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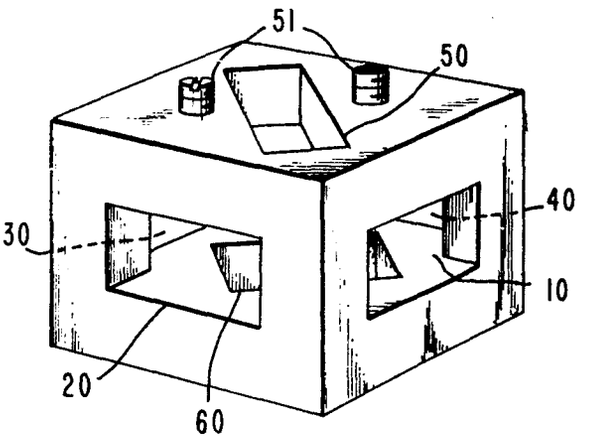
(54) Six port waveguide structure.

(57) A six port waveguide junction which can be used for combining power from four reflection amplifiers is disclosed. One port (50) acts as the input/output and four symmetrically disposed ports (10, 20, 30, 40) are adapted for coupling to respective reflection amplifiers. A sixth port (60) is terminated and provides a ballasting effect to the interaction of the amplifiers. The structure associated with the four symmetrically disposed ports resemble two rectangular waveguides in cross intersection so as to make a 4-way H-plane junction. The rectangular input/output port is located on the axis of the cross formed by the four arms and is rotated 45 degrees so that it couples equally to the four arms. The rectangular sixth port is on the same axis as the input/output port but on the opposite side of the junction and is rotated by 90 degrees with respect to the input/output with which it is thus cross-coupled.



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SIX PORT WAVEGUIDE STRUCTURE

BACKGROUND OF THE INVENTION

This invention relates to the field of waveguides for electromagnetic waves, and more particularly to an improved waveguide structure of the turnstile junction type.

In power combining circuits, there is an upper limit to the number of devices whose signals can be combined and once this limit is reached, to combine more devices it becomes necessary to combine the power outputs of the circuits which are themselves the combiners, i.e., combining of combiners. For example, in order to combine signals from four sources by using hybrid power combiners, the four sources must be grouped into pairs and each pair must be combined in its own 2-way hybrid combiner. Then the outputs of these two 2-way hybrid combiners must be combined in a third 2-way hybrid combiner to finally yield a single output. The process of using three hybrid waveguide combiners to combine the signals from four sources into a single output results in a significant power loss due to inherent circuit losses. Also a relatively large physical area is required due to the size of the three separate hybrid combining circuits. An identical process is required to divide a signal from a single waveguide source into four equal parts when using hybrid circuits.

The subject invention accomplishes the dividing of a signal into four equal parts and the combining of four signals into one output signal through the use of a single device.

As is well known to those skilled in the art, a turnstile junction comprises two waveguides in a 90 degree cross intersection which makes a 4-way H plane junction to which is joined a third section of waveguide at an angle orthogonal to the first two waveguides, i.e., on the axis of the cross formed by the four waveguide arms. This third section does not cross through the junction, but merely enters it from one side. On the opposing side of the junction to this third section is a provision for matching impedances in order to minimize reflected energy in the junction. Means commonly employed in matching impedances is the insertion of two concentric sleeves with a center pin along the symmetry axis of the intersecting waveguide sections. By systematically positioning the pin and the concentric sleeves, the junction may be optimally matched and maximum power transfer can occur. Generally, the two cross intersecting waveguides are of a rectangular cross-section while the third orthogonal waveguide section is of a circular cross-section. For a more complete description of the above, refer to Meyer and Goldberg, Applications of the Turnstile Junction, IRE Transactions-Microwave Theory and Techniques, December 1955, pages 40-45; and Montgomery, Dicke, and Purcell, Principles of Microwave Circuits, Radiation Lab Series, Volume 8, 1948, pages 459-466.

