(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 399 739 A2**

(12) EUROPEAN PATENT APPLICATION

(21) Application number: 90305438.5

(22) Date of filing: 18.05.90

(51) Int. Cl.5: H01P 1/15

(30) Priority: 23.05.89 GB 8911848

(43) Date of publication of application: 28.11.90 Bulletin 90/48

(84) Designated Contracting States: DE FR IT NL SE

(71) Applicant: GEC-MARCONI LIMITED
The Grove Warren Lane
Stanmore Middlesex HA7 4LY(GB)

(72) Inventor: Greed, Robert Brian
7 Coriander Road, Tiptree
Colchester, Essex(GB)

(74) Representative: Waters, Jeffrey et al
The General Electric Company plc Central
Patent Department Marconi Research Centre
West Hanningfield Road
Great Baddow Chelmsford Essex CM2
8HN(GB)

(54) Waveguide switch.

(57) A pair of conductive strips 9, 10 in a waveguide, for example, defining a fin-line transmission line insert have a switching element such as a PIN diode 11 connected to them to reflect or pass r.f. energy in the fin-line section. The switching element 11 forms part of a filter circuit, for example, in conjunction with inductances 12, 13, the characteristic impedance of which is matched to that of the gap. When the PIN diode is forward biased, the strips 9, 10 are in effect short circuited and the r.f. energy is reflected. When the diode is reverse biased, the r.f. energy passes without reflections. Due to the matching of the impedances this obtains over a broad bandwidth.

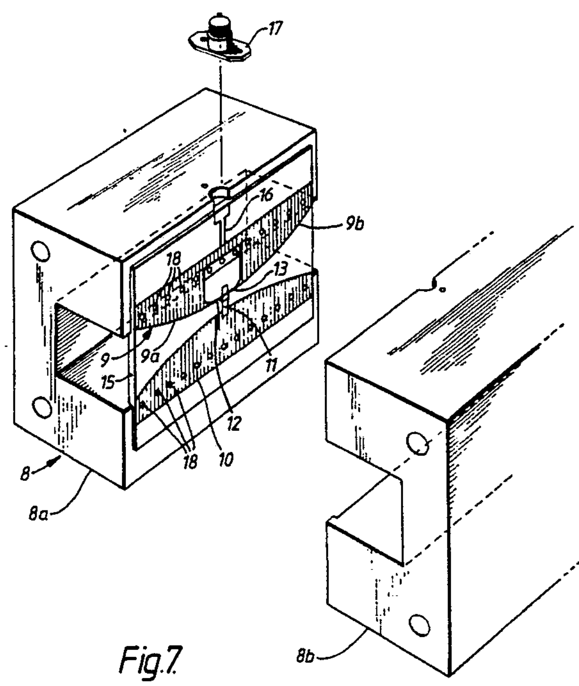

Fig.7

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Waveguide Switch

This invention relates to waveguide switches.

Such switches are used to permit r.f. energy flow along a waveguide, or to prevent it, usually by reflection back along the waveguide.

The invention is particularly concerned with those switches which are suitable for high microwave/millimetric frequency operation. In one known form, a rectangular waveguide 1 has a pair of conductive strips 2, 3 which together define a gap 4 arranged in the waveguide and coupled to it, forming a fin-line transmission line in the waveguide (Figures 1 and 2). The switching element is a PIN diode 5 connected across the gap. When forward biased, this has a low impedance, and the r.f. energy is reflected back along the waveguide. When reverse biased, the diode has a high impedance and most r.f. energy is passed.

In another known form of switch, (Figure 3), in a fin-line transmission line inserted in a rectangular wave guide 1, PIN diode 5 bridges a gap 6 in one of the conductive fins 2, 3, in a series arrangement. This time, r.f. energy is allowed to pass when the diode is forward biased and thus has a low impedance. R.f. energy is reflected when the diode is reverse biased and has a high impedance.

