BIRD ELECTRONIC CORPORATION

INSTRUCTION MANUAL for

THRULINE® model 43 RF Directional Wattmeter

INSTRUCTION BOOK

for the

Thruline

WATTMETER

MODEL 43

BIRD ELECTRONIC CORP.
CLEVELAND, OHIO

Fig. 1-1. Model 43 THRULINE

SECTION 1
GENERAL DESCRIPTION

1. PURPOSE AND APPLICATION

The Model 43 THRULINE Wattmeter is an insertion type RF wattmeter, designed to measure power flow and load match in 50-ohm coaxial transmission lines. It is intended for use on CW, AM, FM, and TV modulation envelopes, but not pulsed modes. The Model 43, when used in 50-ohm applications, has an insertion VSWR of less than 1.05:1 up to a frequency of 1000 MHz. The meter is direct reading in watts, expanded down scale for easy reading, and is graduated 25, 50, and 100 watts full scale. The power ranges used are determined by the Plug-In Elements, which fall in ten frequency band groups covering from 2 to 2300 MHz plus additional special Elements in various power and frequency ranges (see Section 4). Further characteristics may be found in the Summary Sheet on page A.

2. DESCRIPTION

The Model 43 THRULINE, Figure 1-1, is a portable unit contained in a die cast aluminum housing, with a formed metal enclosure on the back which is easily removed. Included with the unit is a leather carrying strap, four rubber shock feet on the base, and four rubber bumpers on the back, which allow the Model 43 to stand or lie flat when used. For additional protection, the microammeter is specially shock mounted. A slotted screw is provided on the lower front face of the meter for zeroing the pointer. Below the meter, the RF line section face protrudes slightly from the wattmeter housing with the Plug-In Element socket in the center.

A shielded cable connects the microammeter to the dc jack which is attached to the side of the RF line section casting. This cable, nearly three feet long, permits removal of the RF line section from the Wattmeter housing. Meter connections may be maintained with any installations outside of the housing. This permits permanent additional installations to be made. See Section 3, INSTALLATION.

Inside the dc jack assembly, there is a filter capacitor which shunts the meter circuit to prevent mis-readings caused by stray RF energy existing in the Plug-In Element. Mounted on the dc jack is a phosphor bronze spring finger, which protrudes through a lateral hole and into the Plug-In Element socket of the RF line section. The finger has a button on its end which mates with the contacts of the Plug-In Element. The nickel plated brass RF line section is precision made to provide the best possible impedance match to the coaxial RF transmission line in which the Model 43 is inserted. The ends of the line section are nested in mating slots to provide additional mechanical support.

At each end of the line section are Bird Quick-Change type RF connectors, which may be quickly interchanged with any other Bird "QC" connector by removing the four screws on the mounting flanges. The Wattmeter housing does not interfere with any connector changes.

To make measurements, the cylindrical shaped Plug-In Element is inserted into the line section socket and rotated against one stop. A small catch in the upper right hand corner of the casting face presses on the shoulder of the Plug-In Element to keep it in proper alignment and assure a good contact with the dc jack and between the lower edge of the Element and line section body. On diametrically opposite sides of the Plug-In Element body are contacts to provide dc pick-up in either direction. These contacts make connection with the spring finger of the dc jack only when the Plug-In Element is in the precise forward or reverse position, and with the index pin on the Element on the lower level of the line section casting face against its respective stop.

SECTION 2
THEORY OF OPERATION

1. TRAVELLING WAVE VIEWPOINT

The best way to visualize the THRULINE idea is from the TRAVELLING WAVE viewpoint on transmission lines, which illustrates that the voltages, currents, standing waves, etc., on any uniform line section are the result of two travelling waves:

FORWARD WAVE travels (and its power flows) from source to load, and has RF voltage E and current I in phase, with $E/I = Z_O$.

REFLECTED WAVE originates by reflection at the load, travels (and its power flows) from the load to source and also has an RF voltage $\mathcal{E}$ and current $\mathcal{I}$ in phase, with $\mathcal{E}/\mathcal{I} = Z_O$.

Note that each component wave is mathematically simple, and is completely described by a single figure for power, for instance:

$$\underset{W}{\backslash F/} = \text{Watts Forward} = E^2/Z_O = I^2 Z_O = EI$$

$$\underset{W}{\backslash R/} = \text{Watts Reverse} = \mathcal{E}^2/Z_O = \mathcal{I}^2 Z_O = \mathcal{E}\mathcal{I}$$

Z_O is the characteristic impedance of the uniform line, and simplifies matters by being a pure resistance, usually 50 ohms, for useful lines. The main RF circuit of the THRULINE is a short piece of uniform air type line section, whose Z_O is a very accurate 50 ohms, in which correct measurements may be made.

2. COUPLING CIRCUIT

The coupling circuit which samples the travelling waves is in the Plug-In Element. The circuitry of the Element and its relationship to the other components of the THRULINE are illustrated in the schematic diagram, Figure 2-1. Energy will be produced in the coupling circuit of the Element by both mutual inductance and capacitance from the travelling RF waves of the line section. The inductive currents will, of course, flow according to the direction of the travelling waves producing them. The capacitive portion of these currents is naturally independent of the direction of the travelling waves. Therefore, assuming that the Plug-In Element remains stationary, it is apparent that the coupling currents produced from the waves of one direction will add in phase, and those produced from waves of the opposite direction will accordingly subtract in phase. The additive or "ARROW" direction is, of course, assigned to the forward wave.

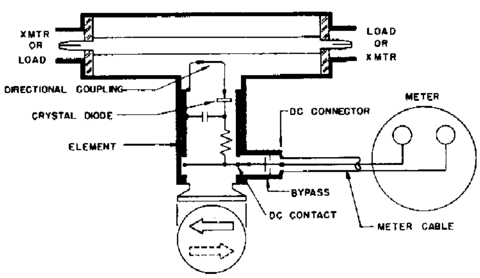


Fig. 2-1. Schematic Diagram

The electrical values of the Element circuits are carefully balanced and so designed that the current produced from the reverse wave will cancel the other almost completely. The resultant is a directivity always higher than 30 dB, which means that the Element is highly insensitive (nulled) to the "REVERSE" direction wave. Being highly directional, the THRULINE Element is sensitive (at one setting) only to one of the travelling waves which produces standing waves by interference. THRULINE measurements are therefore independent of position along standing waves. It may be said that the THRULINE doesn't know, doesn't care, and doesn't need to care where it is along a standing wave.

