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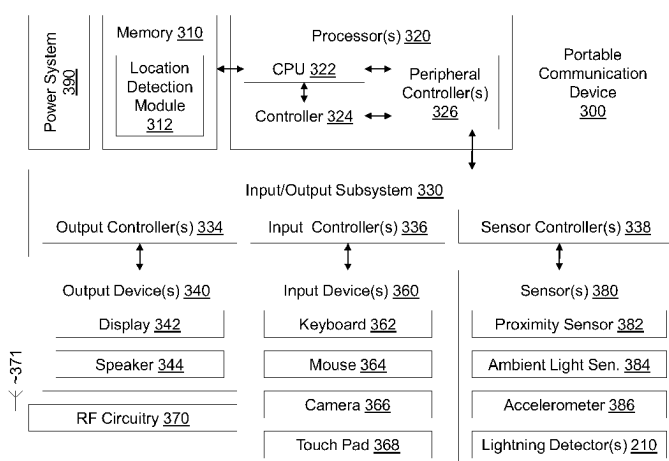


FIG. 3

(57) Abstract: A portable communication device, including a location detection unit configured to determine the location of the device, a lightning detection unit configured to determine a distance between the lightning strike and the device, and a radio frequency circuit configured to output, via a communication network, data indicative of the location of the device and the distance between the lightning strike and the device. A system, including a lightning detection database and an analysis unit configured to receive, from the device via the communication network, data indicative of the location of the device and the distance between a lightning strike and the device, determine the location of the lightning strike based in part on the distance from the lightning strike to the location of the device, and store the location of the lightning strike in the lightning detection database.

LIGHTNING DETECTION SYSTEM, METHOD AND DEVICE

BACKGROUND

[0001] Lightning is an electrostatic discharge between electrically charged regions within clouds or between a cloud and the surface of a planet. There are four primary types of lightning: intra-cloud lightning, cloud-to-cloud lightning, cloud-to-air lightning, and cloud-to-ground lightning. Cloud-to-cloud lightning is prevalent at the beginning of thunderstorms. Lightning detection systems, in combination with weather radar, are utilized by meteorological services to locate and track thunderstorms.

[0002] There are three primary types of lightning detection systems: ground-based systems utilizing multiple detectors, mobile detection systems (often aboard an aircraft), and space-based systems. Each type of lightning detection system has its own limitations. Because mobile detection systems utilize attenuation rather than triangulation to determine lightning location, mobile detection systems may have difficulty discerning whether a weak lightning strike is nearby or a strong lightning strike is far away. Because space-based lightning detection systems take more time to disseminate information than mobile or ground-based systems, information from space-based lightning detection systems is of limited value for real-time applications such as air navigation.

[0003] Meteorological services such as the U.S. National Weather Service utilize ground-based lightning detection systems, which utilize triangulation from multiple detectors in multiple locations to determine the location of lightning strikes. The National Lightning Detection Network (NLDN), for example, includes approximately 100 ground-based detectors located across the continental United States. Those detectors sense the electromagnetic signals of a lightning strike and transmit the data via a satellite to a central processing location in Tucson, Arizona, which estimates the location of the lightning strike by triangulating three or more signals.

[0004] Conventional ground-based lightning detection systems also suffer from a number of drawbacks. The most significant drawback is a lack of accuracy due to the limited number of ground-based detectors. Because ground-based lightning detectors may be hundreds of miles away, the accuracy of even the most advanced ground-based lightning detection systems is limited.

[0005] Detecting cloud-to-cloud lightning with conventional ground-based detection systems is particularly difficult because one detector may detect the location of lightning on

the starting cloud and another detector may detect the location of lightning on the receiving cloud. In order to detect and locate cloud-to-cloud lightning within an acceptable margin of error, ground-based lightning detection systems require at least three detectors within the detection range. Because the number of ground-based lightning detectors is limited, conventional ground-based lightning detection systems underestimate cloud-to-cloud lightning. Conventional ground-based lightning detectors have similar drawbacks when detecting cloud-to-air lightning.

[0006] The accuracy of conventional ground-based lightning detection networks may be improved by increasing the number of ground-based detectors. However, the cost of the network is increased each time a ground-based detector is manufactured, deployed, and maintained. Accordingly, there is a need for a lightning detection network with improved accuracy while minimizing the cost of manufacturing, deploying, and maintaining the ground-based detectors.

SUMMARY

[0007] In order to overcome these and other disadvantages in the related art, aspects of exemplary embodiments are provided.

[0008] According to an aspect of an exemplary embodiment, there is provided a system, including a lightning detection database and an analysis unit configured to receive, from a portable communication device via a communication network, data indicative of a location of the portable communication device and a distance between a lightning strike and the portable communication device, determine a location of the lightning strike based in part on the location of the portable communication device and the distance between the lightning strike and the portable communication device, and store the location of the lightning strike in the lightning detection database.

[0009] According to another aspect of the exemplary embodiment, there is provided a portable communication device, including a location detection unit configured to determine a location of the portable communication device, a lightning detection unit configured to detect a lightning strike and determine a distance between the lightning strike and the portable communication device, and a radio frequency circuit configured to output, via a communication network, data indicative of the location of the portable communication device and the distance between the lightning strike and the portable communication device.

[0010] According to another aspect of exemplary embodiments, there is provided a lightning detection method, including receiving, from a portable communication device via a communication network, data indicative of a location of the portable communication device and a distance between the lightning strike and the portable communication device, determining the location of the lightning strike based in part on the location of the portable communication device and the distance between the lightning strike and the portable communication device, and storing the location of the lightning strike in the lightning detection database.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] Aspects of exemplary embodiments may be better understood with reference to the accompanying drawings. The components in the drawings are not necessarily to scale, emphasis instead being placed upon illustrating the principles of exemplary embodiments.

[0012] FIG. 1 is a top-down view of a conventional ground-based lightning detection system;

[0013] FIG. 2A is a top-down view of a ground-based lightning detection system according to an exemplary embodiment of the present invention;

[0014] FIG. 2B is a side view of the conventional ground-based lightning detection system illustrated in FIG. 1;

[0015] FIG. 2C is a side view of the ground-based lightning detection system illustrated in FIG. 2A;

[0016] FIG. 3 is an overview of a communication device according to the exemplary embodiment of the present invention;

[0017] FIG. 4A is an overview of an electric field detector of a communication device according to the exemplary embodiment of the present invention;

[0018] FIG. 4B is a flowchart illustrating a method of touch sensing and electric field detection utilizing the electric field detector illustrated in FIG. 4A according to the exemplary embodiment of the present invention; and

[0019] FIG. 5 is another overview of the lightning detection system illustrated in FIG. 2A according to an exemplary embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0020] Exemplary embodiments of the present invention will be set forth in detail with reference to the drawings, in which like reference numerals refer to like elements or steps throughout.

[0021] FIG. 1 is a top-down view of a conventional ground-based lightning detection system 100. As illustrated in FIG. 1, the ground-based lightning detection system 100 includes ground-based lightning detectors 101, 102, and 103. The detectors 101, 102, and 103 are configured to detect lightning strike 110, estimate the distance between each detector and the lightning strike 110, and communicate the distance to a central processor (not pictured) configured to estimate the location of a lightning strike 110 by triangulating the location of the lightning strike 110 and known locations of ground based detectors.

[0022] In response to a cloud-to-ground lightning strike 110, the lightning detector 101 estimates a distance 131 from the detector 101 to the lightning strike 110 and the lightning detector 102 estimates a distance 132 from the detector 102 to the lightning strike 110. The conventional lightning detection system 100 can only differentiate between a lightning strike at location 110 and a lightning strike at location 110' if the lightning strike is within the detectable range of a third lightning detector. In this example, the conventional lightning detection system 100 is only able to determine the location of the lightning strike 110 because the lightning detector 103 is within range to estimate a distance 133 from the detector 103 to the lightning strike 110.

[0023] FIG. 2A is a top-down view of a ground-based lightning detection system 200 according to an exemplary embodiment of the present invention. As illustrated in FIG. 2A, the lightning detection system 200 includes a plurality of lightning detectors 210 at locations across the Earth. Because the number of lightning detectors 210 is greater than the number of conventional lightning detectors 101-103, the accuracy and reliability of the lightning detection system 200 is significantly greater than the accuracy of a conventional lightning detection system 100. In the example illustrated in FIG. 2A, the lightning detection system 200 includes lightning detectors 210a, 210b, and 210c and may determine the location of a lightning strike 110 regardless of whether the conventional lightning detector 103 is located within range to detect the lightning strike 110.

[0024] The lightning detection system 200 also has an increased vertical range than the conventional lightning detection system 100. FIG. 2B is a side view of the conventional

lightning detection system 100. Two conventional ground-based lightning detectors 101 and 102 are shown for simplicity. The same analysis, however, is true for systems requiring at least three detectors for triangulation. As illustrated in FIG. 2B, each of the conventional ground-based lightning detectors 101 and 102 has a range R . The overlap of each of the ranges R enables the conventional lightning detection system 100 to have an effective vertical range H_{100} .

[0025] FIG. 2C is a side view of the lightning detection system 200, including the lightning detectors 210*a* and 210*b*. Assuming the lightning detectors 210*a* and 210*b* have the same range R as the conventional ground-based lightning detectors 101 and 102, the proximity of the lightning detectors 210*a* and 210*b* enables the lightning detection system 200 to have an effective vertical range H_{200} that is greater than the effective vertical range H_{100} of the conventional lightning detection system 100.

[0026] The lightning detection system 200 may be combined with a conventional lightning detection system 100. For example, each of the lightning detectors 210 may output a distance between the lightning detectors 210 and a lightning strike 110 to the same central processor utilized by a conventional lightning detection system 100. By combining detections made by the conventional ground-based lightning detectors 101, 102, and 103 and detections made by the plurality of lightning detectors 210, the accuracy of the lightning detection system 200 is significantly greater than the accuracy of a conventional lightning detection system 100. The ground-based lightning detection system 200 may also be combined with one or more mobile lightning detection systems and/or space-based lightning detection systems to further increase the reliability and accuracy of lightning detection.

[0027] As described above, the cost of a conventional ground-based lightning detection system 100 is increased each time a ground-based detector 101-103 is manufactured, deployed, and maintained. As described below, however, the ground-based lightning detection system 200 reduces or eliminates the additional costs by incorporating the lightning detectors 210 into portable communication devices 300. In addition to increasing the accuracy of the lightning detection system 200, incorporating the lightning detectors 210 into portable communication devices 300 shifts the cost of deploying and maintaining the lightning detectors 210 from those who maintain the lightning detection system 200 to those who purchase and maintain the portable communication devices 300.

[0028] FIG. 3 is an overview of a portable communication device 300 according to an exemplary embodiment of the present invention. As illustrated in FIG. 3, the portable communication device 300 may include memory 310, one or more processors 320, an input/output subsystem 330, one or more output devices 340, one or more input devices 360, radio frequency (RF) circuitry 370, one or more sensors 380, and a power system 390.

[0029] The memory 310 may include one or more computer readable storage mediums. For example, the memory 310 may include high-speed random access memory and/or non-volatile memory such as one or more magnetic disk storage devices, flash memory devices, and/or other non-volatile solid-state memory, etc.

[0030] The portable communication device 300 includes a location detection module 312. The location detection module 312 may be any suitable device configured to determine or estimate the location of the communication device 310. As illustrated in FIG. 3, the location detection module 312 may be implemented as a set of instructions stored in the memory 310 executed by the one or more processors 320. Alternatively, the location detection module 312 may be implemented by hardware or a combination of hardware and computer readable instructions. The location detection module 312 may determine or estimate the location of the communication device 310 by any suitable means, including the global positioning system (GPS), assisted GPS (A-GPS), a Wi-Fi-based positioning system, cellular network-based positioning, etc.

[0031] The one or more processors 320 may include a central processing unit (CPU) 322, one or more controllers 324, and/or one or more peripheral controllers 326, etc. The processor(s) 320 may be integrated into a single semiconductor chip or may be implemented by more than one chip. The one or more processors 320 may execute various software programs and/or sets of instructions stored in the memory 310 to process data and/or to perform various functions for the device 300.

[0032] The input/output subsystem 330 couples input/output peripherals on the device 300, such as the output device(s) 340, the input devices 360, and the sensor(s) 380, to the peripheral controller(s) 326. The input/output subsystem 330 may include one or more output controllers 334, one or more input controllers 336 and/or one or more sensor controllers 338, etc. The one or more output controllers 334 send/receive electrical signals to/from the output device(s) 340. The one or more input controllers 334 receive/send

electrical signals from/to the input device(s) 360. The one or more sensor controllers 338 receive/send electrical signals from/to the input device(s) 380.

[0033] The one or more output devices may include a display 342, a speaker 344, one or more external ports, etc. The display 342 may be any suitable device configured to output visible light, such as a liquid crystal display (LCD), a light emitting polymer display (LPD), a light emitting diode (LED), an organic light emitting diode (OLED), etc.

[0034] The one or more input devices 360 may include a keyboard 362, a mouse (or trackball) 364, a still or video camera 366, a touchpad 368, etc. The touchpad 368 may include any suitable technology to determine the location of a finger or stylus relative to the device 300. As described below, the touchpad 368 may include resistive touch sensors, self-capacitive touch sensors, mutually-capacitive touch sensors, etc. The touchpad 368 may be overlaid or integrated with the display 342 to form a touch-sensitive display or touchscreen.

[0035] The RF circuitry 370 may be any suitable device configured to send and/or receive RF signals. The RF circuitry 370 may include an antenna system 371, an RF transceiver, one or more amplifiers, a tuner, one or more oscillators, a digital signal processor, a CODEC chipset, a subscriber identity module (SIM) card, memory, etc. The RF circuitry 370 may communicate via electromagnetic signals with other communications devices or communications networks such as the Internet, an intranet, and/or a wireless network, such as a cellular telephone network, a wireless local area network (LAN), and other devices by wireless communication. The wireless communication may use any of a plurality of communications standards, protocols and technologies, including Global System for Mobile Communications (GSM), Enhanced Data GSM Environment (EDGE), high-speed downlink packet access (HSDPA), wideband code division multiple access (W-CDMA), code division multiple access (CDMA), time division multiple access (TDMA), Bluetooth, Wireless Fidelity (Wi-Fi) (e.g., IEEE 802.11), voice over Internet Protocol (VoIP), Wi-MAX, or any other suitable communication protocol, including communication protocols not yet developed.

[0036] The power system 390 may be any suitable device configured to distribute electric power to components of the device 300. The power system 390 may include one or more power sources (e.g., battery, alternating current (AC), etc.), a power conversion system, a power management system, a recharging system, a power failure detection circuit, a power converter or inverter, a power status indicator (e.g., a light-emitting diode (LED)) and any

other components associated with the generation, management and distribution of power in electronic devices.

[0037] The one or more sensors 380 may include a proximity sensor 382, an ambient light sensor 384, an accelerometer 386, a gyroscope, etc. The proximity sensor 382 may be any suitable device configured to detect whether the portable communication device 300 is within a predetermined distance of an object. For example, the personal communicator device 300 may be configured to deactivate the display 342 and/or the touch pad 368 when the proximity sensor 382 determines that the device 300 is near a user's face during a telephone phone call or a cover of the device 300 has been closed. The ambient light sensor 384 may be any suitable device configured to determine the amount of ambient light. For example, the personal communicator device 300 may be configured to adjust the brightness of the display 342 based on an amount of ambient light detected by the ambient light sensor.

