Correspondence

Status Report on International Millimeter Waveguide Flange Standards*

A variety of approaches to the design of flanges for millimeter waveguide use coupled with the research nature of the work in this field has made standardization a difficult rask.

Shortly after World War II, cover flange designs similar to the UG 385/U shown in Fig. 1 were designed (U. S. Army Air Force at Watson Laboratories). This flange design was intended to provide intimate contact across the important broadwalls of the waveguide and precise alignment of the interior sections of the waveguide by the alignment pins. Also, by means of an "O" ring groove provided around the round section, pressurization of these flanges is possible. Thus, with an asexual flange design, the problem of male or female flanges was eliminated and it appeared that a universal design was at hand.

Workers in the millimeter field soon found basic weaknesses in these flanges; upon joining the flanges, pulling up on one screw alone will bind the flange at that edge and leave a wedge-shaped gap in the junction between the flanges; thus, these flanges were found to be difficult to use. If carefully used, however, they were excellent electrically, but were easily damaged by improper connection.

With the success of the broad-band choke and cover flanges in the larger waveguide sizes, the military then introduced a series of millimeter-wave choke and cover flanges (MS 40055, etc.), a typical example of which is shown in Fig. 2. The choke and cover flange has a number of advantages for quick disconnection, since the requirement for intimate metallic contact is virtually eliminated. However, the problem with these choke flanges is that they are extremely difficult to manufacture because of the close tolerances required for broad-band operation. The actual VSWR contribution also, which is typical of the choke flange, say in the order of 1.02, introduces, in some cases, an undesirable additional mismatch problem, especially in rather complex runs of waveguide where a number of flange junctions are involved.

The British also developed flanges for millimeter-wave work using the union-type principle, but these found little favor in the U. S. As a result of this, early workers in the field of millimeter waveguides started developing waveguide flanges to meet their own particular needs. Several varieties of flanges have come into common usage further complicating the possibility of millimeter waveguide connection standards.

* Received January 21, 1963; revised manuscript received June 20, 1963. This paper was presented at the Millimeter and Submillimeter Conference, Orlando, Fla.; January 7–10, 1963. Although the author operates the Secretariat of the IEC Committee 46B "Waveguides and Their Accessories," the U. S. viewpoint is largely presented here since this is the view the author knows best.

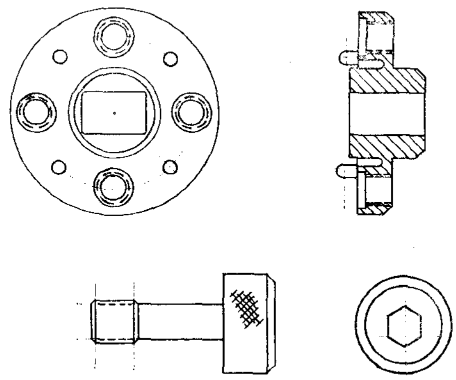


Fig. 1—UG-385/U style millimeter flange used with alignment pins and undercut screws.

