Nov. 26, 1946. A. G. FOX 2,411,534

IMPEDANCE TRANSFORMER

Filed March 30, 1943

FIG. 1

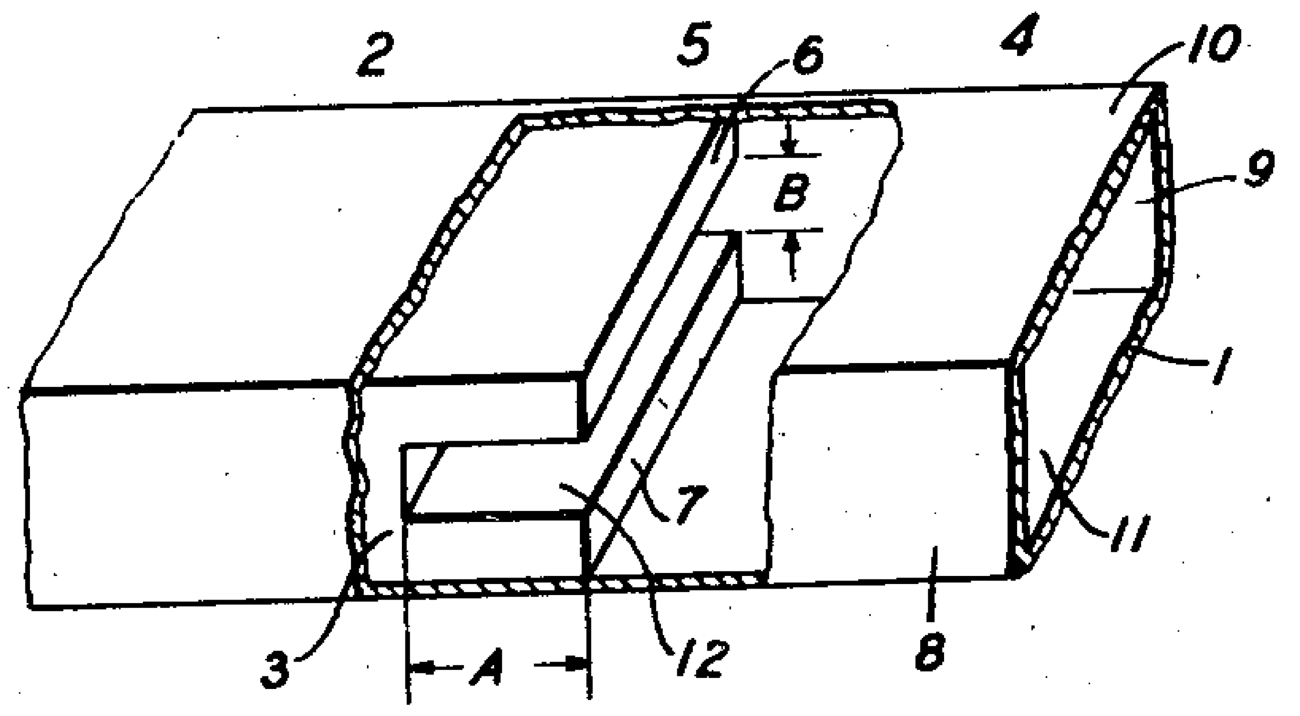


FIG. 2

