(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
19 February 2015 (19.02.2015)

WIPO | PCT

(10) International Publication Number
WO 2015/023204 A1

(51) International Patent Classification:
H01P 5/12 (2006.01)

(21) International Application Number:
PCT/RU2013/000709

(22) International Filing Date:
15 August 2013 (15.08.2013)

(25) Filing Language: English

(26) Publication Language: English

(71) Applicant: **SIEMENS RESEARCH CENTER LIMITED LIABILITY COMPANY** [RU/RU]; ul. Dubininskaja, 96, Moscow, 115093 (RU).

(72) Inventors: **GUDOOVICH,, Alexey Victorovich**; Kashirskoe sh., 92-3-195, Moscow, 115551 (RU). **KRASNOV, Andrey Aleksandrovich**; ul. Miklukho-Maklaya, 30-240, Moscow, 117279 (RU). **NIKOLSKIY, Konstantin Igorevich**; Oranzhereynaya st., 12/13-15, Ivanteevka, 141280 (RU). **SMIRNOV, Alexander Yourievich**; Vasilevskogo str., 1-1-96, Moscow, 123098 (RU).

(74) Agents: **MITS, Alexander Vladimirovich** et al.; LAW FIRM "GORODISSKY & PARTNERS" LTD., B. Spasskaya str., 25, bldg. 3, Moscow, 129090 (RU).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

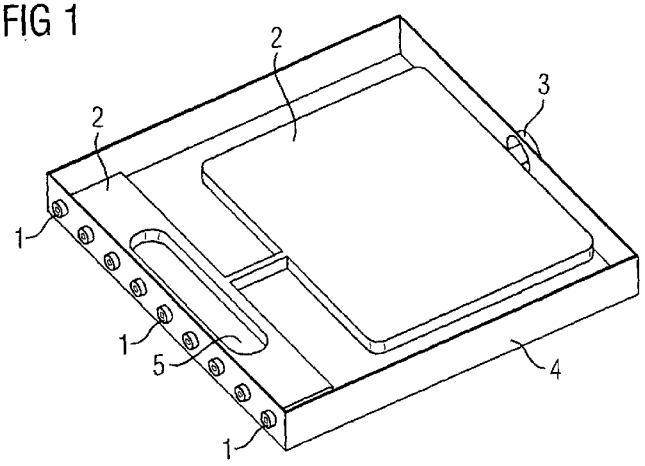
(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

(54) Title: DEVICE FOR RADIO-FREQUENCY POWER COUPLING AND METHOD OF USING THE DEVICE

FIG 1



(57) Abstract: The present invention relates to a device and a method of using the device for radio-frequency (RF) power coupling, particularly a power combiner and/or divider, comprising a box shaped casing as outside conductor (4), connectors (1, 3) for in- and output of RF-power, which are electrically connected to at least one center conductor (2). The electrical connection between the connectors (1, 3) and the at least one center conductor (2) is a direct electrical and mechanical connection.

WO 2015/023204 A1

Description

Device for radio-frequency power coupling and method of using the device

The present invention relates to a device and a method of using the device for radio-frequency power coupling, particularly a power combiner and/or divider, comprising a box shaped casing as outside conductor, connectors for in- and output of RF-power, which are electrically connected to at least one center conductor.

Devices for radio-frequency (RF) power coupling are power dividers and power combiners. Power dividers are used to divide RF power from single RF generators to multiple recipients. Power combiners are used to combine RF power from multiple sources to feed a single recipient with additional power. Recipients receiving RF power are for example loads or antennas. Most devices used as power divider or power combiner are also working reciprocal, i.e. they can be used both as divider and as combiner. In the following the use of the wording divider includes the use of combiner and vice versa. The main parameters for combiner/divider design in terms of RF power handling are heat and breakdown voltage. Requirements in use are the transmission of RF power with low insertion and return loss. Further requirements are compactness, easy assembly and cost effective, easy manufacturing.

There are two main types of power combiners/dividers known from the state of the art, based on printed circuit boards (PCB) or coaxial based combiners/dividers. PCB based combiners/dividers are mainly used in low power applications. Low power in this context is in the range of a couple of kilowatts in continuous wave regime to approximately ten kilowatts in pulsed mode use. PCB based devices are quite compact but not to use with high power. Coaxial based combiners/dividers are usable for low power applications and for extremely high power levels, particularly up to hundreds of

kilowatt. Disadvantage of coaxial based combiners/dividers is the lack of compactness, i.e. high volume respectively size.

