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(54) HIGH-FREQUENCY MODULE

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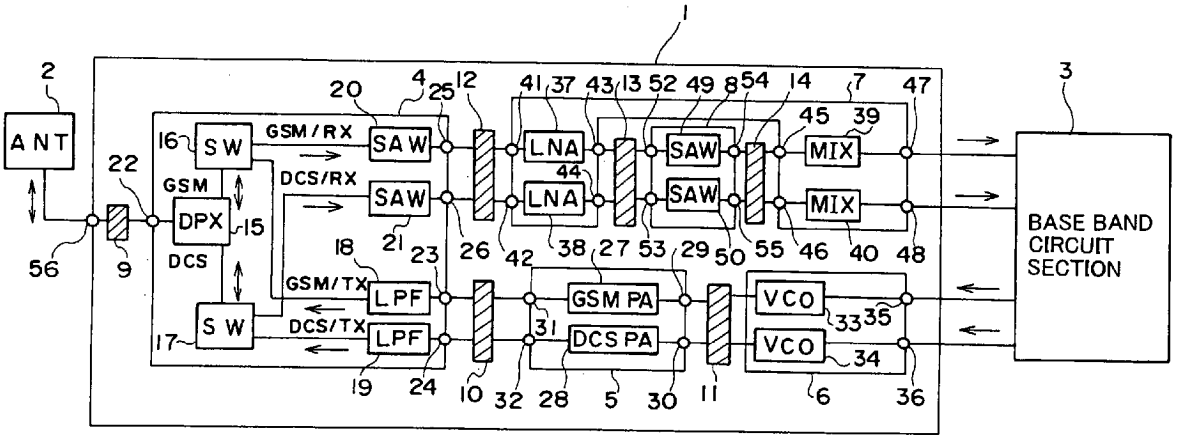
(57) **ABSTRACT**

It is an object of the present invention to provide a high-frequency module whose production yield as a complete module can be prevented from being lowered.

The high-frequency module according to the present invention includes a main module including a first high-frequency circuit at least a part of which is constituted by a conductive pattern built in a multi-layered substrate and a sub-module including a second high-frequency circuit, and the sub-module is inserted into a cavity formed in the main module. According to the present invention, the main module including the first high-frequency circuit and the sub-module including the second high-frequency circuit are constituted as separate components and the main module and the sub-module are integrated by inserting the sub-module into the cavity formed in the main module. Therefore, it is possible to use only a main module and sub-module that have been inspected after manufacture and found to be non-defective. Accordingly, it is possible to markedly increase the yield of the high-frequency module as a whole.



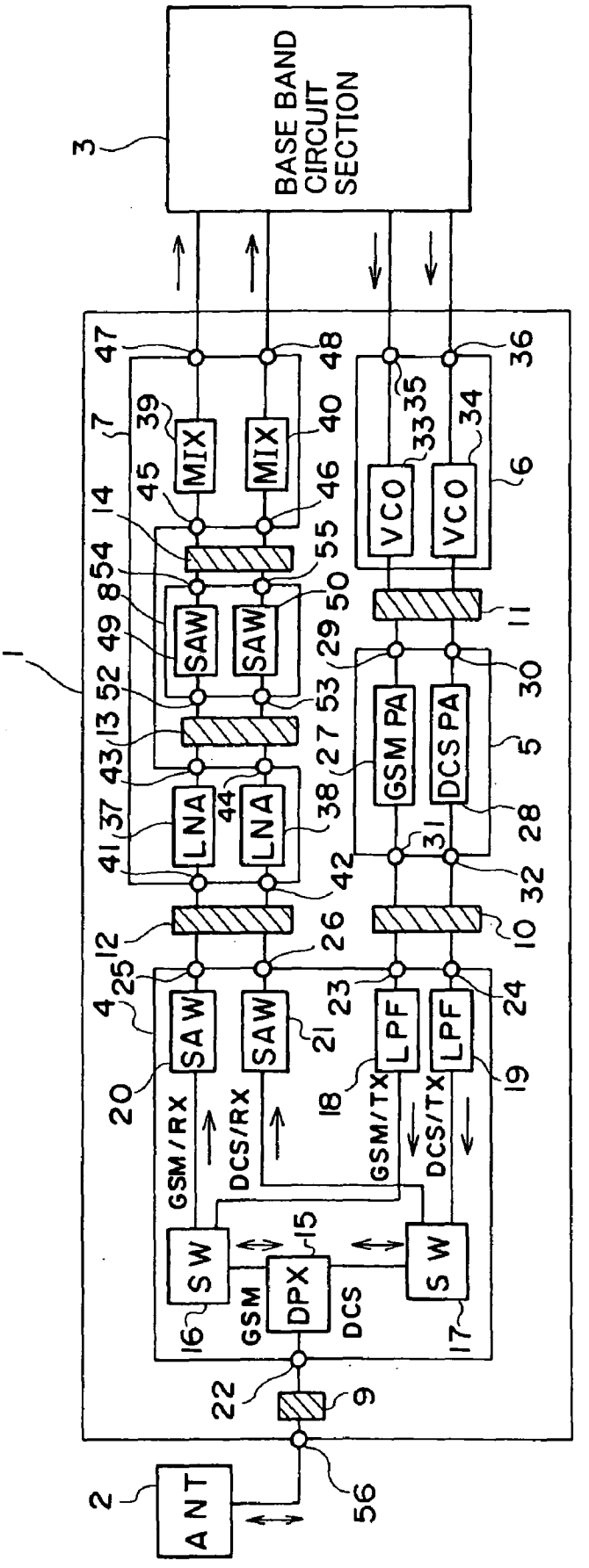
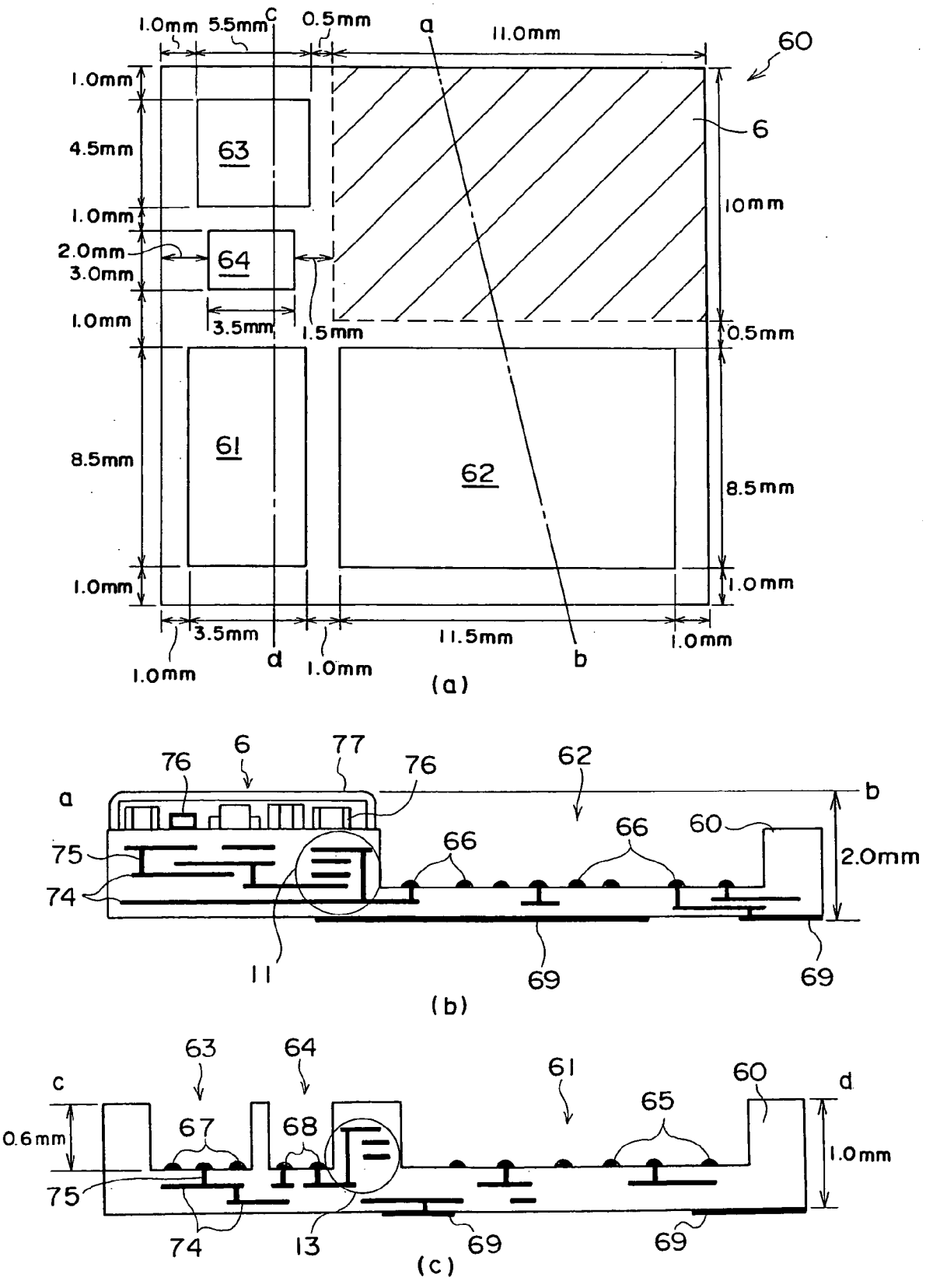

BASE BAND CIRCUIT SECTION
3
1
2
ANT
56
9
22
DPX
15
GSM
DCS
16
SW
17
SW
GSM/RX
DCS/RX
GSM/TX
DCS/TX
4
20
SAW
21
SAW
18
LPF
19
LPF
12
26
10
32
41
37
LNA
44
LNA
38
42
43
27
GSM PA
DCS PA
31
28
5
13
52
53
30
49
8
54
50
29
11
SAW
SAW
14
45
46
55
MIX
MIX
7
39
40
6
VCO
VCO
33
35
34
47
48
36