3. STANDING WAVE RATIO vs. REFLECTED/FORWARD POWER RATIO

As mentioned above, the THRULINE technique uses the TRAVELLING WAVE viewpoint to measure most of the outstanding facts about transmission line operation. Another widely used and related viewpoint, is the STANDING WAVE, which is quite elaborately developed both mathematically and in existing equipment. This technique can be traced to the early development of slotted lines as tools of exploration.

The slotted line is a standing wave instrument, and emphasizes this viewpoint. However, the slotted line is too long, too expensive if good, not portable, and slow in operation. These objections increase rapidly as the frequency drops below 1000 MHz. Whereas the THRULINE is surprisingly quick, convenient, and accurate by comparison. With the exception of phase angle reflection (distance, load to minimum) it tells everything a slotted line will.

The relationships between TRAVELLING WAVES and STANDING WAVE viewpoints are given in most high frequency textbooks.

SECTION 3
INSTALLATION

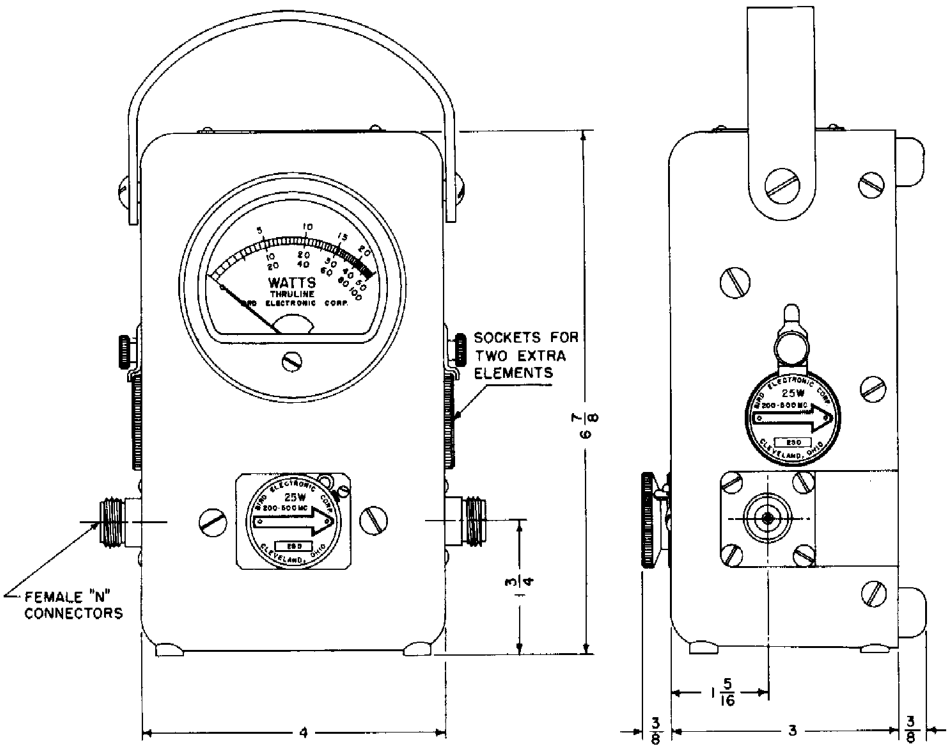


Fig. 3-1. Outline Drawing, Model 43 THRULINE

1. PORTABILITY

The Model 43 is a portable instrument, and the housing is not designed for fixed mounting (see Outline Drawing, Figure 3-1). A strap is provided for carrying purposes.

While transporting the THRULINE, it is best to insert a Plug-In Element, secure with the catch, and point the ARROW upwards. This will shunt the meter circuit and serve to protect the meter by dampening needle action during handling or shipping. Also, secure the spare Plug-In Elements in their receptacles with the thumbscrew and clamp. Handle the Plug-In Elements with care at all times. Calibration could be disturbed if they are dropped.

CAUTION

Do not drop the THRULINE or its Elements or subject them to hard blows. The microammeter is shock mounted in the wattmeter housing, but its delicate mechanism may be damaged by severe impact.

2. CONNECTIONS

Insert the Model 43 THRULINE in coaxial transmission lines of 50 ohms nominal impedance. It is indifferent to which respective side the power source and the load connections are made. If cables other than 50 ohms are used, a mismatch will occur causing probable serious inaccuracies in readings. However, if a mismatch cannot be avoided, the results may be calculated per paragraph 7 of Section 4. We strongly urge that you avoid this condition.

The Model 43 is normally supplied with two Female N-Type connectors which are of the Bird Quick-Change design. Other "QC" connectors are available as listed:

Male N	Female BNC
Female HN	Male BNC
Male HN	Female LC
Female C	Male LC
Male C	Female LT
Female UHF	Male LT
Male UHF	Female TNC
7/8" EIA Air Line	Male TNC

These may be purchased from Bird Electronic Corp., as required. See Section 6, Parts List.

The above connectors are quickly changed by removing the four #8-32 round head machine screws from the corners of the connector flange, and pull straight out. Reverse this procedure to attach connector, making sure the center contact pin aligns properly with the socket.

3. REMOTE INSTALLATION

The RF line section can be removed from the meter housing for remote installation. To remove the line section from its housing:

a. Unscrew the six #8-32 flat head machine screws holding the back cover.

b. Grasp the cover by the side filler tabs and pull directly backwards. The back cover assembly will come off with the speed nuts remaining attached.

c. Remove the two #10-32 oval head machine screws on the front of the housing.

d. Slide the line section backwards out of the housing. Do not loosen the two oval head screws on the sides of the housing in line with the meter. These hold the meter supporting shock ring in place.

e. Substitute the cable which attaches the line section to the meter with a sufficient length of cable to make the remote installation.

f. To replace the RF line section, reverse the above procedure.

