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A Broadband Noncontacting Sliding Short

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A Broadband Noncontacting Sliding Short

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A BROADBAND NONCONTACTING SLIDING SHORT

By

Wilbur Larson and Ronald D. Hunter

ABSTRACT

A new sliding short that eases microwave measurements also yields superior electrical and mechanical properties. Easily fabricated by encasing noncontacting cylindrical brass slugs in a block of polytetrafluoroethylene, the device slides smoothly and prevents metal-to-metal contact with the inside walls of precision waveguide.

Design details and results of intercomparing other short circuits are given.

Key words: microwave; reflection coefficient; return loss; sliding short; shorted termination; waveguide.

1. INTRODUCTION

Many microwave measurement systems require a sliding short circuit to perform specific tuning procedures. An improved sliding short developed at the NBS Boulder Labs reduces the calibration uncertainty of interlaboratory microwave standards.

By encasing cylindrical brass slugs in a block of polytetrafluoroethylene (PTFE), the sliding-short device exhibits superior electrical and mechanical properties. The mechanical PTFE carrier permits stable and precise positioning inside the waveguide, prevents metal-to-metal contact with the waveguide walls, and yields higher attenuation and flatter frequency response than existing dumbbell-type designs.

As well as being a basic waveguide component, the sliding short is an essential tuning element for making general microwave measurements. Specific applications employ it in tunable detector mounts and E-H tuners. The noncontacting sliding short is preferable to continuous-contact types currently employed throughout the microwave industry [1], [2], [3], [4].

As a modification of the so-called dumbbell-type traveling short, the improved sliding short-circuit element for waveguide retains the large cylindrical slugs but omits the axial connecting metal rod of the dumbbell. The new design, therefore, does not allow a continuous coaxial TEM-mode propagation along the dumbbell. It is believed that suppression of the TEM-mode propagation accounts for the improved electrical characteristics. In addition, this new design is easier to fabricate, and its dimensions are less critical than the dumbbell type.

2. NONCONTACTING SLIDING SHORT CIRCUITS

The sliding short described in this paper (fig. 1) is a noncontacting type having good stability. Moreover, the fabrication time is half that required for other types (figs. 2 and 3). The short fabricated as illustrated in figure 1 has three distinct features related to its compactness: (1) the length is reduced about half, (2) the precision-waveguide tuning section can be shortened, and (3) it operates in closer proximity to the tuning plane. Note that the earlier-type (fig. 2) use exposed brass slugs positioned in the waveguide. This type construction can damage precision waveguide walls, particularly large wave guides or where wall irregularities result in erratic scrubbing motions between the short and the waveguide. Also, metal-to-metal contact with the inner walls can induce large errors during tuning procedures or phase-shift measurements.

The noncontacting configuration, which encases the metal slugs in a PTFE carrier, prevents metal-to-metal contact with the waveguide, eliminates a conductive path between the three slugs, accomodates PTFE spacers between slugs, and provides mechanical stability during axial travel. The low static and dynamic coefficient of friction characteristic of PTFE, made it an ideal material for the application. The PTFE slugs that separate the brass slugs also maintain a constant spacing to insure stability.

3. THEORETICAL AND EXPERIMENTAL EVALUATION

A theoretical study accompanied by experimental spacings of dumbbell-type sliding short circuits has been reported by R. N. Assaly of MIT, Lincoln Laboratory [5], in which he varies the dimensions S, D, L, and d of a three-section sliding-short (fig. 4) with connecting rods. Assaly gave optimum values for D, S, L, and d based on attenuation.

At the NBS-Boulder Laboratories, two- and three-section brass dumbbells were milled to meet the optimum values of D, S, L, and d and were placed in PTFE blocks. Insertion-loss measurements of the respective sections, when placed in a matched WR112 waveguide system, agreed closely with the work at Lincoln Laboratory.

4. INSERTION LOSS OF TWO- AND THREE-SLUG SECTIONS

In the new NBS design, the slugs of brass are separated by PTFE slugs instead of brass connecting rods. The PTFE slugs were fabricated in a variety of thicknesses that accomodate a range of spacings between brass slugs (sec. 3, fig. 4).

