feed line 15, and the RFIC 200 altogether may be referred to as an RF system or an RF device.

[28] In a transmitting mode, the RFIC 200 may provide a signal generated by processing a transmitting signal TX provided from the signal processor 300 to the antenna 100 through the feed line 15. Also, in a receiving mode, the RFIC 200 may provide a receiving signal RX to the signal processor 300 by processing a signal received from the antenna 100. For example, the RFIC 200 may include a transmitter, and the transmitter may include a filter, a mixer, and a power amplifier (PA). Also, the RFIC 200 may include a receiver, and the receiver may include a filter, a mixer, and a low noise amplifier (LNA). In some example embodiments, an RFIC may include a plurality of transmitters and receivers and may include a transceiver in which a transmitter and a receiver are combined with each other.

[29] The signal processor 300 may generate a transmitting signal TX by processing a signal including information to be transmitted and may generate a signal including information by processing a receiving signal RX. For example, in order to generate a transmitting signal TX, the signal processor 300 may include an encoder, a modulator, and a digital-to-analog converter (DAC). Also, in order to process a receiving signal RX, the signal processor 300 may include an analog-to-digital converter (ADC), a demodulator, and a decoder. The signal processor 300 may generate a control signal to control the RFIC 200, may set a transmitting mode or a receiving mode through the control signal, and may control power and

[52] FIGS. 5A and 5B are diagrams summarizing simulation results of antenna modules. In detail, FIG. 5A shows simulation results of an antenna module 51 to which a differential signal is fed through two ports and an antenna module 52 to which a signal is fed through a single port. FIG. 5B shows simulation results of an antenna module 53 to which a differential signal is fed through two ports and an antenna module 54 including two patches to which signals are fed through respective single ports. Hereinafter, of the descriptions with respect to FIGS. 5A and 5B, repeated descriptions may be omitted.

[53] Referring to FIG. 5A, the antenna module 51 including the first port PORT1 and the second port PORT2 may be referred to as a dual-fed patch antenna module 51, and the antenna module 52 including only the first port PORT1 may be referred to as a single-fed patch antenna module 52. Referring to the table of FIG. 5A, the dual-fed patch antenna module 51 may have a high antenna gain (that is, 6.52 dBi > 5.92 dBi) as compared to the single-fed patch antenna module 52 at the same power output Pout of port (that is, at 10 dBm) and at different total power inputs Pout total (that is, at 13dBm and 10dBm, respectively). Also, an EIRP and radiated power may be increased by greater than 3 dB without a power combining loss.

[54] Referring to FIG. 5B, the antenna module 53 (may also be referred to as a dual-fed patch antenna module 53) may include the first port PORT1 and the second port PORT2 connected to a single lower patch. The antenna module 54 may include the first port PORT1 and the second port PORT2 respectively connected to two lower patches separated from each other in the Y-axis direction

second feed points P1 and P2 may be disposed on or near to a first center line LY that is parallel to the X-axis and crosses a center of the bottom-patch 62. In some example embodiments, the third and fourth feed points P3 and P4 may be disposed on or near to a second center line LX that is parallel to the Y-axis and crosses the center of the bottom-patch 62.

[61] FIG. 7 is a diagram summarizing simulation results of antenna modules. In detail, FIG. 7 shows simulation results of an antenna module 71 to which two differential signals are fed through four ports and an antenna module 72 to which a signal is fed through a single port.

[62] Referring to FIG. 7, the antenna module 71 including a first port PORT1, a second port PORT2, a third port PORT3, and a fourth port PORT4 may be referred to as a dual-fed/dual-polarized patch antenna module 71, and the antenna module 72 that includes only the first port PORT1 may be referred to as a single-fed patch antenna module 72. Referring to the table of FIG. 7, comparing the dual-fed/dual-polarized patch antenna module 71 to the single-fed patch antenna module 72 at the same power output Pout of port (that is, 10 dBm) and at different total power inputs Pout total (that is, at 13dBm and 10dBm, respectively), the dual-fed/dual-polarized patch antenna module 71 may have the same area (that is, 8 mm x 8 mm) as the single-fed patch antenna module 72, and also, an EIRP and radiated power may be increased by greater than 3 dB without a power combining loss. As a result, the simulation results indicate that a dual-fed structure may be applied to a dual-polarized application without a power combining loss.

[63] FIG. 8 is a diagram of antenna modules according to some example embodiments. In detail, FIG. 8 shows antenna modules 82 and 83 having more favorable characteristics than an antenna module 81 corresponding to a dual-polarized antenna.

