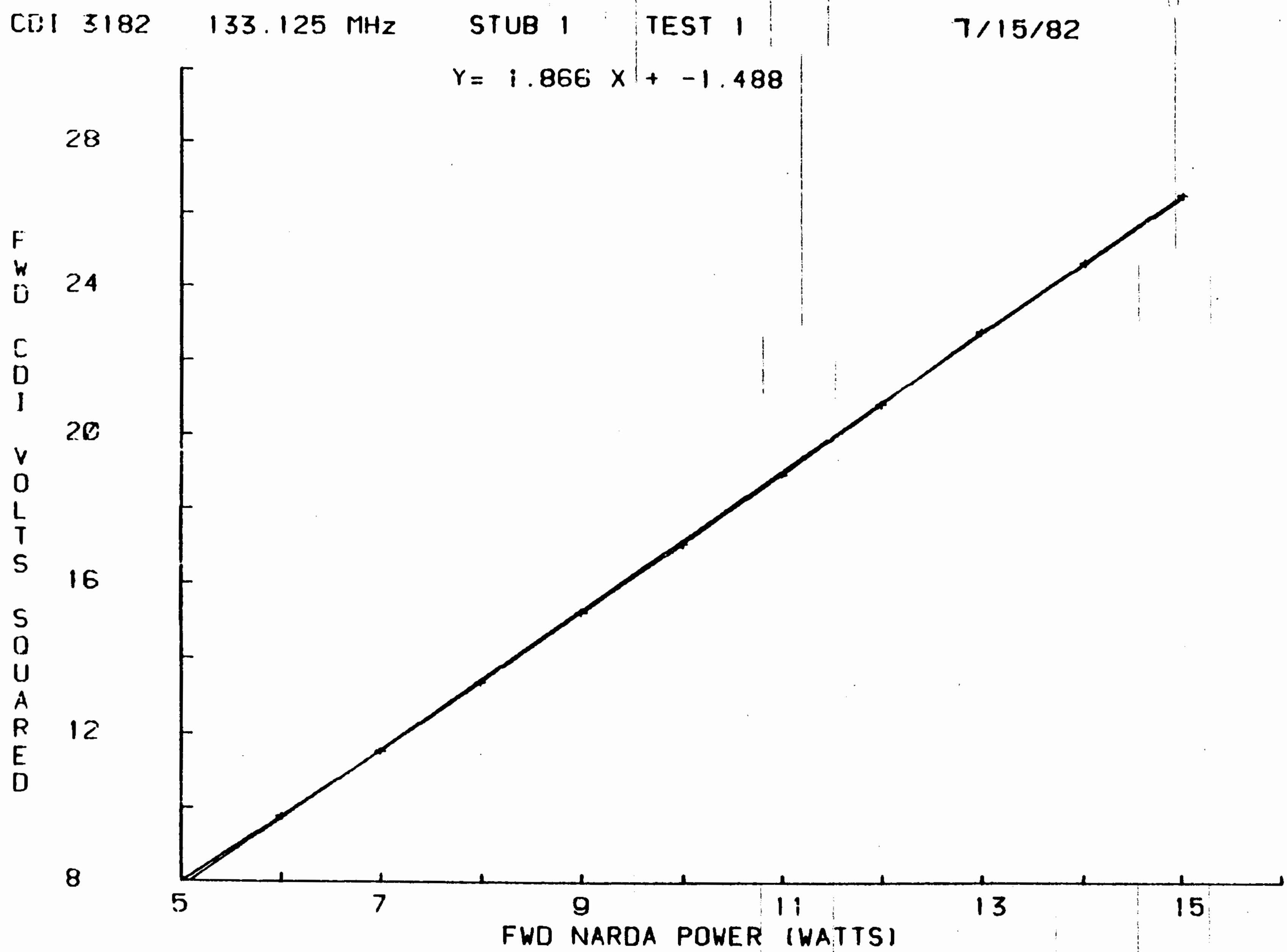


FIGURE 6. FORWARD CDI VOLTABE SQUARED VS. FORWARD NARDA POWER AT 133.125 MHz (FROM TEST 1) WITH STRAIGHT LINE SUPERIMPOSED

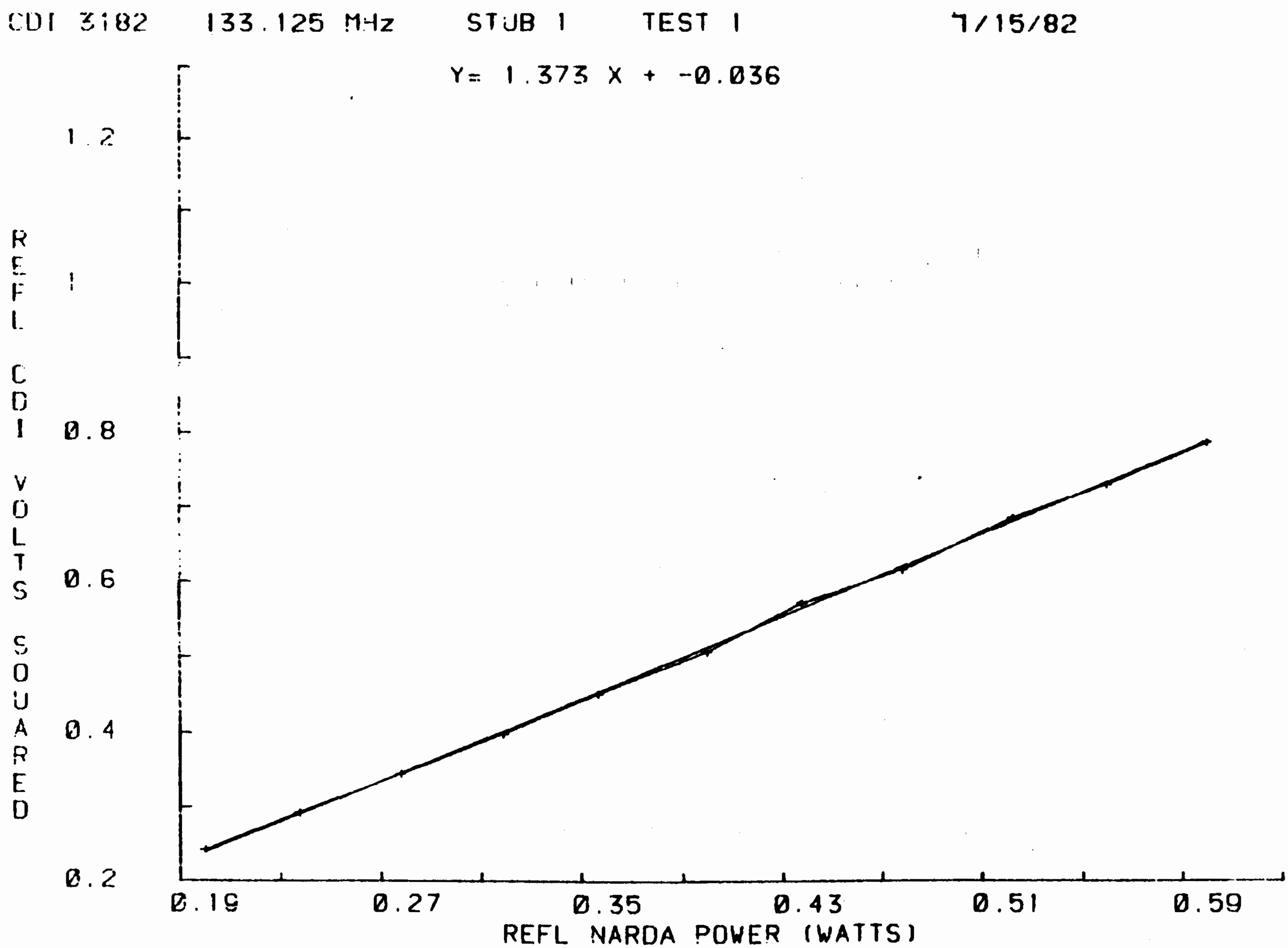


FIGURE 7. REFLECTED CDI VOLTAGE SQUARED VS. REFLECTED NARDA POWER AT 133.125 MHz (FROM TEST 1) WITH STRAIGHT LINE SUPERIMPOSED.

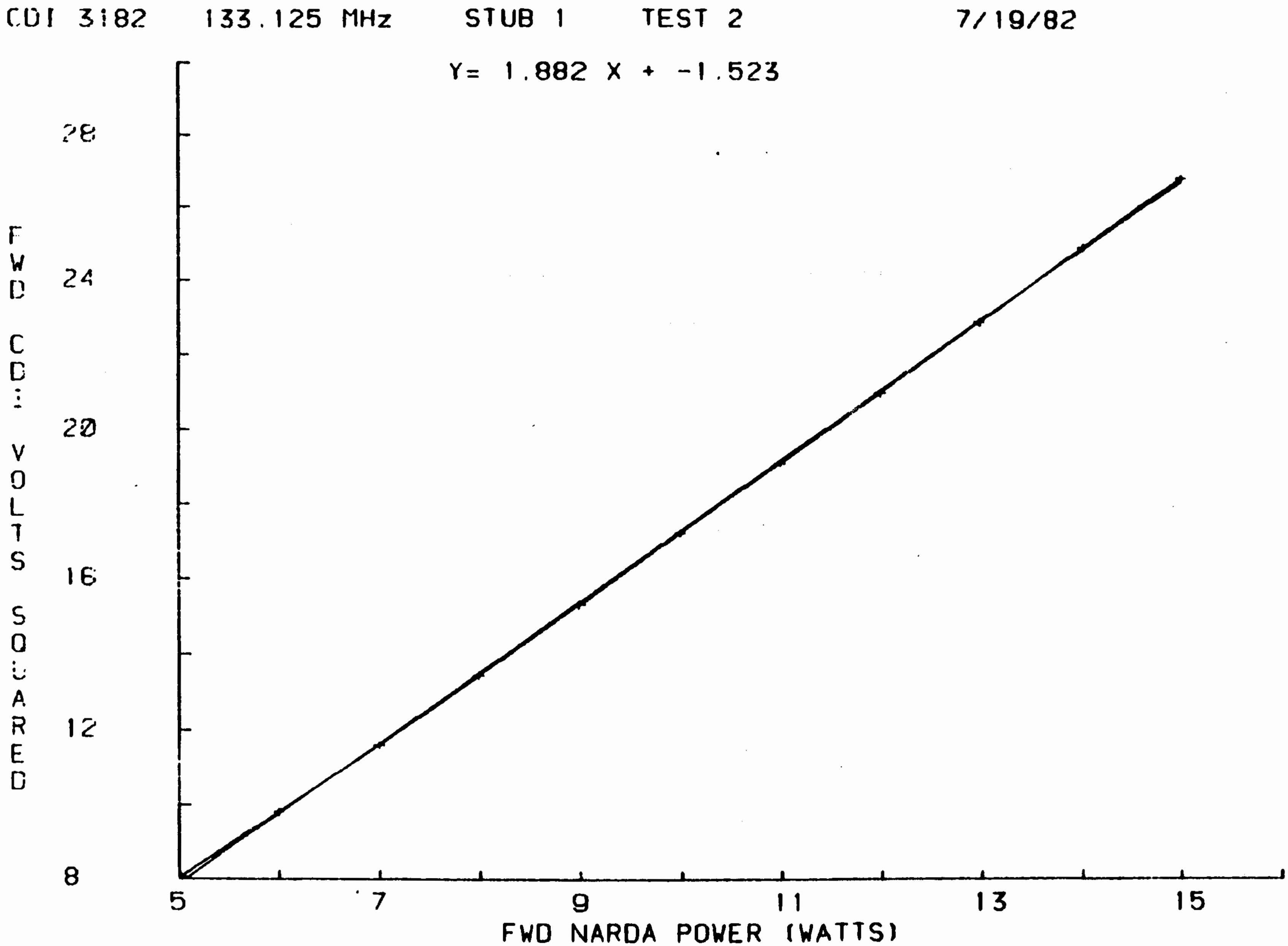


FIGURE 8. FORWARD CDI VOLTAGE SQUARED VS. FORWARD NARDA POWER AT 133.125 MHz (FROM TEST 2) WITH STRAIGHT LINE SUPERIMPOSED

