NATIONAL RADIO ASTRONOMY OBSERVATORY
GREEN BANK, WEST VIRGINIA

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Title: ACCURACY MEASUREMENTS ON THE WEINSCHEL MODEL 3200-1 ATTENUATOR

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ACCURACY MEASUREMENTS ON THE WEINSCHEL MODEL 3200-1 ATTENUATOR

Andrew Keckler*

PURPOSE: The purpose of this experiment was to measure how accurate and repeatable the Weinschel model 3200-1 attenuator was, in order to see if it could be used as a standard in another system.

OBSERVATIONS:

It was determined that the attenuator was fairly accurate in its relative steps, never exceeding 0.1 db of error, which was for the -16db setting, and never exceeding 4% of the total attenuation.

There were, however, problems with the attenuator. Its total attenuation varied with frequency and temperature. The attenuation varied by as much as 2db for a variation in frequency of 1 GHz. This was constant between the different settings, but the slope was not always the same on different days. The attenuation also varied with temperature, and this variation was rather linear. It amounted to between 0.03 and 0.05 db per 5 degrees Celsius.

The repeatibility of the experiment was rather good, varying only 5% at the -1 db setting, over time. The attenuation also varied when the attenuator was switched. This variation seemed to be related to the temperature problem, in that the attenuation became greater after driving some of the cells for a length of time.

One possible source of error in this experiment was that the directional coupler used to level the sweep oscillator had a band width outside of the frequencies used. It was believed not to have affected the experiment in that it was outside of the testing circuit.

* Co-Op Student from University of Cincinnati, Ohio.

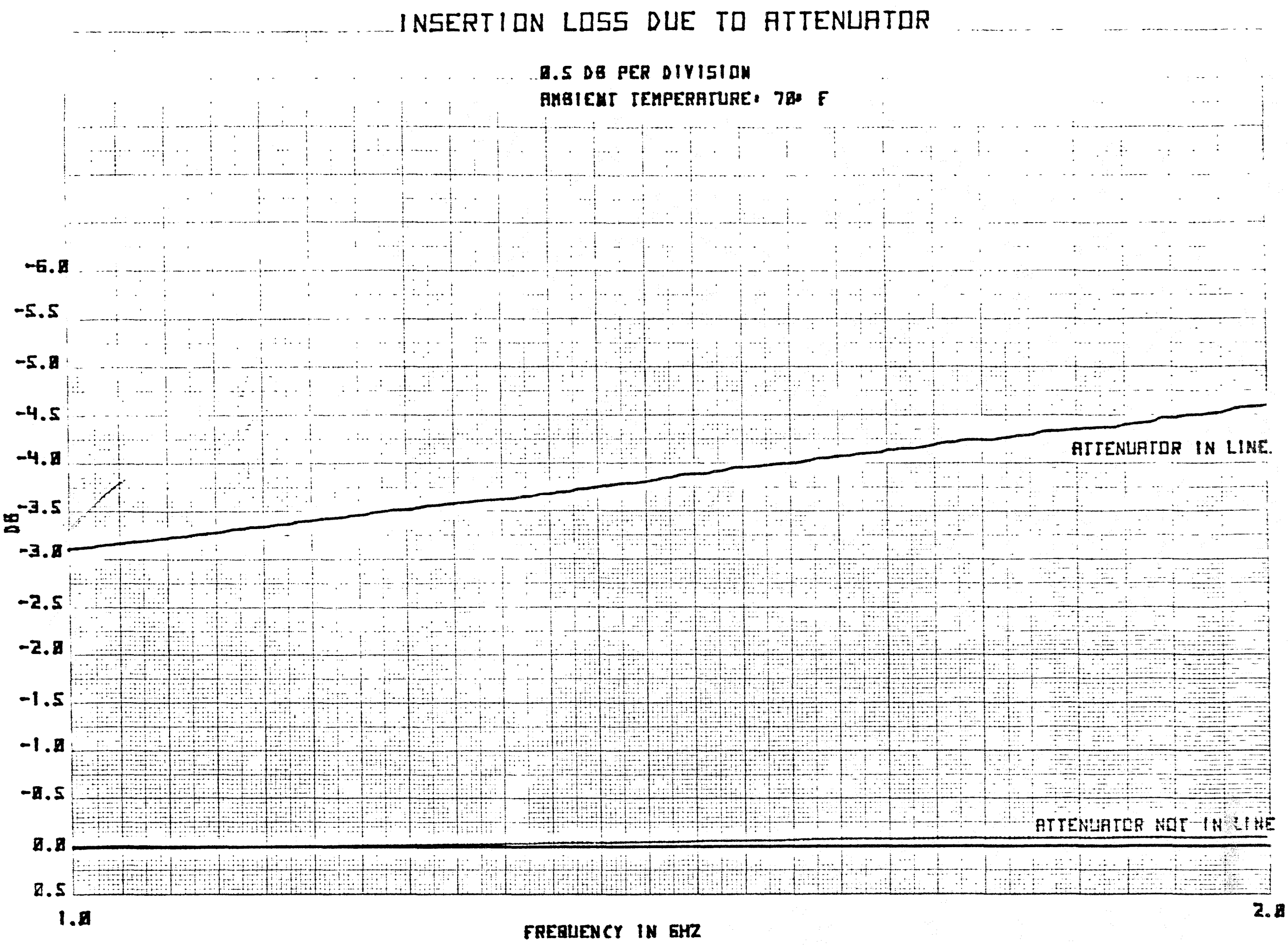
APPLICATIONS:

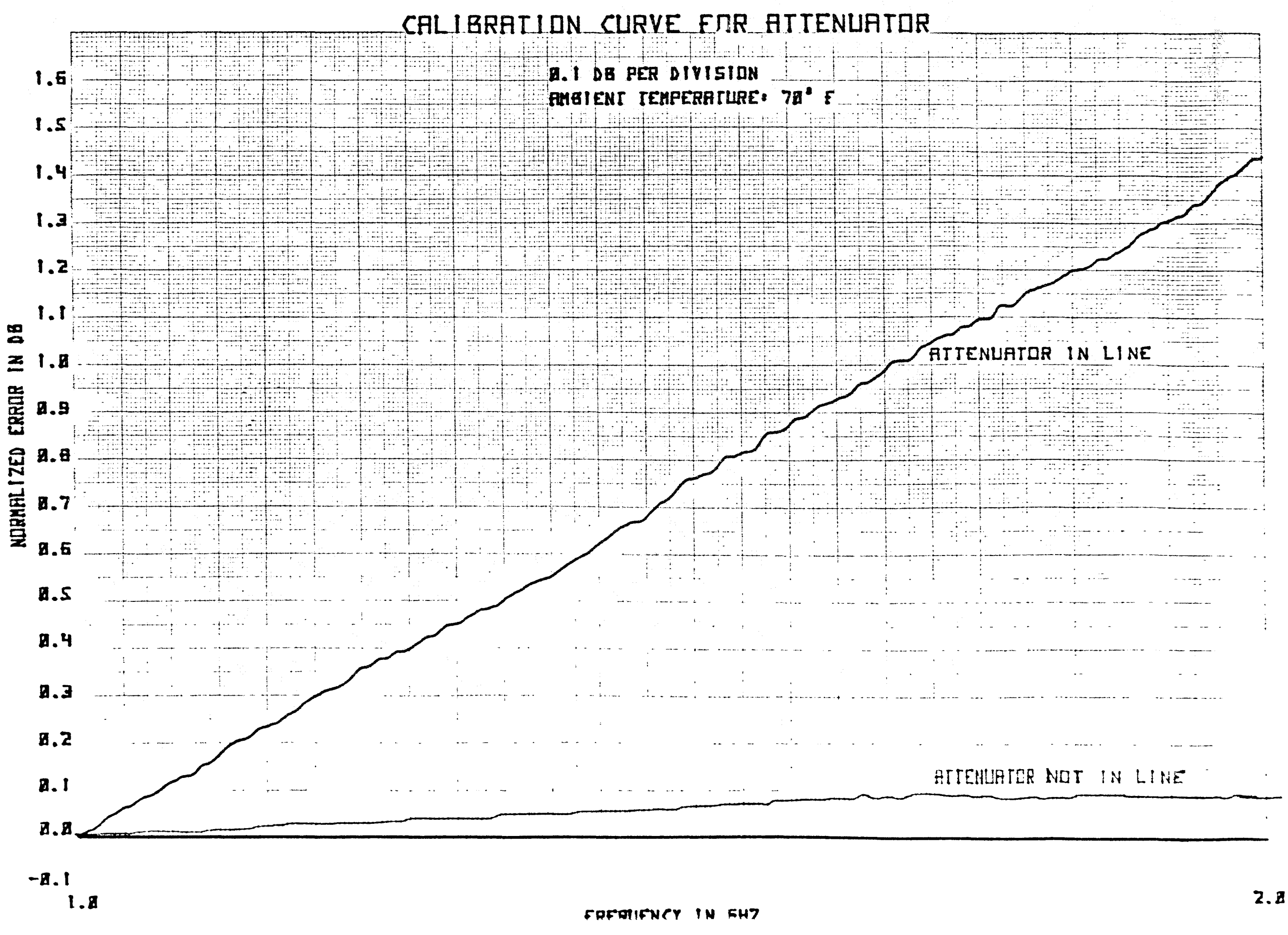
It had been hoped that the Weinschel model 3200-1 attenuator would be accurate enough so that it could be used as a standard in another test system.