[0038] The portable communication device 300 illustrated in FIG. 3 is an electronic device configured to send data to a mobile phone network (i.e., "a smartphone"). It should be appreciated, however, that the portable communication device 300 illustrated in FIG. 3 is only one example of a portable communication device, and that the device 300 may have more or fewer components than shown, may combine two or more components, or a may have a different configuration or arrangement of the components. In exemplary embodiments of the present invention, the portable communication device 300 may be any suitable electronic device configured to detect lightning, communicate with one or more networks 510, and perform at least one other function unrelated to lightning detection. The portable communication device 300 may be, for example, a network-connected computing device (such as a personal digital assistant (PDA), a tablet, a notebook computer, a portable weather detector, a GPS receiver, etc.), or a network-connected vehicle (such as a car, a ship, an airplane, a satellite truck, etc.).

[0039] In other exemplary embodiments, one or more of the lightning detectors 210 may be incorporated in a non-portable communication device such as a network-connected computer, appliance, home, building, or other structure. The non-portable communication device may determine and/or output its location to the lightning detection system 200. Alternatively, the location(s) of the non-portable communication device(s) may be known to the lightning detection system 200.

[0040] The portable communication device 300 includes one or more lightning detectors 210. The various components shown in FIG. 3 may be implemented in hardware, software, or a combination of both hardware and software, including one or more signal processing and/or application specific integrated circuits.

[0041] The one or more lightning detectors 210 may be any suitable device configured to detect lightning. The lightning detector(s) 210 may detect that a lightning strike 110 has occurred proximate to the location of the portable communication device 300 and/or may determine or estimate a distance or direction from the location of the portable communication device 300 to the lightning strike 110.

[0042] In some exemplary embodiments, the one or more lightning detectors 210 may be incorporated into the portable communication device 300 by adding additional hardware specifically configured to detect a lightning strike 110. In other more preferable exemplary embodiments, the one or more lightning detectors 210 are implemented utilizing one or more hardware components of the portable communication device 300 that perform additional functions unrelated to lightning detection. Utilizing one or more hardware components that perform additional functions unrelated to lightning detection further reduces the cost of manufacturing, deploying, and maintaining the lightning detectors 310.

[0043] According to one exemplary embodiment, the one or more lightning detectors 210 may include a radio frequency (RF) lightning detector. The RF lightning detector may be any suitable device configured to detect an RF electromagnetic signal generated by lightning. The RF lightning detector may also determine or estimate the distance between the portable communication device 300 and the lightning strike 110 based on, for example, the amplitude of the detected energy discharge. The RF lightning detector may be implemented as additional hardware incorporated in the portable communication device 300 to detect an RF electromagnetic signal generated by lightning. More preferably, however, the RF lightning detector may utilize the antenna system 371 of the RF circuitry 370 to detect an RF electromagnetic signal generated by lightning. In this more preferable embodiment, the antenna system 371 is also utilized by the RF circuitry 370 to send and/or receive RF signals as described above.

[0044] According to another exemplary embodiment, the one or more lightning detectors 210 may include an interferometer. The interferometer may be any suitable device configured to measure the phase difference between (narrow-band or broad-band) signals

received by two or more sensors. For example, the interferometer may be two closely spaced antennas, each antenna being connected via a narrow band filter to a phase detector that outputs a voltage proportional to the difference in phase between the two signals received by the antennas. In that example, the phase difference may be utilized to identify the direction, on a plane perpendicular to the plane of the two antennas, of a detected lightning strike 110. The interferometer may also determine or estimate the distance between the portable communication device 300 and the lightning strike 110 based on, for example, the amplitude of the signals received by the two or more sensors. The interferometer may be implemented as additional hardware incorporated in the portable communication device 300 to detect two signals generated by lightning. More preferably, however, the interferometer may utilize the antenna system 371 of the RF circuitry 370 to detect two signals generated by lightning. In that more preferable embodiment, the antenna system 371 is also utilized by the RF circuitry 370 to send and/or receive RF signals as described above.

[0045] According to another exemplary embodiment, the one or more lightning detectors 210 may include an optical monitor. The optical monitor may be any suitable device configured to detect a light pulse produced by cloud-to-ground lightning or cloud-to-cloud lightning. In some instances, cloud-to-cloud lightning precedes cloud-to-ground lightning. The optical monitor may also determine or estimate the distance between the portable communication device 300 and the lightning strike 110 based on, for example, the amplitude of the light pulse detected by the optical monitor. The optical monitor may be implemented as additional hardware incorporated in the portable communication device 300 to detect a light pulse generated by lightning. More preferably, however, the optical monitor may utilize hardware components of the portable communication device 300 (such as the proximity sensor 382 and/or camera 366) to detect the light pulse. In this more preferable embodiment, the hardware component used to detect the light pulse generated by lightning is also utilized by the portable communication device 300 to perform additional functions as described above.

[0046] According to another exemplary embodiment, the one or more lightning detectors 210 may include an electric field monitor. The electric field monitor may be any suitable device configured to measure changes in an electric field, for example changes in the potential gradient (voltage) of the Earth's electric field that occur in proximity to a lightning strike 110. The electric field monitor may also determine or estimate the distance between the portable communication device 300 and the lightning strike 110 based on, for example,

the amplitude of the change in the electric field detected by the electric field monitor. The electric field monitor may be implemented as hardware incorporated in the portable communication device 300 (for example, an electric field mill). More preferably, however, the atmospheric electric field monitor may utilize the touch pad 368 (as described below with reference to FIGS. 4A and 4B) to detect changes in an electric field that occur in proximity to a lightning strike 110.

[0047] As one of ordinary skill in the art would recognize, the one or more lightning detectors may include more than one type of lightning detector. In one example, the one or more lightning detectors 210 may include an RF lightning detector and an optical monitor. An RF lightning detector may sense RF interference and misinterpret the RF noise as a detection of a nearby lightning strike 110. In that instance, the lightning detectors 210 may be configured to output a lightning detection signal only if lightning is detected by both the RF lightning detector and the optical monitor. More than one lightning detector may also be used determine or estimate the distance between the portable communication device 300 and the lightning strike 110 based on, for example, the amount of time between the detection of an optical pulse by an optical monitor and the detection of an RF electromagnetic signal by an RF lightning detector.

[0048] The lightning detector 210 may include software instructions, stored in the memory 310 and executed by the one or more processors 320. Regardless of whether a lightning detector 210 utilizes hardware components of the portable communication device 300 that perform additional functions unrelated to lightning detection (such as the antenna system 371, the touch pad 368, etc., as described above) the lightning detector 210 may also include additional hardware (for example to filter or process the signals generated by lightning and detected by the lightning detector 210) which may be additional hardware specifically configured to detect a lightning strike 110 or hardware components of the portable communication device 300 that perform additional functions unrelated to lightning detection.

[0049] FIG. 4A is an overview of an electric field detector 400 of a communication device according to exemplary embodiments of the present invention. As described above with reference to FIG. 3, the portable communication device 300 includes memory 310, one or more processors 320, an input/output subsystem 330 and a touch pad 368. The touch pad 368 includes a drive signal generator 467, a detection unit 469, column traces C1, C2, C3,

etc., and row traces R1, R2, R3, etc. The touch pad may be overlaid or integrated with a display 342 to form a touch-sensitive display or touchscreen.

[0050] According to one exemplary embodiment, the touch pad 368 is a mutual capacitive touch sensor. A mutual capacitive touch sensor pad includes a capacitor at each intersection of a column trace (e.g., C1, C2, etc.) and a row trace (e.g., R1, R2, etc.). A voltage is applied to the columns or rows. When a finger or conductive stylus is near the surface, the finger or stylus changes the local electric field which reduces the mutual capacitance. The capacitance change at every individual point on the grid can be measured to accurately determine the touch location by measuring the voltage in the other axis. For example, if a voltage is applied to columns C1, C2, etc., the capacitive change can be measured by measuring the voltage in each of the rows R1, R2, etc. A mutual capacitive touch sensor is generally preferable to a self-capacitive touch sensor because mutual capacitive touch sensors can accurately track multiple fingers or styli at the same time.

[0051] According to another exemplary embodiment, the touch pad 368 is a self-capacitive touch sensor. Self-capacitive touch sensors have the same grid of columns and rows as mutual capacitance sensors, but the columns and rows operate independently. With self-capacitance, current senses the capacitive load of a finger or stylus on each column or row. A self-capacitive touch sensor cannot accurately resolve more than one simultaneous touch. A self-capacitive touch sensor, however, produces stronger signal than a mutual capacitive touch sensor.

[0052] According to another exemplary embodiment, the touch pad 368 has both self capacitive and mutual capacitive touch sensing capability. With both self-capacitive and mutual capacitive touch sensing capability, the touch pad 368 may include two modes: an electric field detection mode where the touch pad 368 utilizes self-capacitive touch sensing to more accurately detect changes in the electric field and a touch sensing mode where the touch pad 368 utilizes mutual capacitive touch sensing capability to detect more than one simultaneous touch.

[0053] FIG. 4B is a flowchart illustrating an example of a method of touch sensing and electric field detection utilizing the electric field detector 400 illustrated in FIG. 4A. Referring to FIG. 4B, the default state of the touch pad 368 is the electric field detection mode. In electric field detection mode, the drive signal generator 467 drives multiple conductive traces in operation S401, and the detection unit 469 measures the self-capacitance

in operation S403. Because self capacitive sensing produces a stronger signal than mutual capacitive sensing, the touch pad 368 in the electric field detection mode is capable of more accurately detecting changes in the Earth's electric field caused by a lightning strike 110 proximate to the portable communication device 300. By measuring the self-capacitance of multiple conductive traces, the touch pad 368 is also capable of determining if the touch pad 368 is being approached or touched by a finger or stylus.

[0054] As illustrated in FIG. 4B, the touch pad 368 repeatedly determines whether a finger or stylus is touching the touch pad 368 in operation S405. If the touch pad 368 is not being touched by a finger or stylus, the touch pad 368 continues in the electric field detection mode by repeating operations S401 and S403. If the touch pad 368 is being touched by a finger or stylus, the touchpad 368 enters the touch sensing mode.

[0055] In touch sensing mode, the drive signal generator 467 drives one conductive trace at a time (for example, column trace C1) in operation S451 and the detection unit 469 measures the mutual capacitance on one conductive trace along the other axis (in this example, a row trace R1, R2, etc.) in operation S453. Because mutual capacitive sensors are able to resolve more than one touch, the touch pad 368 provides multi-touch capabilities while the touch pad 368 is in the touch sensing mode. While the touch pad 368 is in touch sensing mode, the touch pad 368 repeatedly determines whether the touch pad 368 is being touched by a finger or stylus in operation S405. If the touch pad 368 continues to be touched by a finger or stylus, the touch pad 368 continues in touch sensing mode. Otherwise, the touch pad 368 returns to the electric field detection mode.

[0056] FIG. 5 is another overview of the lightning detection system 200 according to an exemplary embodiment of the present invention. As illustrated in FIG. 5, the lightning detection system 200 includes an analysis unit 500, one or more communications networks 510, a lightning detection database 590, and one or more portable communication devices 300a-n.

[0057] The analysis unit 500 may any suitable computing device (e.g., a server) configured to receive data from the one or more portable communication devices 300a-n through the one or more communications networks 510. The analysis unit 500 may also receive data from a space-based lightning detection system 520 and/or one or more mobile lightning detectors 530 and or one or more conventional ground-based lightning detector(s) 101-103.

[0058] The one or more communications networks 500 may include the Internet, an intranet, and/or a wireless network, such as a cellular telephone network, a wireless local area network (LAN), etc. The wireless communication may utilize any of a plurality of communications standards, protocols and technologies described above regarding the RF circuitry 370. Some or all of the personal communications devices 300a-n may communicate with the one or more communications networks 500 via the RF circuitry 370a-n. Alternatively, some or all of the personal communications devices 300a-n may communicate with the one or more communications networks 510 via a wired connection such as Ethernet, universal serial bus (USB), etc.

[0059] According to an aspect of the exemplary embodiments, the analysis unit 500 is configured to receive, from one or more of the portable communication devices 300a-n via the one or more communications networks 510: data indicative of a lightning strike 110 (detected, for example, by the one or more lightning detectors 210a-n), data indicative of the location of the portable communication device 300a (determined, for example, by the location detection module 312a-n), and data indicative of each of the distances between the one or more of the portable communication devices 300a-n and the lightning strike 110 (determined, for example, by the one or more lightning detectors 210a-n). Similarly, the analysis unit 500 may receive, from one or more of the conventional ground-based lightning detectors 101-103 or mobile lightning detectors 530: data indicative of a lightning strike 110, data indicative of the location of the detector 101-103 or 530, and data indicative of the distances between the detector 101-103 or 530 and the lightning strike 110.

[0060] The analysis unit 500 may also send and/or receive weather data or weather forecast data. For example, the analysis unit 500 may receive weather data or weather forecast data (either directly or via communication network(s) 510) from a weather database 540. The analysis unit 500 may also be configured to output data indicative of a lightning strike 110 (e.g., the time and/or location of one or more lightning strikes 110) and/or weather data and/or weather forecast data to the communication network(s) 510 for transmittal to one or more portable communication devices 300a-n. The analysis unit 500 may also output/transmit the data indicative of a lightning strike 110 via the communication network(s) 510 to one or more communication devices that do not include a lightning detector 210. In one example, the analysis unit 500 may be configured to output to a portable communication device 300 a map and an indication on the map of the location of a lightning strike 110. In another example, the analysis unit may receive the location of a portable communication

device 300 and may output data indicative of a lightning strike 110 if the lightning strike 110 is within a predetermined distance of the location of the portable communication device 300. Data indicative of the location of portable communication devices 300 may be stored in a communication device location database 550. The analysis unit 500 may receive the data indicative of the location of the communication devices from the communication device location database 550 either directly or via the communication network(s) 510.

[0061] The analysis unit 500 of the lightning detection system 200 is configured to determine the location of a lightning strike 110 by triangulating the distance between the lightning strike 110 and three or more detectors 210 $a-c$ or 101-103 (see FIG. 2A) and storing the location of the lightning strike 110 in the lightning detection database 590.

[0062] As described above, the lightning detection system 200 detects the location of lightning strikes 110 with increased reliability and accuracy as compared to conventional ground-based lightning detection systems 100 by increasing the number of lightning detectors 210. The lightning detection system 200 reduces the cost of manufacturing, deploying, and maintaining the additional lightning detectors 210 by incorporating the lightning detectors 210 in portable communication devices 300 and/or utilizing hardware already incorporated in portable communication devices 300 to detect or estimate the location of the portable communication devices 300, detect or estimate a distance between the portable communication devices 300 and a lightning strike 110, and communicate data indicative of the location of the portable communication devices 300 and a distance between the portable communication devices 300 and a lightning strike 110 through one or more communications networks 510 to the analysis unit 500.

[0063] While preferred embodiments have been set forth above, those skilled in the art who have reviewed the present disclosure will readily appreciate that other embodiments can be realized within the scope of the invention. For example, disclosures of specific numbers of hardware components, software modules and the like are illustrative rather than limiting. Therefore, the present invention should be construed as limited only by the appended claims.

