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Radio frequency module and communication device

Abstract

Isolation between a first path and a second path is improved. A radio frequency module is capable of operating in a first mode in which simultaneous transmission, simultaneous reception, or simultaneous transmission and reception using both a first filter and a second filter is possible, and in a second mode in which transmission or reception using only the first filter is possible. A first switching element is provided in a first path that is usable between an antenna terminal and the first filter in the first mode, and a second switching element is provided between the first path and a ground. A third switching element is provided in a second path that is usable between the antenna terminal and the first filter in the second mode, and a fourth switching element is provided between the second path and the ground. The radio frequency module further includes a phase shifter.

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Background/Summary

CROSS REFERENCE TO RELATED APPLICATION (1) This is a continuation of International Application No. PCT/JP2021/033403 filed on Sep. 10, 2021 which claims priority from Japanese Patent Application No. 2020-184587 filed on Nov. 4, 2020. The contents of these applications are incorporated herein by reference in their entireties.

BACKGROUND ART

Technical Field

(1) The present disclosure generally relates to a radio frequency module and a communication device, and more particularly, to a radio frequency module including multiple filters and a communication device including the radio frequency module.

(2) Patent Document 1 discloses a radio frequency module including multiple filters, a switch, and a variable phase shifter.

(3) The multiple filters include a first filter and a second filter. The first filter arrows a signal in a first frequency band to pass through. The second filter arrows a signal in a second frequency band to pass through. The switch electrically connects only the first filter to an antenna in a single mode in which only a signal in the first frequency band is communicated. The switch electrically connects the first filter, the second filter, and the variable phase shifter to the antenna in a carrier aggregation mode in which a signal in the first frequency band and a signal in the second frequency band are simultaneously communicated. Patent Document 1: International Publication No. 2019/187744

BRIEF SUMMARY

(4) In a radio frequency module, in a case that a switch separates a first path through which a signal of a first frequency band passes in a first mode such as a single mode, and a second path through which a signal of the first frequency band passes in a second mode such as a carrier aggregation mode, for example, it is desirable to improve isolation between the first path and the second path.

(5) The present disclosure provides a radio frequency module and a communication device capable of improving the isolation between a first path and a second path.

(6) A radio frequency module according to an aspect of the present disclosure includes an antenna terminal, a first filter, a second filter, and a switch circuit. The first filter is a filter having a pass band of a first frequency band. The second filter is a filter having a pass band of a second frequency band different from the first frequency band. The switch circuit is connected between the antenna terminal and the first filter. The radio frequency module is capable of operating in a first mode in which simultaneous transmission, simultaneous reception, or simultaneous transmission and reception using both the first filter and the second filter is possible, and in a second mode in which transmission or reception using only the first filter out of the first filter and the second filter is possible. The switch circuit includes a first switching element, a second switching element, a third switching element, and a fourth switching element. The first switching element is provided in a first path that is usable between the antenna terminal and the first filter in the first mode. The second switching element is provided between the first path and a ground. The third switching element is provided in a second path that is usable between the antenna terminal and the first filter in the second mode. The fourth switching element is provided between the second path and the ground. The radio frequency module further includes a phase shifter. The phase shifter is provided in at least one of the first path and the second path, and changes a phase of a radio frequency signal.

(7) A radio frequency module according to an aspect of the present disclosure includes an antenna terminal, a first filter, a second filter, and a switch circuit. The first filter is a filter having a pass band of a first frequency band. The second filter is a filter having a pass band of a second frequency band different from the first frequency band. The switch circuit is connected between the antenna terminal and the first filter. The radio frequency module is capable of operating in a first mode in which simultaneous transmission, simultaneous reception, or simultaneous transmission and reception using both the first filter and the second filter is possible, and in a second mode in which transmission or reception using only the first filter out of the first filter and the second filter is possible. The radio frequency module includes a first switching element, a second switching element, and a third switching element. The first switching element is provided in a first path that is usable between the antenna terminal and the first filter in the first mode. The second switching

element is provided in a second path that is usable between the antenna terminal and the first filter in the second mode. The third switching element is provided between a ground and a common path of the first path and the second path. The radio frequency module further includes a phase shifter. The phase shifter is provided in at least one of the first path and the second path, and changes the phase of a radio frequency signal.
(8) A communication device according to an aspect of the present disclosure includes the radio frequency module according to the aspect described above and a signal processing circuit. The signal processing circuit is connected to the radio frequency module.
(9) In the radio frequency module according to the aspects described above and the communication device according to the aspect described above of the present disclosure, it is possible to improve the isolation between a first path and a second path.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
(1) FIG. **1** is a circuit diagram of a radio frequency module according to Embodiment 1 and a communication device including the radio frequency module.
(2) FIG. **2** is a circuit diagram of the radio frequency module according to Embodiment 1.
(3) FIG. **3** is a circuit diagram of the radio frequency module according to Embodiment 1.
(4) FIG. **4**A to FIG. **4**C are explanatory diagrams of the operation of the radio frequency module according to Embodiment 1.
(5) FIG. **5** is a sectional view of the radio frequency module according to Embodiment 1.
(6) FIG. **6** is a circuit diagram of a radio frequency module according to a modification of Embodiment 1.
(7) FIG. **7** is a circuit diagram of a radio frequency module according to Embodiment 2.
(8) FIG. **8** is a circuit diagram of a radio frequency module according to Embodiment 3.
(9) FIG. **9** is a circuit diagram of a radio frequency module according to Embodiment 4.
(10) FIG. **10** is a circuit diagram of a radio frequency module according to Embodiment 5.
(11) FIG. **11** is a circuit diagram of the radio frequency module according to Embodiment 5.
(12) FIG. **12** is a sectional view of the radio frequency module according to Embodiment 5.
(13) FIG. **13** is a sectional view of a radio frequency module according to a modification of Embodiment 5.
(14) FIG. **14** is a circuit diagram of a radio frequency module according to Embodiment 6.
(15) FIG. **15**A to FIG. **15**C are explanatory diagrams of the operation of the radio frequency module according to Embodiment 6.
DESCRIPTION OF EMBODIMENTS
(16) FIG. **5**, FIG. **12**, and FIG. **13** referred to in the following embodiments and the like are all schematic views, and a ratio of each of sizes and thicknesses of constituents in the drawings does not necessarily reflect an actual dimensional ratio.
Embodiment 1
(17) Hereinafter, a radio frequency module **1** and a communication device **300** according to Embodiment 1 will be described with reference to FIG. **1** to FIG. **5**.
(1) Radio Frequency Module and Communication Device
(18) (1.1) Circuit Configuration of Radio Frequency Module and Communication Device
(19) A circuit configuration of the radio frequency module **1** and the communication device **300** according to Embodiment 1 will be described with reference to FIG. **1** to FIG. **3**.
(20) The radio frequency module **1** according to Embodiment 1 is used in the communication device **300**, for example. The communication device **300** is a mobile phone (smartphone, for example), for example, but is not limited thereto, and may be a wearable terminal (smart watch, for

example) or the like, for example. The radio frequency module **1** is a module capable of dealing with the 4th Generation Mobile Communication (4G) standard and the 5th Generation Mobile Communication (5G) standard, for example. The 4G standard is the Third Generation Partnership Project (3GPP) Long Term Evolution (LTE) standard, for example. The 5G standard is 5G New Radio (NR), for example. The radio frequency module **1** is a module capable of dealing with carrier aggregation and dual connectivity.

(21) The radio frequency module **1** is configured to be able to amplify a transmission signal inputted from a signal processing circuit **301** and to output the amplified transmission signal to an antenna **310**, for example. Further, the radio frequency module **1** is configured to be able to amplify a reception signal inputted from the antenna **310** and to output the amplified reception signal to the signal processing circuit **301**. The signal processing circuit **301** is not a constituent of the radio frequency module **1**, but a constituent of the communication device **300** including the radio frequency module **1**. The radio frequency module **1** according to Embodiment 1 is controlled by the signal processing circuit **301** included in the communication device **300**, for example. The communication device **300** includes the radio frequency module **1** and the signal processing circuit **301**. The communication device **300** further includes the antenna **310**.

(22) The signal processing circuit **301** includes an RF signal processing circuit **302** and a baseband signal processing circuit **303**, for example. The RF signal processing circuit **302** is a Radio Frequency Integrated Circuit (RFIC), for example, and performs signal processing on a radio frequency signal. The RF signal processing circuit **302** performs signal processing such as up-conversion on a radio frequency signal (transmission signal) outputted from the baseband signal processing circuit **303**, and outputs the radio frequency signal subjected to the signal processing, for example. Further, the RF signal processing circuit **302** performs signal processing such as down-conversion on a radio frequency signal (reception signal) outputted from the radio frequency module **1**, and outputs the radio frequency signal subjected to the signal processing to the baseband signal processing circuit **303**, for example. The baseband signal processing circuit **303** is a Baseband Integrated Circuit (BBIC), for example. The baseband signal processing circuit **303** generates an I-phase signal and a Q-phase signal from a baseband signal. The baseband signal is an audio signal, an image signal, or the like inputted from the outside, for example. The baseband signal processing circuit **303** performs IQ modulation processing by combining the I-phase signal and the Q-phase signal, and outputs a transmission signal. At this time, the transmission signal is generated as a modulated signal (IQ signal) subjected to amplitude modulation of a carrier signal of a predetermined frequency with a period longer than the period of the carrier signal. The reception signal processed by the baseband signal processing circuit **303** is used as an image signal for image display, or as an audio signal for a call of a user of the communication device **300**, for example. The radio frequency module **1** transfers a radio frequency signal (reception signal and transmission signal) between the antenna **310** and the RF signal processing circuit **302** of the signal processing circuit **301**.

(23) The radio frequency module **1** according to Embodiment 1 includes an antenna terminal **80**, a first filter **21**, a second filter **22**, and a switch circuit **31** as illustrated in FIG. **2**. The antenna terminal **80** is connected to the antenna **310** (see FIG. **1**). The first filter **21** is a filter having a pass band of a first frequency band. The second filter **22** is a filter having a pass band of a second frequency band different from the first frequency band. The switch circuit **31** is connected between the antenna terminal **80** and the first filter **21**. The radio frequency module **1** is capable of operating in a first mode in which simultaneous transmission, simultaneous reception, or simultaneous transmission and reception using both the first filter **21** and the second filter **22** is possible, and in a second mode in which transmission or reception using only the first filter **21** out of the first filter **21** and the second filter **22** is possible. The first mode is a mode in which a radio frequency signal in the first frequency band and a radio frequency signal in the second frequency band are simultaneously communicated (simultaneous transmission, simultaneous reception, or

simultaneous transmission and reception). The second mode is a mode in which only a radio frequency signal in the second frequency band is communicated. The switch circuit **31** includes a first switching element Q**1**, a second switching element Q**2**, a third switching element Q**3**, and a fourth switching element Q**4**. The first switching element Q**1** is provided in a first path r**11** that is usable between the antenna terminal **80** and the first filter **21** in the first mode. The second switching element Q**2** is provided between the first path r**11** and a ground. The third switching element Q**3** is provided in a second path r**12** that is usable between the antenna terminal **80** and the first filter **21** in the second mode. The fourth switching element Q**4** is provided between the second path r**12** and the ground. The radio frequency module **1** further includes a phase shifter **7**. The phase shifter **7** is provided in the first path r**11**.

(24) Hereinafter, the circuit configuration of the radio frequency module **1** will be described in more detail based on FIG. **1** to FIG. **3**.

(25) The first filter **21** is a duplexer including a transmission filter **211** and a reception filter **212**, for example. The first frequency band which is the pass band of the first filter **21** includes a transmission band of a first communication band and a reception band of the first communication band, for example. A pass band of the transmission filter **211** includes the transmission band of the first communication band, for example. A pass band of the reception filter **212** includes the reception band of the first communication band, for example. The second filter **22** is a duplexer including a transmission filter **221** and a reception filter **222**, for example. The second frequency band which is the pass band of the second filter **22** includes a transmission band of a second communication band and a reception band of the second communication band, for example. A pass band of the transmission filter **221** includes the transmission band of the second communication band. A pass band of the reception filter **222** includes the reception band of the second communication band. The first communication band is Band8, Band5, or Band1 of the 3GPP LTE standard, for example. When the first communication band is Band8, the second communication band is any one of Band20 and Band28A/Band28B of the 3GPP LTE standard, and n20 and n28A of 5G NR, for example. When the first communication band is Band5, the second communication band is any one of Band12 and Band13 of the 3GPP LTE standard, and n12 of 5G NR, for example. When the first communication band is Band1, the second communication band is any one of Band3 and Band1 of the 3GPP LTE standard, and n3 and n7 of 5G NR.

(26) Further, the radio frequency module **1** according to Embodiment 1 further includes a second switch circuit **32** in addition to a first switch circuit **31** being the switch circuit **31**, as illustrated in FIG. **2**. The second switch circuit **32** is connected between the antenna terminal **80** and the second filter **22**. The second switch circuit **32** includes a fifth switching element Q**5** and a sixth switching element Q**6**. The fifth switching element Q**5** is provided in a signal path r**2** between the antenna terminal **80** and the second filter **22**. The sixth switching element Q**6** is provided between the signal path r**2** and the ground. In the radio frequency module **1** according to Embodiment 1, the signal path r**2** constitutes a third path.

(27) Further, the radio frequency module **1** according to Embodiment 1 further includes a third filter **23** and a fourth filter **24** as illustrated in FIG. **2**. The third filter **23** is a filter having a pass band of a third frequency band. The fourth filter **24** is a filter having a pass band of a fourth frequency band. The first to fourth frequency bands are different from each other in frequency band. The third filter **23** is a duplexer including a transmission filter **231** and a reception filter **232**, for example. The fourth filter **24** is a duplexer including a transmission filter **241** and a reception filter **242**, for example. The radio frequency module **1** further includes a third switch circuit **33** connected between the antenna terminal **80** and the third filter **23**, and a fourth switch circuit **34** connected between the antenna terminal **80** and the fourth filter **24**. The third switch circuit **33** includes a seventh switching element Q**7** and an eighth switching element Q**8**. The seventh switching element Q**7** is provided in a signal path r**3** between the antenna terminal **80** and the third filter **23**. The eighth switching element Q**8** is provided between the signal path r**3** and the ground.