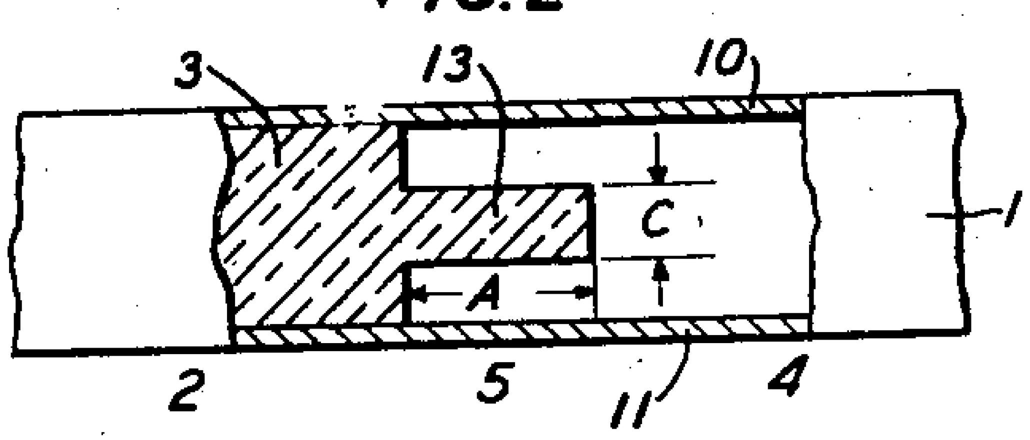


FIG. 3

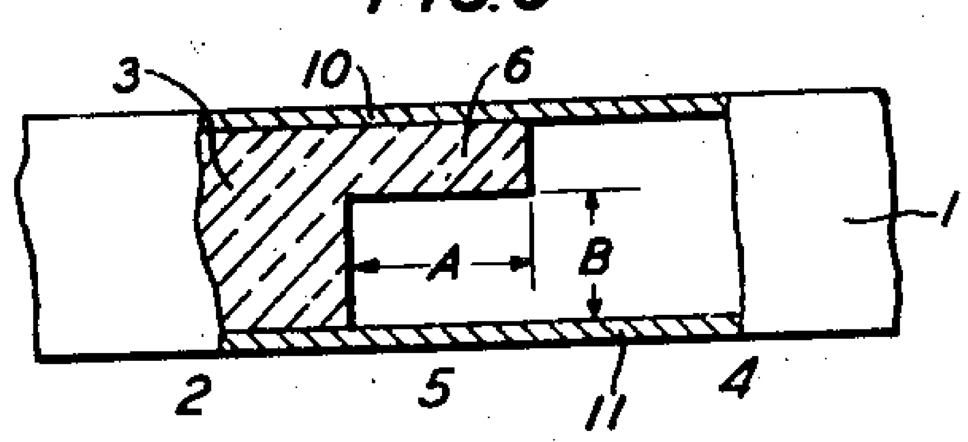


FIG. 6

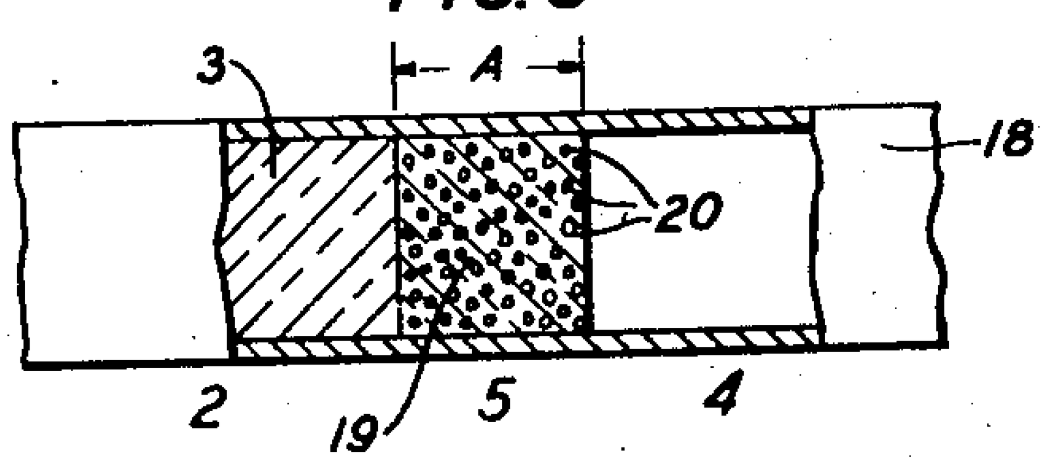