To compare the quality of two- and three-section dumbbells versus two- and three-section cylindrical slugs, the insertion-loss of each section was measured in WR112 waveguide. Insertion-loss-versus-frequency plots over the WR112 wavguide band (fig. 5) indicate that the measured insertion loss of a two-section cylindrical slug is more than that of a dumbbell section, but exhibits slightly more frequency sensitivity than the latter. Note, however, that at the center frequencies the maximum insertion loss approaches the theoretical value [5] based on optimum separation of the cylindrical slugs for the dumbbell design.

Increasing the diameter of the cylindrical slugs slightly and decreasing the spacing between each slug causes more than 20-dB increase in the measured insertion loss at all frequencies for the three-section cylindrical slug as compared to the three-section dumbbell (fig. 6). Also note that the optimum dimensions and spacing of the cylindrical slugs are relatively insensitive to frequency across the entire band of WR112 waveguide. The straight line (fig. 6), which corresponds to the average values of insertion loss, is about 5 dB below the theoretical value that corresponds to optimum spacing for dumbbells.

The lossy material associated with the assembly (figs. 1, 2, and 3) was not used during the insertion-loss measurements.

The random error of measured values (3σ) at 35-dB nominal insertion loss is 0.020 dB; at 50-dB nominal insertion loss, the error is 0.034 dB. The random error is based on the computed standard deviation using five readings at each frequency.

The estimated limits of systematic error at the nominal values of 35- and 50-dB insertion loss are 0.035 and 0.100 dB, respectively.

5. INSERTION LOSS OF A THREE-SECTION DUMBBELL DESIGNED FOR LOWER FREQUENCIES

A model of the dumbbell sliding-short design (fig. 3) was fabricated to yield optimum response at the lower frequencies in WR112 waveguide. The measured insertion-loss curve (fig. 7) confirms this design. This design model is not considered broadband because the insertion-loss variation between maximum and minimum values is about 30 dB.

6. REFLECTION COEFFICIENT OF A BROADBAND SLIDING SHORT

Measuring return loss from the plane of the short circuit is the most common measurement performed. However, the preceding intercomparisons were a direct comparison with the Lincoln Laboratory method of measurement which was based on insertion-loss measurements of the devices. In evaluating more fully the characteristics of the NBS sliding short, measuring return loss at two frequencies allowed the characteristics of the NBS three-slug model to be more fully evaluated. These measurements, performed in the microwave reflection-calibration system, employed the NBS quarter-wave short-circuit standards of reflection.

At 7.75 and 8.56 GHz, the magnitude of the reflection coefficient ($|\Gamma|$) of the sliding short was 0.9990 and 0.9989, respectively. This is remarkably close to 0.9995 and 0.9996 for the quarter-wave short-circuit standards.

The random error of measured values (3σ) of the reflection-coefficient magnitude are 0.000084 and 0.000117. These are based on the computed standard deviation using twelve readings taken during the measurement at 7.75 and 8.56 GHz, respectively.

The estimated limits of systematic error of each measurement of reflection-coefficient magnitude ($|\Gamma|$) are $\pm (0.0002 + 0.0012\,|\Gamma|)$.

7. CONCLUSION

This report describes the design and measurement of the NBS-fabricated sliding short circuit in WR112 waveguide.

Encasing slugs in a PTFE carrier provides an excellent means to empirically evaluate this device at different waveguide sizes. Added benefits include reduced construction costs and improved frequency characteristics. The reflection-coefficient magnitude measured about 0.999 at each frequency. The reflection coefficient of the broadband sliding short circuit is closer to unity than earlier types of sliding short circuits.

8. ACKNOWLEDGMENT

The authors extend their appreciation to J. E. Kluge for suggestions regarding the paper and G. C. Counas for his help in measurements.