In using the turnstile junction as a power divider, the junction will divide a signal entering the orthogonal circular waveguide into equal parts if that signal is linearly polarized and the polarization is oriented such that the signal is equally coupled to all four ports. If the incoming signal were circularly polarized or oriented in a direction other than as described immediately above, equal power division will not occur.

In using the turnstile junction as a combiner, it will function similarly to a hybrid tee, also known as a magic tee. The similarity is found in the hybrid tee's property of phase cancellation which results in the isolation of one collinear arm when the signal is introduced into the other collinear arm. The same property is found in the turnstile junction, i.e., when a signal is fed into one collinear symmetrical arm, that signal will not appear in the associated collinear arm but instead the power will split into parts. One-half of the power will be conducted up the circular waveguide while the other half of the power will divide in halves again and each half will be conducted into an adjacent symmetrical arm. The turnstile junction differs from the hybrid tee in that the turnstile junction contains two pairs of collinear arms (sometimes herein referred to as four symmetrical arms) while the hybrid tee contains only one pair, and further, the turnstile junction employs a circular waveguide as the orthogonal section, while the hybrid tee employs a rectangular waveguide as an E plane arm which cuts off E-mode propagation.

In the case where the turnstile junction is utilized as a 4-way combiner, power differences or imbalances in the four signals input through the two pairs of collinear arms will directly affect the output which is conducted through the orthogonal circular waveguide. This is due to the interaction between these collinear arms. Even though the junction is optimally matched as was discussed previously, the nature of the turnstile junction when used as a combiner is such that differences in the power of the signals entering through the four symmetrical arms will cause an output signal polarization change which may reduce linearly polarized power output. This problem is apparent when four reflection amplifiers are connected to the turnstile junction, one to each port of the two pairs of collinear arms. If all amplifier outputs

were identical and optimal matching in the junction had been effected, detrimental interactions within the junction itself would be eliminated and maximum power combining could occur. However, in practice, amplifier outputs are rarely identical and detrimental interactions within the turnstile junction will probably occur. It is desirable to compensate for or absorb these detrimental interactions in order to avoid a degradation in power output and a possible instability problem due to oscillation, when active components such as amplifiers are used to directly feed the two pairs of collinear arms.

SUMMARY OF THE INVENTION

Therefore, according to this invention, an improvement upon the traditional turnstile junction has been made. A sixth port has been added to the turnstile junction and is utilized to absorb power differences which exist between the ports in the two pairs of collinear ports, i.e, the four symmetrical ports of the 4-way H-plane junction. As used herein, a pair of collinear ports are two ports whose centers are substantially on a straight line. The sixth port is equally coupled to all four ports in the two pairs of collinear ports and may be coupled to a load device which is chosen in accordance with the parameters of the devices connected to the ports of the two pairs of collinear ports. The sixth port aids efficient power transfer because detrimental device interactions are absorbed within the junction due to the phase relationships created by the physical location of the ports. Thus, imbalances between the four ports of the two pairs of collinear ports are neutralized and where active components are directly feeding these collinear ports, this sixth port has the capability of damping out oscillations.

Also, in accordance with the invention, the fifth port is a rectangular waveguide port. The orientation of this fifth port in the invention is critical in that it must be equally coupled to each of the two pairs of collinear ports as the sixth port is, but must be cross-coupled to the sixth port. The preferred method of accomplishing this objective is to cross-couple the sixth and fifth ports by orienting them at 90 degrees to each other. However, both the fifth and sixth ports are equally coupled to all four ports of the two pairs of collinear ports by orientating the fifth and sixth ports so that an axis through the center of each respective port along its long dimension, for example axis 41 of Figure 3, is oriented at 45 degrees with the longitudinal axes which lie through the two pairs of collinear ports. Each longitudinal axis passes through two ports on opposite sides of the 4-way junction. For ports 10 and 30, the longitudinal axis is designated by reference numeral 42 in Figure 3.

