Telecommunications

Courseware Sample

39974-F0

TELECOMMUNICATIONS

COURSEWARE SAMPLE

by
the Staff
of
Lab-Volt Ltd.

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Sample Exercise Extracted from

Microwave Variable-Frequency

Measurements and Applications

Exercise 2

Microwave Variable-Frequency Oscillators

EXERCISE OBJECTIVE

Upon completion of this exercise, you will know how to measure the frequency-versus-control voltage curve of a VCO, and the output power-versus-frequency curve of a VCO. You will know the effect that a change in the frequency of the VCO has on the SWR of a load matched for a specific frequency. Finally, you will know how the amplitude of a VCO signal can be modulated with a square-wave signal so as to produce a microwave pulsed signal (keyed on and off).

DISCUSSION

Microwave Variable-Frequency Oscillators

Microwave variable-frequency oscillators produce a microwave periodic signal whose operating frequency can be changed, either mechanically or electronically.

- Mechanical method: the frequency is changed by using a mechanical tuning device. The following oscillators, for example, use this type of tuning:
  - Gunn oscillators (low power);
  - reflex klystrons (high power);
  - magnetrons (high power).
- Electronic method: the frequency is tuned electronically. The following oscillators, for example, use this type of tuning:
  - Varactor-tunable Gunn oscillators (narrow tuning bandwidth);
  - Voltage-controlled oscillators, or VCO's (medium tuning bandwidth);
  - Yttrium-iron garnet (YIG) oscillators (wide tuning bandwidth). YIG oscillators are often used in laboratory frequency sources to characterize components or systems.

The Lab-Volt Voltage-Controlled Oscillator

As was mentioned in the previous exercise, the Lab-Volt Voltage Controlled RF Oscillator consists of a voltage-controlled oscillator (VCO) providing a sinusoidal signal whose frequency can be changed by varying a DC voltage. The nominal frequency range is approximately 9.6 to 10.6 GHz.

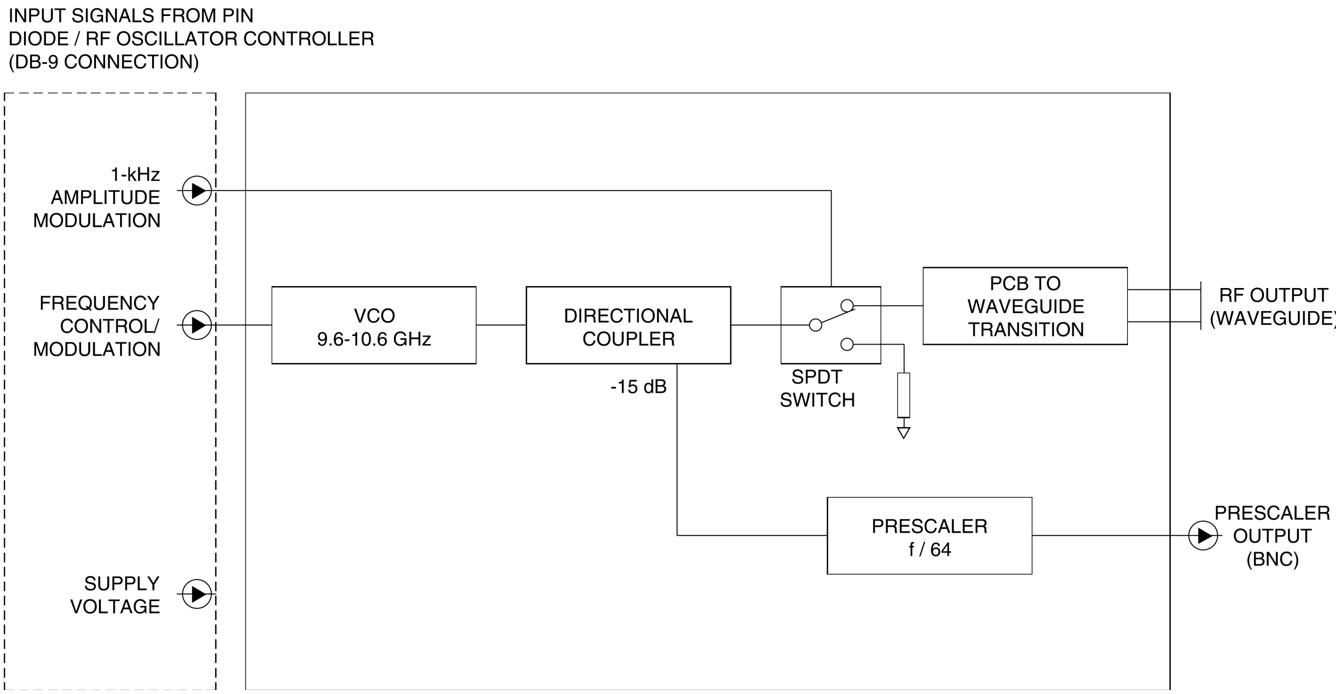

Figure 2-1. Block diagram of the Lab-Volt Voltage Controlled RF Oscillator.

The VCO consists of an oscillator connected to a tank circuit. The tank circuit is an LC resonant circuit made of an inductor in parallel with a variable-capacitance diode (varactor).

The capacitance of the varactor is a function of the DC voltage applied to the Frequency Control input of the VCO (provided by the Lab-Volt PIN Diode/RF Oscillator Controller). Any change in this voltage will change the capacitance of the varactor, thereby changing the resonant frequency of the tank circuit and, therefore, the frequency of the VCO output signal.

At resonance of the LC circuit, an electrical current alternates between the inductor and the varactor, at an angular frequency, ω, of

$$\omega = \sqrt{\frac{1}{LC}} \qquad (2\text{-}1)$$

where ω = resonant frequency (in radians per second);
L = inductance, in henries (H);
C = capacitance of the varactor, in farads (F).

Since ω = 2πf, f being the resonant frequency in hertz (Hz), the above equation can be rewritten as:

$$f = \frac{\omega}{2\pi} = \frac{1}{2\pi\sqrt{LC}} \qquad (2\text{-}2)$$

Modulating signals can be applied to the RF Oscillator's VCO to produce frequency modulation (FM) of the VCO output signal. Moreover, amplitude (on/off) modulation of the VCO output signal can be performed by controlling the SPDT switch to produce a 1-kHz square-wave modulating signal.

Applications

VCO's are typically used in the following applications:

- Point-to-point/multipoint radio
- Test equipment and industrial controls
- Satellite Communications (SATCOM)
- Radar receivers
- Communications systems
- Countermeasure systems
- Clock recovery

Additionally, a great advantage of VCO's is that they can be used as a low-cost substitute for YIG oscillators in certain applications.

Return Loss-Versus-Frequency of a Load

When the impedance of the load is matched to that of the waveguide, it will theoretically absorb all of the incident power on it and none will be reflected. The load is usually matched for a specific frequency. At higher or lower frequencies, standing waves are created, thereby causing return losses.

The usual method of matching out a load, or cancelling the reflections produced by an unmatched load consists in adding a parallel reactance at the nearest point before the load.

This can be done by inserting a slide-screw tuner into the waveguide circuit. The reflected power is monitored by using a directional coupler (Figure 2-2). The position and penetration of the slide-screw tuner are adjusted so as to reduce the reflected power to a minimum and, therefore, to obtain a SWR that is as close as possible to 1 (no standing wave).

> **Note:** *To obtain detailed information on impedance matching with a slide-screw tuner, refer to Exercise 13 of the Lab-Volt "Microwave Fundamentals" manual, part number 28113.*

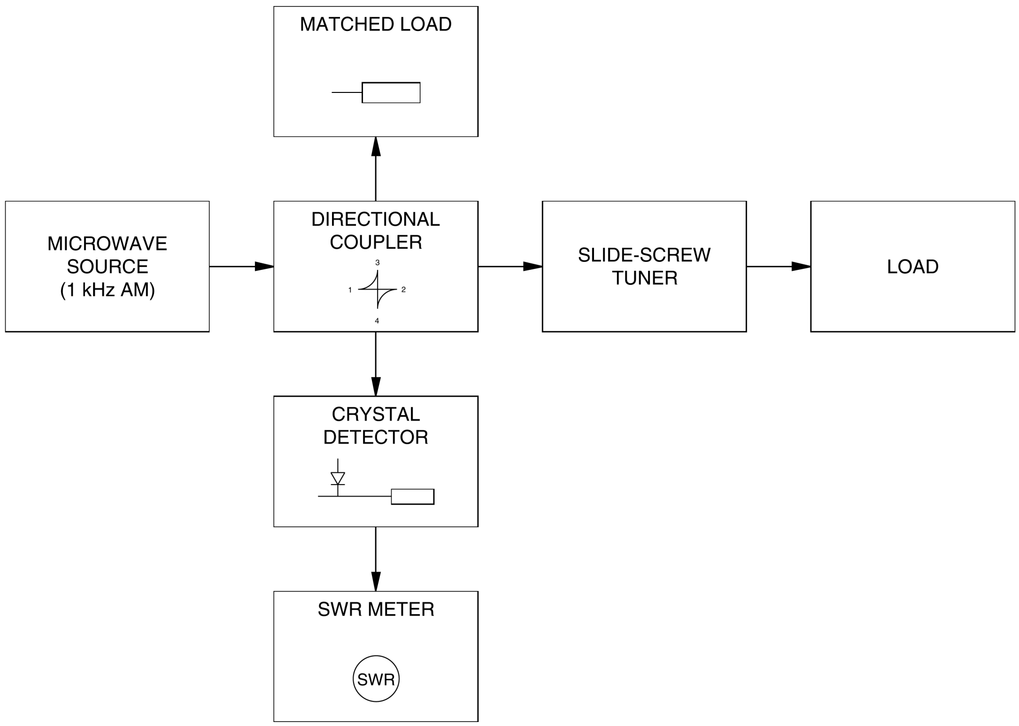

Figure 2-2. Monitoring the reflected power by using a directional coupler.