However, both forms suffer from the disadvantages that the first form allows a small proportion of r.f. energy to be reflected when it should be passed and the second form allows a small proportion to be transmitted when it should be reflected. In the case of the first form, this can be minimised by providing extra shunt diodes bridging the gap 4, the spacing between them being arranged to reduce the amount of r.f. passed in the forward bias state due to destructive interference. In the case of the second form, the rejection of unwanted transmission is maximised by the cut-away region 7 of the fin 1. The loop thus formed provides an inductance in parallel with the capacitance of the PIN diode junction, forming a resonant circuit with a very high impedance.

Despite the success of these measures in overcoming the deficiencies referred to, it will be seen that this happens over a narrow band of frequencies only. In the first form, the cancellation depends on there being a specific (e.g. 90 degrees) phase shift between the diodes, and this will only apply at one frequency. In the second form, the impedance will only attain the high value at a particular r.f. frequency.

Broad band switches for microwave frequencies are known, in which a diode forming part of a filter structure is connected in a gap in a microstrip transmissicn line, but switches capable of operating over a broad band yet suitable for high microwave/millimetric waveguide operation have not been proposed.

The invention provides a waveguide switch comprising a pair of conductive strips which together define a gap, which strips are arranged in a waveguide and are coupled to the waveguide, a switching element arranged, in one state, to permit r.f. energy to flow along the gap and, in another state, to prevent r.f. energy flowing along the gap, the switching element forming part of a filter circuit, the characteristic impedance of which is matched to that of the conductive strips in the waveguide.

The conductive strips defining a gap, such as a fin-line transmission line, in the waveguide, together with the incorporation of the switching element in the filter circuit matched to the impedance of the transmission line render the switch suitable for broadband operation at high microwave or millimetric frequencies.

The switching element may be a diode, for example a PIN diode, or another form of semiconductor diode.

The waveguide may be a rectangular waveguide, ridged waveguide or double ridged waveguide, and the invention is applicable to a wavelength range of from 10 centimetres to 1 millimetre.

In a convenient arrangement, one electrode of the switching element is connected to one of the strips, and another electrode is connected to a pair of inductances connected to spaced apart positions on the other strip. The inductances may simply comprise wires.

The invention will now be described by way of example with reference to the accompanying drawings, in which:

Figure 1 is a perspective view of a known waveguide;

Figure 2 is a longitudinal axial section of a waveguide of the form shown in Figure 1, but with a first prior proposal for the arrangement of a switching element;

Figure 3 is a longitudinal axial section of a waveguide of the form shown in Figure 1, but with a second prior proposal for the arrangement of a switching element;

Figure 4 is a longitudinal axial section of a waveguide with a switching element arranged according to the invention;

Figure 5 is a circuit diagram of a filter network in which the switching element of Figure 4 is incorporated;

Figure 6 is the effective circuit diagram of the filter network of Figure 5 when the switching element is reverse biased;

Figure 7 is a partially exploded perspective view of a waveguide switch according to the invention; and

Figure 8 is a partially exploded perspective view of another waveguide switch according to the invention.

Referring to Figure 4, the waveguide has a rectangular section 8, the direction of propagation being in the plane of the drawing and the electric vector extending normally between the broad walls of the waveguide.

The waveguide has a pair of conducting strips 9, 10 in the plane which extends between opposite broad walls and along the longitudinal centre line of the waveguide. Together the strips 9, 10 form a fin-line transmission line inserted in and coupled to the waveguide. The strip 9 is in two parts 9a, 9b. The r.f. frequency energy propagating along the transmission line thus appears across the gap between the strips when it encounters the fin-line insert. The impedance of the fin-line section and of the waveguide are matched by the curved profile of the fin-line section (although other profiles are possible).

The switching elements which is a PIN diode 11, has one electrode connected to the strip 10 and another electrode connected to a conducting pad 14, which is connected to two wires 12, 13 which are in turn connected to the two parts 9a, 9b of the strip 9. At the r.f. at which the waveguide operates, that is, in the region of 26-40GHz, the wires behave as inductances Lf, and the diode forms part of a filter circuit shown in Figure 5 and 6.

In operation, when the diode is forward biased its impedance is low and the propagating r.f. meets what amounts to a short circuit, and so the r.f. is reflected and no r.f. is passed.

