



(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
17.01.2007 Bulletin 2007/03

(51) Int Cl.:
H01P 5/107^(2006.01) H01P 5/16^(2006.01)

(21) Application number: **05425501.3**

(22) Date of filing: **12.07.2005**

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HU IE IS IT LI LT LU LV MC NL PL PT RO SE SI SK TR
Designated Extension States:
AL BA HR MK YU

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(54) **Microwave power combiners/splitters on high-loss dielectric substrates**

(57) A 3 dB microwave-to-waveguide power combiner for SHF/EHF band up to 50 GHz is appositely designed to be realized on high-loss dielectric substrates such as FR4 with $\tan \delta = 0,025$. In this way PCB manufacturing and surface mounting techniques, traditionally used in lower frequency ranges, are usable. Two microstrips ending with a respective patch are laid down on the front face of a FR4 substrate. The two microstrips are faced to a rectangular slot opened in a thick metal plate adherent to the rear face of the substrate. Slot is filled up with the material of the substrate and is dimensioned so as to optimize in the desired frequency band the transition between quasi-TEM mode of microstrip to TE_{10} mode of a rectangular waveguide obtained in the mechanics in contact with the metal plate around the slot. Both metal plate end the mechanics have milled contiguous tracts

with enlarged cross-section in respect of the slot. These two tracts together behave as a waveguide impedance transformer between first slot and waveguide. The two microstrips maintain parallel to each other and cross the contour of the underneath slot perpendicularly to a longer side. When a 3dB power combiner is manufactured, the two microstrips are coupled to the outputs of two respective power amplifiers which fed them with two signals summed up in-phase into the waveguide. A structure for reducing reflection losses is obtained by inserting a $\lambda/4$ microstrip at the input of a first amplifier and prolonging of $\lambda/4$ the path at the output of second amplifier with respect to the first output path. In this way TE_{10} mode coming from the waveguide, once reflected at the output of the second amplifier reaches the slot again 180 degrees shifted and it becomes a TE_{01} mode which is below waveguide cut-off (fig.8).

COMBINER WITH REDUCED REFLECTION LOSSES

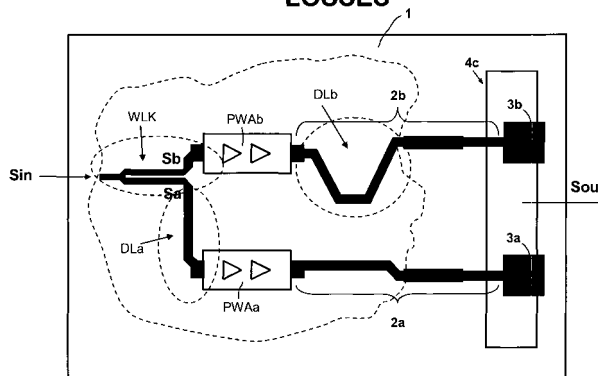


FIG. 8

Description

FIELD OF THE INVENTION

[0001] The present invention relates to the field of the microwave power combiners/splitters manufactured in planar technology, and more precisely to microwave power combiners/splitters on high-loss dielectric substrates.

BACKGROUND ART OF THE INVENTION

[0002] Power combiners/splitters fully realized in planar technology (hybrid) are well known in the art. The book of Robert E. COLLIN, titled: "FOUNDATIONS FOR MICROWAVE ENGINEERING"; SECOND EDITION; published by Mc GRAW-HILL Inc.; year 1992; ISB 0-07-011811-6, constitutes a valid design tool for, e.g.: BRANCH LINE (page 432), LANGE (page 434), HYBRID RING (page 437), WILKINSON (page 442), etc. These types of passive devices are generally constituted by transmission lines of opportune lengths laid down on a dielectric substrate, coupled with each other according to different geometries either absorptive or reflective. Due to the reciprocal behaviour of the hybrids when input and output are exchanged, the same structure is generally used for combiners and splitters. In many cases hybrids have to be interfaced with waveguides or the hybrids themselves embody a waveguide. In these cases some problems arise in consequence of the different mechanical characteristics of metallized substrates in comparison with waveguides, and the difference in propagation modes inside so different transmission lines. Many types of transitions between the two structures are known in the art; some exemplary transitions and criteria for their design are described in the COLLIN's book.

[0003] A power combiner manufactured in planar form is disclosed in the international patent application WO 03/092115 A1, titled: MICROSTRIP-TO-WAVEGUIDE POWER COMBINER FOR RADIO FREQUENCY POWER COMBINING; publication date 6-11-2003. This document constitutes a prior art according to Article 54(3) EPC. **Figures 1 and 2** (Fig.7 and Fig.8A of the citation) show a plan view and a cross-section along the longitudinal symmetry axis of a preferred embodiment of the mentioned combiner, respectively. With reference to **fig. 1**, a dielectric substrate 90 bears three MMICs (Microwave Monolithic Integrated Circuit) power amplifiers 54, 62, 66, a power divider 56 (rate race), and some interconnecting transmission lines 52, 60, 60', 64, and 64' fashioned as microstrips. The first amplifier 54 receives an input signal on a microstrip 52 and forwards a firstly amplified signal to a first port of the power divider 56. Two split signals with 180 degrees phase displacement are present at a second and third port of the power divider 56; these ports are coupled to two microstrips 60' and 64', while a fourth port is terminated on a 50 Ohm matched load. More precisely, the 0 degrees split signal

reaches the input of the amplifier 62, while the 180 degrees split signal reaches the input of the amplifier 66. Microstrips 60' and 64' at the output of respective amplifiers 62 and 66 form right-angle paths in such a way to terminate with opposed microstrip launchers 92, also referred as probes, at the microstrip-to-waveguide transition 68 (shown in dashed line). The two probes 92 are positioned 180 degrees apart orthogonally to the opposite longer sides of the rectangular opening of the waveguide. Signals at the output of the amplifiers 62 and 64 are combined inside the waveguide without additional losses other than normal 0.25 to about 0.30 dB loss. The configuration with two 180 degrees out-of-phase input signals and two output signals summed up in counter-phase is known as push-pull. Other geometries are proposed having four launchers, two by two orthogonally intersecting opposite sides of the rectangular opening of the transition 68, with the launched signals having 180 degrees phase displacement to each other. These other configurations are all referable to the push-pull case, otherwise they are not completely understandable, such as a configuration reproduced in fig.11 (not shown) which generates both the fundamental TE_{10} and an additional TE_{01} mode below the cut-off frequency and hence suppressed. With reference to fig.2, as textually reported in the mentioned application, a metal base plate 94 (e.g.: aluminium or similar material) supports the dielectric substrate 90 and may include an interposed ground layer 94a. A waveguide back-short 96 is positioned opposed a waveguide opening 98 of the transition 68. The waveguide opening 98 is formed in a waveguide support plate or top metal cover as illustrated at 99. The waveguide opening 98 forms a waveguide launch 98a. A back-short cavity 100 is positioned for reflecting energy into the waveguide opening 98. Isolation/ground vias are formed around the transition 68.

OUTLINED TECHNICAL PROBLEM

[0004] A completely satisfactory design for planar power combiners/splitters suitable for microwaves up to 50 GHz are presently unknown in the art. A reason is that low-loss dielectric substrates, such as alumina, are needed in this frequency range. Alumina substrates are indicated for obtaining microwave circuits of good quality, even at the highest frequencies, but the excessive hardness and fragility of alumina prevent the extension to the alumina substrates of the automatic or semiautomatic assembly techniques already widely used in the manufacturing of the printed circuit boards (PCB). As far as concern mechanical limitations, for example, drilling needs laser or ultrasonic drills, and screws are not usable for fixing the substrates. In the end alumina supports are expensive.

