

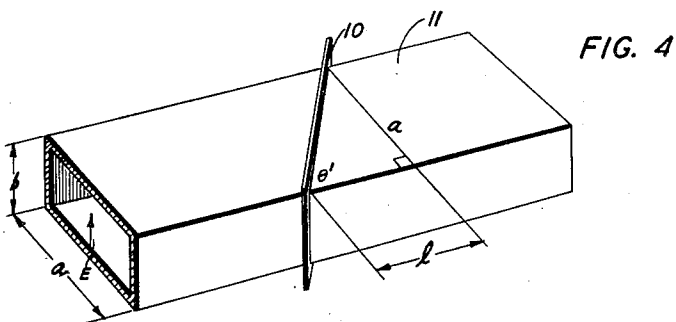
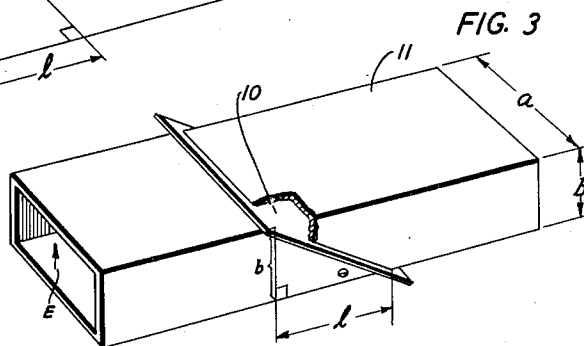
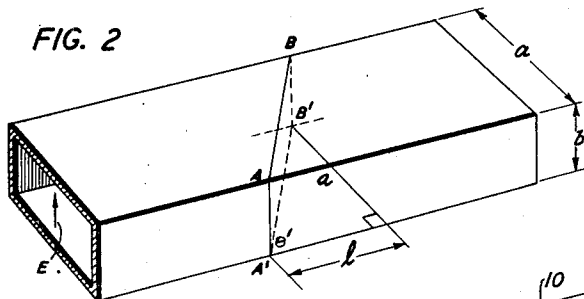
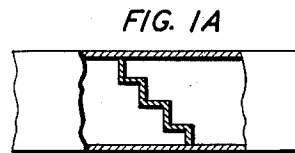
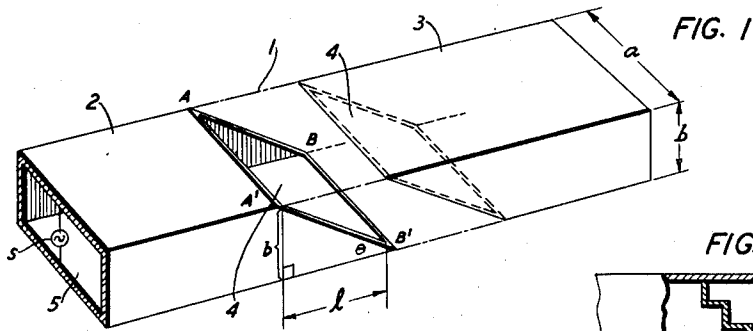
May 5, 1953

