

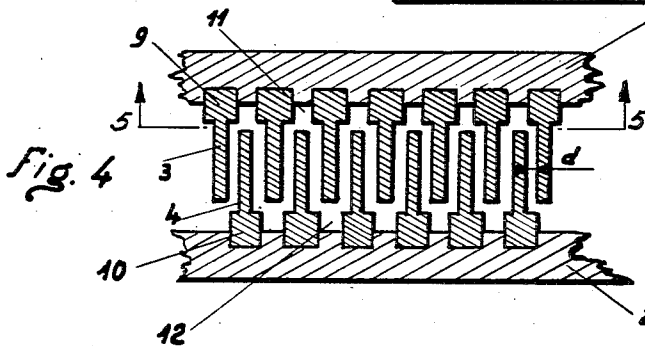
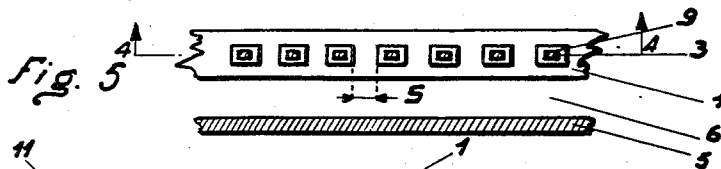
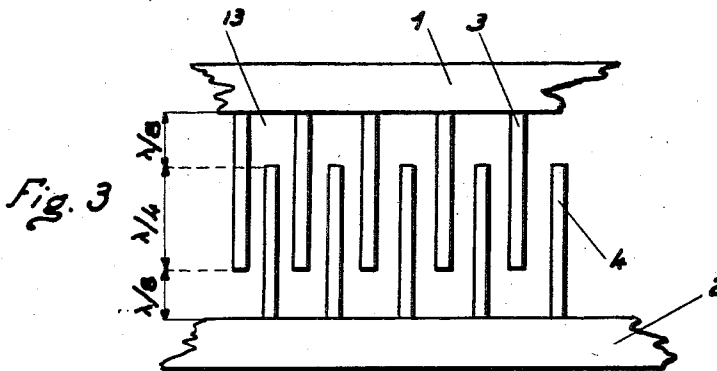
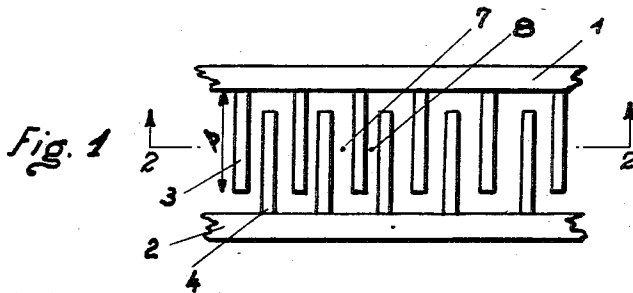
March 18, 1958