[0005] The ideal should be a microwave power combiner/splitter for SHF/EHF band suitable to be realized with low-cost dielectric substrates, for example employing the same manufacturing process of the printed circuit

boards together with surface mounting techniques. A desirable power combiner should sum up the two power signals into the waveguide directly, avoiding in this manner additional transition means similar to beam-leads or the like. Dual behaviour is desirable for a splitter. Unfortunately the power combiner of the **figures 1 and 2**, just for the presence of: (textually) *"the dielectric substrate 90 formed from ceramic substrate or either similar soft board material, including alumina"*, is unsuitable to be implemented as a printed circuit board. Low-loss (and hence costly) dielectric substrates are mandatory with this combiner; the reasons are due to the corner geometry of probes which is suitable to combine push-pull signals into the waveguide directly, the length of the probes, and the position of the metal plate 94 in respect of the waveguide 99. We shall consider that high-loss dielectric substrates, such as FR4, attenuate little more than 1 dB for wavelength. The push-pull summation of the prior art forces to space out the two power amplifiers 62 and 66 in a way that the corner-shaped microstrips 60' and 64' inclusive of the launchers 92 elongate almost two wavelengths altogether. Further considering additional losses attributable to the only probes 92 because of the ground-free zones approximately $\lambda/4$ long, it can easily realize that the total losses amount to at least 3 dB. With that, the initial goal of doubling the transmitted power by two power amplifiers and a combiner should be completely vanished. Increasing the gain of the two amplifiers for compensating these losses is problematic because amplifiers generally works at the maximum permissible gain, often with the addition of linearizers.

SUMMARY OF THE INVENTION

[0006] The main object of the present invention is that to indicate a 3 dB power combiner/splitter for SHF/EHF band up to 50 GHz suitable to be realized on low-cost (and hence high-loss) dielectric substrates, employing the same manufacturing process as printed circuit boards and surface mounting techniques traditionally used in lower frequency ranges.

[0007] The invention achieves said object by providing a microstrip-to-waveguide power combiner, as disclosed in claim 1.

[0008] The starting point to design a combiner/splitter compliant with the present invention is a transition disclosed in the european patent application EP 1367668, titled: "BROADBAND MICROSTRIP TO WAVEGUIDE TRANSITION ON MULTILAYER PRINTED CIRCUIT BOARDS ARRANGED FOR OPERATING IN THE MICROWAVES", filed by the same Applicant in date 30-05-2002 (priority date). The invention disclosed in this document is relevant to a microstrip-to-waveguide transition whose particular combination of features makes it suitable to be implemented at the end of a microstrip laid down on a dielectric substrate characterized by high dielectric losses. Vetronite ® (also termed FR4) is a material made of glass fibres impregnated with epoxy resin,

it is characterized by a $\tan \delta$ from 0,025 to 0,05, which configures it as suitable to the application in the printed circuits field, but not in that of microwave circuits where alumina imposes with $\tan \delta = 0.0001$.

[0009] With reference to **fig.3a** and **fig.3b**, the transition according to EP 1367668 includes a FR4 dielectric substrate 1 bearing a metallic line 2 laid down on its upper surface. The line 2 terminates with a patch 3 in correspondence of a rectangular slot 4 (dashed line) opened into a thick metal plate 5 (copper) in contact with the bottom surface of the dielectric substrate 1 (upper and bottom shall be assumed as a convention). The thick copper plate 5 constitutes an electrical ground plane for the microstrip 2, offers mechanical stiffness to the dielectric substrate 1 adherent to it, and dissipates the heat generated by active devices placed on it (not shown). Starting from the free surface, the copper plate 5 is milled for a certain depth of its thickness around slot 4 in order to obtain a rectangular cavity 6 open at one end and closed on top wall with the exception of slot 4. The latter is filled up with the same material of the substrate, starting from an FR4 prepreg. The rectangular slot 4 is dimensioned to couple energy optimally in the desired frequency band (from 27.5 to 33.5 GHz) between patch 3 and the contiguous cavity 6. A transition from the electromagnetic propagation mode of the microstrip 1 (nearly TEM) to the TE₁₀ mode of the waveguide takes place at slot 4 interface. **Fig.4** shows a longitudinal cross-section taken across the axis A-A of **fig.3a**. With reference to **fig.4**, we see the elements depicted in **fig.3a** and **3b**, plus a metallic waveguide 7 in contact with the copper plate 5, a wafer of two additional FR4 substrates 10 and 11 in contact with the copper plate 5, and a metallic lid 11 placed upon the area of the transition. A small opening 12 is visible in a wall of lid 11 for the passage of the microstrip 2. The cavity 6 opened into the plate 5 continues in a second slot 8 milled in the ending wall of the waveguide 7 with rectangular cavity 9. The zone of the thick metal plate 5 put in contact with the end of the waveguide 7 constitute a flange for screwing the end of the waveguide to the flange, maintaining slots 6 and 8 aligned to complete the transition. The screws penetrate side fins of the upper lid 11 so as to fix it to the dielectric 1. **[0010]** According to the present invention of combiner, two microstrips ending with a respective patch are laid down on the front face of a high-loss dielectric substrate. The two microstrips are faced to a rectangular slot opened in a ground metal plate adherent to the rear face of the substrate. Slot is filled up with the material of the substrate and is dimensioned so as to optimize inside the desired frequency band the transition between quasi-TEM mode of microstrip to TE₁₀ mode of a rectangular waveguide obtained in the mechanics in contact with the metal plate around the slot. Both metal plate end the mechanics have milled contiguous tracts with enlarged cross-section in respect of the slot. These two tracts together behave as a waveguide impedance transformer between first slot and waveguide. The two microstrips

maintain parallel to each other and cross the contour of the underneath slot perpendicularly to a longer side. The two microstrips are coupled to the outputs of two respective power amplifiers which fed them with two signals summed up in-phase into the waveguide.

[0011] Compared to the 3dB power combiner disclosed in WO 03/092115 A1, the two paths from the outputs of power amplifiers and the middle line of the transition are shortened noticeably, and losses decreased too. Another positive contribution is due to the slot filled with dielectric material of the substrate which allows shorter probes and more efficient coupling between different modes in respect of coupling to the waveguide directly. Besides, difficult operations to cut out the substrate around the probes are prevented. Thanks to the aforementioned characteristics of the invention, FR4 or similar substrates are made usable for combiners with tolerable power losses up to 50 GHz.

[0012] Further object of the invention is a variant to improve the return loss measured at the output of the waveguide. According to the variant, a microstrip at the output of a first power amplifier is made $\lambda/4$ longer than the microstrip at the output of the second amplifier, and in the meanwhile the microstrip at the input of the second amplifier is made $\lambda/4$ longer than the microstrip at the input of the first amplifier. The total length crossed by the two signals are the same, but the signal first time reflected from the waveguide towards the output of the first amplifier reaches the transition again 180 degrees out of phase and is suppressed consequently because shifted under the dominant mode. Low additional losses in respect of the preceding structure are due to the longer $\lambda/4$ path of the first microstrip.

[0013] Considering that microstrip-to-waveguide transitions have reciprocal behaviour at their ports when input and output signals are exchanged, the same structure of the combiner can be used as 3dB power splitter simply by entering an input signal in the waveguide and capturing two in-phase split signals at the end of two short microstrips coupled to the waveguide through the transition slot. Microwave balanced circuits avail of this splitter.

[0014] It is therefore, further object of the invention is a 3dB waveguide-to-microstrip power splitter with the same structure of the combiner.

