Dec. 6, 1966 G. MOURIER 3,290,545

ELECTRON DISCHARGE DEVICE WITH EXTERNAL MODE SUPPRESSION MEANS WHICH SEPARATE WANTED FROM UNWANTED MODES AND ALLOW FOR DISSIPATION OF UNWANTED MODES

Filed March 26, 1963 2 Sheets-Sheet 1

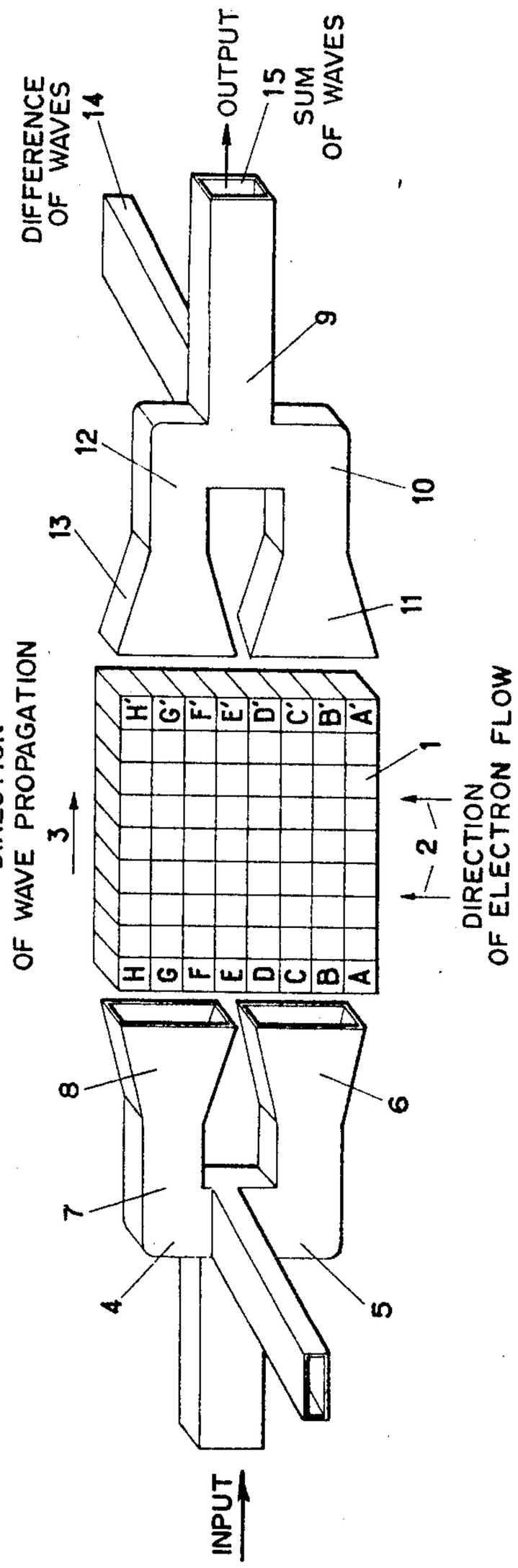


FIG. 1

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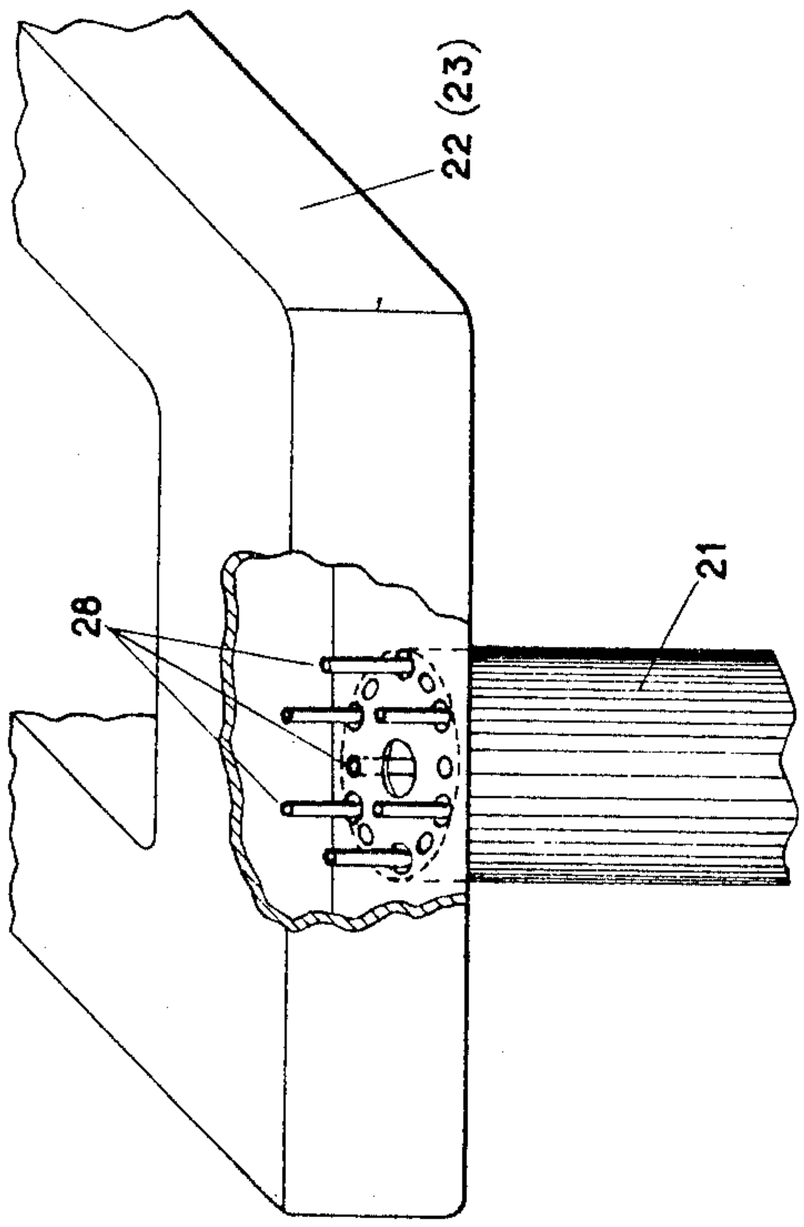