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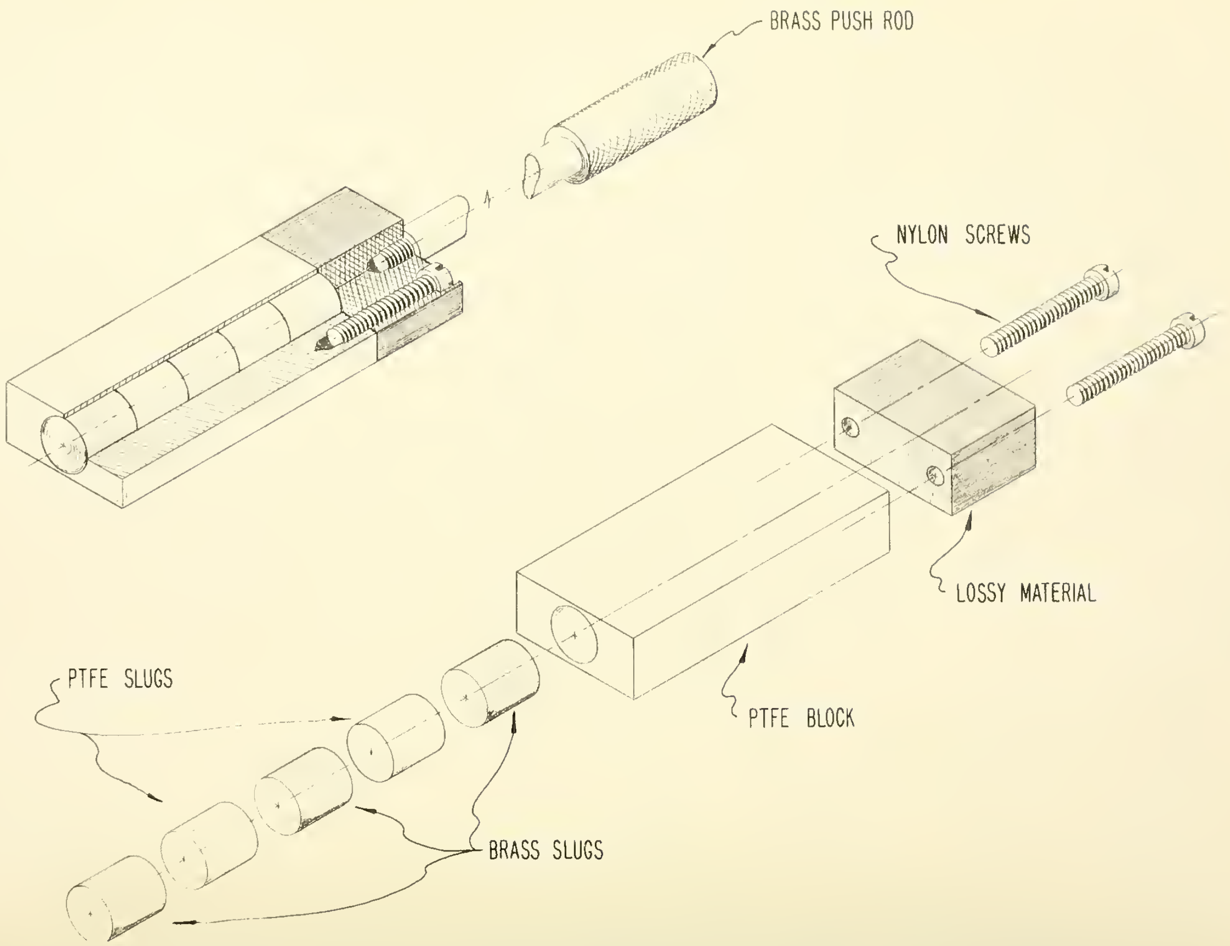

Fig. 1. Assembled and exploded views of a sliding short with a three-section cylindrical brass slug encased in PTFE.