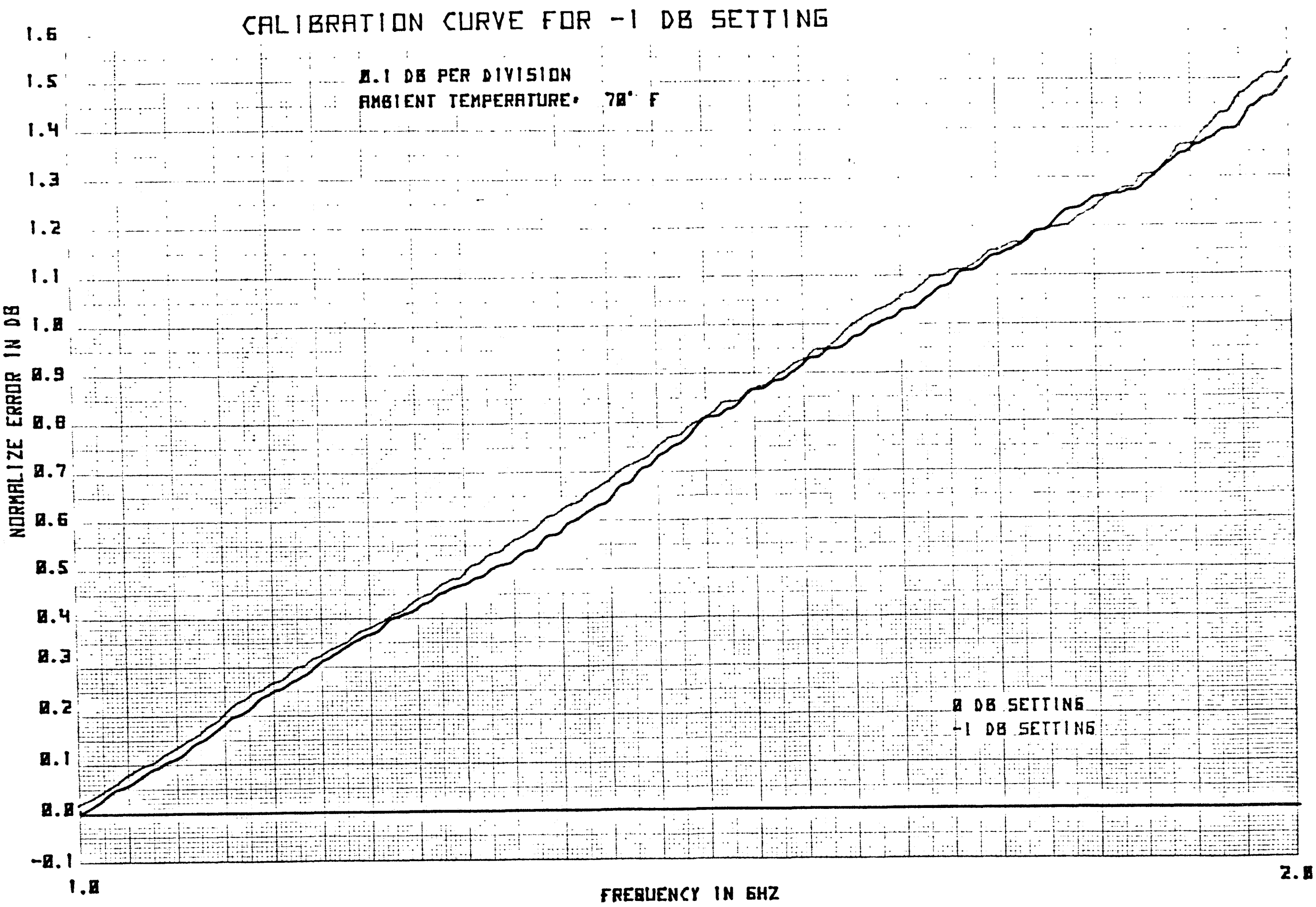
More specifically, it was desired to build an automated test unit that would accurately measure the attenuation need to bring the noise temperature of a receiver with a hot load down to the level of a receiver with a cold load. At present, these measurements are done by hand and are quite time consuming; and, it was thought that a square law detector, in conjunction with a computer, could perform these tests.

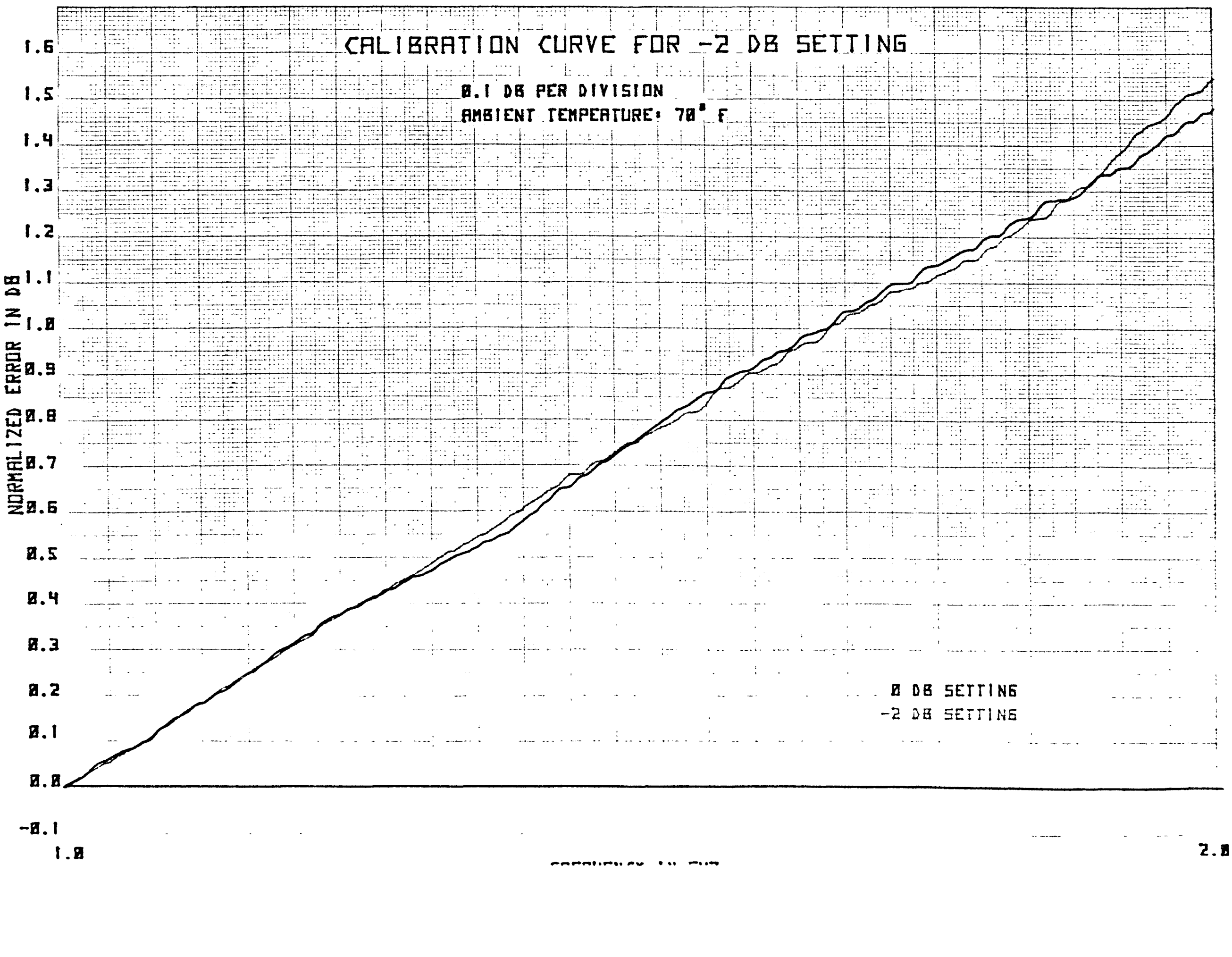
Before this could be done, however, the square law detectors had to be calibrated to determine if they were, indeed, square law detectors and to determine their range. The power meters used for this purpose only had a 10db dynamic range, and uncertainty over the error introduced when the meter changed ranges made another means of calibrating the detectors desirable. Thus the attenuator was to have been used to keep the meter within the range of one scale. Also, once the square-law range of the detector had been determined, the attenuator could then be used in the automated system to keep the power levels within the square law detector's range. Also, as an added benefit, the power meter could also have been calibrated to the attenuator to determine the effects of the scale changes.