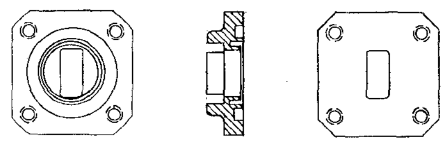
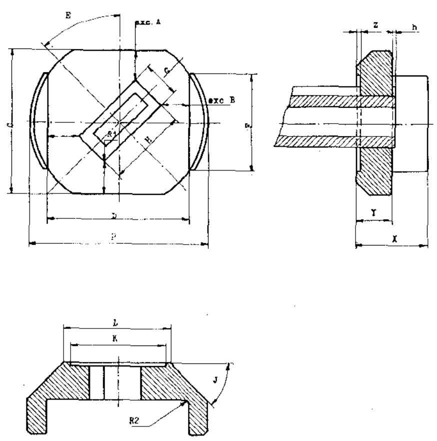
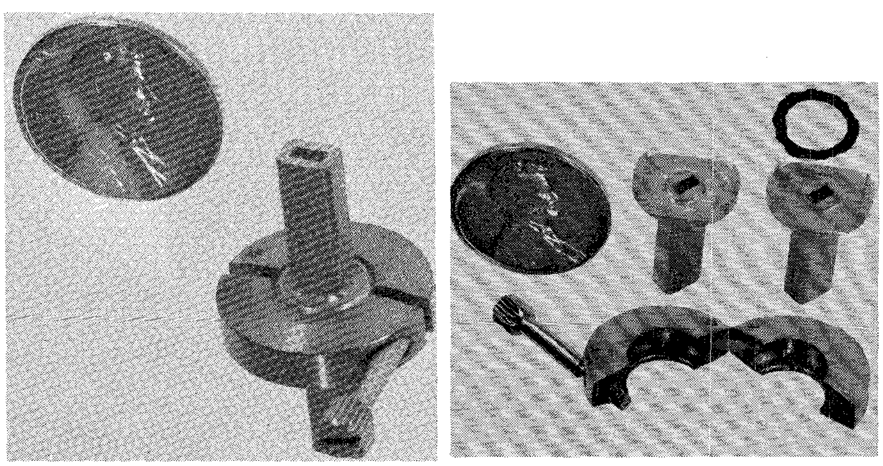


Fig. 2—Millimeter choke flanges, MS 40055 type.



(a)



(b)

Fig. 3—Philips flange proposed as International Standard.

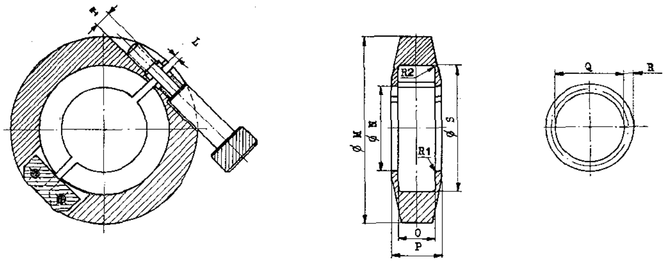
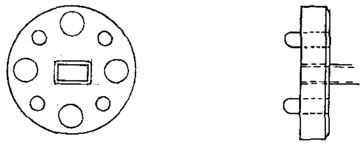


Fig. 4—Clamp and gasket for Philips flange.



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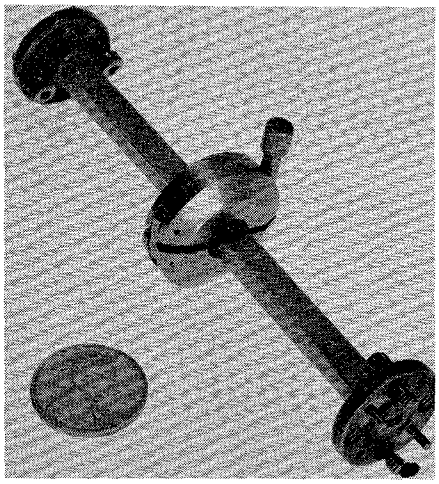

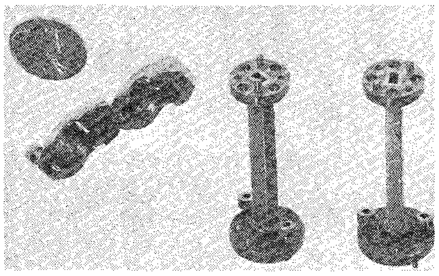

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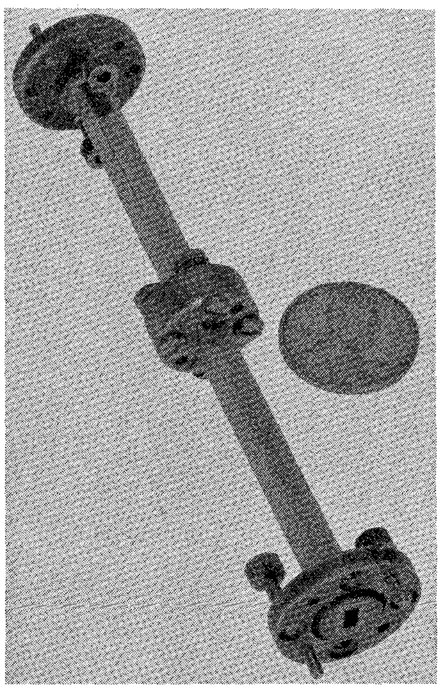

