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Mobile wireless communications device with multiple-band antenna and related methods

(57)

A mobile wireless communications device (30) may include a housing (96), a wireless transceiver (31) carried by the housing, and a multiple-band antenna (32) carried by the housing and coupled to the wireless transceiver. The multiple-band antenna may include a first ra-

diator (33) comprising a radiator element (36) and a parasitic element (35) adjacent to the radiator element. The parasitic element may be selectively switchable between floating and grounded states. The multiple-band antenna may include a second radiator (34) insulated from the first radiator.

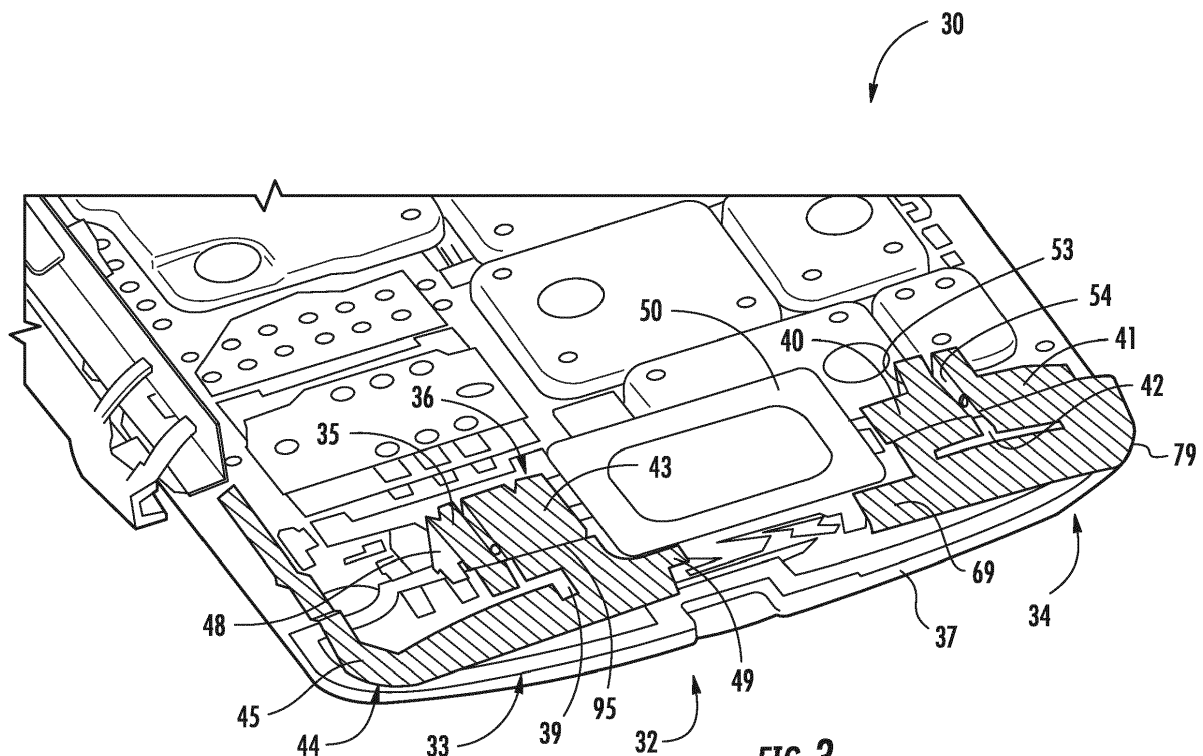


FIG. 3

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Description

Technical Field

[0001] The present invention relates to the field of communications, and, more particularly, to wireless communications and related methods.

Background

[0002] Cellular communication systems continue to grow in popularity and have become an integral part of both personal and business communications. Cellular telephones allow users to place and receive phone calls almost anywhere they travel. Moreover, as cellular telephone technology is improved, so too has the functionality of cellular devices. For example, many cellular devices now incorporate Personal Digital Assistant (PDA) features such as calendars, address books, task lists, calculators; memo and writing programs, etc. These multifunction devices usually allow users to wirelessly send and receive electronic mail (email) messages and access the Internet via a cellular network and/or a wireless local area network (WLAN), for example.

[0003] As the functionality of cellular devices continues to increase, so too does demand for smaller devices that are easier and more convenient for users to carry. Nevertheless, the move towards multi-functional devices makes miniaturization more difficult as the requisite number of installed components increases. Indeed, the typical cellular device may include several antennas, for example, a cellular antenna, a global positioning system antenna, and a WiFi IEEE 802.11g antenna. These antennas may comprise external antennas and internal antennas.

[0004] Generally speaking, internal antennas allow cellular devices to have a smaller footprint. Moreover, they are also preferred over external antennas for mechanical and ergonomic reasons. Internal antennas are also protected by the cellular device's housing and therefore tend to be more durable than external antennas. External antennas may be cumbersome and may make the cellular device difficult to use, particularly in limited-space environments. Yet, one potential drawback of typical internal antennas is that they are in relatively close proximity to the user's head when the cellular device is in use, thereby increasing the specific absorption rate (SAR). Yet more, hearing aid compatibility (HAC) may also be affected negatively. Also, other components within the cellular device may cause interference with or may be interfered by the internal antenna.

Brief Description of the Drawings

[0005] FIG. 1 is a schematic diagram of an example embodiment of the mobile wireless communications device.

[0006] FIG. 2 is a top plan view of an example embod-

iment of a multiple-band antenna from the mobile wireless communications device of FIG. 1.

[0007] FIG. 3 is a perspective view of an example embodiment of the mobile wireless communications device of FIG. 1 with the housing removed.

[0008] FIG. 4 is a top plan view of an example embodiment of a circuit board from the mobile wireless communications device of FIG. 1.

[0009] FIG. 5 is a schematic block diagram of an example embodiment of transmit and receive pathways for the mobile wireless communications device of FIG. 1.

[0010] FIG. 6 is a schematic block diagram of an example embodiment of the feed path for the second radiator of the mobile wireless communications device of FIG. 1.

[0011] FIG. 7 is a schematic circuit diagram of an example embodiment of the feed path for the second radiator of the mobile wireless communications device of FIG. 1.

[0012] FIG. 8 is a schematic block diagram of an example embodiment of the feed and parasitic paths for the first radiator of the mobile wireless communications device of FIG. 1.

[0013] FIG. 9 is a schematic circuit diagram of an example embodiment of the feed and parasitic paths for the first radiator of the mobile wireless communications device of FIG. 1.

[0014] FIG. 10 is a schematic circuit diagram of an example embodiment of the feed path for the first radiator of the mobile wireless communications device of FIG. 1.

[0015] FIG. 11 is a schematic circuit diagram of an example embodiment of the parasitic path for the first radiator of the mobile wireless communications device of FIG. 1.

[0016] FIGS. 12-26 are diagrams illustrating performance of an example embodiment of a multiple-band antenna from the mobile wireless communications device of FIG. 1.

[0017] FIG. 27 is a schematic block diagram illustrating example components of a mobile wireless communications device that may be used with the mobile wireless communications device of FIG. 1.

Detailed Description of the Preferred Embodiments

[0018] The present description is made with reference to the accompanying drawings, in which embodiments are shown. However, many different embodiments may be used, and thus the description should not be construed as limited to the embodiments set forth herein. Rather, these embodiments are provided so that this disclosure will be thorough and complete. Like numbers refer to like elements throughout.

[0019] Generally speaking, a mobile wireless communications device may include a housing, at least one wireless transceiver carried by the housing, and a multiple-band antenna carried by the housing and coupled to the at least one wireless transceiver. Example mobile wire-

less communications devices may include portable or personal media players (e.g., music or MP3 players, video players, etc.), remote controls (e.g., television or stereo remotes, etc.), portable gaming devices, portable or mobile telephones, smartphones, tablet computers, etc. The multiple-band antenna may include a first radiator comprising a radiator element and a parasitic element adjacent thereto, the parasitic element being selectively switchable between floating and grounded states, and a second radiator insulated from the first radiator.

[0020] More specifically, the multiple-band antenna may comprise a dielectric substrate supporting the first and second radiators. The dielectric substrate may have a non-planar shape, for example. The dielectric substrate may be carried by a bottom of the housing, and the first and second radiators may be carried by respective opposing first and second sides of the dielectric substrate.

[0021] Additionally, the second radiator may comprise first and second branches coupled together with a T-shaped slot therebetween. The second radiator may comprise a feed connection on the first branch, and a reference voltage connection on the second branch. For example, the T-shaped slot may open outwardly and between the first and second branches.

[0022] Moreover, the radiator element may comprise a first branch extending alongside the parasitic element, and a second branch extending outwardly from the first branch. The second branch may have a bend in a medial portion thereof. The radiator element may comprise a feed connection on the first branch. For example, the parasitic element may have a rectangular shape.

[0023] Another aspect is directed to a method of making a mobile wireless communications device. The method may comprise forming a multiple-band antenna to comprise a first radiator comprising a radiator element and a parasitic element adjacent thereto, the parasitic element being selectively switchable between floating and grounded states, and a second radiator insulated from the first radiator. The method may also include coupling at least one wireless transceiver to be carried by a housing, and coupling the multiple-band antenna to be carried by the housing and to the at least one wireless transceiver.

[0024] Referring initially to FIGS. 1-3, a mobile wireless communications device **30** illustratively includes a housing **96**, a wireless transceiver **31** carried by the housing, and a multiple-band antenna **32** carried by the housing and coupled to the wireless transceiver. The multiple-band antenna **32** illustratively includes a first radiator **33** comprising a radiator element **36**, and a parasitic element **35** adjacent thereto. For example, the first radiator **33** may comprise a low band radiator operating at a frequency band of 824-960 MHz.

[0025] In particular, the parasitic element **35** is aligned substantially parallel to the radiator element **36**. The parasitic element **35** may be selectively switchable between floating and grounded states, i.e. it is coupled to a plurality of differing impedances. The parasitic element **35** is

switched to change the capacitive load of the radiator element **36** and to control the resonance frequency of the same, thereby improving antenna performance. For example, the parasitic element **35** illustratively has a rectangle shape, but may comprise different shapes in other embodiments, such as a triangle shape, a trapezoid shape, a curved shape, etc.

[0026] Moreover, the radiator element **36** illustratively includes a first branch **43** extending alongside the parasitic element **35**, and a second branch **44** extending outwardly from the first branch. The radiator element **36** illustratively includes a feed connection **47** on the first branch **43**. The portion of the first branch **43** proximal to the feed connection **47** illustratively has a rectangle shape, but may comprise different shapes in other embodiments, such as a triangle shape, a trapezoid shape, a curved shape, etc. The radiator element **36** illustratively includes a medial portion coupling the first branch **43** and the second branch **44**. The medial portion illustratively includes L-shaped slot **39** on an inner side thereof, and a protruding portion **49** on an outer side thereof. The L-shaped slot **39** may comprise different shapes in other embodiments, such as a triangle shape, a trapezoid shape, a curved shape, etc. The protruding portion **49** is substantially rectangle shaped and forms a portion of a speaker receiving recess, but may comprise different shapes in other embodiments, such as a triangle shape, a trapezoid shape, a curved shape, etc. The second branch **44** illustratively includes a bend **45** in a medial portion thereof. The distal end of the second branch **44** is substantially rectangle shaped, but may comprise different shapes in other embodiments, such as a triangle shape, a trapezoid shape, a curved shape, etc.

[0027] The multiple-band antenna **32** illustratively includes a second radiator **34** insulated from the first radiator **33**. More specifically, the multiple-band antenna **32** illustratively includes a dielectric substrate **37** supporting the first and second radiators **33-34**. For example, the second radiator **34** may comprise a high band radiator operating at a frequency band of 1710-2170 MHz.

[0028] As perhaps best seen in FIG. 3, the dielectric substrate **37** illustratively includes a non-planar shape, which provides firm direct support to the multiple-band antenna **32**. Indeed, the substrate **37** illustratively includes a ridge **95** extending across the bottom of the mobile wireless communications device **30**, the ridge indenting the first and second radiators **33-34**. The dielectric substrate **37** is illustratively carried by a bottom of the housing **96**, and the first and second radiators **33-34** are carried by respective opposing first and second sides of the dielectric substrate.

[0029] Additionally, the second radiator **34** illustratively includes first and second branches **40-41** coupled together with a medial portion therebetween. The medial portion illustratively includes a T-shaped slot **42** on an inner side thereon. The T-shaped slot **42** may comprise different shapes in other embodiments, such as a triangle shape, a trapezoid shape, a curved shape, etc. The medial portion

illustratively includes, on an outer side thereof, a curved portion **79** and a protruding portion **69**. The protruding portion **69** is illustratively substantially rectangle shaped, but may comprise different shapes in other embodiments, such a triangle shape, a trapezoid shape, a curved shape, etc. The second radiator **34** illustratively includes a feed connection **53** on the first branch **40**, and a reference voltage connection **54**, for example, a ground connection, on the second branch **41**. The T-shaped slot **42** may open outwardly and between the first and second branches **40-41**.

[0030] The multiple-band antenna **32** illustratively includes a tuning member **59** (FIG. 2) positioned above the second radiator **34**. The tuning member **59** is illustratively rectangle shaped, but may comprise different shapes in other embodiments, such a triangle shape, a trapezoid shape, a curved shape, etc. The mobile wireless communications device **30** illustratively includes a speaker **50** (FIG. 3), and a speaker receiving recess partially defined by the protruding portions **49, 69** of the first and second radiators **33-34**.