The fourth switch circuit **34** includes a ninth switching element Q**9** and a tenth switching element Q**10**. The ninth switching element Q**9** is provided in a signal path r**4** between the antenna terminal **80** and the fourth filter **24**. The tenth switching element Q**10** is provided between the signal path r**4** and the ground.
(28) Further, the radio frequency module **1** further includes a power amplifier **11**, a controller **14**, an output matching circuit **13**, and a low-noise amplifier **15** as illustrated in FIG. **1**.
(29) In addition, the radio frequency module **1** according to Embodiment 1 further includes a first switch **4** including the first switching element Q**1** to the tenth switching element Q**10** (see FIG. **2**), a second switch **5**, and a third switch **6**.
(30) Still further, the radio frequency module **1** includes multiple external connection terminals **8** including the antenna terminal **80** described above. The multiple external connection terminals **8** include an antenna terminal **80**, a signal input terminal **81**, a signal output terminal **82**, multiple first control terminals **83**, multiple second control terminals **84**, multiple ground terminals **85** (see FIG. **5**), and a power supply terminal Vcc. The communication device **300** further includes a circuit substrate on which the radio frequency module **1** is mounted. The circuit substrate is a printed wiring board, for example. The circuit substrate has a ground electrode to which ground electric potential is applied. The multiple ground terminals **85** are terminals that are electrically connected to the ground electrode of the circuit substrate included in the communication device **300** and are supplied with ground electric potential.
(31) The power amplifier **11** has an input terminal and an output terminal. The power amplifier **11** amplifies a transmission signal in the first to fourth frequency bands inputted to the input terminal and outputs the amplified transmission signal from the output terminal. The input terminal of the power amplifier **11** is connected to the signal input terminal **81**. The input terminal of the power amplifier **11** is connected to the signal processing circuit **301** through the signal input terminal **81**. The signal input terminal **81** is a terminal to input a radio frequency signal (transmission signal), outputted from an external circuit (signal processing circuit **301**, for example), to the radio frequency module **1**. In the radio frequency module **1**, the output terminal of the power amplifier **11** and each of the first filter **21** to the fourth filter **24** may be connected with the output matching circuit **13** and the second switch **5** interposed therebetween. The second switch **5** includes a common terminal **50** and multiple (four, for example) selection terminals **51** to **54**. In the radio frequency module **1**, the output terminal of the power amplifier **11** is connected to the common terminal **50** of the second switch **5** with the output matching circuit **13** interposed therebetween, and the four selection terminals **51**, **52**, **53**, and **54** of the second switch **5** are connected to the four transmission filters **211**, **221**, **231**, and **241** on a one-to-one basis. The power amplifier **11** is controlled by the controller **14**.
(32) The power amplifier **11** is a multistage amplifier including a driver stage amplifier and a final stage amplifier, for example. In the power amplifier **11**, an input terminal of the driver stage amplifier is connected to the signal input terminal **81**, an output terminal of the driver stage amplifier is connected to an input terminal of the final stage amplifier, and an output terminal of the final stage amplifier is connected to the output matching circuit **13**. A power supply voltage is applied to the power amplifier **11** from the power supply terminal Vcc. The power amplifier **11** is not limited to the multistage amplifier, but may be an in-phase composite amplifier or a differential composite amplifier, for example.
(33) The controller **14** is connected to the driver stage amplifier and an output stage amplifier of the power amplifier **11**. The controller **14** is connected to the signal processing circuit **301** through multiple (four, for example) first control terminals **83**. Each of the multiple first control terminals **83** is a terminal to input a control signal, outputted from an external circuit (signal processing circuit **301**, for example), to the controller **14**. The controller **14** controls the power amplifier **11** based on control signals acquired through the multiple first control terminals **83**. The controller **14** controls the power amplifier **11** in accordance with a control signal from the RF signal processing

circuit **302**. Here, the controller **14** supplies a first bias current to the driver stage amplifier and a second bias current to the output stage amplifier based on the control signal from the RF signal processing circuit **302**, for example.

(34) The output matching circuit **13** is provided in a signal path between the output terminal of the power amplifier **11** and the common terminal **50** of the second switch **5**. The output matching circuit **13** is a circuit for impedance matching between the power amplifier **11** and the four transmission filters **211**, **221**, **231**, and **241**. The output matching circuit **13** includes an inductor connected between the output terminal of the power amplifier **11** and the common terminal **50** of the second switch **5**, for example. The output matching circuit **13** may include multiple inductors and multiple capacitors, for example.

(35) The low-noise amplifier **15** has an input terminal and an output terminal. The low-noise amplifier **15** amplifies a reception signal in the first to fourth frequency bands inputted to the input terminal, and outputs the amplified reception signal from the output terminal. The input terminal of the low-noise amplifier **15** is connected to a common terminal **60** of the third switch **6**. The radio frequency module **1** may include an input matching circuit provided between the input terminal of the low-noise amplifier **15** and the common terminal **60** of the third switch **6**. The output terminal of the low-noise amplifier **15** is connected to the signal output terminal **82**. The output terminal of the low-noise amplifier **15** is connected to the signal processing circuit **301** through the signal output terminal **82**, for example. The signal output terminal **82** is a terminal to output a radio frequency signal (reception signal), outputted from the low-noise amplifier **15**, to an external circuit (signal processing circuit **301**, for example). In the radio frequency module **1**, the input terminal of the low-noise amplifier **15** and the first filter **21** to the fourth filter **24** are connectable through the third switch **6**. The third switch **6** has the common terminal **60** and multiple (four, for example) selection terminals **61** to **64**. In the radio frequency module **1**, the input terminal of the low-noise amplifier **15** is connected to the common terminal **60** of the third switch **6**, and the four selection terminals **61**, **62**, **63**, and **64** of the third switch **6** are connected to the four reception filters **212**, **222**, **232**, and **242** on a one-to-one basis.

(36) The first switch **4** has a common terminal **49** and five selection terminals **40** to **44**. In the first switch **4**, the common terminal **49** is connected to the antenna terminal **80**. The radio frequency module **1** is not limited to a case that the common terminal **49** and the antenna terminal **80** are connected to each other with no other circuit element interposed therebetween, but the common terminal **49** and the antenna terminal **80** may be connected to each other with a low pass filter and a coupler interposed therebetween, for example. The selection terminal **40** is connected to the first filter **21** (a connection point of an output terminal of the transmission filter **211** and an input terminal of the reception filter **212** in the first filter **21**). Here, the selection terminal **40** is connected to the first filter **21** with the phase shifter **7** described above and the like interposed therebetween. The selection terminal **41** is connected to the first filter **21** (the connection point of the output terminal of the transmission filter **211** and the input terminal of the reception filter **212** in the first filter **21**). The selection terminal **42** is connected to the second filter **22** (a connection point of an output terminal of the transmission filter **221** and an input terminal of the reception filter **222** in the second filter **22**). The selection terminal **43** is connected to the third filter **23** (a connection point of an output terminal of the transmission filter **231** and an input terminal of the reception filter **232** in the third filter **23**). The selection terminal **44** is connected to the fourth filter **24** (a connection point of an output terminal of the transmission filter **241** and an input terminal of the reception filter **242** in the fourth filter **24**). The first switch **4** is a switch capable of connecting at least one or more of the five selection terminals **40** to **44** and the common terminal **49**, for example. Here, the first switch **4** is a switch capable of one-to-one and one-to-many connections, for example.

(37) In the radio frequency module **1**, a signal path r**1** between the antenna terminal **80** and the first filter **21** includes the first path r**11** and the second path r**12** described above. In the first switch **4**,

part of the first path r**11** is formed between the common terminal **49** and the selection terminal **40**, and the first switching element Q**1** is provided between the common terminal **49** and the selection terminal **40** in the part of the first path r**11**, as illustrated in FIG. **2**. In the first switch **4**, the second switching element Q**2** is provided between the part of the first path r**11** and the ground. The second switching element Q**2** is connected to a path between the first switching element Q**1** and the first filter **21** in the first path r**11**. More specifically, the second switching element Q**2** is provided between the ground and a portion of the first path r**11**, the portion between the first switching element Q**1** and the selection terminal **40**, in the part of the first path r**11**. The fourth switching element Q**4** is connected to a path between the third switching element Q**3** and the first filter **21** in the second path r**12**. More specifically, the fourth switching element Q**4** is provided between the ground and a portion of the second path r**12**, the portion between the third switching element Q**3** and the selection terminal **41**, in part of the second path r**12**.
(38) Further, in the first switch **4**, the part of the second path r**12** described above is formed between the common terminal **49** and the selection terminal **41**, and the third switching element Q**3** is provided, between the common terminal **49** and the selection terminal **41**, in the part of the second path r**12**. In addition, in the first switch **4**, the fourth switching element Q**4** is provided between the part of the second path r**12** and the ground. The fourth switching element Q**4** is connected to a path between the third switching element Q**3** and the first filter **21** in the second path r**12**. More specifically, the fourth switching element Q**4** is provided between the ground and a portion of the second path r**12**, the portion between the third switching element Q**3** and the selection terminal **41**, in the part of the second path r**12**.
(39) Further, in the first switch **4**, part of the signal path r**2** described above is formed between the common terminal **49** and the selection terminal **42**, and the fifth switching element Q**5** is provided between the common terminal **49** and the selection terminal **42** in the part of the signal path r**2**. Further, in the first switch **4**, the sixth switching element Q**6** is provided between the part of the signal path r**2** and the ground.
(40) Further, in the first switch **4**, part of the signal path r**3** between the antenna terminal **80** and the third filter **23** is formed between the common terminal **49** and the selection terminal **43**, and the seventh switching element Q**7** is provided between the common terminal **49** and the selection terminal **43** in the part of the signal path r**3**. Further, in the first switch **4**, the eighth switching element Q**8** is provided between the part of the signal path r**3** and the ground.
(41) Further, in the first switch **4**, part of the signal path r**4** between the antenna terminal **80** and the fourth filter **24** is formed between the common terminal **49** and the selection terminal **44**, and the ninth switching element Q**9** is provided between the common terminal **49** and the selection terminal **44** in the part of the signal path r**4**. Further, in the first switch **4**, the tenth switching element Q**10** is provided between the part of the signal path r**4** and the ground.
(42) Each of the first switching element Q**1** to the tenth switching element Q**10** in the first switch **4** is a Filed Effect Transistor (FET). The radio frequency module **1** further includes a control circuit **16** that controls the first switch circuit **31**. The control circuit **16** controls the first to fourth switching elements Q**4** of the first switch circuit **31**. Further, the control circuit **16** also controls the fifth switching element Q**5** and the sixth switching element Q**6** of the second switch circuit **32**. In addition, the control circuit **16** also controls the seventh switching element Q**7** and the eighth switching element Q**8** of the third switch circuit **33**. Still further, the control circuit **16** also controls the ninth switching element Q**9** and the tenth switching element Q**10** of the fourth switch circuit **34**. In short, the control circuit **16** controls each of the first switching element Q**1** to the tenth switching element Q**10** to a conductive state (ON) or a non-conductive state (OFF). The control circuit **16** controls the first switching element Q**1** to the tenth switching element Q**10** of the first switch **4** based on control signals acquired through the multiple second control terminals **84**. The control circuit **16** is a logic circuit that controls the first switch **4** in accordance with a control signal from the signal processing circuit **301**. The control signal received from the RF signal processing circuit

302 by the control circuit **16** is, for example, a first command corresponding to carrier aggregation or dual connectivity of the first communication band and the second communication band, a second command corresponding to single communication in the first communication band, or the like. The radio frequency module **1** operates in the first mode when the control circuit **16** receives the first command, and operates in the second mode when the control circuit **16** receives the second command. The radio frequency module **1** includes a single IC chip **10** (see FIG. **5**) including the first switch **4** and the control circuit **16**.
(43) The second switch **5** includes the common terminal **50** and the four selection terminals **51** to **54**. The common terminal **50** is connected to the output terminal of the power amplifier **11** with the output matching circuit **13** interposed therebetween. The selection terminal **51** is connected to an input terminal of the transmission filter **211** (a transmission terminal of the duplexer constituting the first filter **21**). The selection terminal **52** is connected to an input terminal of the transmission filter **221** (a transmission terminal of the duplexer constituting the second filter **22**). The selection terminal **53** is connected to an input terminal of the transmission filter **231** (a transmission terminal of the duplexer constituting the third filter **23**). The selection terminal **54** is connected to an input terminal of the transmission filter **241** (a transmission terminal of the duplexer constituting the fourth filter **24**). The second switch **5** is a switch capable of connecting at least one or more of the four selection terminals **51** to **54** and the common terminal **50**, for example. Here, the second switch **5** is a switch capable of one-to-one and one-to-many connections, for example.
(44) The second switch **5** is controlled by the controller **14**, for example. The second switch **5** changes over connection states between the common terminal **50** and the four selection terminals **51** to **54** in accordance with a control signal from the controller **14**, for example. The second switch **5** is a switch Integrated Circuit (IC), for example.
(45) The third switch **6** has a common terminal **60** and four selection terminals **61** to **64**. The common terminal **60** is connected to an input terminal of the low-noise amplifier **15**. The selection terminal **61** is connected to an output terminal of the reception filter **212** (a reception terminal of the duplexer constituting the first filter **21**). The selection terminal **62** is connected to an output terminal of the reception filter **222** (a reception terminal of the duplexer constituting the second filter **22**). The selection terminal **63** is connected to an output terminal of the reception filter **232** (a reception terminal of the duplexer constituting the third filter **23**). The selection terminal **64** is connected to an output terminal of the reception filter **242** (a reception terminal of the duplexer constituting the fourth filter **24**). The third switch **6** is a switch capable of connecting at least one or more of the four selection terminals **61** to **64** and the common terminal **60**, for example. Here, the third switch **6** is a switch capable of one-to-one and one-to-many connections, for example.
(46) The third switch **6** is controlled by the controller **14**, for example. The third switch **6** changes over connection states between the common terminal **60** and the four selection terminals **61** to **64** in accordance with a control signal from the controller **14**, for example. The third switch **6** is a switch IC, for example.
(47) The phase shifter **7** is provided in the first path r**11** of the signal path r**1**, and shifts the phase of a radio frequency signal. The phase shifter **7** also serves as a matching circuit for impedance matching between the first filter **21** and the antenna terminal **80** in the first mode. The phase shifter **7** includes a capacitor C**1** as illustrated in FIG. **3**. The capacitor C**1** is provided in the first path r**11** between the first switching element Q**1** and the first filter **21**. More specifically, the capacitor C**1** is provided between a connection point T**1** of the first switching element Q**1** and the second switching element Q**2**, and a connection point T**0**, being connected to the first filter **21**, of the first path r**11** and the second path r**12** in the signal path r**1**. More specifically, the capacitor C**1** is provided between the selection terminal **40** to which the first switching element Q**1** is connected, and the connection point TO. In the radio frequency module **1** according to Embodiment 1, a connection point T**2** of the third switching element Q**3** and the fourth switching element Q**4** is connected to the connection point TO, with no phase shifter **7** interposed therebetween.