FIG. 4

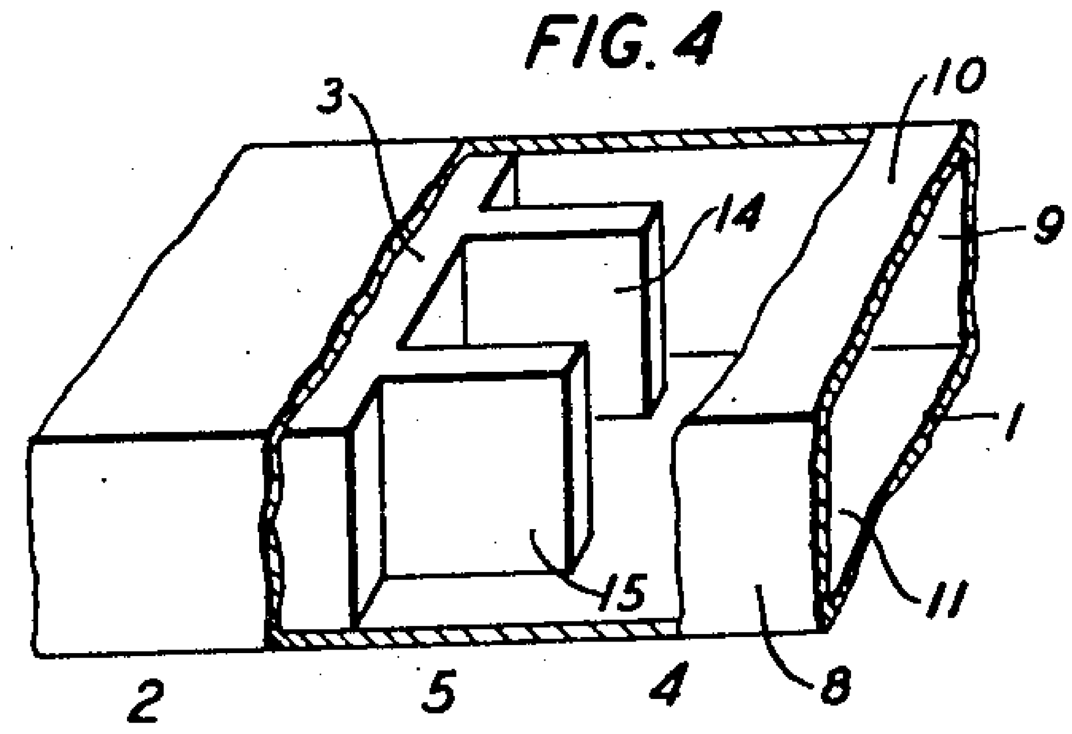


FIG. 5

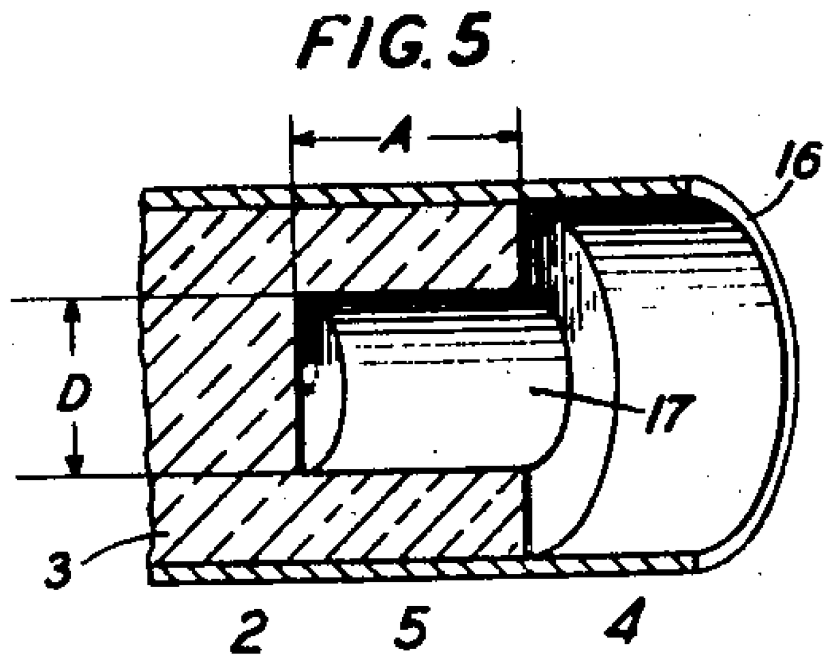
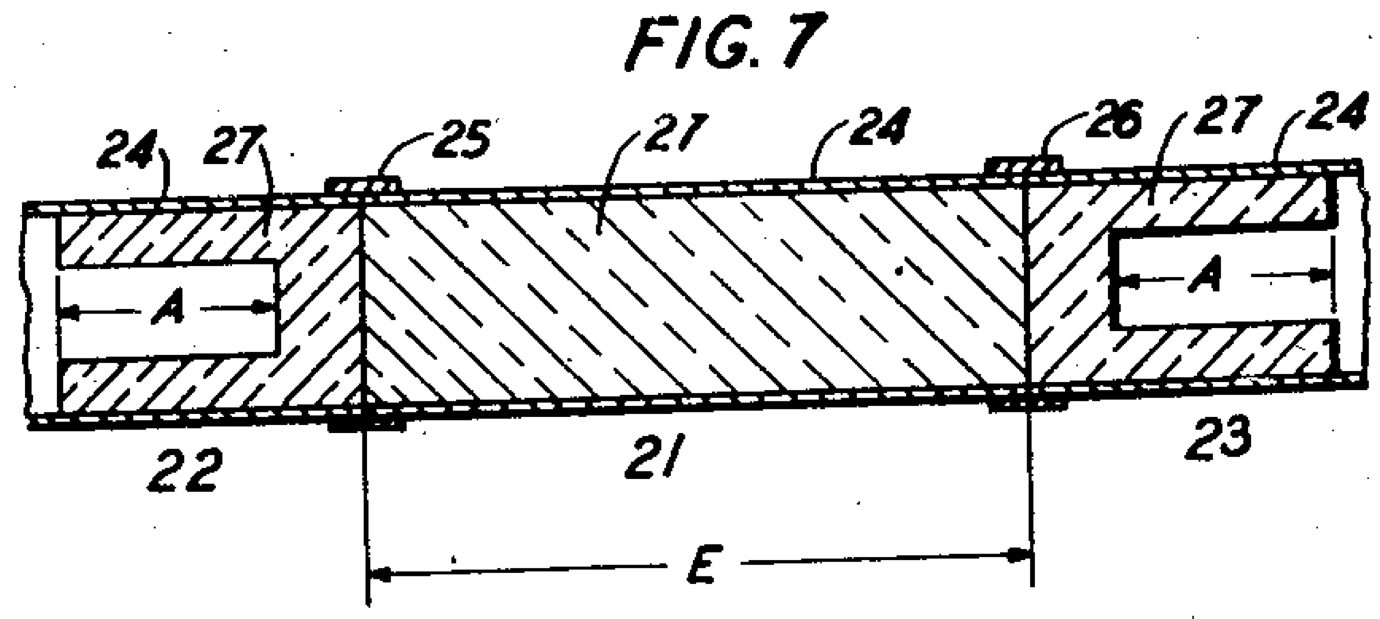