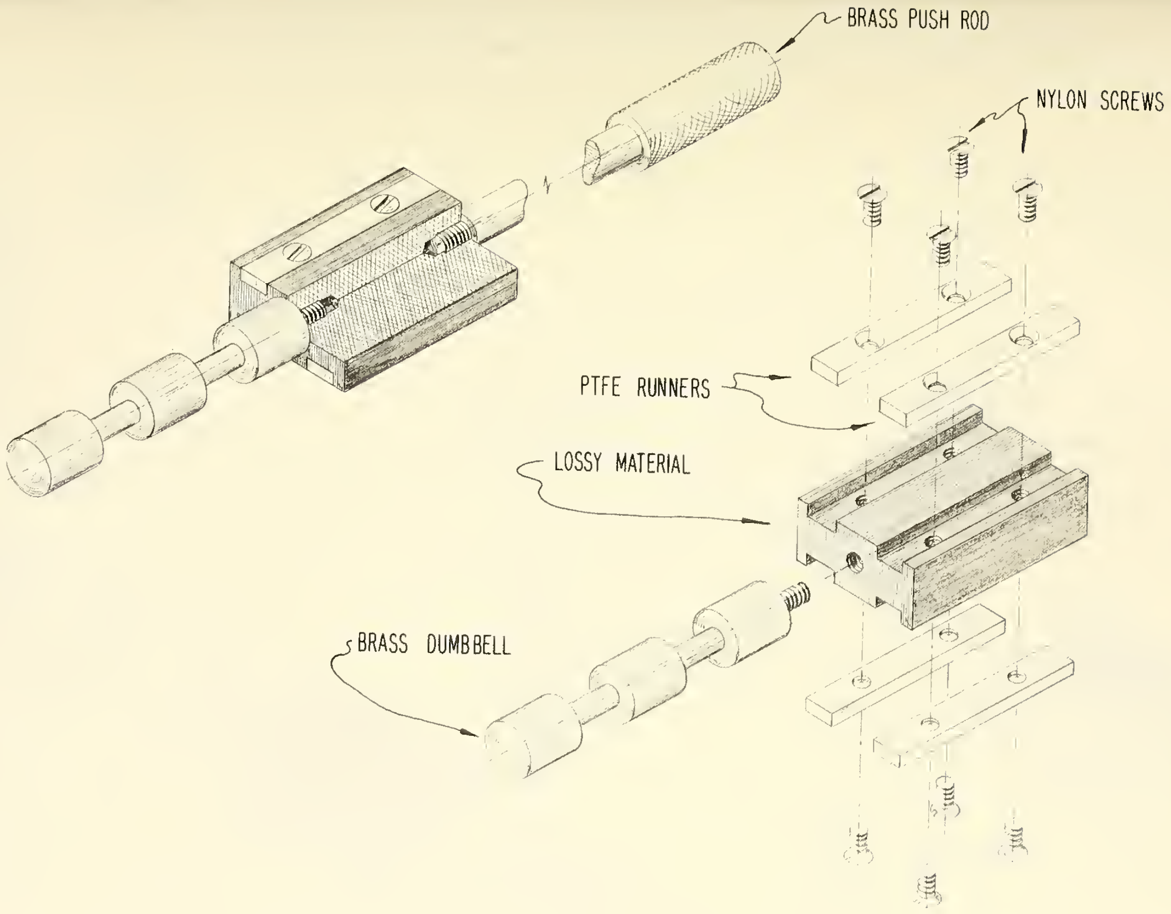

Fig. 2. Assembled and exploded views of a sliding short with a three-section dumbbell and PTFE runners.

