THRULINE RF WATTMETER

4110-185

Operation Manual

Instruction Book Part Number 920-4110-185 Rev. A

Safety Precautions

The following are general safety precautions that are not necessarily related to any specific part or procedure, and do not necessarily appear elsewhere in this publication. These precautions must be thoroughly understood and apply to all phases of operation and maintenance.

WARNING

Keep Away From Live Circuits

Operating Personnel must at all times observe general safety precautions. Do not replace components or make adjustments to the inside of the test equipment with the high voltage supply turned on. To avoid casualties, always remove power.

WARNING

Shock Hazard

Do not attempt to remove the RF transmission line while RF power is present.

WARNING

Do Not Service Or Adjust Alone

Under no circumstances should any person reach into an enclosure for the purpose of service or adjustment of equipment except in the presence of someone who is capable of rendering aid.

WARNING

Safety Earth Ground

An uninterruptible earth safety ground must be supplied from the main power source to test instruments. Grounding one conductor of a two conductor power cable is not sufficient protection. Serious injury or death can occur if this grounding is not properly supplied.

WARNING

Resuscitation

Personnel working with or near high voltages should be familiar with modern methods of resuscitation.

WARNING

Remove Power

Observe general safety precautions. Do not open the instrument with the power applied.

Safety Symbols

WARNING
Warning notes call attention to a procedure, which if not correctly performed, could result in personal injury.

CAUTION
Caution notes call attention to a procedure, which if not correctly performed, could result in damage to the instrument.

The caution symbol appears on the equipment indicating there is important information in the instruction manual regarding that particular area

Note: *Calls attention to supplemental information.*

Warning Statements

The following safety warnings appear in the text where there is danger to operating and maintenance personnel, and are repeated here for emphasis.

WARNING
Never attempt to connect or disconnect RF equipment from a transmission line while RF power is applied.
Leaking RF energy is a potential health hazard.

Refer to page 10.

Caution Statements

The following equipment cautions appear in the text whenever the equipment is in danger of damage, and are repeated here for emphasis.

CAUTION

Though the test set is ruggedly constructed, rough handling or severe impact could damage the meter.
Use reasonable care when handling the unit.

Refer to page 10.

CAUTION

Do not attempt to remove the RF center conductor.
This will damage the line section.

Refer to page 15

Safety Statements

USAGE

ANY USE OF THIS INSTRUMENT IN A MANNER NOT SPECIFIED BY THE MANUFACTURER MAY IMPAIR THE INSTRUMENT'S SAFETY PROTECTION.

USO

EL USO DE ESTE INSTRUMENTO DE MANERA NO ESPECIFICADA POR EL FABRICANTE, PUEDE ANULAR LA PROTECCIÓN DE SEGURIDAD DEL INSTRUMENTO.

BENUTZUNG

WIRD DAS GERÄT AUF ANDERE WEISE VERWENDET ALS VOM HERSTELLER BESCHRIEBEN, KANN DIE GERÄTESICHERHEIT BEEINTRÄCHTIGT WERDEN.

UTILISATION

TOUTE UTILISATION DE CET INSTRUMENT QUI N'EST PAS EXPLICITEMENT PRÉVUE PAR LE FABRICANT PEUT ENDOMMAGER LE DISPOSITIF DE PROTECTION DE L'INSTRUMENT.

IMPIEGO

QUALORA QUESTO STRUMENTO VENISSE UTILIZZATO IN MODO DIVERSO DA COME SPECIFICATO DAL PRODUTTORE LA PROZIONE DI SICUREZZA POTREBBE VENIRNE COMPROMESSA.

SERVICE

SERVICING INSTRUCTIONS ARE FOR USE BY SERVICE - TRAINED PERSONNEL ONLY. TO AVOID DANGEROUS ELECTRIC SHOCK, DO NOT PERFORM ANY SERVICING UNLESS QUALIFIED TO DO SO.

SERVICIO

LAS INSTRUCCIONES DE SERVICIO SON PARA USO EXCLUSIVO DEL PERSONAL DE SERVICIO CAPACITADO. PARA EVITAR EL PELIGRO DE DESCARGAS ELÉCTRICAS, NO REALICE NINGÚN SERVICIO A MENOS QUE ESTÉ CAPACITADO PARA HACERIO.

WARTUNG

ANWEISUNGEN FÜR DIE WARTUNG DES GERÄTES GELTEN NUR FÜR GESCHULTES FACHPERSONAL. ZUR VERMEIDUNG GEFÄHRLICHE, ELEKTRISCHE SCHOCKS, SIND WARTUNGSARBEITEN AUSSCHLIEßLICH VON QUALIFIZIERTEM SERVICEPERSONAL DURCHZUFÜHREN.

ENTRENTIEN

L'EMPLOI DES INSTRUCTIONS D'ENTRETIEN DOIT ÊTRE RÉSERVÉ AU PERSONNEL FORMÉ AUX OPÉRATIONS D'ENTRETIEN. POUR PRÉVENIR UN CHOC ÉLECTRIQUE DANGEREUX, NE PAS EFFECTUER D'ENTRETIEN SI L'ON N'A PAS ÉTÉ QUALIFIÉ POUR CE FAIRE.

