Double-Ridge Waveguide for Commercial Airlines Weather Radar Installation

T. N. ANDERSON†

Summary—**This paper describes the design and development of a double-ridge waveguide designed to propagate both C-band and X-band (5,400 and 9,300 mc) so as to allow for a common waveguide installation in commercial airliners which could use either a C-band or an X-band weather penetration radar. This double-ridge waveguide is capable of propagating over the desired frequency range with single mode operation only; it yields attenuation at C-band which is only slightly higher than that of normal C-band waveguide and has somewhat reduced attenuation at X-band compared to standard $1\times\frac{1}{2}$ rectangular waveguide. This double-ridge guide has been adopted by Aeronautical Radio, Inc. and is specified in their Characteristic No. 529 entitled "5.7 Cm Weather Penetration Airborne Radar."**

This paper also gives an analysis of the calculated guide wavelength in this double-ridge guide, attenuation, and peak power-handling capabilities; and compares the results of these calculations with measured data. Peak power-handling capability for this double-ridge guide is well within the requirements of this application. The testing procedures used for high-power breakdown measurements are described. This paper also covers the development of double-ridge waveguide flanges, elbows, bends, twists, transitions, and flexible waveguide for use over this extremely broad band.

THE COMMERCIAL airlines, through their co-ordinating agency Aeronautical Radio, Inc., have long been working on the problem of an airborne weather penetration radar. As a result of considerable effort by the interested airlines and manufacturing concerns, such as Bendix Radio and RCA, a characteristic describing the weather radar, ARINC Characteristic No. 529, has been written. From the results of work done at McGill University, Montreal, Canada, it was decided that the best frequency for this weather penetration radar was 5,400 mc, and United Airlines, in co-operation with RCA, flight-tested an experimental system at C-band. Comparison tests were also made with existing military types of navigational radars, principally the AN/APS-42 which operates at X-band.

As a result of this work, the ARINC Characteristic was written around a 5,400 mc radar system. Bendix Radio, on the other hand, felt that because of the tremendous wealth of experience with the X-band AN/APS-42 systems and the availability of components for $1\times\frac{1}{2}$ X-band waveguide systems, they would offer for sale a commercial weather radar using X-band. RCA, on the other hand, decided to go to C-band weather radar.

The problem of co-ordinating the installation of electronic systems is a prime function of ARINC. The interconnecting cabling, typical of most commercial airlines radio and navigational electronic equipment, is well standardized by ARINC, and it was hoped that some common medium of waveguide transmission could be evolved which would allow for the installation in an aircraft of either an X-band or a C-band weather radar system. Originally, a single-ridge waveguide for this application was proposed by Mr. Sam Hopfer at Polytechnic Research and Development. The manufacturing difficulties of a single-ridge guide are rather severe, and as a result, a double-ridge guide was suggested. Double-ridge guide requires half the depth of penetration of the ridges and is a symmetrical structure so that the design of bending tools and actual fabrication of bends and twists is greatly simplified. This double-ridge guide construction also simplifies the problem of making a flexible ridge waveguide, as will be described later.

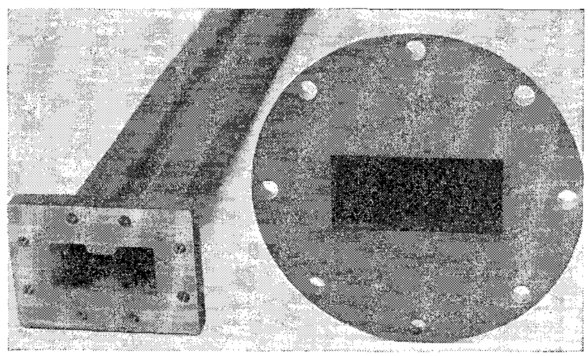

Fig. 1—Comparison of C-band weather radar double-ridge waveguide with conventional C-band 2×1 waveguide.

Fig. 1 shows the double-ridge waveguide which was finally decided upon, compared to a conventional C-band guide showing the tremendous saving in size for this double-ridge guide over a conventional rectangular guide for C-band. This double-ridge guide has been adopted as the standard waveguide installation for commerical airlines weather penetration radar installations in accordance with ARINC Characteristic No. 529.

Design Considerations

It was originally suggested that a conventional 2×1 waveguide be used for both X-band and C-band. This would involve the propagation under conditions which might allow the existence of high-order modes. This leaves a great deal to be desired in actual practice in that higher-order modes are almost always present in practical components involving transitions, bends and elbows. It was therefore felt that a waveguide which

† Airtron, Inc., Linden, N.J.

was capable of only a single mode of propagation would furnish the most satisfactory answers to this problem. The use of TEM modes, coaxial lines, etc., for the type of peak power-handling capabilities and the required low VSWR's would be extremely difficult, especially in view of the attenuation problems, and peak power-handling capabilities of coaxial lines. For a single mode operation, then, it was necessary to go to a waveguide configuration which could propagate the extended ranges. Such an arrangement is shown in Fig. 2 for single- and double-ridge guides.

