RF Applications, Inc.

Specializing in RF Power Measurement Since 1992

User's Manual

VFD Series

RF Wattmeters

Digital RF Power/

V.S.W.R. Indicator

INTRODUCTION

Thank you very much for purchasing the RF Applications, Inc. VFD Series RF Power/V.S.W.R. Indicator. The VFD Series represents a breakthrough in flexibility for measurement of the performance of your transmitting system. CMOS microprocessor control insures fast capture time and low power dissipation. With the ability to monitor your V.S.W.R. (and power levels) at all times, you will know that your antenna system is performing within its design specifications.

IMPORTANT

The VFD is designed to operate from a 12 to 16 vdc DC power source. Do not connect it to AC (especially line voltage). As with all electronic equipment, keep the VFD out of direct sunlight and keep it dry.

IF YOU HAVE PROBLEMS

We want you to be satisfied with your purchase. If you have any type of problem, please check the Trouble Shooting section of this manual. If your problem persists, call our Customer Service Department at 440.974.1961. Please have the VFD and this manual at hand when you call.

UNPACKING AND SETUP

INITIAL SETUP

Unpack the VFD. The box should contain:

- One Display Head
- One Directional Coupler
- One 12VDC Power Cable or Optional Power Pack
- One Warranty Card
- This Manual

If anything is missing, give us a call and we'll remedy the problem. Please take a few moments now to send in your Warranty Card.

The VFD consists of two major components: the Display Unit and the Directional Coupler. The Directional Coupler is installed in series with the output of your transmitter and antenna. A six-foot (1.8m) cable is provided for the interconnection between the Display Head and the Directional Coupler. You may use a longer cable if you wish (consult the Special Applications section later in this manual).

Most users want to see how the unit works as quickly as possible after receiving it. If you want to do this, read on. If you would prefer to install the VFD permanently now, move ahead to the Installation section of this manual.

If you are currently using a wattmeter in your setup, you have everything you need for a test. If you are not using a wattmeter, then you will need a suitable jumper to connect the Directional Coupler to your station.

Connect the Directional Coupler as follows:

Using RIG-8 or RIG-58 cables:

SOURCE goes to your transmitter (directly)

ANTENNA goes to your antenna (or tuner)

Plug the mini-phone connector into the Directional Coupler and connect 12VDC to the power cable provided. The black wire goes to ground, and the wire with the white stripe goes to plus.

The VFD is protected against polarity reversals, but be careful just the same. Apply 12 volt DC power. You should observe that the V.S.W.R. lamp on the Display Head comes on. The firmware version number will be displayed and then the unit will display the message "IDLE." You are now ready for a test.

Simply use your normal procedure to transmit. The VFD will give you an instant indication of your current status. If your transmitter has an internal tuner, you might want to turn it off. The internal tuner will cause a 50 ohm impedance to be presented to the finals of your transmitter, thereby changing the characteristic impedance present at the antenna jack on the transmitter. This will affect the accuracy of the VFD (just as it would any other measuring device).

If you are having other problems, refer to the Trouble Shooting section of this manual. Otherwise, you are now ready for a permanent installation.

INSTALLATION

DISPLAY HEAD AND COUPLER LOCATION

The Display Head is designed to be either table-top or wall-mounted. Once the position is chosen, mount the Display Head using the supplied Velcro strips if desired. Choose a suitable location for the Directional Coupler and mount it as well. Be sure that you mount the Directional Coupler close enough to the Display Head so that the supplied cable can reach. If you want to use a longer cable, this is fine--any shielded three wire jumper cable will suffice, up to 100 feet.

Connect the 12VDC cable to the Display Head. If you purchased the optional power pack, go ahead and plug it in now. If you are using the power cable, connect the black lead to ground and the white striped lead to plus. The Display Head is protected against polarity reversal, but try to get the polarity right anyway.

DIRECTIONAL COUPLER WIRING

Since the purpose of the VFD is to provide an indication of the match of your antenna system to your transmitter, it is critical that the Directional Coupler be installed as the first element after the antenna jack on your transmitter (or amplifier if you are using one). If you install it after your tuner, you will be quite frustrated by your inability to change the V.S.W.R. readings on the VFD. With this in mind, run a suitable jumper cable from your transmitter's antenna jack to the SOURCE connector on the Directional Coupler. The standard Directional Coupler comes with SO-239 connectors. You can order optional "N" connectors if you prefer.

