



## Two New Test Sets for SHF Measurements

SEE PAGE 4 FOR CONCLUSION OF "GOOD PRACTICE IN SLOTTED LINE MEASUREMENTS."

**R**ECENTLY, two new test sets have been developed for testing SHF receivers and transmitters.

Basically, these sets are signal generators with added circuitry for measuring external power levels and external frequencies. One of the sets, the Model 624A, covers a range from 8500 to 10,000 megacycles. The other set, Model 623B, can be obtained for any one of six frequency ranges\*.

5925 - 6225 mc	6850 - 7150 mc
6125 - 6425 mc	7125 - 7425 mc
6575 - 6875 mc	7425 - 7725 mc

Both sets are designed for general-purpose testing such as measuring receiver sensitivity, receiver selectivity, receiver and transmitter tuning, and transmitter power level. However, the design of the sets has been influenced by the particular use being made of the frequencies at which each set operates.

For example, the Model 624A is especially useful in testing radar transmitters and receivers, and includes a versatile pulser to facilitate such testing. The Model 623B has been designed for testing SHF relay stations such as are used in video and communications work.

Since many applications for the sets involve field use, the sets have been kept small and each housed in a convenient carrying case. For production and laboratory applications, the panels of the sets have been designed to fit standard relay racks when the instrument case is removed.

Other features that enhance the usability of the sets include: a high power output of one milliwatt, an accurate power output control system, and a precision frequency meter. A waveguide-coax adapter having a VSWR less than 1.25 is provided with each set.

### 8500-10,000 MC SET

The Model 624A Test Set is continuously tunable over a range from 8500 to 10,000 megacycles and provides a maximum output of at least one milliwatt over this range. The output attenuator is calibrated to be direct-reading. The frequency control is approximately calibrated; precise frequency settings are made with the aid of the internal frequency meter.

The general circuitry of the set

\*In some cases other ranges or wider bands can be supplied. Correspondence invited.

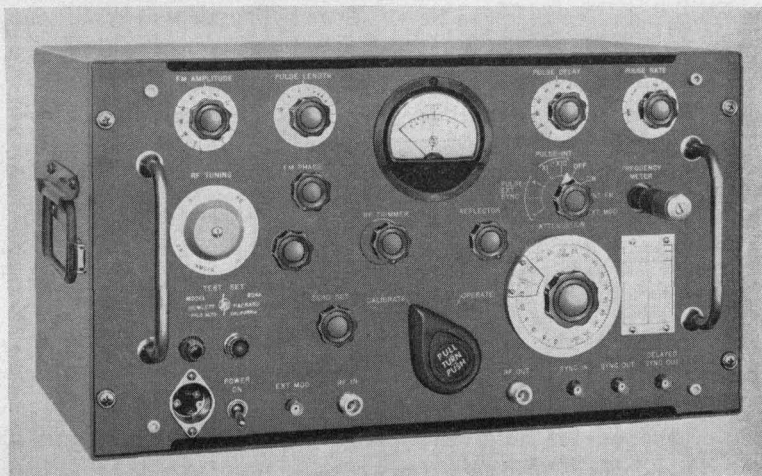


Fig. 1. -hp- Model 624A Test Set covers range from 8500 to 10,000 megacycles at maximum power output of 1 milliwatt. Instrument case includes a snap-on cover (not shown).

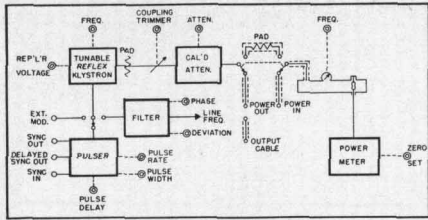


Fig. 2. Circuit block diagram of *hp-Model 624A Test Set*.

is indicated in Fig. 2. The oscillator operates with an associated modulator so that either pulsed or f-m output, as well as c-w, can be obtained. Following the oscillator is a 0-100 db attenuator calibrated in 1 db divisions, 0 db being taken as an output of 1 mw. The attenuator is followed by a coaxial switch that operates so as to connect the generated power either to a power meter and a frequency meter or to the Power Out jack. Such a switching arrangement permits the level of the oscillator output to be adjusted to a known reference level after which proper attenuation can be inserted to obtain the desired output level. At the same time the output frequency can be adjusted accurately by means of the frequency meter.

