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GEOS-C C-BAND TRANSPONDER PRELAUNCH CALIBRATION AND TEST DATA

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A.R. Selser

National Aeronautics and Space Administration
Wallops Flight Center
Wallops Island, Virginia 23337
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16. Abstract

The delay characteristics and spacecraft telemetry housekeeping data for the GEOS-C C-Band transponders are presented. The data is presented in graphical form to provide a convenient method for computing radar range measurement corrections as a function of signal strength at the transponder and spacecraft environment. The data is also presented in tabular form along with the mathematical models used to derive the curves. Also included are a list of the operating characteristics of each transponder and a description of the calibration test equipment set-up.

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TABLE OF CONTENTS

	PAGE
LIST OF TABLES	iv
LIST OF ILLUSTRATIONS	iv
INTRODUCTION	1
TRANSPONDER PERFORMANCE CHARACTERISTICS	1
PRELAUNCH TESTING PROGRAM	3
COHERENT TRANSPONDER CALIBRATION DATA	5
NONCOHERENT TRANSPONDER CALIBRATION DATA	8
REFERENCES	10

LIST OF TABLES

TABLE	TITLE	PAGE
1	GEOS - C C-Band Transponder Characteristics	11
2	Telemetry Function Subcommutator/Channel Identification	12
3	Nominal Values of TM Functions	13
4	Reduced Data for PRF TM Voltage vs. PRF Curve (COHO)	14
5	Thermal Vacuum Performance Test Data (COHO)	15
6	Signal Strength TM Voltage Linear Regression Coefficients (COHO)	20
7	Reduced Data for Delay Variation vs. Signal Strength Curve (COHO)	21
8	Reduced Data for PRF TM Voltage vs. PRF Curve (NCHO)	22
9	Thermal Vacuum Performance Test Data (NCHO)	23
10	Signal Strength TM Voltage Linear Regression Coefficients (NCHO)	28
11	Reduced Data for Delay Variation vs. Signal Strength Curve (NCHO)	29

LIST OF ILLUSTRATIONS

FIGURE	TITLE	PAGE
1	Transponder Hardware	30
2	Input Current vs. PRF	31
3	C-Band Test Console, Simplified Block Diagram	32
4	PRF TM Voltage vs. PRF (COHO)	33
5	Signal Strength TM Voltage vs. Base Plate Temperature at 160 PRF (COHO)	34

LIST OF ILLUSTRATIONS

FIGURE	TITLE	PAGE
6	Signal Strength TM Voltage vs. Base Plate Temperature at 640 PRF (COHO)	35
7	Signal Strength TM Voltage vs. Signal Strength at 5°C (COHO)	36
8	Signal Strength TM Voltage vs. Signal Strength at 20°C (COHO)	37
9	Signal Strength TM Voltage vs. Signal Strength at 35°C (COHO)	38
10	Signal Strength TM Voltage at 640 PRF vs. Signal Strength TM Voltage at 160 PRF (COHO)	39
11	Delay Variation vs. Signal Strength (COHO)	40
12	Delay vs. Base Plate Temperature (COHO)	41
13	Average Delay Variation vs. Base Plate Temperature (COHO)	42
14	PRF TM Voltage vs. PRF (NCHO)	43
15	Signal Strength TM Voltage vs. Base Plate Temperature at 160 PRF (NCHO)	44
16	Signal Strength TM Voltage vs. Base Plate Temperature at 640 PRF (NCHO)	45
17	Signal Strength TM Voltage vs. Signal Strength (NCHO)	46
18	Signal Strength TM Voltage at 640 PRF vs. Signal Strength TM Voltage at 160 PRF (NCHO)	47
19	Delay Variation vs. Signal Strength (NCHO)	48
20	Delay vs. Base Plate Temperature (NCHO)	49
21	Average Delay Variation vs. Base Plate Temperature (NCHO)	50

INTRODUCTION

The purpose of the GEOS-C Project is to design, develop, and launch a geodetic satellite and to perform experiments in support of the application of geodetic satellite techniques to geosciences. The experiment subsystem complement on board the spacecraft consists of a radar altimeter, C-band transponders (coherent and noncoherent), S-band transponders, laser retroreflectors, and doppler transmitters. Details on the mission objectives and descriptions of the spacecraft and experiment subsystems are available in the literature.[1]

The C-band system on GEOS-C consists of two transponders: one coherent and one noncoherent type. Each transponder is connected to its own antenna, and the units may be operated independently or simultaneously with no interference. Both transponders may be tracked by all C-band radars to obtain range and angle position data. In addition, those C-band radars equipped with pulse doppler capabilities will provide the measurement of range rate. Operationally, the only significant difference between the two types of transponder is that the coherent transponder replies at the same frequency at which it is interrogated (rather than at an offset frequency), and appears as a skin target to the tracking radar.

The principal effort in the calibration of the transponders lies in the identification of range measurement error sources. The most significant error sources are the variation in delay as a function of signal level and spacecraft environment. Prelaunch calibration data is presented in this report in tabular and graphical form to provide a means for calculating range corrections from the spacecraft TM data. Also included in this report are descriptions of the transponders, test equipment, and the prelaunch testing program.

TRANSPONDER PERFORMANCE CHARACTERISTICS

The coherent transponder is a new design developed for the GEOS-C mission by Vega Precision Laboratories under contract to the Wallops Flight Center. Primary emphasis was placed on the development of a coherent transponder which has predictable delay characterisitcs, low power consumption, and long life. The nominal operating characteristics of the coherent transponder are shown in Table 1.

The noncoherent transponder is one of eight units built by Vega for the GEOS-B Program. This unit was maintained in semiactive storage between programs and was operated only enough to keep the magnetron outgassed. The nominal operating characteristics of the noncoherent transponder are shown in Table 1.

Figure 1 shows a picture of the noncoherent transponder on the left and the coherent transponder on the right. The antennas shown in Figure 1 are identical to the two flown on the satellite. They are manufactured by Vega (Model 820C) and are the same design as the antennas used on GEOS-B. The antenna is a quartz-loaded, cavity backed helix radiator which produces a right hand circular polarized radiation pattern. The beamwidth is sufficient to provide horizon-to-horizon coverage on GEOS-C.[1,2]

Both transponders feature the same three operating modes which are initiated by spacecraft command. These modes are defined as follows:

OFF - All power to the transponder is turned Off.

ON/NORMAL - When commanded into this mode, the transponder will enter a STANDBY state where only the receiver is turned on (to conserve spacecraft power). Upon receipt of approximately 10 valid interrogations the transmitter will turn on, and initiate the turn-on time delay (See Table 1) which allows for magnetron filament warm-up. At the end of the turn-on time delay the transponder will reply to all valid interrogations. If no valid interrogations are received for a period equal to or greater than the turn-off time delay (See Table 1), the transponder will automatically switch back to the STANDBY state.

ON/OVERRIDE - When commanded into this mode the entire transponder is turned on and after the turn-on time delay has elapsed, it will reply to all valid interrogations.

Each transponder provides inputs to the spacecraft telemetry subsystem for housekeeping and post pass data correction purposes. A detailed description of the GEOS-C telemetry subsystem can be found in Reference 1. Channel number, function identification, full scale voltage, and scale factor information is contained in Reference 3. Table 2 shows a list of the telemetry functions for each transponder along with their analog subcommutator and channel numbers. Table 3 lists the expected range of values for the TM functions of each transponder in the spacecraft environment for three operating modes. Figure 2 shows the input current vs. PRF curves for both transponders. Note that the input current of the noncoherent transponder is independent of input voltage. The error bars shown on the noncoherent curve are the one sigma values for the measurements at the indicated PRF's. The one sigma values for the coherent transponder input current are about an order of magnitude smaller then those shown for the noncoherent and were not plotted on the curves.

PRELAUNCH TESTING PROGRAM

Component level flight acceptance tests were performed on both transponders to demonstrate that the units meet specifications before, during and after being subjected to a simulated spacecraft environment and to establish baseline measurements for the evaluation of performance during spacecraft level tests. Spacecraft level tests were performed for the purpose of calibration and performance verification of the transponders during spacecraft acceptance testing. Calibration data was obtained with the transponders hard-lined to the C-band test console and quick-look performance verification was obtained via air link using a Sperry (Model C201C) radar simulator. Detailed test procedures for the spacecraft level testing of the coherent and noncoherent transponders are given in References 4 and 5. Given below is a list of the tests performed during the calibration effort:

Turn-On Time Delay

TM Functions vs. PRF

Receiver Sensitivity

Receiver 3 db Bandwidth

Receiver Code Spacing

Peak Power Output

Transmitter Pulse Width and Pulse Width Jitter

Delay, Delay Jitter, and Signal Strength TM Voltage vs. Signal Strength

Frequency Error (coherent)

Pulling Range (coherent)

Interline Noise (coherent)

Transmit Frequency (noncoherent)

Turn-Off Time Delay

All of the above vs. Input Voltage and Temperature.

The performance characteristics listed in Table 1 represent the nominal results of the prelaunch calibration tests for each transponder.

A simplified block diagram of the test equipment set-up used to calibrate the transponders is shown in Figure 3. The test equipment was assembled in a mobile console called the C-band test console. The same equipment set-up was used for component and spacecraft level testing except that the DC power and TM voltage interface was through an external power supply and digital voltmeter in the component level tests and through the spacecraft power and TM systems for the spacecraft level tests. A block diagram description of the test console operation is given below. More detailed information on the equipment used, the test set-up and the test procedures can be found in References 4 and 5.

The C-band test console operates as follows (refer to Figure 3). The coherent transmitter generates three output signals: one interrogation signal and two local oscillator (LO) signals. The first LO signal is a C-band CW signal tunable in 1.2 Hz steps, and is normally tuned exactly to the interrogation signal frequency plus 30.1 MHz. The second LO signal is a CW signal that is fixed at 30.0 MHz. Both LO signals are fed to the receiver for down converting the transponder's reply signal. The interrogation signal is tunable across C-band (5.4 to 5.9 GHz) in 1.2 Hz steps and is normally set at 5.69 GHz. The pulse width is variable but normally set at one-half microsecond. It has double pulse capability with variable spacing, which is normally set to eight microseconds (leading edge to leading edge). The maximum output power available in the interrogation signal is +20 dbm. The interrogation signal passes out of the transmitter through a directional coupler. A detector on the coupled port samples the interrogation signal and provides a start count pulse for the computing counter (to start the delay measurement). The output of the directional coupler passes through a variable attenuator which is used to zero set the signal strength at the transponder, and then through the step attenuator which is used to vary the signal strength at the transponder. The step attenuator has a range from 0 to 99 db in 1 db steps. After leaving the step attenuator, the interrogation signal passes through the circulator and a directional coupler to the transponder. A power meter measures the transponder's average power through the coupled port of the directional coupler. The reply pulse leaves the transponder and passes through the directional coupler and circulator to a variable attenuator which is used to set the signal level at the detector and receiver. The reply pulse passes through the variable attenuator to a directional coupler. The direct output of the coupler passes through a wavemeter to a detector which provides a stop pulse to the computing counter. The wavemeter is used to determine the transmit frequency of the noncoherent transponder. The coupled port of the directional coupler feeds the receiver. The receiver is used to process the reply pulse train from the coherent transponder. The receiver down converts the input to a 100 KHz carrier frequency using the two LO signals supplied by the coherent transmitter, and filters the 100 KHz output to a 40 Hz pass band. The resulting output is the central spectral line in the coherent pulse spectrum. The amplitude of the central line is measured on the AC voltmeter and the frequency characteristics are determined by the computing counter.

The test set is calibrated for signal strength by disconnecting the cable at the transponder and measuring the power at that point with the power meter. The signal strength is set at that point (normally to 0 dbm with the step attenuator at 0 db) using the variable attenuator at the output of the coherent transmitter. With the test set disconnected from the transponder, the internal delay of the test set is measured by reflecting the interrogation signal back down the open cable to the stop pulse detector.

COHERENT TRANSPONDER CALIBRATION DATA

The calibration curves for the coherent transponder are presented in Figures 4 through 13, and include the following:

PRF TM Voltage vs. PRF

Signal Strength TM Voltage vs. Base Plate Temperature and Signal Strength at 160 and 640 PRF

Signal Strength TM Voltage vs. Signal Strength and Input Voltage at three selected temperatures

Signal Strength TM Voltage at 640 PRF vs. Signal Strength TM Voltage at 160 PRF

Delay Variation vs. Signal Strength

Delay vs. Base Plate Temperature and Signal Strength

Average Delay Variation vs. Temperature

In order to compute the actual delay of the transponder the outputs of the following four TM channels must be known: Input Voltage, Signal Strength, PRF, and Base Plate Temperature. The signal strength TM voltage varies with input voltage, PRF, and temperature as well as with signal strength, and must be corrected for those variations before the actual signal strength can be determined. The transponder delay varies with signal strength and temperature, but is independent of input voltage and PRF.

Figure 4 shows the curve of PRF TM Voltage vs. PRF for the coherent transponder. This curve was derived from the data in Table 4.

The signal strength TM circuit contains a peak detector which will respond to the strongest interrogation signal it receives; therefore, it can only be used for calibration purposes when one radar is interrogating the transponder. Because of this the calibration data has been concentrated at the primary radar PRF's of 160 and 640, with the majority of the data being taken at 640 to minimize the averaging time for the delay and pulse width measurements.

Figure 5 and 6 show the family of curves of Signal Strength TM Voltage vs. Temperature at 160 and 640 PRF. The individual points plotted are the raw data points listed in Table 5. These curves are not in a convenient form for interpolating signal strength as a function of signal strength TM voltage; however, the shape of the curves suggests that they could be modeled by computing a least squares linear regression equation in two variables (input voltage and temperature) at each signal strength. The regression equation is of the form:

$$Y_i = B_O + B_T * T_i + B_V * V_i$$

where:

Y_i = $_i$th Signal Strength TM Voltage Measurement

B_O = Constant

B_T = Temperature Coefficient

T_i = $_i$th Base Plate Temperature Measurement

B_V = Input Voltage Coefficient

V_i = $_i$th Input Voltage Measurement

The computed coefficients for each curve are listed in Table 6, and the resulting regression lines for 14.7 V (input voltage) are shown in Figures 5 and 6 at selected signal strengths. The total rms of the residuals to the model at 640 PRF is .028 volts. Using this linear model the signal strength TM voltage has been replotted as a function of signal strength in Figures 7, 8, and 9. The family of curves are valid only at 640 PRF. If the signal strength TM voltage is known at 160 PRF, it can be scaled to 640 PRF using the curve in Figure 10. This curve was computed using a least squares linear fit to the data in Table 5. The regression equation is:

$$V(640) = 1.03153 * V(160) + .11265$$

The rms of the residuals to this curve is .027 volts.

Actual delay measurements in the calibration tests are referenced to the half-amplitude point on the leading edge of the reply pulse, and unless otherwise stated, all delay data presented in this report is referenced to the leading edge. Only the average delay variation vs. base plate temperature curve (Figure 13) includes a controid correction, because both the leading edge delay and the pulse width vary with temperature. All delay and pulse width measurements were made using an Hewlett-Packard 5360A Computing Counter. Each data point represents a real-time average of 1000 samples taken at the PRF rate.

Figure 11 shows the curve of delay variation vs. signal strength. The curve was computed from a least squares fit of a seventh degree polynomial to 219 measurements made at ambient temperature and pressure. This data is summarized in Table 7. The total rms of the residuals to the fitted curve is 0.4 nanoseconds.

Figure 12 shows a plot of selected portions of the delay data taken during the spacecraft thermal vacuum performance test. The complete data set is listed in Table 5. The delay data in Table 5 may only be interpreted for its relative variation with signal strength and temperature. The family of curves in Figure 12 shows a signal strength dependence of delay vs. temperature for signal levels below -61 dbm. The average delay variation has been computed by fitting a least squares parabola through each signal strength curve between -26 dbm and -61 dbm and then by averaging the coefficients to determine the average slope, which is .01424 * T + .1977 nsec/°C. In addition to the leading edge delay varying with temperature, the pulse width also varies with temperature. Therefore, the motion in the pulse centroid with temperature must be added to the leading edge delay variations. The pulse width versus base plate temperature data is listed in Table 5. A least squares linear fit to this data yields a slope of .478 nsec/°C. The centroid variation is one-half that of the pulse width; and the total slope of the centroid delay variation with temperature is the sum of the leading edge and centroid variations.

$$\text{TOTAL SLOPE} = .01424 * T + .4367 \text{ nsec/°C}$$

The average delay variation vs. base plate temperature (including centroid correction) can be computed by integrating this equation with respect to temperature (T) and solving relative to 23.6°C (The reference temperature for delay calibration, see Figure 11). The curve resulting from the integration is plotted in Figure 13.