When the diode is reverse biased its impedance is high, and it behaves like a capacitor Cj (Figure 6). The resulting network is a low pass filter with a characteristic impedance Zo. By a suitable choice of Lf, which depends upon the length of the wire, and of the diode junction capacitance Cj, Zo can be made the same as that of the central region of the fin-line transmission line. Further, the cut-off frequency can be set above maximum frequency it is desired to pass along the waveguide. Thus, when the diode is biased to pass r.f., the switching element is matched to the fin-line which is in turn matched to the waveguide, and reflections are reduced or eliminated. Further, this happens over a broad band, the whole of the waveguide bandwidth, and not just over a narrow band. And it also applies to high microwave, millimetric frequencies.

The width of the slot in the conducting strip 9 is chosen so that it cannot resonate with the r.f. radiation. For example, its resonant frequency could be chosen to exceed the maximum r.f. to be propagated. The width of the gap at its narrowest region is in the region of 0.1 millimetre.

Figure 7 shows a practical realisation of the arrangement shown in Figure 4, like reference numerals being given to like parts. The waveguide is in two halves 8a, 8b, and the fin-line transmission line consists of two conducting strips 9, 10 on substrate 15 which is sandwiched between the two waveguide halves.

The upper strip 9 is insolated from the waveguide and is connected via a conducting track 16 to the centre terminal of bias connector 17. The outer terminal of the coaxial connector 17 connects to the other strip via the body of the waveguide.

Both tracks have a series of plated through holes 18 to prevent the escape of r.f. radiation in the region of the substrate bearing the conducting strips. This is described and claimed in co-pending patent application No. 8716508.

The operation of the Figure 7 embodiment is as described for the basic system described in Figure 4.

Referring to Figure 8, the diode mount, that is the pair of strips and its substrate, inherently has a much greater bandwidth than a normal rectangular waveguide can usefully propagate. It is therefore particularly suited to the double ridged waveguide structure of Figure 8, like reference numerals again being given to like parts. The ridge section is cut away to allow sufficient space for the cut away regions surrounding the diodes. The waveguide illustrated is a WRD 180C 2.4 waveguide, which can transmit r.f. in a bandwidth of from 18-40 GHz. Very good performance in respect of return loss, insertion loss and isolation (switching ratio) is maintained over the band.

To enhance performance further, two or more diode mounts may be cascaded in series. Unlike the series of diodes used in the prior art construction referred to, the spacing of the diode mounts is not critical. In this embodiment, plated through slots 19 are used instead of plated through holes 18.

In the ridge waveguide, the transition between the ridge and the fin-line can be a smooth taper profile or a stepped transformer. Equally, the transition between the ridge and the diode mount sections can be a smooth tapered profile or stepped transformer. Additionally, a cross-sectional reduction within the diode mount region can be embodied to enhance the frequency performance. The transition to this region will also employ smooth tapers or stepped transformers. Applications of the diode amount to other structures employing co-planar conductors on a substrate can easily be implemented.

Of course variations may be made to the

above embodiments without departing from the scope of the invention. Thus, the switching elements may be used in a single ridged waveguide or in a circular waveguide. Also, other semi-conductor diodes could be used in place of a PIN diode. Equally, slot-line transmission line inserts could be used instead of the fin-line transmission line insert. Also, the transition between the slot-line transmission line or fin-line transmission line can be smooth or stepped to match the transmission line to the waveguide.

Claims

1. A waveguide switch comprising a pair of conductive strips which together define a gap, which strips are arranged in a waveguide and are coupled to the waveguide, a switching element arranged, in one state, to permit r.f. energy to flow along the gap and, in another state, to prevent r.f. energy flowing along the gap, the switching element forming part of a filter circuit, the characteristic impedance of which is matched to that of the conductive strips in the waveguide.

2. A waveguide switch as claimed in claim 1, in which the switching element is a diode.

3. A waveguide switch as claimed in claim 2, in which the switching element is a PIN diode.

4. A waveguide switch as claimed in claim 2 or claim 3, in which the filter circuit is a low pass filter circuit.

5. A waveguide switch as claimed in any one of claims 1 to 4, in which one electrode of the switching element is connected to one of the strips.