A combiner known from the state of the art, e.g. described in US 4459568 is an air-stripe coupler. Power propagates in the gap between two strip lines. The device contains PCB, not enabling high voltage usage. From US 2012029327 a power combiner/divider is known permitting high power signals. This power combiner/divider is relatively large in size and not compact, and due to its cylindrical shape it can not be used in racks. There is excessive empty space within the structure of the power combiner/divider. In US 5111166 an electrical length equalization system for multiple inputs is described with inter alia power combining applications. Due to its PCB basing it can only be used in low power applications. Further, the handling and manufacturing of the system is not easy. The assembly comprises a complicated structure.

Described devices like power combiner/divider with PCB, known from the state of the art, can not be used for high power due to high losses particularly producing high amounts of waste heat. The heat and high voltage can lead to irreversible damage of the devices. Devices for high power are not compact and have high insertion losses, leading to low efficiency.

The object of the present invention is to present a compact device for radio-frequency power coupling, which is easy to manufacture with low costs, and can be used in high power applications with high efficiency. A further object of the present invention is to present a method of using the assembly in a compact way. The electrical length from output/input to input/output connectors of the device should be adjustable for high efficiency.

The above objects are achieved by the device for radio-frequency power coupling according to claim 1, and the method of using a device for radio-frequency (RF) power coupling, particularly the device described before, according to claim 12. Advantageous embodiments of the present invention are

given in dependent claims. Features of the main claims can be combined with each other and with features of dependent claims, and features of dependent claims can be combined together.

A device for radio-frequency RF power coupling according to the present invention, particularly a power combiner and/or divider, comprises a box shaped casing as outside conductor. Further it comprises connectors for in- and output of RF-power, which are electrically connected to at least one center conductor. The electrical connection between the connectors and the at least one center conductor is a direct electrical and/or mechanical connection. Direct in this content is used as without additional electrical or mechanical parts in between.

The construction of the device enables high power applications. The direct electrical connection reduces electrical losses. Low electrical losses are equivalent with low waste heat production. This enables a stable use with time without damage particularly by waste heat. The simple structure of the device, particularly power combiner and/or divider, enables an easy assembling and manufacturing, with low costs.

The device can comprise at least one power combining or dividing part and at least one impedance transforming part. The impedance transforming part can be a narrow band or wideband frequency element, particularly a RF matching element for reducing the reflection of RF power. This further reduces electrical losses and waste heat.

The impedance transforming part can be an electrical conduction line with outer stepped, tapered or binomial shape. The shape can be adjusted to applications and used frequency and power. It can be optimized for low power losses.

The at least one power combining or dividing part and at least one impedance transforming part can be electrically and mechanically connected directly or via a electrically con-

ducting bridge, particularly in form of a bar. This leads to a simple assembling of the device, easy to manufacture with low costs.

A recess for equalization of RF electrical length from output or input to input or output connectors can be comprised, particularly within the power combining or dividing part. The recess improves the RF characteristics of the device and can be adjusted to applications, particularly voltage, power and RF range in use.

The box shaped casing can be a parallelepiped, particularly a cuboid, particularly with a substantially dimension of a 19-inch rack and/or with a module front panel wide of 482.6 mm. This enables a compact storage and use in racks, where 19-inch racks are the most common used in electronic applications.

Parts, particularly all parts can be made of solid metal pieces, particularly comprising or consisting of copper, aluminum and/or steel with copper coating. These materials have good electrical properties, low resistance and high heat transfer properties. A low loss and/or good transfer of waste heat can be assured by using these materials. Also other materials like conducting polymers, gold or silver can be used with low electrical losses. Depending on application the material can be chosen taking into account RF behavior, electrical losses, heat transfer properties and price.

At least one fluid cooling device can be comprised, particularly a water cooling device to transfer heat from the device to the environment. Especially for high power applications heat transfer can be necessary to enable proper function and/or to prevent damage of the device.