FIG. 1

FIG. 2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a
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4.5mm
63
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3.0mm
64
1.0mm
3.5mm
1.5mm
0.5mm
8.5mm
61
62
8.5mm
1.0mm
1.0mm
3.5mm
11.5mm
1.0mm
1.0mm
d
1.0mm
b
(a)
76
6
77
76
62
a
b
66
66
60
75
2.0mm
74
11
69
69
(b)
63
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61
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c
d
65
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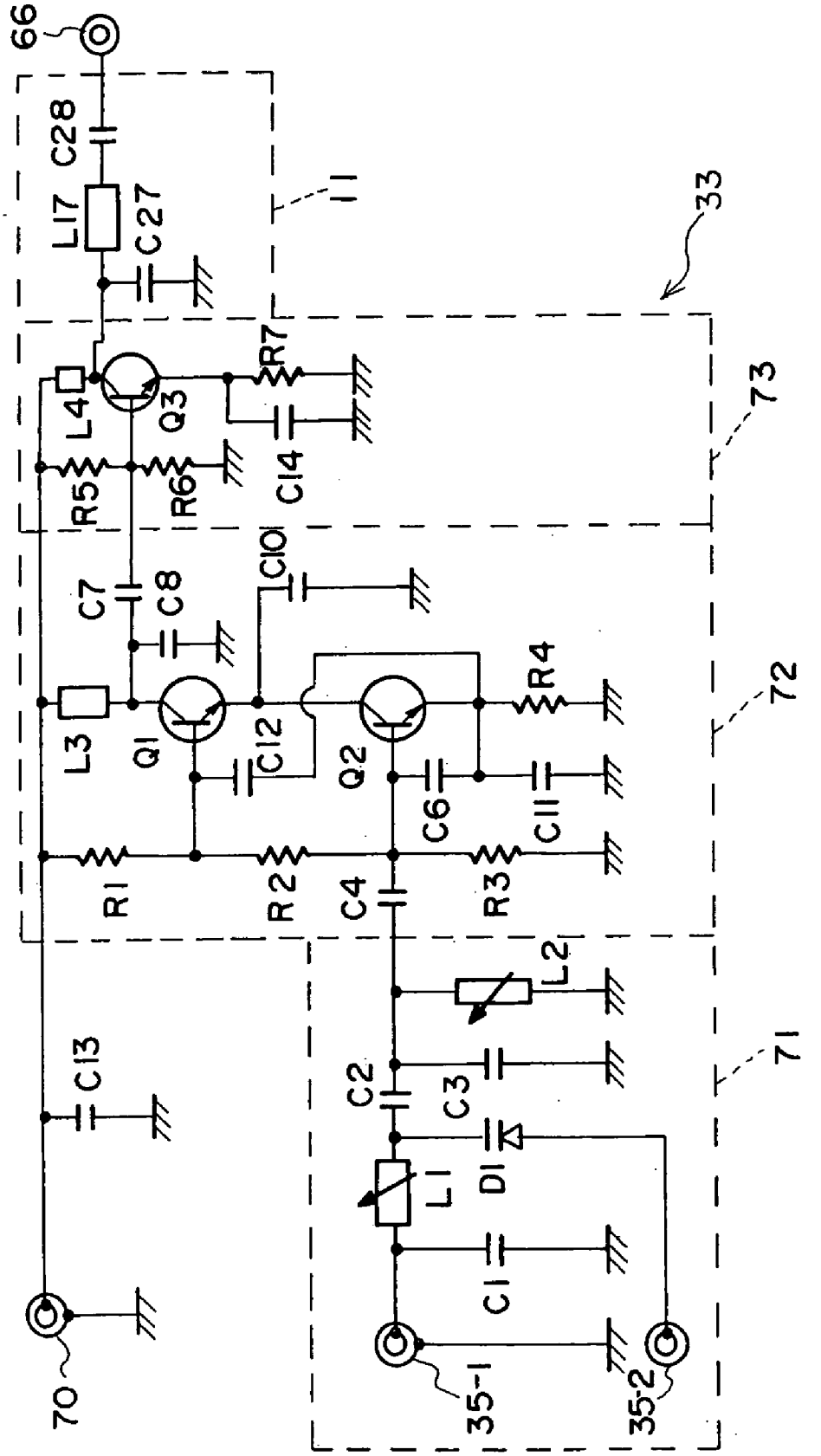
69
(c)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C28
L17
C27
11
33
R7
L4
Q3
73
R5
R6
C14
C10
C7
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72
L3
Q1
C12
Q2
C6
C11
R1
R2
C4
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C13
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C2
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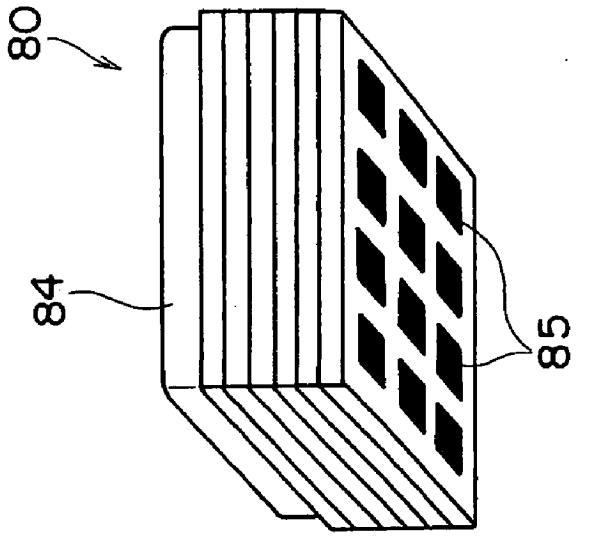
D1
L1
C1
70
35-1
35-2

FIG. 3



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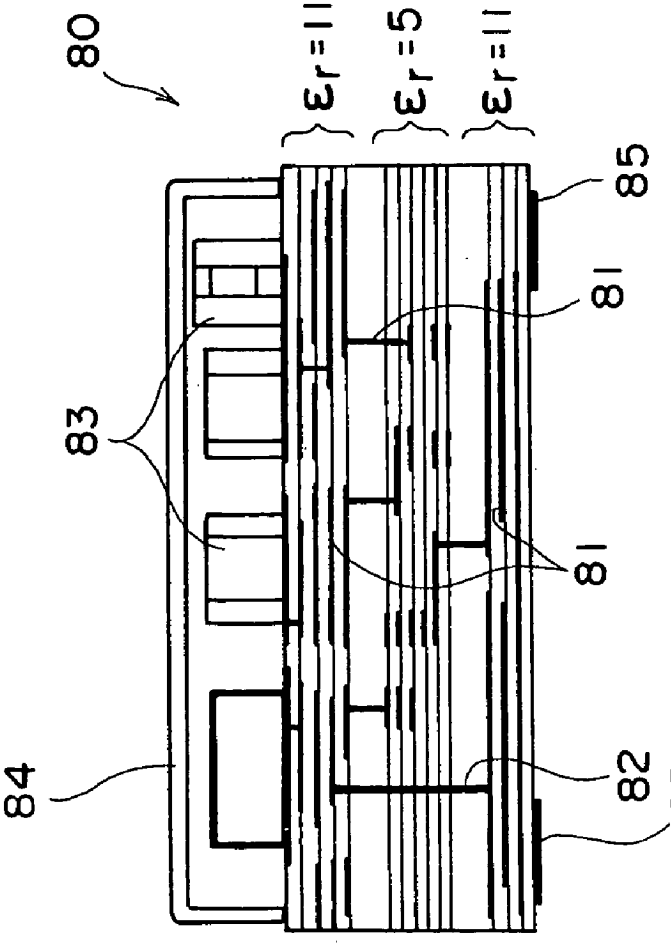
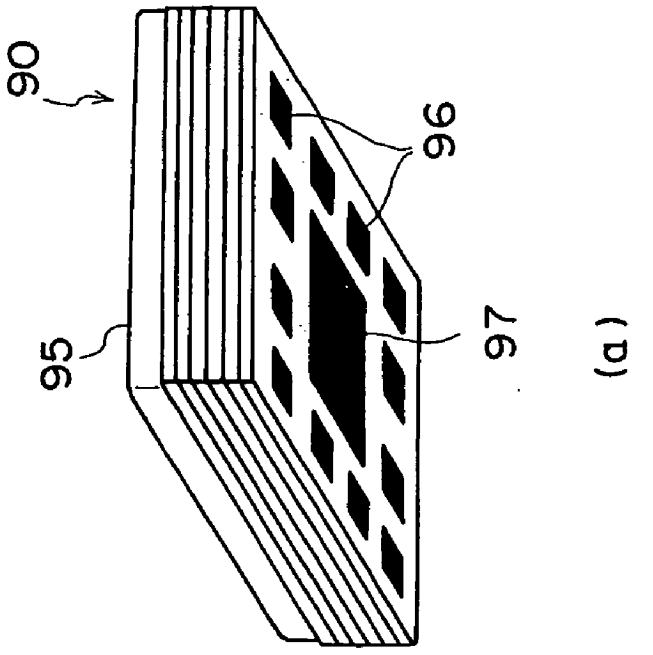


(b)