WHAT IS CLAIMED IS:

1. A system, comprising:
a lightning detection database; and
an analysis unit configured to:
receive, from a portable communication device via a communication network,
data indicative of a location of the portable communication device and a distance between a
lightning strike and the portable communication device;
determine a location of the lightning strike based in part on the distance from
the lightning strike to the location of the portable communication device; and
store the location of the lightning strike in the lightning detection database.
2. The system of Claim 1, wherein the portable communication device comprises
one or more antennas, and the portable communication device is configured to:
output the data to the communication network using the one or more antennas; and
determine the distance between the lightning strike and the portable communication
device based on radio frequency signals received by the one or more antennas.
3. The system of Claim 2, wherein the portable communication device is
configured to determine the distance between the lightning strike and the portable
communication device by detecting a radio frequency electromagnetic signal using the one or
more antennas.
4. The system of Claim 2, wherein one or more antennas comprises two
antennas, and the portable communication device is configured to determine the distance
between the lightning strike and the portable communication device by detecting a phase
difference between two signals received by the two antennas.
5. The system of Claim 1, wherein the portable communication device comprises
a display and a proximity sensor, and the portable communication device is configured to:
deactivate the display when the proximity sensor determines that the portable
communication device is within a predetermined distance of an object; and
determine the distance between the lightning strike and the portable communication
device based on the output of the proximity sensor.

6. The system of Claim 1, wherein the portable communication device comprises a display and an ambient light sensor, and the portable communication device is configured to:

adjust a brightness of the display based on the output of the ambient light sensor; and
determine the distance between the lightning strike and the portable communication device based on the output of the ambient light sensor.

7. The system of Claim 1, wherein the portable communication device comprises a camera, and the portable communication device is configured to:

capture still images and/or motion pictures based on the output of the camera; and
determine the distance between the lightning strike and the portable communication device based on the output of the camera.

7. The system of Claim 1, wherein the portable communication device comprises a touch pad, and the portable communication device is configured to determine the distance between the lightning strike and the portable communication device based on changes in an electric field detected by the touch pad.

9. The system of Claim 8, wherein the touch pad is a capacitive touch pad including a plurality of conductive traces, and the portable communication device is configured to:

drive two or more of the conductive traces; and
determine the distance between the lightning strike and the portable communication device based on a self capacitance of two or more of the conductive traces.

10. The system of Claim 8, wherein the touch pad is a capacitive touch pad including a plurality of conductive traces, the plurality of conductive traces including a plurality of conductive rows and a plurality of conductive columns, and the portable communication device is configured to:

sequentially drive the conductive columns or the conductive rows; and
determine the distance between the lightning strike and the portable communication device based on a mutual capacitance between the conductive columns and conductive rows.

11. The system of Claim 8, wherein the touch pad is a capacitive touch pad including a plurality of conductive traces, the plurality of conductive traces including a plurality of conductive rows and a plurality of conductive columns, and the portable communication device is configured to:

drive two or more of the conductive traces;

determine the distance between the lightning strike and the portable communication device based on a self capacitance of the two or more conductive traces;

determine whether one or more fingers or conductive styli are proximate to the touch pad based on the self capacitance of the multiple conductive traces;

sequentially drive the conductive columns or the conductive rows in response to a determination that one or more fingers or conductive styli are proximate to the touch pad;

determine a location of the one or more fingers or conductive styli based on a mutual capacitance between the conductive columns and the conductive rows.

12. A portable communication device, comprising:

a location detection unit configured to determine a location of the portable communication device;

a lightning detection unit configured to detect a lightning strike and determine a distance between the lightning strike and the portable communication device; and

a radio frequency circuit configured to output, via a communication network, data indicative of the location of the portable communication device and the distance between the lightning strike and the portable communication device

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13. The portable communication device of Claim 12, wherein the radio frequency circuit comprises one or more antennas, and the portable communication device is configured to determine the distance between the lightning strike and the portable communication device based on radio frequency signals received by the one or more antennas.

14. The portable communication device of Claim 13, wherein the portable communication device is configured to determine the distance between the lightning strike and the portable communication device by detecting a radio frequency electromagnetic signal using the one or more antennas.

15. The portable communication device of Claim 13, wherein one or more antennas comprises two antennas, and the portable communication device is configured to determine the distance between the lightning strike and the portable communication device by detecting a phase difference between two signals received by the two antennas.

16. The portable communication device of Claim 12, further comprising a display and a proximity sensor, wherein the portable communication device is configured to:
deactivate the display when the proximity sensor determines that the portable communication device is within a predetermined distance of an object; and
determine the distance between the lightning strike and the portable communication device based on the output of the proximity sensor.

17. The portable communication device of Claim 12, further comprising a display and an ambient light sensor, wherein the portable communication device is configured to:
adjust a brightness of the display based on the output of the ambient light sensor; and
determine the distance between the lightning strike and the portable communication device based on the output of the ambient light sensor.

18. The portable communication device of Claim 12, further comprising a camera, wherein the portable communication device is configured to:
capture still images and/or motion pictures based on the output of the camera; and
determine the distance between the lightning strike and the portable communication device based on the output of the camera.

19. The portable communication device of Claim 12, further comprising a touch pad, wherein the portable communication device is configured to determine the distance between the lightning strike and the portable communication device based on changes in an electric field detected by the touch pad.

20. The portable communication device of Claim 19, wherein the touch pad is a capacitive touch pad including a plurality of conductive traces, and the portable communication device is configured to:

drive two or more of the conductive traces; and

determine the distance between the lightning strike and the portable communication device based on a self capacitance of two or more of the conductive traces.

21. The portable communication device of Claim 19, wherein the touch pad is a capacitive touch pad including a plurality of conductive rows and a plurality of conductive columns, and the portable communication device is configured to:

sequentially drive the conductive columns or the conductive rows; and

determine the distance between the lightning strike and the portable communication device based on a mutual capacitance between the conductive columns and conductive rows.

22. The portable communication device of Claim 19, wherein the touch pad is a capacitive touch pad including a plurality of conductive traces, the plurality of conductive traces including a plurality of conductive rows and a plurality of conductive columns, and the portable communication device is configured to:

drive two or more of the conductive traces;

determine the distance between the lightning strike and the portable communication device based on a self capacitance of the two or more conductive traces;

determine whether one or more fingers or conductive styli are proximate to the touch pad based on the self capacitance of the multiple conductive traces;

sequentially drive the conductive columns or the conductive rows in response to a determination that one or more fingers or conductive styli are proximate to the touch pad;

determine a location of the one or more fingers or conductive styli based on a mutual capacitance between the conductive columns and the conductive rows.

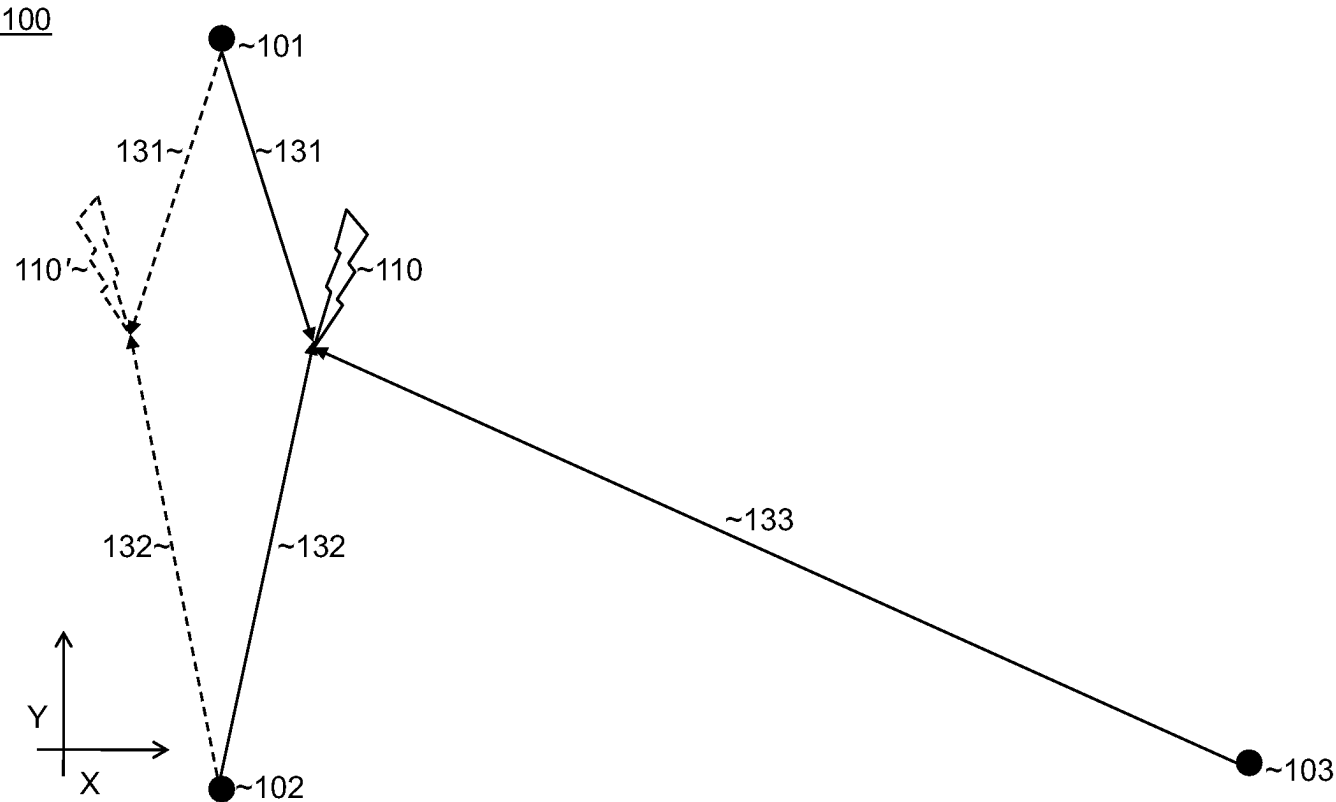
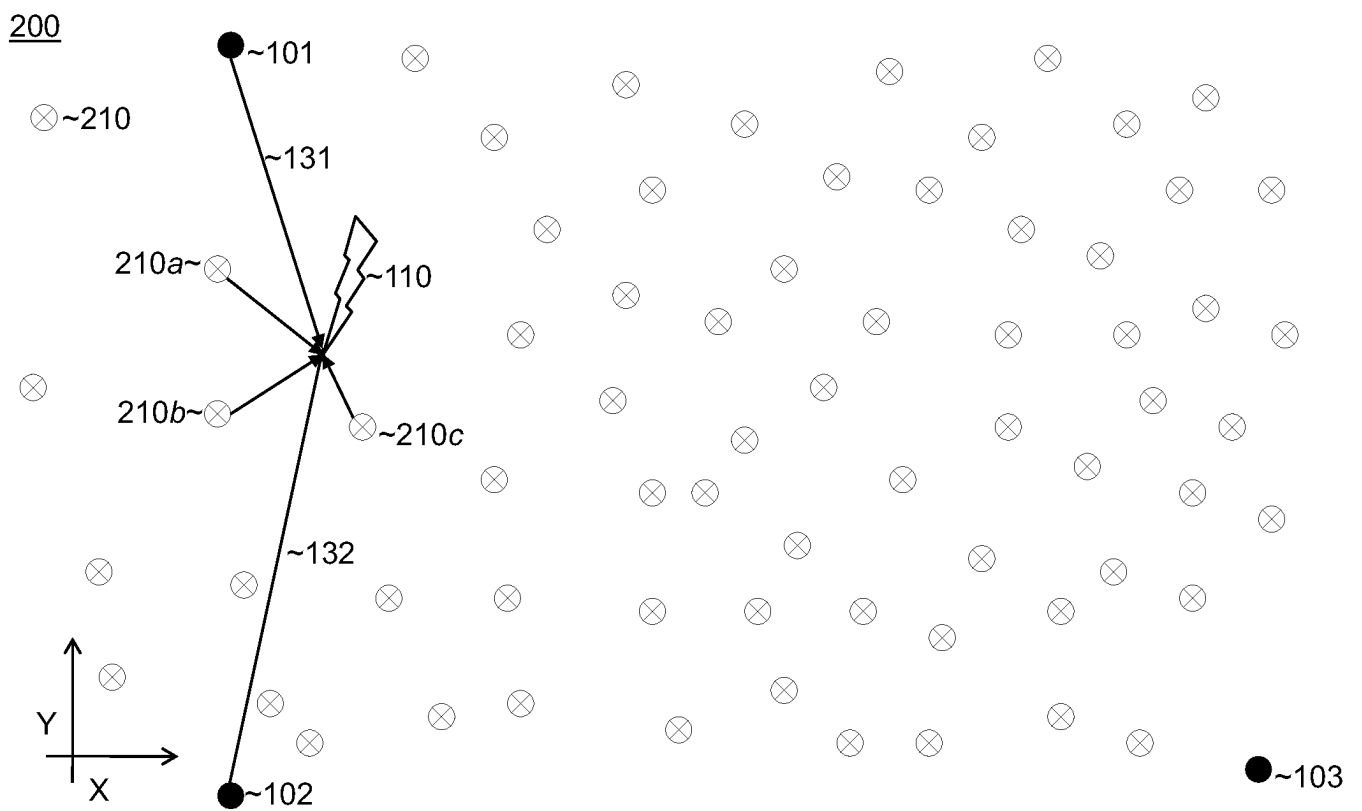


FIG. 1
(RELATED ART)

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**FIG. 2A**

100

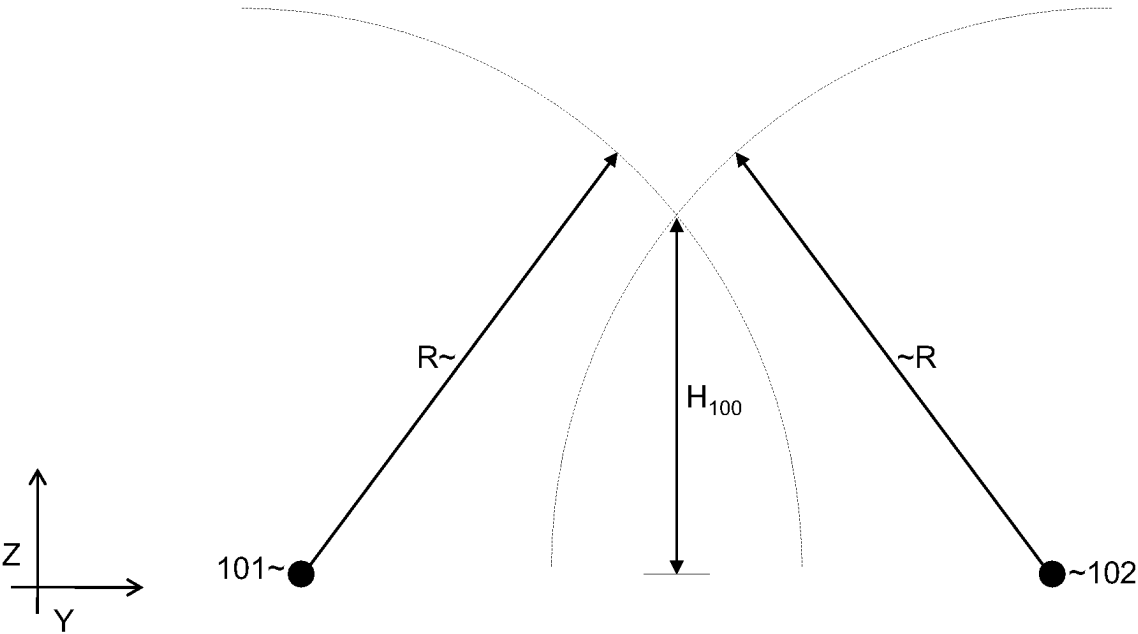


FIG. 2B
(RELATED ART)