A separate panel jack is provided so that external power sources can be connected to the internal frequency and power meters. This feature is convenient for such purposes as measuring and adjusting the power output and frequency of transmitters.

The oscillator tube is a Varian V50 reflex klystron, selected because of its reduced sensitivity to frequency changes caused by temperature variations and its resistance to mechanical shock damage. The tube design includes an expanded tuning mechanism that gives relatively high resolution to the frequency control. Repeller voltage for the tube is adjusted by a panel control.

The modulating system provides for internal f-m or pulse modulation of the oscillator. Internal f-m occurs at the power line frequency, and controls are provided for adjusting the phase and deviation. A filter is

included in the internal modulating system in order to reduce the harmonic content of the power line voltage used for f-m, thus permitting the swept frequency to follow a smooth, symmetrical pattern. A maximum of at least  $\pm 7.5$  megacycles deviation is available on f-m operation.

The internal pulser generates modulating pulses that are adjustable by means of a direct-reading control over a range from approximately 0.25 to 10 microseconds. Considerable care has been taken to achieve a modulating pulse that has good waveform and to minimize deterioration of the pulse in the modulating system. The r-f pulse obtained on internal pulse modulation has a rise and a decay time that are each approximately 0.05 microsecond between the 10% and 90% amplitude points. The quality of the pulse is observable in the oscillogram of Fig. 3.

If desired, the internal pulser can be synchronized from external pulses, positive or negative, or from external sine waves over a range from 35 to 3500 pps. A synchronizing voltage of 5 volts peak is required on pulses, 5 volts rms on sine waves.

External voltages can also be used to frequency modulate the oscillator directly. A wide audio range can be used, approximately 1 volt per megacycle of deviation being required.

In addition to the modulating pulse generated by the internal pulser, the pulser generates a Sync Out and a Delayed Sync Out pulse for use with external equipment. The Delayed Sync Out pulse can be adjusted by a panel control to occur from less than 3 to 250 microseconds after the Sync Out pulse and is arranged to start coincidentally with the start of the output r-f pulse. Thus, the pulse delay control affects both the Delayed Sync Out and the output r-f pulses.

Both the Sync Out and Delayed Sync Out pulses have an amplitude

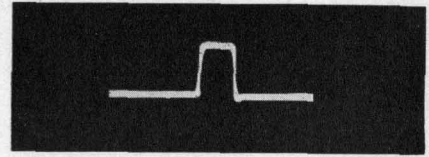


Fig. 3. Oscilloscope of typical r-f pulse (rectified) generated by *hp-Model 624A*. Pulse shown is of one-quarter microsecond duration.

greater than 10 volts across a parallel combination of 10,000 ohms and 100 mmf. The duration of the pulses is approximately 2 microseconds and rise time of each pulse is less than 0.5 microsecond.

The oscillator tube couples into a section of waveguide loaded with a length of lossy material that isolates the tube from the load. The waveguide section leading from the tube is rectangular in cross-section and is terminated with a piston-type attenuator circular in cross-section. To achieve an efficient coupling between these two systems, a special adaptation of an iris is used. Usually, an iris in a waveguide is used as a frequency-selective device having characteristics similar to a parallel-resonant circuit shunting the waveguide. In the Model 624A, the iris is located at the opening of the attenuator and is shunted by a cylindrical pillar, which is mounted on a threaded shaft so as to be tunable. This arrangement allows the spacing of the iris to be changed when frequency is changed, so that optimum coupling between the rectangular waveguide and the circular attenuator can be obtained at all frequencies within the range of the instrument. The tunable iris has an efficiency of power transfer of approximately 50% compared with 10% or less achieved by conventional methods.