[0015] The proposed combiner/splitter shows a large bandwidth and low losses with any kind of substrate included FR4. This allows saving costs by using standard PCB and mechanical manufacturing. The invention may be used in several configurations in order to improve output waveguide return losses; direct coupling to the antenna without circulators is therefore possible. The integration of the microstrip-to-waveguide transition on the suggested FR4 structure allows obtaining a complete transmitter, or receiver, or both on the same board. Moreover, as the transition shows low sensitivity to manufacturing tolerances, the above process is characterized by high reliability and reproducibility.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] The features of the present invention which are considered to be novel are set forth with particularity in the appended claims. The invention and its advantages may be understood with reference to the following detailed description of an embodiment thereof taken in conjunction with the accompanying drawings given for purely non-limiting explanatory purposes and wherein:

- **fig.1**, already described, shows a plant view of a microstrip-to-waveguide power combiner of the prior art;
- **fig.2**, already described, shows a fragmentary side sectional view of the microstrip-to-waveguide power combiner of fig.1;
- **fig.3a**, already described, shows a top view of a microstrip-to-waveguide transition according to a published patent application filed by the Applicant;
- **fig.3b**, already described, shows a rear view of the microstrip-to-waveguide transition of fig.3a;
- **fig.4**, already described, shows cross-section along the axis A-A of fig.3a;
- **fig.5** shows a (quoted) top view of the microstrip-to-waveguide power combiner/splitter of the present invention;
- **fig.6** shows an exploded partially sectioned view of the microstrip-to-waveguide power combiner/splitter of the present invention;
- **fig.7** shows a (quoted) cross-section along the axis B-B of fig.5;
- **fig.8** shows a variant of the power combiner of fig.5 for reducing reflection losses;
- **figures 9, 10 and 11** show some curves of insertion and return losses vs. frequency obtained by a simulator of the combiner/splitter structure of the invention.

DETAILED DESCRIPTION OF AN EMBODIMENT OF THE INVENTION

[0017] As a description rule, same elements in the drawings are referenced by the same labels, and the elements represented in the figures are not a scaled reproduction of the original ones.

[0018] With reference to **fig.5**, two parallel lines 2b and 2c terminating with a respective square patch 3b and 3c are visible on a conventionally named front face of a dielectric substrate 1c characterized by high losses. Vetrinite® (FR4) or lead free material are used. A hollow metallic lid 11c is superimposed to the substrate 1c constituting the first layer upon the zone around the patches 3b and 3c. Lid 11c includes four threaded holes in the corners for fixing it to the substrate 1c, by means of screws penetrating the underneath mechanical part. The plant view shows three dashed rectangular lines concentric to each other and referred to elements of the rear face: the inmost 4c is the trace of a first slot opened into

a thick metal plate; the intermediate 6c is the trace of a second slot in communication with the first one; and the outer is the trace of a cross-section of a waveguide 7c. For the purpose of the description the following dimensions (mm) are indicated for a combiner operating in the 27.5 - 29.5 GHz frequency band:

L0	0.2;
L1	3.38;
L2 x L3	1.4x7.12;
L4	1;
L5	0.5;
L6 x L7	2 x 7.12;
L8 x L9	3.56 x 7.52.

[0019] With reference to **fig.6**, the exploded sectioned view shows the thick metal plate 5c as a second layer (core), which is both electrical ground and heat sink for microwave devices and it offers a strong support to the upper thin FR4 layer. Slot 4c is milled in the thickness of plate 5c, opposite to the patches 3a and 3b, and successively filled with FR4 to be homogeneous with the material of first layer. The thick metal plate 5c is further milled for a certain depth around slot 4c to obtain a second slot 6c of rectangular cross-section. The mechanics in contact with plate 5c is milled for obtaining a third slot 8c, as a continuation of the second slot 6c, in the top of a rectangular waveguide 7c with standard cross-section. **Fig. 7** is a cross-section along the axis B-B of **fig.5** which shows the elements of the preceding figure with the indication of the following dimensions (mm):

L10	0.1 ;
L11	0.3;
L12	1 ;
L13	3.8;
L14	3.

[0020] Although not shown in the figures, a third and fourth dielectric layers can be provided to form a multilayer structure like the one of **fig.4**. Additional paths for bias, IF and control signals can be housed on the third layer whereas the fourth layer is a further ground plane.

[0021] In operation, considering the depicted structure as 3dB power combiner, the two microstrips 2a and 2b of equal length are coupled to the output of respective FETs which output two microwave signals Sa and Sb with the same phase. These signals reach the patches 3a and 3b in phase where are irradiated towards slot 4c undergoing a transformation from quasi-TEM propagation mode of microstrips 2a, 2b to TE₁₀ dominant mode of the waveguide 7c. Lid 11c is a metallic hollow body placed upon the transition zone to reflect back energy toward slot 4c avoiding on air propagation. The short-circuit present at the top wall of lid 11c is transformed into an open circuit at the transition plane by the internal

$\lambda/4$ depth. Lines and patches, so as the length and width of slot 4c, are properly shaped to match the coupling between the microstrip and the waveguide, over the desired frequency band. The two contiguous opening 6c and 8c in the metal plate 5c and the top wall of waveguide 7c, respectively, constitute together a waveguide impedance transformer to match the slot 4c to the waveguide 7c below which is directly obtained in the mechanics. Simulation results show how the use of the waveguide impedance transformer can improve the working frequency bandwidth (up to 20%).

[0022] The production steps of a multilayer (four layers) PCB including the power combiner of **figures 5 to 7** are summarized as in the following:

1. The slot 4c is milled in the whole thickness of the metal plate 5c.
2. The PCB is built up inserting the metal plate 5c as the second metal layer; in this way the slot 4c results filled with FR4 prepreg.
3. A first milling process removes the lower layers up to the thick metal plate 5c smoothing its surface to make it clean and ready to be joined to the metal housing.
4. A second milling process creates the part 6c of the waveguide impedance transformer on the thick metal plate 5c and reduces the thickness of the slot 4c.
5. The waveguide 7c and the other part 8c of the impedance transformer are embedded in the metal housing during its fabrication process.

[0023] The described steps don't require critical processes and the transition is automatically achieved just screwing the lid 11 c on the board on the metal housing.

[0024] The combiner of **fig.5** is used in the balanced structure of **fig.8** which is aimed to reduce reflection losses. With reference to **fig.8**, a left part (in dashed contour) is joined to the two preceding microstrips 2a and 2b. The input signal Sin is coupled to a Wilkinson hybrid which splits Sin in two equal signals Sb, Sa in-phase to each other. These signals are coupled to the input of respective power amplifiers PWAb and PWAa: signal Sb is coupled directly while signal Sa through a $\lambda/4$ microstrip DLa. The output of the PWAb and PWAa amplifiers are respectively coupled to the microstrip 2b and 2a terminating with the patches 3b and 3a. Microstrip 2b includes a supplementary path DLb which extend of $\lambda/4$ the length of 2b in respect of 2a. In this way it's possible to improve the return loss at the waveguide side. In fact, the TE₁₀ mode coming from the waveguide, once reflected at the output of PWAb reaches slot 4c again 180 degrees shifted and it becomes a TE₀₁ mode which is below waveguide cut-off. After the second reflection, the field becomes a TE₁₀ again and the overall effect is that the measure of return loss is doubled (in negative dB), as shown in **fig.11**.

[0025] Changing the length of both DLa and DLb tracts from $\lambda/4$ to $\lambda/2$, a push-pull configuration is obtained. With

respect to the push-pull configuration of the prior art represented in fig.1, the difference between the lengths of microstrips 2b and 2a, measured from the outputs of the two power amplifiers to the two patches 3b and 3a, is now little more than $\lambda/2$ against nearly 2λ of the prior art. This save power of at least 1.5 dB.

[0026] For evaluating the performances of the combiner/splitter of the invention, the structure depicted in **figures 5 to 7** has been simulated for a splitter operating within 27.5 - 29.5 GHz band. Ansoft electromagnetic simulator is used. With reference to **fig.9** and **fig.10**, simulation results show return losses better than 20 dB and the insertion loss is only 0.5 dB greater than an ideal 3dB splitter. Simulation results relevant to the combiner structure of **fig.8** are shown in **fig.11**. Two curves of return loss are compared in the figure: the single device return loss and waveguide return loss. The latter is 10 dB lower than the first curve thanks to the suppression of the firstly reflected TE_{10} mode coming from waveguide.