FIG. 7



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UNITED STATES PATENT OFFICE

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IMPEDANCE TRANSFORMER

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24 Claims. (Cl. 178—44)

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This invention relates to the transmission of guided electromagnetic waves and more particularly to an impedance transforming section for connecting two wave guides which differ in characteristic impedance.

The object of the invention is to connect together without reflection two metal sheathed wave guides which have different characteristic impedances.

One form of guide for electromagnetic waves consists of a metallic sheath within which is a core of dielectric material. The characteristic impedance of a wave guide of this type depends upon the dielectric constant of the core material. If two such wave guides having the same cross-section but cores with different dielectric constants are to be connected together without wave reflection it is necessary to insert a suitable impedance transforming device therebetween.

In accordance with the present invention there is provided an impedance transformer of simple construction which is suitable for this purpose. The transformer comprises a section of metallic sheath having the same cross-section as that of the wave guides to be connected and a length approximately equal to a quarter wave-length. The section has a dielectric core having an effective dielectric constant which is intermediate between the dielectric constants of the cores of the wave guides to be joined and of a value to provide an impedance match at each end of the section. The core of the section may, for example, comprise a plurality of dielectric materials which differ in dielectric constants. One or more of these materials may be the same as used in the cores of the guides to be connected. The relative proportions of the materials are chosen to provide the desired impedance match.

In one form of the transformer one of the wave guides has a core of solid dielectric material and the other guide has a fluid core such, for example, as air or some other gas. The core in the interposed section may, for example, comprise one or more projections of the core of solid material. In some cases it is preferable that the projections be symmetrical in cross-section.

The nature of the invention will be more fully understood from the following detailed description and by reference to the accompanying drawing in which like reference characters refer to similar or corresponding parts and in which:

Fig. 1 is a perspective view, partly cut away, of one form of the impedance transforming section in accordance with the invention as applied to a sheath of rectangular cross-section;

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Figs. 2 and 3 are longitudinal cross-sectional views of alternative forms of the transforming section shown in Fig. 1;

Fig. 4 is a perspective view, partly cut away, of another form of the transformer;

Fig. 5 is a perspective view of a circular impedance transforming section, cut in two longitudinally;

Fig. 6 is a longitudinal cross-section of still another form of the transformer; and

Fig. 7 is a longitudinal cross-section of a wave guide attenuator having at each end an impedance transformer of the type shown in Fig. 1 or Fig. 5.

