



(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:  
**01.04.2009 Bulletin 2009/14**

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

(21) Application number: **07291176.1**

(22) Date of filing: **28.09.2007**

(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 MT NL PL PT RO SE SI SK TR**  
 Designated Extension States:  
**AL BA HR MK RS**

(72) Inventors:  
 • **Jeppesen, Poul**  
**201613 Songjiang Industrial Zone**  
**Shanghai (CN)**  
 • **Riisberg, Alexander**  
**3400 Hillenod (DK)**

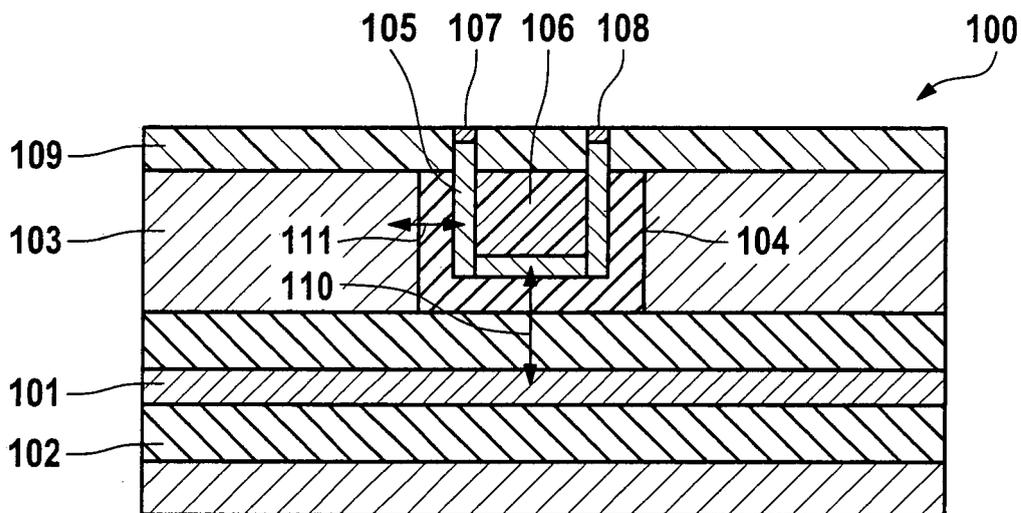
(71) Applicant: **Alcatel Lucent**  
**75008 Paris (FR)**

(74) Representative: **Richardt, Markus Albert**  
**Richardt Patents & Trademarks**  
**Leergasse 11**  
**65343 Eltville am Rhein (DE)**

(54) **A directional coupler and a method thereof**

(57) The invention relates to a directional coupler, comprising:  
 a first conductor;  
 an insulator surrounding said first conductor having an outer surface;  
 a second conductor surrounding said insulator, the first and the second conductor being adapted for power RF (radio-frequency) transmission;  
 a cavity in said second conductor extending to at least

the outer surface of the insulator;  
 a third conductor in a mounting position in the interior of said cavity having a portion substantially parallel to the first conductor and end portions substantially perpendicular to the first conductor, the third conductor being arranged for receiving a portion of said power RF transmission; and,  
 a filling element, for filling at least part of the cavity, permanently holding the third conductor in said mounting position.



**Fig 1**

**Description****Technical field**

5 [0001] The invention relates to the field of microwave communication, and more particularly without limitation to a directional coupler in radio frequency power transmissions and a method of producing a directional coupler.

**Background and related art**

10 [0002] Impedance matching is a critical term in order to understand the performance of a power transmission between source and load in any arbitrary system. The voltage standing wave ratio (VSWR) is a scalar measurement that reveals how well the load impedance is matched to the source.

[0003] Directional couplers are used for sampling the power transmission with a minimum disturbance of the transmitted signal. These are passive devices configured as four-port circuits. Two of the ports are used for power input and trans-  
15 mission, while the remaining two receive a coupled fraction of the transmitted power as well as being used for isolation purposes.