ASSISTENZA TECNICA

LE ISTRUZIONI RELATIVE ALL'ASSISTENZA SONO PREVISTE ESCLUSIVAMENTE PER IL PERSONALE OPPORTUNAMENTE ADDESTRATO. PER EVITARE PERICOLOSE SCOSSE ELETTRICHE NON EFFETTUARRE ALCUNA RIPARAZIONE A MENO CHE QUALIFICATI A FARLA.

About This Manual

This manual provides operation and maintenance instructions for the following models:

4110-185 Thruline Wattmeter

Changes to this Manual

We have made every effort to ensure this manual is accurate. If you discover any errors, or if you have suggestions for improving this manual, please send your comments to our Solon, Ohio factory. This manual may be periodically updated. When inquiring about updates to this manual refer to the part number and revision on the title page.

Chapter Layout

Introduction — Describes the features of the 4110-185 Wattmeter, lists equipment supplied and optional equipment, and provides power-up instructions.

Theory of Operation — Describes how the Wattmeter works and VSWR theory.

Installation — This chapter provides information for on-site requirements, unpacking, inspection, and preparing the load for use.

Operation — All instructions necessary to operate the equipment appears in this chapter.

Maintenance — Lists routine maintenance tasks as well as troubleshooting for common problems, and provides replacement procedures in the unlikely event of component failure.

Table of Contents

Chapter 1 Introduction

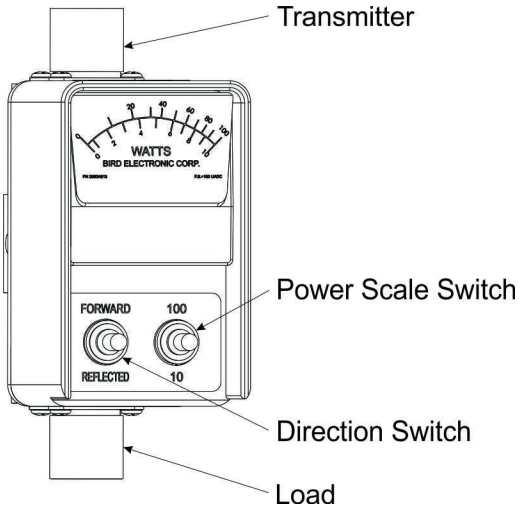
The 4110-185 Wattmeter is a portable wattmeter that measures RF power and load match in 50 ohm transmission lines. The line section is precision machined, with two couplers sealed inside.

The front of the meter has a dial power display and two switches. A clamping screw on the back of the Wattmeter can be used to secure the unit to a convenient handle near the transmitter. The Wattmeter is designed for rugged field use on mobile, airborne, or pack-carried transmitters and transceivers.

A toggle switch on the front of the meter allows measurement of either 10 or 100 Watts full-scale. There is a separate scale for each power range. A second toggle switch is used to switch between forward and reflected power measurements. Load match can then be easily calculated from these readings. The unit is sensitive over a frequency range of 30 to 76 MHz.

Items Supplied

- Bird 4110-185 RF Thruline Wattmeter
- Operations Manual, P/N 920-4110-185



Chapter 2 Theory of Operation

Traveling Wave Viewpoint

The easiest way to visualize Thruline operation is from a traveling wave viewpoint. In transmission lines the voltages, currents, standing waves, etc., on any uniform line section result from the interaction of two traveling waves:

- The forward wave (and its power) travels from the source to the load. It has RF voltage E_f and current I_f in phase, with $E_f / I_f = Z_o$.
- The reflected wave (and its power) originates by reflection at the load and travels from the load back to the source. It has an RF voltage E_r and current I_r in phase, with $E_r / I_r = Z_o$.

Each wave is mathematically simple and has a constant power:

W_f = Watts Forward = $E_f^2 / Z_o = I_f^2 Z_o = E_f I_f$

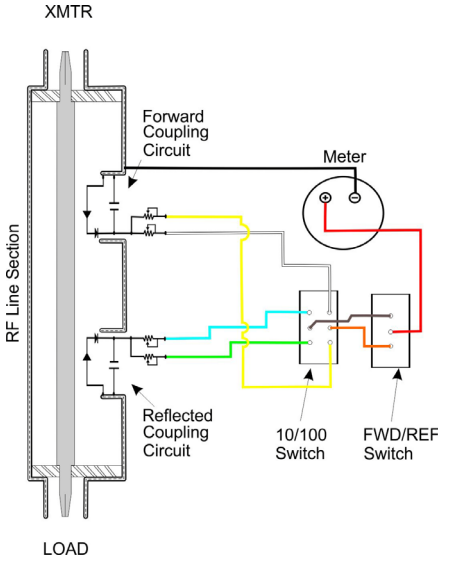
W_r = Watts Reflected = $E_r^2 / Z_o = I_r^2 Z_o = E_r I_r$

Z_o is the characteristic impedance of a uniform line section. For useful lines it is usually a pure resistance of 50 ohms. The RF circuit of Bird Thruline Wattmeters is a length of uniform air line with $Z_o = 50\Omega$.

