(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 2 827 441 A1

(12) **EUROPEAN PATENT APPLICATION**
published in accordance with Art. 153(4) EPC

(43) Date of publication:
21.01.2015 Bulletin 2015/04

(21) Application number: **12871488.8**

(22) Date of filing: **14.09.2012**

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

(86) International application number:
PCT/JP2012/073664

(87) International publication number:
WO 2013/136557 (19.09.2013 Gazette 2013/38)

(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

(30) Priority: **14.03.2012 JP 2012057525**

(71) Applicant: **Kabushiki Kaisha Toshiba**
Minato-ku
Tokyo 105-8001 (JP)

(72) Inventors:
- **HASUIKE, Kenichi**
  Tokyo 105-8001 (JP)
- **ITAGAKI, Hiromu**
  Tokyo 105-8001 (JP)

(74) Representative: **Hoffmann Eitle**
Patent- und Rechtsanwälte PartmbB
Arabellastraße 30
81925 München (DE)

(54) **DIRECTIONAL COUPLER**

(57) A directional coupler according to the present embodiment includes a dielectric substrate (10), a main line (11) formed on the front surface of the dielectric substrate (10), a sub-line (12) formed on the front surface or the rear surface of the dielectric substrate (10) and placed with a predetermined gap from the main line (11) in the plan view of the dielectric substrate (10), and an opening (14) provided between the main line (11) and the sub-line (12) through the dielectric substrate (10).

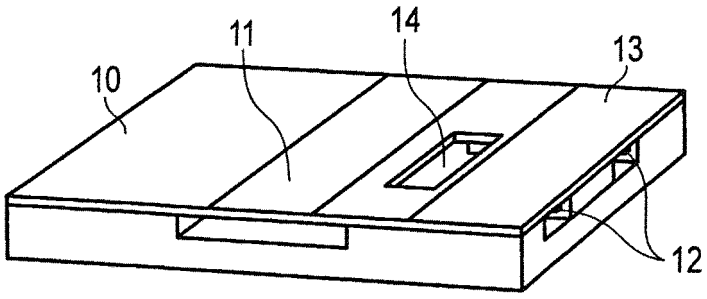

FIG. 1

EP 2 827 441 A1

Description

FIELD OF THE INVENTION

[0001] The embodiment of the present invention relates to a directional coupler used in a power amplifier for high-power transmission in a digital television transmitter.

BACKGROUND OF THE INVENTION

[0002] A directional coupler is conventionally provided using a microstrip line structure. A pattern of a main line and a pattern of a sub-line (a directional coupler) are formed on the front surface of a dielectric substrate which has a conductive ground on its rear surface. A coupled line which partly constitutes the sub-lines has an appropriate length, and is formed on the substrate in a manner such that there is a micro-space from the main line.

[0003] It is known that the length of a coupled line (a distance between a coupling port and an isolation port) is generally a quarter-wavelength ($\lambda/4$) of a transmit signal detected from a main line in order to obtain optimal directivity. However, a quarter-wavelength ($\lambda/4$) in the UHF band is long, and thus, a circuit tends to be large. To avoid this, a loop-coupled line having an appropriate length shorter than a quarter-wavelength ($\lambda/4$) is often used despite a certain level of degradation in directivity.

CITATION LIST

Patent Literature

[0004] Patent Literature 1: Jpn. Pat. Appln. KOKAI Publication No. 7-336117

SUMMARY OF INVENTION

TECHNICAL PROBLEM

[0005] An output power level on a transmission path is high in an apparatus of transmitting a high-power signal, such as a power amplifier for a digital television transmitter, therefore, during the detection of high-power, the directivity (isolation property) of a directional coupler is of great concern. Thus, a compact-size directional coupler that is capable of improving directivity has been desired.

[0006] The purpose of the present embodiment is to provide a directional coupler with high directivity and in a compact size.