R. C. EDSON
SEALED WAVE GUIDE WINDOW

2,637,776

Filed April 20, 1948

2 SHEETS—SHEET 1



INVENTOR
R. C. EDSON
BY
N. D. Ewing
ATTORNEY

May 5, 1953

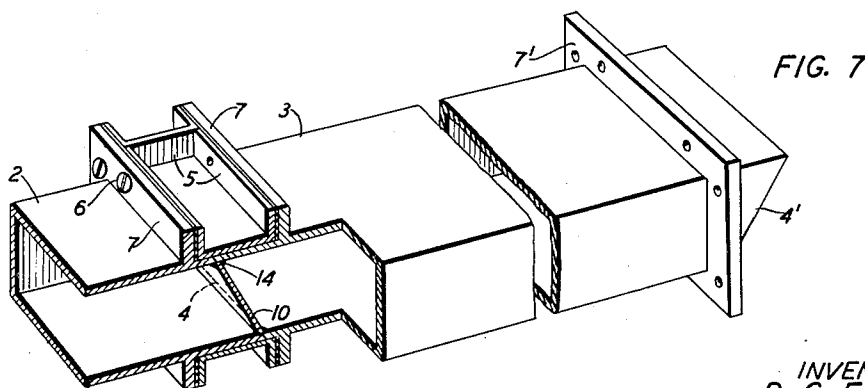
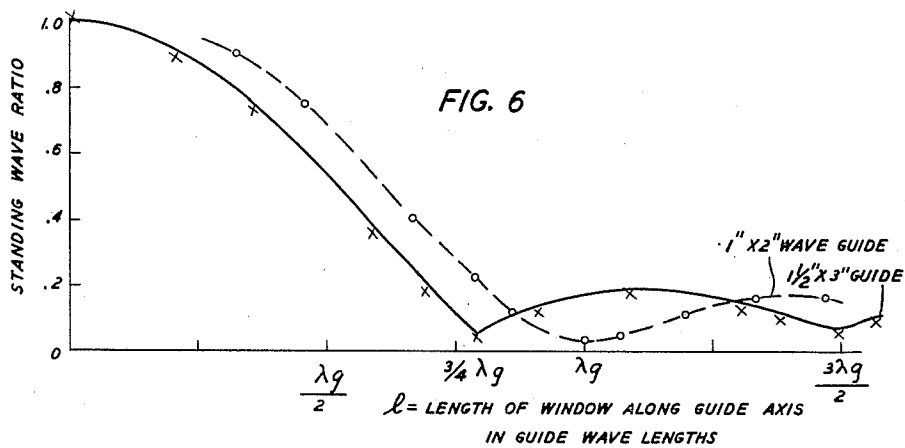
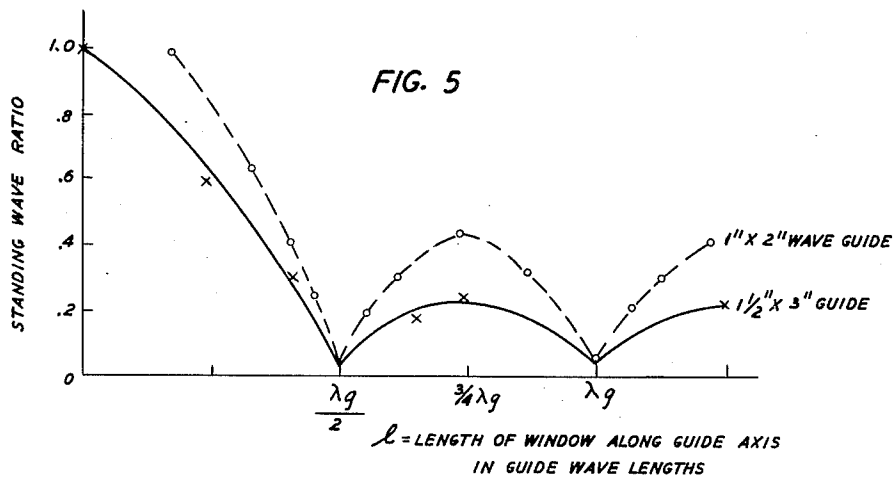
R. C. EDSON

2,637,776

SEALED WAVE GUIDE WINDOW

Filed April 20, 1948

2 SHEETS—SHEET 2



INVENTOR
R. C. EDSON
BY
N. S. Ewing
ATTORNEY

UNITED STATES PATENT OFFICE

2,637,776

SEALED WAVE GUIDE WINDOW

Robert C. Edson, Livingston, N. J., assignor to
Bell Telephone Laboratories, Incorporated, New
York, N. Y., a corporation of New York

Application April 20, 1948, Serial No. 22,195

5 Claims. (Cl. 178-44)

1

This invention relates to wave guide transmission lines and more particularly to wave guide joints and gas-tight partitions therein.

An object of the invention is to render wave guide transmission lines substantially reflectionless at such joints and partitions therein.

A feature of the invention is a wave guide joint with contiguous sloping faces, the angle of slope being designed to cause mutual cancellation of reflections resulting from impedance irregularities due to slight misalignment or slight differences in wave guide dimensions of the two pieces of wave guide being joined together.

Another feature of the invention is a reflectionless, sloping, gas-tight wave guide partition or seal, or so-called "pressurized window," the slope being so related to the wavelength of the electric wave propagated in the guide as to cause mutual cancellation of reflections set up at elemental areas of the window surface.

Heretofore, in the hollow wave guide transmission art, joints and pressurized windows have been constructed with the plane of the contacting faces of the joint or the plane of the pressurized window perpendicular to the principal axis of the wave guide.