(48) In the radio frequency module **1**, for example, the first filter **21** is designed to have predetermined frequency characteristics when the radio frequency module **1** operates in the second mode, and the phase shifter **7** is designed to perform impedance matching between the first filter **21** and the antenna terminal **80** when the radio frequency module **1** operates in the first mode.
(49) (1.2) Operation of Radio Frequency Module
(50) As described above, the radio frequency module **1** is capable of operating in the first mode in which simultaneous transmission, simultaneous reception, or simultaneous transmission and reception using both the first filter **21** and the second filter **22** is possible, and in the second mode in which transmission or reception using only the first filter **21** out of the first filter **21** and the second filter **22** is possible. Further, the radio frequency module **1** is capable of operating also in a third mode in which transmission or reception using only the second filter **22** out of the first filter **21** and the second filter **22** is possible. In the radio frequency module **1**, when simultaneous transmission using both the first filter **21** and the second filter **22** is performed in the first mode, the common terminal **50** of the second switch **5** is connected to the two selection terminals **51** and **52**. In the radio frequency module **1**, when simultaneous reception using both the first filter **21** and the second filter **22** is performed in the first mode, the common terminal **60** of the third switch **6** is connected to the two selection terminals **61** and **62**. Further, in the radio frequency module **1**, when transmission is performed using only the first filter **21** in the second mode, the common terminal **50** of the second switch **5** is connected to the one selection terminal **51**. In addition, in the radio frequency module **1**, when reception is performed using only the second filter **22** in the third mode, the common terminal **60** of the third switch **6** is connected to the one selection terminal **62**. The second switch **5** and the third switch **6** are controlled by the controller **14**, for example. Further, the controller **14** controls the second switch **5** and the third switch **6** based on a control signal from the signal processing circuit **301**, for example. Note that the controller **14** also controls the power amplifier **11**.
(51) Hereinafter, an operation example of the radio frequency module **1** will be described with reference to FIG. **4**A to FIG. **4**C. In FIG. **4**A to FIG. **4**C, in order to easily recognize the conductive state (ON) and the non-conductive state (OFF) of the first switching element Q**1** to the tenth switching element Q**10**, graphic symbols of the first switching element Q**1** to the tenth switching element Q**10** are represented by graphic symbols of switches instead of graphic symbols of FETs. In a case that each of the first switching element Q**1** to the tenth switching element Q**10** is an FET, each of the first switching element Q**1** to the tenth switching element Q**10** is in the conductive state when a gate-source voltage of the FET is equal to or higher than a gate-threshold voltage, and is in the non-conductive state when the gate-source voltage of the FET is lower than the gate-threshold voltage. The control circuit **16** controls the first to the tenth switching elements Q**10** by controlling the gate-source voltage of the FET constituting each of the first switching element Q**1** to the tenth switching element Q**10**. The control circuit **16** controls the first switching element Q**1** to the tenth switching element Q**10** based on a control signal from the signal processing circuit **301**, for example. In the radio frequency module **1**, upon receiving the first command from the signal processing circuit **301**, the control circuit **16** controls the first switching element Q**1** to the tenth switching element Q**10** so as to deal with the first mode. Further, upon receiving the second command from the signal processing circuit **301**, the control circuit **16** controls the first switching element Q**1** to the tenth switching element Q**10** so as to deal with the second mode.
(52) In the radio frequency module **1**, in the first mode in which simultaneous transmission, simultaneous reception, or simultaneous transmission and reception is performed using both the first filter **21** and the second filter **22**, each of the first switching element Q**1** to the tenth switching element Q**10** is in a state illustrated in FIG. **4**B. Further, in the radio frequency module **1**, in the second mode in which transmission or reception is performed using only the first filter **21** out of the first filter **21** and the second filter **22**, each of the first switching element Q**1** to the tenth switching element Q**10** is in a state illustrated in FIG. **4**A. In addition, in the radio frequency

module **1**, in the third mode in which transmission or reception is performed using only the second filter **22** out of the first filter **21** and the second filter **22**, each of the first switching element Q**1** to the tenth switching element Q**10** is in a state illustrated in FIG. **4**C.

(53) In the first mode, as illustrated in FIG. **4**B, in the first switch circuit **31**, the first switching element Q**1** in the first path r**11** is in the conductive state (ON), the third switching element Q**3** in the second path r**12** is in the non-conductive state (OFF), and the second switching element Q**2** and the fourth switching element Q**4** are in the non-conductive state (OFF). In the radio frequency module **1**, in the first mode, since the fourth switching element Q**4** is in the non-conductive state (OFF), the second path r**12** is not electrically connected to the ground, and is in an open state with respect to the ground. This makes it possible to prevent that a radio frequency signal is not able to pass through the first path r**11** during the simultaneous transmission.

(54) Further, in the first mode, as illustrated in FIG. **4**B, in the second switch circuit **32**, the fifth switching element Q**5** in the signal path r**2** is in the conductive state (ON), and the sixth switching element Q**6** between the signal path r**2** and the ground is in the non-conductive state (OFF). In addition, in the first mode, as illustrated in FIG. **4**B, in the third switch circuit **33**, the seventh switching element Q**7** in the signal path r**3** is in the non-conductive state (OFF), and the eighth switching element Q**8** between the signal path r**3** and the ground is in the conductive state (ON). Since the eighth switching element Q**8** is in the conductive state (ON), the signal path r**3** of the third switch circuit **33** is electrically connected to the ground (is in a state being short-circuited to the ground). In addition, in the first mode, as illustrated in FIG. **4**B, in the fourth switch circuit **34**, the ninth switching element Q**9** in the signal path r**4** is in the non-conductive state (OFF), and the tenth switching element Q**10** between the signal path r**4** and the ground is in the conductive state (ON). Since the tenth switching element Q**10** is in the conductive state (ON), the signal path r**4** of the fourth switch circuit **34** is electrically connected to the ground (is in a state being short-circuited to the ground).

(55) In the second mode, as illustrated in FIG. **4**A, in the first switch circuit **31**, the first switching element Q**1** in the first path r**11** is in the non-conductive state (OFF), the third switching element Q**3** in the second path r**12** is in the conductive state (ON), and the second switching element Q**2** and the fourth switching element Q**4** are in the non-conductive state (OFF). In the radio frequency module **1**, in the second mode, since the second switching element Q**2** is in the non-conductive state (OFF), the first path r**11** is not electrically connected to the ground (is in an open state with respect to the ground). This makes it possible to prevent that the second path r**12** is connected to the ground through the phase shifter **7** and the second switching element Q**2**, and to suppress the deterioration in characteristics. Further, since the fourth switching element Q**4** is in the non-conductive state (OFF), the second path r**12** is not electrically connected to the ground (is in an open state with respect to the ground).

(56) In the second mode, as illustrated in FIG. **4**A, in the second switch circuit **32**, the fifth switching element Q**5** in the signal path r**2** is in the non-conductive state (OFF), and the sixth switching element Q**6** between the signal path r**2** and the ground is in the conductive state (ON). Since the sixth switching element Q**6** is in the conductive state (ON), the signal path r**2** of the second switch circuit **32** is electrically connected to the ground (is in a state being short-circuited to the ground). Further, in the second mode, as illustrated in FIG. **4**A, in the third switch circuit **33**, the seventh switching element Q**7** in the signal path r**3** is in the non-conductive state (OFF), and the eighth switching element Q**8** between the signal path r**3** and the ground is in the conductive state (ON). Since the eighth switching element Q**8** is in the conductive state (ON), the signal path r**3** of the third switch circuit **33** is electrically connected to the ground (is in a state being short-circuited to the ground). Further, in the second mode, as illustrated in FIG. **4**A, in the fourth switch circuit **34**, the ninth switching element Q**9** in the signal path r**4** is in the non-conductive state (OFF), and the tenth switching element Q**10** between the signal path r**4** and the ground is in the conductive state (ON). Since the tenth switching element Q**10** is in the conductive state (ON), the signal path

r**4** of the fourth switch circuit **34** is electrically connected to the ground (is in a state being short-circuited to the ground).
(57) In the third mode, as illustrated in FIG. **4**C, in the first switch circuit **31**, the first switching element Q**1** in the first path r**11** is in the non-conductive state (OFF), the third switching element Q**3** in the second path r**12** is in the non-conductive state (OFF), and the second switching element Q**2** and the fourth switching element Q**4** are in the conductive state (ON). Since the second switching element Q**2** is in the conductive state (ON), the first path r**11** is electrically connected to the ground (is in a state being short-circuited to the ground). Further, since the fourth switching element Q**4** is in the conductive state (ON), the second path r**12** is electrically connected to the ground (is in a state being short-circuited to the ground). In the radio frequency module **1**, in the third mode, each of the second switching element Q**2** and the fourth switching element Q**4** is in the conductive state. This makes it possible to suppress the deterioration in characteristics due to the influence of parasitic capacitance in the non-conductive state of each of the second switching element Q**2** and the fourth switching element Q**4**.
(58) In the third mode, as illustrated in FIG. **4**C, in the second switch circuit **32**, the fifth switching element Q**5** in the signal path r**2** is in the conductive state (ON), and the sixth switching element Q**6** between the signal path r**2** and the ground is in the non-conductive state (OFF). Further, in the third mode, as illustrated in FIG. **4**C, in the third switch circuit **33**, the seventh switching element Q**7** in the signal path r**3** is in the non-conductive state (OFF), and the eighth switching element Q**8** is in the conductive state (ON). In addition, in the third mode, as illustrated in FIG. **4**C, in the fourth switch circuit **34**, the ninth switching element Q**9** in the signal path r**4** is in the non-conductive state (OFF), and the tenth switching element Q**10** is in the conductive state (ON).
(59) Hereinafter, the operation of the control circuit **16** will be described in more detail.
(60) Upon receiving the first command, as illustrated in FIG. **4**B described above, the control circuit **16** controls the first switching element Q**1** and the fifth switching element Q**5** to be in the conductive state, controls the second switching element Q**2**, the third switching element Q**3**, the fourth switching element Q**4**, the sixth switching element Q**6**, the seventh switching element Q**7**, and the ninth switching element Q**9** to be in the non-conductive state, and controls the eighth switching element Q**8** and the tenth switching element Q**10** to be in the conductive state. Therefore, in the first mode, the control circuit **16** brings both the third switching element Q**3** and the fourth switching element Q**4** corresponding to the second path r**12** into the non-conductive state.
(61) Further, upon receiving the second command, as illustrated in FIG. **4**A described above, the control circuit **16** controls the third switching element Q**3** to be in the conductive state, controls the first switching element Q**1**, the second switching element Q**2**, the fourth switching element Q**4**, the fifth switching element Q**5**, the seventh switching element Q**7**, and the ninth switching element Q**9** to be in the non-conductive state, and controls the eighth switching element Q**8** and the tenth switching element Q**10** to be in the conductive state. Therefore, in the second mode, the control circuit **16** brings both the first switching element Q**1** and the second switching element Q**2** into the non-conductive state.
(62) Hereinafter, for the convenience of description, each of the first switching element Q**1**, the third switching element Q**3**, the fifth switching element Q**5**, the seventh switching element Q**7**, and the ninth switching element Q**9** may sometimes be referred to as a series switch without necessarily being distinguished from one another. Further, each of the second switching element Q**2**, the fourth switching element Q**4**, the sixth switching element Q**6**, the eighth switching element Q**8**, and the tenth switching element Q**10** may sometimes be referred to as a shunt switch without necessarily being distinguished from one another. The radio frequency module **1** includes multiple (five) pairs of a series switch and a shunt switch. The multiple pairs include a pair of the first switching element Q**1** and the second switching element Q**2**, a pair of the third switching element Q**3** and the fourth switching element Q**4**, a pair of the fifth switching element Q**5** and the sixth switching element Q**6**, a pair of the seventh switching element Q**7** and the eighth switching element Q**8**, and a

