INITIAL SET-UP PROCEDURES

SEE CAUTION ON PREVIOUS PAGE

The following steps will help you test your new 510A solid state power supply to make sure it is fully operational and ready for use. It also will give you the opportunity to operate and become familiar with the entire system before attempting the experiments listed in this manual.

Equipment & Components

510A ..... Power Supply
503A ..... Klystron Mount - with 2k25 Klystron installed.
506 ...... Flap Attenuator
518 ...... Crystal Detector
508 ...... Thermistor Mount
515 ...... 24" BNC Cables (2)
523 ...... Waveguide Stands (2)

Part 1: Control Settings

Set switches and controls on 510A as follows:

1. AC Power Switch .... OFF
2. Speaker Switch .... ON
3. RF Switch .... ON
4. Attenuator Switch 0dB
5. Meter Switch .... POWER
6. VSWR Output Control .... MAX. COUNTER CLOCKWISE
7. Power Balance Control .... 12 O'CLOCK
8. Klystron Repeller Control .... 12 O'CLOCK

Part 2: Waveguide Component Assembly Procedure

1. Connect 503A Klystron Tube Mount to left side of 506 Variable Flap Attenuator.
2. Connect right side of 506 Variable Flap Attenuator to left side of 518 Detector Mount with the BNC Connector in the UP position.
3. Connect right side of 518 Detector Mount to the 508 Thermistor Mount with the BNC Connector in the UP position.
4. Using BNC Cable, connect 518 Detector Mount to VSWR input connector located on right side of 510A Power Supply.
5. Using second BNC Cable, connect 508 Thermistor Mount to POWER input connector located at center of 510A Power Supply.
6. Insert 8-Prong Plug from 503A Klystron Mount into socket located on left side of 510A Power Supply.
7. Place a 523 Waveguide Stand under each side of Test Assembly, and adjust each stand until the assembly is elevated in a stable position.

Part 3. Operation and Checkout.

1. Turn AC POWER switch ON.
2. Turn 506 Flap Attenuator to 24dB.
3. Observe meter and adjust POWER BALANCE knob to obtain a zero meter reading. Turning knob clockwise increases meter reading; counter-clockwise deceases reading.
4. Allow 3-5 minutes warm-up at this time.
5. Readjust POWER BALANCE Knob to compensate for drift if necessary.

NOTE: The meter reading must be at zero to progress further.

6. Set Variable Flap Attenuator to 0dB.

7. Slowly turn Klystron Repeller knob clockwise and stop when you get a peak reading on the meter. (Normally about 2:00 o'clock).

NOTE: Adjust variable flap attenuator as needed to keep meter level between 70% and 100%.

8. Turn METER knob to VSWR position.

9. Fine tune KLYSTRON REPELLER knob as needed to obtain a stable, peak meter reading.

NOTE: This reading should be between 50% and 100% and must be stable. If not, adjust VSWR OUTPUT knob on right side of 510A Power Supply.

10. Turn METER knob to KLYSTRON position.

11. Remove BNC cable from VSWR Input Connector at right side of 510A Power Supply and reconnect Cable to KLYSTRON connector on left side of 510A Power Supply.

12. Adjust variable Flap Attenuator as needed to attain a peak meter reading. DO NOT exceed a 100% reading on the Meter.

13. Record meter reading and variable Flap Attenuator level as your klystron life reading.

NOTE: You can compare this reading to current readings anytime in the future to determine the condition of the klystron tube.

14. You have now successfully operated and checked out your Microwave Trainer. It is important that you turn off the Trainer properly as described below.

Part 4: Shut Down Procedure

1. Turn off AC POWER Switch located on right side of 510A Power Supply.
2. Unplug 510A Power Supply from 115AC Power Source.
3. Wait for Klystron Tube to cool down (minimum of 10 minutes).
4. Disconnect all Cables and disassemble Waveguide Components.