It may be desirable to have two or more line sections permanently installed in continuous operating equipment. In this case, one set of Elements and one meter may be used to measure several RF transmission lines WITHOUT INTERRUPTION OF RF LINES for insertion of the THRULINE. Additional RF line sections (Figure 3-2) are available.

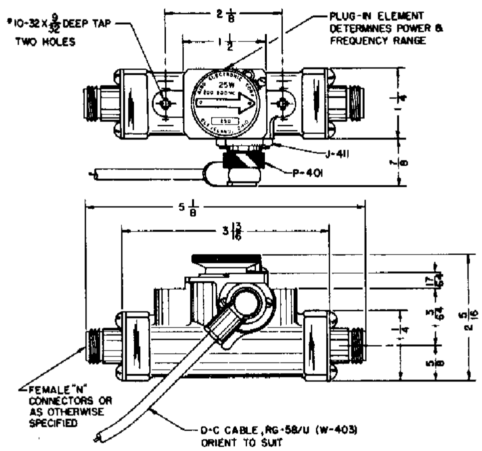


Fig. 3-2. Installation Drawing, RF Line Section

The RF Line Section of the Model 43 blends very readily to panel type mounting. A layout for the panel mount cut is given in Figure 3-3. The thickness of the panel should be about 1/4 inch. On panels less than this, build up the thickness with pads or washers to achieve a flush-face mounting. Cable connections are simplified because the RF line section may be mounted in any convenient direction. Attach the line section so that the finger catch is in the most accessible position.

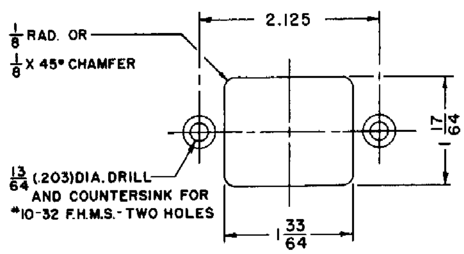


Fig. 3-3. Panel Cut for Mounting RF Body

SECTION 4
OPERATION

1. GENERAL

The apparent features of the THRULINE equipment have been discussed in Section 1, GENERAL DESCRIPTION, and in the instructions of Section 3, INSTALLATION. Measurements are made by the insertion and operation of the Plug-In Elements previously mentioned.

The Elements determine the power range to be read on the meter scale, and the major markings (viz. 50W, 100W, etc.) are the FULL SCALE POWER value for that Element. Elements are also marked for FREQUENCY RANGE. The transmitter frequency must be within the band of the Element used. Elements are available according to those identified in the tables on page 4-6.

See paragraph 6 of this chapter for frequency band flatness, and performance of the Elements outside of stated frequencies. Elements for additional ranges (power or frequency) may be ordered without returning the THRULINE for calibration, since the RF bodies and meters are standardized, and are designed for a wide range of coaxial transmission power values and frequencies.

ARROW on Plug-In Element indicates Sensitive DIRECTION, i.e., the direction of power flow which the meter will read. ARROW and REVERSE are directional terms used in reference to the THRULINE ELEMENT, and mean respectively the sensitive and null directions of the Element. ROTATE ELEMENT to reverse the sensitive direction. FORWARD and REFLECTED are directional terms used in reference to the source - load circuit. Note that the transmitter may attach to either connector of the THRULINE. It makes no difference which external RF connection is selected, since the Elements are reversible and the RF circuit is symmetrical end for end. Before taking readings be sure that the meter pointer has been properly zeroed under no-power conditions.

The THRULINE used with a TERMALINE resistor of proper power rating forms a highly useful absorption wattmeter. With ARROW set toward the load, it is unnecessary to reverse because reflected power may be neglected.

In cases where readings are being made when the meter unit is connected to an auxiliary RF line section body, <u>always remove</u> any <u>measuring Element</u> from the unused RF line section. Otherwise, the dc circuit will be unbalanced or shorted according to the arrow position of the other Element, causing inaccurate or no reading on the meter.

2. LOAD POWER

Power delivered to (and dissipated in) a load is given by:

$$\overset{L}{W} = \text{Watts into Load} = \overset{F}{W} - \overset{R}{W}$$

i.e., where appreciable power is reflected, as with an antenna, it is necessary to subtract reflected from forward power to get load power. This correction is negligible (less than 1 percent) if the load is such as to have a VSWR of 1.2 or less. Good load resistors, such as our TERMALINES, will thus show negligible or unreadable reflected power.

VSWR scales, and their attendant controls, for setting the reference point, have been intentionally omitted from the THRULINE for two reasons:

(a) Why make something similar to a hypothetical dc volt ohmmeter with control pots for the voltmeter multipliers? Even more complications arise when diodes at RF are involved.

(b) Experience using the THRULINE on transmitter tune-up, antenna matching etc., i.e., on OPERATING PROBLEMS shows that the power ratio ϕ is no mean competitor, in practical usefulness, to the ratio ρ = VSWR.