The following is an example of how to use the curves to determine the delay under a given set of conditions, they are:

Input Voltage	13.04 V
Signal Strength TM Voltage	2.497 V
PRF TM Voltage	.258 V
Base Plate Temperature	7.45 °C

From Figure 4 a PRF TM Voltage of .258 volts gives a 160 PRF; therefore, the signal strength TM voltage must be scaled to 640 PRF using Figure 10. The scaled signal strength TM voltage is 2.69 Volts. Since the base plate temperature is between 5°C and 20°C, Figures 7 and 8 must be used to determine the Signal Strength. From Figure 7 a signal strength of -34.6 dbm is obtained by using linear interpolation to obtain the signal strength at an input voltage of 13.04 volts. From Figure 8 a signal strength of -36.9 dbm is obtained by using linear interpolation again to obtain the signal strength at an input voltage of 13.04 volts.

Linear interpolation is used again between the two above results, to determine a signal strength of -35.0 dbm at 7.45°C and 13.04 volts. From Figure 11 and starting with an absolute delay of 2530 nsec (-30 dbm and 23.6°C) add a correction of +3.1 nsec (-35 dbm) delay variation with signal level and from Figure 13 add a correction of -10.6 nsec (7.45°C). The total delay is the sum of the absolute delay and the corrections and is equal to 2522.5 nsec.

NONCOHERENT TRANSPONDER CALIBRATION DATA

The calibration curves for the noncoherent transponder are presented in Figures 14 through 21, and include the following:

PRF TM Voltage vs. PRF

Signal Strength TM Voltage vs. Base Plate Temperature and Signal Strength at 160 and 640 PRF

Signal Strength TM Voltage vs. Signal Strength at three selected temperatures

Signal Strength TM Voltage at 640 PRF vs. Signal Strength TM Voltage at 160 PRF

Delay Variation vs. Signal Strength

Delay vs. Base Plate Temperature and Signal Strength

Average Delay Variation vs. Temperature

The structure and use of these curves is identical to that for the coherent transponder with one exception. That is, the signal strength TM voltage of the noncoherent transponder is independent of the input voltage. Because of the similarities in the curves for the two transponders, all of the details on their derivation will not be repeated in this section.

Figure 14 shows the curve of PRF TM Voltage vs. PRF, and the data from which this curve was derived is listed in Table 8.

The signal strength TM voltage vs. temperature and signal strength data listed in Table 9 is plotted in Figures 15 and 16 for PRF's of 160 and 640 respectively. Unlike the coherent transponder, this data is independent of input voltage, and therefore, a simple linear model in one variable (temperature) can be used. The regression equation is of the form:

$$Y_i = B_o + B_T * T_i$$

The computed coefficients for the curve at each signal strength are listed in Table 10, and the resulting regression lines are shown in Figures 15 and 16 for selected signal strengths. The total rms of the residuals to the model at 640 PRF is .006 volts. Using this model the signal strength TM voltage has been replotted as a function of signal strength in Figure 17 at three selected temperatures. This curve is valid for signal strength TM voltages at 640 PRF. The signal strength TM voltage at 160 PRF can be scaled to 640 PRF using the curve in Figure 18. This curve was derived by computing a least squares linear fit to the data in Table 9. The regression equation is:

$$V(640) = 1.15 * V(160) - .00232$$

The rms of the residuals of this curve is .006 volts.

Figure 19 shows the curve of delay variation vs. signal strength. This curve was computed from a least squares fit of a seventh degree polynominal to 176 measurements made at ambient temperature and pressure. This data is summarized in Table 11. The curve was fitted in two segments from -20 dbm to -35 dbm and from -35 dbm to -60 dbm. The total rms of the residuals to the fitted curve is 0.5 nanoseconds.

Figure 20 shows selected portions of the delay data taken during the spacecraft thermal vacuum performance test. The complete data set is listed in Table 9. The delay data in Table 9 may only be interpreted for its relative variation with signal strength and temperature. Like the coherent transponder, the delay vs. temperature characteristics show some signal strength dependence, and the same type of model will be used to determine the average delay variation with temperature for signal strengths between -24 dbm and -59 dbm. After computing a least squares parabolic fit to each signal strength curve at 640 PRF, the average slope of the leading edge delay variation with temperature has been determined to be .0313021 * T - .2984 nsec/°C.

A least squares parabolic fit to the pulse width vs. temperature data in Table 9 yields a slope of the pulse centroid variations with temperature equal to .032397 * T - .1717 nsec/°C. The total slope is of the sum of the leading edge and centroid variations:

$$\text{TOTAL SLOPE} = .063518 * T - .4701 \text{ nsec/°C}$$

By integrating this equation with respect to temperature (T) and solving with respect to 25.5°C (the reference temperature for delay calibration, Figure 19) the average delay variation (referenced to the centroid) can be computed. The resulting curve is plotted in Figure 21.

For an example on how to use these curves to calculate the actual transponder delay, refer to the preceding section on the coherent transponder.

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TABLE 1

GEOS-C C-BAND TRANSPONDER CHARACTERISTICS

	COHERENT	NONCOHERENT
Manufacturer	Vega	Vega
Model Number	355C	313C
Serial Number	3	7
Delivery Date	Sep 73	Oct 67
Supply Voltage	11.9 to 16.9V	11.9 to 16.9V
Power Consumption @ 14.7V:		
Standby	1.2W	4.0W
Override	7.8W	13.5W
160 PRF	8.0W	14.2W
640 PRF	8.7W	17.5W
2560 PRF	11.1W	27.0W
Turn-On Time Delay	40 ± 1 sec	51 ± 2 sec
Receiver Sensitivity @ 5690 MHz	-67 ± 1 dbm	-72 ± 1 dbm
Receiver 3 db Bandwidth	15.0 ± 0.6 MHz	13.2 ± 0.6 MHz
Receiver Pulse Width	.25 to 1.0 usec	.25 to 1.0 usec
Pulse Code Spacing:		
100% Accept	7.75 to 8.15 usec	7.70 to 8.20 usec
100% Reject High	>8.25 usec	>8.30 usec
100% Reject Low	<7.65 usec	<7.60 usec
Peak Power Output	130W	490W
Transmit Frequency	NA	5764.5 ± 0.5 MHz
Frequency Error	<.1 Hz rms	NA
Pulling Range	5690 ± 5 MHz	NA
Interline Noise (160 PRF, 40 Hz)	>22 db down	NA
Transmit Pulse Width	486 nsec	481 nsec
Pulse Width Jitter	.9 nsec rms	2.1 nsec rms
Nominal Delay	2.5 usec	5.0 usec
Delay Variation with Signal Level from -20 to -60 dbm	26 nsec	24 nsec
Delay Jitter @ -40 dbm	2.4 nsec rms	2.2 nsec rms
Turn-Off Time Delay	59 ± 1 sec	41 ± 2 sec
Total Operating Time Prior to Launch	74 Hrs	69 Hrs

TABLE 2

TELEMETRY FUNCTION SUBCOMMUTATOR/CHANNEL IDENTIFICATION

FUNCTION	COHERENT TRANSPONDER		NONCOHERENT TRANSPONDER	
	SUBCOMM	CHANNEL	SUBCOMM	CHANNEL
INPUT VOLTAGE	1	28	1	28
INPUT CURRENT	2	07	2	06
RECEIVED SIGNAL STRENGTH	1	00	1	32
PULSE REPETITION FREQUENCY	1	16	1	48
PEAK POWER OUTPUT	1	25	0	25
LOCAL OSCILLATOR TM VOLTAGE	1	24	0	24
MAGNETRON FILAMENT CURRENT	1	23	NA	NA
MAGNETRON FILAMENT VOLTAGE	NA	NA	0	23
BASE PLATE TEMPERATURE	1	51	1	52

TABLE 3

NOMINAL VALUES OF TM FUNCTIONS

INPUT VOLTAGE RANGE: 11.9 TO 16.9V   BASE PLATE TEMPERATURE RANGE: 5 TO 35°C

COHERENT TRANSPONDER

OPERATING MODE	INPUT CURRENT	SIGNAL STRENGTH TM VOLTAGE	PRF TM VOLTAGE	PEAK POWER TM VOLTAGE	LOCAL OSCILLATOR TM VOLTAGE	FILAMENT CURRENT TM VOLTAGE
STANDBY	.085 ± .015A	0	0	0	2.06 ± .04V	0
OVERRIDE/ UNINTERROGATED	.550 ± .065A	.04V	0	.47 ± .04V	3.78 ± .04V	3.99 ± .09V
INTERROGATED	See Fig. 2	Variable	See Fig. 4	2.44 ± .43V	3.72 ± .11V	3.95 ± .04V

NONCOHERENT TRANSPONDER

OPERATING MODE	INPUT CURRENT	SIGNAL STRENGTH TM VOLTAGE	PRF TM VOLTAGE	PEAK POWER TM VOLTAGE	LOCAL OSCILLATOR TM VOLTAGE	FILAMENT VOLTAGE TM VOLTAGE
STANDBY	.28 ± .02A	.07 ± .01V	0	1.44 ± .11V	-6.54 ± .09V	0
OVERRIDE/ UNINTERROGATED	.921 ± .004A	.09 ± .02V	0	1.46 ± .04V	-6.57 ± .06V	-4.89 ± .03V
INTERROGATED	See Fig. 2	Variable	See Fig. 14	2.15 ± .09V	-6.54 ± .09V	-4.83 ± .09V

TABLE 4

REDUCED DATA FOR PRF TM VOLTAGE VS. PRF CURVE

COHERENT TRANSPONDER

PRF (HZ)	AVERAGE PRF TM VOLTAGE (V)	RMS (V)
160	.268	.018
320	.550	.019
480	.816	.014
640	1.078	.010
960	1.617	.022
1280	2.158	.017
2560	4.197	.072

NOTE: These results are independent of input voltage, signal strength, and temperature.

TABLE 5

THERMAL VACUUM PERFORMANCE TEST DATA (SHEET 1 OF 5)

COHERENT TRANSPONDER 160 PRF

INPUT VOLTAGE (V)	14.7		14.6		14.7		16.9		12.1	
BASE PLATE TEMPERATURE (°C)	17.8		24.8		31.8		33.3		33.6	
SIGNAL STRENGTH (DBM)	DELAY (NSEC)	SS TM (V)	DELAY (NSEC)	SS TM (V)	DELAY (NSEC)	SS TM (V)	DELAY (NSEC)	SS TM (V)	DELAY (NSEC)	SS TM (V)
-26	2584.2	3.093	2586.0	3.093	2588.9	3.136	2588.4	3.265	2592.5	3.050
-36	2588.5	2.664	2590.8	2.664	2594.2	2.707	2593.3	2.835	2597.6	2.621
-46	2594.1	2.062	2596.6	2.105	2600.2	2.105	2599.9	2.191	2603.9	2.019
-66	2640.4	.558	2645.7	.558	2652.3	.558	2650.8	.601	2670.6	.515
INPUT VOLTAGE (V)	14.7		14.7		14.7		14.7		16.9	
BASE PLATE TEMPERATURE (°C)	32.4		19.7		12.5		4.6		5.8	
SIGNAL STRENGTH (DBM)	DELAY (NSEC)	SS TM (V)	DELAY (NSEC)	SS TM (V)	DELAY (NSEC)	SS TM (V)	DELAY (NSEC)	SS TM (V)	DELAY (NSEC)	SS TM (V)
-26	2588.4	3.136	2582.9	3.007	2580.7	3.007	2578.8	2.921	2578.1	3.050
-36	2593.3	2.707	2587.4	2.578	2585.0	2.578	2582.9	2.492	2582.5	2.621
-46	2599.6	2.105	2592.6	1.976	2590.2	1.976	2587.8	1.890	2587.2	1.976
-66	2655.1	.558	2657.3	.515	2643.3	.515	2659.4	.472	2648.4	.515

TABLE 5

THERMAL VACUUM PERFORMANCE TEST DATA (SHEET 2 OF 5)

COHERENT TRANSPONDER 160 PRF

INPUT VOLTAGE (V)	12.1		14.7		14.6		14.7		14.7	
BASE PLATE TEMPERATURE (°C)	6.0		5.7		16.0		23.9		13.5	
SIGNAL STRENGTH (DBM)	DELAY (NSEC)	SS TM (V)	DELAY (NSEC)	SS TM (V)	DELAY (NSEC)	SS TM (V)	DELAY (NSEC)	SS TM (V)	DELAY (NSEC)	SS TM (V)
-26	2581.8	2.792	2577.4	2.921	2581.1	2.964	2584.0	3.050	2581.5	2.964
-36	2586.0	2.406	2581.6	2.492	2586.0	2.578	2589.0	2.621	2585.8	2.535
-46	2590.4	1.804	2586.7	1.933	2591.3	1.976	2594.9	2.019	2591.2	1.933
-66	2647.1	.515	2656.3	.472	2655.5	.515	2655.7	.515	2654.5	.515
INPUT VOLTAGE (V)	14.7		14.7		14.7		14.7			
BASE PLATE TEMPERATURE (°C)	15.7		24.0		33.1		4.9			
SIGNAL STRENGTH (DBM)	DELAY (NSEC)	SS TM (V)	DELAY (NSEC)	SS TM (V)	DELAY (NSEC)	SS TM (V)	DELAY (NSEC)	SS TM (V)		
-26			2585.2	3.050	2590.3	3.136	2578.2	2.878		
-36	2586.0	2.578	2589.8	2.621	2595.7	2.707	2582.5	2.492		
-46			2595.7	2.019	2601.9	2.062	2587.2	1.890		
-66			2657.3	.515	2671.0	.515	2641.9	.515		

TABLE 5

THERMAL VACUUM PERFORMANCE TEST DATA (SHEET 3 OF 5)

COHERENT TRANSPONDER 640 PRF

INPUT VOLTAGE (V)	14.7		14.6		14.7		16.9		12.1	
BASE PLATE TEMPERATURE (°C)	17.6		24.6		31.6		33.3		33.6	
SIGNAL STRENGTH (DBM)	DELAY (NSEC)	SS TM (V)	DELAY (NSEC)	SS TM (V)	DELAY (NSEC)	SS TM (V)	DELAY (NSEC)	SS TM (V)	DELAY (NSEC)	SS TM (V)
-26	2584.7	3.308	2587.3	3.308	2589.1	3.351	2589.3	3.437	2593.5	3.179
-31	2586.4	3.050	2589.1	3.093	2591.9	3.093	2591.5	3.179	2595.8	2.964
-36	2589.3	2.878	2592.2	2.835	2595.2	2.921	2594.5	3.007	2598.7	2.792
-41	2592.1	2.578	2595.1	2.578	2598.1	2.621	2597.5	2.707	2601.8	2.492
-46	2595.0	2.234	2598.3	2.234	2601.4	2.277	2601.0	2.363	2605.2	2.191
-51	2598.7	1.933	2602.0	1.890	2605.2	1.933	2604.8	1.976	2609.2	1.804
-56	2601.1	1.460	2604.5	1.460	2608.1	1.460	2607.8	1.503	2612.3	1.375
-61	2608.5	1.031	2611.7	1.031	2616.5	1.031	2616.1	1.074	2621.4	.945
-66	2640.9	.687	2649.2	.687	2654.8	.687	2652.4	.730	2671.8	.601
INPUT VOLTAGE (V)	14.7		14.7		14.7		14.7		16.9	
BASE PLATE TEMPERATURE (°C)	32.2		19.7		12.5		4.5		5.7	
SIGNAL STRENGTH (DBM)	DELAY (NSEC)	SS TM (V)	DELAY (NSEC)	SS TM (V)	DELAY (NSEC)	SS TM (V)	DELAY (NSEC)	SS TM (V)	DELAY (NSEC)	SS TM (V)
-26	2589.7	3.308	2583.6	3.222	2582.0	3.222	2579.2	3.136	2579.6	3.265
-31	2591.6	3.050	2585.4	2.964	2583.3	2.964	2581.0	2.878	2581.1	3.007
-36	2594.9	2.878	2588.5	2.792	2586.2	2.792	2584.1	2.664	2584.1	2.835
-41	2597.9	2.578	2590.9	2.535	2588.7	2.535	2586.1	2.406	2586.6	2.535
-46	2601.0	2.234	2594.0	2.148	2591.5	2.148	2588.8	2.062	2588.9	2.191
-51	2604.7	1.890	2597.5	1.847	2594.9	1.847	2592.6	1.761	2592.3	1.847
-56	2607.8	1.417	2599.9	1.375	2597.1	1.417	2595.1	1.289	2594.3	1.417
-61	2616.4	.988	2608.8	.945	2604.1	.988	2605.5	.902	2602.5	.988
-66	2658.9	.687	2659.7	.644	2644.5	.687	2665.0	.601	2651.6	.644