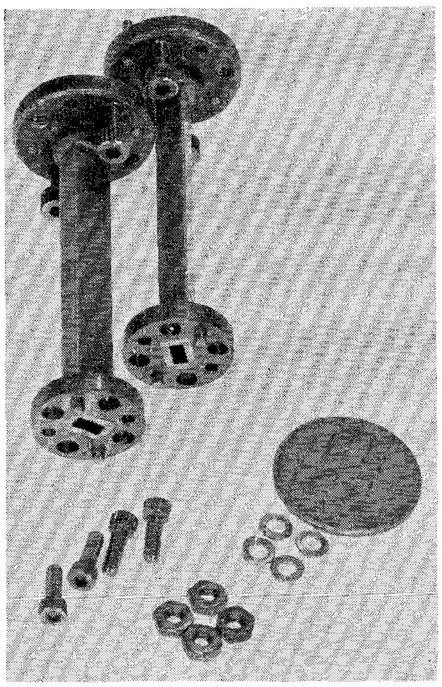

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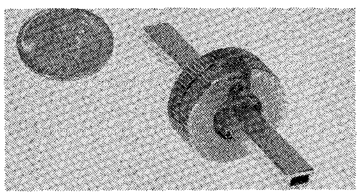

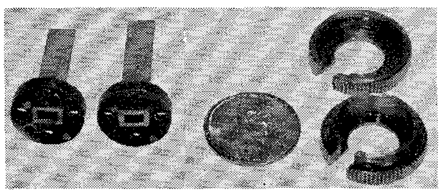

(d)

Fig. 5—Basic design for millimeter waveguide flange proposed by E.I.A. Alignment pins are used with either screws and nuts or a quick clamp similar in principle to the Philips.

In 1956 the International Electrotechnical Commission, which is the international body which has for over half a century been involved in the standardization of all matters electronic and electrical, formed a working group under Technical Committee No. 40 to look into the matter of waveguide standardization. In 1959 in Ulm, Germany, at a meeting of the TC 40-2 "Working Group on Waveguides and Their Accessories," an initial draft was prepared for flanges for waveguide systems.

At that time, the American organizations involved in waveguide standardization had no unified millimeter flange design to present at this meeting. The Dutch on the other hand, sponsored the inclusion of the Philips designed millimeter waveguide flange which is shown in Fig. 3 and has a number of important features.

The Philips flange uses two corral-like sections which are carefully machined with respect to the inside section of the waveguide to provide for precise alignment of the waveguides. A raised surface around the waveguide opening provides an area for intimate metallic contact and the recessed area below this provides a space for a pressurizing gasket. A circular split clamp which is fastened with a single screw couples the waveguide junction quickly and very neatly so that there are a good many points to commend the Philips flange design.

Figs. 3 and 4 show some of the details of the Philips flange design as they presently appear in the draft of "International Recommendation for Waveguide Flanges, I.E.C. Publication No. 154." This document will be published some time during 1964 and will establish a fairly strong position internationally for the Philips flange design. Details of the clamp are shown in Fig. 4(b).

The U. S. National Committee in 1959 attempted to delay the proceedings on millimeter waveguide flange standardization in an effort to consolidate the U. S. position in the field and present a U. S. viewpoint. Work was then started in the Electronic Industries Association which is the organization that has been largely instrumental in preparing commercial standards for waveguides under its Engineering Committee TR 21.1. A task group for millimeter waveguide flanges was set up headed by L. Bertan of the FXR Division of Amphenol-Borg.

