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(54) **RADIO FREQUENCY CIRCUIT**

(71) Applicant: **Murata Manufacturing Co., Ltd.**, Nagaokakyo-shi (JP)

(72) Inventors: **Hirotsugu MORI**, Nagaokakyo-shi (JP); **Morio TAKEUCHI**, Nagaokakyo-shi (JP)

(73) Assignee: **Murata Manufacturing Co., Ltd.**, Nagaokakyo-shi (JP)

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(57) **ABSTRACT**

A radio frequency circuit includes: a first filter having a passband including a first frequency band that is at least one of a transmission band or a receiving band of a first Non-Terrestrial Network (NTN) band; a second filter having a passband including a second frequency band that is at least one of a transmission band or a receiving band of a second NTN band; a third filter having a passband including a third frequency band that is at least one of a transmission band or a receiving band of a first Terrestrial Network (TN) band; and a first switch that includes a first terminal connected to an antenna connection terminal, a second terminal connected to the first and second filters, and a third terminal connected to the third filter. The third frequency band at least partially overlaps a frequency gap between the first and second frequency bands.

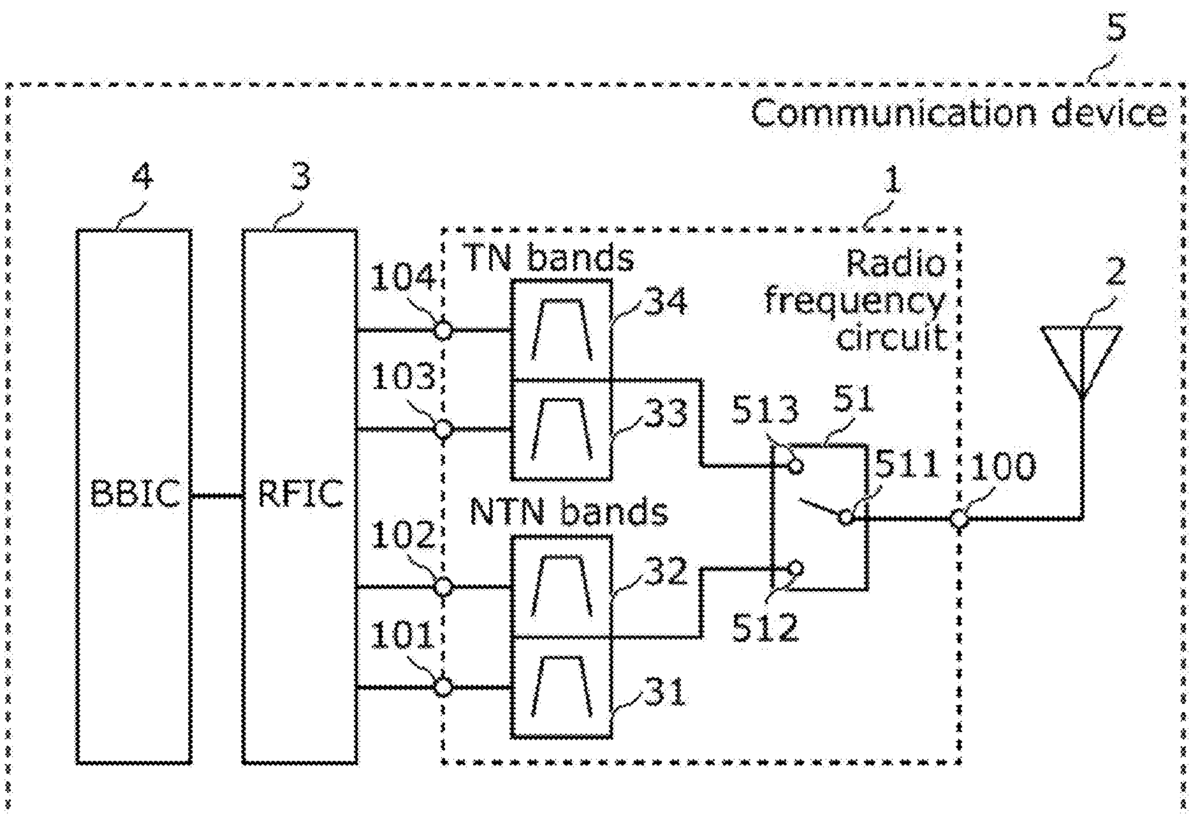


FIG. 1

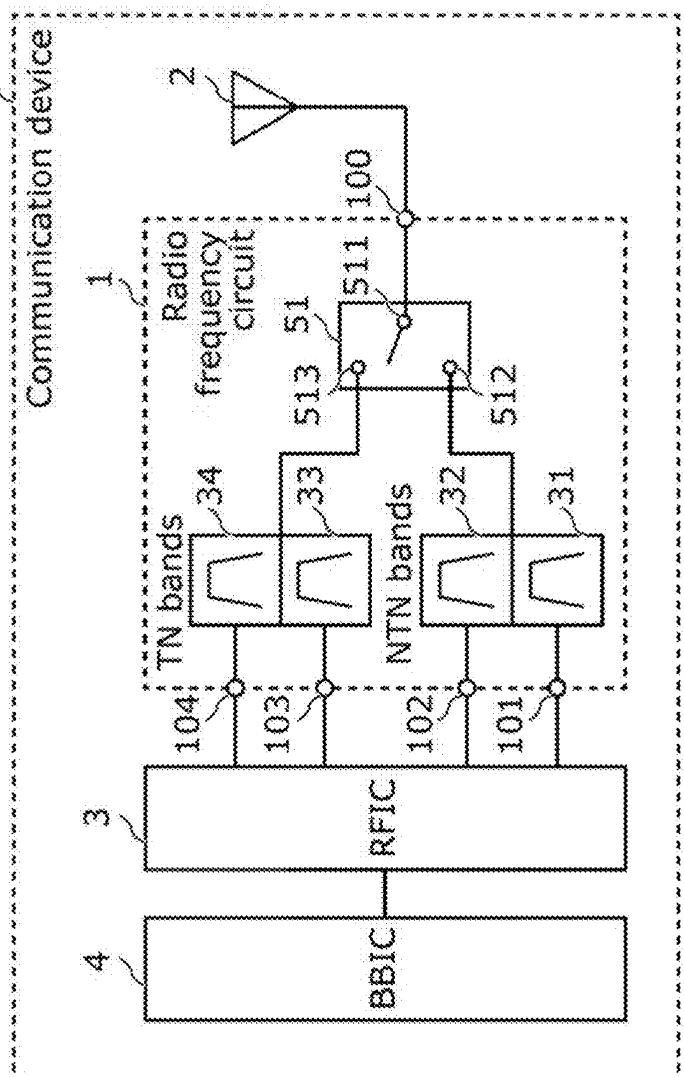

5
Communication device
2
100
1
Radio frequency circuit
51
511
513
512
34
33
TN bands
32
31
NTN bands
104
103
102
101
3
RFIC
4
BBIC

FIG. 2

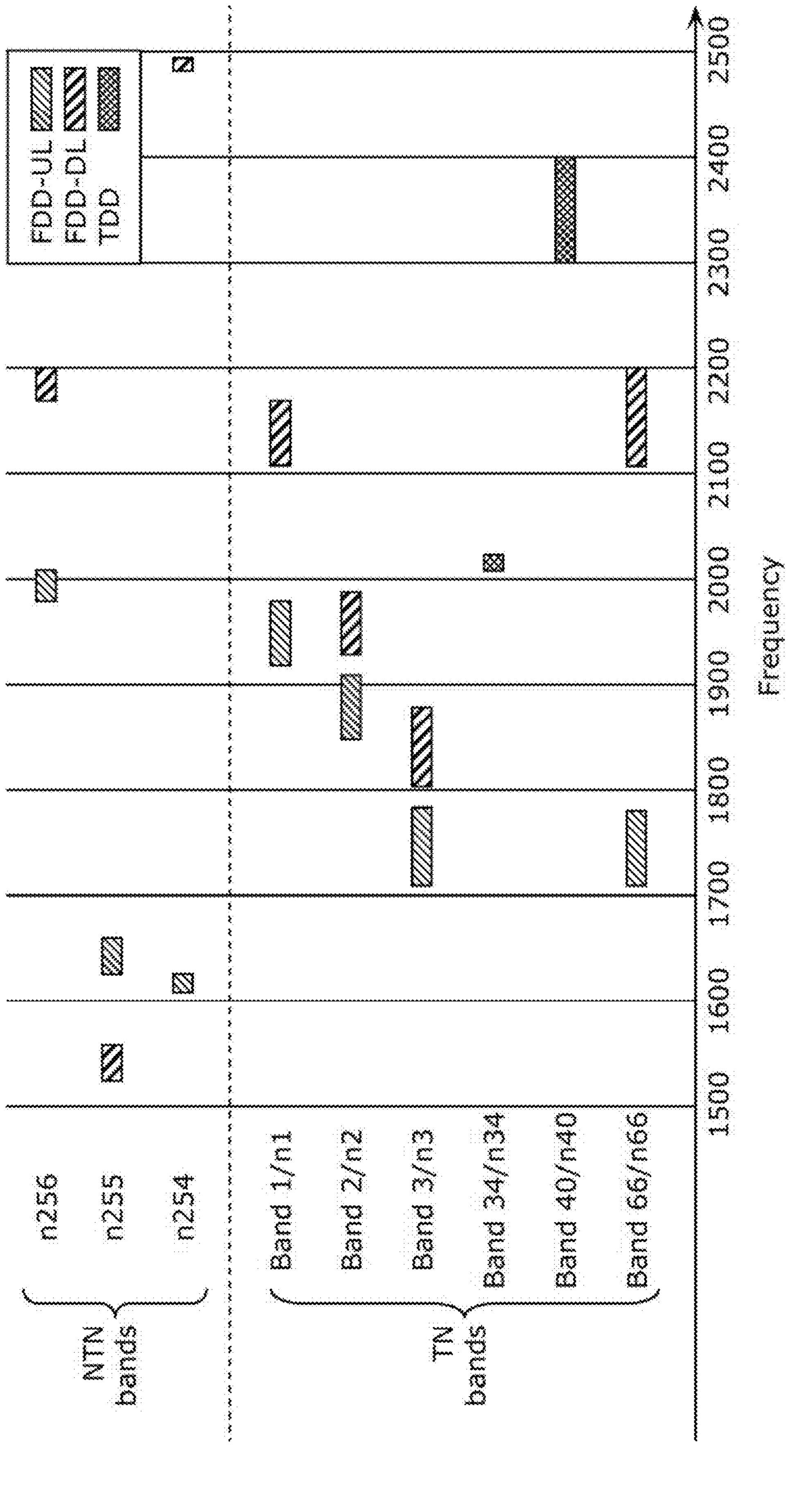

FDD-UL
FDD-DL
TDD
NTN bands
n256
n255
n254
TN bands
Band 1/n1
Band 2/n2
Band 3/n3
Band 34/n34
Band 40/n40
Band 66/n66
1500
1600
1700
1800
1900
2000
2100
2200
2300
2400
2500
Frequency