TABLE 5

THERMAL VACUUM PERFORMANCE TEST DATA (SHEET 4 OF 5)

COHERENT TRANSPONDER 640 PRF

INPUT VOLTAGE (V)	12.1		14.7		14.6		14.7		14.7	
BASE PLATE TEMPERATURE (°C)	6.0		5.5		15.8		23.7		13.4	
SIGNAL STRENGTH (DBM)	DELAY (NSEC)	SS TM (V)	DELAY (NSEC)	SS TM (V)	DELAY (NSEC)	SS TM (V)	DELAY (NSEC)	SS TM (V)	DELAY (NSEC)	SS TM (V)
-26	2583.2	3.007	2578.9	3.136	2581.8	3.222	2585.0	3.265	2582.0	3.222
-31	2584.8	2.792	2580.5	2.878	2583.5	2.964	2586.9	3.007	2583.7	2.964
-36	2587.8	2.621	2583.5	2.707	2586.8	2.792	2590.2	2.835	2586.8	2.750
-41	2590.0	2.320	2585.6	2.449	2589.5	2.492	2592.9	2.535	2589.3	2.492
-46	2592.5	2.019	2588.9	2.105	2592.4	2.148	2596.2	2.191	2592.0	2.148
-51	2595.7	1.675	2592.4	1.761	2595.9	1.804	2599.7	1.847	2595.2	1.804
-56	2598.3	1.289	2594.5	1.332	2598.6	1.375	2602.4	1.417	2598.0	1.375
-61	2608.7	.902	2602.6	.945	2607.2	.945	2611.3	.988	2606.2	.945
-66	2674.7	.601	2658.8	.644	2656.4	.644	2657.8	.644	2654.7	.644
INPUT VOLTAGE (V)	14.7		14.7		14.7		14.7			
BASE PLATE TEMPERATURE (°C)	15.6		23.9		33.0		-4.8			
SIGNAL STRENGTH (DBM)	DELAY (NSEC)	SS TM (V)	DELAY (NSEC)	SS TM (V)	DELAY (NSEC)	SS TM (V)	DELAY (NSEC)	SS TM (V)		
-26	2582.4	3.222	2586.4	3.222	2591.2	3.308	2579.7	3.136		
-31			2588.2	3.007	2593.4	3.050	2581.1	2.878		
-36	2587.2	2.792	2591.6	2.792	2596.7	2.878	2584.0	2.706		
-41			2594.4	2.535	2599.5	2.578	2586.3	2.406		
-46	2592.4	2.191	2597.3	2.191	2603.1	2.234	2588.9	2.062		
-51			2600.8	1.847	2606.8	1.890	2591.7	1.761		
-56	2598.2	1.375	2603.2	1.375	2610.2	1.417	2594.0	1.289		
-61			2612.5	.988	2620.1	.988	2604.4	.902		
-66	2650.7	.644	2661.4	.644	2673.7	.644	2669.0	.609		

TABLE 5

THERMAL VACUUM PERFORMANCE TEST DATA (SHEET 5 OF 5)

COHERENT TRANSPONDER

BASE PLATE TEMPERATURE (°C)	PULSE WIDTH (NSEC)
17.3	484
24.2	487
31.7	490
32.2	490
19.7	485
12.5	481
4.4	477
5.4	478
15.7	483
23.6	488
13.3	482
15.5	483
23.8	486
32.9	492
4.8	478

TABLE 6

SIGNAL STRENGTH TM VOLTAGE LINEAR REGRESSION COEFFICIENTS

COHERENT TRANSPONDER

PRF (HZ)	SIGNAL STRENGTH (DBM)	B_O (V)	B_T (V/°C)	B_V (V/V)
160	-26	2.1461	.008380	.049338
160	-36	1.8074	.007741	.044473
160	-46	1.3354	.007258	.036084
160	-66	.3645	.001827	.008548
640	-26	2.3212	.006313	.054326
640	-31	2.2056	.006565	.044916
640	-36	2.0247	.006611	.044691
640	-41	1.7432	.006045	.045258
640	-46	1.5393	.006138	.035689
640	-51	1.2130	.004833	.036540
640	-56	.9288	.003910	.026498
640	-61	.5926	.002868	.022305
640	-66	.3552	.001632	.018114

TABLE 7

REDUCED DATA FOR DELAY VARIATION VS. SIGNAL STRENGTH CURVE

COHERENT TRANSPONDER

SIGNAL STRENGTH (DEM)	COMPUTED CURVE (NSEC)	MEASUREMENTS		
		NUMBER	AVERAGE (NSEC)	STD. DEV. (NSEC)
-20	- 3.0	19	- 3.1	.2
-21	- 2.8			
-22	- 2.6	3	- 2.4	
-23	- 2.4			
-24	- 2.1	3	- 2.2	
-25	- 1.8	19	- 1.7	.2
-26	- 1.5	3	- 1.6	
-27	- 1.2			
-28	- .7	3	- .9	
-29	- .3			
-30	.2	19	0	0
-31	.7			
-32	1.3	3	1.4	
-33	1.9			
-34	2.5	3	2.3	
-35	3.1	19	3.3	.1
-36	3.8	3	4.0	
-37	4.5			
-38	5.2	3	5.3	
-39	5.9			
-40	6.6	19	6.8	.2
-41	7.4			
-42	8.1	3	8.4	
-43	8.9			
-44	9.6	3	9.4	
-45	10.3	19	10.0	.3
-46	11.1	3	11.0	
-47	11.8			
-48	12.5	3	12.6	
-49	13.2			
-50	14.0	19	14.1	.4
-51	14.7			
-52	15.4	3	16.3	
-53	16.2			
-54	16.9	3	17.2	
-55	17.7	19	17.5	.5
-56	18.5	3	18.6	
-57	19.4			
-58	20.4	3	20.2	
-59	21.4			
-60	22.6	19	22.6	.6

TABLE 8

REDUCED DATA FOR PRF TM VOLTAGE VS. PRF CURVE

NONCOHERENT TRANSPONDER

PRF (HZ)	AVERAGE PRF TM VOLTAGE (V)	RMS (V)
160	.120	0
320	.225	.005
480	.319	.002
640	.401	.002
960	.539	.003
1280	.652	.008
2560	.952	.013

NOTE: These results are independent of input voltage, signal strength, and temperature.

TABLE 9

THERMAL VACUUM PERFORMANCE TEST DATA (SHEET 1 OF 5)

NONCOHERENT TRANSPONDER 160 PRF

INPUT VOLTAGE (V)	14.7		14.6		14.7		16.9		11.9	
BASE PLATE TEMPERATURE (°C)	18.1		25.4		33.2		35.8		35.4	
SIGNAL STRENGTH (DBM)	DELAY (NSEC)	SS TM (V)	DELAY (NSEC)	SS TM (V)	DELAY (NSEC)	SS TM (V)	DELAY (NSEC)	SS TM (V)	DELAY (NSEC)	SS TM (V)
-24	5040.5	.56	5046.3	.55	5051.9	.53	5055.1	.52	5058.0	.52
-34	5045.0	.52	5050.7	.51	5055.9	.49	5059.4	.48	5062.3	.47
-44	5039.2	.41	5044.6	.40	5048.2	.37	5051.3	.36	5054.3	.36
-64	5023.0	.08	5031.5	.08	5042.4	.08	5049.4	.08	5051.8	.08
INPUT VOLTAGE (V)	14.7		14.7		14.7		14.6		12.1	
BASE PLATE TEMPERATURE (°C)	33.4		22.3		14.2		5.9		7.3	
SIGNAL STRENGTH (DBM)	DELAY (NSEC)	SS TM (V)	DELAY (NSEC)	SS TM (V)	DELAY (NSEC)	SS TM (V)	DELAY (NSEC)	SS TM (V)	DELAY (NSEC)	SS TM (V)
-24	5053.9	.53	5045.8	.56	5044.8	.58	5043.3	.59	5041.2	.59
-34	5057.8	.48	5049.9	.51	5048.3	.53	5046.2	.54	5044.6	.54
-44	5049.7	.37	5044.0	.41	5042.7	.43	5041.2	.44	5049.8	.44
-64	5045.6	.08	5028.5	.08	5023.6	.08	5019.0	.07	5018.2	.08

TABLE 9

THERMAL VACUUM PERFORMANCE TEST DATA (SHEET 2 OF 5)

NONCOHERENT TRANSPONDER 160 PRF

INPUT VOLTAGE (V)	14.6		14.6		14.7		14.7		14.7	
BASE PLATE TEMPERATURE (°C)	6.7		16.4		24.5		15.2		16.2	
SIGNAL STRENGTH (DBM)	DELAY (NSEC)	SS TM (V)	DELAY (NSEC)	SS TM (V)	DELAY (NSEC)	SS TM (V)	DELAY (NSEC)	SS TM (V)	DELAY (NSEC)	SS TM (V)
-24	5042.0	.59	5043.1	.57	5045.8	.55	5044.7	.57		
-34	5045.3	.54	5046.8	.52	5049.9	.51	5048.3	.53	5047.7	.52
-44	5040.4	.44	5041.2	.42	5043.7	.40	5042.8	.42		
-64	5018.0	.07	5023.3	.07	5031.8	.08	5023.8	.08		

INPUT VOLTAGE (V)	14.6		14.7		14.7	
BASE PLATE TEMPERATURE (°C)	24.5		35.3		6.1	
SIGNAL STRENGTH (DBM)	DELAY (NSEC)	SS TM (V)	DELAY (NSEC)	SS TM (V)	DELAY (NSEC)	SS TM (V)
-24	5046.6	.55	5054.8	.52	5041.3	.59
-34	5050.8	.51	5059.3	.47	5044.5	.54
-44	5044.3	.40	5050.8	.36	5039.9	.44
-64	5031.1	.08	5050.1	.08	5017.1	.08

TABLE 9

THERMAL VACUUM PERFORMANCE TEST DATA (SHEET 3 OF 5)

NONCOHERENT TRANSPONDER 640 PRF

INPUT VOLTAGE (V)	14.7		14.6		14.7		16.9		11.9	
BASE PLATE TEMPERATURE (°C)	17.6		25.0		32.9		35.3		35.1	
SIGNAL STRENGTH (DBM)	DELAY (NSEC)	SS TM (V)	DELAY (NSEC)	SS TM (V)	DELAY (NSEC)	SS TM (V)	DELAY (NSEC)	SS TM (V)	DELAY (NSEC)	SS TM (V)
-24	5045.6	.64	5051.3	.63	5056.1	.61	5058.2	.60	5062.4	.59
-29	5048.2	.63	5053.5	.61	5058.5	.59	5060.8	.58	5065.0	.57
-34	5049.6	.59	5055.2	.58	5059.8	.55	5062.0	.55	5066.5	.54
-39	5046.8	.54	5052.4	.53	5056.1	.50	5058.8	.49	5063.5	.48
-44	5041.1	.47	5046.4	.46	5049.2	.42	5051.9	.42	5056.5	.41
-49	5034.0	.40	5039.2	.38	5042.8	.35	5046.0	.34	5050.5	.34
-54	5029.1	.32	5035.0	.30	5039.8	.27	5043.8	.27	5048.2	.26
-59	5023.7	.20	5031.5	.20	5038.0	.17	5042.7	.17	5046.5	.16
-64	5027.3	.09	5035.0	.09	5047.1	.08	5052.8	.09	5056.1	.08

INPUT VOLTAGE (V)	14.7		14.7		14.7		14.6		11.9	
BASE PLATE TEMPERATURE (°C)	33.2		21.9		13.9		5.6		7.1	
SIGNAL STRENGTH (DBM)	DELAY (NSEC)	SS TM (V)	DELAY (NSEC)	SS TM (V)	DELAY (NSEC)	SS TM (V)	DELAY (NSEC)	SS TM (V)	DELAY (NSEC)	SS TM (V)
-24	5058.4	.60	5052.9	.64	5051.9	.66	5051.5	.69	5047.7	.67
-29	5060.8	.58	5054.8	.62	5054.2	.64	5053.9	.67	5050.3	.66
-34	5061.8	.55	5055.8	.59	5054.8	.61	5053.5	.63	5050.5	.62
-39	5058.4	.50	5052.6	.53	5051.7	.55	5050.6	.57	5047.9	.56
-44	5051.5	.42	5046.8	.47	5046.5	.48	5045.9	.50	5043.1	.50
-49	5045.1	.35	5039.5	.39	5039.5	.41	5039.2	.43	5036.6	.43
-54	5042.0	.27	5034.9	.31	5033.9	.33	5032.7	.35	5030.5	.34
-59	5039.6	.16	5030.2	.21	5026.2	.21	5022.2	.21	5021.0	.21
-64	5049.4	.08	5032.7	.09	5027.9	.09	5023.7	.09	5022.0	.09

TABLE 9

THERMAL VACUUM PERFORMANCE TEST DATA (SHEET 4 OF 5)

NONCOHERENT TRANSPONDER 640 PRF

INPUT VOLTAGE (V)	14.6		14.6		14.7		14.6		14.7	
BASE PLATE TEMPERATURE (°C)	6.4		15.9		24.3		15.0		15.9	
SIGNAL STRENGTH (DBM)	DELAY (NSEC)	SS TM (V)	DELAY (NSEC)	SS TM (V)	DELAY (NSEC)	SS TM (V)	DELAY (NSEC)	SS TM (V)	DELAY (NSEC)	SS TM (V)
-24	5050.3	.68	5050.0	.66	5051.8	.63	5051.2	.66	5050.3	.66
-29	5052.6	.66	5052.4	.64	5054.3	.61	5053.7	.64		
-34	5052.0	.62	5053.1	.60	5055.7	.58	5054.3	.60	5053.3	.60
-39	5049.2	.57	5050.3	.55	5052.2	.53	5051.5	.55		
-44	5044.4	.50	5045.0	.48	5046.5	.46	5046.4	.48	5045.1	.48
-49	5037.8	.43	5037.9	.41	5039.1	.38	5039.3	.41		
-54	5031.6	.34	5032.5	.32	5034.9	.31	5033.9	.33	5032.8	.32
-59	5021.6	.21	5025.2	.20	5030.2	.20	5026.4	.21		
-64	5022.5	.09	5027.6	.09	5034.9	.09	5028.0	.09	5028.3	.09

INPUT VOLTAGE (V)	14.6		14.7		14.7	
BASE PLATE TEMPERATURE (°C)	24.2		35.1		5.8	
SIGNAL STRENGTH (DBM)	DELAY (NSEC)	SS TM (V)	DELAY (NSEC)	SS TM (V)	DELAY (NSEC)	SS TM (V)
-24	5052.1	.63	5058.0	.59	5048.7	.68
-29	5054.7	.61	5060.6	.57	5051.2	.66
-34	5055.9	.58	5062.0	.54	5051.0	.62
-39	5053.0	.53	5058.5	.48	5048.4	.57
-44	5047.1	.46	5051.5	.41	5043.6	.50
-49	5039.9	.39	5054.8	.33	5036.8	.43
-54	5035.6	.31	5043.6	.26	5030.5	.41
-59	5031.1	.20	5042.9	.16	5050.7	.22
-64	5035.0	.09	5053.9	.08	5021.3	.09

TABLE 9

THERMAL VACUUM PERFORMANCE TEST DATA (SHEET 5 OF 5)

NONCOHERENT TRANSPONDER

BASE PLATE TEMPERATURE (°C)	PULSE WIDTH (NSEC)
17.3	486
24.7	484
32.6	494
33.1	488
21.7	480
13.7	472
5.4	467
6.2	472
15.5	476
23.8	482
14.9	475
15.7	475
24.0	483
34.8	511
5.6	477

TABLE 10

SIGNAL STRENGTH TM VOLTAGE LINEAR REGRESSION COEFFICIENTS

NONCOHERENT TRANSPONDER

PRF (HZ)	SIGNAL STRENGTH (DBM)	B_O (V)	B_T (V/°C)
160	-24	.6071	-.002364
160	-34	.5578	-.002211
160	-44	.4615	-.002713
160	-64	.0745	.000179
640	-24	.7009	-.002960
640	-29	.6832	-.003032
640	-34	.6421	-.002722
640	-39	.5887	-.002761
640	-44	.5232	-.002963
640	-49	.4538	-.003147
640	-54	.3666	-.002806
640	-59	.2296	-.001702
640	-64	.0935	-.000277

