



## Recent Developments in -hp- Waveguide Type Measuring Equipment

THE February, 1951, issue of the *Journal* announced the -hp- program for a complete series of waveguide measuring equipment to cover the frequency range from 2600 to 18,000 megacycles. At that time the Model 810 interchangeable slotted sections, the Model 442 and 444 probes, and the Model 440 detector mount were described. The succeeding issue described the Model 485 detector mounts, the Model 370 fixed attenuators, and the Model 912 high-power terminations.

Since those issues were published, a number of other items have been put into production. In addition, considerable interest has been shown in the Model 444 untuned probe and Model 806B coaxial slotted section, and pertinent application data regarding these devices will be presented here.

### UNTUNED PROBE

A realistic measure of electrical quality for an r-f probe designed for slotted line work is the relation of probe rectified output to loading on the line caused by the probe.\* However, since probe output is obtained at the expense of extracting energy from the line, the characteristics of probe output and

loading are interdependent. To obtain high probe output, then, the designer must construct a probe having high efficiency; that is, a probe having maximum output for a given loading effect on the line.

In tuned type probes the probe tuner increases the efficiency of the probe by adjusting the match between the probe antenna and the detector element. From an operational standpoint, however, a tuned probe is inconvenient to use. If the probe is a single adjustment type, the probe must be retuned for each change of frequency. If the probe is a two-adjustment type, not only must the probe be retuned when frequency is changed but the tuning operation itself is often difficult. Consideration of these factors led to a decision to design the Model 444A as an untuned probe. To accomplish such a design, it becomes necessary to make the probe as efficient as possible.

Since no tuner was to be incorporated in the probe, it was extremely important that residual reactances between the probe antenna and the probe detector element be held at a minimum. This was achieved by locating the detector element unusually close to the antenna and by using a type 1N26 silicon crystal whose construction was more suitable than other types for the purpose. As a result of this design, the rectified output of the Model 444A was high, relatively constant over wide r-f frequency ranges, and did not exhibit the large peaks and troughs common with conventional probes.

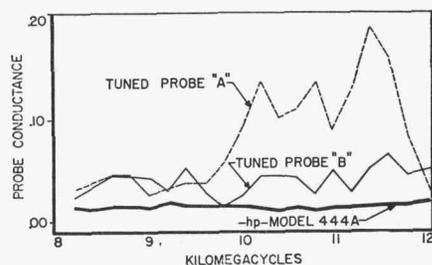


Fig. 1. Comparison of probe loading at constant penetration for -hp- Model 444A untuned probe and for two tuned probes.

\*For a description of probe loading effects, see "Good Practice in Slotted Line Measurements," Hewlett-Packard Journal, Vol. 3, Nos. 1 and 2, September and October, 1951.

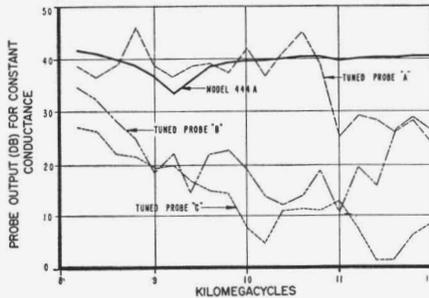


Fig. 2. Comparison of normalized output for several waveguide probes.

When making slotted line measurements, it is desirable that loading on the line caused by presence of the probe be minimized. However, since the output of probes commonly exhibits large peaks and troughs even though probe penetration is held constant, it is to be expected that probe loading will also vary widely with frequency. While probe loading can be measured, the measurement is tedious and seldom made in practice. Fig. 1 shows probe loading at a representative antenna penetration for the Model 444A and for two conventional tuned probes. It can be seen that loading by the untuned probe is both small and constant. These characteristics enhance the accuracy of slotted line measurements, for one type of variable is eliminated for all practical purposes.

Fig. 2 is a plot of the measure of quality of several probes, including the Model 444A. The ordinate in Fig. 2 represents probe output normalized for each probe at each frequency for a constant loading conductance. From this data it can be seen that the untuned Model 444A compares very favorably with tuned probes of the best design. At the same time the Model 444A has the desirable features of constant output with frequency, constant loading for a fixed penetration, and no necessity for tuning. The data presented show the operation of the probe over the 8 to 12 kmc range; however, it can be used with equal efficiency over the 2.4 to 8 kmc range.