FIG. 3A

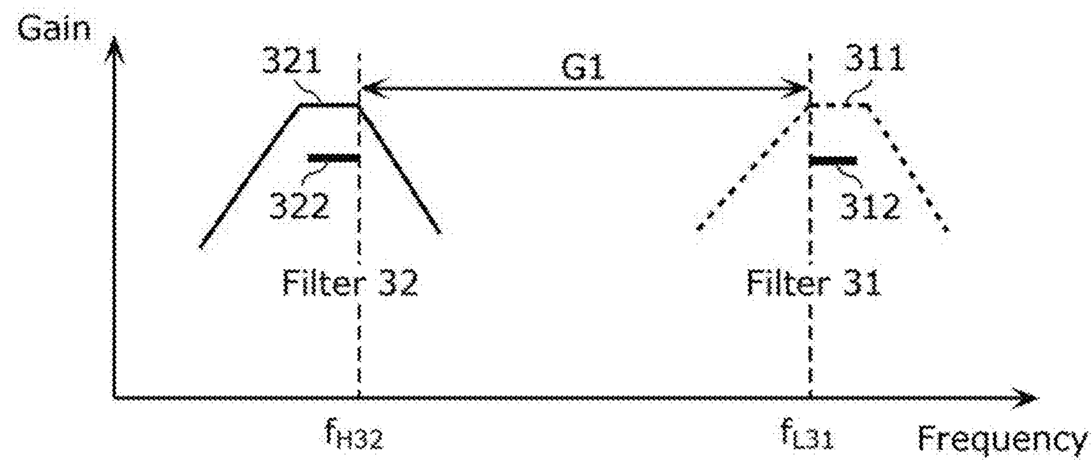

Gain
321
G1
311
322
312
Filter 32
Filter 31
$f_{H32}$
$f_{L31}$
Frequency

FIG. 3B

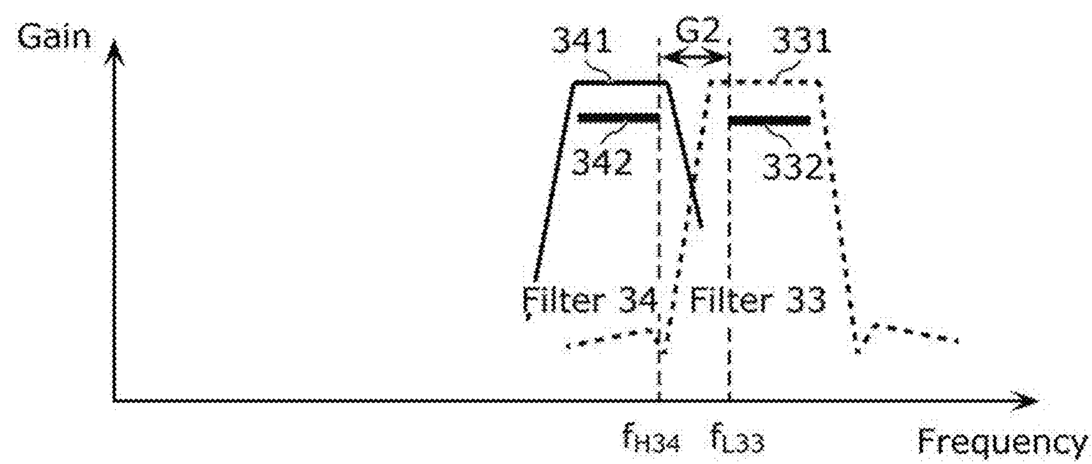

Gain
341
G2
331
342
332
Filter 34
Filter 33
$f_{H34}$
$f_{L33}$
Frequency

FIG. 4

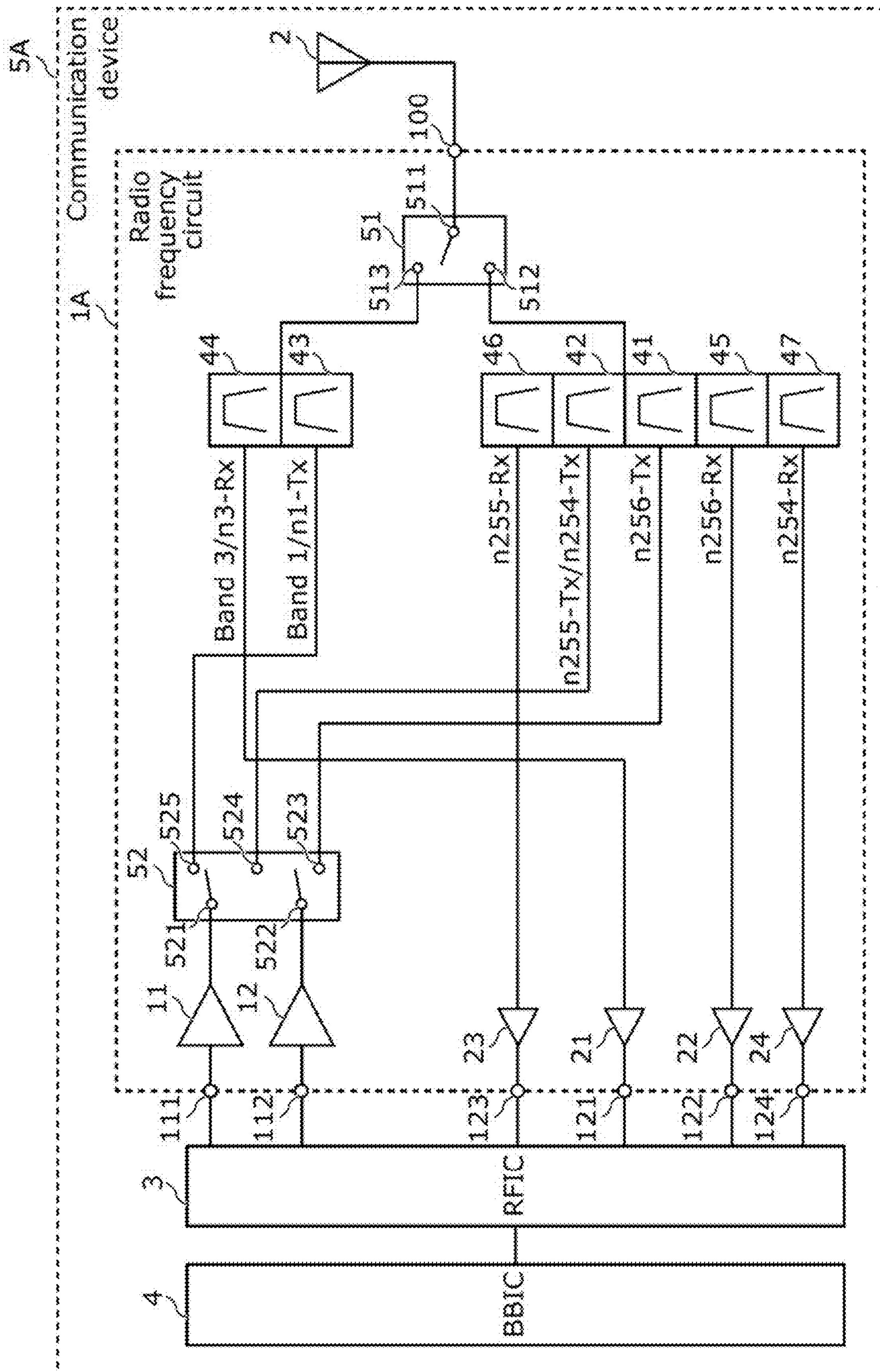
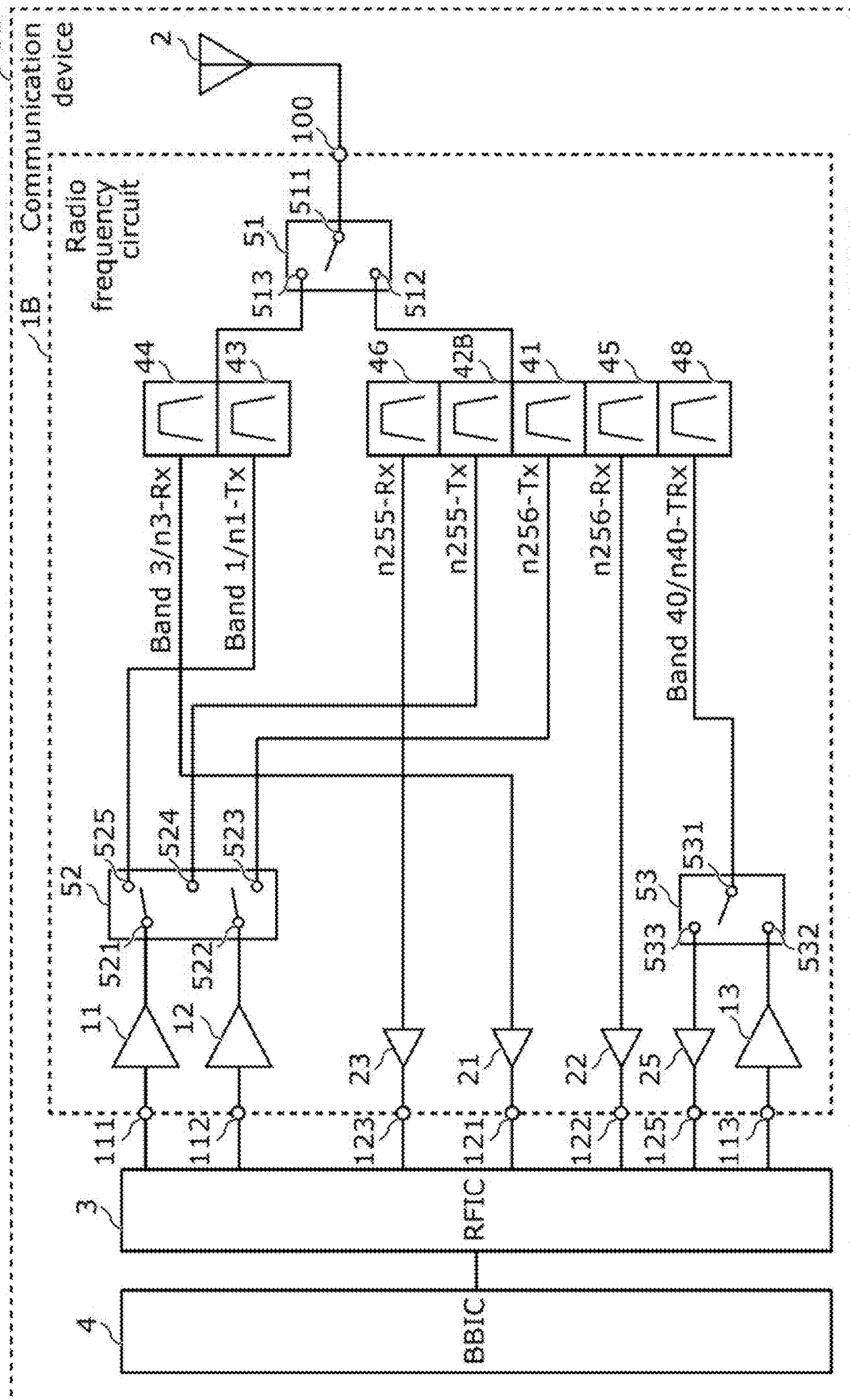

5A
Communication device
2
100
1A
Radio frequency circuit
51
511
513
512
44
43
46
42
41
45
47
Band 3/n3-Rx
Band 1/n1-Tx
n255-Rx
n255-Tx/n254-Tx
n256-Tx
n256-Rx
n254-Rx
52
525
524
523
521
522
11
12
23
21
22
24
111
112
123
121
122
124
3
RFIC
4
BBIC

FIG. 5



5B
Communication device
2
100
1B
Radio frequency circuit
51
511
513
512
44
43
46
42B
41
45
48
Band 3/n3-Rx
Band 1/n1-Tx
n255-Rx
n255-Tx
n256-Tx
n256-Rx
Band 40/n40-TRx
52
525
524
523
521
522
53
531
533
532
11
12
23
21
22
25
13
111
112
123
121
122
125
113
3
RFIC
4
BBIC

# RADIO FREQUENCY CIRCUIT

## CROSS-REFERENCE TO RELATED APPLICATIONS

**[0001]** This is a continuation application of PCT International Application No. PCT/JP2023/027628 filed on Jul. 27, 2023, designating the United States of America, which is based on and claims priority to Japanese Patent Application No. 2022-183885 filed on Nov. 17, 2022. The entire disclosures of the above-identified applications, including the specifications, drawings and claims are incorporated herein by reference in their entirety.

