



(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
22.06.2011 Bulletin 2011/25

(51) Int Cl.:
H01P 3/08 (2006.01) H01P 5/18 (2006.01)

(21) Application number: **10194348.8**

(22) Date of filing: **09.12.2010**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME

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(30) Priority: **14.12.2009 IT MI20092185**

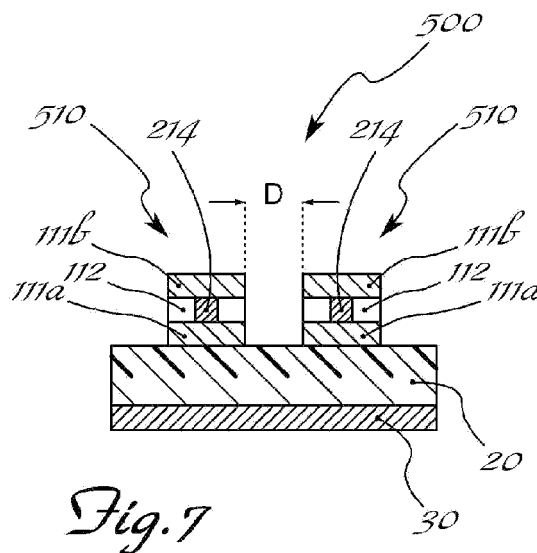
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(54) **Microstrip line coupler for microwave transmission**

(57) Line coupler comprising at least two coupling lines (510) formed by microstrips, comprising an insulating substrate (20) on one side of which an earth conducting layer (30) is applied and on the other side of which

at least one central conductor for transmission of the signal is applied, said central conductor comprising at least two conducting layers (111a;111b) which are separated by a dielectric layer (112) and are connected together by a longitudinal, interconnecting, conducting rib (214).



Description

[0001] The present invention relates to a microstrip coupler with improved directivity at microwave frequencies.

[0002] It is known in the telecommunications sector to use monolithic microwave integrated circuits (MMIC) for the manufacture of active and/or passive microwave devices, such as oscillators operating at the frequencies of GHz or tens of GHz.

[0003] An important component of these integrated circuits for forming the resonant circuit in oscillators is the transmission line, which is normally of the microstrip type and consists of a thin conductive strip (central conductor) deposited on one side of a flat support medium made of dielectric material (dielectric substrate), for example gallium arsenide (GaAs), of small thickness, while a layer of conducting material which forms the earth layer is applied onto the other side of the said dielectric substrate.

[0004] It is also known that the electrical characteristics of the microstrip line (referred to below in short as "microstrip"), such as the inductance, the distributed capacity per unit of length and the characteristic impedance (Z_0), depend on the geometry of the microstrip itself; in particular the characteristic impedance (Z_0) depends on the ratio between the width (W) of the central conductor and the thickness (d) of the dielectric substrate, as well as on the dielectric constant of the substrate itself.

[0005] The microstrips used in monolithic microwave circuits have a length of the order of a few mm, widths of the order of tens of μm and a thickness of the order of μm .

[0006] The insulating substrate, which is made for example of gallium arsenide (GaAs), has a thickness of the order of hundreds of μm .

[0007] In the case of the design of an oscillator circuit, an important parameter influencing the quality thereof, or relevant factor, is the attenuation (α) affecting the signal owing to the losses occurring in the microstrip line forming the resonant circuit.

[0008] This attenuation (α) is composed mainly of two components: the losses (α_c) which arise in the central conductor and in the earth layer and the losses (α_d) which occur in the dielectric substrate.

[0009] At the microwave frequencies (>4 GHz), to which reference is made in this invention, the loss component due to the resistance of the central conductor and the affected portion of the earth layer (α_c) is greater than the losses occurring in the dielectric substrate (α_d).

[0010] Since the losses of the central conductor are substantially due to its resistance and to the dispersion by means of radiation in the free space, in order to reduce the losses, without modifying the electrical characteristics of the line formed in the microstrip and in particular the characteristic impedance (Z_0), it is required the diminish the RF resistance of the conductor; said resistance, as is known, is proportional to the resistivity of the material and to the length (ℓ) of the line and inversely

proportional to the penetration thickness of the RF currents. Since the width (W) and the length (ℓ) determine the desired electrical characteristics they consequently may not be modified.