[0031] In the typical cellular device, low band resonance may cause performance issues for the high band antenna. Advantageously, the second radiator **34** is electrically insulated from the first radiator **33** and the parasitic element **35** is appropriately switched to enhance the isolation therebetween. For example, if the second radiator **34** (high band) is in use, the first radiator **33** is terminated with an isolation optimizing impedance, both the parasitic element **35** and the radiator element **36**. Also, the two radiator approach with an active low band antenna and a passive high band antenna may give enough design freedom to achieve design goals (low and high band can be tuned independently, and coupling between low and high band can be controlled).

[0032] Referring now additionally to FIG. 4, the mobile wireless communications device **30** illustratively includes a circuit board **51** carrying the multiple-band antenna **32**, and a speaker metal support can **91** for supporting the speaker **50**. The mobile wireless communications device **30** illustratively includes a plurality of electrical contacts **52a-52c, 92a-92b** carried by the circuit board **51** and for being coupled to the first and second radiators **33-34**. In particular, electrical contact **52b** is coupled to the parasitic element **35**, electrical contact **52c** is connected to the radiator element **36**, electrical contact **92a** is connected to the feed connection **53**, and electrical contact **92b** is connected to the reference voltage connection **54**.

[0033] Referring now additionally to FIG. 5, the mobile wireless communications device **30** illustratively includes a transmit-receive path **60**. The transmit-receive path **60** illustratively includes a processor **65**, a power amplifier **64** coupled downstream therefrom, an antenna switch block **62** coupled downstream from the power amplifier, and an antenna tuner block **61** coupled between the first radiator **33** and the processor. The transmit-receive path **60** illustratively includes a diplexer block **63** coupled to the power amplifier **64**, the processor **65**, and the antenna

switch block **62**. The transmit-receive path **60** illustratively includes a pair of GSM receiver blocks (900 MHz, and 1900 MHz) **66-67** coupled between the antenna switch block **62** and the processor **65**.

[0034] Referring now additionally to FIGS. 6-7, the mobile wireless communications device **30** illustratively includes a second radiator feed path **57** including an antenna feed connection **53**, a matching network (impedance) block **55** coupled downstream therefrom, and an electrostatic discharge (ESD) protection block **56** coupled downstream therefrom and configured to provide an RF input. The second radiator feed path **57** illustratively includes a switch connector block **58** coupled between the ESD protection block **56** (inductor **302**) and the matching network block **55**. The switch connector block **58** is for use during production testing methods.

[0035] The matching network (impedance) block **55** illustratively includes an inductor **300**, and a capacitor **301** coupled in parallel. The second radiator feed path **57** illustratively includes a resistor **309** coupling the matching network block **55** and the switch connector block **58**, and a capacitor **340** coupling the switch connector block **58** to the ESD protection block **56**.

[0036] Referring now to FIGS. 8-11, the mobile wireless communications device **30** illustratively includes a first radiator feed path **89** including an antenna feed connection **47**, a matching network (impedance) block **71** (capacitors **306, 332**, resistors **307, 333**, and inductor **334**) coupled downstream therefrom, and an ESD protection block **72** (capacitors **304-305, 331**, resistor **303**, and inductor **330**) coupled downstream therefrom and providing an RF input. The first radiator feed path **89** illustratively includes a parasitic path comprising a parasitic feed **48**, an ESD protection block **73** (capacitors **311, 345**, resistor **310**, and inductor **344**) coupled downstream therefrom, a switch block **78** coupled thereto and configured to selective coupled the parasitic element connection **48** to a pair of impedances **75-76** (capacitors **347, 343**, resistor **342**, and capacitors **340-341**). The switch block **78** is also coupled to the processor **65** and includes a single pole double throw switch **74**, for example, capacitors **312, 314, 316-317**, and resistors **313, 315**). Capacitors **320-321** are coupled between the processor **65** and the switch block **78**. The first radiator feed path **89** illustratively includes a switch connector block **77** coupled between the ESD protection block **72** and the matching network block **71** (capacitor **332**, resistor **333**, and inductor **334**). The switch connector block **77** is for use during production testing methods. As will be appreciated by those skilled in the art, FIGS. 10-11 illustrate example implementations of the schematic diagram of FIG. 9. These are presented for illustrative and exemplary purposes only. Indeed, not all components from FIG. 9 are included in the specific implementations of FIGS. 10-11, and some components have been altered slightly.

[0037] Referring now to FIGS. 12-16, several diagrams illustrate performance of an embodiment of the multiple-band antenna **32**. In particular, diagrams **100, 110** show

first radiator **33** performance in a first switched parasitic state while diagrams **120**, **130** show first radiator performance in a second switched parasitic state. Data points **101-108** (FIG. 12), **111-118** (FIG. 13), **121-128** (FIG. 14), and **131-138** (FIG. 15) specify performance at operating frequencies of 824.20 MHz, 849.00 MHz, 869.00 MHz, 894.00 MHz, 880.00 MHz, 915.00 MHz, 925.00 MHz, and 960.00 MHz, respectively. In FIG. 15, curve **110** illustrates performance of the parasitic switch state from FIG. 13. Diagram **250** shows first radiator **33** efficiency performance in first **252** and second **251** switched parasitic states.

[0038] In particular, diagrams **100** and **120** show the shift of the antenna resonance in the low band (frequency range 800-1000 MHz). The active antenna was designed to extend the bandwidth in the low band area.

[0039] Referring now additionally to FIGS. 17-22 diagrams **140**, **150**, **230** illustrate coupling effects between the first and second radiators **33-34** in a first switched parasitic state while diagrams **170**, **180**, **220** show coupling effects between the first and second radiators in a second switched parasitic state. Data points **141a-146a**, **141b-146b** (FIG. 17), **151-156** (FIG. 18), **121-171a-176a**, **171b-176b** (FIG. 20), and **181-186** (FIG. 21) specify performance at operating frequencies of 824.00 MHz, 960 MHz, 1.71 GHz, 1.99 GHz, 2.11 GHz, and 2.17 GHz, respectively. Diagram **230** includes curves **231-232**, and diagram **220** includes curves **221-222**.

[0040] The low band antenna (first radiator **33**) also shows a 2nd resonance in the range of the high band antenna (second radiator **34**). In the illustrated embodiments, the high band and low band antennas **33-34** are close together. The 2nd resonance of the low band antenna **33** will also interact with the 1st resonance of the high band antenna **34**. In diagrams **140**, **150**, **230**, the frequency range is extended, and the higher frequencies are shown. The diagrams include the range (800 MHz-2300 MHz), and aid in understanding the control enabled with the active antenna radiator switching state for the isolation between our low band and high band antennas **33-34**. Diagram **140** shows return loss of both radiators for the switching state 1 (y-axis in dB, x-axis is frequency in MHz), and this figure shows the 1st and the 2nd resonances of the active antenna (low band radiator **33**). The second resonance is overlapping with the resonance of the high band radiator **34** (antenna with T slot). This 2nd resonance causes a coupling between both radiators with impact to antenna isolation. Diagrams **150** and **230** show the coupling/isolation between both radiators, diagram **230** being another format (smith chart) of diagram **150**. The antenna isolation impacts the efficiency, HAC and SAR.

[0041] Diagrams **170**, **180**, **220** show the same situation for the switched state 2. It is visible that not only the first resonance is affected, but also the 2nd resonance is shifted. The isolation between both antennas is changed (compare FIGS. 18 and 21). Again, diagram **220** provides another Smith diagram format.

[0042] FIGS. 23-26 include diagrams **190**, **195**, which illustrate hearing aid compatibility (HAC) E-field results in first and second switched parasitic states. In typical cellular devices with multiple-band antennas, the reduced housing size and close proximity of the antenna and hearing aid components may cause self-interference issues. HAC requirements for the GSM 1900 band are stricter than that for the GSM 850 band. For below 0.96 GHz, the HAC category M3 limits (AWF = -5 dB) include a maximum electric field (E field) of 266.1 V/m and a maximum magnetic field (M field) of 0.80 A/m. For above 0.96 GHz, the HAC category M3 limits (AWF = -5 dB) include a maximum electric field (E field) of 84.1 V/m and a maximum magnetic field (M field) of 0.25 A/m. In particular, peak E-field measurements in V/m for the first switched parasitic state include: grid 1 75.4; grid 2 63.5; grid 3 65.4; grid 4 76.4; grid 5 9B.G; grid 6 98.3; grid 7 101.5; grid 8 111.0; and grid 9 107.3. Peak E-field measurements in V/m for the second switched parasitic state include: grid 1 74.6; grid 2 59.9; grid 3 62.0; grid 4 76.0; grid 5 95.3; grid 6 94.7; grid 7 101.3; grid 8 109.1; and grid 9 103.8.

[0043] Diagrams **200**, **205** illustrate hearing aid compatibility H-field in first and second switched parasitic states. In particular, peak H-field measurements in A/m for the first switched parasitic state include: grid 1 0.271; grid 2 0.281; grid 3 0.270; grid 4 0.272; grid 5 0.278; grid 6 0.265; grid 7 0.322; grid 8 0.253; and grid 9 0.205. Peak H-field measurements in V/m for the second switched parasitic state include: grid 1 0.223; grid 2 0.236; grid 3 0.231; grid 4 0.230; grid 5 0.235; grid 6 0.230; grid 7 0.272; grid 8 0.211; and grid 9 0.192. Advantageously, the first and second resonances of the first radiator **33** are managed, thereby mitigating a near field effect for the hearing aid earpiece. Indeed, as shown in diagrams **190**, **195**, **200**, **205**, the HAC values are clearly reduced in the second switched parasitic state.

[0044] Advantageously, in the mobile wireless communications device **30**, the isolation (2nd resonance low band radiator **33** and 1st resonance high band radiator **34**) between both antennas is controlled with the different switching states of our active low band antenna. In one case, high isolation is necessary to have the best antenna efficiency (GSM 1800, GSM 1900 RX, W-CDMA Band 1,2,4). This permits the multiple-band antenna **32** to realize this disclosed mechanical arrangement of the antennas being close together in a small volume. But in other cases (GSM 1900 TX (transmit)), the other switching state that gets less isolation can be used, which changes the field distribution on the PCB (printed wire board) and reduces HAC values. Of course, the antenna efficiency is compromised in this case. Nevertheless, mobile wireless communications device **30** does not need an extra HAC reduction structure, as required in typical cellular devices (traditional HAC reduction structures are separate metalized structures (L-stub, for example) mounted close to antenna). The design of the disclosed low band radiator **33** is made so that the 2nd resonance

of the low band radiator is in the frequency range where we want to reduce HAC (GSM 1900 TX).

[0045] Example components of a mobile wireless communications device **1000** that may be used in accordance with the above-described embodiments are further described below with reference to FIG. 27. The device **1000** illustratively includes a housing **1200**, a keyboard or keypad **1400** and an output device **1600**. The output device shown is a display **1600**, which may comprise a full graphic liquid crystal display (LCD). Other types of output devices may alternatively be utilized. A processing device **1800** is contained within the housing **1200** and is coupled between the keypad **1400** and the display **1600**. The processing device **1800** controls the operation of the display **1600**, as well as the overall operation of the mobile device **1000**, in response to actuation of keys on the keypad **1400**.

[0046] The housing **1200** may be elongated vertically, or may take on other sizes and shapes (including clam-shell housing structures). The keypad may include a mode selection key, or other hardware or software for switching between text entry and telephony entry.

[0047] In addition to the processing device **1800**, other parts of the mobile device **1000** are shown schematically in FIG. 27. These include a communications subsystem **1001**; a short-range communications subsystem **1020**; the keypad **1400** and the display **1600**, along with other input/output devices **1060**, **1080**, **1100** and **1120**; as well as memory devices **1160**, **1180** and various other device subsystems **1201**. The mobile device **1000** may comprise a two-way RF communications device having data and, optionally, voice communications capabilities. In addition, the mobile device **1000** may have the capability to communicate with other computer systems via the Internet.

[0048] Operating system software executed by the processing device **1800** is stored in a persistent store, such as the flash memory **1160**, but may be stored in other types of memory devices, such as a read only memory (ROM) or similar storage element. In addition, system software, specific device applications, or parts thereof, may be temporarily loaded into a volatile store, such as the random access memory (RAM) **1180**. Communications signals received by the mobile device may also be stored in the RAM **1180**.

[0049] The processing device **1800**, in addition to its operating system functions, enables execution of software applications **1300A-1300N** on the device **1000**. A predetermined set of applications that control basic device operations, such as data and voice communications **1300A** and **1300B**, may be installed on the device **1000** during manufacture. In addition, a personal information manager (PIM) application may be installed during manufacture. The PIM may be capable of organizing and managing data items, such as e-mail, calendar events, voice mails, appointments, and task items. The PIM application may also be capable of sending and receiving data items via a wireless network **1401**. The PIM data

items may be seamlessly integrated, synchronized and updated via the wireless network **1401** with corresponding data items stored or associated with a host computer system.

5 [0050] Communication functions, including data and voice communications, are performed through the communications subsystem **1001**, and possibly through the short-range communications subsystem **1020**. The communications subsystem **1001** includes a receiver **1500**, a transmitter **1520**, and one or more antennas **1540** and **1560**. In addition, the communications subsystem **1001** also includes a processing module, such as a digital signal processor (DSP) **1580**, and local oscillators (LOs) **1601**. The specific design and implementation of the communications subsystem **1001** is dependent upon the communications network in which the mobile device **1000** is intended to operate. For example, a mobile device **1000** may include a communications subsystem **1001** designed to operate with the Mobitex™, Data TAG™
10 or General Packet Radio Service (GPRS) mobile data communications networks, and also designed to operate with any of a variety of voice communications networks, such as Advanced Mobile Phone System (AMPS), time division multiple access (TDMA), code division multiple access (CDMA), Wideband code division multiple access (W-CDMA), personal communications service (PCS), GSM (Global System for Mobile Communications), enhanced data rates for GSM evolution (EDGE), etc. Other types of data and voice networks, both separate and integrated, may also be utilized with the mobile device **1000**. The mobile device **1000** may also be compliant with other communications standards such as 3GSM, 3rd Generation Partnership Project (3GPP), Universal Mobile Telecommunications System (UMTS), 4G, etc.