TABLE 11

REDUCED DATA FOR DELAY VARIATION VS. SIGNAL STRENGTH CURVE

NONCOHERENT TRANSPONDER

SIGNAL STRENGTH (DBM)	COMPUTED CURVE (NSEC)	MEASUREMENTS NUMBER	MEASUREMENTS AVERAGE (NSEC)	MEASUREMENTS STD. DEV. (NSEC)
-20	- 4.2	16	- 4.2	.4
-21	- 4.0			
-22	- 3.8	2	- 3.7	
-23	- 3.6			
-24	- 3.4	2	- 3.4	
-25	- 3.0	16	- 3.0	.5
-26	- 2.6	2	- 2.4	
-27	- 2.1			
-28	- 1.5	2	- 1.2	
-29	- .8			
-30	- .2	16	- .2	.5
-31	.4			
-32	.9	2	1.0	
-33	1.1			
-34	.9	2	.9	
-35	0	16	0	0
-36	- .2	2	- .5	
-37	- .8			
-38	- 1.5	2	- 1.7	
-39	- 2.4			
-40	- 3.6	16	- 3.5	.3
-41	- 4.8			
-42	- 6.1	2	- 6.4	
-43	- 7.6			
-44	- 9.0	2	- 8.4	
-45	-10.4	16	-10.5	.4
-46	-11.8	2	-11.9	
-47	-13.2			
-48	-14.4	2	-14.5	
-49	-15.6			
-50	-16.7	16	-16.7	.3
-51	-17.6			
-52	-18.4	2	-18.6	
-53	-19.1			
-54	-19.6	2	-19.3	
-55	-20.1	16	-20.1	.5
-56	-20.5	2	-20.4	
-57	-20.9			
-58	-21.4	2	-21.6	
-59	-21.9			
-60	-22.7	16	-22.7	1.2