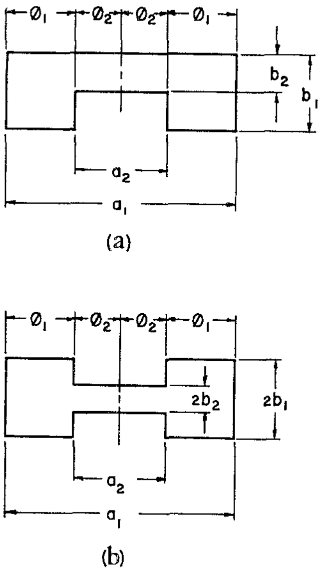

Fig. 2—Ridge guide parameters, single- and double-ridge.

With the use of a ridge guide, extremely broadband performance can be obtained with single mode operation. This is accomplished for a given broad dimension by reducing the TE_{10} mode cutoff frequency and for a lesser extent by extending the TE_{20} mode cutoff frequency. There are, of course, an unlimited number of shapes for waveguide cross sections which will propagate a fundamental mode over a broad band; however, analysis shows that a double-ridge guide can be considered a close approximation to the optimum provided that the form factors of the guide and the ridge are chosen properly.

The design of a ridge guide then can be handled as follows:

1. The TE_{20} cutoff frequency is generally increased only slightly for moderate ridge penetration, thus, the choice of TE_{20} cutoff frequency approximately determines a_1.
2. For best peak power and attenuation characteristics, the ratio of a_1 to $2b_1$ is generally made approximately 2 to 1. This establishes b_1.
3. From the required TE_{10} cutoff frequency, then, the ridge parameters for a given a_1 dimension can be determined as given by Cohn and others; thus a_2 and b_2 are determined.
4. A generous radius is usually provided at the ridge to improve peak power handling and a wall thickness chosen from mechanical considerations.

The required operating characteristics for a double ridge guide for this service are shown in Table I.

TABLE I

CHARACTERISTICS OF DOUBLE-RIDGE GUIDE FOR COMMERCIAL AIRLINES WEATHER RADAR

Desired characteristics		Design values	
Operating bandwidth	5,260 to 9,415 mc	Theoretical bandwidth	4,200 to 10,000 mc
Attenuation	2.0 db maximum for 30 feet typical aircraft run (0.067 db per foot)	Theoretical attenuation, aluminum	Low as possible
Peak power-handling capability	100 kw at 16,000 feet altitude 1.5 VSWR (equivalent to 510 kw at atmospheric pressure VSWR 1.0)	Theoretical power-handling capacity, safety factor 2.0	1,020 kw

Since only a bandwidth of 2.38 is required, the amount of ridge penetration will be rather small (dimension b_2, Fig. 2). Thus the ridge gaps may be rather large in order to meet the peak handling capabilities.

The TE_{20} mode cutoff frequency increase which can be expected because of the ridge will then only be very slight. This approximately establishes the broad dimension of the guide of 1.222 inches with a b_1/a_1 ratio of .5 which is the most desirable in order to obtain the greatest bandwidth between the TE_{01} and TE_{10} mode, and from the curves shown in Figs. 3 and 4 (next page), it is obvious that to obtain a given bandwidth, the largest gap can be used if the ridge width is in between 0.25 and 0.3 times the width of the guide.

One would also suspect that lower attenuation and greater power-handling capabilities would result for a given bandwidth if the gap were as large as possible, because of the larger volume-to-area ratio. This is borne out in actual practice. The power-handling capacity curves plotted as a function of ridge width for constant bandwidths are very similar to those in Fig. 4, with flat peaks always at normalized ridge widths of approximately 3. Similar curves for attenuation have very nearly the same properties showing very close to the minimum in the same region. It has been shown then that the optimum width is approximately 1/3 the wide dimension of the guide, since this results in the largest gap, lowest attenuation, and greatest power-handling capabilities. From these considerations, then, the depth of penetration of the ridge can be established by the required TE_{10} mode cutoff frequency and allowance is made for an increase in TE_{20} mode frequency that can be expected.

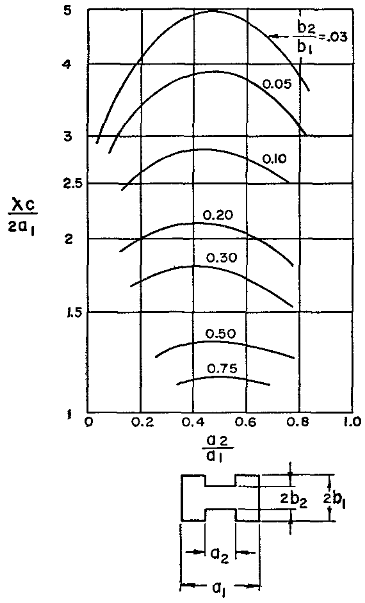

Fig. 3—Curves giving the cut-off wavelength of ridge guide.