35 [0051] Network access requirements vary depending upon the type of communication system. For example, in the Mobitex and DataTAC networks, mobile devices are registered on the network using a unique personal identification number or PIN associated with each device. In GPRS networks, however, network access is associated with a subscriber or user of a device. A GPRS device therefore typically involves use of a subscriber identity module, commonly referred to as a SIM card, in order to operate on a GPRS network.

45 [0052] When required network registration or activation procedures have been completed, the mobile device **1000** may send and receive communications signals over the communication network **1401**. Signals received from the communications network **1401** by the antenna **1540** are routed to the receiver **1500**, which provides for signal amplification, frequency down conversion, filtering, channel selection, etc., and may also provide analog to digital conversion. Analog-to-digital conversion of the received signal allows the DSP **1580** to perform more complex communications functions, such as demodulation and decoding. In a similar manner, signals to be transmitted to the network **1401** are processed (e.g. modulated and encoded) by the DSP **1580** and are then provided to the

transmitter **1520** for digital to analog conversion, frequency up conversion, filtering, amplification and transmission to the communication network **1401** (or networks) via the antenna **1560**.

[0053] In addition to processing communications signals, the DSP **1580** provides for control of the receiver **1500** and the transmitter **1520**. For example, gains applied to communications signals in the receiver **1500** and transmitter **1520** may be adaptively controlled through automatic gain control algorithms implemented in the DSP **1580**.

[0054] In a data communications mode, a received signal, such as a text message or web page download, is processed by the communications subsystem **1001** and is input to the processing device **1800**. The received signal is then further processed by the processing device **1800** for an output to the display **1600**, or alternatively to some other auxiliary I/O device **1060**. A device may also be used to compose data items, such as e-mail messages, using the keypad **1400** and/or some other auxiliary I/O device **1060**, such as a touchpad, a rocker switch, a thumb-wheel, or some other type of input device. The composed data items may then be transmitted over the communications network **1401** via the communications subsystem **1001**.

[0055] In a voice communications mode, overall operation of the device is substantially similar to the data communications mode, except that received signals are output to a speaker **1100**, and signals for transmission are generated by a microphone **1120**. Alternative voice or audio I/O subsystems, such as a voice message recording subsystem, may also be implemented on the device **1000**. In addition, the display **1600** may also be utilized in voice communications mode, for example to display the identity of a calling party, the duration of a voice call, or other voice call related information.

[0056] The short-range communications subsystem enables communication between the mobile device **1000** and other proximate systems or devices, which need not necessarily be similar devices. For example, the short-range communications subsystem may include an infrared device and associated circuits and components, a Bluetooth™ communications module to provide for communication with similarly-enabled systems and devices, or a NFC sensor for communicating with a NFC device or NFC tag via NFC communications.

[0057] Many modifications and other embodiments will come to the mind of one skilled in the art having the benefit of the teachings presented in the foregoing descriptions and the associated drawings. Therefore, it is understood that various modifications and embodiments are intended to be included within the scope of the appended claims.

Claims

1. A mobile wireless communications device (30) com-

prising:

a housing (96);
at least one wireless transceiver (36) carried by said housing; and
a multiple-band antenna (32) carried by said housing and coupled to said at least one wireless transceiver, said multiple-band antenna comprising
a first radiator (33) comprising a radiator element (36) and a parasitic element (35) adjacent thereto, said parasitic element being selectively switchable between floating and grounded states, and
a second radiator (34) insulated from said first radiator.

2. The mobile wireless communications device of claim 1 wherein said multiple-band antenna comprises a dielectric substrate (37) supporting said first and second radiators.

3. The mobile wireless communications device of claim 2 wherein said dielectric substrate has a non-planar shape.

4. The mobile wireless communications device of claim 2 wherein said dielectric substrate is carried by a bottom of said housing; and wherein said first and second radiators are carried by respective opposing first and second sides of said dielectric substrate.

5. The mobile wireless communications device of claim 1 wherein said second radiator comprises first and second branches (40, 41) coupled together with a T-shaped slot (42) therebetween.

6. The mobile wireless communications device of claim 5 wherein said second radiator comprises a feed connection (53) on said first branch, and a reference voltage connection (54) on said second branch.

7. The mobile wireless communications device of claim 5 wherein said T-shaped slot opens outwardly and between said first and second branches.

8. The mobile wireless communications device of claim 1 wherein said radiator element comprises a first branch (43) extending alongside said parasitic element, and a second branch (44) extending outwardly from said first branch.

9. The mobile wireless communications device of claim 1 wherein said parasitic element has a rectangular shape.

10. A method of making a mobile wireless communications device (30) comprising:

- forming a multiple-band antenna (32) to comprise
 a first radiator (33) comprising a radiator element (36) and a parasitic element (35) adjacent thereto, the parasitic element being selectively switchable between floating and grounded states, and
 a second radiator (34) insulated from the first radiator;
 coupling at least one wireless transceiver (31) to be carried by a housing (96); and
 coupling the multiple-band antenna to be carried by the housing and to the at least one wireless transceiver.
11. The method of claim 10 wherein forming the multiple-band antenna comprises forming a dielectric substrate (37) to support the first and second radiators.
12. The method of claim 11 wherein forming the multiple-band antenna comprises forming the dielectric substrate to have a non-planar shape.
13. The method of claim 11 further comprising coupling the dielectric substrate to be carried by a bottom of the housing, and coupling the first and second radiators to be carried by respective opposing first and second sides of the dielectric substrate.
14. The method of claim 10 wherein forming the multiple-band antenna comprises forming the second radiator to comprise first and second branches (40, 41) coupled together with a T-shaped slot therebetween (42).
15. The method of claim 14 wherein forming the multiple-band antenna comprises forming the second radiator to comprise a feed connection (53) on the first branch, and a reference voltage connection (54) on the second branch.

Amended claims in accordance with Rule 137(2) EPC.

1. A mobile wireless communications device (30) comprising:
- a housing (96);
 at least one wireless transceiver (36) carried by said housing; and
 a multiple-band antenna (32) carried by said housing and coupled to said at least one wireless transceiver, said multiple-band antenna comprising
- a first radiator (33) comprising a radiator element (36) and a parasitic element (35) ad-

jacent thereto, said parasitic element being selectively switchable between floating and grounded states, and
 a second radiator (34) insulated from said first radiator and comprising

a first branch(40)
 a second branch (41) coupled to said first branch,
 said first and second branches defining a slot (42) extending therebetween.

2. The mobile wireless communications device of claim 1 wherein said multiple-band antenna comprises a dielectric substrate (37) supporting said first and second radiators.

3. The mobile wireless communications device of claim 2 wherein said dielectric substrate has a non-planar shape.

4. The mobile wireless communications device of claim 2 wherein said dielectric substrate is carried by a bottom of said housing; and wherein said first and second radiators are carried by respective opposing first and second sides of said dielectric substrate.

5. The mobile wireless communications device of claim 1 wherein said slot (42) comprises a first rectangle shaped portion extending into both said first and second branches, and a second rectangle shaped portion coupled to said first rectangle shaped portion and dividing said first and second branches.

6. The mobile wireless communications device of claim 5 wherein said second radiator comprises a feed connection (53) on said first branch, and a reference voltage connection (54) on said second branch.

7. The mobile wireless communications device of claim 1 wherein said radiator element comprises a first branch (43) extending alongside said parasitic element, and a second branch (44) extending away from said first branch.

8. The mobile wireless communications device of claim 1 wherein said parasitic element has a rectangular shape.

9. A method of making a mobile wireless communications device (30) comprising:

forming a multiple-band antenna (32) to comprise

a first radiator (33) comprising a radiator el-

ement (36) and a parasitic element (35) adjacent thereto, the parasitic element being selectively switchable between floating and grounded states, and
 a second radiator (34) insulated from the first radiator and comprising

a first branch(40)
 a second branch (41) coupled to the first branch,
 the first and second branches defining a slot (42) extending therebetween;

coupling at least one wireless transceiver (31) to be carried by a housing (96); and
 coupling the multiple-band antenna to be carried by the housing and to the at least one wireless transceiver.

10. The method of claim 9 wherein forming the multiple-band antenna comprises forming a dielectric substrate (37) to support the first and second radiators.

11. The method of claim 10 wherein forming the multiple-band antenna comprises forming the dielectric substrate to have a non-planar shape.

12. The method of claim 10 further comprising coupling the dielectric substrate to be carried by a bottom of the housing, and coupling the first and second radiators to be carried by respective opposing first and second sides of the dielectric substrate.

13. The method of claim 9 wherein forming the multiple-band antenna comprises forming the slot (42) to comprise a first rectangle shaped portion extending into both the first and second branches, and a second rectangle shaped portion coupled to the first rectangle shaped portion and dividing the first and second branches.

14. The method of claim 13 wherein forming the multiple-band antenna comprises forming the second radiator to comprise a feed connection (53) on the first branch, and a reference voltage connection (54) on the second branch.

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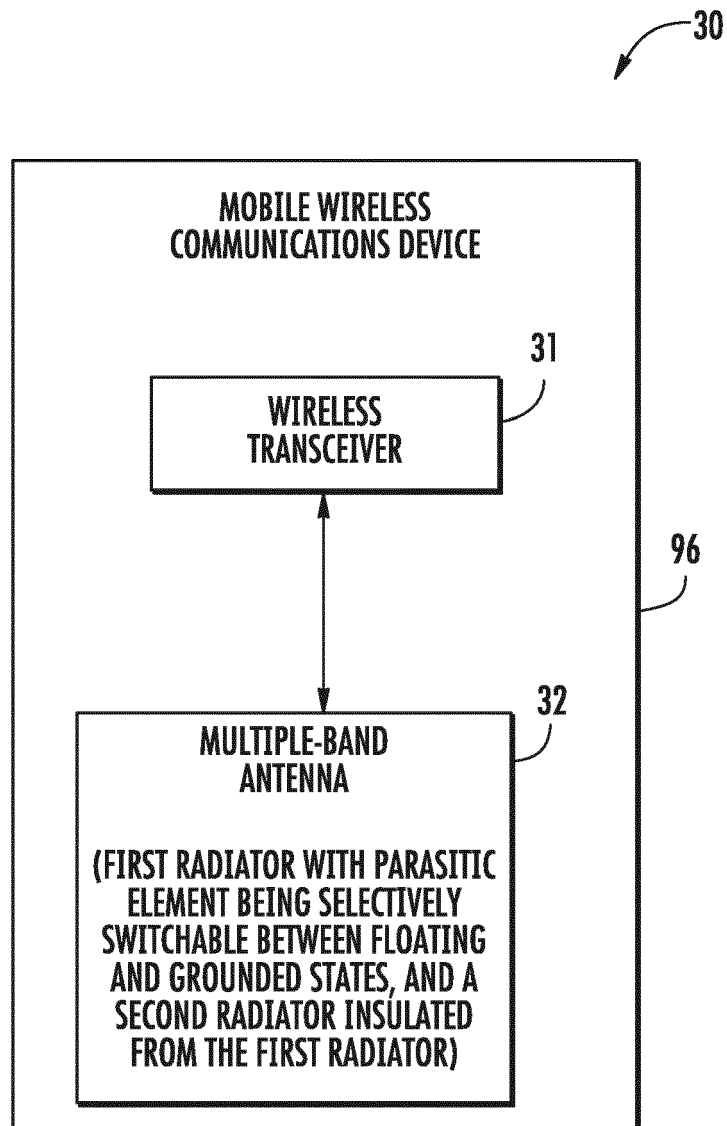
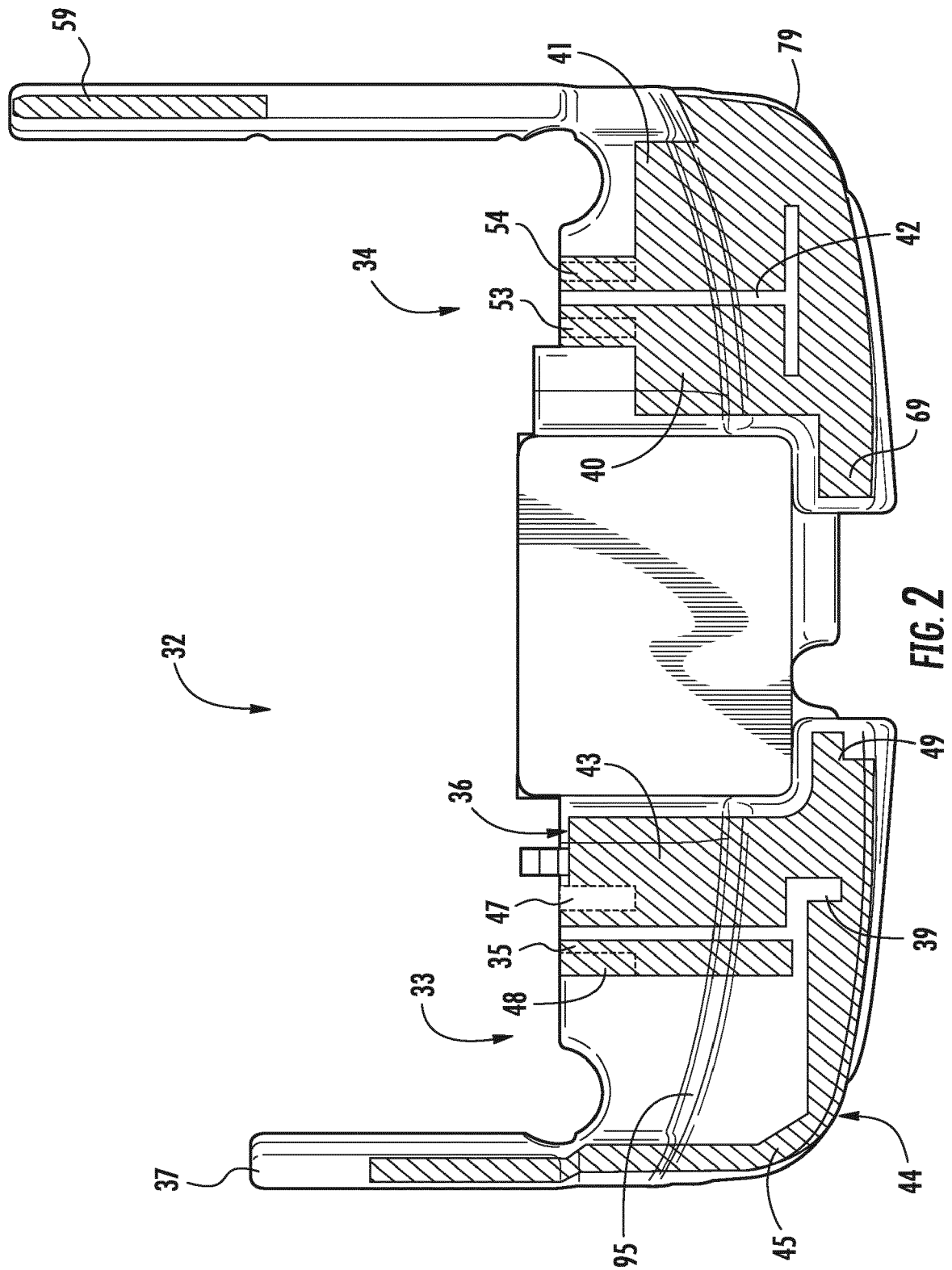