Impedance matching is effective **only for a narrow range of frequencies** around the frequency at which it has been performed. This implies that, as the frequency of the oscillator output signal moves farther away from this range, the amount of reflected power increases, thereby increasing the return losses and the SWR, and decreasing the efficiency of energy transfer between the source and load.

Figure 2-3 shows an example of SWR-versus-frequency response of a load matched at 10.5 GHz. The SWR, and therefore the return losses, increase as the operating frequency is moved away from 10.5 GHz.

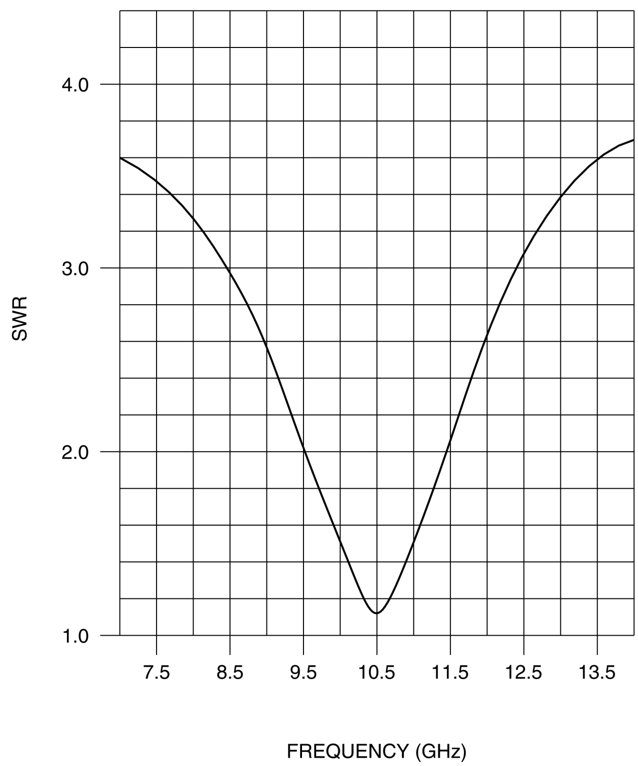

Figure 2-3. Example of SWR-versus-frequency response of a load matched for 10.5 GHz.

Amplitude Modulation

The amplitude of the microwave signal produced by a VCO can be modulated by using an amplitude modulator, as shown in Figure 2-4 (a). The amplitude modulator applies a modulating signal of lower frequency that conveys information to be transmitted over a microwave link.

Figure 2-4 (b) shows a simple example of amplitude modulation by a square wave of a microwave signal. This type of amplitude modulation, also called on/off modulation, causes the microwave modulated signal to be pulsed (keyed on and off) at the frequency of the modulating signal.

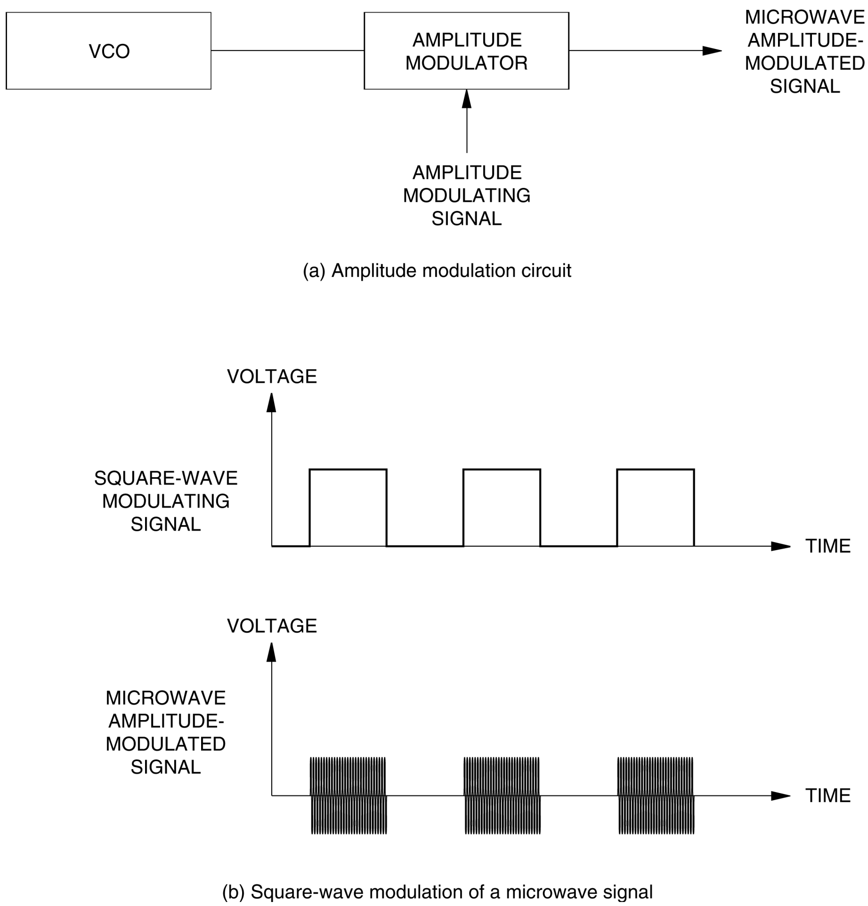

Figure 2-4. Amplitude modulation of a microwave signal with a square-wave signal.

With the Lab-Volt Voltage Controlled RF Oscillator, on/off modulation is performed by applying a 1-kHz square-wave signal to the SPDT switch (see Figure 2-1). This signal repeatedly toggles the switch and modulates the amplitude of the VCO output signal at a 1-kHz frequency.

The modulation depth of the modulated signal is equal to the power output ratio between the on and off states. With the Lab-Volt Voltage Controlled RF Oscillator, a typical modulation depth of at least 20 dB can be obtained.

$$\text{Modulation Depth} = \frac{\text{Output Power}_{ON}}{\text{Output Power}_{OFF}}$$

Procedure Summary

In the first part of this exercise, you will plot the output frequency-versus-control voltage curve of the VCO contained in the Lab-Volt Voltage Controlled RF Oscillator.

In the second part of this exercise, you will plot the output power-versus-frequency curve of the RF oscillator's VCO, for the nominal variation range of 9.6 to 10.6 GHz.

In the last part of this exercise, you will plot the SWR-versus-frequency curve of a load before and after impedance matching at 10.1 GHz.

PROCEDURE

VCO Output Frequency as a Function of the Control Voltage

☐ 1. Make sure that all power switches are in the O (off) position. Set up the modules as shown in Figure 2-5.

As the figure shows, connect the DB-9 supply cable of the PIN Diode/RF Oscillator Controller to the DB-9 connector at the top of the SWR Meter. This will allow the controller to be powered via the internal power buses of the Gunn Oscillator Power Supply, Power Meter, and SWR Meter when these modules are turned on.

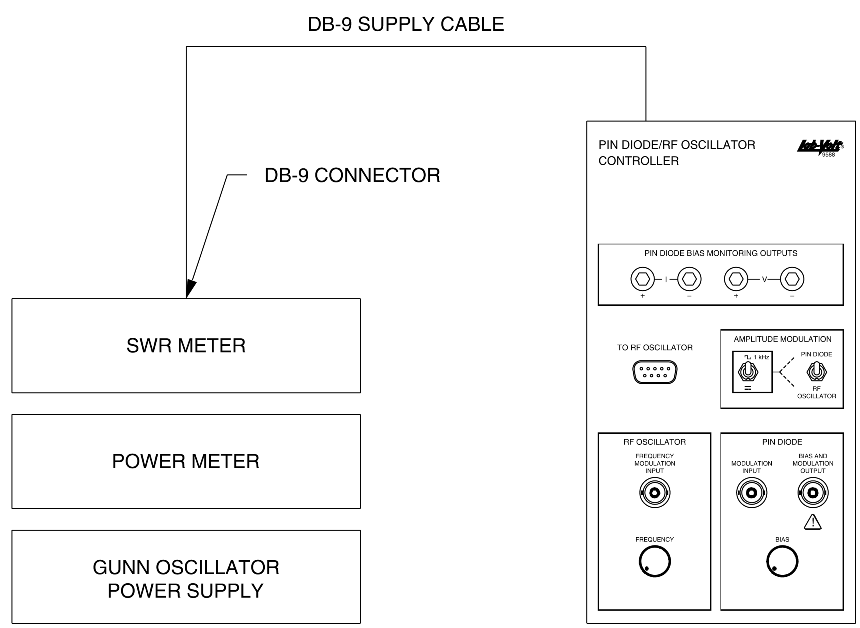

Figure 2-5. Module arrangement.