EXPERIMENT 2

Measurement of Voltage Standing Wave Ratio

Introduction:

When r-f is transmitted down a line into a load, even one with a good match, some of the signal reflects back toward the source. The amount of signal sent vs. the amount reflected back is compared and referred to as the standing wave ratio. When this pattern deals with measurements of voltage, it is called the voltage standing wave ratio (VSWR). It is simply expressed as:

$$VSWR = \frac{e_{max}}{e_{min}}$$

Discussion:

The equation of $VSWR = \frac{e_{max}}{e_{min}}$

would be very easy to use to calculate VSWR if the voltage measurements were as easy to take, but they are not.

The most popular method of measuring VSWR employs the use of a slotted line. To help us understand this device, let us look at Figure 2-1a.

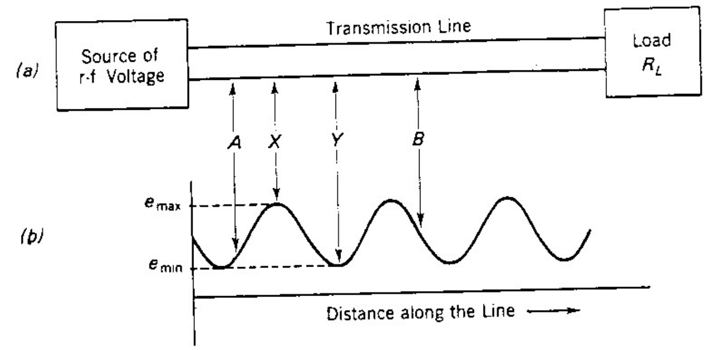


Figure 2.1 Voltage Distribution along a Transmission Line

This diagram shows us a sample length of transmission line, in our case X-band waveguide. In Figure 2-1b, we see an expanded view of the r-f sine wave rising and falling along the length of the line. Placing a slotted line into the transmission line from point a to point b allowing us to inspect a probe into the slot in the line. We can then move the probe along the line reading peaks and dips, e_{max} and e_{min} which are shown as X and Y. Because r-f voltages are so difficult to measure, we will make the probe like the one in Fig 2-2a.

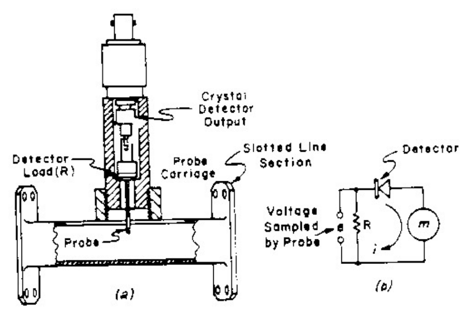


Figure 2.2 Slotted Transmission Line and Probe (a) Cutaway Sketch of a Slotted Section with Probe, Carriage, and Detector (b) Equivalent Detector Circuit

The key addition here is the crystal detector which will change the r-f voltage into a dc current and will be read by the meter in Figure 2-2b. Because some detectors act differently from others, we will use a "square law" detector. These detectors have an output proportional to the square of the input. So if we place the probe at Y on the slotted line, we will get:

$$i_{min} = ke_{min}^{2}$$

Or:

$$e_{min} = \sqrt{i_{min}/K}$$

Then if we move the probe to point X, we get:

$$i_{max} = ke_{max}^{2}$$

Or:

$$e_{max} = \sqrt{i_{max}/K}$$

Together we get:

$$VSWR = \frac{e_{max}}{e_{min}} = \sqrt{\frac{i_{max}/k}{i_{min}/k}} = \sqrt{\frac{i_{max}}{i_{min}}}$$

Now we can measure the X and the Y on the meter in Figure 2-2b and we see:

$$VSWR = \sqrt{\frac{\text{maximum meter reading}}{\text{minimum meter reading}}}$$

This way of measuring VSWR is by far the easiest, but if the minimum meter reading cannot be measured with a reliable degree of accuracy, the inherent flaws in the detector may create distortion increasing the chance of error.

When standing wave ratios are larger than ten to one, the "double minimum" measurement system can be used to in crease the accuracy and reduce the percentage of error. Let us examine this method in Figure 2-3.