FIG. 3

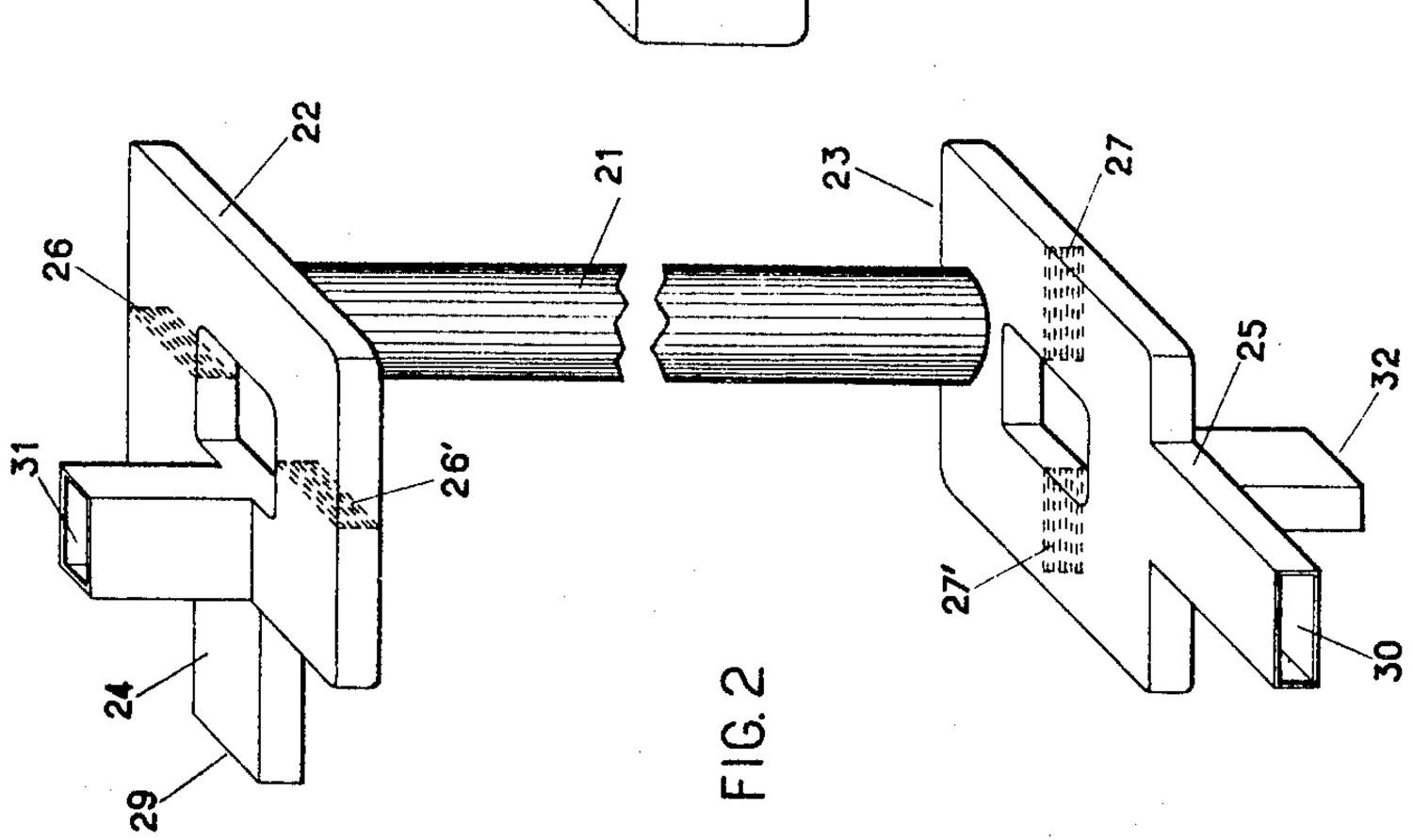


FIG. 2

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United States Patent Office

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ELECTRON DISCHARGE DEVICE WITH EXTERNAL MODE SUPPRESSION MEANS WHICH SEPARATE WANTED FROM UNWANTED MODES AND ALLOW FOR DISSIPATION OF UNWANTED MODES

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6 Claims. (Cl. 315—3.6)

The present invention relates to ultra-high-frequency amplifier tubes with bi-dimensional delay circuits such as described, for example, in United States Patent No. 2,954,505 of September 27, 1960.

In the tubes of this type, in which the interaction between the electron beam and the ultra-high-frequency energy to be amplified takes place along one direction parallel to one of the dimensions of the delay circuit, while the propagation of the ultra-high-frequency energy takes place, transversely to the beam, along a direction parallel to the other dimension of the delay circuit, one encounters certain difficulties due to the multiplicity of possible modes of propagation.

There always exists, in effect, one or several modes having phase velocities and bands of frequencies of propagation near those of the utilized mode, and a danger of auto-oscillation or of operation under unfavorable conditions follows therefrom. This danger is still further aggravated by the coupling elements at the output and/or input circuits.

The present invention has for its object a circuit arrangement which permits to remedy these difficulties.

According to the present invention, the construction and circuit connections of an electron tube comprising a bi-dimensional delay circuit, means for producing one or several electron beams propagating in one direction parallel to one of the dimensions of the delay circuit, an input circuit permitting to inject at one of the extremities of the tube ultra-high-frequency waves to be amplified, propagating in a direction parallel to the other dimension of the delay circuit, and an output circuit at the opposite extremity of the tube to extract the amplified ultra-high-frequency waves, is characterized by the disposition of means enabling to produce the sum and the difference of the half-waves at least at one of the extremities of the tube, and to cause these sums and differences of waves to pass through distinct paths.