FIG. 4



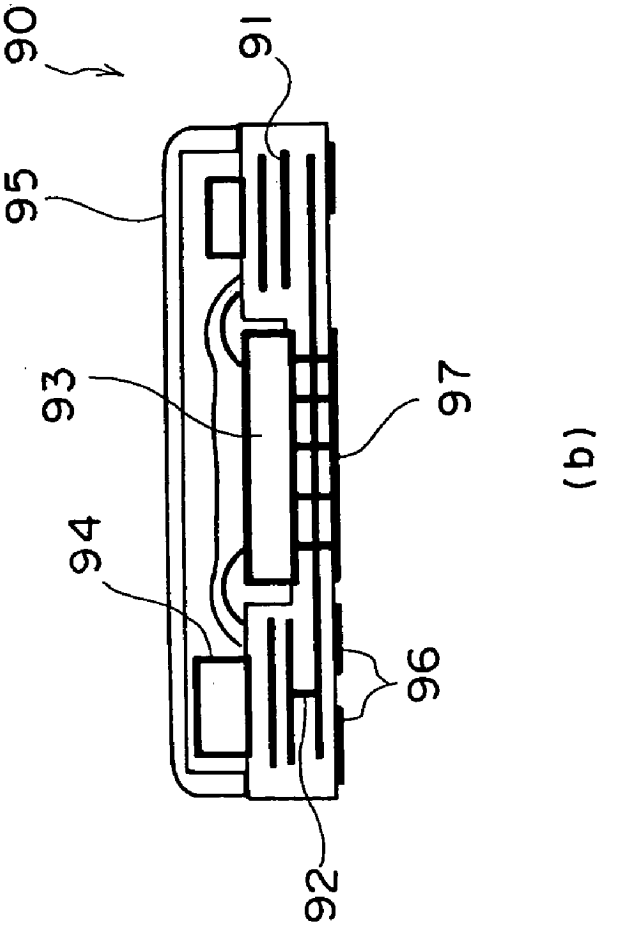
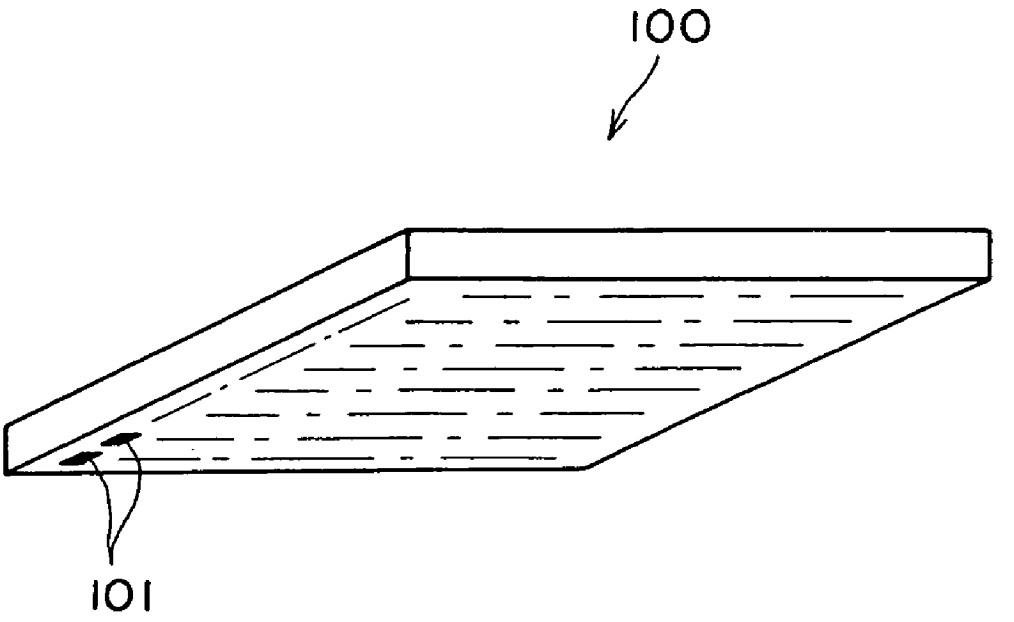
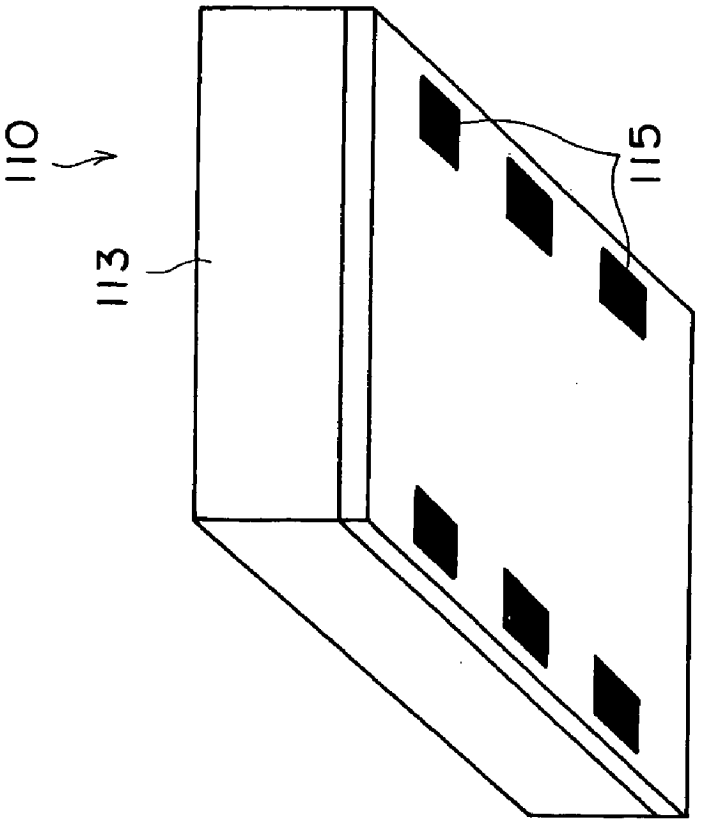


FIG. 5

FIG. 6





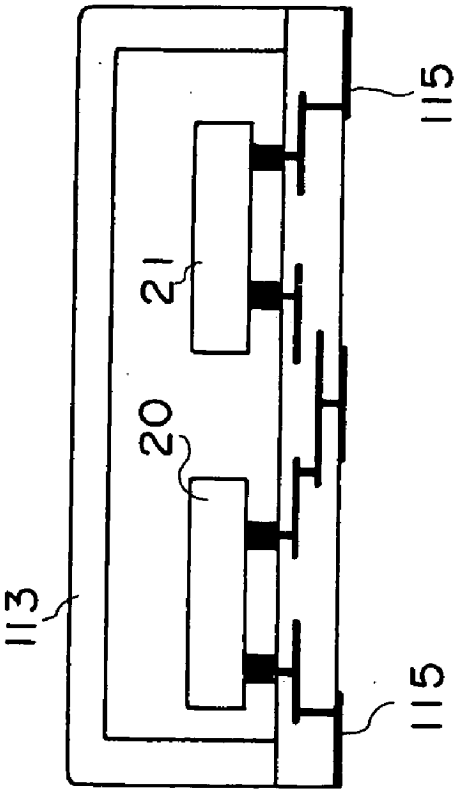
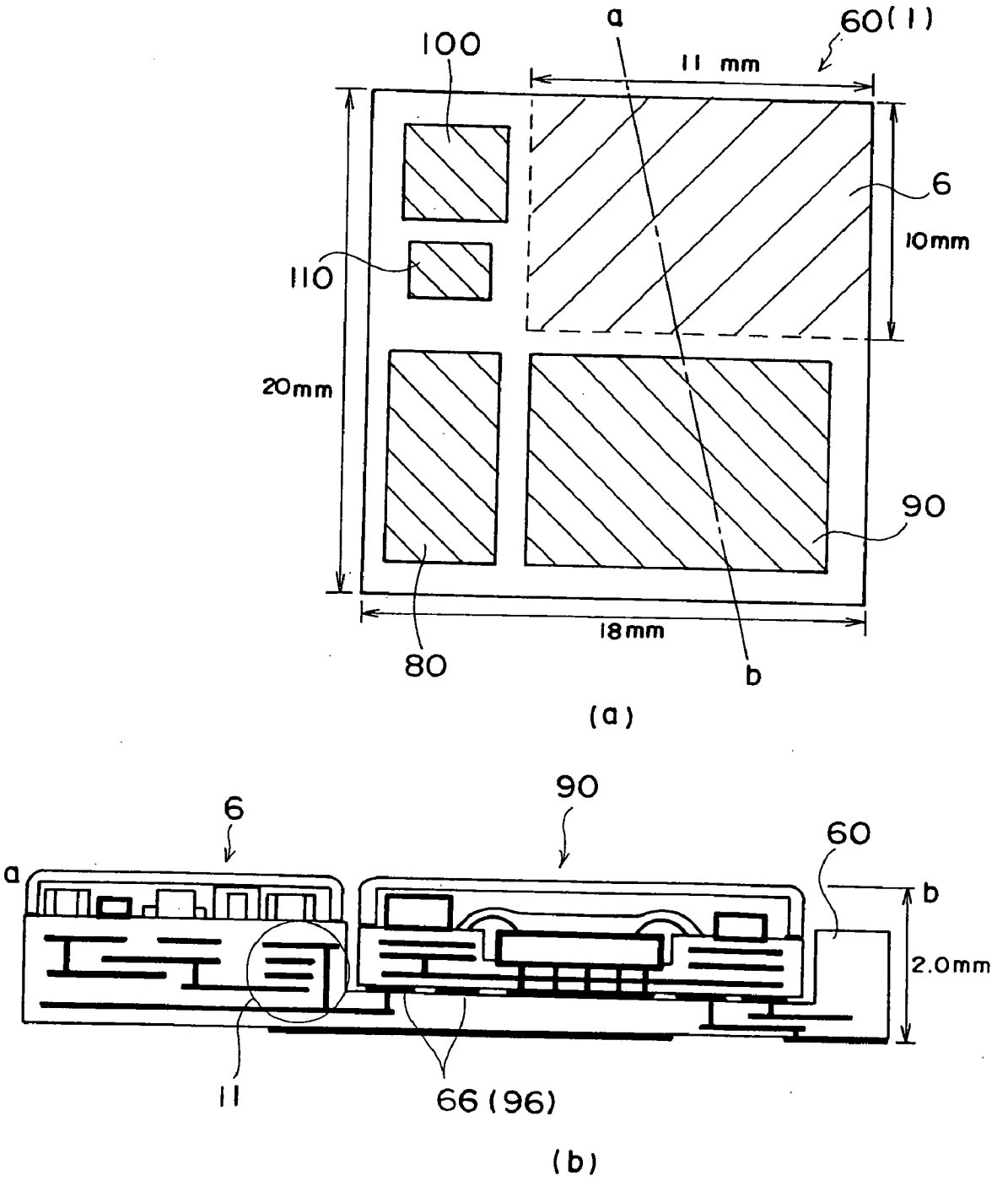