☐ 2. Assemble the components as shown in Figure 2-6.

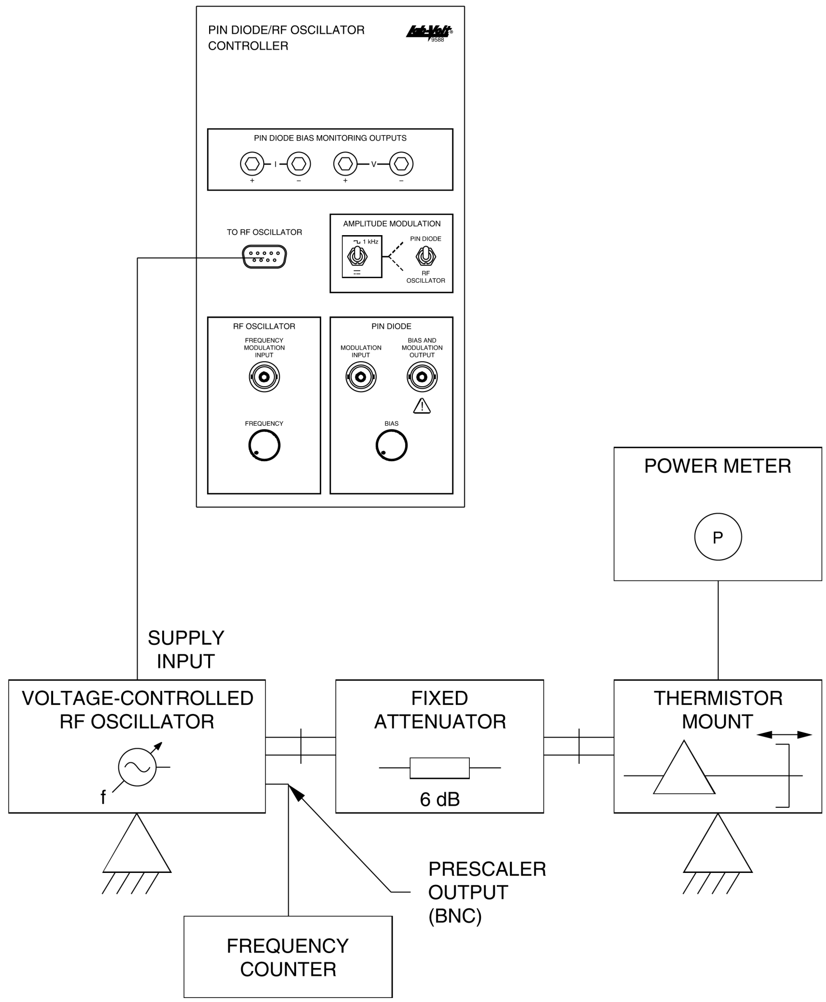

Figure 2-6. Setup used to perform VCO output frequency and power measurements.

☐ 3. Turn on the Gunn Oscillator Power Supply, the Power Meter, and the SWR Meter by setting their POWER switches to the I (ON) position.

Wait for about 1-2 minutes to allow the power supply to warm up.

☐ 4. On the PIN Diode/RF Oscillator Controller, set the AMPLITUDE MODULATION switches to "⎓" (DC) and to "RF OSCILLATOR". This will cause the controller to apply an unmodulated DC voltage to the VCO.

☐ 5. Examine the data recorded in the first two columns of Table 2-1. This data indicates that, when turning the RF OSCILLATOR FREQUENCY knob of the PIN Diode/RF Oscillator Controller from the fully CCW to the fully CW position, the control voltage applied to the VCO varies from approximately 0 to 10.5 V (that is, a variation of around 1.05 V per knob turn).

Fill in the column "VCO OUTPUT SIGNAL FREQUENCY" of Table 2-1: adjust the RF OSCILLATOR FREQUENCY knob to each setting listed in Table 2-1; for each knob setting, multiply the reading of the frequency counter **by 64** and record your result in the column "VCO OUTPUT SIGNAL FREQUENCY".

> **Note:** *The frequency meter might indicate a null reading if the Thermistor Mount is improperly matched, as high reflections will be reflected back towards the VCO. In that case, unscrew the two matching screws on the Thermistor Mount so that they do not penetrate into the waveguide. Adjust the position of the thermistor's moveable short circuit to obtain a reading on the frequency meter.*

> **Note:** *The nominal variation range of the RF oscillator's VCO is 9.6-10.6 GHz. However, the lower or higher frequency of your VCO's frequency range could be different, which might cause the VCO output signal to be null for knob positions out of the 9.6 to 10.6 GHz range.*

RF OSCILLATOR FREQUENCY KNOB	CONTROL VOLTAGE (V)	VCO OUTPUT SIGNAL FREQUENCY (GHz)
FULLY CCW	0.00	
1 TURN CW	1.05	
2 TURNS CW	2.10	
3 TURNS CW	3.15	
4 TURNS CW	4.20	
5 TURNS CW	5.25	
6 TURNS CW	6.30	
7 TURNS CW	7.35	
8 TURNS CW	8.40	
9 TURNS CW	9.45	
FULLY CW	10.50	

Table 2-1. VCO output signal frequency as a function of the control voltage.

☐ 6. From the results you obtained in Table 2-1, plot in Figure 2-7 the VCO output signal frequency as a function of the control voltage.

According to the obtained curve, does the VCO output signal frequency vary linearly in direct proportion to the control voltage?

☐ Yes ☐ No

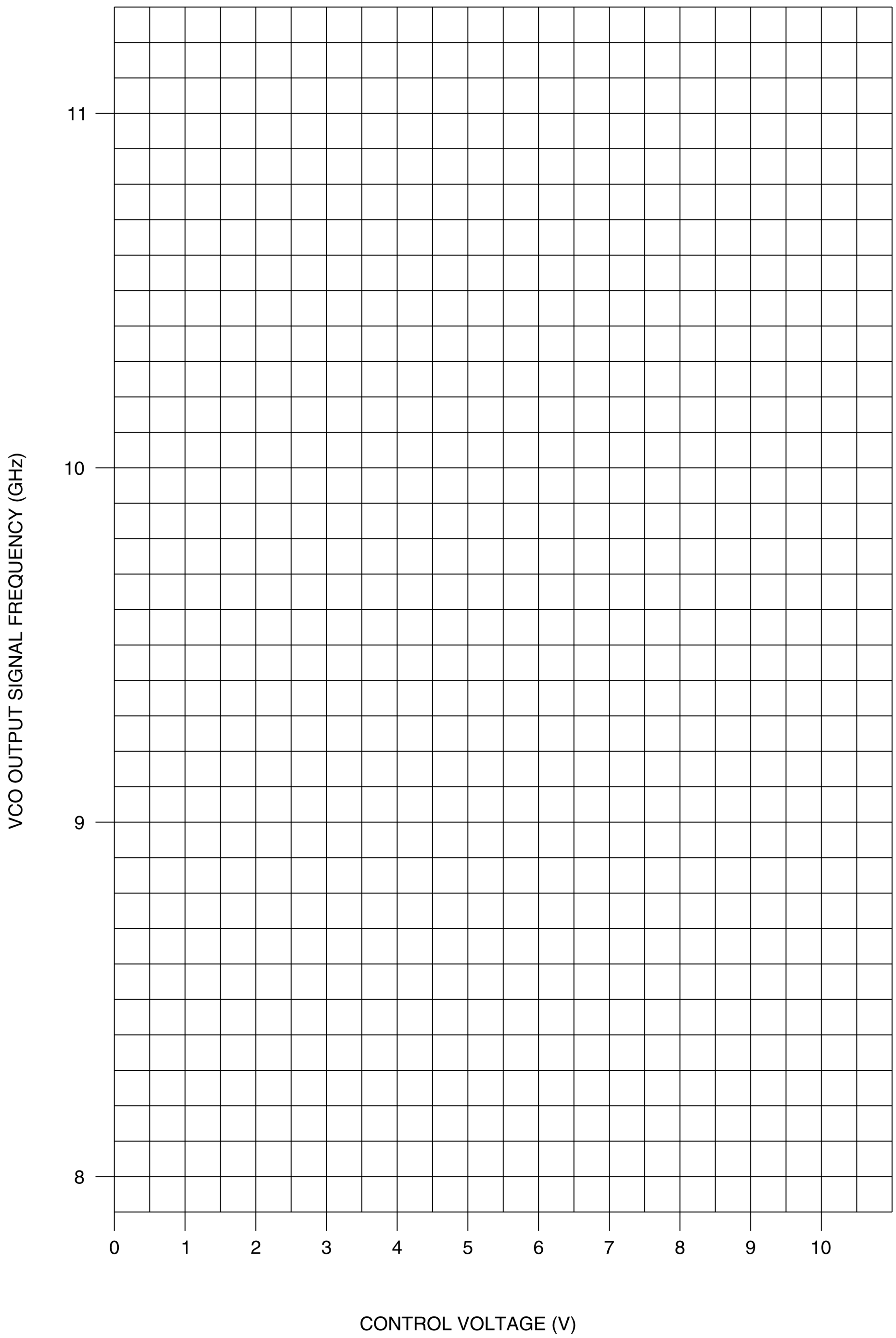

Figure 2-7. VCO output signal frequency as a function of the control voltage.

