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Nothing Replaces the Slotted Line

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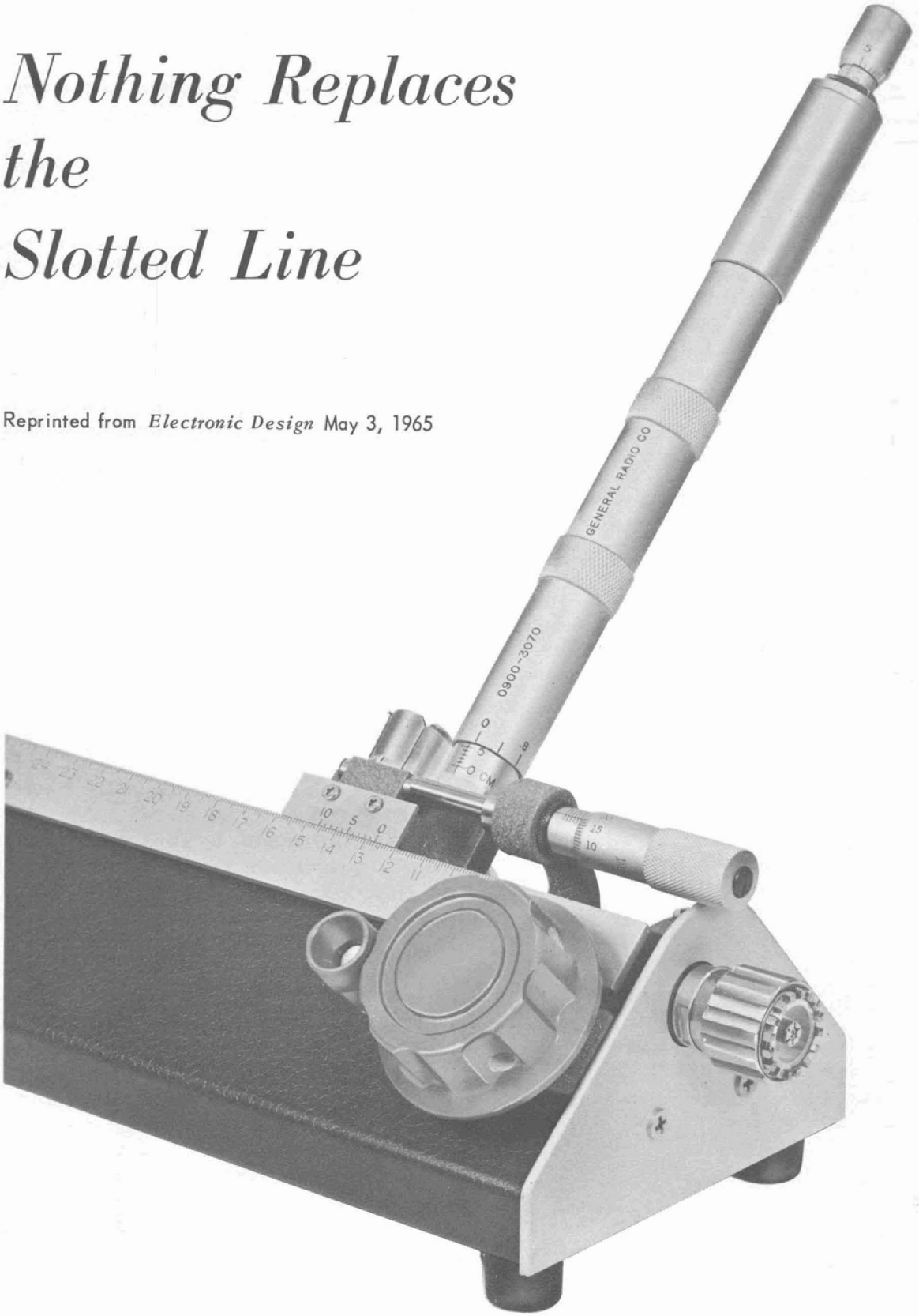


Nothing Replaces the Slotted Line

Frederick Van Veen

THE SLOTTED LINE remains the basic instrument for standing-wave microwave measurements, such as impedance, phase, vswr and reflection coefficient.

It is a section of coaxial or waveguide transmission line, with a longitudinal slot cut into its outer wall to permit the insertion of a probe. The probe, which is usually mounted on a movable carriage, travels the length of the line to explore the electromagnetic field inside. A detector and meter, connected to the probe, indicate the relative voltage or current magnitudes along the line.

What to Look For In Picking a Slotted Line

Any irregularities on the inside wall surfaces of the outer conductor, or on the outside of the inner conductor will disturb the fields, and introduce errors in the measurements. Other sources of errors may be the connectors of coaxial slotted lines and noisy detectors. So, if you are on the verge of buying a slotted line, it would be a good idea to consider these factors:

- Residual vswr.
- Flatness or slope.
- Frequency range.
- Connector series.
- Accessories available.