In the case of such prior right-angle, butt joints, reflections have been found to arise from discontinuities due to manufacturing tolerances and inexact fit of cross-sectional dimensions of wave guide sections, which ideally should match exactly. Such lack of perfect fit at junction sections introduces impedance irregularities which set up undesired wave reflections. For a long run of wave guide with many jointed sections the reflections are multiplied and interfere with the propagation of signals therealong.

Pressurized windows of the prior art have also been found to give rise to undesirable reflections. In the case of thick windows, reflections have heretofore been suppressed by providing a critical thickness of window related to the wavelength, whereby reflections from opposite faces would mutually cancel out.

In accordance with the present invention, reflectionless, sloping wave guide joints are provided for long wave guide transmission lines by inclining the contacting faces so that the slope angle is critically related to the wavelength in the guide, whereby reflections from impedance irregularities balance out. Likewise, in accordance with the invention, reflectionless wave guide windows may be provided in a wave guide by sloping their planar surfaces with respect to the principal axis of the guide, so that re-

2

flections from elemental areas of the window spaced apart an even or odd multiple of a quarter wavelength, mutually cancel out.

Referring to the figures of the drawing:

Figs. 1, 1A and 2 show wave guides having joints with sloping faces;

Figs. 3 and 4 show sloping joints with inclined pressurized windows clamped therein;

Figs. 5 and 6 are explanatory curves of standing wave ratios versus wavelength for the structures of Figs. 3 and 4 respectively;

Fig. 7 shows a modified form of sloping joint.

Referring to Fig. 1, a diagonal or sloping wave guide joint 1 is shown in exploded view. A pair of rectangular wave guide sections 2, 3, are provided with complementary sloping end faces 4, which are in registry and mate to form a rectangular wave guide 5 having dimensions $a \times b$ for propagation of microwaves. The mating faces 4 form a tight joint, leakproof with respect to electromagnetic energy. In manufacture, the joint may be formed by cutting a rectangular wave guide, for example $1\frac{1}{2} \times 3$ inches in cross-section along a sloping plane P corresponding to faces 4. The slope of the plane P is defined by an angle θ , such that

$$\tan \theta = \frac{b}{l}$$

where

$$l = \frac{n\lambda_g}{4}, \quad n \text{ being an odd integer}$$

λ_g = wavelength in the rectangular guide a, b

The plane P intersects the broad faces of the rectangular guide 5 in lines AA' and BB'. The vertical projections of diagonal lines AB, A'B' are represented by length l.

Impedance irregularities along positions AA' and BB', due to mismatches in cross-sectional dimensions of sections 2, 3, give rise to respective reflections thereat. Thus, the signal wave from source S incident along AA', is reflected back in the opposite direction. Likewise, the wave incident at BB' is reflected back but in different phase. An initial shift of 90 degrees in phase is contributed by the extra path length l, to the forward wave. In traversing the length l in the opposite direction as a reflected wave, another 90 degrees shift is added, making a total of 180 degrees shift. The reflected waves, i. e., from AA' and BB', assuming the irregularities to be of like character, therefore mutu-

ally cancel due to their being 180 degrees out of phase.

The standing wave ratios at joint 1 were experimentally measured, with the guide sections 2, 3 separated a given amount. The results were then compared to the standing wave ratios measured for the same separations in a straight, butt joint, wherein the plane of the contacting surfaces was perpendicular to the principal axis of the rectangular guide. The comparative results are tabulated below:

TABLE I

Standing wave ratios in decibels at a frequency of 3950 megacycles

Amt. of Separation	Straight Butt Joint, db	Sloping Joint, db
1/16 inch	.14	.04
1/8 inch	.24	.1
3/16 inch	.4	.15
1/4 inch	.6	.18

Fig. 2 illustrates a sloping wave guide joint similar to that disclosed in Fig. 1, except that the sloping plane P is now determined by an angle θ' defined by

$$\tan \theta' = \frac{a}{l}$$

where

a = longer dimension of the rectangle ($a \times b$)

$$l = \frac{n\lambda_g}{4}, n \text{ being an odd integer}$$

λ_g = wavelength in the guide

Impedance irregularities of like character at positions AA' and BB', which project into the wave guide at a spacing

$$l = \frac{n\lambda_g}{4}$$

apart, set up reflected waves which mutually cancel out as explained in connection with Fig. 1.

It is also within the purview of the invention to provide an interfitting stepped formation in Figs. 1, 2 along lines AB, A'B' in lieu of the straight line slope as illustrated in Fig. 1A, or any other desirable interlock between guide sections may be used.