According to a preferred mode of realization of the present invention, the means to produce the sum and the difference of the half-waves are constituted by so-called "magic T's."

Accordingly, it is an object of the present invention to provide an ultra-high-frequency electron discharge device of the type described hereinabove in which the drawbacks and inconveniences due to the presence of undesired modes are effectively minimized by simple means.

It is another object of the present invention to provide an arrangement which reduces the danger of auto-oscillations or operation under unfavorable conditions in connection with electron discharge tubes having a bi-dimensional delay structure.

Still another object of the present invention resides in the provision of an ultra-high-frequency electron discharge tube producing signal amplification which includes a bi-dimensional wave guiding structure and means operable to minimize any interference by undesirable modes with the mode on which the tube is intended to operate.

These and other objects, features and advantages of the present invention will become more obvious from the following description when taken in connection with the

accompanying drawing which shows, for purposes of illustration only, two embodiments in accordance with the present invention and wherein:

FIGURE 1 is a schematic perspective view of one circuit arrangement according to the present invention for a tube provided with a bi-dimensional delay circuit of rectangular form,

FIGURE 2 is a schematic perspective view of a similar circuit arrangement for a tube with a bi-dimensional delay circuit and of cylindrical structure, and

FIGURE 3 is a perspective view, on an enlarged scale and with parts thereof broken away, of the assembly of FIGURE 2.

Referring now to the drawing wherein like reference numerals are used throughout the various views to designate like parts, and more particularly to FIGURE 1, reference numeral **1** designates a conventional bi-dimensional delay circuit illustrated therein only schematically which may be utilized in an ultra-high-frequency amplifier tube of high power. This circuit comprises rows A, A′, B, B′ . . . G, G′, H, H′, each formed by distinct delay cells which are schematically shown in the drawing by square blocks.

To simplify the drawing, the complete tube has not been illustrated therein but it suffices to recall that in such a tube one produces, according to well-known techniques, one or several electron beams, subjected to crossed electric and magnetic fields in such a manner that the electrons propagate parallelly to one of the dimensions of the delay circuit; the ultra-high-frequency waves to be amplified, which are injected through an input circuit at one extremity of the tube, propagate along the delay circuit parallelly to the other dimension of the delay circuit, and an output circuit, at the opposite extremity of the tube, permits to collect the amplified waves.

In the embodiment of FIGURE 1, the direction of propagation of the electrons is indicated by the arrows **2** and the direction of propagation of the ultra-high-frequency energy on the inside of the tube by the arrow **3**.

The input circuit, coupled to the left side of the tube as viewed in FIGURE 1, comprises a magic "T" **4** of which the branch or section **5** is coupled, by means of a horn **6**, to the cells A, B, C, and D, and the branch or section **7** is, in a similar manner, coupled to the cells E, F, G, and H by means of a horn **8**.

In an analogous manner, the output circuit, coupled to the right side of the tube as viewed in FIGURE 1, may comprise a magic "T" **9** having a branch or section **10** coupled to the cells A′, B′, C′ and D′ by means of a horn **11** and a branch or section **12**, coupled to the cells E′, F′, G′ and H′ by means of a horn **13**.

When the tube is caused to operate according to the fundamental mode (mode 0), all the cells A to H are in phase at the input of the tube, and in a similar manner, all the cells A′ to H′ are in phase at the output of the tube. The waves collected in that case at the output by the horns **11** and **13**, combine in the magic "T" **9** which, by virtue of the well-known properties of magic "T's," produces the difference of these waves, that is zero, in the wave guide **14**, and the sum, that is all the ultra-high-frequency energy available, in the wave guide **15**.

However, alongside the utilized fundamental mode appear generally also diverse undesirable modes.