Residual vswr is usually the first specification you should look at, for this is the fundamental measure of a line's accuracy. In practice, this figure is determined chiefly by the connector and by any transitions, as, for instance, from a slab-type line to its coaxial connector.

A serious shortcoming of this specification with many coaxial slotted lines is that it is based on measurements made with a uniquely matched load through a custom-built connector. Precision slotted lines, on the other hand, are calibrated in terms of generally available air-line impedance standards.

Flatness (sometimes called "slope") refers to the constancy of probe coupling as a function of the probe's position on the line. While flatness is itself independent of frequency, its effects are not. The lower the frequency, the greater the portion of slotted line that must be used, and thus the greater the over-all effect of any departures from flatness. At the high end of the line's frequency range, only a very small section is normally used, and flatness is less of a consideration.

The frequency range is obviously a critical factor in finding a proper line. The low frequency limit of the slotted line is the frequency at which its length equals a half wavelength. (Low-frequency coverage can, however, be extended by the addition of air-line sections.) The high-frequency limit, a function of line size, is the frequency at which the coaxial line begins to propagate higher order modes.

The coaxial slotted line is a very broadband instrument, and engineers should have no trouble in selecting a single slotted line to cover the frequency range in which they are working.

The connector series used on the slotted line is important. It is hard to predict what connectors one will encounter in the laboratory; the availability of adaptors from the slotted line's connector to other coaxial series could be a significant factor. For example, a set of precision adaptors from the slotted line's connector to types N, TNC, and BNC in effect gives the user several slotted lines for the price of one. It is also a good idea to find out just what other coaxial elements (terminations, air lines, ells, tees, etc.) are available in the connector series used by the slotted line. The slotted line is, after all, usually surrounded in a measurement setup by auxiliary equipment, and if there's one thing better than a drawerful of adaptors, it's a drawerful of components for which you don't need any adaptors.

The accessories available should be checked over carefully by the prudent shopper. Among

1. **When shopping for a slotted line,** it is a good idea to keep an eye on the needed accessories. These may not be readily available, or may cost more if bought separately.

the more important items one may or may not find included are detectors, micrometer probe-position indicators, short- and open-circuit terminations, tunable probes, patch cords and a storage case (Fig. 1).

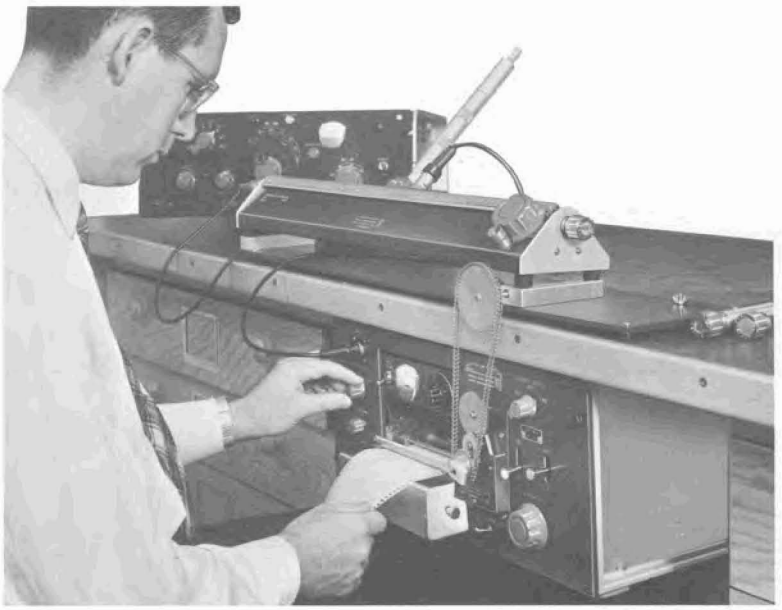
Precision Connectors and Recorders Enhance Value of Slotted Lines

The precision of slotted lines was considerably improved in recent years by two developments:

- Precision coaxial connectors.
- Recorders that can replace detectors.

The impact of the precision connector on coaxial slotted-line development cannot be overstated. Coaxial slotted lines are now capable of the same high performance as rectangular waveguide lines, but with bandwidths up to 30 to 1. Vswr measurements down to 1.001 are becoming routine. Second-order effects such as source mismatch, probe reflections, slope and line flatness can easily be taken into account and eliminated from the measurement results.

The recorder (Fig. 2) increased the resolution of measurements. For example, it is possible to detect variations in the vswr as small as 0.0002. ■ ■



2. **A slotted line becomes very precise** when a servo-type strip recorder is used for the readout. The chart effectively represents a 10-foot long conventional meter. The driving link of the recorder is designed to duplicate the position of the probe along the horizontal axis of the chart. The full scale vswr can be as small as 1.008, and it can vary as little as 0.0002 and still be detected.