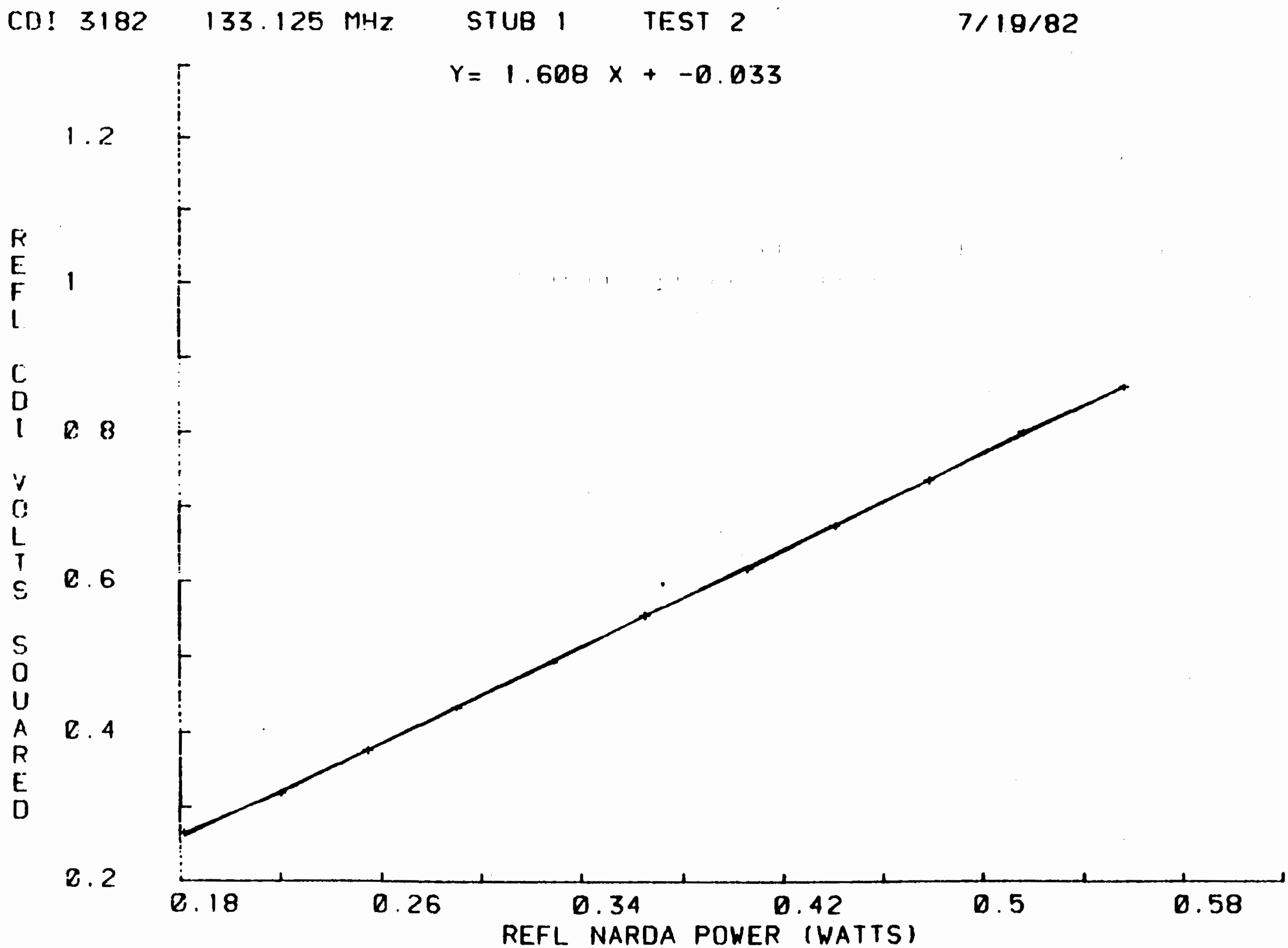


FIGURE 9. REFLECTED CDI VOLTAGE SQUARED VS. REFLECTED NARDA POWER AT 133.125 MHz (FROM TEST 2) WITH STRAIGHT LINE SUPERIMPOSED

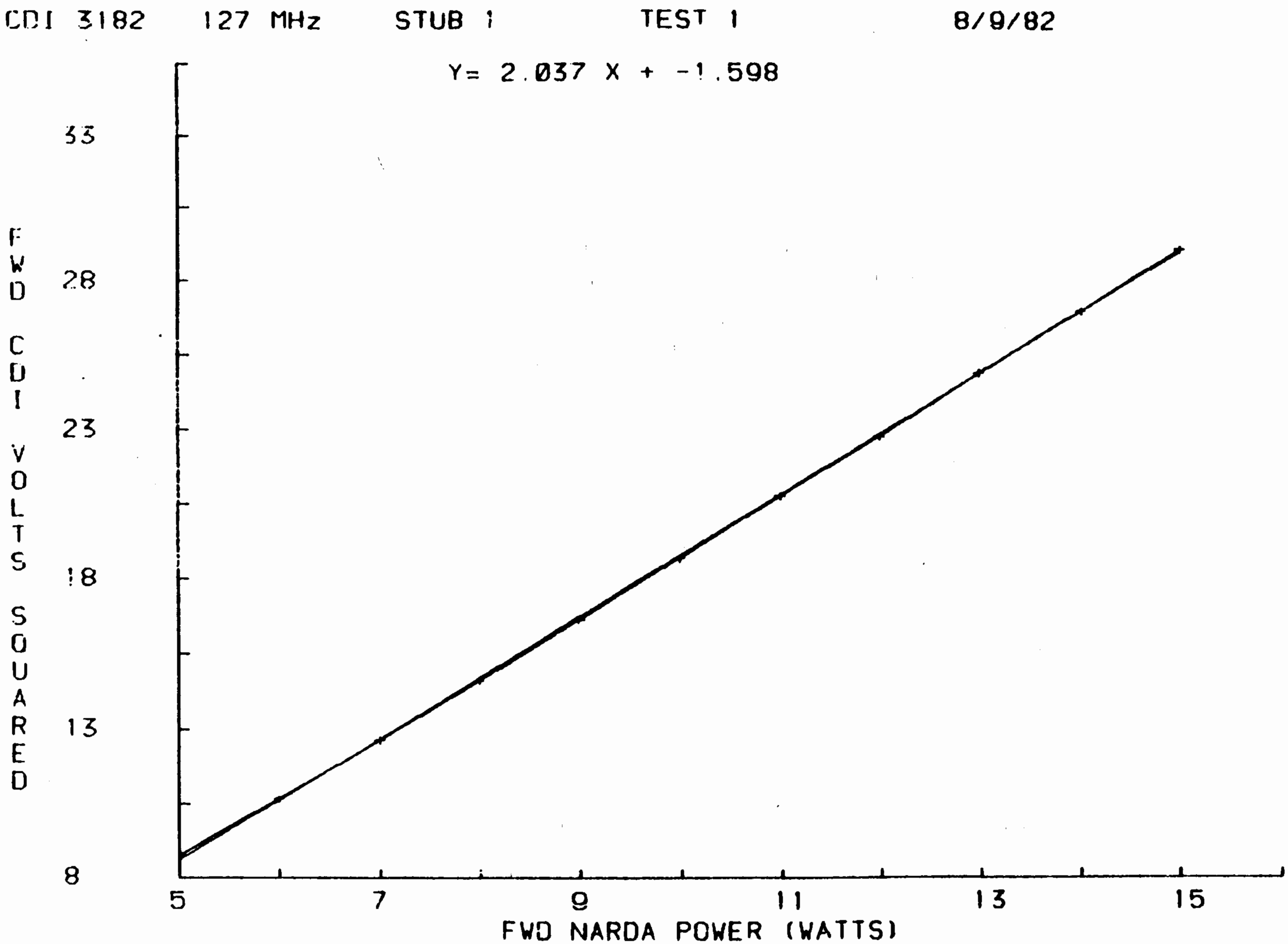


FIGURE 10. FORWARD CDI VOLTAGE SQUARED VS. FORWARD NARDA POWER AT 127 MHz (FROM TEST 1) WITH STRAIGHT LINE SUPERIMPOSED

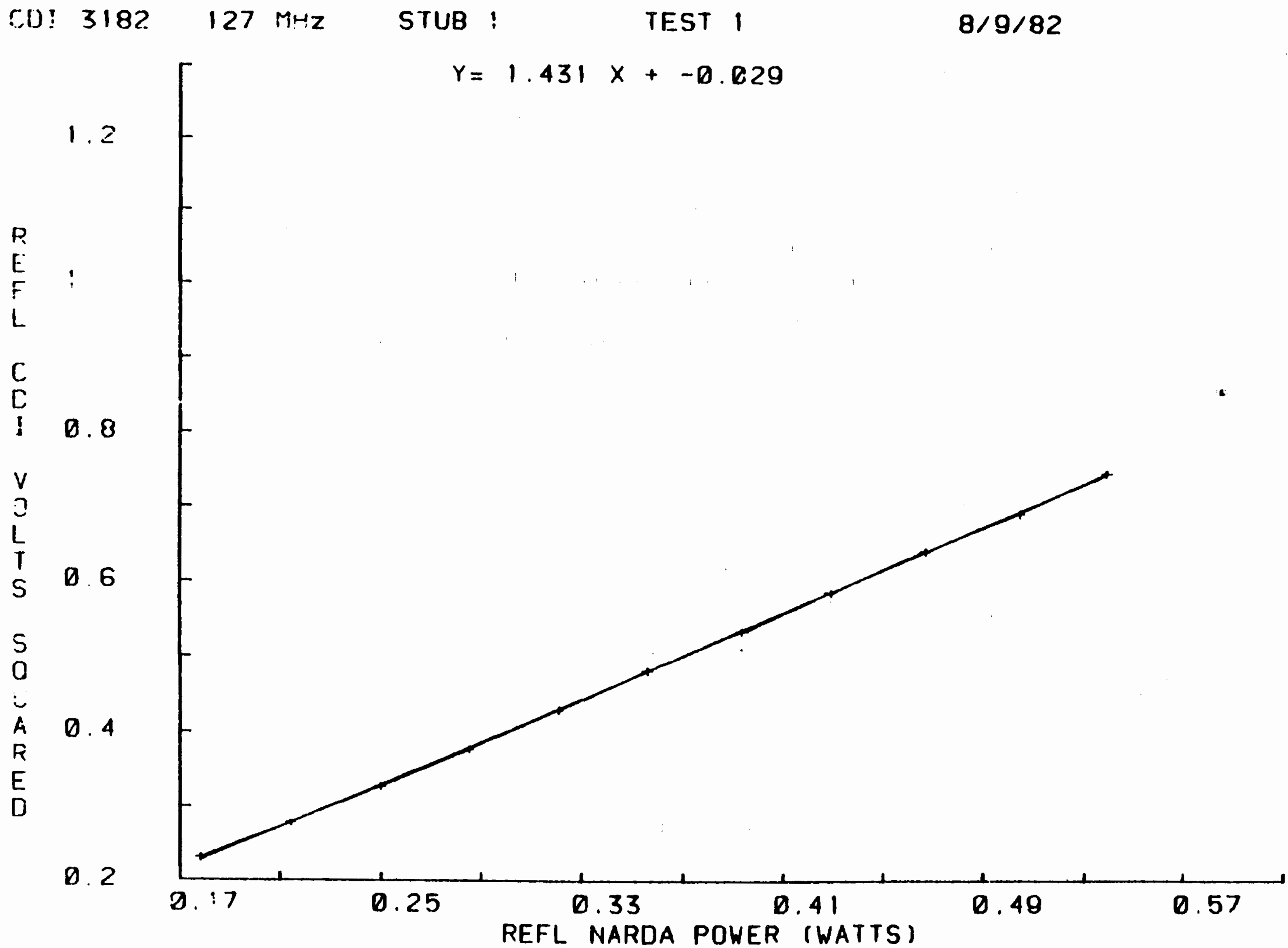


FIGURE 11. REFLECTED CDI VOLTAGE SQUARED VS. REFLECTED NARDA POWER AT 127 MHz (FROM TEST 1) WITH STRAIGHT LINE SUPERIMPOSED