## TECHNICAL FIELD

**[0002]** The present disclosure relates to a radio frequency circuit.

## BACKGROUND

**[0003]** The 3rd Generation Partnership Project (3GPP (registered trademark)) has been examining integration of Terrestrial Networks (TNs) into Non-Terrestrial Networks (NTNs) and standardizing the NTNs.

## SUMMARY

### Technical Problems

**[0004]** However, as recognized by the present inventor, there are concerns with conventional radio frequency circuits disclosed by, for instance, US Patent Application Publication No. 2015/0133067, such as an increase in the size of a communication device and/or deterioration of characteristics, in a case in which TNs and NTNs are both supported.

**[0005]** In view of this, the present disclosure provides a radio frequency circuit that can support both TNs and NTNs and contribute to reduction in the size of a communication device and/or improvement of properties.

### Solutions

**[0006]** A radio frequency circuit according to an aspect of the present disclosure includes: a first filter having a passband that includes a first frequency band that is at least one of a transmission band or a receiving band of a first Non-Terrestrial Network (NTN) band; a second filter having a passband that includes a second frequency band that is at least one of a transmission band or a receiving band of a second NTN band; a third filter having a passband that includes a third frequency band that is at least one of a transmission band or a receiving band of a first Terrestrial Network (TN) band; and a first switch that includes a first terminal connected to an antenna connection terminal, a second terminal connected to the first filter and the second filter, and a third terminal connected to the third filter. The third frequency band at least partially overlaps a frequency gap between the first frequency band and the second frequency band.

**[0007]** A radio frequency circuit according to an aspect of the present disclosure includes: a first filter having a passband that includes a first frequency band that is a transmission band of a Non-Terrestrial Network (NTN) band; a second filter having a passband that includes a second frequency band that is a receiving band of the NTN band; a third filter having a passband that includes a third frequency band that is at least one of a transmission band or a receiving band of a Terrestrial Network (TN) band; and a switch that includes a first terminal connected to an antenna connection terminal, a second terminal connected to the first filter and the second filter, and a third terminal connected to the third filter. The third frequency band at least partially overlaps a frequency gap between the first frequency band and the second frequency band.

### Advantageous Effects

**[0008]** According to a radio frequency circuit, it is possible to support both TNs and NTNs and contribute to reduction in the size of a communication device and/or improvement of characteristics.

## BRIEF DESCRIPTION OF DRAWINGS

**[0009]** These and other advantages and features will become apparent from the following description thereof taken in conjunction with the accompanying Drawings, by way of non-limiting examples of embodiments disclosed herein.

**[0010]** FIG. **1** illustrates a circuit configuration of a communication device according to Embodiment 1.

**[0011]** FIG. **2** illustrates Non-Terrestrial Network (NTN) bands and Terrestrial Network (TN) bands.

**[0012]** FIG. **3**A illustrates frequency characteristics of filters for NTN bands according to Embodiment 1.

**[0013]** FIG. **3**B illustrates frequency characteristics of filters for TN bands according to Embodiment 1.

**[0014]** FIG. **4** illustrates a circuit configuration of a communication device according to Embodiment 2.

**[0015]** FIG. **5** illustrates a circuit configuration of a communication device according to Embodiment 3.

## DESCRIPTION OF EMBODIMENTS

**[0016]** The following describes in detail embodiments of the present disclosure, with reference to the drawings. Note that the embodiments described below each show a general or specific example. The numerical values, shapes, materials, elements, and the arrangement and connection of the elements, for instance, described in the following embodiments are examples, and thus are not intended to limit the present disclosure.

**[0017]** Note that the drawings are schematic diagrams to which emphasis, omission, and ratio adjustment are appropriately added in order to illustrate the present disclosure, and thus are not necessarily accurate illustrations. The drawings may show shapes, positional relations, and ratios that are different from actual shapes, actual positional relations, and actual ratios. Throughout the drawings, the same numeral is given to substantially the same element, and redundant description may be omitted or simplified.

**[0018]** In the circuit configuration of the present disclosure, "being connected" includes not only the case of being directly connected by a connection terminal and/or a line conductor, but also the case of being electrically connected via another circuit element. "Being connected between A and B" means being connected between A and B and to both A and B, and means being connected in series onto a path that connects A and B. A "terminal" means a point at which a conductor in an element ends. Note that under a condition that an impedance of a conductor between elements is sufficiently low, a terminal can be interpreted not only as a single fixed point, but as any point on the conductor between the elements or as the entire conductor.

**[0019]** In the present disclosure, Terrestrial Network (TN) bands and Non-Terrestrial Network (NTN) bands are frequency bands for TNs and NTNs, which are established using radio access technology (RAT) and are predefined by, for instance, standardizing bodies (such as the 3GPP and the Institute of Electrical and Electronics Engineers (IEEE), for example).

**[0020]** In the present disclosure, a "frequency gap between Band A and Band B" means a range between the highest frequency in Band A (that is, the high-frequency edge of Band A) and the lowest frequency in Band B (that is, the low-frequency edge of Band B) under a condition that Band A has a range of frequencies lower than the frequencies of the range of Band B. At this time, the high-frequency edge of Band A is lower than the low-frequency edge of Band B. The expression "Band C at least partially overlaps a frequency gap" means there is an overlapping portion between Band C and the frequency gap. At this time, the overlapping portion may be a band edge only. Thus, the expression "Band C at least partially overlaps a frequency gap" includes the high-frequency edge of Band C matching the low-frequency edge of the frequency gap and the low-frequency edge of Band C matching the high-frequency edge of the frequency gap.

**[0021]** In the present disclosure, a "transmission band" means a frequency band used for transmission in a communication device. For example, a frequency band different from the receiving band is used as a transmission band in a Frequency Division Duplex (FDD) band. On the other hand, a frequency band the same as the receiving band is used as a transmission band in a Time Division Duplex (TDD) band. In particular, in a case in which a communication device functions as a user equipment (UE) for TNs or NTNs, an uplink operation band is used as a transmission band in an FDD band. Conversely, in a case in which a communication device functions as a base station (BS) for TNs or NTNs, the downlink operation band is used as the transmission band in an FDD band.

**[0022]** In the present disclosure, "a passband of a filter" is defined as a frequency band which is a portion of a frequency spectrum of a signal transferred by a filter and in which an output power is not attenuated from a maximum output power by 3 dB or more.

## Embodiment 1

**[0023]** Embodiment 1 is to be described. Communication device **5** according to the present embodiment functions as a user equipment (UE) in Terrestrial Networks (TNs) and Non-Terrestrial Networks (NTNs), and typically is a mobile phone, a smartphone, a tablet computer, or a wearable device, for instance. Note that communication device **5** may be an Internet of Things (IoT) sensor/device, a medical/health care device, a vehicle, an unmanned aerial vehicle (UAV) (a so-called drone), or an automated guided vehicle (AGV). Communication device **5** may function as a base station (BS) in TNs and NTNs.

**[0024]** A circuit configuration of communication device **5** and radio frequency circuit **1** according to the present embodiment is to be described with reference to FIG. **1**. FIG. **1** illustrates a circuit configuration of communication device **5** according to the present embodiment.

**[0025]** Note that FIG. **1** illustrates an exemplary circuit configuration, and communication device **5** and radio frequency circuit **1** may be implemented using any of various types of circuit implementations and circuit technologies. Thus, the description of communication device **5** and radio frequency circuit **1** provided below should not be interpreted in a limited manner.

### [1.1 Circuit Configuration of Communication Device 5]

**[0026]** First, a circuit configuration of communication device **5** according to the present embodiment is to be described with reference to FIG. **1**. Communication device **5** includes radio frequency circuit **1**, antenna **2**, radio frequency integrated circuit (RFIC) **3**, and baseband integrated circuit (BBIC) **4**.

**[0027]** Radio frequency circuit **1** transfers radio frequency signals between antenna **2** and RFIC **3**. A circuit configuration of radio frequency circuit **1** is to be described later.

**[0028]** Antenna **2** is connected to antenna connection terminal **100** of radio frequency circuit **1**. Antenna **2** receives radio frequency signals from radio frequency circuit **1** and outputs the radio frequency signals to the outside of communication device **5**. Antenna **2** receives radio frequency signals from the outside of communication device **5** and outputs the radio frequency signals to radio frequency circuit **1**. Note that antenna **2** may not be included in communication device **5**. Communication device **5** may further include one or more antennas in addition to antenna **2**.

**[0029]** RFIC **3** is an example of a signal processing circuit that processes radio frequency signals. Specifically, RFIC **3** processes transmission signals input from BBIC **4** by, for instance, up-conversion, and outputs radio frequency transmission signals generated by processing the transmission signals to radio frequency circuit **1**. Furthermore, RFIC **3** processes radio frequency received signals input through a reception path of radio frequency circuit **1** by down-conversion, for instance, and outputs received signals generated by processing the radio frequency received signals to BBIC **4**. RFIC **3** may include a controller configured to control, for instance, a switch and a power amplifier that are included in radio frequency circuit **1**. Note that the controller may be partially or entirely provided outside of RFIC **3** and may be partially or entirely provided in BBIC **4** or radio frequency circuit **1**, for example.

**[0030]** BBIC **4** is a base band signal processing circuit that processes signals using an intermediate frequency band lower than the frequency of a radio frequency signal transferred by radio frequency circuit **1**. A signal processed by BBIC **4** is used, for example, as an image signal for image display or as an audio signal for talk through a loudspeaker. Note that BBIC **4** may not be included in communication device **5**.

### [1.2 Circuit Configuration of Radio Frequency Circuit 1]

**[0031]** Next, a circuit configuration of radio frequency circuit **1** according to the present embodiment is to be described with reference to FIG. **1**. Radio frequency circuit **1** includes filters **31** to **34**, switch **51**, antenna connection terminal **100**, and input-output terminals **101** to **104**.