Type 900-LB PRECISION SLOTTED LINE

USES: In the field of microwave impedance measurement, the slotted line is *the* fundamental instrument, because of its inherent accuracy, broadband characteristics, and phase-measuring capability. Of the several types of instruments commonly used to measure VSWR, only the slotted line gives the design engineer all the information he needs to evaluate the over-all performance of devices and networks over a wide band. Among the many parameters that can be determined by use of the slotted line are VSWR, reflection-coefficient magnitude and phase, impedance or admittance, insertion loss, and wavelength.

The most precise coaxial connector, the GR900, and a nearly perfect section of coaxial transmission line combine to give the TYPE 900-LB Precision Slotted Line unparalleled performance specifications. The residual VSWR of the instrument is that of its GR900 connector: $1.001 + 0.001\ f_{Gc}$. Equipped with the appropriate GR900 low-VSWR adaptor the TYPE 900-LB becomes a type N, BNC, TNC, C, or GR874 slotted line whose specifications still exceed those of slotted lines originally equipped with the other series (see curve below).

DESCRIPTION: The TYPE 900-LB is a slotted section of 14-mm (0.5625-in) coaxial transmission line whose characteristic impedance is very accurately known (50.0 ohms ± 0.1%). The outer conductor is precision-forged brass tubing lined with pure silver for low loss. The inner conductor is a precision-machined steel tube with a layer of silver. The true coaxial cross-section of the TYPE 900-LB allows reflectionless extension of the slotted section into the connector without gross diameter change or transition pieces.

The removable, barrel-type probe tuner, which includes precisely calibrated adjustments for probe penetration (in increments of 0.001 inch) and for detector resonance (300 Mc/s to 8.5 Gc/s), mounts on the movable carriage. Probe position with reference to the GR900 contact surfaces is indicated by a vernier scale with an accuracy of 0.1 mm ± 0.05%. A micrometer carriage drive, also supplied, extends resolution to 0.002 mm.

Accessories supplied with the slotted line include, in addition to the probe tuner already mentioned, short- and open-circuit terminations, patch cord, micrometer carriage drive, and a separate probe accessory for applications requiring a direct rf output.

The outstandingly low VSWR of the TYPE 900-LB should save users the many hours required to calibrate less accurate instruments. For those whose applications demand the ultimate in accuracy, the TYPE 900-LB can be calibrated against a TYPE 900-LZ Reference Air Line, an impedance standard with a VSWR under 1.0025 at 8.5 Gc/s. A TYPE 900-TUA or 900-TUB Tuner can be used to tune out small residual reflections.

SPECIFICATIONS

Characteristic Impedance: 50.0 Ω ± 0.1%.

Probe Travel: 50 cm. Scale calibrated in centimeters from reference plane. Attached vernier can be read to 0.1 mm, micrometer carriage drive (supplied) to 0.002 mm.

Scale Accuracy: ±(0.1 mm + 0.05%).

Frequency Range: 0.3 to 8.5 Gc/s. At 300 Mc/s, covers a half wavelength. Operates below 300 Mc/s with TYPE 900-L or -LZ Precision Air Line (page 102).

Constancy of Probe Pickup (Flatness): ±0.5%.

Residual VSWR: Less than $1.001 + 0.001\ f_{Gc}$ (e.g., 1.002 at 1 Gc/s). VSWR calibration data is supplied.

Repeatability: Within 0.05% (0.0005 in VSWR).

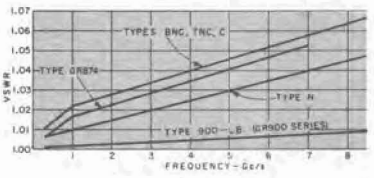
Dc Contact Resistance of Type 900-BT Connector: Inner conductor, less than 0.5 mΩ; outer conductor, less than 0.07 mΩ.

Accessories Supplied: TYPE 874-R22A Patch Cord; TYPE 900-WN Precision Short-Circuit Termination; TYPE 900-WO Precision Open-Circuit Termination; adjustable probe-tuner assembly; 1N21C and 1N23C detector diodes; rf probe accessory; micrometer carriage drive (accurate to 0.01 mm); attractive storage case; Smith charts.

Accessories Required: Generator and detector.

Dimensions: Width 27½, height 10, depth 4¾ in (700, 255, 125 mm).

Net Weight: 10¾ lb (4.9 kg). **Shipping Weight:** 34 lb (15.5 kg).



Combined VSWR specification of Type 900-LB Precision Slotted Line and type N, BNC, TNC, C, and GR874 adaptors. Bottom curve is VSWR specification of slotted line without adaptor.

Catalog No.	*Description*	*Price*
0900-9651	**Type 900-LB Precision Slotted Line**	**$800.00**

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