[0004] When a wave is present along the transmission line, a percentage of the wave is reflected while the rest of the signal passes through. This percentage is known as the reflection coefficient. Depending on the position of the coupling and the isolating port within the directional coupler and whether or not it's terminated farthest from or closest to the input  
20 from the outside connection, the coupled signal will correspond to the forward or the reverse wave. There are some important definitions related to directional couplers, the most important are: coupling factor, isolation and directivity. Let the input port be P1, transmitted port P2, coupled port P3 and isolated port P4, then the definitions may be expressed as:

$$25 \quad \text{Coupling Factor (CF)} = 10 \cdot \log(P1/P4)$$

$$30 \quad \text{Isolation (I)} = 10 \cdot \log(P1 \cdot P3)$$

$$\text{Directivity (D)} = \text{Isolation (I)} - \text{Coupling Factor (CF)}$$

35 [0005] Using a forward and a reverse directional coupler, the voltage standing wave ratio (VSWR) may be calculated when the forward and the reverse waves are added to form a composite signal, the maximum and minimum voltage is measured and the ratio of the maximum and the minimum is calculated.

[0006] One of the shortcomings regarding VSWR measurements is the low directivity values of the directional couplers, the instability of the coupling factor and long tuning times. In prior art, the values of the directional coupler fluctuate more  
40 often and a more frequent tuning of attenuation network (e.g. a potentiometer) around the coupler is required in order to balance the Coupling Factor back in place. There is therefore, a need to improve the directivity values without further disturbing the transmission power. There is a further need to improve the stability of the measurements to obtain a more precise value of the directivity (and thereby any VSWR detection) and, as a consequence, a reduction of the tuning time.

**Summary of the invention**

[0007] The present invention provides a directional coupler that comprises a first conductor, an insulator that surrounds the first conductor and that includes an outer surface. Another element is a second conductor, which surrounds the insulator and together with the first conductor is adapted for power radio frequency transmission. Within the second  
50 conductor, there is a cavity that is extended to at least the outer surface of the insulator. In its interior there is a third conductor in a mounting position, with a portion substantially parallel to the first conductor and with the end portions or the extremes of the third conductor substantially perpendicular to the first conductor. This third conductor is arranged for receiving a portion of the power radio frequency transmission. A further component is a filling element made of a non-conductive material that fills at least a part of the cavity permanently holding the third conductor in the mounting  
55 position.

[0008] The directional coupler has the advantage that the filling element keeps the predefined distances between the first and the third conductor, as well as between the second and the third conductor. This maintains stable coupling

factors and directivity values, reducing tuning time, and avoiding fluctuation in the measured signal.

Another advantage by stabilizing the directional coupler is that, as there is an element that fixes the third conductor within the cavity, the coupler is easier to reproduce as the directivity values are set up by the distances between the conductors.

5 [0009] Another advantage is that the amount of defective directional couplers is diminished and the amount of repair loops is reduced, bringing an overall decrease of production time and costs. An even further advantage is that the consistency of the coupling and the isolation levels increases the directivity values compared to prior art. According to the inventors, the directional coupler reaches directivity values up to 38 dB, whereas the prior art reaches only a maximum of 30 dB. Surprisingly, the filling element in the interior of the cavity has not shown greater disadvantage in terms of  
10 coupling factor and directivity values, compared with directional couplers with no filling element. The non-conductive material has the advantage of minimizing power radio frequency transmission interference.

[0010] In a further embodiment the filling element is made of milled Teflon (PTFE), or molded Polyethylene or Fluorinated Ethylene Propylene (FEP). These filling elements have shown the best directivity and coupling values among all the non-conductive materials analyzed. However, the filling element could be made of any material with non-conductive  
15 properties.

[0011] In another preferred embodiment the insulator is air. One of the advantages of using air as an insulator when measuring the transmission power is that the coupling factor levels can reach high levels, as the parallel portion of third conductor can be arbitrarily close to the first conductor.