[0027] On the basis of the above description some changes may be introduced in the exemplary embodiment by the skilled in the art without departing from the scope of the invention.

Claims

1. Microstrip-to-waveguide power combiner including at least two microstrips (2b, 2a) laid down on a dielectric substrate (1 c) adherent to a ground metal plate (5c), each microstrip terminating with a probe (3b, 3a) at the microstrip-to-waveguide transition in order to launch two amplified microwave signals (Sb, Sa) from the microstrips to the opening (8c, 9c) of the waveguide (7c) where they sum up, and also including a waveguide back-short (11c) positioned opposite the waveguide opening at the transition, **characterized in that:**

- said dielectric substrate (1 c) is of the high-loss type usable for printed circuit board;
- said ground metal plate (5c) includes a rectangular slot (4c, 6c) opposite to said probes (3b, 3a), at one side, and opposite to said opening (8c) of the waveguide (7c) at the other side;
- said rectangular slot (4c) is filled up with the same material of the dielectric substrate;
- said probes (3b, 3a) are aligned to the respective microstrips (2b, 2a);
- said microstrips (2b, 2a) are parallel to each other and cross the contour of said rectangular slot (4c) perpendicularly to a longer side.
- said microwave signals (Sb, Sa) arriving in-phase on said probes (3b, 3a).

2. The microstrip-to-waveguide power combiner of claim 1, **characterized in that** said slot (4c, 6c) in the metal plate (5c) includes a tract (6c) with enlarged

cross-section faced to the opening (8c) of the waveguide (7c) for acting as waveguide impedance transformer between the remaining tract (4c) and the waveguide (7c).

3. The microstrip-to-waveguide power combiner of claim 2, **characterized in that** said waveguide (7c) is obtained in a metallic body, or mechanics, in contact with said metal plate (5c) including an opening (8c) opposite to said tract with enlarged cross-section (6c) for acting together as waveguide impedance transformer..

4. The microstrip-to-waveguide power combiner of any preceding claim, **characterized in that:**

- said microwave signals (Sb, Sa) are present at the output of two power amplifiers (PWAb, PWAAa);
- a microstrip (2b) at the output of a first power amplifier (PWAb) is made $\lambda/4$ longer (DLb) than the microstrip (2a) at the output of the second power amplifier (PWAAa), being λ the wavelength at the central frequency of the operating band;
- the inputs of the two power amplifiers (PWAb, PWAAa) are fed by two input signals coming from an in-phase splitter (WLK);
- a microstrip tract $\lambda/4$ long (DLa) is coupled to the input of the second power amplifier (PWAAa) for receiving a respective input signal (Sa).

5. The microstrip-to-waveguide power combiner of any preceding claim from 1 to 4, **characterized in that:**

- said microwave signals (Sb, Sa) are present at the output of two power amplifiers (PWAb, PWAAa);
- a microstrip (2b) at the output of a first power amplifier (PWAb) is made $\lambda/2$ longer (DLb) than the microstrip (2a) at the output of the second power amplifier (PWAAa), being λ the wavelength at the central frequency of the operating band;
- the inputs of the two power amplifiers (PWAb, PWAAa) are fed by two input signals coming from an in-phase splitter (WLK);
- a microstrip tract $\lambda/2$ long (DLa) is coupled to the input of the second power amplifier (PWAAa) for receiving a respective input signal (Sa).

6. Waveguide-to-microstrip power splitter including at least two microstrips (2b, 2a) laid down on a dielectric substrate (1 c) adherent to a ground metal plate (5c), each microstrip originating from a probe (3b, 3a) positioned at the waveguide-to-microstrip transition in order to capture a respective microwave signal (Sb, Sa) from the opening (8c, 9c) of the waveguide (7c), and also including a waveguide back-short (11c) po-

sitioned opposite the waveguide opening at the transition, **characterized in that**:

- said dielectric substrate (1 c) is of the high-loss type usable for printed circuit board; 5
 - said ground metal plate (5c) includes a rectangular slot (4c, 6c) opposite to said probes (3b, 3a), at one side, and to said opening (8c) of the waveguide (7c) at the other side;
 - said rectangular slot (4c) is filled up with the same material of the dielectric substrate; 10
 - said probes (3b, 3a) are aligned to the respective microstrips (2b, 2a);
 - said microstrips (2b, 2a) are parallel to each other and cross the contour of said rectangular slot (4c) perpendicularly to a longer side. 15
7. The waveguide-to-microstrip power splitter of claim 6, **characterized in that** said slot (4c, 6c) in the metal plate (5c) includes a tract (6c) with enlarged cross-section faced to the opening (8c) of the waveguide (7c) for acting as waveguide impedance transformer between the waveguide (7c) and the remaining tract (4c). 20
8. The waveguide-to-microstrip power splitter of claim 7, **characterized in that** said waveguide (7c) is obtained in a metallic body, or mechanics, in contact with said metal plate (5c) including an opening (8c) opposite to said tract with enlarged cross-section (6c) for acting together as waveguide impedance transformer. 25 30

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MICROSTRIP-TO-WAVEGUIDE 3dB POWER COMBINER (KNOWN ART)