Referring to Fig. 3, an inclined pressurized window 10 is shown in a rectangular wave guide 11, having the cross-sectional dimensions, a, b as indicated. The window 10 comprises, for example, a thin sheet of mica, polystyrene, or other low-loss dielectric material either snugly fitting within the wave guide 11 and cemented to the inner faces of the guide along all four edges preferably with a material introducing a minimum of reflection, or clamped in a sloping joint as shown.

The window 10 may be inclined as shown in Fig. 3 at an angle θ defined by

$$\tan \theta = \frac{b}{l}$$

where

$$l = \frac{n\lambda_g}{2}$$

or as shown in Fig. 4, at an angle θ defined by

$$\tan \theta = \frac{a}{l}$$

where

$$l = \lambda_g + \frac{n\lambda_g}{2}$$

a = long side of rectangle

b = short side of rectangle

λ_g = wavelength in the guide

n = an integer

When the pressurized windows 10 are clamped in a sloping joint, the projection l of the joint should be made equal to

$$\frac{n\lambda_g}{2}$$

for the form shown in Fig. 3, and equal to

$$\lambda_g + \frac{n\lambda_g}{2}$$

for the form illustrated in Fig. 4. Under these circumstances, the windows 10 will slope at the proper angle for cancelling reflections from elemental areas thereof, and consequently the summation of reflections from the window will necessarily also be zero.

The curves shown in Figs. 5 and 6 give experimental data of standing wave ratio for sloping pressurized windows. For a window 10 with a slant as in Fig. 3, the values of l which give minimum reflection are represented by

$$\frac{n\lambda_g}{2}$$

When the slope of the window 10 is as shown in Fig. 4 the values of l for minimum reflection depart somewhat from the length as given by

$$\lambda_g + \frac{n\lambda_g}{2}$$

which theory indicates should hold for vanishingly thin windows. This departure increases from the first order theoretical values as the wavelength in the guide approaches a length such that a higher order mode can be propagated.

The explanation of the low standing wave ratios may be better appreciated from the following analysis of the reflection phenomena occurring at elemental areas of the window 10.

Thus, in Fig. 3, the electric field vectors for a dominant input wave E are uniform along the slant face of the window. This results from the existence of equal field strength at small increments of window area, which are equidistant from the "b" side of the rectangle. For two such areas which are a quarter wavelength apart, the reflection is equal and opposite with respect to some point back in the guide. When the incline of the window is such that

$$l = \frac{n\lambda_g}{2}$$

the summation, including both phase and amplitude of all small elemental areas is zero.

For the window construction shown in Fig. 4, the field is not uniform along the slant face of the window. In this case, the field has a half sine wave distribution across the broad "a," dimension of the rectangle and is zero at the sides. Small increments of area on the window, which are a quarter wavelength apart, do not reflect equal amounts of opposite phase. The total reflection or summation of elemental reflections is only zero

5

both in amplitude and phase, when the length l along the guide is about

$$\lambda_g + \frac{n\lambda_g}{2}$$

The frequency variation of the standing wave ratio for polystyrene windows $\frac{1}{8}$ inch thick (Figs. 3 and 4), compared to each other and to right angle windows is illustrated in Table II below.

TABLE II

Frequency	Fig. 3 Window, db	Fig. 4 Window, db	Right Angle Window, db
3,800 megacycles.....	.06	.15	.95
3,950 megacycles.....	.04	.04	1.00
4,200 megacycles.....	.06	.46	1.10

It is obvious from this table that the window of Fig. 3 is less critical with respect to frequency than that of Fig. 4 or the right angle window, and therefore would be more suitable for wide frequency band transmissions.

Various dielectric materials may be used in lieu of polystyrene, such as glass, quartz, plates, and the like.

Comparative improvements in standing wave ratio produced by inclined windows are apparent from the data of Table III below:

TABLE III

Standing wave ratios in various kinds of windows

Frequency, megacycles	Fig. 3 Window			Right Angle Window	
	.008" Mica, db	.019" Mica, db	$\frac{1}{8}$ " Polystyrene, db	.008" Mica, db	$\frac{1}{8}$ " Polystyrene, db
3,800.....	.1	.1	.1	.8	.95
3,950.....	.04	.08	.06	.8	1.0
4,200.....	.04	.04	.06	.8	1.1
4,400.....	.1	.04	.1	.8	1.2

Fig. 7 shows the construction of a sloping joint or a combined sloping joint and window, wherein the wave guide sections 2, 3 are securely clamped together at the joint 4, for example, by a clamp consisting of channel plates 5, thumb-screws 6 and wave guide flanges 7. The sloping window 10 has the same inclination as the joint and is cemented to the guide by rubber or plastic cementing material. The opposite end of the wave guide section 3 is shown provided with a sloping, male part 4' and an apertured, peripheral flange 7' for fastening to the channel members 5.