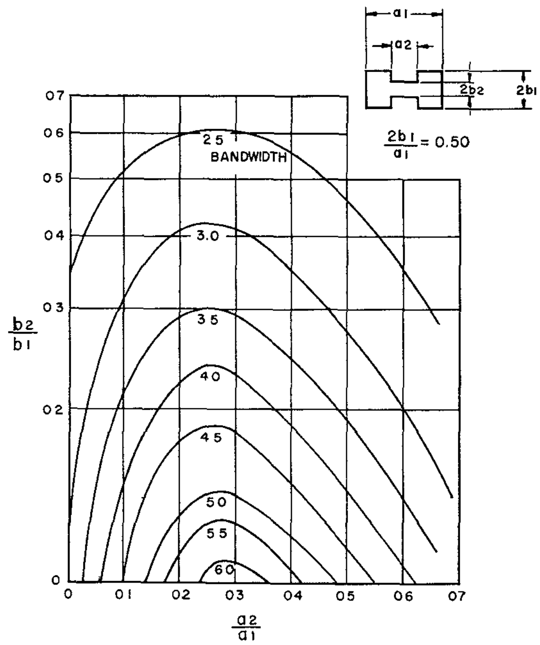

Fig. 4—Curves giving the bandwidth of ridge guide for $2b_1/a_1=0.50$.

The full set of parameters which define this double-ridge waveguide are shown in Table II and the theoretical values of TE_{10} and TE_{20} mode cutoff frequencies are given, along with peak power handling capabilities and the theoretical attenuation.

TABLE II

PARAMETERS FOR DOUBLE-RIDGE GUIDE, FIG. 5

$\frac{b_1}{a_1}=0.50$	TE_{10} mode cutoff=4,200 mc
$\frac{b_2}{b_1}=0.675$	TE_{20} mode cutoff=10,200 mc
$\frac{a_2}{b_1}=.275$	Theoretical peak power handling capabilities =1,840 kw
$\frac{\lambda_{c1}}{2_a}=1.15$	Theoretical attenuation, aluminum =0.019 db per foot at 5,400 mc
$_{c1}$=2.812 inch=7.14 cm	=0.0092 db per foot at 9,300 mc

The peak power handling capability of this design was calculated by the following approximation. Assuming the electric field fringing at the ridge is negligible due to the generous radius, the power at breakdown is then equivalent to a section of rectangular guide whose narrow dimension b is the ridge gap ($2b_2$ in Fig. 2) and whose broad dimension is the same as that which will yield the same TE_{10} mode cutoff. The power at breakdown, P in watts, then is given by

$$P = 3.60 \times 10^6 \quad ab \frac{\lambda}{\lambda_g}; \qquad (1)$$

where a = wide dimension, inches of equivalent rectangular guide, same TE_{10} cutoff; b = distance between gaps, inches. λ = free space wavelength; and λg = guide wavelength. Eq. (1) uses the breakdown strength of air at microwave frequencies of 2.9 kv per millimeter.

The attenuation was calculated from the equation given by Cohn. Attenuation in db per foot:

$$\alpha = 1.83 \times 10^{-6} k\sqrt{f} \left\{ \frac{\frac{1}{a_1} + \frac{2}{b_1}\left(\frac{f_c^1}{f}\right)^2}{\sqrt{1 - \left(\frac{f_c^1}{f}\right)^2}} \right\} \frac{60\pi^2 \frac{b_1}{a_1}}{Z_{0_\infty}};$$

where k = unity approximately, f = operating frequency, f_c^1 = cutoff frequency, a_1 and b_1 are as in Fig. 2, and z_{0_∞} = characteristic impedance at infinite frequency, as given by Cohn.

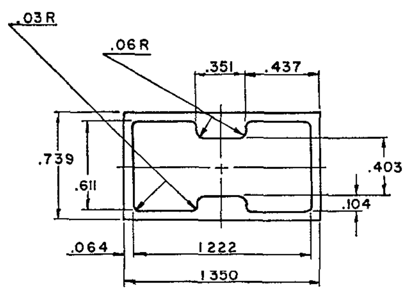

Fig. 5—Final dimensions of double-ridge guide for commercial airlines weather penetration radar, Airtron No. ARA-136.

To evaluate this design for this application, a standard section was milled from two blocks as shown in Fig. 6 (on the facing page). It was milled from L-shaped blocks, contrary to normal practice, which is to split a waveguide down the middle of the broad wall. It has been found at Airtron that this is the most satisfactory method for producing VSWR standards in that it allows for precise control of the height and width dimensions of the guide.

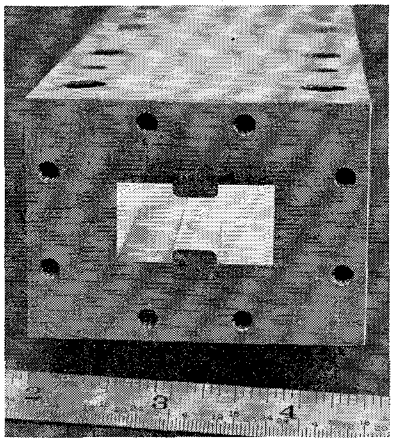

Fig. 6—Reference standard of double-ridge guide milled from two L-shaped blocks.