[0011] Solutions able to reduce said attenuation, while reducing the equivalent resistivity of the conductor via the microstrip lines, as described and illustrated in JP-09-093005 or WO-02/103838, have therefore been proposed.

[0012] In the transmissions sector and in particular the sector of microwave transmissions there exists, however, a further technical problem relating to the line coupler devices, namely those passive devices formed by two lines arranged at a relative distance from each other so as to allow the partial transfer of power from one line to the other line.

[0013] Couplers may be used to remove part of the signal for measurement purposes or as signal dividers if the input power must be shared between two coupled/direct output sections.

[0014] It is also known that the essential characteristics which determine the quality of the coupler are reduced attenuation and high directivity thereof.

[0015] The technical problem, therefore is to provide a microstrip coupler, for monolithic microwave integrated circuits which operate in the microwave range ($f > 4\text{GHz}$), particularly but not exclusively, for transmission lines, which has an improved directivity compared to couplers of the prior art.

[0016] In connection with this problem it is also required that the coupler should be easy and inexpensive to produce and be able to be used easily also on already existing devices.

[0017] These results are achieved according to the present invention by a coupler according to the characteristic features of Claim 1.

[0018] Further details may be obtained from the following description of a non-limiting example of embodiment of the method and the device according to the present invention provided with reference to the accompanying drawings in which:

Figure 1 shows a schematic view of a microstrip line according to the prior art;

Figure 2 shows a cross-sectional view along the transverse plane indicated by II-II in Fig. 1;

Figure 3 shows a cross-sectional view along the longitudinal plane indicated by III-III in Fig. 1;

Figure 4 shows a cross-sectional view, along the plane indicated by IV-IV in Fig. 5, of a variant of the microstrip line according to the prior art;

Figure 5 shows a cross-sectional view along the plane indicated by V-V in Fig. 4;

Figure 6 shows a circuit diagram of a coupler realized with microstrips according to the present invention;

Figure 7 shows a cross-sectional view along the plane indicated by VII-VII in Fig. 6;

Figure 8 shows a graph illustrating the percentage increase in the directivity of a coupler according to the present invention compared to a conventional coupler;

Figure 9 shows a graph illustrating the directivity of a conventional multiple-line (Lange) coupler; and

Figure 10 shows a graph illustrating the improved directivity of a multiple-line (Lange) coupler according to the present invention.

[0019] As shown in Figs. 1-3 and assuming solely for the sake of convenience of the description and without any limitation of meaning a set of three reference axes in a longitudinal direction X-X, transverse direction Y-Y and vertical direction Z-Z, respectively, a first embodiment of a microstrip line according to the present invention comprises:

- an insulating substrate 20 on the opposite sides of which the following are respectively applied:
- a conducting layer 30 forming the earth layer and
- a central conductor 200 comprising a longitudinal conducting rib 214 interconnecting two metal layers, i.e. a bottom layer 111a in contact with the insulating substrate 20 and a top layer 111b of the central conductor itself.

[0020] Figs. 4-5 show, respectively, a cross-sectional view and longitudinally sectioned view of a variant of the embodiment of the microstrip line according to the prior art, said variant envisaging a further dielectric layer 212a and a further conducting layer 211c arranged between the previous conducting layers 111a and 111b of the central conductor 210; moreover a second longitudinal rib 214a interconnects the outer conducting layer 111b to the intermediate conducting layer 211c.

[0021] According to preferred embodiments it is envisaged that, for both variants, the longitudinal ribs may consist of a longitudinal, continuous, metal bar or equivalent interconnecting conductive posts (not shown) or equivalent metallized holes passing through the dielectric layer situated between the two layers of the central conductor.

[0022] The relative distance between the said posts or metallized holes in the longitudinal direction X-X is preferably set so as to be less than or equal to $\lambda/20$, λ being the wavelength in the microstrip.

[0023] Figs. 6 and 7 show a line coupler 500 in which the following are defined:

- P1 = signal input port;
- P2 = Coupled signal output port;
- P3 = Direct output port for remainder of input signal;
- P4 = Isolated port (remainder of coupled signal)
- Coupling factor = $P2/P1$
- Directivity = $P4/P2$

and which is provided according to the present invention by means of coupling lines 510 formed, in a microstrip 200 or 210 as described above with ribs 214 interconnecting the bottom conducting layer 111a and top conducting layer 111b.