☐ 7. Leave the set up as it is and proceed with the next part of the exercise.

VCO Output Power as a Function of Frequency

☐ 8. Select the 5-dBm RANGE on the Power Meter.

On the PIN Diode/RF Oscillator Controller, disconnect the DB-9 cable from the connector "TO RF OSCILLATOR" to remove power from the VCO.

Using the ZERO ADJUST knobs of the Power Meter, align the Power Meter needle with the 0-mW mark.

Reconnect the DB-9 cable to the connector "TO RF OSCILLATOR" of the PIN Diode/RF Oscillator Controller.

☐ 9. Fill in the column "VCO OUTPUT POWER" of Table 2-2: adjust the VCO output signal to each of the frequencies listed in Table 2-2 (by referring to the frequency counter reading **multiplied by 64**). For each frequency setting, perform the following steps:

a. On the Thermistor Mount, unscrew the two matching screws so that they do not penetrate into the waveguide. Adjust the position of the moveable short circuit to maximize the power reading of the Power Meter. Then adjust each matching screw to further maximize the power reading, if possible. Redo these three adjustments to optimize the reading.

b. Add 6 dB to the power reading to account for the power lost through the 6-dB attenuator, and record your result in the column "OUTPUT POWER".

Note: *If the RF power to measure is less than 0 dBm, select the 0-dBm RANGE on the POWER METER. On the PIN Diode/RF Oscillator Controller, disconnect the DB-9 cable from the connector "TO RF OSCILLATOR" to remove power from the VCO. Using the ZERO ADJUST knobs of the Power Meter, align the Power Meter needle with the 0-mW mark. Then, reconnect the DB-9 cable to the connector "TO RF OSCILLATOR" of the PIN Diode/RF Oscillator Controller and perform your power measurement.*

Note: *For accurate results, it is suggested that you verify the zero adjustment of the Power Meter a couple of times while making the measurements.*

VCO OUTPUT SIGNAL FREQUENCY (GHz)	VCO OUTPUT POWER (dBm)
9.6	
9.8	
10.0	
10.2	
10.4	
10.6	

Table 2-2. VCO output signal power at different output signal frequencies.

☐ 10. From the results you obtained in Table 2-2, plot in Figure 2-8 the VCO output power for each of the listed frequencies.

According to the obtained curve, describe how the VCO output power varies over its nominal operating range of 9.6 to 10.6 GHz.

____

____

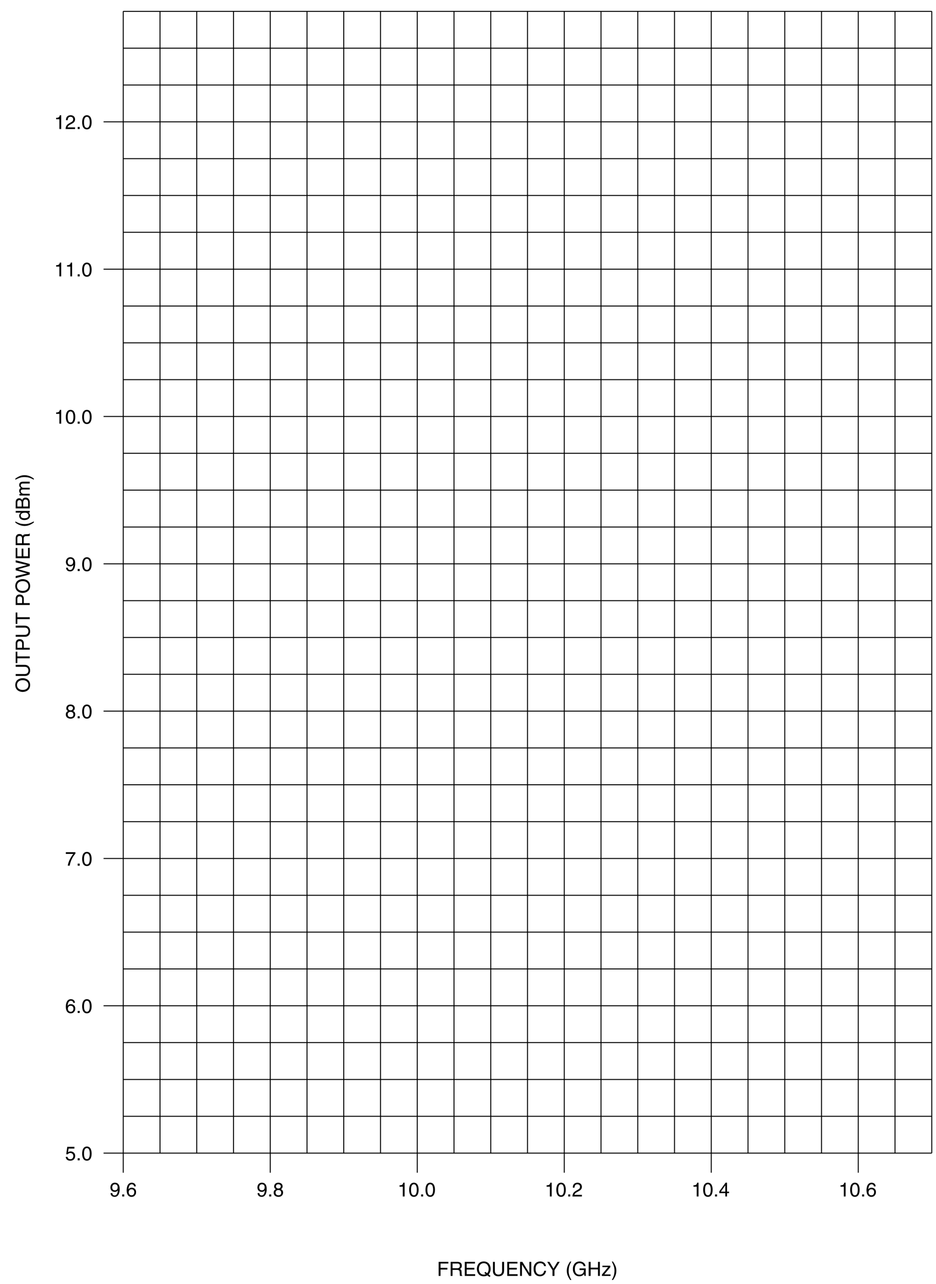

Figure 2-8. VCO output signal power over its nominal frequency range.

SWR-Versus-Frequency Curve of a Load Before and After Load Matching

☐ 11. Disconnect the supply cable PIN Diode/RF Oscillator Controller from the SWR Meter in order to remove power from the controller.

Assemble the components as shown in Figure 2-9. The capacitive iris is the iris that has a horizontal rectangular orifice.

Reconnect the PIN Diode/RF Oscillator Controller supply cable to the SWR Meter.

Wait for about 5 minutes to allow the Voltage Controlled RF Oscillator circuitry to warm up.