The frequency meter is a reaction type giving a minimum dip in power of at least 2 db at its resonant frequency. The meter is provided with a micrometer drive and is calibrated to be accurate within 0.03% at an ambient temperature of 25° C. Correction data is provided for using the meter at other temperatures.



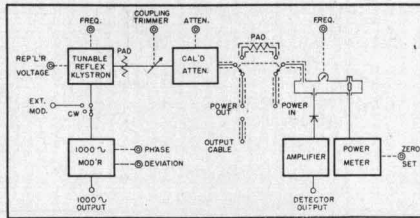


Fig. 4. Circuit block diagram of *hp*-Model 623B Test Set.

The power meter is a two-thermistor d-c bridge in which thermistors are used to compensate for temperature and sensitivity drift. The power-absorbing element itself is also a thermistor, which permits measurements of average power in both c-w and pulsed systems. Accuracy of the power meter on measurements of external power is  $\pm 1$  db.

The output system has been carefully designed to obtain good accuracy and is calibrated to indicate the power level at the end of the six-foot output cable provided with the set. However, when the oscillator reference level is being adjusted, the coaxial switch connects the output attenuator directly to the power meter through a length of cable significantly shorter than the output cable. This difference in cable length is corrected in the switching circuit by use of a fixed pad whose loss is adjusted to be equal to the loss in the output system.

Special precautions have also been taken in the output system to minimize errors caused by reflection from the various connectors. The number of connectors has been held to a minimum by special switch design, and in most cases the supporting beads in the connectors have been redesigned for low reflection.

In production units, the output system is accurate within 2 db at levels below  $-10$  dbm when operated into a matched system. Combined with this accuracy, the sets have the conveniences of a direct-reading output system and a switch for checking and setting reference level.

The power meter has a maximum reading of 2 milliwatts, sufficient to

permit the usual low-power system to be read directly. With medium-power systems having average powers in the order of 1 watt, a 20- or 30-db directional coupler or attenuator can be used to reduce the transmitter power to the range of the meter. With transmitters having higher average powers, directional couplers with lower coupling can be used.

#### MODEL 623B

The Model 623B Test Set has been designed principally for use in testing communications and video relay station equipment where a given system handles a band of frequencies less than 300 megacycles wide. The set is valuable for testing relay equipment both in the field and in production work.

A block diagram of the set is shown in Fig. 4. In general, the circuit is similar to that of the Model 624A

described above, except that a pulser is not included. However, the set is arranged so that it can be pulse- or square-wave modulated from an external source. An external voltage of approximately 30 volts peak-to-peak is required. External square-waves having frequencies from 60 cps to 10 kc can be used.

Where the Model 624A has an internal pulser, the Model 623B has a 1000-cps sine-wave generator that can be used to f-m the oscillator. Deviations of at least  $\pm 15$  megacycles can be obtained at all frequencies, and phase and deviation controls are provided. The circuit is further arranged so that the 1000-cps voltage used for f-m is available from a separate terminal for external use. From this terminal approximately 5 volts rms can be obtained across an external 5000-ohm load.

Depending upon the frequency

#### SPECIFICATIONS MODEL 623B TEST SET

**FREQUENCY RANGE:** Supplied in any one of six ranges:

5925 - 6225 mc	6850 - 7150 mc
6125 - 6425 mc	7125 - 7425 mc
6575 - 6875 mc	7425 - 7725 mc

**OUTPUT RANGE:** 0 dbm (1 mw) to  $-60$  dbm into 50-ohm load. Direct-reading output control. Type N coaxial output jack.

**OUTPUT ACCURACY:** Within 2 db from 0 to  $-70$  dbm into matched load.

**INTERNAL MODULATION:** F-m from 1000-cps internal source; phase and deviation adjustable; maximum deviation at least  $\pm 15$  mc.