If you are using an amplifier, you want to install the Directional Coupler after your amplifier. Connect the cable that goes to your antenna system to the ANTENNA jack on the Directional Coupler.

You may ground the Directional Coupler to your station grounding system if you desire. There is a further discussion on this in the Technical Discussion section of this manual.

Recheck your cables and fasten them down appropriately. Turn on the power to the Display Head (you should see the firmware version number displayed, then the VFD will go to its idle state).

OPTIONS

If you ordered the V.S.W.R. Relay Option or the Power Monitor Option, consult the documentation supplied with that option to make the proper connections to your amplifier.

TECHNICAL DISCUSSION

RF POWER AND V.S.W.R. MEASUREMENT

The purpose of this section of the manual is certainly not to go into great detail on the theory of the measurement of RF power and voltage standing wave ratio (V.S.W.R.). There are many more publications on the subject dating back 50 or more years. But we do want to discuss the most important issues pertaining to this matter.

For the purpose of this discussion, RF power refers to the peak voltage measured on the line, multiplied by itself, and divided by 50 (voltage squared divided by the impedance of the load, which is watts).

$$\text{V.S.W.R.} = \frac{\text{Forward Voltage} + \text{Reflected Voltage}}{\text{Forward Voltage} - \text{Reflected Voltage}}$$

V.S.W.R. is calculated by finding the sum of the forward and reflected voltages on the line and dividing by the difference of the forward and reflected voltages on the line.

You can see that if there is no reflected voltage, you will be dividing the forward voltage by the forward voltage, which is 1.0. A V.S.W.R. of 1.0 is ideal (and actually unobtainable because there is always a small amount of reflected voltage on the line). A V.S.W.R. of 2.0 indicates a power loss of about 10%, at 3.0 the loss is about 25%, and it goes worse from there. By loss, we mean that, for example, a transmitter looking into a 3.0 to 1 V.S.W.R. will only be able to deliver 75% of its output power to the load (the antenna). To summarize, the transmitter must see an exact impedance match (50 ohms in this case) to deliver full power to the load.

Again, to achieve maximum power transfer from the transmitter to the antenna, an impedance match between the antenna system and the transmitter is required. Normally, the desired impedance is 50 ohms. Antennas need to be designed and built to match this impedance.

In any antenna system, the object is to get the most power delivered to the actual antenna. Feedlines, antenna switches, connectors, and yes, wattmeters all contribute to losses between an RF source and an antenna. You can conclude from all this that the best place to make a power or V.S.W.R. measurement is actually at the antenna, and this is indeed the best place. In most installations, however, power and V.S.W.R. measurements are made in the shack near the transmitter. This is generally not a problem, as long as the user realizes that the readings that are being taken represent those of the entire antenna system, not just the antenna. And in some cases, the readings can be misleading.

For example, you might have a perfectly resonant (50 ohm) antenna running on 10 meters. You connect it with 150 feet of RG-58 cable. Your station-mounted wattmeter shows that you are delivering 100 watts from your transmitter into this antenna system.

Here's the problem: the RG-58 cable exhibits a loss of 2.0 dB per one hundred feet at 30 MHz. This means that if you mounted your wattmeter at the antenna, you would read only 50 watts!

Your V.S.W.R. measurements can be affected, because losses in the feedline reduce the level of the reflected voltages as well. Therefore, you can be lulled into a sense of security about your V.S.W.R., when, in fact, it is higher at your antenna than you see on your meter.

Wattmeters like the VFD allow you to mount the Directional Coupler at the antenna (or at least near it, with some restrictions). By doing this, you can see what is happening near the antenna. However, additional installation costs are incurred, because you must bring the sensing cables back to the shack.

In most installations, it is still most practical to install the measurement equipment in the shack. The best solution to the above problem is to use high quality feedlines, connectors, etc. to make your installation. By high quality, we mean components that are rated for the power, frequencies, and distances you will be using them. Many times, a 50 ohm dummy load to test each feedline system after you have installed it. You can verify that your feedlines have the predicted losses and low V.S.W.R. readings. With this knowledge in mind, you can now use the information your shack-mounted power and V.S.W.R. meter gives us.