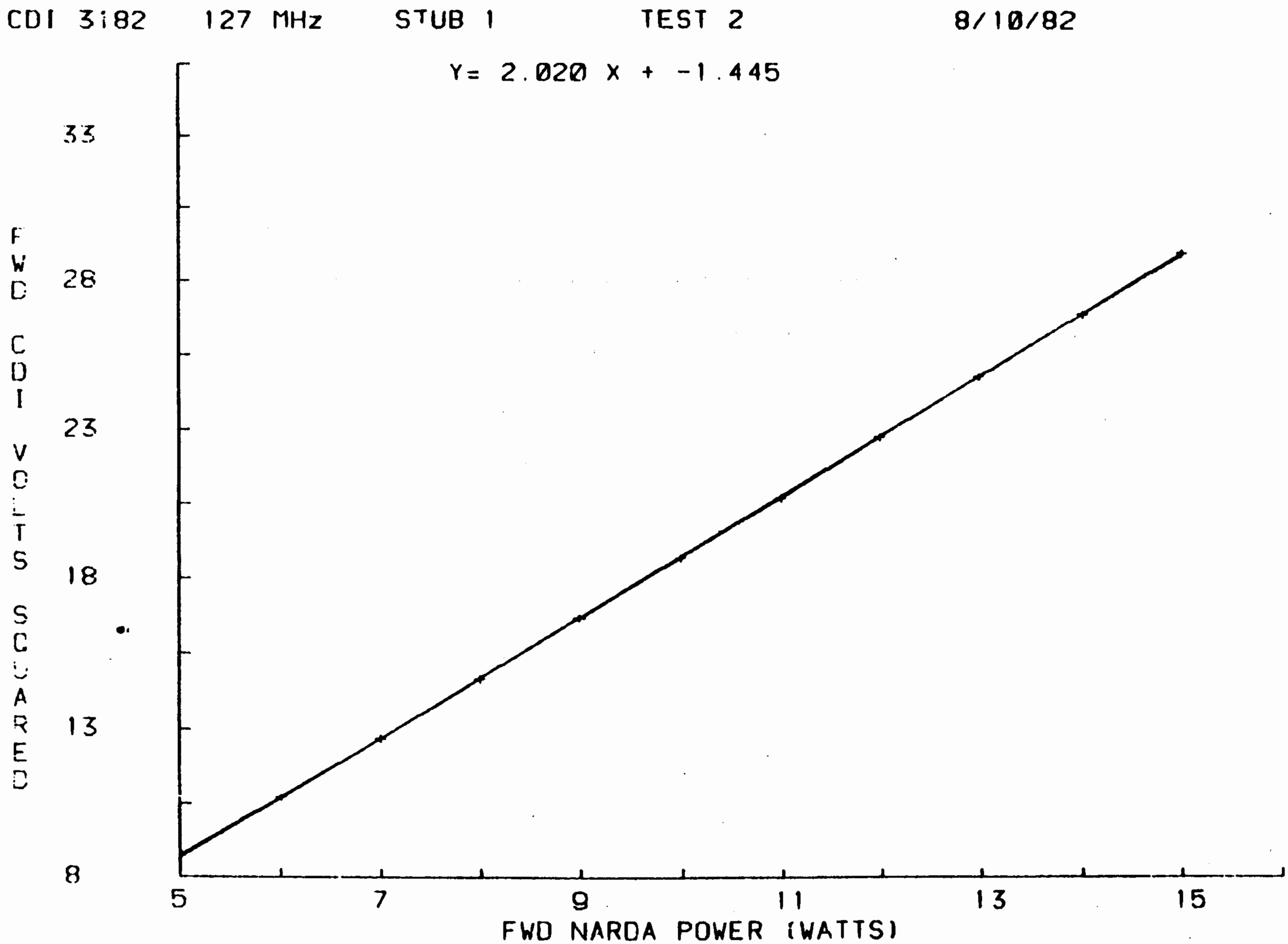


FIGURE 12. FORWARD CDI VOLTAGE SQUARED VS. FORWARD NARDA POWER AT 127 NHz (FROM TEST 2) WITH STRAIGHT LINE SUPERIMPOSED

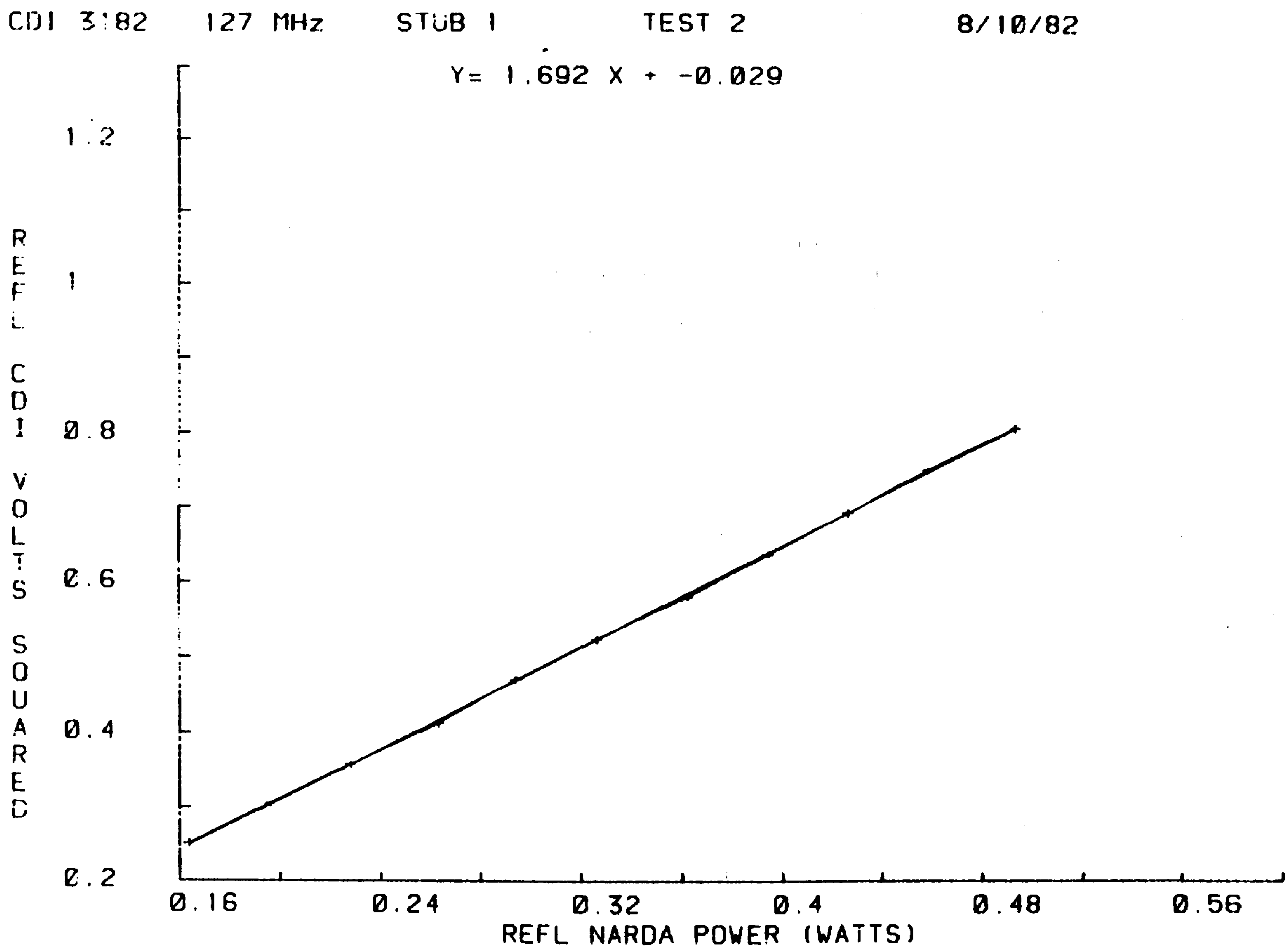


FIGURE 13. REFLECTED CDI VOLTAGE SQUARED VS. REFLECTED NARDA POWER AT 127 MHz (FROM TEST 2) WITH STRAIGHT LINE SUPERIMPOSED