SOLUTION TO PROBLEM

[0007] The directional coupler according to the present embodiment includes a dielectric substrate, a main line formed on the front surface of the dielectric substrate, a sub-line formed on the front surface or the rear surface of the dielectric substrate and placed with a predetermined gap from the main line in the plan view of the dielectric substrate, and an opening provided between the main line and the sub-line through the dielectric substrate.

BRIEF DESCRIPTION OF DRAWINGS

[0008]

FIG. 1 is a perspective view of the directional coupler according to the present embodiment.
FIG. 2 is a plan view and a cross-sectional view of the directional coupler illustrated in FIG. 1.
FIG. 3 shows a simulation result of the directional coupler shown in FIG. 1.
FIG. 4 is a perspective view of the directional coupler according to a comparison example.
FIG. 5 is a plan view and a cross-sectional view of the directional coupler illustrated in FIG. 4.
FIG. 6 shows a simulation result of the directional coupler shown in FIG. 4.

DESCRIPTION OF EMBODIMENTS

[0009] In the following, the directional coupler according to the present embodiment will be described in detail with reference to the drawings.

[0010] FIG. 1 is a perspective view of the directional coupler according to the present embodiment. FIG. 1 shows an example of the directional coupler used in a high-power amplifier for a terrestrial digital television transmitter. FIG. 2 (a) is a plan view of the directional coupler illustrated in FIG. 1, and FIG. 2(b) is a cross-sectional view of the directional coupler with respect to the cross section A-A'. Note that a shield 15 is omitted in FIG. 1.

[0011] A main line 11 is arranged on the front surface of a dielectric substrate 10, and a sub-line 12 is formed on the rear surface of the dielectric substrate 10, and is placed with a predetermined space from the main line 11 in the plan view of the dielectric substrate. A ground surface 13 of the sub-line 12 is formed on the front surface of the dielectric substrate 10 in a manner such that the ground surface 13 is superposed on the sub-line 12. Taking power withstand characteristic into account, a suspended line structure is adopted for the main line 11 as the structure allows a wider line width. A microstrip structure is adopted for the sub-line 12. It is possible to arrange the sub-line 12 on the front surface of the dielectric substrate 10 by replacing the sub-line 12 with the ground surface 13.

[0012] Furthermore, an opening 14 is provided between the main line 11 and the sub-line 12. The opening 14 is formed through the dielectric substrate 10. The width W and the length L of the opening 14, the distance D1 between the main line 11 and the opening 14, and the distance D2 between the opening 14 to the coupling line part of the sub-line 12 are optimized using electromagnetic field simulation.

[0013] Herein, the effect of the opening 14 is explained. The main line 11 and the sub-line 12 are arranged in a manner such that they are opposed to each other with the dielectric substrate 10 therebetween, and since the dielectric substrate 10 is surrounded by the air, the even-mode phase velocity is faster than the odd-mode phase velocity; as a result, directivity is degraded. In contrast, in the present embodiment the phase velocities of even and odd modes can be approximated by providing the opening 14 to eliminate part of the dielectric substrate 10. As a consequence, it is possible to improve directivity of the directional coupler.

[0014] FIG. 3 shows a simulation result of the directional coupler according to the present embodiment. As shown in the expression (1) below, directivity D of the directional coupler can be calculated by the difference of a coupling I of a coupling port P3 relative to an input port P1 and a coupling C of an isolation port P4 relative to an input port P1, i.e.,

$$\text{Directivity } D = |\, I-C \,| \ [\text{dB}] \quad \ldots \ (1)$$

[0015] It can be understood that if the directivity D is calculated by the expression (1) using the result shown in FIG. 3, the directivity of 31 dB or so can be obtained. "S2, 1" in FIG. 3 corresponds to I, and "S3, 1" corresponds to C.

[0016] Herein, the configuration of the directional coupler according to a comparison example is illustrated in FIG. 4 for the purpose of comparison with the present embodiment. FIG. 5 (a) is a plan view of the directional coupler shown in FIG. 4, and FIG. 5(b) is a cross-sectional view of the directional coupler with respect to the cross section B-B'. The directional coupler of the comparison example is the same as the directional coupler according to the present embodiment, except for the opening 14.