[0024] Although not shown, it is envisaged that the coupling lines may be also be formed using also interconnecting conducting posts or by equivalent metallized holes passing through the dielectric layer situated between the two layers of the central conductor with a relative distance between the said posts or metallized holes in the longitudinal direction X-X less than or equal to $\lambda/20$, λ being the wavelength in the microstrip.

[0025] In the experimental tests performed, couplers with the following dimensional parameters were used:

- length of the coupling section $L=1,800 \mu\text{m}$;
- distance between the two coupling lines $D=2/10 \mu\text{m}$ and using lines with central conductors having the same length of 1.84 mm, all of which being formed on a GaAs substrate of $100 \mu\text{m}$ thickness, with the same characteristic impedance of 50Ω and with a central conductor formed by two metal layers which are superimposed and in direct contact with each, forming a total thickness of $3 \mu\text{m}$.

[0026] In this case the microstrips were formed with a first metal layer of thickness $1.0 \mu\text{m}$, a second metal layer of thickness $2.0 \mu\text{m}$ and an intermediate dielectric layer of thickness $1.6 \mu\text{m}$.

[0027] According to preferred embodiments the transverse thickness (Y-Y) of the rib is between 3 and $20 \mu\text{m}$ and preferably between 6 and $10 \mu\text{m}$.

[0028] As illustrated in the graph of Fig. 8, the x axis of which shows the working frequencies and the y axis the percentage improvement in directivity expressed in dB and standardized with respect to the line 0 representing the directivity values which can be obtained with couplers formed by means of microstrips of the known type of thickness $3 \mu\text{m}$, there is a marked improvement in the directivity both in the case of a coupler with a distance between the lines $D=2 \mu\text{m}$ (broken line curve) and in the case of a coupler with distance $D=10 \mu\text{m}$ (solid line curve).

[0029] Further experimental tests were carried out using a multiple line coupler known as Lange coupler made using conventional technology and a similar Lange coupler designed according to the present invention with microstrip lines comprising central conductors of the same length equal to 1.025 mm, all formed on a GaAs substrate of $100 \mu\text{m}$ thickness, with the same character-

istic impedance of 60Ω (single line) of thickness $3\mu\text{m}$, with distance $D=5\mu\text{m}$ suitable for forming a Lange coupler with a characteristic impedance at the ports of 30Ω .

[0030] As illustrated in the graphs of Figs. 9 and 10, the x axis of which shows the working frequencies and the y axis the directivity values expressed in dB depending on the frequency it can be seen how with the coupler according to the invention (Fig. 10), it is possible to obtain a directivity in the predefined band 6-20 GHz always greater than 20 dB, while the corresponding solid line in Fig. 9 relating to a conventional coupler shows a directivity which drops to 15 dB in the range 16.5 - 20 GHz.

[0031] It is therefore clear how the microstrip line with central conductor according to the present invention is able to improve significantly in a simple, low-cost and easily achievable manner the directivity of a coupler for microwave (MW) applications, with the result also that, if a working band is fixed, an improved directivity is obtained and, vice versa, if the minimum acceptable directivity limit is fixed, the working band is widened and, therefore, when used for forming balanced circuits, an improvement in the overall performance is obtained.

[0032] Although described in connection with the design and manufacture of monolithic microwave integrated circuits (MMIC), it is envisaged, however, that the microstrip line according to the invention is applicable also in microwave circuits which use technologies able to support several metal layers which are isolated from each other, such as circuits made using LTCC (Low Temperature Cofired Ceramics) technology or the like.