P. GUENARD ET AL
TRAVELLING WAVE DISCHARGE TUBE ARRANGEMENTS
UTILIZING DELAY LINES

2,827,588

Filed April 17, 1952

3 Sheets-Sheet 1



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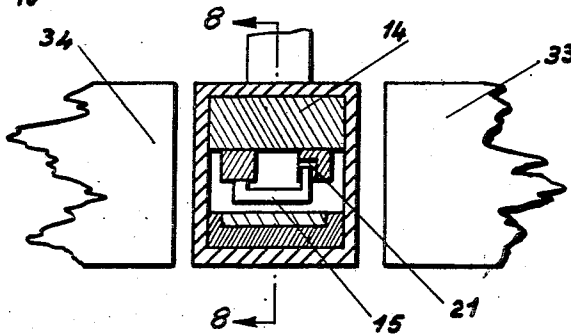
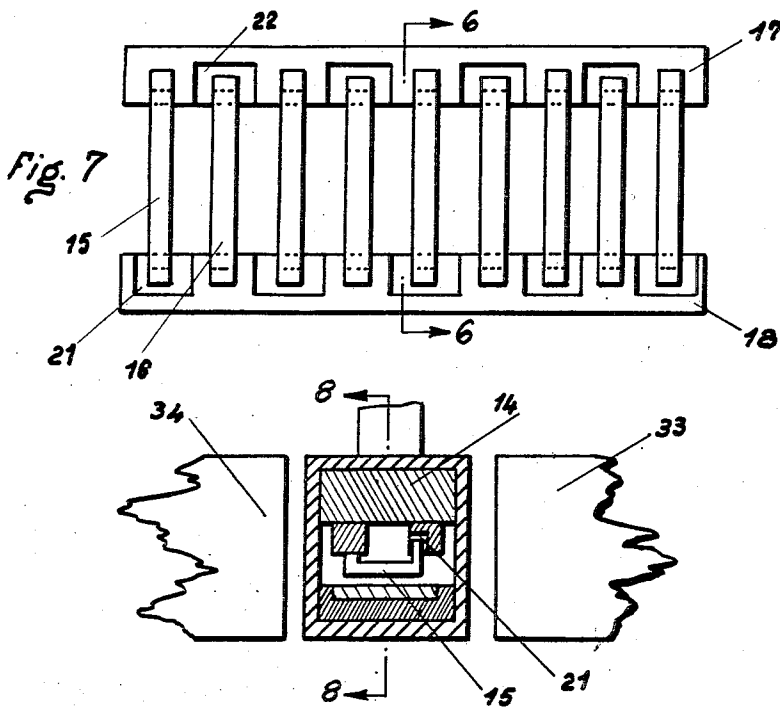
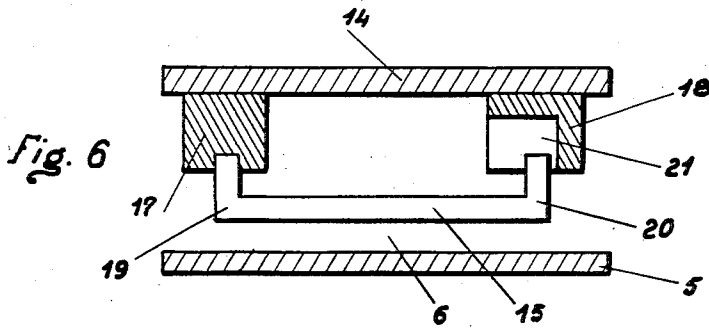
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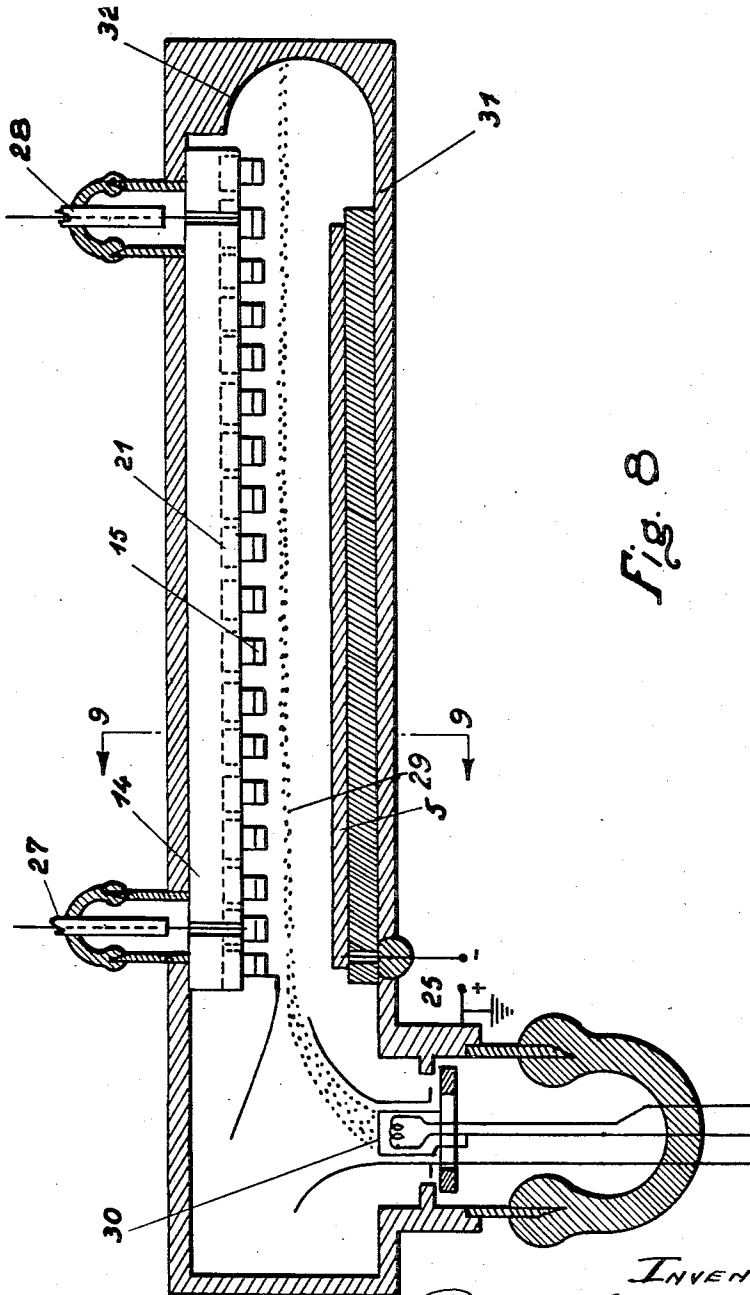