#### COAXIAL SLOTTED LINE

In an ordinary coaxial system where connections are made with

flexible cable and type N connectors, it is usually impractical at frequencies above a kilomegacycle or so to measure the VSWR of devices that have a low VSWR of less than about 1.1. This limitation arises from the fact that type N connectors and coaxial cables themselves have rather high VSWR's (Fig. 3) which obscure the VSWR of the device to be measured. For example, it is difficult to measure a device having a VSWR of 1.1 when the system itself has a VSWR of 1.2.

In spite of this general limitation, there are many applications where measurements are desired of coaxial devices with low VSWR's. For this reason, much work has gone into the design of all of the *-hp-* coaxial slotted sections to achieve a low residual VSWR. Thus, the VSWR of the Model 805A slotted section is less than 1.04 below 4000 mc, while the Model 806B VSWR is less than 1.06 below 10,000 megacycles.

In each of these slotted sections, the specified VSWR includes the reflections caused by the connector provided on the end of the section. However, to make practical use of the low specified VSWR, it is necessary to take special precautions when connecting the device to be measured to the connector on the slotted section. In general, these precautions consist of using a specially-made connector and a section of rigid line if a connecting line is necessary.

The guiding philosophy in the design of the *-hp-* coaxial slotted sections has been to equip the sections with a connector that will have improved performance and that will mate with a type N connector, since the type N is more or less an industry standard. Before describing the construction of the improved connector, consider Fig. 4 which shows the internal dimensions of two type N connectors of the "B" series. Several constructional features of these connectors cause reflections that are substantial in magnitude from the standpoint of laboratory measure-

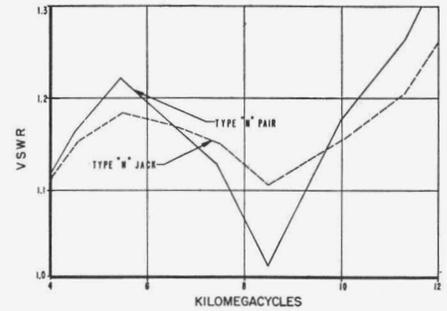


Fig. 3. Measured VSWR of type N plug and of connected plug and jack, all of "B" series.

ments where, ideally, a completely flat system is desired. First, a source of substantial reflection in each connector is the bead that supports the center conductor. Next, a gap occurs between the two portions of the center conductor when the parts are connected. This gap is partially compensated by the use of a capacitive ring in the outer conductor, but the width of the gap depends on the assembly technique used with the connectors. Also, the gap compensation is designed to be most effective at certain frequencies. Another feature causing reflections is that the center pin of the plug does not expand the center contact of the jack to the full diameter of the center conductor, there being a step of some 0.006". Other features causing reflections include the presence of slots in the center contact of the jack and the step that occurs in the outer conductor owing to compression of the plug outer conductor.

The *-hp-* coaxial slotted sections are provided with a plug at one end and a jack at the other. In the center contact of the jack the slots have been shortened and the diameter of the hole in the center contact has been made the same as the diameter of a plug center pin so as to avoid the 0.006" step. In the plug the diameter of the center pin has been increased to expand the center contact of a mating jack to full size to avoid the center conductor step. There remains then the matter of the gap. Eliminating this gap improves the performance of the connectors. Hence, the capacitive ring on the plug end of the sections, has been removed to allow for a no-gap con-

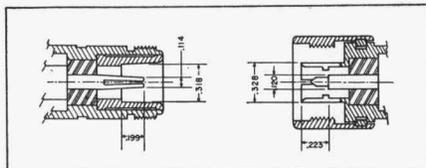


Fig. 4. Simplified cross-section of type N ("B") plug and jack.

nection if desired.

In order to obtain a no-gap joint in the center conductor when connecting to the line, it is necessary that the connector to be attached to the slotted section be assembled with accurately-held axial dimensions. This is difficult, and it usually becomes desirable to construct a combined connector and rigid line so that conductor dimensions can be held accurately. To facilitate construction of this line, both the Model 805A and 806B are marked to show the set-back of the center conductor in thousandths of an inch from the end of the line. Information for constructing the line and modified connector is given in the equipment instruction manual.