At least one coaxial, and/or one microstrip line, and/or at least one rectangular waveguide, and/or at least one circular waveguide connector can be comprised. Particularly multiple 50 Ohm coaxial connectors at one side and a single 50 Ohm

connector at the other side of the device can be comprised. These connectors, chosen according to the application and depending from the devices to connect with, give good electrical connection in RF applications. Inter alia depending on price, compactness, electrical loss and RF power and frequency the connectors can be chosen.

The at least one center conductor can be in the form of a flat plate, particularly arranged parallel to a ground plane of the box shaped casing as outside conductor, particularly with isolating spacers in between. This enables a compact, space-saving arrangement and/or use in racks.

A method of using a device for radio-frequency power coupling according to the present invention, particularly a device described above, comprises the direct electrical and/or mechanical connection of connectors for in- and output of RF-power to at least one center conductor, arranged in a box shaped casing, where the casing serves as outside conductor.

This method enables a use of devices for radio-frequency power coupling with high power, compact arranged for example in a rack, with low losses and/or heat production in use.

For equalization of RF the electrical length from output/input to input/output connectors can be adjusted by arranging a recess within the at least one center conductor, particularly within a power combining or dividing part of the device. This enables a simple setting with easy adjustment to applications, frequency as well as power used. This enables further an easy design and manufacturing, with low costs.

The form, size and/or position of the recess can be chosen according to a predefined electrical length from output/input to input/output connectors.

The method can further comprise the stacking of box shaped devices next and/or on top of each other, particularly in 19-

inch racks. This enables a compact assembling with low space consumption in use.

The advantages in connection with the described method of using a device for radio-frequency power coupling according to the present invention are similar to the previously, in connection with the device for radio-frequency power coupling described advantages and vice versa.

The present invention is further described hereinafter with reference to illustrated embodiments shown in the accompanying drawings, in which:

FIG. 1 illustrates a device according to the present invention for radio-frequency RF power coupling in angular view, with view to inner parts, and

FIG. 2 illustrates a top view I) and a side view II) to the device of FIG. 1 with a power combining or dividing part A and an impedance transforming part B, and

FIG. 3 illustrates a top view to the device of FIG. 1 with an additional cooling device, and

FIG. 4 illustrates a top view to the device of FIG. 1 with an impedance transforming part B with I) stepped and II) tapered form, and

FIG. 5 illustrates the device of FIG. 1 in angular view, with connectors in microstrip line form 9 on one side and rectangular waveguide form 10 on the other side of a casing 4.

In FIG. 1 an angular view of a device according to the present invention with its inner parts is shown. The device comprises a power combiner/divider with a flat box shaped casing as outside conductor 4, connectors 1 and 3, and a center conductor 2 with a recess 5.

In use as a power divider the connector 3 is electrically connected to a device to recieve an input signal. Connectors 1 provide the output signal, for example to connected devices like external loads. In use as a power combiner the connectors 1 are electrically connected to the input signals and the connector 3 provides the output signal. The signals are in the range of radio-frequency RF.

As shown in FIG. 2 in top view I) and in side view II) as a cross section along a longitudinal axis of the device, the power combiner/divider consists of a power combining or dividing part A and an impedance transforming part B. Both parts A and B are in form of a flat solid metal plate, for example made of copper, aluminum or copper plated steel. A recess in part A is used for equalization of RF electrical length from output/input to input/output connectors 1, 3. The form and size is predefined by the electrical parameters the device has to fulfill.

The impedance transforming part B in form of flat solid metal plate has a rectangular shape, particularly with rounded corners. It is electrically and mechanically directly connected with connector 3. On the opposite side of casing 4 an electrically and mechanically connection to the power combining or dividing part A is comprised, particularly in form of a solid metal bridge shaped as a nose to the plate. The power combining or dividing part A in form of a rectangular solid metal plate with recess 5 is directly electrically and mechanically connected to connectors 1, to electrically connect to external devices like loads.

As shown in FIG. 3 a fluid cooling device can be comprised within or at the device according to the present invention, particularly a water cooling device. The cooling device or assembly comprises an inlet 7 for the cooling fluid like water or air, coming from an external device like a pump. The inlet 7 in the box shaped casing 4 is in form of a hole and is fluid sealed connected to a pipe 6 within the casing 4.