200

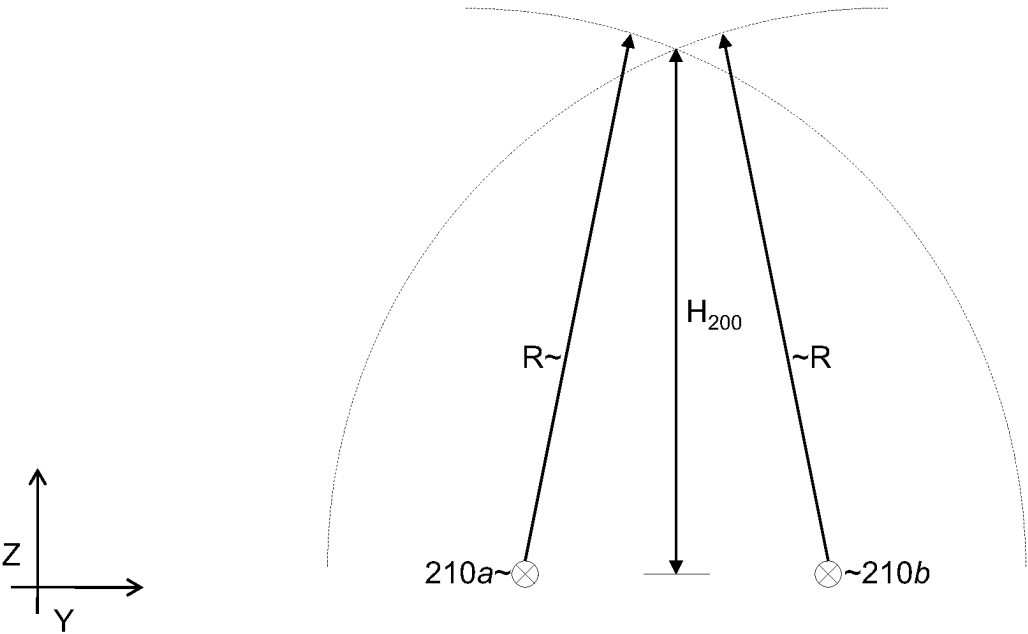
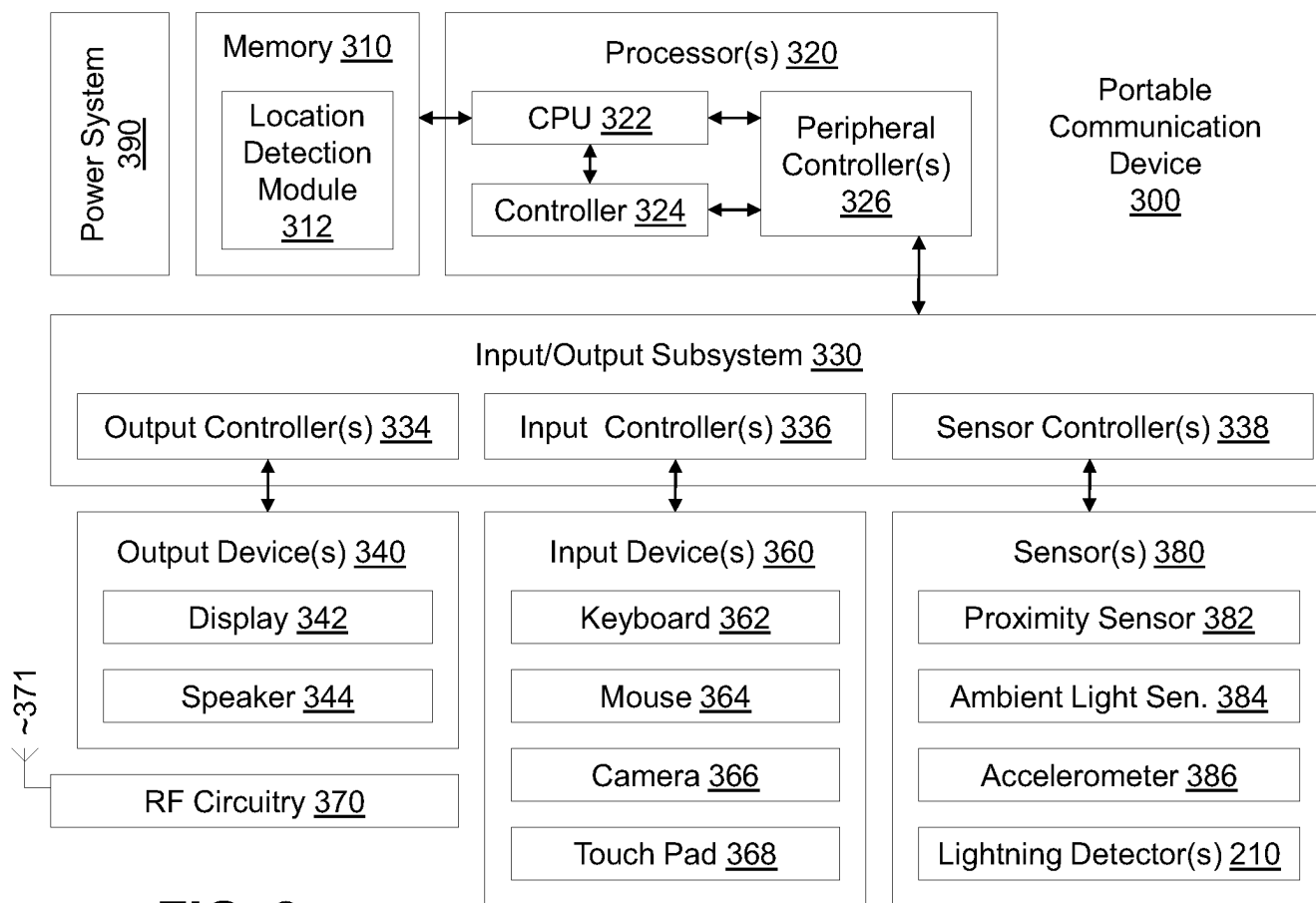


FIG. 2C

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**FIG. 3**

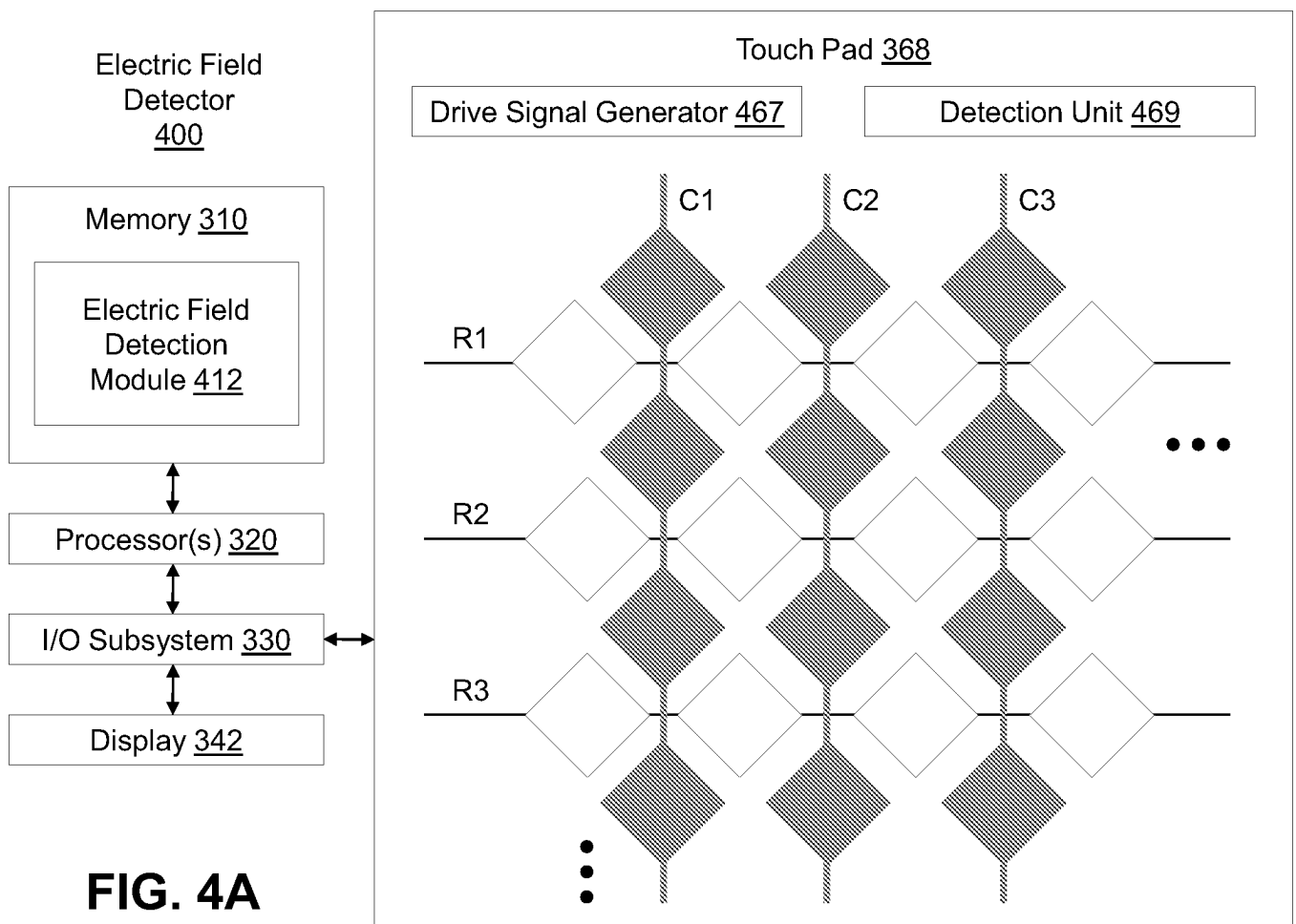
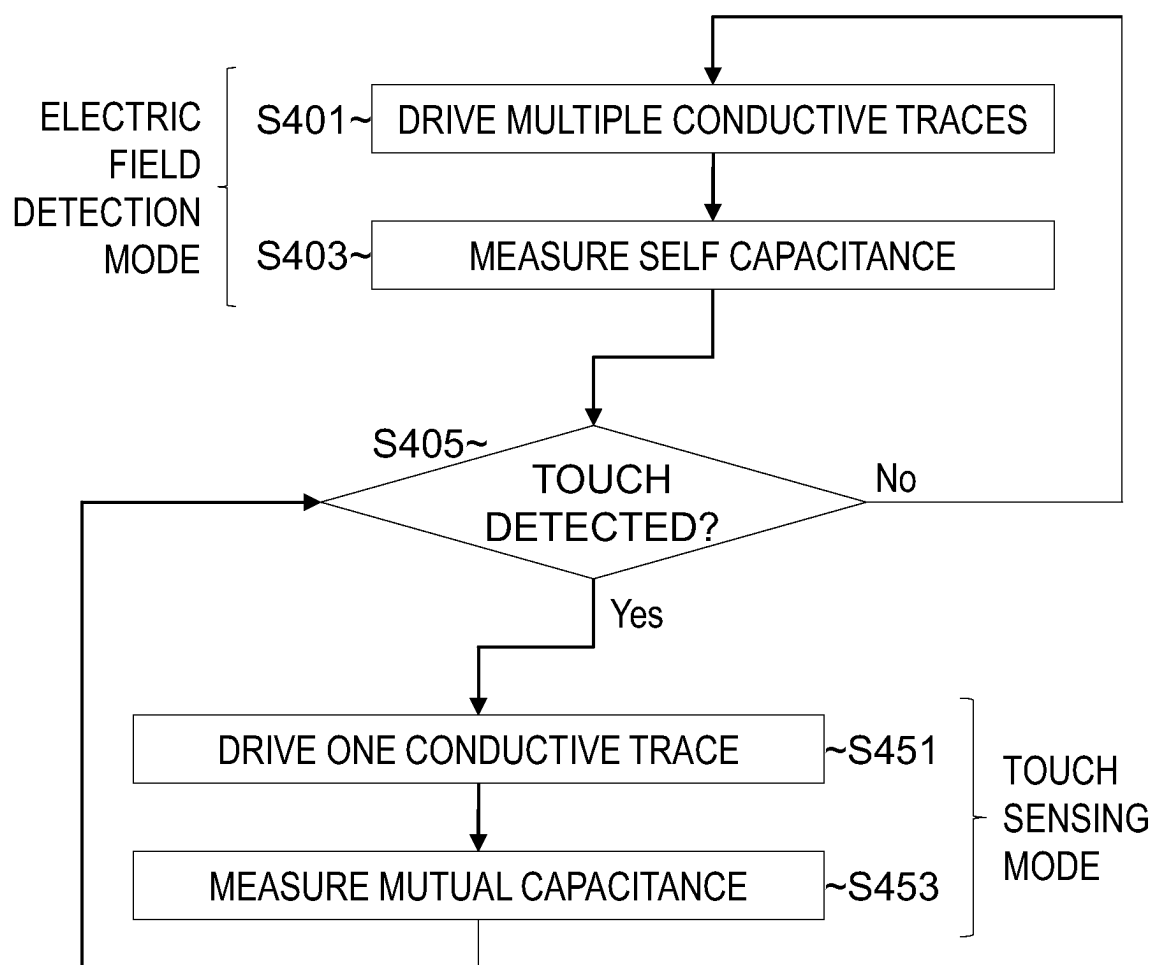
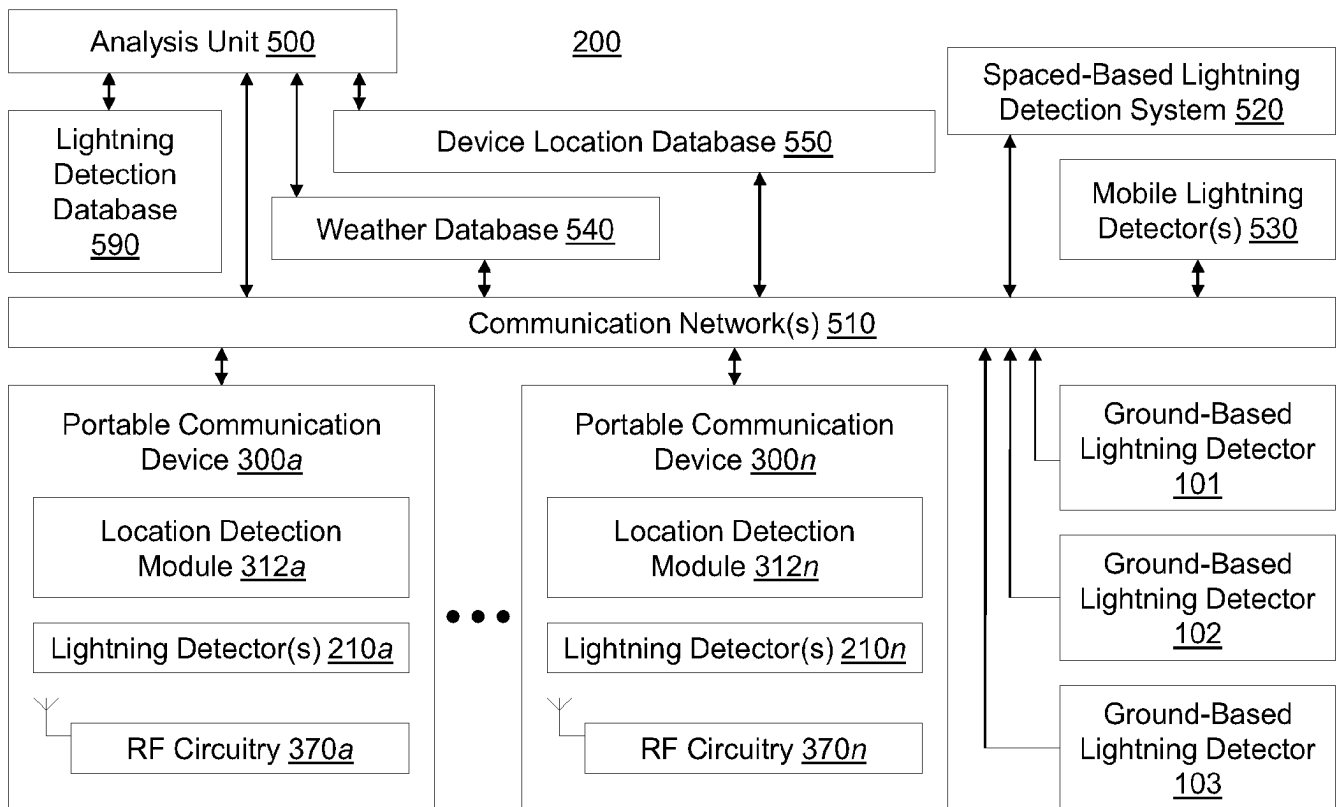