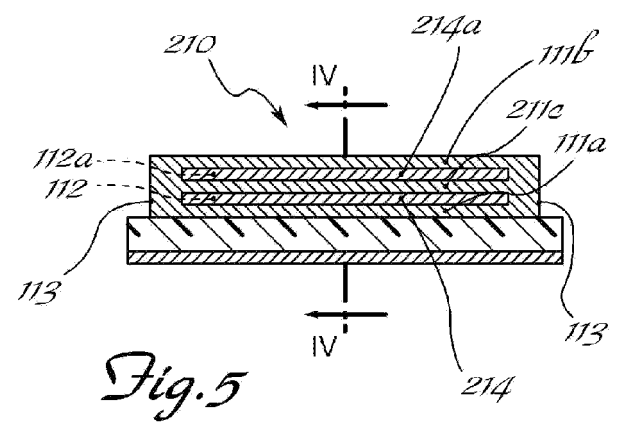
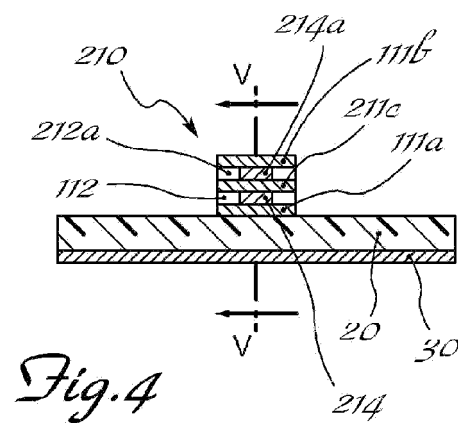
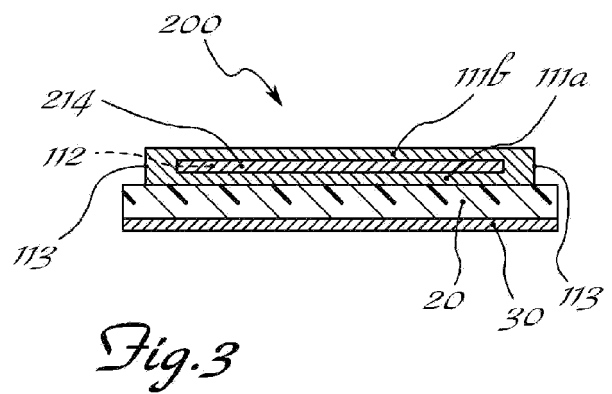
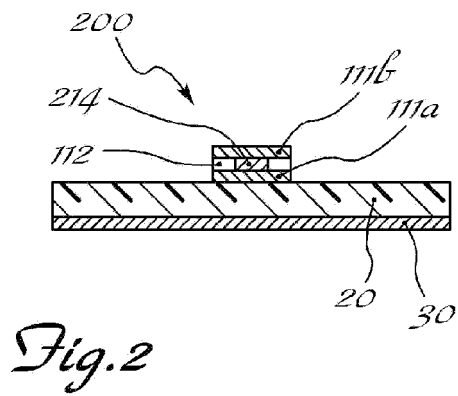
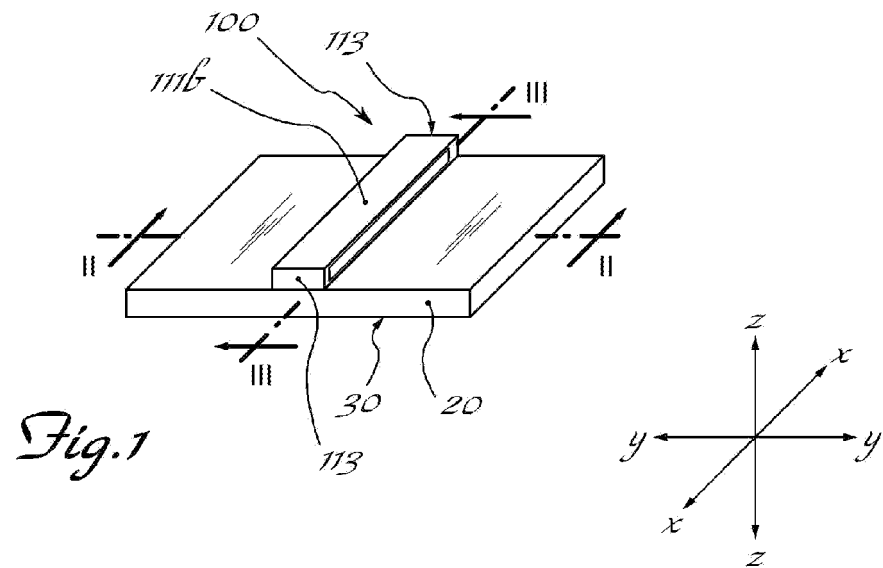
[0033] Although described in connection with certain constructional forms and certain preferred examples of embodiment of the invention, it is understood that the scope of protection of the present patent is defined solely by the following claims.