Such a rigid line is used in production-testing the Model 806B 3000-12,000 mc slotted section. The line is terminated with a low-VSWR load constructed in such a way as to be movable in the line. By moving the load, the small reflections from the connectors on the line can be isolated from reflections from the movable load.

The result of using the rigid line and modified connector with the 806B is shown in Fig. 5, which is a plot of the measured residual VSWR of thirty production slotted sections. From this it can be seen that very good results are obtainable with the Model 806B at frequencies as high as 12,000 megacycles.

It should be emphasized that the foregoing steps are useful only when best performance is required such as when measuring low-VSWR devices. In other cases standard type N connectors can be used.

#### ADJUSTABLE SHORTS AND E-H TUNERS

A series of adjustable shorts and E-H tuners are in production in five

waveguide sizes that collectively cover a range from 2,600 to 18,000 megacycles. Each of these devices uses a contacting type short, selected for its freedom from spurious responses and for high electrical and mechanical performance.

The quality of the contacting short is such that the loss in the short is very small. For example, at 10,000 megacycles, the loss in the contacting short is less than 0.01 db over that introduced by a carefully-made fixed short. This loss is less than the conductor loss in a few inches of waveguide. Thus, the percentage reflection from the short is not limited by the short but by the system itself. To achieve comparable performance from a choke type non-contacting short over broad frequency ranges requires costly machining because of prohibitive tolerances.

The contacting shorts are constructed from sheet beryllium copper fingers on which are mounted solid silver overlay contacts. The contacts are lapped after final assembly to obtain a flat contacting surface. The walls of the waveguide section in which the short operates are plated with a thick silver layer. As a result of this type of construction, the short shows no increase in loss after 25,000 cycles of operation.

E-H tuners are used to flatten waveguide systems so as to achieve maximum power absorption by the load. However, E-H tuners themselves have a loss owing to high current flow in the shorted arms although the -hp- Model 880A E-H tuners have lower than usual loss. The loss is approximately proportional to the VSWR tuned out and is less than 2 db at a VSWR of 20. The operation of the tuner will reduce a VSWR of 20 to less than 1.02.

#### FREQUENCY METERS

Reaction type frequency meters have been developed and are in production for  $1\frac{1}{2}'' \times \frac{3}{4}''$ ,  $1\frac{1}{4}'' \times \frac{5}{8}''$ , and  $1'' \times \frac{1}{2}''$  sizes of waveguide. These frequency meters consist of a tunable cavity coupled at the side of a

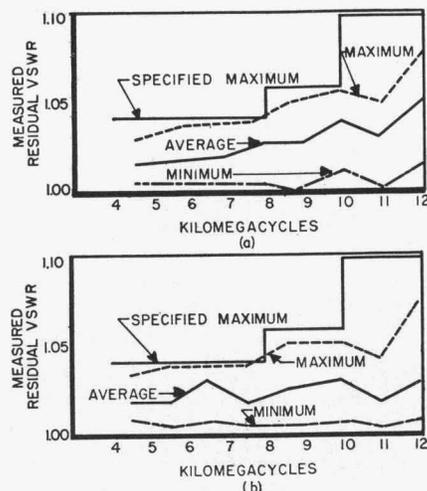


Fig. 5. Summary of residual VSWR of thirty -hp- Model 806B coaxial slotted sections. Solid line shows average VSWR; dashed lines show extremes. (a) is for jack end of line, (b) for plug end.

waveguide section. The coupling is arranged so that the reflection at meter resonance, plotted as a function of frequency, is relatively constant throughout the specified frequency range. The reflection from the meters is approximately 20% at the resonant frequency and the meters are otherwise free of spurious responses in their specified range.

The drive system for the meters consists of a micrometer for which a standard calibration chart is mounted on the meter. The chart is accurate within 0.1% over wide temperature and humidity ranges. Each meter is also provided with a sheet showing the results of the frequency checks measured at the factory. Data for interpolating between check points are also included.