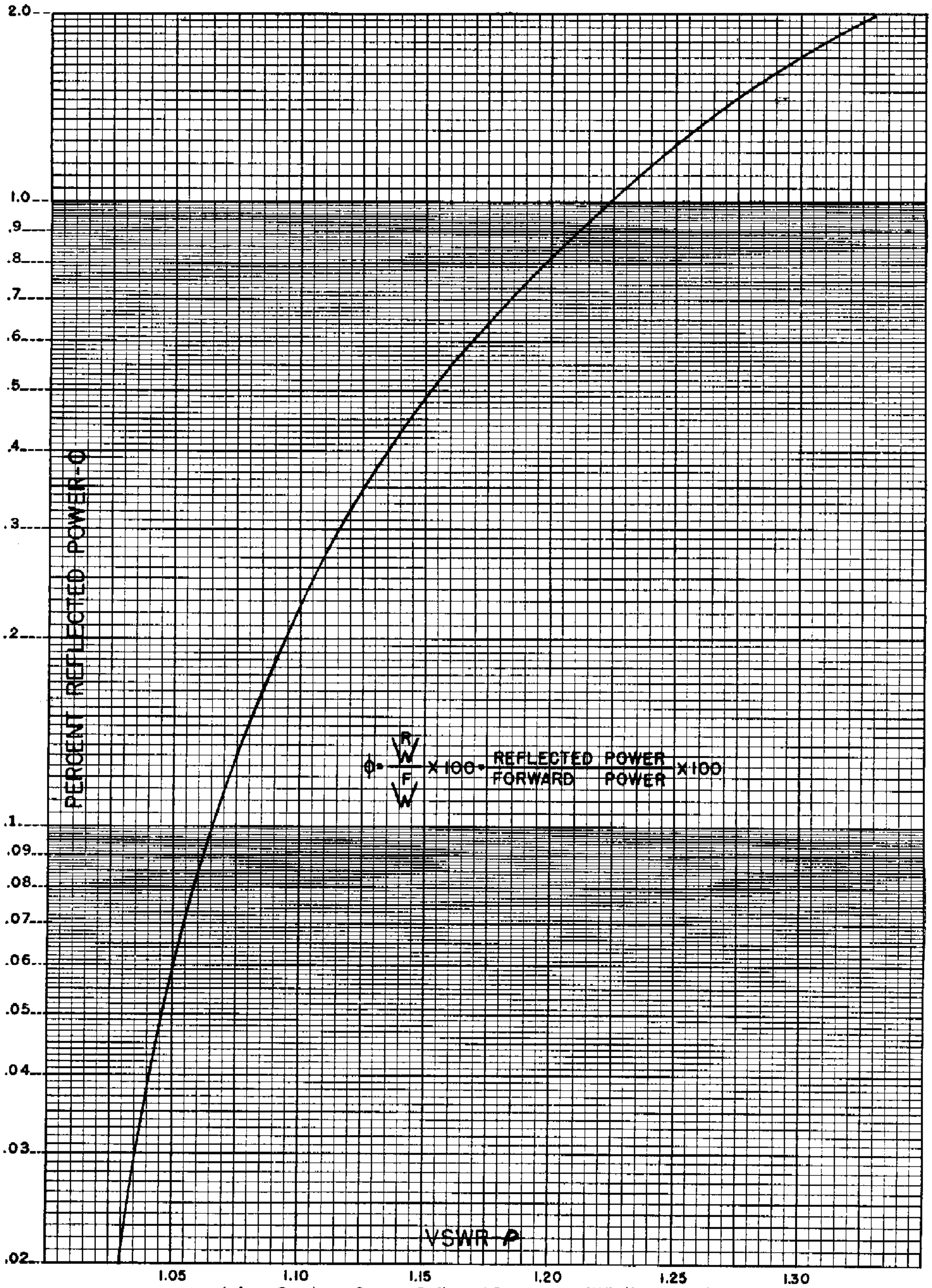
A trial is suggested for a few days — forget VSWR and try thinking in terms of $\phi = \overset{R}{W} / \overset{F}{W}$ when the THRULINE is used. It will be noted that, even without bothering to calculate the ratio exactly, the two meter readings $\overset{R}{W}$ and $\overset{F}{W}$ give an automatic mental impression which pictures the situation. Thus, in an antenna matching problem, the main thing usually is to minimize $\overset{R}{W}$, and anything done experimentally to this end is directly indicated when the THRULINE is in the reflected position. Furthermore, the ratio of readings, only mentally evaluated, is a reliable guide to the significance of the remaining reflected power.

3. GRAPH—ρ VS. ϕ AND ITS SIGNIFICANCE

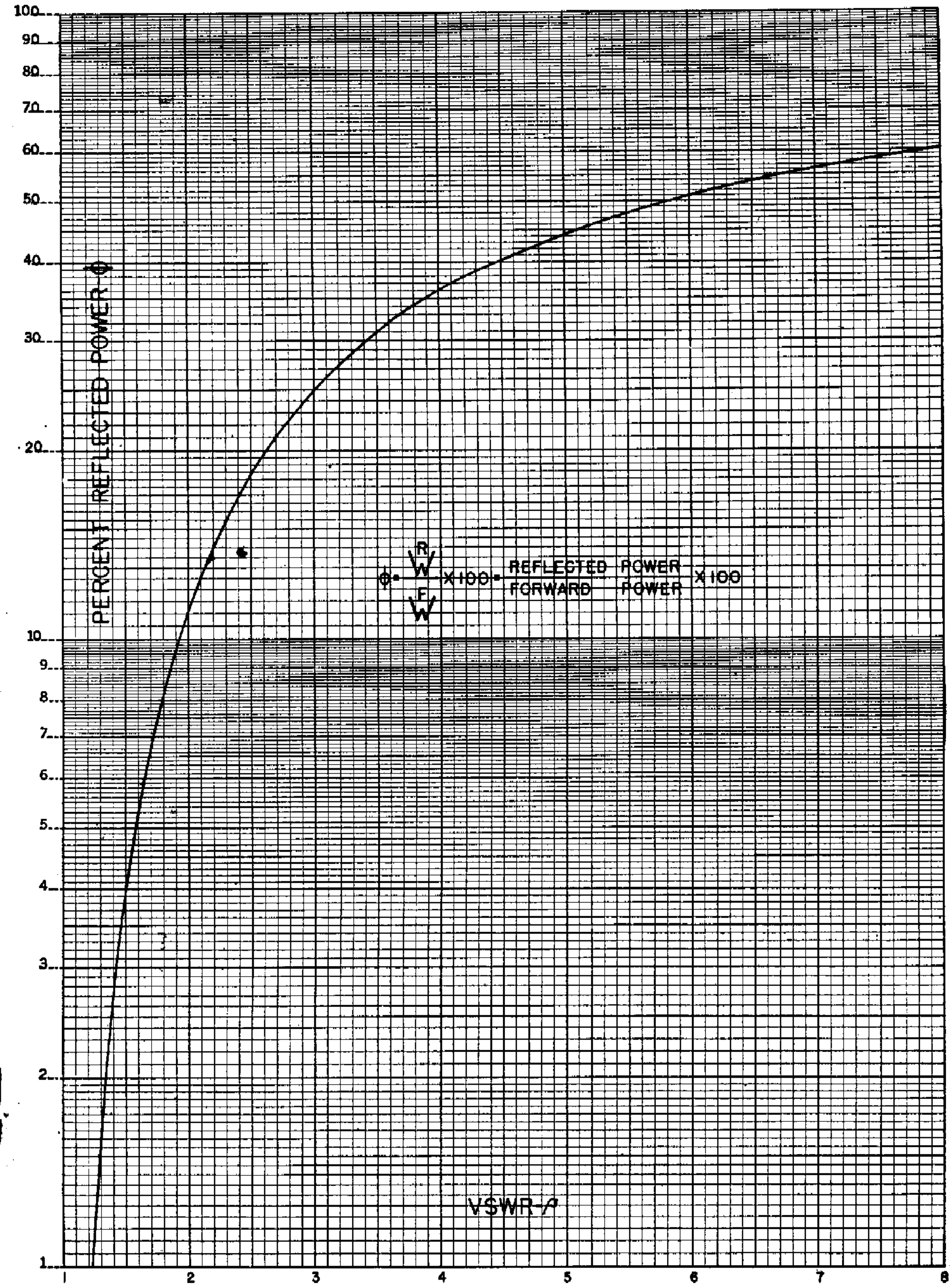
Since there are definite simple relationships