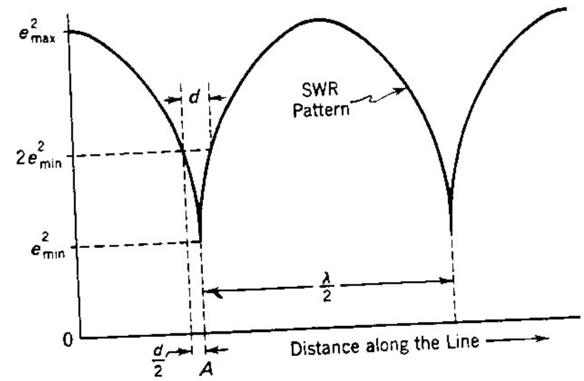


Figure 2.3 Double Minimum Method

The mathematical expression of this curve is:

$$e = e_{min}^2 + (e_{max}^2 - e_{min}^2)\sin^2\left(\frac{2\pi l}{\lambda}\right)$$

Starting at point "A", we move to the right until the reading is twice what it was at point "A". This gives us:

$$2e_{min}^2 = e_{min}^2 + e_{max}^2 \sin\left(\frac{\pi d}{\lambda}\right) - e_{min}^2 \sin^2\left(\frac{\pi d}{\lambda}\right)$$

This relationship can also be expressed as:

$$\frac{e_{max}^2}{e_{min}^2} = \frac{1 + \sin^2(\pi d/\lambda)}{\sin^2(\pi d/\lambda)}$$

Because in mathematics:

$$\sin^2\theta = 1 - \cos^2\theta$$

we can restate the formula as:

$$\frac{e_{max}^2}{e_{min}^2} = \frac{2 - \cos^2(\pi d/\lambda)}{\sin^2(\pi d/\lambda)}$$

and also as:

$$VSWR = \frac{e_{max}}{e_{min}} = \frac{\sqrt{2 - \cos^2(\pi\, d\,\lambda\,)}}{\sin\,(\,\pi\, d/\lambda\,)}$$

The actual measurement of VSWR, however, is done by measuring the distance between two "double minimum" measurements. Then we use this information and a trigonometric table like the one in Table 2-2.

VSWR's with ten or greater angle $\pi d/\lambda$ will be small and so will $\sin\,(\,\pi\, d\,/\lambda\,)$ because of this:

$$1 + \sin^2(\pi\, d/\lambda\,) \approx 1.$$

So then:

$$VSWR \approx \frac{1}{\sin\,(\,\pi\, d/\lambda\,)}$$

because of the small angle:

$$\sin\left(\frac{\pi\, d}{\lambda}\right) \approx \frac{\pi\, d}{\lambda}$$

Now we can reduce this equation to:

$$VSWR \approx \frac{\lambda}{\pi\, d}$$

This is only required when VSWR is greater than ten. In some cases, the measurements of e_{max} and e_{min} can be amplified to provide better accuracy.

Equipment and Materials:

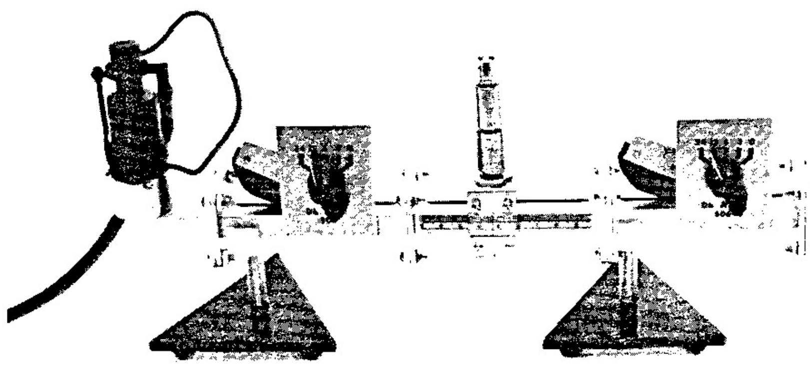
1 Microwave source (supplied).
2 Waveguide attenuators (supplied).
1 Slotted line with probe and detector (supplied).
1 D-C microammeter (supplied).
1 Short circuit terminator (supplied).
2 Waveguide stands (supplied).