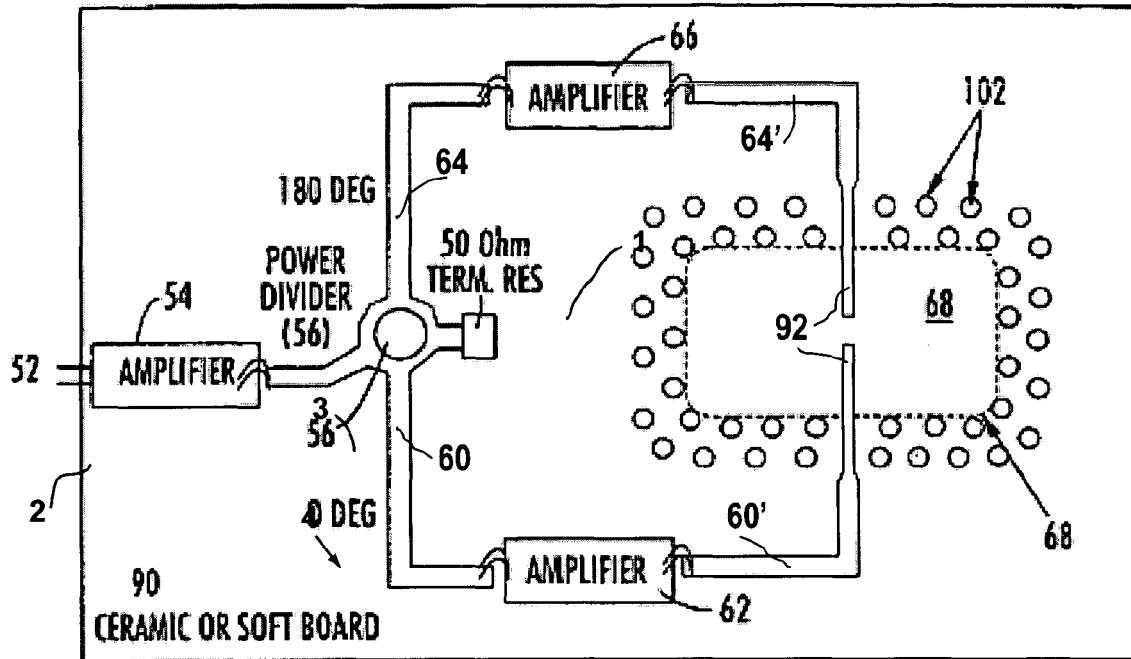


FIG. 1

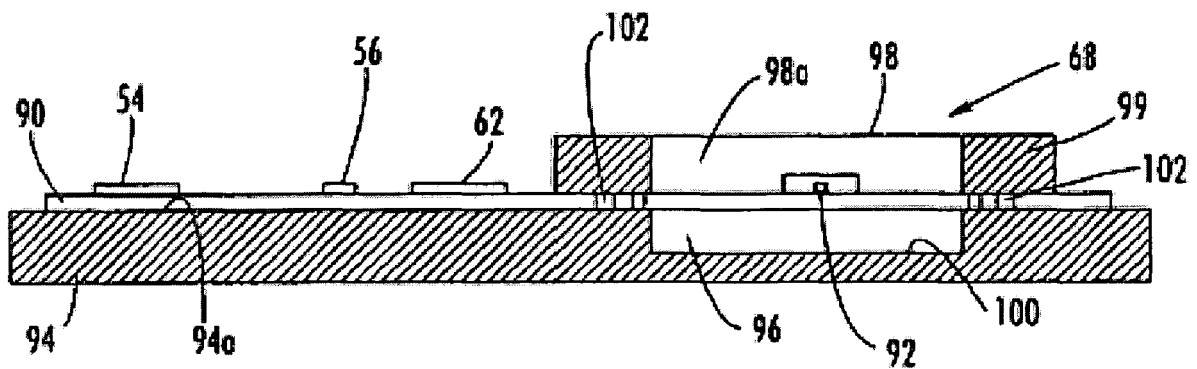


FIG. 2

MICROSTRIP TO WAVEGUIDE TRANSITION (KNOWN ART)

FR4 Metal plate Metallic layout

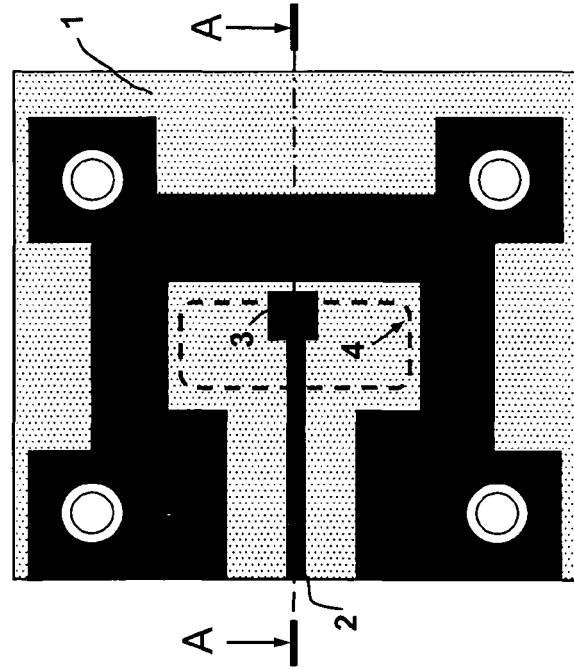


FIG. 3a (top view)

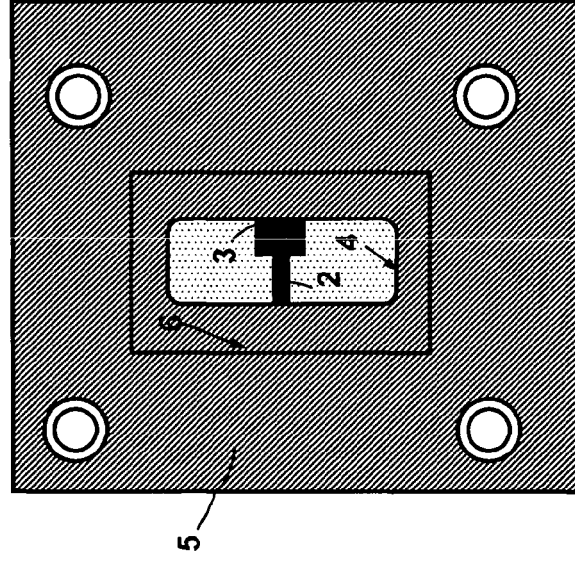


FIG. 3b (rear view)

A-A LONGITUDINAL CROSS-SECTION (KNOWN ART)