**[0032]** Antenna connection terminal **100** is an external connection terminal of radio frequency circuit **1** and is connected to antenna **2** outside radio frequency circuit **1**. Antenna connection terminal **100** is connected to switch **51**

inside radio frequency circuit **1**. Accordingly, radio frequency circuit **1** can supply transmission signals to antenna **2** via antenna connection terminal **100**, and can be supplied with received signals from antenna **2** via antenna connection terminal **100**.

**[0033]** Input-output terminals **101** to **104** are external connection terminals of radio frequency circuit **1** and are connected to RFIC **3** outside radio frequency circuit **1**. Input-output terminals **101** to **104** are connected to filters **31** to **34** inside radio frequency circuit **1**, respectively. Accordingly, input-output terminals **101** to **104** can receive radio frequency signals from RFIC **3** and/or can supply radio frequency signals to RFIC **3**.

**[0034]** Filter **31** is an example of a first filter, and has a passband that includes a first frequency band. Filter **31** is connected between input-output terminal **101** and terminal **512** of switch **51**. As the first frequency band, one of the transmission band or the receiving band of a first NTN band can be used.

**[0035]** Filter **32** is an example of a second filter, and has a passband that includes a second frequency band. Filter **32** is connected between input-output terminal **102** and terminal **512** of switch **51**. Accordingly, filter **32** is connected to the same terminal as the terminal to which filter **31** is connected. As the second frequency band, a remaining one of the transmission band or the receiving band of the first NTN band or one of the transmission band or the receiving band of a second NTN band can be used.

**[0036]** Filter **33** is an example of a third filter, and has a passband that includes a third frequency band. Filter **33** is connected between input-output terminal **103** and terminal **513** of switch **51**. Accordingly, filter **33** is connected to a terminal different from the terminal to which filters **31** and **32** are connected. As the third frequency band, at least one of the transmission band or the receiving band of a first TN band can be used.

**[0037]** Filter **34** is an example of a fourth filter, and has a passband that includes a fourth frequency band. Filter **34** is connected between input-output terminal **104** and terminal **513** of switch **51**. Accordingly, filter **34** is connected to a terminal different from the terminal to which filters **31** and **32** are connected and is connected to the same terminal as the terminal to which filter **33** is connected. As the fourth frequency band, at least one of the transmission band or the receiving band of a second TN band can be used. Note that filter **34** may not be included in radio frequency circuit **1**.

**[0038]** A surface acoustic wave (SAW) filter, a bulk acoustic wave (BAW) filter, an inductor-capacitor (LC) resonator filter, a dielectric resonator filter, or a combination of any of these may be used as each of such filters **31** to **34**, and furthermore, filters **31** to **34** are not limited to these.

**[0039]** Switch **51** is an example of a first switch, and is connected between antenna connection terminal **100** and filters **31** to **34**. Specifically, switch **51** includes terminals **511** to **513**. Terminal **511** is an example of a first terminal, and is connected to antenna connection terminal **100**. Terminal **512** is an example of a second terminal, and is connected to filters **31** and **32**. Terminal **513** is an example of a third terminal, and is connected to filters **33** and **34**.

**[0040]** With this connection configuration, switch **51** can connect terminal **511** exclusively to terminal **512** or can connect terminal **511** exclusively to terminal **513**, based on a control signal from RFIC **3**, for example. Stated differently, terminal **511** is prohibited from being simultaneously connected to terminals **512** and **513** in switch **51**. Switch **51** includes a single-pole double-throw (SPDT) switch circuit, for example.

**[0041]** Switch **51** may be mounted on a semiconductor integrated circuit that includes a plurality of metal-oxide-semiconductor field-effect transistors (MOSFETs), for example. Note that the method for mounting switch **51** is not limited thereto.

[1.3 Description of First to Fourth Frequency Bands]

**[0042]** Here, the first to fourth frequency bands that can be used in the present embodiment are to be described with reference to FIG. **2**. FIG. **2** illustrates frequency bands that can be used in the present embodiment. In FIG. **2**, the vertical axis shows band names, and the horizontal axis shows frequencies (MHZ).

**[0043]** The first to fourth frequency bands satisfy the following conditions. Note that in a case in which radio frequency circuit **1** does not include filter **34**, (4) and (5) are not included in the conditions. (1) The first frequency band is included in the first NTN band. (2) The second frequency band is included in the first NTN band or the second NTN band. (3) The third frequency band is included in the first TN band and at least partially overlaps the frequency gap between the first frequency band and the second frequency band. (4) The fourth frequency band is included in the first TN band or the second TN band and at least partially overlaps the frequency gap between the first frequency band and the second frequency band. (5) The frequency gap between the first frequency band and the second frequency band is wider than the frequency gap between the third frequency band and the fourth frequency band.

**[0044]** As combinations of the first to fourth frequency bands that satisfy (1) to (5) stated above, combinations stated in Table 1 shown below can be used, for example. In the following, "n" represents a band for 5th Generation New Radio (5G NR), whereas "Band" represents a band for Long Term Evolution (LTE). The numerical values following "n" and "Band" represent numbers for identifying bands. Tx represents transmission in FDD bands, Rx represents reception in FDD bands, and TRx represents transmission and reception in TDD bands.

TABLE 1

| No. | First freq. band | Second freq. band | Third freq. band | Fourth freq. band |
|---|---|---|---|---|
| 1 | n256-Tx/Rx | n255-Tx/Rx | Band 1/n1-Tx | Band 3/n3-Tx/Rx |
| 2 | or | or | Band 2/n2-Tx/Rx | Band 66/n66-Tx |
| 3 | n254-Rx | n254-Tx | Band 2/n2-Tx | Band 2/n2-Rx |
| 4 | | | Band 3/n3-Tx | Band 3/n3-Rx |
| 5 | n256-Rx | | Band 1/n1-Tx | Band 1/n1-Rx |
| 6 | or | | Band 1/n1-Rx | Band 3/n3-Tx/Rx |
| 7 | n254-Rx | | Band 1/n1-Tx/Rx | Band 34/n34-TRx |
| 8 | | | Band 3/n3-Tx/Rx | Band 34/n34-TRx |
| 9 | | | Band 2/n2-Tx/Rx | Band 66/n66-Rx |
| 10 | | | Band 66/n66-Tx | |
| 11 | n254-Rx | | Band 1/n1-Tx/Rx | Band 40/n40-TRx |
| 12 | | | Band 3/n3-Tx/Rx | |
| 13 | | | Band 34/n34-TRx | |
| 14 | n256-Rx | n256-Tx | Band 1/n1-Rx | Band 34/n34-TRx |
| 15 | | | Band 66-Rx | — |

**[0045]** For example, according to No. 1 of the combinations, the transmission band or the receiving band of n256 or the receiving band of n254 is used as the first frequency band, and the transmission band or the receiving band of n255 or the transmission band of n254 is used as the second frequency band. At this time, the transmission band of Band 1 or n1 is used as the third frequency band, and the transmission band or the receiving band of Band 3 or n3 is used as the fourth frequency band.

**[0046]** Note that the first frequency band and the second frequency band can be interchanged with each other, and the third frequency band and the fourth frequency band can also be interchanged with each other. FDD bands are used as NTN bands, but TDD bands may be used. In this case, transmission-receiving bands of TDD bands may be used as the first frequency band and/or the second frequency band.

[1.4 Filter Characteristics]

**[0047]** Filter characteristics of filters **31** to **34** having passbands that include the first frequency band to the fourth frequency band are to be described with reference to FIG. **3**A and FIG. **3**B. FIG. **3**A illustrates frequency characteristics of filters **31** and **32** for NTN bands according to the present embodiment. FIG. **3**B illustrates frequency characteristics of filters **33** and **34** for TN bands according to the present embodiment. In FIG. **3**A and FIG. **3**B, the horizontal axis represents frequency, and the vertical axis represents gain.

**[0048]** FIG. **3**A illustrates frequency characteristics **311** of filter **31** and frequency characteristics **321** of filter **32**. In frequency characteristics **311**, the passband of filter **31** includes first frequency band **312**. In frequency characteristics **321**, the passband of filter **32** includes second frequency band **322**.

**[0049]** FIG. **3**B illustrates frequency characteristics **331** of filter **33** and frequency characteristics **341** of filter **34**. In frequency characteristics **331**, the passband of filter **33** includes first frequency band **332**. In frequency characteristics **341**, the passband of filter **34** includes second frequency band **342**.

**[0050]** Note that in FIG. **3**A, frequency gap G**1** between first frequency band **312** and second frequency band **322** is defined by low-frequency edge $f_{L31}$ of the first frequency band and high-frequency edge $f_{H32}$ of the second frequency band. In FIG. **3**B, frequency gap G**2** between third frequency band **332** and fourth frequency band **342** is defined by low-frequency edge $f_{L33}$ of the third frequency band and high-frequency edge $f_{H34}$ of the fourth frequency band. Frequency gap G**1** thus defined is wider than frequency gap G**2**. Thus, the steepness of attenuation characteristics on the lower frequency side of filter **31** can be made less than the steepness of attenuation characteristics on the lower frequency side of filter **33**. Similarly, the steepness of attenuation characteristics on the higher frequency side of filter **32** can be made less than the steepness of attenuation characteristics on the higher frequency side of filter **34**.

**[0051]** [1.5 Advantageous effects and others]

**[0052]** As described above, radio frequency circuit **1** according to the present embodiment includes: filter **31** having a passband that includes a first frequency band that is at least one of a transmission band or a receiving band of a first Non-Terrestrial Network (NTN) band; filter **32** having a passband that includes a second frequency band that is at least one of a transmission band or a receiving band of a second NTN band; filter **33** having a passband that includes a third frequency band that is at least one of a transmission band or a receiving band of a first Terrestrial Network (TN) band; and switch **51** that includes terminal **511** connected to antenna connection terminal **100**, terminal **512** connected to filter **31** and filter **32**, and terminal **513** connected to filter **33**. The third frequency band at least partially overlaps a frequency gap between the first frequency band and the second frequency band.

**[0053]** According to this, terminal **513** of switch **51** to which filter **33** for the first TN band is connected is different from terminal **512** of switch **51** to which filters **31** and **32** for the first NTN band and the second NTN band are connected. Thus, switch **51** can ensure the isolation of filters **31** and **32** from filter **33**. As a result, the need for attenuation in the third frequency band included in the first TN band can be reduced in filters **31** and **32**, and resistance loss of filters **31** and **32** can be decreased and/or the sizes of filters **31** and **32** can be reduced. In particular, the frequency gap between bands is wider in an NTN than in a TN. Thus, since the need for attenuation in the third frequency band that at least partially overlaps the frequency gap between the first frequency band and the second frequency band is reduced, steepness of attenuation characteristics at passband edges of filters **31** and **32** can be made less, which is effective in reducing resistance loss and sizes of filters **31** and **32**.

**[0054]** For example, in radio frequency circuit **1** according to the present embodiment, switch **51** may be configured to connect terminal **511** exclusively to terminal **512** or to connect terminal **511** exclusively to terminal **513**.