The E.I.A. task group on millimeter waveguide flange standardization has representatives from Bell Telephone Laboratories, Lincoln Laboratories and others in industry interested in the field of millimeter waveguides and they have made a comprehensive survey to evaluate the best features of the various designs. FXR had developed, under an Atomic Energy Commission contract, a flange style which had a great deal to commend it. Bell Telephone Laboratories, in its extensive work in the millimeter waveguide field for its waveguide communication system, had also designed some interesting flanges. As a result of this work the flange design shown in Fig. 5 has been chosen by the E.I.A. task group as a possible U. S. commercial standard for millimeter waveguide use and it is hoped that this will shortly be submitted for industry-wide comment. Unfortunately, at the moment the design is available only for waveguide sizes WR-15, WR-12, and WR-10 although it is planned that variations of this same flange design will be made for the smaller waveguide sizes. The E.I.A. Task Group feels that this flange is simpler to make than the Philips flange. It was felt that the claw-type arrangement took considerably more complicated machining. It was the consensus, however, by the tests that were run at Lincoln Laboratories and Bell Telephone Laboratories, that the Philips flange and the E.I.A. proposed flange are electrically satisfactory and very nearly identical. Unfortunately, the proposed design is not pressurizable and therefore has to be redesigned and a task group of the E.I.A. has this under consideration.

Thus, it appears that the international position on millimeter waveguide flanges is as follows. With the U. S. National Committee unable to present at this time a flange design that is capable of meeting the criteria that have been established by the I.E.C. Committee on waveguide standardization, that is:

1) The flange must be asexual;
2) Capable of operation both pressurized and unpressurized;
3) Provide good electrical performance;
4) Relatively simple to machine and manufacture;

there is little to compete with the Philips flange as an International Standard.

Tore N. Anderson
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Millimeter Transmission by Oversize and Shielded-Beam Waveguides*

A transmission line for the interconnection of systems was required for frequencies above 100 Gc. This requirement is different from the point-to-point propagation. For this particular application the transmission line should have low attenuation, reasonable manufacturing cost, simplicity in component construction and system adaptability.

After a careful evaluation of the presently known means of transmission for millimeter waves an oversize waveguide in a single mode (not necessarily the dominant mode) and an optical waveguide (beam waveguide) were chosen.

The attenuation of a standard waveguide has a prohibitively large value at frequencies above 100 Gc. The attenuation for any mode in a pipe of arbitrary cross section can be reduced by increasing the transverse dimensions of the waveguide. In the oversize waveguide a large number of modes can propagate if they are excited in any manner.

The larger the cross-sectional dimensions of the waveguide in relation to the wavelength of the propagating mode, the smaller the longitudinal component of the field becomes. When the longitudinal component is negligible compared with the transverse components of the electromagnetic field, the field is for all practical purposes a TEM mode and optical techniques can be used in the design of components.

The dominant mode in rectangular waveguide, the H_{10} mode, was launched in a *C*-band waveguide (RG-95/U) 10 ft long, at 70 and 141 Gc.

Solymar's theory[1] for the spurious mode generation in a nonuniform line was used to obtain an estimate of the mode purity in a linear taper in rectangular waveguide. An expression for the H_{30} mode was obtained for a symmetrical taper with a flare angle θ in the broad dimension (the H_{30} is the higher order mode of largest amplitude to be excited in our work).

$$|H_{30}| \simeq \frac{3}{4}\left\{\left[\mathrm{Si}\left(\frac{\pi\lambda}{a_0\tan\theta}\right)-\mathrm{Si}\left(\frac{\pi\lambda}{a_1\tan\theta}\right)\right]^2 + \left[\mathrm{Ci}\left(\frac{\pi\lambda}{a_0\tan\theta}\right)-\mathrm{Ci}\left(\frac{\pi\lambda}{a_1\tan\theta}\right)\right]^2\right\}^{1/2} \quad (1)$$

where $a_0<a_1$, $\lambda/2a_0<1.0$, $\mathrm{Si}(x)$ and $\mathrm{Ci}(x)$ are the conventional sine and cosine integral functions, λ = free-space wavelength, θ = the flare angle in the *H* plane, a_0 = input broad dimension of the taper, a_1 = output broad dimension of the taper. The power of the H_{10} mode is unity.