FIG. 7

FIG. 8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110
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80
b
(a)
6
90
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a
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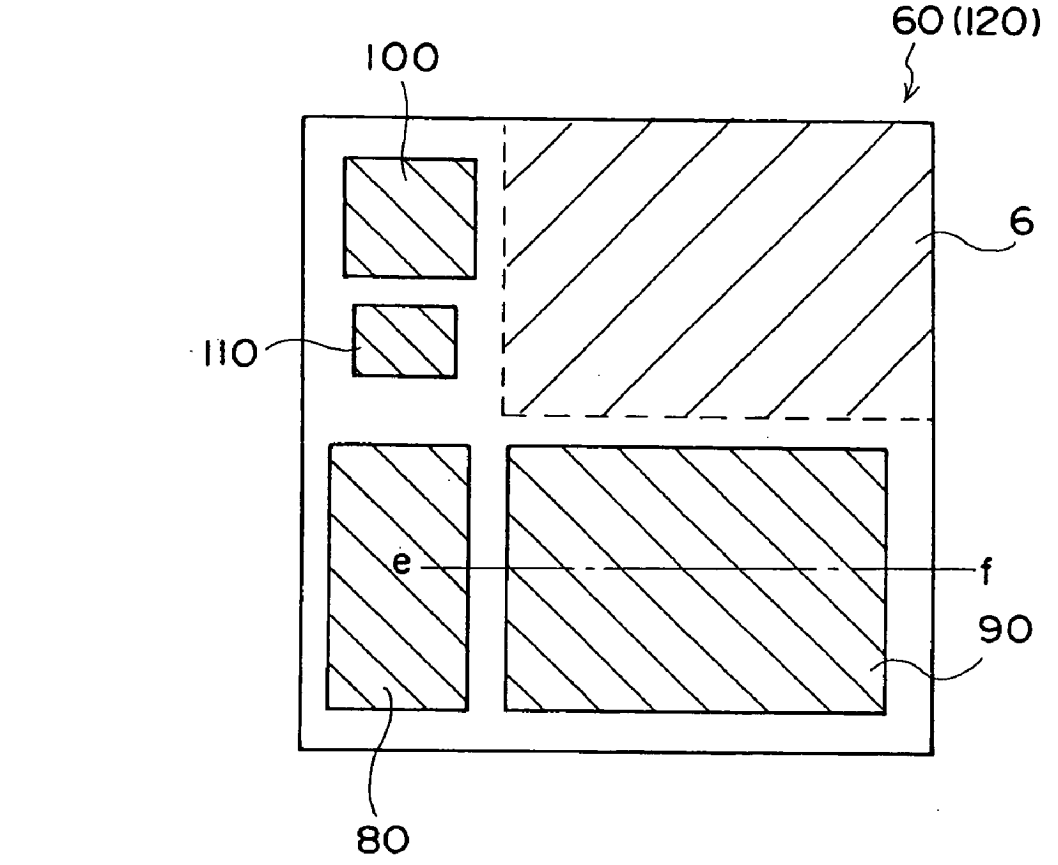
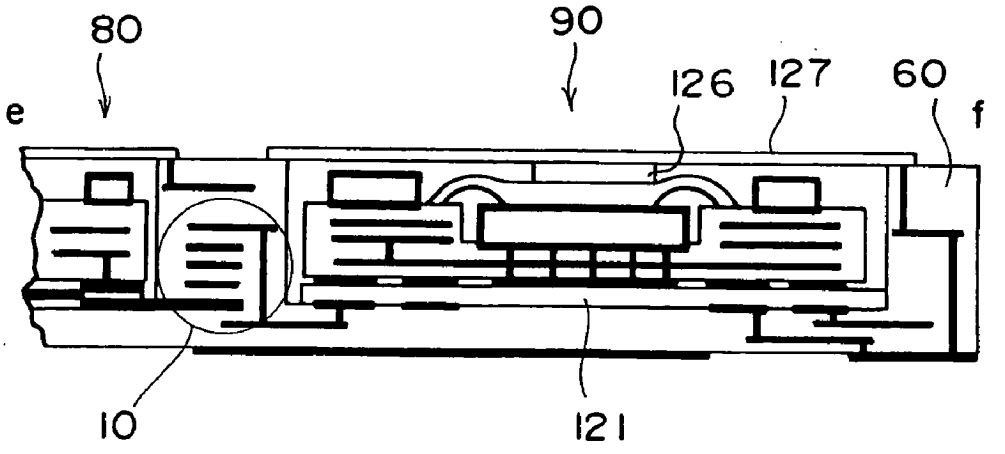
11
66(96)
(b)

FIG. 9

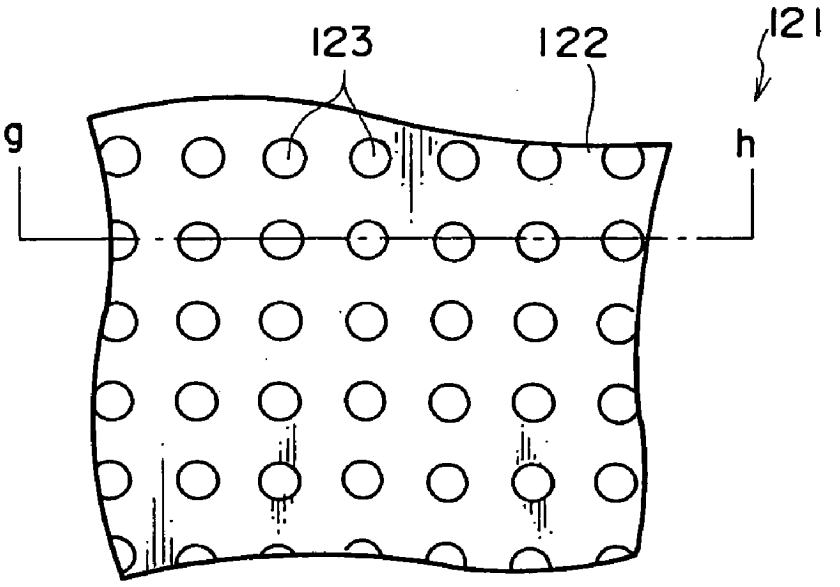


(a)



(b)

FIG. 10



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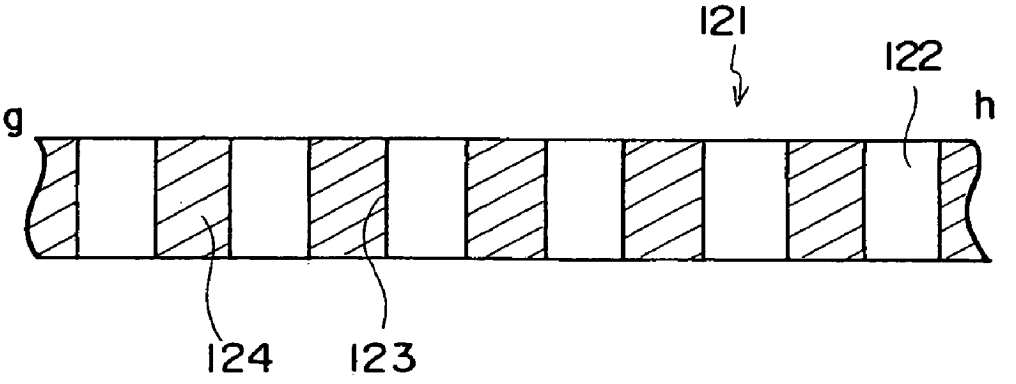

(b)

HIGH-FREQUENCY MODULE

BACKGROUND OF THE INVENTION

[0001] The present invention relates to a high-frequency module and, in particular, such a module having high production yield and excellent general utility.

DESCRIPTION OF THE PRIOR ART

[0002] In recent years, the size of information communication terminals, typically cellular phones, has decreased rapidly and size reduction of the various components incorporated into information communication terminals is making a large contribution in this direction. Illustrative examples of components incorporated into an information communication terminal include a power amplifier, a voltage-controlled oscillator (VCO) and the like for a transmitter circuit, a low-noise amplifier, a mixer and the like for a receiver circuit, in addition to a high-frequency switch for switching transmitted and received signals.

[0003] Many attempts have been made to further reduce the sizes of components incorporated into information communication terminals by integrally combining two or more components. If two or more components are integrated to fabricate a module in this manner, the area on a mother board required for mounting the components can be reduced in comparison with the case where these components are individually mounted and, therefore, the overall size of the information communication terminal can be reduced.

[0004] Although the overall size of the information communication terminal can be reduced by integrating two or more components to fabricate a module in this manner, if too many components are integrated to fabricate a module, there is a risk of the yield of the module being lowered. Specifically, when two or more components are integrated to fabricate a module, if even one of the components incorporated into the module is defective, the module as a whole becomes defective, so that the yield of a module is determined by the product of yields of the components incorporated into the module. For example, if a module is fabricated by incorporating five components each having a yield of 95%, the yield of the module is lowered to about 77% ($=0.95^5$). Thus, in the case where many components are integrated to fabricate a module, there is a problem of the yield of the module as a whole being lowered.

[0005] Further, in the case where many components are integrated to fabricate a module, if the characteristics of some components need to be changed, the entire module must be redesigned and, therefore, the module is poor in general utility.

SUMMARY OF THE INVENTION

[0006] It is therefore an object of the present invention to provide a high-frequency module whose production yield as a complete module can be prevented from being lowered.

[0007] It is another object of the present invention to provide a high-frequency module having excellent general utility.

[0008] The above and other objects of the present invention can be accomplished by a high-frequency module comprising a main module including a first high-frequency circuit at least a part of which is constituted by a conductive pattern built in a multi-layered substrate and a sub-module including a second high-frequency circuit, the sub-module being inserted into a cavity formed in the main module.

[0009] According to the present invention, the main module including the first high-frequency circuit and the sub-module including the second high-frequency circuit are constituted as separate components and the main module and the sub-module are integrated by inserting the sub-module into the cavity formed in the main module. Therefore, it is possible to use only a main module and sub-module that have been inspected after manufacture and found to be non-defective. Accordingly, it is possible to markedly increase the yield of the high-frequency module as a whole. Further, according to the present invention, since the main module and the sub-module are constituted as separate components, when, for example, characteristics of the second high-frequency circuit included in the sub-module need to be changed for example, it is sufficient to redesign only the sub-module without redesigning the main module and, therefore, the general utility of the high-frequency module can be improved.

[0010] In a preferred aspect of the present invention, the first high-frequency circuit is constituted by the conductive pattern built in the multi-layered substrate and electronic components mounted on the multi-layered substrate.

[0011] In a further preferred aspect of the present invention, the sub-module is constituted using a multi-layered substrate.

[0012] In a further preferred aspect of the present invention, the multi-layered substrate of the main module and the multi-layered substrate of the sub-module are made of different materials.

[0013] In a further preferred aspect of the present invention, the multi-layered substrate of the main module is constituted as a laminate including a plurality of resin substrates.

[0014] In a further preferred aspect of the present invention, the multi-layered substrate of the sub-module is constituted as a laminate including a plurality of ceramic substrates.

[0015] In a further preferred aspect of the present invention, a plurality of electrodes provided on a bottom surface of the cavity of the main module and a plurality of electrodes provided on a bottom surface of the sub-module are electrically connected.