It should be understood that for pressurizing of the windows aforementioned, it is within the scope of the invention to seal the joint and window by suitable cements or other sealing compounds, the effect of which may slightly alter the previously recommended values for slope angle. It should be understood further that the invention may be embodied also in wave guides of suitable non-rectangular cross-section.

What is claimed is:

1. In combination, a pressurized hollow pipe wave guide of constant characteristic impedance, an electro-magnetic window comprising a sheet of low-loss dielectric material therein for permitting the passage of microwaves and sealing said guide, said window being inclined at a

6

critical angle such that its projection on a wall of said guide is equal to

$$\frac{n\lambda_g}{4}$$

where λ_g is the wavelength in the guide and n is an even integer, whereby reflections from elemental areas of said window mutually cancel to render said window substantially reflectionless.

2. In combination, a pressurized rectangular hollow pipe wave guide of uniform cross section comprising two separable sections having sloping mating surfaces adapted to abut and to form a gas-tight joint, a low-loss dielectric window transparent to microwaves clamped therebetween, the propagating medium of the guide being alike and isotropic on both sides of said window, the intercept of said window's slope on the longitudinal axis of said wave guide being integrally related to

$$\frac{\lambda_g}{2}$$

where λ_g is the wavelength of the microwaves in the guide, whereby reflections from elemental areas of said window mutually cancel to render said window reflectionless.

3. In combination, a pressurized rectangular hollow pipe wave guide comprising a pair of separable sections, each section having complementary inclined ends adapted to mate to form a leakproof joint, the slope of one incline being a function of the side of the rectangular cross-section and the intercept of the incline on the longitudinal guide axis, said intercept being equal to

$$\frac{n\lambda_g}{2}$$

where n is an integer and λ_g is the wavelength in the guide, and a thin, dielectric window transparent to microwaves contained in said guide, said window being located between the separable sections, said window being inclined and having the same slope as said mating surfaces, whereby reflections from elemental areas of said window are out of phase and mutually cancel and the characteristic impedance of said guide is uniform with reference to its input and output ends.

4. In combination, a pressurized rectangular hollow pipe wave guide comprising a pair of contiguous separable sections, each section having complementary inclined ends adapted to form a leakproof joint with respect to microwaves, the angle of incline being defined by

$$\tan \phi = \frac{b}{l}$$

where b is the small dimension of the rectangular cross section and l is the orthogonal projection of the incline on the longitudinal guide axis, said projection

$$l = \frac{n\lambda_g}{4}$$

n being an even integer and λ_g being the wavelength in the guide, and a microwave permeable window clamped between said ends, said window having an incline equal to ϕ .

5. In combination, a pressurized hollow rectangular wave guide having a uniform characteristic impedance Z , said guide comprising two contiguous hollow pipe sections having complementary sloping faces adapted to abut, a thin sheet of low-loss dielectric forming a transparent window clamped between said sloping faces to

7

provide a gas-tight seal, the slope of said faces and window being

$$\tan \varphi = \frac{b}{l}$$

where φ is the slope angle, b is the short side of the guide's rectangular cross section,

$$l = \frac{n\lambda_g}{2}$$

n being an integer, λ_g being the wavelength in the guide, whereby reflections from elemental areas of the window cancel and their summation is zero.

ROBERT C. EDSON.

8

References Cited in the file of this patent

UNITED STATES PATENTS

	Number	Name	Date
5	2,427,098	Keizer	Sept. 9, 1947
	2,473,724	Okress	June 21, 1949

OTHER REFERENCES

10 "Microwave Transmission Circuits," vol. 9 of the Radiation Laboratory Series, 1st edition. Copyright May 21, 1948. Published by McGraw-Hill. Copy in Div. 69.

15 "Technique of Microwave Measurements," vol. 11 of the Radiation Laboratory Series, 1st edition. Copyright December 18, 1947. Published by McGraw-Hill. Copy in Div. 69.