$$\rho = \frac{1+\sqrt{\phi}}{1-\sqrt{\phi}} \text{ and } \phi = \left[\frac{\rho - 1}{\rho + 1}\right]^2 \text{ where } \rho = \text{VSWR and } \phi = \frac{\overset{R}{W}}{\overset{F}{W}}$$

between standing wave ratio ρ and the reflected/forward power ratio ϕ indicated by the THRULINE, the latter may be conveniently used to measure VSWR. The relationship is given in Fig. 4-1a and b.



4-1a. Graph. — Percent Reflected Power vs. VSWR (1.0 to 1.3).



4-1b. Graph. — Percent Reflected Power vs. VSWR (1.0 to 8.0).

Note, that around $\emptyset = 10\%$, below which $\overset{R}{W}$ will appear insignificant and become hard to read, you are close to the commonly accepted lower limit $\rho = 2$, below which improved antenna match becomes less and less worthwhile in many systems. Experimentally, using the THRULINE, it is readily shown that minimizing $\emptyset$ below 10% produces little gain in $\overset{L}{W}$. TV transmitter antenna lines, and VHF Omnirange transmitters, are among systems requiring much lower levels of reflected power for reasons other than simple power transmission. Note also in Fig. 4-1a, the very small level of reflected power, $\emptyset = .06$ percent, corresponding to $\rho = 1.05$. With a single Element, detection of reflected power is possible down to about $\emptyset = 1$ percent, $\rho = 1.2$; if $\overset{F}{W}$ approaches full scale, measurement is possible down to about $\emptyset = 5$ percent, $\rho = 1.5$.

LOW-REFLECTION MEASUREMENTS may be extended below this with two Elements. Say 80 watts are available, and you have 100 watt and 10 watt Elements.

Measure $\overset{F}{W}$ with the 100 watt Element. Remove 100W Element and insert 10 watt Element.

CAUTION: 10 watt Element must be ONLY in the REFLECTED direction. ARROW toward TRANSMITTER. Insert and remove ONLY this way.

Now read $\overset{R}{W}$ on the 10 watt Element.

SPECIAL NOTE

DON'T ROTATE 10 watt Element while TRANSMITTER is on. Always use great care with LOW SCALE Elements on HIGH power RF lines. Inadvertent exposure of these Elements to too much FORWARD or even too high reflected power may permanently damage the measuring Element or the microammeter.

In this case, measurement down to at least .5 watt reflected is possible which means to

$$\emptyset = \frac{.5}{80}, \text{ say .6 percent, or to about } \rho = 1.16$$

and detection of reflections is possible down to about .1 watt,

$$\emptyset = \frac{.1}{80} = .00125, \text{ say .1 percent, or to about } \rho = 1.06$$

Caution is necessary in the above method, and preferably it should not be used with Element ranges differing more than 100 to 10, although 250 to 10 can **be used with extreme caution. With certain Elements now available down to 1 watt full scale this method is usable with medium and low power transmitters.**

4. MEASUREMENT & MONITORING OF TRANSMITTER POWER

Little more need be said about this, in view of LOAD POWER paragraph above. The THRULINE is useful for continuous monitoring of transmitter output, and may be found useful in continuous monitoring of reflected power, for instance in checking intermittent antenna or line faults.

Like diode devices generally, the THRULINE indicates the carrier component on amplitude modulation, with very little response to sideband components added by modulation.

5. TESTING OF LINES, CONNECTORS, FILTERS, ETC.

The THRULINE is highly useful for this purpose, and may be employed in several ways.

(a) VSWR (Insertion) or $\emptyset$ (Insertion) may be measured with the line terminated in a good load resistor (TERMALINE). The lower limits of sensitivity in this are given above under LOW REFLECTION MEASUREMENTS.

(b) ATTENUATION (Power lost by heat in the line) as well as VSWR (Insertion) and $\emptyset$ (Insertion) may be measured by inserting the unknown line between two THRULINES, or between two RF bodies used with one meter and one set of Elements. (End of line to be terminated in a load resistor). This method applies also to insertion between the THRULINE and a TERMALINE absorption wattmeter.