FIG. 4A

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**FIG. 4B**

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**FIG. 5**

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2015/040697

A. CLASSIFICATION OF SUBJECT MATTER
IPC (2015.01) G01W 1/16

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC (2015.01) G01W 1/16, H02G 13/00, G01R

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

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

Databases consulted: THOMSON INNOVATION, Esp@cenet, Google Patents, Google Scholar, FamPat database
Search terms used: Lightning, sensor, detector, cellular, portable device/system, distance, location, Touch screen/pad

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2005197776 A1 NOKIA CORP 08 Sep 2005 (2005/09/08) Entire document	1-3,12-14
A	MY 135780 A UNIV PUTRA MALAYSIA [MY] 30 Jun 2008 (2008/06/30) Entire document	1-22
A	US 2005258971 A1 GREENSTEIN LAWRENCE T [US]; ROSS JAY B [US] 24 Nov 2005 (2005/11/24)	1-22
A	US 2007088504 A1 NOKIA CORP 19 Apr 2007 (2007/04/19)	1-22
A	WO 2007042600 A1 NOKIA CORP [FI]; JANTUNEN JONI [FI]; MAEKELAE JAKKE [FI]; KAIKURANTA TERHO [FI]; REUNAMAEMI JUKKA [FI]; AHOLA TOM [FI]; UUSITALO ARTTU [FI]; KALLIOJAERVI KARI [FI] 19 Apr 2007 (2007/04/19)	1-22

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:

“A” document defining the general state of the art which is not considered to be of particular relevance

“E” earlier application or patent but published on or after the international filing date

“L” document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

“O” document referring to an oral disclosure, use, exhibition or other means

“P” document published prior to the international filing date but later than the priority date claimed

“T” later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

“X” document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

“Y” document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

“&” document member of the same patent family

Date of the actual completion of the international search
15 Nov 2015

Date of mailing of the international search report
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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/US2015/040697

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(51)Int.Cl.

G01W 1/16(2006.01)

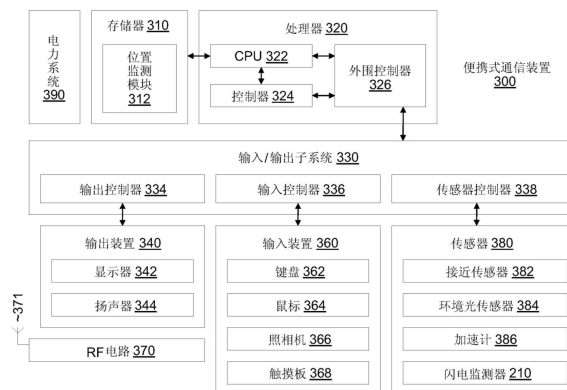
权利要求书3页 说明书8页 附图7页

(54)发明名称

闪电监测系统、方法和装置

(57)摘要

一种便携式通信装置,包括:位置监测单元,被配置为确定所述便携式通信装置的位置;闪电监测单元,被配置为确定雷击与所述便携式通信装置之间的距离;以及射频电路,被配置为经由通信网络输出表示所述便携式通信装置的位置以及所述雷击与所述便携式通信装置之间的距离的数据。一种系统,包括:闪电监测数据库;以及分析单元,被配置为:经由通信网络从便携式通信装置接收表示所述便携式通信装置的位置以及雷击与所述便携式通信装置之间的距离的数据;部分地基于从所述雷击到所述便携式通信装置的位置的距离来确定所述雷击的位置;以及将所述雷击的位置存储到所述闪电监测数据库中。



1. 一种系统,包括:

闪电监测数据库;以及

分析单元,被配置为:

经由通信网络从便携式通信装置接收表示所述便携式通信装置的位置以及雷击与所述便携式通信装置之间的距离的数据;

部分地基于从所述雷击到所述便携式通信装置的位置的距离来确定所述雷击的位置;以及

将所述雷击的位置存储到所述闪电监测数据库中。

2. 根据权利要求1所述的系统,其中,所述便携式通信装置包括一个或多个天线,并且所述便携式通信装置被配置为:

使用所述一个或多个天线将所述数据输出到所述通信网络;以及

基于所述一个或多个天线所接收到的射频信号来确定所述雷击与所述便携式通信装置之间的距离。

3. 根据权利要求2所述的系统,其中,所述便携式通信装置被配置为通过使用所述一个或多个天线监测射频电磁信号来确定所述雷击与所述便携式通信装置之间的距离。

4. 根据权利要求2所述的系统,其中,所述一个或多个天线包括两个天线,并且所述便携式通信装置被配置为通过监测所述两个天线所接收到的两个信号之间的相位差来确定所述雷击与所述便携式通信装置之间的距离。

5. 根据权利要求1所述的系统,其中,所述便携式通信装置包括显示器和接近传感器,并且所述便携式通信装置被配置为:

在所述接近传感器确定为所述便携式通信装置处于对象的预定距离以内的情况下,去激活所述显示器;以及

基于所述接近传感器的输出来确定所述雷击与所述便携式通信装置之间的距离。

6. 根据权利要求1所述的系统,其中,所述便携式通信装置包括显示器和环境光传感器,并且所述便携式通信装置被配置为:

基于所述环境光传感器的输出来调整所述显示器的亮度;以及

基于所述环境光传感器的输出来确定所述雷击与所述便携式通信装置之间的距离。

7. 根据权利要求1所述的系统,其中,所述便携式通信装置包括照相机,并且所述便携式通信装置被配置为:

基于所述照相机的输出来获取静止图像和/或运动影片;以及

基于所述照相机的输出来确定所述雷击与所述便携式通信装置之间的距离。

7. 根据权利要求1所述的系统,其中,所述便携式通信装置包括触摸板,并且所述便携式通信装置被配置为基于所述触摸板所监测到的电场的变化来确定所述雷击与所述便携式通信装置之间的距离。

9. 根据权利要求8所述的系统,其中,所述触摸板是包括多个导电迹线的电容式触摸板,并且所述便携式通信装置被配置为:

驱动两个或多个所述导电迹线;以及

基于两个或多个所述导电迹线的自电容来确定所述雷击与所述便携式通信装置之间的距离。

10. 根据权利要求8所述的系统, 其中, 所述触摸板是包括多个导电迹线的电容式触摸板, 多个所述导电迹线包括多个导电行和多个导电列, 并且所述便携式通信装置被配置为: 依次驱动所述导电列或所述导电行; 以及

基于所述导电列与所述导电行之间的交互电容来确定所述雷击与所述便携式通信装置之间的距离。

11. 根据权利要求8所述的系统, 其中, 所述触摸板是包括多个导电迹线的电容式触摸板, 多个所述导电迹线包括多个导电行和多个导电列, 并且所述便携式通信装置被配置为: 驱动两个或多个所述导电迹线;

基于两个或多个所述导电迹线的自电容来确定所述雷击与所述便携式通信装置之间的距离;

基于多个所述导电迹线的自电容来确定一个或多个手指或导电触针是否接近所述触摸板;

响应于确定为一个或多个手指或导电触针接近所述触摸板而依次驱动所述导电列或所述导电行; 以及

基于所述导电列与所述导电行之间的交互电容来确定一个或多个手指或导电触针的位置。

12. 一种便携式通信装置, 包括:

位置监测单元, 被配置为确定所述便携式通信装置的位置;

闪电监测单元, 被配置为监测雷击并确定所述雷击与所述便携式通信装置之间的距离; 以及

射频电路, 被配置为经由通信网络输出表示所述便携式通信装置的位置以及所述雷击与所述便携式通信装置之间的距离的数据。

13. 根据权利要求12所述的便携式通信装置, 其中, 所述射频电路包括一个或多个天线, 并且所述便携式通信装置被配置为基于所述一个或多个天线所接收到的射频信号来确定所述雷击与所述便携式通信装置之间的距离。

14. 根据权利要求13所述的便携式通信装置, 其中, 所述便携式通信装置被配置为通过使用所述一个或多个天线监测射频电磁信号来确定所述雷击与所述便携式通信装置之间的距离。

15. 根据权利要求13所述的便携式通信装置, 其中, 所述一个或多个天线包括两个天线, 并且所述便携式通信装置被配置为通过监测所述两个天线所接收到的两个信号之间的相位差来确定所述雷击与所述便携式通信装置之间的距离。

16. 根据权利要求12所述的便携式通信装置, 其中, 所述便携式通信装置还包括显示器和接近传感器, 以及所述便携式通信装置被配置为:

在所述接近传感器确定为所述便携式通信装置处于对象的预定距离以内的情况下, 去激活所述显示器; 以及

基于所述接近传感器的输出来确定所述雷击与所述便携式通信装置之间的距离。

17. 根据权利要求12所述的便携式通信装置, 其中, 所述便携式通信装置还包括显示器和环境光传感器, 以及所述便携式通信装置被配置为:

基于所述环境光传感器的输出来调整所述显示器的亮度; 以及

基于所述环境光传感器的输出来确定所述雷击与所述便携式通信装置之间的距离。

18. 根据权利要求12所述的便携式通信装置, 其中, 所述便携式通信装置还包括照相机, 以及所述便携式通信装置被配置为:

基于所述照相机的输出来获取静止图像和/或运动影片; 以及

基于所述照相机的输出来确定所述雷击与所述便携式通信装置之间的距离。

19. 根据权利要求12所述的便携式通信装置, 其中, 所述便携式通信装置还包括触摸板, 以及所述便携式通信装置被配置为基于所述触摸板所监测到的电场的变化来确定所述雷击与所述便携式通信装置之间的距离。

20. 根据权利要求19所述的便携式通信装置, 其中, 所述触摸板是包括多个导电迹线的电容式触摸板, 并且所述便携式通信装置被配置为:

驱动两个或多个所述导电迹线; 以及

基于两个或多个所述导电迹线的自电容来确定所述雷击与所述便携式通信装置之间的距离。

21. 根据权利要求19所述的便携式通信装置, 其中, 所述触摸板是包括多个导电行和多个导电列的电容式触摸板, 并且所述便携式通信装置被配置为:

依次驱动所述导电列或所述导电行; 以及

基于所述导电列与所述导电行之间的交互电容来确定所述雷击与所述便携式通信装置之间的距离。

22. 根据权利要求19所述的便携式通信装置, 其中, 所述触摸板是包括多个导电迹线的电容式触摸板, 多个所述导电迹线包括多个导电行和多个导电列, 并且所述便携式通信装置被配置为:

驱动两个或多个所述导电迹线;

基于两个或多个所述导电迹线的自电容来确定所述雷击与所述便携式通信装置之间的距离;

基于多个所述导电迹线的自电容来确定一个或多个手指或导电触针是否接近所述触摸板;

响应于确定为一个或多个手指或导电触针接近所述触摸板而依次驱动所述导电列或所述导电行; 以及

基于所述导电列与所述导电行之间的交互电容来确定一个或多个手指或导电触针的位置。

闪电监测系统、方法和装置

背景技术

[0001] 闪电是云内的带电区域之间或者云与行星的表面之间的静电放电。存在四种基本类型的闪电：云内闪电；云间闪电；云空闪电；以及云地闪电。云间闪电普遍发生在雷雨的开始时。气象局使用闪电监测系统与天气雷达结合来定位并追踪雷雨。

[0002] 存在三种基本类型的闪电监测系统：使用多个监测器的基于地的系统；移动监测系统（通常在航空器上）；以及基于空间的系统。每种闪电监测系统都具有它们自身的局限性。由于移动监测系统利用衰减而非三角测量来确定闪电位置，因此移动监测系统可能难以辨别是弱的雷击在靠近还是强的雷击在远去。由于基于空间的闪电监测系统与移动监测系统或基于地的系统相比花费更多的时间去传播信息，因此来自基于空间的闪电监测系统的信息对于诸如空中导航的实时应用程序来说价值有限。

[0003] 诸如美国国家气象局等的气象局使用基于地的闪电监测系统，这些基于地的闪电监测系统使用来自多个位置的多个监测器的三角测量来确定雷击的位置。例如，国家雷电监测网（NLDN）包括贯穿美国大陆而分布的大约100个基于地的监测器。这些监测器感测雷击的电磁信号，并且经由卫星将数据发送至美国亚利桑那州的图森的中央处理位置，该中央处理位置通过对三个或更多个信号进行三角测量来估计雷击的位置。

[0004] 传统的基于地的闪电监测系统也存在一些缺陷。最显著的缺陷是由于有限数量的基于地的监测器而引起精度不够。由于基于地的闪电监测器之间相隔可能数百英里，因此即使最先进的基于地的闪电监测系统的精度也是受限制的。

[0005] 由于可能是一个监测器监测发起云上的闪电的位置而另一个监测器监测接收云上的闪电的位置，因此利用传统的基于地的监测系统来监测云间闪电尤其困难。为了在可接受的误差范围内监测并定位云间闪电，基于地的闪电监测系统在监测范围内需要至少三个监测器。由于基于地的闪电监测器的数量受限，因此传统的基于地的闪电监测系统低估云间闪电。在监测云空闪电的情况下，传统的基于地的闪电监测器也具有类似的缺陷。

[0006] 可以通过增加基于地的监测器的数量来提高传统的基于地的闪电监测网络的精度。然而，每次制造、部署以及维护基于地的监测器时，网络的成本都增加。因此，需要提高闪电监测网络的精度的同时降低基于地的监测器的制造、部署和维护的成本。

发明内容

[0007] 为了克服现有技术中的这些缺陷和其它缺陷，提供示例性实施例的多个方面。

[0008] 根据示例性实施例的一个方面，提供一种系统，包括：闪电监测数据库；以及分析单元，被配置为：经由通信网络从便携式通信装置接收表示所述便携式通信装置的位置以及雷击与所述便携式通信装置之间的距离的数据；部分地基于所述便携式通信装置的位置以及所述雷击与所述便携式通信装置之间的距离来确定所述雷击的位置；以及将所述雷击的位置存储到所述闪电监测数据库中。

[0009] 根据示例性实施例的另一个方面，提供一种便携式通信装置，包括：位置监测单元，被配置为确定所述便携式通信装置的位置；闪电监测单元，被配置为监测雷击并确定所

述雷击与所述便携式通信装置之间的距离；以及射频电路，被配置为经由通信网络输出表示所述便携式通信装置的位置以及所述雷击与所述便携式通信装置之间的距离的数据。

[0010] 根据示例性实施例的另一个方面，提供一种闪电监测方法，其包括：经由通信网络从便携式通信装置接收表示所述便携式通信装置的位置以及雷击与所述便携式通信装置之间的距离的数据；部分地基于所述便携式通信装置的位置以及所述雷击与所述便携式通信装置之间的距离来确定所述雷击的位置；以及将所述雷击的位置存储到闪电监测数据库中。