As mentioned above, each element in the connection system between the transmitter and the antenna introduces some amount of loss and increased V.S.W.R. The goal of any design is to minimize the losses and V.S.W.R., while maximizing instrument accuracy over the specified frequency range.

As in any engineering exercise, tradeoffs must be made between performance and cost. You will find that most commercially available instruments do not introduce significant losses or V.S.W.R. However, you can find wide variations in accuracy among several watt/V.S.W.R. meters. Therefore, you have to be cautious in comparing readings between various meters.

In addition, your station grounding might affect your power and V.S.W.R. measurements. When you connect all of your equipment together, you introduce new paths for RF energy to flow (in addition to your coax shields).

As an interesting point, however, many users find that the absolute value of the displays on their meters doesn't really matter that much. For power, the idea is to maximize it. For V.S.W.R., the idea is to come as close to 1.0 as possible (below a certain minimum, of course).

Most measurements systems for low frequency (HF) power and V.S.W.R. measurement consist of two major components. The first is the sensing system (Directional Coupler), the other is the display system. There are commercially available systems that integrate both of these components into one package (a conventional watt/V.S.W.R. meter) and some that separate the two (such as the VFD).

USING THE VFD

GENERAL OPERATION

In addition to the 2x16 vacuum fluorescent display, there are two buttons on the front of the VFD. The top button is labeled "TUNE/OPERATE" and the lower one is labeled "SET ALARM LIMIT." There is an LED that is used to signal you when your V.S.W.R. exceeds a preset limit.

THE VFD DISPLAY

When no RF is present, the VFD will indicate the selected operating mode (Tune or Operate), the letters RFA on the right side of the top line, any vanity text (if the Vanity Option was ordered) on the lower line and IDLE on the right side of the bottom line.

As soon as RF is applied, the top line will indicate, in bargraph mode, the relative amount of power you are applying. The RF power will be displayed on the second line.

RF POWER DISPLAY

Your RF power is displayed on the second line. There is a "sharp attack, long decay" peak detector used for the numerical RF power display. You will find that the displayed value ramps up quickly and holds your peak value for a certain amount of time. This time is about 3 seconds when in "OPERATE" mode (the default) and about 1/2 second when in "TUNE" mode. You can choose which mode you would like to use by pressing the top button on the display.

In order to provide a pleasing display regardless of CW or SSB operation, we have carefully selected the update interval for the "OPERATE" display mode. This can be a problem when you are trying to set an antenna tuner. For this reason, the display update interval is about six times faster when you are in "TUNE" mode.

IMPORTANT

The display will occasionally indicate a small wattage at the end of a transmission. This is normal. The data capture time is fast. One dash (or whistle) will provide enough signal for you to get a reading. This is a nice feature that helps to reduce QRM, too.

The VFD indicates the mode you have selected whenever there is no RF present. If you notice the power indication "bouncing," you have probably left the unit in TUNE mode. Simply switch it back to OPERATE mode to correct this problem.

V.S.W.R. DISPLAY

The V.S.W.R. display gives you continuous readout of your V.S.W.R. The display indicates V.S.W.R. from 1.0 to 29.9. Above 29.9, the display reads "MAX." When your preset V.S.W.R. limit is exceeded, the display will indicate "ALARM" and "VSWR HI." The red LED on the front panel will light. If you have the V.S.W.R. relay option, the relay will be de-energized also.

The power-on default for the V.S.W.R. alarm is 3.0:1. By pressing the "SET ALARM LIMIT" button, you can set this trip point to 1.5:1, 2.0:1, 2.5:1 or back to 3.0:1. This value is not "remembered" when you remove power from the unit, therefore, it must be set each time after the unit is powered up.

AUTORANGING BARGRAPH

The VFD incorporates a unique bargraph display. This display answers one of the major complaints about digital wattmeters. Many users are used to and feel most comfortable with analog meters, because they can "see what they are sending." Digital displays remove this feature (who wants to see a bunch of meaningless numbers bouncing around?). The VFD updates the bargraph much more quickly than the numeric displays. The resulting display is pleasing and quite useful.