Taking up the figures in more detail, Fig. 1 shows in perspective a wave guide comprising a metallic sheath 1 of uniform rectangular cross-section. The section 2 to the left has a core 3 of solid dielectric material such, for example, as nitro-wax or polystyrene. The section 4 to the right has an air core. Since the cores of the sections 2 and 4 have different dielectric constants the sections will differ in characteristic impedance. Therefore, in order to prevent wave reflection at the point of junction an impedance transforming section 5 must be interposed between the sections 2 and 4. In accordance with the invention, section 5 has a length A which is approximately equal to a quarter wave-length, for waves within the section and a dielectric core made up partly of the material of the core 3 of section 2 and partly of the core material of section 4, which is air. By properly choosing the relative proportions of the solid core material and air in section 5 a good impedance match may be obtained at each end of the interposed section 5.

As shown in Fig. 1, the core 3 is extended into the section 5 in the form of two projections 6 and 7 which extend from one side 8 to the opposite one 9 and are parallel with and adjacent to the sides 10 and 11 having the longer transverse dimension. The projections 6 and 7 may be conveniently formed by first filling section 5 with the material of the core 3 and then cutting out a rectangular slot, as shown at 12. For some types of electromagnetic waves it is preferable that the slot 12 be centrally located, in order to preserve the symmetry of the structure.

The proper width B for the slot 12 is perhaps best found by trial. A suggested procedure is to terminate the far end of section 2 in its characteristic impedance and to introduce radio frequency power at the right of section 4. The standing waves set up in section 4 are then measured by a standing wave detector, and their amplitude and position noted. Starting with a rather narrow slot in section 5, this is widened in small steps, and at each step the standing wave is observed and the length of section 5 readjusted if necessary so that the interface between section 4 and section 5 will always be a position of voltage minimum in the standing wave pattern. Using this procedure a width of slot will finally be found for which the standing wave entirely disappears, indicating that section 5 is properly matching section 2 to section 4.

Although the impedance transformer shown in Fig. 1 has two projections 6 and 7 it is to be understood that any number of projections, either more or less than two, may be used. Fig. 2, for example, is a longitudinal cross-sectional view of an alternative form, similar to the one shown in Fig. 1 except that the two projections 6 and 7 are replaced by a single projection 13 which, for the sake of symmetry, is centrally located between the sides 10 and 11. The projection 13 has a length A equal to a quarter wave-length and a width C chosen, as explained above, to provide an impedance match.

The transformer shown in the longitudinal cross-sectional view of Fig. 3 is similar to the one shown in Fig. 1 except that the projection 7 has been omitted. Although the structure is not symmetrical, it is suitable for use where only the dominant wave may be propagated in section 2 and section 4.

Fig. 4 is a perspective view of a transformer similar to the one shown in Fig. 1 except that the two projections 14 and 15 are parallel with the sides 8 and 9, instead of the sides 10 and 11, and, instead of being adjacent to the sides with which they are parallel, are separated therefrom. Here again, any number of projections, either greater or less than two, may be used, and one or more may be adjacent to the side 8 or 9.

Fig. 5 is a perspective view showing the invention applied to a wave guide which comprises a metallic sheath 16 of circular cross-section. The impedance transforming section 5 is formed by drilling into the solid dielectric core 3 a coaxial hole 17 of diameter D and depth A. Of course, any number of holes may be drilled. It is generally advisable, however, to locate the holes in such a way that axial symmetry is maintained.

Fig. 6 is a longitudinal cross-section showing how the invention may be applied to a wave guide comprising a sheath 18 which may be either circular or rectangular in cross-section. The quarter wave section 5 is filled with a solid dielectric material 19 in which a number of air pockets or bubbles 20 are formed. The air pockets 20 may, for example, be produced by some chemical process or by whipping a wax with a mechanical beater. Alternatively, the filler 19 may be an amorphous granular material with interstices 20 of air. Another method of obtaining the air pockets 20 is by mechanically removing portions of the solid material 19, as, for example, by drilling holes which may extend in any direction and go either part way or all the way through the material. In any case, a sufficient amount of air is introduced that the effective dielectric constant of the filler 19 is of the proper value to provide an impedance match at each end of section 5.

The longitudinal cross-sectional view of Fig. 7 shows the invention applied to a wave guide attenuator comprising a central section 21 to the ends of which are connected the impedance

transforming sections 22 and 23 for joining the attenuator without reflection to air-filled wave guides. Each of the sections 21, 22 and 23 has a metallic sheath 24 which may be either rectangular or circular in cross-section. The sections are joined together by means of the metallic bands 25 and 26 which preferably extend all the way around the sheaths 24. The central section 21 is filled with a solid dielectric material 27. Each of the end sections 22 and 23, for a distance A equal to a quarter wave-length, is filled partly with the solid dielectric material 27 and partly with air. If the sheath 24 is of rectangular cross-section, the transformer sections 22 and 23 may be of the form shown in Fig. 1, 2, 3 or 4, or some modification thereof. If the sheath 24 is circular, the end sections 22 and 23 may, for example, be of the form shown in Fig. 5. Also, of course, with either a rectangular or circular sheath 24 the sections 22 and 23 may be of the type shown in Fig. 6. The length E of the central section 21 is chosen to give the desired overall attenuation for the attenuator.