The pipe 6 is fixed to the casing 4 with a pipe support 7, to mechanically stabilize it within the device. On the opposite side of the pipe 6 to the inlet 7, the pipe 6 is connected to the plate of the power combining or dividing part A with recess 5. Within the plate fluid channels, not shown in FIG. for simplicity, are provided for the cooling fluid. The fluid coming from pipe 6 can flow through the channels and collect heat from the plate. On the opposite side a second pipe 6, fixed to the casing 4 with the help of a support 8 is provided, to transport cooling fluid with waste heat to a outlet 7 in form of a hole in the casing 4. The cooling fluid transfers heat from the power combining or dividing part A to the outside of the device according to the present invention.

In Fig. 3 one possible embodiment is shown just as an example. The cooling device can comprise additional parts or be of different structure. For example supports 8, to fix the pipes 6 mechanically to the casing 4, can be at an other position not to influence RF power within the device. Also a different number and/or form of supports 8 can be used. The cooling fluid inlets/outlets can be arranged at other positions within the casing 4, not to interfere with electrical parts. Different materials for the cooling device parts can be used. For example plastic material can be used not to influence RF power within the device according to the present invention.

As shown in FIG. 4 the impedance transforming part B can have different shapes, depending on the application and power as well as frequency in use of the device according to the present invention. The impedance transforming part B can be a narrow band or a wideband frequency element. It is a RF matching element for reducing the reflection of RF power.

In Fig. 4 two embodiments are shown just as an example. In FIG. 4 I) a stepped shaped impedance transforming part B is shown. In FIG. 4 II) a tapered shaped impedance transforming part B is shown. The impedance transforming part B is in form of a flat solid plate in both examples, just with base area

of stepped or tapered form. As shown in the embodiment of FIG. 4 II) the impedance transforming part B can directly merge to the power combining or dividing part A, for example directly connected along one full side of the power combining or dividing part A without nose in between. Other connections are possibly too, for example with a power combining or dividing part A and a impedance transforming part B made of one piece.

Different connectors 1 and 3 can be used. In the embodiment of FIG 1 coaxial connectors 1 and 3 are used, for input and output of electrical signals. For example 50 Ohm coaxial connectors can be used. In FIG. 5 an embodiment with a microstrip line 9 as connector 1 and with a rectangular waveguide 10 as connector 3 is shown. Further connectors, not shown in FIG. for simplicity, can be used for input and/or output signals, for example circular waveguide connectors. The connectors 1 can be arranged like shown in FIG. 1 in a row along one side of the casing 4. Other arrangements are possible, depending on application and number of necessary inputs/outputs as well as the size of the device. For example parallel rows of connectors 1 next to or above each other or rows, bent lines, stacks and so on particularly at different sides of the casing 4 can be used.

As shown in FIG. the flat center conductor 2 is arranged in parallel to the ground plane of the box shaped casing 4. Depending on the form and compactness necessary of the casing 4, other forms of the center conductor 2 can be used. The box shaped casing 4 can be electrically conducting. The outside conductor 4 as well as other parts of the device according to the present invention can be made from a metal sheet, particularly from copper, aluminum or copper plated steel. Outside 4 and inside 2 conductors can be electrically separated inter alia by distance pieces, isolating layers and/or air gaps.

Features described above can be used single or in combination, and in combination with embodiments known from the state of the art. Other materials like metals as gold or sil-

ver, semiconductors, or conducting polymers can be used for all elements like connectors for RF-power 1, center conductor 2, connector for RF-power 3 and outside conductor in form of a box shaped casing 4. The elements can be made of the same or different materials.

The box 4 can be of cuboid form, a parallelepiped or other forms like flattened conus. There can be elements, not shown in FIG. for simplicity, to fix and arrange parts together. The devices can have an outer shape to be easy arranged in a rack. In electronic applications 19-inch racks are common.

Advantages of the device according to the present invention are inter alia its compactness, high efficiency of RF power transfer with low electrical losses and/or a low waste heat production in use.