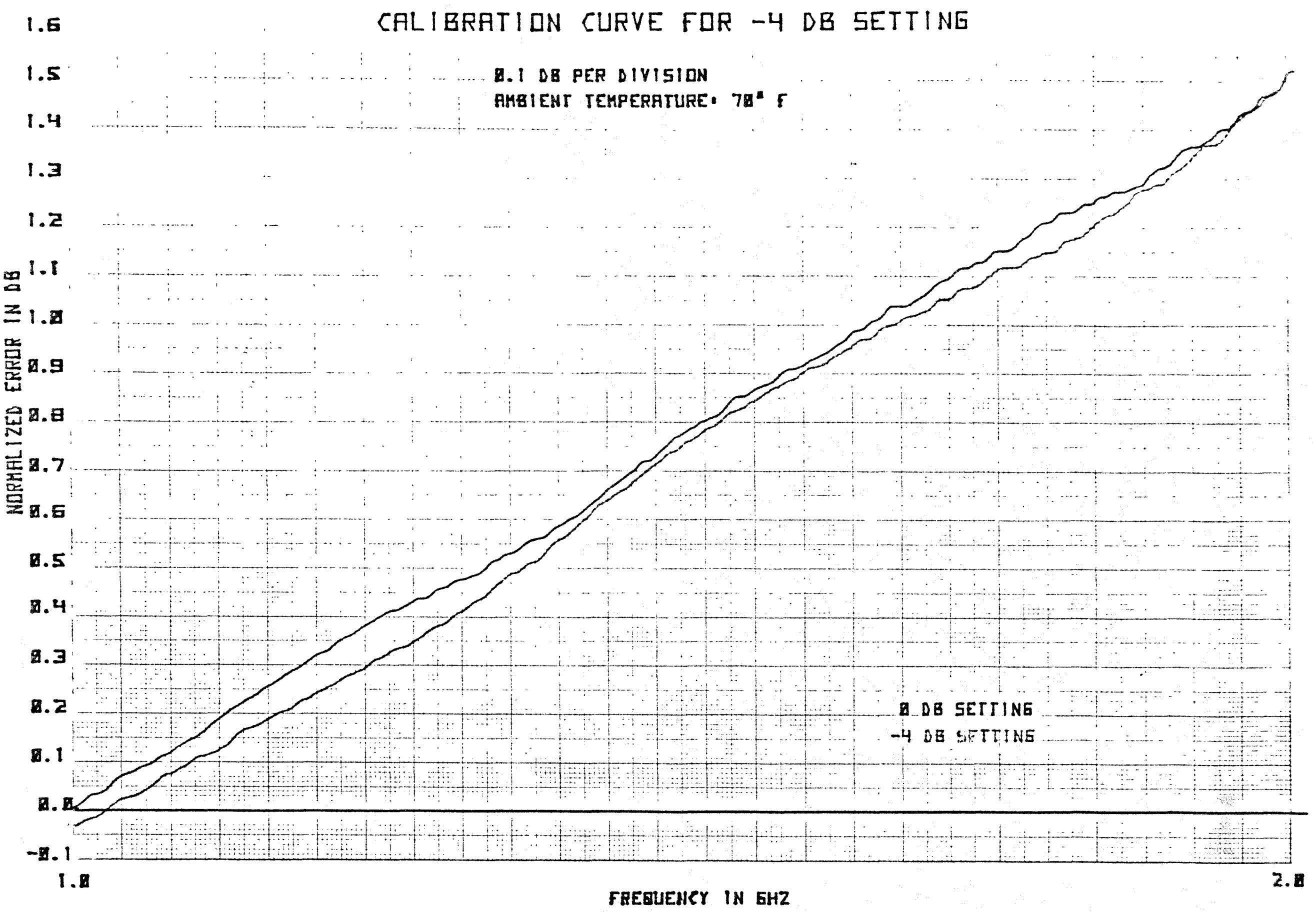
However, due to the inaccuracies of the attenuator over frequency and temperature, it was decided that the use of it to calibrate other devices would become too complex and inaccurate. It is therefore suggested that another, more accurate attenuator be sought.

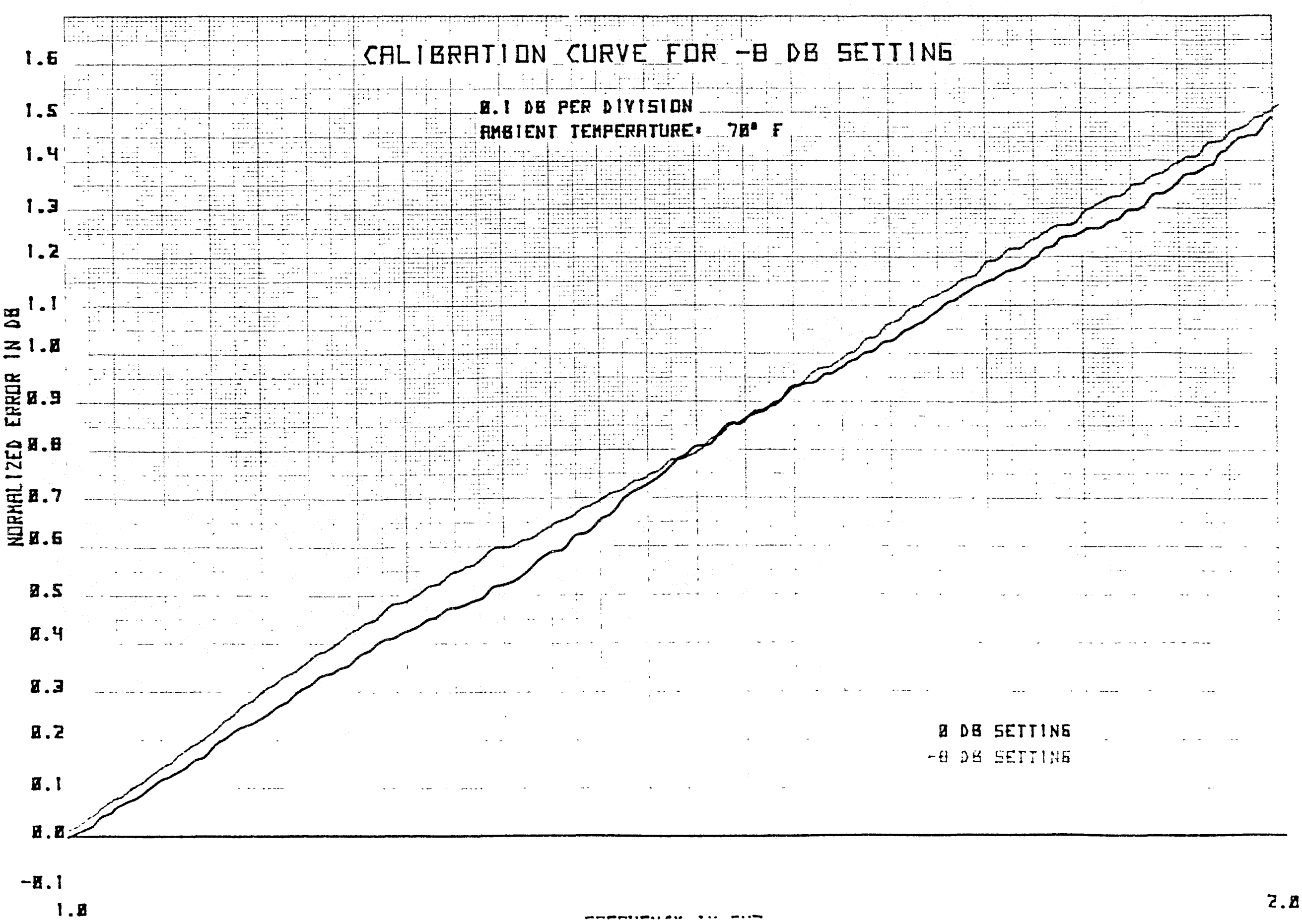

INSERTION LOSS DUE TO ATTENUATOR
0.5 DB PER DIVISION
AMBIENT TEMPERATURE: 70° F
-6.0
-5.5
-5.0
-4.5
-4.0
-3.5
-3.0
-2.5
-2.0
-1.5
-1.0
-0.5
0.0
0.5
DB
ATTENUATOR IN LINE.
ATTENUATOR NOT IN LINE
1.0
2.0
FREQUENCY IN GHZ

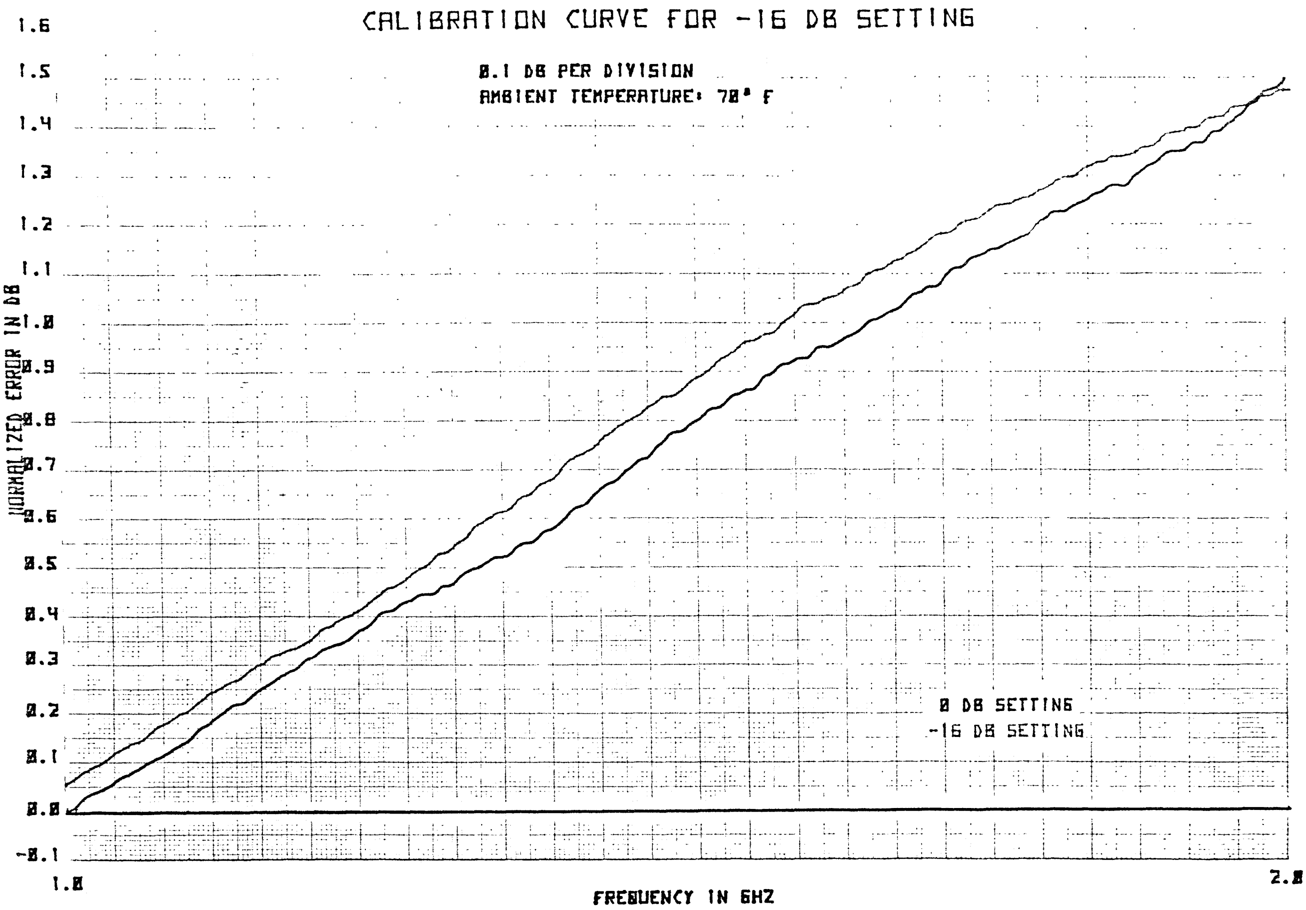

CALIBRATION CURVE FOR ATTENUATOR
0.1 DB PER DIVISION
AMBIENT TEMPERATURE: 70° F
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
NORMALIZED ERROR IN DB
ATTENUATOR IN LINE
ATTENUATOR NOT IN LINE
1.0
2.0
FREQUENCY IN GHZ