Fig. 8

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2,827,588

TRAVELLING WAVE DISCHARGE TUBE ARRANGEMENTS UTILIZING DELAY LINES

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Application April 17, 1952, Serial No. 282,762

Claims priority, application France April 28, 1951

5 Claims. (Cl. 315—3.5)

This invention relates to travelling wave discharge tube arrangements of the kind in which a delay line is used in association with an electron beam discharge tube.

The invention is illustrated in and explained in connection with the accompanying drawings.

Figure 1 is a plan view of Figure 2 showing a prior art delay line of the interdigital type;

Figure 2 is a cross-sectional view taken along line 2—2 of Figure 1;

Figure 3 is a top plan view of a delay line of the interdigital type in accordance with the present invention;

Figure 4 is a cross-sectional view taken along line 4—4 of still another embodiment of a delay line in accordance with the present invention;

Figure 5 is a cross-sectional view taken along line 5—5 of Figure 4;

Figure 6 is a cross-sectional view taken along line 6—6 of Figure 7 showing a still further embodiment of a delay line in accordance with the present invention;

Figure 7 is a bottom plan view of the delay line illustrated in Figure 6;

Figure 8 is a longitudinal cross-sectional view through a travelling wave tube utilizing a delay line in accordance with the present invention of the type illustrated in Figures 6 and 7; and

Figure 9 is a cross-sectional view taken along line 9—9 of Figure 8.

The so-called symmetrical interdigital line is most advantageous for use in a travelling wave tube arrangement of the kind referred to. This form of line is illustrated in Figures 1 and 2 which are mutually perpendicular views of part of such a line.

As will be seen from Figures 1 and 2, which are respectively plan and longitudinal sections, such a line consists of two supports 1, 2 on which are disposed interleaved fingers 3, 4 for example metal bars or plates. In a travelling wave tube of the kind referred to, such a line may be disposed parallel to a plate 5, an electronic beam being injected into the space 6.

In the co-pending application of Warnecke and Guénard Serial No. 275,928, filed March 11, 1952, an examination is made of the propagation of waves in the zig-zag guide path which is bounded by the fingers of such a line, and it is indicated that, for a certain direction of propagation of energy, there exists an infinity of waves being propagated at speeds such that their phase shift between the points 7 and 8 representing the centres of successive lengths of the zig-zag is given by the general expression:

$$\psi = \frac{2\pi s}{\lambda} - \pi + 2\pi m \quad (1)$$

where s is (to a close degree of approximation) the length of a finger, λ is the wavelength in vacuo, and m any positive or negative whole number including 0.