If one calls N the number of rows of the cells, this number being 8 in the case of FIGURE 1, the mode $2\pi/N$ is among the undesirable modes, the nearest to the fundamental mode and generally also the most objectionable. However, in the $2\pi/N$ mode, the outermost cells A and H or A′ and H′ are out of phase by 2π. Consequently, there exists between the cells A and H a full wave, presenting a positive phase along one-half of the cells and a negative phase along the other half.

Under these conditions, one can readily see immediately that the waves of the mode $2\pi/N$, that arrive at the magic "T" **9**, appear exclusively in the wave guide **14** and do not manifest themselves at all in the wave guide **15**, which is exactly the reverse of what takes place, as described hereinabove, for the fundamental mode. It suffices, therefore, to terminate the wave guide **14** by an appropriate impedance to absorb thereat all of the energy of the undesirable mode in question without the possibility that the latter might be reflected toward the interior of the tube which generally has as its effect to suppress the possibilities of auto-oscillation on this mode.

The reasoning applied to the output side is equally valid for the input side in which the magic "T" **4** behaves obviously in the same manner as the magic "T" **9** of the output circuit.

It is to be noted, however, that one may also utilize at the input a different circuit from that of the output. Thus, the input circuit may be a simple wave guide, without any magic "T," if the dispositions of the output circuit suffice by themselves to eliminate the undesirable mode.

In certain cases, one may also seek to eliminate an undesirable mode at one extremity of the tube and another undesirable mode at the other extremity thereof. One may, in effect, always find the number of magic "T's" and of horns necessary for the coupling to the tube to combat thereat a given mode of propagation.

FIGURE 2 represents schematically a cylindrical amplifier tube with a bi-dimension delay circuit, connected in accordance with the present invention.

The bi-dimensional delay circuits for cylindrical tubes may be assimilated to that of FIGURE 1, wound or rolled upon itself about the axis of the tube in such a manner that the cells H . . . H′ come to be adjacent the cells A . . . A′. Such a circuit is, therefore, formed by a number of rectilinear delay lines, disposed as columns or bars about the axis of the tube, and lends itself to be disposed more particularly about an emissive cathode of the magnetron type.

The circuit connection of FIGURE 2 comprises at each extremity of the tube **21** a wave guide **22** and **23**, coupled to the tube **21** and connected to the two arms of the magic "T" **24** and **25**, respectively. Windows **26**, **26′** and **27**, **27′**, which are vacuum-tight and transparent to the electromagnetic waves, are disposed, as indicated in dash lines, within the wave guides **22** and **23**, respectively.

FIGURE 3 shows the manner in which the tube **21** is coupled to the guides **22** and **23**. This figure illustrates, on an enlarged scale, one extremity of the tube **21** with its bi-dimensional delay circuit. The bi-dimensional delay circuit is represented schematically by twelve bars or columns **28** of which six, longer than the others, emerge into the wave guide to which they are thus coupled.

With circuits of this type, there exists generally an interest to cause the tubes to operate in the π mode, that is, with a phase shift between adjacent columns equal to π. If the number of columns k is even, $k=2n$, n being an integer, one has n full waves along the circumference of the tube.

However, alongside the π mode which one desires to utilize, the circuit may also become the locus or seat of undesirable modes and particularly of that in which two adjacent columns are out of phase by

$$\frac{n-1}{n}\pi$$

which gives rise, along the circumference of the tube, to a number of waves $(n-1)$, less by one to that obtained with the π mode.

In the given example in which $k=12$, the tube operating on the π mode presents along its circumference six full waves, and the six columns **28** coupled to the wave guides are all in phase. These waves combine therefore in the magic "T" which produces the sum thereof in the branch

or section **29** or **30** (FIGURE 2) while no energy appears in the branch or section **31** or **32** which would represent the differences of waves.

If now the delay circuit becomes also the seat of the undesirable mode $5\pi/6$, that is,

$$\frac{n-1}{n}\pi$$

with $n=6$, this mode produces five full waves along the circumference of the tube and the six columns **28** are no longer all in phase. Three consecutive columns will, therefore, present an opposite phase to that of three other columns in such a manner that within the magic "T's" one will find substantially all the energy corresponding to the undersired mode in the branch or section **31** or **32**, provided that one chooses for the magic "T's" the optimum orientation which depends on the relative position of the nodes of the undesired waves with respect to the columns **28**.