[0012] In another embodiment, the end portions of the third conductor of the directional coupler are connected and  
20 integrated to a printed circuit board that also includes a low noise amplifier (LNA). This type of connection has the advantage of reducing the insertion loss and material costs by keeping the connections between the devices close to each other.

[0013] In another aspect, the invention relates to a voltage standing-wave ratio measurement system that includes a coaxial cable, a first and a second directional coupler as described in the preferred embodiment, arranged at separate  
25 distance of the coaxial cable, and at the same time, allowing the processing of the forward and reverse RF power transmission in order to calculate the VSWR.

[0014] In a preferred embodiment, the distance between the third and the first conductor, as well as the distances between a third conductor and the second conductor define the directivity values of the directional coupler.

[0015] In another embodiment, the invention relates to a coaxial cable that includes a directional coupler as mentioned  
30 above. The advantage of using a directional coupler within a coaxial cable is that the coupler is in a close distance to the first and the second conductor, and therefore better coupled to the transmitted signal.

[0016] In another aspect, the invention relates to a method of producing a directional coupler that includes providing a coaxial cable that has a first conductor, an insulator surrounding the first conductor and having an outer surface, and a second conductor surrounding the insulator. Then, a cavity in the second conductor is formed, extending to at least  
35 the outer surface of the insulator. Subsequently, in the interior of the cavity a third conductor is placed, having a portion that is substantially parallel to the first conductor and the end portions or the extremes substantially perpendicular to the first conductor. After that, at least a portion of the cavity is then filled with a filling element made of a non-conductive material, holding permanently the third conductor.

[0017] In a further embodiment, the invention relates to a method of producing a directional coupler as mentioned in  
40 previous embodiments with a filling element made of milled Teflon (PTFE), or molded Polyethylene or Fluorinated Ethylene Propylene (FEP).

[0018] In a further embodiment, the invention relates to a method of producing a directional coupler as mentioned in previous embodiments wherein the insulator is air

#### 45 **Brief description of the drawings**

[0019] In the following preferred embodiments of the invention are described in greater detail by way of example only making reference to the drawings in which:

- 50 Fig. 1 is a schematic of a longitudinal cut of the directional coupler,  
Fig. 2 is a schematic of a 3-D view of the directional coupler,  
Fig. 3 is a representation of a transversal cut of the directional coupler.

#### **Detailed description**

55 [0020] Fig. 1 shows a longitudinal cut of the directional coupler 100, allowing a detailed description of the inner elements that structure it. The first conductor 101 is surrounded by an insulator 102. The insulator 102 is surrounded by a second conductor 103; these two conductors allow a power radio frequency transmission. On the top of second conductor 103,

printed circuit board (PCB) 109 is located. In the second conductor 103, there is a cavity 104 that it extends from printed circuit board 109 to the interface with the insulator 102. Inside this cavity 104, there is located a third conductor 105 made of a non-conductive material; this third conductor 105 is formed by a portion that is substantially parallel to the first conductor and with both ends substantially perpendicular to the first conductor 101. In the cavity 104, a filling element 106 fills at least a portion of the cavity 104.

**[0021]** When a signal is transmitted through first conductor 101 and second conductor 103 a fraction of the signal is received by third conductor 105. The third conductor 105 allows a coupling of the transmitted radio frequency power. This sample signal can be measured through the output port 107 of the third conductor 105, while the isolated port 108 may be connected to a 50 Ohm termination. The filling element 106 fills at least a portion of the cavity 104, holding all the portions of third conductor 105 and keeping the distances between third conductor 105 and first conductor 110, and between third conductor 105 and second conductor 111.

**[0022]** One of the advantages of the invention is that there is no need of adjusting the mounting height of the third conductor to obtain the designed coupling factor using for example locking screw; there is also no need of turning or rotating the third conductor in order to obtain the desired directivity; there is also no need of iterative measurements and adjustments of either the coupling factor or the directivity after the position of the third conductor has been changed. In all this cases, the filling element keeps the right distances and designed values obtained during the development phase of the product.