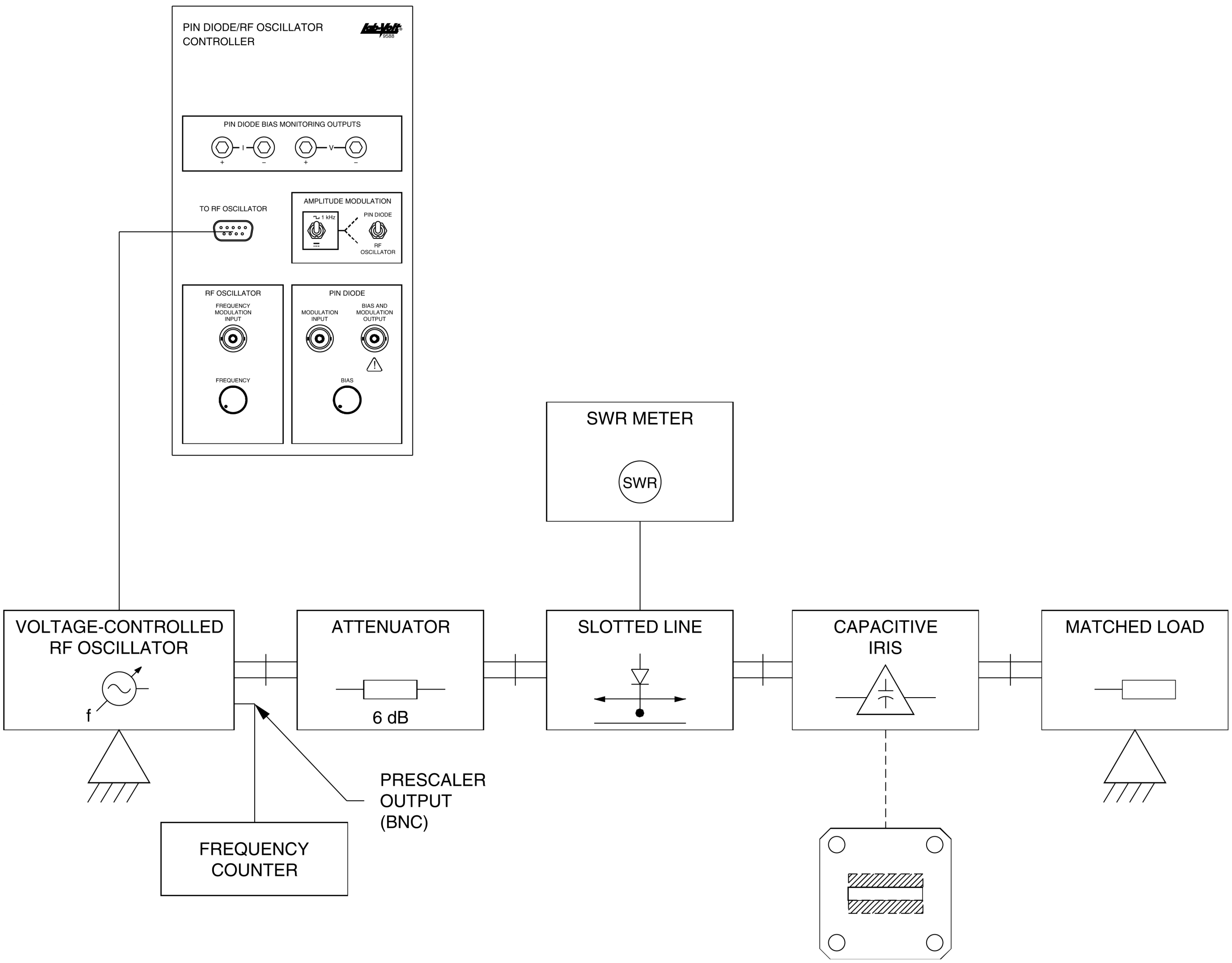

Figure 2-9. Measuring the SWR at different frequencies before and after the matching of a load.

Measuring the SWR at Different Frequencies Before Load Matching

☐ 12. On the Slotted Line, use the pointer and horizontal markers on the probe holder to adjust the depth of the probe to about 1/3 of maximum (second uppermost marker).

☐ 13. On the PIN Diode/RF Oscillator Controller, set the AMPLITUDE MODULATION switches to "1 kHz" and to "RF OSCILLATOR". This will cause the controller to modulate the amplitude of the VCO output signal with a 1-kHz square-wave signal, allowing SWR measurements to be performed with the Slotted Line and the SWR Meter.

☐ 14. Fill in the column "SWR BEFORE LOAD MATCHING" of Table 2-3: adjust the VCO output signal to each of the frequencies listed in the table (by referring to the frequency counter reading **multiplied by 64**). For each frequency setting, perform the following steps:

a. Move the Slotted Line probe to the 40.0-mm position.

b. Make the following adjustments on the SWR Meter:

RANGE . . . . -10 dB
SCALE . . . . NORMAL
GAIN . . . . mid range
CENTER FREQUENCY . . . . mid position
BANDWIDTH . . . . 100 Hz

c. On the Slotted Line, slowly move the probe carriage along the waveguide until you encounter a maximum.

Note: *If the needle goes beyond the maximum of the SWR Meter scale, slightly decrease the probe depth on the Slotted Line so that the needle is below the scale maximum (to obtain a reading of −2 to −3 dB, for instance), and slightly move the probe carriage until a maximum is detected.*

If no significant deflection of the needle is observed on the SWR Meter when slowly moving the probe carriage along the waveguide, select the next lower RANGE on the SWR Meter and redo the manipulation.

Note: *If there is still no significant deflection of the meter needle when you have reached the −40-dB range of the SWR Meter, slightly increase the probe depth and redo the manipulation.*

d. On the SWR Meter, set the BANDWIDTH to 20 Hz and carefully adjust the CENTER FREQUENCY knob so as to maximize the needle deflection.

Note: *If the scale goes beyond the maximum of the SWR Meter scale, slightly readjust the GAIN control so that the needle is below the scale maximum, and complete the center frequency adjustment.*

e. On the SWR Meter, set the GAIN control so that the needle is aligned with the 0-dB (SWR = 1.0) graduation. This sets a reference level (change RANGEs on the SWR Meter as necessary).

f. Move the Slotted Line probe until you encounter the null which is closest to the load.

g. Record the SWR indicated by the SWR Meter in Table 2-3.

VCO OUTPUT SIGNAL FREQUENCY (GHz)	SWR BEFORE LOAD MATCHING	SWR AFTER LOAD MATCHING @ 10.1 GHz
9.7		
9.9		
10.1		
10.3		
10.5		

Table 2-3. SWR measured at different frequencies before and after load matching at a specific frequency (10.1 GHz).

Matching of a Load at a Specific Frequency (10.1 GHz)

> **Note:** *To obtain detailed information on impedance matching, please refer to Exercise 13 of the Lab-Volt Student Manual "Microwave Fundamentals", part number 28113.*

☐ 15. Disconnect the PIN Diode/RF Oscillator Controller supply cable from the SWR Meter to remove power from the controller.

Assemble the components as shown in Figure 2-10.

Adjust the probe penetration of the Slide-Screw Tuner to 0.00 mm.

Reconnect the PIN Diode/RF Oscillator Controller supply cable to the SWR Meter.

Wait for about 5 minutes to allow the Voltage Controlled RF Oscillator circuitry to warm up.

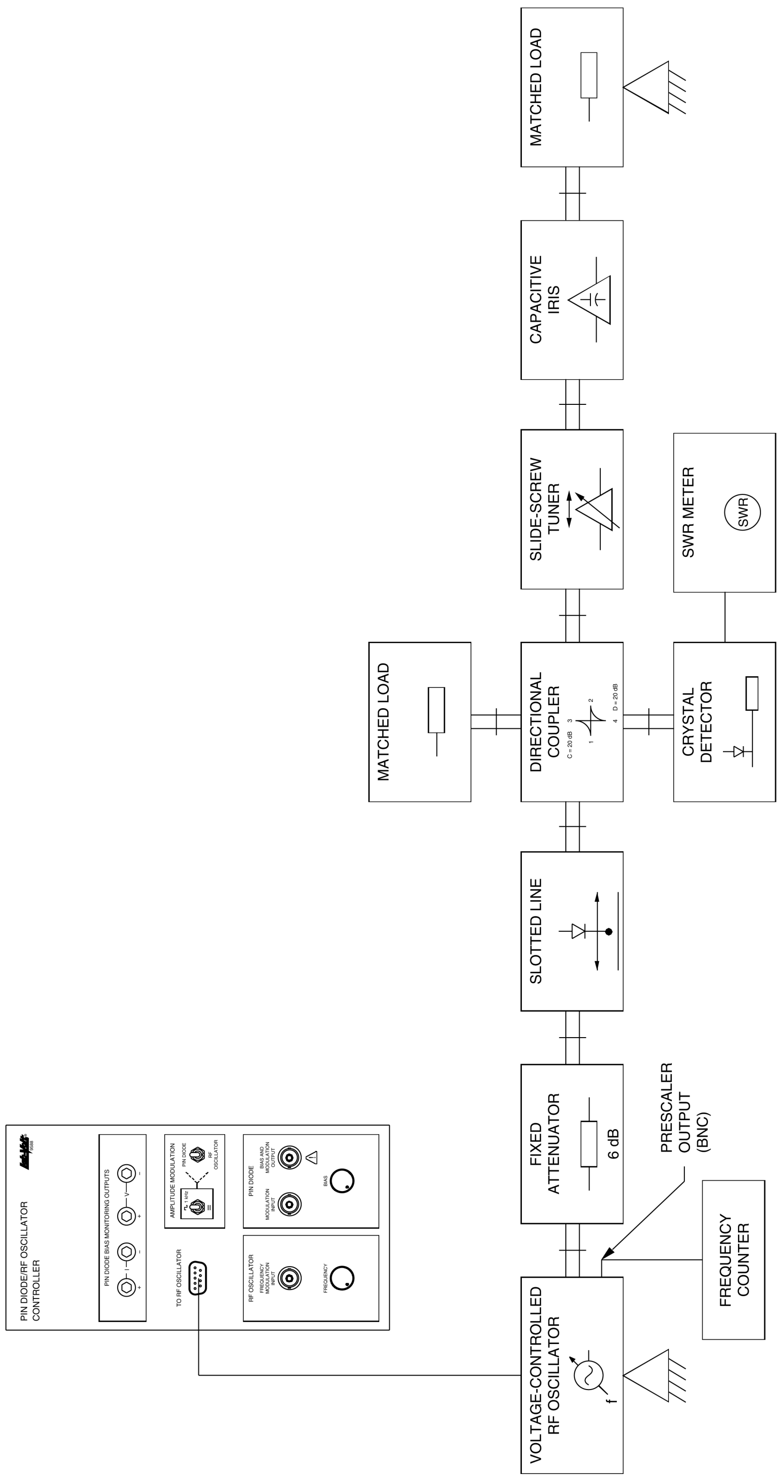

Figure 2-10. Setup used to match the load with the Slide-Screw Tuner.

☐ 16. Set the VCO output signal to 10.1 GHz (by referring to the frequency counter reading **multiplied by 64**).

☐ 17. On the SWR Meter, select the −30-dB RANGE, then adjust the GAIN control to obtain a convenient reading (−33 dB, for instance). If this is not possible, select the next range in order to be able to do the adjustment.

☐ 18. Set the probe of the Slide-Screw Tuner to the 40-mm position. Increase the depth of penetration of this plunger until the level of the reflected power, as read on the SWR Meter, has increased or decreased by about 1 dB.