Coupling Circuit

The coupling circuits that sample the traveling waves are in the line section Assembly. The coupling circuitry and its relationship to the rest of the Wattmeter is illustrated in Figure 1.

Figure 1 Schematic Diagram



Current is produced in the coupling circuit by the traveling waves in the line section. Both inductive and capacitive coupling contribute to this. The inductive current flows in the direction of the traveling wave. The capacitive current is independent of the direction of the traveling wave. Therefore, the inductive current produced by one of the traveling waves will add in phase with the corresponding capacitive current, while that produced by the wave traveling in the opposite direction will subtract. The additive direction is assigned to the forward wave.

The electrical characteristics of the couplers are carefully adjusted so that, for the reverse traveling wave, the inductive current will completely cancel the capacitive current. The result is directivity greater than 25 dB. Thus, the couplers are sensitive at either of the settings, but to only one of the two traveling waves. Measurements are also independent of position along the transmission line.

Like similar diode devices, Bird Thruline Wattmeters indicate the carrier component of amplitude modulation, with very little response to side band components added by modulation.

Load Power

For loads with a VSWR of 1.2 or less, the power dissipated in a load (W_l) is equivalent (with less than one percent error) to the forward power (W_f). When appreciable power is reflected, as with an antenna, it is necessary to use the exact load power which is given by:

W_l = Watts into Load = W_f - W_r

Good load resistors, such as Bird Termaline loads, will give negligible reflected power.

Standing Wave vs. Traveling Wave Viewpoint

As mentioned previously, the Thruline Wattmeter reacts to forward and reverse traveling waves to measure power in a transmission line. The standing wave viewpoint, also widely used, is highly developed both in theory and in practice. This viewpoint can be traced to the early use of slotted transmission lines.

The slotted line measures the standing wave ratio by mechanically positioning a voltage detector at peaks and nulls along a length of line section. Its drawbacks are that it is too long, too expensive for good accuracy, not portable, and too slow. These problems grow rapidly as the measurement frequency drops below 1000 MHz.

The Thruline Wattmeter, however, is fast, convenient, and accurate. It provides the same information as a slotted line with the exception of the phase angle of the reflection coefficient (distance, load to minimum).

ρ vs. Φ

The simple relationships:

$$\rho = \frac{1+\sqrt{\phi}}{1-\sqrt{\phi}} \quad and \quad \phi = \left[\frac{\rho - 1}{\rho + 1}\right]^2 \qquad \begin{array}{l} Where\ \rho = \mathrm{VSWR} \\ and\ \phi = W_r / W_f \end{array}$$

can be used to convert between the standing wave ratio (ρ) and the reflected/forward power ratio (Φ), which can be directly read from the Thruline Wattmeter. The relationship between ρ and Φ is graphed in Figure 2 on page 6 and Figure 3 on page 7.

> **Note:** *Attenuation, measured in dB, can be derived from the power ratio by the equation* $N_{db} = 10 \log \Phi$.

VSWR scales and their attendant controls for setting the reference point have been intentionally omitted from this unit. Experience using the Thruline Wattmeter for transmitter tune-up, antenna matching, etc. will show that the power ratio measurement is as useful in practice as the standing wave ratio.

A trial is suggested, forget about VSWR for a few days and think in terms of $\Phi = W_r / W_f$. The two meter readings, W_r and W_f, give a useful, approximate picture of the results without bothering to calculate the power ratio exactly. Consider that, for an antenna matching problem, the main objective usually is to minimize W_r. Anything done experimentally to this end will be seen when the switch is turned to the reflected power position.

Figure 2 Percent Reflected Power vs. VSWR (1.0 to 1.3)