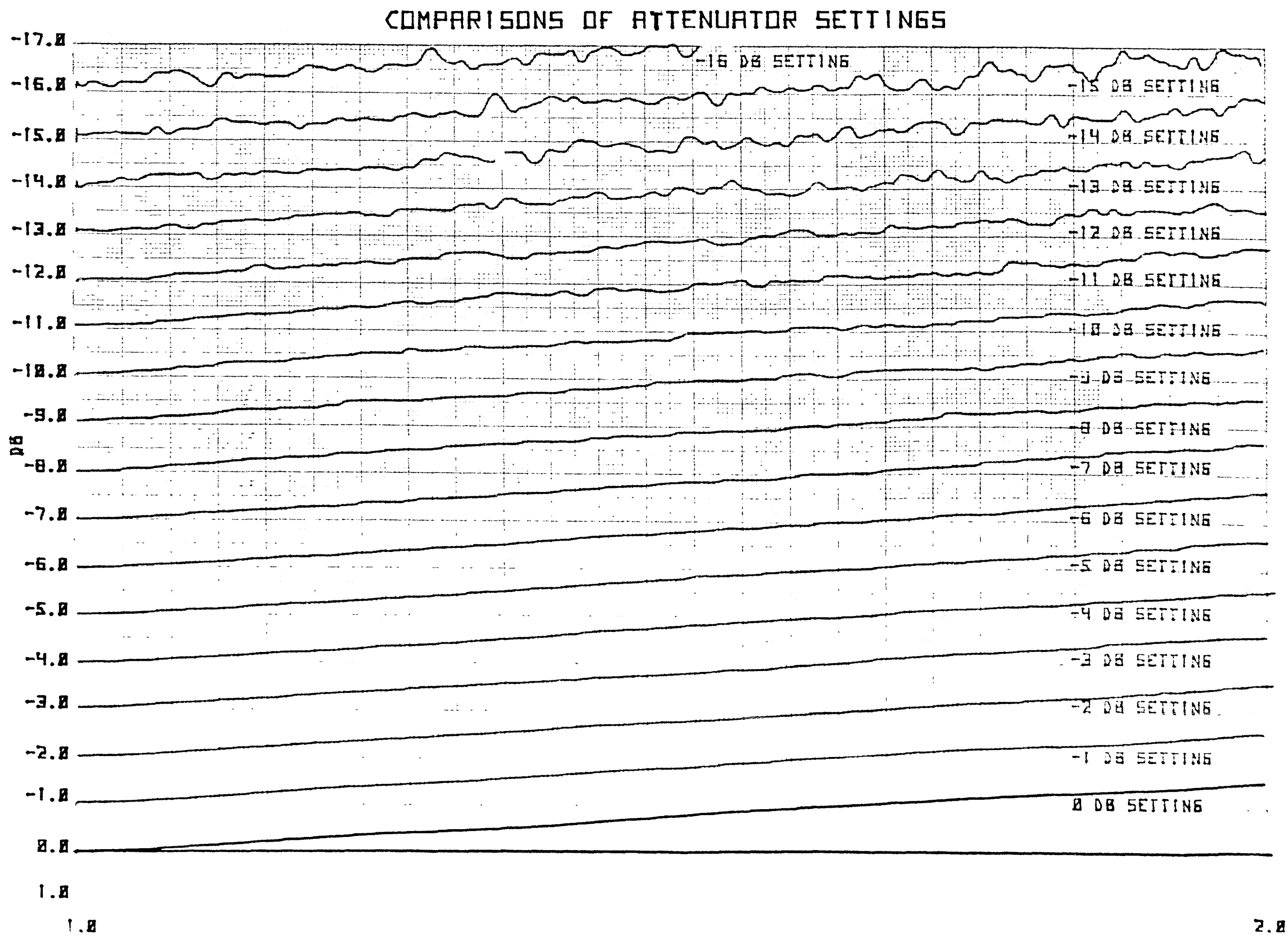

CALIBRATION CURVE FOR -1 DB SETTING
0.1 DB PER DIVISION
AMBIENT TEMPERATURE: 70° F
NORMALIZE ERROR IN DB
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
0 DB SETTING
-1 DB SETTING
1.0
2.0
FREQUENCY IN GHZ


CALIBRATION CURVE FOR -2 DB SETTING
0.1 DB PER DIVISION
AMBIENT TEMPERATURE: 70° F
NORMALIZED ERROR IN DB
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
0 DB SETTING
-2 DB SETTING
1.0
2.0

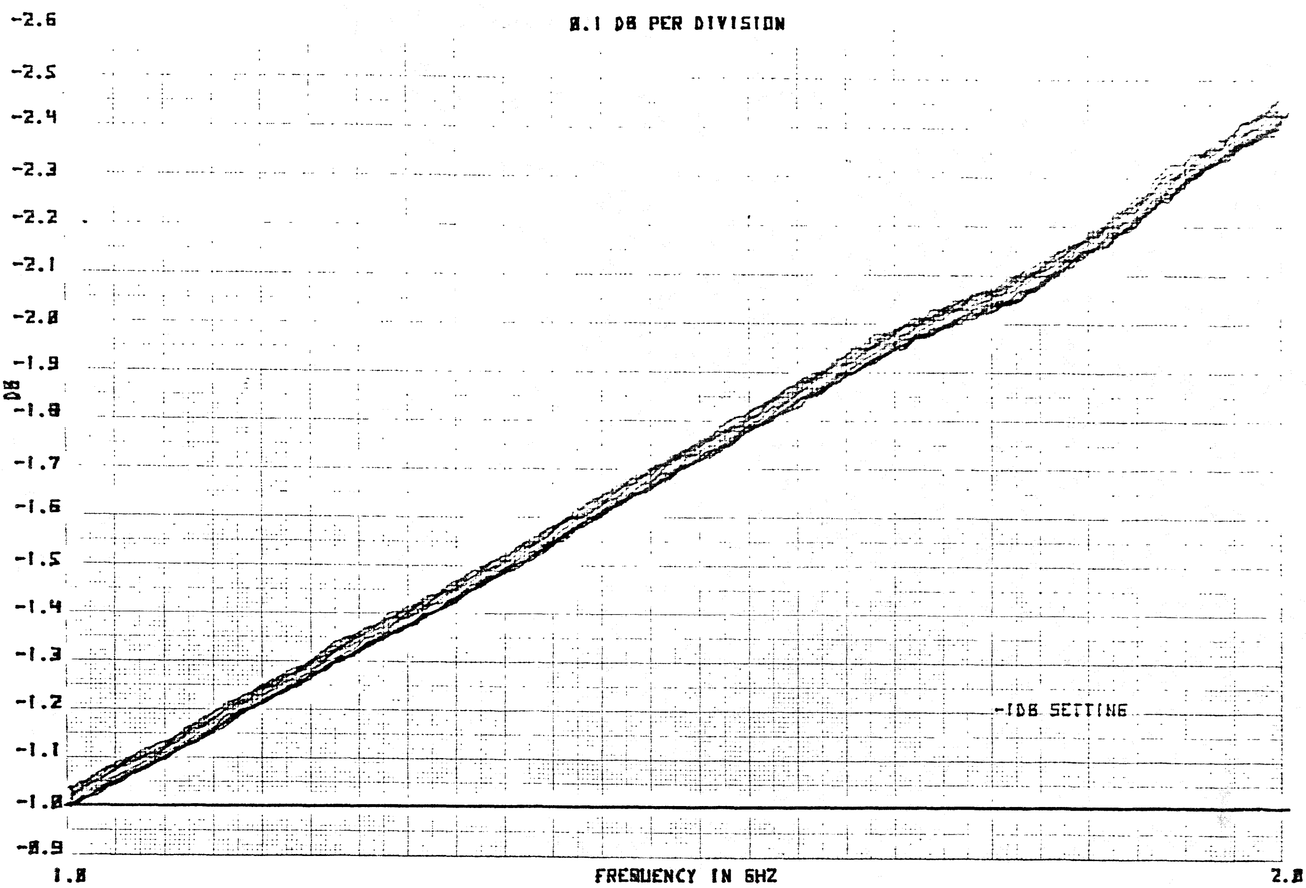

CALIBRATION CURVE FOR -4 DB SETTING
0.1 DB PER DIVISION
AMBIENT TEMPERATURE: 70° F
NORMALIZED ERROR IN DB
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
1.0
2.0
FREQUENCY IN GHZ
0 DB SETTING
-4 DB SETTING