☐ 19. If the level of the reflected power has increased, move the carriage of the Slide-Screw Tuner to minimize the power reading. Select another RANGE on the SWR if necessary.

☐ 20. Alternately adjust the penetration and the position of the probe of the Slide-Screw Tuner to obtain the lowest possible power reading on the SWR Meter.

Measuring the SWR at Different Frequencies After Load Matching

☐ 21. Keep the setup as it is. Referring to Figure 2-11, disconnect the SWR Meter from the Crystal Detector and connect it to the Slotted Line.

☐ 22. With the frequency set to 10.1 GHz, measure the SWR of the matched load:

a. Move the Slotted Line probe to the 40.0-mm position.

b. Make the following adjustments on the SWR Meter:

RANGE . . . . -10 dB
SCALE . . . . NORMAL
GAIN . . . . mid range
CENTER FREQUENCY . . . . mid position
BANDWIDTH . . . . 100 Hz

c. On the Slotted Line, slowly move the probe carriage along the waveguide until you encounter a maximum.

Note: *If the needle goes beyond the maximum of the SWR Meter scale, slightly decrease the probe depth on the Slotted Line so that the needle is below the scale maximum (to obtain a reading of −2 to −3 dB, for instance), and slightly move the probe carriage until a maximum is detected.*

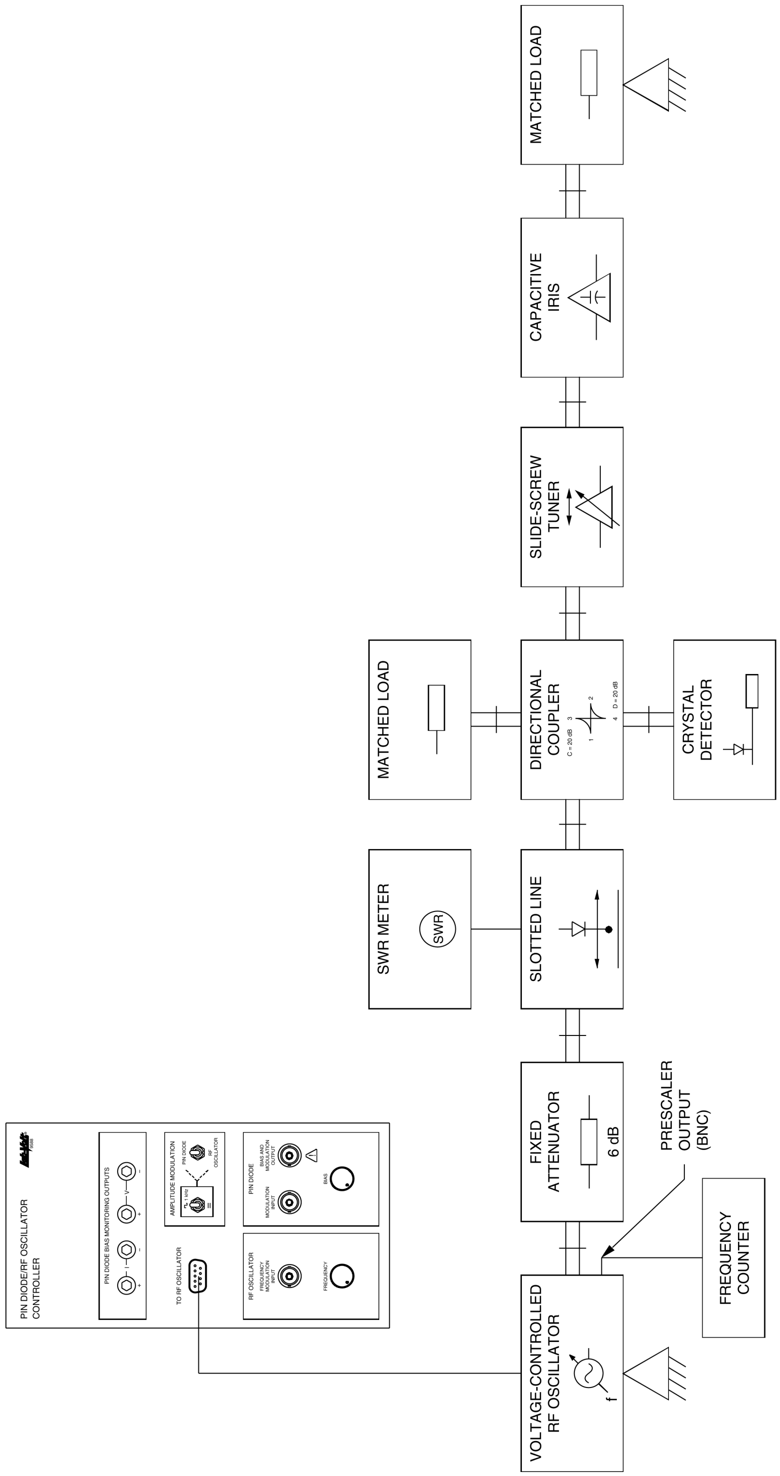

Figure 2-11. Measuring the SWR after load matching at 10.1 GHz.

If no significant deflection of the needle is observed on the SWR Meter when slowly moving the probe carriage along the waveguide, select the next lower RANGE on the SWR Meter and redo the manipulation.

> **Note:** *If there is still no significant deflection of the meter needle when you have reached the −40-dB range of the SWR Meter, slightly increase the probe depth and redo the manipulation.*

d. On the SWR Meter, set the BANDWIDTH to 20 Hz and carefully adjust the CENTER FREQUENCY knob so as to maximize the needle deflection.

> **Note:** *If the scale goes beyond the maximum of the SWR Meter scale, slightly readjust the GAIN control so that the needle is below the scale maximum, and complete the center frequency adjustment.*

e. On the SWR Meter, set the GAIN control so that the needle is aligned with the 0-dB (SWR = 1.0) graduation to set a reference level. (Change RANGEs on the SWR Meter as necessary).

f. Move the Slotted Line probe until you encounter the null which is closest to the load.

g. Record the SWR indicated by the SWR Meter below:

SWR of load at 10.1 GHz: ______

☐ 23. Fill in the column "SWR AFTER LOAD MATCHING @ 10.1 GHz" of Table 2-3: adjust the VCO output signal to each frequency listed in this table. For each frequency setting, redo step 22, recording the SWR in the proper row of the table.

☐ 24. From the results recorded in Table 2-3, plot in Figure 2-12 the SWR-versus-frequency curve before load matching. Then, plot this curve after load matching.

Do the obtained curves differ? If so, how do they differ and what does this indicate?

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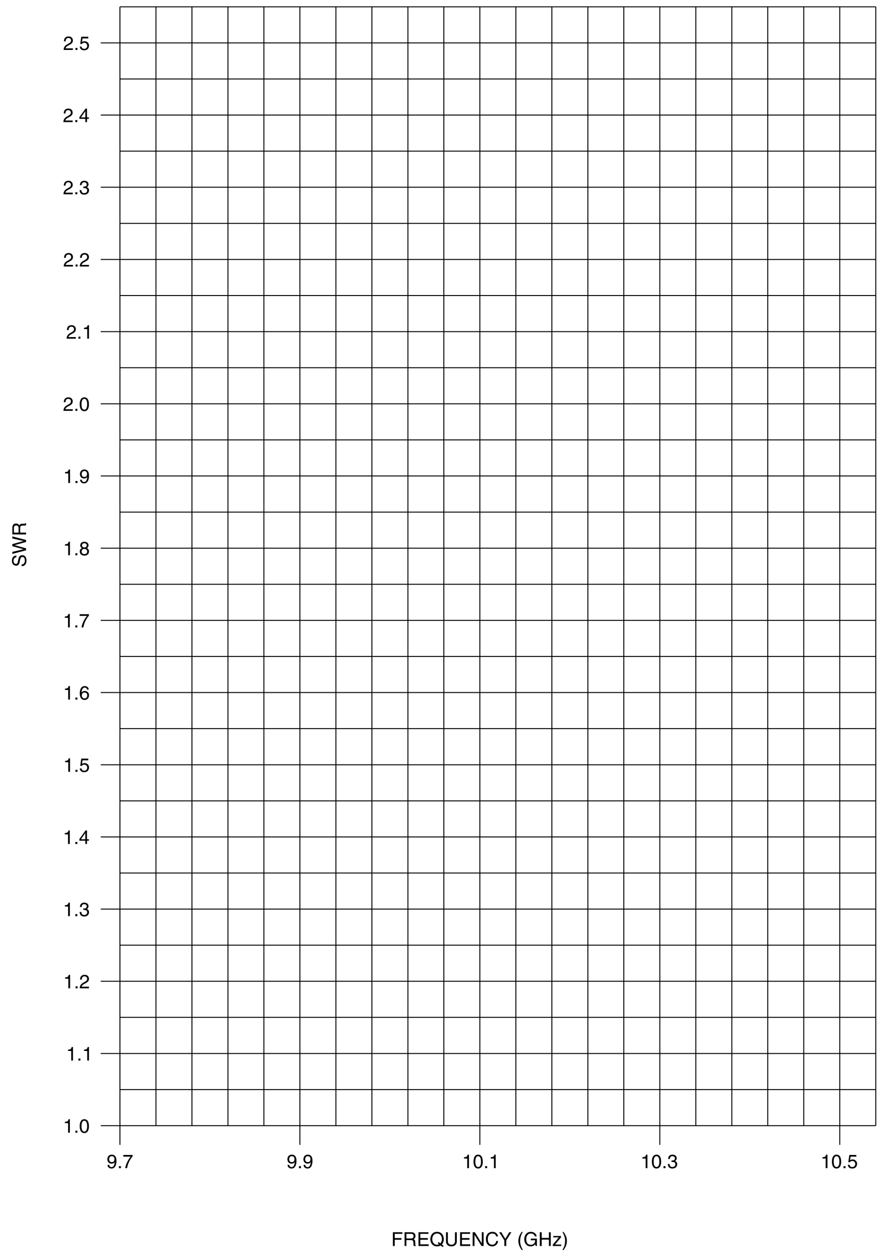

Figure 2-12. SWR-versus-frequency curve before and after load matching.