Very small values of attenuation require allowance for normal instrument errors. The correction may be determined by direct rigid connection of the THRULINES, or of the THRULINE-TERMALINE combination, in cascade. Slight juggling of zero settings is permissible for convenience in eliminating computation, provided readings are being taken fairly well up on scale.

(c) ATTENUATION BY OPEN OR SHORT CIRCUIT METHOD. Neater by far than method (b) is one depending on the high directivity (null balance) to which the THRULINE Elements are held. They should, and do, exhibit good equality between forward and reflected readings when the load connector is open or short circuited. In this condition $\emptyset = 100$ percent, the forward and reflected waves being equal in magnitude, and $\rho = \infty$ Say that this is checked on open circuit, and then a length of line of unknown attenuation, also open circuited, is connected to the load connector. The ratio $\emptyset$ then shown is the attenuation in two passes along the line (down and back).

Expressed in dB, (using the equation $N_{dB} = \log \frac{\overset{F}{W}}{\overset{R}{W}}$),

the dB figure may be compared with published data for line type and length by remembering to halve N_{dB}* because twice the line length is actually being measured.

This measurement should be supplemented by one of $\emptyset$ (Insertion) as in (a) above, or at least by dc con-

*Or to double the line length.

tinuity and leakage checks, since the attenuation measurement alone can be in error from faults such as open or short circuits part way down the line.

Open circuit testing is somewhat to be preferred to short circuit, since the reference short (used to check equality initially) must be good, and because the initial equality is somewhat better on open than on short circuit.

Again, for quite low values of measured attenuation, it is advisable to note exact readings (or difference) on the initial equality check, and to allow for this difference.

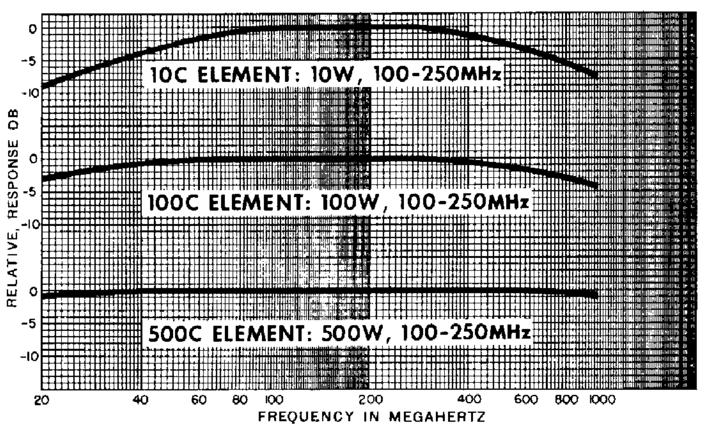
6. FREQUENCY RESPONSE

The Plug-In Elements have a very flat frequency response over a frequency ratio of more than 2-1/2 to one. This characteristic provides a practically flat response within the assigned frequency ranges for all the Elements, see Table I in this Section.

An illustrative set of curves for three Elements of one of these frequency bands is shown in Fig. 4-2. Notice that on the LOW POWER Element, the fall-off above and below the assigned frequency band is more pronounced than it is for the HIGH POWER Element. The degree of drop in response varies progressively less for each power level from low to high, with the average difference at approximately the mean power level. These curves, Fig. 4-2, may be assumed to be about typical for all of the listed band types (H, A, B, C, D & E) at their respective stated frequencies.

Harmonics, or sub-harmonics, may be known to exist in the measured circuit (outside of the Element frequency band). If so, a rough approximation of the response of the Element to these harmonics may be made by the use of these curves. The frequency ordinate to be read on the graph will be obtained by proportioning the frequency of the Element used with that of the one illustrated. Interpolation of the curve values will give an approximation of the extent that these harmonic signals are being measured by your Element.

The use of the Elements for direct power measurements outside of their stated frequency range is not recommended.



FREQUENCY RESPONSE
THRULINE ELEMENTS
100-250 MHz

Fig. 4-2. Graph — Representative Frequency Response

3. CALIBRATION CHECKS—THRULINE VS. TERMALINE WATTMETERS

It is recognized that calibration of absorption wattmeters is difficult and likely to be inaccurate unless comparison is made with a transmission (through) type of standard. The THRULINE being of such type, a natural question is: can a THRULINE be used to check or recalibrate absorption wattmeters, such as the Bird Electronic TERMALINE, both being rated at ±5 percent accuracy? The main question is one of exact power calibration.

The answer is a qualified yes, although with both instruments being about equally old and known to be undamaged, there is not too much reason to prefer either on probable accuracy. The edge is somewhat in favor of the THRULINE, because each Element covers only 2-1/2 to 1 in frequency and will be flatter originally over this range than the TERMALINE can be held initially over its very much wider (16.7 to 1) frequency range. Also the THRULINE will probably exhibit smaller changes with time, because of the narrower frequency range, because it is simpler in general design and easier in function (does not have to serve as a power load), and because it does not become heated in operation.

Certainly if the absorption wattmeter has gone years since calibration, or is reasonably suspected of inaccuracy, it may well be calibrated against the THRULINE as standard. (Rather than use correction factors, one can, with the TERMALINE Wattmeter, make use of the calibration adjustment screws used in factory calibration. These are concealed and not mentioned in instruction book to discourage tampering. Correspondence is necessary.)

If such calibration is undertaken, care and thoroughness are advised.