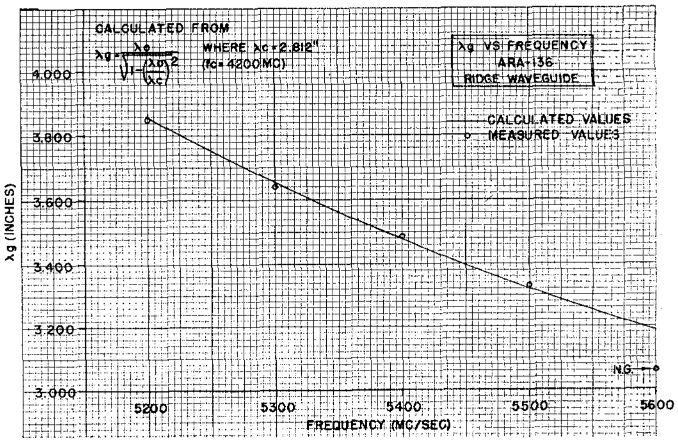

Fig. 7

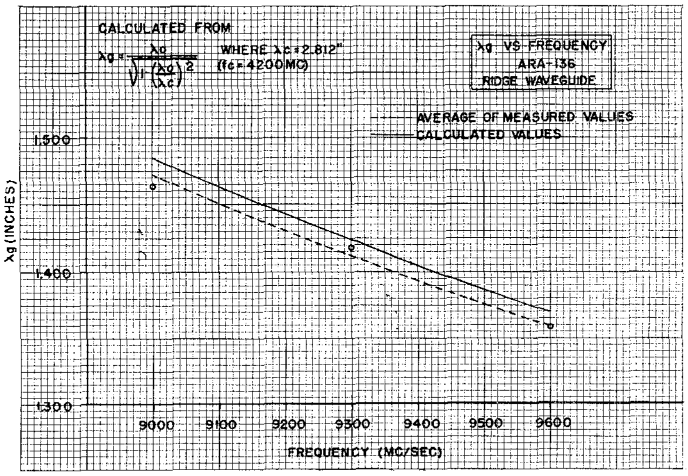

Fig. 8

Using this section, the TE_{10} mode cutoff and the guide wavelength which is required for computation purposes, design of components, etc., were measured using the sliding short circuit technique. The results of these are shown in Fig. 7 for C-band and in Fig. 8 for X-band.

The agreement between measured and calculated values for λg at C-band is excellent. At X-band, however, it is felt that there are other factors entering into the determination of λg which make its calculation somewhat less accurate. Measured values, therefore, have been accepted for measurement and computation.

From this reference standard of guide, only approximate numbers could be obtained from attenuation and peak power handling capabilities. Tests were run to ascertain that it was well within the theoretical limits and drawn tubing was procured. Using this reference standard, transition blocks to X-band (quarter-wavelength step) and C-band (quarter-wavelength step) were designed which show a VSWR of less than 1.03 over a 6 per cent bandwidth at each of the design center frequencies of 9,300 and 5,400 mc, respectively.

TABLE III

MEASURED ELECTRICAL PERFORMANCE OF DOUBLE-RIDGE GUIDE AS IN FIG. 6. (DRAWN 28 ALUMINUM TUBING AIRTRON NO. ARA-136)

Peak power-handling capabilities	1,500 kw, 2.5-second pulse at 400 pulses per second at 5,400 mc
	1,280 kw, same conditions as above except 9,375 mc
Attenuation, one way	0.047 db per foot at 5,400 mc
	0.043 db per foot at 9,375 mc

The drawn samples of guide were then checked for peak power operating capabilities using these quarter-wave block transitions for X-band with a 4J50 magnetron. From these tests, an equivalent peak power-handling capability at X-band was determined and a similar test was run at 5,400 mc. using a 200 kw tunable magnetron, Raytheon QK-235. These results are shown in Table III. Attenuation measurements were then made on short sections of drawn tubing by the standing wave method as described by Vogelman. These results are tabulated for both C-band and X-band. Using twelve or fourteen foot runs with elbows and straight sections, measurements of attenuation were checked by the insertion loss method, and were found to agree very closely with the standing-wave method, so that the values tabulated are felt to be accurate to within 5 per cent.

The attenuation values of .047 db per foot for C-band operation can be compared to published values for aluminum 2×1 waveguide of .018 db per foot which is roughly $2\frac{1}{2}$ times as great. The discrepancy between the theoretical attenuation and this measured attenuation is rather high and it is felt that these initial samples of drawn tubing showed somewhat higher surface roughness around the ridge than is normal and that perhaps with later samples, somewhat lesser attenuation than this might be achieved. However, the attenuation is still well within the goal set for this guide and it is felt that with production samples, a .05 db per foot at X-band or C-band could be guaranteed.