**[0055]** According to this, the isolation between (i) filters **31** and **32** connected to terminal **512** and (ii) filter **33** connected to terminal **513** can be effectively ensured, and resistance loss and sizes of filters **31** and **32** can be more effectively reduced.

**[0056]** For example, in radio frequency circuit **1** according to the present embodiment, the first frequency band may be the transmission band of the first NTN band, the second frequency band may be the transmission band of the second NTN band, and the third frequency band may be the transmission band of the first TN band.

**[0057]** According to this, radio frequency circuit **1** can support transmission of radio frequency signals in NTNs and TNs.

**[0058]** For example, in radio frequency circuit **1** according to the present embodiment, the first NTN band may be n256 for 5th Generation New Radio (5G NR), the second NTN band may be n255 or n254 for 5G NR, and the first TN band may be Band 1 for Long Term Evolution (LTE) or n1 for 5G NR.

**[0059]** According to this, radio frequency circuit **1** can use n256 for 5G NR and n255 or n254 for 5G NR to transmit radio frequency signals in NTNs, and can use Band 1 for LTE or n1 for 5G NR to transmit radio frequency signals in TNs.

**[0060]** For example, radio frequency circuit **1** according to the present embodiment may further include: filter **34** connected to terminal **513** of switch **51** and having a passband that includes a fourth frequency band that is at least one of a transmission band or a receiving band of a second TN band. The fourth frequency band may at least partially overlap the frequency gap between the first frequency band and the second frequency band, and the frequency gap between the first frequency band and the second frequency band may be wider than a frequency gap between the third frequency band and the fourth frequency band.

**[0061]** According to this, filter **34** for the second TN band is connected to terminal **513** of switch **51**. Thus, switch **51** can ensure the isolation of filters **31** and **32** from filter **34**, and radio frequency circuit **1** can further support the second TN band and can reduce resistance loss of filters **31** and **32** and/or the sizes of filters **31** and **32**.

**[0062]** For example, in radio frequency circuit **1** according to the present embodiment, the fourth frequency band may be the receiving band of the second TN band.

**[0063]** According to this, radio frequency circuit **1** can support reception of radio frequency signals in TNs.

**[0064]** For example, in radio frequency circuit **1** according to the present embodiment, the first NTN band may be n256 for 5th Generation New Radio (5G NR), the second NTN band may be n255 or n254 for 5G NR, the first TN band may be Band 1 for Long Term Evolution (LTE) or n1 for 5G NR, and the second TN band may be Band 3 for LTE or n3 for 5G NR.

**[0065]** According to this, radio frequency circuit **1** can use n256 for 5G NR and n255 or n254 for 5G NR to transmit radio frequency signals in NTNs, whereas in TNs, radio frequency circuit **1** can use Band 1 for LTE or n1 for 5G NR to transmit radio frequency signals and can use Band 3 for LTE or n3 for 5G NR to receive radio frequency signals.

**[0066]** For example, in radio frequency circuit **1** according to the present embodiment, the first frequency band may be the transmission band of the first NTN band, the second frequency band may be the transmission band of the second NTN band, and the third frequency band may be the receiving band of the first TN band.

**[0067]** According to this, radio frequency circuit **1** can support transmission of radio frequency signals in NTNs and reception of radio frequency signals in TNs.

**[0068]** For example, in radio frequency circuit **1** according to the present embodiment, the first NTN band may be n256 for 5th Generation New Radio (5G NR), the second NTN band may be n255 or n254 for 5G NR, and the first TN band may be Band 3 for Long Term Evolution (LTE) or n3 for 5G NR.

**[0069]** According to this, radio frequency circuit **1** can use n256 for 5G NR and n255 or n254 for 5G NR to transmit radio frequency signals in

**[0070]** NTNs, and can use Band 3 for LTE or n3 for 5G NR to transmit radio frequency signals in TNs.

**[0071]** Radio frequency circuit **1** according to the present embodiment includes: filter **31** having a passband that includes a first frequency band that is a transmission band of a Non-Terrestrial Network (NTN) band; filter **32** having a passband that includes a second frequency band that is a receiving band of the NTN band; filter **33** having a passband that includes a third frequency band that is at least one of a transmission band or a receiving band of a Terrestrial Network (TN) band; and switch **51** that includes terminal **511** connected to antenna connection terminal **100**, terminal **512** connected to filters **31** and **32**, and terminal **513** connected to filter **33**. The third frequency band at least partially overlaps a frequency gap between the first frequency band and the second frequency band.

**[0072]** According to this, terminal **513** of switch **51** to which filter **33** for the TN band is connected is different from terminal **512** of switch **51** to which filters **31** and **32** for the NTN band are connected. Thus, switch **51** can ensure the isolation of filters **31** and **32** from filter **33**. As a result, the need for attenuation in the third frequency band included in the TN band can be reduced in filters **31** and **32**, resistance loss of filters **31** and **32** and/or the sizes of filters **31** and **32** can be reduced. In particular, the frequency gap between bands is wider in an NTN than in a TN. Thus, since the need for attenuation in the third frequency band that at least partially overlaps the frequency gap between the first frequency band and the second frequency gap is reduced, steepness of attenuation characteristics at passband edges of filters **31** and **32** can be made less, which is effective in reducing resistance loss and sizes of filters **31** and **32**.

**[0073]** For example, in radio frequency circuit **1** according to the present embodiment, the NTN band may be n256 for 5th Generation New Radio (5G NR), and the TN band may be a band selected from among Band 1, Band 34, and Band 66 for Long Term Evolution (LTE) and n1, n34, and n66 for 5G NR.

**[0074]** According to this, radio frequency circuit **1** can use n256 for 5G NR to transmit and receive radio frequency signals in NTNs, and can use Band 1, Band 34, or Band 66 for LTE or n1, n34, or n66 for 5G NR to transmit and/or receive radio frequency signals in TNs.

## Embodiment 2

**[0075]** Embodiment 2 is to be described in the following. In the present embodiment, a specific example of a radio frequency circuit under a condition that No. 1 of the combinations in Table 1 is used in Embodiment 1 described above is to be described with reference to FIG. **4**. FIG. **4** illustrates a circuit configuration of communication device **5**A according to the present embodiment.

**[0076]** Note that FIG. **4** illustrates an exemplary circuit configuration, and communication device **5**A and radio frequency circuit **1**A may be mounted using any of various types of circuit implementations and circuit technologies. Thus, the description of communication device **5**A and radio frequency circuit **1**A provided below should not be interpreted in a limited manner.

**[0077]** Since communication device **5**A according to the present embodiment is the same as communication device **5** according to Embodiment 1 except that radio frequency circuit **1**A is included instead of radio frequency circuit **1**, and thus description of elements of communication device **5**A other than radio frequency circuit **1**A is omitted.

### [2.1 Circuit Configuration of Radio Frequency Circuit 1A]

**[0078]** Radio frequency circuit **1**A according to the present embodiment includes power amplifiers **11** and **12**, low-noise amplifiers **21** to **24**, filters **41** to **47**, switches **51** and **52**, antenna connection terminal **100**, radio frequency input terminals **111** and **112**, and radio frequency output terminals **121** to **124**.

**[0079]** Radio frequency input terminals **111** and **112** are external connection terminals of radio frequency circuit **1**A and can receive transmission signals from RFIC **3**. Specifically, radio frequency input terminals **111** and **112** are connected to RFIC **3** outside radio frequency circuit **1**A and are connected to power amplifiers **11** and **12** inside radio frequency circuit **1**A, respectively.

**[0080]** Radio frequency output terminals **121** to **124** are external connection terminals of radio frequency circuit **1**A and can supply received signals to RFIC **3**. Specifically, radio frequency output terminals **121** to **124** are connected to RFIC **3** outside radio frequency circuit **1**A and are connected to low-noise amplifiers **21** to **24** inside radio frequency circuit **1**A, respectively.

**[0081]** Power amplifier **11** is an example of a first power amplifier. The input end of power amplifier **11** is connected to radio frequency input terminal **111**. The output end of power amplifier **11** is connected to any one of filters **41** to **43** via switch **52**. Power amplifier **11** can amplify radio frequency signals received via radio frequency input terminal **111**, using power supplied from a power supply (not illustrated).

**[0082]** Power amplifier **12** is an example of a second power amplifier. The input end of power amplifier **12** is connected to radio frequency input terminal **112**. The output end of power amplifier **12** is connected to any one of filters **41** to **43** via switch **52**. Power amplifier **12** can amplify radio frequency signals received via radio frequency input terminal **112**, using power supplied from a power supply (not illustrated).

**[0083]** Power amplifiers **11** and **12** can include heterojunction bipolar transistors (HBTs), and can be manufactured using semiconductor material. As the semiconductor material, silicon-germanium (SiGe) or gallium arsenide (GaAs) can be used, for example. Note that amplifier transistors of power amplifiers **11** and **12** are not limited to HBTs. For example, at least one of power amplifier **11** or power amplifier **12** may include a high electron mobility transistor (HEMT) or a metal-semiconductor field effect transistor (MESFET). In this case, gallium nitride (GaN) or silicon carbide (SIC) may be used as the semiconductor material.

**[0084]** Note that power amplifier **11** and/or power amplifier **12** may not be partially or entirely included in radio frequency circuit **1**A. In this case, power amplifier **11** may be partially or entirely connected between RFIC **3** and radio frequency input terminal **111**, and power amplifier **12** may be partially or entirely connected between RFIC **3** and radio frequency input terminal **112**. Power amplifier **11** and/or power amplifier **12** may be partially or entirely included in RFIC **3**.

**[0085]** The input end of low-noise amplifier **21** is connected to filter **44**. The output end of low-noise amplifier **21** is connected to radio frequency output terminal **121**. Low-noise amplifier **21** can amplify a received signal that has passed through filter **44**, by using power supplied from a power source (not illustrated).

**[0086]** The input end of low-noise amplifier **22** is connected to filter **45**. The output end of low-noise amplifier **22** is connected to radio frequency output terminal **122**. Low-noise amplifier **22** can amplify a received signal that has passed through filter **45**, by using power supplied from a power source (not illustrated).

**[0087]** The input end of low-noise amplifier **23** is connected to filter **46**. The output end of low-noise amplifier **23** is connected to radio frequency output terminal **123**. Low-noise amplifier **23** can amplify a received signal that has passed through filter **46**, by using power supplied from a power source (not illustrated).

**[0088]** The input end of low-noise amplifier **24** is connected to filter **47**. The output end of low-noise amplifier **24** is connected to radio frequency output terminal **124**. Low-noise amplifier **24** can amplify a received signal that has passed through filter **47**, by using power supplied from a power source (not illustrated).

**[0089]** Low-noise amplifiers **21** to **24** can include field effect transistors (FETs), and can be manufactured using semiconductor material. As the semiconductor material, for example, monocrystal silicon, gallium nitride (GaN), or a silicon carbide (SiC) can be used. Note that amplifier transistors of low-noise amplifiers **21** to **24** are not limited to FETs. For example, one or more or all of low-noise amplifiers **21** to **24** may each include a bipolar transistor.