**EXTERNAL MODULATION:** Type BNC panel jack provided for modulation by external voltages. F-m modulation over frequency range from 50 cps to 10 kcs. Pulse-modulation by external positive pulses of 30 volts peak.

**POWER METER:** 2 mw full scale. Type N input jack. Accurate within 1 db.

**DETECTOR OUTPUT:** Power meter circuit includes crystal detector so that rectified output can be obtained when f-m or pulse power is applied.

**FREQUENCY METER:** Calibrated from 5825 to 7725 mc. Accurate within 0.03% at 25° C. Temperature correction data supplied.

**POWER SOURCE:** Operates from nominal 115-volt, 50/60 cps supply. Requires approx. 150 watts.

**ACCESSORIES SUPPLIED:** 1½" x ¾" waveguide to type N adapter having VSWR less than 1.25. Special 6' measured output cable and detachable power cable also supplied.

**DIMENSIONS:** 20" w x 11½" h x 14" d.

**WEIGHT:** Approx. 52 lbs.; shipping weight, approx. 88 lbs.

Price and delivery upon request.

#### SPECIFICATIONS MODEL 624A TEST SET

**FREQUENCY RANGE:** 8500 to 10,000 megacycles. Frequency dial provided with approximate calibrations.

**OUTPUT RANGE:** 0 dbm (1 mw) to  $-100$  dbm into 50-ohm load. Type N coaxial output jack.

**OUTPUT ACCURACY:** Within 2 db from  $-10$  to  $-100$  dbm into matched load.

**INTERNAL MODULATION:** Pulse or f-m.

**PULSE MODULATION:** Pulse length variable from approx. 0.25 to 10 microseconds. Pulse rate variable from 35 to 3500 pps.

**EXTERNAL SYNCHRONIZATION:** Internal pulser can operate free-running or synchronized from external pulses of 5 volts peak, positive or negative, or sine waves of 5 volts rms. Type BNC panel jack provided for external sync pulse.

**F-M:** Internal f-m at power line frequency.  $\pm 7.5$  mc deviation obtainable. Can also be f-m modulated by external voltages from 35 to 3500 cps.

**TRIGGER PULSES:** Two provided; one coincident with start of output r-f pulse; second is from 3 to 250 microseconds ahead of output r-f pulse as determined by panel control. Both pulses are positive and provided at BNC panel jacks.

**POWER METER:** 2 mw full scale. Accurate within 1 db. Type N input jack provided.

**FREQUENCY METER:** Covers complete range of set. Accurate within 0.03% at 25° C. ambient. Temperature correction data supplied.

**POWER SOURCE:** Operates from nominal 115-volt, 50/60 cps supply. Requires approx. 200 watts.

**ACCESSORIES SUPPLIED:** 1" x ½" waveguide to type N adapter having VSWR less than 1.25. Special 6' measured output cable and detachable power cable also supplied.

**DIMENSIONS:** 20" w x 11½" h x 14" d.

**WEIGHT:** Approx. 56 lbs.; shipping weight, approx. 92 lbs.

Price and delivery upon request.

Data subject to change without notice.

range of the particular set, the oscillator in the Model 623B uses one of six reflex klystrons of the Varian X26 series. A maximum power output of at least 1 milliwatt is available at all frequencies, although sufficient margin is provided so that 2 milliwatts are usually available. The oscillator power is coupled to the attenuator by means of a tunable iris similar to that in the Model 624A. The tuning control for the oscillator is calibrated every 50 megacycles. The attenuator has a range of 70 db and is calibrated in 1 db steps.

The frequency meter in this set is also a reaction type and is calibrated over the complete 5825 to 7725 megacycle range. Thus the test set can be used with relay equipment where a transmitter operates at a substantially different frequency from the receiver. As part of the frequency meter in the Model 623B an easily-replaced desiccant is included to minimize humidity effects.

