

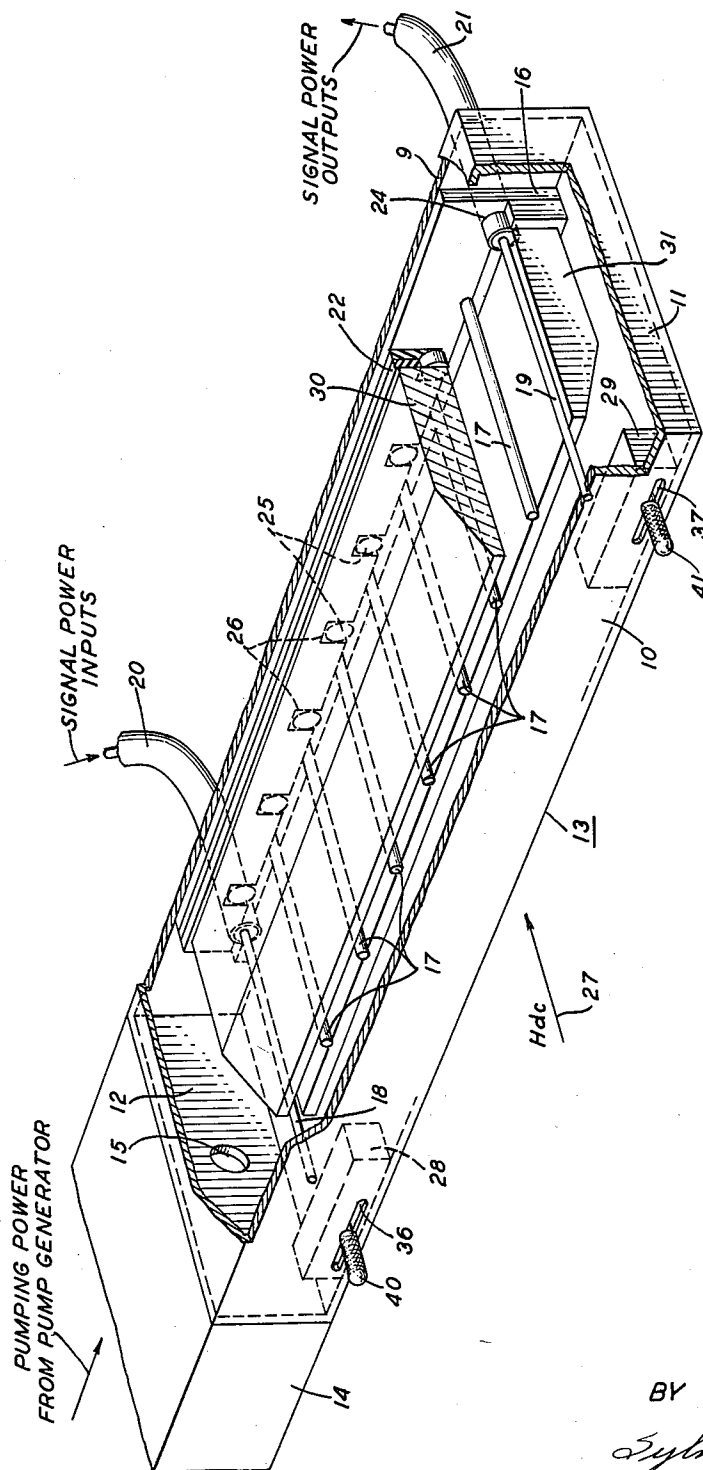
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BROADBAND COUPLING TO COMB-STRUCTURE

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BROADBAND COUPLING TO COMB-STRUCTURE
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This invention relates to electromagnetic wave devices and, in particular, to means for coupling to slow-wave structures.

It is often advantageous to modify the velocity of propagation of a traveling wave in order to enhance the interaction of the wave with another wave or structure. Various types of slow-wave structures have been developed for this purpose including, for example, the helix in a traveling wave tube; the transverse, conductive fins described by H. Suhl in United States Patent 2,922,126, issued January 19, 1960, to enhance the interaction of electromagnetic waves and ionized gas; and, more recently, the comb-structure used in the traveling wave maser as described by De Grasse et al. in their copending application Serial No. 744,563, filed June 25, 1958, now Patent No. 3,004,225. All of these devices have one problem in common, i.e., the difficulty of coupling to and from the slow-wave structure.

It is a generally accepted fact of life that broad-band matches to slow-microwave structures are arrived at more by experimentation and intuition than as a result of theory and analysis. Some experts refer to the business of matching as a "black magic." In the present state of the art, transducers of various shapes and dimensions are determined empirically and used if found to be satisfactory for the specific purpose.