CALIBRATION CURVE FOR -8 DB SETTING
0.1 DB PER DIVISION
AMBIENT TEMPERATURE: 70° F
NORMALIZED ERROR IN DB
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
1.0
2.0
0 DB SETTING
-8 DB SETTING

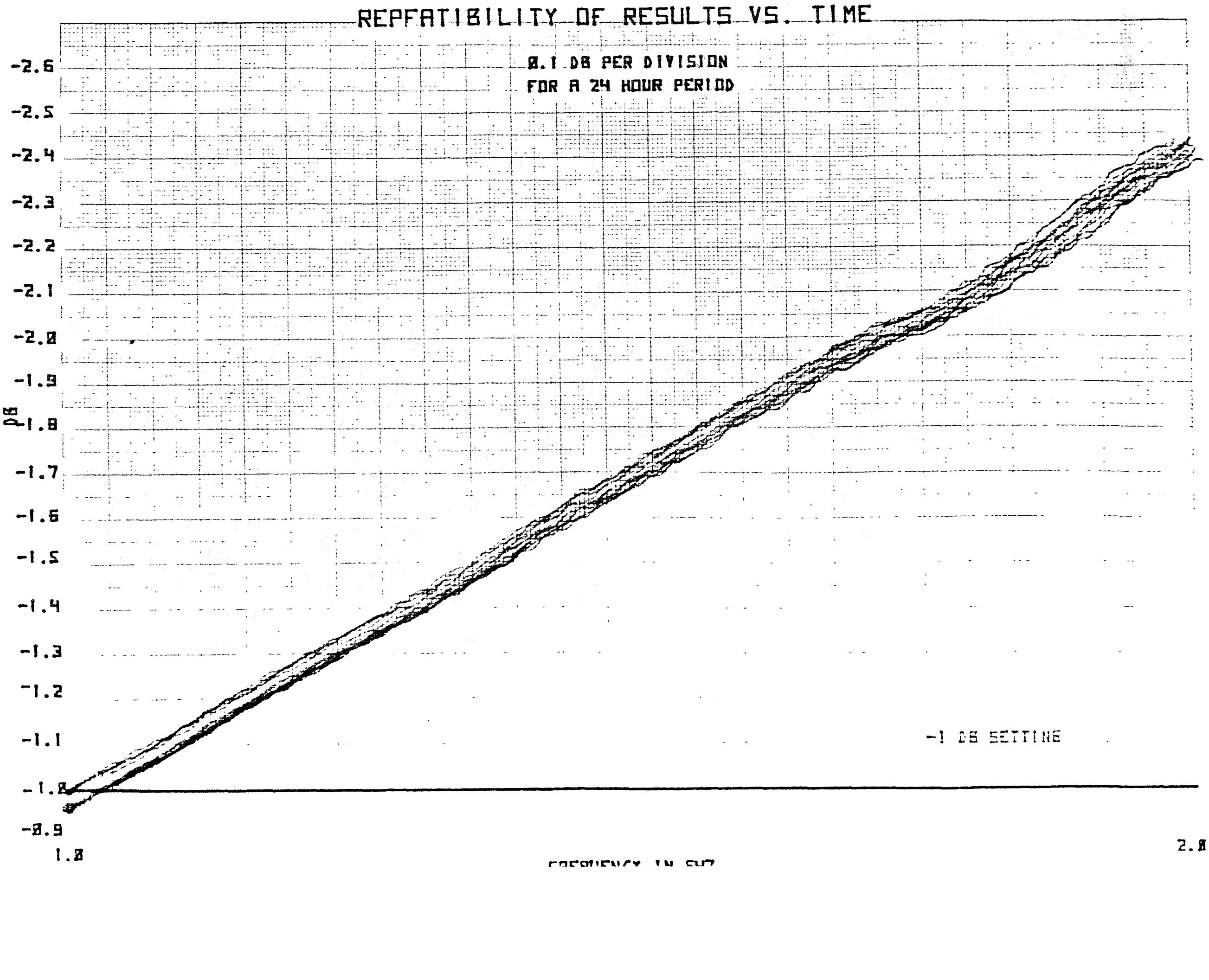

CALIBRATION CURVE FOR -16 DB SETTING
0.1 DB PER DIVISION
AMBIENT TEMPERATURE: 70° F
NORMALIZED ERROR IN DB
0 DB SETTING
-16 DB SETTING
FREQUENCY IN GHZ
1.0
2.0


COMPARISONS OF ATTENUATOR SETTINGS
DB
-16 DB SETTING
-15 DB SETTING
-14 DB SETTING
-13 DB SETTING
-12 DB SETTING
-11 DB SETTING
-10 DB SETTING
-9 DB SETTING
-8 DB SETTING
-7 DB SETTING
-6 DB SETTING
-5 DB SETTING
-4 DB SETTING
-3 DB SETTING
-2 DB SETTING
-1 DB SETTING
0 DB SETTING
1.0
2.0

