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W. W. HANSEN ET AL  
WAVE GUIDE IMPEDANCE TRANSFORMER

2,656,515

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Fig. 1.

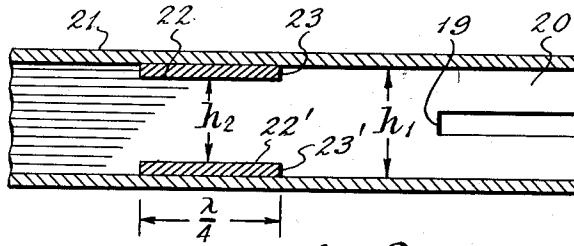


Fig. 2.

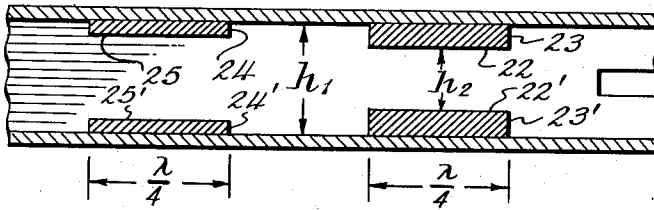


Fig. 3.

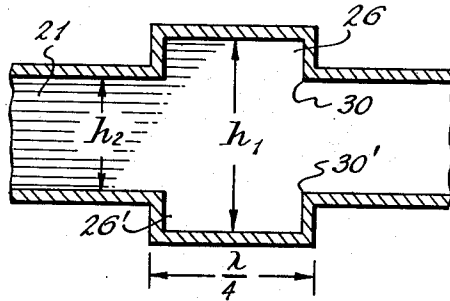
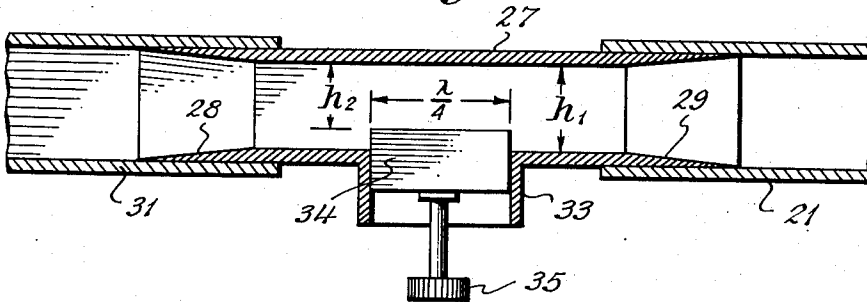


Fig. 4.



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## UNITED STATES PATENT OFFICE

2,656,515

## WAVE GUIDE IMPEDANCE TRANSFORMER

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Application May 5, 1945, Serial No. 592,092, now Patent No. 2,531,437, dated November 28, 1950, which is a division of application Serial No. 437,004, March 31, 1942, now Patent No. 2,433,368, dated December 30, 1947. Divided and this application April 6, 1950, Serial No. 154,214

14 Claims. (Cl. 333—33)

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The present invention relates to the art including impedance matching and transforming devices especially adapted for use in systems utilizing high frequency electromagnetic energy conducted in wave guides.

The present application constitutes a division of prior copending application Serial No. 592,092, filed May 5, 1945, which became an issued Patent No. 2,531,437, on November 28, 1950, and was, in turn, a division of prior copending application Serial No. 437,004, filed March 31, 1942, which became an issued Patent No. 2,433,368, on December 30, 1947, for Wave Guide Construction.

In transferring energy from one high frequency device to another, it is well known that the impedances thereof must be properly matched in order to avoid the production of standing waves, with their attendant increase in losses and decrease in the energy transmitting capacity of the system. In addition, for greater efficiency of power transfer, it is known that the impedance of a load device must be properly matched to that of the high frequency source.

The present invention is directed toward the provision of improved impedance transforming devices which are adapted to transform and impedance connected at one end to a different value at the other end of such a transforming device, whereby this transformed impedance may be matched to a load or other impedance connected at such other end.

Accordingly, it is an object of the present invention to provide improved impedance transformers for transforming a given impedance into a desired impedance.

Another object of the present invention is to provide an improved adjustable impedance transformer for use in the system having a maximum ease of adjustment and range of impedance transformation.

Other objects and advantages will become apparent from the following specification and drawings, in which

Fig. 1 shows a longitudinal sectional view of a wave guide incorporating an impedance transformer according to the present invention.

Figs. 2 and 3 show corresponding longitudinal sectional views of modified forms of a fixed impedance transformer.

Fig. 4 shows a longitudinal sectional view of an adjustable wave guide impedance transformer.

The present invention is useful especially in the connection between a high frequency source and a radiating wave guide, such as shown in said Patent No. 2,433,368. Such radiating wave

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guides in general require impedance matching devices to match them to the wave guides through which the input energy flows. Such devices form the present invention.