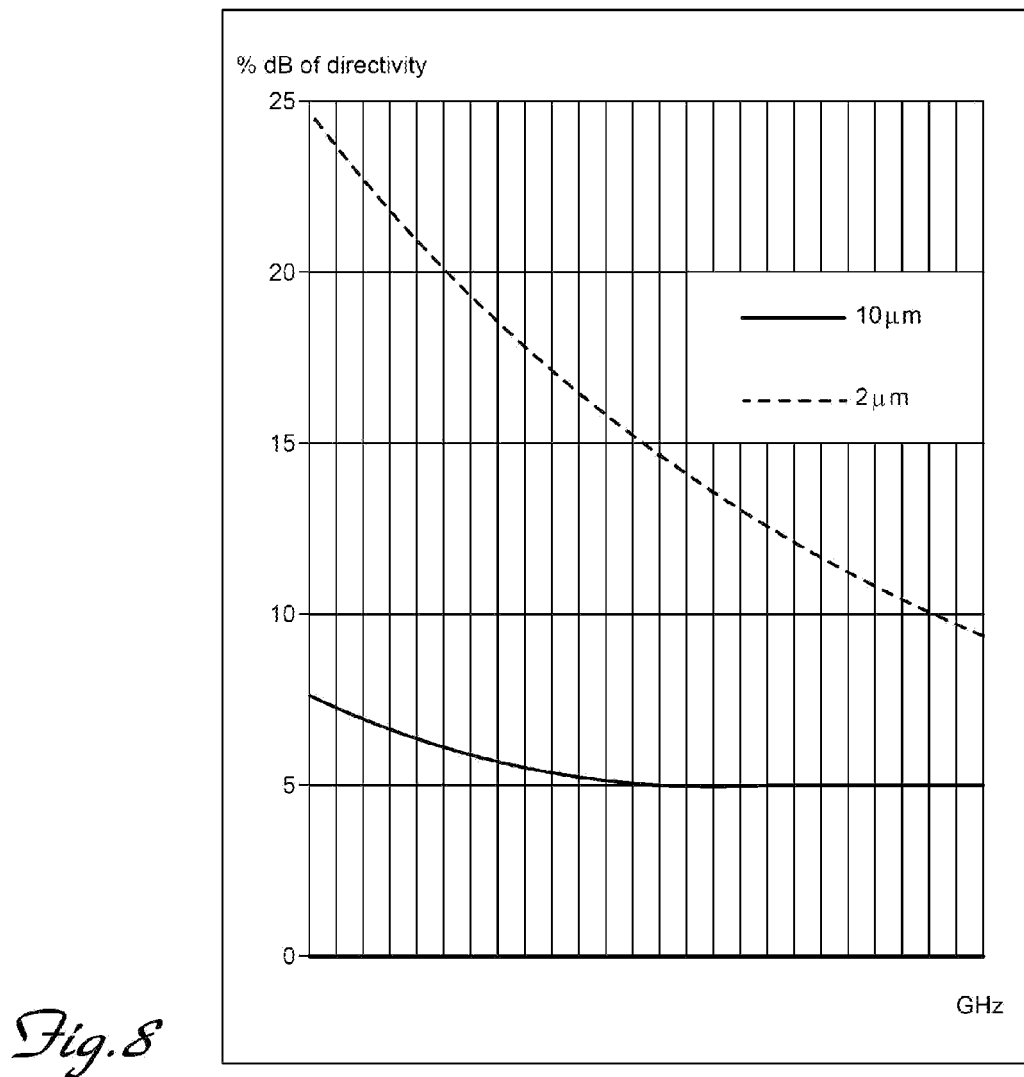
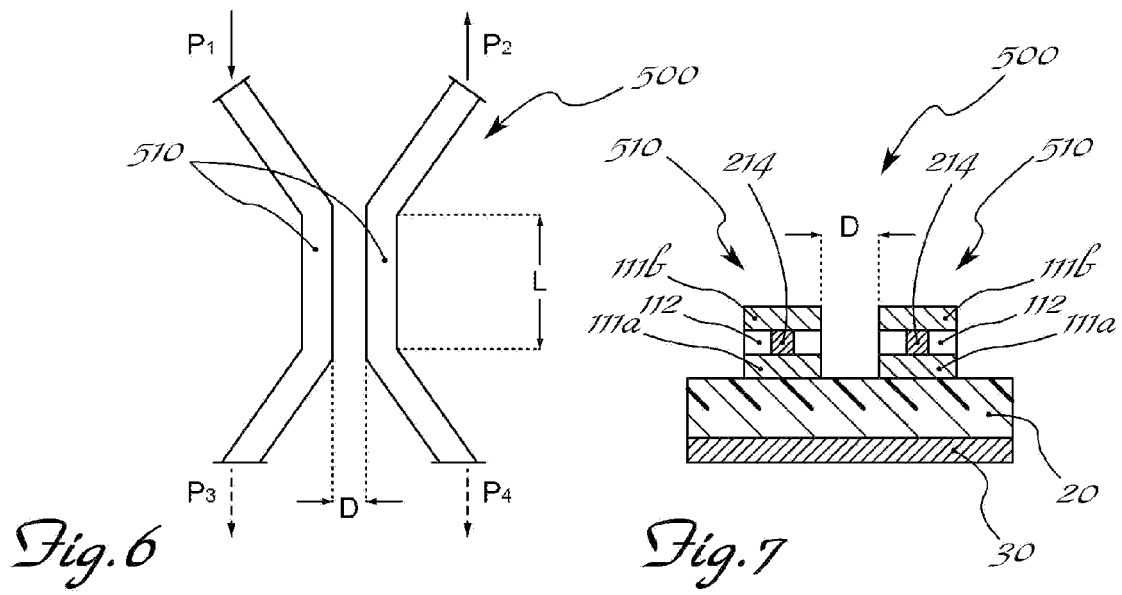
Claims