The basis for requiring the coupling of the six ports to one another as detailed above is shown by a primary application of the invention. Where each of the collinear ports is connected to its own reflection amplifier which, for example, is composed of negative resistance diodes, then the fifth port will function as both an input port and an output port. The original signal will enter through this fifth port, and since the fifth port is equally coupled to each of the four collinear ports, and cross-coupled to the sixth port, the signal will divide into four equal parts and each part will enter a reflection amplifier. These amplifiers will amplify the signal and output it back into the junction. The junction will combine the four reflection amplifier outputs and this combined signal will be conducted out through the fifth port. Differences in the outputs of

the reflection amplifiers as compared to each other will be absorbed by the sixth port which contains a load device. This beneficial power absorption occurs because of the phase relationships established by the physical symmetry of the invention.

Since the sixth port has been added, the matching means which are commonly associated with the turnstile junction as discussed previously, has been removed; however, any conventional matching arrangement may be used so long as junction symmetry is maintained. A preferred arrangement is the use of capacitive posts or screws protruding into the junction from the direction orthogonal to the two pairs of collinear ports and the use of reactive irises over any port. The amount of protrusion of the posts and the size of the irises employed may be adjustable in order to achieve optimum matching.

Therefore, it is a purpose of the invention to provide a single waveguide structure which is capable of dividing the power of an input signal into four equal parts.

It is another purpose of the invention to provide a single waveguide structure which is capable of combining the power of four input signals into a single output.

It is another purpose of the invention to provide a single waveguide structure which is capable of operating over a broad frequency range.

It is another purpose of the invention to provide a single waveguide structure which is capable of operating with relatively high efficiency.

It is another purpose of the invention to provide an improved turnstile type junction which is more easily manufactured than prior art and which, for many applications, is more readily adapted for connection to external devices.

The novel features which are believed to be characteristic of this invention, both as to its organization

and method of operation, together with further objects and advantages thereof, will be better understood from the following description considered in connection with the accompanying drawings:

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a perspective view of the front and top of an improved turnstile type waveguide junction in accordance with the subject invention;

Figure 2 is a perspective view of the rear and bottom of the structure of Figure 1;

Figure 3 is a top view of Figure 1;

Figure 4 shows a second embodiment of the invention where the structure is composed of rectangular waveguide;

Figure 5 shows a third embodiment of the invention which is formed within two halves of a metal block. The termination and input/output ports are constructed in the metal block halves to connect to external devices. The devices (not shown) which connect to the two pairs of collinear ports are adapted to be located within the metal block and directly connected to the ports through channels formed in the metal; and

Figure 6 is a schematic diagram of the invention which shows the connection of reflection amplifiers to the two pairs of collinear ports and the connection of a load device.

DETAILED DESCRIPTION OF THE INVENTION

In Figures 1, 2 and 3 there is shown a waveguide turnstile type junction. The junction depicted in these figures comprises two pairs of collinear ports 10, 20, 30 and 40; an input/output port 50; and a termination port 60. The two pairs of collinear ports 10, 20, 30 and 40 are identical in size; however, ports 50 and 60 need not be identical to any other port. Ports 10, 20,

30, 40, 50 and 60 are preferably rectangular in cross-section. Ports 10, 20, 30 and 40 are preferably identical in cross-section size in order to obtain equal splitting of the input signal introduced through port 50. Ports 50 and 60 need not be identical in size to ports 10, 20, 30 and 40 but are to be of a size which will achieve the desired efficiency in power transfer. The two pairs of colliner ports consist of ports 10 and 30 which are collinear and ports 20 and 40 which are also collinear. There is an angle of 90° between each adjacent port.