[64] Referring to FIG. 8, the antenna module 81 may include first through fourth patches 81_1 through 81_4, and each of the first through fourth patches 81_1 through 81_4 may have a single-fed/dual-polarized structure. For example, in each of the first through fourth patches 81_1 through 81_4, an electric field having a size that varies in a direction parallel to the X-axis is formed by a signal applied to a feed point indicated by a filled circle, and also, an electric field having a size that varies in a direction parallel to the Y-axis is formed by a signal applied to a feed point indicated by a blank circle.

[65] As described with reference to FIGS. 4, 5A, and 5B, an antenna module having a dual-fed structure may have an increased EIRP, and the antenna modules 82 and 83 having a dual-fed structure may be employed according to constraints of an application. For example, in the case of a communication device with spatial constraints, the antenna module 82 having a dual-fed/dual-polarized 1x2 patch array structure including two patches 81_1 and 82_2 may be used. Comparing the antenna module 82 to the antenna module 81 at the same power input, the antenna module 82 may have a reduced area while providing a similar EIRP. Also, in the case of a communication device using high emission power with limited power

resources, the antenna module 83 having a dual-fed/dual-polarized 2by2 patch array structure including four patches 83_1 through 83_4 may be used. When the antenna module 83 is compared with the antenna module 81 at the same power input, the antenna module 83 may provide a higher EIRP while having the same area. The antenna modules 82 and 83 are examples, and thus, it should be understood that antenna modules having a dual-fed structure including patches disposed in various ways according to an application may be employed.

[66] FIGS. 9A through 9C are antennas according to some example embodiments. In detail, FIG. 9A shows an antenna module 90a having a single-fed 1x2 patch array structure according to a comparative example, FIG. 9B shows an antenna module 90b having a dual-fed 1x2 patch array structure according to some example embodiments, and FIG. 9C shows an antenna module 90c having a dual-fed single patch structure.

[67] Referring to FIG. 9A, a first patch 91a and a second patch 92a included in the antenna module 90a may each receive a signal from a single power amplifier through a single feed point. Referring to FIG. 9B, a first patch 91b and a second patch 92b included in the antenna module 90b may each receive a differential signal from two power amplifiers through two feed points. Referring to FIG. 9C, a first patch 91c included in the antenna module 90c may receive a differential signal from two power amplifiers through two feed points. In FIGS. 9A through 9C, it is assumed that the lengths of the feed lines connected to the patches are equal,

[78] The phase shifters 221_2 and 221_4 of the first transceiver 221' and the phase shifters 223_2 and 223_4 of the third transceiver 223' may provide a phase difference of 180 degrees. For example, the transmission phase shifter 221_2 of the first transceiver 221' may provide an output signal having a phase difference of zero degree with respect to an input signal directed to the power amplifier 221_1, and the transmission phase shifter 223_2 of the third transceiver 223' may provide an output signal having a phase difference of 180 degrees with respect to an input signal, which is same with the input signal provided to the transmission phase shifter 221_2 of the first transceiver 221', directed to the power amplifier 223_1. Accordingly, the first transmitting signal TX1 and the third transmitting signal TX3 may have a phase difference of 180 degrees, and may correspond to a differential signal. Also, the reception phase shifter 221_4 of the first transceiver 221' may output a signal having a phase difference of zero degree with respect to an output signal of the low noise amplifier 221_3, and the reception phase shifter 223_4 of the third transceiver 223' may output a signal having a phase difference of 180 degrees with respect to an output signal of the low noise amplifier 223_3.

[79] FIG. 12 is a diagram of an antenna module 100'' according to some example embodiments. As described above with reference to the drawings, the antenna module 100'' may include patch antennas 111 through 114 respectively connected to a plurality of feed lines supplying differential signals. Also, to achieve dual-

WHAT IS CLAIMED IS:

1. A radio frequency (RF) device, comprising:

a radio frequency integrated circuit (RFIC) chip; and

an antenna module on an upper surface of the RFIC chip, the antenna module comprises:

a first patch parallel to the RFIC chip and having an upper surface configured to emit radiation in a vertical direction opposite the first patch from the RFIC chip,

a ground plate parallel to the first patch, and between the first patch and the RFIC chip, and

a first plurality of feed lines connected to a lower surface of the first patch and configured to supply a plurality of first differential signals to the first patch from the RFIC chip, wherein

the first plurality of feed lines comprise a first feed line and a second feed line respectively connected to a first feed point and a second feed point on the lower surface of the first patch and configured to supply one of the plurality of first differential signal to the first patch, and

the first feed point and the second feed point are separated in a first horizontal direction,

the first plurality of feed lines further comprise a third feed line and a fourth feed line respectively connected to a third feed point and a fourth feed point

on the lower surface of the first patch and configured to supply another one of the plurality of first differential signal to the first patch, and

the third feed point and the fourth feed point are separated in a second horizontal direction perpendicular to the first horizontal direction to achieve a dual polarization.