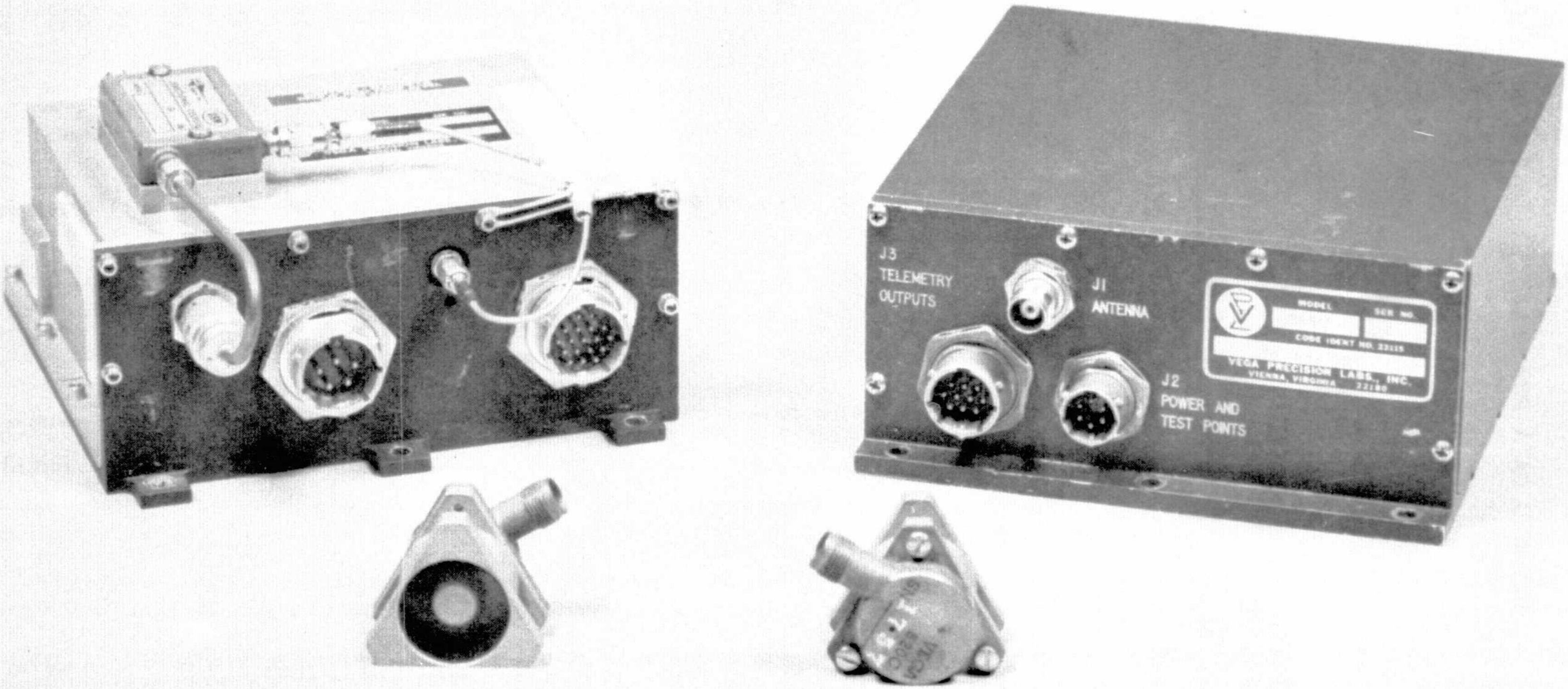

FIGURE 1. - TRANSPONDER HARDWARE

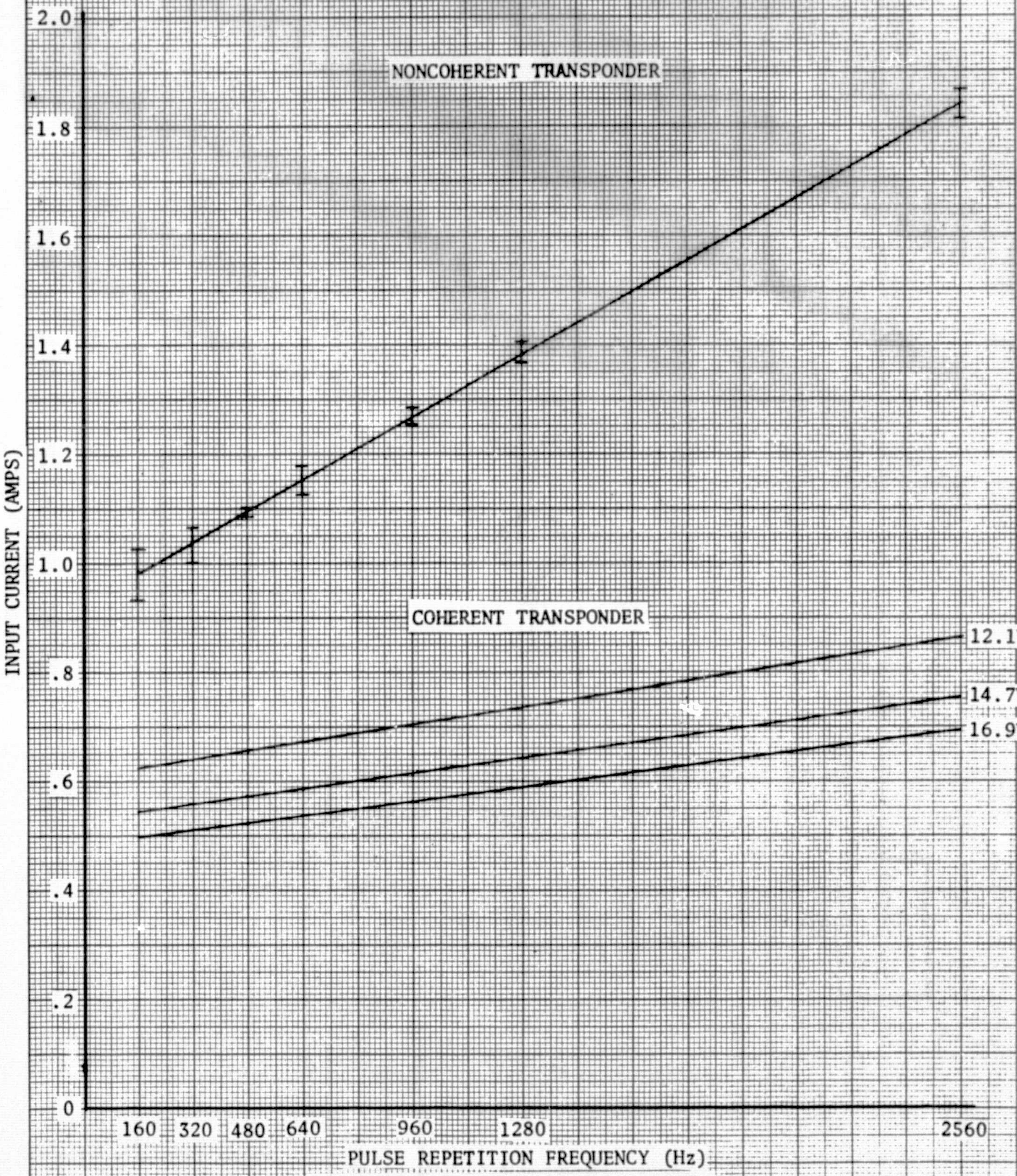

FIGURE 2. - INPUT CURRENT VS. PRF

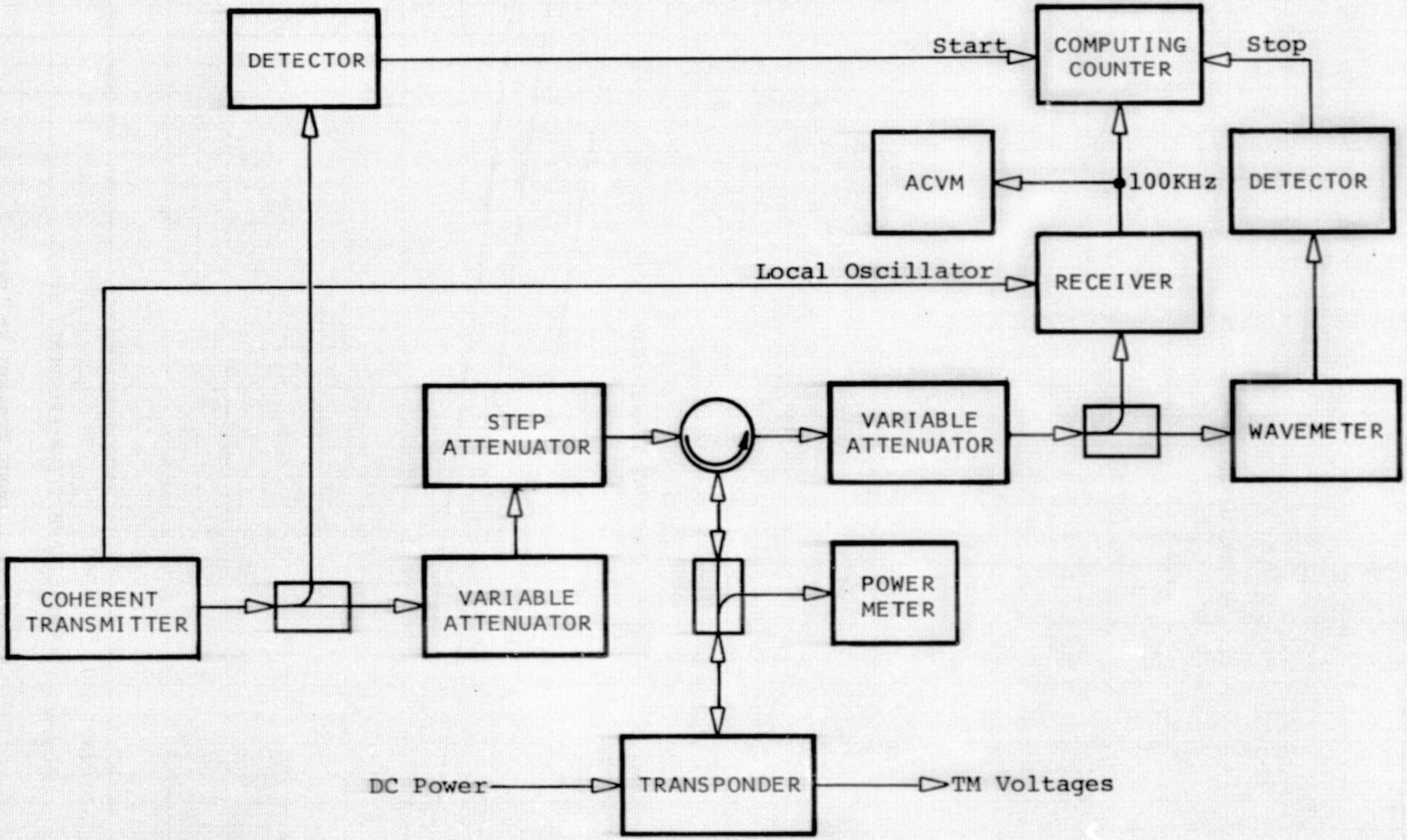

FIGURE 3. - C-BAND TEST CONSOLE, SIMPLIFIED BLOCK DIAGRAM

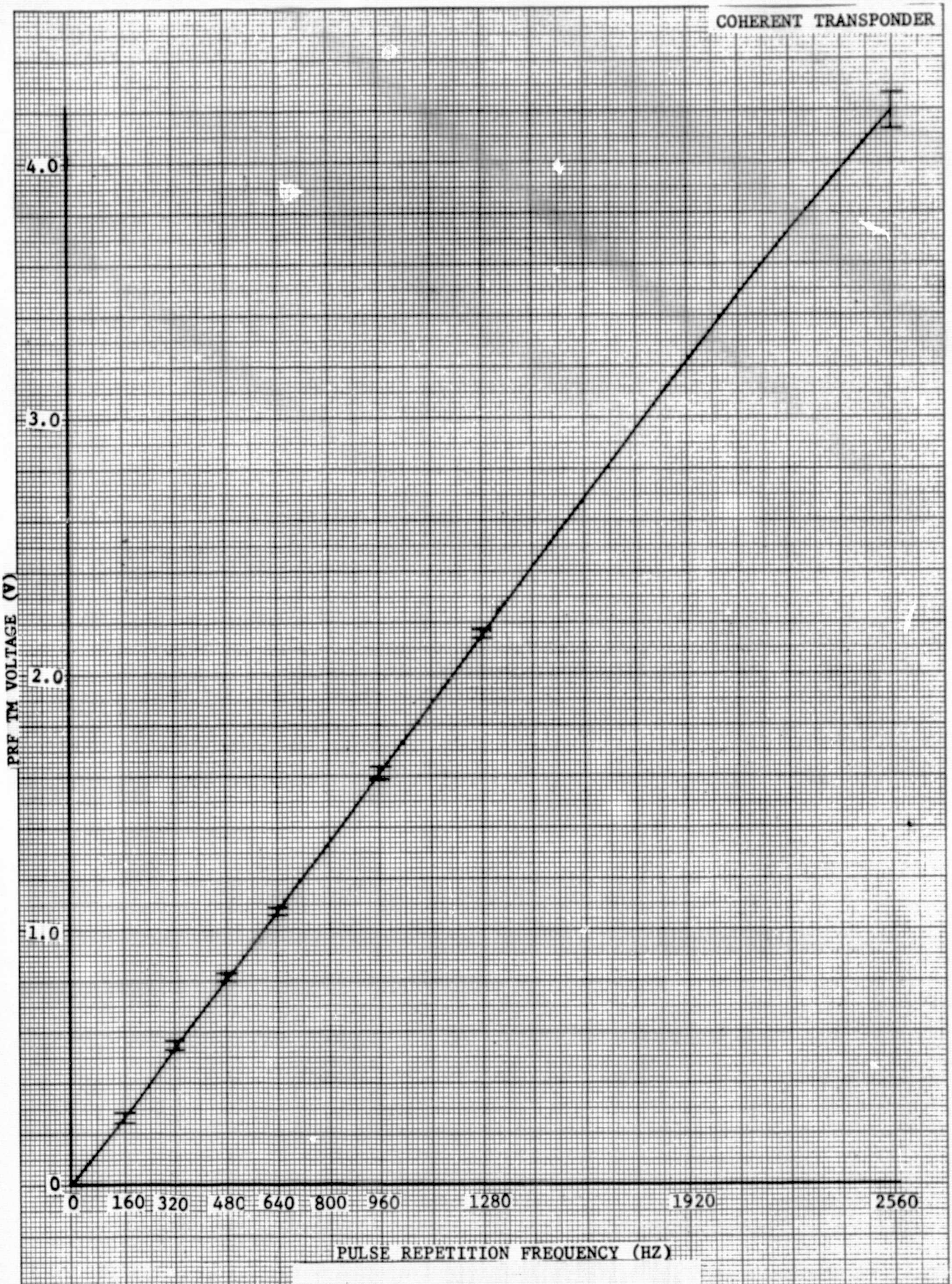

FIGURE 4. - PRF TM VOLTAGE VS. PRF

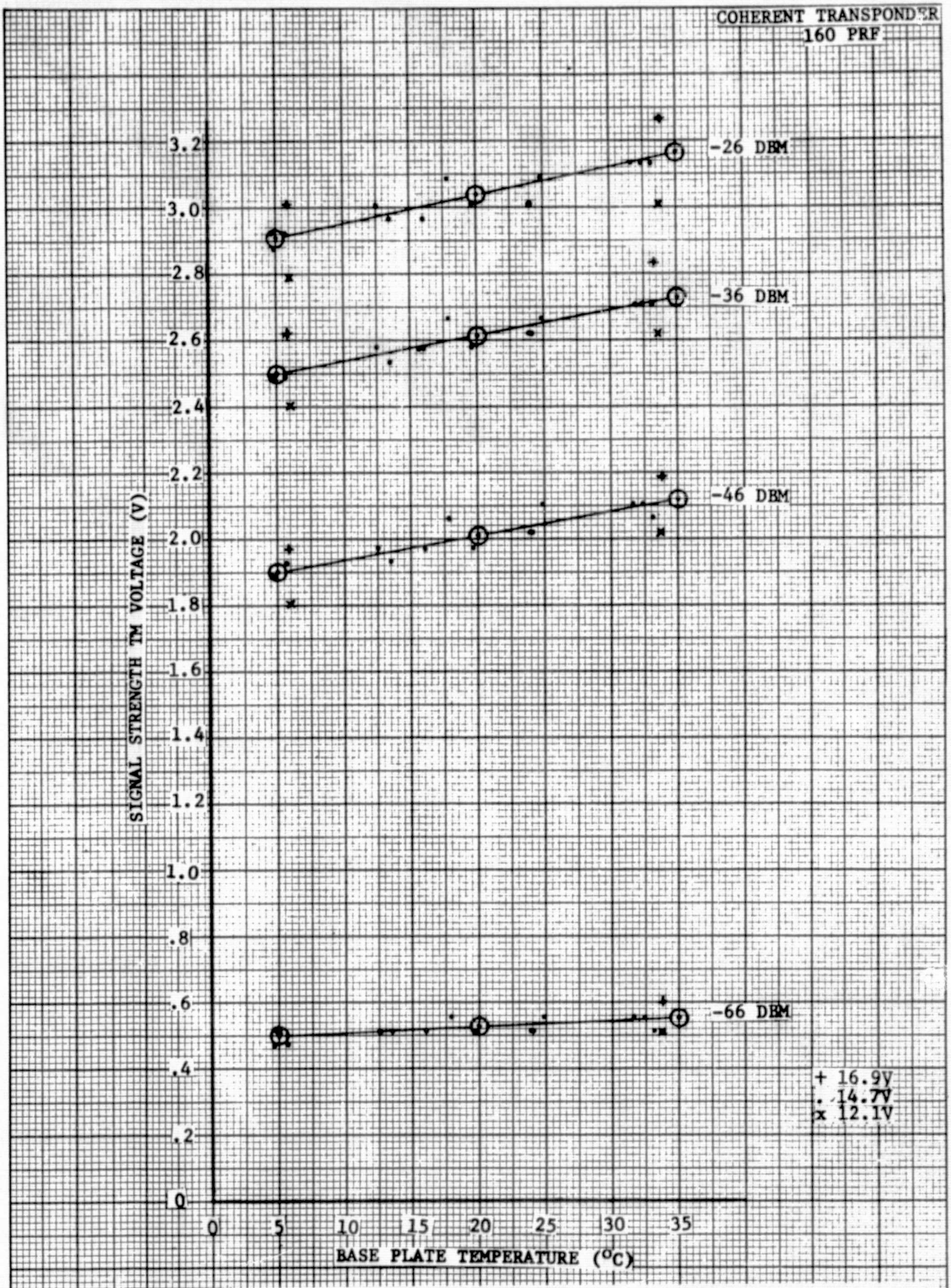

FIGURE 5. - SIGNAL STRENGTH TM VOLTAGE VS. BASE PLATE TEMPERATURE AT 160 PRF

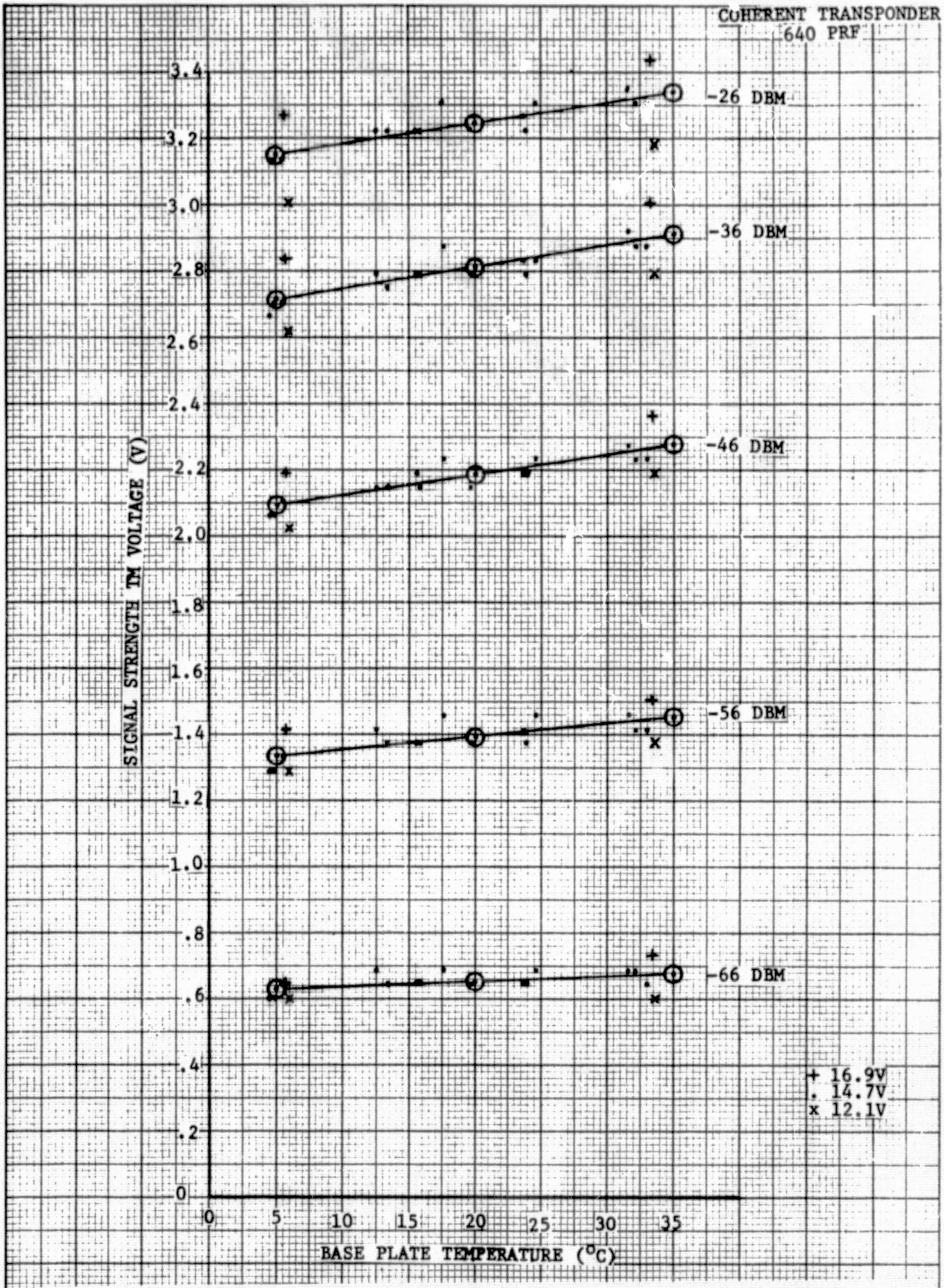

FIGURE 6. - SIGNAL STRENGTH TM VOLTAGE VS. BASE PLATE TEMPERATURE AT 640 PRF