**[0023]** The filling element 106 can be made for example from a non-conductive material. This non-conductive material can be for example milled Teflon and Polyethylene. In one example, the insulator 102 is air. In another example the output ports 107 and 108 and the third conductor 105 is integrated or connected to a printed circuit board 109.

**[0024]** One of the most important advantages of the filling element 106 is that the positions between the first and the third conductor 110 and the distance between second and third conductor 111 can be fixed permanently. This ensures stable measurement and reduced adjustment of the directivity and coupling values.

**[0025]** Fig. 2 illustrates a three-dimensional view of the directional coupler, where the form of the conductors is represented. The figure 2 shows the insulator 102 surrounding first conductor 101, and second conductor 103 surrounding the insulator 102. The figure 2 also depicts the cylindrical shape of the first 101, second 103 and third conductors 105. Also, the cavity 104 with a substantially rectangular shape within second conductor is shown. In the interior of cavity 104, the parallel portion and the perpendicular ends of third conductor in respect to the first conductor is illustrated. The filling element 106 fills the section of the cavity 104 between the parallel portion and the perpendicular ends of third conductor 105.

**[0026]** Fig. 3 illustrates a transversal cut of the directional coupler, representing the cavity 104 location within the second conductor 103, having a rectangular shape and starting on the interface with the printed circuit board (PCB) and ending at least in the interface with the insulator 102. The insulator 102 surrounds the first conductor 101 and the second conductor 103 surrounding the insulator 102. On the top of second conductor 103, the printed circuit board (PCB) 109 is located. The cavity 104 starts at the printed circuit board 109 reaching the outer surface of the insulator 102. The third conductor 105 is located in a substantially central position within the cavity 104. The filling element 106 fills the section of the cavity 104 between the parallel portion and third conductor 105 and the interface with the printed circuit board (PCB) 109. Fig. 3 also shows the filling element 106 keeping the distance between the third conductor and the first conductor 105 and the distance between third conductor and second conductor 111.

**[0027]**

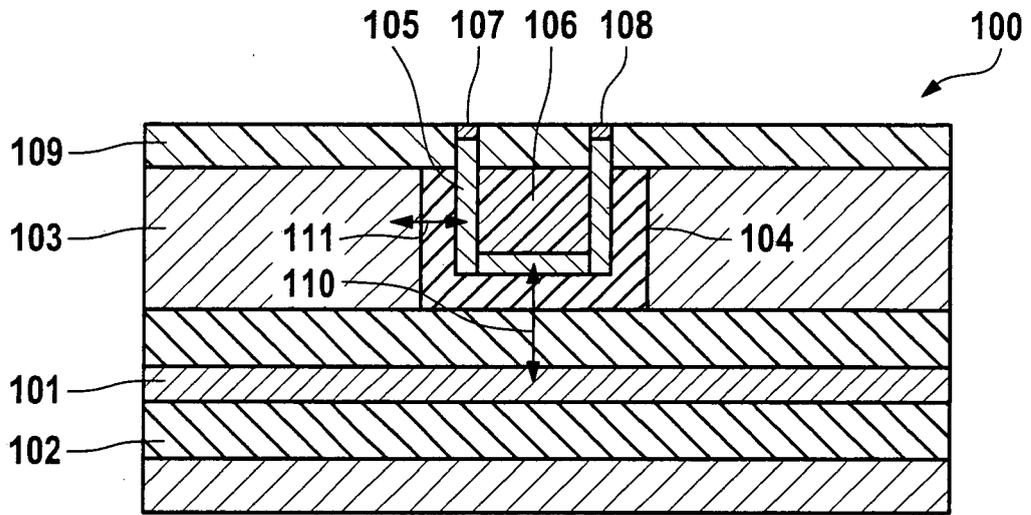
List of Reference Numerals	
100	Directional coupler
101	First conductor
102	Insulator
103	Second conductor
104	Cavity
105	Third conductor
106	Filling Element
107	Coupled port
108	Isolated port
109	Printed Circuit Board (PCB)