What is claimed is:

1. An impedance transforming section for connecting together without reflection two wave guides, said section and each of said guides comprising a metallic sheath of the same cross-section, one of said guides having a core of solid dielectric material, the other of said guides having a core of dielectric material which has a dielectric constant different from that of said core in said one guide, and said section having a length approximately equal to a quarter wave-length and a dielectric core which has an effective dielectric constant of a value to provide an impedance match at each end of said section.

2. An impedance transforming section in accordance with claim 1 in which said core of said section comprises a plurality of dielectric materials which differ in dielectric constants.

3. An impedance transforming section in accordance with claim 1 in which said core of said section comprises a solid dielectric material and a fluid dielectric material.

4. An impedance transforming section in accordance with claim 1 in which said core of said section comprises a solid dielectric material and a gas.

5. An impedance transforming section in accordance with claim 1 in which said core of said section comprises a solid dielectric material and air.

6. An impedance transforming section in accordance with claim 1 in which said core of said section is made partly of the material of said core in said one guide and partly of the material of said core in said other guide.

7. An impedance transforming section in accordance with claim 1 in which said core in said other guide is a gas.

8. An impedance transforming section in accordance with claim 1 in which said core in said other guide is a gas and said core of said section is made partly of solid material and partly of gas.

9. An impedance transforming section in accordance with claim 1 in which said core in said other guide is air and said core of said section is made partly of the material of said core in said one guide and partly of air.

10. In a metal sheathed wave guide of uniform cross-section, a first section having a core made of a solid dielectric material, a second section having a core of dielectric material which has a

dielectric constant different from that of said core in said first section and an interposed section of quarter wavelength having a dielectric core which has an effective dielectric constant of a value to provide an impedance match at each end of said interposed section.

11. The combination in accordance with claim 10 in which said core of said interposed section comprises a plurality of dielectric materials which differ in dielectric constants.

12. The combination in accordance with claim 10 in which said core of said interposed section comprises a solid dielectric material and air.

13. The combination in accordance with claim 10 in which said core of said interposed section is made partly of the material of said core in said first section and partly of the material of said core in said second section.

14. The combination in accordance with claim 10 in which said core in said second section is air and said core of said interposed section is made partly of the material of said core in said first section and partly of air.

15. The combination in accordance with claim 10 in which said core in said interposed section comprises a projection of said core in said first section.

16. The combination in accordance with claim 10 in which said core in said interposed section comprises a symmetrical projection of said core in said first section.

17. The combination in accordance with claim 10 in which said core in said interposed section comprises a plurality of projections of said core in said first section.

18. The combination in accordance with claim 10 in which said core in said interposed section comprises a plurality of symmetrical projections of said core in said first section.

19. The combination in accordance with claim 10 in which said core in said second section is

air and said core in said interposed section comprises a projection of said core in said first section.

20. The combination in accordance with claim 10 in which said core in said second section is air and said core in said interposed section comprises a plurality of projections of said core in said first section.

21. A metal sheathed wave guide of uniform cross-section containing a solid dielectric element and a medium having a different dielectric constant, said element having a quarter wavelength terminal portion of reduced cross-section extending into said medium for matching the impedance of the section of the guide containing said element to said medium.

22. A wave guide in accordance with claim 21 in which said terminal portion is of uniform cross-section.

23. A metal sheathed wave guide of uniform cross-section containing a solid dielectric element and a medium having a different dielectric constant, said element having a quarter wavelength terminal portion of reduced cross-section extending into said medium and the section of the guide containing said terminal portion having an effective dielectric constant of a value to provide an impedance match at each end thereof.

24. A metal sheathed wave guide of uniform cross-section containing a solid dielectric element and a medium having a different dielectric constant, said element having at one end a longitudinal slot extending to a depth of a quarter wave-length and the medium extending into said slot together with the material in which said slot is formed combining to provide an effective dielectric constant of proper value to match the impedance of the section of the guide containing said element to said medium.

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