pair of the ninth switching element Q**9** and the tenth switching element Q**10**.
(63) When the radio frequency module **1** operates in the first mode, the control circuit **16** brings both the series switch and the shunt switch corresponding to the second path r**12** into the non-conductive state, and exclusively controls the series switch and the shunt switch in a pair of the series switch and the shunt switch corresponding to each of the first path r**11**, the signal path r**2**, the signal path r**3**, and the signal path r**4**. “Exclusively controls the series switch and the shunt switch in a pair” means that, with respect to a pair of a series switch and a shunt switch, one of the series switch and the shunt switch is controlled to be in the conductive state, and the other of the series switch and the shunt switch is controlled to be in the non-conductive state. Further, when the radio frequency module **1** operates in the second mode, the control circuit **16** brings both the series switch and the shunt switch corresponding to the first path r**11** into the non-conductive state, and exclusively controls the series switch and the shunt switch in a pair of the series switch and the shunt switch corresponding to each of the second path r**12**, the signal path r**2** (third path), the signal path r**3**, and the signal path r**4**.
(64) (1.3) Structure of Radio Frequency Module
(65) Hereinafter, the structure of the radio frequency module **1** will be described with reference to FIG. **5**.
(66) The radio frequency module **1** includes a mounting substrate **9** on which multiple circuit components (first filter **21**, second filter **22**, IC chip **10**, and the like) of the radio frequency module **1** are mounted. Further, the radio frequency module **1** includes multiple external connection terminals **8**. In addition, the radio frequency module **1** further includes a first resin layer **17**, a second resin layer **18**, and a shield layer **19**.
(67) The mounting substrate **9** has a first main surface **91** and a second main surface **92** opposed to each other in a thickness direction D**1** of the mounting substrate **9**. The mounting substrate **9** is a multilayer substrate including multiple dielectric layers and multiple conductive layers, for example. The multiple dielectric layers and the multiple conductive layers are laminated in the thickness direction D**1** of the mounting substrate **9**. The multiple conductive layers are formed in a predetermined pattern designated for each layer. Each of the multiple conductive layers includes one or multiple conductive portions in one plane orthogonal to the thickness direction D**1** of the mounting substrate **9**. The material of each conductive layer is copper, for example. The multiple conductive layers include a ground layer. In the radio frequency module **1**, the multiple ground terminals **85** and the ground layer are electrically connected to each other through via conductors or the like provided to the mounting substrate **9**. The mounting substrate **9** is a Low Temperature Co-fired Ceramics (LTCC) substrate, for example. The mounting substrate **9** is not limited to the LTCC substrate, but may be a printed wiring board, a High Temperature Co-fired Ceramics (HTCC) substrate, or a resin multilayer substrate, for example.
(68) Further, the mounting substrate **9** is not limited to the LTCC substrate, but may be a wiring structure body, for example. The wiring structure body is a multilayer structure body, for example. The multilayer structure body includes at least one insulation layer and at least one conductive layer. The insulation layer is formed in a predetermined pattern. When there are multiple insulation layers, the multiple insulation layers are formed in a predetermined pattern designated for each layer. The conductive layer is formed in a predetermined pattern different from the predetermined pattern of the insulation layer. When there are multiple conductive layers, the multiple conductive layers are formed in a predetermined pattern designated for each layer. The conductive layer may include one or multiple redistribution portions. In the wiring structure body, a first surface, of two surfaces opposed to each other in a thickness direction of the multilayer structure body, is the first main surface **91** of the mounting substrate **9**, and a second surface is the second main surface **92** of the mounting substrate **9**. The wiring structure body may be an interposer, for example. The interposer may be made of a silicon substrate, or may be a substrate formed of multiple layers.
(69) The first main surface **91** and the second main surface **92** of the mounting substrate **9** are

separated from each other in the thickness direction D**1** of the mounting substrate **9**, and intersect with the thickness direction D**1** of the mounting substrate **9**. The first main surface **91** of the mounting substrate **9** is orthogonal to the thickness direction D**1** of the mounting substrate **9**, for example, but may include a side surface of a conductive portion or the like as a surface not orthogonal to the thickness direction D**1**, for example. Further, the second main surface **92** of the mounting substrate **9** is orthogonal to the thickness direction D**1** of the mounting substrate **9**, for example, but may include a side surface of a conductive portion or the like as a surface not orthogonal to the thickness direction D**1**, for example. In addition, on the first main surface **91** and the second main surface **92** of the mounting substrate **9**, a fine irregularity, a concave portion, or a convex portion may be formed. For example, when a concave portion is formed in the first main surface **91** of the mounting substrate **9**, an inner surface of the concave portion is included in the first main surface **91**.
(70) In the radio frequency module **1** according to Embodiment 1, first group circuit components among the multiple circuit components are mounted on the first main surface **91** of the mounting substrate **9**. The first group circuit components include the first filter **21** to the fourth filter **24** (see FIG. **1**), the power amplifier **11**, a circuit element of the output matching circuit **13** (see FIG. **1**), and a circuit element (capacitor C**1**) of the phase shifter **7**, for example. The capacitor C**1** is a surface mount capacitor, for example. “The circuit component is mounted on the first main surface **91** of the mounting substrate **9**” includes that the circuit component is disposed on (mechanically connected to) the first main surface **91** of the mounting substrate **9**, and that the circuit component is electrically connected to (an appropriate conductive portion of) the mounting substrate **9**. In the radio frequency module **1**, second group circuit components among the multiple circuit components are mounted on the second main surface **92** of the mounting substrate **9**. The second group circuit components include the IC chip **10** including the first switch **4** and the control circuit **16**, the second switch **5** (see FIG. **1**), the third switch **6** (see FIG. **1**), the controller **14** (see FIG. **1**), and the low-noise amplifier **15** (see FIG. **1**). “The circuit component is mounted on the second main surface **92** of the mounting substrate **9**” includes that the circuit component is disposed on (mechanically connected to) the second main surface **92** of the mounting substrate **9**, and that the circuit component is electrically connected to (an appropriate conductive portion of) the mounting substrate **9**. The radio frequency module **1** may include a circuit element provided in the mounting substrate **9**, not limited to the circuit components mounted on the mounting substrate **9**.
(71) Each of the multiple transmission filters **211**, **221**, **231**, and **241** is an acoustic wave filter including multiple Surface Acoustic Wave (SAW) resonators. The acoustic wave filter is a surface acoustic wave filter using a surface acoustic wave, for example. Each of the multiple reception filters **212**, **222**, **232**, and **242** is an acoustic wave filter including the multiple SAW resonators. The acoustic wave filter is a surface acoustic wave filter using a surface acoustic wave, for example. The first filter **21** is a single circuit component (duplexer) including the transmission filter **211** and the reception filter **212**. The second filter **22** is a single circuit component (duplexer) including the transmission filter **221** and the reception filter **222**. The third filter **23** is a single circuit component (duplexer) including the transmission filter **231** and the reception filter **232**. The fourth filter **24** is a single circuit component (duplexer) including the transmission filter **241** and the reception filter **242**. Each of the first filter **21** to the fourth filter **24** has a rectangular shape in a plan view from the thickness direction D**1** of the mounting substrate **9**, but is not limited thereto, and may have a square shape, for example.
(72) The power amplifier **11** is a power amplification IC chip. The power amplifier **11** is flip-chip mounted on the first main surface **91** of the mounting substrate **9**. An outer peripheral shape of the power amplifier **11** is a quadrangular shape, in a plan view from the thickness direction D**1** of the mounting substrate **9**. Each of the driver stage amplifier and the final stage amplifier in the power amplifier **11** includes an amplification transistor. The amplification transistor is a Heterojunction Bipolar Transistor (HBT), for example. In the case above, the power amplification IC chip

constituting the power amplifier **11** is a GaAs-based IC chip, for example. The amplification transistor is not limited to the bipolar transistor such as the HBT, but may be a Field Effect Transistor (FET), for example. The FET is Metal-Oxide-Semiconductor Field Effect Transistor (MOSFET), for example. The power amplification IC chip constituting the power amplifier **11** is not limited to the GaAs-based IC chip, but may be a Si-based IC chip, a SiGe-based IC chip, or a GaN-based IC chip, for example.

(73) The inductor included in the output matching circuit **13** is a chip inductor, and is mounted on the first main surface **91** of the mounting substrate **9**, for example.

(74) The IC chip **10** including the first switch **4** and the control circuit **16** is a Si-based IC chip, for example. The IC chip **10** is flip-chip mounted on the second main surface **92** of the mounting substrate **9**. An outer peripheral shape of the IC chip **10** is a quadrangular shape, in a plan view from the thickness direction D**1** of the mounting substrate **9**.

(75) The low-noise amplifier **15** is flip-chip mounted on the second main surface **92** of the mounting substrate **9**. In the radio frequency module **1** according to Embodiment 1, a Si-based IC chip including the low-noise amplifier **15**, the second switch **5**, and the third switch **6** may be mounted on the second main surface **92** of the mounting substrate **9**. The low-noise amplifier **15** includes a field effect transistor as an amplification transistor. The amplification transistor in the low-noise amplifier **15** is not limited to the field effect transistor, but may be the bipolar transistor, for example.

(76) The multiple external connection terminals **8** are disposed on the second main surface **92** of the mounting substrate **9**. “The external connection terminal **8** is disposed on the second main surface **92** of the mounting substrate **9**” includes that the external connection terminal **8** is mechanically connected to the second main surface **92** of the mounting substrate **9**, and that the external connection terminal **8** is electrically connected to (an appropriate conductive portion of) the mounting substrate **9**. The material of the multiple external connection terminals **8** is metal (copper, a copper alloy, or the like, for example), for example. Each of the multiple external connection terminals **8** is a columnar electrode. The columnar electrode is a cylindrical electrode, for example. The multiple external connection terminals **8** are bonded to the conductive portion of the mounting substrate **9** by solder, for example, but are not limited thereto. The external connection terminals **8** may be bonded using a conductive adhesive (conductive paste, for example), or may directly be bonded, for example.

(77) The multiple external connection terminals **8** include the antenna terminal **80**, the signal input terminal **81** (see FIG. **1**), the signal output terminal **82** (see FIG. **1**), the multiple first control terminals **83** (see FIG. **1**), the multiple second control terminals **84** (see FIG. **1**), and the multiple ground terminals **85**. The multiple ground terminals **85** are electrically connected to the ground layer of the mounting substrate **9**. The ground layer is a circuit ground of the radio frequency module **1**, and the multiple circuit components of the radio frequency module **1** include circuit components electrically connected to the ground layer.

(78) The first resin layer **17** is disposed on the first main surface **91** of the mounting substrate **9**. The first resin layer **17** covers each of the first group circuit components mounted on the first main surface **91** of the mounting substrate **9** among the multiple circuit components. The first resin layer **17** includes resin (epoxy resin, for example). The first resin layer **17** may contain a filler in addition to resin.

(79) The second resin layer **18** covers an outer peripheral surface of each of the second group circuit components mounted on the second main surface **92** of the mounting substrate **9** and the multiple external connection terminals **8**. The second resin layer **18** includes resin (epoxy resin, for example). The second resin layer **18** may contain a filler in addition to resin. The material of the second resin layer **18** may be the same as the material of the first resin layer **17**, or may be different from the material of the first resin layer **17**.

(80) The shield layer **19** covers the first resin layer **17**. The shield layer **19** has conductivity. The

shield layer **19** has a multilayer structure in which multiple metal layers are laminated, but is not limited thereto, and may have one metal layer. The metal layer includes one or more types of metal. The shield layer **19** covers a main surface **171** of the first resin layer **17** on a side opposite to the mounting substrate **9** side, an outer peripheral surface **173** of the first resin layer **17**, and an outer peripheral surface **93** of the mounting substrate **9**. Further, the shield layer **19** also covers an outer peripheral surface **183** of the second resin layer **18**. The shield layer **19** is in contact with at least part of an outer peripheral surface of the ground layer included in the mounting substrate **9**. As a result, the electric potential of the shield layer **19** may be made equal to the electric potential of the ground layer. In the radio frequency module **1**, main surfaces, of some circuit components among the first group circuit components mounted on the first main surface **91** of the mounting substrate **9**, on a side opposite to the mounting substrate **9** side, may be in contact with the shield layer **19**.
(81) In the radio frequency module **1**, the circuit element (capacitor C**1**) of the phase shifter **7** is mounted on the first main surface **91** of the mounting substrate **9**, and the IC chip **10** including the switch circuit **31** (see FIG. **2** and FIG. **3**) is mounted on the second main surface **92** of the mounting substrate **9**. In the radio frequency module **1**, the circuit element (capacitor C**1**) of the phase shifter **7** overlaps with the IC chip **10** in a plan view from the thickness direction D**1** of the mounting substrate **9**. In the radio frequency module **1**, the whole of the circuit element (capacitor C**1**) of the phase shifter **7** overlaps with part of the IC chip **10** in a plan view from the thickness direction D**1** of the mounting substrate **9**. However, without necessarily being limited to this, part of the circuit element (capacitor C**1**) of the phase shifter **7** may overlap with part of the IC chip **10**, or the whole of the circuit element (capacitor C**1**) of the phase shifter **7** may overlap with the whole of the IC chip **10**.
(82) In the radio frequency module **1**, the first filter **21** is positioned between the power amplifier **11** and the circuit element (capacitor C**1**) of the phase shifter **7** in a plan view from the thickness direction D**1** of the mounting substrate **9**.
(83) In the radio frequency module **1**, the circuit element (capacitor C**1**) of the phase shifter **7** is adjacent to the first filter **21** in a plan view from the thickness direction D**1** of the mounting substrate **9**. "The circuit element of the phase shifter **7** is adjacent to the first filter **21**" means that there is no other circuit component between the circuit element of the phase shifter **7** and the first filter **21**, and the circuit element of the phase shifter **7** and the first filter **21** are adjacent to each other in a plan view from the thickness direction D**1** of the mounting substrate **9**.
(84) In the radio frequency module **1**, part of the first filter **21** overlaps with part of the IC chip **10** in a plan view from the thickness direction D**1** of the mounting substrate **9**. However, without necessarily being limited to this, it is acceptable that the first filter **21** does not overlap with the IC chip **10**.
(85) In the radio frequency module **1**, the power amplifier **11** and other circuit components do not overlap with each other in a plan view from the thickness direction D**1** of the mounting substrate **9**.
(2) Effect
(86) (2.1) Radio Frequency Module
(87) The radio frequency module **1** according to Embodiment 1 includes the antenna terminal **80**, the first filter **21**, the second filter **22**, and the switch circuit **31**. The first filter **21** is a filter having a pass band of the first frequency band. The second filter **22** is a filter having a pass band of the second frequency band different from the first frequency band. The switch circuit **31** is connected between the antenna terminal **80** and the first filter **21**. The radio frequency module **1** is capable of operating in the first mode in which simultaneous transmission, simultaneous reception, or simultaneous transmission and reception using both the first filter **21** and the second filter **22** is possible, and in the second mode in which transmission or reception using only the first filter **21** out of the first filter **21** and the second filter **22** is possible. The switch circuit **31** includes the first switching element Q**1**, the second switching element Q**2**, the third switching element Q**3**, and the fourth switching element Q**4**. The first switching element Q**1** is provided in the first path r**11** that is

usable between the antenna terminal **80** and the first filter **21** in the first mode. The second switching element Q**2** is provided between the first path r**11** and the ground. The third switching element Q**3** is provided in the second path r**12** that is usable between the antenna terminal **80** and the first filter **21** in the second mode. The fourth switching element Q**4** is provided between the second path r**12** and the ground. The radio frequency module **1** further includes the phase shifter **7**. The phase shifter **7** is provided in the first path r**11** and changes the phase of a radio frequency signal.