The power meter-frequency meter section in the Model 623B is designed to include a crystal detector arranged so that a rectified output is

available at a panel jack. By connecting the output of this jack to the vertical deflection system of an oscilloscope and sweeping the horizontal system with the 1000-cps output mentioned earlier, the f-m deviation can be examined and adjusted accurately using the notch caused by the frequency meter. When measuring power in pulsed systems, the rectified output can be applied to an oscilloscope in order to examine pulse details.

*Development of the Models 623B and 624A is due to Messrs. Arthur Fong, G. S. Kan, and P. D. Lacy.*

## Good Practice in Slotted Line Measurements (Conclusion)

### LOW VSWR's (Continued)

Accurate measurement of the position of the minimum, when the VSWR is low, becomes difficult because of the broadness of the minimum. When the precise location of the minimum is desired, it is helpful to establish points on each side of the minimum that have the same value. By averaging the location of these points, the minimum can be located with greater accuracy than with a direct measurement. The locations of equal-amplitude points are more easily established because of their higher slope.

### MEASUREMENTS

The two types of quantities that are actually measured with the slotted line are the voltage standing-wave ratio and the physical location of minima. This information permits the magnitude and phase of the load to be calculated or to be plotted on a transmission-line calculator.

To obtain the impedance of the load, the VSWR can first be measured. Then, the distance (in cm) between two adjacent minima can be determined. Most slotted lines are equipped with an accurate scale and indicator for this purpose. This measurement will give the length in the line or waveguide of a half wavelength.

Next, the location of a convenient

minimum should be measured accurately, although this will have more or less been done in the preceding measurement. Then, the load should be shorted and the amount of shift in the location of the minimum should be measured with the scale.

Next, the electrical length of the shift in the minimum can be calculated from the expression

$$\pm L = \frac{(\text{shift in cm})}{(\text{half-wavelength in cm})} \times 180 \text{ degrees}$$

If the minimum is shifted toward the load when the load is shorted, L should be assigned a + value; if toward the generator, L should be assigned a - value.

The impedance of the load can then be calculated from the expression

$$Z_1 = Z_0 \left( \frac{1 - j(\text{VSWR}) \tan L}{\text{VSWR} - j \tan L} \right)$$

These calculations are based upon the assumption that no losses occur in the transmission system. For laboratory set-ups where the line lengths are short, this assumption is customary. It is also assumed that the  $Z_0$  of the lines is entirely resistive. Some rules-of-thumb that are helpful in making slotted-line measurements are:

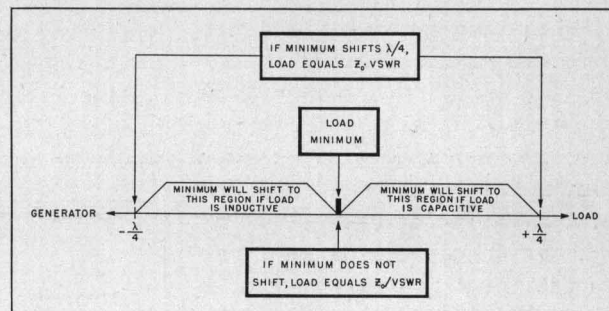


Figure 7. Diagram illustrating shift in minimum when shorting various loads.

(1) The shift in the minimum when the load is shorted is never more than  $\pm$  one-quarter wavelength.

(2) If shorting the load causes the minimum to move toward the load, the load has a capacitive component.

(3) If shorting the load causes the minimum to shift toward the generator, the load has an inductive component.

(4) If shorting the load does not cause the minimum to move, the load is completely resistive and has a value  $Z_0/\text{VSWR}$ .

(5) If shorting the load causes the minimum to shift exactly one-quarter wavelength, the load is completely resistive and has a value  $Z_0 \cdot \text{VSWR}$ .

(6) When the load is shorted, the minimum will always be a multiple of a half-wavelength from the load.

-W. B. Wholey