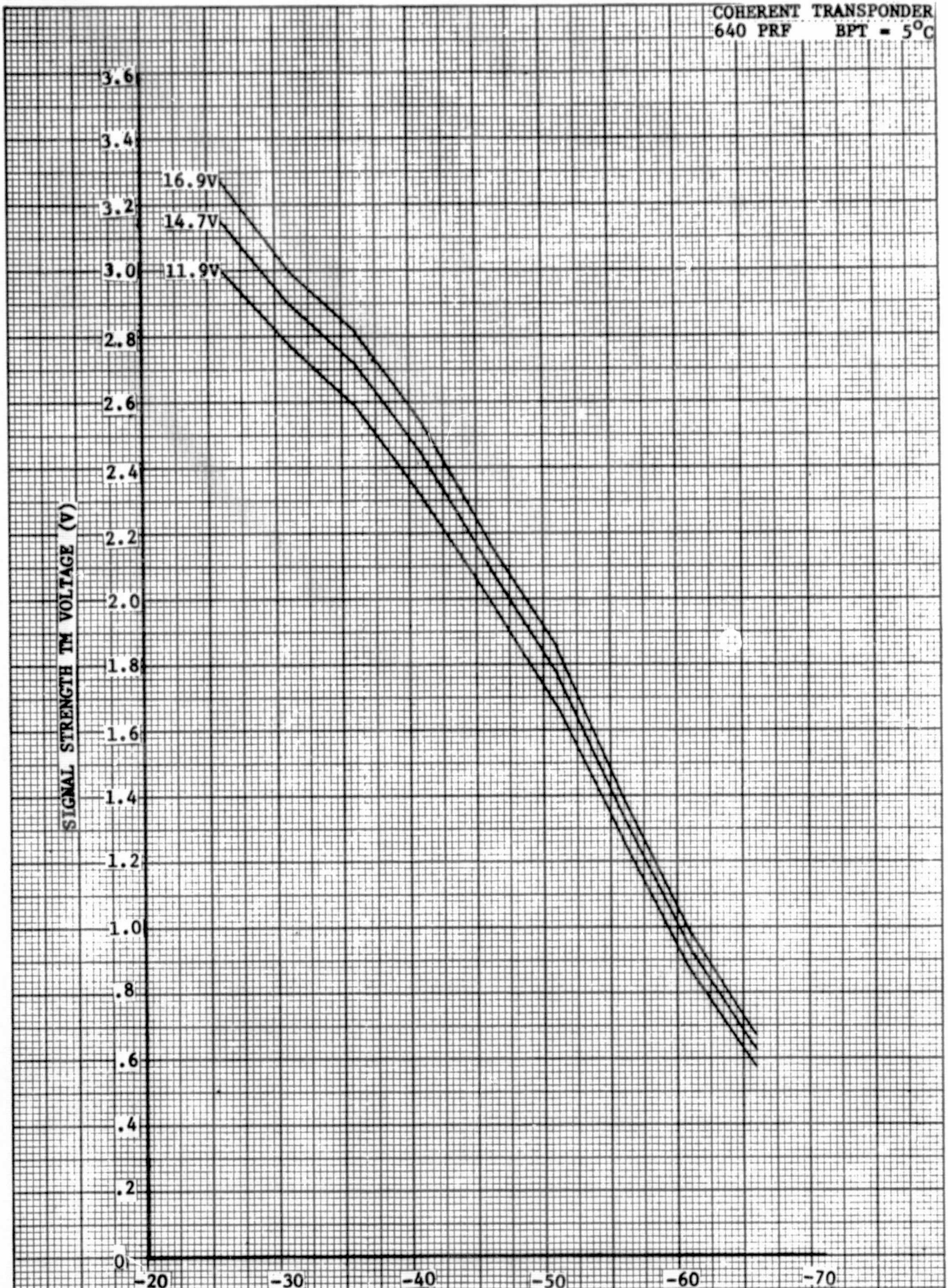

FIGURE 7. - SIGNAL STRENGTH TM VOLTAGE VS. SIGNAL STRENGTH AT 5°C

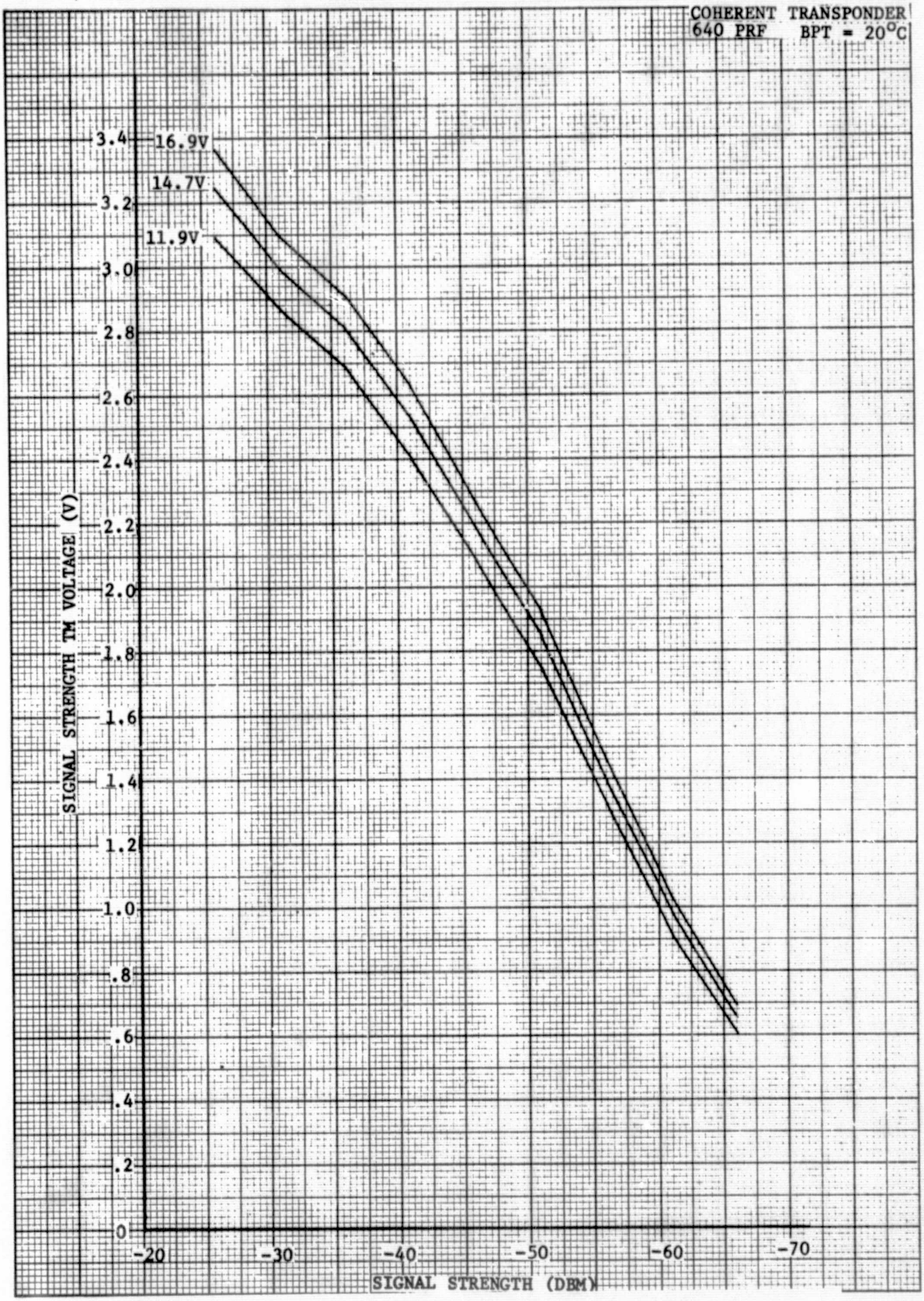

FIGURE 8. - SIGNAL STRENGTH TM VOLTAGE VS. SIGNAL STRENGTH AT 20°C

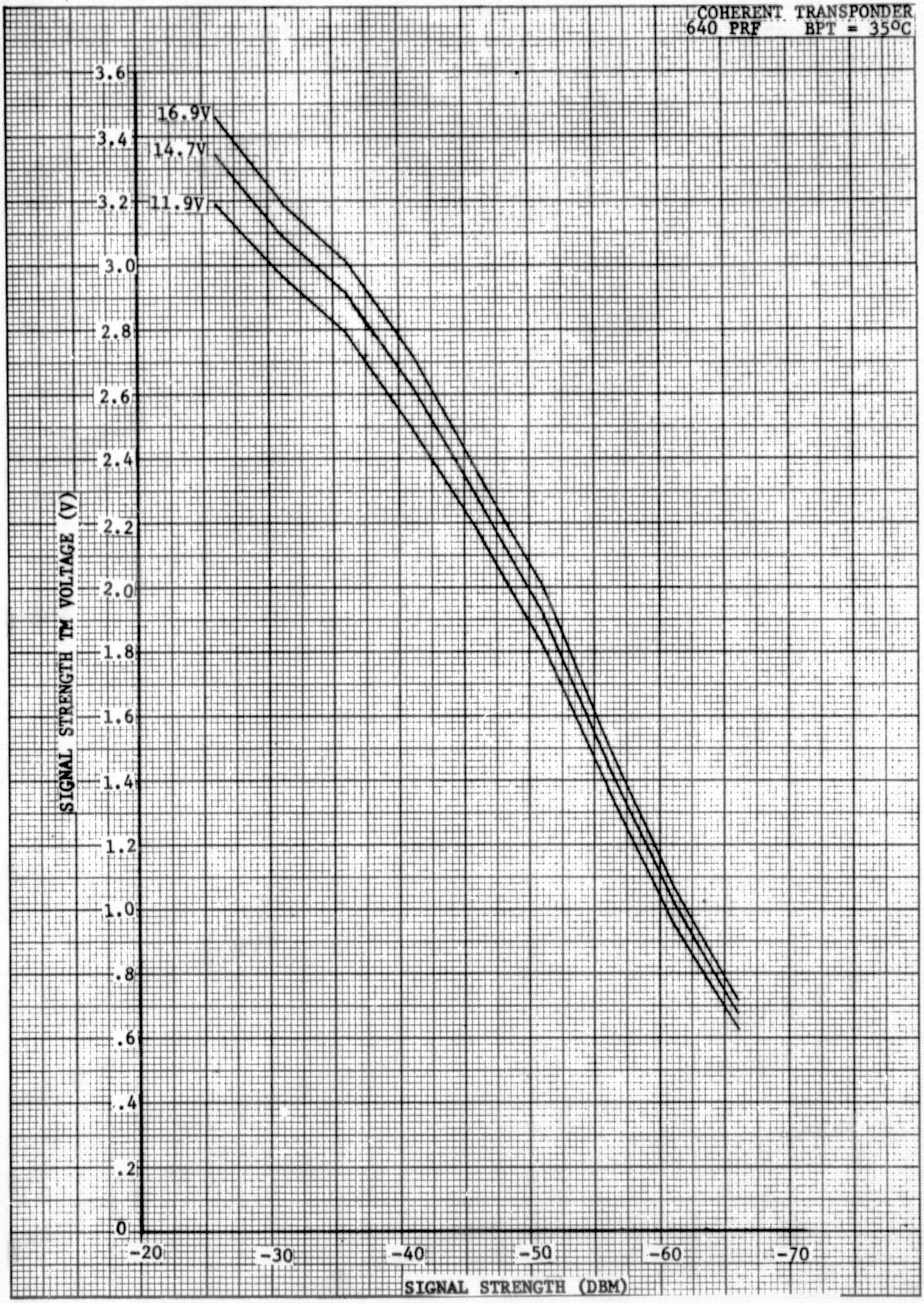

FIGURE 9. - SIGNAL STRENGTH TM VOLTAGE VS. SIGNAL STRENGTH AT 35°C

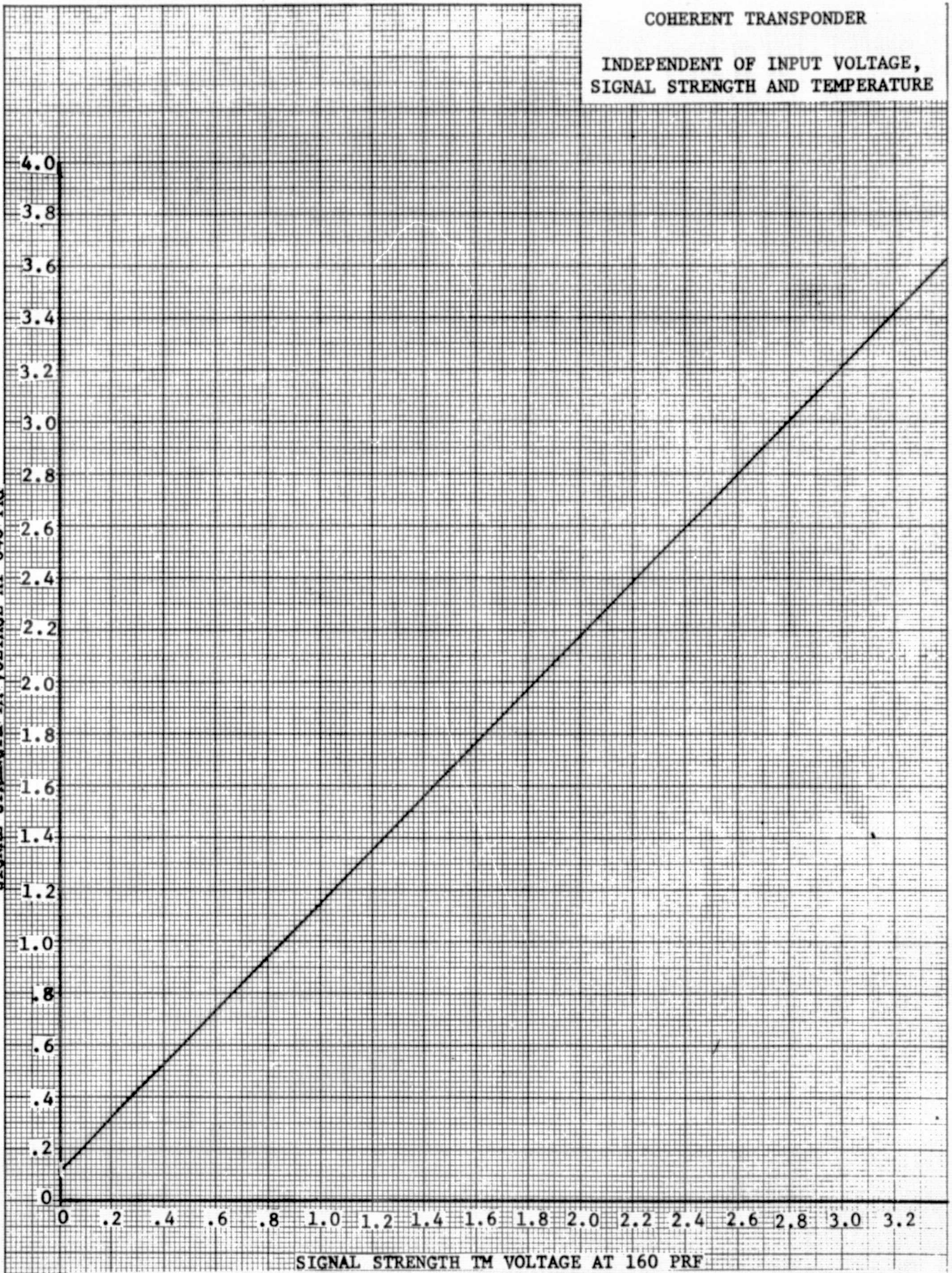

FIGURE 10. - SIGNAL STRENGTH TM VOLTAGE AT 640 PRF VS. SIGNAL STRENGTH TM VOLTAGE AT 160 PRF

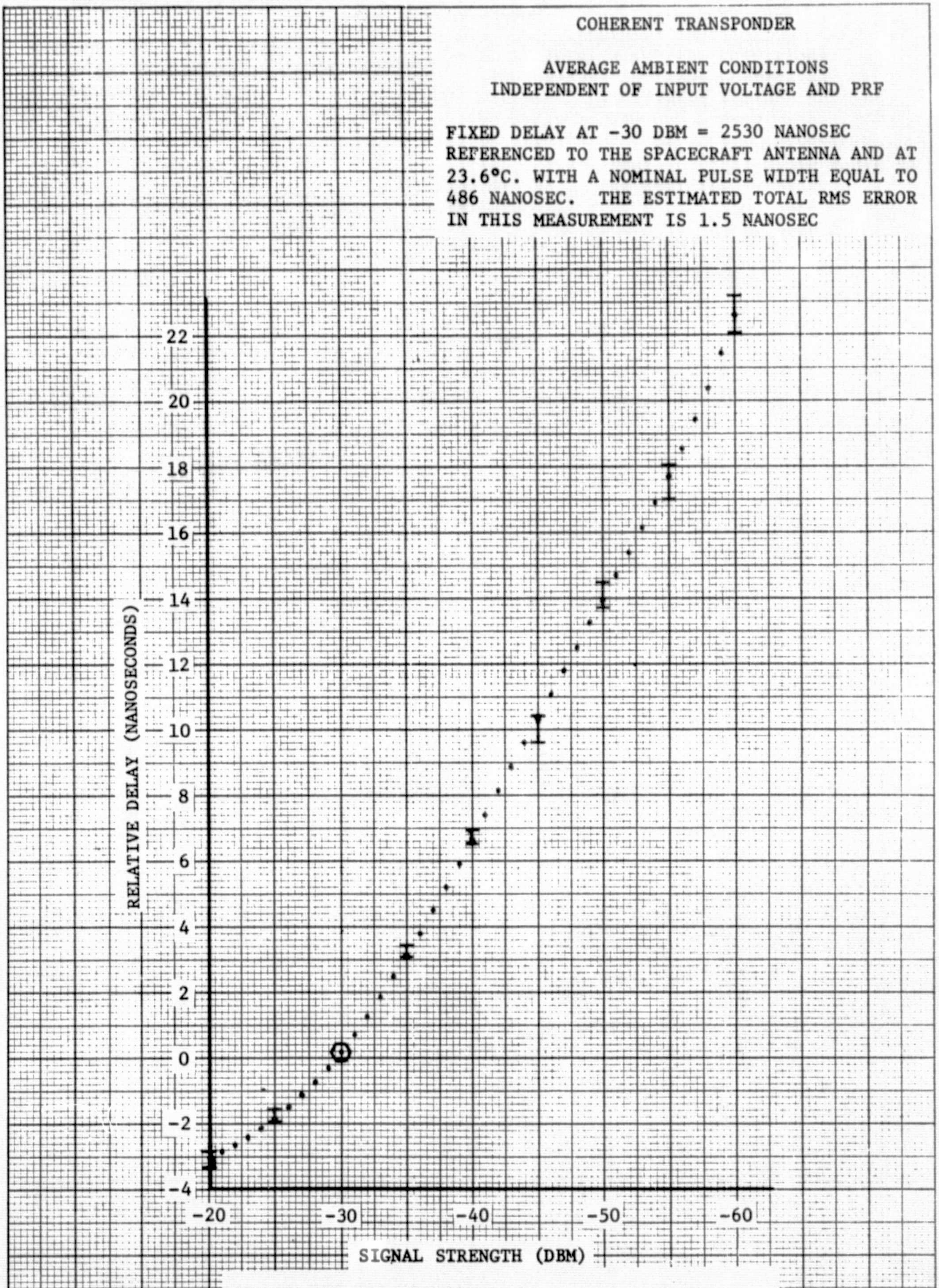