The display uses 13 of the character positions on the top line of the vacuum fluorescent display. Each of these character positions has five vertical lines. Therefore, the resolution of the bargraph function is 65 elements. The microprocessor in the VFD uses all 65 positions up to about 500 watts, then it "autoranges" above 500 watts to use the 65 positions over about 3000 watts (300 watts on the VHF version). Once it ranges up, it does not "range down" until RF is removed for a few seconds (long enough for the unit to return to the idle state).

In normal use, however, you can use the digital display to find out what your actual power is. The bargraph is very handy for a relative indication of what your station is doing, and you can "see what you are sending."

The bargraph is particularly useful for tuning up amplifiers. Simply adjust your amplifier for the longest bar.

ACCURACY AND CALIBRATION

The VFD uses an eight-bit analog to digital converter. This results in a display that cannot indicate every single power value from zero to 3,000 (there are only 256 codes available from the analog to digital converter). You will notice that this display will indicate power in steps, for example, 100, 104, 109, 113 watts, etc. The general specifications for the VFD call for accuracy that is plus or minus ten percent, plus or minus the analog to digital converter resolution (which is one power step increment).

We calibrate the VFD at 500 watts at 14.100MHz and then verify its operation on 1.8 and 28MHz. If your application calls for better accuracy on a certain band, you can easily recalibrate the unit to suit your needs. In this case, you can enjoy plus or minus five percent (or better), plus or minus the resolution accuracy.

You will be adjusting the potentiometers on the PC board. Be careful not to blast the board with static electricity.

The calibration procedure is as follows:

1. Open the VFD.
2. Press and hold "TUNE/OPERATE" while applying power to the VFD. Hold until "CALIBRATE" appears on the display.
3. Apply a known power, ideally 500 watts, to the Directional Coupler.
4. Set potentiometer R10 (upper) to display the correct power next to the "F" on the display.
5. Turn off the RF source.
6. Reverse the RF cables on the Directional Coupler.
7. Apply a known power, ideally 500 watts, to the Directional Coupler.
8. Set potentiometer R11 (lower) to display the correct power next to the "R" on the display.
9. Turn off the RF source and DC power to the VFD.
10. Reassemble the VFD.

The most accurate V.S.W.R. readings are made with at least 25 watts of forward power. You will sometimes notice a small change in V.S.W.R. as you change power levels. This is normal. Cables, connectors, traps and other items can respond differently under high power conditions. Variations of 0.2 in V.S.W.R. are not uncommon. If your variation is higher, you might have a problem with one or more of the items mentioned above.

If you are having problems, give us a call.

REMOTE COUPLER MOUNTING

There is no reason that you cannot mount the Directional Coupler remotely. You will need to use a high quality, shielded, two conductor (plus shield) cable. In addition, the Directional Coupler is not designed for outdoor use, so you will have to put it in another enclosure.

You can expect changes in accuracy with extremely low temperature. We have tested to -10 degrees C, and the changes are minimal at that temperature.

We have tested the Directional Coupler with 100 feet of cable, and it performs well. Be aware though, you will be reading power at the other end of a feedline. Maybe you don't really want to know what's out there!

SPECIAL DIRECTIONAL COUPLER CONNECTORS

If you like to use "N-" type connectors, contact the factory. "N" connectors are available.

IN CASE OF TROUBLE

The VFD is well-designed and should give you many years of trouble free service. Most of the problems you will encounter usually occur during installation and startup. If the items below aren't sufficient to help you solve your problem, please give us a call.

Unit will not come on

Check power connections. Is the unit on? Polarity OK?

High V.S.W.R. displayed, no forward power displayed

Be sure that the SOURCE input to the Directional Coupler goes to your transmitter (or amplifier).

V.S.W.R. doesn't change when adjusting a tuner

Be sure that you have installed the Directional Coupler **AHEAD OF** the tuner. If your rig has an internal tuner, you should turn it off to make your measurements.

Power display grossly inaccurate

Someone might have recalibrated the unit. Perform the calibration procedure in this manual. Your internal antenna tuner might be turned on. Turn it off.

If you are experiencing other problems, give us a call. We'll help you out as quickly as possible.