The attenuation at X-band presents an entirely different picture and is less than the standard attenuation for $1 \times \frac{1}{2}$ guide which runs nominally around .06 db per foot so that there is some saving in using this double-ridge guide at X-band. It is, of course, slightly larger than the equivalent X-band guide, but it does have somewhat higher peak power handling capabilities in addition. The principal feature of this double-ridge guide obviously is its much reduced size in comparison to an equivalent C-band waveguide.

In the electrical measurements of the straight sections of elbows and other double-ridge waveguide components, an interesting observation was made. Apparently, the stiffness of the broad wall of the waveguide due to the corrugation by the double ridge adds considerably to the rigidity of the guide and thus, individual discontinuities along the length of the guide which normally account for production VSWR's are very largely eliminated and, apparently, very slight distortion occurs with brazing and perhaps with subsequent handling. Therefore, it is felt that somewhat lower VSWR's can be achieved with this double-ridge guide despite the fact that for an equivalent operating frequency range, the gap dimensions are more critical than conventional guide.

On the whole, insofar as tolerances are concerned, the tolerances for this particular double-ridge guide are no more severe than they are for $1 \times \frac{1}{2}$ waveguide.

Flanges

In order to use this double-ridge guide, sections must be provided with flanges, but because of the extreme operating bandwidth the use of choke flanges is quite out of the question. The runs that are planned for this double-ridge guide (from equipment rack to the nose of the aircraft) require a pressurized junction and, therefore, a pressurized contact flange has been designed based on a combination rf and air-gasket principle which has seen considerable use in duplexers and similar applications, and has been adopted for a number of miniature contact flange applications.

Basic Connector Design

Fig. 9 shows the basic principle for the single-contact flange junction. A full circle cross-section O-ring gasket is used for the air pressure seal and to provide a satisfactory rf joint, a soft metal shim suitably plated depending on the flange material, silver plated for brass and cadmium for aluminum, is mounted as shown.

Under ordinary conditions, the gap existing between flange faces is very small, but it has been determined experimentally that the VSWR contributions are exceptionally low even with a gap as large as 0.015. It has also been determined that a joint of this type will take up to the full peak power rating of the waveguide without breakdown, provided the gap spacing is not greater than .008 inch. By bringing the mounting screws close to the gasket groove, the resulting flange junction is much more compact and superior mechanically to the standard choke and cover flange combination.

The basic hole layout is derived from the principles that have been set forth in the miniaturized contact flanges which are now up for standardization at RETMA with the addition of this pressurizing rf gasket.

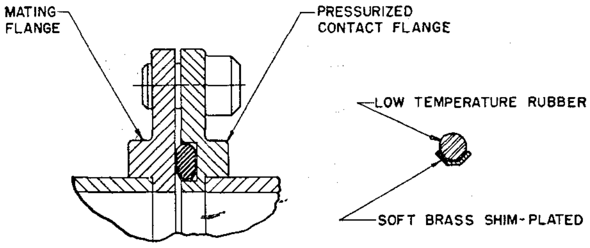

Fig. 9

Fig. 10 shows this gasket and flange combination. This gasket design features a soft copper liner which is silver plated and lines the inner surface of the rectangular O-ring gasket. The rubber O-ring gasket provides a full circle O-ring for pressurization and is designed in accordance with the standard O-ring design practice. This gasket provides an excellent rf seal as well as an air seal, and has been checked at extremely high power levels. The entire layout and basic design of this gasket are shown in Fig. 11 (facing page). These flanges are designed as pairs, one with a gasket groove and another one plane—the latter having tapped holes, the former having clearance holes for #8-32 socket head cap screws. The gasket material is low temperature neoprene designed for operation down to −55 degrees C.

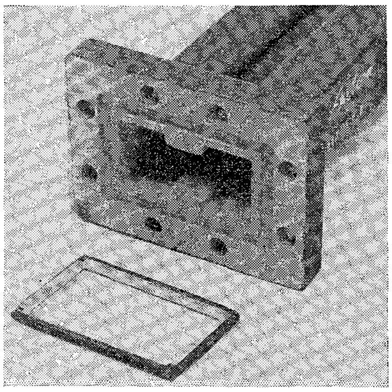

Fig. 10—Pressurized contact flange for double-ridge guide with rf and air gasket.

The actual drawn tubing in contrast to that shown earlier in Fig. 5 has been formed by dimpling in the middle of the broad wall so as to provide a corrugation on the outer surface as well as the region down the middle of the inner surface of the broad wall. In order, therefore, to provide a satisfactory brazable flange, a socket type flange is used which is shown in Fig. 11. This provides for a butt-ended joint which is straddle-milled in the flange block and the waveguide opening of the flange itself is broached to the standard double-ridge waveguide dimensions. In aluminum brazing, this technique is found to be the most acceptable one from the point of view of eliminating bleeding due to microporosity and the remachining of brazed aluminum surfaces.