It is likewise indicated in said co-pending application that it is advantageous to select for interaction with the electron beam, the fastest of the possible waves available

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i. e. the wave corresponding to a phase angle ψ which is as low as possible in absolute value. It follows from the Expression 1 that for a finger length of the order of $\lambda/4$, the lowest possible value of ψ is of the order of

$$-\frac{\pi}{2}$$

for $m=0$, and the next higher value is of the order of

$$+\frac{3\pi}{2}$$

for $m=1$. The positive sign here indicates that the wave is propagated in the same direction as the energy, and the negative sign indicates that the wave and the energy are being propagated in opposite directions. In view of the fact that in amplifiers, in which the energy is propagated in the direction of the beam, the interaction requires a component of positive sign, the symmetrical interdigital line is not advantageous for application to amplifiers, because the first wave utilisable corresponding to the phase shift

$$+\frac{3\pi}{2}$$

is not a predominating component, the greatest amount of energy being carried by the wave corresponding to the phase shift

$$-\frac{\pi}{2}$$

which is propagated in the undesirable negative direction. For this reason it is proposed in the aforesaid co-pending application to introduced into the line a dissymmetry which favours the wave of positive sign to the detriment of the fundamental wave of negative sign.

The present invention seeks to solve the problem thus raised in a different manner, without requiring the introduction of any dissymmetry into the line.

The invention is characterised in that the line is so constructed that outside the region of the beam, that is to say at the corners of the zig-zag guide formed between the fingers of the line, the wave passes through guide elements which introduce a positive or negative phase shift supplementary to the variation of phase undergone by the wave in the course of its propagation, that is to say behaving, at ultra-high frequencies, as the equivalents of reactive impedance elements.

The elements may be arranged to act as the equivalents either of inductances or of capacities and although the action is different in the two cases the final effect obtained is the same. If a guide element in question behaves like an inductance, it is arranged to introduce a supplementary phase shift comprised between

$$+\frac{\pi}{2} \text{ and } +\frac{3\pi}{2}$$

so that the phase shift of

$$-\frac{\pi}{2}$$

corresponding to the negative slow mode is brought between 0 and π . If the element behaves like a capacity it is arranged to introduce a phase shift between

$$-\frac{\pi}{2} \text{ and } -\frac{3\pi}{2}$$

so that the phase shift of

$$+\frac{3\pi}{2}$$

of the positive fast mode is brought between 0 and π . In

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both cases there is therefore obtained a positive mode, the phase shift of which is between 0 and π , that is to say it corresponds to the lowest value possible, as is desired.

There will now be described examples of construction of delay lines for carrying out the present invention.

The reactive impedance element required by the invention may be introduced into the zig-zag guide by simply moving apart the combs shown in Figure 1, in such manner as to increase the distance between the ends of the fingers and the support of the opposite comb, as shown in Figure 3. Here the finger length is made as $\frac{3}{8}\lambda$, with a distance of $\lambda/8$ between the ends of the fingers and the support of the opposite comb. The space 13, the dimension of which measured in the direction of the width of the line is less than $\lambda/4$, behaves like an inductance inserted in series in the zig-zag guide. This dimension of the space 13 could be made greater than $\lambda/4$, so as to obtain the equivalent of a capacity, but this alternative is less advantageous, because for practical reasons of construction it is advantageous to make the total line width as small as possible.

Figures 4 and 5 illustrate diagrammatically a further embodiment. Here the fingers 3, 4 are fixed on supports 9, 10 having transverse dimensions greater than those of the fingers and themselves fixed on the general supports 1, 2, so that the profile of each comb has a series of notches 11, 12 of which the width S is slightly larger than twice the distance of the fingers d . In this way there is obtained the equivalent of a considerable inductance, with a relatively small depth for the notches 11, 12.