**[0090]** Note that one or more or all of low-noise amplifiers **21** to **24** may not be partially or entirely included in radio frequency circuit **1**A. In this case, low-noise amplifier **21** may be partially or entirely connected between radio frequency output terminal **121** and RFIC **3**, low-noise amplifier **22** may be partially or entirely connected between radio frequency output terminal **122** and RFIC **3**, low-noise amplifier **23** may be partially or entirely connected between radio frequency output terminal **123** and RFIC **3**, and low-noise amplifier **24** may be partially or entirely connected between radio frequency output terminal **124** and RFIC **3**. One or more or all of low-noise amplifiers **21** to **24** may be partially or entirely included in RFIC **3**.

**[0091]** Filter **41** is an example of a first filter and has a passband that includes a transmission (n256-Tx) band of n256 (an example of a first NTN band) for 5G NR. In the present embodiment, the n256-Tx band is used as a first frequency band. Filter **41** is connected between switches **51** and **52**. Specifically, one end of filter **41** is connected to terminal **512** of switch **51**, and another end of filter **41** is connected to terminal **523** of switch **52**.

**[0092]** Filter **42** is an example of a second filter and has a passband that includes a transmission (n255-Tx) band of n255 (an example of a second NTN band) for 5G NR and a transmission (n254-Tx) band of n254 (an example of a third NTN band) for 5G NR. In the present embodiment, the n255-Tx band is used as a second frequency band. Filter **42** is connected between switches **51** and **52**. Specifically, one end of filter **42** is connected to terminal **512** of switch **51**, and another end of filter **42** is connected to terminal **524** of switch **52**.

**[0093]** Filter **43** is an example of a third filter and has a passband that includes a transmission (Band 1/n1-Tx) band of Band 1 for LTE or n1 for 5G NR (an example of a first TN band). In the present embodiment, the Band 1/n1-Tx band is used as a third frequency band. Filter **43** is connected between switches **51** and **52**. Specifically, one end of filter **43** is connected to terminal **513** of switch **51**, and another end of filter **43** is connected to terminal **525** of switch **52**.

**[0094]** Filter **44** is an example of a fourth filter and has a passband that includes a receiving (Band 3/n3-Rx) band of Band 3 for LTE or n3 for 5G NR (an example of a second TN band). In the present embodiment, the Band 3/n3-Rx band is used as a fourth frequency band. Filter **44** is connected between switch **51** and low-noise amplifier **21**. Specifically, one end of filter **44** is connected to terminal **513** of switch **51**, and another end of filter **44** is connected to low-noise amplifier **21**.

**[0095]** Filter **45** is an example of a fifth filter and has a passband that includes a receiving (n256-Rx) band of n256 (an example of the first NTN band) for 5G NR. Filter **45** is connected between switch **51** and low-noise amplifier **22**. Specifically, one end of filter **45** is connected to terminal **512** of switch **51**, and another end of filter **45** is connected to low-noise amplifier **22**.

**[0096]** Filter **46** is an example of a sixth filter and has a passband that includes a receiving (n255-Rx) band of n255 (an example of the second NTN band) for 5G NR. Filter **46**

is connected between switch **51** and low-noise amplifier **23**. Specifically, one end of filter **46** is connected to terminal **512** of switch **51**, and another end of filter **46** is connected to low-noise amplifier **23**.

**[0097]** Filter **47** is an example of a seventh filter and has a passband that includes a receiving (n254-Rx) band of n254 (an example of the third NTN band) for 5G NR. Filter **47** is connected between switch **51** and low-noise amplifier **24**. Specifically, one end of filter **47** is connected to terminal **512** of switch **51**, and another end of filter **47** is connected to low-noise amplifier **24**.

**[0098]** Similarly to filters **31** to **34** according to Embodiment 1, a SAW filter, a BAW filter, an LC resonator filter, a dielectric resonator filter, or a combination of any of these may be used as each of filters **41** to **47**, and furthermore, filters **41** to **47** are not limited to these.

**[0099]** Switch **51** is an example of a first switch, and is connected between antenna connection terminal **100** and filters **41** to **47**. Specifically, switch **51** includes terminals **511** to **513**. Terminal **511** is an example of a first terminal, and is connected to antenna connection terminal **100**. Terminal **512** is an example of a second terminal, and is connected to filters **41**, **42**, and **45** to **47**. Terminal **513** is an example of a third terminal, and is connected to filters **43** and **44**.

**[0100]** With such a connection configuration, switch **51** can connect terminal **511** exclusively to terminal **512** or can connect terminal **511** exclusively to terminal **513**, based on a control signal from RFIC **3**, for example. Stated differently, terminal **511** is prohibited from being simultaneously connected to terminals **512** and **513** in switch **51**. Switch **51** includes an SPDT switch circuit, for example.

**[0101]** Switch **52** is an example of a second switch, and is connected between (i) power amplifiers **11** and **12** and (ii) filters **41** to **43**. Specifically, switch **52** includes terminals **521** to **525**. Terminal **521** is an example of a first terminal, and is connected to power amplifier **11**. Terminal **522** is an example of a second terminal, and is connected to power amplifier **12**. Terminal **523** is an example of a third terminal, and is connected to filter **41**. Terminal **524** is an example of a fourth terminal, and is connected to filter **42**. Terminal **525** is an example of a fifth terminal, and is connected to filter **43**.

**[0102]** With such a connection configuration, switch **52** can connect terminals **521** and **522** each exclusively to terminal **523**, **524**, or **525**, based on a control signal from RFIC **3**, for example. Thus, switch **52** connects terminal **521** to any terminal among terminals **523** to **525**, and connects terminal **522** to any remaining terminal among terminals **523** to **525**. Switch **52** includes a multi-connection type switch circuit, for example.

**[0103]** Switches **51** and **52** may be mounted on a single semiconductor integrated circuit that includes a plurality of MOSFETs, for example, but the method for mounting switches **51** and **52** is not limited thereto.

**[0104]** Note that radio frequency circuit **1**A is not limited to the configuration illustrated in FIG. **4**. For example, radio frequency circuit **1**A may further include one or more filters. As the one or more filters, for example, a filter having a passband that includes the receiving band of Band 1 for LTE or n1 for 5G NR, a filter having a passband that includes the transmission band of Band 3 for LTE or n3 for 5G NR, a filter having a passband that includes the transmission-receiving band of Band 34 for LTE or n34 for 5G NR, a filter having a passband that includes the transmission-receiving band of Band 40 for LTE or n40 for 5G NR, or any combinations thereof. At this time, one or more filters may be connected to terminal **513** of switch **51**.

**[0105]** As the one or more filters, for example, a filter having a passband that includes the transmission band of Band 2 for LTE or n2 for 5G NR, a filter having a passband that includes the receiving band of Band 2 for LTE or n2 for 5G NR, a filter having a passband that includes the transmission band of Band 66 for LTE or n66 for 5G NR, a filter having a passband that includes the receiving band of Band 66 for LTE or n66 for 5G NR, or any combinations thereof. At this time, the one or more filters may be connected to a terminal/terminals not illustrated and different from terminals **512** and **513** of switch **51**.

[2.2 Advantageous Effects and Others]

**[0106]** As described above, radio frequency circuit **1**A according to the present embodiment includes: filter **41** having a passband that includes a first frequency band that is at least one of a transmission band or a receiving band of a first Non-Terrestrial Network (NTN) band; filter **42** having a passband that includes a second frequency band that is at least one of a transmission band or a receiving band of a second NTN band; filter **43** having a passband that includes a third frequency band that is at least one of a transmission band or a receiving band of a first Terrestrial Network (TN) band; and switch **51** that includes terminal **511** connected to antenna connection terminal **100**, terminal **512** connected to filters **41** and **42**, and terminal **513** connected to filter **43**. The third frequency band at least partially overlaps a frequency gap between the first frequency band and the second frequency band.

**[0107]** According to this, advantageous effects equivalent to those yielded by radio frequency circuit **1** according to Embodiment 1 above can be yielded.

**[0108]** For example, radio frequency circuit **1**A according to the present embodiment may further include: power amplifiers **11** and **12**; and switch **52** that includes terminal **521** connected to power amplifier **11**, terminal **522** connected to power amplifier **12**, terminal **523** connected to filter **41**, terminal **524** connected to filter **42**, and terminal **525** connected to filter **43**.

**[0109]** According to this, radio frequency circuit **1**A can amplify transmission signals in three bands by using two power amplifiers **11** and **12**, which can contribute to reduction in the size of communication device **5**A.

**[0110]** For example, radio frequency circuit **1**A according to the present embodiment may further include: filter **45** having a passband that includes the receiving band of the first NTN band.

**[0111]** According to this, radio frequency circuit **1**A can support reception of radio frequency signals in the first NTN band in addition to transmission of radio frequency signals in the first NTN band.

**[0112]** For example, radio frequency circuit **1**A according to the present embodiment may further include: filter **46** having a passband that includes the receiving band of the second NTN band.

**[0113]** According to this, radio frequency circuit **1**A can support reception of radio frequency signals in the second NTN band in addition to transmission of radio frequency signals in the second NTN band.

**[0114]** For example, in radio frequency circuit **1**A according to the present embodiment, the passband of filter **42** may further include a transmission band of a third NTN band.

**[0115]** According to this, radio frequency circuit **1**A can support transmission of radio frequency signals in the third NTN band. At this time, single filter **42** can support transmission of radio frequency signals in the second NTN band and the third NTN band, which can contribute to reduction in the size of communication device **5**A.

**[0116]** For example, in radio frequency circuit **1**A according to the present embodiment, the first NTN band may be n256 for 5th Generation New Radio (5G NR), the second NTN band may be n255 for 5G NR, and the third NTN band may be n254 for 5G NR.

**[0117]** According to this, radio frequency circuit **1**A can use n256, n255, and n254 for 5G NR to transmit radio frequency signals in NTNs.

**[0118]** For example, radio frequency circuit **1**A according to the present embodiment may further include: filter **47** having a passband that includes a receiving band of the third NTN band.

**[0119]** According to this, radio frequency circuit **1**A can support reception of radio frequency signals in the third NTN band in addition to transmission of radio frequency signals in the third NTN band.

## Embodiment 3

**[0120]** Next, Embodiment 3 is to be described. The present embodiment is mainly different from Embodiment 2 described above in that a filter for an NTN band and a filter for a TN band are connected to the same terminal of a switch. In the following, the present embodiment is to be described with reference to FIG. **5**, focusing on different points from Embodiment 2 above. FIG. **5** illustrates a circuit configuration of communication device **5**B according to the present embodiment.

**[0121]** Note that FIG. **5** illustrates an exemplary circuit configuration, and communication device **5**B and radio frequency circuit **1**B may be implemented using any of various types of circuit implementations and circuit technologies. Thus, the description of communication device **5**B and radio frequency circuit **1**B provided below should not be interpreted in a limited manner.

**[0122]** Since communication device **5**B according to the present embodiment is the same as communication device **5** according to Embodiment 1 except that radio frequency circuit **1**B is included instead of radio frequency circuit **1**, and thus description of elements of communication device **5**B other than radio frequency circuit **1**B is omitted.