List of Reference Characters

1	connector
2	center conductor
3	connector
4	box shaped casing as outside conductor
5	recess
6	fluid pipe
7	cooling fluid inlet/outlet
8	pipe support
9	microstrip line connector
10	rectangular waveguide connector
RF	radio-frequency
A	power combining or dividing part
B	impedance transforming part

Claims

1. Device for radio-frequency (RF) power coupling, particularly a power combiner and/or divider, comprising a box shaped casing as outside conductor (4), connectors (1, 3) for in- and output of RF-power, which are electrically connected to at least one center conductor (2),
characterized in that the electrical connection between the connectors (1, 3) and the at least one center conductor (2) is a direct electrical and mechanical connection.

2. Device according to claim 1, characterized in that at least one power combining or dividing part (A) and at least one impedance transforming part (B) are comprised.

3. Device according to claim 2, characterized in that the impedance transforming part (B) is a narrow band or wideband frequency element, particularly a RF matching element for reducing the reflection of RF power.

4. Device according to any one of the claims 2 or 3, characterized in that the impedance transforming part (B) is an electrical conduction line with outer stepped, tapered or binomial shape.

5. Device according to any one of the claims 2 to 4, characterized in that at least one power combining or dividing part (A) and at least one impedance transforming part (B) are electrically and mechanically connected with each other directly or via an electrically conducting bridge, particularly in form of a bar.

6. Device according to any one of the claims 1 to 5, characterized in that a recess (5) for equalization of RF electrical length from output/input to input/output connectors (1, 3) is comprised, particularly within the power combining or dividing part (A).

7. Device according to any one of the claims 1 to 6, characterized in that the box shaped casing is a parallelepiped, particularly a cuboid, particularly with a substantially dimension of a 19-inch rack part and/or with a module front panel wide of 482.6 mm.

8. Device according to any one of the claims 1 to 7, characterized in that parts, particularly all parts are made of solid metal pieces, particularly comprising or consisting of copper, aluminum and/or steel with copper coating.

9. Device according to any one of the claims 1 to 8, characterized in that at least one fluid cooling device is comprised, particularly a water cooling device to transfer heat from the device to the environment.

10. Device according to any one of the claims 1 to 9, characterized in that at least one coaxial, and/or one microstrip line, and/or at least one rectangular waveguide, and/or at least one circular waveguide connector (1, 4) is comprised, particularly multiple 50 Ohm coaxial connectors at one side and a single 50 Ohm connector at the other side of the device.

11. Device according to any one of the claims 1 to 10, characterized in that the at least one center conductor (2) is in the form of a flat plate, particularly arranged parallel to a ground plane of the box shaped casing (4), particularly with isolating spacers in between.

12. Method of using a device for radio-frequency (RF) power coupling, particularly a device according to any one of the claims 1 to 11, characterized in that connectors (1, 3) for in- and output of RF-power are direct electrically and/or mechanically connected to at least one center conductor (2), arranged in a box shaped casing as outside conductor (4).

13. Method according to claim 12, characterized in that for equalization of RF the electrical length from output/input to

input/output connectors (1, 3) is adjusted by arranging a recess (5) within the at least one center conductor (2), particularly within a power combining or dividing part (A) of the device.

14. Method according to claim 12, characterized in that the form, size and/or position of the recess (5) is chosen according to a predefined electrical length from output/input to input/output connectors (1, 3).

15. Method according to any one of the claims 12 or 14, comprising the stacking of box shaped devices next and/or on top of each other, particularly in 19-inch racks.

