OPERATING AND SERVICING MANUAL

FOR

MODEL 415B

STANDING WAVE INDICATOR

SERIAL 498 AND ABOVE



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SPECIFICATIONS

FREQUENCY: $1000 \text{ cps } \pm 2\%$. Other frequencies 315 to 3000 cps available

on special order.

SENSITIVITY: 0.1 μ v at a 200 ohm level for full scale deflection.

NOISE LEVEL: Less than 0.03 μv .

AMPLIFIER Q: 25 to 30; bandwidth of 40 cycles.

CALIBRATION: Square law. Voltage standing wave ratio indicated directly;

standing wave ratio indicated in db.

RANGE AND ACCURACY: 70 db. Input attenuator provides 60 db in 10 db steps.

Accuracy ±0.1 db per range; 0.2 db maximum accumulative

error (range to range).

SCALE SELECTOR: "Normal", "Expand", and "-5 db".

METER SCALES: SWR 1-4, SWR 3-10, Expanded SWR 1-1.3, db 0-10,

Expanded db 0-2.

INPUT IMPEDANCE

AND BIAS CURRENT: "Bolo" (200 ohms). Bias provided for 8.4 ma barretter

or 1/100 amp fuse; or 4.3 ma for low current barretter.

"Crystal". 200 ohms for crystal detector.

"200,000 ohms". For use with high impedance signal source.

OUTPUT: For recording milliammeter having 1 ma full scale deflection.

Requires 1500 external load for correct operation.

POWER: $115/230 \text{ volts } \pm 10\%$, 50/60 cps, 60 watts.

DIMENSIONS: Cabinet Mount: 7-1/2" wide, 11-1/2" high, 12-1/4" deep.

Rack Mount: 19" wide, 7" high, 11" deep.

WEIGHT: Cabinet Mount: Net 19 lbs. Shipping 21 lbs.

Rack Mount: Net 18 lbs. Shipping 35 lbs.

ACCESSORIES

FURNISHED: 41A-16E Cable Assembly.

CONTENTS

SECTION I	GENER	RAL DESCRIPTION	
	1-1 1-2 1-3 1-4	Introductory I - 1 Description I - 1 Electrical Characteristics I - 1 Applications I - 2	
SECTION II	OPERA	ATING INSTRUCTIONS	
	2-1 2-2 2-3 2-4 2-5 2-6 2-7 2-8 2-9 2-10 2-11 2-12 2-13 2-14	Introduction III - 1 Installation III - 1 Required Signal Source III - 1 Measurements III - 2 Mount of Operate the 415B III - 4 Precautions when using Crystal Detector III - 5 Detector Probe Penetration III - 5 Precautions with Signal Sources III - 6 Pricautions with Signal Sources III - 7 Low VSWR'S III - 7 Impedance Measurement Rules III - 8 Impedance Measurement Procedure III - 8 Impedance Measurement and the Smith Chart III - 9 Procedure for Smith Chart Calculations III - 10	
SECTION III	THEO	RY OF OPERATION	
	3-1 3-2 3-3 3-4	Circuit Description	
SECTION IV	MAIN	TENANCE	
	4-1 4-2 4-3 4-4 4-5	Trouble Shooting the 415B	
SECTION V	TABI	LE OF REPLACEABLE PARTS	
	5-1	Table of Replaceable Parts	_

SECTION I GENERAL DESCRIPTION

1-1 INTRODUCTORY

In high frequency applications, standing-wave measurements are the customary means of investigating the impedance match of transmission systems, various types of terminations such as antennas and loads, and other high-frequency devices such as connectors, transitions, etc. The Model 415B Standing Wave Indicator is a laboratory-quality instrument designed primarily for use in making accurate standing-wave measurements in conjunction with a suitable detector probe and slotted coaxial and waveguide sections. The 415B can also be used as a detector in bridge circuits and for other applications requiring a very sensitive fixed-frequency indicator.

1-2 DESCRIPTION

The Hewlett-Packard Model 415B Standing Wave Indicator is a highly sensitive, fixed-frequency electronic meter calibrated to indicate directly both voltage and power standing-wave ratios when used with square law detectors such as crystal diodes and barretters. Expanded meter scales are provided for easy reading of extremely small increments. The highly accurate input RANGE switch permits range-to-range reading without loss of accuracy. Because of the low noise level in the 415B, measurement of signal levels to below 0.1 microvolt is possible.

A front panel selector switch adapts the input circuit of the 415B to either a crystal diode, a barretter or a high impedance signal source. For barretters, the correct bias current is automatically supplied through the input jack, the current value being selected by a toggle switch for either of two different barretter resistances in common use.

The 415B responds to a single frequency only, 1000 cycles per second. The frequency may be changed in the field by installing a new plug-in filter tuned to the desired frequency, no further adjustment being required. Plug-in filters tuned to frequencies be-

tween 315 and 2000 cycles are available from the Hewlett-Packard Company, on special order.

Provision is made in the Model 415B for passing the meter current through an external recorder. This current can also be used to operate earphones or an oscilloscope.

1-3 ELECTRICAL CHARACTERISTICS

The Model 415B Standing Wave Indicator is designed and calibrated to measure a signal obtained from square-law devices such as crystal diodes (at low signal levels) and barretters; however, it may also be used as a peak or null indicator in conjunction with linear signal sources. The indicating meter is calibrated to indicate standing wave ratio directly in vswr and in db and includes expanded scales for very accurate readings of small increments. The range-to-range accuracy is within ±0.1 db between each range. The maximum sensitivity of the 415B (when set for CRYSTAL or BOLO operation) is 0.1 microvolt for full scale meter deflection. The noise level is less than 0.03 microvolt as referred to a signal obtained from a 200 ohm resistor connected to the input jack. Useful measurements may be made down to the actual noise level.

The sensitivity of the 415B is varied 10 db steps over a range of 60 decibels by the front panel RANGE switch. The GAIN control provides a further adjustment of the sensitivity over an approximate 12.5 decibel range to obtain a convenient meter reading for any input signal level. The EXPAND-NORMAL-5 DB switch selects an expanded meter scale when desired and in the -5 db position shifts the meter reading downscale by 5 db so that readings normally read from a down scale position can be read up scale on the next lower step on the RANGE switch.

The internal impedance of the 415B as seen at the INPUT jack is either 200 ohms, or 200,000 ohms as selected by the BOLO-CRYSTAL-200,000 selector switch. When set to BOLO, a d-c bias of approximately 8.4 milliamperes is automatically applied to a 200-ohm barretter connected to the INPUT jack.

A toggle switch on the front panel changes the bias current to approximately 4.3 milliamperes. The BOLO CURRENT jack on the front panel permits the bias current supplied to the external barretter to be monitored by an external meter and decreased by insertion of added series resistance.

The frequency of the 415B as supplied from Hewlett-Packard Company is 1000 cycles per second $\pm 2\%$ with a bandwidth of approximately 38 cycles at the half power points. The selectivity of the tuned amplifier is determined by a single plug-in filter having an effective Q between 25 and 30.

The frequency of the amplifier may be changed without adjustment by installing a new filter tuned to the desired frequency. The RECORDER jack on the front panel provides sufficient signal current to operate a 1 milliampere recorder (or other indicating devise) having an input resistance of 1500 ohms. The current through the recorder is the same current that flows through the vswr meter.

The 415B operates on 115 volt or 230 volt, 50 to 1000 cycles a-c power and consumes 46 watts of power. The instrument is normally supplied with a 1 ampere "Slo-Blo" fuse. For 230 volt operation use a 0.5 ampere fuse.

1-4 APPLICATIONS

The \$\phi\$ Model 415B Standing Wave Indicator has been specifically designed for use with the \$\phi\$ series of Slotted Lines and Detector Mounts. A complete series of Slotted Line equipment for impedance and swr measurements in coaxial and waveguide transmission systems is available to cover the entire frequency range from 500 mc to 18 kmc. Also available is a convenient line of waveguide and coaxial Detector Mounts for the range from 10 mc to 12.4 kmc. Table 1-1 shows the various Hewlett-Packard instruments for these services arranged by frequency coverage.

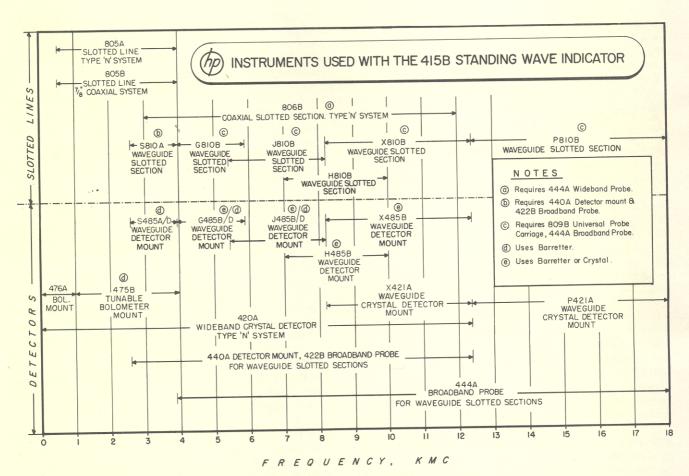


Table 1-1. Suitable @ Microwave Equipment for Slotted Line Measurement arranged by frequency range





SECTION II OPERATING INSTRUCTIONS

2-1 INTRODUCTION

This section contains complete operating instructions for the Model 415B Standing Wave Indicator, test set-up instructions, measurement possibilities and measurement precautions. Because the accuracy of standing wave measurement depends largely on measurement techniques, considerable attention should be given to the various measurement discussions, Low VSWR, High VSWR, Precautions with Detectors, etc. The material in this section is outlined below:

- 2-2 Installation
- 2-3 Required Signal Source
- 2-4 Measurements
- 2-5 How to Operate the Model 415B
- 2-6 Precautions when using Crystal Detectors
- 2-7 Detector Probe Penetration
- 2-8 Precautions with Signal Sources
- 2-9 High VSWR's
- 2-10 Low VSWR's
- 2-11 Impedance Measurement Rules
- 2-12 Impedance Measurement Procedure
- 2-13 Impedance Measurement and the Smith Chart
- 2-14 Procedure for Smith Chart Calculations

2-2 INSTALLATION

The 415B Standing Wave Indicator has been rigidly tested and inspected before being shipped and is ready for use when received. When the instrument is unpacked, it should be carefully inspected for damage received in shipment. If any damage is found, follow the procedure outlined in the "Claim for Damage in Shipment" paragraph on the last page of this instruction book.