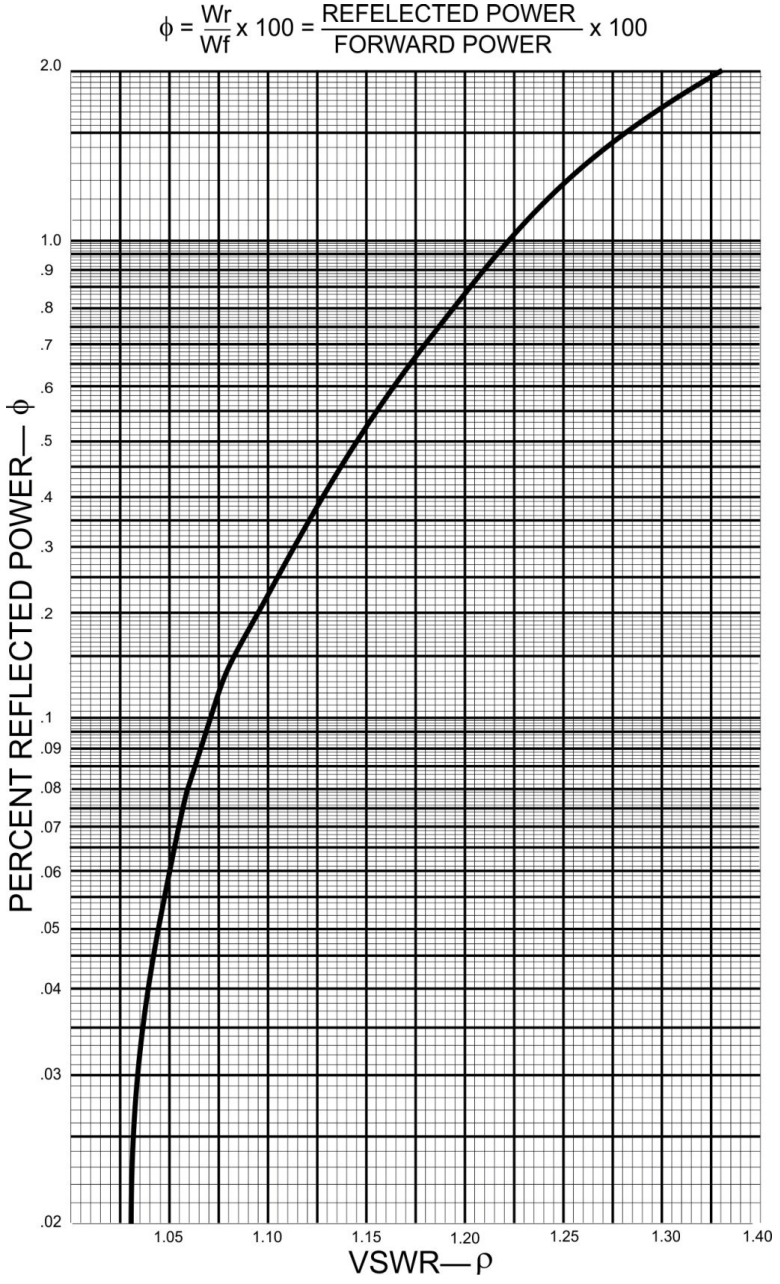
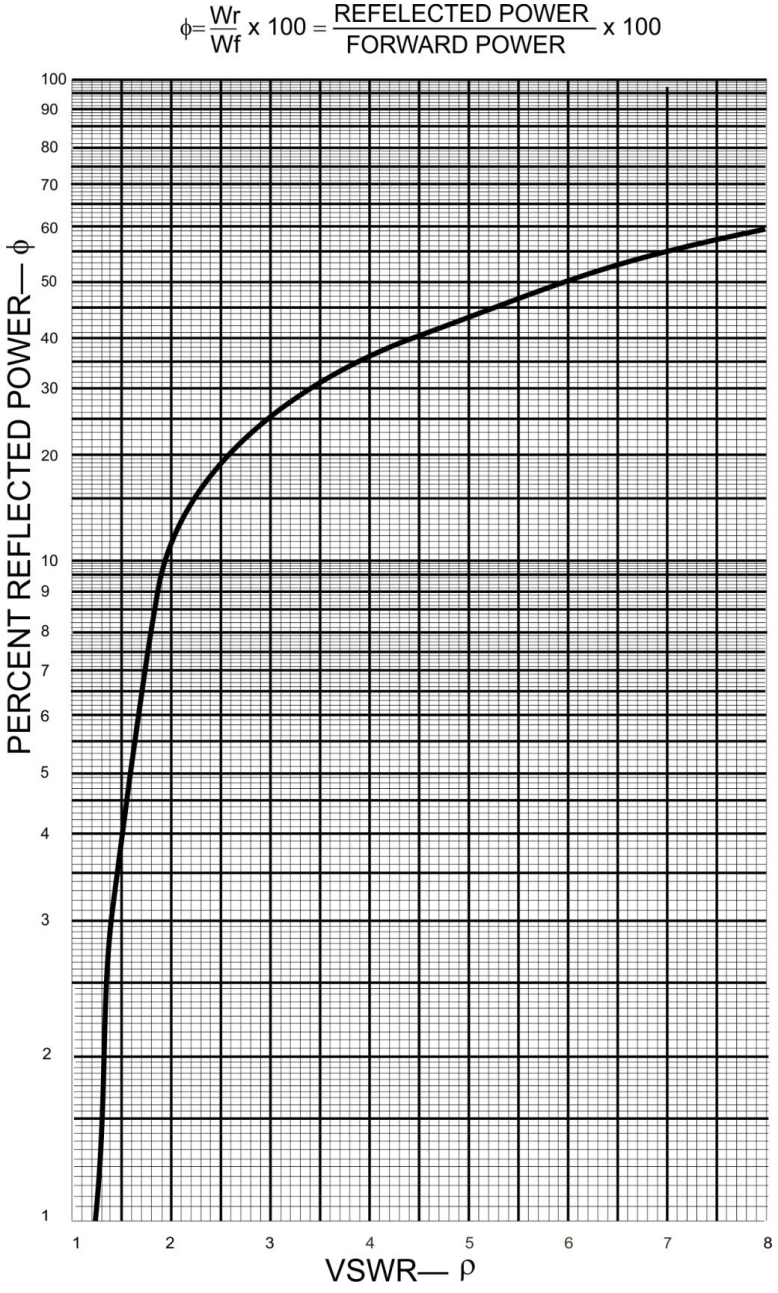


Figure 3 Percent Reflected Power vs. VSWR (1.0 to 8.0)



Transmitter Monitoring

The Thruline Wattmeter can be used for the continuous monitoring of transmitter output or reflected power, for instance in checking intermittent antenna or line faults.