#### WAVEGUIDE-COAX ADAPTERS

A series of five waveguide-to-coax adapters has been developed to cover the 2,600 to 12,400 megacycle range. These adapters consist of a shorted section of waveguide into which is connected a coaxial fitting terminated with a capacitive probe. A sheath of dielectric material surrounds the probe.

In the design of the adapters emphasis has been placed on achieving a favorable impedance match over a complete waveguide range of frequencies. The factors having great

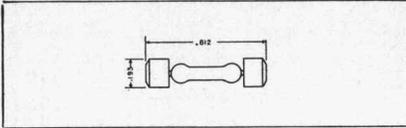


Fig. 6. Recommended overall dimensions and diameter of terminals for mounting W. E. type D166382 glass-insulated bead thermistor in -hp- Model 485 detector mounts.

est significance in the performance of the adapters are the insertion depth of the probe into the waveguide, the diameter of the probe, the diameter of the dielectric surrounding the probe, the distance from the probe to the shorted end of the waveguide section, and the existence of discontinuities in the coaxial portion of the adapter. Each of these five factors has been investigated, and by suitable selection of values both the shape and position of the impedance loci of the adapters have

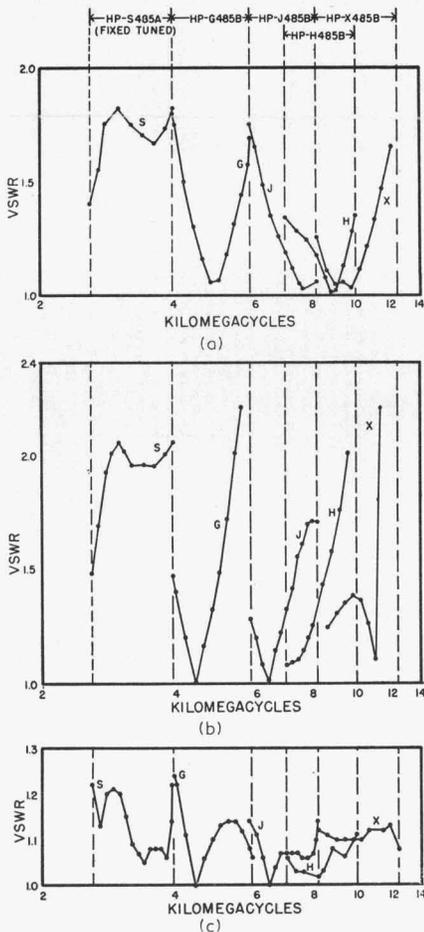


Fig. 7. Measured VSWR curves of -hp- Model 485 detector mounts using (a) W. E. type 23A bead thermistor soldered in barretter cartridge, (b) W. E. type D166382 thermistor mounted as recommended in Fig. 6, (c) Sperry 821 barretter. All detector elements were operated at 200 ohms.

been adjusted to achieve the most desirable characteristics.

Production adapters have a VSWR within 1.25 over a complete waveguide range of frequencies. This measurement represents the performance of the adapter itself and was made in design work by the null shift method. In production measurements the adapters are checked by using the specially-designed movable load described above. By using this load reflections from the adapter can be isolated from any load reflections.

#### USE OF THERMISTORS IN DETECTOR MOUNTS

The -hp- Model 485 mounts were designed as a means for detecting microwave powers and for measuring power levels in waveguide systems. The Model 485B mounts are provided in four waveguide sizes that cover a range from 3,950 to 12,400 megacycles. These mounts are tunable by means of an adjustable waveguide short located behind the detector element. Another mount, the Model S485A, for use with 3" x 1 1/2" waveguide over the 2,600 to 3,950 megacycle range, is fixed tuned and is designed to use a Sperry 821 barretter. The Model 485B mounts were designed to use either a silicon crystal or an 821 barretter. In all five of these mounts, however, bead type

thermistors can also be used so as to measure average power in pulsed systems, although a suitable contact arrangement must be provided for the thermistor.

A suggested method for mounting a capsule-enclosed bead thermistor is indicated in Fig. 6. An uninsulated thermistor such as the Western Electric 23A can be mounted in the cartridge of a burned-out barretter by opening the window provided in the cartridge.