(88) In the radio frequency module **1** according to Embodiment 1, it is possible to improve the isolation between the first path rill and the second path r**12**. In the radio frequency module **1** according to Embodiment 1, since the switch circuit **31** includes the second switching element Q**2** and the fourth switching element Q**4**, it is possible to improve the isolation between the signal path r**2** (third path) on which the second filter **22** is provided and the first path r**11**, and the isolation between the signal path r**2** (third path) on which the second filter **22** is provided and the second path r**12**. When the radio frequency module **1** according to Embodiment 1 operates in the first mode, both the third switching element Q**3** and the fourth switching element Q**4** corresponding to the second path r**12** are in the non-conductive state, and out of the first switching element and the second switching element Q**2** corresponding to the first path r**11**, the first switching element Q**1** is in the conductive state, and the second switching element Q**2** is in the non-conductive state. Therefore, in the radio frequency module **1** according to Embodiment 1, out of the fifth switching element Q**5** and the sixth switching element Q**6** corresponding to the third path (signal path r**2**), the fifth switching element Q**5** is in the conductive state and the sixth switching element Q**6** is in the non-conductive state, for example. This makes it possible to improve the isolation between the first path r**11** and the third path r**2**. Further, when the radio frequency module **1** according to Embodiment 1 operates in the second mode, both the first switching element Q**1** and the second switching element Q**2** corresponding to the first path r**11** are in the non-conductive state, and out of the third switching element Q**3** and the fourth switching element Q**4** corresponding to the second path r**12**, the third switching element Q**1** is in the conductive state and the fourth switching element Q**4** is in the non-conductive state. Therefore, in the radio frequency module **1** according to Embodiment 1, out of the fifth switching element Q**5** and the sixth switching element Q**6** corresponding to the third path (signal path r**2**), the fifth switching element Q**5** is in the conductive state and the sixth switching element Q**6** is in the non-conductive state, for example. This makes it possible to improve the isolation between the second path r**12** and the third path r**2**.

(89) Further, in the radio frequency module **1** according to Embodiment 1, when one of the first switching element Q**1** and the third switching element Q**3** is in the conductive state and the other of the first switching element Q**1** and the third switching element Q**3** is in the non-conductive state, the second switching element Q**2** and the fourth switching element Q**4** are in the non-conductive state. As a result, in the radio frequency module **1** according to Embodiment 1, it is possible to suppress the deterioration in characteristics when operating in each of the first mode and the second mode.

(90) Further, the radio frequency module **1** further includes a second switch circuit **32** connected between the antenna terminal **80** and the second filter **22** in addition to the first switch circuit **31** being the switch circuit **31**. In the second switch circuit **32**, the fifth switching element Q**5** is provided in the signal path r**2** (third path) between the antenna terminal **80** and the second filter **22**, and the sixth switching element Q**6** is provided between the signal path r**2** and the ground. As a result, in the radio frequency module **1** according to Embodiment 1, it is possible to improve each of the isolation between the first path r**11** and the signal path r**2**, and the isolation between the second path r**12** and the signal path r**2**.

(91) (2.2) Communication Device

(92) The communication device **300** according to Embodiment 1 includes the radio frequency module **1** and the signal processing circuit **301**. The signal processing circuit **301** is connected to

the radio frequency module **1**.
(93) Since the communication device **300** according to Embodiment 1 includes the radio frequency module **1**, it is possible to improve the isolation between the first path r**11** and the second path r**12**.
(94) The multiple electronic components constituting the signal processing circuit **301** may be mounted on the circuit substrate described above, or may be mounted on a circuit substrate (second circuit substrate) different from the circuit substrate (first circuit substrate) on which the radio frequency module **1** is mounted, for example.
(3) Modification of Radio Frequency Module
(95) A radio frequency module **1***a* according to a modification of Embodiment 1 will be described with reference to FIG. **6**. With respect to the radio frequency module **1***a* according to the modification, the same constituents as those of the radio frequency module **1** according to Embodiment 1 are denoted by the same reference signs, and a description thereof is omitted.
(96) The radio frequency module **1***a* according to the modification is different from the radio frequency module **1** according to Embodiment 1 in that the phase shifter **7** is a digital tunable capacitor C**11**.
(97) The digital tunable capacitor C**11** is controlled by the control circuit **16** (see FIG. **1**), for example. The radio frequency module **1***a* according to the modification may adjust the phase of a radio frequency signal passing through the first path r**11** by changing the capacitance of the digital tunable capacitor C**11**, in accordance with a combination of communication bands in which simultaneous transmission or simultaneous communication is performed. The radio frequency module **1***a* according to the modification may adjust the phase of a radio frequency signal passing through the first path r**11** in accordance with a pass band of a filter simultaneously used with the first filter **21**, even when there is a frequency band other than the second frequency band to be simultaneously used with the first frequency band (when there is a third frequency band or a fourth frequency band, for example) in simultaneous transmission or simultaneous reception. The phase adjustment is achieved by changing the capacitance of the digital tunable capacitor C**11** in accordance with the frequency band simultaneously used with the first frequency band.
Embodiment 2
(98) A radio frequency module **1***b* according to Embodiment 2 will be described with reference to FIG. **7**. With respect to the radio frequency module **1***b* according to Embodiment 2, the same constituents as those of the radio frequency module **1** according to Embodiment 1 are denoted by the same reference signs, and a description thereof is omitted.
(99) The radio frequency module **1***b* according to Embodiment 2 is different from the radio frequency module **1** according to Embodiment 1 in that the phase shifter **7** is provided in the second path r**12**.
(100) In the radio frequency module **1***b* according to Embodiment 2, the phase shifter **7** is provided between the third switching element Q**3** and the first filter **21** in the second path r**12** of the signal path r**1**. More specifically, the phase shifter **7** is provided between a connection point T**2** of the third switching element Q**3** and the fourth switching element Q**4**, and a connection point TO, being connected to the first filter **21**, of the first path r**11** and the second path r**12** in the signal path r**1**. More specifically, the phase shifter **7** is provided between the connection point TO and the selection terminal **41** to which the third switching element Q**3** is connected. In the radio frequency module **1***b* according to Embodiment 2, the connection point T**1** of the first switching element Q**1** and the second switching element Q**2** is connected to the connection point T**0**, with no phase shifter **7** placed therebetween.
(101) In the radio frequency module **1***b*, the phase shifter **7** is designed such that, in the second mode, a radio frequency signal between the first filter **21** and the antenna terminal **80** has a predetermined phase suitable for the second mode, for example.
(102) Since the radio frequency module **1***b* according to Embodiment 2 includes the second switching element Q**2** and the fourth switching element Q**4** as in the radio frequency module **1**

according to Embodiment 1, it is possible to improve the isolation between the first path r**11** and the second path r**12**. Further, the radio frequency module **1***b* according to Embodiment 2 may include a digital tunable capacitor C**11** (see FIG. **6**) instead of the capacitor C**1** (see FIG. **3**) of the phase shifter **7**. In the case above, the capacitance of the phase shifter **7** may be adjusted in accordance with the pass band of the first filter **21** connected to the second path r**12**.

Embodiment 3

(103) A radio frequency module **1***c* according to Embodiment 3 will be described with reference to FIG. **8**. With respect to the radio frequency module **1***c* according to Embodiment 3, the same constituents as those of the radio frequency module **1** according to Embodiment 1 are denoted by the same reference signs, and a description thereof is omitted.

(104) The radio frequency module **1***c* according to Embodiment 3 is different from the radio frequency module **1** according to Embodiment 1 in that the switch circuit **31** includes multiple (two, for example) first paths r**11** and multiple (two, for example) phase shifters **7**. The multiple phase shifters **7** are provided in a one-to-one basis with the multiple first paths r**11**. In the radio frequency module **1***c* according to Embodiment 3, the multiple phase shifters **7** are different from each other in impedance. More specifically, in the radio frequency module **1***c* according to Embodiment 3, each of the multiple phase shifters **7** includes the capacitor C**1**, and the capacitors C**1** of the multiple phase shifters **7** are different from each other in capacitance. The radio frequency module **1***c* according to Embodiment 3 includes multiple (two) selection terminals **40** connected to the first filter **21**, and a pair of the first switching element Q**1** and the second switching element Q**2** is provided for each of the multiple first paths r**11**. Therefore, the radio frequency module **1***c* has multiple (two) pairs of the first switching element Q**1** and the second switching element Q**2** for one first filter **21**.

(105) The radio frequency module **1***c* according to Embodiment 3 may adjust the phases of radio frequency signals passing through the first paths r**11** in accordance with a pass band of a filter simultaneously used with the first filter **21**, even when there is a frequency band other than the second frequency band to be simultaneously used with the first frequency band (when there is a third frequency band or a fourth frequency band, for example) in simultaneous transmission or simultaneous reception. The phase adjustment is achieved by changing a pair of the first switching element Q**1** to be in the conductive state and the second switching element Q**2** to be in the non-conductive state among multiple pairs of the first switching element Q**1** and the second switching element Q**2**, in accordance with the frequency band simultaneously used with the first frequency band. In the radio frequency module **1***c* according to Embodiment 3, in simultaneous transmission, simultaneous reception, or simultaneous transmission and reception, the first switching element Q**1** is in the conductive state and the second switching element Q**2** is in the non-conductive state in one pair, among the multiple pairs of the first switching element Q**1** and the second switching element Q**2**. However, the first switching elements Q**1** and the second switching elements Q**2** in the remaining pairs are in the non-conductive state.

(106) Since the radio frequency module **1***c* according to Embodiment 3 includes the second switching element Q**2** and the fourth switching element Q**4** as in the radio frequency module **1** according to Embodiment 1, it is possible to improve the isolation between the first path r**11** and the second path r**12**.

(107) In the radio frequency module **1***c* according to Embodiment 3, the number of the first paths r**11** is not limited to two and may be three or more.

Embodiment 4

(108) A radio frequency module **1***d* according to Embodiment 4 will be described with reference to FIG. **9**. With respect to the radio frequency module **1***d* according to Embodiment 4, the same constituents as those of the radio frequency module **1***c* according to Embodiment 3 are denoted by the same reference signs, and a description thereof is omitted.

(109) The radio frequency module **1***d* according to Embodiment 4 is different from the radio

frequency module **1** according to Embodiment 1 in that at least one of the multiple (two, for example) phase shifters **7** configures an LC filter. The phase shifter **7** configuring the LC filter includes a capacitor C**1** and an inductor L**1** connected in parallel with the capacitor C**1**. The LC filter is configured to block the passage of a radio frequency signal in a predetermined frequency band different from the first frequency band.

(110) As in the radio frequency module **1***c* according to Embodiment 3, the radio frequency module **1***d* according to Embodiment 4 may adjust the phases of radio frequency signals passing through the first paths r**11** in accordance with a pass band of a filter simultaneously used with the first filter **21**, even when there is a frequency band other than the second frequency band to be simultaneously used with the first frequency band (when there is a third frequency band or a fourth frequency band, for example) in simultaneous transmission or simultaneous reception. The phase adjustment is achieved by changing a pair of the first switching element Q**1** to be in the conductive state and the second switching element Q**2** to be in the non-conductive state among multiple pairs of the first switching element Q**1** and the second switching element Q**2**, in accordance with the frequency band simultaneously used with the first frequency band.

(111) Further, since the radio frequency module **1***d* according to Embodiment 4 includes the second switching element Q**2** and the fourth switching element Q**4** as in the radio frequency module **1***c* according to Embodiment 3, it is possible to improve the isolation between the first path r**11** and the second path r**12**.

(112) In the radio frequency module **1***d* according to Embodiment 4, one of the multiple phase shifters **7** configures an LC filter, but it is sufficient that at least one phase shifter **7** configures an LC filter, and each of the multiple phase shifters **7** may configures an LC filter.

Embodiment 5

(113) A radio frequency module **1***e* according to Embodiment 5 will be described with reference to FIG. **10** to FIG. **12**. With respect to the radio frequency module **1***e* according to Embodiment 5, the same constituents as those of the radio frequency module **1** according to Embodiment 1 are denoted by the same reference signs, and a description thereof is omitted.

(114) The radio frequency module **1***e* according to Embodiment 5 is different from the radio frequency module **1** according to Embodiment 1 in that the IC chip **10** includes the phase shifter **7** as well. The IC chip **10** includes the first switch **4**, the control circuit **16**, and the phase shifter **7**, that is, includes the first switch circuit **31**, the second switch circuit **32**, the third switch circuit **33**, and the fourth switch circuit **34**, the control circuit **16**, and the phase shifter **7**, but is not limited thereto. It is sufficient that the IC chip **10** includes at least the switch circuit **31** and the phase shifter **7**. The phase shifter **7** is provided between the selection terminal **40** of the first switch **4** and the first filter **21**, but is not limited thereto, and may be provided between the selection terminal **40** and the connection point T**1** of the first switching element Q**1** and the second switching element Q**12**, for example.

(115) The phase shifter **7** includes a digital tunable capacitor C**11** provided in the first path r**11** as illustrated in FIG. **11**, for example.

(116) Further, the radio frequency module **1***e* according to Embodiment 5 is different from the radio frequency module **1** according to Embodiment 1 in that the IC chip **10** mounted on the second main surface **92** of the mounting substrate **9** includes the phase shifter **7**, as illustrated in FIG. **12**. That is, in the radio frequency module **1***e* according to Embodiment 5, (the circuit element of) the phase shifter **7** is not mounted on the first main surface **91** of the mounting substrate **9**.

(117) In the radio frequency module **1***e*, since the phase shifter **7** and the switch circuit **31** are included in the one IC chip **10**, it is possible to shorten the wiring length between the phase shifter **7** and the switch circuit **31**.