☐ 25. Turn off the Gunn Oscillator Power Supply, the Power Meter, and the SWR Meter by setting their POWER switches to the O (OFF) position. Disassemble the setup and return all components to their storage location.

CONCLUSION

In this exercise, you were introduced to variable-frequency oscillators. You learned that the VCO of the Lab-Volt Voltage Controlled RF Oscillator consists of an oscillator connected to a tank circuit. This VCO provides a signal whose frequency can be varied by varying a DC voltage.

You learned that the amplitude of this VCO output signal can be modulated by using a signal of lower frequency. For example, a square-wave signal can be used for modulating in order to pulse (key) the microwave signal on and off.

Finally, you learned that impedance matching is effective only for a narrow range around the frequency at which it is performed. As the oscillator frequency moves farther from this range, the amount of power reflected by the load increases, and so does the SWR.

REVIEW QUESTIONS

1. What are the two usual methods of changing the operating frequency of variable-frequency oscillators? Give three types of oscillators for which each tuning method is used.

   ____
   ____
   ____
   ____
   ____

2. What does the VCO contained in the Lab-Volt Voltage Controlled RF Oscillator consist of? Explain why any change in the DC voltage applied to the VCO causes the frequency of the VCO output signal to change.

   ____
   ____
   ____
   ____
   ____

3. Name five applications in which voltage-controlled oscillators (VCO's) are used.

   ____
   ____
   ____
   ____

4. Briefly describe the method you used in this exercise to match out, or to cancel the reflections produced by an unmatched load. After impedance matching, was the SWR enhanced over all the VCO's variation range of 9.7 to 10.5 GHz? Explain.

____

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5. How can the amplitude of a microwave signal be modulated so as to produce a pulsed (on/off keyed) signal? How is the modulation depth of the resulting modulated signal calculated?

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____

____

Instructor Guide Sample Exercise

Extracted from

Microwave Variable-Frequency

Measurements and Applications

EXERCISE 2 MICROWAVE VARIABLE-FREQUENCY OSCILLATORS

ANSWERS TO PROCEDURE STEP QUESTIONS

☐ 5.

RF OSCILLATOR FREQUENCY KNOB	CONTROL VOLTAGE (V)	VCO OUTPUT SIGNAL FREQUENCY (GHz)
FULLY CCW	0.00	8.886
1 TURN CW	1.05	9.098
2 TURNS CW	2.10	9.288
3 TURNS CW	3.15	9.472
4 TURNS CW	4.20	9.663
5 TURNS CW	5.25	9.858
6 TURNS CW	6.30	10.058
7 TURNS CW	7.35	10.266
8 TURNS CW	8.40	10.490
9 TURNS CW	9.45	10.714
FULLY CW	10.50	10.929

Table 2-1. VCO output signal frequency as a function of the control voltage.

☐ 6. Yes.

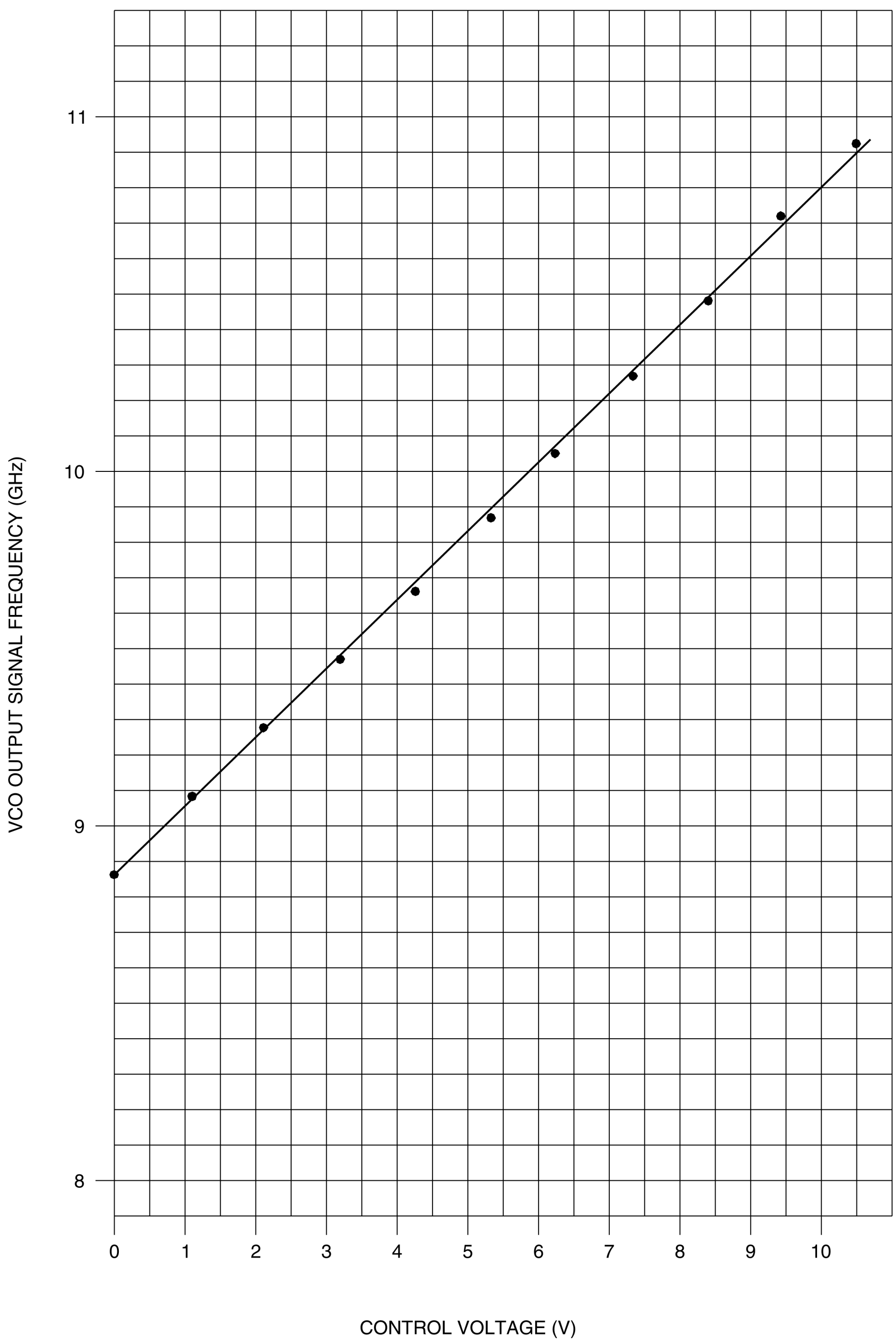

Figure 2-7. VCO output signal frequency as a function of the control voltage.

☐ 9.

VCO OUTPUT SIGNAL FREQUENCY (GHz)	VCO OUTPUT POWER (dBm)
9.6	7.4
9.8	7.4
10.0	7.3
10.2	7.0
10.4	6.5
10.6	5.9

Table 2-2. VCO output signal power at different output signal frequencies.

☐ 10. The curve shown in Figure 2-8 is an example of what you might obtain. Your curve can be a bit different, due to the fact that the power-versus-frequency response varies from one VCO to another.