Fig. 1 shows a rectangular radiating wave guide 20 in section, whose radiating slot begins at the point 19 and which is attached to a rectangular wave guide 21 whose cross-section is equal to that of the radiating guide. Preferably equal height conducting plugs 22, 22' are attached to opposite surfaces of the wave guide 20 perpendicular to the side containing the slot. The distance between these wave guide surfaces is  $h_1$  and is the minor cross-sectional dimension of the guide, while the distance between the opposed faces of the plugs 22 and 22' is  $h_2$ . The length of the plugs 22, 22' is approximately a quarter wavelength of the operating frequency or an odd multiple thereof, as measured in the guide 20. The proper position of the plugs 22, 22' along the longitudinal axis of guide 21 may be determined by measuring the standing wave ratio

$$\frac{V_{\max}}{V_{\min}}$$

in the guide 21 as a function of distance along this guide. Here

$$\frac{V_{\max}}{V_{\min}}$$

is the ratio of the magnitude of the voltage antinodes to the voltage nodes in the guide 21 before the plugs are in place. The plugs 22, 22' are then inserted and fastened so that one edge of the plugs, at 23, 23', is at a voltage nodal point for the standing wave found in the guide. The thickness of the plugs is determined by the standing wave ratio

$$\frac{V_{\max}}{V_{\min}}$$

and the height  $h_1$  of the guide, as expressed by the relation:

$$\frac{V_{\max}}{V_{\min}} = \frac{h_1}{h_2} \quad (1)$$

The point 23 is preferably the first minimum in the standing wave found in the non-radiating guide 21 adjacent to the slot end 19. A single plug 22 may be used if the standing wave ratio is nearly unity as the wave traveling through the guide is less distorted by a small unsymmetrical disturbance than by a large one.

If one such trial at reduction of the standing wave due to impedance mismatch is insufficient, the procedure may be repeated as shown in Fig.

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2, a new nodal point 24, 24' being found to determine the position of smaller plugs 25, 25', the plugs 25, 25' also being approximately a quarter-wave long in the guide 21.

The matching sections need not be reentrant, as in Figs. 1 and 2, but may enlarge the guide in one or two oppositely spaced enlargements, as at 26, 26' in Fig. 3. If the larger dimension is still defined as  $h_1$ , it will here refer to the height of the enlarged portion 26, 26' while the smaller distance  $h_2$  will refer to the height of the guide 21 itself. With these definitions, the size of the enlarged portion 26, 26' is again determined by Equation 1. The edges 30, 30' are now placed at the voltage anti-node nearest the slot, each enlargement 26, 26' being approximately a quarter-wave long in the guide 21. This type of transformer may be preferred to the reentrant type, as it avoids high electric fields and lessens the likelihood of arch-overs at high power levels.

While the edges 23, 23' of the plugs 22, 22' of Fig. 1 and the edges 30, 30' of the enlarged section 26, 26' of Fig. 3 are described as being positioned at a voltage nodal point and voltage anti-nodal point respectively, it will be understood that these edges could equally well be defined as to position in terms of current along the guide, the edges 23, 23' being positioned at a current maximum and the edges 30, 30' being positioned at a current minimum. Thus, both edges 23, 23' and 30, 30' may be described as being positioned at a point of maximum amplitude of one of the two electrical quantities, i. e., voltage or current.

The devices of Figs. 1 and 3 may be made adjustable in the manner shown in Fig. 4. A slidable guide 27 with ends preferably tapered over a distance large relative to one-half-wavelength in the guide 21, as at 28, 29 (shown foreshortened here for convenience of illustration) is mounted to slide in the end of the excited wave guide 31 and the non-radiating guide 21 feeding directly into the radiating guide 20 or any other device, as desired. Projecting preferably at right angles to guide 27 and mounted thereon is a rectangular tube 33 in which a conducting rectangular piston 34 may be positioned by means of knob 35. Piston 34 is substantially a quarter-wavelength long as measured in the guide 21 or 31 in the direction of energy flow, and is substantially as deep as guide 27. The procedure in adjusting the transformer may be similar to that for adjusting or selecting the location of the transformer of Figs. 1, 2 or 3. If desired, two plugs similar to 34 but at opposite sides of section 27 may be used, to more closely approach the type of transformer shown in Figs. 1 and 3.

Since many changes could be made in the above construction and many apparently widely different embodiments of this invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. A means of matching impedances coupled to a portion of a rectangular conducting wave guide excited by electromagnetic waves, said guide having a pair of oppositely positioned plugs of substantially equal thickness and of a length approximately an odd multiple including one of a quarter wavelength of the exciting waves, corresponding edges of said plugs being placed at a voltage nodal point for said waves and the dis-

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tance between the plugs being equal to the height of the guide multiplied by the ratio of amplitudes of the voltage nodes to the voltage loops.