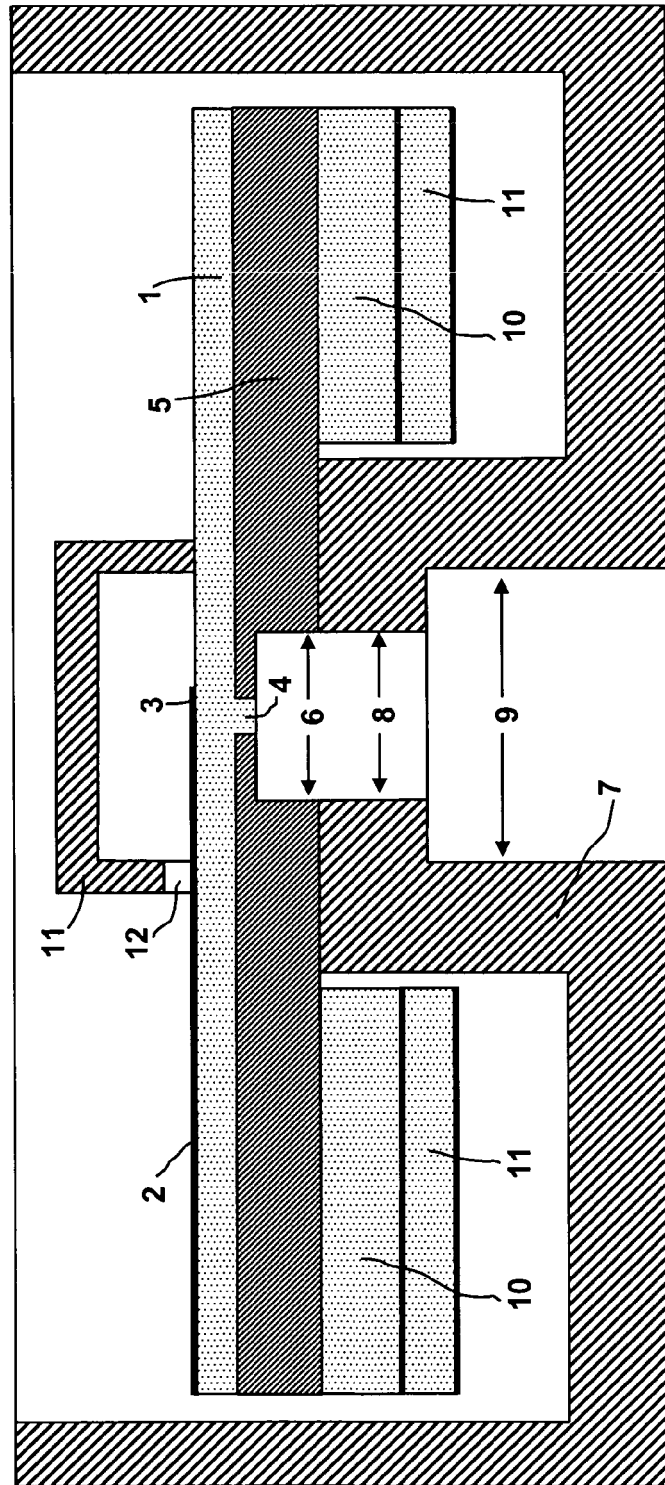
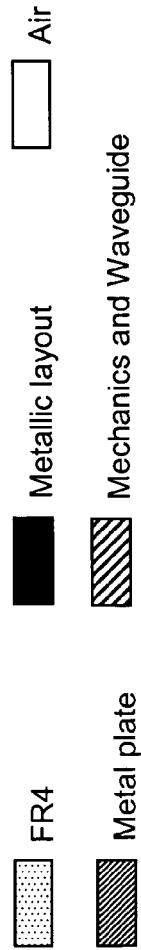
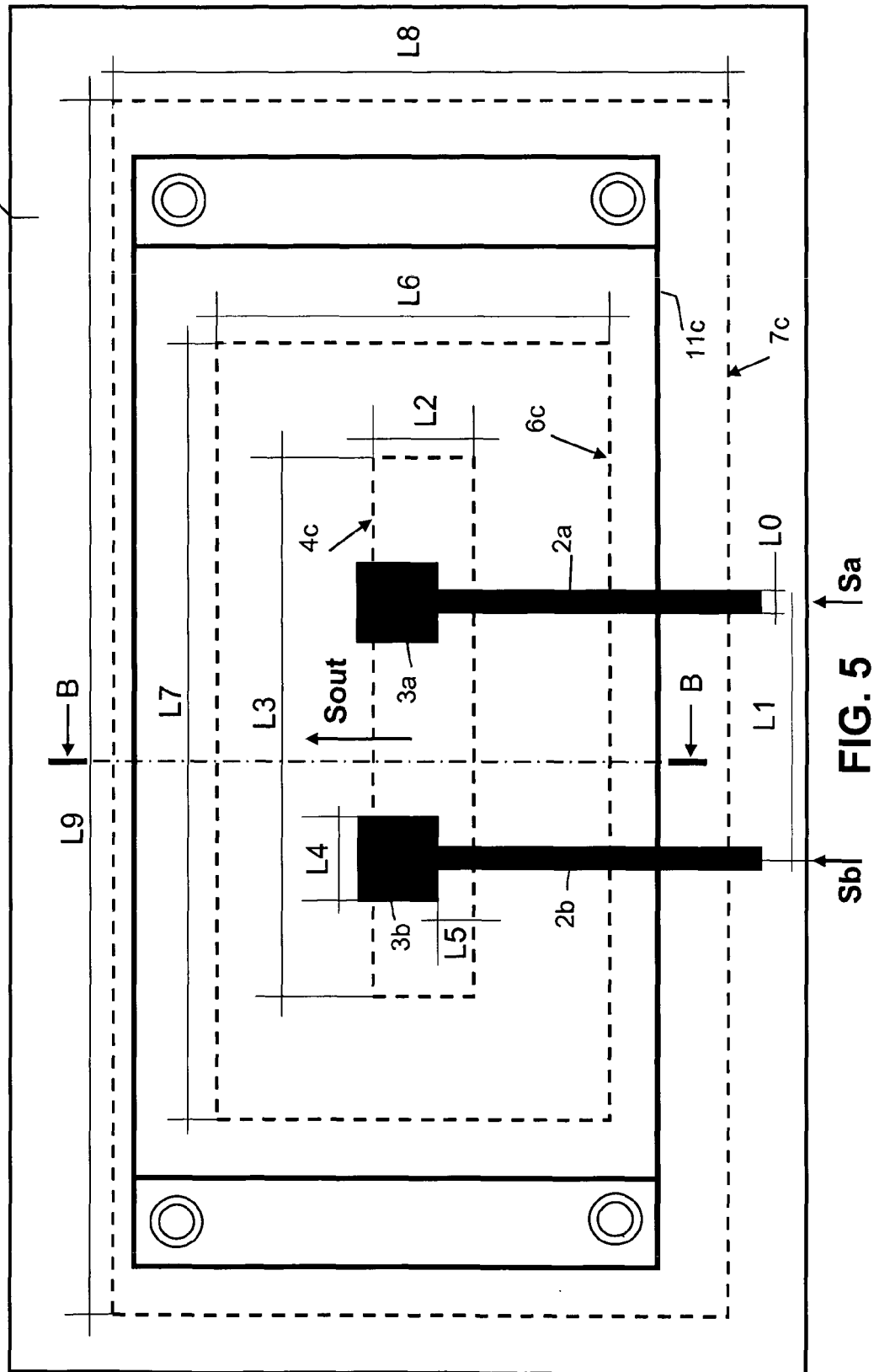
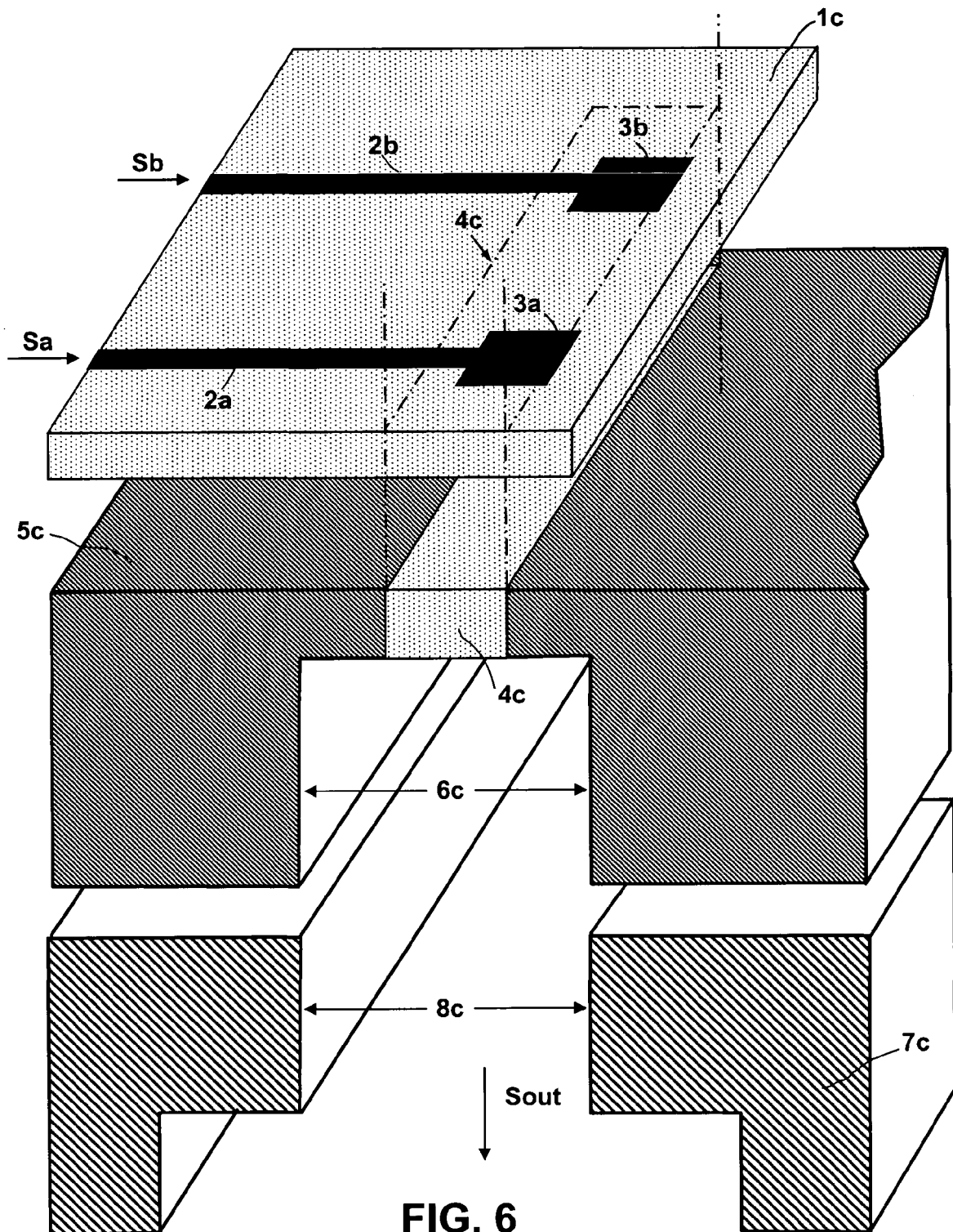