### [3.1 Circuit Configuration of Radio Frequency Circuit 1B]

**[0123]** Radio frequency circuit **1**B according to the present embodiment includes power amplifiers **11** to **13**, low-noise amplifiers **21** to **23** and **25**, filters **41**, **42**B, **43** to **46**, and **48**, switches **51** to **53**, antenna connection terminal **100**, radio frequency input terminals **111** to **113**, and radio frequency output terminals **121** to **123** and **125**.

**[0124]** Radio frequency input terminal **113** is an external connection terminal of radio frequency circuit **1**B and can receive transmission signals from RFIC **3**. Specifically, radio frequency input terminal **113** is connected to RFIC **3** outside radio frequency circuit **1**B and is connected to power amplifier **13** inside radio frequency circuit **1**B.

**[0125]** Radio frequency output terminal **125** is an external connection terminal of radio frequency circuit **1**B and can supply received signals to RFIC **3**. Specifically, radio frequency output terminal **125** is connected to RFIC **3** outside radio frequency circuit **1**B and is connected to low-noise amplifier **25** inside radio frequency circuit **1**B.

**[0126]** Power amplifier **13** is an example of a third power amplifier. The input end of power amplifier **13** is connected to radio frequency input terminal **113**. The output end of power amplifier **13** is connected to filter **48** via switch **53**. Power amplifier **13** can amplify radio frequency signals received via radio frequency input terminal **113**, using power supplied from a power supply (not illustrated).

**[0127]** Similarly to power amplifier **11** according to Embodiment 2, power amplifier **13** can include an HBT and can be manufactured by using semiconductor material. Note that an amplifier transistor of power amplifier **13** is not limited to an HBT.

**[0128]** Note that power amplifier **13** may not be partially or entirely included in radio frequency circuit **1**B. In this case, power amplifier **13** may be partially or entirely connected between RFIC **3** and radio frequency input terminal **113** or may be partially or entirely included in RFIC **3**.

**[0129]** The input end of low-noise amplifier **25** is connected to filter **48** via switch **53**. The output end of low-noise amplifier **25** is connected to radio frequency output terminal **125**. Low-noise amplifier **25** can amplify a received signal that has passed through filter **48**, by using power supplied from a power source (not illustrated).

**[0130]** Similarly to low-noise amplifiers **21** to **24** according to Embodiment 2, low-noise amplifier **25** can include an FET and can be manufactured by using semiconductor material. Note that an amplifier transistor of low-noise amplifier **25** is not limited to an FET.

**[0131]** Note that low-noise amplifier **25** may not be partially or entirely included in radio frequency circuit **1**B. In this case, low-noise amplifier **25** may be partially or entirely connected between radio frequency output terminal **125** and RFIC **3** or may be partially or entirely included in RFIC **3**.

**[0132]** Filter **42**B is an example of a second filter and has a passband that includes a transmission (n255-Tx) band of n255 (an example of a second NTN band) for 5G NR. Filter **42**B is connected between switches **51** and **52**. Specifically, one end of filter **42**B is connected to terminal **512** of switch **51**, and another end of filter **42**B is connected to terminal **524** of switch **52**.

**[0133]** Filter **48** is an example of an eighth filter and has a passband that includes a transmission-receiving (Band 40/n40-TRx) band of Band 40 for LTE or n40 for 5G NR (an example of a third TN band). Filter **48** is connected between switches **51** and **53**. Specifically, one end of filter **48** is connected to terminal **512** of switch **51**, and another end of filter **48** is connected to terminal **531** of switch **53**.

**[0134]** The Band 40/n40-TRx band included in the passband of filter **48** does not overlap the frequency gap between the first frequency band (the n256-Tx band) and the second frequency band (the n255-Tx band). Furthermore, the Band 40/n40-TRx band does not overlap the frequency gap between the n256-Rx band and the n255-Rx band either. Thus, the passband of filter **48** does not overlap the frequency gap between the highest passband (the passband of filter **45**) and the lowest passband (the passband of filter **46**), among the passbands of the other filters connected to terminal **512** of switch **51**.

**[0135]** Note that the passband of filter **48** may include the band(s) stated below as at least one of the transmission band or the receiving band of the third TN band, instead of the Band 40/n40-TRx band.

**[0136]** (1) The transmission band and/or the receiving band of Band 11 for LTE

**[0137]** (2) The transmission band and/or the receiving band of Band 21 for LTE

**[0138]** (3) The receiving band of Band 32 for LTE

**[0139]** (4) The transmission band and/or the receiving band of Band 74 for LTE

**[0140]** (5) The receiving band of Band 75 for LTE

**[0141]** (6) The receiving band of Band 76 for LTE

**[0142]** (7) The transmission band and/or the receiving band of n74 for 5G NR

**[0143]** (8) The receiving band of n75 for 5G NR

**[0144]** (9) The receiving band of n76 for 5G NR

**[0145]** (10) The transmission-receiving band of Band 40 for LTE

**[0146]** (11) The transmission-receiving band of n40 for 5G NR

**[0147]** Similarly to filters **31** to **34** according to Embodiment 1, a SAW filter, a BAW filter, an LC resonator filter, a dielectric resonator filter, or a combination of any of these may be used as each of filters **42**B and **48**, and furthermore, filters **42**B and **48** are not limited to these.

**[0148]** Switch **53** is an example of a third switch, and is connected between (i) filter **48** and (ii) power amplifier **13** and low-noise amplifier **25**. Specifically, switch **53** includes terminals **531** to **533**. Terminal **531** is an example of a first terminal, and is connected to filter **48**. Terminal **532** is an example of a second terminal, and is connected to power amplifier **13**. Terminal **533** is an example of a third terminal, and is connected to low-noise amplifier **25**.

**[0149]** With such a connection configuration, switch **53** can connect terminal **531** exclusively to terminal **532** or can connect terminal **531** exclusively to terminal **533**, based on a control signal from RFIC **3**, for example. Stated differently, terminal **531** is prohibited from being simultaneously connected to terminals **532** and **533** in switch **53**. Switch **53** includes an SPDT switch circuit, for example.

**[0150]** Switches **51** to **53** may be mounted on a single semiconductor integrated circuit that includes a plurality of MOSFETs, for example, but the method for mounting switches **51** to **53** is not limited thereto.

[3.2 Advantageous Effects and Others]

**[0151]** As described above, radio frequency circuit **1**B according to the present embodiment includes: filter **41** having a passband that includes a first frequency band that is at least one of a transmission band or a receiving band of a first Non-Terrestrial Network (NTN) band; filter **42**B having a passband that includes a second frequency band that is at least one of a transmission band or a receiving band of a second NTN band; filter **43** having a passband that includes a third frequency band that is at least one of a transmission band or a receiving band of a first Terrestrial Network (TN) band; and switch **51** that includes terminal **511** connected to antenna connection terminal **100**, terminal **512** connected to filters **41** and **42**B, and terminal **513** connected to filter **43**. The third frequency band at least partially overlaps a frequency gap between the first frequency band and the second frequency band.

**[0152]** According to this, advantageous effects equivalent to those yielded by radio frequency circuit **1** according to Embodiment 1 described above can be yielded.

**[0153]** For example, radio frequency circuit **1**B according to the present embodiment may further include: filter **48** connected to terminal **512** of switch **51** and having a passband that includes at least one of a transmission band or a receiving band of a third TN band. The at least one of the transmission band or the receiving band of the third TN band may not overlap the frequency gap between the first frequency band and the second frequency band.

**[0154]** According to this, filter **48** having a passband that includes at least one of the transmission band or the receiving band of the third TN band can be connected to terminal **512** that is the same as the terminal to which filters **41** and **42**B for the NTN bands are connected. Also in this case, at least one of the transmission band or the receiving band of the third TN band does not overlap the frequency gap between the first frequency band and the second frequency band, and thus the steepness of attenuation characteristics at at least one of the two edges of the passband of each of filters **31** and **32** can be made less, and resistance loss of filters **31** and **32** and/or the sizes thereof can be reduced.

**[0155]** For example, in radio frequency circuit **1**B according to the present embodiment, the first NTN band may be n256 for 5th Generation New Radio (5G NR), the second NTN band may be n255 or n254 for 5G NR, and the third TN band may be Band 40 for Long Term Evolution (LTE) or n40 for 5G NR.

**[0156]** According to this, radio frequency circuit **1**B can further use Band 40 for LTE or n40 for 5G NR to transmit and/or receive radio frequency signals in TNs.

**[0157]** For example, radio frequency circuit **1**B according to the present embodiment may further include: power amplifier **13**; low-noise amplifier **25**; and switch **53** that includes terminal **531** connected to filter **48**, terminal **532** connected to power amplifier **13**, and terminal **533** connected to low-noise amplifier **25**.

**[0158]** According to this, a transmission signal and a received signal that pass through filter **48** can be amplified, and filter **48** can be used for both transmitting and receiving TDD signals.

## Other Embodiments

**[0159]** The above has described radio frequency circuits according to the present disclosure, based on the embodiments, yet the radio frequency circuits according to the present disclosure are not limited to the above embodiments. The present disclosure also encompasses another embodiment achieved by combining arbitrary elements in the above embodiments, variations resulting from applying, to the embodiments, various modifications that may be conceived by those skilled in the art within a range that does not depart from the scope of the present disclosure, and various devices that each include the radio frequency circuit.

**[0160]** For example, in the circuit configurations of the radio frequency circuits according to the above embodiments, another circuit element and a line, for instance, may be provided between circuit elements and paths connecting signal paths, which are disclosed in the drawings. For example, an impedance matching circuit may be provided between (i) a power amplifier and/or a low-noise amplifier and (ii) a filter. Furthermore, for example, an impedance matching circuit may be provided between a filter and an antenna connection terminal. An impedance matching circuit can include an inductor and/or a capacitor, for example, but is not limited to such a configuration.

**[0161]** The following states features of the radio frequency circuits described based on the above embodiments.

<1>

**[0162]** A radio frequency circuit including:

**[0163]** a first filter having a passband that includes a first frequency band that is at least one of a transmission band or a receiving band of a first Non-Terrestrial Network (NTN) band;

**[0164]** a second filter having a passband that includes a second frequency band that is at least one of a transmission band or a receiving band of a second NTN band;

**[0165]** a third filter having a passband that includes a third frequency band that is at least one of a transmission band or a receiving band of a first Terrestrial Network (TN) band; and

**[0166]** a first switch that includes a first terminal connected to an antenna connection terminal, a second terminal connected to the first filter and the second filter, and a third terminal connected to the third filter,

**[0167]** wherein the third frequency band at least partially overlaps a frequency gap between the first frequency band and the second frequency band.

<2>

**[0168]** The radio frequency circuit according to <1>,

**[0169]** wherein the first switch is configured to connect the first terminal exclusively to the second terminal or to connect the first terminal exclusively to the third terminal.