Currently there has been much interest shown in the traveling wave maser, particularly the kind described in said De Grasse et al. application. The importance of this solid state device stems from the fact that it is the amplifier of lowest noise known today.

The coupling and matching technique which usually has been used in such a maser was introduced by R. W. De Grasse in 1958 and is described in an article entitled "The Three-Level Solid State Traveling Wave Maser" by R. W. De Grasse, E. O. Schulz-Du Bois and H. E. D. Scovil, published in the March 1959 Bell System Technical Journal. As described in the above-mentioned article, the center conductor of the input (and output) coaxial cable penetrates the base of the slow-wave comb-structure through a hole some distance away from the first finger of the comb. The coupling conductor is generally thinner than the comb fingers and is bent so as to come close to the first finger over a small region of its length. The exact shape of the bend is determined experimentally by observing the electrical characteristics of the match. Using this configuration, a voltage standing wave ratio of better than 1.5 is obtained over a 180 megacycle per second bandwidth. This would be 20 or 22 percent of the total bandwidth available from the comb-structure. While this type of performance was adequate for many applications, there is currently a need for broader band matches.

It is therefore the object of this invention to broaden the frequency range over which a coaxial cable is matched to a comb-type slow-wave structure.

In accordance with the invention an improved broad-band match is obtained by making the coupling element have essentially the same electrical characteristics as the comb fingers. Accordingly, the mechanical configuration of the coupling conductor is preferably similar to that of the comb fingers. In particular, the coupling conductor which, advantageously, has the same cross-sectional dimensions as the fingers, extends parallel to the

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comb fingers and is separated from the next adjacent finger by approximately the finger-to-finger spacing of the comb. The coupling conductor, however, extends completely across the slow-wave structure enclosure and is conductively connected to the far side thereof. By way of contrast, the fingers of the comb terminate short of the far side of the enclosure so as to have one end open circuited.

Matching means in the form of an electrical discontinuity adjacent the coupling conductor are also provided. Considering the important role that dielectric loading plays with respect to the pass band and slowing of the comb-structure, dielectric loading is advantageously utilized to match the coupling conductor to the comb-structure. Matching means in the form of a block of dielectric material having a dielectric constant of at least two have proved satisfactory. However, metallic matching members have also been used successfully.

Typically, matches produced in accordance with the invention have increased the useful part of the structure pass band to as much as 75 percent of the total bandwidth available from the comb-structure.

These and other objects and advantages, the nature of the present invention, and its various features, will appear more fully upon consideration of the illustrative embodiment now to be described in detail in connection with the accompanying drawing.

Referring to the drawing, there is shown a device utilizing a comb-type slow-wave structure and coaxial-to-comb coupling means in accordance with the teachings of this invention. Specifically, the device is a traveling wave maser comprising a waveguiding medium within which there is located a slow-wave comb-structure, a pair of slabs of active material of a type which is capable of amplifying by the stimulated emission of wave energy, and an isolator. In the particular embodiment of the invention shown, the waveguiding medium comprises a length of rectangular waveguide 10 terminated at both ends by means of transverse conductive members 11 and 12. The resulting cavity 13 is proportioned to support a standing wave of pumping power, which pumping power is derived from a pump generator (not shown) by way of a waveguide 14 and applied to cavity 13 through an aperture 15 in member 12.

The slow-wave comb-structure comprises a conductive base member 16 disposed within cavity 13 along which there is mounted an array of conductive rods or fingers 17 which are orthogonally disposed with respect to the longitudinal axis of the section of rectangular waveguide 10. Rods 17 are conductively secured to the base member 16 which, in turn, is located contiguous to one of the narrow walls 9 of waveguide 10. Alternatively, rods 17 are secured in holes drilled directly in one of the narrow walls of guide 10, the separate base member 16 then being omitted, its role being served by the wall of the guide.

Situated between the array of posts and the upper and lower wide walls of guide 10 are a pair of slabs 30 and 31 of active material, typically ruby, whose geometry is described in detail in the copending application of E. O. Schulz-Du Bois, Serial No. 120,675, filed June 29, 1961. Various paramagnetic salts are suitable for use as the active or negative temperature material of a maser device of the type described herein. The desired properties of these materials are described by N. Bloembergen in an article entitled "Proposal for a New Type Solid State Maser" published in The Physical Review, vol. 104, No. 2, pages 324-327.

Because the gain through the amplifier in the reverse direction is appreciable, a nonreciprocal loss mechanism is preferably included for stability. Such loss is provided by an isolator incorporated directly into the amplifier

structure. In the arrangement shown, the isolator comprises a plurality of gyromagnetic elements 25 supported within apertures 26 located in a dielectric spacer 22.