Representative VSWR curves for the detector mounts when using thermistors operated at 200 ohms are shown in Fig. 7. It will be seen that somewhat better general performance is obtained using the uninsulated rather than glass-mounted type thermistor. The performance of the mounts when using an 821 barretter is shown in Fig. 7(c).

These VSWR curves show that the power loss caused by mismatch of the mounts is small. For example, a VSWR of 1.2 corresponds to a mismatch loss of approximately 0.1 db, while a VSWR of 2 corresponds to a loss of approximately 0.5 db. These figures assume that the generator is "flat." If the source is not flat or if optimum performance is desired, an E-H or slide-screw tuner can be inserted in the system ahead of the detector mount.

—J. K. Hunton  
and N. B. Schrock

#### SPECIFICATIONS

##### -hp- MODEL 281A WAVEGUIDE-COAX ADAPTERS

VSWR: 1.25 maximum.  
COAXIAL CONNECTOR: Type N jack.  
FREQUENCY RANGES AVAILABLE:  
Model S281A: 2.6-3.95 kmc (3"x1 1/2"). \$75.00  
Model G281A: 3.95-5.85 kmc (2"x1"). 55.00  
Model J281A: 5.85-8.2 kmc (1 1/2"x3/4"). 50.00  
Model H281A: 7.05-10 kmc (1 1/4"x5/8"). 45.00  
Model X281A: 8.2-12 kmc (1"x1/2"). 35.00  
(Dimensions in parentheses indicate waveguide sizes)

##### -hp- MODEL 530A FREQUENCY METERS

ACCURACY: Within 0.1% over wide range of temperature and humidity.  
REFLECTION: Approximately 20% at resonant frequency.  
FREQUENCY RANGES AVAILABLE:  
Model J530A: 5.85-8.2 kmc (1 1/2"x3/4"). \$120.00  
Model H530A: 7.05-10 kmc (1 1/4"x5/8"). 120.00  
Model X530A: 8.2-12.4 kmc (1"x1/2"). 120.00  
(Dimensions in parentheses indicate waveguide sizes)

##### -hp- MODEL 806B COAXIAL SLOTTED SECTION

FREQUENCY RANGE: 3 to 12 kmc.  
RESIDUAL VSWR: Less than 1.04 below 8 kmc, less than 1.06 from 8 to 10 kmc, less than 1.1 from 10 to 12 kmc.  
CONNECTIONS: Type N (one male, one fe-

male) modified to provide low VSWR. Either end can be connected to load. Male and female shorting connectors for use in impedance measurements also provided.  
PRICE: \$200.00 f.o.b. Palo Alto, California.  
(Also requires probe and -hp- 809B carriage)

##### MODEL 880A E-H TUNERS

VSWR RANGE: Will reduce VSWR's up to 20 to less than 1.02.  
INSERTION LOSS: Varies with VSWR; loss is less than 2 db at VSWR of 20.  
FREQUENCY RANGES AVAILABLE:  
Model S880A: 2.6-3.95 kmc (3"x1 1/2"). \$175.00  
Model G880A: 3.95-5.85 kmc (2"x1"). 155.00  
Model J880A: 5.85-8.2 kmc (1 1/2"x3/4"). 145.00  
Model H880A: 7.05-10 kmc (1 1/4"x5/8"). 135.00  
Model X880A: 8.2-12.4 kmc (1"x1/2"). 130.00  
Model P880A: 12.4-18 kmc (.702x.391") 135.00

##### -hp- MODEL 920A ADJUSTABLE SHORTS

FREQUENCY RANGES AVAILABLE:  
Model S920A: 2.6-3.95 kmc (3"x1 1/2"). \$80.00  
Model G920A: 3.95-5.85 kmc (2"x1"). 70.00  
Model J920A: 5.85-8.2 kmc (1 1/2"x3/4"). 65.00  
Model H920A: 7.05-10 kmc (1 1/4"x5/8"). 60.00  
Model X920A: 8.2-12.4 kmc (1"x1/2"). 50.00  
Model P920A: 12.4-18 kmc (.702x.391") 55.00  
(Dimensions in parentheses indicate waveguide sizes)

Prices f.o.b. Palo Alto, Calif.  
Data subject to change without notice.