附图说明

[0011] 通过参考附图可以更好地理解示例性实施例的各方面。附图中的组件不一定按比例，而是重点在于示出示例性实施例的原理。

[0012] 图1是示出传统的基于地的闪电监测系统的自上而下视图。

[0013] 图2A是根据本发明的示例性实施例的基于地的闪电监测系统的自上而下视图。

[0014] 图2B是图1所示的传统的基于地的闪电监测系统的侧视图。

[0015] 图2C是图2A所示的基于地的闪电监测系统的侧视图。

[0016] 图3是根据本发明的示例性实施例的通信装置的概要图。

[0017] 图4A是根据本发明的示例性实施例的通信装置的电场监测器的概要图。

[0018] 图4B是示出使用根据本发明的示例性实施例的图4A所示的电场监测器的触摸感测和电场监测的方法的流程图。

[0019] 图5是根据本发明的示例性实施例的图2A所示的闪电监测系统的另一概要图。

具体实施方式

[0020] 现在将参照附图来详细说明本发明的示例性实施例，在这些附图中，相同的附图标记代表相同的元素或步骤。

[0021] 图1是传统的基于地的闪电监测系统100的自上而下视图。如图1所示，基于地的闪电监测系统100包括基于地的闪电监测器101、102和103。监测器101、102和103被配置为监测雷击110，估计各个监测器与雷击110之间的距离，以及将该距离通信至中央处理器（未图示），其中该中央处理器被配置为通过对雷击110的位置和已知的基于地的监测器的位置进行三角测量来估计雷击110的位置。

[0022] 响应于云地雷击110，闪电监测器101估计从监测器101到雷击110的距离131，并且闪电监测器102估计从监测器102到雷击110的距离132。如果雷击在第三个闪电监测器的可监测范围内，则传统的闪电监测系统100仅可以区分位置110处的雷击和位置110'处的雷击。在本示例中，由于闪电监测器103位于估计从监测器103到雷击110的距离133的范围内，因此传统的闪电监测系统100仅能够确定雷击110的位置。

[0023] 图2A是根据本发明的示例性实施例的基于地的闪电监测系统200的自上而下视图。如图2A所示，闪电监测系统200包括遍布在地球上的多个位置处的多个闪电监测器210。由于闪电监测器210的数量大于传统的闪电监测器101~103的数量，因此闪电监测系统200的精度和可靠度显著大于传统的闪电监测系统100的精度和可靠度。在图2A所示的示例中，闪电监测系统200包括闪电监测器210a、210b和210c，并且无论传统的闪电监测器103是否

位于监测雷击110的范围之内,均可以确定雷击110的位置。

[0024] 与传统的闪电监测系统100相比,闪电监测系统200还具有增大的垂直范围。图2B是传统的闪电监测系统100的侧视图。简便起见,示出了两个传统的基于地的闪电监测器101和102。但是,相同的分析适用于需要用于三角测量的至少三个监测器的系统。如图2B所示,传统的基于地的闪电监测器101和102各自具有范围R。各个范围R的重叠使得传统的闪电监测系统100具有有效的垂直范围 H_{100} 。

[0025] 图2C是包括闪电监测器210a和210b的闪电监测系统200的侧视图。在假定闪电监测器210a和210b与传统的基于地的闪电监测器101和102具有相同的范围R的情况下,闪电监测器210a和210b的接近使得闪电监测系统200具有比传统的闪电监测系统100的有效垂直范围 H_{100} 大的有效垂直范围 H_{200} 。

[0026] 闪电监测系统200可以与传统的闪电监测系统100相结合。例如,各个闪电监测器210可以将闪电监测器210与雷击110之间的距离输出至传统的闪电监测系统100所使用的同一中央处理器。通过将传统的基于地的闪电监测器101、102和103所进行的监测与多个闪电监测器210所进行的监测相结合,闪电监测系统200的精度显著大于传统的闪电监测系统100的精度。还可以将基于地的闪电监测系统200与一个或多个移动闪电监测系统和/或基于空间的闪电监测系统相结合,以进一步提高闪电监测的可靠度和精度。

[0027] 如上所述,在每次制造、部署和维护基于地的监测器101~103时,传统的基于地的闪电监测系统100的成本增加。然而,如下文所述,通过将闪电监测器210并入便携式通信装置300,基于地的闪电监测系统200降低或消除了附加的成本。除了提高闪电监测系统200的精度,将闪电监测器210并入便携式通信装置300,这使得将部署和维护闪电监测器210的成本从维护闪电监测系统200的人转移到购买和维护便携式通信装置300的人身上。

[0028] 图3是根据本发明的示例性实施例的便携式通信装置300的概要图。如图3所示,便携式通信装置300可以包括存储器310、一个或多个处理器320、输入/输出子系统330、一个或多个输出装置340、一个或多个输入装置360、射频(RF)电路370、一个或多个传感器380以及电力系统390。

[0029] 存储器310可以包括一个或多个计算机可读存储介质。例如,存储器310可以包括高速随机存取存储器以及/或者诸如一个或多个磁盘存储装置、闪存装置和/或其它非易失性固态存储器等的非易失性存储器。

[0030] 便携式通信装置300包括位置监测模块312。位置监测模块312可以是被配置为确定或估计通信装置310的位置的任何合适的装置。如图3所示,位置监测模块312可以被实现为存储器310中所存储的由一个或多个处理器320执行的指令集。作为选择,位置监测模块312可以通过硬件或者硬件和计算机可读指令的组合来实现。位置监测模块312可以通过任何合适的部件来确定或估计通信装置310的位置,这些合适的部件包括全球定位系统(GPS)、辅助GPS(A-GPS)、基于Wi-Fi的定位系统、基于蜂窝网络的定位等。

[0031] 一个或多个处理器320可以包括中央处理单元(CPU) 322、一个或多个控制器324、以及/或者一个或多个外围控制器326等。处理器320可以集成到单个半导体芯片中或者可以由多于一个的芯片来实现。一个或多个处理器320可以执行存储器310中所存储的各种软件程序和/或指令集,以处理数据和/或针对装置300执行各种功能。

[0032] 输入/输出子系统330将装置300上的诸如输出装置340、输入装置360和传感器380

等的输入/输出外围设备连接至外围控制器326。输入/输出子系统330可以包括一个或多个输出控制器334、一个或多个输入控制器336、以及/或者一个或多个传感器控制器338等。一个或多个输出控制器334相对于输出装置340发送/接收电信号。一个或多个输入控制器334相对于输入装置360接收/发送电信号。一个或多个传感器控制器338相对于输入装置380接收/发送电信号。

[0033] 一个或多个输出装置可以包括显示器342、扬声器344、一个或多个外部端口等。显示器342可以是被配置为输出可见光的任何合适的装置，例如液晶显示器 (LCD)、发光聚合物显示器 (LPD)、发光二极管 (LED)、有机发光二极管 (OLED) 等。

[0034] 一个或多个输入装置360可以包括键盘362、鼠标 (或轨迹球) 364、静态或视频照相机366、触摸板368等。触摸板368可以包括任何合适的技术来确定手指或触针相对于装置300的位置。如下文所述，触摸板368可以包括电阻式触摸传感器、自电容式触摸传感器、交互电容式触摸传感器等。触摸板368可以被显示器342覆盖或者与显示器342集成，以形成触感显示器或触摸屏。

[0035] RF电路370可以是被配置为发送和/或接收RF信号的任何合适的装置。RF电路370可以包括天线系统371、RF收发器、一个或多个放大器、调谐器、一个或多个振荡器、数字信号处理器、CODEC芯片组、用户身份识别模块 (SIM) 卡、存储器等。RF电路370可以经由电磁信号与其它通信装置或诸如因特网、内联网和/或无线网络 (例如蜂窝电话网络、无线局域网 (LAN)、以及无线通信所利用的其它装置等) 的通信网络进行通信。无线通信可以使用多个通信标准、协议和技术中的任何一种，其包括全球移动通信系统 (GSM)、增强的数据GSM环境 (EDGE)、高速下行分组接入 (HSDPA)、宽带码分多址 (W-CDMA)、码分多址 (CDMA)、时分多址 (TDMA)、蓝牙、无线保真 (Wi-Fi) (例如IEEE 802.11)、互联网协议电话 (VoIP)、Wi-MAX、或者包括尚未开发的通信协议的任何其它合适的通信协议。

[0036] 电力系统390可以是被配置为向装置300的元件分配电力的任何合适的装置。电力系统390可以包括一个或多个电源 (例如，电池、交流电 (AC) 等)、电力转换系统、电力管理系统、再充电系统、电力故障监测电路、电力转换器或换流器、电力状态指示器 (例如，发光二极管 (LED)) 以及与在电子装置中生成、管理和分配电力相关联的任何其它元件。

[0037] 一个或多个传感器380可以包括接近传感器382、环境光传感器384、加速计386和陀螺仪等。接近传感器382可以是被配置为监测便携式通信装置300是否处于对象的预定距离以内的任何合适的装置。例如，当接近传感器382确定为在电话通话期间装置300位于用户的面部附近或者装置300的盖被关闭时，便携式通信装置300可以被配置为去激活 (deactivate) 显示器342和/或触摸板368。环境光传感器384可以是被配置为确定环境光的量的任何合适的装置。例如，便携式通信装置300可以被配置为基于环境光传感器所监测到的环境光的量来调整显示器342的亮度。

[0038] 图3所示的便携式通信装置300是被配置为向移动电话网络发送数据的电子装置 (即，“智能手机”)。但是，应当理解，图3所示的便携式通信装置300仅仅是便携式通信装置的一个示例，并且装置300可以具有与示出的示例相比更多或更少的元件、可以组合两个或更多个元件、或者可以具有元件的不同结构或配置。在本发明的示例性实施例中，便携式通信装置300可以是被配置为监测闪电、与一个或多个网络510通信、以及进行与闪电监测不相关的至少一个其它功能的任何合适的电子装置。便携式通信装置300可以是例如连接网

络的计算装置(例如个人数字助理(PDA)、平板、笔记本电脑、便携式天气监测器、GPS接收器等)或者连接网络的交通工具(例如汽车、轮船、飞机、卫星车等)。

[0039] 在其它示例性实施例中,一个或多个闪电监测器210可以并入诸如连接网络的计算机、家电、住宅、办公楼或其它结构等的非便携式通信装置中。非便携式通信装置可以确定自身的位置以及/或者将自身的位置发送给闪电监测系统200。作为选择,非便携式通信装置的位置对于闪电监测系统200来说可以是已知的。

[0040] 便携式通信装置300包括一个或多个闪电监测器210。图3所示的各种元件可以以硬件、软件、或者硬件和软件两者的结合的方式来实现,包括一个或多个信号处理和/或专用集成电路。

[0041] 一个或多个闪电监测器210可以是被配置为监测闪电的任何合适的装置。闪电监测器210可以监测到在便携式通信装置300的位置附近发生了雷击110以及/或者可以确定或估计从便携式通信装置300的位置到雷击110的距离或方向。

[0042] 在一些示例性实施例中,可以通过添加专门被配置为监测雷击110的附加硬件来将一个或多个闪电监测器210并入便携式通信装置300中。在其它更优选的示例性实施例中,使用便携式通信装置300中的用于执行与闪电监测无关的其它功能的一个或多个硬件元件来实现一个或多个闪电监测器210。使用执行与闪电监测无关的其它功能的一个或多个硬件元件进一步降低了制造、部署以及维护闪电监测器310的成本。

[0043] 根据一个示例性实施例,一个或多个闪电监测器210可以包括射频(RF)闪电监测器。RF闪电监测器可以是被配置为监测闪电所生成的RF电磁信号的任何合适的装置。RF闪电监测器还可以基于例如所监测到的能量放电的大小来确定或估计便携式通信装置300与雷击110之间的距离。RF闪电监测器可以被实现为并入便携式通信装置300的用于监测闪电所生成的RF电磁信号的附加硬件。然而,更优选地,RF闪电监测器可以利用RF电路370的天线系统371来监测闪电所生成的RF电磁信号。在该更优选的实施例中,天线系统371还可以被RF电路370用来发送和/或接收RF信号(如上所述)。

[0044] 根据另一示例性实施例,一个或多个闪电监测器210可以包括干涉仪。干涉仪可以是被配置为测量两个或更多个传感器所接收到的(窄带或宽带)信号之间的相位差的任何合适的装置。例如,干涉仪可以是两个间隔紧密的天线,各个天线经由窄带滤波器连接至相位监测器,该相位监测器用于输出与天线所接收到的两个信号之间的相位差成比例的电压。在该示例中,相位差可以用来识别所监测到的雷击110在与两个天线的平面垂直的平面上的方向。干涉仪还可以基于例如两个或更多个传感器所接收到的信号的大小来确定或估计便携式通信装置300与雷击110之间的距离。干涉仪可以被实现为并入便携式通信装置300中的用于监测闪电所生成的两个信号的附加硬件。然而,更优选地,干涉仪可以利用RF电路370的天线系统371来监测闪电所生成的两个信号。在该更优选的实施例中,天线系统371还可以被RF电路370用来发送和/或接收RF信号(如上所述)。

[0045] 根据另一示例性实施例,一个或多个闪电监测器210可以包括光学监视器。光学监视器可以是被配置为监测云地闪电或云间闪电所产生的光脉冲的任何合适的装置。在一些示例中,云间闪电在云地闪电之前。光学监视器还可以基于例如光学监视器所监测到的光脉冲的大小来确定或估计便携式通信装置300与雷击110之间的距离。光学监视器可以被实现为并入便携式通信装置300中的用于监测闪电所产生的光脉冲的附加硬件。然而,更优选

地,光学监视器可以利用便携式通信装置300的硬件元件(例如接近传感器382和/或照相机366等)来监测光脉冲。在该更优选的实施例中,用于监测闪电所生成的光脉冲的硬件元件还可以被便携式通信装置300用来执行其它功能(如上所述)。

[0046] 根据另一示例性实施例,一个或多个闪电监测器210可以包括电场监视器。电场监视器可以是配置为测量电场的变化(例如,在雷击110附近发生的地球电场的电势梯度(电压)的变化)的任何合适的装置。电场监视器还可以基于例如电场监视器所监测到的电场的变化的大小来确定或估计便携式通信装置300与雷击110之间的距离。电场监视器可以被实现为并入便携式通信装置300中的硬件(例如,电场仪)。然而,更优选地,大气电场监视器可以利用触摸板368(如以下参照图4A和图4B所述)来监测雷击110附近发生的电场的变化。

[0047] 如本领域技术人员会意识到的,一个或多个闪电监测器可以包括多于一种类型的闪电监测器。在一个示例中,一个或多个闪电监测器210可以包括RF闪电监测器和光学监视器。RF闪电监测器可以感测RF干涉并且将RF噪声误认为监测到附近的雷击110。在这种情况下,闪电监测器210可以被配置为仅在RF闪电监测器和光学监视器都监测到闪电的情况下才输出闪电监测信号。多于一个的闪电监测器还可以用于基于例如光学监视器监测到光学脉冲与RF闪电监测器监测到RF电磁信号之间的时间量来确定或估计便携式通信装置300与雷击110之间的距离。