6. A waveguide switch as claimed in claim 5, in which another electrode is connected to two conductors which are connected to spaced apart positions on the other strip.

7. A waveguide switch as claimed in claim 6, in which a region of the strip between the spaced apart positions and extending towards the wall of the waveguide is cut away.

8. A waveguide switch as claimed in claimed in claim 6 or claim 7, in which two or more switching elements each forming part of a filter circuit are provided, the characteristic impedance of each being matched to that of the conducting strips in the waveguide, one electrode of each element being connected to one of the strips and another electrode being connected to two conductors which are in turn connected to spaced apart positions on the other strip.

9. A waveguide switch as claimed in any one of claims 1 to 8, in which the waveguide is ridged.

10. A waveguide switch as claimed in any one of claims 1 to 9, including a connector for biasing the switching element, one pole of which is connected to the body of the waveguide, one of the strips being in electrical contact to the body of the waveguide, the other pole being connected to the other strip which is not in electrical contact with the body of the waveguide.

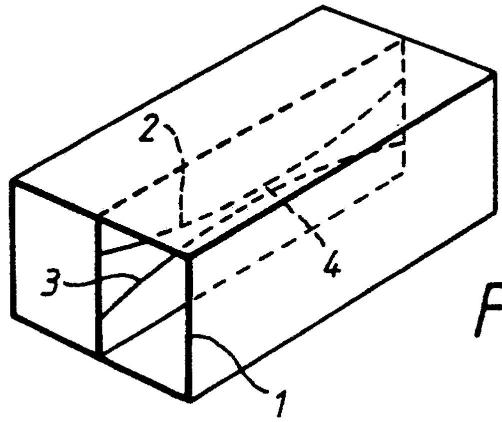


Fig.1.

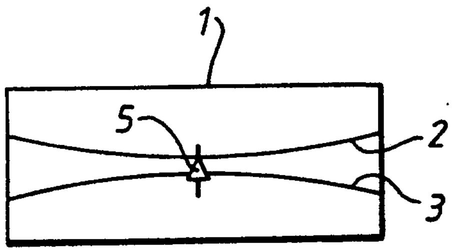


Fig.2.

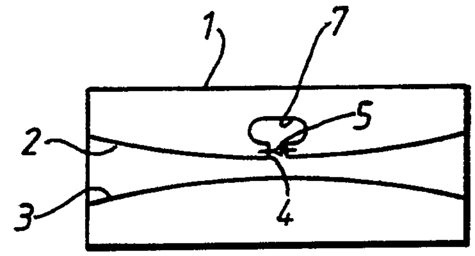


Fig.3.

Fig.4.

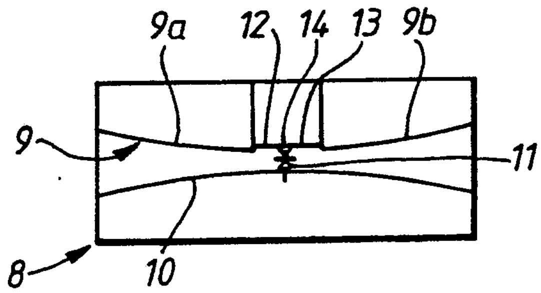


Fig.5.

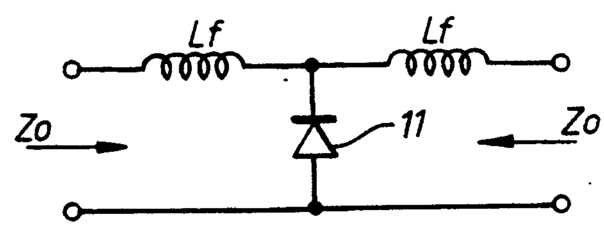
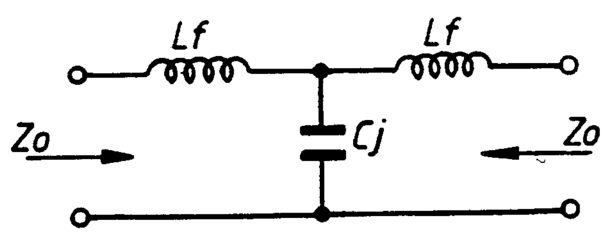


Fig.6.