The gyromagnetic material and the maser material are magnetically biased by means of a common steady field H_{dc} , indicated by an arrow 27, directed parallel to the rods 17. The source of this field is not shown. However, it is understood that field H_{dc} can be supplied in any convenient manner well known in the art such as, for example, by using an electromagnet or permanent magnet and can, in addition, include means for varying the intensity of the field such as a potentiometer or a magnetic shunt.

Signal input energy is transmitted to the amplifier by means of a coaxial cable 20 and signal output energy is abstracted from the amplifier by means of a second coaxial cable 21.

As indicated previously, a problem commonly faced in connection with slow-wave structures is how to best couple into (and out of) such devices so as to achieve a broadband impedance match. In accordance with the invention, broadband matches are obtained by extending the center conductors of the coaxial cables 20 and 21 into, and across the cavity 13 in a direction parallel to the comb fingers 17 and conductively connecting them to the opposite wall thereof. The distance between each of these coupling conductors 18 and 19 and the next adjacent comb finger is made substantially equal to the finger-to-finger spacing of the comb-structure. In contrast to the comb fingers, the coupling conductors 18 and 19 are electrically insulated from the base of the comb structure, being short circuited instead to the opposite narrow wall. On the other hand, the outer conductors of coaxial cables 20 and 21 are conductively connected to the wall of the guide which supports the base member.

Advantageously, though not necessarily, coupling conductors 18 and 19 and the fingers 17 have the same cross-sectional shape and dimensions.

Fine adjustment of the impedance match at each coupling network is made by means of a matching member or blocks 28 and 29. These members modify the electric field conditions in the region between the coupling conductor and the comb-structure and are, accordingly, located at the open end of the comb fingers in the illustrated embodiment. Each extends longitudinally along the slow-wave structure from a point adjacent one of the coupling conductors to a point along the slow-wave structure adjacent at least the first comb finger. Typically, the maximum length of the matching blocks is of the order of twice the finger-to-finger spacing so that each number extends from a point before the coupling conductor to a point between the first and the second finger from the coupling conductor.

The transverse dimensions of the matching members are determined experimentally. It has been found that the transverse dimension perpendicular to the comb finger is more critical than the transverse dimension parallel to the fingers. The former dimension typically is no greater than the distance between the coupling conductor and one of the wide walls. This permits for longitudinal motion along the slow-wave structure. In the illustrative embodiment the transverse dimension parallel to the comb fingers is limited by the distance between the opposite narrow wall and the maser material.

Both metallic and dielectric matching blocks of ex-

perimentally determined shapes have been successfully used.

In the illustrative embodiment, the matching blocks 28 and 29 are located in a corner of guide 10 in contact with one of the wide walls and the narrow wall adjacent the open end of the comb-structure. The position of each block is adjusted by means of a control knob 40 or 41. The latter are secured to the blocks and extend outside the device through elongated slots 36 and 37, respectively, cut through one of the guide walls adjacent to the blocks. Means (not shown) for locking the blocks in place can be provided to make secure the proper setting once it is obtained. Alternatively, the blocks can be preset at manufacture and no adjustable feature provided.

While the invention has been described in connection with a traveling wave maser, it is to be understood that the coupling and matching techniques herein disclosed can be readily used in connection with other devices employing a comb-type slow-wave structure. Accordingly, it is to be understood that the above-described arrangement is merely illustrative of one of the many possible specific embodiments which can represent applications of the principles of the invention. Numerous and varied other arrangements can readily be devised in accordance with these principles by those skilled in the art without departing from the spirit and scope of the invention.

What is claimed is:

1. In combination:

a section of hollow waveguide, means disposed within said waveguide for forming a slow wave circuit comprising a coplanar array of rods longitudinally distributed therein, each of said rods extending transverse to the guide axis in a direction substantially parallel to one another and each rod being equally spaced from the next adjacent rod, each rod having one end short-circuited to one wall of the waveguide and the other end open-circuited,

means for coupling electromagnetic wave energy to said slow-wave circuit comprising a coaxial transmission line having an outer and an inner conductor, the outer conductor being short-circuited to said one wall of said waveguide, the inner conductor forming a coupling element extending through said one wall and across the guide to the opposite wall of said guide and being short-circuited thereto, said coupling element being substantially parallel to and coplanar with the rods of said array with the spacing between said coupling element and the next adjacent rod being substantially the same as the spacing between adjacent rods of said array, and matching means positioned adjacent to said coupling element for matching the coupling element to the array.

2. The combination according to claim 1 wherein said matching means extends longitudinally along said slow-wave circuit over an interval equal to at least the spacing between adjacent rods but less than twice said spacing.

3. A microwave maser comprising the combination according to claim 1 in further combination with means forming a negative temperature medium.

No references cited.