[0048] 闪电监测器210可以包括存储在存储器310中并且由一个或多个处理器320执行的软件指令。不管闪电监测器210是否使用便携式通信装置300中的用于执行与闪电监测无关的其它功能的硬件元件(例如,天线系统371、触摸板368等,如上文所述),闪电监测器210还可以包括(例如,用以对闪电所生成的并且被闪电监测器210所监测到的信号进行滤波或处理的)附加硬件,这些附加硬件可以是专门被配置为监测雷击110的附加硬件或者是便携式通信装置300的用于执行与闪电监测不相关的附加功能的硬件元件。

[0049] 图4A是根据本发明的示例性实施例的通信装置的电场监测器400的概要图。如上文参照图3所述,便携式通信装置300包括存储器310、一个或多个处理器320、输入/输出子系统330和触摸板368。触摸板368包括驱动信号生成器467、监测单元469、列迹线C1、C2、C3等、以及行迹线R1、R2、R3等。触摸板可以被显示器342覆盖或者与显示器342集成,以形成触感显示器或触摸屏。

[0050] 根据一个示例性实施例,触摸板368是交互电容式触摸传感器。交互电容式触摸传感器板包括位于列迹线(例如,C1、C2等)与行迹线(例如,R1、R2等)的各交叉点处的电容。对列或行施加电压。当手指或导电触针位于表面附近时,手指或触针改变本地电场,这减小了交互电容。可以通过测量另一个轴上的电压来测量网格上的每一点处的电容变化,以精确地确定触摸位置。例如,如果对列C1、C2等施加电压,则可以通过测量各个行R1、R2等中的电压来测量电容变化。由于交互电容式触摸传感器能够同时精确地追踪多个手指或触针,因此通常来说,交互电容式触摸传感器优于自电容式触摸传感器。

[0051] 根据另一示例性实施例,触摸板368是自电容式触摸传感器。自电容式触摸传感器具有与交互电容式传感器相同的由列和行构成的网格,但是列和行是独立工作的。利用自电容,电流感测手指或触针施加在各个列或各个行上的电容负荷。自电容式触摸传感器无法精确地解决多于一个的同时触摸。然而,自电容式触摸传感器比交互电容式触摸传感器

产生更强的信号。

[0052] 根据另一示例性实施例,触摸板368具有自电容式触摸感测能力和交互电容式触摸感测能力两者。由于具有自电容式触摸感测能力和交互电容式触摸感测能力这两者,因此触摸板368可以包括如下两个模式:触摸板368使用自电容式触摸感测来更精确地监测电场的变化的电场监测模式;以及触摸板368使用交互电容式触摸感测能力来监测多于一个的同时触摸的触摸感测模式。

[0053] 图4B是示出使用图4A所示的电场监测器400进行触摸感测和电场监测的示例方法的流程图。参照图4B,触摸板368的默认状态是电场监测模式。在电场监测模式中,在操作S401中,驱动信号生成器467驱动多个导电迹线,并且在操作S403中,监测单元469测量自电容。由于自电容式感测与交互电容式感测相比产生更强的信号,因此处于电场监测模式的触摸板368能够更精确地监测便携式通信装置300附近的雷击110所引起的地球电场的变化。通过测量多个导电迹线的自电容,触摸板368还能够确定手指或触针是否正在触摸或靠近触摸板368。

[0054] 如图4B所示,触摸板368重复地在操作S405中确定手指或触针是否正在触摸触摸板368。如果手指或触针没有正在触摸触摸板368,则触摸板368通过重复操作S401和S403来继续处于电场监测模式。如果手指或触针正在触摸触摸板368,则触摸板368进入触摸感测模式。

[0055] 在触摸感测模式中,在操作S451中,驱动信号生成器467一次驱动一个导电迹线(例如,列迹线C1),并且在操作S453中,监测单元469测量沿着另一个轴的一个导电迹线(在本示例中为行迹线R1、R2等)上的交互电容。由于交互电容式传感器能够解决多于一个的触摸,因此触摸板368在处于触摸感测模式时提供多触摸能力。当触摸板368处于触摸感测模式时,触摸板368重复地在操作S405中确定手指或触针是否正在触摸触摸板368。如果触摸板368继续被手指或触针触摸,则触摸板368继续处于触摸感测模式。否则,触摸板368返回到电场监测模式。

[0056] 图5是根据本发明的示例性实施例的闪电监测系统200的另一概要图。如图5所示,闪电监测系统200包括分析单元500、一个或多个通信网络510、闪电监测数据库590、以及一个或多个便携式通信装置300a~300n。

[0057] 分析单元500可以是被配置为通过一个或多个通信网络510从一个或多个便携式通信装置300a~300n接收数据的任何合适的计算装置(例如,服务器)。分析单元500还可以从基于空间的闪电监测系统520和/或一个或多个移动闪电监测器530和/或一个或多个传统的基于地的闪电监测器101~103接收数据。

[0058] 一个或多个通信网络500可以包括因特网、内联网和/或诸如蜂窝电话网络、无线局域网(LAN)等的无线网络。无线通信可以使用上文中针对RF电路370所述的多个通信标准、协议和技术中的任何一个。一些或全部便携式通信装置300a~300n可以经由RF电路370a~370n与一个或多个通信网络500通信。作为选择,一些或全部个人通信装置300a~300n可以经由诸如以太网、通用串行总线(USB)等的有线连接与一个或多个通信网络510通信。

[0059] 根据示例性实施例的方面,分析单元500被配置为经由一个或多个通信网络510从一个或多个便携式通信装置300a~300n接收如下数据:(例如,一个或多个闪电监测器210a

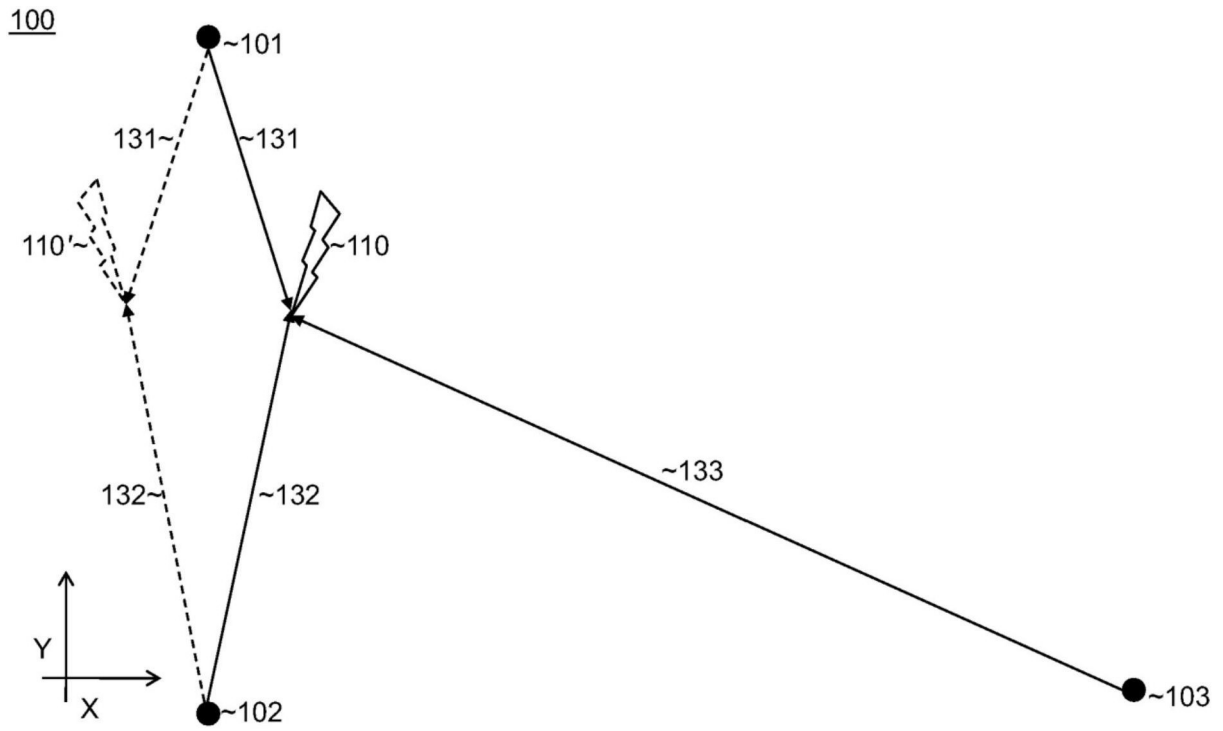
~210n所监测到的)表示雷击110的数据;(例如,位置监测模块312a~312n所确定的)表示便携式通信装置300a的位置的数据;以及(例如,一个或多个闪电监测器210a~210n所确定的)表示一个或多个便携式通信装置300a~300n与雷击110之间的各个距离的数据。类似地,分析单元500可以从一个或多个传统的基于地的闪电监测器101~103或移动闪电监测器530接收如下数据:表示雷击110的数据;表示监测器101~103或530的位置的数据;以及表示监测器101~103或530与雷击110之间的距离的数据。

[0060] 分析单元500还可以发送和/或接收天气数据或天气预报数据。例如,分析单元500可以(直接或经由通信网络510)从天气数据库540接收天气数据或天气预报数据。分析单元500还可以被配置为向通信网络510输出表示雷击110的数据(例如,一个或多个雷击110的时间和/或位置)和/或天气数据和/或天气预报数据,以用于传送至一个或多个便携式通信装置300a~300n。分析单元500还可以经由通信网络510将表示雷击110的数据输出/发送至不包括闪电监测器210的一个或多个通信装置。在一个示例中,分析单元500可以被配置为向便携式通信装置300输出地图和地图上对雷击110的位置的指示。在另一示例中,分析单元可以接收便携式通信装置300的位置,并且可以在雷击110处于便携式通信装置300的位置的预定距离以内的情况下输出表示雷击110的数据。可以将表示便携式通信装置300的位置的数据存储在通信装置位置数据库550中。分析单元500可以直接或经由通信网络510从通信装置位置数据库550接收表示通信装置的位置的数据。

[0061] 闪电监测系统200的分析单元500被配置为通过对雷击110与三个或更多个监测器210a~210c或101~103(见图2A)之间的距离进行三角测量来确定雷击110的位置,并将雷击110的位置存储到闪电监测数据库590中。

[0062] 如上文所述,与传统的基于地的闪电监测系统100相比,闪电监测系统200通过增加闪电监测器210的数量,以提高的可靠度和精度来监测雷击110的位置。闪电监测系统200通过将闪电监测器210并入便携式通信装置300以及/或者使用便携式通信装置300中已并入的硬件进行以下操作来降低制造、部署和维护附加的闪电监测器210的成本,该操作包括:监测或估计便携式通信装置300的位置;监测或估计便携式通信装置300与雷击110之间的距离;以及将表示便携式通信装置300的位置和便携式通信装置300与雷击110之间的距离的数据经由一个或多个通信网络510通信至分析单元500。

[0063] 尽管上文描述了优选实施例,但是阅览了本公开的本领域技术人员能够容易理解在本发明的范围内能够实现其它实施例。例如,特定数量的硬件元件、软件模块等的公开仅仅是示例性的而非限制性的。因此,本发明应当被解释为仅受所附权利要求的限制。



(现有技术)

图1

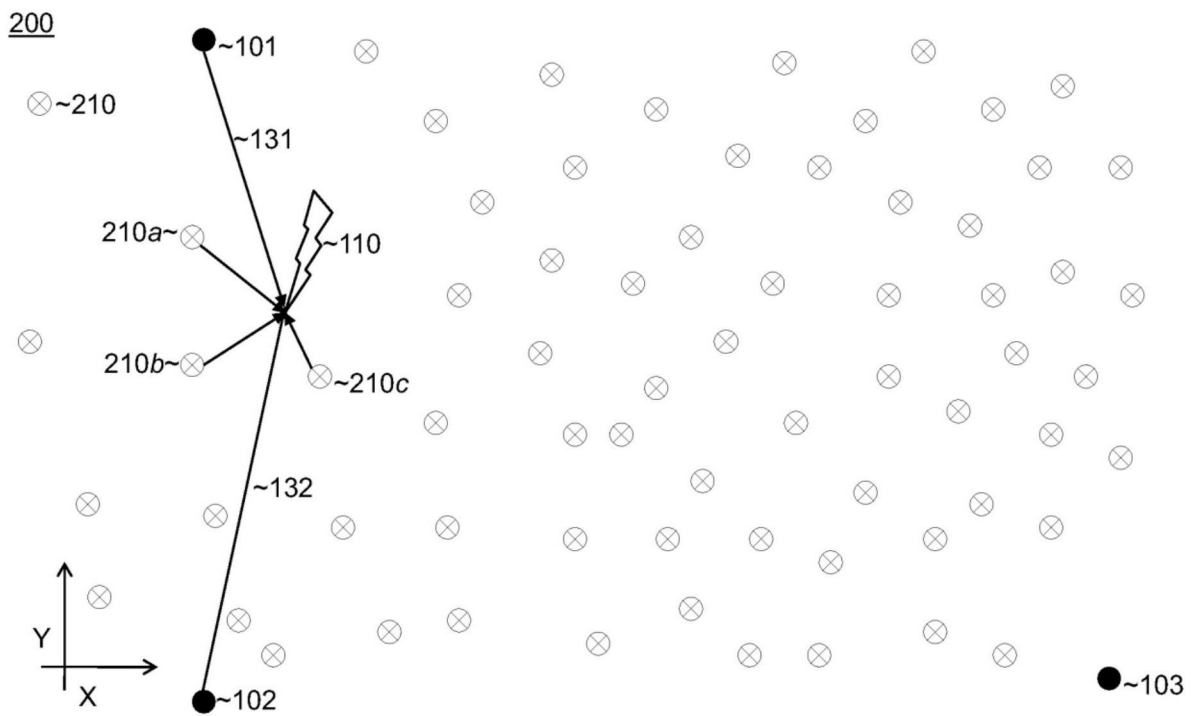
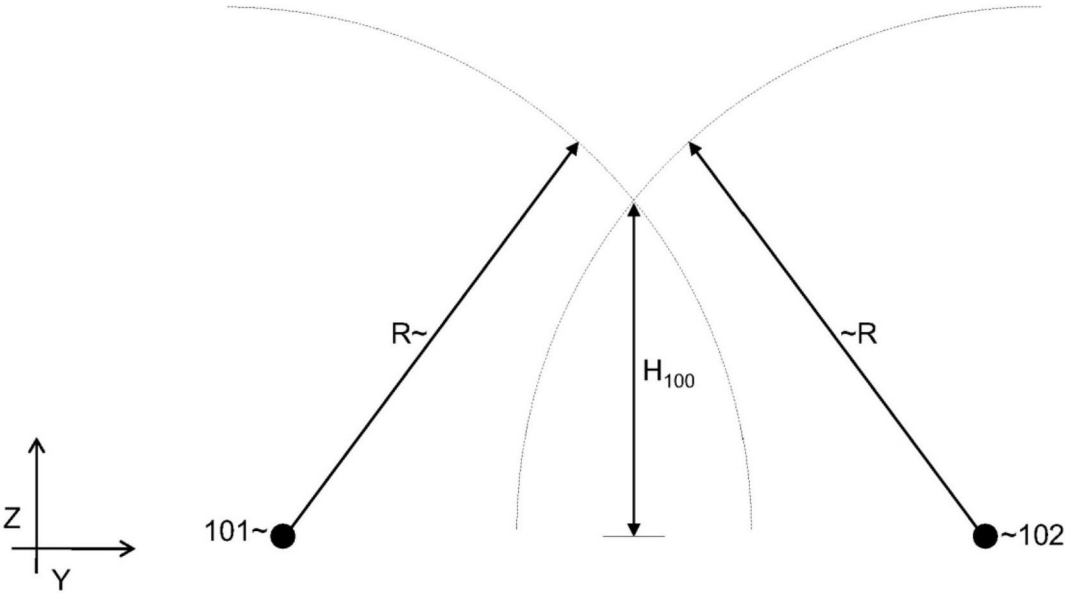