Component Testing

Thruline Wattmeters are very helpful in component testing, and may be employed in several ways:

1. Insertion VSWR or Φ may be measured by placing the component between the wattmeter and a good load resistor.
2. Attenuation (power lost by heat in a line) as well as insertion VSWR or Φ may be measured by inserting the unknown line between two Thruline Wattmeters, or between a Thruline Wattmeter and a Termaline absorption wattmeter.

   > **Note:** *Very small attenuations require allowance for normal instrument errors. Make sure to note exact readings, or their difference, on the initial equality check and correct for this. To correct for this without any calculations, connect the watt-meters directly, with no line between them, and zero them.*

3. Line loss using open circuit calibration: The high directivity of couplers can be exploited in line loss measurements, because of the equality of forward and reflected power with the load connector open or short circuited. In this state the forward and reflected waves have equal power, so that Φ = 100% and $\rho = \infty$. Open circuit testing is preferred to short circuit, because a high quality open is easier to create than a high quality short. To measure insertion loss, use a high quality open to check forward and reverse power equality, then connect an open, unknown line to the wattmeter. The measured Φ is the attenuation for two passes along the line (down and back). This can then be compared with published data for line type and length (remember to halve N_{db} or double the line length to account for the measurement technique).

   This measurement should be supplemented by either time domain reflectometry or DC continuity and leakage checks, since the attenuation measurement alone cannot account for faults such as open or short circuits partway down the line.

Impedance Mismatch

There may be cases where it is necessary to use the Wattmeter with a non-50 ohm transmission line. If the reflected power is less than 10% and the frequency is below 200 MHz, the resulting mismatch will not be too serious. At higher test frequencies and/or higher reflected power levels, the load impedance will change when the wattmeter is removed from the circuit.

When the line and load impedances are known, the system's VSWR is the ratio of the two. Always divide the larger impedance by the smaller, since VSWR must always be greater than 1.

As an example, consider using a wattmeter to tune a 70 ohm line. If the load impedance is also 70 ohms, the wattmeter will measure a VSWR of 70/50 = 1.4.

However, if you remove the wattmeter, the VSWR will actually be 1.0. Similarly, if the load impedance is 35.7 ohms, the VSWR will be 50/35.7 = 1.4 with the wattmeter and 70/35.7 = 2.0 without it. Caution must therefore be used, since both good and bad matches can have the same measured VSWR. In this case, the correct impedance can be determined by slightly changing the load impedance. When the load impedance is near 70 ohms, a Wattmeter will read increasing VSWR as the load impedance is increased.

> **Note:** *When working with non-50 ohm lines, it is especially important to calculate the load power by subtracting the reflected power from the forward power.*

Chapter 3 Installation

This chapter provides information for on-site requirements, unpacking, inspection, and preparing the load for use.

Unpacking and Inspection

1. Carefully inspect shipping container for signs of damage.
   - If the shipping container is damaged, do not unpack the unit. Immediately notify the shipping carrier and Bird Technologies.
   - If the shipping container is not damaged, unpack the unit. Save shipping materials for repackaging.
2. Inspect unit for visual signs of damage.

   Note: *If there is damage, immediately notify the shipping carrier and Bird Technologies.*

Mounting

WARNING

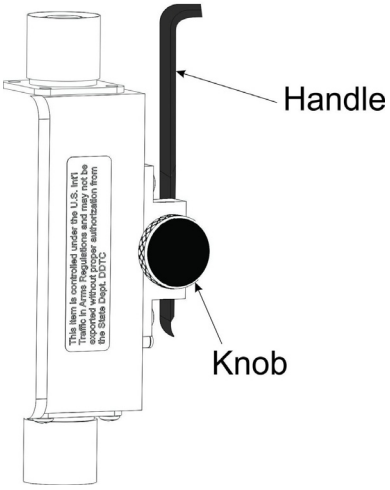
Never attempt to connect or disconnect RF equipment from a transmission line while RF power is applied.
Leaking RF energy is a potential health hazard.

CAUTION

Though the test set is ruggedly constructed, rough handling or severe impact could damage the meter.
Use reasonable care when handling the unit.

1. Clamp the meter to the transmitter handle or other convenient post so that the cable can reach the antenna output jack. See Figure 4 on page 11.
2. Connect the transmitter to the top of the Wattmeter.
3. Connect the antenna/load to the bottom of the Wattmeter.

Figure 4 Wattmeter Clamp Installation

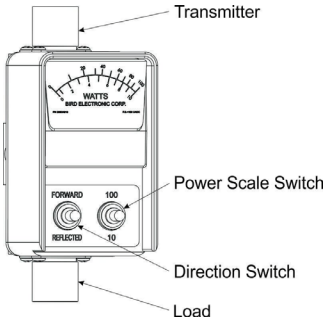


Once the Bird 4110-185 Wattmeter is set up, you are ready to take measurements:

1. Set the wattmeter to read forward power by flipping the direction toggle up.
2. Turn on the RF source.
3. Read the meter. If the power is less than 10 W hold down the power toggle to switch to the low power (0 - 10 W) scale. The toggle will automatically return to high power when released.
4. Flip the direction toggle down to read the reflected power in the same way.
5. Subtract the reflected power from the forward power to determine the power dissipated in the load.