The Model 415B is a portable measuring instrument designed for table top use, or in the rack-mounting model, for permanent installation in a standard relay rack. No special installation instructions are required other than to assure that the ventilating louvers are not obstructed.

When shipped from the Hewlett-Packard factory, the 415B is connected for operation on 115-volt power. If the 415B is to be operated on 230-volt power, the power transformer primary winding must be rewired as shown in the schematic diagram at the end of the manual.

2-3 REQUIRED SIGNAL SOURCE

The signal sources used with the 415B Standing Wave Indicator are of two common types; signal generators and variable frequency klystron tubes. To be used with the 415B, the signal source must be capable of 1000 cycle per second amplitude modulation and should generate up to 0.1 milliwatt of power. Since shf oscillator circuits for the most part use reflex klystrons (which are incapable of sinusoidal amplitude modulation without serious frequency modulation) it is common practice to key the modulating electrode of the klystron from a square-wave generator to obtain 100% square-wave modulation of the signal source. The frequency of the square wave must then be tuned accurately to 1000 cps (to the frequency of the 415B).

For most flexible and versatile operation the signal source should indicate power output and should contain an accurately calibrated output attenuator. Figure 2-1 illustrates a typical test set-up using such a signal generator.

When using a variable frequency klystron tube as a signal source connected directly to waveguide or coaxial sections a suitable attenuator should be used between the klystron and the guide to prevent reflections and to control the signal level from the klystron. In this application the power supply used to power the klystron tube must supply the 1000 cycle modulation or must be capable of being modulated from an external source of square waves.

The 415B is basically a very high gain amplifier driving a meter. Precautions applicable to any high gain system must be considered in operation of the instrument. If the signal source is pulse modulated, care must be taken that the 415B is not overloaded,

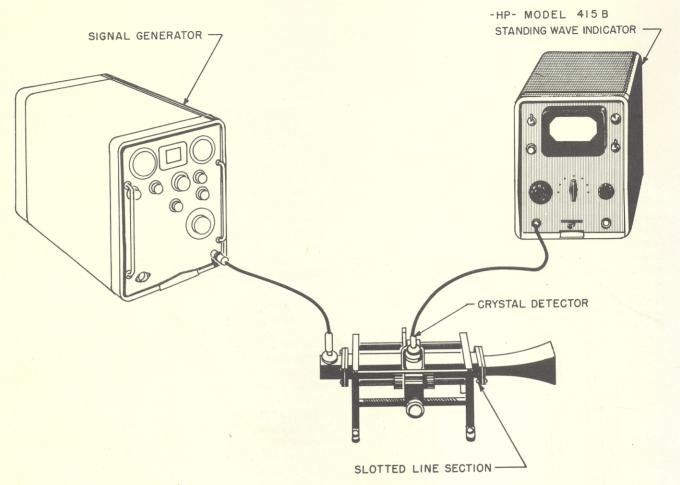


Figure 2-1. Test Setup

as this will result in severe errors. If pulse modulation is used, the duty cycle should be not less than approximately 40%. Since the 415B input in the CRYSTAL position is through a transformer, short pulse type signals can give trouble due to ringing and overload effects. For these reasons it is recommended that only square-wave modulation be used, if at all possible.

2-4 MEASUREMENTS

The Model 415B Standing Wave Indicator can be used to measure the magnitude and phase of the reflection coefficient of any r-f load. This information is obtained by measuring the magnitude of the standing wave and the position of its minimum or maximum. From a knowledge of the reflection coefficient, all other information pertaining to the load can be easily calculated.

Basically, the measurement of standing wave ratio consists of setting a pick-up probe in a slotted section

at a position of maximum voltage and then setting the gain of the standing wave indicator so that a reading of 1.0 is obtained at this position. The probe is then moved along the line section until a minimum voltage point is reached. The standing-wave ratio can then be read directly from the standing-wave indicator scale. This is a basic and straight-forward method of making an swr measurement which, under certain conditions, may lead to relatively large errors. These errors, along with techniques for minimizing them, are discussed later in this section.

In many cases a knowledge of the standing-wave ratio is sufficient as this is a direct measure of the mismatch of the load. There are nevertheless some cases, particularly in design and development, where a greater knowledge of the load is required, and this can be obtained by measuring the position of the minimum in the standing-wave pattern (probe carriages are usually equipped with an accurate scale and indicator for this purpose). The minimum is usually not used directly, but is compared to the position of the minimum when some known load (for

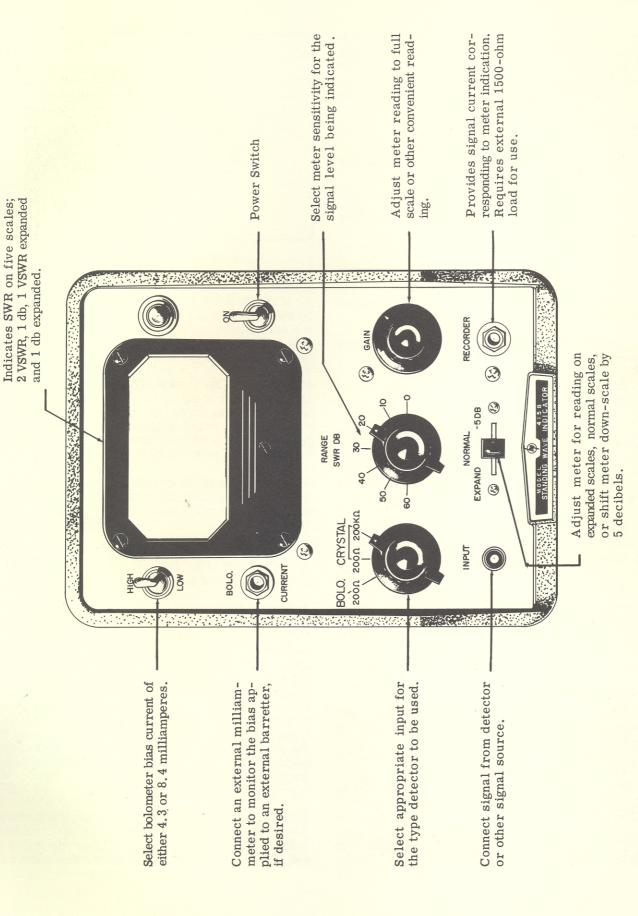


Figure 2-2. Controls and Terminals Diagram

convenience usually a short circuit) is placed at a reference point in the line. The detailed instructions for such measurements are given in paragraphs 2-12 to 2-14 on impedance measurements.

2-5 HOW TO OPERATE THE 415B

As a precaution to prevent possible damage to low current barretters, always set bias current switch to LOW before turning on the instrument.

- a. Connect the 415B Standing Wave Indicator to a nominal 115-volt a-c power source, turn the power switch to ON and allow instrument to warm up.
- b. Set the input selector switch for the type of detector that is to be used with the standing wave indicator.
- c. Connect the INPUT jack to the detector or other signal source to be used.
- d. Set the SWR-DB RANGE switch to obtain an upscale reading on the vswr meter.
- e. Peak the meter reading by adjusting the modulation frequency of the signal source.
- f. If reading swr from a slotted section, move the probe along the line to obtain a peak on the vswr meter.
- g. Set the GAIN control to obtain an exact full-scale reading on the vswr meter.
- h. Move probe along the slotted section to obtain a minimum reading, if necessary reducing the SWR-DB RANGE switch setting to maintain an upscale reading.
- i. Read the vswr, which is now indicated directly on the 415B.

Examples - refer to Figure 2-3.

- 1) If at the minimum the 415B reads 1.3 on the uppermost scale (solid pointer line in Figure 2-3), the vswr would be 1.3 to 1.
- 2) If the reading at the minimum is lower than 3 on the uppermost scale (dashed pointer line A in Figure 2-3), set the SWR-DB RANGE switch to the next range and read the indication on the second vswr (3 to 10) scale. In this case the reading is 3.25 (dashed pointer line B).

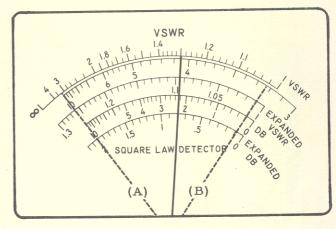


Figure 2-3. Detail of Meter Face

- 3) If the SWR-DB RANGE switch has to be changed by two ranges the scale shifts twice, back to the top scale again; however, the full-scale reading is now 10 instead of 1.
- 4) If the vswr is 1.3 or less it can be read on the EXPANDED VSWR scale after the lever switch on the front panel is set to EXPAND. When the lever switch is set to EXPAND, the meter pointer will "pin" downscale and must be reset to full-scale by increasing the meter sensitivity using the GAIN control and/or the SWR-DB RANGE switch.
- 5) The standing wave ratio is also indicated in decibels on the DB and EXPANDED DB scales. Swr's of less than 2.2 can be read on the EXPANDED DB scale.

A graph of swr in decibels vs. voltage standing wave ratio is shown in Figure 2-4.

PRECAUTIONS

Both the BOLO. and RECORDER jacks on the front panel of the 415B receive the three-circuit 1/4 inch diameter "tip-ring sleeve" phone plug supplied with the instrument. Do not use the standard two-circuit phone plug in these jacks. To do so will short an internal voltage circuit to ground in either jack. In both jacks the sleeve connection is grounded to the instrument chassis and is not used as part of the output circuits; the ring and tip provide the connections to the appropriate signal circuit and must not be grounded externally.

An external recorder connected to the RECORDER jack on the 415B must have approximately 1500 ohms resistance. If the recorder has higher resistance it can be shunted so the total resistance connected to the

RECORDER jack on the 415B is 1500 ohms. If the recorder resistance is lower than 1500 ohms, resistance must be added in series with the recorder. In addition the recorder input terminals must be isolated from ground.