Input/output port 50 orthogonally intersects the junction made by ports 10, 20, 30 and 40. Port 50 is oriented at the junction so as to equally electrically couple to all of the ports 10, 20, 30 and 40. In order to accomplish this an axis 41 through the center of the broad dimension of port 50 forms a 45° angle with both longitudinal axes 42 and 43 which lie through the two pairs of collinear ports 10 and 30, 20 and 40. Termination port 60 also orthogonally intersects the junction made by ports 10, 20, 30 and 40; however, port 60 intersects this junction on the opposite side from port 50. Port 60 is so oriented that it too equally electrically couples with all of the collinear ports 10, 20, 30 and 40. However, it is oriented so that it does not electrically couple with port 50. In order to accomplish this orientation, the broad dimension of port 60 also forms a 45° angle with both longitudinal axes 42 and 43 and is also oriented so that the broad dimension of port 60 forms a 90° angle with broad dimension of port 50.

Effective operation of the junction does not require that there be no reflected energy, however, in most applications of the junction, it is desirable that

reflected energy be eliminated. That is, the junction should be optimally matched in order to obtain maximum power transfer to and from the two pairs of collinear ports and to and from the input/output port. Figures 1, 2 and 3 show some arrangements for matching the junction. Screws 51 and 61 are utilized to provide capacitive reactance in an amount appropriate to compensate for or match electrical discontinuities in the junction and impedance differences between attached external devices. Iris 47 or similar projections are utilized to provide additional reactance. The iris or similar projection may be installed in any port as required for compensation and matching.

As Figures 1, 2 and 3 show, the capacitive screws or posts are placed on two sides of the junction, i.e., on the side where port 50 is located and on the side where port 60 is located. In addition, they are placed adjacent to the broad walls of the ports and are equally spaced in order to maintain junction symmetry. The posts as shown are adjustable through the means of threading. Thus, adjustment is accomplished by turning the post in one direction or the other which results in more or less protrusion into the junction as required for matching. However, fixed capacitive posts are also acceptable. In Figure 2, iris 47 has been installed in port 40, however, it could be installed in any port. The size of the actual opening may be varied in order to achieve the desired amount of matching. It is to be understood that the above described matching methods are well known in the art and matching can also be accomplished by other matching arrangements well known in the art.

Figure 4 is a second embodiment of the invention wherein the structure is formed by waveguide sections 92 through 97.

Figure 5 is a third embodiment wherein the invention is constructed within the halves of a metal block. Four reflection amplifiers (not shown) could be fabricated in spaces numbered 70. These amplifiers are not shown in the drawing in order to maintain the clarity thereof. The reflection amplifiers would be connected to the two pairs of ports 10, 20, 30 and 40 formed in the metal halves. The remaining two ports 50 and 60 of the invention are constructed so that they extend completely through the metal halves in order to connect to external devices.

Figure 6 is a schematic diagram of the invention showing four reflection amplifiers 80 through 83 connected to the two pairs of collinear ports 10, 20, 30 and 40. Port 50 is utilized as an input/output port and port 60 is connected to a load device 84 which absorbs power reflections which occur between the collinear ports and port 60.

Thus, there has been described a new and useful six port waveguide structure.

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CLAIMS

What is Claimed is:

1. A waveguide structure comprising two pairs of collinear ports arranged to form a 4-way H-plane junction of the turnstile type and an orthogonal fifth port wherein a signal applied to the fifth port is divided into four portions each of which is applied through a different one of said collinear ports and signals applied through said collinear ports are combined within the structure and output through said fifth port, wherein the improvement comprises:

said fifth port comprising a rectangular waveguide port which is oriented in such a manner as to electrically couple to each port of said two pairs of collinear ports equally; and

said waveguide structure further comprising an orthogonal rectangular sixth port disposed on the opposite side of said junction from said fifth port and oriented such that said sixth port electrically couples to each port of said two pairs of collinear ports and is electrically isolated from said fifth port.