(continued)

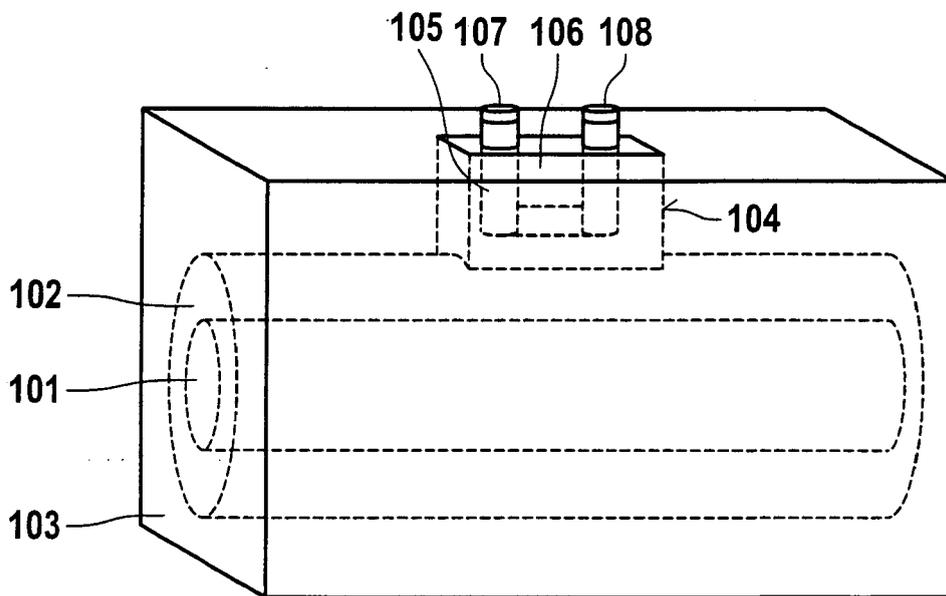
List of Reference Numerals	
110	Distance between third and first conductor
111	Distance between third and second conductor