FIGURE 11. - DELAY VARIATION VS. SIGNAL STRENGTH

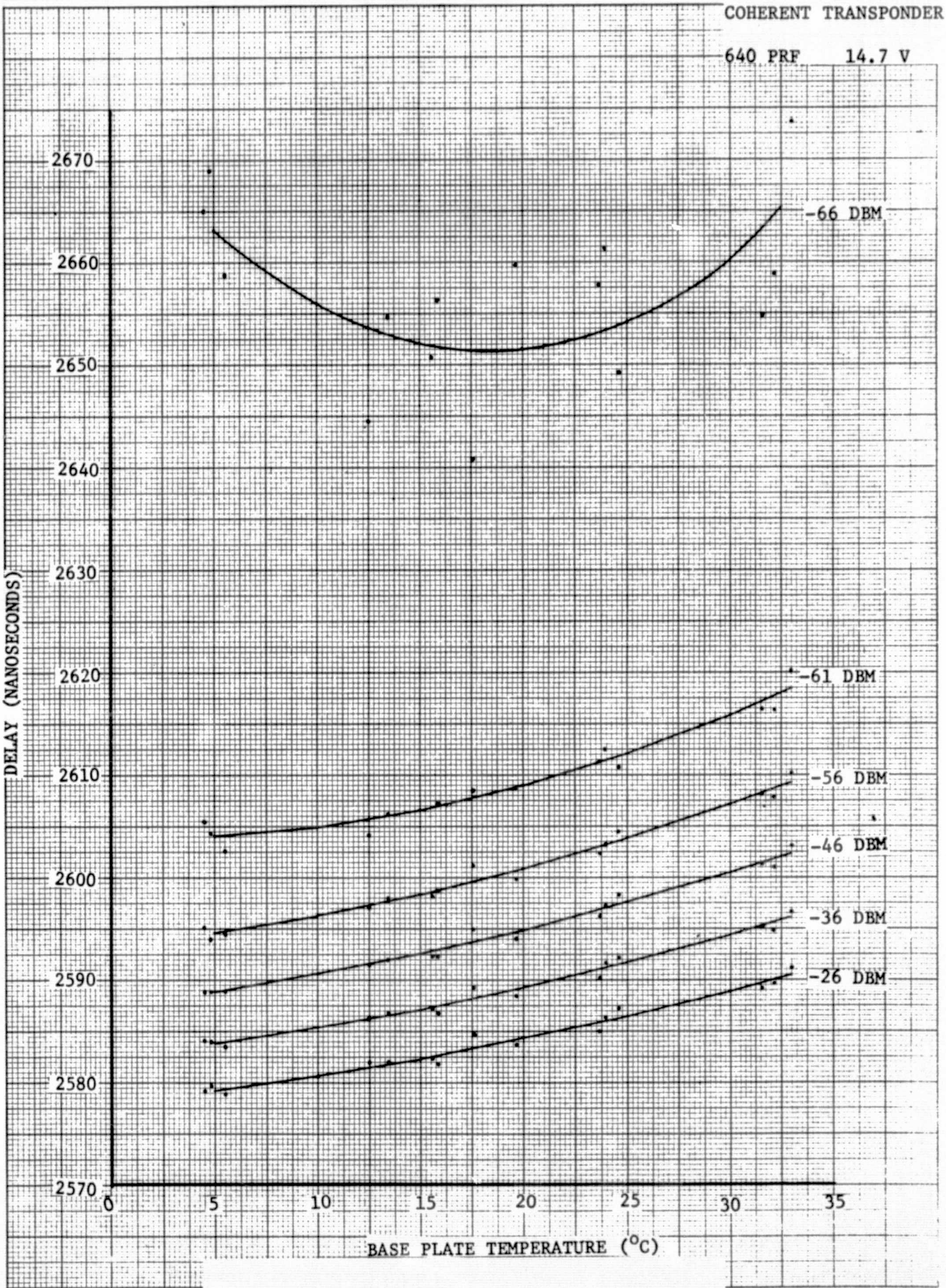

FIGURE 12. - DELAY VS. BASE PLATE TEMPERATURE

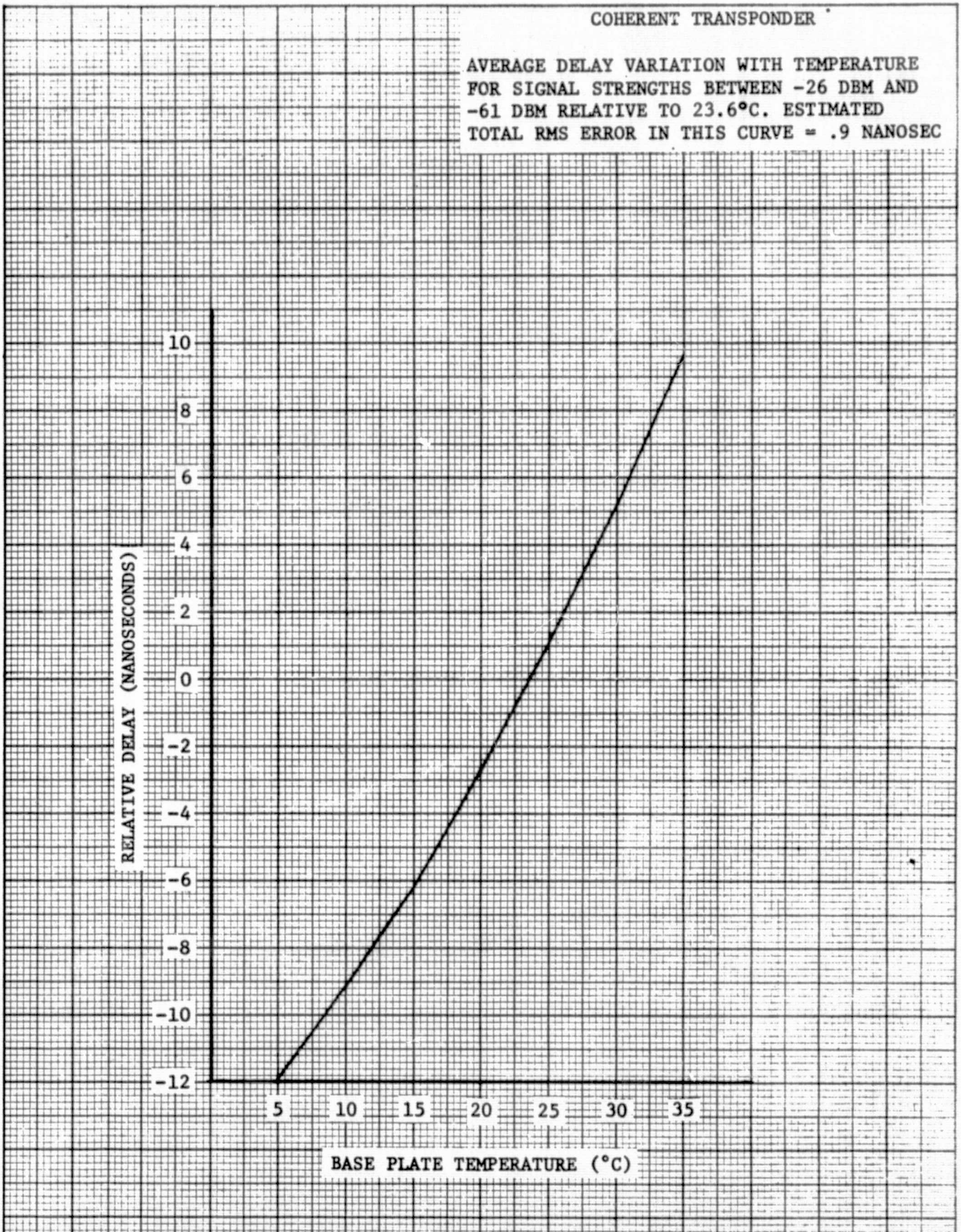

FIGURE 13. - AVERAGE DELAY VARIATION VS. BASE PLATE TEMPERATURE

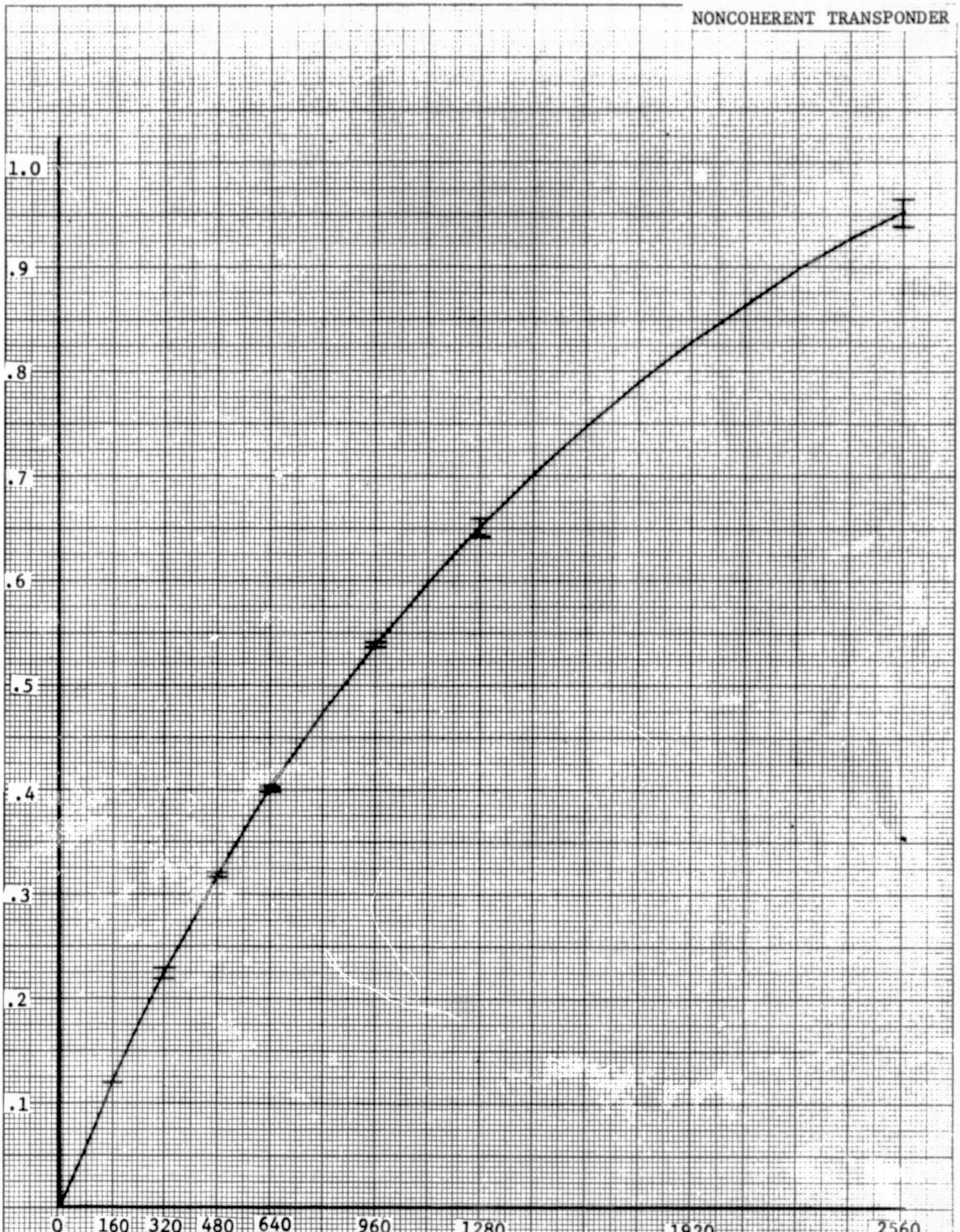

FIGURE 14. - PRF TM VOLTAGE VS. PRF

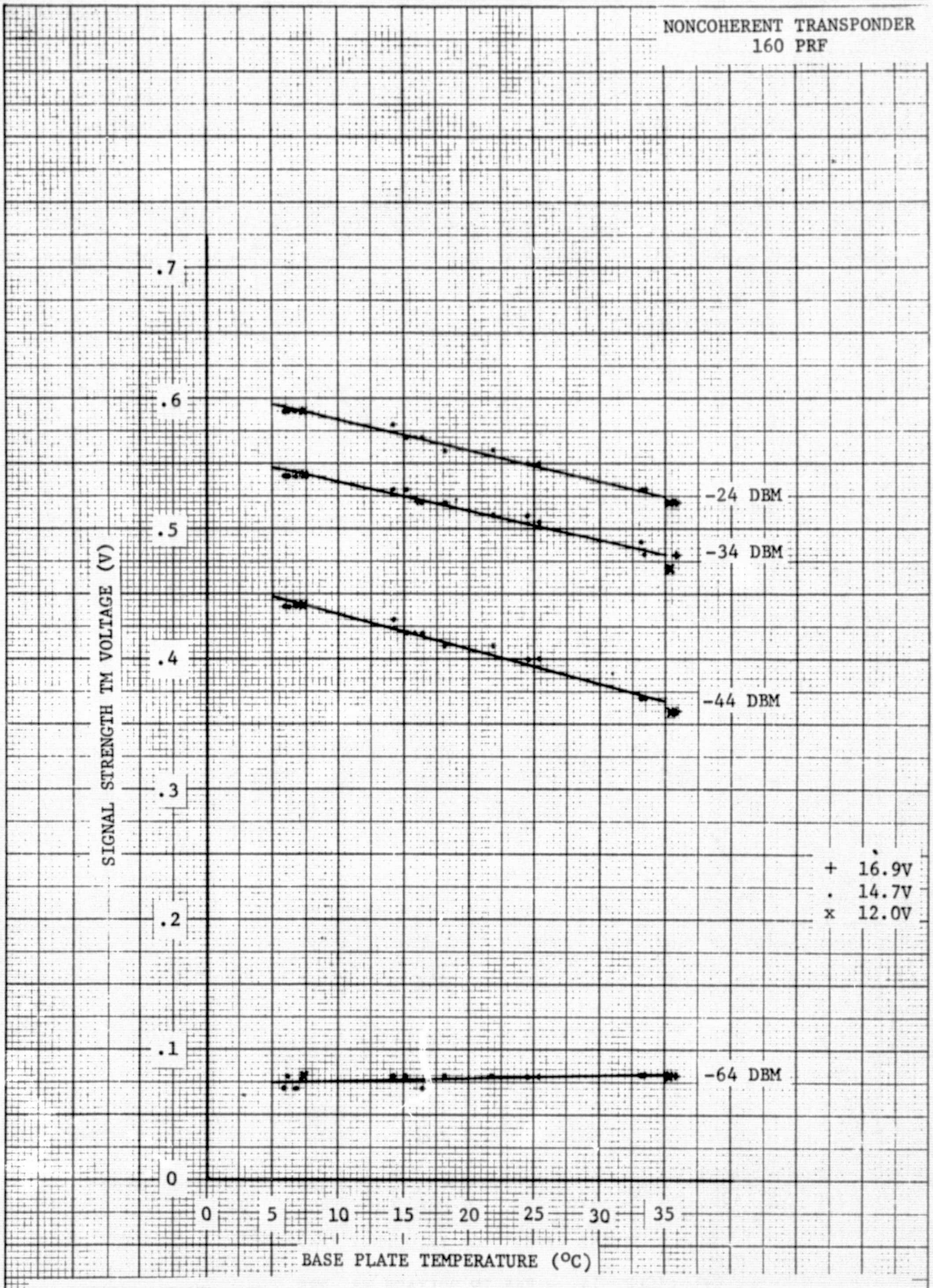

FIGURE 15. - SIGNAL STRENGTH TM VOLTAGE VS. BASE PLATE TEMPERATURE AT 160 PRF

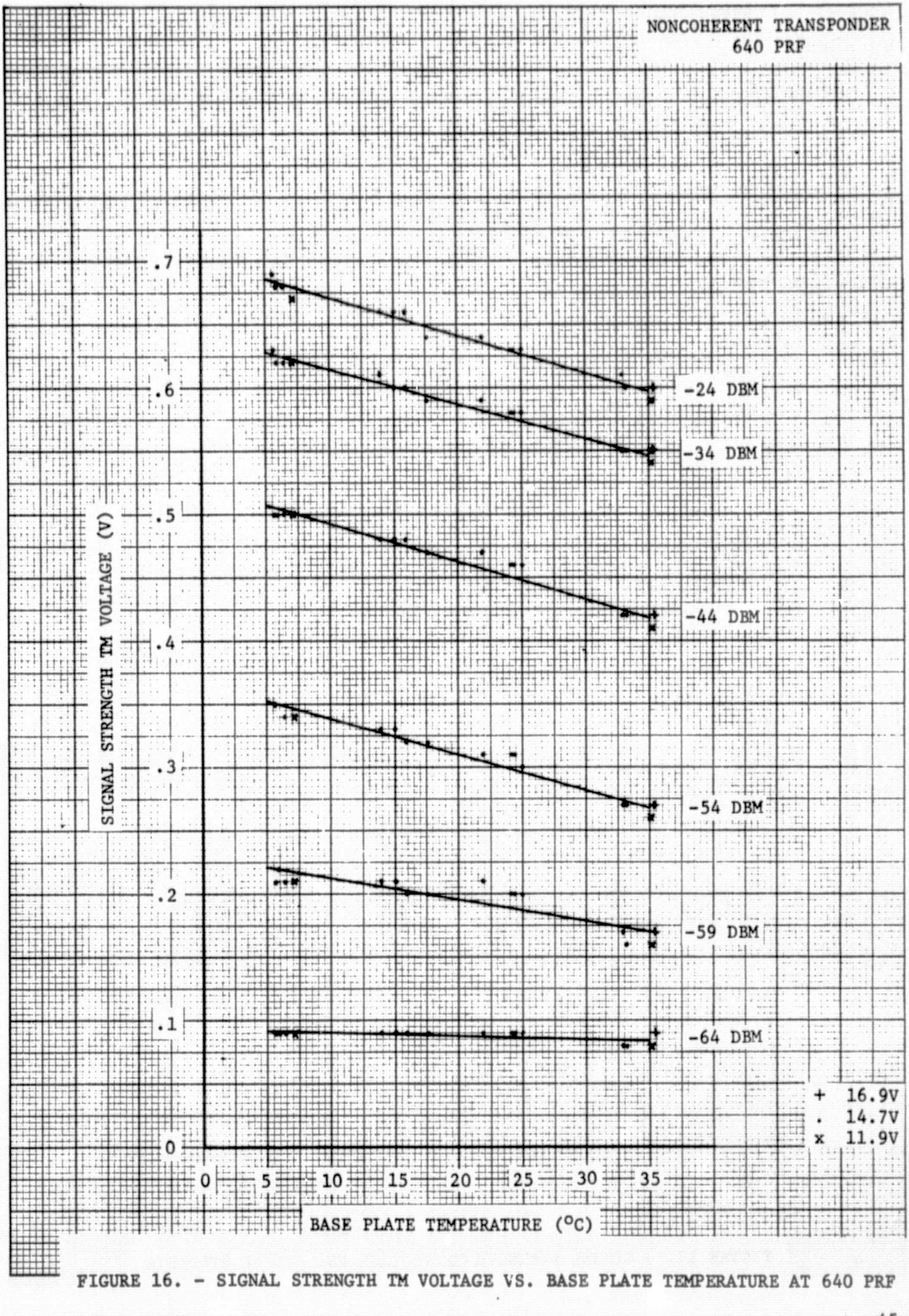

FIGURE 16. - SIGNAL STRENGTH TM VOLTAGE VS. BASE PLATE TEMPERATURE AT 640 PRF