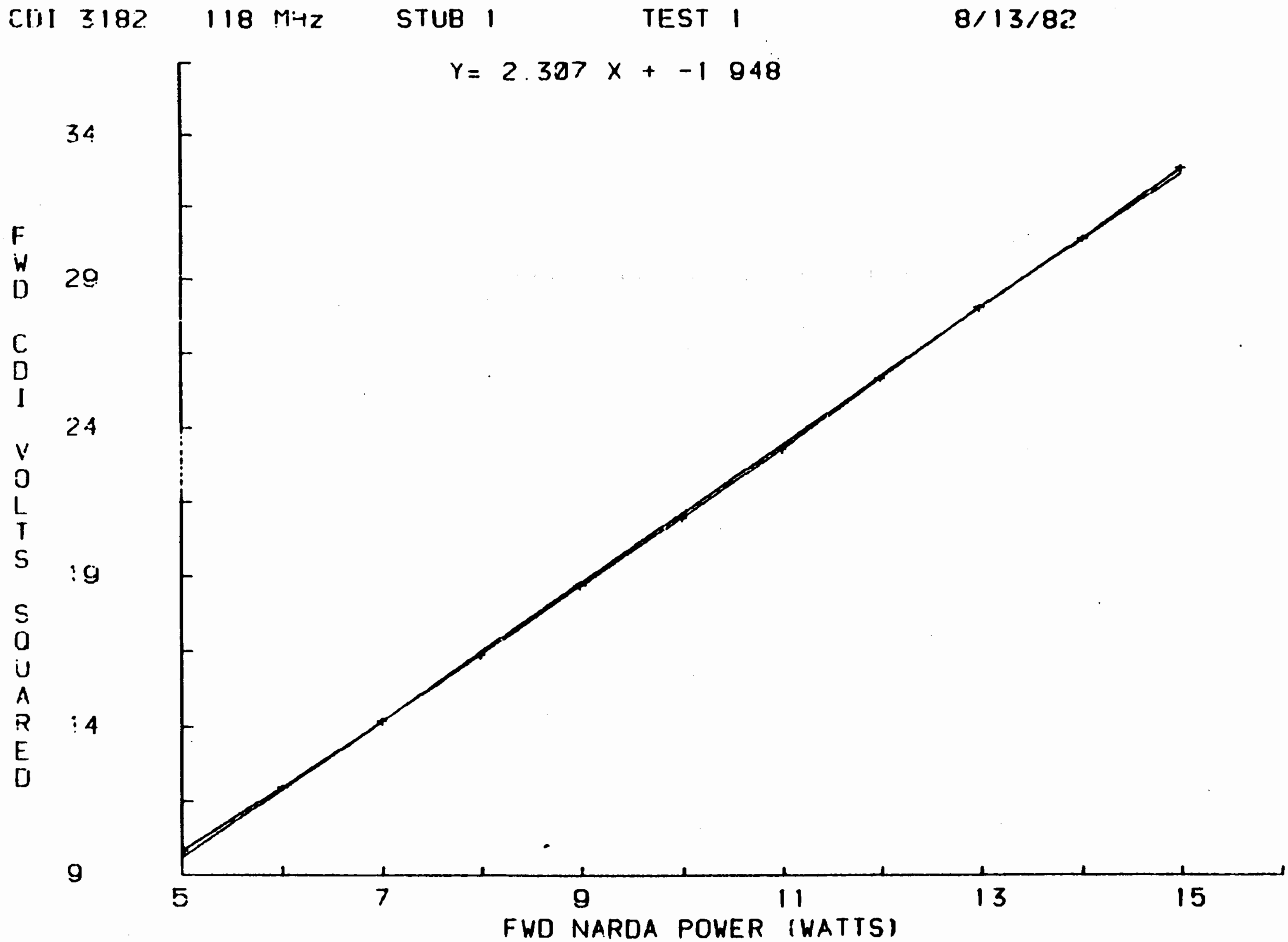


FIGURE 14. FORWARD CDI VOLTAGE SUARED VS. FORWARD NARDA POWER AT 118 MHz (FROM TEST 1) WITH STRAIGHT LINE SUPERIMPOSED

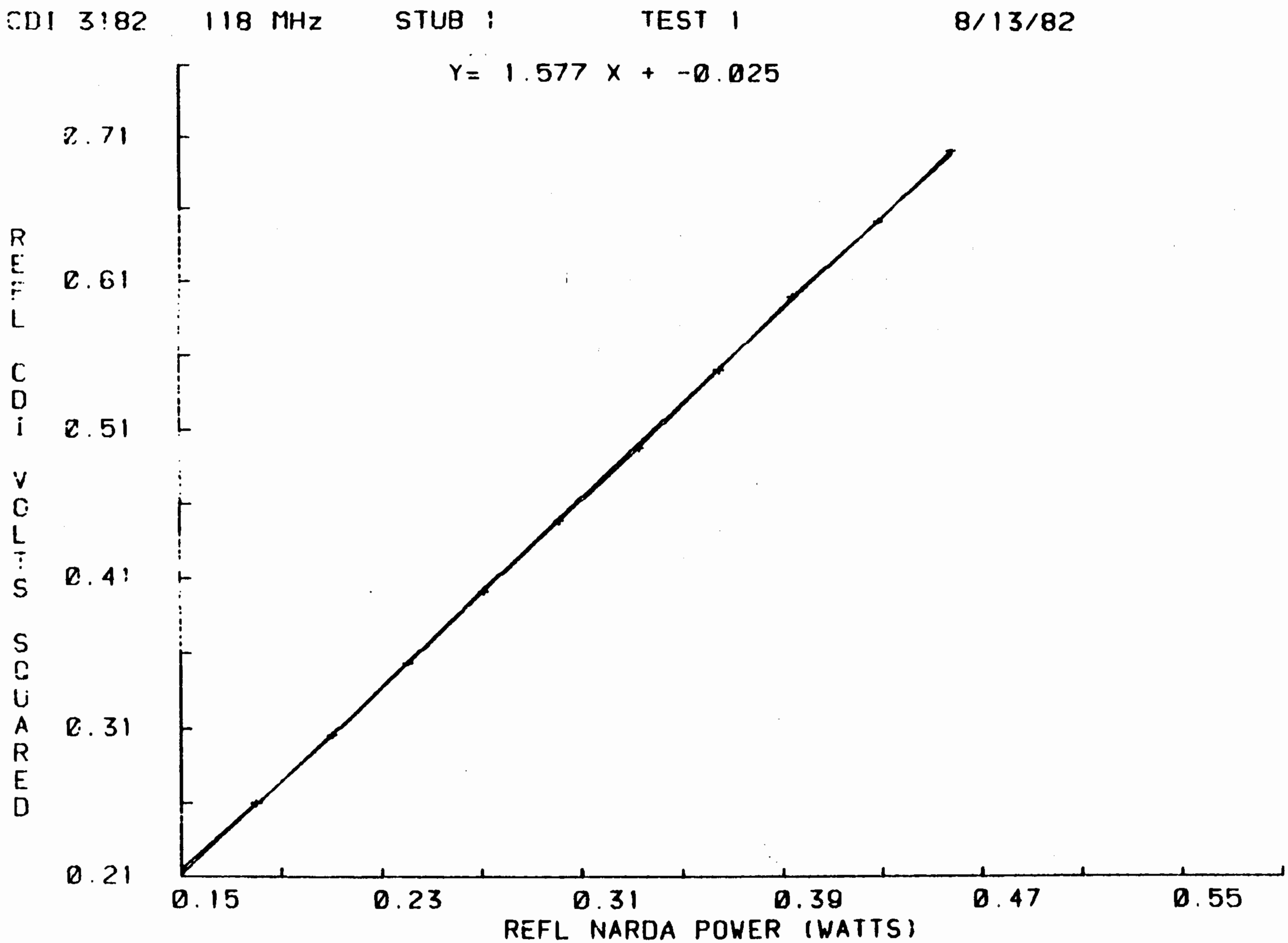


FIGURE 15. REFLECTED CDI VOLTAGE SQUARED VS. REFLECTED NARDA POWER AT 118 MHz (FROM TEST 1) WITH STRAIGHT LINE SUPERIMPOSED