<3>

**[0170]** The radio frequency circuit according to <1> or <2>,

**[0171]** wherein the first frequency band is the transmission band of the first NTN band,

**[0172]** the second frequency band is the transmission band of the second NTN band, and

**[0173]** the third frequency band is the transmission band of the first TN band.

<4>

**[0174]** The radio frequency circuit according to <3>,

**[0175]** wherein the first NTN band is n256 for 5th Generation New Radio (5G NR),

**[0176]** the second NTN band is n255 or n254 for 5G NR, and

**[0177]** the first TN band is Band 1 for Long Term Evolution (LTE) or n1 for 5G NR.

<5>

**[0178]** The radio frequency circuit according to <3> or <4>, further including:

**[0179]** a first power amplifier;

**[0180]** a second power amplifier; and

**[0181]** a second switch that includes a first terminal connected to the first power amplifier, a second terminal connected to the second power amplifier, a third terminal connected to the first filter, a fourth terminal connected to the second filter, and a fifth terminal connected to the third filter.

<6>

**[0182]** The radio frequency circuit according to any one of <3> to <5>, further including:

**[0183]** a fourth filter connected to the third terminal of the first switch and having a passband that includes a fourth frequency band that is at least one of a transmission band or a receiving band of a second TN band,

**[0184]** wherein the fourth frequency band at least partially overlaps the frequency gap between the first frequency band and the second frequency band, and

**[0185]** the frequency gap between the first frequency band and the second frequency band is wider than a frequency gap between the third frequency band and the fourth frequency band.

<7>

**[0186]** The radio frequency circuit according to <6>,

**[0187]** wherein the fourth frequency band is the receiving band of the second TN band.

<8>

**[0188]** The radio frequency circuit according to <7>,

**[0189]** wherein the first NTN band is n256 for 5th Generation New Radio (5G NR),

**[0190]** the second NTN band is n255 or n254 for 5G NR,

**[0191]** the first TN band is Band 1 for Long Term Evolution (LTE) or n1 for 5G NR, and

**[0192]** the second TN band is Band 3 for LTE or n3 for 5G NR.

<9>

**[0193]** The radio frequency circuit according to any one of <3> to <8>, further including:

**[0194]** a fifth filter having a passband that includes the receiving band of the first NTN band.

<10>

**[0195]** The radio frequency circuit according to <3> to <9>, further including:

**[0196]** a sixth filter having a passband that includes the receiving band of the second NTN band.

<11>

**[0197]** The radio frequency circuit according to any one of <3> to <10>,

**[0198]** wherein the passband of the second filter further includes a transmission band of a third NTN band.

<12>

**[0199]** The radio frequency circuit according to <11>,

**[0200]** wherein the first NTN band is n256 for 5th Generation New Radio (5G NR),

**[0201]** the second NTN band is n255 for 5G NR, and

**[0202]** the third NTN band is n254 for 5G NR.

<13>

**[0203]** The radio frequency circuit according to <12>, further including:

**[0204]** a seventh filter having a passband that includes a receiving band of the third NTN band.

<14>

**[0205]** The radio frequency circuit according to any one of <3> to <8>, further including:

**[0206]** an eighth filter connected to the second terminal of the first switch and having a passband that includes at least one of a transmission band or a receiving band of a third TN band,

**[0207]** wherein the at least one of the transmission band or the receiving band of the third TN band does not overlap the frequency gap between the first frequency band and the second frequency band.

<15>

**[0208]** The radio frequency circuit according to <14>,

**[0209]** wherein the first NTN band is n256 for 5th Generation New Radio (5G NR),

**[0210]** the second NTN band is n255 or n254 for 5G NR, and

**[0211]** the third TN band is Band 40 for Long Term Evolution (LTE) or n40 for 5G NR.

<16>

**[0212]** The radio frequency circuit according to <14> or <15>, further including:

**[0213]** a third power amplifier;

**[0214]** a low-noise amplifier; and

**[0215]** a third switch that includes a first terminal connected to the eighth filter, a second terminal connected to the third power amplifier, and a third terminal connected to the low-noise amplifier.

<17>

**[0216]** The radio frequency circuit according to <1> or <2>,

**[0217]** wherein the first frequency band is the transmission band of the first NTN band,

**[0218]** the second frequency band is the transmission band of the second NTN band, and

**[0219]** the third frequency band is the receiving band of the first TN band.

<18>

**[0220]** The radio frequency circuit according to <17>,

**[0221]** wherein the first NTN band is n256 for 5th Generation New Radio (5G NR),

**[0222]** the second NTN band is n255 or n254 for 5G NR, and

**[0223]** the first TN band is Band 3 for Long Term Evolution (LTE) or n3 for 5G NR.

<19>

**[0224]** A radio frequency circuit including:

**[0225]** a first filter having a passband that includes a first frequency band that is a transmission band of a Non-Terrestrial Network (NTN) band;

**[0226]** a second filter having a passband that includes a second frequency band that is a receiving band of the NTN band;

**[0227]** a third filter having a passband that includes a third frequency band that is at least one of a transmission band or a receiving band of a Terrestrial Network (TN) band; and

**[0228]** a switch that includes a first terminal connected to an antenna connection terminal, a second terminal connected to the first filter and the second filter, and a third terminal connected to the third filter,

**[0229]** wherein the third frequency band at least partially overlaps a frequency gap between the first frequency band and the second frequency band.

<20>

**[0230]** The radio frequency circuit according to <19>,

**[0231]** wherein the NTN band is n256 for 5th Generation New Radio (5G NR), and

**[0232]** the TN band is a band selected from among Band 1, Band 34, and Band 66 for Long Term Evolution (LTE) and n1, n34, and n66 for 5G NR.

**[0233]** Although only some exemplary embodiments of the present disclosure have been described in detail above, those skilled in the art will readily appreciate that many modifications are possible in the exemplary embodiments without materially departing from the novel teachings and advantages of the present disclosure. Accordingly, all such modifications are intended to be included within the scope of the present disclosure.

## INDUSTRIAL APPLICABILITY

**[0234]** The present disclosure is widely applicable to communication devices such as mobile phones as radio frequency circuits disposed in front end portions.

**1**. A radio frequency circuit comprising:

a first filter having a passband that includes a first frequency band that is at least one of a transmission band or a receiving band of a first Non-Terrestrial Network (NTN) band;

a second filter having a passband that includes a second frequency band that is at least one of a transmission band or a receiving band of a second NTN band;

a third filter having a passband that includes a third frequency band that is at least one of a transmission band or a receiving band of a first Terrestrial Network (TN) band; and

a first switch that includes a first terminal connected to an antenna connection terminal, a second terminal connected to the first filter and the second filter, and a third terminal connected to the third filter,

wherein the third frequency band at least partially overlaps a frequency gap between the first frequency band and the second frequency band.

**2**. The radio frequency circuit according to claim **1**,

wherein the first switch is configured to connect the first terminal exclusively to the second terminal or to connect the first terminal exclusively to the third terminal.

**3**. The radio frequency circuit according to claim **1**,

wherein the first frequency band is the transmission band of the first NTN band,

the second frequency band is the transmission band of the second NTN band, and

the third frequency band is the transmission band of the first TN band.

**4**. The radio frequency circuit according to claim **3**,

wherein the first NTN band is n256 for 5th Generation New Radio (5G NR),

the second NTN band is n255 or n254 for 5G NR, and

the first TN band is Band 1 for Long Term Evolution (LTE) or n1 for 5G NR.

**5**. The radio frequency circuit according to claim **3**, further comprising:

a first power amplifier;

a second power amplifier; and

a second switch that includes a first terminal connected to the first power amplifier, a second terminal connected to the second power amplifier, a third terminal connected to the first filter, a fourth terminal connected to the second filter, and a fifth terminal connected to the third filter.

**6**. The radio frequency circuit according to claim **3**, further comprising:

a fourth filter connected to the third terminal of the first switch and having a passband that includes a fourth frequency band that is at least one of a transmission band or a receiving band of a second TN band, wherein the fourth frequency band at least partially overlaps the frequency gap between the first frequency band and the second frequency band, and

the frequency gap between the first frequency band and the second frequency band is wider than a frequency gap between the third frequency band and the fourth frequency band.

**7**. The radio frequency circuit according to claim **6**,

wherein the fourth frequency band is the receiving band of the second TN band.

**8**. The radio frequency circuit according to claim **7**,

wherein the first NTN band is n256 for 5th Generation New Radio (5G NR),

the second NTN band is n255 or n254 for 5G NR,

the first TN band is Band 1 for Long Term Evolution (LTE) or n1 for 5G NR, and

the second TN band is Band 3 for LTE or n3 for 5G NR.

**9**. The radio frequency circuit according to claim **3**, further comprising:

a fifth filter having a passband that includes the receiving band of the first NTN band.

**10**. The radio frequency circuit according to claim **3**, further comprising:

a sixth filter having a passband that includes the receiving band of the second NTN band.

**11**. The radio frequency circuit according to claim **3**,

wherein the passband of the second filter further includes a transmission band of a third NTN band.

**12**. The radio frequency circuit according to claim **11**,

wherein the first NTN band is n256 for 5th Generation New Radio (5G NR),

the second NTN band is n255 for 5G NR, and

the third NTN band is n254 for 5G NR.

**13**. The radio frequency circuit according to claim **12**, further comprising:

a seventh filter having a passband that includes a receiving band of the third NTN band.

**14**. The radio frequency circuit according to claim **3**, further comprising:

an eighth filter connected to the second terminal of the first switch and having a passband that includes at least one of a transmission band or a receiving band of a third TN band,

wherein the at least one of the transmission band or the receiving band of the third TN band does not overlap the frequency gap between the first frequency band and the second frequency band.

**15**. The radio frequency circuit according to claim **14**,

wherein the first NTN band is n256 for 5th Generation New Radio (5G NR),

the second NTN band is n255 or n254 for 5G NR, and

the third TN band is Band 40 for Long Term Evolution (LTE) or n40 for 5G NR.

**16**. The radio frequency circuit according to claim **14**, further comprising:

a third power amplifier;

a low-noise amplifier; and

a third switch that includes a first terminal connected to the eighth filter, a second terminal connected to the third power amplifier, and a third terminal connected to the low-noise amplifier.

**17**. The radio frequency circuit according to claim **1**,

wherein the first frequency band is the transmission band of the first NTN band,

the second frequency band is the transmission band of the second NTN band, and

the third frequency band is the receiving band of the first TN band.

**18**. The radio frequency circuit according to claim **17**,

wherein the first NTN band is n256 for 5th Generation New Radio (5G NR),

the second NTN band is n255 or n254 for 5G NR, and

the first TN band is Band 3 for Long Term Evolution (LTE) or n3 for 5G NR.

**19**. A radio frequency circuit comprising:

a first filter having a passband that includes a first frequency band that is a transmission band of a Non-Terrestrial Network (NTN) band;

a second filter having a passband that includes a second frequency band that is a receiving band of the NTN band;

a third filter having a passband that includes a third frequency band that is at least one of a transmission band or a receiving band of a Terrestrial Network (TN) band; and

a switch that includes a first terminal connected to an antenna connection terminal, a second terminal connected to the first filter and the second filter, and a third terminal connected to the third filter,

wherein the third frequency band at least partially overlaps a frequency gap between the first frequency band and the second frequency band.

**20**. The radio frequency circuit according to claim **19**,

wherein the NTN band is n256 for 5th Generation New Radio (5G NR), and

the TN band is a band selected from among Band 1, Band 34, and Band 66 for Long Term Evolution (LTE) and n1, n34, and n66 for 5G NR.

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