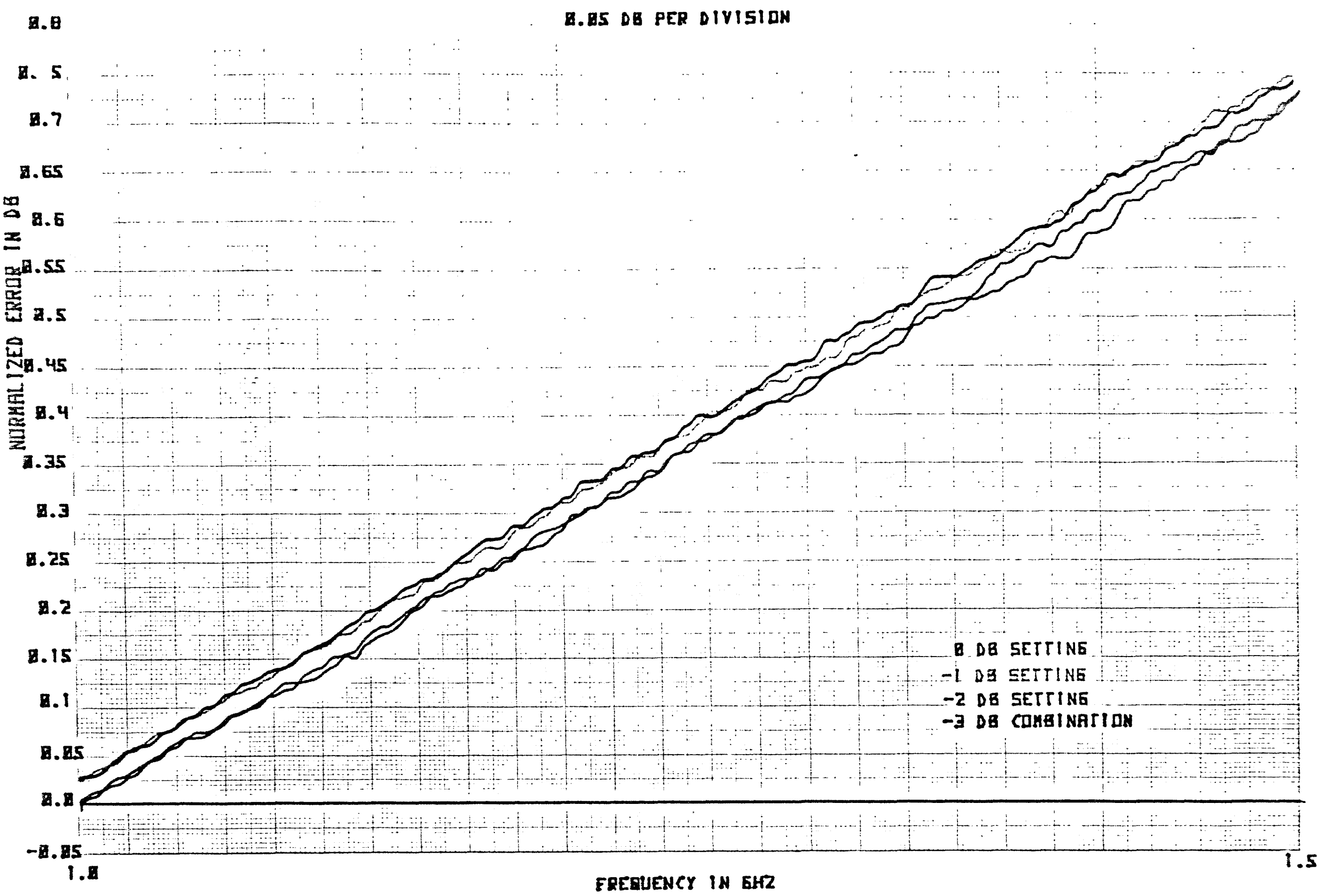
REPEATIBILITY OF RESULTS VS. SWITCHING

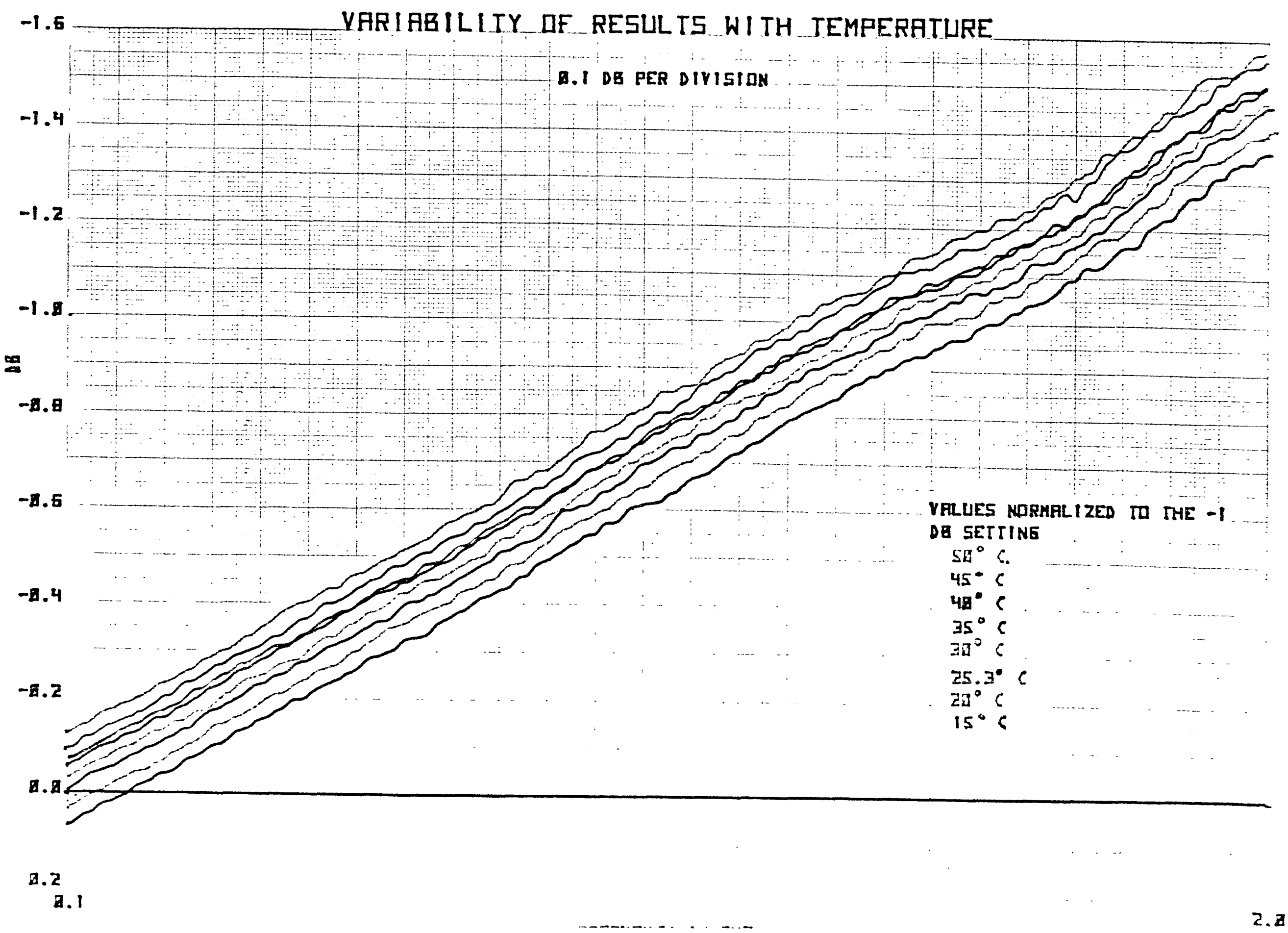


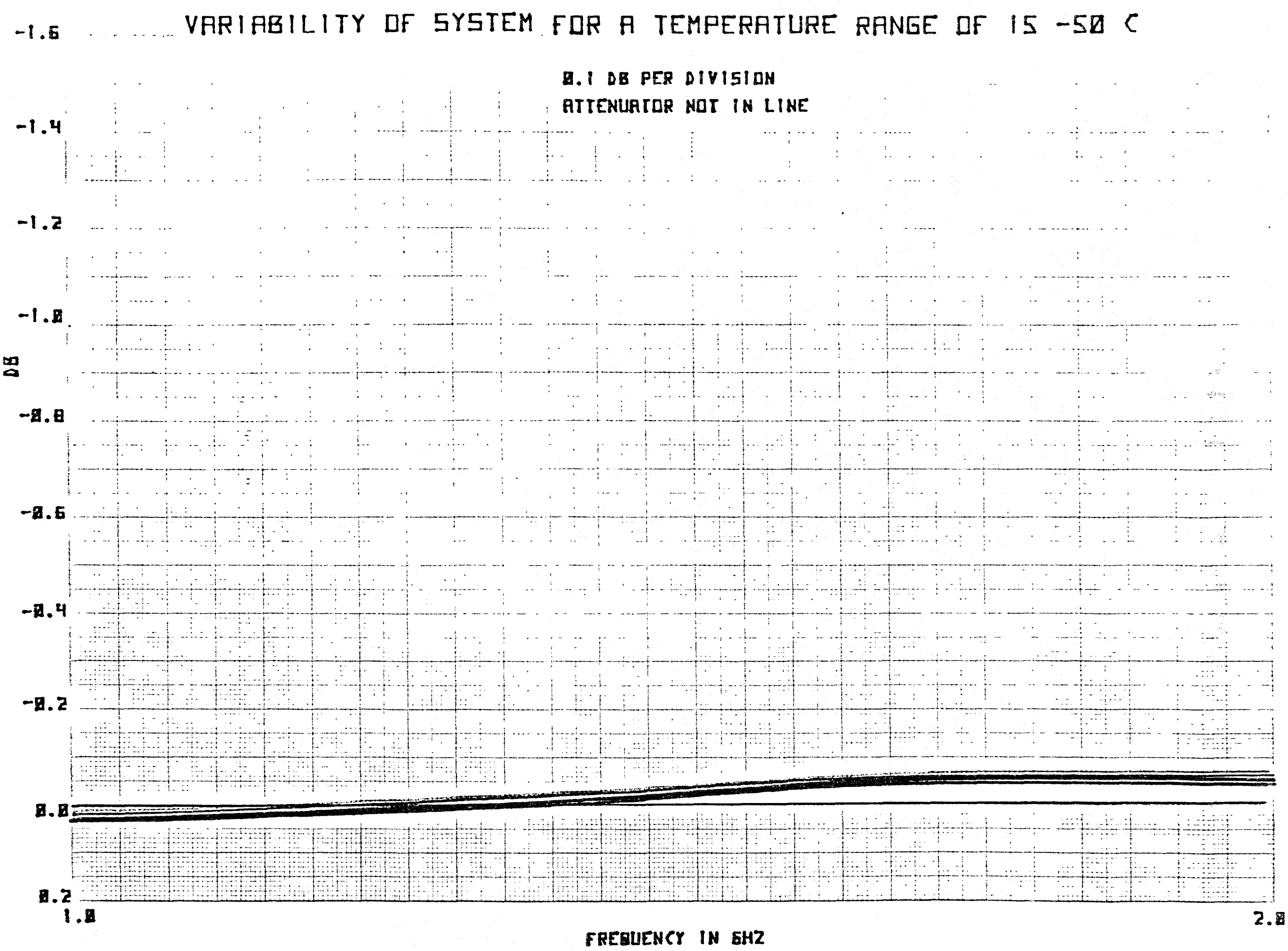
REPEATIBILITY OF RESULTS VS. TIME



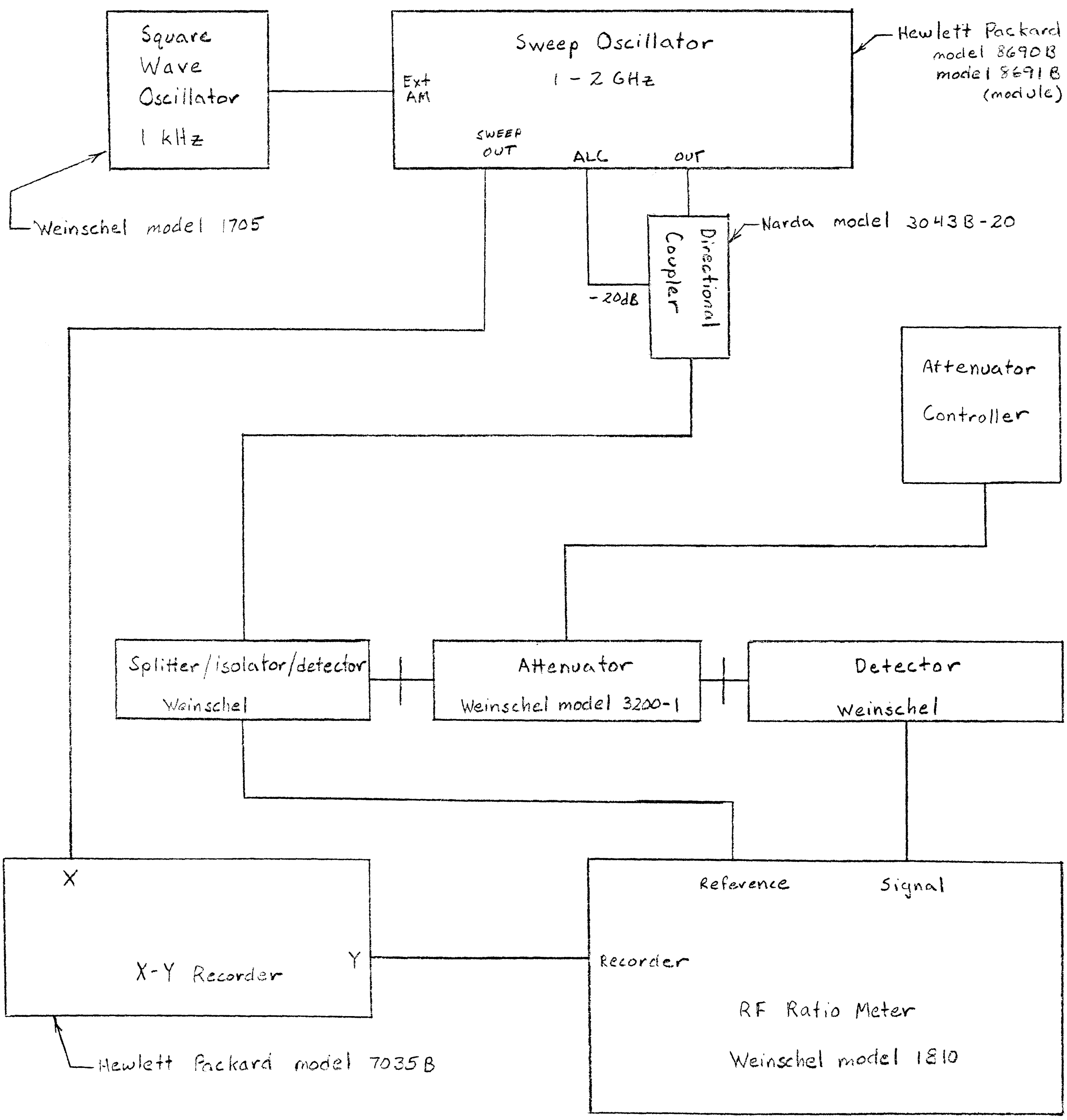
LINEARITY OF THE DIFFERENT CELLS






VARIABILITY OF SYSTEM FOR A TEMPERATURE RANGE OF 15 -50 C
0.1 DB PER DIVISION
ATTENUATOR NOT IN LINE
-1.6
-1.4
-1.2
-1.0
-0.8
-0.6
-0.4
-0.2
0.0
0.2
DB
1.0
2.0
FREQUENCY IN GHZ