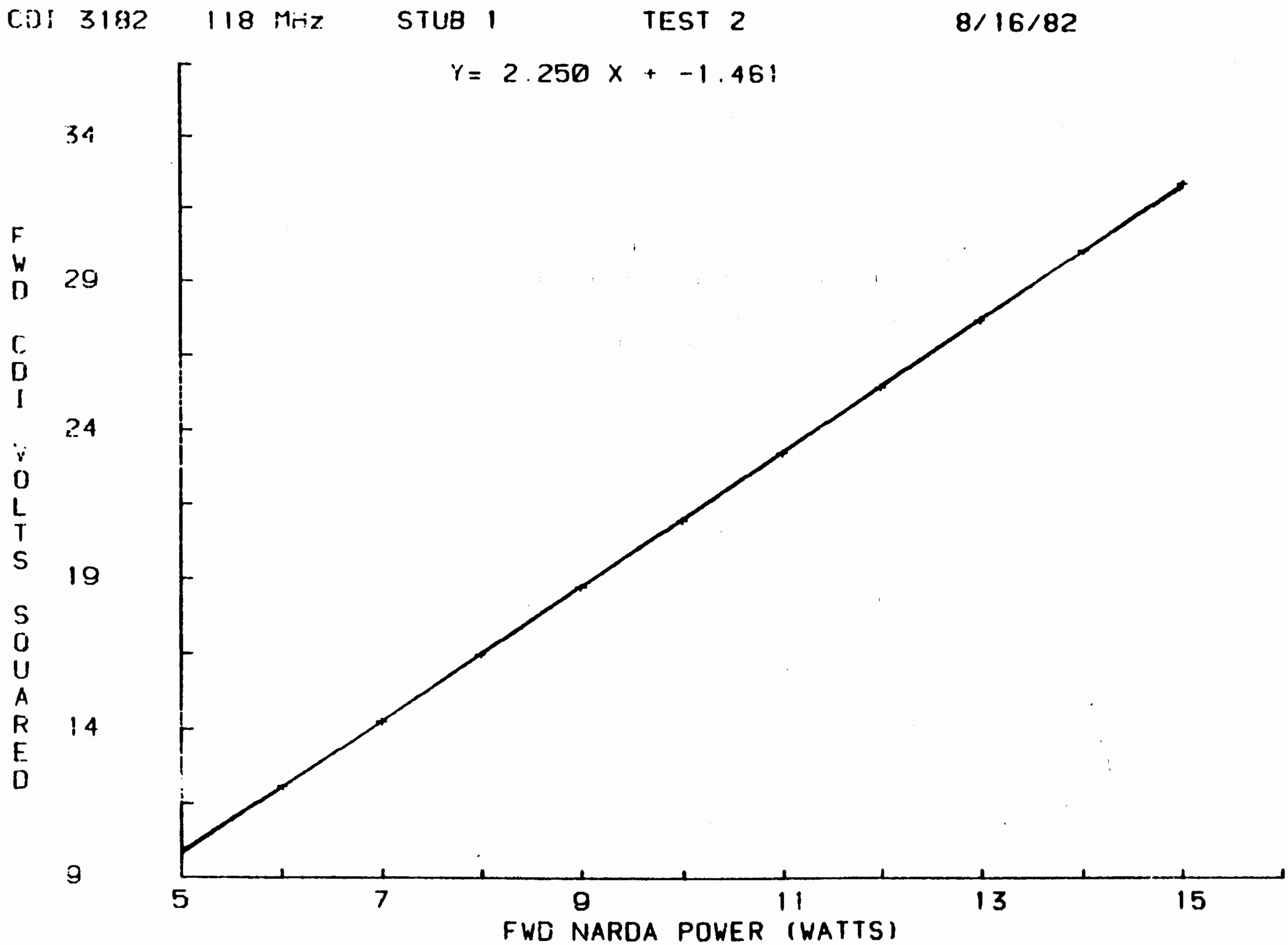


FIGURE 16. FORWARD CDI VOLTAGE SQUARED VS. FORWARD NARDA POWER AT 118 MHz (FROM TEST 2) WITH STRAIGHT LINE SUPERIMPOSED

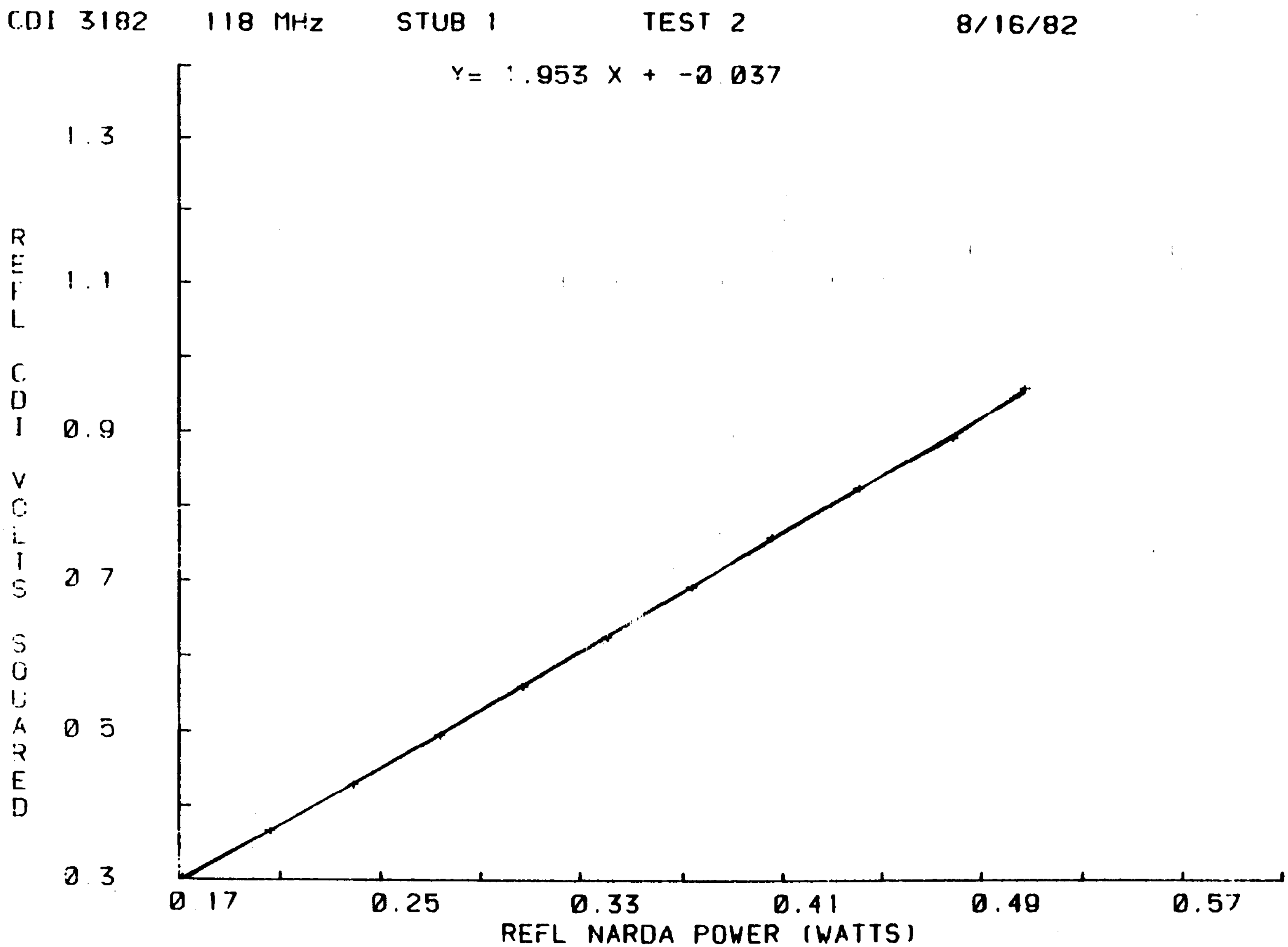


FIGURE 17. REFLECTED CDI VOLTAGE SQUARED VS. REFLECTED NARDA POWER AT 118 MHz (FROM TEST 2) WITH STRAIGHT LINE SUPERIMPOSED

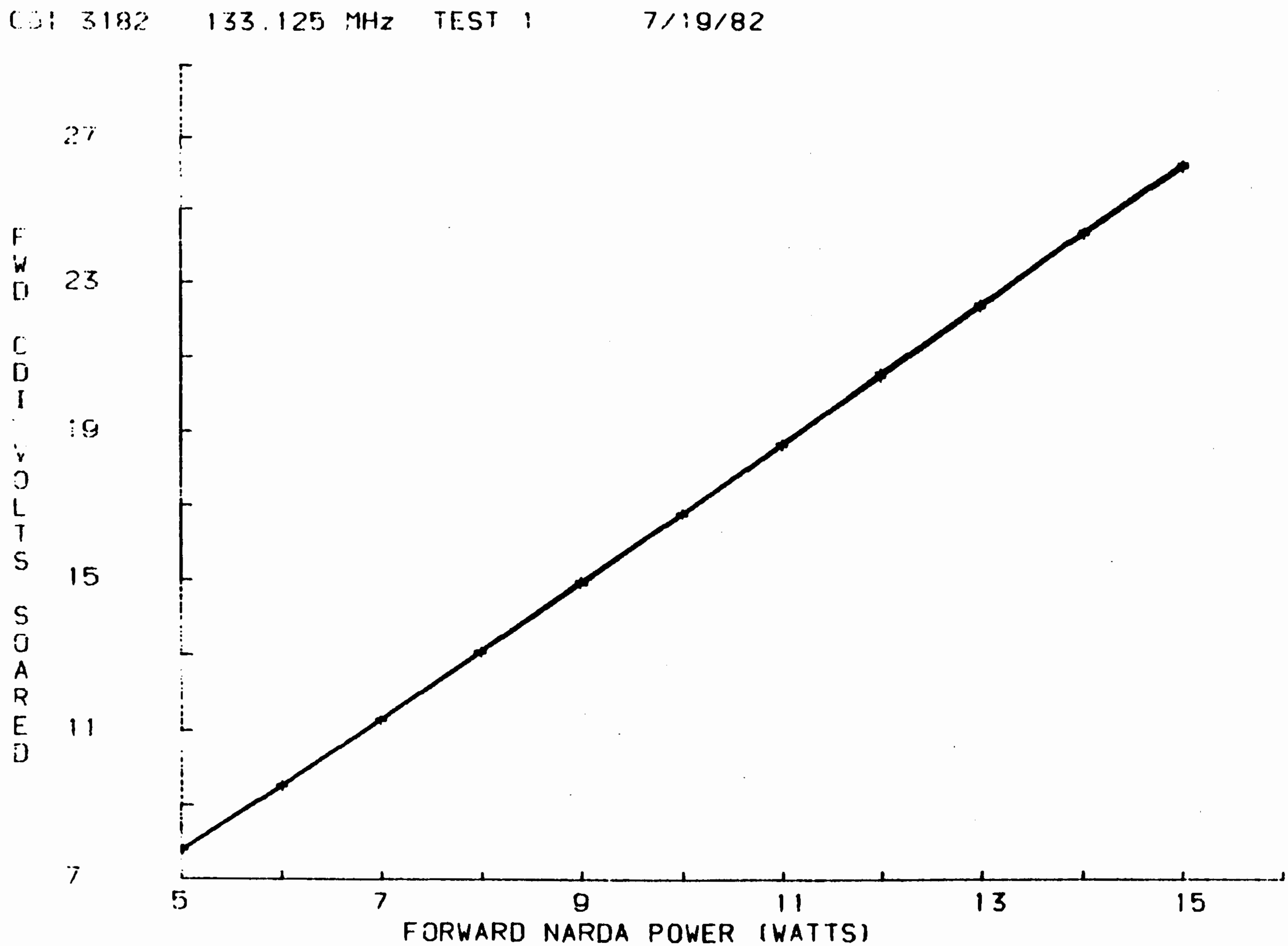


FIGURE 18. FORWARD CDI VOLTAGE SQUARED VS. FORWARD NARDA POWER AT 133.125 MHz (FROM TEST 1) WITH DATA FROM ALL 7 STUBS SUPERIMPOSED

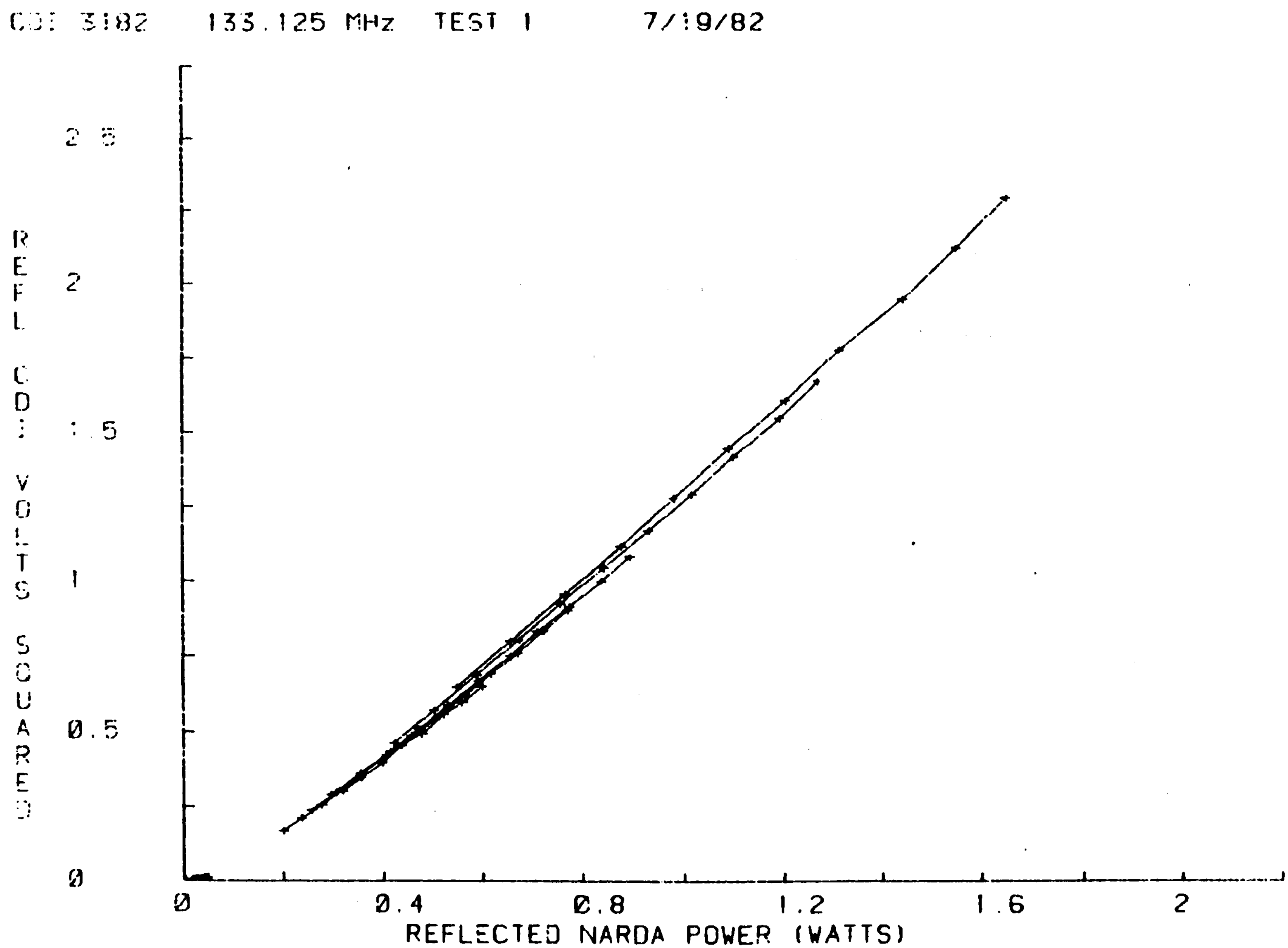


FIGURE 19. REFLECTED CDI VOLTAGE SQUARED VS. REFLECTED NARDA POWER AT 133.125 MHz (FROM TEST 1) WITH DATA FROM ALL 7 STUBS SUPERIMPOSED