In order to obtain better separation of the region where the beam is injected from the regions where the supplementary phase shift is effected, and in order to reduce the width of the line, it may be of advantage to bend the fingers of the line so that they penetrate into the spaces equivalent to the phase-shifting circuits at the ends which are bent back at right-angles to the plane of the line. A delay line arranged in this way is illustrated in Figures 6 and 7. Here the fingers 15, 16, shown by way of example as rectangular bars (Figure 6 is a cross section and Figure 7 a view from below), are embedded in solid supports 17, 18 fixed on a common plate 14. These fingers are bent back at 19 and 20, and dip alternately into the notches 21 and 22 provided in the supports 18 and 17 and constituting the equivalent of phase-shifting quadripoles similarly to the spaces 13 and 11 in Figures 3 and 4. At 5 there has been shown, as in Figures 2 and 5, a parallel electrode defining, together with the delay line, a space 6 into which the beam is injected, the latter thus being well insulated from the phase-shifting regions 21 and 22.

Figure 8 illustrates in longitudinal section, and Figure 9 in section taken on the line 9-9 in Figure 8, a travelling wave tube having crossed magnetic and electric fields and utilising a line as illustrated in Figures 6 and 7. The various elements are mounted in a vacuum-tight metal casing 31 ending at the right hand end in a collector anode 32. The coaxial input line 27 for the ultra-high frequency input energy to be amplified is coupled in for example at the middle of a finger, and the coaxial output line 28 is coupled to the line in the same manner. An electron beam 29 issuing from an electron gun 30 is injected between the electrode 5, which may be brought to a high negative potential by the source 25, and the line 14 which may be connected to the ground connection of the tube and thus brought to zero D. C. potential so as to create in the space traversed by the beam an electrostatic field the lines of force of which run parallel to the plane of the drawing and at right-angles to the trajectory of the beam 29. A magnet, the pole-pieces 33, 34 of which are illustrated in Figure 9, creates a magnetic field the lines of force of which are perpen-

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dicular both to the beam and to the preceding electric field.

Some of the fingers 15 of the delay line may, if desired, be made of resistive material, in order to introduce attenuation into the said line.

We claim:

1. A travelling wave electron tube, comprising means for producing an electron beam; a delay line having two mutually uncoupled extremities, traversed by an ultra-high frequency travelling wave and comprising a first support and a second support parallel to one another and parallel to the mean trajectory of said beam, a series of parallel fingers positioned between said supports and said beam, each of said fingers being bent so as to have at least two mutually perpendicular portions, the first portion thereof being essentially perpendicular to the plane of said supports and the second portion thereof being essentially parallel to said plane, the extremities of said first portions being alternately carried by said first and second supports, and each of said fingers terminating by a free extremity positioned adjacent and spaced from the support opposite said first portion carrying support, so as to be capacitively coupled therewith, thereby forming an interdigital structure having a longitudinal symmetry plane in the direction of said beam.

2. A tube as claimed in claim 1, wherein said supports are provided with cavities each disposed between two adjacent fingers carried by the same support, said free extremities of fingers carried by one support penetrating into respective cavities provided in the other support.

3. A tube as claimed in claim 1, wherein each of said fingers comprises a third portion perpendicular to the plane of said supports, said third portion terminating by said free extremity.

4. A tube as claimed in claim 1, wherein each of said fingers comprises a third portion perpendicular to the plane of said supports and terminating by said free extremity, said supports being provided with cavities each disposed between two adjacent fingers carried by the same support, said free extremities of fingers carried by one support penetrating into respective cavities provided in the other support.

5. A delay line for a travelling wave tube of the type in which an electron beam moves in an interaction space adjacent said line and in energy transfer relationship therewith, comprising a first support and a second support for said delay line essentially parallel to each other, a series of parallel fingers positioned between said supports, each of said fingers being built so as to have at least two mutually perpendicular portions, the first portion thereof being essentially perpendicular to the plane of said supports and the second portion thereof being essentially parallel to said plane, the extremities of said first portions being alternately carried by said first and second supports to thereby form a delay line of the interdigitated type, and each of said fingers terminating with the free extremity thereof positioned adjacent and spaced from the support opposite said first portion carrying support thereof so as to be capacitively coupled therewith, thereby forming an interdigital structure having a longitudinal plane of symmetry in the direction of said beam.

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