FIG. 1



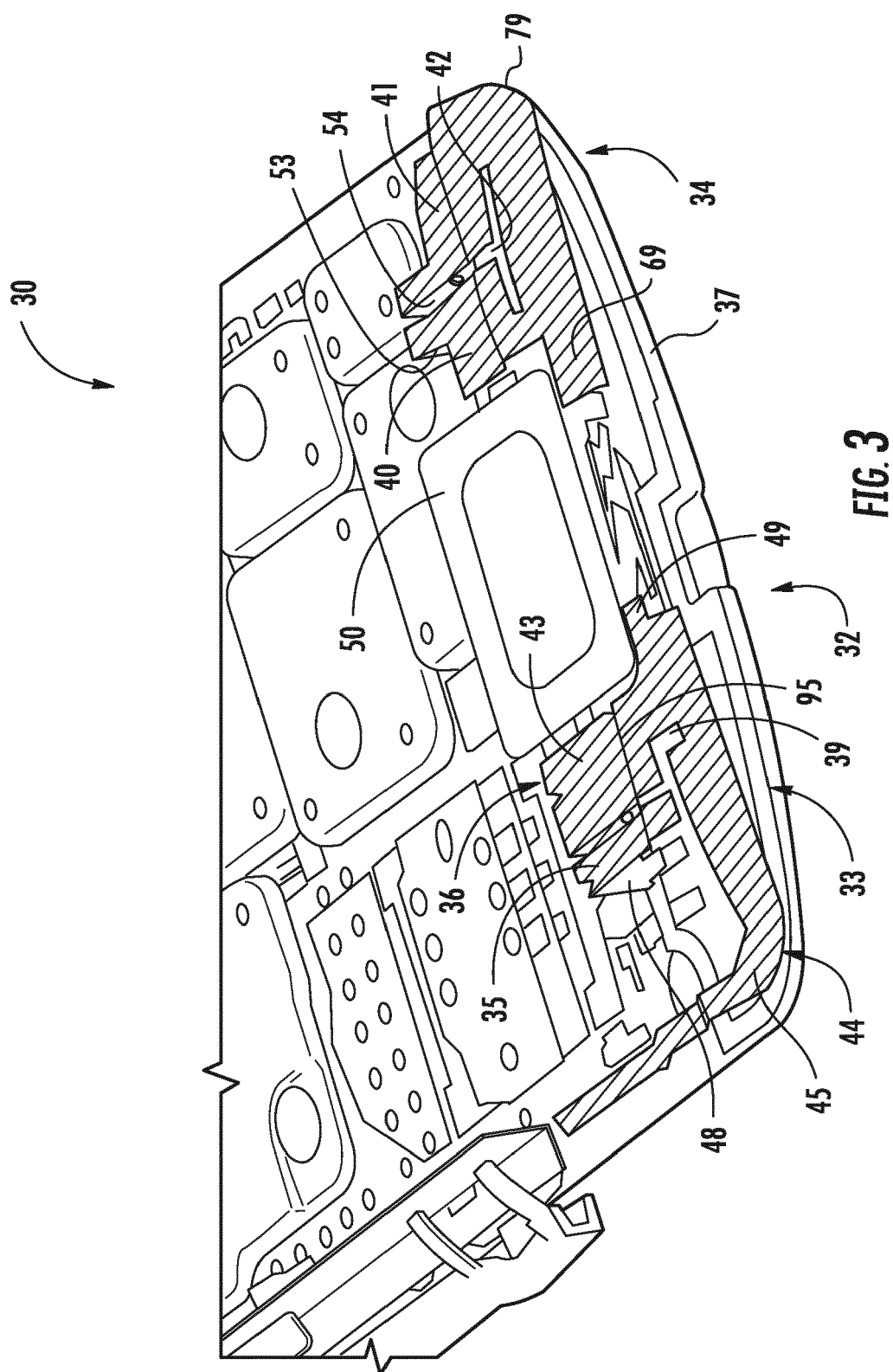


FIG. 3

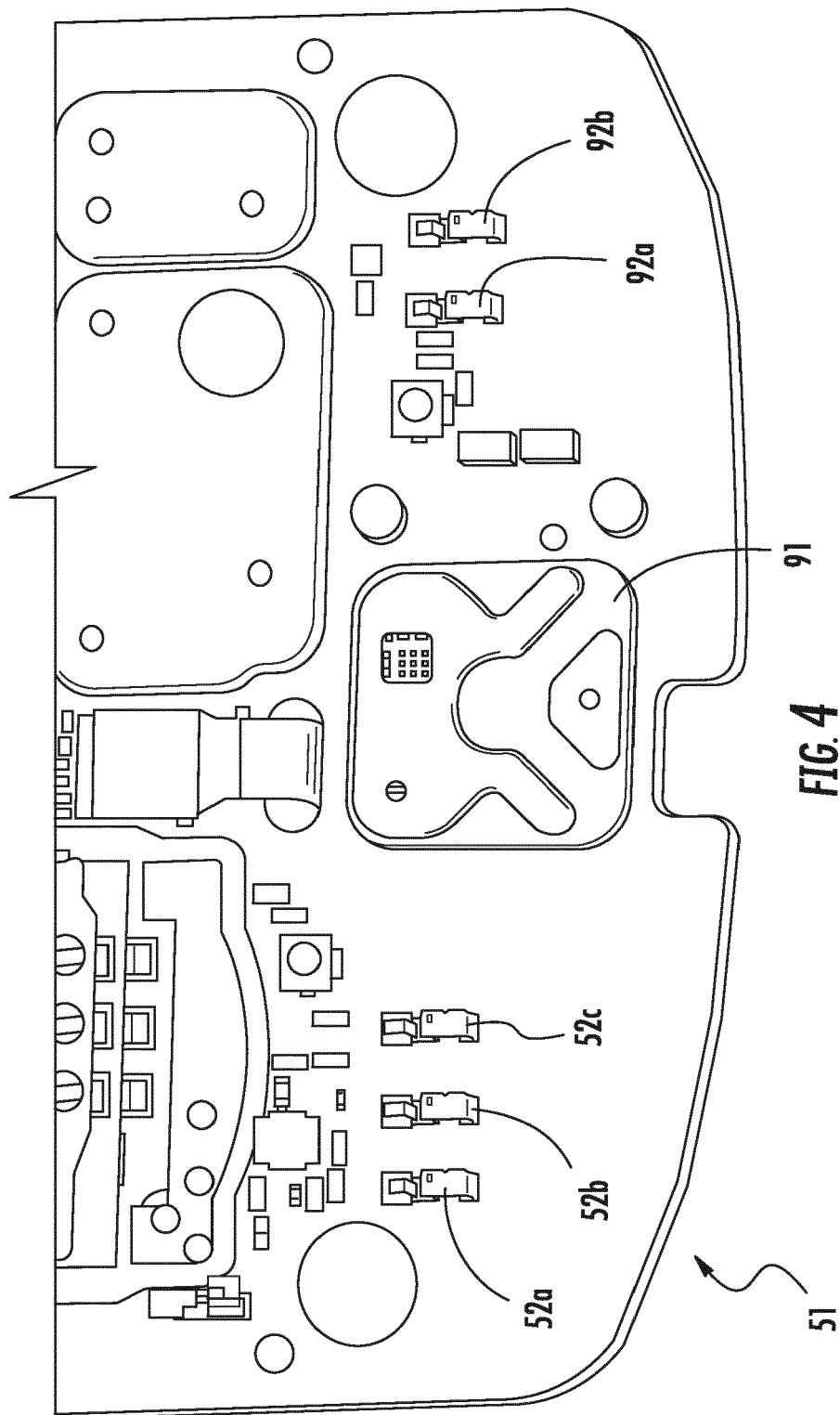


FIG. 4

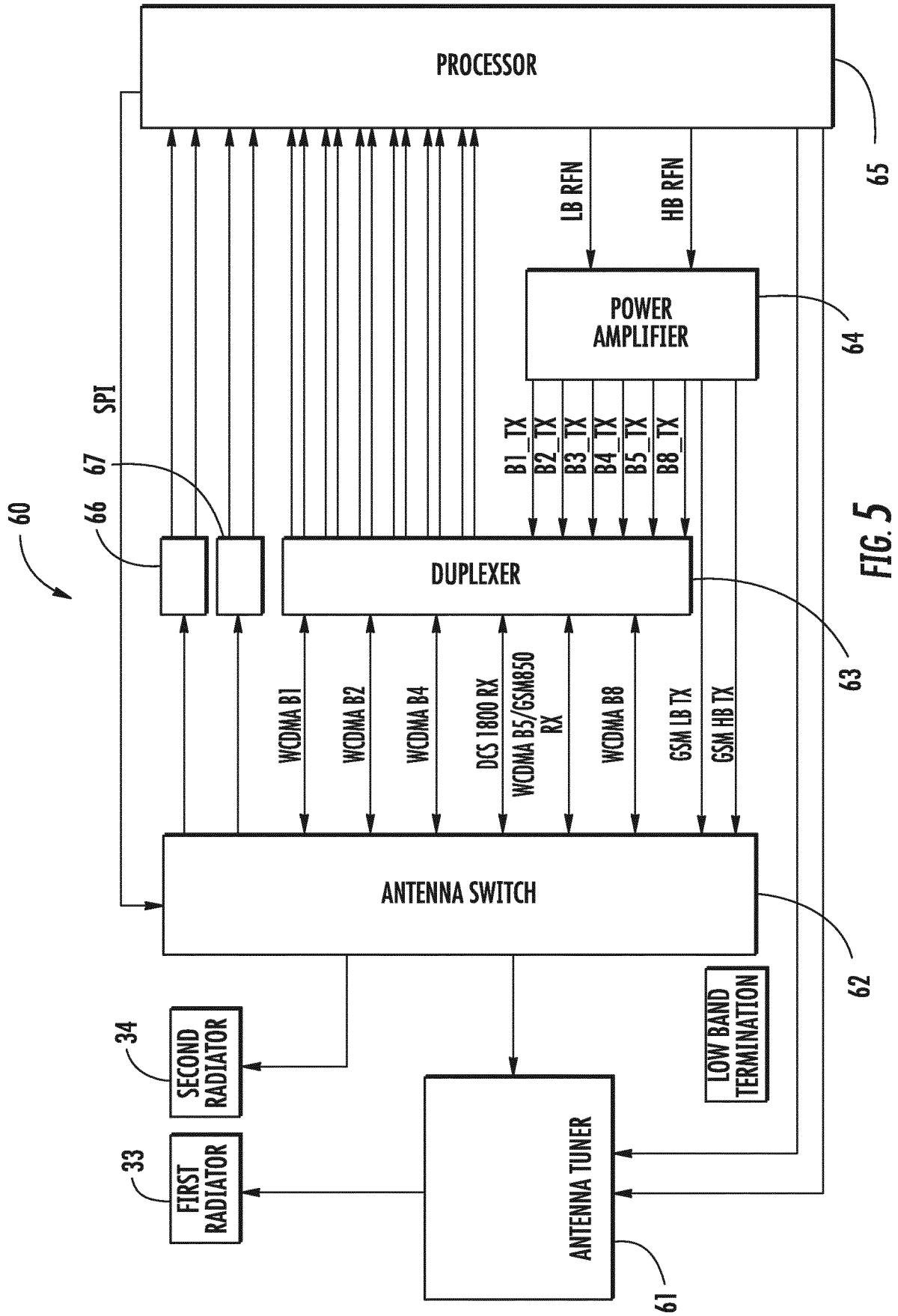


FIG. 5

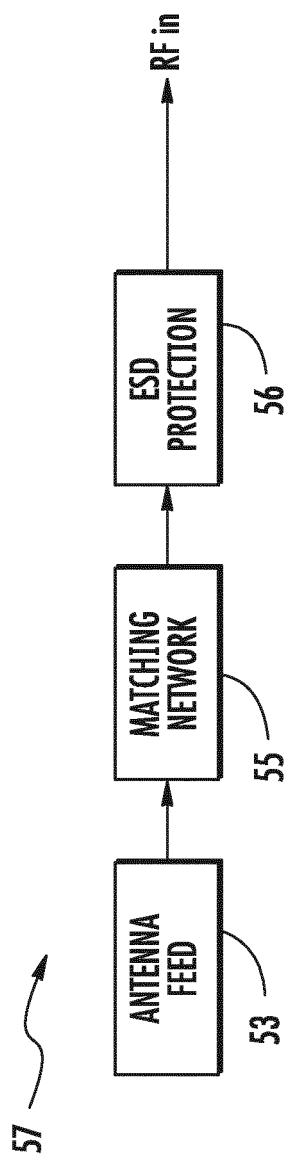


FIG. 6

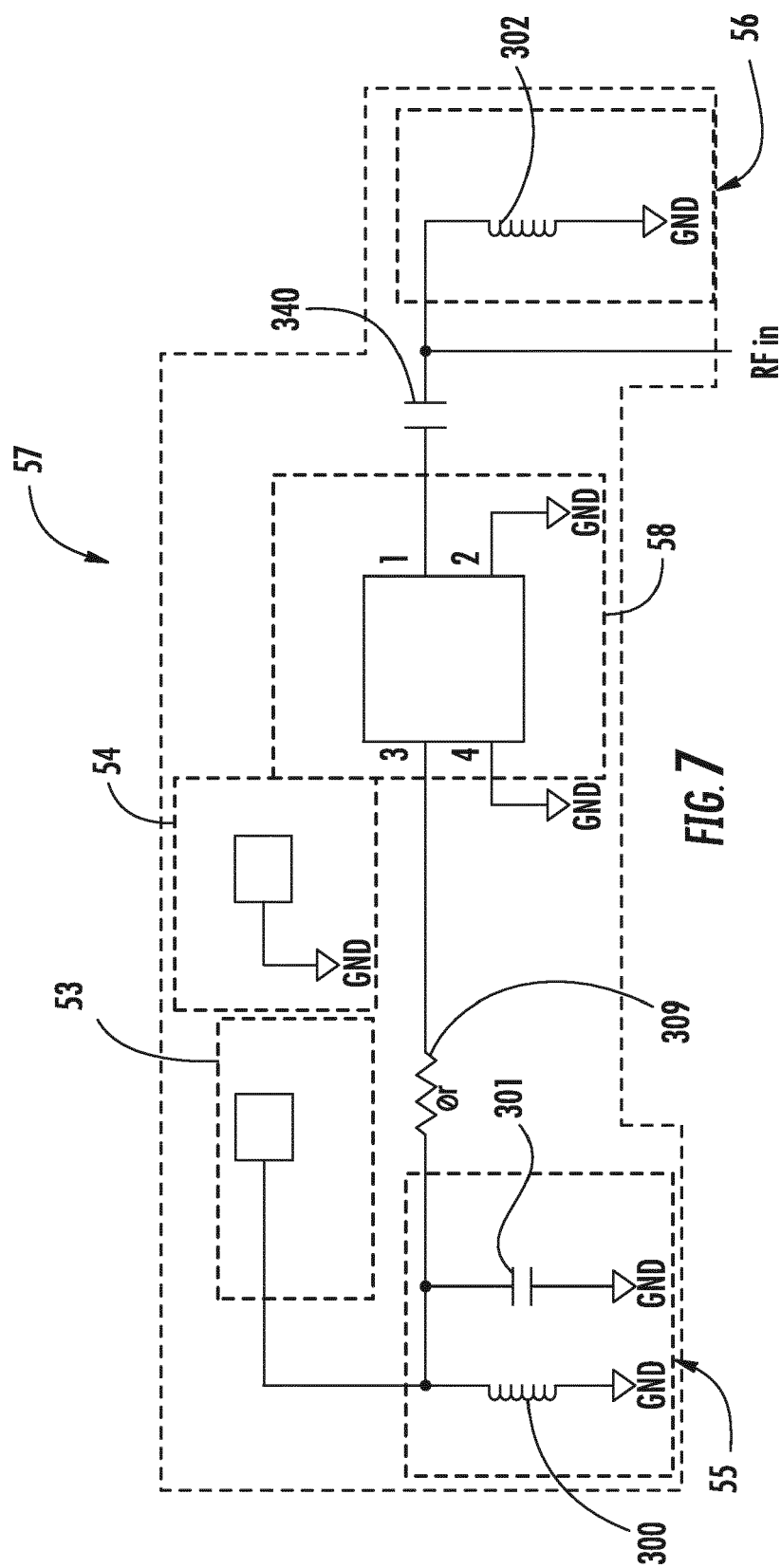