1. Line coupler comprising at least two coupling lines (510) formed by microstrips (200), comprising an insulating substrate (20) on one side of which an earth conducting layer (30) is applied and on the other side of which at least one central conductor (200) for transmission of the signal is applied, **characterized in that** said central conductor (200) comprises at least two conducting layers (111a;111b) which are separated by a dielectric layer (112) and are connected together by a longitudinal, interconnecting, conducting rib (214).
2. Coupler according to Claim 1, **characterized in that** said central conductor (200) comprises at least one further dielectric layer (212a) and at least one further conducting layer (211c) which are superimposed on the previous conducting layer (111b) of the central conductor (210) and longitudinal ribs (214a) interconnecting said at least one further conducting layer

(211c) and the conducting layer (111b) adjacent in the vertical direction (Z-Z).

3. Coupler according to Claim 1, **characterized in that** said longitudinal rib is continuous.
4. Coupler according to Claim 1, **characterized in that** said longitudinal rib is discontinuous.
5. Coupler according to Claim 1, **characterized in that** said rib has a transverse thickness (Y-Y) of between 3% and 20% of the thickness of the insulating substrate (20).
6. Coupler according to Claim 5, **characterized in that** said rib has a transverse thickness preferably of between 6% and 10 % of the thickness of the insulating substrate (20).
7. Coupler according to Claim 4, **characterized in that** said longitudinal rib is formed by equivalent posts and/or metallized holes passing through the dielectric layer situated between the two adjacent conducting layers.
8. Coupler according to Claim 7, **characterized in that** the relative distance in the longitudinal direction X-X between said posts or metallized holes is equal to or less than $\lambda/20$, λ being the wavelength in the microstrip.
9. Coupler according to Claim 1, **characterized in that** the thickness of the dielectric layer (112) is of the same order of magnitude as the thickness of the conducting layers (111a,111b) of the central conductor (10).
10. Coupler according to Claim 1, **characterized in that** it has a structure of the monolithic microwave integrated circuit (MMIC) type.
11. Coupler according to Claim 1, **characterized in that** the ratio between the width (W) of the central conductor and the thickness of the insulating layer (20) is between 0.1 and 10.
12. Coupler according to Claim 11, **characterized in that** the ratio is preferably between 0.8 and 1.5.
13. Coupler according to Claim 1, **characterized in that** the working frequencies are higher than 4 GHz.