[0017] In FIG. 5 (a), the length of the coupled line is Lc ($< \lambda/4$), and a distance to the main line is Dc. Coupling is determined by Dc. Generally, a loop antenna-shaped lining which is shorter than $\lambda/4$ is widely used for the coupling line of a directional coupler. However, this leads to degradation of directivity of the directional coupler because the phase propagation velocities of even and odd modes are different. Moreover, directivity may be further degraded in a case of a weak connection due to a loose coupling.

[0018] FIG. 6 shows a simulation result of the directional coupler shown in FIG. 4. It can be understood that if the directivity D is calculated by the expression (1) using the result shown in FIG. 6, the directivity of 11 dB or so can be obtained.

[0019] Comparing FIG. 3 with FIG. 6, the directivity of the directional coupler according to the present embodiment is improved by 20 dB compared to the comparison example; accordingly, even if the coupled line part of the sub-line 12 is shorter than $\lambda/4$, sufficient directivity can be achieved. Therefore, it can be understood that directivity of the directional coupler can be improved by providing the opening 14.

[0020] As explained above, directivity can be improved in the present embodiment by providing an opening for adjustment between a main line and a sub-line. High directivity can be achieved even when a coupled line is shorter than $\lambda/4$. Therefore, according to the present embodiment, it is possible to realize a directional coupler with high directivity in a compact size.

[0021] As an example of one of the applications of the directional coupler according to the present embodiment, the directional coupler is provided in an output transmit path of a high power amplifier for a digital television transmitter in the UHF (ultra-high frequency) band. It is placed between a synthesized output and an output connector of a power amplifier to be used as a circuit for detecting an output level and a reflection level of an output power.

[0022] While certain embodiments have been described, these embodiments have been presented by way of example only, and are not intended to limit the scope of the inventions. Indeed, the novel embodiments described herein may be

embodied in a variety of other forms; furthermore, various omissions, substitutions, and changes in the form of the embodiments described herein may be made without departing from the spirit of the inventions. The accompanying claims and their equivalents are intended to cover such forms or modifications as would fall within the scope and spirit of the inventions.

Claims

1. A directional coupler **characterized by** comprising:

a dielectric substrate;
a main line formed on a front surface of the dielectric substrate;
a sub-line formed on the front surface or a rear surface of the dielectric substrate, the sub-line being placed with a predetermined gap from the main line in the plan view of the dielectric substrate; and
an opening provided between the main line and the sub-line through the dielectric substrate.

2. The directional coupler according to claim 1, **characterized in that** a length of the sub-line is shorter than $\lambda/4$ with respect to a wavelength λ of a transmit signal detected at the main line.