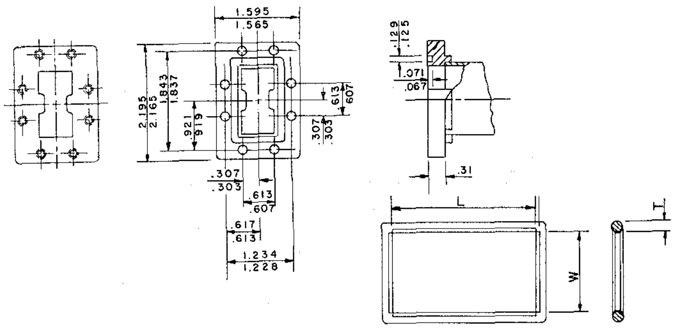

Fig. 11—Hole patterns and flange details for double-ridge guide, as in Fig. 6.

In order to design a quick disconnect for this type of flange, tests were run under high power conditions to determine the force required to press together two of these flanges. Under these conditions, it was determined that a force of 32 pounds to 35 pounds was required to provide satisfactory operation at 200-kw peak power. This was run at atmospheric pressure and the current flow which would normally be encountered with 200 kw was used as a criterion for the peak power failure under these conditions. At this point, there was a .008-inch gap between the flanges, and satisfactory operation of this connector design was obtained.

TABLE IV

Pressure	VSWR
Bolted tight	1.02
50 pounds	1.015
40 pounds	1.01
30 pounds	1.01
20 pounds	1.025
10 pounds	1.03

The joint was also checked for changes in VSWR and Table IV gives the results of this test. This shows that there was no measurable effect with variations in contact pressure on VSWR, however, it was felt that a minimum of 30 pounds force was required for good electrical contact under high power conditions. Thus, as a criterion for quick disconnects, it was decided at least 100 pounds force should be provided in any of these flange designs to furnish adequate mating pressures. A quick disconnect for this double-ridge flange requiring a minimum of mounting space has been worked out and is shown in Fig. 12.

Because of the requirements for 100 pounds force, and the need for a disconnectable flange between the sharp mount bracketing and the RT units in the weather radar installations, choke flange designs are required for double-ridge guide to operate either at C-band or X-band. A choke flange design has been worked out for C-band and is shown in Fig. 13. At X-band it has been simpler to use conventional X-band choke and accomplish a transition from $1\times\frac{1}{2}$ guide to double-ridge guide beyond this choke junction.

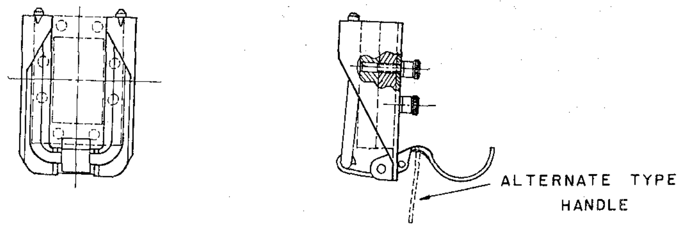

Fig. 12—Quick disconnect for double-ridge guide.

Single quarter-wave step transitions from both C- and X-Band for narrow-band operation as required by this application have been worked out using conventional quarter-wave transition design theory. Fig. 13 shows X-band and C-band transition blocks which were used for the experimental standard section so that the drilling pattern is not that which is finally used for transition sections. Transition type flanges which have an integral flange assembly and are brazed to double-ridge tubing also have been designed and used. These transition blocks exhibit a VSWR of less than 1.02 over a 6 per cent bandwidth centered at 5,400 and 9,300 mc.

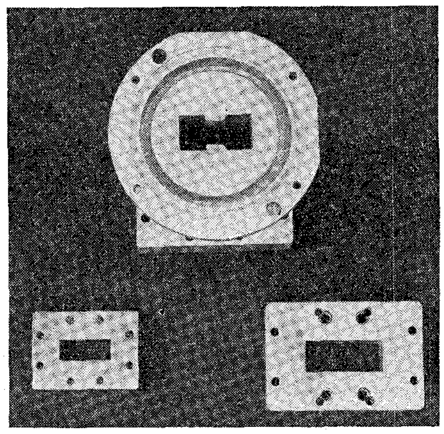

Fig. 13—Double-ridge choke flange C-band and step transitions for X-band and C-band.