[0016] In a further preferred aspect of the present invention, the plurality of electrodes provided on the bottom surface of the cavity of the main module and the plurality of electrodes provided on the bottom surface of the sub-module are electrically connected by solder.

[0017] In a further preferred aspect of the present invention, the plurality of electrodes provided on the bottom surface of the cavity of the main module and the plurality of electrodes provided on the bottom surface of the sub-module are electrically connected via an anisotropic conductive sheet.

[0018] In a further preferred aspect of the present invention, an upper portion of the cavity into which the sub-module is inserted is covered by a metal plate.

[0019] In a further preferred aspect of the present invention, the metal plate is connected to a ground pattern formed on an upper surface of the main module.

[0020] In a further preferred aspect of the present invention, an impedance matching section is further built in the multi-layered substrate of the main module for matching impedance of the first high-frequency circuit and that of the second high-frequency circuit.

[0021] In a further preferred aspect of the present invention, the first high-frequency circuit is constituted as at least one circuit selected from the group consisting of a front-end module section, a power amplifier module section, a synthesizer module section, an LSI section and a SAW filter module section.

[0022] In a further preferred aspect of the present invention, the second high-frequency circuit is constituted as at least one circuit selected from the group consisting of a front-end module section, a power amplifier module section, a synthesizer module section, an LSI section and a SAW filter module section and other than the circuit constituting the first high-frequency circuit.

[0023] The above and other objects of the present invention can be also accomplished by a high-frequency module comprising a first cavity and a second cavity constituted so that a first sub-module and a second sub-module can be inserted therein, prescribed high-frequency circuits integrated therewith and an impedance matching circuit built therein for matching impedance of the first sub-module and that of the second sub-module.

[0024] According to this aspect of the present invention, since the first sub-module and second sub-module can be inserted into the first cavity and second cavity, it is possible to use only sub-modules inspected after manufacture and found to be non-defective. Accordingly, it is possible to markedly increase the yield of the high-frequency module as a whole. Further, according to this aspect of the present invention, when characteristics of the circuit included in either of the sub-modules needs to be changed, it is sufficient to redesign only the sub-module whose circuit is to be changed and, therefore, the general utility of the high-frequency module can be improved. Furthermore, since the impedance matching circuit for matching impedance of the first sub-module and that of the second sub-module is built in the high-frequency module, it is unnecessary to add a separate impedance matching circuit to the high-frequency module and, therefore, the overall size of the high-frequency module can be reduced.

[0025] In a preferred aspect of the present invention, an impedance matching circuit is further built in the high-frequency module for matching impedance of the high-frequency circuit and that of the first sub-module.

BRIEF DESCRIPTION OF THE DRAWINGS

[0026] **FIG. 1** is a block diagram schematically showing the circuit configuration of a high-frequency module which is a preferred embodiment of the present invention.

[0027] **FIG. 2** shows the structure of a main module constituting a high-frequency module which is a preferred embodiment of the present invention, wherein **FIG. 2**(*a*) is a plan view thereof, **FIG. 2**(*b*) is a cross sectional view taken along a line a-b in **FIG. 2**(*a*) and **FIG. 2**(*c*) is a cross sectional view taken along a line c-d in **FIG. 2**(*a*).

[0028] **FIG. 3** is a circuit diagram showing one example of a circuit configuration of a voltage-controlled oscillator and part of an impedance matching section constituting a synthesizer module section.

[0029] **FIG. 4**(*a*) is a schematic perspective view showing the rear surface of a sub-module for constituting a front-end module section and **FIG. 4**(*b*) is a cross sectional view thereof.

[0030] **FIG. 5**(*a*) is a schematic perspective view showing the rear surface of a sub-module for constituting a power amplifier module section and **FIG. 5**(*b*) is a cross sectional view thereof.

[0031] **FIG. 6** is a schematic perspective view showing the rear surface of a semiconductor chip package for constituting an LSI section.

[0032] **FIG. 7**(*a*) is a schematic perspective view showing the rear surface of a sub-module for constituting a SAW filter module section and **FIG. 7**(*b*) is a cross sectional view thereof.

[0033] **FIG. 8** shows the structure of a high-frequency module fabricated by inserting a first sub-module, a second sub-module, a semiconductor chip package and a third sub-module into first to fourth cavities formed in a main module, wherein **FIG. 8**(*a*) is a plan view of thereof and **FIG. 8**(*b*) is a cross sectional view taken along a line a-b in **FIG. 8**(*a*).

[0034] **FIG. 9** shows the structure of a high-frequency module which is another embodiment of the present invention, wherein **FIG. 9**(*a*) is a plan view thereof and **FIG. 9**(*b*) is a cross sectional view taken along a line e-f in **FIG. 9**(*a*).

[0035] **FIG. 10**(*a*) is a plan view schematically showing an anisotropic sheet and **FIG. 10**(*b*) is a cross sectional view taken along a line g-h in **FIG. 10**(*a*).

DESCRIPTION OF THE PREFERRED EMBODIMENT

[0036] A preferred embodiment of the prese4nt invention will now be described in detail with reference to accompanying drawings.

[0037] **FIG. 1** is a block diagram schematically showing the circuit configuration of a high-frequency module **1** which is a preferred embodiment of the present invention. The high-frequency module **1** according to this embodiment is adapted to be incorporated into a dual-band cellular phone by which communication can be performed by two systems, although it is not limited to such use. The two systems are the GSM system and the DCS system, for example. These are cellular phone systems employed in Europe. In the GSM system, the receiving frequency is from 925 to 960 MHz and the transmitting frequency is from 880 to 915 MHz. In the DCS system, the receiving frequency is from 1805 to 1880 MHz and the transmitting frequency is from 1710 to 1785 MHz.

[0038] As shown in **FIG. 1**, the high-frequency module **1** according to this embodiment is disposed between an antenna **2** and a base band section **3** of the dual-band type cellular phone and serves to feed a received signal from the

antenna **2** to the base band section **3** and feed out a transmitting signal fed from the base band section **3** to the antenna **2**.

[**0039**] More specifically, the high-frequency module **1** includes a front-end module section **4**, a power amplifier module section **5**, a synthesizer module section **6**, an LSI section **7**, a SAW (Surface Acoustic Wave) filter module section **8** and impedance matching sections **9** to **14**.

[**0040**] The front-end module section **4** includes a diplexer (DPX) **15** for separating signals whose frequencies are within the frequency band used in the GSM system and signals whose frequencies are within the frequency band used in the DCS system, a high-frequency switch (SW) **16** for switching between transmitted and received signals on the GSM system side, a high-frequency switch (SW) **17** for switching between transmitted and received signals on the DCS system side, low-pass filters (LPF) **18**, **19** connected to node points of the high-frequency switches **16**, **17** on the respective signal transmission sides, and SAW filters (SAW) **20**, **21** connected to node points of the high-frequency switches **16**, **17** on the respective signal reception sides. As explained later in detail, the diplexer **15**, the high-frequency switches **16**, **17**, the low-pass filters **18**, **19** and the SAW filters **20**, **21** are integrated as a single module.

[**0041**] The front-end module section **4** further includes an antenna terminal **22**, a GSM-side signal transmitting terminal **23**, a DCS-side signal transmitting terminal **24**, a GSM-side signal receiving terminal **25** and a DCS-side signal receiving terminal **26** as external terminals. The antenna terminal **22** is connected to an antenna node point of the diplexer **15**. The GSM-side signal transmitting terminal **23** is connected to the low-pass filter **18** and the DCS-side signal transmitting terminal **24** is connected to the low-pass filter **19**. The GSM-side signal receiving terminal **25** is connected to the SAW filter **20** and the DCS-side signal receiving terminal **26** is connected to the SAW filter **21**.

[**0042**] The power amplifier module section **5** includes a GSM-side power amplifier (GMSPA) **27** for amplifying transmitted signals on the GMS system side and a DCS-side power amplifier (DCSPA) **28** for amplifying transmitted signals on the DCS system side and as explained later in detail, the GSM-side power amplifier **27** and the DCS-side power amplifier **28** are integrated. The power amplifier module section **5** further includes as external terminals, input terminals **29**, **30** to which input signals to the GSM-side power amplifier **27** and the DCS-side power amplifier **28** are fed and output terminals **31**, **32** to which output signals from the GSM-side power amplifier **27** and the DCS-side power amplifier **28** are fed.

[**0043**] The synthesizer module section **6** includes a voltage-controlled oscillator (VCO) **33** for modulating audio signals in the GSM system and the like and a voltage-controlled oscillator (VCO) **34** for modulating audio signals and the like in the DCS system and, as explained later in detail, the voltage-controlled oscillator **33** and the voltage-controlled oscillator **34** are built in the main module. The synthesizer module section **6** further includes, as external terminals, input terminals **35**, **36** to which input signals to the voltage-controlled oscillator **33** and the voltage-controlled oscillator **34** are fed. As shown in **FIG. 1**, the input terminals **35**, **36** are connected to the base band circuit section **3**.

[**0044**] The LSI section **7** includes a GSM-side low-noise amplifier (LNA) **37** for amplifying received signals on the GSM system side, a DCS-side low-noise amplifier (LNA) **38** for amplifying received signals on the DCS system side, a GSM-side mixer (MIX) **39** for synthesizing an intermediate frequency signal based on the received signal on the GSM system side and a DCS-side mixer (MIX) **40** for synthesizing an intermediate frequency signal based on the received signal on the DCS system side. As explained later in detail, these are integrated in a single semiconductor chip. The LSI section **7** further includes, as external terminals, input terminals **41**, **42** to which input signals to the GSM-side low-noise amplifier **37** and the DCS-side low-noise amplifier **38** are fed, output terminals **43**, **44** to which output signals from the GSM-side low-noise amplifier **37** and the DCS-side low-noise amplifier **38** are fed, input terminals **45**, **46** to which input signals to the GSM-side mixer **39** and the DCS-side mixer **40** are fed, and output terminals **47**, **48** to which output signals from the GSM-side mixer **39** and the DCS-side mixer **40** are fed. As shown in **FIG. 1**, the output terminals **47**, **48** are connected to the base band circuit section **3**.