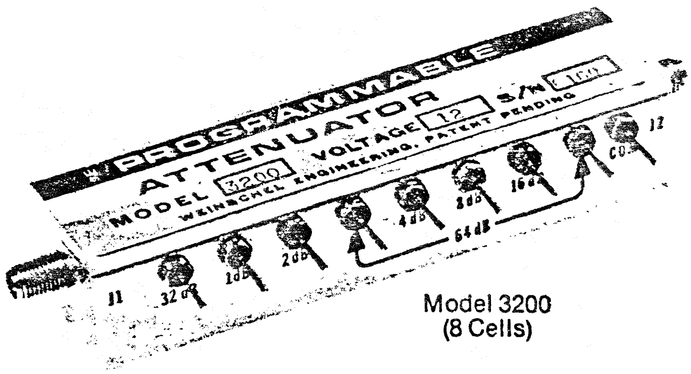
Experimental Set-up for the Calibration of the Model 3200-1 Attenuator



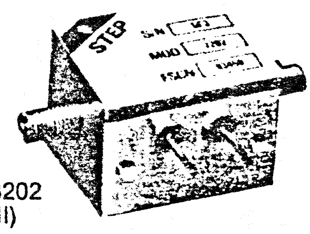
1 WATT

SMA TYPE CONNECTORS

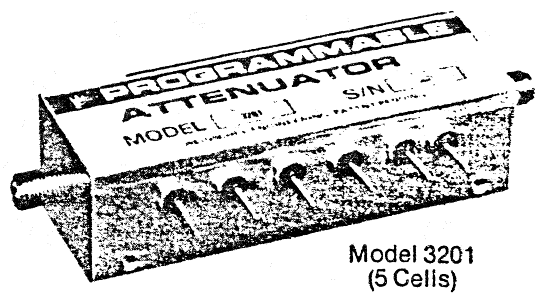
MODELS 3200 SERIES DC TO 2 GHz



Model 3200
(8 Cells)



Model 3202
(1 Cell)



Model 3201
(5 Cells)

BROADBAND — DC to 2 GHz

WIDE SELECTION OF ATTENUATION RANGES AND STEPS — 127 dB /1 dB steps
63.75 dB/0.25 dB steps
31 dB/1 dB steps
120 dB/10 dB steps
0.5 dB/0.5 dB steps

EXCELLENT REPEATABILITY — ±0.001 dB per cell (±3σ value for 10 cycles within 1 minute, 30 MHz, 25°C) Reference IEEE Standard 474-1973.

HIGH SPEED SWITCHING — Cell switching is completed, after electrical command, in 6 msec.

LONG SWITCH LIFE — Each cell has a switch life in excess of 10,000,000 switching operations.

COMPACT SIZES — Over dimensions are 2.54 centimeters wide x 2.22 centimeters high (1 x 7/8 inches) for all units. Length varies from 10.16 centimeters (4 inches), 8 cells to 3.05 centimeters (1.2 inches), 1 cell.

The 3200 Series Programmable Step Attenuators are designed for use in automatic test equipment and OEM systems operating in the dc to 2 GHz frequency range. This Series is available in eight standard attenuation ranges and cell configurations. Custom designed configurations are available upon request. Each cell contains a standard TO-5 type double-pole, double-throw relay that provides a minimum loss or attenuated path* for the RF signal.

Microstrip circuitry and special compensation techniques** produce flat attenuation versus frequency characteristics. The microstrip construction, using thick-film circuit elements, assures product uniformity and minimizes special hand work usually required to achieve the performance specified.

To minimize RF leakage, the 3200 Series Attenuators are provided with gold-plated contact areas and feedthru filters at each control terminal. In addition, microstrip construction reduces cross section and minimizes feedthru leakage, thereby eliminating the need for baffles, special grounding, and lossy materials usually required to achieve high attenuation ranges.

Housed in rugged, light-weight compact cases, the 3200 Series meets many of the environmental requirements of MIL-A-3933. Environmentalized units withstanding salt spray environments are available on special order.

*U.S. Patent 3,157,846
**Patent Pending

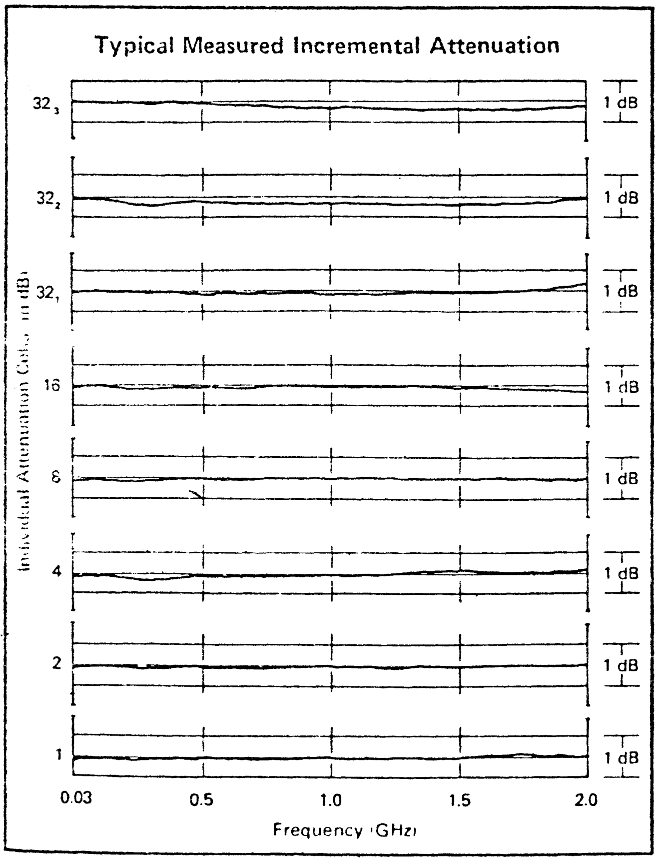
SPECIFICATIONS

NOMINAL IMPEDANCE: 50 ohms
FREQUENCY RANGE: DC to 2 GHz.
STANDARD ATTENUATION RANGES, INCREMENTS, AND CELL CONFIGURATIONS:

Model Number	No. Cells	Attenuation Range/Steps (dB)	Cell Increments (dB)
3200-1	8	127/1	1, 2, 4, 8, 16, 32, and 64*
3200-2	8	63.75/0.25	1, 2, 4, 8, 16, 32, 0.5 and 0.25
3200-4	8	150/10	10, 20, 20, 20, 20, 20, 20, and 20
3201-1	5	31/1	1, 2, 4, 8, and 16
3201-2	5**	120/10	10, 20, 30 and 60**
3201-3	4	12/1	1, 2, 3, and 6
3201-4	4	1.2/0.1	0.1, 0.2, 0.3, and 0.6
3202	1	0.5/0.5	0.5

**64 dB cell comprised of two 32 dB cells*
***60 dB cell comprised of two 30 dB cells*

ACCURACY OF INCREMENTAL ATTENUATION: DC to 0.5 GHz: ±0.2 dB or 1/2%, whichever is greater.
0.5 to 1 GHz: ±0.2 dB or 1%, whichever is greater.
1 to 2 GHz: ±0.3 dB or 2%, whichever is greater.
INCREMENTAL PHASE SHIFT: ~ 0.25° per dB x f(GHz)



POWER COEFFICIENT: $<0.002 \frac{dB}{dB \times W}$

MONOTONICITY: DC to beyond 1.5 GHz.
VSWR: DC to 1 GHz: 1.25:1
1 to 2 GHz: 1.35:1
CHARACTERISTIC ZERO INSERTION LOSS, @ 25°C,* MAXIMUM (dB):

Model Number	3200-1, -2, -4	3201-1, -2, -3, -4	3202-1
dc to 0.5 GHz	3.0	2.25	0.5
0.5 to 1 GHZ	3.5	2.75	0.6
1.0 to 1.5 GHz	4.25	3.25	0.75
1.5 to 2 GHZ	4.75	3.75	0.75

POWER CAPABILITY: 1 watt average, 100 watts peak derated linearly to 0.25 watts at 71°C.
INCREMENTAL TEMPERATURE COEFFICIENT:
30 and 32 dB Cells: $<0.00005 \frac{dB}{dB \times W}$

All other cells: $<0.00002 \frac{dB}{dB \times W}$

TEMPERATURE RANGE (Operating): -55°C to 71°C
RATED SWITCH LIFE: 10^7 operations per cell
SWITCHING SPEED: 6 msec. maximum at 12.0 Vdc average.
OPERATING VOLTAGE: 9 Vdc min., 20 Vdc max., 12 Vdc average for all cells (except 64 dB and 60 dB, require 28 mA).
CONTROL CONFIGURATION: One terminal is provided for a common return and is connected to case ground. The remaining terminals are provided for activiation of individual cells. Attenuation is fail-safe to "0" setting in the absence of a control voltage. Application of voltage (+ or -) to a particular cell causes it to switch to the attenuate position.