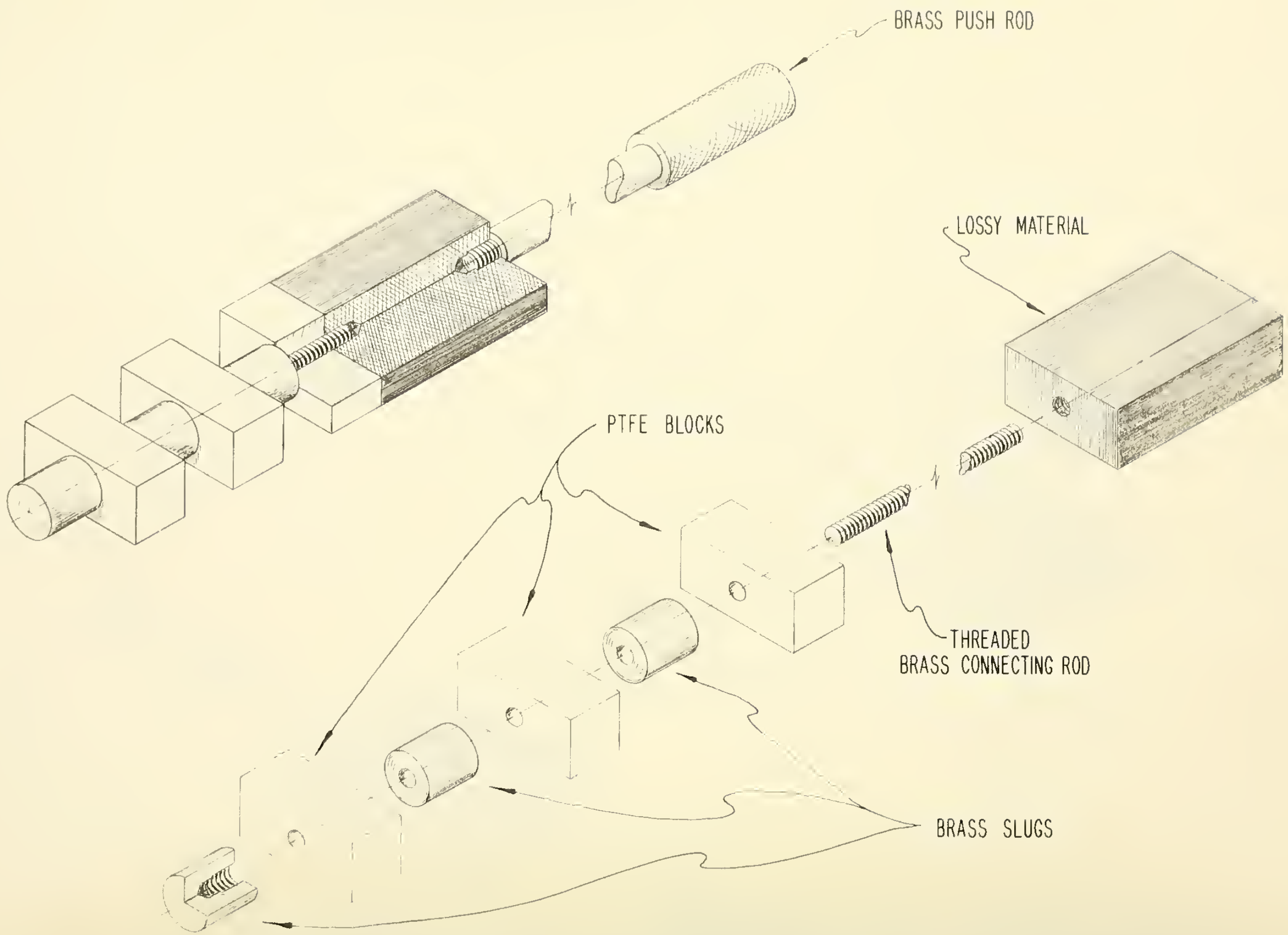

Fig. 3. Assembled and exploded views of a sliding short with a three-section cylindrical brass slug and rectangular PTFE spacer blocks.

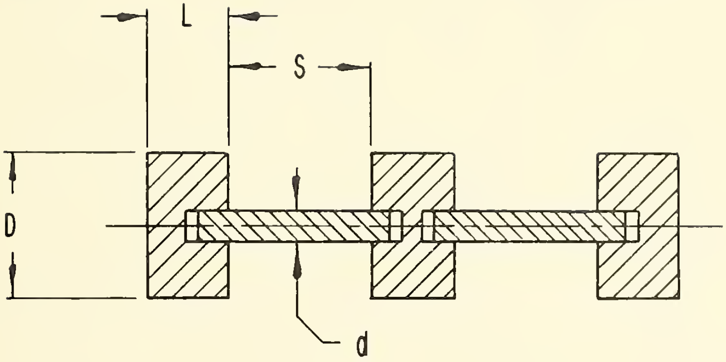

Fig. 4. A three-section sliding short circuit with connecting rods in which the distance S may be varied.