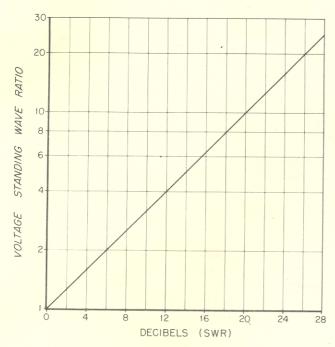


Figure 2-4. Graph Showing Standing Wave Ratio in DB vs. VSWR

2-6 PRECAUTIONS WHEN USING CRYSTAL DETECTOR

There are precautions to be observed concerning all crystal detector elements. The limitations of these devices are well known and will be mentioned only briefly. Crystal diodes exhibit a departure from the ideal square-law response for which standing-wave indicators are calibrated. This departure tends to occur when the r-f power level exceeds a few microwatts, or when a reading of full scale on the 30-db range of the standing wave indicator with the GAIN control set to maximum is obtained.

If the quality of a crystal detector is in question, its performance may quickly be checked against a signal generator having an accurately calibrated attenuator. The step-by-step procedure for making such a check follows. Any new crystal being used for the first time should be thus checked, as there is often a significant variation between one crystal and another.

To check a crystal detector using a calibrated signal source, proceed as follows:

- a. With the equipment in operation, adjust the detector to obtain a full-scale reading on the 30 db-range of the standing wave indicator (GAIN control set to maximum).
- b. Accurately reduce the output of the signal generator 10 decibels by its attenuator.
- c. Set the SWR-DB RANGE switch to the 40-db range. The meter on the standing-wave indicator should again read full-scale, thereby showing a decrease of 10 decibels. A deviation from full-scale indicates a departure from square-law characteristics at the higher level.
- d. Adjust GAIN control on standing-wave indicator, if necessary, to again obtain a full-scale reading with the SWR-DB RANGE switch set to the 40-db range.
- e. Again reduce the signal generator output to 10 db by means of its attenuator.
- f. Set the SWR-DB RANGE switch to the 50-db range. The meter should again read full-scale, indicating a reduction of signal strength of 10 db. If the reading differs noticeably from that on the attenuator of the signal generator, a lower signal level should be used or another crystal detector should be tried.

2-7 DETECTOR PROBE PENETRATION

A general rule in slotted line work is that the penetration of a sampling probe into the line should be held to a minimum. However, this rule is so generally disregarded that it is one of the major sources of errors in standing wave measurements.

Since the sampling probe must extract some power from the line in order to supply the detector and indicating device, it is to be expected that the probe can have an effect on the fields within the line. This effect usually becomes greater as probe penetration is increased. The probe can be considered as an admittance shunting the line. In practical work this admittance is kept small by coupling as loosely as possible (small penetration) and by using a signal source having a power output in the order of a milliwatt or more.

If the coupling between the probe and line is not small, the shunt admittance introduced by the probe will cause the measured vswr to be lower than the true vswr and will shift both the maxima and minima from their natural positions. In general, the shift in the maxima and minima will not be equal, but will depend upon the shunting admittance of the probe. In one special case where the susceptance of the

load is zero, there is no shift of maximum or minimum. A minimum will suffer less shift than the maximum. The impedance along a line varies from a maximum at a voltage maximum to a minimum at a voltage minimum. The effect of the probe conductance is to lower these line impedances, and the effect will be greater at a voltage maximum than at a voltage minimum.

An exception to the minimum-penetration rule occurs when it is desired to examine in detail a minimum point in a standing wave of high ratio (see paragraph 2-9, "High VSWR's", for example of this form of measurement). For this work a greater probe penetration can be tolerated than otherwise because the minimum corresponds to a low-impedance point in the line. However, the minimum should be definitely small (high vswr) before tolerating substantial probe penetration.

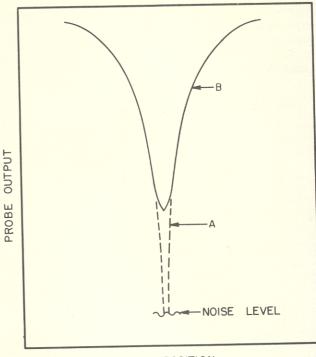
It is more desirable to locate a voltage minimum than a voltage maximum since the effect of probe loading on the minimum is less than on the maximum. However, location of the minimum in a low standing wave ratio by a single measurement is usually inaccurate since the minimum is generally quite broad. A more accurate method of locating the minimum is to obtain the position of probe at two equal output readings on either side of the minimum and then average these two readings.

Besides absorbing power and affecting the standingwave pattern as a shunting element in the line, the probe will also cause reflections in the line. These reflections will travel towards the generator. If the generator is not matched, they will be reflected down the line toward the load.

2-8 PRECAUTIONS WITH SIGNAL SOURCES

Signal sources can introduce at least three undesirable characteristics that will affect slotted line measurements. These include presence of r-f harmonics, frequency modulation, and spurious signals. Signal sources used for standing wave measurements should have relatively low harmonic content in their output. The standing wave ratio at a harmonic frequency may be considerably higher than at the fundamental. Spurious frequencies in the signal source are also undesirable, for, unless very slight, they will obscure the minimum points at high vswr values. Figure 2-5 shows plot of an swr pattern made with signal source producing unwanted f-m

Instances are common where the presence of r-f harmonics has led to very serious errors in vswr



PROBE POSITION

Figure 2-5. High Standing Wave Ratio Pattern
(A) Free of FM

(B) With Moderate FM

measurements. Such harmonics are usually present to an excessive degree only in signal sources that have coaxial outputs. Coaxial pickups of a broad-band type will often pass harmonic frequencies with greater efficiency than the fundamental. In waveguide systems, signal sources such as internal cavity klystrons have a more or less fixed coupling and in addition do not have pickups extending into the tuned cavity to cause perturbations of the cavity fields. Consequently, the harmonic problem is generally limited to coaxial systems. Harmonics become especially troublesome when the reflection coefficient of a load at a harmonic frequency is much larger than at the fundamental frequency - a common condition. When the harmonic content of the signal source is high, the large reflection coefficient of the load at the harmonic frequency can cause the harmonic standing wave fields to be of the same order of magnitude as the fields at the fundamental frequency. Thus, a device having a vswr of 2.0 at the fundamental frequency will often have a vswr of 20 or more at the second harmonic frequency. If such a device is driven from a signal source having, say, 15% second harmonic content, the peaks of the standing waves of second harmonic will be about oneforth the amplitude of the peaks at the fundamental frequency. Figure 2-6 shows a typical swr pattern obtained when the r-f signal contains harmonics.

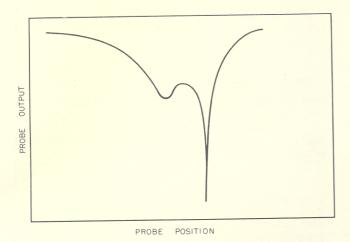


Figure 2-6. Typical Pattern of High VSWR to Spurious Frequency in Signal Source

2-9 HIGH VSWR'S

The straightforward measurement of vswr with conventional methods is generally applicable when measuring nominal vswr's up to the range of 10-12, but at higher vswr's special considerations are desirable.

When the vswr is high, the coupling of the probe must be high if a reading is to be obtained at the minimum. This requirement may result in a deformation of the pattern when a maximum is measured, with the consequent error in the reading. In addition to the error caused by probe coupling, there is danger of the error caused by a change in detector characteristics as the r-f energy increases to a much higher level.

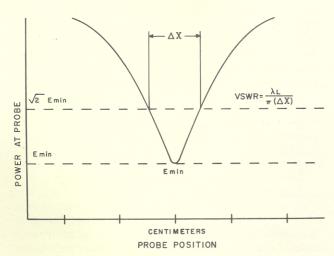


Figure 2-7. Graph Showing Double Minimum Method for Computing VSWR

There is available for measuring high vswr's a method that is accurate within approximately 1% down to the region where conventional methods can be used. This method is the twice-minimum-power method and is predicted on the approximation of a high-ratio power standing-wave pattern to a parabola in the vicinity of a minimum. (See Figure 2-7)

In the twice-minimum method it is only necessary to establish the electrical distance between the points that are twice the power amplitude of the minimum. The vswr can then be obtained by substituting this electrical distance into the expression

$$VSWR = \frac{\lambda L}{\pi (d_1 - d_2)}$$

Where λL is the guide wavelength in cm and d₁ and d₂ are the locations of the two twice-minimum points, also in cm.

NOTE: It should be noted that the value referred to in this method is the twice-power value. If a standing wave indicator such as the 415B calibrated for use with a square-law detector is used, or if a linear receiver is used, the voltage ratio of the two readings will be 1.4:1. If a linear voltage indicator is used with a square-law detector, the voltage indication of the twice-power point will be twice that of the minimum.

For this method of reading vswr, the probe penetration should be sufficient to give a clear reading of the minimum. For this work a greater probe penetration can be tolerated than otherwise because the minimum corresponds to a low-impedance point in the line. However, the minimum should be definitely small (high vswr) before tolerating substantial probe penetration.

2-10 LOW VSWR'S

When a sampling probe is lowered into a slotted section it gives rise to reflections from the probe itself. Reflections from the probe travel back toward the generator, and what happens there depends upon the match between the generator and the line. If the generator is mismatched, these reflections are again reflected, this time toward the load. When the probe is moved under these conditions, the phase of the reflections is changed, leading to errors. Since the reflection from the generator is a secondorder effect, it only becomes important when measuring low vswr's in the order of 2 or less, in which case it is desirable to achieve a moderately good match between generator and load. Probe reflections, of course, should be kept as low as possible by minimizing probe penetration.

Accurate measurement of the position of the minimum, when the vswr is low, becomes difficult because of the broadness of the minimum. When the precise location of the minimum is desired, it is helpful to establish points on each side of the minimum that have the same value. By averaging the location of these points, the minimum can be located with greater accuracy than with a direct measurement. The locations of equal-amplitude points are more easily established because of their higher slope.