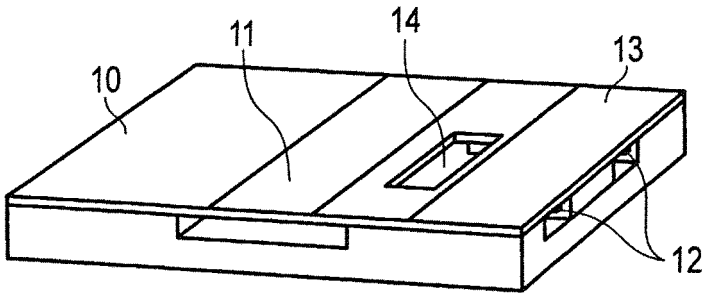

FIG. 1

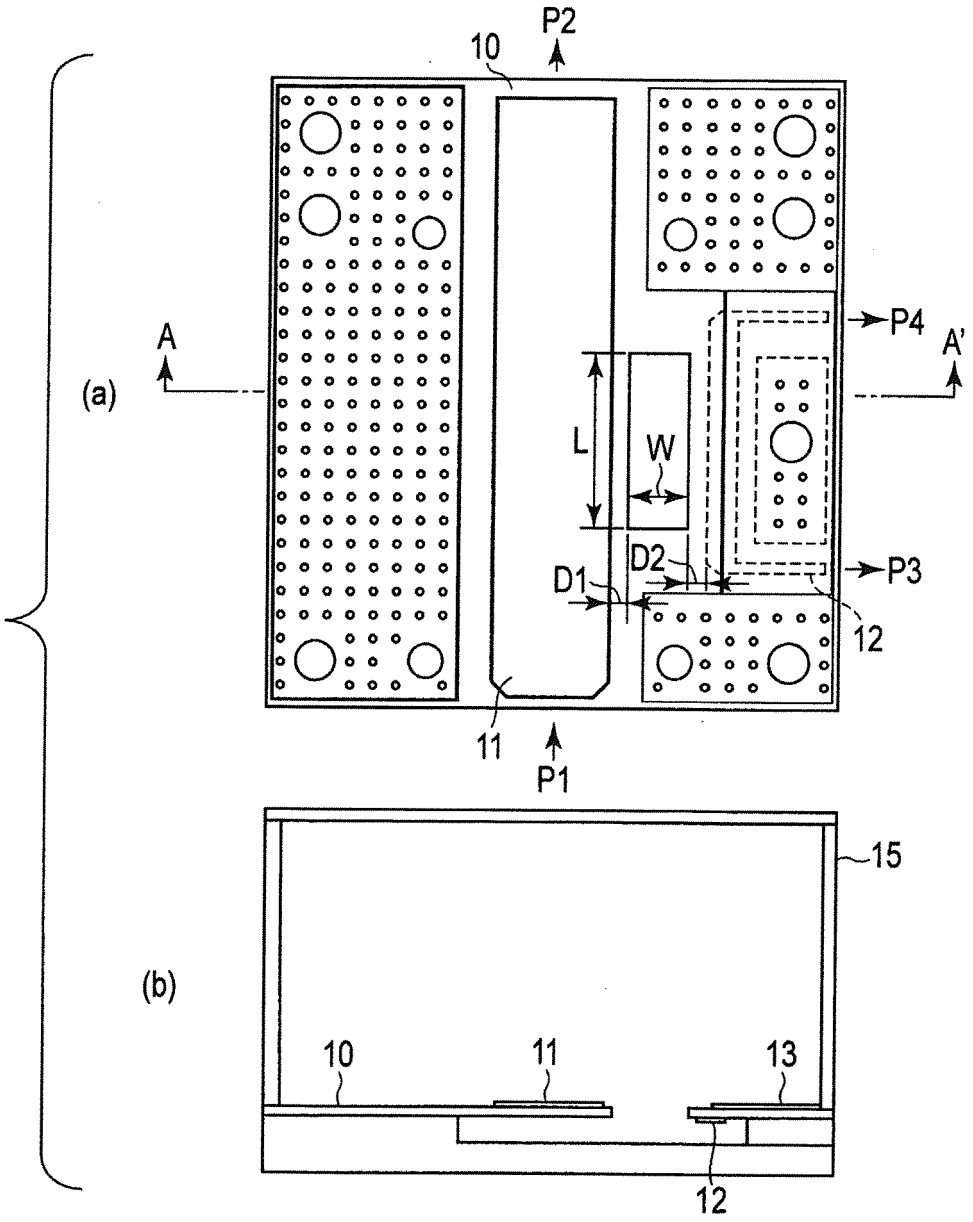

FIG. 2

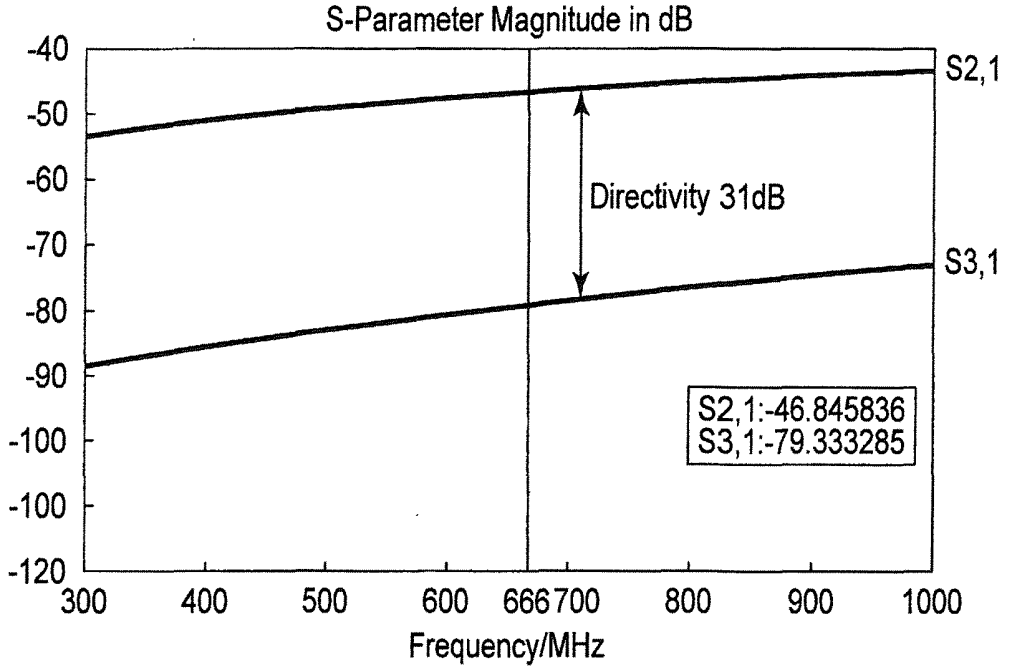
S-Parameter Magnitude in dB
-40
-50
-60
-70
-80
-90
-100
-100
-120
300
400
500
600
666
700
800
900
1000
Frequency/MHz