2. The structure of Claim 1 wherein said fifth port is oriented such that an axis through the center of said port along its long dimension is oriented at 45 degrees with respect to the longitudinal axis of each of said two pairs of collinear ports, whereby said fifth port couples equally to each port of said two pairs of collinear ports.

3. The structure of Claims 1 or 2 wherein said sixth port is oriented such that an axis through the center of said port along its long dimension is oriented at 45 degrees with respect to the longitudinal axis of each of said two pairs of collinear ports, whereby said sixth port couples equally to each port of said two ports of collinear ports.

4. The structure of Claims 1 or 2 further comprising means coupled to said sixth port for absorbing power reflections which occur between said collinear ports and said sixth port.

5. The structure of Claim 1 or 2 wherein said fifth and sixth ports are oriented at approximately 90 degrees with respect to each other.

6. A waveguide structure comprising two pairs of collinear waveguide sections which intersect at a 90 degree angle to form a 4-way H-plane junction of the turnstile type and an orthogonal fifth waveguide section wherein a signal applied to the fifth waveguide section is divided into four portions each of which is applied through a different one of said collinear waveguide sections and signals applied through said collinear waveguide sections are combined within the structure and output through said fifth waveguide section, wherein the improvement comprises:

said fifth waveguide section comprising a rectangular waveguide section which is oriented in such manner as to electrically couple to each waveguide section of the two pairs of collinear waveguide sections equally; and

said waveguide structure further comprising an orthogonal rectangular sixth waveguide section disposed on the opposite side of said junction from said fifth waveguide section and oriented such that the sixth waveguide section electrically couples to each waveguide secton of the two pairs of collinear waveguide sections and is electrically isolated from said fifth waveguide section.

Fig. 1.

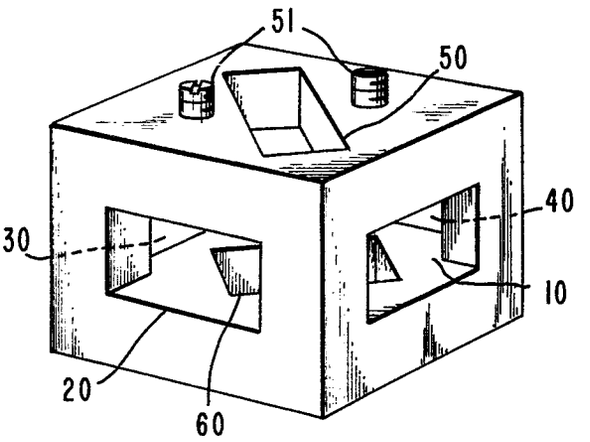
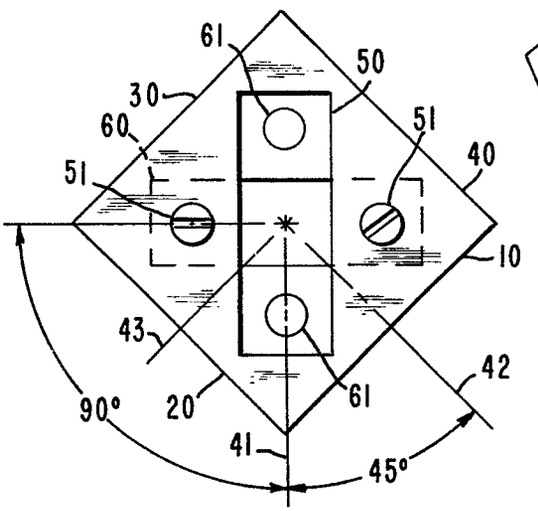


Fig. 3.