2-11 IMPEDANCE MEASUREMENT RULES

Some rules of thumb that are helpful in making slotted line measurements are:

The shift in the minimum when the load is shorted is never more than \pm one-quarter wavelength.

If shorting the load causes the minimum to move toward the load, the load has a capacitive component.

If shorting the load causes the minimum to shift toward the generator, the load has an inductive component.

If shorting the load does not cause the minimum to move, the load is completely resistive and has a value $Z_{\rm O}/VSWR$.

If shorting the load causes the minimum to shift exactly one-quarter wavelength, the load is completely resistive and has a value of $Z_0 \times VSWR$.

When the load is shorted, the minimum will always be a multiple of a half-wavelength from the load.

Shifts in voltage minima resulting from various types of loads are illustrated in Figure 2-8.

2-12 IMPEDANCE MEASUREMENT PROCEDURE

The technique for performing actual impedance measurement is as follows:

- a. Connect the load under test to the slotted section and measure the vswr and the position of the minimum in the standing wave pattern.
- b. Replace the load with a short at the load end of the slotted line.
- Determine the new minimum position with the line shorted.
- d. The normalized load impedance may be computed by the formulas below. Refer to Figure 2-9.

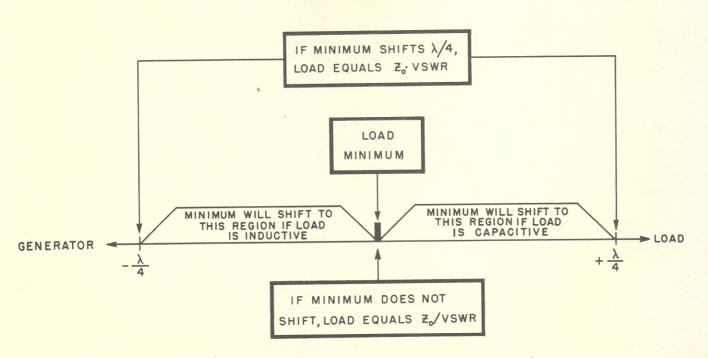


Figure 2-8. Summary of Rules for Impedance Measurement

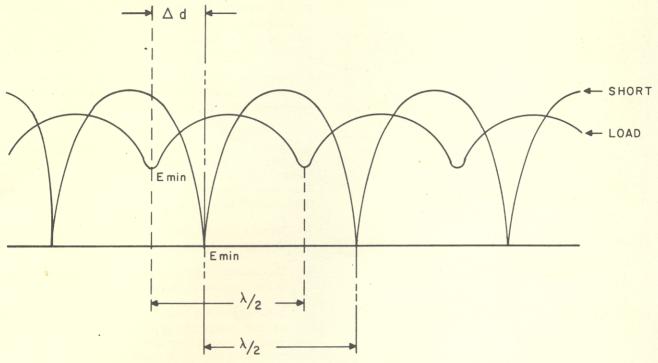


Figure 2-9. Graph Showing Standing Wave Patterns with a Load and Short

$$zL = \frac{1 - j (VSWR) Tan X}{(VSWR) - j Tan X}$$

Where:
$$X = \frac{180^{\circ} (\pm \Delta d)}{\frac{\lambda}{2}}$$

And: $\pm \Delta d =$ Shift in centimeters of the minimum point when the short is applied.

 Δ d takes a positive (+) sign when the minimum shifts toward the load.

 Δ d takes a negative (-) sign when the minimum shifts toward the generator.

 $\frac{\lambda}{2}$ = One-half line or guide wavelength. It is the distance in centimeters as measured between two adjacent minima.

These calculations are based upon the assumption that no losses occur in the transmission system. For laboratory set-ups where the line lengths are short this assumption is customary. It is also assumed that the $\rm Z_{\rm O}$ for the lines is entirely resistive.

2-13 IMPEDANCE MEASUREMENT AND THE SMITH CHART

When data is obtained from slotted line measurement, one of the most indispensable tools and certainly the simplest to use, is the Smith Chart. This chart represents an impedance coordinate system so arranged that the variable quantities in impedance relationships are conveniently displayed for the solution of transmission line problems. *

The values of resistance and reactance shown on the Smith Chart in Figure 2-10 are based upon the normalized values. The normalized impedance, resistance or reactance is obtained by dividing the actual value by the characteristic impedance of the line. For example, if the actual impedance of a 50 ohm transmission line were found to be 100 ohms at some point, the normalized impedance would be 2.

The circles on the Smith Chart tangent to bottom of the chart are circles of constant and normalized resistance.

^{*} Smith, P.H. "Transmission-line Calculator" Electronics, Jan. 1939, McGraw-Hill.

Ragain, G.L. Ch.2, Vol. 9 M.I.T. Rad. Lab. Series, 1948, McGraw-Hill.

The straight line forming the vertical diameter of the chart is the line of zero reactance. To the right and left of this line are seen lines which curve away from the zero reactance line. The curved lines to the right are the lines of positive reactance +jX.

The curved line to the left are the lines of negative reactance, $\frac{-j\,X}{Z_0}$.

For example, the impedance point of a line terminated by its characteristic impedance would be the center of the chart (with a normalized resistance of 1.0 and no reactive component).

In another example of actual impedance calculation:

$$ZL = 5 + j 25$$
 ohms

Normalized for a 50 ohm line would be:

$$zN = 0.1 + j0.5$$

2-14 PROCEDURE FOR SMITH CHART CALCULATIONS

The step by step procedure for employing the Smith Chart when solving transmission line problems is outlined below. It should be understood that there are various methods employed for entering the Smith Chart with data obtained from the slotted line, and that the method outlined in this section has been found practical and simple.

- a. Set up slotted line in system.
- b. Measure vswr in manner described in section 2-5.
- c. Determine wavelength of transmission line (λ L). Paragraph 2-8 showed that the distance as measured on slotted line between two adjacent minima was equal to one-half the wavelength of the line.
- d. Find a convenient minimum point.
- e. Replace load with short.
- f. Measure $\triangle d$ (the shift in centimeters of the minimum point with the short applied).

g. Determine the number of wavelength of shift $(\Delta \lambda)$.

$$\Delta \lambda = \frac{\Delta d}{\lambda L}$$

- h. Starting at center of Smith Chart draw circle with vswr as radius. Read vswr on zero reactance line down from center.
- i. Enter the Smith Chart at the top and proceeding in a direction of probe movement (either toward the load or toward the generator) when the load was replaced by a short to the quantity $\Delta\lambda$ established in step g.
- j. Draw a line to the center of the chart from the $\Delta \lambda$ point.
- k. The intersection of this line and the vswr circles is the normalized impedance.
- 1. It is important that the convention be followed of first finding the minimum reference with the load on the line and then sliding the probe to the new minimum when the line is shorted. Should it be necessary to establish the shorted minimum point first, the Smith Chart would be entered with $\Delta\,\lambda$ in a direction opposite to the direction of probe movement. That is, the probe movement toward the load would be entered on the chart in a direction toward the generator.
- m. An example will clarify this procedure.

The vswr is measured as 3.3.

The distance between two adjacent minima is 15 cm. Therefore, the wavelength of the line is 30 cm (λL).

A convenient minimum is located at 22 cm.

The line is shorted.

The minimum point shifts to 19 cm (toward generator).

$$\Delta d = 22 - 19 = 3 \text{ cm}$$

$$\Delta \lambda = \frac{\Delta d}{\lambda L} = 3/30 = 0.1$$
 wavelength

Construct vswr circle on Smith Chart. See Figure 2-10.

Construct radius to wavelength shift point. See Figure 2-11.

Read impedance at intersection at point A on Figure 2-12. Normalized impedance equals .44 + j 0.64.