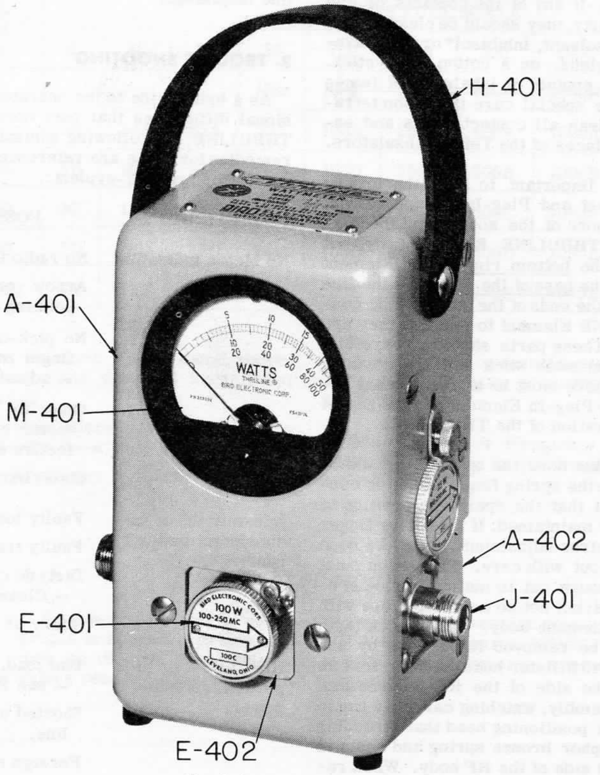


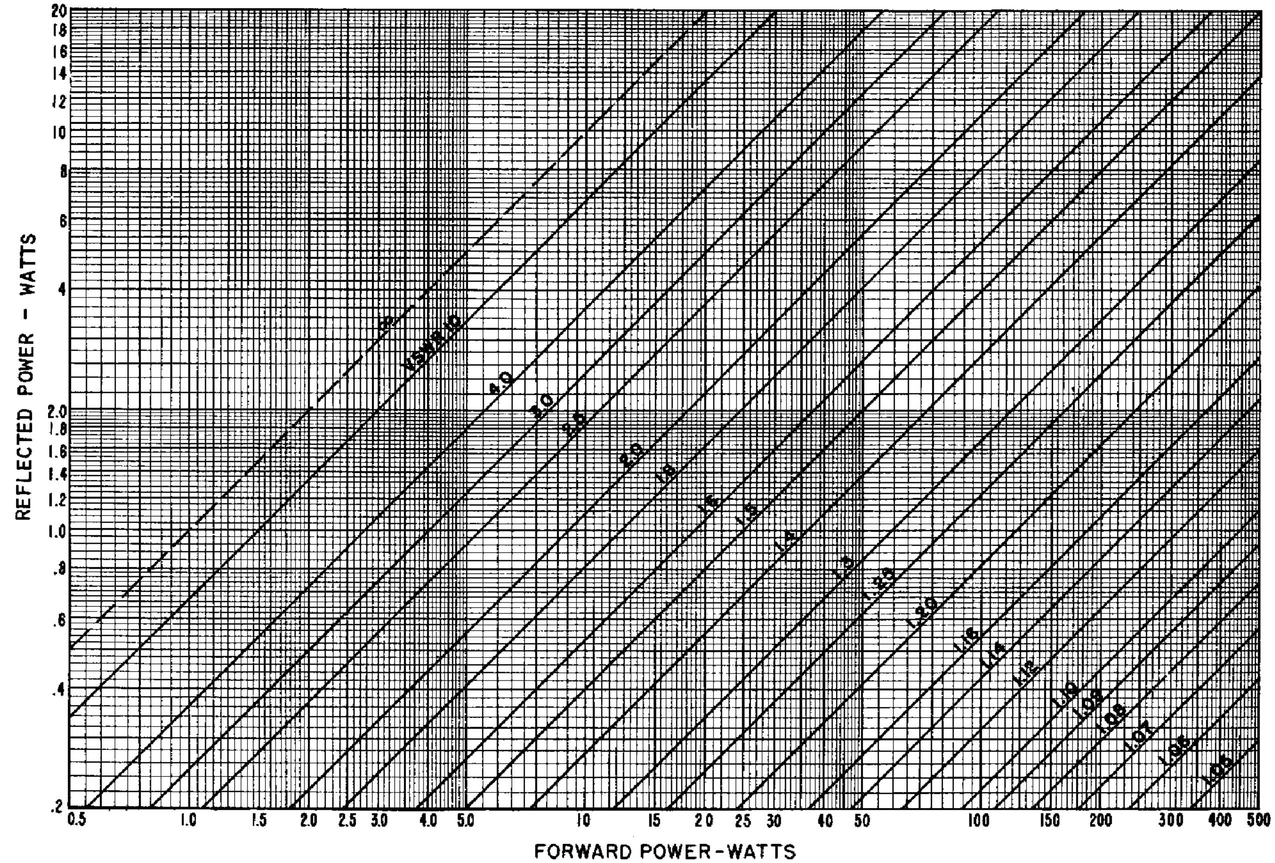
Fig. 5-1. Parts Illustration.