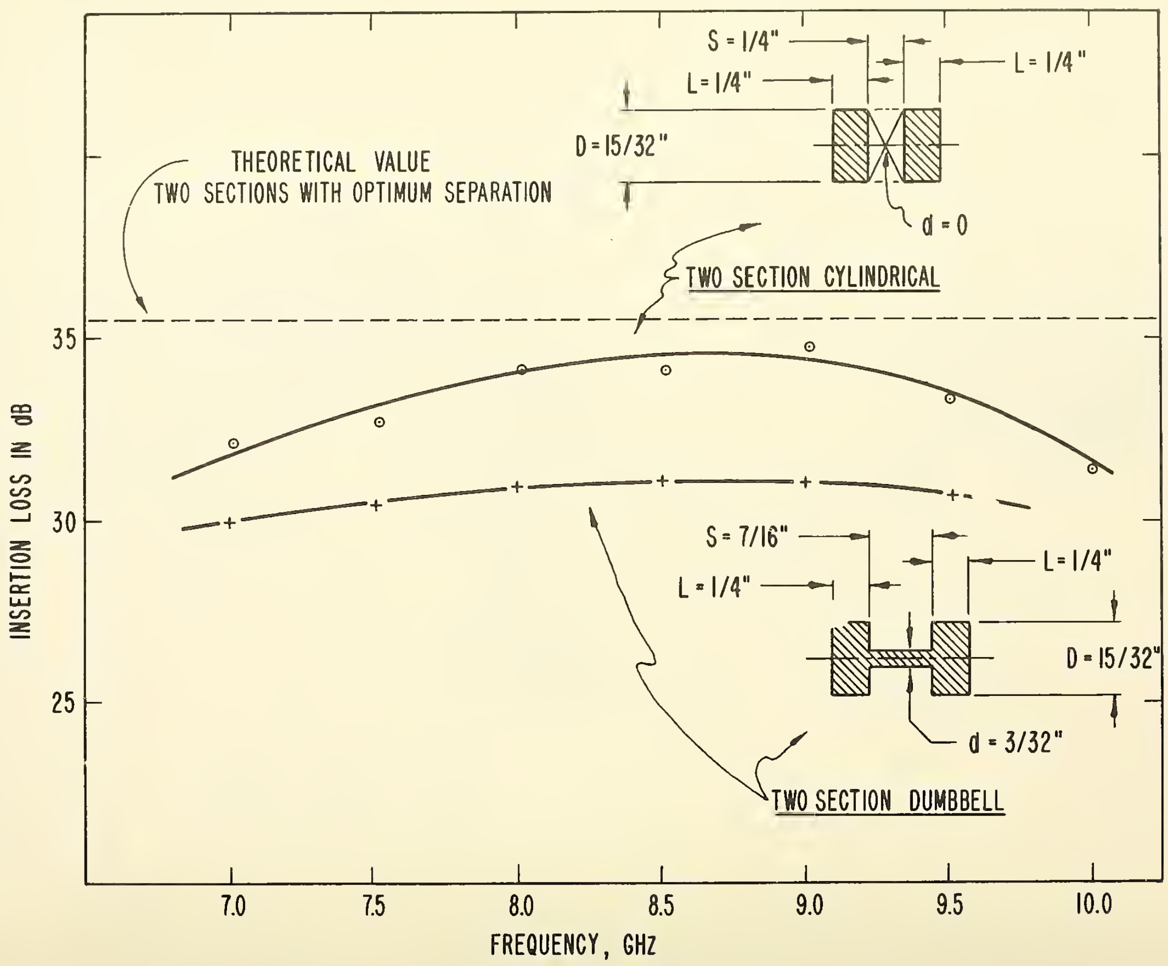

Fig. 5. Sliding shorts with optimum spacing and dimensions, a two-section cylindrical and a two-section dumbbell (NBS and MIT design, respectively); and curves that show their measured insertion loss over the frequency range of WR112 waveguide.