> **Note:** *When substantial power is reflected, for example in most antennas, this subtraction is necessary to obtain the actual radiated or dissipated power value. If the load is a good termination, the reflected power will be negligible and the forward power will be basically equal to the dissipated power.*

Figure 5 Wattmeter Operation



Voltage Standing Wave Ratio (VSWR)

For your convenience, a set of VSWR conversion nomographs is included in this manual. With these charts, VSWR may be determined from the forward and reflected power readings. Find the intersection of the forward and reflected power measurements. The slanted line passing closest to this point indicates the VSWR.

Figure 6 VSWR Conversion Graph (Reflected Power 0.2 to 20.0)

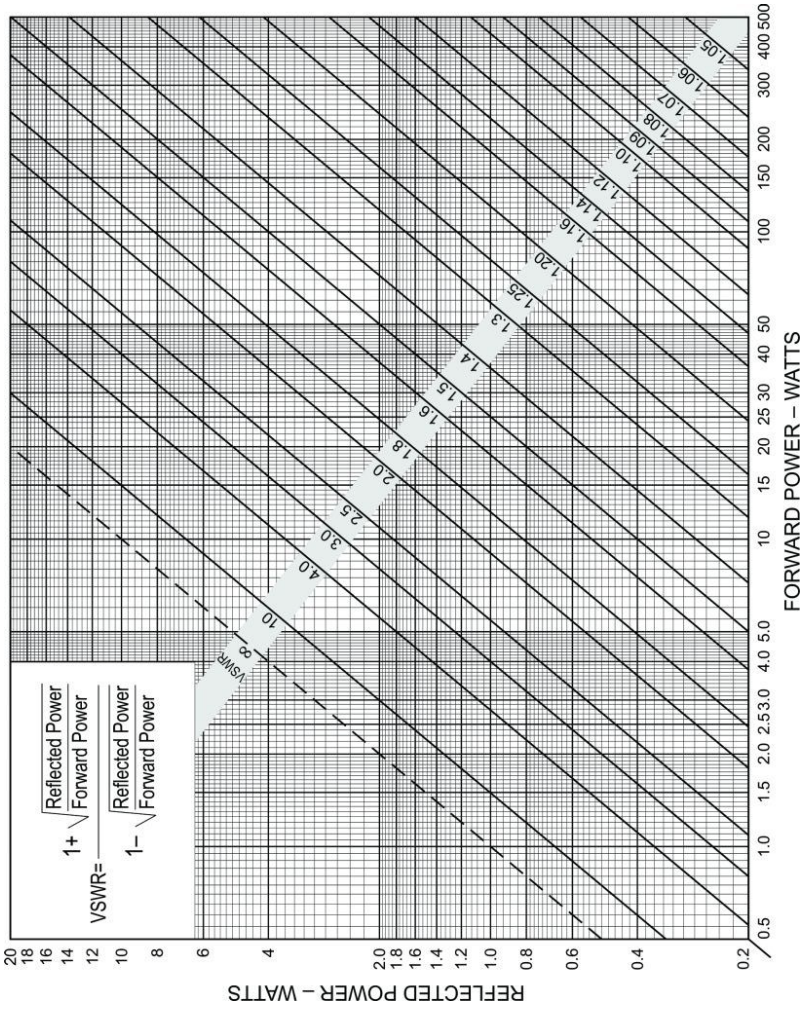
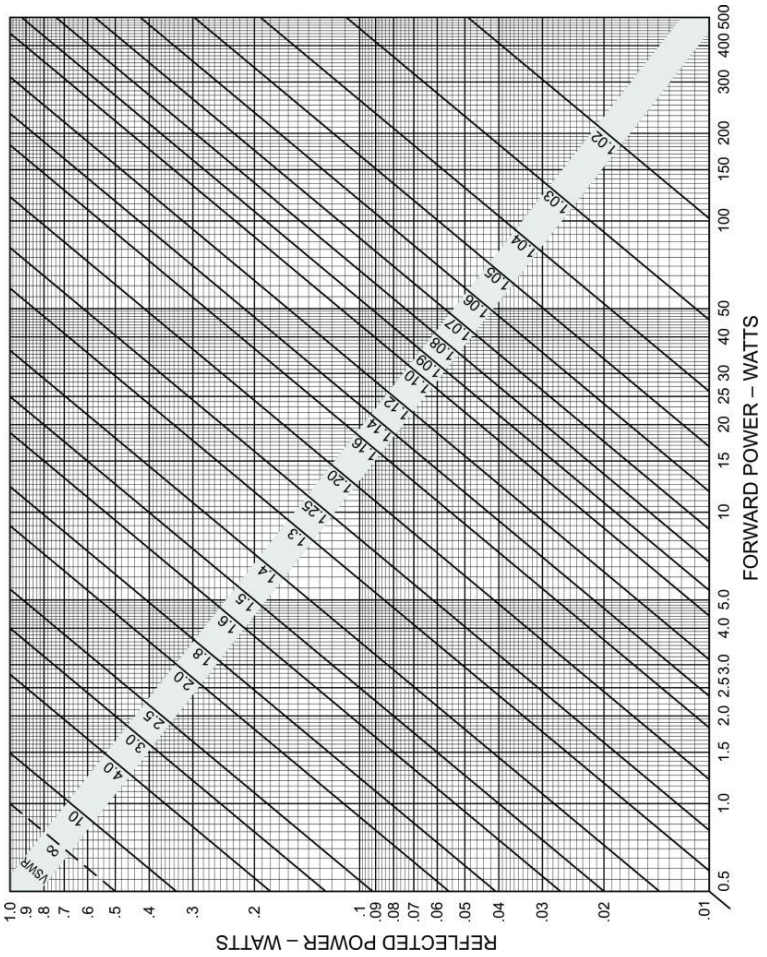