SECTION 6 - PARTS LIST

Reference Designation	Part Name and Description	Function	Drawing No.
A-401	Housing Assembly: Aluminum die casting, 7 lg x 4w x 3h, w/latch and thumbscrew each side for spare Elements, four rubber bumpers on base, leather carrying strap at top. Gray Enamel.	Houses and protects meter, holds RF line section and spare Element.	4210-018
A-402	Cover Assembly: Aluminum alloy sheet, .040 thk., 6-1/2 lg x 4w x 1-1/2h overall, has four rubber bumpers and slot closing ears. Gray Enamel.	Closes back of housing.	4210-005
E-401	Elements, Plug-In: Brass, w/teflon bottom cover, 1-7/16 lg x 1-1/4 cap dia. x 1 body dia. Gold Plate. Furnished in power and frequency types per Table I, Section 4.	Measuring Element for THRULINE.	4250-020
E-402	Line Section Assembly: Brass Casting, normally supplied w/two female "N" connectors, 5-1/8 lg x 1-1/4w x 1-15/16h, 50-ohm line section and socket for Plug-In Element. Has dc jack at side. Nickel Plate.	RF Line insertion section and measuring base.	4230-018
H-401	Carry Strap: Black Leather, 9 lg between centers, 5/32 x 7/8 section.	Carries meter housing.	8580-003
J-400	Connectors, RF: All types have 1-1/4 sq. mtg. flange, and 1/8 dia. x 5/16 lg. slotted connector pin at rear. Brass, with Teflon insulator. Nickel plate. Fifteen types, viz:	RF connection for standard type connectors.	See individual part numbers listed below.
J-401	Female "N" - 1-5/32 lg.		4240-062
J-402	Male "N" - 1-1/4 lg.		4240-063
J-403	Female "HN" - 1-5/32 lg.		4240-268
J-404	Male "HN" - 1-3/8 lg.		4240-278
J-405	Female "C" - 1-1/16 lg.		4240-100
J-406	Male "C" - 1-7/16 lg.		4240-110
J-407	Female UHF (SO-239) 1-1/4 lg.		4240-050
J-408	Male UHF (PL-259) 1-5/8 lg.		4240-179
J-409	Female "BNC" - 1-5/32 lg.		4240-125
J-410	Male "BNC" - 1-9/32 lg.		4240-132
J-413	Female "LC" - 2-1/32 lg.		4240-031
J-414	Male "LC" - 2-1/2 lg.		4240-025
J-415	Female "LT" - 2-3/32 lg.		4240-018
J-416	Male "LT" - 2-1/2 lg.		4240-012
J-417	7/8" EIA Air Line 2-3/4 lg.		4240-002
J-411	DC Connector Assembly: Brass fitting, w/phosphor bronze spring at rear, 1" dia. flange x 1-1/4 overall, 5/8 -24 thd. on connector body, center contact on front, teflon insulators. Nickel Plate.	DC Jack for line section assembly.	4230-010
M-401	Microammeter: 30ua full scale. Flush 3-1/2" bakelite case, solder terminals, special scale.	Meter for power reading. (For replacement usually furnished as 8-000 Kit.	2080-002
	Replacement Meter Kit Consisting of: 1 - 2080-002 Meter 1 - 4220-097-1 Cable Assembly 3 - 4220-098 Bumper Feet		8-000
P-401	Connector, Plug: Part of cable W-403, Brass fitting 1-1/4 lg x 5/8h x 3/4d, water proof. Nickel Plate. Navy type DS-491859.	DC Plug for RG-58/U meter cord.	7500-076
W-403	Meter Cable Assembly: RG-58/U cable, 2-3/4 feet long, w/dc plug P-401 at one end.	Meter Cord.	4220-097-1

HIGHER RATIOS

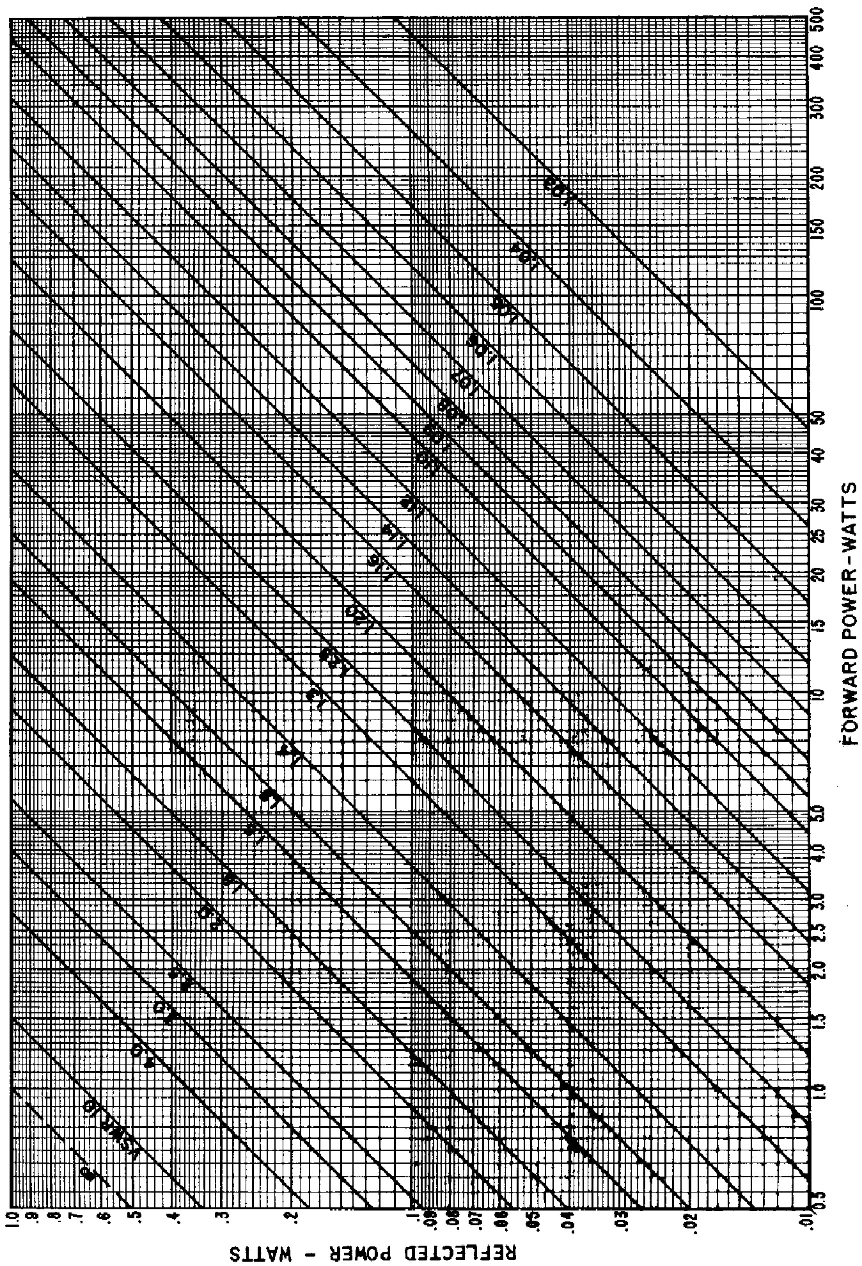
POWER VALUES vs. VSWR



APPENDIX

LOWER RATIOS

POWER VALUES vs. VSWR



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