SEE CAUTION ON PREVIOUS PAGE

Objective:
In this experiment, we will look at some common ways to measure VSWR.

Part 1: Medium VSWR

1. Set up test fixture in Figure 2-4.



2. Connect one of the video cable from the detector on the slotted line to the input marked VSWR on the power supply.

3. Turn on power supply and apply r-f power.

4. Move probe on slotted line and adjust for maximum deflection (try to keep this at the center of the slotted line if possible).

5. With the shorted attenuator set at maximum, adjust the r-f feed attenuator for a close to full scale reading.

6. Move the probe for a minimum reading.

7. Adjust the short feed attenuator for a reading of about 1/4 scale.

8. Measure and record the readings at the points indicated on Table 2-1.

Table 2.1 Data

Distance along the Line (in cm)	Meter Readings in μamp		
	Part 1	Part 2	Part 3
0.0			
0.2			
0.4			
0.6			
0.8			
1.0			
1.2			
1.4			
1.6			
1.8			
2.0			
2.2			
2.4			
2.6			
2.8			
3.0			
3.2			
3.4			
3.6			
3.8			
4.0			
4.2			
4.4			
4.6			
4.8			
5.0			

9. Plot a curve of distance and readings.

10. Using Table 2-2 and equations from the discussion section, fill in the VSWR calculations on Table 2-1.

Part 2: High VSWR

1. Use the same test fixture and adjust the r-f feed attenuator to minimum attenuation.

2. Move the probe to minimum reading and then adjust the short attenuator for a reading of 1/10 full scale.

3. Repeat steps 8, 9, and 10 of part 1 (record any off scale readings as off scale).

Part 3: Low VSWR

1. Adjust short attenuator to maximum attenuation.

2. Adjust r-f feed attenuator for a 50% of full scale with probe at a peak point.

3. Repeat steps 8, 9, and 10 of part 1.

Table 2.2

$\frac{\pi d}{\lambda}$	sin	cos	$\frac{\pi d}{\lambda}$	sin	cos	$\frac{\pi d}{\lambda}$	sin	cos
0.00	0.00000	1.00000	0.17	0.16918	0.98558	0.34	0.33349	0.94275
0.01	0.01000	0.99995	0.18	0.17903	0.98384	0.35	0.34290	0.93937
0.02	0.02000	0.99980	0.19	0.18886	0.98200	0.36	0.35227	0.93590
0.03	0.03000	0.99955	0.20	0.19867	0.98007	0.37	0.36162	0.93233
0.04	0.03999	0.99920	0.21	0.20846	0.97803	0.38	0.37092	0.92866
0.05	0.04998	0.99875	0.22	0.21823	0.97590	0.39	0.38019	0.92491
0.06	0.05996	0.99820	0.23	0.22798	0.97367	0.40	0.38942	0.92106
0.07	0.06994	0.99755	0.24	0.23770	0.97134	0.41	0.39861	0.91712
0.08	0.07991	0.99680	0.25	0.24740	0.96891	0.42	0.40776	0.91309
0.09	0.08988	0.99595	0.26	0.25708	0.96639	0.43	0.41687	0.90897
0.10	0.09983	0.99500	0.27	0.26673	0.96377	0.44	0.42594	0.90475
0.11	0.10978	0.99396	0.28	0.27636	0.96106	0.45	0.43497	0.90045
0.12	0.11971	0.99281	0.29	0.28595	0.95824	0.46	0.44395	0.89605
0.13	0.12963	0.99156	0.30	0.29552	0.95534	0.47	0.45289	0.89157
0.14	0.13954	0.99022	0.31	0.30506	0.95233	0.48	0.46178	0.88699
0.15	0.14944	0.98877	0.32	0.31457	0.94924	0.49	0.47063	0.88233
0.16	0.15932	0.98723	0.33	0.32404	0.94604	0.50	0.47943	0.87758