CIRCULAR BENDS

The design of waveguide circular bend principles as laid out for rectangular guide have been followed with considerable success. In the design of waveguide bends, the designer has two choices: (1) either make the electrical length of the elbow such that the transition from straight waveguide to the bend section is very gradual, or (2) make the bend so short a finite electrical length, generally approximately one-half wavelength long, that the discontinuity at the input is exactly cancelled by the discontinuity of the far end. The guide wavelength in inches for the two operating frequency ranges in this

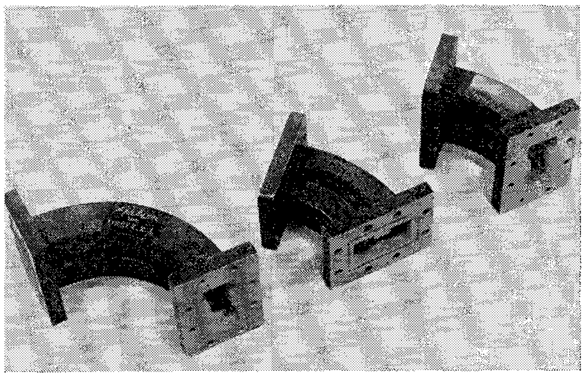

Fig. 14—Typical elbow sections, 2.214-inch radius to centerline.

double ridge guide are tabulated below:

Frequency	Guide Wavelength
5,400	3.479 inch
9,375	1.409 inch

This dictates then for circular elbows of the short type, a radius of 1.107 inches to the centerline for both E and H plane radii, or to a radius of 2.214 inches for both E and H plane bends. To apply the large radius rule will require elbows in excess of 7 inches. The experimental sections of the E and H plane bends similar to those shown in Fig. 13 were made up to evaluate these design criteria. It was found that the elbows which were tooled up to this application were 2.214 inches to the centerline of the waveguide and that this VSWR contribution from these elbows were negligible. The biggest contributions are discontinuities in the manufacture of the waveguide flange openings. Therefore, it was felt that 2.214 inches should be a minimum bending radius of this guide unless a specific short radius is chosen for this application, and these would have to be verified experimentally. Since this radius seems to have fit most applications, no work has been done to date on getting an extremely short elbow. The use of compensated elbows such as the broadband miters and corners would be very dangerous for an E-plane band, therefore the circular bends have been standardized for this type guide from a high peak power point of view. A typical H plane section is shown in Fig. 14 and an experimental twist section with a twist of 7 inch length is shown in Fig. 15.

Flexible Waveguide

For flexible waveguides for this application, a two-piece construction has been developed; this consists of two identical half sections which are stamped from sheet by continuous process and joined at the narrow edge of the guide where the corrugations interlock. This provides an annular double-ridge guide and a section of the tubing is shown in Fig. 16. To avoid the peak power penalty imposed by normal flexaguide, this double-ridge flexible has been deliberately oversized as so to provide a satisfactory safety margin under actual operating conditions. This double-ridge flexible is jacketed and flanged in a normal manner for flexible guide (Fig. 17, opposite). An installation for commercial airlines use using flexible double-ridge guide and typical elbows is given in Fig. 18 (opposite).

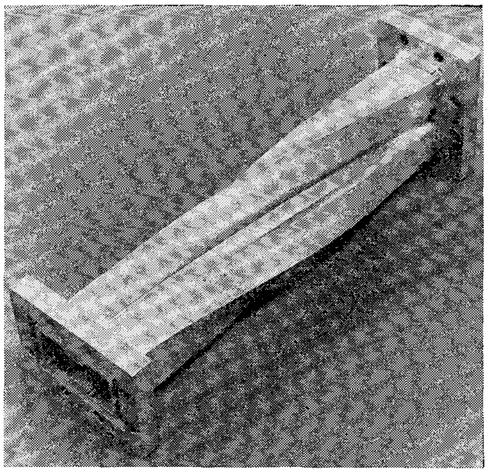

Fig. 15—Twist section, 7 inches long.

Over-all VSWR

As contemplated in these commercial airlines installations, there will be long runs of waveguide from the radio equipment rack to the nose of the ship where the antenna is mounted. The VSWR requirements for such long runs of waveguide are extremely stringent. With typical magnetrons, a total VSWR of 1.50 is all that can be allowed. The duplexer designs for these weather radar systems have been held to 1.15 VSWR over the operating frequency range and the antennas to a 1.20 specification. This leaves still a narrow margin of approximately 1.10 VSWR for the installation waveguide for satisfactory magnetron operation. This double-ridge guide to date has exhibited rather excellent VSWR, however, the individual contribution of mismatch along such a long section is bound to be rather high. At this writing, the order of magnitude of this problem has not been definitely resolved, but there are several alternatives which make themselves attractive: The use of a

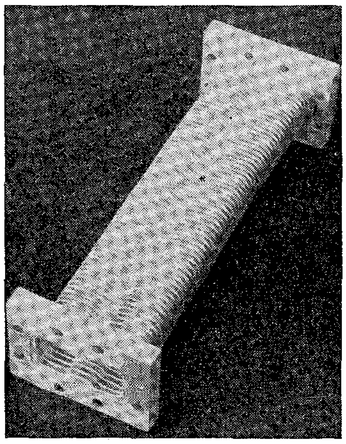

Fig. 16—Double-ridge flexible waveguide two-piece construction.