S2,1
S3,1
Directivity 31dB
S2,1:-46.845836
S3,1:-79.333285

FIG. 3

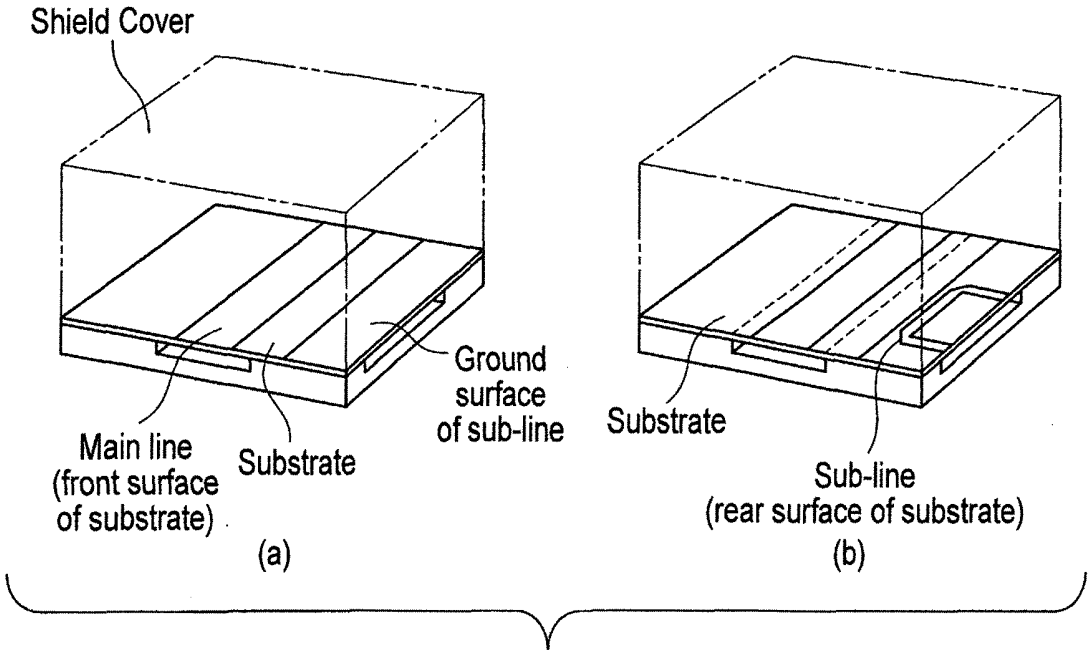
Shield Cover
Ground surface of sub-line
Main line (front surface of substrate)
Substrate
(a)
Substrate
Sub-line (rear surface of substrate)
(b)