Figure 7 VSWR Conversion Graph, (Reflected Power 0.01 to 1.00)



Chapter 5 Maintenance

The rugged and simple design of the Bird 4110-185 Wattmeter means that it requires minimal routine maintenance.

Cleaning

If any of the contacts or line connectors are dirty, clean them with a cotton swab dipped in contact cleaner or isopropyl alcohol.

CAUTION

Do not attempt to remove the RF center conductor.
This will damage the line section.

If the RF line section seems dirty, do not loosen any connections. Clean accessible components as described above and use dry, clean air to blow out the interior.

The outside of the meter housing can be cleaned with a soft cloth dampened with a mild detergent solution. Do not wipe the meter glass with a dry cloth, or a static charge could develop that would cause an erroneous meter indication.

Troubleshooting

The following table contains troubleshooting information for problems that can occur during normal operation. Find the problem on the table, review possible causes, and perform the corrective action listed. This manual can not list all malfunctions that may occur, or all corrective actions. If a problem is not listed or not corrected by the listed actions, contact the nearest Bird Service Center for assistance.

Problem	Possible Cause	Corrective Action
No meter reading	No RF power	Check RF source and cables
	Direction or power scale switch in wrong position	Check switch settings
	Meter burned out or damaged	Return wattmeter for service
Intermittent or inconsistent meter reading	Faulty transmission line or antenna	Inspect line
	Sticky or defective meter	Return wattmeter for service
High VSWR or reflected power	Reading wrong scale	Read scale matching the power switch setting
	Foreign material in line section or in RF connector	Clean connectors (See "Cleaning" on page 15)
	Open or shorted transmission line	Inspect line
	Bad load or poor connectors	Inspect load, antenna, and connectors

Repair and Replacement

Replace Wattmeter Connectors

This procedure covers the removal and installation of the wattmeter input and output connectors.

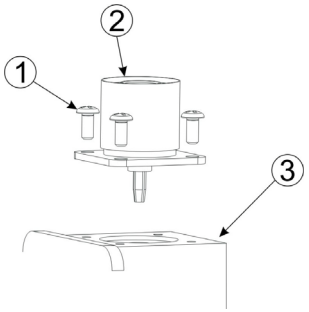
Remove

1. Remove four screws (1) securing defective connector (2) to wattmeter (3).
2. Remove defective connector (2) from wattmeter (3) by pulling straight out.

Install

1. Align pin on new connector (2) with receptacle in wattmeter (3), push connector (2) into wattmeter (3).
2. Secure connector (2) to wattmeter (3) with four screws (1).

Figure 8 RF Connector Replacement



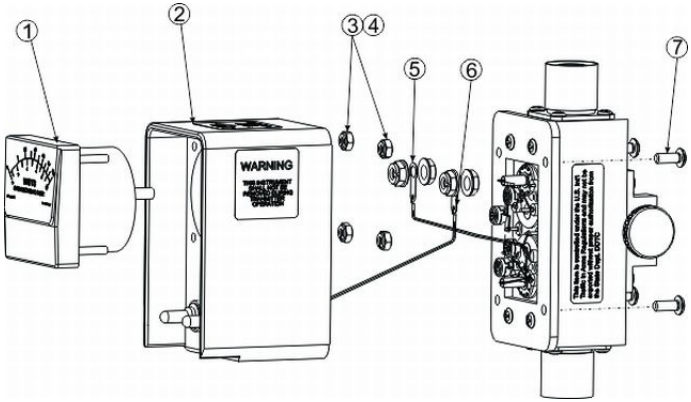
Replace Meter

This procedure covers the removal and installation of the meter.

Remove

1. Remove four screws (7) securing meter housing (2).

Figure 9 Meter Replacement



2. Detach red lead (6) from meter positive terminal and black lead (5) from meter negative terminal by removing attaching hardware.
3. Remove four nuts (3) and lock washers (4) securing meter (1) to meter housing (2).
4. Remove meter (1) from meter housing (2).

Install

1. Position meter (1) into meter housing (2).
2. Secure the meter (1) with four lock washers (4) and nuts (3).
3. Attach red lead (6) to meter positive terminal and black lead (5) to meter negative terminal using attaching hardware.
4. Secure meter housing (2) using four screws (7).