FIG. 7

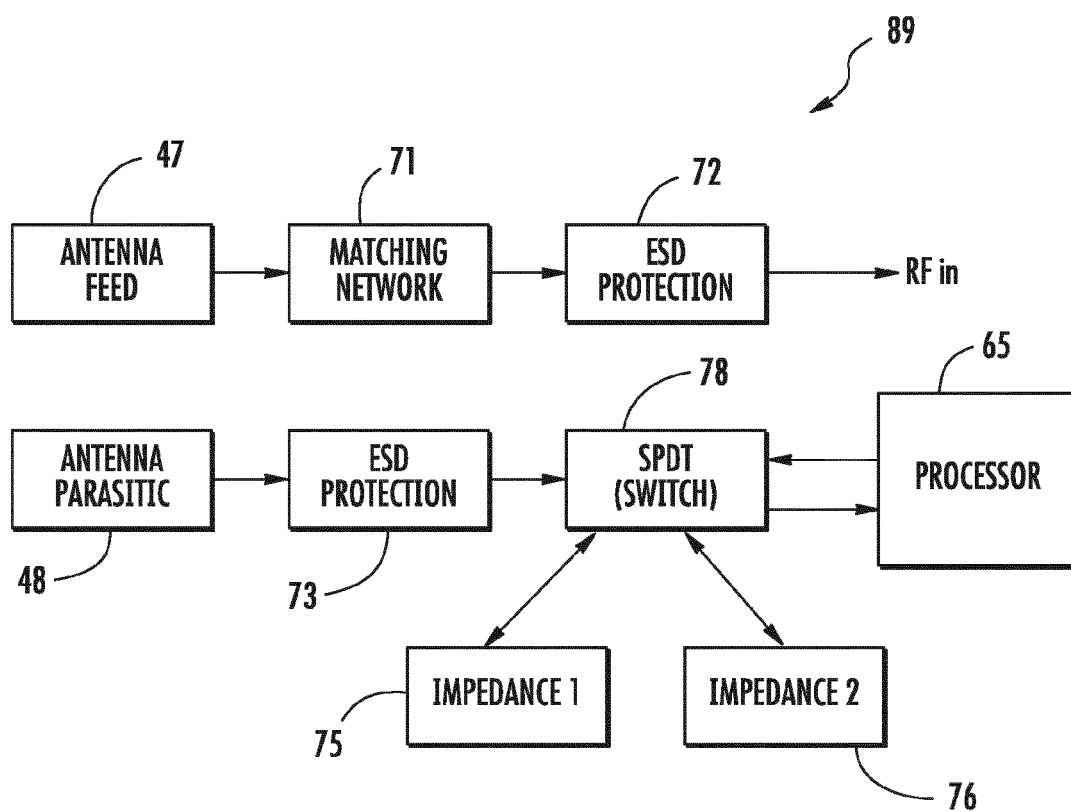


FIG. 8

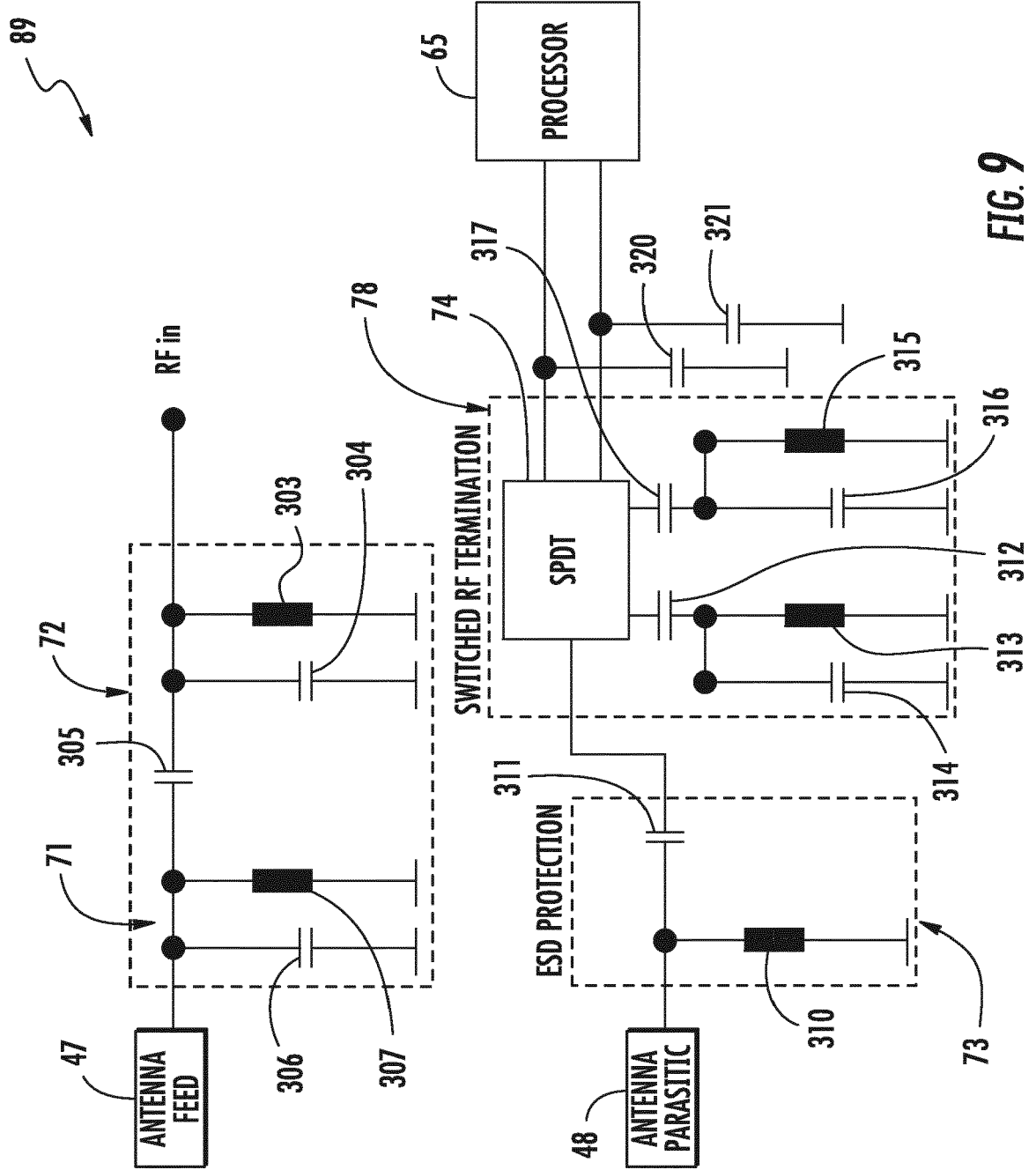


FIG. 9

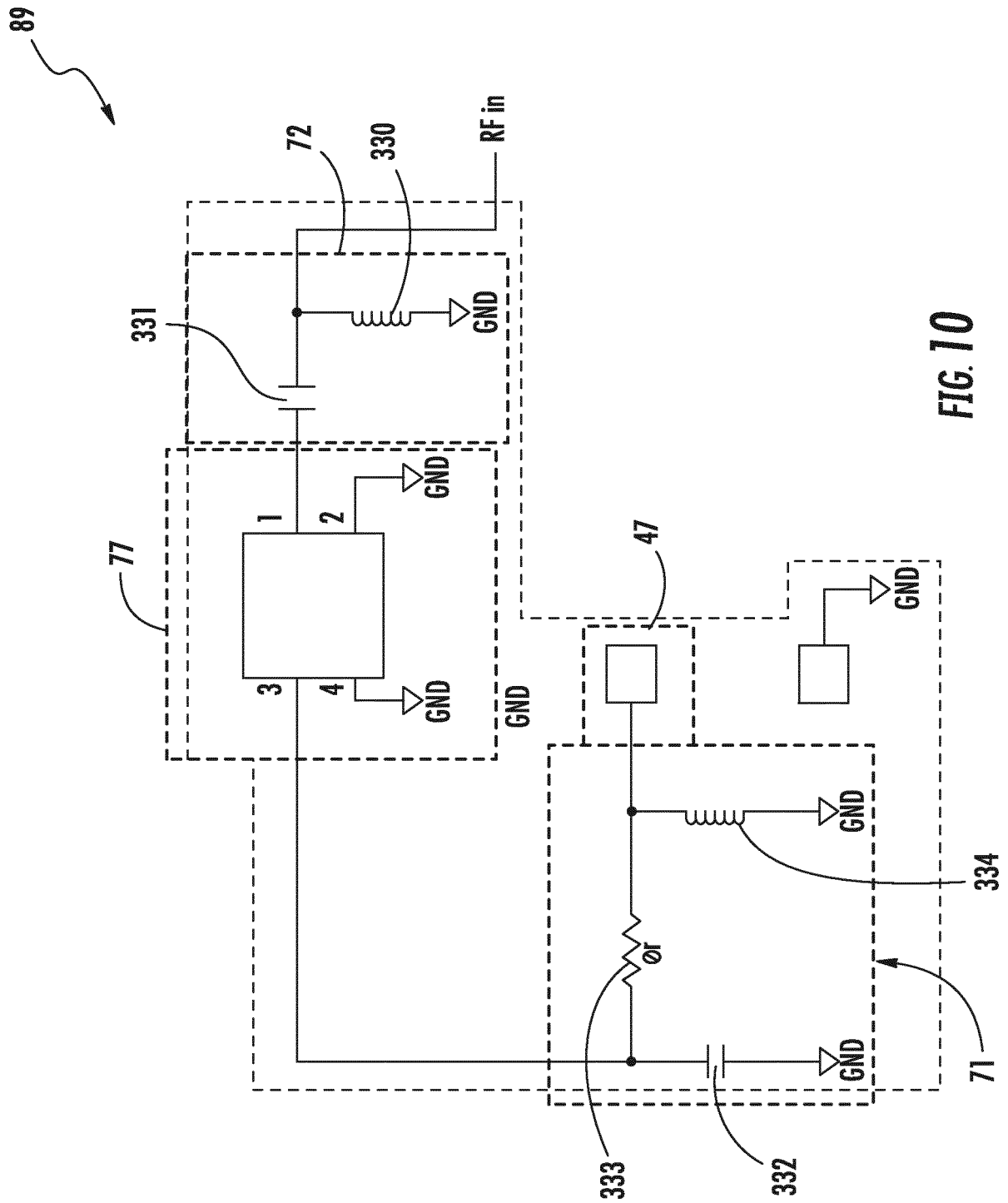


FIG. 10

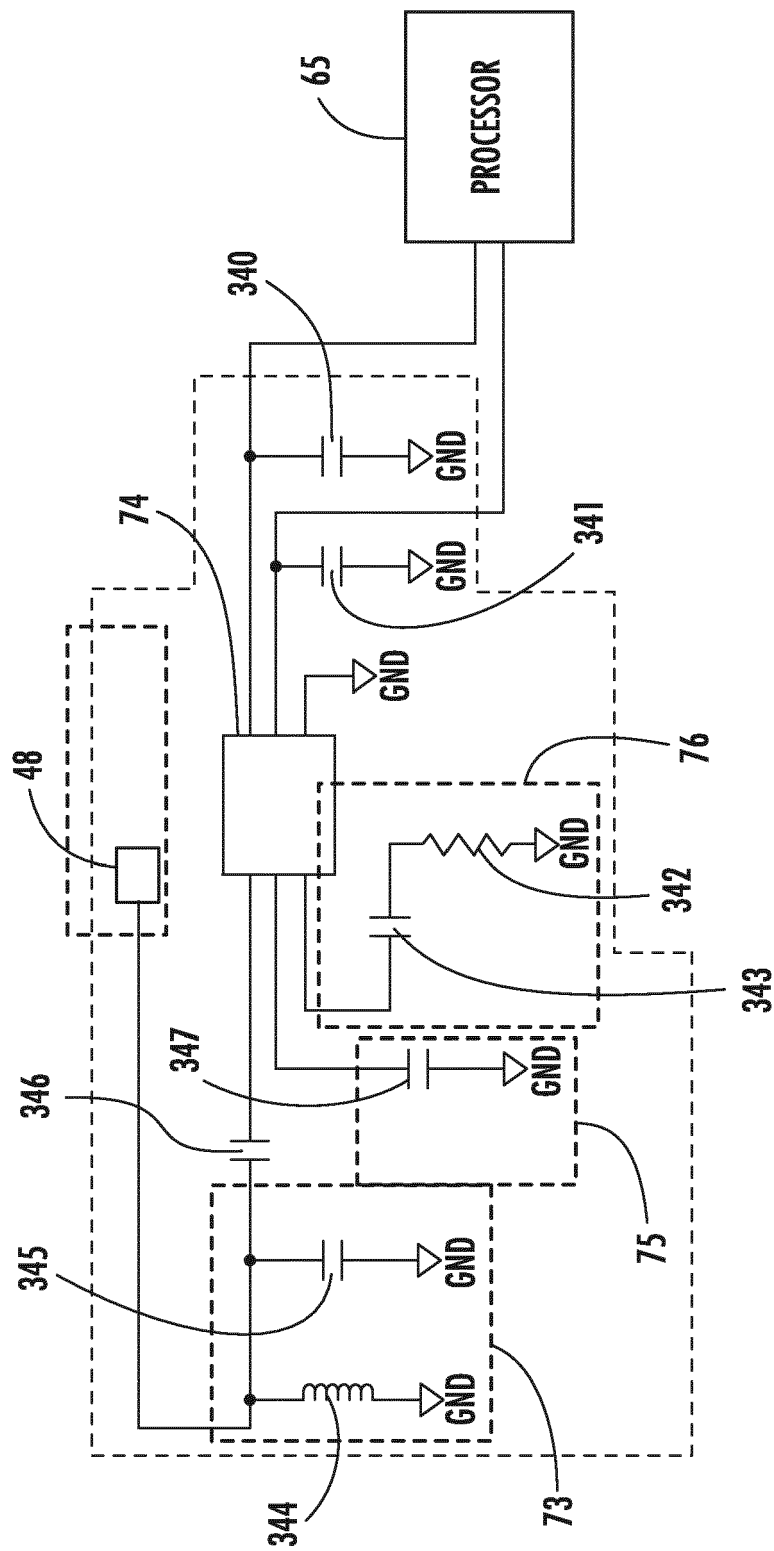
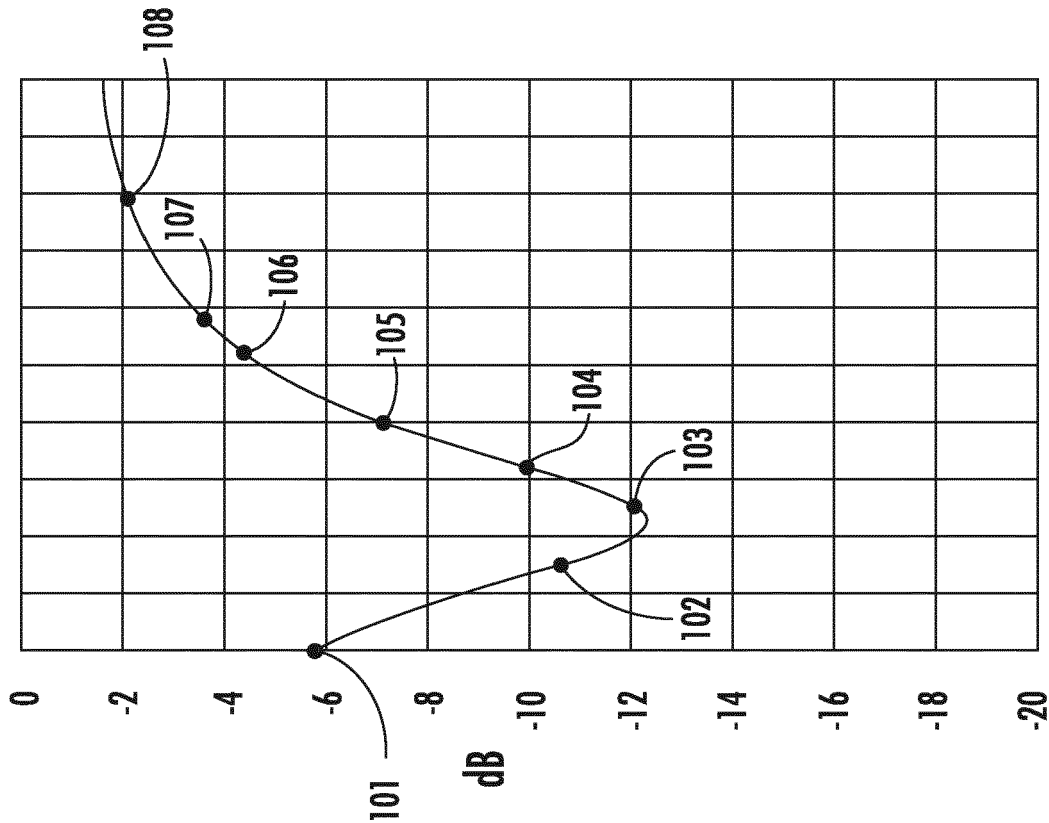


FIG. 11