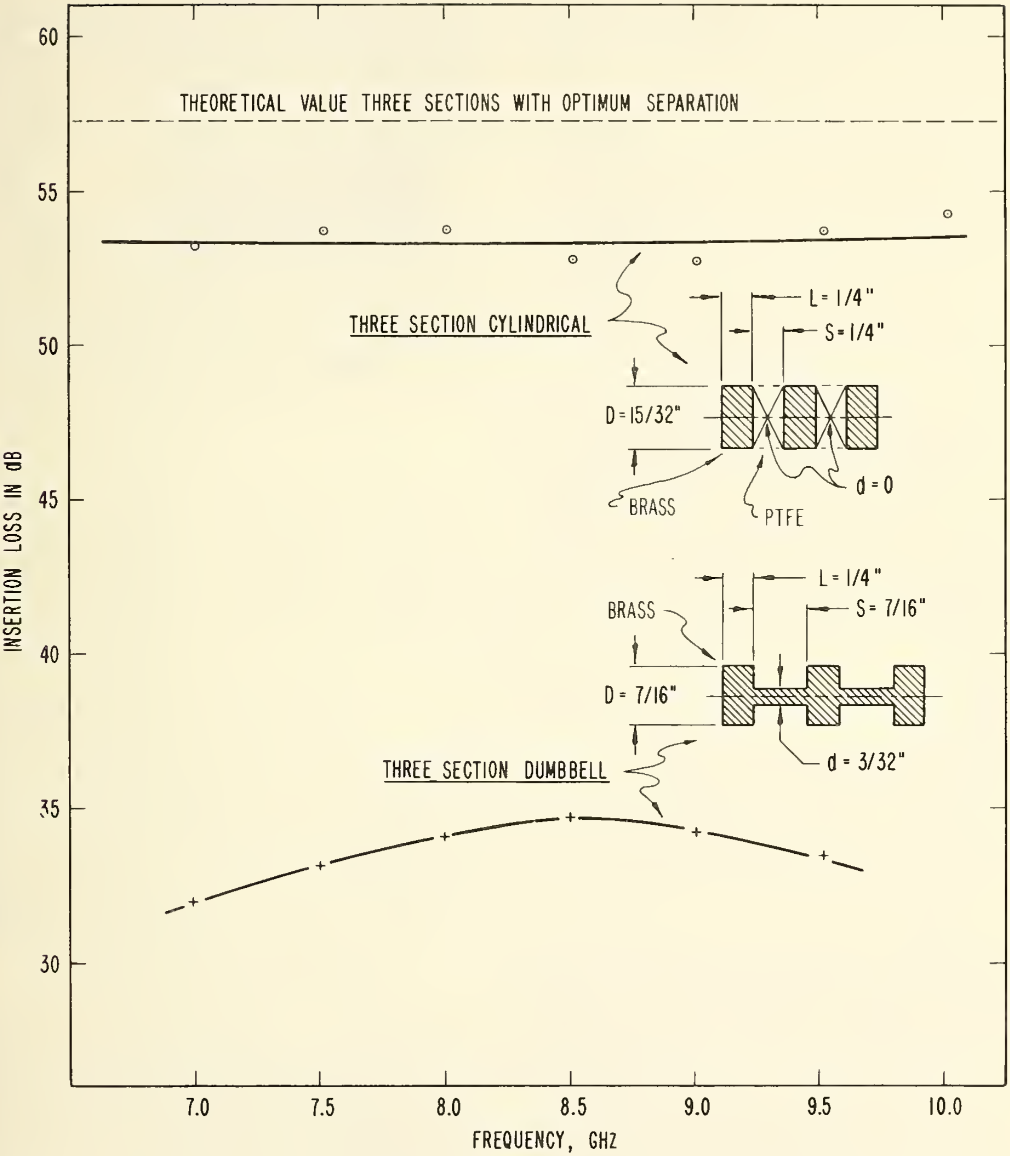

Fig. 6. Sliding shorts with optimum spacing and dimensions, a three-section cylindrical and a three-section dumbbell short (NBS and MIT design, respectively); and smooth curves that show their measured insertion loss over the frequency range of WR112 waveguide.