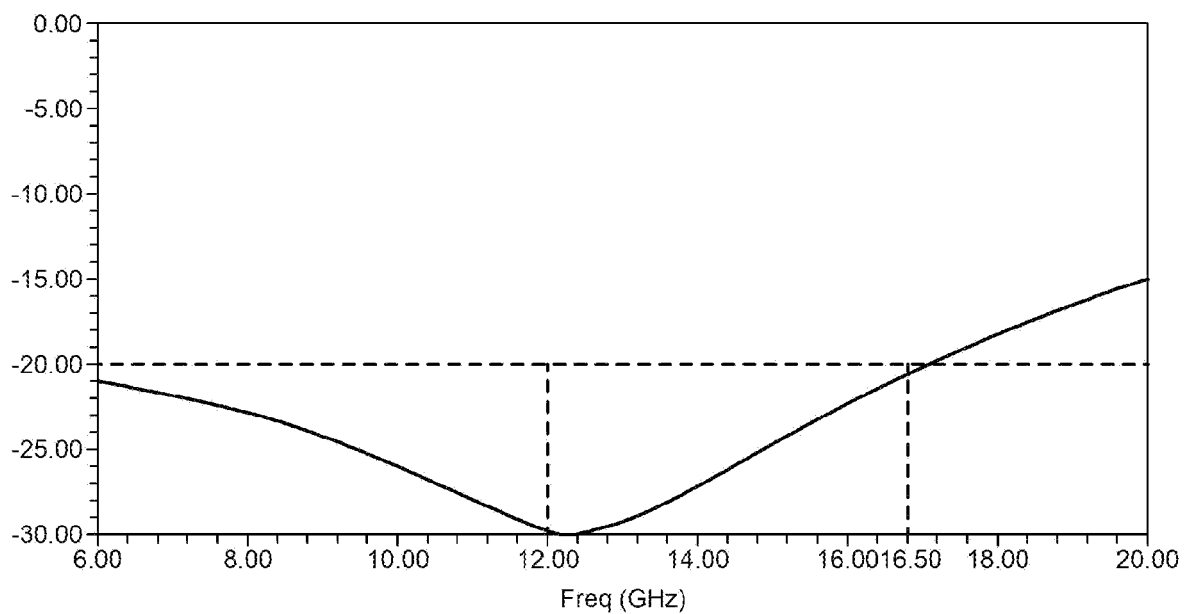


Fig.9

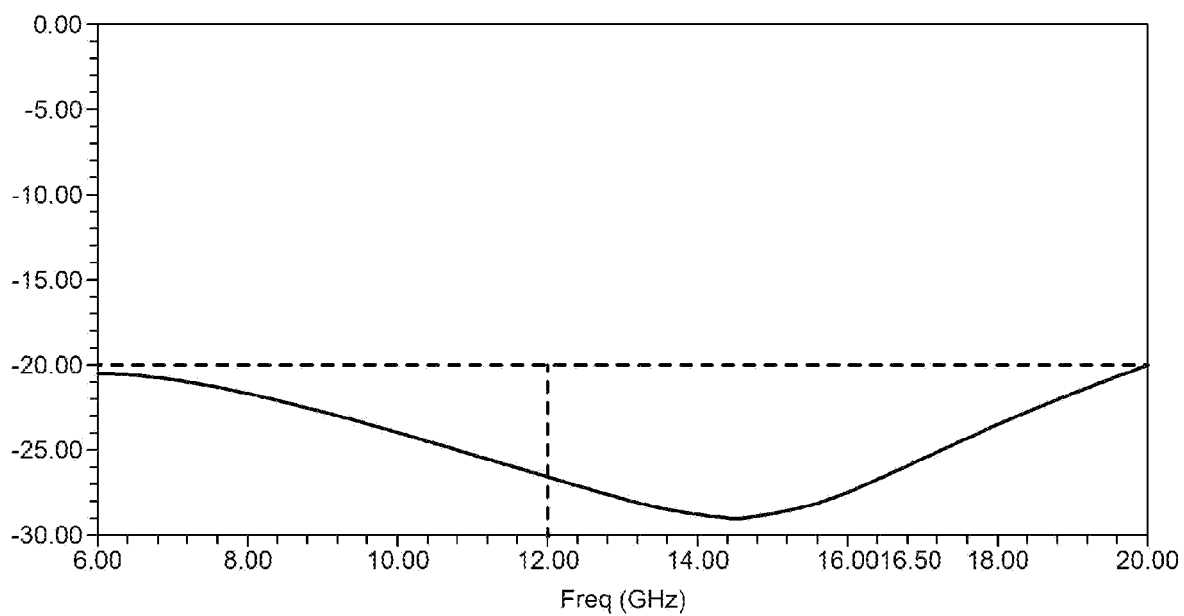


Fig.10



EUROPEAN SEARCH REPORT

Application Number
EP 10 19 4348

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The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 9 March 2011	Examiner von Walter, Sven-Uwe
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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**ANNEX TO THE EUROPEAN SEARCH REPORT
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The members are as contained in the European Patent Office EDP file on
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