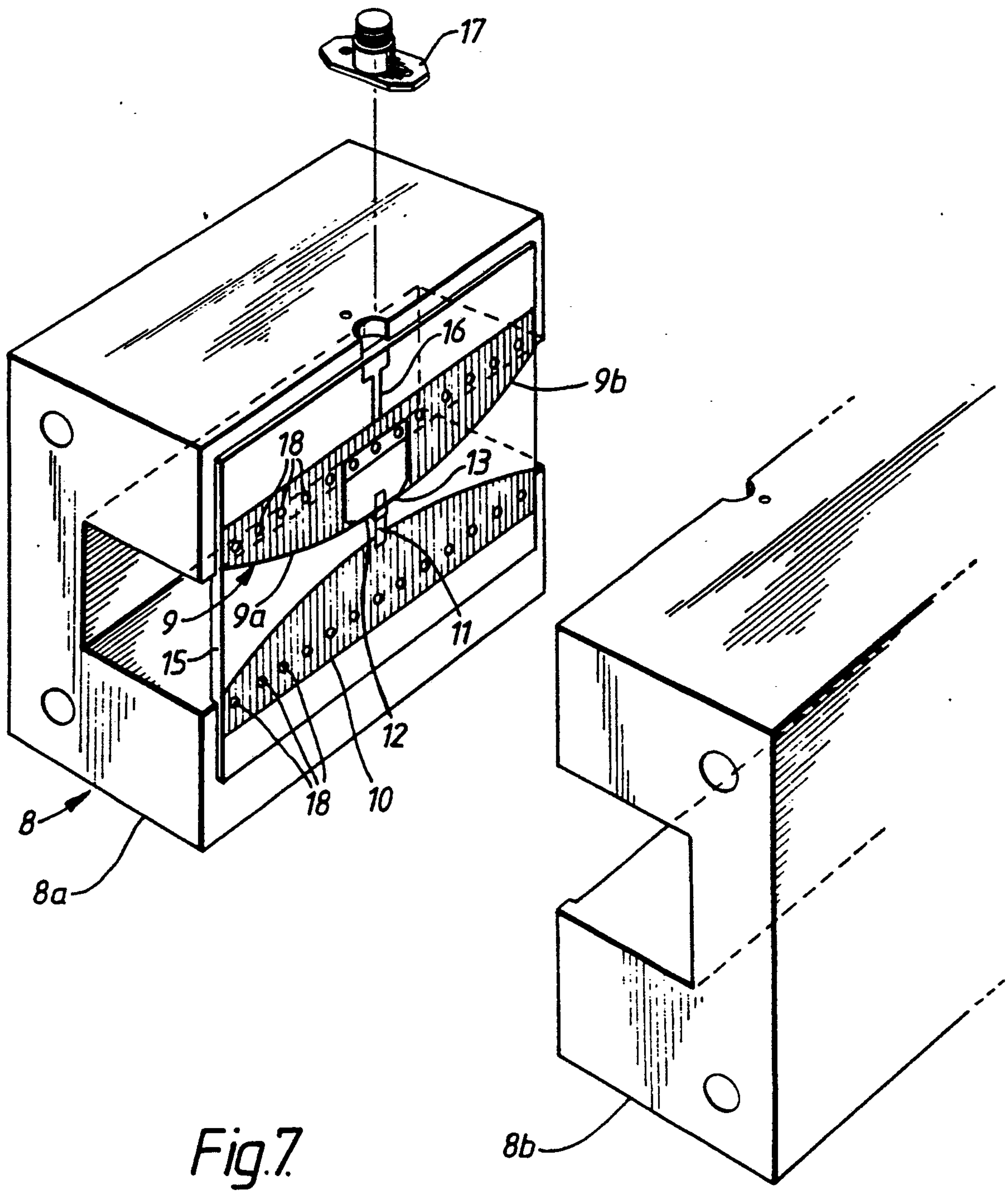


Fig.7.