FIG 1

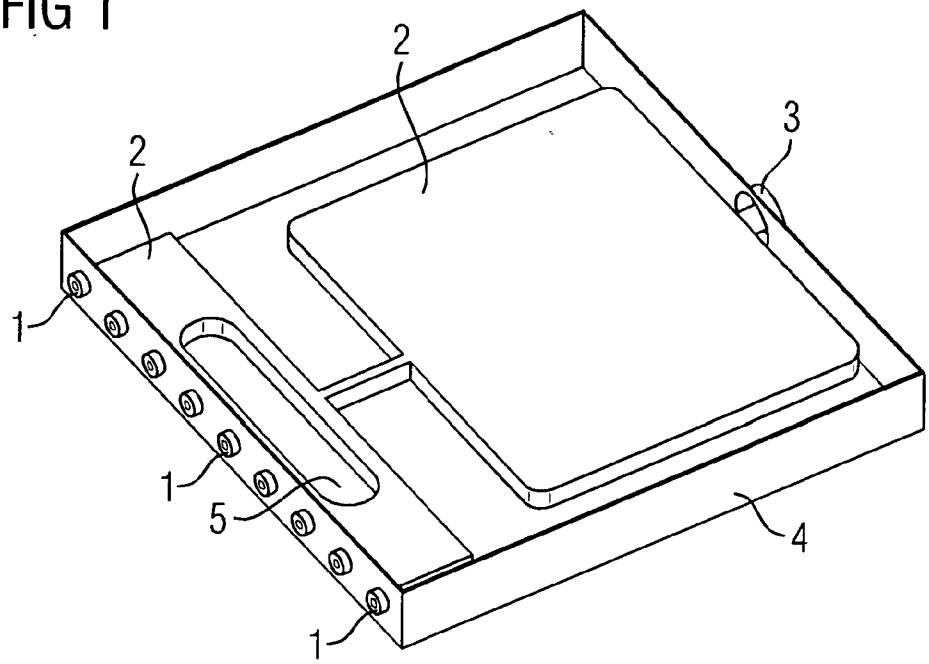


FIG 2

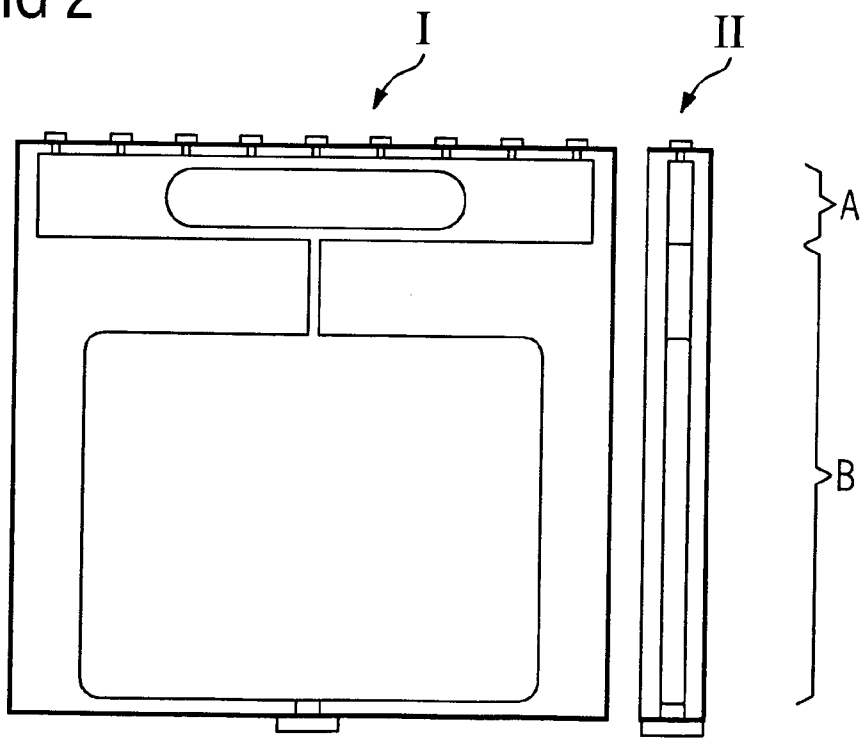


FIG 3