FIG. 4

PLANT VIEW OF 3dB MICROSTRIP-TO-WAVEGUIDE POWER SPLITTER/COMBINER^{1c}



3dB MICROSTRIP-TO-WAVEGUIDE POWER COMBINER/SPLITTER



B-B CROSS-SECTION

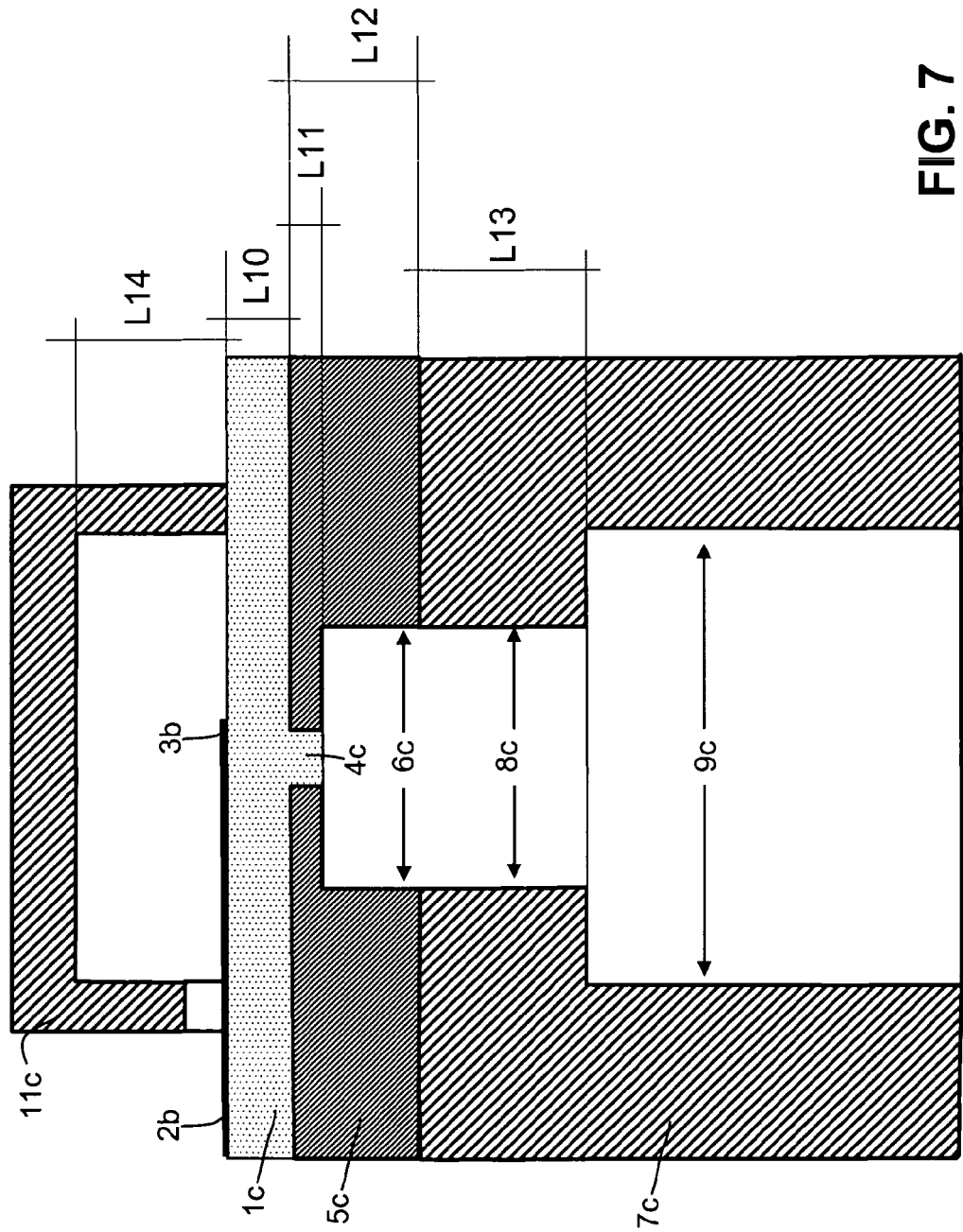


FIG. 7

COMBINER WITH REDUCED REFLECTION LOSSES

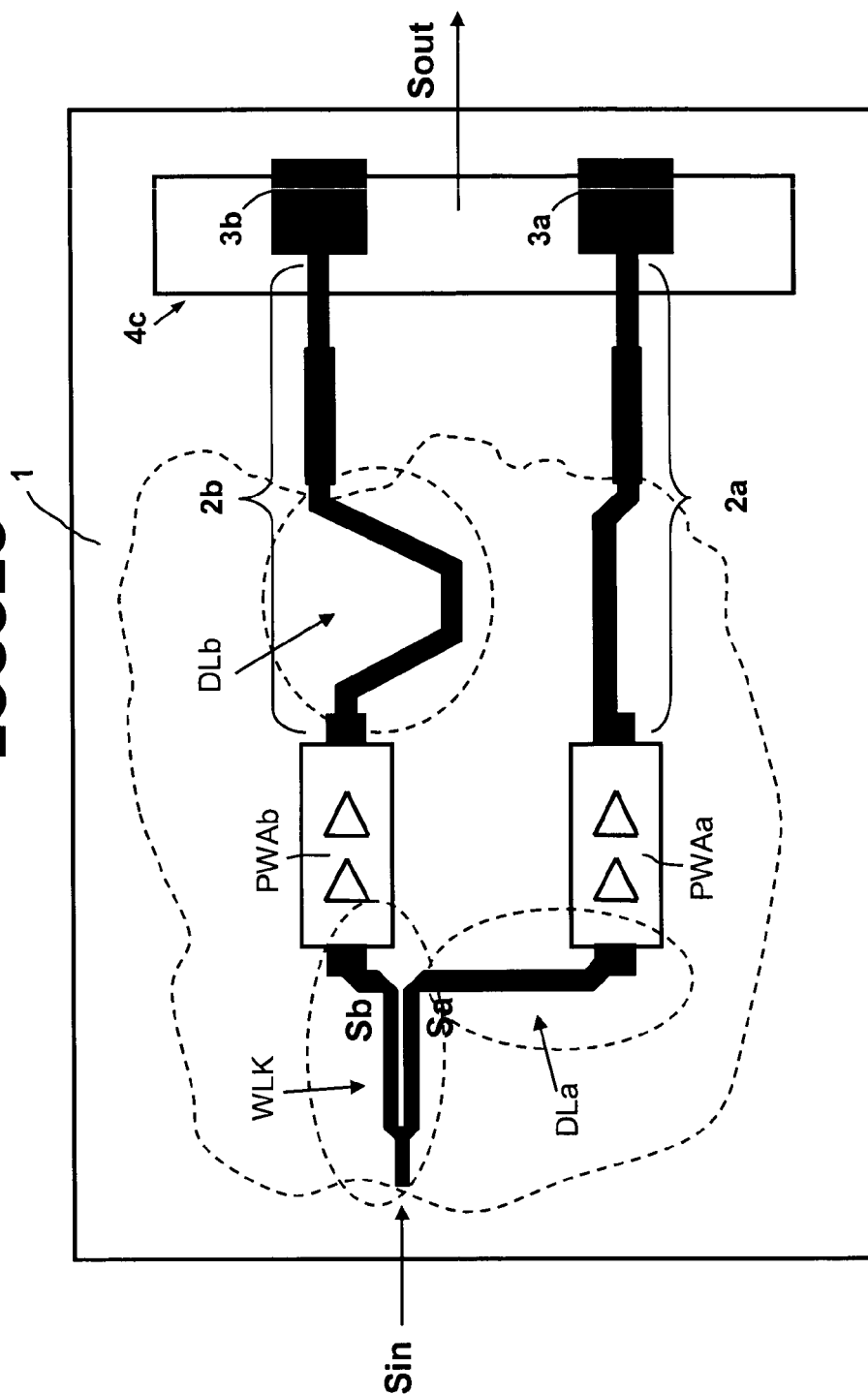


FIG. 8

SPLITTER INSERTION AND RETURN LOSSES

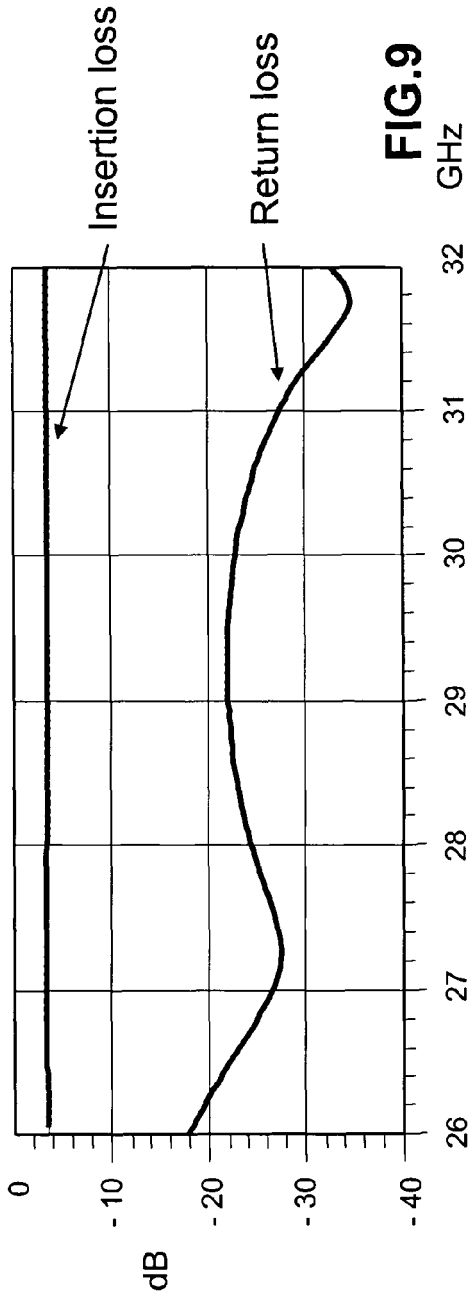


FIG. 9

DETAIL OF INSERTION LOSSES