(118) Further, in the radio frequency module **1***e*, the first filter **21** is mounted on the first main surface **91** of the mounting substrate **9**, and the first filter **21** overlaps with the IC chip **10** in a plan view from the thickness direction D**1** of the mounting substrate **9**. In the radio frequency module

1*e*, part of the first filter **21** overlaps with part of the IC chip **10** in a plan view from the thickness direction D**1** of the mounting substrate **9**. However, without necessarily being limited to this, the whole of the first filter **21** may overlap with part of the IC chip **10**, or the whole of the first filter **21** may overlap with the whole of the IC chip **10**.
(119) In the radio frequency module **1***e*, since the first filter **21** overlaps with the IC chip **10** in a plan view from the thickness direction D**1** of the mounting substrate **9**, it is possible to shorten the wiring length between the first filter **21** and the IC chip **10**.
(120) Since the radio frequency module **1***e* according to Embodiment 5 includes the second switching element Q**2** and the fourth switching element Q**4** as in the radio frequency module **1** according to Embodiment 1, it is possible to improve the isolation between the first path r**11** and the second path r**12**.
(121) The phase shifter **7** is not limited to a case of including the digital tunable capacitor C**11**, but may be configured to include a capacitor instead of the digital tunable capacitor C**11**, for example.
Modification of Embodiment 5
(122) A radio frequency module **1***f* according to a modification of Embodiment 5 will be described with reference to FIG. **13**. With respect to the radio frequency module **1***f* according to the modification, the same constituents as those of the radio frequency module **1***e* according to Embodiment 5 are denoted by the same reference signs, and a description thereof is omitted.
(123) The radio frequency module **1***f* according to the modification is different from the radio frequency module **1***e* according to Embodiment 5 in that the multiple external connection terminals **8** are ball bumps. Further, the radio frequency module **1***f* according to the modification is different from the radio frequency module **1***e* according to Embodiment 5 in that the second resin layer **18** of the radio frequency module **1***e* according to Embodiment 5 is not included. The radio frequency module **1***f* according to the modification may include an underfill portion provided in a gap between the IC chip **10** flip-chip mounted on the second main surface **92** of the mounting substrate **9** and the second main surface **92** of the mounting substrate **9**.
(124) The material of the ball bump constituting each of the multiple external connection terminals **8** is gold, copper, solder, or the like, for example.
(125) The multiple external connection terminals **8** may include an external connection terminal **8** configured of a ball bump and an external connection terminal **8** configured of a columnar electrode.
(126) The radio frequency module **1***f* according to the modification may improve the isolation between the first path r**11** and the second path r**12**, as in the radio frequency module **1***e* according to Embodiment 5.
Embodiment 6
(127) A radio frequency module **1***g* according to Embodiment 6 will be described with reference to FIG. **14**, and FIG. **15**A to FIG. **15**C. With respect to the radio frequency module **1***g* according to Embodiment 6, the same constituents as those of the radio frequency module **1** according to Embodiment 1 are denoted by the same reference signs, and a description thereof is omitted.
(128) The radio frequency module **1***g* according to Embodiment 6 includes a first switching element Q**11**, a second switching element Q**12**, and a third switching element Q**13** instead of the first switching element Q**1** to the fourth switching element Q**4** of the radio frequency module **1** according to Embodiment 1. The first switching element Q**11** is provided in the first path r**11** that is usable between the antenna terminal **80** and the first filter **21** in the first mode. The second switching element Q**12** is provided in the second path r**12** that is usable between the antenna terminal **80** and the first filter **21** in the second mode. The third switching element Q**13** is provided between the ground and a common path r**10** of the first path r**11** and the second path r**12**. The radio frequency module **1***g* further includes the phase shifter **7**. The phase shifter **7** is provided in the first path r**11** and changes the phase of a radio frequency signal.
(129) The phase shifter **7** is provided between the first switching element Q**11** and the first filter **21**

in the first path r**11**. More specifically, the phase shifter **7** is provided between the selection terminal **40** of the first switch **4** and the first filter **21**. The phase shifter **7** includes a digital tunable capacitor, for example.

(130) Hereinafter, an operation example of the radio frequency module **1***g* will be described with reference to FIG. **15**A to FIG. **15**C. In FIG. **15**A to FIG. **15**C, in order to easily recognize the conductive state (ON) and the non-conductive state (OFF) of the first switching element Q**11** to the third switching element Q**13** and the fifth switching element Q**5** to the tenth switching element Q**10**, graphic symbols of the first switching element Q**11** to the third switching element Q**13** and the fifth switching element Q**5** to the tenth switching element Q**10** are represented by graphic symbols of switches instead of graphic symbols of FETs. The control circuit **16** (see FIG. **1**) controls the first switching element Q**11** to the third switching element Q**13** and the fifth switching element Q**5** to the tenth switching element Q**10** by controlling the gate-source voltage of the FET constituting each of the first switching element Q**11** to the third switching element Q**13** and the fifth switching element Q**5** to the tenth switching element Q**10**. The control circuit **16** controls the first switching element Q**11** to the third switching element Q**13** and the fifth switching element Q**5** to the tenth switching element Q**10**, based on a control signal from the signal processing circuit **301** (see FIG. **1**), for example. In the radio frequency module **1***g*, upon receiving the first command from the signal processing circuit **301**, the control circuit **16** controls the first switching element Q**11** to the third switching element Q**13** and the fifth switching element Q**5** to the tenth switching element Q**10** so as to deal with the first mode. Further, upon receiving the second command from the signal processing circuit **301**, the control circuit **16** controls the first switching element Q**11** to the third switching element Q**13** and the fifth switching element Q**5** to the tenth switching element Q**10** so as to deal with the second mode.

(131) In the radio frequency module **1***g*, in the first mode in which simultaneous transmission, simultaneous reception, or simultaneous transmission and reception is performed using both the first filter **21** and the second filter **22**, each of the first switching element Q**11** to the third switching element Q**13** and the fifth switching element Q**5** to the tenth switching element Q**10** is in a state illustrated in FIG. **15**B. Further, in the radio frequency module **1***g*, in the second mode in which transmission or reception is performed using only the first filter **21** out of the first filter **21** and the second filter **22**, each of the first switching element Q**11** to the third switching element Q**13** and the fifth switching element Q**5** to the tenth switching element Q**10** is in a state illustrated in FIG. **15**A. In addition, in the radio frequency module **1***g*, in the third mode in which transmission or reception is performed using only the second filter **22** out of the first filter **21** and the second filter **22**, each of the first switching element Q**11** to the third switching element Q**13** and the fifth switching element Q**5** to the tenth switching element Q**10** is in a state illustrated in FIG. **15**C.

(132) In the first mode, as illustrated in FIG. **15**B, in the first switch circuit **31**, the first switching element Q**11** in the first path r**11** is in the conductive state (ON), the second switching element Q**12** in the second path r**12** is in the non-conductive state (OFF), and the third switching element Q**13** is in the non-conductive state (OFF). In the radio frequency module **1***g*, in the first mode, since the third switching element Q**13** is in the non-conductive state (OFF), the common path r**10**, the first path r**11**, and the second path r**12** are not electrically connected to the ground, and are in an open state with respect to the ground. This makes it possible to prevent that a radio frequency signal is not able to pass through the first path r**11** during the simultaneous transmission.

(133) Further, in the first mode, as illustrated in FIG. **15**B, in the second switch circuit **32**, the fifth switching element Q**5** in the signal path r**2** (third path) is in the conductive state (ON), and the sixth switching element Q**6** between the signal path r**2** and the ground is in the non-conductive state (OFF). Further, in the first mode, as illustrated in FIG. **15**B, in the third switch circuit **33**, the seventh switching element Q**7** in the signal path r**3** is in the non-conductive state (OFF), and the eighth switching element Q**8** between the signal path r**3** and the ground is in the conductive state (ON). Since the eighth switching element Q**8** is in the conductive state (ON), the signal path r**3** of

the third switch circuit **33** is electrically connected to the ground (is in a state being short-circuited to the ground). Further, in the first mode, as illustrated in FIG. **15**B, in the fourth switch circuit **34**, the ninth switching element Q**9** in the signal path r**4** is in the non-conductive state (OFF), and the tenth switching element Q**10** between the signal path r**4** and the ground is in the conductive state (ON). Since the tenth switching element Q**10** is in the conductive state (ON), the signal path r**4** of the fourth switch circuit **34** is electrically connected to the ground (is in a state being short-circuited to the ground).

(134) In the second mode, as illustrated in FIG. **15**A, in the first switch circuit **31**, the first switching element Q**11** in the first path r**11** is in the non-conductive state (OFF), the second switching element Q**12** in the second path r**12** is in the conductive state (ON), and the third switching element Q**13** is in the non-conductive state (OFF). In the radio frequency module **1***g*, in the second mode, since the third switching element Q**13** is in the non-conductive state (OFF), the first path r**11** and the second path r**12** are not electrically connected to the ground (are in an open state with respect to the ground).

(135) In the second mode, as illustrated in FIG. **15**A, in the second switch circuit **32**, the fifth switching element Q**5** in the signal path r**2** is in the non-conductive state (OFF), and the sixth switching element Q**6** between the signal path r**2** and the ground is in the conductive state (ON). Since the sixth switching element Q**6** is in the conductive state (ON), the signal path r**2** of the second switch circuit **32** is electrically connected to the ground (is in a state being short-circuited to the ground). Further, in the second mode, as illustrated in FIG. **15**A, in the third switch circuit **33**, the seventh switching element Q**7** in the signal path r**3** is in the non-conductive state (OFF), and the eighth switching element Q**8** between the signal path r**3** and the ground is in the conductive state (ON). Since the eighth switching element Q**8** is in the conductive state (ON), the signal path r**3** of the third switch circuit **33** is electrically connected to the ground (is in a state being short-circuited to the ground). Further, in the second mode, as illustrated in FIG. **15**A, in the fourth switch circuit **34**, the ninth switching element Q**9** in the signal path r**4** is in the non-conductive state (OFF), and the tenth switching element Q**10** between the signal path r**4** and the ground is in the conductive state (ON). Since the tenth switching element Q**10** is in the conductive state (ON), the signal path r**4** of the fourth switch circuit **34** is electrically connected to the ground (is in a state being short-circuited to the ground).

(136) In the third mode, as illustrated in FIG. **15**C, in the first switch circuit **31**, the first switching element Q**11** in the first path r**11** is in the non-conductive state (OFF), the second switching element Q**12** in the second path r**12** is in the non-conductive state (OFF), and the third switching element Q**13** is in the conductive state (ON). Since the third switching element Q**13** is in the conductive state (ON), the first path r**11** and the second path r**12** are electrically connected to the ground (are in a state being short-circuited to the ground).

(137) In the third mode, as illustrated in FIG. **15**C, in the second switch circuit **32**, the fifth switching element Q**5** in the signal path r**2** is in the conductive state (ON), and the sixth switching element Q**6** between the signal path r**2** and the ground is in the non-conductive state (OFF). Further, in the third mode, as illustrated in FIG. **15**C, in the third switch circuit **33**, the seventh switching element Q**7** in the signal path r**3** is in the non-conductive state (OFF), and the eighth switching element Q**8** is in the conductive state (ON). In addition, in the third mode, as illustrated in FIG. **15**C, in the fourth switch circuit **34**, the ninth switching element Q**9** in the signal path r**4** is in the non-conductive state (OFF), and the tenth switching element Q**10** is in the conductive state (ON).

(138) Hereinafter, the operation of the control circuit **16** will be described in more detail.

(139) Upon receiving the first command, as illustrated in FIG. **15**B described above, the control circuit **16** controls the first switching element Q**11** and the fifth switching element Q**5** to be in the conductive state, controls the second switching element Q**12**, the third switching element Q**13**, the sixth switching element Q**6**, the seventh switching element Q**7**, and the ninth switching element Q**9**

to be in the non-conductive state, and controls the eighth switching element Q**8** and the tenth switching element Q**10** to be in the conductive state. Therefore, in the first mode, the control circuit **16** brings the third switching element Q**13** corresponding to the first path r**11** and the second path r**12** into the non-conductive state.
(140) Further, upon receiving the second command, as illustrated in FIG. **15**A described above, the control circuit **16** controls the second switching element Q**12** to be in the conductive state, controls the first switching element Q**11**, the third switching element Q**13**, the fifth switching element Q**5**, the seventh switching element Q**7**, and the ninth switching element Q**9** to be in the non-conductive state, and controls the eighth switching element Q**8** and the tenth switching element Q**10** to be in the conductive state. Therefore, in the second mode, the control circuit **16** brings the first switching element Q**11** and the third switching element Q**13** into the non-conductive state with respect to the first switch circuit **31**.
(141) Hereinafter, for the convenience of description, each of the first switching element Q**11**, the second switching element Q**12**, the fifth switching element Q**5**, the seventh switching element Q**7**, and the ninth switching element Q**9** may sometimes be referred to as a series switch without necessarily being distinguished from one another. Further, each of the third switching element Q**13**, the sixth switching element Q**6**, the eighth switching element Q**8**, and the tenth switching element Q**10** may sometimes be referred to as a shunt switch without necessarily being distinguished from one another. The radio frequency module **1***g* includes multiple (five) pairs of a series switch and a shunt switch. The multiple pairs include a pair of the first switching element Q**11** and the third switching element Q**13**, a pair of the second switching element Q**12** and the third switching element Q**13**, a pair of the fifth switching element Q**5** and the sixth switching element Q**6**, a pair of the seventh switching element Q**7** and the eighth switching element Q**8**, and a pair of the ninth switching element Q**9** and the tenth switching element Q**10**. The third switching element Q**13** is paired with each of the first switching element Q**11** and the second switching element Q**12**.
(142) When the radio frequency module **1***g* operates in the first mode, the control circuit **16** brings both the series switch and the shunt switch corresponding to the second path r**12** into the non-conductive state, and exclusively controls the series switch and the shunt switch in a pair of the series switch and the shunt switch corresponding to each of the first path r**11**, the signal path r**2**, the signal path r**3**, and the signal path r**4**. “Exclusively controls the series switch and the shunt switch in a pair” means that, with respect to a pair of a series switch and a shunt switch, one of the series switch and the shunt switch is controlled to be in the conductive state, and the other of the series switch and the shunt switch is controlled to be in the non-conductive state. Further, when the radio frequency module **1***g* operates in the second mode, the control circuit **16** brings both the series switch and the shunt switch corresponding to the first path r**11** into the non-conductive state, and exclusively controls the series switch and the shunt switch in a pair of the series switch and the shunt switch corresponding to each of the second path r**12**, the signal path r**2**, the signal path r**3**, and the signal path r**4**.
(143) Since the radio frequency module **1***g* according to Embodiment 6 includes the third switching element Q**13**, it is possible to improve the isolation between the first path r**11** and the second path r**12**.
(144) The phase shifter **7** may include a capacitor instead of a digital tunable capacitor. The phase shifter **7** is not limited to be provided between the selection terminal **40** of the first switch **4** and the first filter **21**, but may be provided between the first switching element Q**11** and the selection terminal **40**, for example. Further, the phase shifter **7** may be provided in the second path r**12** instead of the first path r**11**.
Other Modifications
(145) Each of Embodiment 1 to Embodiment 6 described above is merely one of diverse embodiments of the present disclosure. Each of Embodiment 1 to Embodiment 6 described above may variously be modified in accordance with the design or the like as long as the object of the