2. The RF device of claim 1, wherein the first feed point and the second feed point are proximate to a first center line crossing a center of the first patch in the first horizontal direction.

3. The RF device of claim 1 or claim 2, wherein the first feed point and the second feed point are equally proximate to the center of the first patch.

4. The RF device of any one of claims 1 to 3, wherein

the first feed line comprises a first portion extending in the first horizontal direction and a second portion extending in the vertical direction, and

the second feed line comprises a first portion extending in the first horizontal direction and a second portion extending in the vertical direction.

5. The RF device of any one of claims 1 to 4, wherein each of the upper surface of the first patch and the lower surface of the first patch have a rectangular shape including a pair of sides parallel to the first horizontal direction.

6. The RF device of claim 1, wherein the third feed point and the fourth feed point are proximate to a second center line crossing a center of the first patch in the second horizontal direction.

7. The RF device of any one of claims 1 to 6, wherein the third feed point and the fourth feed point are equally proximate to the center of the first patch.

8. The RF device of any one of claims 1 to 7, wherein

the third feed line comprises a first portion extending in the second horizontal direction and a second portion extending in the vertical direction, and

the fourth feed line comprises a first portion extending in the second horizontal direction and a second portion extending in the vertical direction.

9. The RF device of any one of claims 1 to 8, wherein the antenna module further comprises:

a second patch separated from the first patch in the first horizontal direction; and

a second plurality of feed lines connected to a lower surface of the second patch and configured to supply at least one second differential signal to the second patch from the RFIC chip.

10. The RF device of claim 9, wherein the antenna module further comprises:

a third patch separated from the first patch in the second horizontal direction;

a fourth patch separated from the second patch in the second horizontal direction; and

a third plurality of feed lines respectively connected to lower surfaces of the third patch and the fourth patch and configured to supply at least one third differential signal to the third patch and the fourth patch from the RFIC chip.

11. The RF device of any one of claims 1 to 10, wherein the antenna module further comprises a top-patch parallel to the first patch over the upper surface of the first patch.

12. The RF device of any one of claims 1 to 11, wherein the RFIC chip comprises:

at least one phase shifter configured to generate the at least one first differential signal.

13. The RF device of any one of claims 1 to 12, wherein

the upper surface of the first patch is further configured to receive radiation and provide corresponding signals to the RFIC chip via the first plurality of feed lines, and

the RFIC chip comprises at least one phase shifter configured to process the signals received through the first plurality of feed lines.

14. An antenna module comprising:

a ground plate;

a first patch parallel to the ground plate and having an upper surface configured to emit radiation in a vertical direction opposite the first patch from the ground plate; and

a first plurality of feed lines respectively connected to a first plurality of feed points on a lower surface of the first patch and configured to receive a plurality of differential signals, the first plurality of feed points including a first feed point and a second feed point separated from each other in a first horizontal direction, and a third feed point and a fourth feed point separated from each other in a second horizontal direction perpendicular to the first horizontal direction to achieve a dual polarization,

wherein the first feed point and the second feed point are configured to receive one of the plurality of differential signals, and

the third feed point and the fourth feed point are configured to receive another one of the plurality of differential signals.

15. The antenna module of claim 14, wherein

the first feed point and the second feed point are proximate to a first center line crossing a center of the first patch in the first horizontal direction, and

the third feed point and the fourth feed point are proximate to a second center line crossing the center of the first patch in the second horizontal direction.

16. The antenna module of claim 14 or claim 15, wherein

the first feed point and the second feed point are equally proximate to the center of the first patch, and

the third feed point and the fourth feed point are equally proximate to the center of the first patch.

17. The antenna module of any one of claims 14 to 16, further comprising:

a second patch separated from the first patch in the first horizontal direction; and

a second plurality of feed lines respectively connected to a second plurality of feed points on a lower surface of the second patch.

18. The antenna module of claim 17, further comprising:

a third patch separated from the first patch in the second horizontal direction;

a fourth patch separated from the second patch in the second horizontal direction; and

a third plurality of feed lines respectively connected to a third plurality of feed points on lower surfaces of the third patch and the fourth patch.