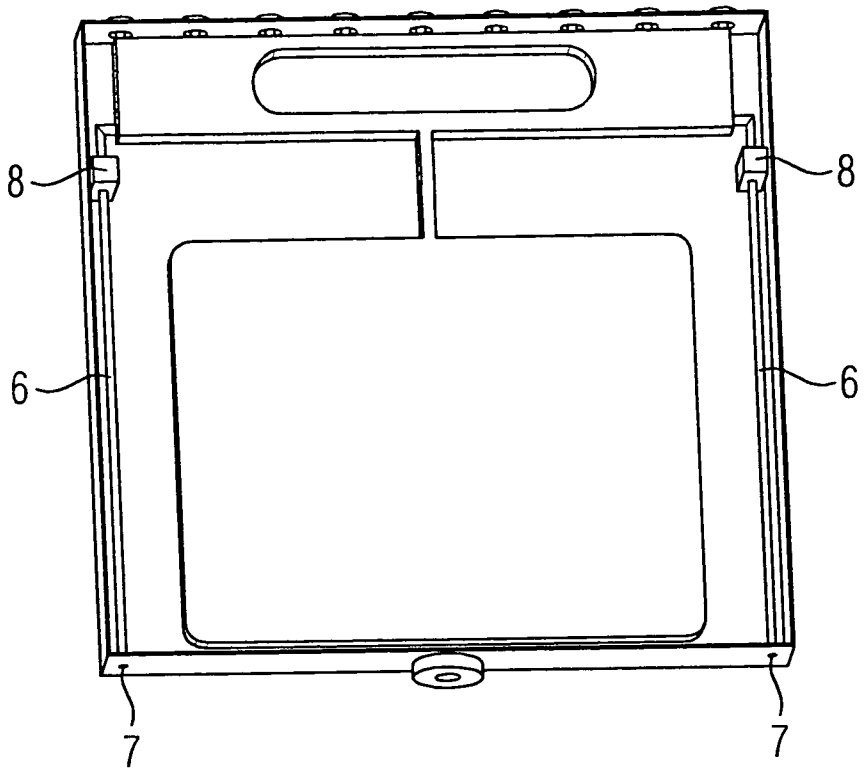


FIG 4

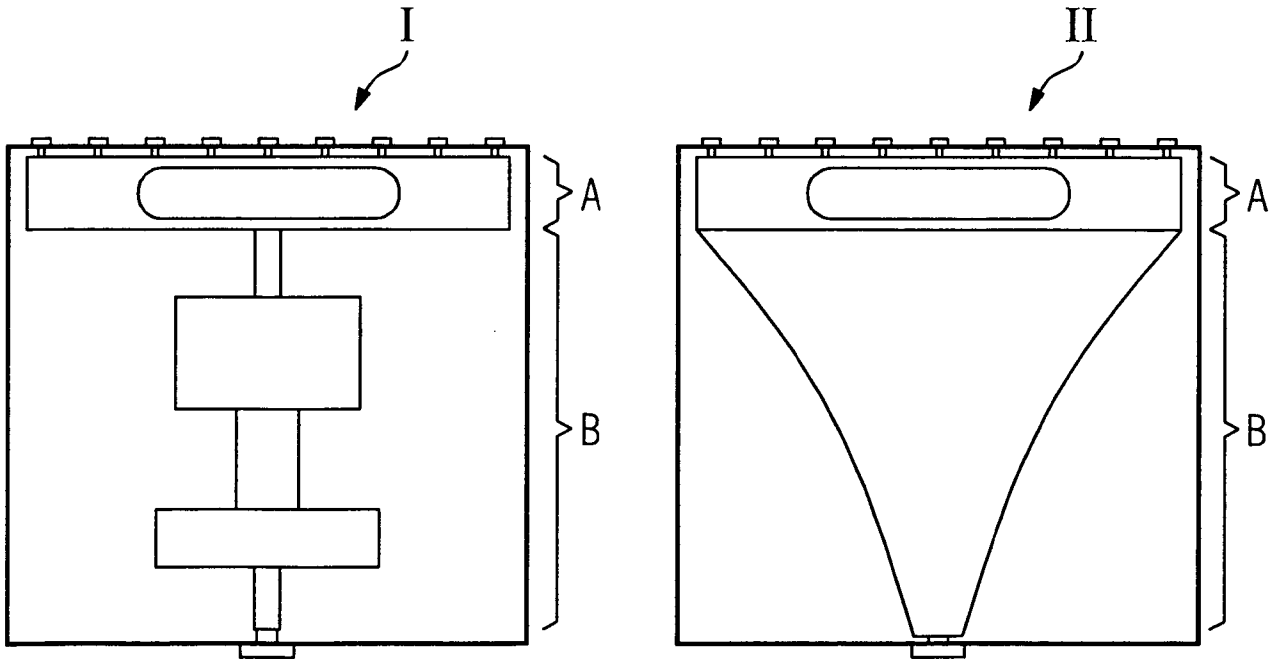
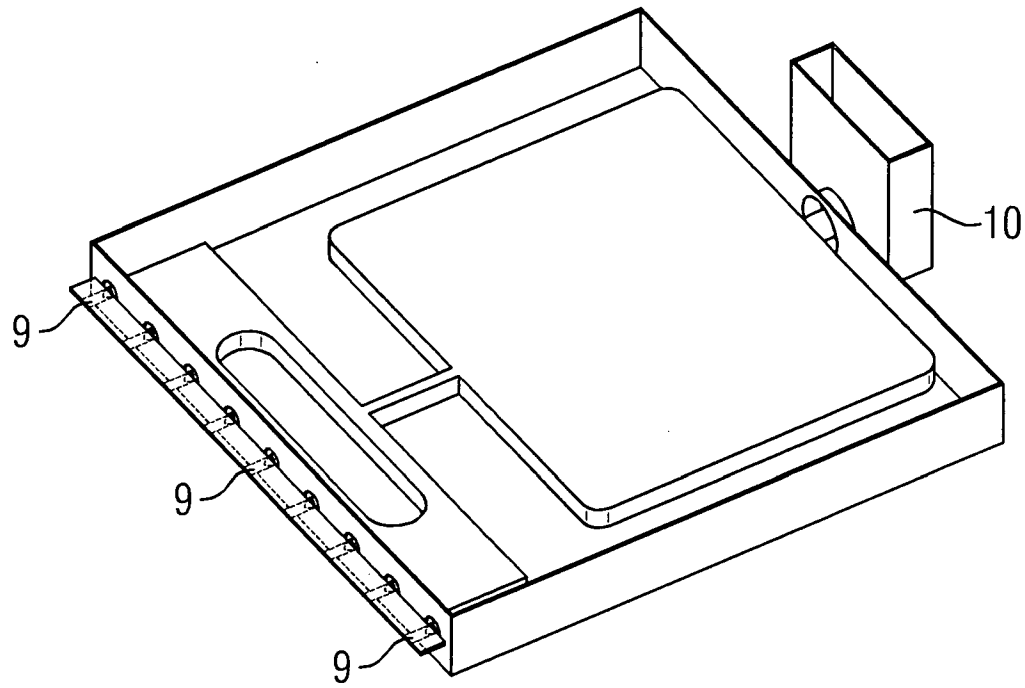