**Claims**

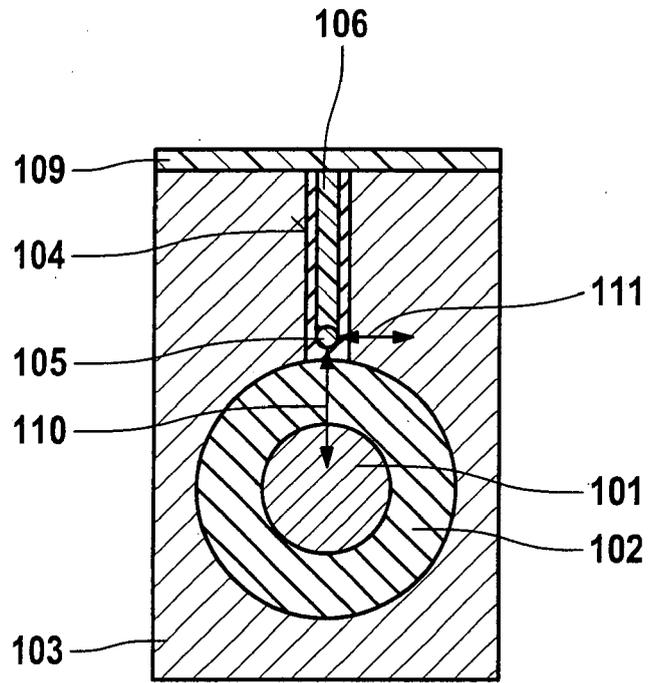
1. A directional coupler 100, comprising:
  - a first conductor 101;
  - an insulator 102 surrounding said first conductor 101 having an outer surface;
  - a second conductor 103 surrounding said insulator 102, the first and the second conductor being adapted for power RF (radio-frequency) transmission;
  - a cavity 104 in said second conductor 103 extending to at least the outer surface of the insulator 102;
  - a third conductor 105 in a mounting position in the interior of said cavity 104 having a portion substantially parallel to the first conductor and end portions substantially perpendicular to the first conductor 101, the third conductor 103 being arranged for receiving a portion of said power RF transmission; and a filling element 106 made of a non-conductive material, for filling at least part of the cavity, permanently holding the third conductor 105 in said mounting position.
2. A directional coupler 100 as claimed in claim 1, wherein the insulator 102 is air.
3. A directional coupler 100 as claimed in claim 1, wherein the filling element 106 is made of milled Teflon (PTFE), or molded Polyethylene or Fluorinated Ethylene Propylene (FEP).
4. A directional coupler 100 as claimed in claim 1, wherein said end portions of said third conductor 105 are connected to a printed circuit board 109.
5. A voltage standing wave ratio (VSWR) measurement system, comprising:
  - a coax cable;
  - first and second directional couplers as claimed in claim 1, arranged at separate distances of said coax cable and arranged for processing of the forward and reverse RF power transmission wave and calculating the VSWR ;
6. A directional coupler 100 as claimed in claim 1, wherein the distances between said third conductor 105 and said first conductor 101 and the distance between said third conductor 105 and said second conductor 103 define directivity values.
7. A coaxial cable comprising at least one directional coupler 100 as claimed in claim 1.
8. A method of producing a directional coupler 100, comprising the steps of:
  - providing a coaxial cable, having a first conductor 101, an insulator 102 surrounding said first conductor 101 having an outer surface and a second conductor 103 surrounding said insulator 102;
  - forming a cavity 104 in said second conductor 103 extending to at least the outer surface of the insulator 102;
  - placing a third conductor 105 in the interior of said cavity 104 having a portion substantially parallel to the first conductor 101 and end portions substantially perpendicular to said first conductor 101;
  - filling at least part of said cavity 104 with a filling element for permanently holding the third conductor 105, said filling element made of a non-conductive material.
9. A method of producing a directional coupler 100 as claimed in claim 9, wherein the filling element 106 is made of milled Teflon (PTFE), or molded Polyethylene or Fluorinated Ethylene Propylene (FEP).
10. A method of producing a directional coupler 100 as claimed in claim 9, wherein the insulator 102 is air



**Fig 1**



**Fig 2**



**Fig 3**



DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	WO 2007/099202 A (POWERWAVE COMTEK OY [FI]; TERVO MATTI [FI]) 7 September 2007 (2007-09-07) * page 7, line 13 - page 8, line 30; figures 4a-4c,5 *	1-10	INV. H01P5/18
X	US 2004/196115 A1 (FALLON DAN [US] ET AL) 7 October 2004 (2004-10-07) * paragraph [0026] - paragraph [0027]; figures 1-7 *	1	
A	US 2 770 779 A (TURNER THOMAS F) 13 November 1956 (1956-11-13) * column 3, line 41 - column 4, line 20; figures 1,2 * * column 4, line 48 - line 71 *	1	
A	US 6 400 235 B1 (PEREZ HENRY [US]) 4 June 2002 (2002-06-04) * column 3, line 22 - column 4, line 43; figures 1-3B *	1	
			TECHNICAL FIELDS SEARCHED (IPC)
			H01P
The present search report has been drawn up for all claims			
Place of search		Date of completion of the search	Examiner
The Hague		17 March 2008	Pastor Jiménez, J
CATEGORY OF CITED DOCUMENTS		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	
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		& : member of the same patent family, corresponding document	

3

EPO FORM 1503 03.82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT  
ON EUROPEAN PATENT APPLICATION NO.**

EP 07 29 1176

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

17-03-2008

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2007099202 A	07-09-2007	NONE	
US 2004196115 A1	07-10-2004	NONE	
US 2770779 A	13-11-1956	NONE	
US 6400235 B1	04-06-2002	NONE	

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82