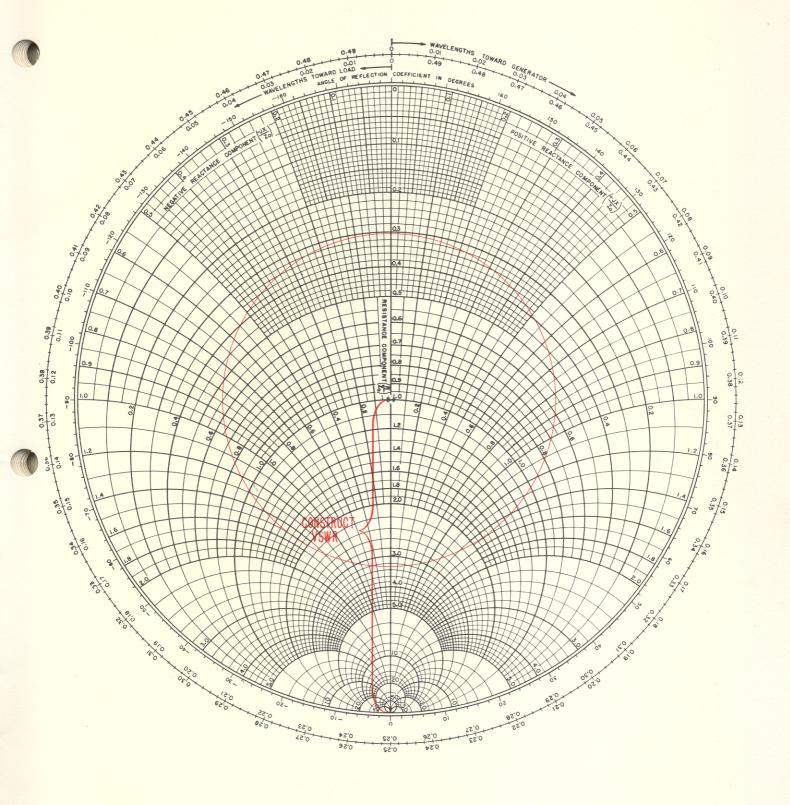


Figure 2-10. Smith Chart with Constructed VSWR Circle, VSWR = 3.3

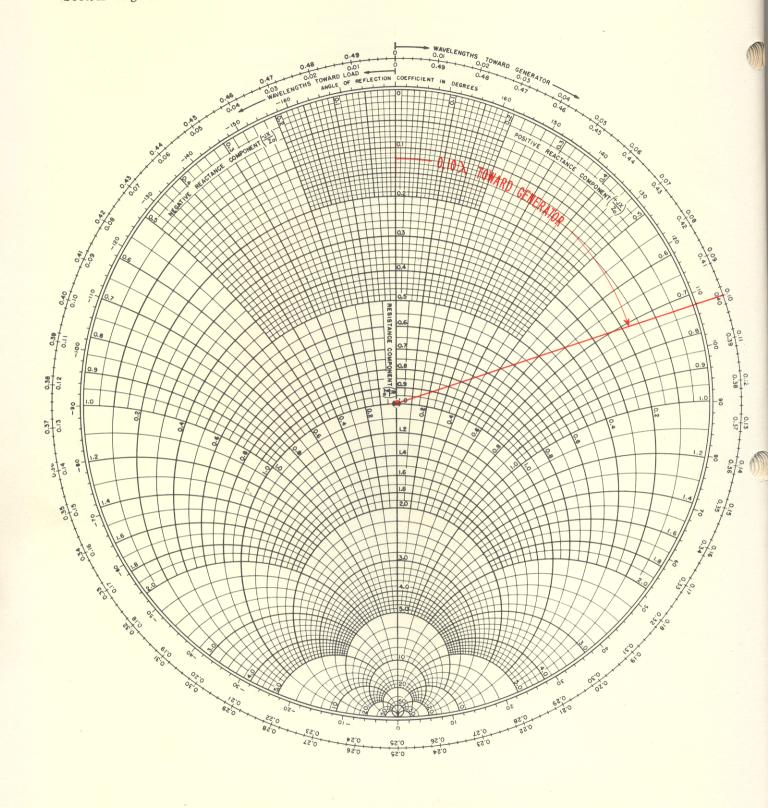


Figure 2-11. Smith Chart with Wavelength Shift Point Constructed as a Radius.

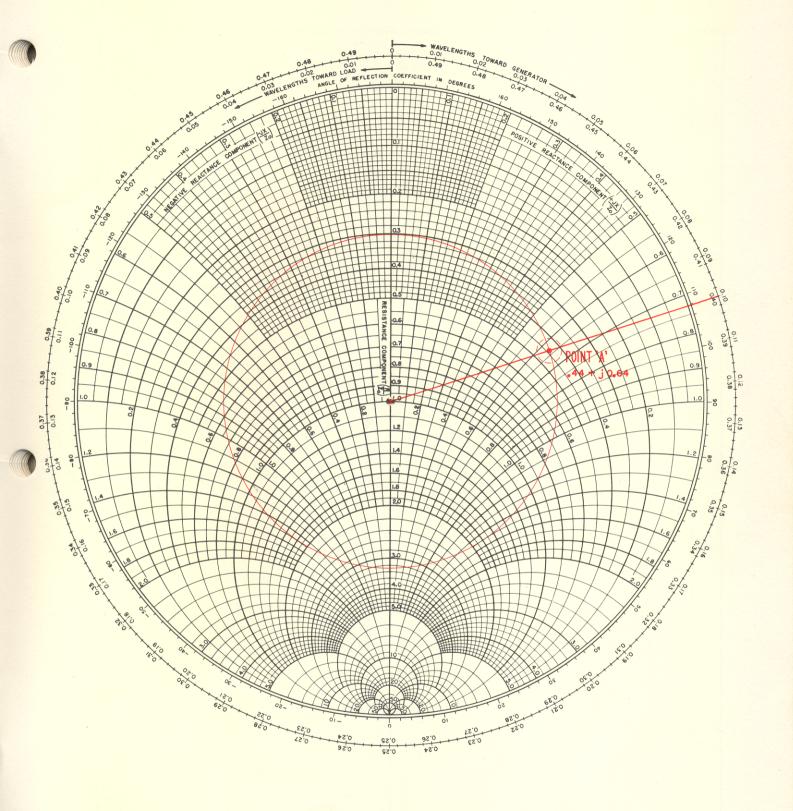


Figure 2-12. Smith Chart Showing Impedance Point, Δ

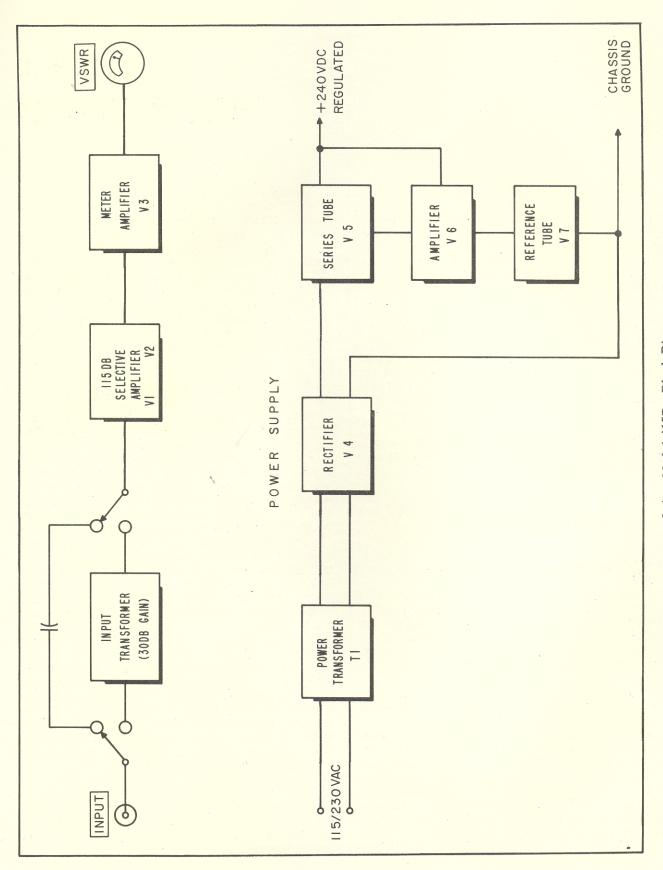


Figure 3-1. Model 415B Block Diagram

SECTION III THEORY OF OPERATION

3-1 CIRCUIT DESCRIPTION

The Model 415B Standing Wave Indicator consists of a high-gain amplifier, a 1000 cycle resonant circuit, an indicating meter and an electronically regulated power supply. All tubes of the instrument are shown in the block diagram in Figure 3-1. Basically, operation of the instrument is as follows:

- a. A four-stage, frequency selective amplifier amplifies the input signal a maximum of 115 decibels for application to the indicating circuit. The sensitivity of the selective amplifier is adjusted by two front panel controls, the SWR-DB RANGE selector and the GAIN control.
- b. The 1000-cycle signal from the selective amplifier is fed to a feedback amplifier which in turn operates the vswr meter.
- All circuits are powered from the electronically regulated +240-volt power supply.

3-2 FREQUENCY SELECTIVE AMPLIFIER

The frequency selective amplifier consists of 31:1 step-up input transformer T2, three resistance coupled hi-mu triode stages and a fourth stage which is plate tuned to 1000 cps. The amplifier without the input transformer provides a total of 115-db gain, while T2 provides an additional 30 db.

The input circuit to the selective amplifier is arranged to match various external signal sources such as a crystal diode, barretter or a relatively high-impedance device (bridge circuit, etc.). When the input circuit is switched to 200,000 the input jack connects through the SWR-DB RANGE switch S3 to the grid of the first amplifier tube. In the CRYSTAL position the INPUT jack connects to the primary of T2 which provides a reflected load of 200 ohms to any device connected to the INPUT jack.

In the BOLO. position the input jack connects to the primary of the input transformer as above; except that the primary winding is now returned to a current source, R2 and R3, providing d-c operating bias through the transformer winding to any 200 ohm detector element connected to the input jack. The HIGH-LOW toggle switch shunts the current source with R1 so that two different values of bias (4.3 and 8.4 milliamperes) may be used. The bias current is fed also through a jack on the front panel so that an external milliammeter may be used to measure the bias current passing through the detector.

The SWR-DB RANGE switch, S3, consists of a threesection step attenuator which changes the gain of the amplifier in 20-db steps. However, to obtain square law meter calibration, the steps are calibrated 10 db on the front panel. The three sections of the attenuator are located in the grid circuits of the first three amplifier stages, V1A, B and V2A. The third section provides the first attenuation step, the second section the second attenuation step and the first section provides the remaining four attenuation steps. Selected precision resistors are used throughout the range switch. Because of the extremely high gain in this amplifier, the grounding of all parts in the first and second stages is very critical and is specially indicated on the schematic diagram. The heavy lines indicate common negative tie points which in turn are together and connected to chassis only a J1.

The output level from the amplifier is controlled by a two-section potentiometer (GAIN control R22A and B) in the grid circuit of the last amplifier stage. The potentiometers are connected in series, one providing approximately 25 db (12.5 db on the meter scale) of control for coarse adjustments, the other approximately 1.5 db (0.75 db on the meter scale) of control for fine adjustments.

Switch S4a between the second and third amplifier stages, when in the -5 db position, reduces the sensitivity of the amplifier to decrease the vswr

meter indication by 5 db so that down-scale meter readings may be made upscale on the next lower range of the VSWR-DB RANGE switch.

To make the amplifier frequency selective, the plate circuit of the last stage is loaded with parallel resonant circuit, Z1, having an effective Q between 25 and 35. The tuned circuit allows a 1000-cps signal to pass unattenuated, while the decreased impedance at off resonant frequencies attenuates these frequencies considerably. The effective bandwidth is approximately 40 cycles at the half-power points.

3-3 METER CIRCUIT

The 1000-cps signal from the selective amplifier is applied to a two-stage feedback amplifier which operates crystal rectifiers CR1, CR2 and the indicating meter M1. To assure linear operation, negative feedback is used around both the amplifier and the rectifier circuit. A 0.46-volt rms signal is required at the first grid of V3 to obtain a full scale meter indication. The signal from the second plate of V3 is fed to crystal diode CR2 which allows current to flow through R37 and the meter during the negative half of the signal cycle. During the positive half cycle the current returns through CR1 and R36, causing a circulating current through the meter.