2. A means of matching impedances coupled to a portion of a rectangular conducting wave guide excited by electromagnetic waves, said guide having a conductive plug therein of a length approximately an odd multiple including one of a quarter wavelength of the exciting waves, an edge of said plug being positioned at a voltage nodal point for said waves and the thickness of said plug being equal to the height of the guide multiplied by the factor unity minus the ratio of amplitudes of the voltage nodes to the voltage loops.

3. A means of matching impedances coupled to a wave guide of rectangular section excited by electromagnetic waves, comprising an enlarged width section of said guide, said enlarged width section being of length approximately an odd multiple including one of a quarter wavelength of the exciting waves, the height of said enlarged section being equal to the height of said wave guide multiplied by the ratio of amplitudes of the voltage loops to the voltage nodes for said waves.

4. Apparatus as in claim 3 wherein one end of said enlarged section is positioned in said wave guide at a voltage nodal point for said waves.

5. A means for matching impedances coupled to a portion of a rectangular conducting wave guide excited by electromagnetic waves, said guide having a pair of oppositely positioned plugs of a length approximately an odd multiple including one of a quarter wavelength of the exciting waves, the distance between the plugs being equal to the height of the guide multiplied by the ratio of the amplitudes of the voltage nodes to the voltage loops.

6. Apparatus as in claim 5 wherein said plugs are of equal thickness.

7. A means of matching impedances coupled to a portion of a rectangular conducting wave guide excited by electromagnetic waves, said guide having a conductive plug therein of a length approximately an odd multiple including one of a quarter wavelength of the exciting waves, the thickness of said plug being equal to the height of the guide multiplied by the factor unity minus the ratio of amplitudes of the voltage nodes to the voltage loops.

8. A means of matching impedances coupled to a portion of a rectangular conducting wave guide excited by electromagnetic waves, said guide having a plurality of pairs of oppositely positioned plugs each of a length approximately an odd multiple including one of a quarter wavelength of the exciting waves, corresponding edges of said pairs of plugs being placed at a voltage nodal point for said waves, and the distance between the plugs of each of said pairs being equal to the height of the guide multiplied by the ratio of amplitudes of the voltage nodes to the voltage loops.

9. An adjustable impedance transformer in a wave guide, comprising means forming a quarter-wave section of wave guide having adjustable cross-sectional dimensions, and means for adjusting the position of said section axially relative to the remaining portions of said wave guide.

10. An adjustable impedance transformer for use with a wave guide excited by electromagnetic waves comprising a section of wave guide whose

length equals an odd multiple including one of a quarter wavelength of the exciting waves, means for adjusting the cross-sectional dimensions of said wave guide section, and means for adjusting the longitudinal position of said wave guide section relative to said wave guide.

11. Microwave transmission apparatus comprising a hollow rectangular wave guide section having predetermined major and minor cross-sectional dimensions, and at least one conductive plug positioned in the guide, the plug having a length extending along the longitudinal axis of the guide of approximately an odd multiple including a quarter wave length of the exciting wave, a transverse edge of the plug being positioned at a voltage nodal point of the exciting wave, the plug providing a reduced minor cross-sectional dimension equal to the normal minor cross-sectional dimension multiplied by the ratio of the amplitudes of the voltage nodes to the voltage loops.

12. Microwave transmission apparatus comprising a rectangular wave guide section having predetermined major and minor cross-sectional dimensions, and at least one conductive plug positioned in the guide and providing a reduced minor cross-sectional dimension, the plug having a length extending along the longitudinal axis of the guide of approximately an odd multiple including a quarter wavelength of the exciting wave, a transverse edge of the plug being positioned at a voltage nodal point of the exciting wave.

13. Microwave transmission apparatus for matching a load impedance to a rectangular wave guide excited by electromagnetic waves, said apparatus comprising a section of rectangular wave guide having major and minor cross-sectional dimensions, a portion of said section having a minor cross-sectional dimension different than the remainder of the section, said portion being of a length approximately an odd multiple including one of a quarter wavelength of the exciting waves, the larger minor cross-sectional dimension

along said section being equal to the smaller minor cross-sectional dimension along said section multiplied by the ratio of amplitudes of the voltage loops to the voltage nodes for said waves.

14. Microwave transmission apparatus for matching a load impedance to a rectangular wave guide excited by electromagnetic waves of a predetermined frequency and wavelength, said apparatus comprising at least three tandem sections of said rectangular wave guide for transmission of the energy from the source to the load, the first section having major and minor cross-sectional dimensions substantially equal to the respective major and minor cross-sectional dimensions of the third section, and the intermediate section being of an electrical length approximately an odd multiple including one of a quarter wavelength of the exciting energy, the junction of said intermediate section and said third section being situated at a position of the maximum amplitude of one of the two electrical quantities including voltage and current along the wave guide, and the minor cross-sectional dimension of said intermediate section being related to the minor cross-sectional dimension of said third section in the ratio of the amplitude of the voltage at said junction to the amplitude of the voltage in said third section at a distance from said junction of one quarter wave guide wavelength therein.

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MONTGOMERY H. JOHNSON.

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