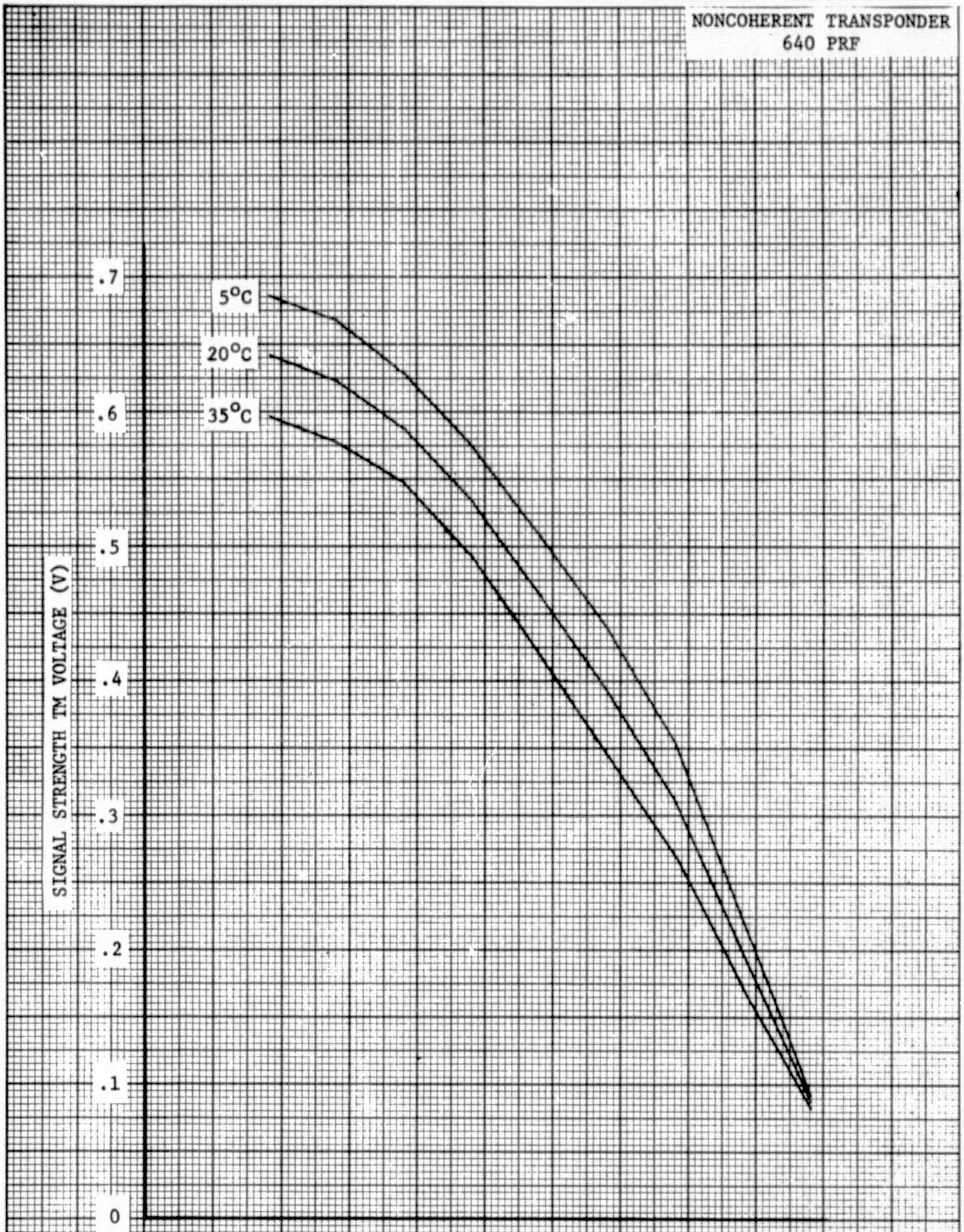

FIGURE 17. - SIGNAL STRENGTH TM VOLTAGE VS. SIGNAL STRENGTH

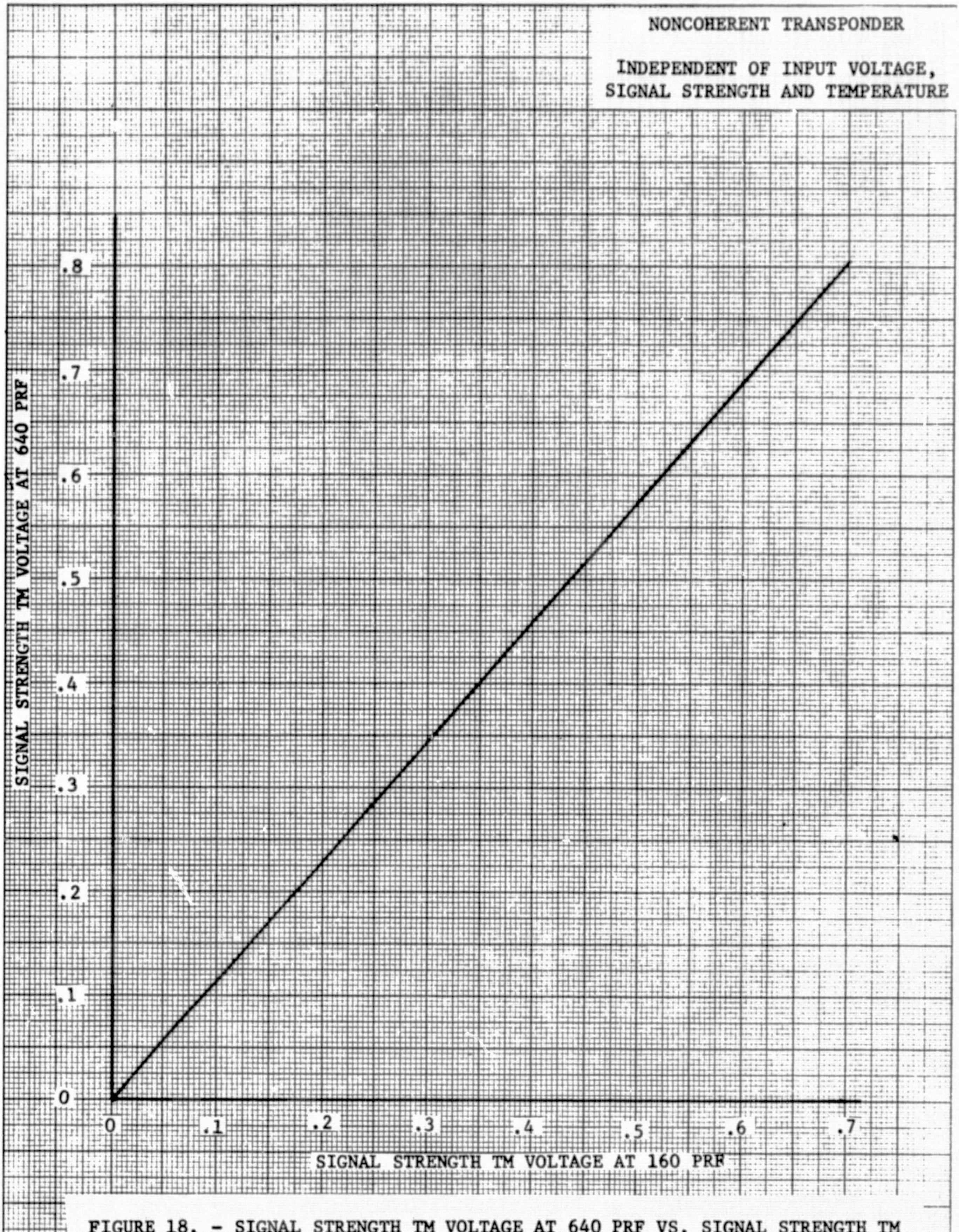

FIGURE 18. - SIGNAL STRENGTH TM VOLTAGE AT 640 PRF VS. SIGNAL STRENGTH TM VOLTAGE AT 160 PRF

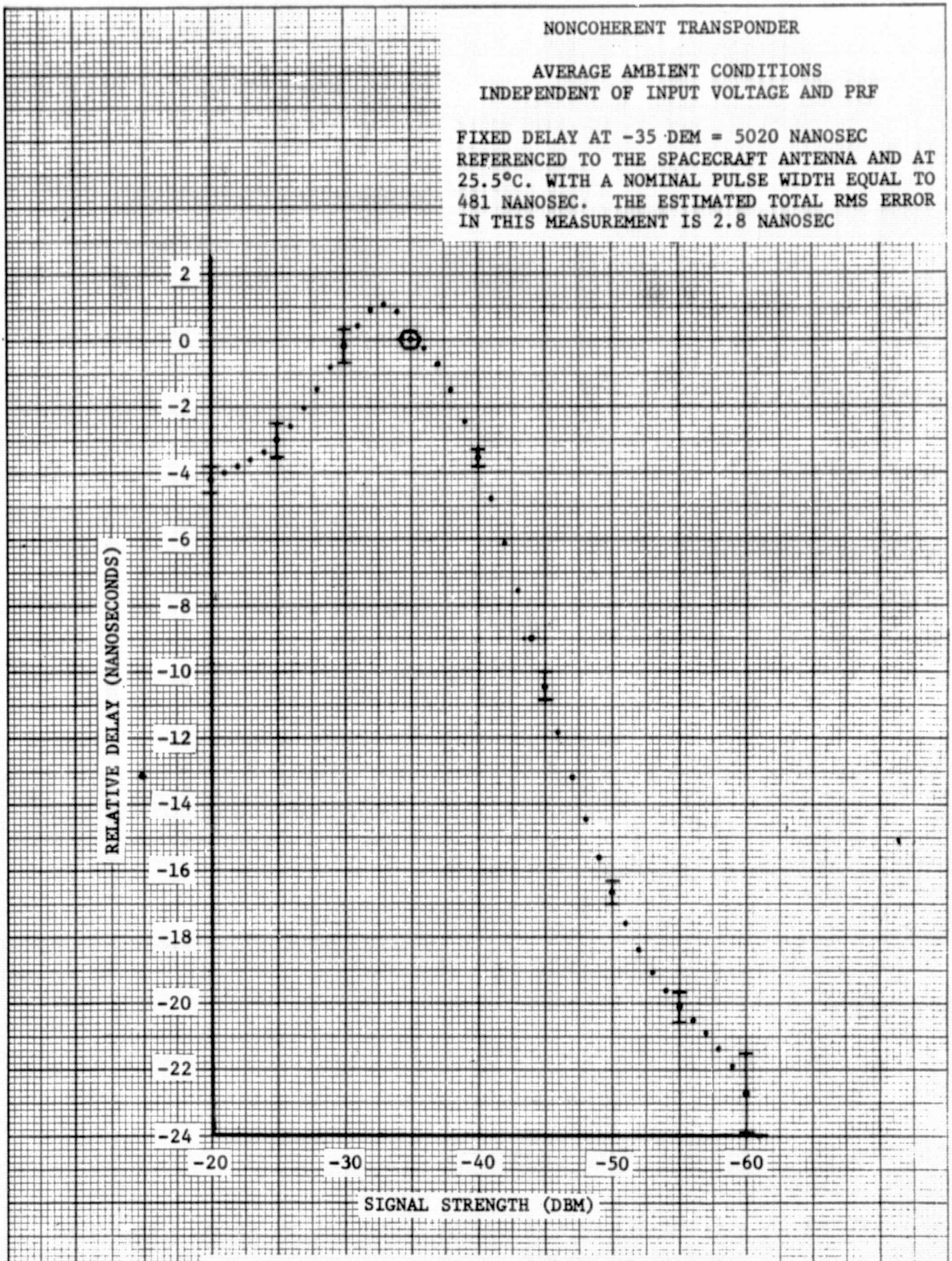

FIGURE 19. - DELAY VARIATION VS. SIGNAL STRENGTH

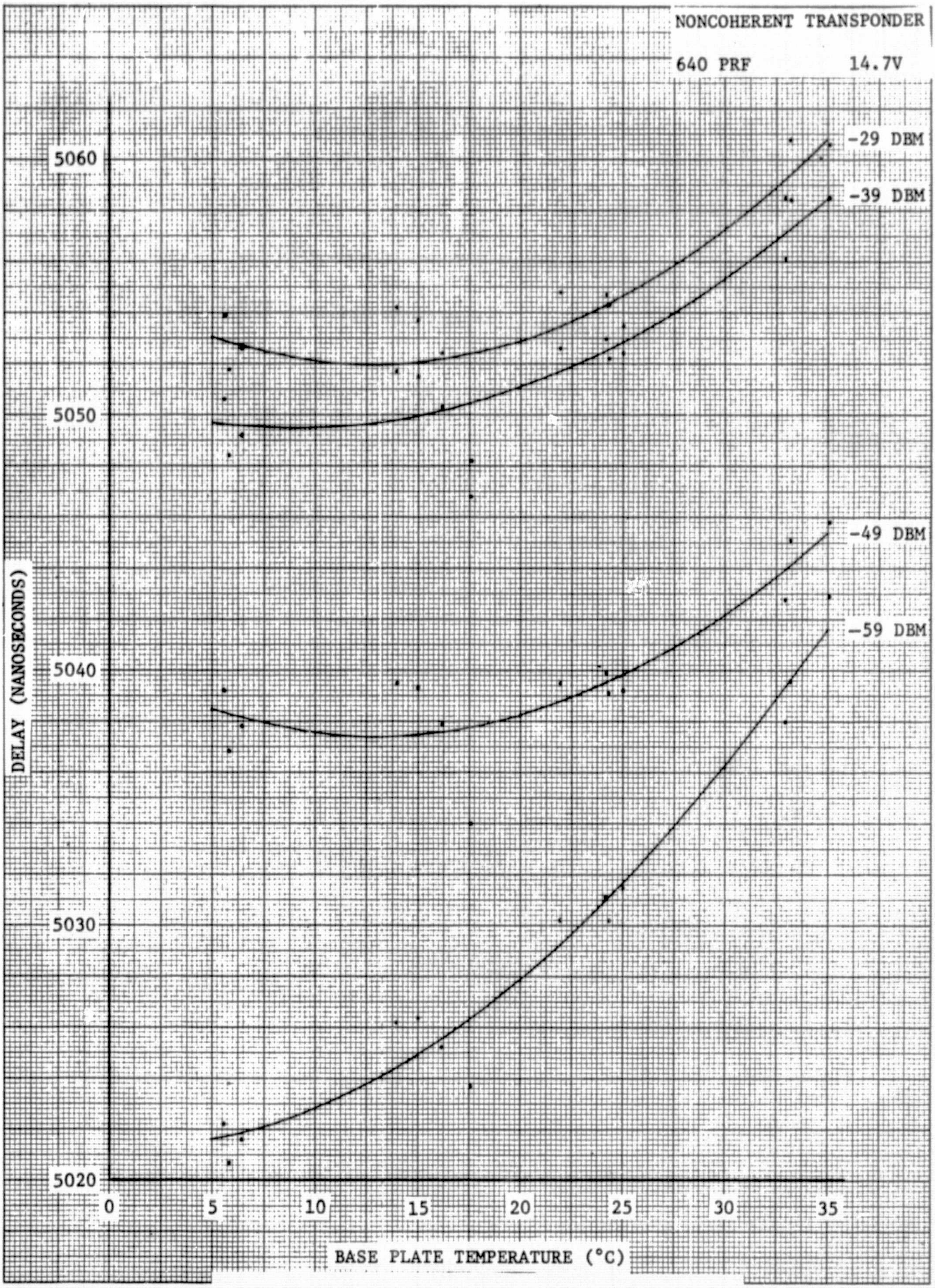

FIGURE 20. - DELAY VS. BASE PLATE TEMPERATURE

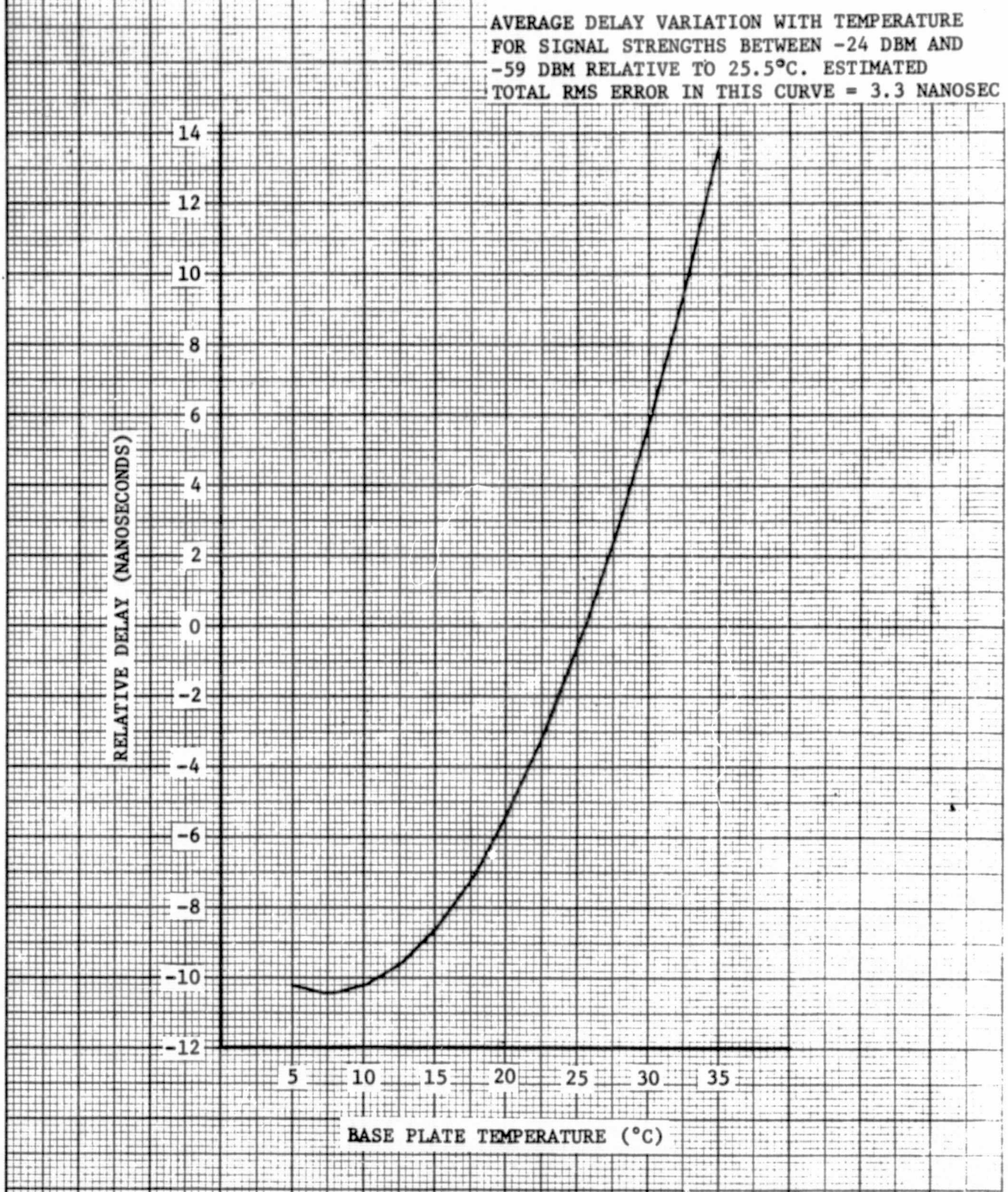

FIGURE 21. - AVERAGE DELAY VARIATION VS. BASE PLATE TEMPERATURE