Front panel selector S4, when set to the EXPAND position, applies a d-c bucking voltage to meter rectifier CR2 so that a meter reading is forced off-scale, i.e., downward. The amplifier sensitivity must then be increased to obtain an upscale reading; which can then be read on the expanded meter scales. An equal bucking voltage is applied to the rectifier CR1 so that a bias voltage is not applied to the two diodes.

3-4 POWER SUPPLY

The power supply consists of a power transformer with a single high-voltage winding feeding a full wave rectifier and electronic voltage regulator supplying +240 volts dc to all the circuits of the standing wave indicator. The voltage regulator circuit maintains constant output voltage with wide changes in load current and line voltage.

V5, V6 and V7 constitute the voltage regulator circuit. V7 is a constant-voltage tube which provides the reference bias for V6. V5 operates as a series tube, or variable resistor, controlled by the voltage at the grid of V6. If the regulated B+ at the cathode of V5 tends to increase, the grid voltage for V6 increases causing V6 to draw more current. This lowers the plate voltage of V6 and therefore the grid voltage of V5 and results in greater plate resistance for V5. The greater plate resistance causes a greater voltage drop across V5, compensating for the increased voltage at its cathode and resulting in a substantially constant voltage output.

If the regulated B+ voltage tends to decrease, the reverse of the above action occurs, also tending to maintain the cathode voltage substantially constant. Ripple in the output voltage is coupled to the grid of V6 by capacitor C12. Variations in the d-c voltage are coupled to the grid of V6 through the voltage divider R44, R45 and R46. The bias for V6 and the level of the output voltage from V5 are determined by the setting of R45.

The heaters of amplifier tubes V1, V2 and V3 are operated from a positive biased heater winding to reduce hum pickup from the heaters of these tubes. The bias voltage is obtained from a 10 volt point on the voltage divider stick R44, R45, R46 and R47 in the power supply.

SECTION IV MAINTENANCE

4-1 TROUBLE SHOOTING THE 415B

Because the 415B is essentially a high-gain amplifier with a "relative" indicating meter there are few critical or troublesome circuits. Electron tubes which weaken with age decrease the maximum sensitivity of the instrument without affecting accuracy and the tubes can be replaced with new tubes without adjustments. The accuracy of the meter calibration is largely determined by the two crystal diodes CR1 and CR2, and to a lesser degree by the mechanical tracking of the meter itself and the linearity of the selective amplifier, the latter not ordinarily being subject to change.

Any form of instability is usually attributable to power supply trouble and is quickly checked by measuring the power supply voltage and by noting the noise level as read on the vswr meter. An incorrect regulated voltage and/or high noise level are easily corrected by adjustment or by changing tubes as described in paragraph 4-2, "Replacing Tubes". A high noise level that is not caused by a power supply fault is usually due to noise generated in tube V1 and is cured by replacement of V1.

The gain of each amplifier stage is easily checked with an audio oscillator and voltmeter by applying a small voltage (0.01 volt) to each stage in turn and measuring the output. The expected gain from each stage is as follows:

Input Transformer = 30 db

Stage	Gain (db)		
V1a (1st)	34		
V1b	27.5		
V2a	31		
V2b	22		

The gain of V3 is such that 0.46 volt rms at the input grid should give fullscale meter deflection.

4-2 REPLACING TUBES

Except for those in the regulated power supply, the tubes in the 415B may be replaced without adjustment. When changing tubes in the power supply, measure the d-c output voltage at the cathode of Series Tube V5. If necessary, adjust R45 to obtain exactly 240 volts at the cathode of V5. This voltage should be checked at line voltages of 105 and 125 volts and should show no appreciable variation.

When changing V1 it will be necessary to select a tube which generates very low noise and is not microphonic. With the new tube installed, turn on the meter and set the SWR-DB RANGE switch to the 60 db (most sensitive) position. Note the noise level as read on the vswr meter; also note the sensitivity to mechanical shock. Select a tube for V1 that minimizes the noise reading and if possible the microphonics also.

4-3 REPLACING THE CRYSTAL DIODES

When replacing the crystal diodes used in the meter circuit, use good quality diodes which have a high ratio of forward to back resistance (several hundred to one or better).

4-4 RANGE SWITCH REPAIRS

The precision resistors mounted on the SWR-DB RANGE switch are carefully selected and matched for accuracy during manufacture, and it is usually not practical to attempt to replace individual resistors. It is recommended that the whole switch be replaced in the event of malfunction, thereby saving time and gaining assurance that the accuracy of the original calibration will be retained. If it becomes necessary to change one resistor on the range switch the range to range accuracy must be checked and the value of the new resistor selected or padded to obtain the correct amount of attenuation to the

specified accuracy of $\pm .2$ db or better between ranges. When soldering these resistors care must be taken not to heat or bend the resistor leads more than absolutely necessary.

4-5 CALIBRATING THE EXPANDED METER SCALE

To calibrate the expanded meter scale, set the input selector to 200,000 Ω , the SWR-DB RANGE selector to 0 db and the lever switch to EXPAND.

Apply a sine wave voltage of 1000 cps to the input jack to obtain exact full scale meter deflection. Attenuate the input signal exactly 4 decibels. The meter should now indicate 2 db on the EXPANDED DB scale. If it does not, adjust R33 so that the new reading is equally in error on the other side of the 2 db calibration point. Remove the 4 db attenuation and readjust input signal for exact full scale reading. Insert the 4 db attenuation and, if necessary, readjust R33 for exactly 2 db. Repeat above adjustment until 4 db attenuation of the applied voltage produces a 2 db deflection on the meter.