The magic "T's" have been illustrated in FIGURE 2 at the two extremities of the tube with a phase shift of 90° between themselves as such an arrangement permits the elimination of the undesirable waves of two different orientations. However, depending on the case, it is also possible to orient the two magic "T's" in the same direction or to utilize only a single magic "T," preferably at the output side of the tube.

While I have shown and described two embodiments in accordance with the present invention, it is understood that the same is not limited thereto but is susceptible of numerous changes and modifications within the spirit and scope thereof and I, therefore, do not wish to limited to the details shown and described herein but intend to cover all such changes and modifications as are encompassed by the scope of the appended claims.

I claim:

1. An ultra-high-frequency arrangement comprising:
an electron discharge tube including a two dimensional wave delay structure, means for propagating at least one electron stream approximately parallelly to one of the dimensions of said delay structure, coupling means operatively connected to said wave delay structure to enable the propagation of electromagnetic waves along said wave delay structure approximately parallelly to another dimension thereof and in energy transfer relationship to said electron stream,
and means for producing the sum and the difference of two half-waves at least within the area of said coupling means and for separating the energies obtained in said sum and difference, respectively.

2. An ultra-high-frequency arrangement comprising:
an electron discharge tube including a two dimensional wave delay structure, means for propagating at least one electron stream approximately parallelly to one of the dimensions of said delay structure, coupling means operatively connected to said wave delay structure to enable the propagation of electromagnetic waves along said wave delay structure approximately parallelly to another dimension thereof and in energy transfer relationship to said electron stream,
and means for producing the sum and the difference of two half-waves at least within the area of said coupling means and for separating the energies obtained in said sum and difference, respectively, including magic "T" means.

3. In an electron discharge tube of the type in which electromagnetic waves propagate substantially parallelly to one dimension of a two-dimensional wave-guiding structure in energy exchange relationship with at least one electron stream propagating substantially parallelly to the other dimension of said structure, and in which energy of the electromagnetic waves is adapted to be extracted from said wave-guiding structure through an output circuit,
the improvement essentially consisting of means for

producing the sum and the difference of two half-waves in said output circuit and for separating the energies in said sum and difference, respectively.

4. In an electron discharge tube effectively having at least one end and of the type in which electromagnetic waves propagate substantially parallelly to one dimension of a two dimensional wave-guiding structure in energy exchange relationship with at least one electron beam propagating substantially parallelly to the other dimension of said structure,

the improvement essentially consisting of means for producing the sum and the difference of two half waves at said one end of the tube and means for separating the energies in said sum and difference, respectively.

5. An ultra-high-frequency arrangement comprising:

an electron discharge tube effectively having two ends and including a two dimensional wave delay structure, means for propagating at least one electron stream approximately parallelly to one of the dimensions of said delay structure,

output means operatively connected to said wave delay structure near a respective end of the tube to enable the energy transfer of electromagnetic waves operable to propagate in said wave delay structure approximately parallelly to another dimension thereof,

and means for producing the sum and the difference of two half-waves at least within the area of said tube near said output means and separating the energies

obtained in said sum and difference, respectively, including magic "T" means.

6. An ultra-high-frequency arrangement comprising:

an electron discharge tube effectively having two ends and including a two dimensional wave delay structure, means for propagating at least one electron stream approximately parallelly to one of the dimensions of said delay structure,

input and output means operatively connected to said wave delay structure near a respective end of the tube to enable the energy transfer of electromagnetic waves operable to propagate in said wave delay structure approximately parallelly to another dimension thereof,

and means for producing the sum and the difference of two half-waves at least within the area of said tube near one of said input and output means and separating the energies obtained in said sum and difference, respectively, including magic "T" means.

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