Eq. (1) has been plotted in Fig. 1 for a range of values applicable to this work. A flare angle of 2° was used in the linear taper from the RG-98/U to the *C*-band waveguide. The spurious modes should be under −10 db in relation to the dominant mode for this flare angle. For the 141 Gc transmission experiments a linear taper of a 1° flare angle was used in addition to join the *G*-band waveguide (0.075″×0.034″ ID) to the RG-98/U input of the other taper. The mode purity was checked by probing the field of the oversize waveguide. Table I shows the theoretical and experimental attenuation at 70 and 141 Gc.

The beam waveguide was developed by Goubau and associates.[2,3] The beam waveguide is an open structure, therefore a metallic shield was used to enclose the line to eliminate crosstalk or external noise.

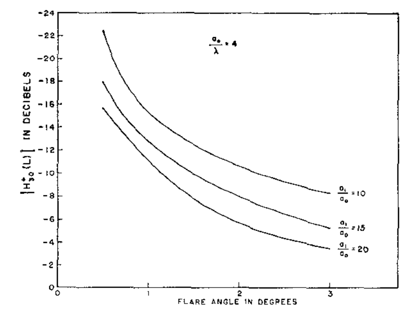

Fig. 1—Amount of H_{30}^+ mode vs flare angle.

TABLE I

Attenuation—(Decibel/100 feet)				
Frequency Gc	Standard Silver Waveguide $\sigma=6.1\times10^7$ mhos/meter		2″×1″ Aluminum Waveguide $\sigma=3.54\times10^7$ mhos/meter	
	Theoretical	Measured	Theoretical	Measured
70	RG-98/U 41.0	—	2.8	4.0
141	RG-138/U 99.0	—	4.0	6.0

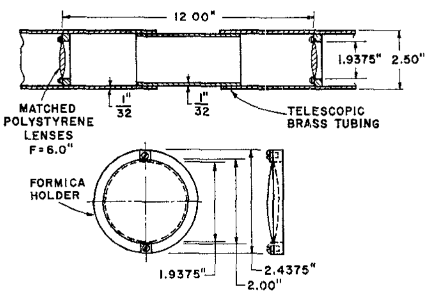

Fig. 2—Drawing of section of the shielded-beam waveguide.

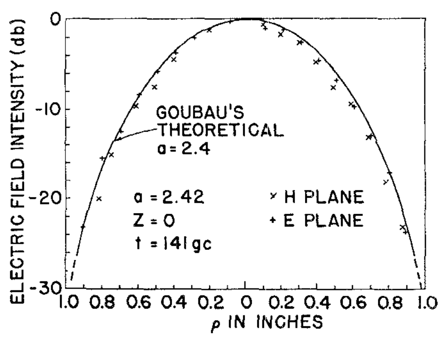

Fig. 3—Cross-sectional field configuration at $Z=0$.

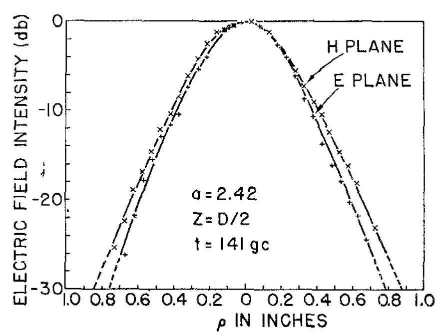

Fig. 4—Cross-sectional field configuration at $z=D/2$.

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[1] L. Solymar, "Spurious mode generation in nonuniform waveguide," IRE Trans. on Microwave Theory and Techniques, vol. MTT-7, pp. 379–383; July, 1959.

[2] G. Goubau and F. Schwering, "On the guided propagation of electromagnetic wave beams," IRE Trans. on Antennas and Propagation, vol. AP-9, pp. 248–256; May, 1961.

[3] J. R. Christian and G. Goubau, "Experimental studies on the beam waveguide for millimeter waves," IRE Trans. on Antennas and Propagation, vol. AP-9, pp. 256–263; May, 1961.