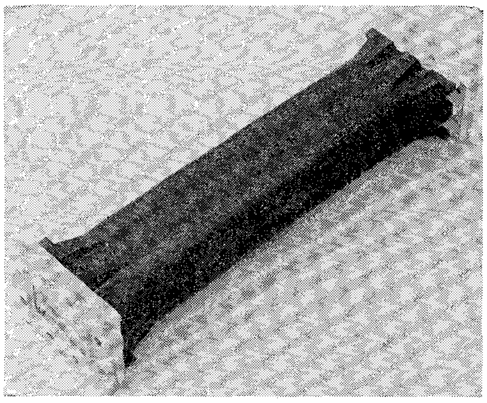

Fig. 17—Same double-ridge flexible waveguide with jacketing.

reflectometer and VSWR introducer near the TR unit so as to provide for matching the line—this to be checked at suitable intervals in a maintenance schedule. This would allow for discontinuities and irregularities that occur with usage in the aircraft. Another application might be to provide a pulse type high-level ferrite isolator so as to isolate the magnetron from the effect of discontinuities. This latter application has considerable promise although the complexities of an additional pulser and the weight of such a unit may make its use prohibitive.

Waveguide Miniaturization

One of the paramount advantages for double-ridge guide in this aircraft installation has been the size reduction possible without much sacrifice in peak power handling capabilities or attenuation for a practical radar application. A method is in sight for reducing the complexity of aircraft installation for lower frequency radar systems operating at 10 cm and perhaps even 30 cm. By use of similar techniques, extremely high peak power performance can be obtained from such structures at considerable saving in size and weight, and by using a two piece (Airtron type *S*) flexible guide construction, it should be possible to fabricate flexible guides and thus make installations in modern aircraft practical. The contributions of Mr. W. T. Carnes, Chairman of the Airlines Electronic Engineering Committee in co-ordinating and adapting this double-ridge guide are here gratefully acknowledged.

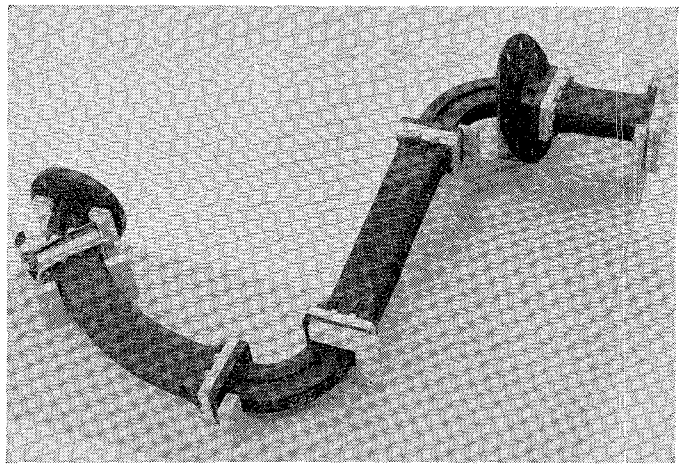

Fig. 18—Typical aircraft installation of double-ridge waveguide.

Bibliography

1. Cohn, S. B., "Properties of Ridge Waveguide." Proceedings of the IRE, Vol. 35 (August, 1947), pp. 783–788.
2. *Ridged Waveguide—A Transmission for a Wider Frequency Range.* PRD Reports, Vol. 1, No. 2 (July, 1952).
3. Ramo, S , and Whinney, J. R., *Fields and Waves in Modern Radio.* New York, John Wiley and Sons, Inc., 1953.
4. Marcuvitz, N., *Waveguide Handbook.* New York, McGraw-Hill Book Co., Inc., 1951.
5. *5.7 Cm Weather Penetration Airborne Radar.* ARINC Characteristic No. 529.

Simplified Calculation of Antenna Patterns, with Application to Radome Problems*

J. H. RICHMOND†

Summary—**Generally, the calculation of antenna far-field patterns from known near-field distributions is tedious and may require the use of a large computer. The calculations are simplified for certain types of antennas having separable near fields. This simplifying assumption is found to yield satisfactory results with pyramidal horns and parabolic reflector antennas. Calculations are further simplified by approximating a complex line integral with two real summations.**

Measured and calculated far-field patterns are included to indicate the accuracy of the calculations. Results are presented for horns and parabolic antennas and for a horn covered with a hollow dielectric wedge. The method is applicable to both *E*-plane and *H*-plane pattern calculations. The main lobe of a far-field pattern is calculated in less than one hour on a desk calculating machine by the simplified method. In radome work an important feature is that it permits rapid evaluation of the far-field distortion associated with any given near-field distortion in any given small region in the near field.

* The research reported in this paper was sponsored by the Air Res. and Dev. Command, Wright Air Dev. Center, Wright-Patterson AFB, Ohio.

† Antenna Lab., Dept. Elec. Engrg., Ohio State Univ., Columbus, Ohio.

Introduction

THE FOLLOWING problem frequently arises in antenna work. Given the tangential electric and magnetic field intensity distributions on some surface *S* enclosing an antenna, calculate the far-field pat-