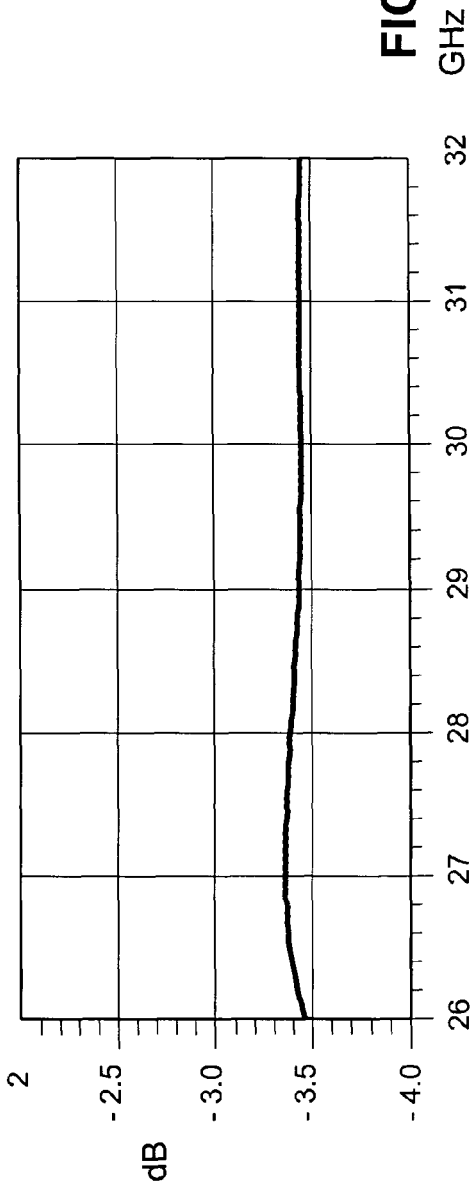


FIG. 10

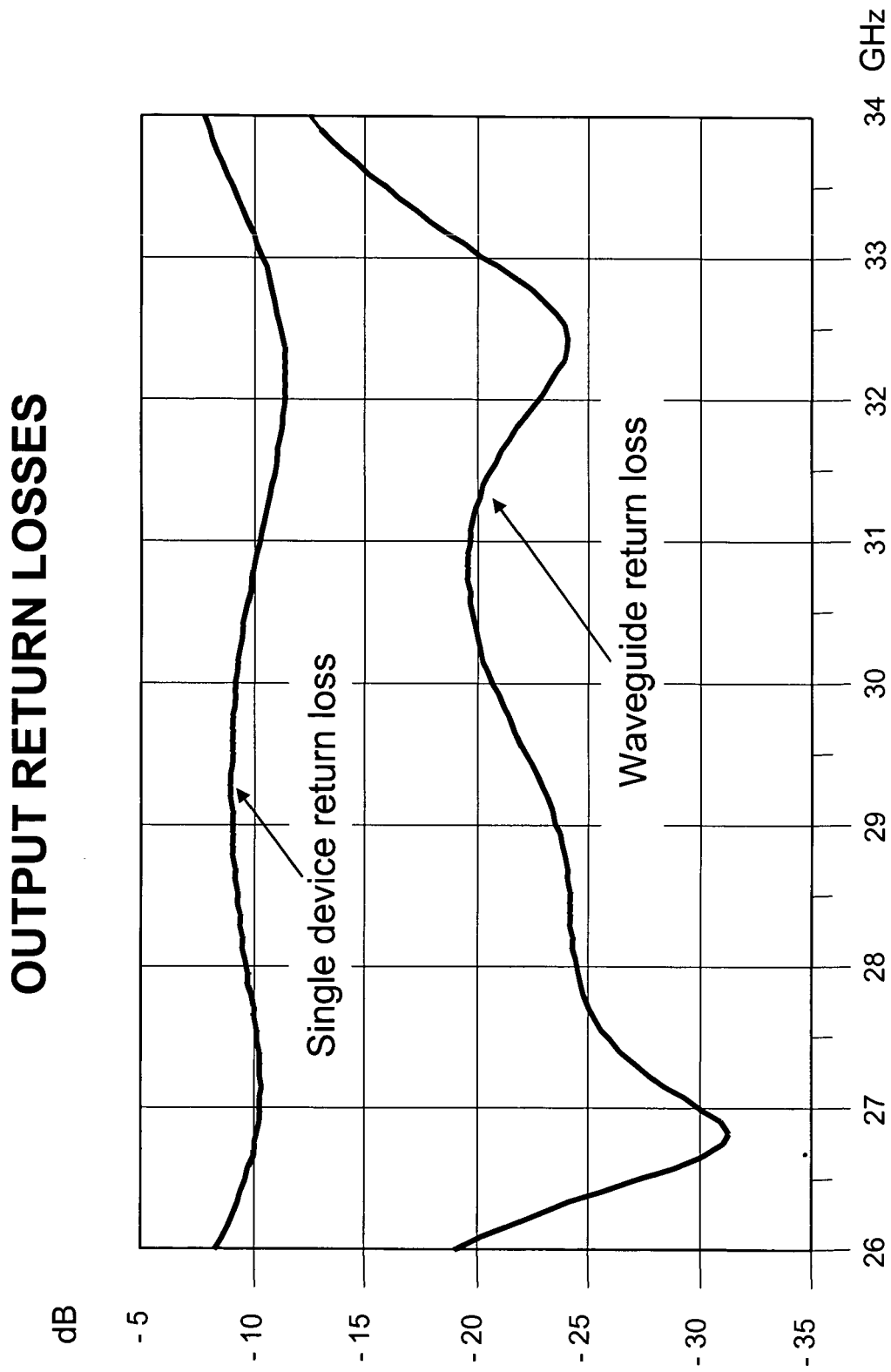


FIG. 11



European Patent
Office

EUROPEAN SEARCH REPORT

Application Number
EP 05 42 5501

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The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 25 November 2005	Examiner Pastor Jiménez, J-V
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