[**0045**] The SAW filter module section **8** includes a GSM-side SAW filter (SAW) **49** for extracting from among signals received on the GSM system side those that are in the desired frequency band (925 to 960 MHz), and a DCS-side SAW filter (SAW) **50** for extracting from among signals received on the DCS system side those that are in the desired frequency band (1805 to 1880 MHz) As explained later in detail, the GSM-side SAW filter **49** and the DCS-side SAW filter **50** are integrated as a single sub-module. The SAW filter module section **8** further includes, as external terminals, input terminals **52**, **53** to which input signals to the GSM-side SAW filter **49** and the DCS-side SAW filter **50** are fed, and output terminals **54**, **55** to which output signals from the GSM-side SAW filter **49** and the DCS-side SAW filter **50** are fed.

[**0046**] The output terminals mentioned in connection with the front-end module section **4**, the power amplifier module section **5**, the synthesizer module section **6**, the LSI section **7** and the SAW filter module section **8** are only primary output terminals included therein and other external terminals such as a power source terminal, various control terminals such as a control terminal for controlling the switching operation of the high-frequency switch **16** and the like are provided in addition to the above mentioned output terminals.

[**0047**] Further, the high-frequency module **1** includes an antenna terminal **56** connected to the antenna **2** and the impedance matching section **9** is connected to a point between the antenna terminal **56** and the antenna terminal **22** of the front-end module section **4** and serves to match the impedance of the antenna **2** and that of the front-end module section **4**.

[**0048**] Similarly, the impedance matching section **10** is connected to a point between the GMS-side signal transmitting terminal **23** and the DCS-side signal transmitting terminal **24** of the front-end module section **4** and the output terminals **31**, **32** of the power amplifier module section **5** and serves to match the impedance of the front-end module section **4** and that of the power amplifier module section **5**. The impedance matching section **11** is connected to a point

between the input terminals **29**, **30** of the power amplifier module section **5** and an output node point of the voltage-controlled oscillators **33**, **34** of the synthesizer module section **6** and serves to match the impedance of the power amplifier module section **5** and that of the synthesizer module section **6**. The impedance matching section **12** is connected to a point between the GMS-side signal receiving terminal **25** and the DCS-side signal receiving terminal **26** of the front-end module section **4** and the input terminals **41**, **42** of the LSI section **7** and serves to match the impedance of the front-end module section **4** and that of the LSI section **7**. The impedance matching section **13** is connected to a point between the output terminals **33**, **34** of the LSI section **7** and the input terminals **52**, **53** of the SAW filter module section **8** and serves to match the impedance of the LSI section **7** and that of the SAW filter module section **8**. The impedance matching section **14** is connected to a point between the input terminals **45**, **46** of the LSI section **7** and the output terminals **54**, **55** of the SAW filter module section **8** and serves to match the impedance of the LSI section **7** and that of the SAW filter module section **8**.

[**0049**] Next, explanation will be made regarding the concrete structure of the high-frequency module **1** according to this embodiment.

[**0050**] **FIG. 2** shows the structure of a main module **60** constituting the high-frequency module **1** according to this embodiment, wherein **FIG. 2**(*a*) is a plan view thereof, **FIG. 2**(*b*) is a cross sectional view taken along a line a-b in **FIG. 2**(*a*) and **FIG. 2**(*c*) is a cross sectional view taken along a line c-d in **FIG. 2**(*a*).

[**0051**] As shown in FIGS. **2**(*a*) to **2**(*c*), the main module **60** constituting the high-frequency module **1** according to this embodiment has a rectangular footprint measuring about 18 mm×about 20 mm and a thickness of about 2.0 mm. The main module **60** is consists of a multi-layered substrate constituted by laminating a plurality of resin substrates and formed with prescribed elements such as inductors and the like, a conductive pattern **74** constituting wiring and a through-hole electrode **75**, and various electronic components **76** such as diodes mounted on the multi-layered substrate. As shown in FIGS. **2**(*b*) and **2**(*c*), a part of the main module **60** measuring about 11 mm×about 10 mm constitutes the synthesizer module section **6**. The remainder of the main module **60** other than the synthesizer module section **6** is formed with first to fourth cavities **61** to **64**. A metal cap **77** is provided on the upper surface of the portion of the main module **60** constituting the synthesizer module section for blocking electromagnetic waves.

[**0052**] The first cavity **61** is a cavity into which a sub-module constituting the front-end module section **4** is inserted and has a footprint measuring 3.5 mm×8.5 mm and a depth of 0.6 mm. The second cavity **62** is a cavity into which a sub-module constituting the power amplifier module section **5** is inserted and has a footprint measuring 11.5 mm×8.5 mm and a depth of 0.6 mm. The third cavity **63** is a cavity into which a semiconductor chip package constituting the LSI section **7** is inserted and has a footprint measuring 5.5 mm×4.5 mm and a depth of 0.6 mm. The fourth cavity **64** is a cavity into which a sub-module constituting the SAW filter module section **8** is inserted and has a footprint measuring 3.5 mm×3.0 mm and a depth of 0.6 mm.

[**0053**] As shown in **FIG. 2**(*c*), a plurality of solder bumps **65** are provided on the bottom surface of the first cavity **61** and when the sub-module constituting the front-end module section **4** is inserted into the first cavity **61**, the external terminals of the sub-module such as the antenna terminal **22**, the GSM-side signal transmitting terminal **23**, the DCS-side signal transmitting terminal **24**, the GSM-side signal receiving terminal **25**, the DCS-side signal receiving terminal **26** and the like are electrically connected to the solder bumps **65**.

[**0054**] Similarly, as shown in **FIG. 2**(*b*), a plurality of solder bumps **66** are provided on the bottom surface of the second cavity **62** and when the sub-module constituting the power amplifier module section **5** is inserted into the second cavity **62**, the external terminals of the sub-module such as the input terminals **29**, **30**, the output terminals **31**, **32** and the like are electrically connected to the solder bumps **66**.

[**0055**] Similarly, as shown in **FIG. 2**(*c*), a plurality of solder bumps **67** are provided on the bottom surface of the third cavity **63** and when the semiconductor chip package constituting the LSI section **7** is inserted into the third cavity **63**, the external terminals of the semiconductor chip package such as the input terminals **41**, **42**, **45**, **46**, the output terminals **43**, **44**, **47**, **48** and the like are electrically connected to the solder bumps **67**.

[**0056**] Similarly, as shown in **FIG. 2**(*c*), a plurality of solder bumps **68** are provided on the bottom surface of the fourth cavity **64** and when the sub-module constituting the SAW filter module section **8** is inserted into the fourth cavity **64**, the external terminals of the sub-module such as the input terminals **52**, **53**, the output terminals **54**, **55** and the like are electrically connected to the solder bumps **68**.

[**0057**] Further, the rear surface of the main module **60** is formed with a plurality of external terminals **69** such as the antenna terminal **56** and the like and when the main module **60** is mounted on a mother board (not shown), the external terminals **69** are electrically connected to terminals provided on the mother board.

[**0058**] Furthermore, as shown in FIGS. **2**(*b*) and **2**(*c*), the impedance matching sections **9** to **14** formed using conductive patterns **74** are built in the main module **60** in addition to the synthesizer module section **6**. In FIGS. **2**(*b*) and **2**(*c*), only the impedance matching sections **11** and **13** are shown.

[**0059**] **FIG. 3** is a circuit diagram showing one example of the circuit configuration of the voltage-controlled oscillator **33** and a part of the impedance matching section **11** constituting the synthesizer module section **6**.

[**0060**] As shown in **FIG. 3**, the voltage-controlled oscillator **33** includes a voltage variable resonant circuit **71**, an oscillation circuit **72** and an output amplifying circuit **73**. A control voltage and modulation signal are fed to the voltage variable resonant circuit **71** from the base band circuit section **3** via the input terminals **35** (**35-1** and **35-2**), and the oscillation circuit **72** and the output amplifying circuit **73** generate a modulation signal as output based on an output signal supplied from the voltage variable resonant circuit **71** and power-supply voltage supplied from the power supply terminal **70**. The output of the output amplifying circuit **73** is fed to the impedance matching section **11** and the output of the impedance matching section **11** is fed to the solder bumps **66**. As described above, since the solder bumps **66**

are electrodes formed on the bottom surface of the second cavity **62**, the external terminals (input terminals) of the sub-module constituting the power amplifier module **5** are electrically connected to the solder bumps **66** when the sub-module is inserted into the second cavity **62**.

[**0061**] The voltage-controlled oscillator **34** constituting the synthesizer module section **6** has the same circuit configuration as that of the voltage-controlled oscillator **33** shown in **FIG. 4** and the output thereof is fed to the impedance matching section **11** similarly to that of the voltage-controlled oscillator **33**.

[**0062**] As shown in FIGS. **2**(*a*) and **2**(*b*), a part of the voltage-controlled oscillator **33** and the voltage-controlled oscillator **34** having such circuit configurations are constituted as conductive patterns provided inside of the main module **60** and remaining portions thereof are constituted as electronic components mounted on the upper surface of the main module **60**. As a result, the synthesizer module section **6** and the impedance matching sections **9** to **11** are integrated with the main module **60** and other sections such as the front-end module section **4** and the like are constituted so as to be insertable into the main module **60**.

[**0063**] In this manner, since only the synthesizer module section **6** and the impedance matching sections **9** to **11** are integrated with the main module **60**, the production yield of the main module **60** becomes the same as that of the synthesizer module section **6**.

[**0064**] **FIG. 4**(*a*) is a schematic perspective view showing the rear surface of a sub-module for constituting the front-end module section **4** and **FIG. 4**(*b*) is a cross sectional view thereof.

[**0065**] As shown in FIGS. **4**(*a*) and **4**(*b*), the sub-module **80** constituting the front-end module section **4** has a rectangular footprint measuring about 3.0 mm×about 8.0 mm and a thickness of about 1.5 mm. The sub-module **80** is consists of a multi-layered substrate constituted of a plurality of laminated ceramic substrates and formed with conductive patterns **81** and a through-hole electrode **82** that form prescribed elements and wiring therein, and various electronic components **83** mounted on the multi-layered substrate. A metal cap **84** for blocking electromagnetic waves is provided on the upper surface of the multi-layered substrate.

[**0066**] As shown in **FIG. 4**(*a*), the ceramic substrates constituting the sub-module **80** include two kinds of ceramic substrates having different dielectric constants. The ceramic substrates having a high dielectric constant ϵr, for example, $\epsilon r=11$, are disposed at an upper layer portion and a lower layer portion, and conductive patterns **81** on these ceramic substrates mainly constitute capacitor electrodes. On the other hand, the ceramic substrates having a low dielectric constant ϵr, for example, $\epsilon r=5$, are disposed at an intermediate layer portion and conductive patterns **81** on these ceramic substrates mainly constitute inductor electrodes.