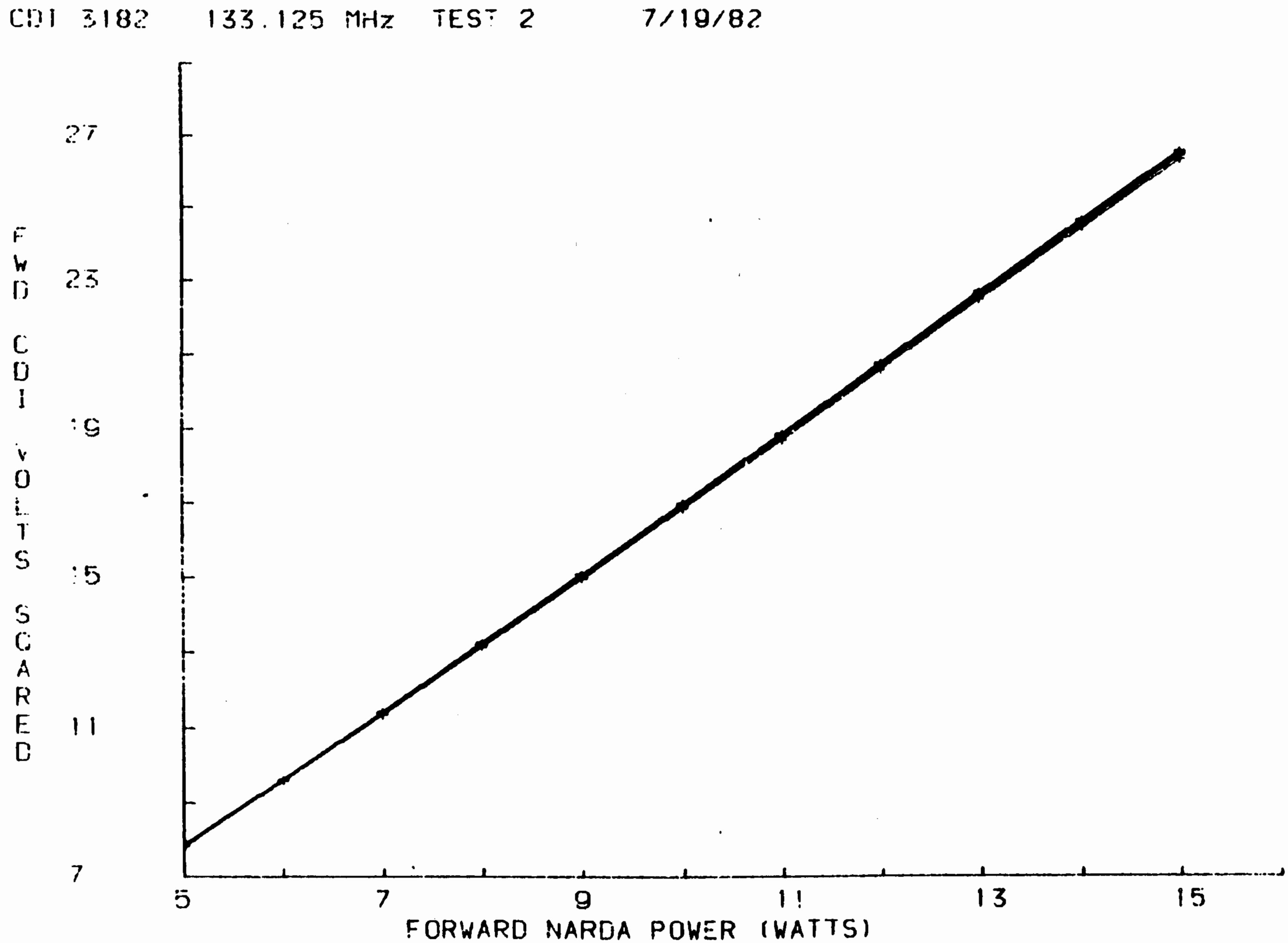


FIGURE 20. FORWARD CDI VOLTAGE SQUARED VS. FORWARD NARDA POWER AT 133.125 MHz (FROM TEST 2) WITH DATA FROM ALL 7 STUBS SUPERIMPOSED

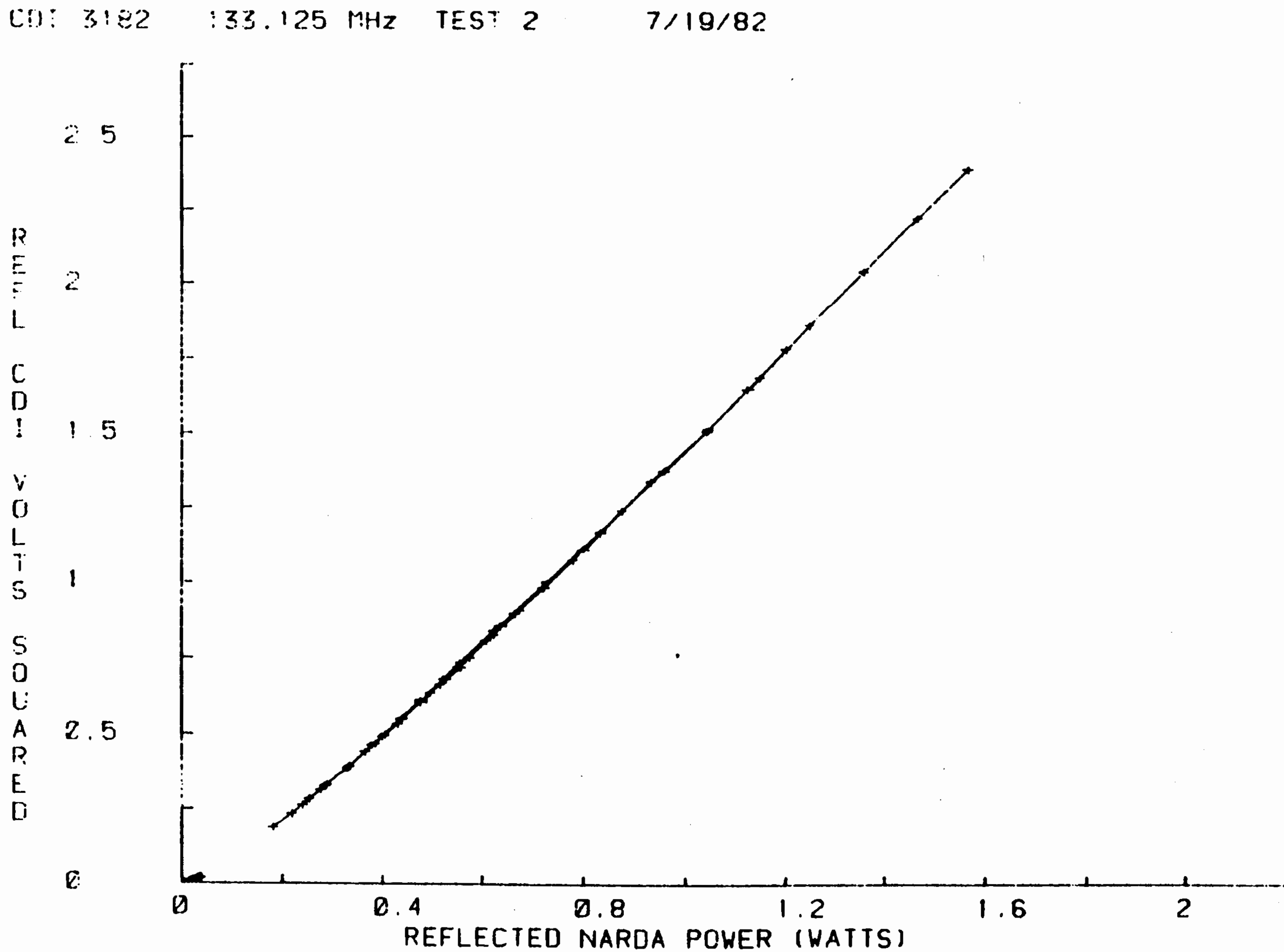


FIGURE 21. REFLECTED CDI VOLTAGE SQUARED VS. REFLECTED NARDA POWER AT 133.125 MHz (FROM TEST 2) WITH DATA FROM ALL 7 STUBS SUPERIMPOSED