present disclosure is achieved.
(146) It is acceptable that the radio frequency modules **1** to **1***g* may be configured such that the first switch **4** is controlled by the controller **14** without necessarily including the control circuit **16**, or the first switch **4** is directly controlled by the signal processing circuit **301**.
(147) Further, in the radio frequency module **1** to the radio frequency module **1***f*, each of the first switching element Q**1** to the tenth switching element Q**10** is not limited to an FET, but may be a bipolar transistor, a CMOS switch, or a MEMS switch, for example. Further, in the radio frequency module **1***g*, each of the first switching element Q**11** to the third switching element Q**13** and the fifth to tenth switching elements Q**10** is not limited to an FET, but may be a bipolar transistor or a CMOS switch, for example.
(148) The phase shifter **7** is not limited to be provided in one of the first path r**11** and the second path r**12** of the switch circuit **31**, but may be provided in both the first path r**11** and the second path r**12**.
(149) Further, the transmission filters **211**, **221**, **231**, and **241** and the reception filters **212**, **222**, **232**, and **242** are acoustic wave filters using a surface acoustic wave, but are not limited thereto, and may be acoustic wave filters using a boundary acoustic wave, a plate wave, or the like, for example.
(150) The acoustic wave filter is not limited to have a configuration including multiple SAW resonators, but may have a configuration including multiple Bulk Acoustic Wave (BAW) resonators, for example.
(151) Further, the radio frequency modules **1** to **1***g* may include a multiplexer, a coupler, and the like between the antenna terminal **80** and the first switch **4**. The multiplexer is a diplexer or a triplexer, for example.
(152) Circuit configurations of the radio frequency modules **1** to **1***g* are not limited to the examples described above. Further, each of the radio frequency modules **1** to **1***g* may include a radio frequency front-end circuit dealing with Multi Input Multi Output (MIMO) as a circuit configuration, for example.
(153) In addition, the communication device **300** according to Embodiment 1 may include any one of the radio frequency modules **1***a*, **1***b*, **1***c*, **1***d*, **1***e*, **1***f*, and **1***g* instead of the radio frequency module **1**.
(154) (Aspect)
(155) The following aspects are disclosed in the present description.
(156) A radio frequency module (**1**; **1***a*; **1***b*; **1***c*; **1***d*; **1***e*; **1***f*) according to a first aspect includes an antenna terminal (**80**), a first filter (**21**), a second filter (**22**), and a switch circuit (**31**). The first filter (**21**) is a filter having a pass band of a first frequency band. The second filter (**22**) is a filter having a pass band of a second frequency band different from the first frequency band. The switch circuit (**31**) is connected between the antenna terminal (**80**) and the first filter (**21**). The radio frequency module (**1**; **1***a*; **1***b*; **1***c*; **1***d*; **1***e*; **1***f*) is capable of operating in a first mode in which simultaneous transmission, simultaneous reception, or simultaneous transmission and reception using both the first filter (**21**) and the second filter (**22**) is possible, and in a second mode in which transmission or reception using only the first filter (**21**) out of the first filter (**21**) and the second filter (**22**) is possible. The switch circuit (**31**) includes a first switching element (Q**1**), a second switching element (Q**2**), a third switching element (Q**3**), and a fourth switching element (Q**4**). The first switching element (Q**1**) is provided in a first path (r**11**) that is usable between the antenna terminal (**80**) and the first filter (**21**) in the first mode. The second switching element (Q**2**) is provided between the first path (r**11**) and a ground. The third switching element (Q**3**) is provided in a second path (r**12**) that is usable between the antenna terminal (**80**) and the first filter (**21**) in the second mode. The fourth switching element (Q**4**) is provided between the second path (r**12**) and the ground. The radio frequency module (**1**; **1***a*; **1***b*; **1***c*; **1***d*; **1***e*; **1***f*) further includes a phase shifter (**7**). The phase shifter (**7**) is provided in at least one of the first path (r**11**) and the second path (r**12**), and

changes the phase of a radio frequency signal.
(157) In the radio frequency module (**1**; **1***a*; **1***b*; **1***c*; **1***d*; **1***e*; **1***f*) according to the first aspect, it is possible to improve the isolation between the first path (r**11**) and the second path (r**12**).
(158) In a radio frequency module (**1**; **1***a*; **1***b*; **1***c*; **1***d*; **1***e*; **1***f*) according to a second aspect, in the first aspect, when one of the first switching element (Q**1**) and the third switching element (Q**3**) is in a conductive state and the other of the first switching element (Q**1**) and the third switching element (Q**3**) is in a non-conductive state, the second switching element (Q**2**) and the fourth switching element (Q**4**) are in the non-conductive state.
(159) In the radio frequency module (**1**; **1***a*; **1***b*; **1***c*; **1***d*; **1***e*; **1***f*) according to the second aspect, it is possible to suppress the deterioration in characteristics when operating in each of the first mode and the second mode.
(160) In a radio frequency module (**1**; **1***a*; **1***c*; **1***d*; **1***e*; **1***f*) according to a third aspect, in the first or second aspect, the second switching element (Q**2**) is connected to a path between the first switching element (Q**1**) and the first filter (**21**) in the first path (r**11**). The fourth switching element (Q**4**) is connected to a path between the third switching element (Q**3**) and the first filter (**21**) in the second path (r**12**).
(161) In the radio frequency module (**1**; **1***a*; **1***c*; **1***d*; **1***e*; **1***f*) according to the third aspect, when the reception using only the second filter (**22**) out of the first filter (**21**) and the second filter (**22**) is performed, the second switching element (Q**2**) and the fourth switching element (Q**4**) may be brought into the non-conductive state, for example.
(162) A radio frequency module (**1**; **1***a*; **1***c*; **1***d*; **1***e*; **1***f*) according to a fourth aspect, in any one of the first to third aspects, further includes a second switch circuit (**32**) in addition to a first switch circuit (**31**) being the switch circuit (**31**). The second switch circuit (**32**) is connected between the antenna terminal (**80**) and the second filter (**22**). The second switch circuit (**32**) includes a fifth switching element (Q**5**) and a sixth switching element (Q**6**). The fifth switching element (Q**5**) is provided in a third path (signal path r**2**) between the antenna terminal (**80**) and the second filter (**22**). The sixth switching element (Q**6**) is provided between the third path (signal path r**2**) and the ground.
(163) The radio frequency module (**1**; **1***a*; **1***b*; **1***c*; **1***d*; **1***e*; **1***f*) according to the fourth aspect may bring the fifth switching element (Q**5**) into the conductive state and the sixth switching element (Q**6**) into the non-conductive state when operating in the first mode, and may bring the fifth switching element (Q**5**) into the non-conductive state and the sixth switching element (Q**6**) into the conductive state when operating in the second mode. Thus, in the radio frequency module (**1**; **1***a*; **1***b*; **1***c*; **1***d*; **1***e*; **1***f*) according to the fourth aspect, it is possible to improve each of the isolation between the first path (r**11**) and the third path (signal path r**2**), and the isolation between the second path (r**12**) and the third path (signal path r**2**).
(164) In a radio frequency module (**1**; **1***a*; **1***c*; **1***d*; **1***e*; **1***f*) according to a fifth aspect, in any one of the first to fourth aspects, the phase shifter (**7**) is provided in the first path (r**11**).
(165) The radio frequency module (**1**; **1***a*; **1***c*; **1***d*; **1***e*; **1***f*) according to the fifth aspect may change the phase of a radio frequency signal passing through the first path (r**11**).
(166) In a radio frequency module (**1***b*) according to a sixth aspect, in any one of the first to fourth aspects, the phase shifter (**7**) is provided in the second path (r**12**).
(167) The radio frequency module (**1***b*) according to the sixth aspect may change the phase of a radio frequency signal passing through the second path (r**12**).
(168) In a radio frequency module (**1***c*; **1***d*) according to a seventh aspect, in the fifth aspect, the switch circuit (**31**) includes multiple first paths (r**11**). The radio frequency module (**1***c*; **1***d*) includes multiple phase shifters (**7**). The multiple phase shifters (**7**) are provided in a one-to-one basis with the multiple first paths (r**11**). The multiple phase shifters (**7**) are different from each other in impedance.
(169) The radio frequency module (**1***c*; **1***d*) according to the seventh aspect may adjust the phases

of radio frequency signals passing through the first paths (r**11**) in accordance with a pass band of a filter simultaneously used with the first filter (**21**), even when there is a frequency band simultaneously used with the first frequency band other than the second frequency band (when there is a third frequency band or a fourth frequency band, for example) in simultaneous transmission or simultaneous reception. The phase adjustment is achieved by changing a pair of the first switching element (Q**1**) to be in the conductive state and the second switching element (Q**2**) to be in the non-conductive state among multiple pairs of the first switching element (Q**1**) and the second switching element (Q**2**), in accordance with the frequency band simultaneously used with the first frequency band.
(170) In a radio frequency module (**1***d*) according to an eighth aspect, in the seventh aspect, at least one of the multiple phase shifters (**7**) configures an LC filter.
(171) The radio frequency module (**1***d*) according to the eighth aspect may block a radio frequency signal in a frequency band different from the pass band of the first filter (**21**) in the phase shifter (**7**) configuring an LC filter.
(172) In a radio frequency module (**1**; **1***a*; **1***b*; **1***c*; **1***d*; **1***e*; **1***f*) according to a ninth aspect, in any one of the first to eighth aspects, each of the first switching element (Q**1**), the second switching element (Q**2**), the third switching element (Q**3**), and the fourth switching element (Q**4**) is an FET.
(173) In the radio frequency module (**1**; **1***a*; **1***b*; **1***c*; **1***d*; **1***e*; **1***f*) according to the ninth aspect, power consumption of each of the first switching element (Q**1**), the second switching element (Q**2**), the third switching element (Q**3**), and the fourth switching element (Q**4**) may be reduced.
(174) A radio frequency module (**1***g*) according to a tenth aspect includes the antenna terminal (**80**), the first filter (**21**), the second filter (**22**), and the switch circuit (**31**). The first filter (**21**) is a filter having a pass band of the first frequency band. The second filter (**22**) is a filter having a pass band of the second frequency band different from the first frequency band. The switch circuit (**31**) is connected between the antenna terminal (**80**) and the first filter (**21**). The radio frequency module (**1***g*) is capable of operating in a first mode in which simultaneous transmission, simultaneous reception, or simultaneous transmission and reception using both the first filter (**21**) and the second filter (**22**) is possible, and in a second mode in which transmission or reception using only the first filter (**21**) out of the first filter (**21**) and the second filter (**22**) is possible. The radio frequency module (**1***g*) includes a first switching element (Q**11**), a second switching element (Q**12**), and a third switching element (Q**13**). The first switching element (Q**11**) is provided in a first path (r**1**) that is usable between the antenna terminal (**80**) and the first filter (**21**) in the first mode. The second switching element (Q**12**) is provided in a second path (r**12**) that is usable between the antenna terminal (**80**) and the first filter (**21**) in the second mode. The third switching element (Q**13**) is provided between the ground and a common path (r**10**) of the first path (r**11**) and the second path (r**12**). The radio frequency module (**1***g*) further includes the phase shifter (**7**). The phase shifter (**7**) is provided in at least one of the first path (r**11**) and the second path (r**12**), and changes the phase of a radio frequency signal.
(175) In the radio frequency module (**1***g*) according to the tenth aspect, it is possible to improve the isolation between the first path (r**11**) and the second path (r**12**).
(176) In a radio frequency module (**1***g*) according to an eleventh aspect, in the tenth aspect, when one of the first switching element (Q**11**) and the second switching element (Q**12**) is in the conductive state and the other of the first switching element (Q**11**) and the second switching element (Q**12**) is in the non-conductive state, the third switching element (Q**13**) is in the non-conductive state.
(177) In a radio frequency module (**1***g*) according to a twelfth aspect, in the tenth or eleventh aspect, each of the first switching element (Q**11**), the second switching element (Q**12**), and the third switching element (Q**13**) is an FET.
(178) In the radio frequency module (**1***g*) according to the twelfth aspect, power consumption of each of the first switching element (Q**11**), the second switching element (Q**12**), and the third