[**0067**] On the rear surface of the sub-module **80**, a plurality of external electrodes **85** are provided so as to constitute the antenna terminal **22**, the GSM-side signal transmitting terminal **23**, the DCS-side signal transmitting terminal **24**, the GSM-side signal receiving terminal **25**, the DCS-side signal receiving terminal **26** and the like, and the planar configuration of the external electrodes **85** corresponds to that of the solder bumps **65** provided on the bottom surface of the first cavity **61**. Therefore, as described above, when the sub-module **80** is inserted into the first cavity **61**, these external electrodes **85** and the solder bumps **65** are electrically connected.

[**0068**] The sub-module **80** for constituting the front-end module section **4** is designed and manufactured independently of the main module **60** and is inspected independently of the main module **60** before being inserted into the first cavity **61**. Therefore, the yield of the sub-module **80** is substantially independent of that of the main module **60**.

[**0069**] **FIG. 5**(*a*) is a schematic perspective view showing the rear surface of a sub-module for constituting the power amplifier module section **5** and **FIG. 5**(*b*) is a cross sectional view thereof.

[**0070**] As shown in FIGS. **5**(*a*) and **5**(*b*), the sub-module **90** constituting the power amplifier module section **5** has a rectangular footprint measuring about 11.0 mm×about 8.0 mm and a thickness of about 1.5 mm. The sub-module **90** consists of a multi-layered substrate constituted of a plurality of laminated resin substrates and formed with conductive patterns **91** and a through-hole electrode **92** forming predetermined elements and wiring therein, a semiconductor chip (MMIC) **93** embedded in the multi-layered substrate, and various electronic components **94** mounted on the multi-layered substrate. A metal cap **95** for blocking electromagnetic waves is provided on the upper surface of the multi-layered substrate. As the resin substrates for constituting the sub-module **90**, the same kind of the resin substrates as those for constituting the main module **60** may be used or different kind of resin substrates or resin substrates having different dielectric constants from those for constituting the main module **60** may be used.

[**0071**] Further, the rear surface of the sub-module **90** is formed with a plurality of external electrodes **96** for constituting the input terminals **29**, **30**, the output terminals **31**, **32** and the like and a radiator electrode **97** for radiating heat generated by the semiconductor chip **93**. The planar configuration of the external electrodes **96** corresponds to that of the solder bumps **66** provided on the bottom surface of the second cavity **62**. Therefore, as described above, when the sub-module **90** is inserted into the second cavity **62**, these external electrodes **96** and the solder bumps **66** are electrically connected.

[**0072**] The sub-module **90** for constituting the power amplifier module section **5** is designed and manufactured independently of the main module **60** and is inspected independently of the main module **60** before being inserted into the second cavity **62**. Therefore, the yield of the sub-module **90** is substantially independent of that of the main module **60**.

[**0073**] **FIG. 6** is a schematic perspective view showing the rear surface of a semiconductor chip package for constituting the LSI section **7**.

[**0074**] As shown in **FIG. 6**, the semiconductor chip package **100** constituting the LSI section **7** has a rectangular footprint measuring about 5.0 mm×about 4.0 mm and a thickness of about 5.0 mm. The semiconductor chip package **100** is a package obtained by plastic molding a semiconductor chip that integrates circuits for accomplishing the functions of the DSM-side low noise amplifier **37**, the

DCS-side low noise amplifier **38**, the DSM-side mixer **39**, the DCS-side mixer **40** and the like. A plurality of external electrodes **101** are provided array-like on the rear surface of the semiconductor chip package **100** so as to constitute the input terminals **41**, **42**, **45**, **46**, the output terminals **43**, **44**, **47**, **48** and the like. The planar configuration of the external electrodes **101** corresponds to that of the solder bumps **67** provided on the bottom surface of the third cavity **63**. Therefore, as described above, when the semiconductor chip package **100** is inserted into the third cavity **63**, these external electrodes **101** and the solder bumps **67** are electrically connected.

[**0075**] Similarly to the sub-modules **80** and **90**, the semiconductor chip package **100** for constituting the LSI section **7** is designed and manufactured independently of the main module **60** and is inspected independently of the main module **60** before being inserted into the third cavity **63**. Therefore, the yield of the semiconductor chip package **100** is substantially independent of those of the main module **60** and the sub-modules **80** and **90**. In this specification, the semiconductor chip package **100** is sometimes called a "sub-module" and this term is used to conceptually include the semiconductor chip package **100**.

[**0076**] **FIG. 7**(*a*) is a schematic perspective view showing the rear surface of a sub-module for constituting the SAW filter module section **8** and **FIG. 7**(*b*) is a cross sectional view thereof.

[**0077**] As shown in FIGS. **7**(*a*) and **7**(*b*), the sub-module **110** constituting the SAW filter module section **7** has a rectangular footprint measuring about 3.0 mm×about 2.5 mm and a thickness of about 1.0 mm. The sub-module **110** consists of a multi-layered ceramic base formed with conductive patterns **111** and a through-hole electrode **112** therein, the SAW filters **20**, **21**, and a sealing cap **113**. The SAW filters **20**, **21** are air-tightly sealed by the sealing cap **113**.

[**0078**] A plurality of external electrodes **115** are provided on the rear surface of the sub-module **110** for constituting the input terminals **52**, **53**, the output terminals **54**, **55** and the like, and the planar configuration of the external electrodes **115** correspond to that of the solder bumps **68** provided on the bottom surface of the fourth cavity **64**. Therefore, as described above, when the sub-module **110** is inserted into the fourth cavity **64**, these external electrodes **115** and the solder bumps **68** are electrically connected.

[**0079**] Similarly to the sub-modules **80**, **90** and the semiconductor chip package **100**, the sub-module **110** for constituting the SAW filter module section **8** is designed and manufactured independently of the main module **60** and is inspected independently of the main module **60** before being inserted into the fourth cavity **64**. Therefore, the yield of the sub-module **110** is substantially independent of those of the main module **60**, the sub-modules **80**, **90** and the semiconductor chip package **100**.

[**0080**] The high-frequency module **1** is completed by inserting the sub-module **80**, the sub-module **90**, the semiconductor chip package **100** and the sub-module **110** into the first to fourth cavities **61** to **64** and establishing electrical connection. The sub-module **80**, the sub-module **90**, the sub-module **110** and the semiconductor chip package **100** can be easily handled by grasping the metal caps **84**, **95** and **115** provided at the upper portions of the sub-module **80**, the sub-module **90** and the sub-module **110** and the surface of the semiconductor chip package **100**. After sub-modules have been inserted, the solder bumps **65** to **68** provided on the bottom surfaces of the first to fourth cavity **61** to **64** are once melted by reflow soldering, whereby the electrical and mechanical connection between the solder bumps **65** to **68** and the corresponding external electrodes **85**, **96**, **101**, **115** is established.

[**0081**] **FIG. 8** shows the structure of the high-frequency module **1** fabricated by inserting the sub-module **80**, the sub-module **90**, the semiconductor chip package **100** and the sub-module **110** into the first to fourth cavities **61** to **64** formed in the main module **60**, wherein **FIG. 8**(*a*) is a plan view of the high-frequency module **1** and **FIG. 8**(*b*) is a cross sectional view taken along a line a-b in **FIG. 8**(*a*).

[**0082**] As shown in **FIG. 8**, when the sub-module **80**, the sub-module **90**, the semiconductor chip package **100** and the sub-module **110** have been inserted into the first to fourth cavities **61** to **64** and the electrical and mechanical connection has been established, the main module **60** can be handled as a large scale module having all functions of the high-frequency module **1** shown in **FIG. 1**.

[**0083**] Thus, although the high-frequency module **1** according to the above described embodiment is a large scale module including the front-end module section **4**, the power amplifier module section **5**, the synthesizer module section **6**, the LSI section **7**, the SAW filter module section **8** and the impedance matching sections **11** to **14**, only some of the circuits, namely, only the synthesizer module section **6** and the impedance matching sections **11** to **14** are integrated with or built in the main module **60** as the main body and the remaining circuits, namely, the front-end module section **4**, the power amplifier module section **5**, the LSI section **7** and the SAW filter module section **8** are inserted into the main module **60** as sub-modules. Therefore, since the high-frequency module **1** can be fabricated using only sub-modules inspected after manufacture and found to be good, the production yield of the high-frequency module **1** can be markedly increased.

[**0084**] Further, in the high-frequency module **1** according to the above described embodiment, since the sub-module **80**, the sub-module **90**, the main module **60**, the semiconductor chip package **100** and the sub-module **110** constituting the front-end module section **4**, the power amplifier module section **5**, the synthesizer module section **6**, the LSI section **7** and the SAW filter module section **8** are separate components, it is possible when the characteristics of some of these circuits needs to be changed to implement the required changes by redesigning only the corresponding sub-modules. The general utility of the high-frequency module **1** is therefore improved.

[**0085**] Moreover, in the high-frequency module **1** according to the above described embodiment, since the wiring for interconnecting the front-end module section **4**, the power amplifier module section **5**, the LSI section **7** and the SAW filter module section **8** and the impedance matching sections **11** to **14** are built in the main module **60** together with the synthesizer module section **6**, it is unnecessary to provide the wiring and the impedance matching sections on the mother board. Therefore, the area required for mounting the components can be markedly reduced in comparison with

the case where components such as the front-end module section **4** and the like are individually mounted on the mother board.

[**0086**] Furthermore, since the external electrodes **85**, **96**, **101**, **115** of the sub-module **80**, the sub-module **90**, the semiconductor chip package **100** and the sub-module **110** are provided on the bottom surfaces thereof, the inner dimensions of each of the first to fourth cavities **61** to **64** can be determined so as to be the substantially same as those of the corresponding one of the sub-module **80**, the sub-module **90**, the semiconductor chip package **100** and the sub-module **110**. Therefore, the planar size of the main module **60** can be minimized.

[**0087**] Next, explanation will be made regarding another preferred embodiment of the present invention.

[**0088**] **FIG. 9** shows the structure of a high-frequency module which is another embodiment of the present invention, wherein **FIG. 9**(*a*) is a plan view thereof and **FIG. 9**(*b*) is a cross sectional view taken along a line e-f in **FIG. 9**(*a*).