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FREQUENCY

FIG. 12

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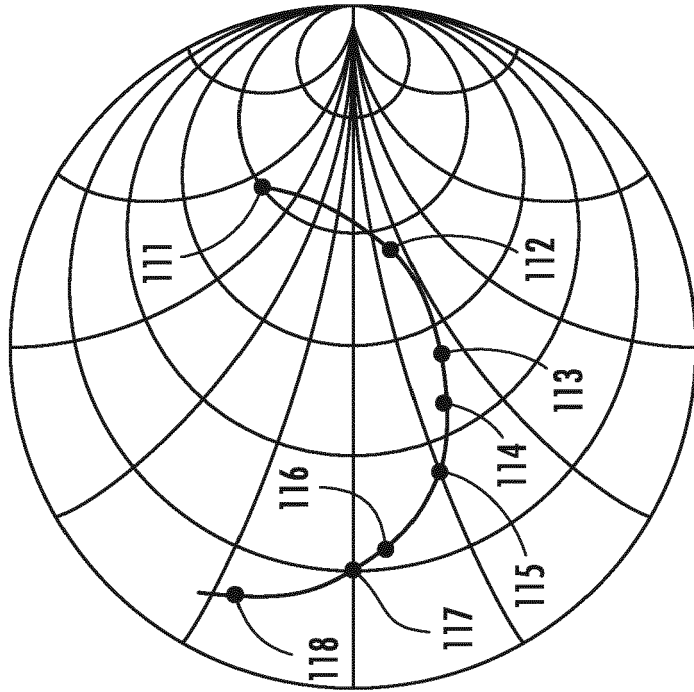
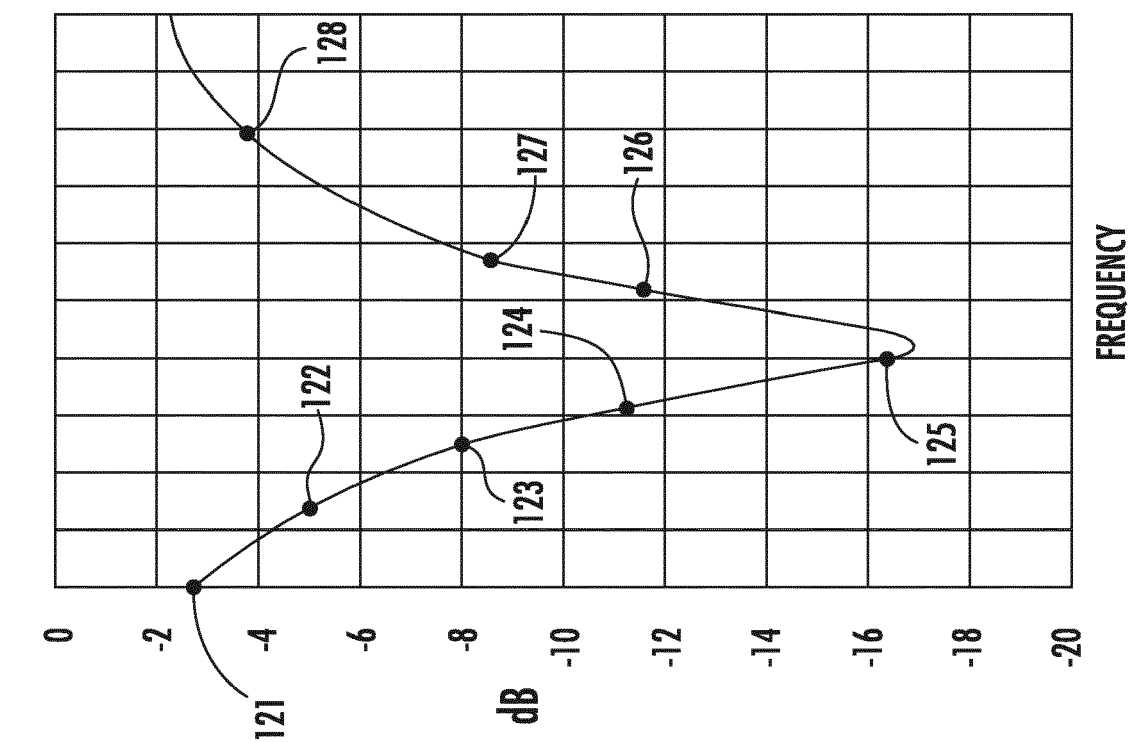
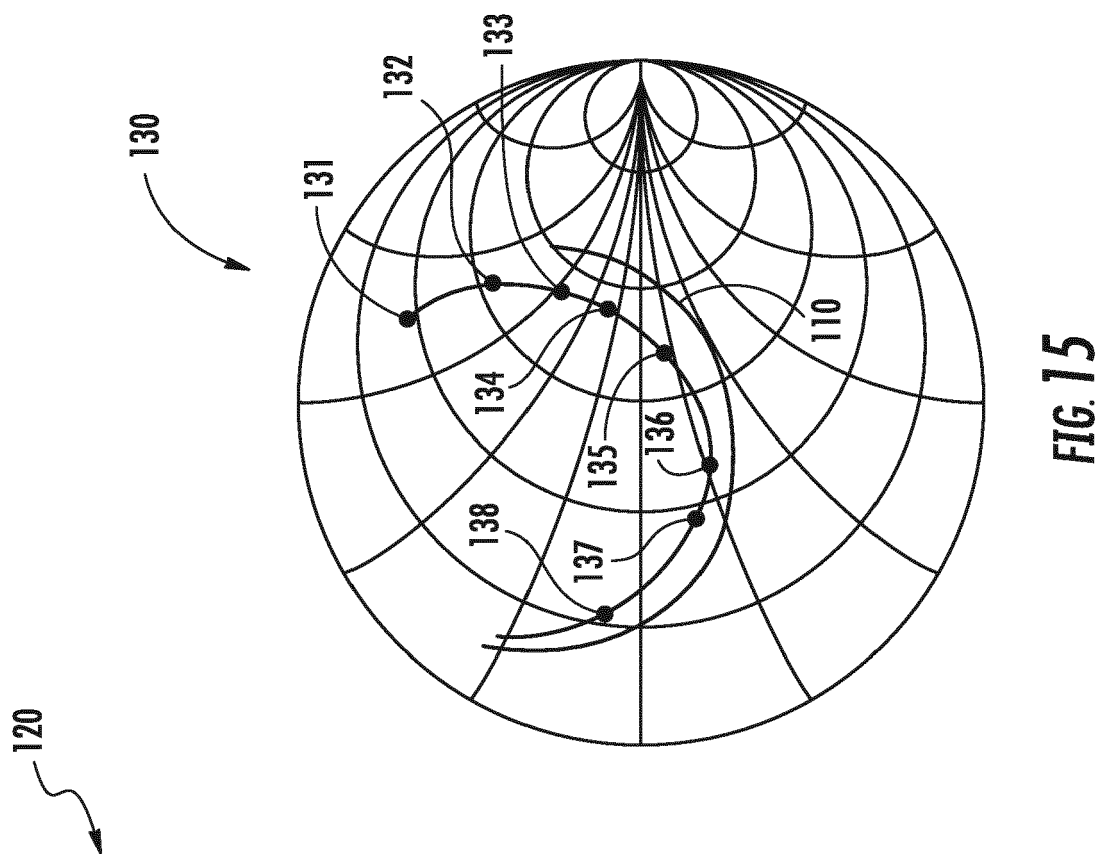