switching element (Q**13**) may be reduced.
(179) A radio frequency module (**1**; **1***a*; **1***b*; **1***c*; **1***d*; **1***e*; **1***f*; **1***g*) according to a thirteenth aspect, in any one of the first to twelfth aspects, further includes a control circuit (**16**). The control circuit (**16**) controls the switch circuit (**31**).
(180) In the radio frequency module (**1**; **1***a*; **1***b*; **1***c*; **1***d*; **1***e*; **1***f*; **1***g*) according to the thirteenth aspect, the switch circuit (**31**) may be controlled by the control circuit (**16**).
(181) In a radio frequency module (**1**; **1***a*; **1***b*; **1***c*; **1***d*; **1***e*; **1***f*; **1***g*) according to a fourteenth aspect, in any one of the first to thirteenth aspects, the first filter (**21**) is a duplexer including a transmission filter (**211**) and a reception filter (**212**).
(182) When the radio frequency module (**1**; **1***a*; **1***b*; **1***c*; **1***d*; **1***e*; **1***f*; **1***g*) according to the fourteenth aspect operates in the first mode, the first filter (**21**) may deal with both the simultaneous transmission and simultaneous reception. Further, when the radio frequency module (**1**; **1***a*; **1***b*; **1***c*; **1***d*; **1***e*; **1***f*; **1***g*) according to the fourteenth aspect operates in the second mode, the first filter (**21**) may deal with both the transmission and reception.
(183) In a radio frequency module (**1**; **1***b*; **1***c*; **1***d*) according to a fifteenth aspect, in any one of the first to fourteenth aspects, the phase shifter (**7**) includes a capacitor (C**1**).
(184) The radio frequency module (**1**; **1***b*; **1***c*; **1***d*) according to the fifteenth aspect may change the phase of a radio frequency signal by the capacitor (C**1**).
(185) In a radio frequency module (**1***a*; **1***b*; **1***e*; **1***f*; **1***g*) according to a sixteenth aspect, in any one of the first to fourteenth aspects, the phase shifter (**7**) includes a digital tunable capacitor (C**11**).
(186) The radio frequency module (**1***a*; **1***b*; **1***e*; **1***f*; **1***g*) according to the sixteenth aspect may adjust the phase of a radio frequency signal passing through the first path (r**11**) in accordance with a pass band of a filter simultaneously used with the first filter (**21**), even when there is a frequency band simultaneously used with the first frequency band other than the second frequency band in simultaneous transmission or simultaneous reception. The phase adjustment is achieved by changing the capacitance of the digital tunable capacitor (C**11**) in accordance with the frequency band simultaneously used with the first frequency band.
(187) A radio frequency module (**1***e*; **1***f*) according to a seventeenth aspect, in the sixteenth aspect, further includes an IC chip (**10**) including at least the switch circuit (**31**) and the phase shifter (**7**).
(188) In the radio frequency module (**1***e*; **1***f*) according to the seventeenth aspect, it is possible to shorten the wiring length between the switch circuit (**31**) and the phase shifter (**7**).
(189) A radio frequency module (**1**; **1***a*; **1***b*; **1***c*; **1***d*) according to an eighteenth aspect, in any one of the first to sixteenth aspects, further includes a mounting substrate (**9**). The mounting substrate (**9**) has a first main surface (**91**) and a second main surface (**92**) opposed to each other. A circuit element (capacitor C**1**) of the phase shifter (**7**) is mounted on the first main surface (**91**) of the mounting substrate (**9**). The IC chip (**10**) including the switch circuit (**31**) is mounted on the second main surface (**92**) of the mounting substrate (**9**). The circuit element (capacitor C**1**) of the phase shifter (**7**) overlaps with the IC chip (**10**) in a plan view from the thickness direction (D**1**) of the mounting substrate (**9**).
(190) In the radio frequency module (**1**; **1***a*; **1***b*; **1***c*; **1***d*) according to the eighteenth aspect, it is possible to shorten the wiring length between the phase shifter (**7**) and the switch circuit (**31**).
(191) In a radio frequency module (**1***e*; **1***f*) according to a nineteenth aspect, in the eighteenth aspect, the first filter (**21**) is mounted on the first main surface (**91**) of the mounting substrate (**9**). The first filter (**21**) overlaps with the IC chip (**10**) in a plan view from the thickness direction (D**1**) of the mounting substrate (**9**).
(192) In the radio frequency module (**1**; **1***a*; **1***b*; **1***c*; **1***d*) according to the nineteenth aspect, it is possible to shorten the wiring length between the first filter (**21**) and the IC chip (**10**).
(193) A communication device (**300**) according to a twentieth aspect includes the radio frequency module (**1**; **1***a*; **1***b*; **1***c*; **1***d*; **1***e*; **1***f*; **1***g*) according to any one of the first to nineteenth aspects, and a signal processing circuit (**301**). The signal processing circuit (**301**) is connected to the radio

frequency module (**1**; **1***a*; **1***b*; **1***c*; **1***d*; **1***e*; **1***f*; **1***g*).
(194) In the communication device (**300**) according to the twentieth aspect, it is possible to improve the isolation between the first path (r**11**) and the second path (r**12**).
(195) A radio frequency module radio frequency module (**1**; **1***a*; **1***b*; **1***c*; **1***d*; **1***e*; **1***f*) according to a twenty-first aspect includes the antenna terminal (**80**), the first filter (**21**), the second filter (**22**), and the switch circuit (**31**). The first filter (**21**) is a filter having a pass band of the first frequency band. The second filter (**22**) is a filter having a pass band of the second frequency band different from the first frequency band. The switch circuit (**31**) is connected between the antenna terminal (**80**) and the first filter (**21**). The switch circuit (**31**) includes the first switching element (Q**1**), the second switching element (Q**2**), the third switching element (Q**3**), and the fourth switching element (Q**4**). The first switching element (Q**1**) is provided in the first path (r**11**) between the antenna terminal (**80**) and the first filter (**21**). The second switching element (Q**2**) is provided between the first path (r**11**) and the ground. The third switching element (Q**3**) is provided in the second path (r**12**) between the antenna terminal (**80**) and the first filter (**21**). The fourth switching element (Q**4**) is provided between the second path (r**12**) and the ground. The radio frequency module (**1**; **1***a*; **1***b*; **1***c*; **1***d*; **1***e*; **1***f*) further includes the phase shifter (**7**). The phase shifter (**7**) is provided in at least one of the first path (r**11**) and the second path (r**12**), and changes the phase of a radio frequency signal.
(196) In the radio frequency module (**1**; **1***a*; **1***b*; **1***c*; **1***d*; **1***e*; **1***f*) according to the twenty-first aspect, it is possible to improve the isolation between the first path (r**11**) and the second path (r**12**).
(197) In the radio frequency module (**1**; **1***a*; **1***b*; **1***c*; **1***d*; **1***e*; **1***f*) according to the twenty-first aspect, the configurations according to the second to ninth and thirteenth to nineteenth aspects may be added as appropriate. Further, the communication device (**300**) according to the twentieth aspect may include the radio frequency module (**1**; **1***a*; **1***b*; **1***c*; **1***d*; **1***e*; **1***f*) according to the twenty-first aspect, instead of the radio frequency module (**1**; **1***a*; **1***b*; **1***c*; **1***d*; **1***e*; **1***f*) according to the first aspect.
REFERENCE SIGNS LIST
(198) **1**, **1***a*, **1***b*, **1***c*, **1***d*, **1***e*, **1***f*, **1***g* RADIO FREQUENCY MODULE **4** FIRST SWITCH **40** to **44** SELECTION TERMINAL **49** COMMON TERMINAL **5** SECOND SWITCH **50** COMMON TERMINAL **51** to **54** SELECTION TERMINAL **6** THIRD SWITCH **60** COMMON TERMINAL **61** to **64** SELECTION TERMINAL **7** PHASE SHIFTER **8** EXTERNAL CONNECTION TERMINAL **80** ANTENNA TERMINAL **81** SIGNAL INPUT TERMINAL **82** SIGNAL OUTPUT TERMINAL **83** FIRST CONTROL TERMINAL **84** SECOND CONTROL TERMINAL **85** GROUND TERMINAL **9** MOUNTING SUBSTRATE **91** FIRST MAIN SURFACE **92** SECOND MAIN SURFACE **93** OUTER PERIPHERAL SURFACE **10** IC CHIP **11** POWER AMPLIFIER **13** OUTPUT MATCHING CIRCUIT **14** CONTROLLER **15** LOW-NOISE AMPLIFIER **16** CONTROL CIRCUIT **17** FIRST RESIN LAYER **171** MAIN SURFACE **173** OUTER PERIPHERAL SURFACE **18** SECOND RESIN LAYER **183** OUTER PERIPHERAL SURFACE **21** FIRST FILTER **211** TRANSMISSION FILTER **212** RECEPTION FILTER **22** SECOND FILTER **221** TRANSMISSION FILTER **222** RECEPTION FILTER **23** THIRD FILTER **231** TRANSMISSION FILTER **232** RECEPTION FILTER **24** FOURTH FILTER **241** TRANSMISSION FILTER **242** RECEPTION FILTER **31** SWITCH CIRCUIT (FIRST SWITCH CIRCUIT) **32** SECOND SWITCH CIRCUIT **33** THIRD SWITCH CIRCUIT **34** FOURTH SWITCH CIRCUIT **300** COMMUNICATION DEVICE **301** SIGNAL PROCESSING CIRCUIT **302** RF SIGNAL PROCESSING CIRCUIT **303** BASEBAND SIGNAL PROCESSING CIRCUIT **310** ANTENNA C**1** CAPACITOR (CIRCUIT ELEMENT) C**11** DIGITAL TUNABLE CAPACITOR D**1** THICKNESS DIRECTION L**1** INDUCTOR Q**1** FIRST SWITCHING ELEMENT Q**2** SECOND SWITCHING ELEMENT Q**3** THIRD SWITCHING ELEMENT Q**4** FOURTH SWITCHING ELEMENT Q**11** FIRST SWITCHING ELEMENT Q**12** SECOND SWITCHING ELEMENT Q**13** THIRD SWITCHING ELEMENT r**1** SIGNAL PATH r**10**

COMMON PATH r**11** FIRST PATH r**12** SECOND PATH r**2** SIGNAL PATH (THIRD PATH) r**3** SIGNAL PATH r**4** SIGNAL PATH

Claims

1. A radio frequency module, comprising: an antenna terminal; a first filter comprising a pass band of a first frequency band; a second filter comprising a pass band of a second frequency band different from the first frequency band; and a switch circuit connected between the antenna terminal and the first filter, wherein the radio frequency module is configured to operate: in a first mode in which simultaneous transmission, simultaneous reception, or simultaneous transmission and reception that utilizes both the first filter and the second filter, and in a second mode in which transmission or reception that utilizes only the first filter out of the first filter and the second filter, the switch circuit comprises: a first switching element in a first path that is usable between the antenna terminal and the first filter in the first mode, a second switching element between the first path and a ground, a third switching element in a second path that is usable between the antenna terminal and the first filter in the second mode, and a fourth switching element between the second path and the ground, and the radio frequency module further comprising: a phase shifter circuit in at least one of the first path and the second path and is configured to change a phase of a radio frequency signal.
2. The radio frequency module according to claim 1, wherein when one of the first switching element and the third switching element is in a conductive state and another of the first switching element and the third switching element is in a non-conductive state, the second switching element and the fourth switching element are in the non-conductive state.
3. The radio frequency module according to claim 1, wherein the second switching element is connected between the first switching element and the first filter in the first path, and the fourth switching element is connected between the third switching element and the first filter in the second path.
4. The radio frequency module according to claim 1, further comprising: a second switch circuit connected between the antenna terminal and the second filter in addition to a first switch circuit comprising the switch circuit, wherein the second switch circuit comprises: a fifth switching element in a third path between the antenna terminal and the second filter, and a sixth switching element between the third path and the ground.
5. The radio frequency module according to claim 1, wherein the phase shifter circuit is in the first path.
6. The radio frequency module according to claim 5, wherein the switch circuit comprises: a plurality of the first paths, the radio frequency module comprises: a plurality of the phase shifter circuits and the plurality of the phase shifter circuits are in the plurality of the first paths on a one-to-one basis, and the plurality of the phase shifter circuits are different from each other in impedance.
7. The radio frequency module according to claim 6, wherein at least one of the plurality of the phase shifter circuits comprises an inductor-capacitor (LC) filter.
8. The radio frequency module according to claim 1, wherein the phase shifter circuit is in the second path.
9. The radio frequency module according to claim 1, wherein each of the first switching element, the second switching element, the third switching element, and the fourth switching element comprises a field-effect transistor (FET).
10. The radio frequency module according to claim 1, further comprising: a control circuit configured to control the switch circuit.
11. The radio frequency module according to claim 1, wherein the first filter comprises a duplexer comprising a transmission filter and a reception filter.

12. The radio frequency module according to claim 1, wherein the phase shifter circuit comprises a capacitor.
13. The radio frequency module according to claim 1, wherein the phase shifter circuit comprises a digital tunable capacitor.
14. The radio frequency module according to claim 13, further comprising: an integrated circuit (IC) chip that comprises at least the switch circuit and the phase shifter circuit.
15. The radio frequency module according to claim 1, further comprising: a mounting substrate comprising a first main surface and a second main surface that are opposed to each other, wherein a circuit element of the phase shifter circuit is mounted on the first main surface of the mounting substrate, an integrated circuit (IC) chip, comprising the switch circuit, is mounted on the second main surface of the mounting substrate, and the circuit element of the phase shifter circuit overlaps with the IC chip in a plan view from a thickness direction of the mounting substrate.
16. The radio frequency module according to claim 15, wherein the first filter is mounted on the first main surface of the mounting substrate, and the first filter overlaps with the IC chip in a plan view from the thickness direction of the mounting substrate.
17. A communication device, comprising: the radio frequency module according to claim 1; and a signal processing circuit connected to the radio frequency module.
18. A radio frequency module, comprising: an antenna terminal; a first filter comprising a pass band of a first frequency band; a second filter comprising a pass band of a second frequency band different from the first frequency band; and a switch circuit connected between the antenna terminal and the first filter, wherein the radio frequency module is configured to operate: in a first mode in which simultaneous transmission, simultaneous reception, or simultaneous transmission and reception that utilizes both the first filter and the second filter, and in a second mode in which transmission or reception that utilizes only the first filter out of the first filter and the second filter, the radio frequency module further comprises: a first switching element in a first path that is usable between the antenna terminal and the first filter in the first mode, a second switching element in a second path that is usable between the antenna terminal and the first filter in the second mode, and a third switching element between a ground and a common path of the first path and the second path, and the radio frequency module further comprises: a phase shifter circuit that is in at least one of the first path and the second path and is configured to change a phase of a radio frequency signal.
19. The radio frequency module according to claim 18, wherein when one of the first switching element and the second switching element is in a conductive state and another of the first switching element and the second switching element is in a non-conductive state, the third switching element is in the non-conductive state.
20. The radio frequency module according to claim 18, wherein each of the first switching element, the second switching element, and the third switching element comprises a field-effect transistor (FET).