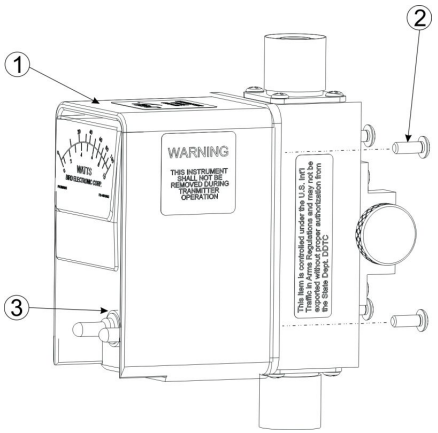
Replace Selection Switch

This procedure covers the removal and installation of either of the wattmeter selection switches.

Remove

1. Remove four screws (2) securing meter housing (1).

Figure 10 Selector Switch Replacement

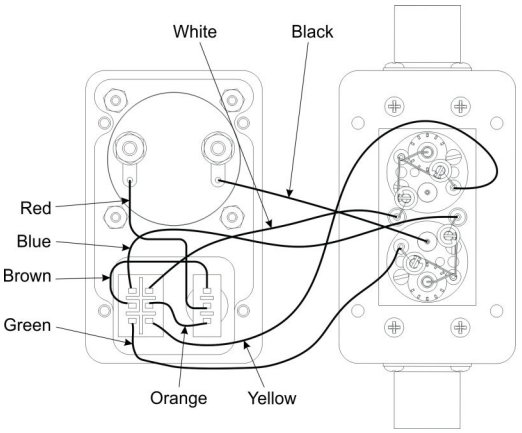


2. Remove switch retaining nut (3).
3. Unsolder leads from switch being replaced.

Install

1. Solder leads to the switch terminals according to diagram.

Figure 11 Wattmeter Wiring Diagram



2. Position switch into meter housing (1).
3. Secure switch in place using retaining nut (3).
4. Secure meter housing (1) using four screws (2).

Customer Service

Any maintenance or service procedure beyond the scope of those in this chapter should be referred to a qualified service center.

If the unit needs to be returned for any reason, request an Return Material Authorization (RMA) through the Bird Technologies website. All instruments returned must be shipped prepaid and to the attention of the RMA number.

Bird Service Center
30303 Aurora Road
Cleveland (Solon), Ohio 44139-2794
Fax: (440) 248-5426
E-mail: *bsc@birdrf.com*

For the location of the Sales Office nearest you, visit our Web site at:

http://www.birdrf.com

Specifications

Frequency Range	30 - 76 MHz
RF Power Fwd Rfl	 100 W max. 10 W max.
Impedance 50 ohms (Nominal)	VSWR 1.1 max.
Insertion Loss	0.5 dB max.
Accuracy 25° C (77° F) -20° to +60° C (-4° to +140° F)	 ± 5% of full scale ± 15% of full scale
Connectors	Bird “SQC” BNC Female with protective shield
Dimensions, Nominal	4.2”L x 2”W x 4.8”H (106.7 x 50.8 x 121.6 mm)
Weight, Nominal	1.25 lbs
Finish	Fine Textured Black Powder Coat

Limited Warranty

All products manufactured by Seller are warranted to be free from defects in material and workmanship for a period of one (1) year, unless otherwise specified, from date of shipment and to conform to applicable specifications, drawings, blueprints and/or samples. Seller's sole obligation under these warranties shall be to issue credit, repair or replace any item or part thereof which is proved to be other than as warranted; no allowance shall be made for any labor charges of Buyer for replacement of parts, adjustment or repairs, or any other work, unless such charges are authorized in advance by Seller.

If Seller's products are claimed to be defective in material or workmanship or not to conform to specifications, drawings, blueprints and/or samples, Seller shall, upon prompt notice thereof, either examine the products where they are located or issue shipping instructions for return to Seller (transportation-charges prepaid by Buyer). In the event any of our products are proved to be other than as warranted, transportation costs (cheapest way) to and from Seller's plant, will be borne by Seller and reimbursement or credit will be made for amounts so expended by Buyer. Every such claim for breach of these warranties shall be deemed to be waived by Buyer unless made in writing within ten (10) days from the date of discovery of the defect.

The above warranties shall not extend to any products or parts thereof which have been subjected to any misuse or neglect, damaged by accident, rendered defective by reason of improper installation or by the performance of repairs or alterations outside of our plant, and shall not apply to any goods or parts thereof furnished by Buyer or acquired from others at Buyer's request and/or to Buyer's specifications. Routine (regularly required) calibration is not covered under this limited warranty. In addition, Seller's warranties do not extend to the failure of tubes, transistors, fuses and batteries, or to other equipment and parts manufactured by others except to the extent of the original manufacturer's warranty to Seller.

The obligations under the foregoing warranties are limited to the precise terms thereof. These warranties provide exclusive remedies, expressly in lieu of all other remedies including claims for special or consequential damages. SELLER NEITHER MAKES NOR ASSUMES ANY OTHER WARRANTY WHATSOEVER, WHETHER EXPRESS, STATUTORY, OR IMPLIED, INCLUDING WARRANTIES OF MERCHANTABILITY AND FITNESS, AND NO PERSON IS AUTHORIZED TO ASSUME FOR SELLER ANY OBLIGATION OR LIABILITY NOT STRICTLY IN ACCORDANCE WITH THE FOREGOING.