FIG. 13



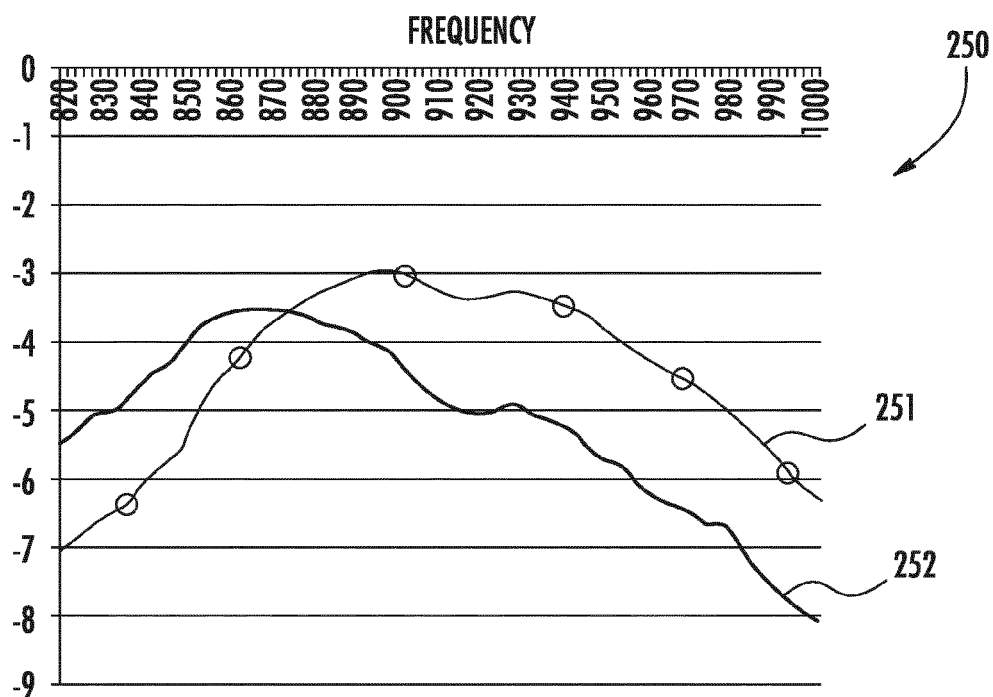


FIG. 16

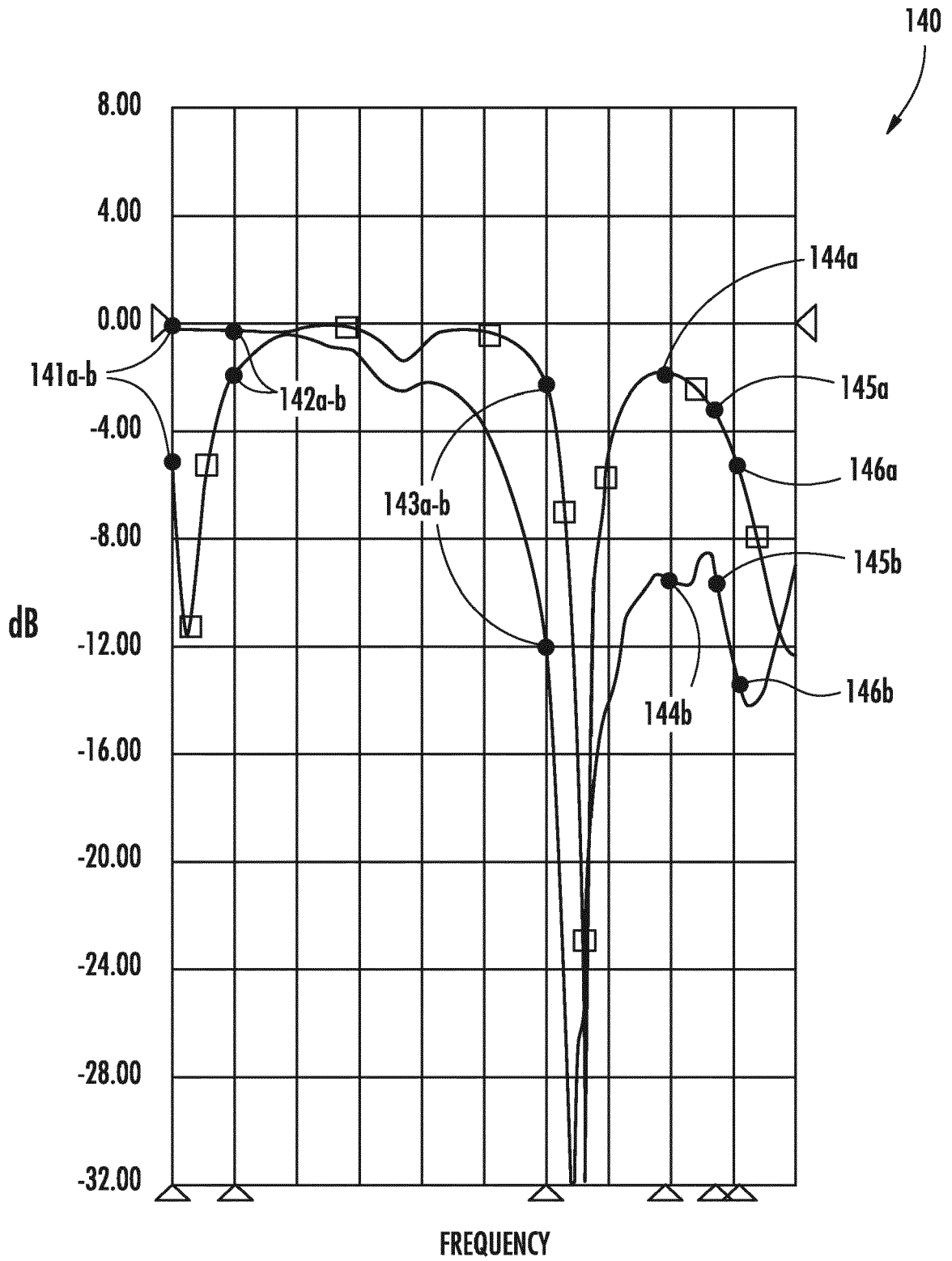


FIG. 17

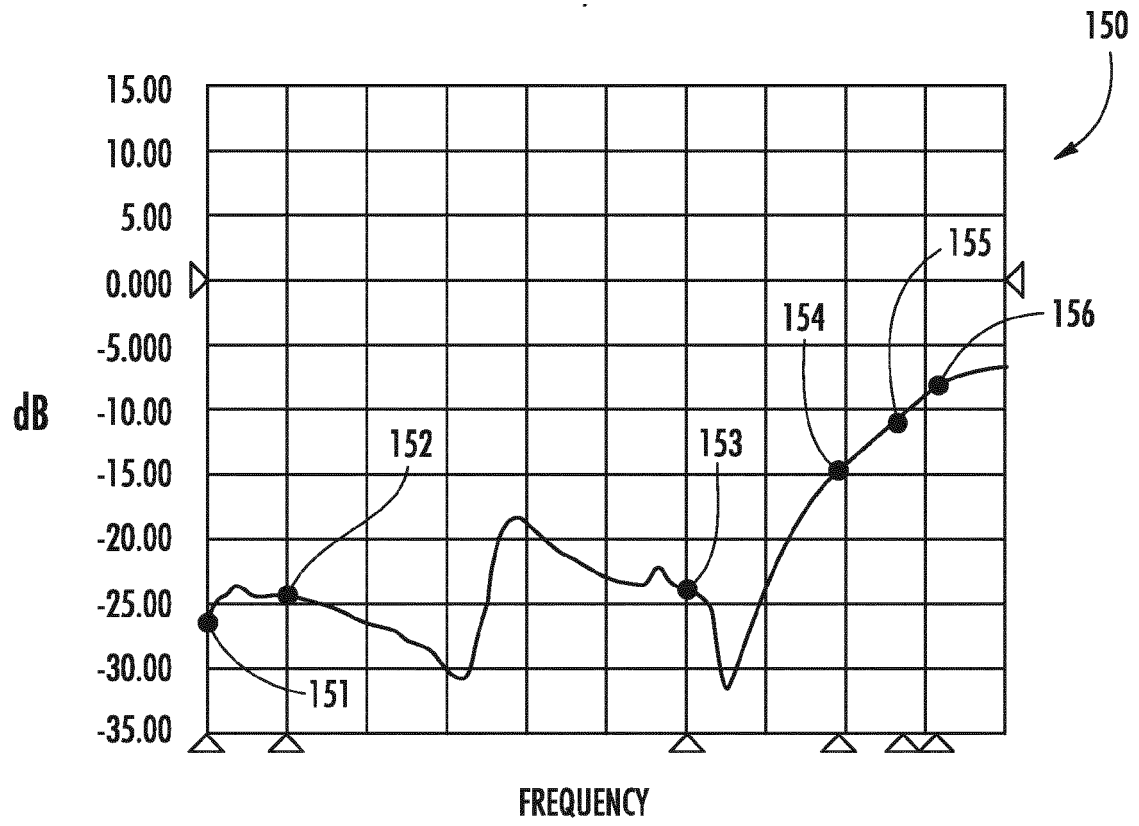


FIG. 18

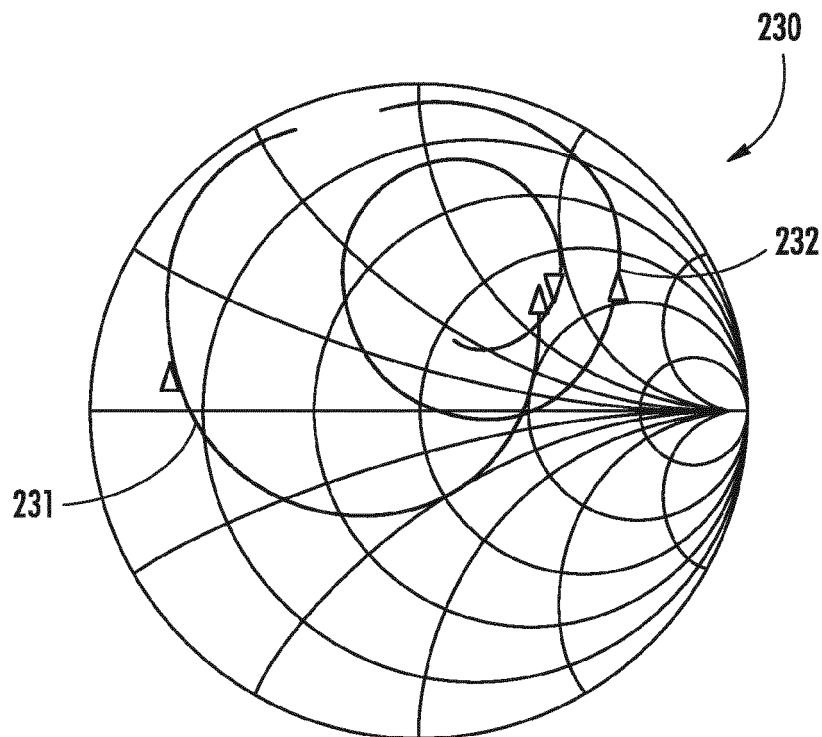


FIG. 19