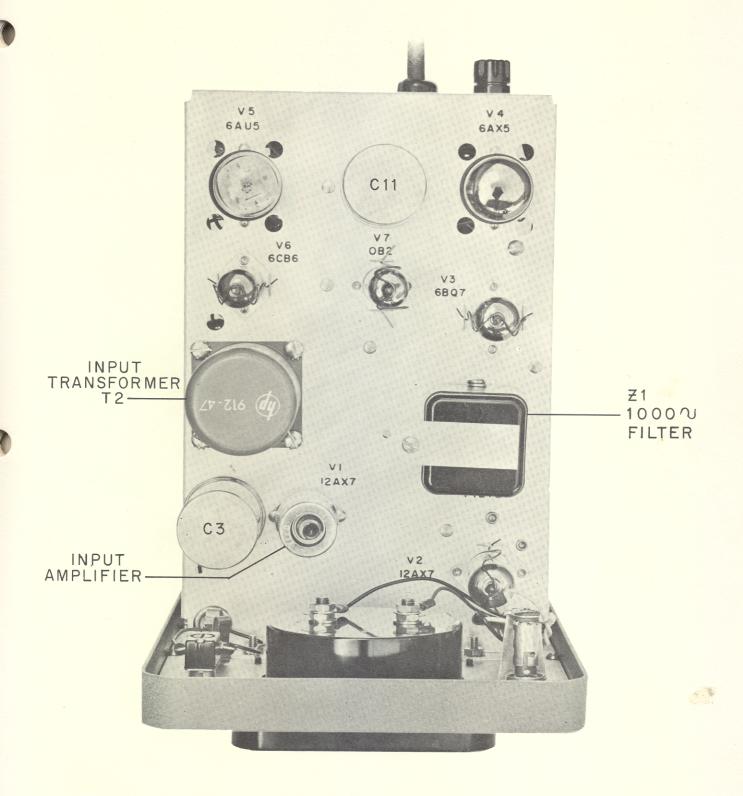


Figure 4-1. Model 415B Top View

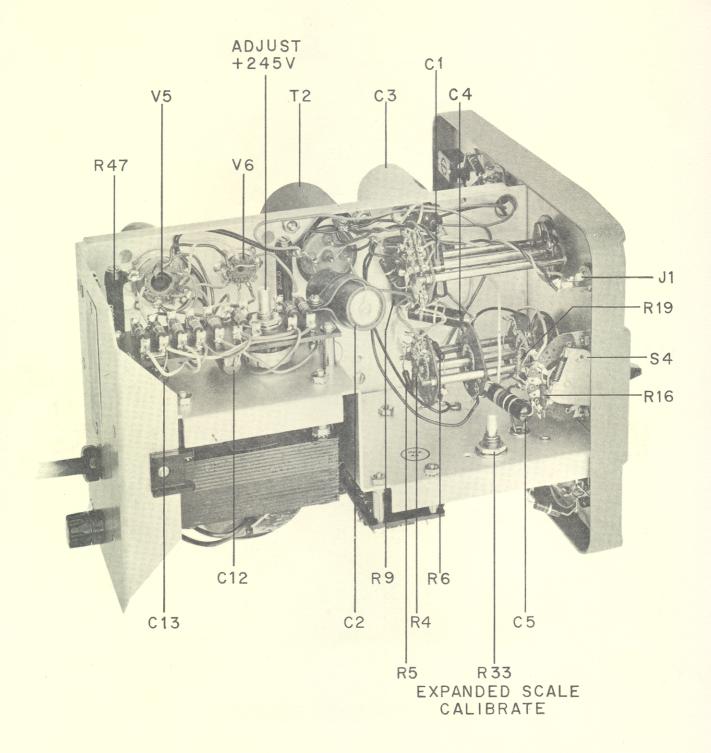


Figure 4-2. Model 415B Bottom View

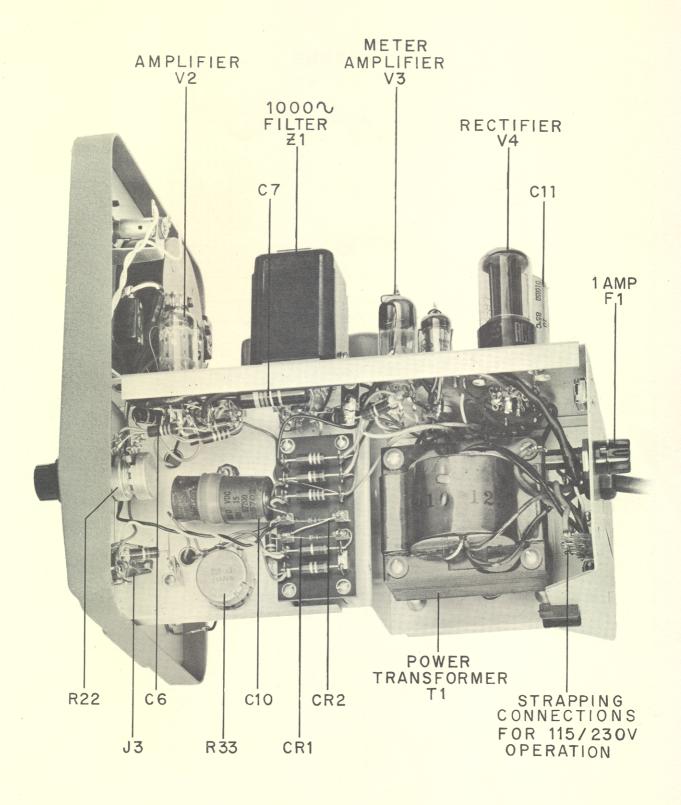
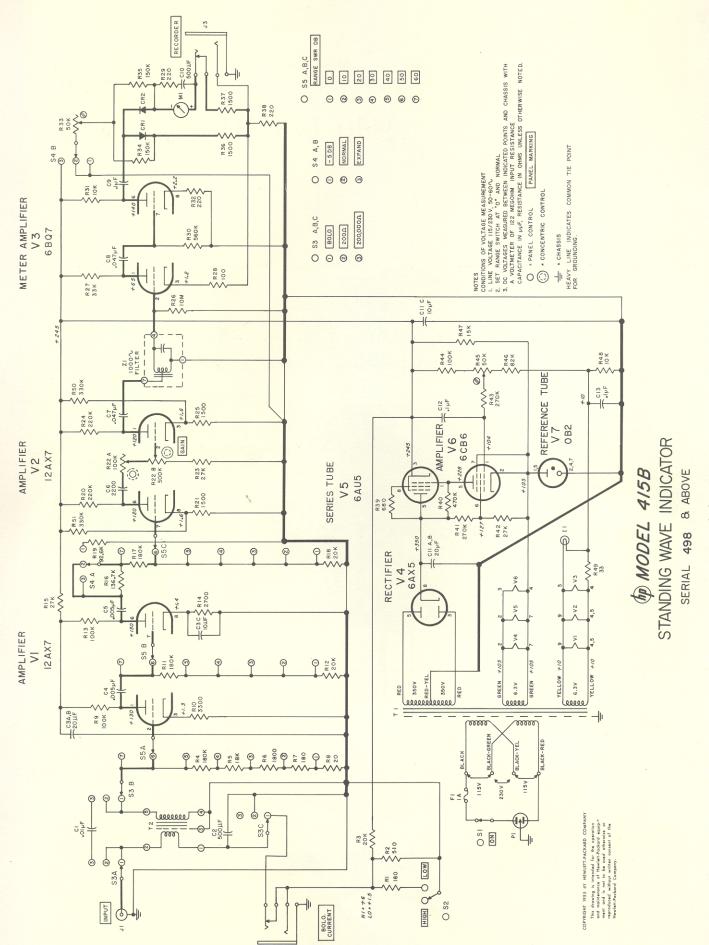


Figure 4-3. Model 415B Right Side



12

Figure 4-4.

SECTION V TABLE OF REPLACEABLE PARTS

NOTE

Any changes in the Table of Replaceable Parts will be listed on a Production Change sheet at the front of this manual.

When ordering parts from the factory always include the following information:

Instrument Model Number

Serial Number

Stock Number of Part

Description of Part

Circuit Ref.	Description	Stock No.	Mfr. * & Mfrs. Designation
C1	Capacitor: fixed, paper dielectric, .01 μ f, $\pm 10\%$, 600 vdcw	16-11	CC 109P10396
C2	Capacitor: fixed, electrolytic, 500 μ f, 15 vdcw	18-5	X TC 1505
C3A, B, C	Capacitor: fixed, electrolytic, 3 section: 10 μ f/sect., 450 vdcw	18-31 131 HP	CC D16650
C4, 5	Capacitor: fixed, paper dielectric, .0047 μf, ±10%, 600 vdcw	16-25	CC 109P47296
C6	Capacitor: fixed, paper dielectric, .0022 μf, ±10%, 600 vdcw	16-22	CC 109P22296
C7, 8	Capacitor: fixed, paper dielectric, .047 µf, ±10%, 600 vdcw	16-15	CC 109P47396
C9	Capacitor: fixed, paper dielectric, 0.1 μ f, $\pm 10\%$, 400 vdcw	16-35	CC 109P10494
C10	Same as C2		
C11A, B, C	Same as C3A, B, C		
C12, 13	Same as C9		
CR1, 2	Rectifier, crystal: germanium diode	212-G12	Transitron S142G
F1	Fuse, cartridge: 1 amp, 250V	211-18 211-20	E MDL1
I1	Lamp incandescent: 6-8V, 0.15 amp	211-47	0
J1	Connector, receptacle: 52 ohms impedance	125-UG-1094/U	LL UG-1094/U
J2, 3	Jack telephone: for 3-cond.plug	124-10	KK Dave Ross 2J-1230
M1	Meter: d-c milliammeter	112-60	BF Type 801
R1	Resistor: fixed, composition, 160 ohms, ±5%, 1 W	24-160-5	B GB 1615
R2	Resistor: fixed, composition, 510 ohms, ±5%, 1 W	24-510-5	B GB 5115
R3	Resistor: fixed, wirewound, 20,000 ohms, ±10%, 10W	26-77	S 1-3/4
R4	Resistor: fixed, deposited carbon, 180,000 ohms, ±1%, 1/2 W	33-180K	NN DC-1/2C
R5	Resistor: fixed, deposited carbon, 18,000 ohms, ±1%, 1/2 W	33-18K	NN DC-1/2C

^{*}See "List of Manufacturers Code Letters for Replaceable Parts Table".

Circuit		(II)	Mfr. * & Mfrs.
Ref.	Description	Stock No.	Designation
R6	Resistor: fixed, deposited carbon, 1800 ohms, $\pm 1\%$, $1/2$ W	33-1800	NN DC-1/2C
R7	Resistor: fixed, deposited carbon, 180 ohms, ±1%, 1/2W	33-180	NN DC-1/2C
R8	Resistor: fixed, deposited carbon, 20 ohms, ±1%, 1/2 W	33-20	NN DC-1/2C
R9	Resistor: fixed, deposited carbon, 100,000 ohms, ±1%, 1 W	31-100K	NN DC-1
R10	Resistor: fixed, composition, 3300 ohms, ±10%, 1 W	24-3300	B GB 3321
R11	Same as R4		
R12	Resistor: fixed, deposited carbon, 20,000 ohms, ±1%, 1/2 W	33-20K	NN DC-1/2C
R13	Resistor: fixed, composition, 100,000 ohms, ±10%, 1 W	24-100K	B GB 1041
R14	Resistor: fixed, composition, 2700 ohms, ±10%, 1 W	24-2700	B GB 2721
R15	Resistor: fixed, composition, 27,000 ohms, ±10%, 1 W	24-27K	B GB 2731
R16	Resistor: fixed, composition, 136.7K ohms, ±1%, 1/2 W	33-136.7K	NN DC-1/2C
R17	Same as R4		
R18	Same as R12	1	
R19	Resistor: fixed, deposited carbon, 92.6K ohms, ±1%, 1/2 W	33-92.6K	NN DC-1/2C
R20	Resistor: fixed, composition, 220,000 ohms, ±10%, 1 W	24-220K	B GB 2241
R21	Resistor: fixed, composition, 1500 ohms, ±10%, 1 W	24-1500	B GB 1521
R22A, B	Resistor: variable, composition, dual section, front section = 500,000 ohms, rear section = 100,000 ohms	210-106	G Model 2 Radiohm
R23	Same as R15		
R24	Same as R20		
R25	Same as R21		

^{*}See "List of Manufacturers Code Letters for Replaceable Parts Table".

Circuit Ref.	Description	Stock No.	Mfr. * & Mfrs. Designation
R26	Resistor: fixed, composition, 10 megohms, ±10%, 1 W	24-10M	B GB 1061
R27	Resistor: fixed, composition, 33,000 ohms, ±10%, 1 W	24-33K	B GB 3331
R28	Resistor: fixed, composition, 100 ohms, ±10%, 1 W	24-100	B GB 1011
R29	Resistor: fixed, composition, 220 ohms, ±10%, 1 W	24-220	B GB 2211
R30	Resistor: fixed, composition, 560,000 ohms, ±10%, 1 W	24-560K	B GB 5641
R31	Resistor: fixed, composition, 10,000 ohms, $\pm 10\%$, 1 W	24-10K	B GB 1031
R32	Same as R29		
R33	Resistor: variable, composition, 50,000 ohms, ±20%, 1/2 W	210-18	I Type 37 Stamped 210-18
R34, 35	Resistor: fixed, composition, 150,000 ohms, ±10%, 1 W	24-150K	B GB 1541
R36, 37	Same as R21		
R38	Same as R29		
R39	Resistor: fixed, composition, 680 ohms, ±10%, 1 W	24-680	B GB 6811
R40	Resistor: fixed, composition, 470,000 ohms, $\pm 10\%$, 1 W	24-470K	B GB 4741
R41	Resistor: fixed, composition, 270,000 ohms, ±10%, 1 W	24-270K	B GB 2741
R42	Same as R15		
R43	Same as R41		
R44	Same as R13		
R45	Same as R33		
R46	Resistor: fixed, composition, 82,000 ohms, $\pm 10\%$, 1 W	24-82K	B GB 8231
R47	Resistor: fixed, wirewound, 15,000 ohms, $\pm 10\%$, 10 W	26-25	S 10 watt Type 1-3/4E

^{*}See "List of Manufacturers Code Letters for Replaceable Parts Table".