图2A

100



(现有技术)

图2B

200

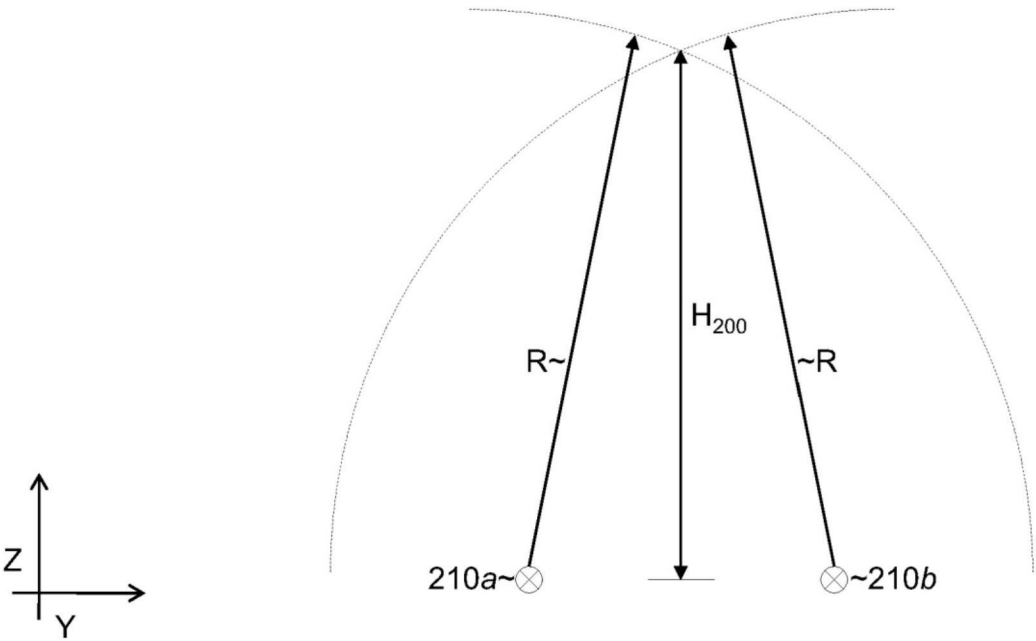


图2C

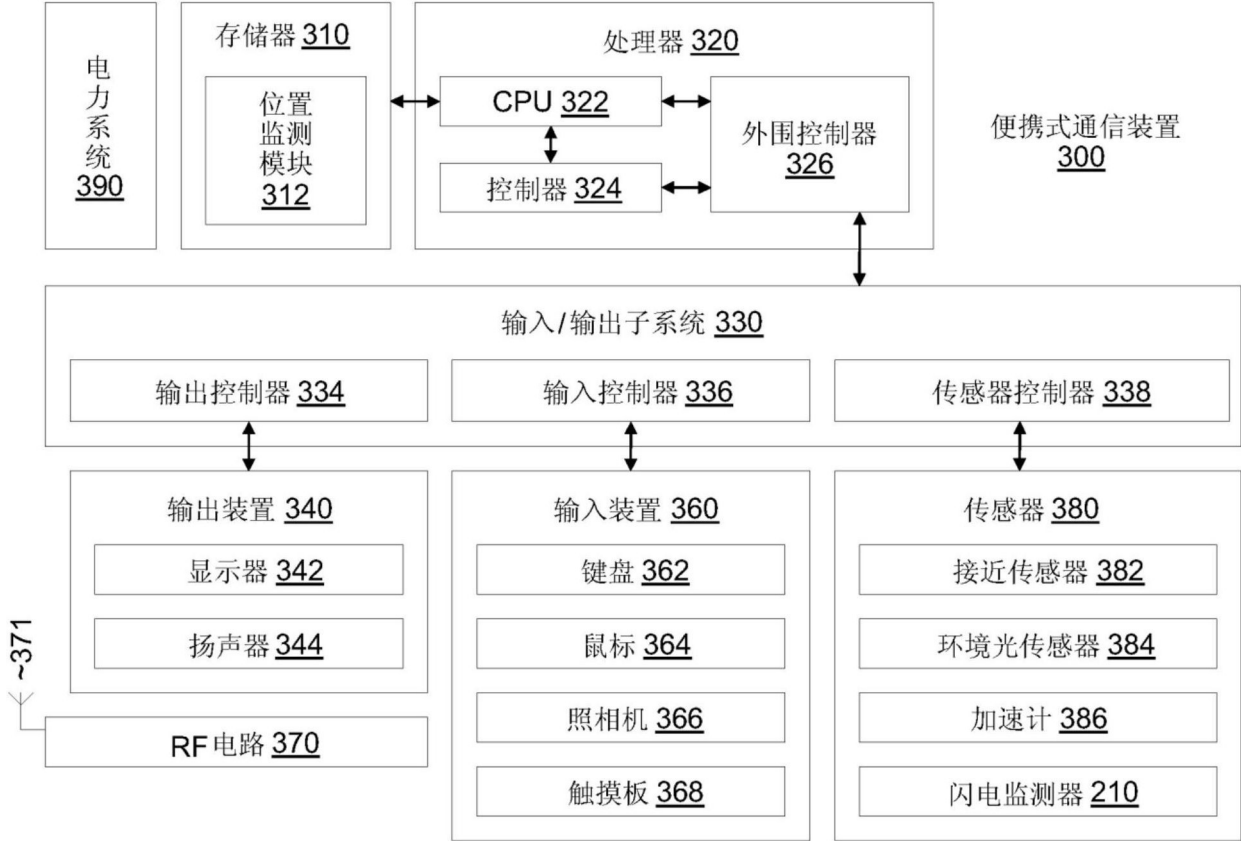


图3

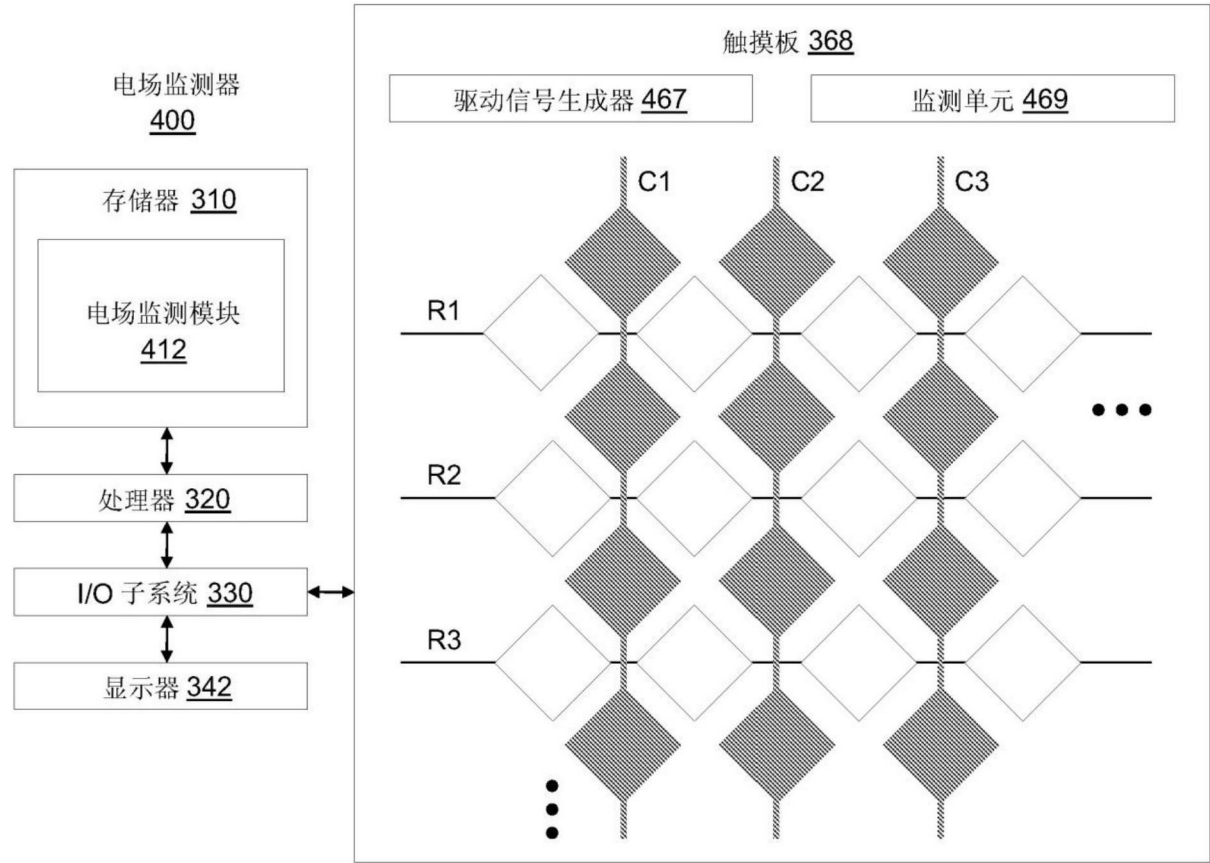


图4A

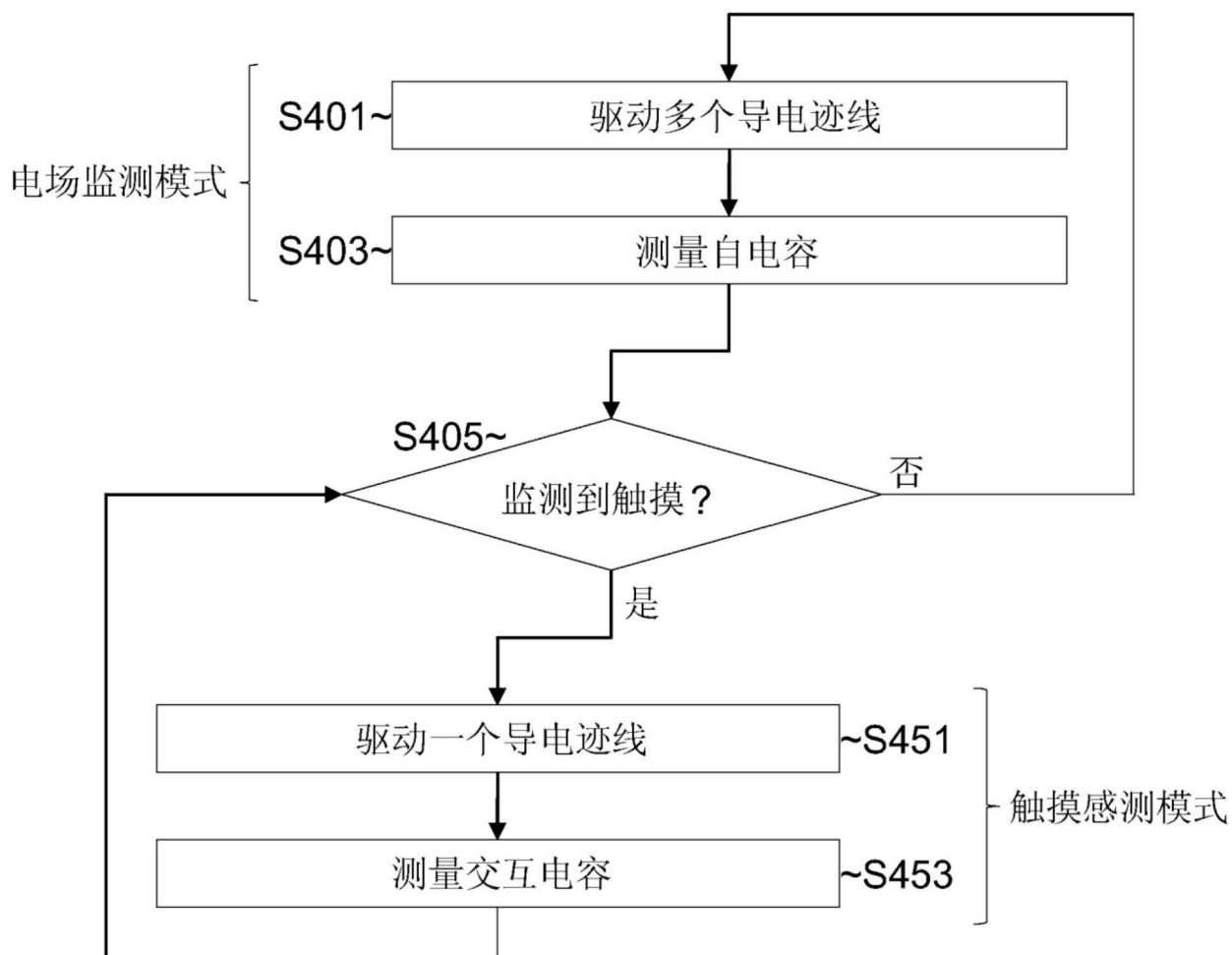


图4B

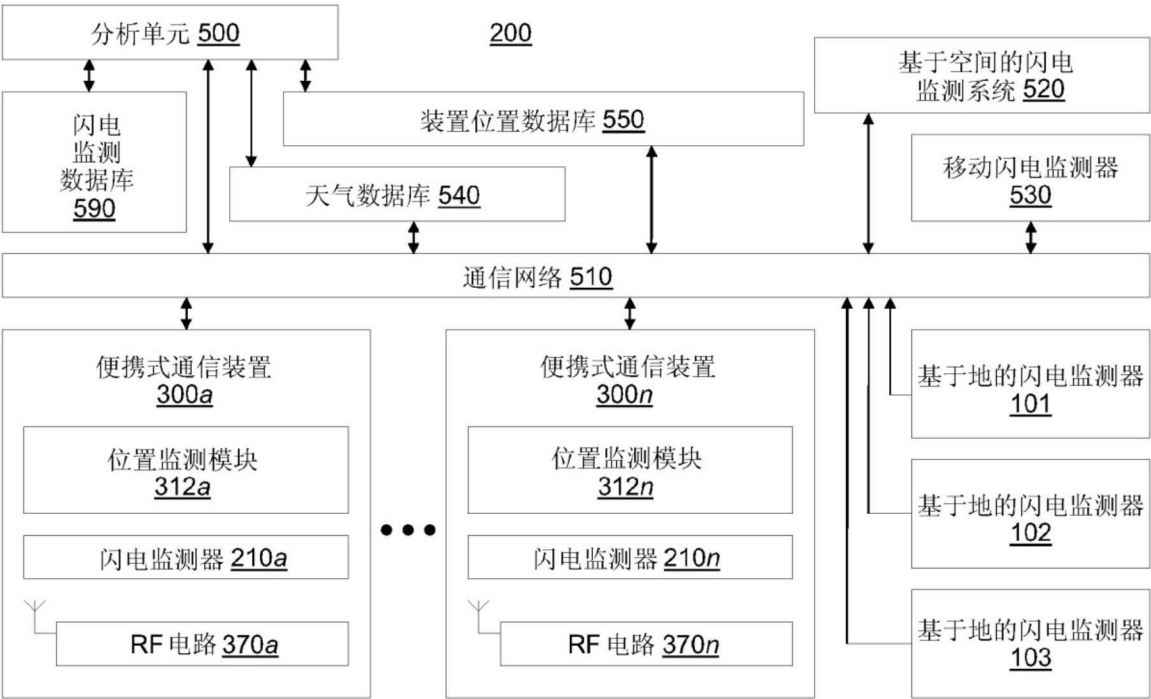


图5