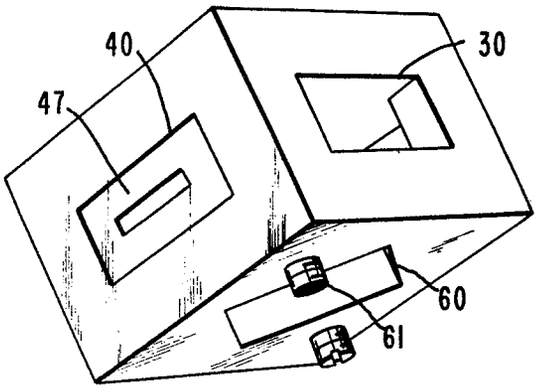


Fig. 2.

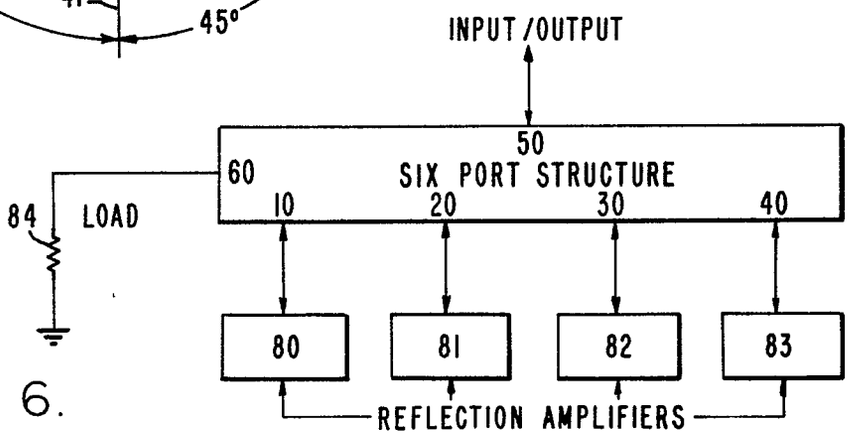
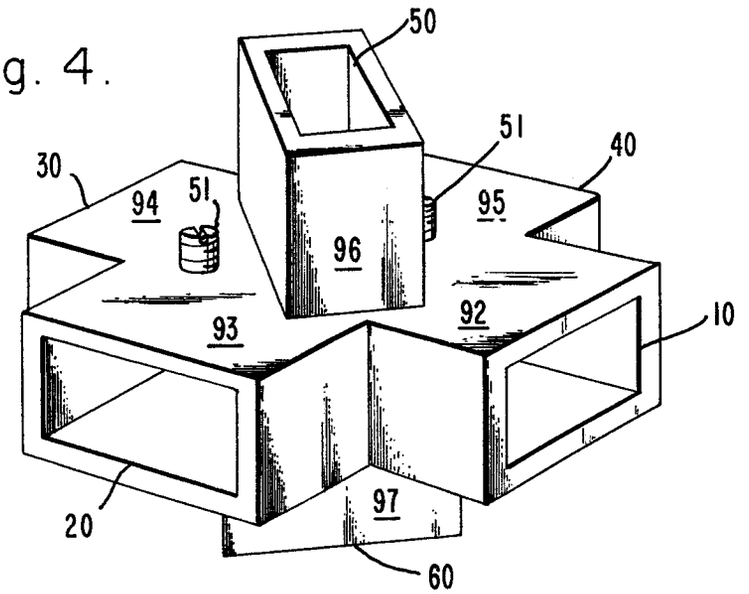


Fig. 6.