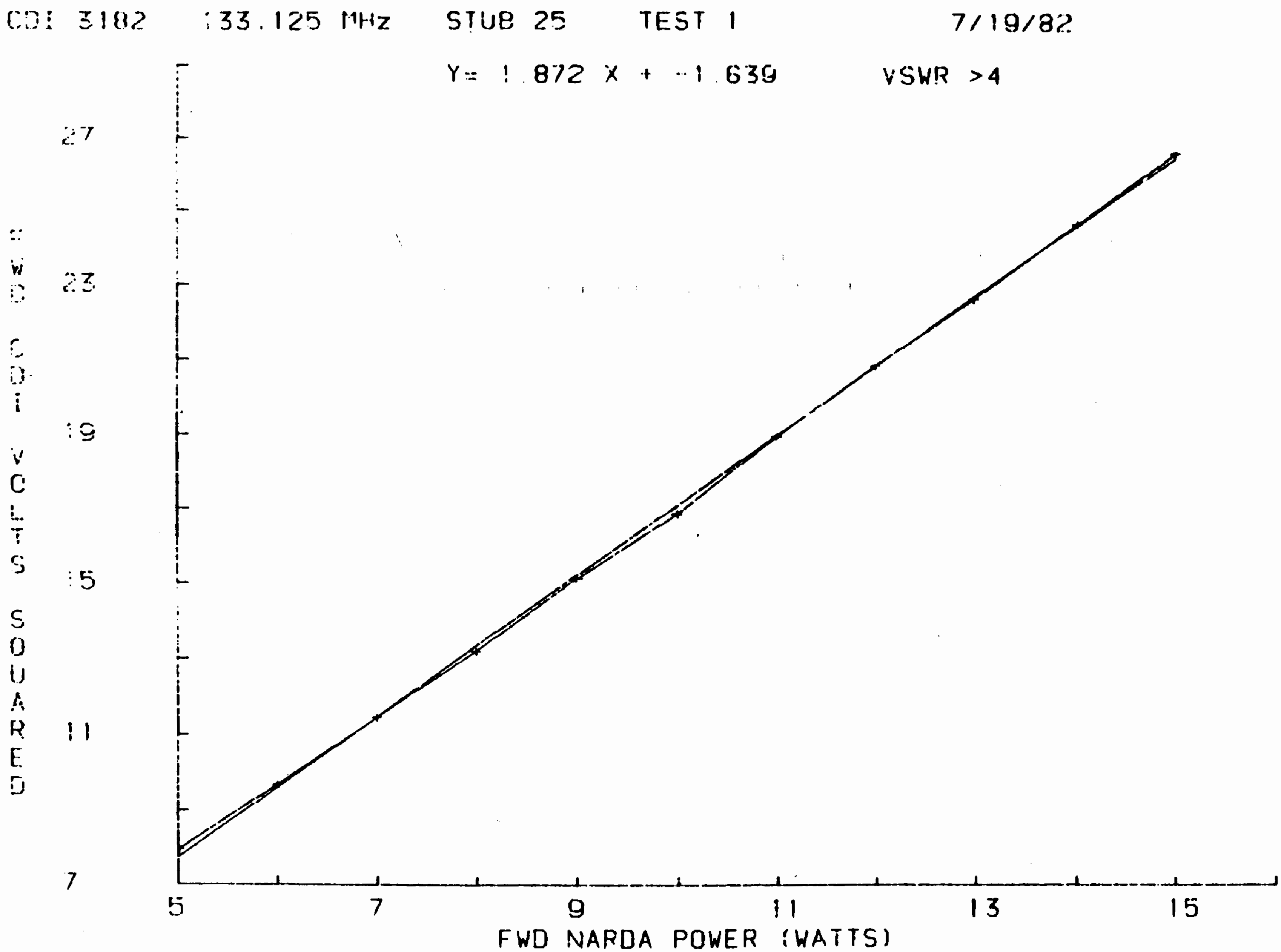


FIGURE 22. FORWARD CDI VOLTAGE SQUARED VS. FORWARD NARDA POWER AT 133.125 MHz (FROM TEST 1) WITH A VSWR GREATER THAN 4:1

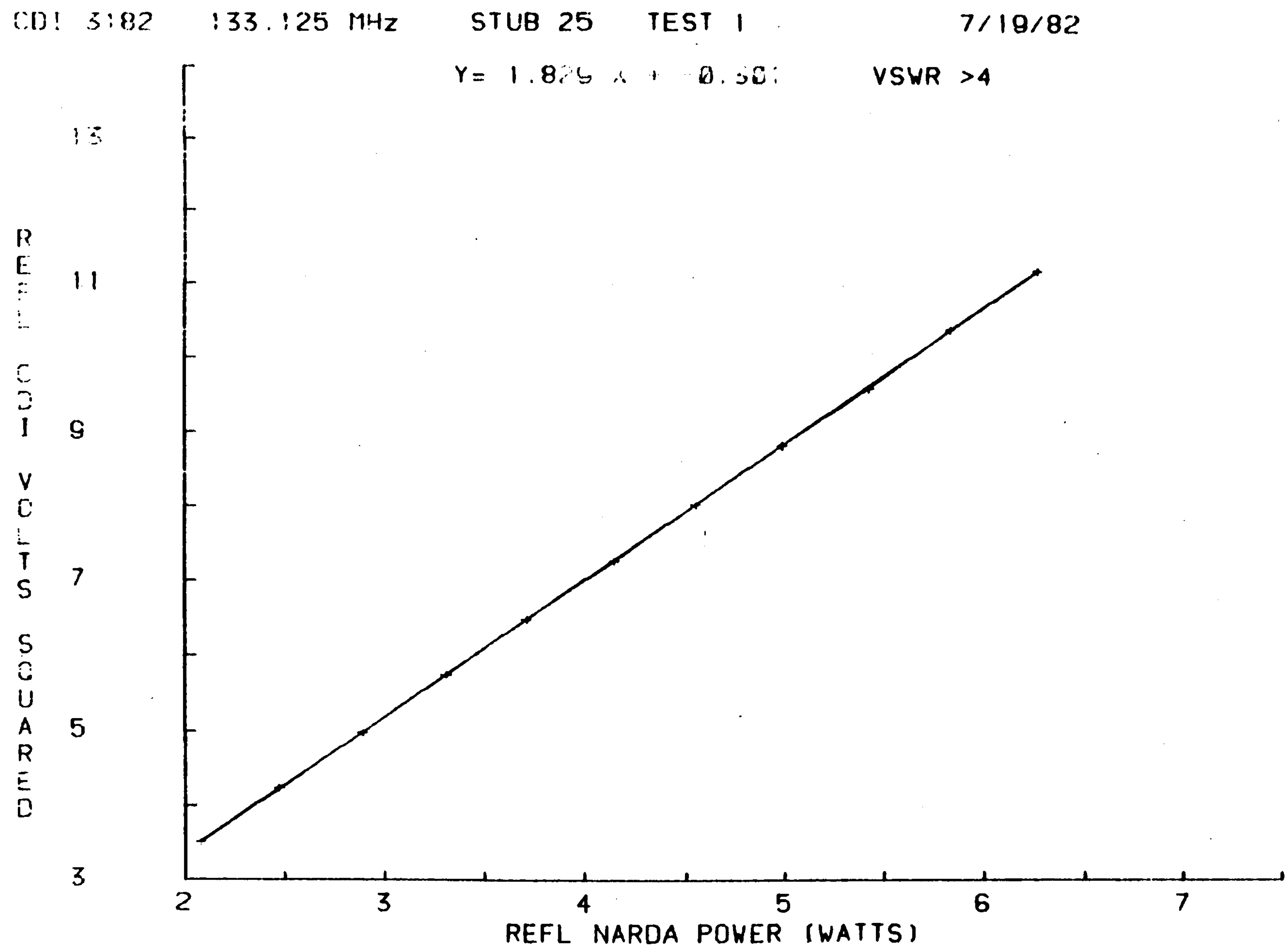


FIGURE 23. REFLECTED CDI VOLTAGE SQUARED VS. REFLECTED NARDA POWER AT 133.125 MHz (FROM TEST 1) WITH A VSWR GREATER THAN 4:1

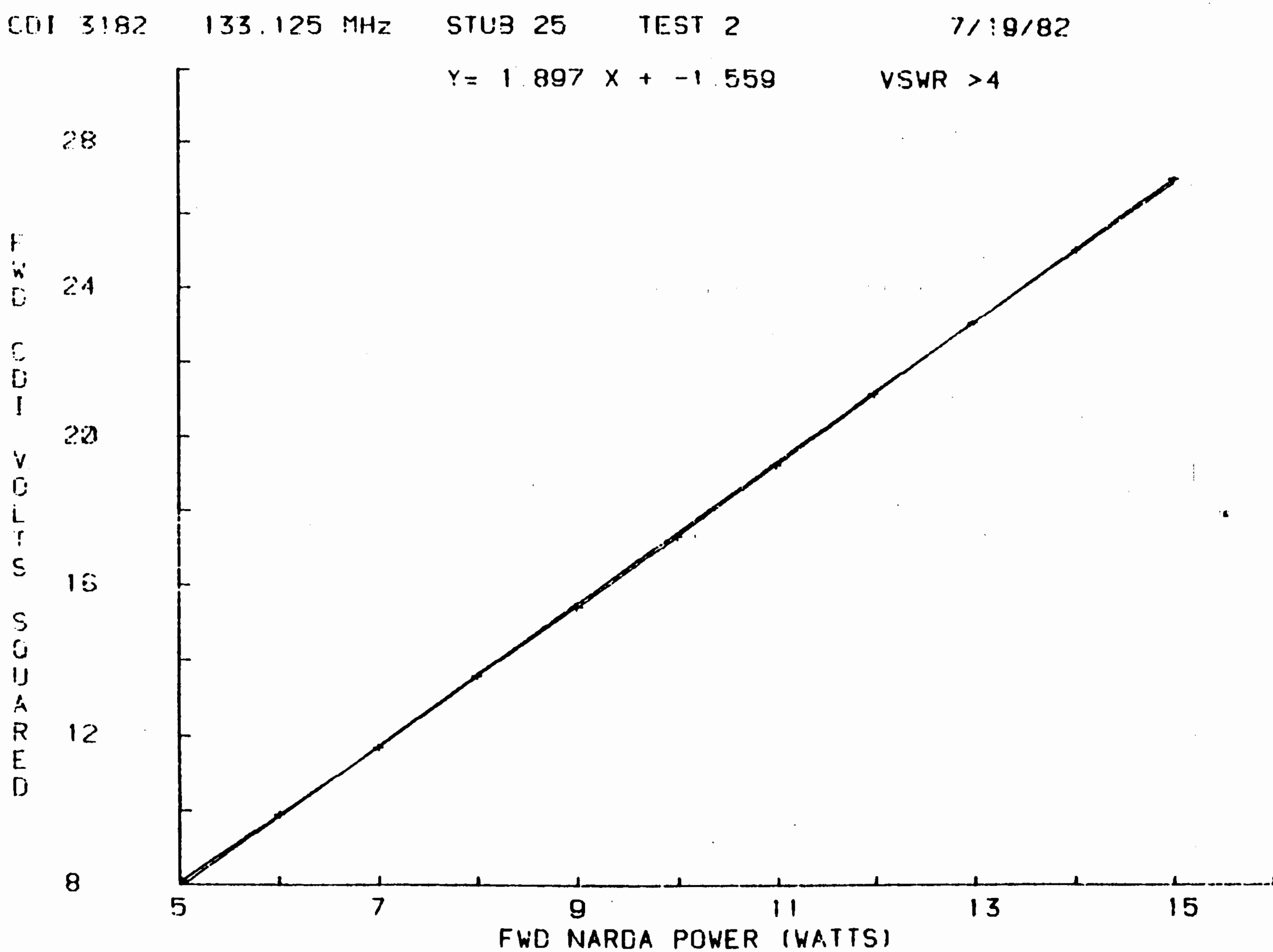


FIGURE 24. FORWARD CDI VOLTAGE SQUARED VS. FORWARD NARDA POWER AT 133.125 MHz (FROM TEST 2) WITH A VSWR GREATER THAN 4:1

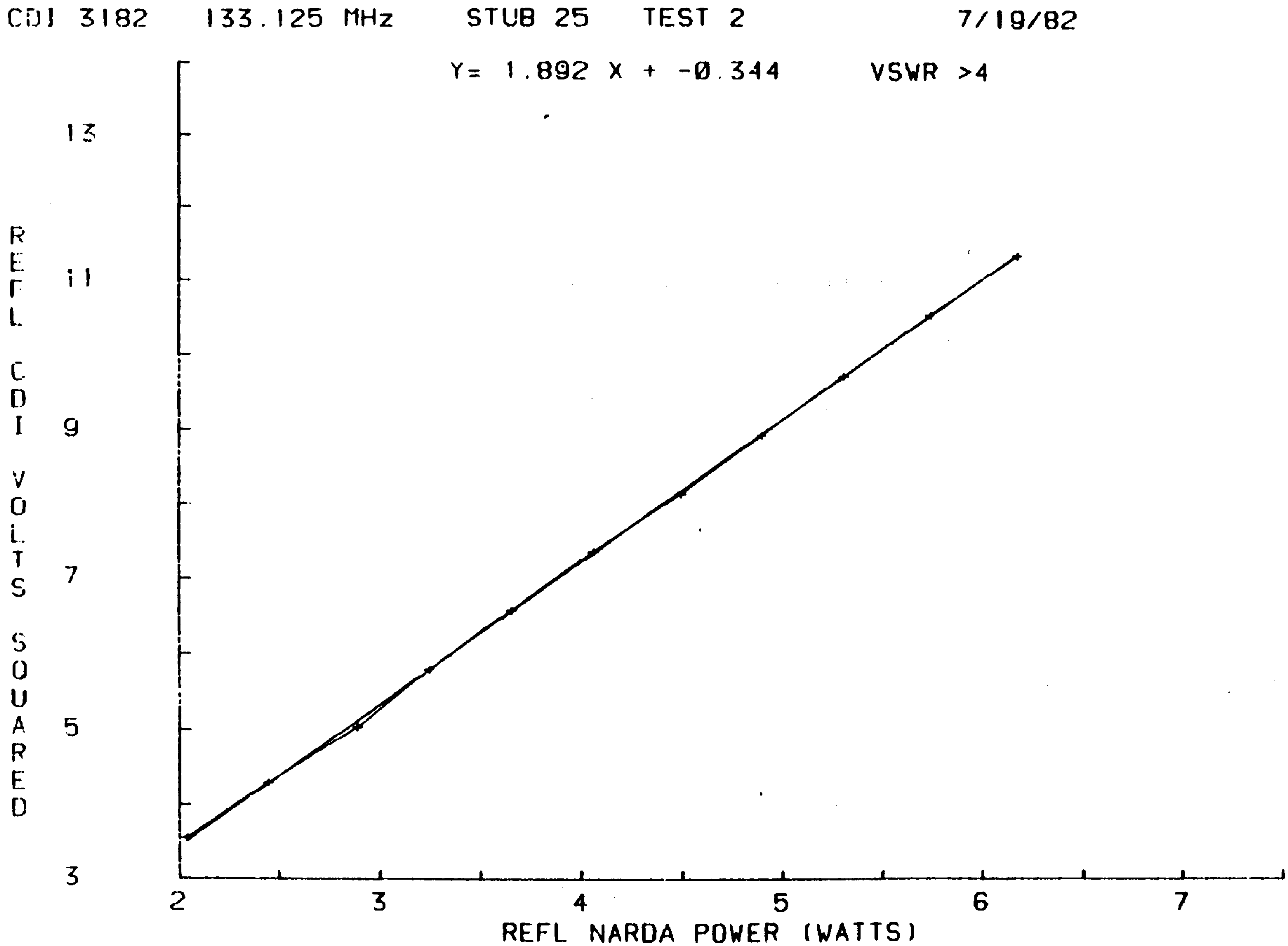


FIGURE 25. REFLECTED CDI VOLTAGE SQUARED VS. REFLECTED NARDA POWER AT 133.125 MHz (FROM TEST 2) WITH A VSWR GREATER THAN 4:1