Circuit Ref.	Description	Stock No.	Mfr. * & Mfrs. Designation
R48	Same as R31		
R49	Resistor: fixed, composition, 33 ohms, ±10%, 1 W	24-33	B GB 3301
R50, 51	Resistor: fixed, composition, 330,000 ohms, ±10% 1 W	24-330K	B GB 3341
S1, 2	Switch, toggle: SPST	310-11	Federal Screw & Prod. Co. 780
S3A, B	Switch, rotary: 1 section, 3 positions	310-161	w
S4A, B	Switch, lever: 3 positions	310-160	G
S5A, B, C	Switch, rotary: 3 sections, 7 positions	310-162	w
Т1	Transformer, power: primary, 115/230 volts, 50-60 cps	910-123	Paeco
T2	Transformer, input: primary 2000 ohms, secondary 200, 000 ohms	912-47	Paeco
V1, 2	Tube, electron: 12AX7	212-12AX7	zz
V3	Tube, electron: 6BQ7A	212-6BQ7A	ZZ
V4	Tube, electron: 6AX5GT	212-6AX5GT	zz
V5	Tube, electron: 6AU5GT	212-6AU5GT	ZZ
V6	Tube, electron: 6CB6	212-6CB6	ZZ
V7	Tube, electron: OB2	212-OB2	ZZ
XF1	Holder, fuse: extractor post type	140-16	Т 342003
XI1	Light, indicator: with 1/2 diam.frosted lens	145-2	II 810B-121
XV1	Socket, tube: miniature; 9 contact	120-2	Н 44В-20965
XV2, 3	Socket, tube: noval, 9 contact	120-10	н 44F-16388
XV4, 5	Socket, tube: 7 contact miniature	120-11	AE 316PH
XV6, 7	Socket, tube: octal	120-27	Н 51А12272
XZ1	Same as XV4, 5		-
Z1	Circuit, tuned: 1000-cycle filter	415-42A	НР
		*	
		*	

^{*}See "List of Manufacturers Code Letters for Replaceable Parts Table".

Circuit Ref.	Description	© Stock No.	Mfr. * & Mfrs. Designation
	Knob: NORMAL	G-74AA	HP
	Knob: GAIN (3/4 inch)	G-74A	HP
	Knob: GAIN (1 inch)	G-74L	HP
	Knob: RANGE, BOLO.CRYSTAL	G-74N	HP
	1		
	,		

^{*}See "List of Manufacturers Code Letters for Replaceable Parts Table".

LIST OF CODE LETTERS USED IN TABLE OF REPLACEABLE PARTS TO DESIGNATE THE MANUFACTURERS

Code Letter	Manufacturer	Address	Code Letter	Manufacturer	Address
A	Aerovox Corporation	New Bedford, Mass.	AI	General Ceramics & Steatite Corp.	Keasbey, N. J.
В	Allen-Bradley Company	Milwaukee 4, Wis.	AJ	The Gudeman Company	Sunnyvale, Calif.
C	Amperite Company	New York, N.Y.	AK	Hammerlund Mfg. Co., Inc.	New York l. N. Y.
D	Arrow, Hart & Hegeman	Hartford, Conn.	AL	Industrial Condenser Corporation	Chicago 18, Ill.
E	Bussman Manufacturing Company	St. Louis, Mo.	AM	Insuline Corporation of America	Manchester, N. H.
F	Carborundum Company	Niagara Falls, N.Y.	AN	Jennings Radio Mfg. Corporation	San Jose, Calif.
G	Centralab	Milwaukee l, Wis.	AO	E. F. Johnson Company	Waseca, Minn,
H	Cinch-Jones Mfg. Company	Chicago 24, Ill.	AP	Lenz Electric Mfg. Company	Chicago 47, Ill.
HP	Hewlett-Packard Company	Palo Alto, Calif.	AQ	Micro-Switch	Freeport, Ill.
I	Clarostat Mfg. Company	Dover, N. H.	AR	Mechanical Industries Prod. Co.	Acron 8, Ohio
J	Cornell Dubilier Elec. Company	South Plainfield, N. J.	AS	Model Eng. & Mfg., Incorporated	Huntington, Ind.
K	Hi-Q Division of Aerovox	Olean, N. Y.	AT	The Muter Company	Chicago 5, Ill.
L	Erie Resistor Corporation	Erie 6, Penn.	AU	Ohmite Mfg. Company	Skokie, Ill.
M	Fed. Telephone & Radio Corporation	Clifton, N. J.	AV	Resistance Products Company	Harrisburg, Penn.
N	General Electric Company	Schenectady 5, N.Y.	AW	Radio Condenser Company	Camden 3, N. J.
0	General Electric Supply Corporation	San Francisco, Calif.	AX	Shallcross Manufacturing Company	Collingdale, Penn.
P	Girard-Hopkins	Oakland, Calif.	AY	Solar Manufacturing Company	Los Angeles 58, Calif.
Q	Industrial Products Company	Danbury, Conn.	AZ	Sealectro Corporation	New Rochelle, N. Y.
R	International Resistance Company	Philadelphia 8, Penn.	BA	Spencer Thermostat	Attleboro, Mass.
S	Lectrohm Incorporated	Chicago 20, Ill.	BC	Stevens Manufacturing Company	Mansfield, Ohio
T	Littlefuse Incorporated	Des Plaines, Ill.	BD	Torrington Manufacturing Company	Van Nuys, Calif.
U	Maguire Industries Incorporated	Greenwich, Conn.	BE	Vector Electronic Company	Los Angeles 65, Calif.
V	Micamold Radio Corporation	Brooklyn 37, N. Y.	BF	Weston Electrical Inst. Corporation	Newark 5, N. J.
W	Oak Manufacturing Company	Chicago 10, Ill.	BG	Advance Electric & Relay Co.	Burbank, Calif.
X	P. R. Mallory Co., Incorporated	Indianapolis, Ind.	вн	E. I. DuPont	Los Angeles 58, Calif.
Y	Radio Corporation of America	Harrison, N. J.	BI	Electronics Tube Corporation	Philadelphia 18, Penn.
Z	Sangamo Electric Company	Marion, Ill.	BJ	Aircraft Radio Corporation	Boontan, N. J.
AA	Sarkes Tarzian	Bloomington, Ind.	BK	Allied Control Co., Incorporated	New York 21, N.Y.
BB	Signal Indicator Company	Brooklyn 37, N. Y.	BL	Augat Brothers, Incorporated	Attleboro, Mass.
CC	Sprague Electric Company	North Adams, Mass.	BM	Carter Radio Division	Chicago, Ill.
DD	Stackpole Carbon Company	St. Marys, Penn.	BN	CBD Hytron Radio & Electric	Danvers, Mass.
EE FF	Sylvania Electric Products Company	Warren, Penn.	ВО	Chicago Telephone Supply	Elkhart, Ind.
	Western Electric Company	New York 5, N. Y.	BP	Henry L. Crowley Co., Incorporated	West Orange, N. J.
GG HH	Wilkor Products, Incorporated	Cleveland, Ohio	BQ	Curtiss-Wright Corporation	Carlstadt, N. J.
II	Amphenol	Chicago 50, Ill.	BR	Allen B. DuMont Labs	Clifton, N. J.
JJ	Dial Light Co. of America	Brooklyn 37, N. Y.	BS	Exsel Transformer Company	Oakland, Calif.
KK	Leecraft Manufacturing Company	New York, N. Y.	BT	General Radio Company	Cambridge 39, Mass.
LL	Switchcraft, Incorporated	Chicago 22, Ill.	BU BV	Hughes Aircraft Company	Culver City, Calif.
MM	Gremar Manufacturing Company	Lynn, Mass.		International Rectifier Corporation	El Segundo, Calif.
NN	Carad Corporation	Redwood City, Calif.	BW BX	James Knight Company	Sandwich, Ill.
00	Electra Manufacturing Company	Kansas City, Mo.	BY	Mueller Electric Company	Cleveland, Ohio
PP	Acro Manufacturing Company	Columbus 16, Ohio	BZ	Precision Thermometer & Inst. Co.	Philadelphia 30, Penn.
99	Alliance Manufacturing Company	Alliance, Ohio	CA	Radio Essentials Incorporated	Mt. Vernon, N. Y.
RR	Arco Electronics, Incorporated Astron Corporation	New York 13, N. Y.	CB	Raytheon Manufacturing Company	Newton, Mass.
SS		East Newark, N. J.	CD	Tung-Sol Lamp Works, Incorporated	Newark 4, N. J.
TT	Axel Brothers Incorporated	Long Island City, N. Y.	CE	Varian Associates	Palo Alto, Calif.
UU	Belden Manufacturing Company Bird Electronics Corporation	Chicago 44, Ill. Cleveland 14, Ohio	CF	Victory Engineering Corporation Weckesser Company	Union, N. J.
VV	Barber Colman Company	Rockford, Ill.	CG		Chicago 30, Ill.
ww	Bud Radio Incorporated	Cleveland 3, Ohio	CH	Wilco Corporation	Indianapolis, Ind.
XX	Allen D. Cardwell Mfg. Company	Plainville, Conn.	CI	Winchester Electric Incorporated Malco Tool	Santa Monica, Calif.
YY		Burbank, Calif.	CJ		Los Angeles 42, Calif.
ZZ	Cinema Engineering Company Any brand tube meeting RETMA	Durbuik, Calli.	CK	Oxford Electric Corporation Camlo Fastner Corporation	Chicago 15, Ill.
	characteristics.		CL		Paramus, N. J.
AB	Corning Glass Works	Corning, N. Y.	CM	George K. Garrett Union Switch	Philadelphia 34, Penn.
AC	Dale Products, Incorporated	Columbus, Neb.	CN	Radio Receptor	Swissvale, Penn.
AD	The Drake Mfg. Company	Chicago 22, Ill.	CO	Automatic & Precision Mfg. Co.	New York II, N. Y.
AE	Elco Corporation	Philadelphia 24, Penn.	CP	Bassick Company	Yonkers, N. Y. Bridgeport 2, Conn.
AF	Hugh H. Eby Company	Philadelphia 44, Penn.	CQ	Birnbach Radio Company	New York 13, N. Y.
AG	Thomas A. Edison, Incorporated	West Orange, N.J.	CR	Fischer Specialties	Cincinnati 6, Ohio
AH	Fansteel Metallurgical Corporation	North Chicago, Ill.	CS	Telefunken (The American Elite Co)	New York, N. Y.