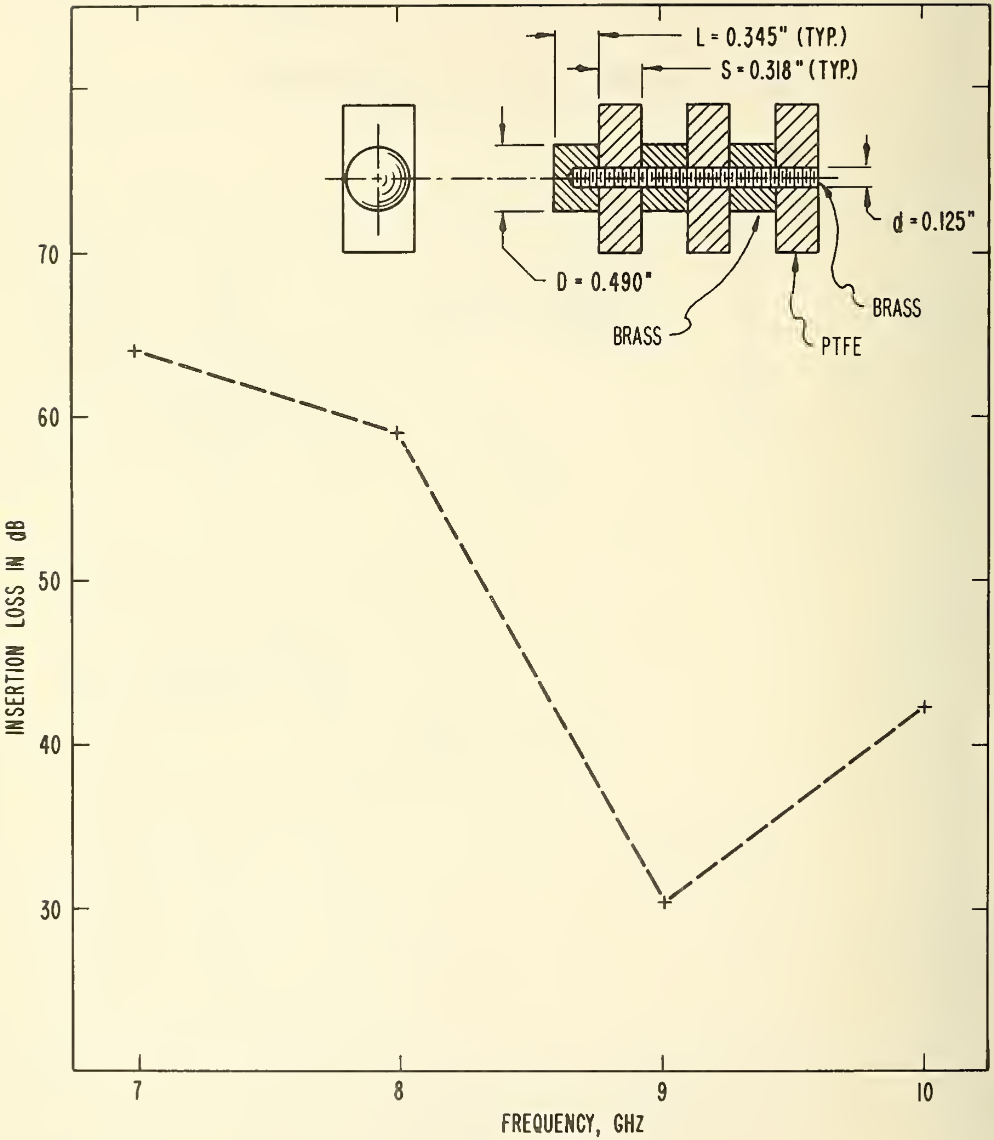

Fig. 7. Three-section dumbbell sliding short (Fig. 3 configuration) and a curve that shows the measured insertion loss over the frequency range of WR112 waveguide.

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