[**0089**] The high-frequency module **120** according to this embodiment is different from the high-frequency module in the above described embodiment in the method for connecting each of the sub-modules **80**, **90** and **110** and the semiconductor chip package **100** with the main module **60**.

[**0090**] Specifically, as shown in **FIG. 9**, in the high-frequency module **120** according to this embodiment, an anisotropic sheet **121** is disposed at connections between the main module **60**, and the sub-modules **80**, **90**, **110** and the semiconductor chip package **100** and the main module **60**, and the sub-modules **80**, **90**, **110** and the semiconductor chip package **100** are electrically connected via the anisotropic sheet **121**.

[**0091**] **FIG. 10**(*a*) is a plan view schematically showing the anisotropic sheet **121** and **FIG. 10**(*b*) is a cross sectional view taken along a line g-h in **FIG. 10**(*a*).

[**0092**] As shown in FIGS. **10**(*a*) and **10**(*b*), the anisotropic sheet **121** is constituted by forming a number of through holes **123** in an insulating film **122** having a thickness of about 0.2 mm so that they pass through from one side to the other side of the insulating film **122**. The diameter of each of the through holes **123** and the distance between neighboring through holes **123** are respectively set to be sufficiently smaller than the diameter of the corresponding one of the external electrodes **85**, **96**, **101**, **115** of the sub-modules **80**, **90**, the semiconductor chip package **100** and the sub-module **110** and the distance between neighboring external electrodes **85**, **96**, **101**, **115** thereof. Conductive material **124** is charged in each of the through-holes **123** and electric conductivity from one side to the other side of the anisotropic sheet **121** is established by the conductive material **124** continuously charged in each of the through holes **123** from one side to the other side of the anisotropic sheet **121**. The conductive material **124** is not particularly limited but gold is preferably used.

[**0093**] On the other hand, since the insulating film **122** that is the main body of the anisotropic sheet **121** is formed of an insulating material, the anisotropic sheet **121** performs as an insulator in the planar direction thereof. Therefore, the anisotropic sheet **121** has conductivity in the thickness direction thereof and an insulation property in the planar direction thereof.

[**0094**] Further, as shown in **FIG. 9**(*b*), in this embodiment, no metal cap is provided in the sub-module **90** and a metal plate **127** placed on the sub-module **90** via a fixed pad **126** after the sub-module **90** has been inserted into the second cavity **62** serves as the metal cap of the previous embodiment. Specifically, after the sub-module **90** has been inserted into the second cavity **62**, the fixed pad **126** is placed on the upper surface portion of the sub-module **90** and the second cavity **62** is then blocked by the metal plate **127**. At this time, ground potential is applied to the metal plate **127**, because a ground pattern is formed at the part of the upper surface portion of the main module **60** that makes contact with the end portion of the metal plate **127**. The sub-modules **80**, **110** are similarly constituted.

[**0095**] The metal plate **127** and the ground pattern are connected via the anisotropic sheet **121** by using the metal plate **127** to apply pressure to the sub-modules **80**, **90**, **110** via the fixed pad **126** and fixing the end portion of the metal plate **127** and the ground pattern formed at the upper surface portion of the main module **60** with solder or the like. As a result, the main module **60** and each of the sub-modules **80**, **90**, **110** are connected by pressure bonding via the anisotropic sheet **121**, thereby establishing electrical connection.

[**0096**] According to this embodiment, since the main module **60**, and the sub-modules **80**, **90**, the semiconductor chip package **100** and the sub-module **110** are connected via the anisotropic sheet **121**, it is unnecessary to form the solder bumps **65** to **68** on the bottom surfaces of the first to fourth cavities **61** to **64**. Further, since the main module **60**, and the sub-modules **80**, **90**, the semiconductor chip package **100** and the sub-module **110** are not soldered, any defective component discovered can be easily replaced even after the sub-modules **80**, **90**, the semiconductor chip package **100** and the sub-module **110** have been inserted into the first to fourth cavities **61** to **64** and sealed with the metal plates **127**.

[**0097**] Further, according to this embodiment, the first to fourth cavities are blocked by the metal plates **127** so as to substantially air-tight seal the sub-modules **80**, **90**, the semiconductor chip package **100** and the sub-module **110** and thus prevent entry of foreign substances.

[**0098**] The present invention has thus been shown and described with reference to specific embodiments. However, it should be noted that the present invention is in no way limited to the details of the described arrangements but changes and modifications may be made without departing from the scope of the appended claims.

[**0099**] For example, in each of the high-frequency modules **1** and **120** according to the above described embodiments, the synthesizer module section **6** is built in the main module **60** and each of the front-end module section **4**, the power amplifier module section **5**, the synthesizer module section **6**, the LSI section **7** and the SAW filter module section **8** is constituted as an independent sub-module or semiconductor chip package. However, the circuit section to be built in the main module **60** is not limited to the synthesizer module section **6** and some other circuit section may instead be built in the main module **60**. Still, since the size of the main module **60** is larger than those of the sub-modules and the semiconductor chip package, it is preferable from the viewpoint of reducing the total weight of the high-frequency module **1**, **120** to form the main module **60** of a light material such as resin and it is therefore

preferable to select as the circuit section to be built in the main module **60** one that can be built in the multi-layered substrate formed of resin or the like.

[**0100**] Further, two or more circuit sections selected from among the front-end module section **4**, the power amplifier module section **5**, the synthesizer module section **6**, the LSI section **7** and the SAW filter module section **8** may be built in the main module **60**. If two or more circuit sections are built in the main module **60**, the total size of the high-frequency module **1**, **120** can be reduced but there is a risk of the production yield being lowered. Therefore, it is preferable to determine the number of circuit sections built in the main module **60** based upon the required size and yield.

[**0101**] Moreover, in each of the high-frequency modules **1** and **120** according to the above described embodiments, although all impedance matching sections **11** to **14** are built in the multi-layered substrate constituting the main module **60**, it is not absolutely necessary to build all impedance matching sections **11** to **14** in the multi-layered substrate constituting the main module **60** and some or all of them may be constituted as electronic components mounted on the upper surface of the main module **60**.

[**0102**] Furthermore, in the high-frequency module **1** according to the above described embodiment, although the solder bumps **65** to **68** are provided on the bottom surfaces of the first to fourth cavities **61** to **64**, the solder bumps **65** to **68** may be provided on the sides of the sub-modules or the semiconductor chip package to be inserted into the first to fourth cavities **61** to **64** instead of providing them on the sides of the first to fourth cavities **61** to **64**.

[**0103**] As described above, according to the present invention, since some circuit sections among a plurality of circuit sections for constituting a high-frequency module are built in a main module and other circuit sections are constituted as a sub-module or semiconductor chip package so as to be insertable into cavities formed in the main module, it is possible to prevent decrease the production yield of a high-frequency module including a number of circuit sections and to improve the general utility of the high-frequency module.

1. A high-frequency module comprising a main module including a first high-frequency circuit at least a part of which is constituted by a conductive pattern built in a multi-layered substrate and a sub-module including a second high-frequency circuit, the sub-module being inserted into a cavity formed in the main module.

2. A high-frequency module in accordance with claim 1, wherein the first high-frequency circuit is constituted by the conductive pattern built in the multi-layered substrate and electronic components mounted on the multi-layered substrate.

3. A high-frequency module in accordance with claim 1, wherein the sub-module is constituted using a multi-layered substrate.

4. A high-frequency module in accordance with claim 3, wherein the multi-layered substrate of the main module and the multi-layered substrate of the sub-module are made of different materials.

5. A high-frequency module in accordance with claim 1, wherein the multi-layered substrate of the main module is constituted as a laminate including a plurality of resin substrates.

6. A high-frequency module in accordance with claim 3, wherein the multi-layered substrate of the sub-module is constituted as a laminate including a plurality of ceramic substrates.

7. A high-frequency module in accordance with claim 5, wherein the multi-layered substrate of the sub-module is constituted as a laminate including a plurality of ceramic substrates.

8. A high-frequency module in accordance with claim 1, wherein a plurality of electrodes provided on a bottom surface of the cavity of the main module and a plurality of electrodes provided on a bottom surface of the sub-module are electrically connected.

9. A high-frequency module in accordance with claim 8, wherein the plurality of electrodes provided on the bottom surface of the cavity of the main module and the plurality of electrodes provided on the bottom surface of the sub-module are electrically connected by solder.

10. A high-frequency module in accordance with claim 8, wherein the plurality of electrodes provided on the bottom surface of the cavity of the main module and the plurality of electrodes provided on the bottom surface of the sub-module are electrically connected via an anisotropic conductive sheet.

11. A high-frequency module in accordance with claim 1, wherein an upper portion of the cavity into which the sub-module is inserted is covered by a metal plate.

12. A high-frequency module in accordance with claim 10, wherein an upper portion of the cavity into which the sub-module is inserted is covered by a metal plate.

13. A high-frequency module in accordance with claim 11, wherein the metal plate is connected to a ground pattern formed on an upper surface of the main module.

14. A high-frequency module in accordance with claim 12, wherein the metal plate is connected to a ground pattern formed on an upper surface of the main module.

15. A high-frequency module in accordance with claim 1, wherein an impedance matching section is further built in the multi-layered substrate of the main module for matching impedance of the first high-frequency circuit and that of the second high-frequency circuit.

16. A high-frequency module in accordance with claim 1, wherein the first high-frequency circuit is constituted as at least one circuit selected from a group consisting of a front-end module section, a power amplifier module section, a synthesizer module section, an LSI section and a SAW filter module section.

17. A high-frequency module in accordance with claim 16, wherein the second high-frequency circuit is constituted as at least one circuit selected from the group consisting of a front-end module section, a power amplifier module section, a synthesizer module section, an LSI section and a SAW filter module section and other than the circuit constituting the first high-frequency circuit.

18. A high-frequency module comprising a first cavity and a second cavity constituted so that a first sub-module and a second sub-module can be inserted therein, prescribed high-frequency circuits integrated therewith and an impedance matching circuit built therein for matching impedance of the first sub-module and that of the second sub-module.

19. A high-frequency module in accordance with claim 18, wherein an impedance matching circuit is further built in the high-frequency module for matching impedance of the high-frequency circuit and that of the first sub-module.

20. A high-frequency module wherein a first circuit selected from a group consisting of a front-end module section, a power amplifier module section, a synthesizer module section, an LSI section and a SAW filter module section and a second circuit selected from the group and other than the first circuit are integrated and at least one of the first circuit and the second circuit is constituted to be detachable.

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