Fig. 4.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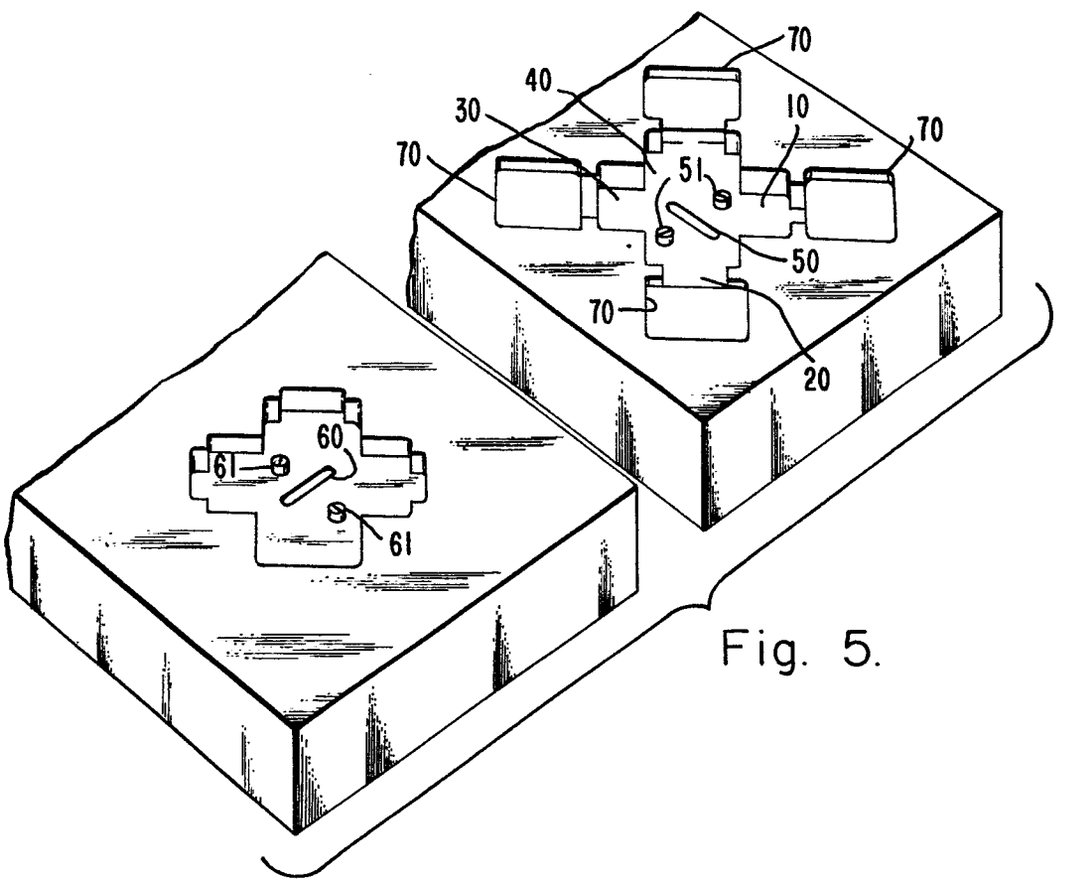
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Fig. 5.

European Patent Office

EUROPEAN SEARCH REPORT

0075394
Application number

EP 82 30 4509

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. ³)
Y	PROCEEDINGS OF THE I.R.E., vol. 37, no. 6, June 1949, pages 634-639, New York (USA); M.CHODOROW et al.: "A microwave impedance bridge". *The whole article*	1-6	H 01 P 5/16
Y	GB-A- 742 948 (ELLIOTT BROTHERS) *Figure 3*	1,5,6	
A,D	IRE TRANSACTIONS ON MICROWAVE THEORY AND TECHNIQUES, vol. MTT-3, no. 6, December 1955, pages 40-45, New York (USA); M.A.MEYER et al.: "Applications of the turnstile junction".		TECHNICAL FIELDS SEARCHED (Int. Cl. ³)
A,D	C.G.MONTGOMERY et al.: "Principles of microwave circuits", First Edition, 1948, pages 459-466, NcGraw-Hill Book Company, Inc., New York (USA); *Paragraph 12.26, The Turnstile Junction*		H 01 P
A	IEEE TRANSACTIONS ON MICROWAVE THEORY AND TECHNIQUES, vol. MTT-27, no. 1, January 1979, pages 58 to 64, New York (USA); U.BARABAS: "On an ultrabroad-band hybrid tee". *Figure 1*		

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	15-12-1982	LAUGEL R.M.L.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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