Note — control is non-latching and requires a continuous control signal for the period of time in which attenuation is required.

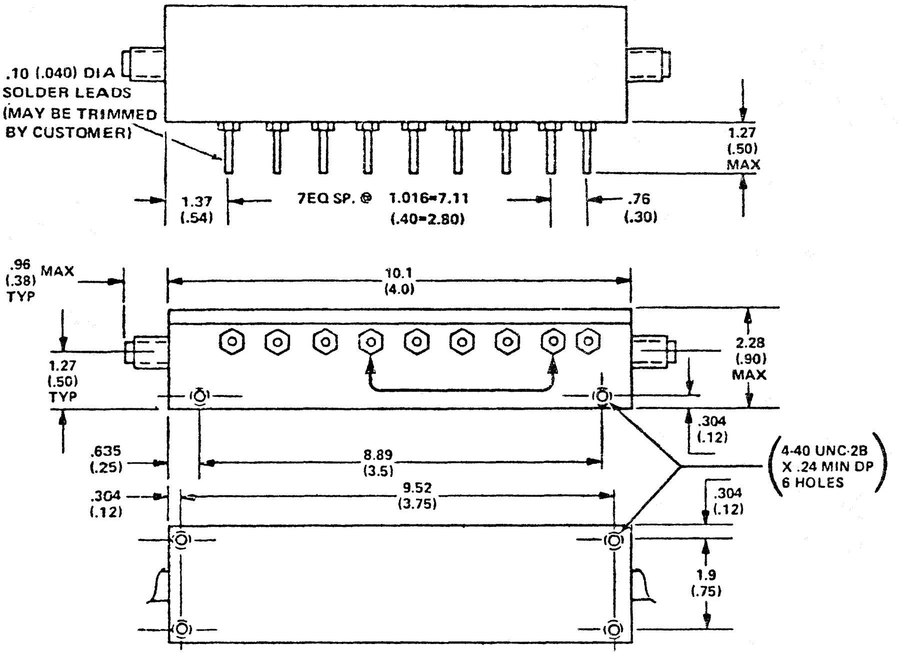
CONNECTORS: RF: Stainless-steel female SMA mates with male SMA per MIL-C-39012.
Control: 1mm (0.040-inch) diameter tinned copper wire for soldering or use with PC board jacks.
HOUSING: Aluminum.
MOUNTING PROVISIONS AND DIMENSIONS: 3200, 3201, and 3202 see drawings.
WEIGHT:

Model	Net	Shipping
3200-1	140 g (5 oz)	680 g (1.5 lbs)
3200-2	140 g (5 oz)	680 g (1.5 lbs)
3200-4	140 g (5 oz)	680 g (1.5 lbs)
3201-1	84.5 g (3.8 oz)	680 g (1.5 lbs)
3201-2	84.5 g (3.8 oz)	680 g (1.5 lbs)
3201-3	77.5 g (3.5 oz)	680 g (1.5 lbs)
3201-4	77.5 g (3.5 oz)	680 g (1.5 lbs)
3202-1	46 g (1.6 oz)	680 g (1.5 lbs)

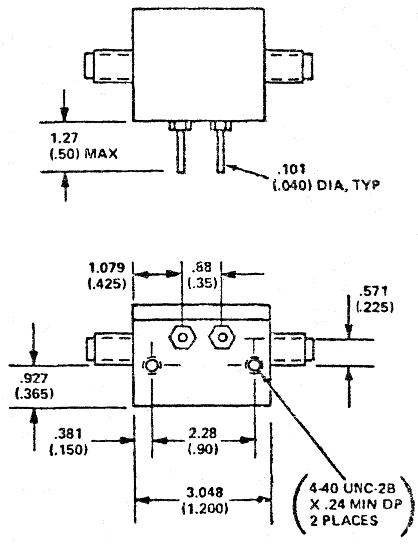
* ±0.7 dB from nominal per cell from 25°C to maximum temperature. Example: 3200-1 with 8 cells: ±0.56 dB

SPECIFICATIONS (cont.)

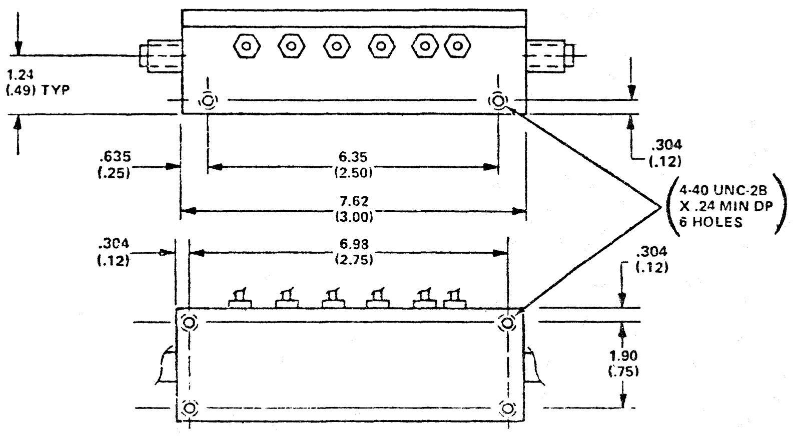
Model 3200 (8 cells)

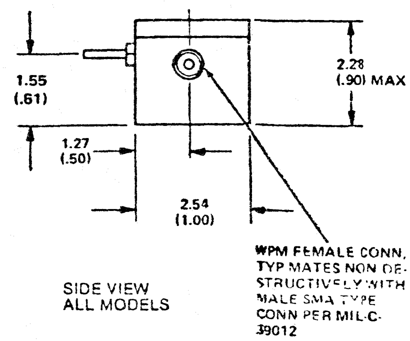


Model 3202 (1 cell)



Model 3201 (5 cells)





Dimensions are in centimeters (inches) and are nominal.

PRICES:

3200-1	$550
3200-2	$575
3200-4	$550
3201-1	$435
3201-2	$435
3201-3	$435
3201-4	$450
3202	$200
3210 IEEE Interface Driver (For Model 3200-1)	$995
3210-01 IEEE Interface Driver (With Model 3200-1)	$1,545

For prices on custom units and quantities, contact factory. (OEM discounts available.)

SPECIAL CONFIGURATIONS: Customer-specified attenuation Ranges and Increments can be designed from the following cell inventory: 0.2, 0.25, 0.4, 0.5, 0.8, 1, 2, 4, 8, 10, 16, 20, 25, 30, 32 and 40* dB (Additional lead time should be considered when ordering custom units.)

*dc to 1 GHz.

Table 2. Definitions and Conditions of Attenuator Related Parameters

A. Attenuation
A general term used to denote a decrease in magnitude in transmission from one point to another. NOTE: It may be expressed as a ratio, or by extension of the term, in decibels.*

B. VSWR
Input VSWR – When terminated in load characteristic impedance Z_o.
Output VSWR – When input is connected to characteristic impedance Z_o.
VSWR Measurements of other than type N, 7mm and 14mm precision connectors – Measurements of C, SC, TNC, BNC, and WPM connectors are made through low VSWR adapters on a slotted line having 14mm or 7mm precision connectors. Measured VSWR is attenuator VSWR plus adapter residual VSWR, with GR-900 adapters limited to 8.5 GHz and 7mm to 18.0 GHz.

C. Frequency Sensitivity of Insertion Loss
Peak-to-peak variation in dB when swept through the frequency range at 20°C.

D. Power Coefficient of Insertion Loss
Variation in dB of insertion loss when input power is varied from 10 milliwatts to full rated power after steady state condition has been reached at 20°C. To obtain ΔdB, multiply power coefficient by dB and watts.

E. Maximum Average Power
That maximum input power applied for a long time at the maximum operating temperature (see Definition G-2), with output terminated in the characteristic impedance, which will not permanently change the specifications of the attenuator (item 12 or 14, Table 1) after return to 20°C at 10 mW input. Rating, particularly for smaller attenuators, is influenced by structure(s) in thermal contact with unit. Heat sources and sinks can significantly alter the input power handling of an attenuator.

F. Maximum Peak Power
That peak power which when applied for a long time at the maximum operating temperature at a pulse duration of 5 microseconds, while the output is terminated in the characteristic impedance, will not permanently change the specifications of the attenuator when returned to 20°C and 10 mW input.

G1. Temperature Coefficient
Maximum change of insertion loss in db/°C from 20°C over maximum operating temperature range. To obtain ΔdB, multiply temperature coefficient by dB and temperature in °C.

G2. Operating Temperature Limit
Maximum temperature in °C at which attenuator will operate with full input power; derating function for maximum power vs. temperature is specified if required.

H. Shock, Vibration
In the three major axes, case or body must be solidly supported when tested.

I. Deviation of Insertion Loss from Nominal
At 20°C and an input power of 10 mW at a specified reference frequency.

J. Input and Output Connector Types
Refer to Table 3 for connector types available from Weinschel Engineering which mate non-destructively with connectors complying with the listed specifications for each type.

K. Connector Life
Connect/disconnect cycles with complete axial engagement/disengagement without side thrust; all electric and mechanical specifications must be complied with after specified life cycle.

*IEEE STD. 100.