FIG 5



INTERNATIONAL SEARCH REPORT

International application No
PCT/RU2013/000709

A. CLASSIFICATION OF SUBJECT MATTER
INV. H01P5/12
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H01P

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	CN 202 487 735 U (SHENZHEN WINHAP COMM INC) 10 October 2012 (2012-10-10) abstract figures 1,2	1-8, 10-15 9

X Y	KR 101 236 367 B1 (JIN MYNG TAE KU [KR]) 22 February 2013 (2013-02-22) abstract figures 1-3	1-8, 10-15 9

X Y	CN 202 651 330 U (GUANGDONG TONGYU COMM INC) 2 January 2013 (2013-01-02) abstract figures 3-5	1-8, 10-15 9

	-/--	

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
17 April 2014	28/04/2014

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Kruck, Peter

1

Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No
PCT/RU2013/000709

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CN 202 797 937 U (SHENZHEN HAIPENGXIN ELECTRONICS CO LTD) 13 March 2013 (2013-03-13)	1-8, 10-15
Y	abstract figures 1-3	9

X	CN 202 721 251 U (ANHUI HUADONG PHOTOELEC TECH) 6 February 2013 (2013-02-06) abstract figures 1-6	1-15

X	DE 12 76 764 B (DEUTSCHES POST RUNDFUNK UND FE) 5 September 1968 (1968-09-05)	1-8, 10-15
Y	columns 1-4 figures 1-4	9

Y	CN 201 904 430 U (JINGZHOU NANHU MACHINERY FACTORY) 20 July 2011 (2011-07-20)	9
A	abstract figures 1,2	1,12

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/RU2013/000709

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
CN 202487735 U	10-10-2012	NONE	
KR 101236367 B1	22-02-2013	NONE	
CN 202651330 U	02-01-2013	NONE	
CN 202797937 U	13-03-2013	NONE	
CN 202721251 U	06-02-2013	NONE	
DE 1276764 B	05-09-1968	NONE	
CN 201904430 U	20-07-2011	NONE	