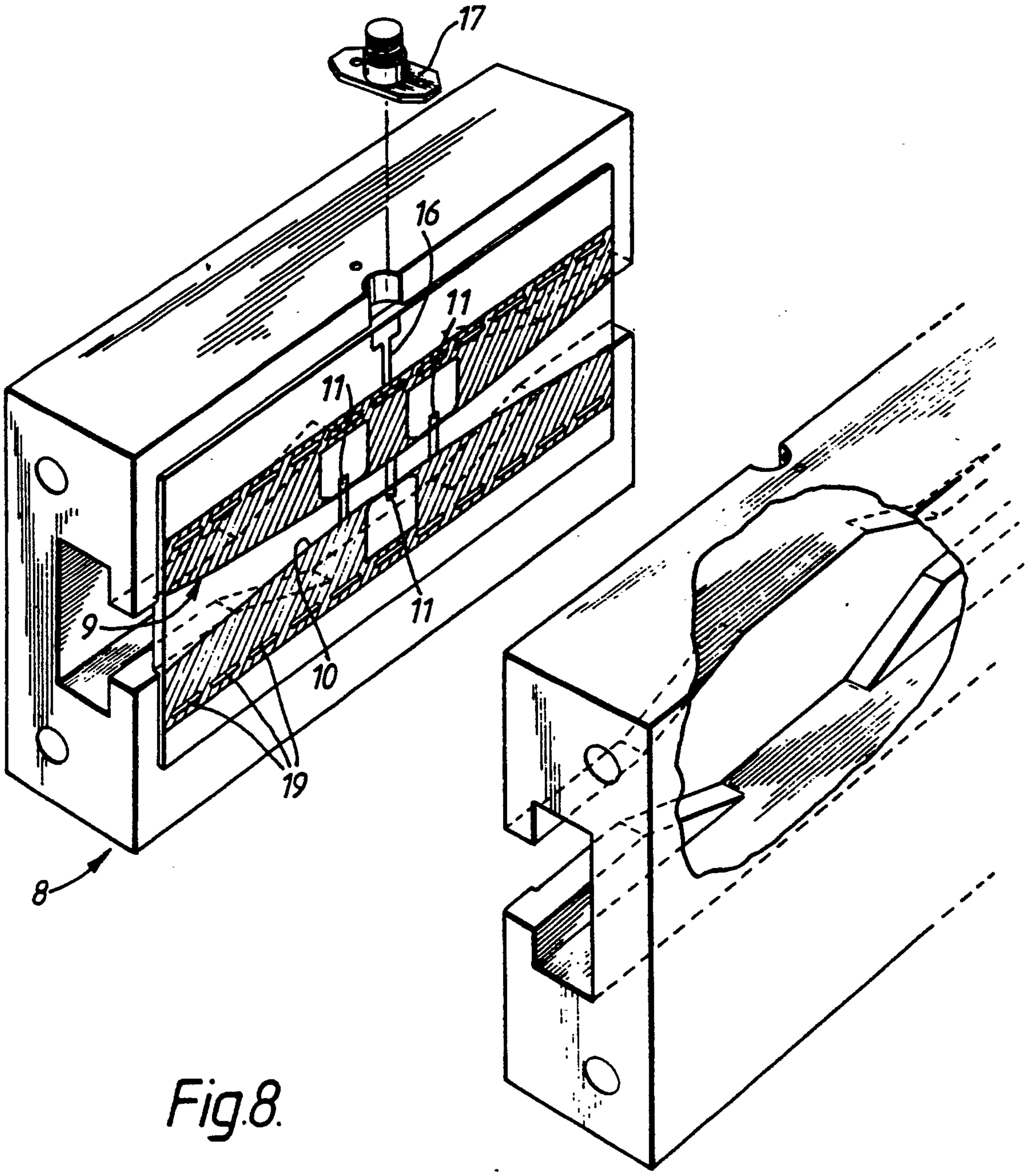


Fig.8.