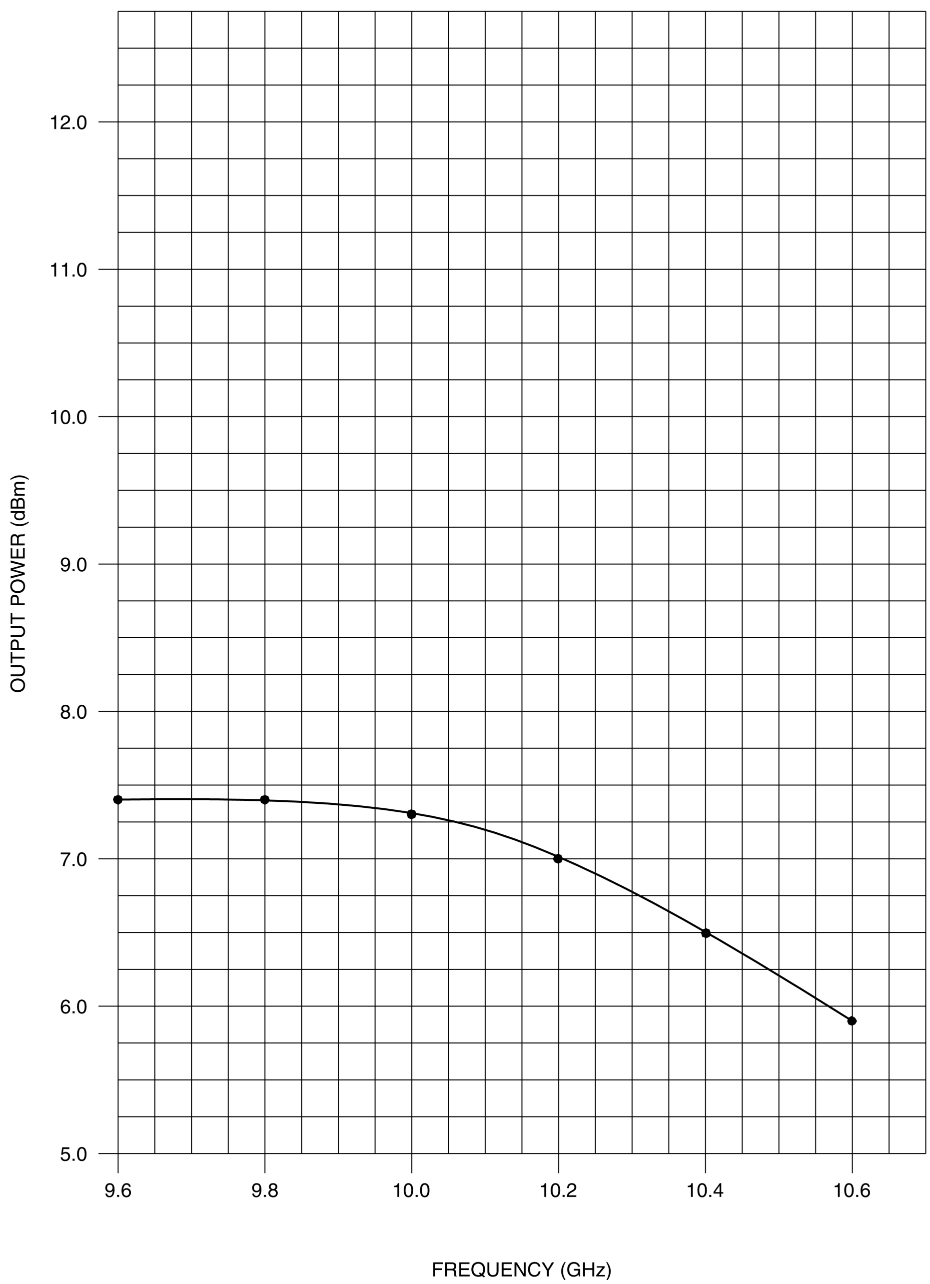

Figure 2-8. VCO output signal power over its nominal frequency range.

☐ 14.

VCO OUTPUT SIGNAL FREQUENCY (GHz)	SWR BEFORE LOAD MATCHING	SWR AFTER LOAD MATCHING @ 10.1 GHz
9.7	1.51	1.49
9.9	1.50	1.21
10.1	1.49	1.04
10.3	1.52	1.31
10.5	1.47	1.43

Table 2-3. SWR measured at different frequencies before and after load matching at a specific frequency (10.1 GHz).

☐ 22. SWR of the load at 10.1 GHz: 1.04

☐ 24. The curves obtained before and after the matching of the load differ markedly.

- The curve obtained before the matching of the load is rather flat. This curve indicates that the SWR is quite constant over the variation range of 9.7 to 10.5 GHz.

- On the other hand, the curve obtained after the matching of the load at 10.1 GHz has a quite linear downslope before and above the match frequency. The SWR is minimum around this frequency. As the frequency moves farther from 10.1 GHz, the SWR increases, causing the efficiency of energy transfer between the source and load to become less and less efficient.

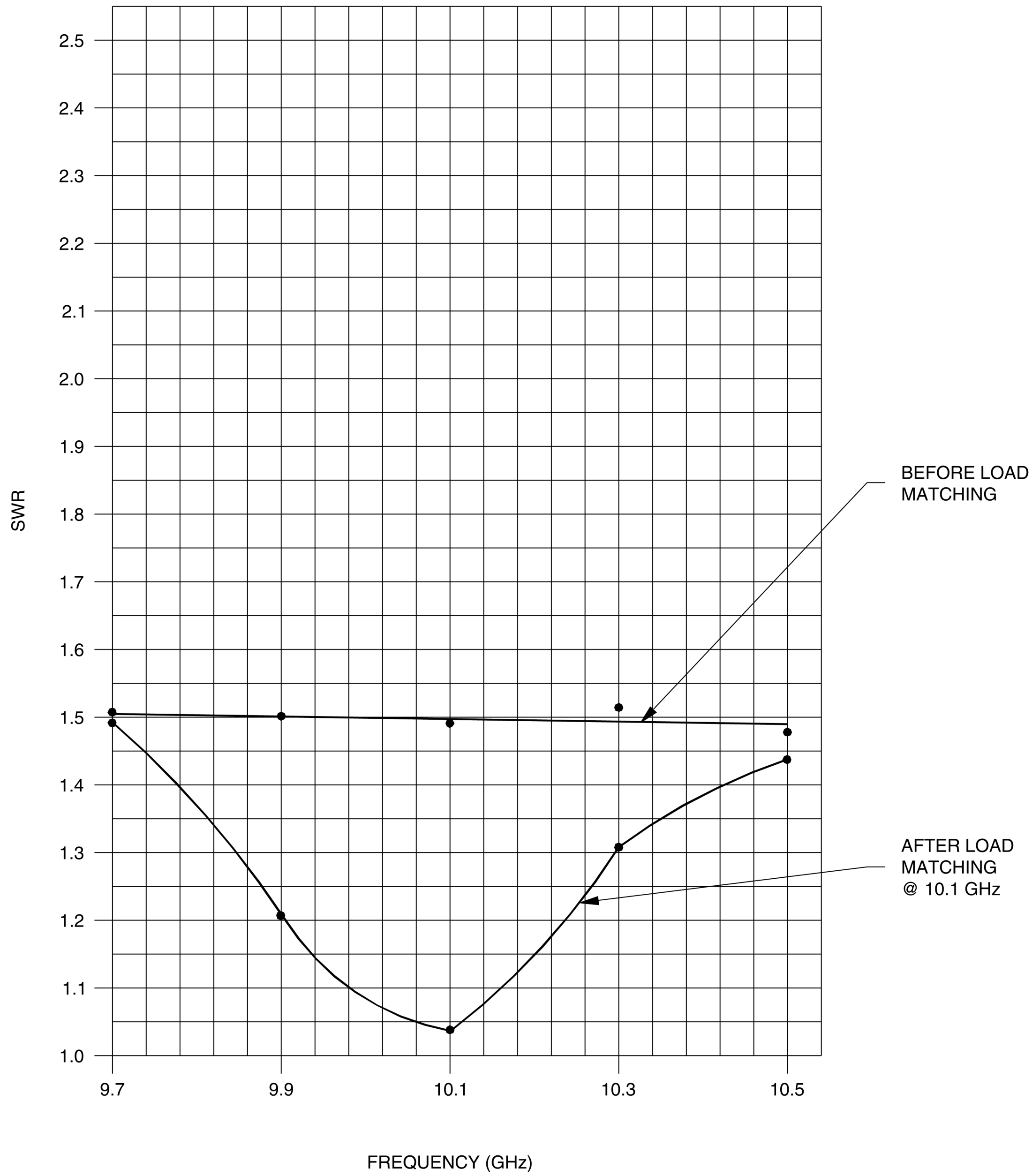

Figure 2-12. SWR-versus-frequency curve before and after load matching.

ANSWERS TO REVIEW QUESTIONS

1. a. The mechanical method: the frequency is changed by using a mechanical tuning device. The following oscillators use this tuning method: the Gunn oscillators (low power), the reflex klystrons (high power), and the magnetrons (high power).

b. The electronic method: the frequency is tuned electronically. The following oscillators use this tuning method: varactor-tunable Gunn oscillators (narrow tuning bandwidth), the voltage-controlled oscillators, or VCO's (medium tuning bandwidth), and the Yttrium-iron garnet (YIG) oscillators (wide tuning bandwidth).

2. The VCO contained in the Lab-Volt Voltage Controlled RF Oscillator consists of an oscillator connected to a tank circuit. The tank circuit is an LC resonant circuit made of an inductor in parallel with a variable-capacitance diode (varactor).

   Any change in the DC voltage applied to the VCO will change the capacitance of the varactor. This, in turn, will change the resonant frequency of the tank circuit, thereby changing the frequency of the VCO output signal.

3. VCO's are used, for example, in the following applications: point-to-point/multipoint radio, test equipment and industrial controls, Satellite Communications (SATCOM), radar receivers, communication systems, countermeasure systems, clock recovery, etc.

4. To match out, or to cancel the reflections produced by the unmatched load, a slide-screw tuner was added upstream of the load and set to produce a parallel reactance. After impedance matching, the SWR was enhanced only around the frequency at which the load was matched (10.1 GHz).

5. To produce a microwave pulsed (on/off keyed) signal, the amplitude of the microwave signal is modulated by a square-wave signal of lower frequency. The modulation depth of the resulting modulated signal is equal to the power output ratio between the on and off states.