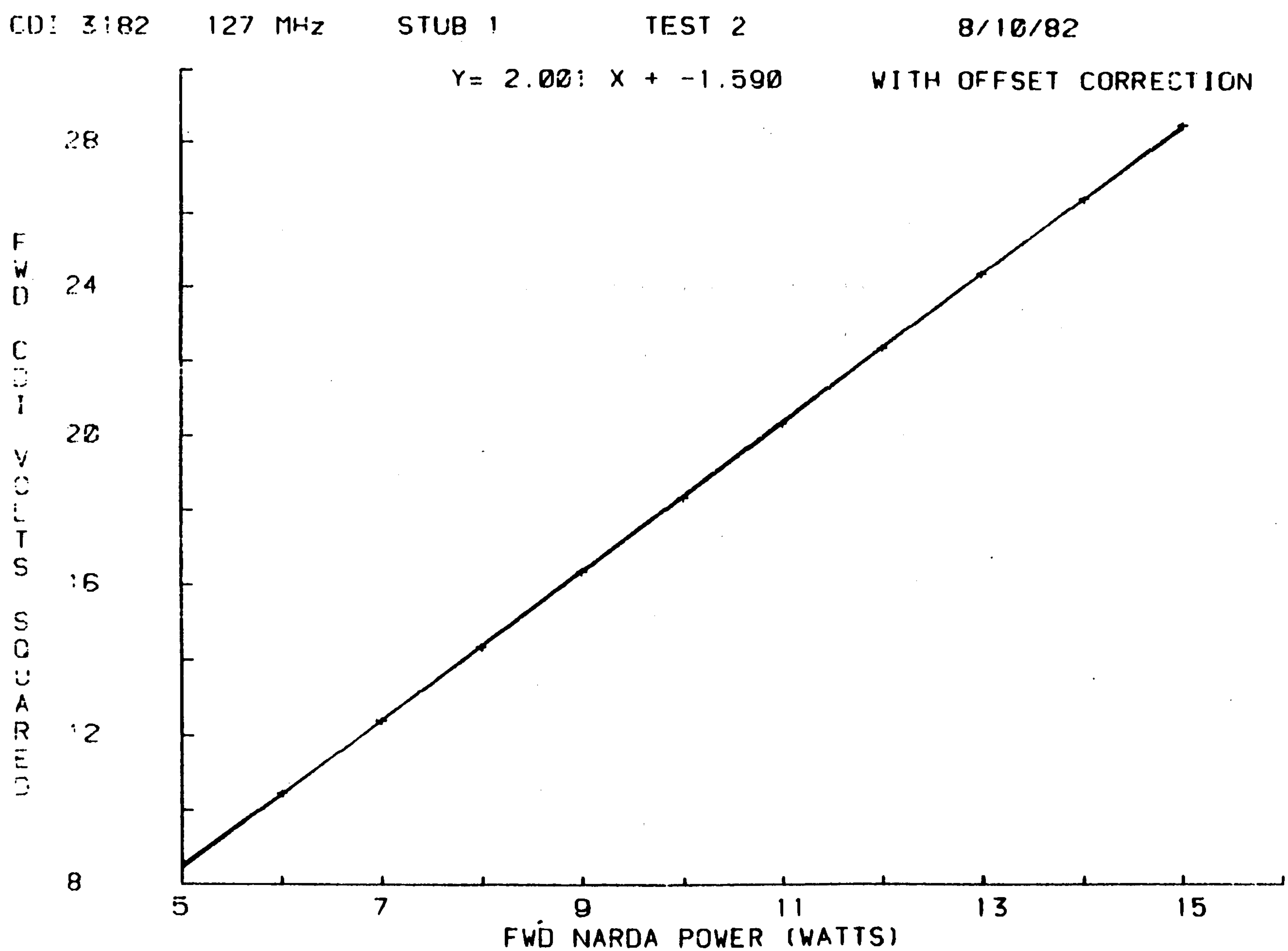


FIGURE 26. FORWARD CDI VOLTAGE SQUARED VS. FORWARD NARDA POWER AT 127 MHz (FROM TEST 2) WITH OFFSET CORRECTION WITH STRAIGHT LINE SUPERIMPOSED

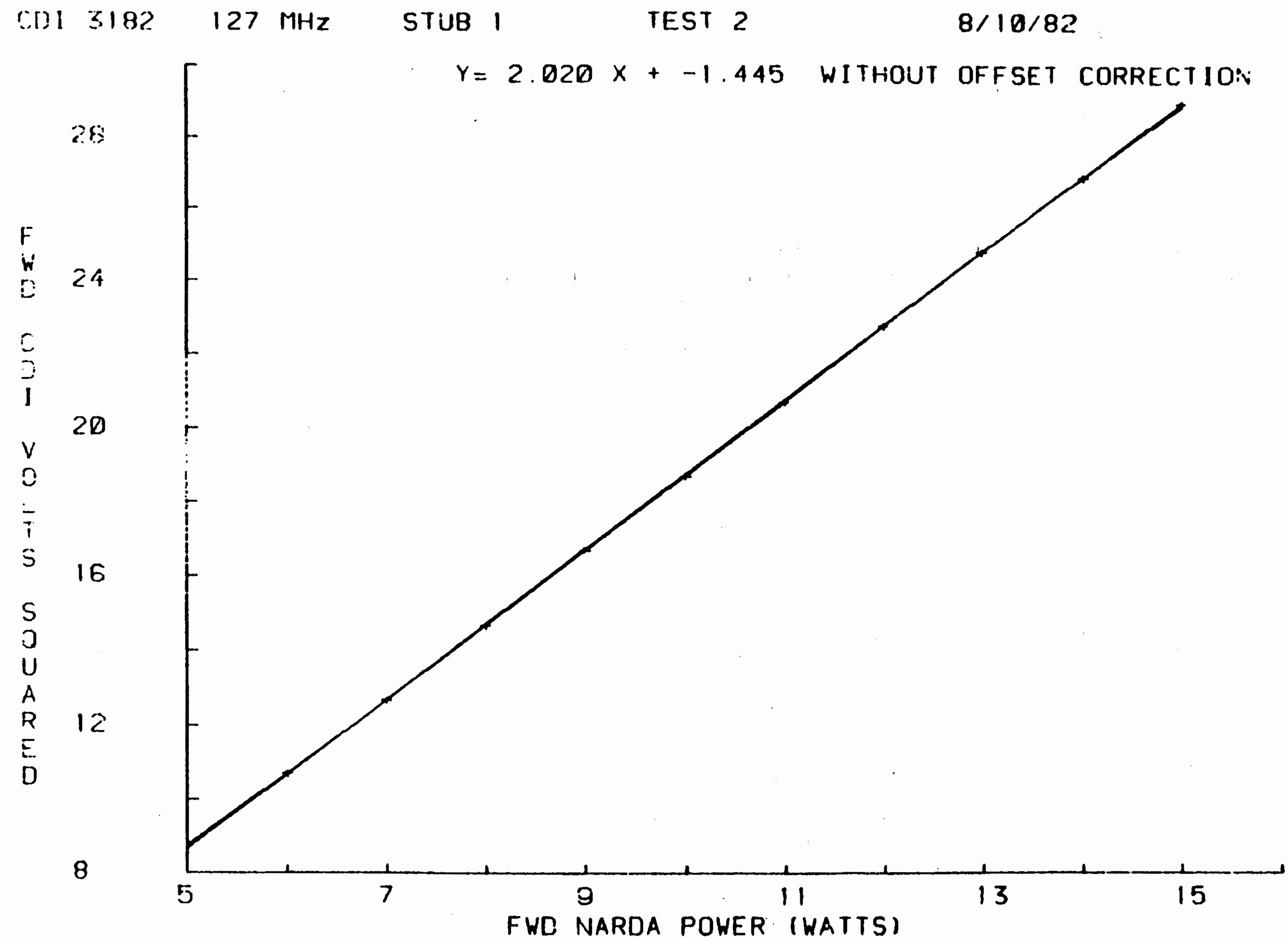


FIGURE 27. FORWARD CDI VOLTAGE SQUARED VS. FORWARD NARDA POWER AT 127 MHz (FROM TEST 2) WITHOUT OFFSET CORRECTION (STRAIGHT LINE SUPERIMPOSED)

APPENDIX A

VSWR EQUATIONS FOR THE CDI POWER DETECTOR

Transmission line VSWR is calculated using the expression:

$$[A\text{-}1]\quad VSWR = \frac{1+\sqrt{Pr/Pf}}{1-\sqrt{Pr/Pf}}$$

Where: Pf = Forward Power
Pr = Reflected Power

Power can also be expressed as the following:

$$[A\text{-}2]\quad Power = \frac{V^2}{Z}$$

Where: V = Voltage
Z = Impedance

Therefore,

$$[A\text{-}3]\quad VSWR = \frac{1+\sqrt{(Vr^2/Zr)/(Vf^2/Zf)}}{1-\sqrt{(Vr^2/Zr)/(Vf^2/Zf)}}$$

Where: Vf = Forward CDI Voltage
Vr = Reflected CDI Voltage
Zf = Impedance seen by Forward CDI Probe
Zr = Impedance seen by Reflected CDI Probe

Since the probes of the CDI detector are spaced very close together, it can be assumed that the line impedance at each CDI's probe is essentially the same. This allows equation A-3 to become:

$$[A\text{-}4]\quad VSWR = \frac{1+\sqrt{Vr^2/Vf^2}}{1-\sqrt{Vr^2/Vf^2}}$$

Where: Vf = Forward CDI Voltage
Vr = Reflected CDI Voltage

Equation A-4 can be rewritten as:

$$[A\text{-}5]\quad VSWR = \frac{1+(Vr/Vf)}{1-(Vr/Vf)}$$

Where: Vf = Forward CDI Voltage
Vr = Reflected CDI Voltage