FIG. 4

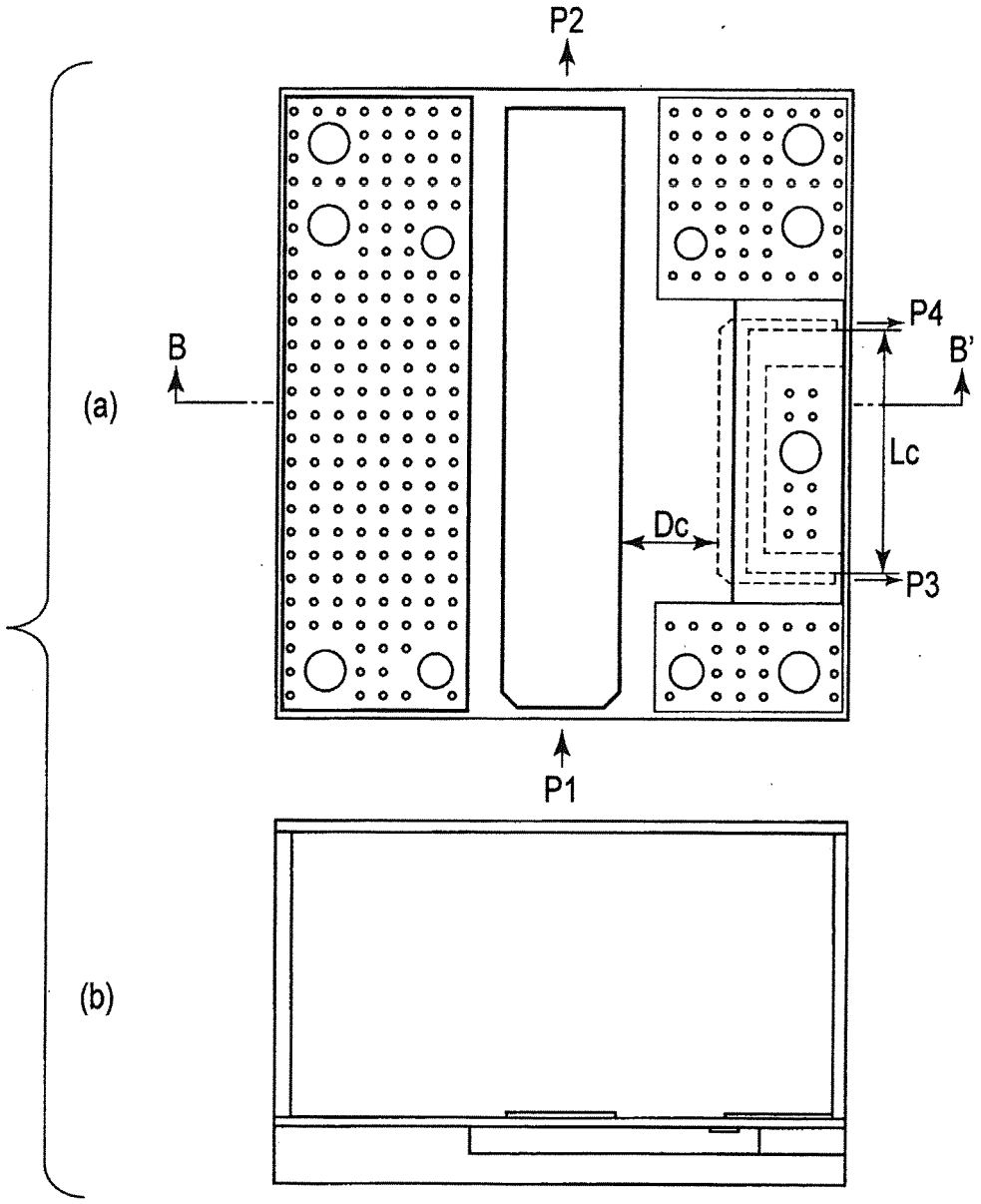

FIG. 5

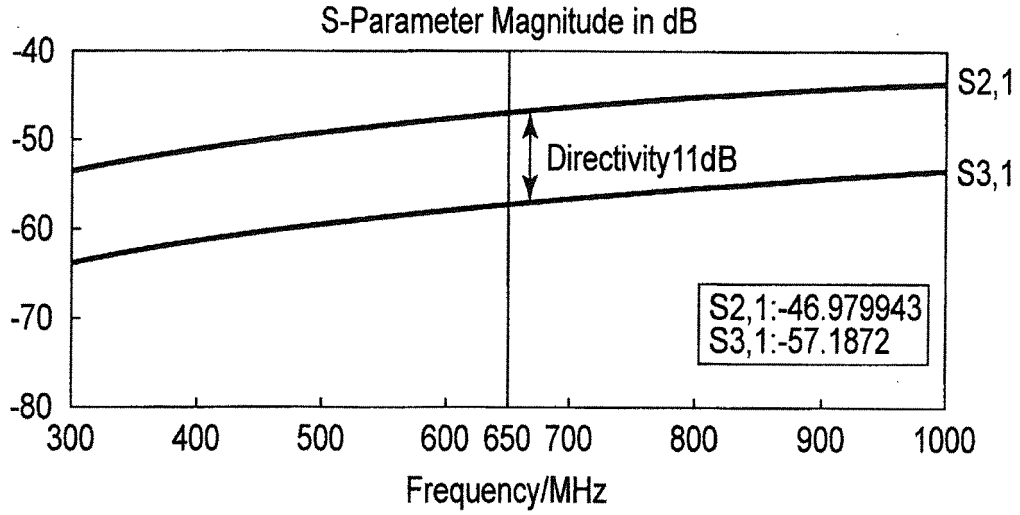
S-Parameter Magnitude in dB
-40
-50
-60
-70
-80
300
400
500
600
650
700
800
900
1000
Frequency/MHz
S2,1
S3,1
Directivity11dB
S2,1:-46.979943
S3,1:-57.1872

FIG. 6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2012/073664

A. CLASSIFICATION OF SUBJECT MATTER
H01P5/18(2006.01)i

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)
H01P5/18

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2012
Kokai Jitsuyo Shinan Koho 1971-2012 Toroku Jitsuyo Shinan Koho 1994-2012

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	JP 2005-210672 A (Mitsubishi Electric Corp.), 04 August 2005 (04.08.2005), paragraphs [0050] to [0055]; fig. 19A to 19C (Family: none)	1 2
Y	JP 2006-238063 A (NEC Corp.), 07 September 2006 (07.09.2006), paragraph [0014] (Family: none)	2
A	JP 05-090810 A (Ube Industries, Ltd.), 09 April 1993 (09.04.1993), entire text; all drawings (Family: none)	1,2

☐ Further documents are listed in the continuation of Box C. ☐ 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
29 November, 2012 (29.11.12)	11 December, 2012 (11.12.12)
Name and mailing address of the ISA/ Japanese Patent Office Facsimile No.	Authorized officer Telephone No.

Form PCT/ISA/210 (second sheet) (July 2009)

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- JP 7336117 A **[0004]**