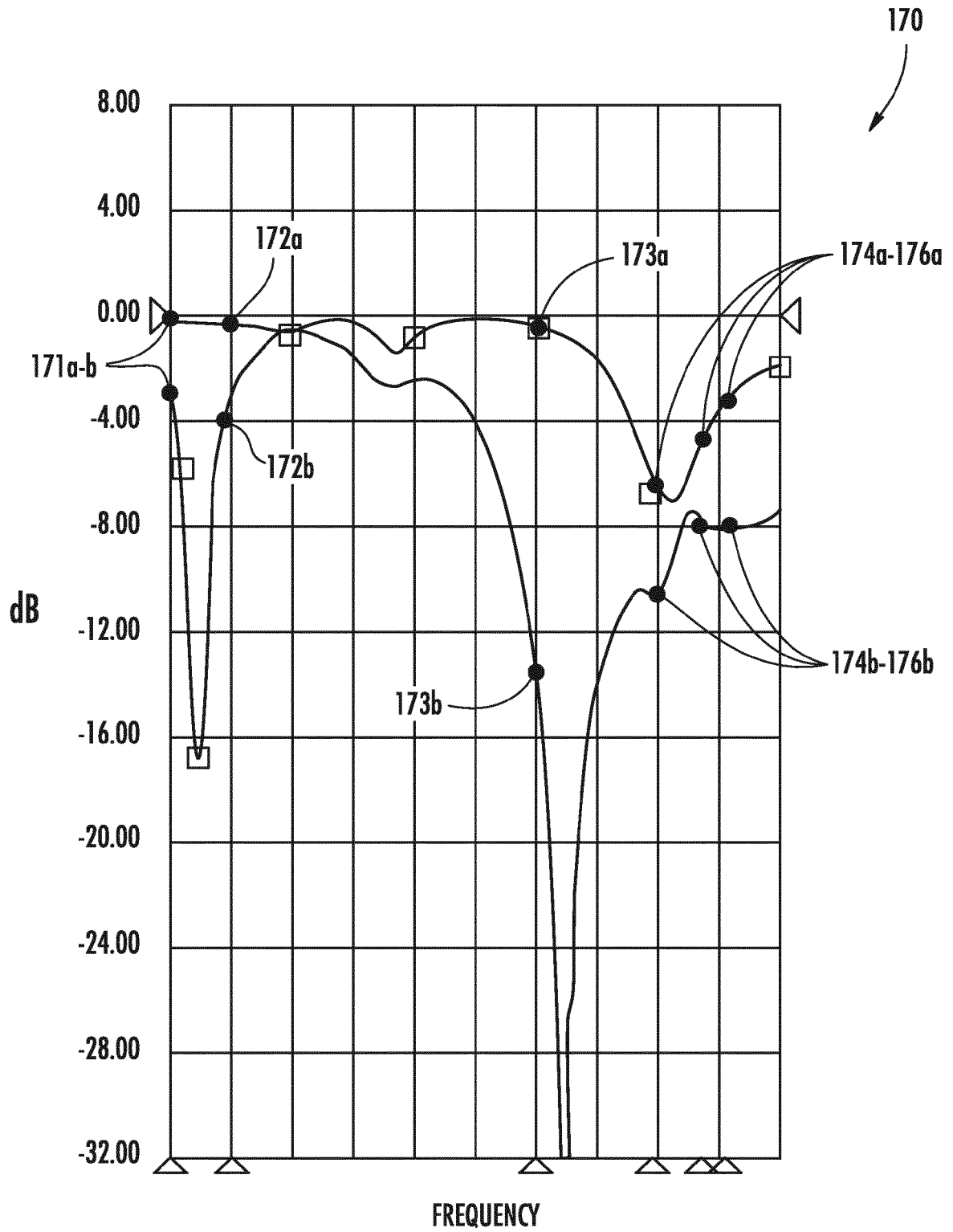


FIG. 20

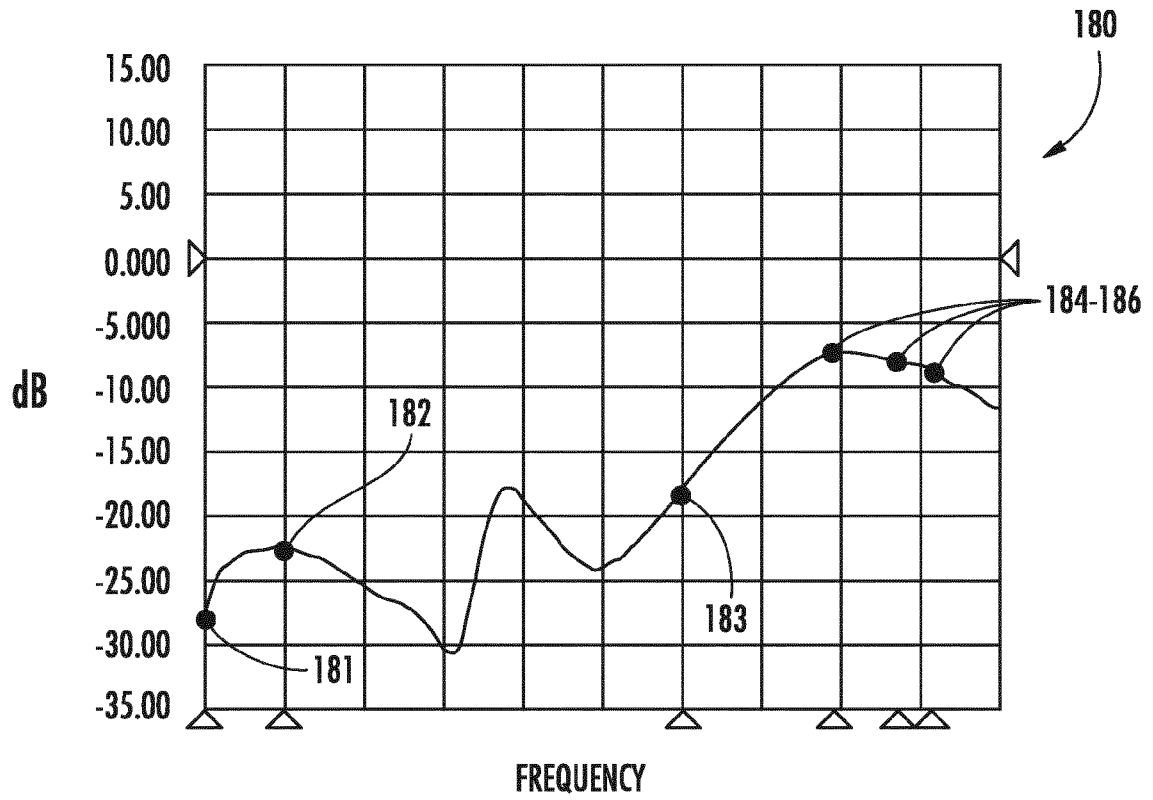


FIG. 21

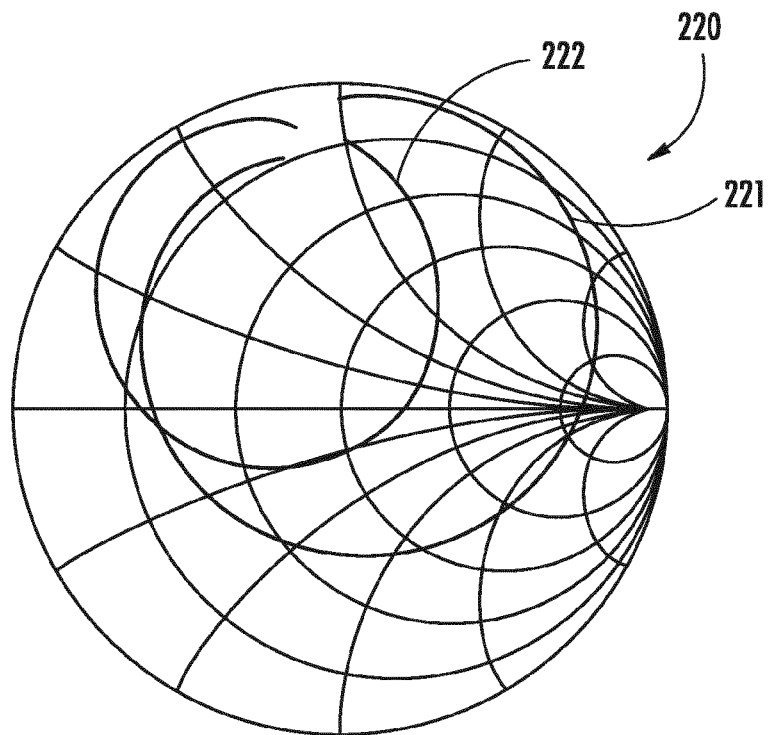


FIG. 22

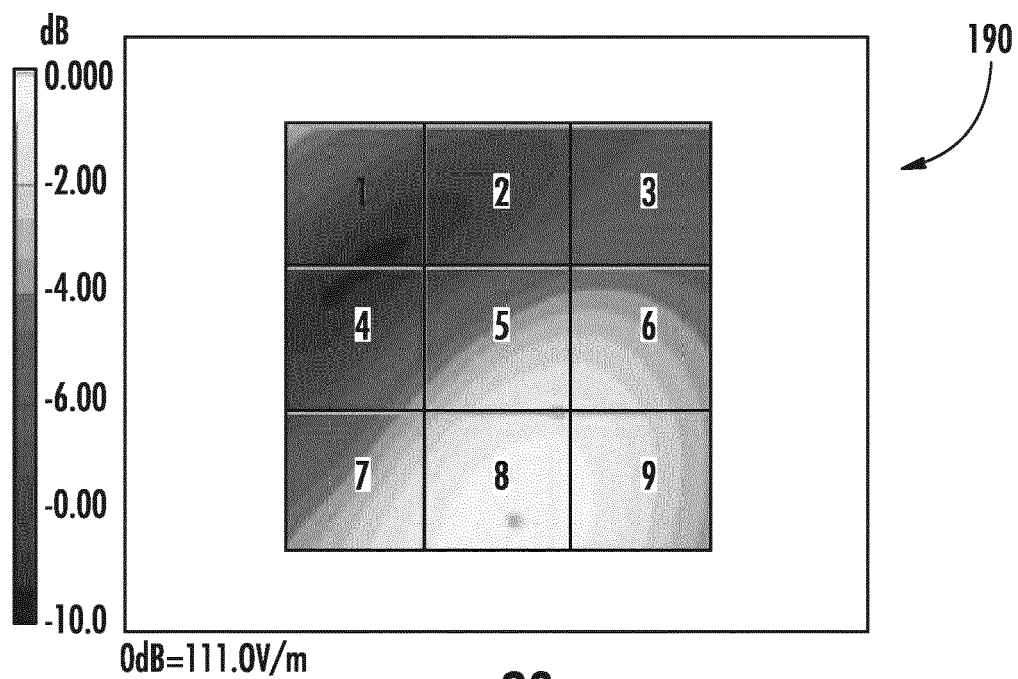


FIG. 23

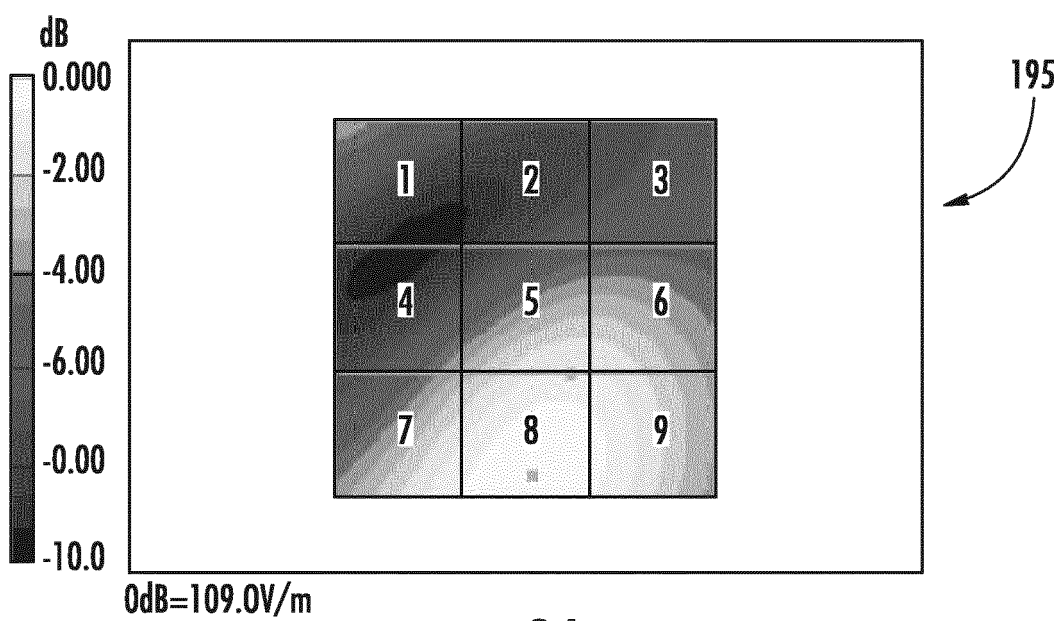


FIG. 24

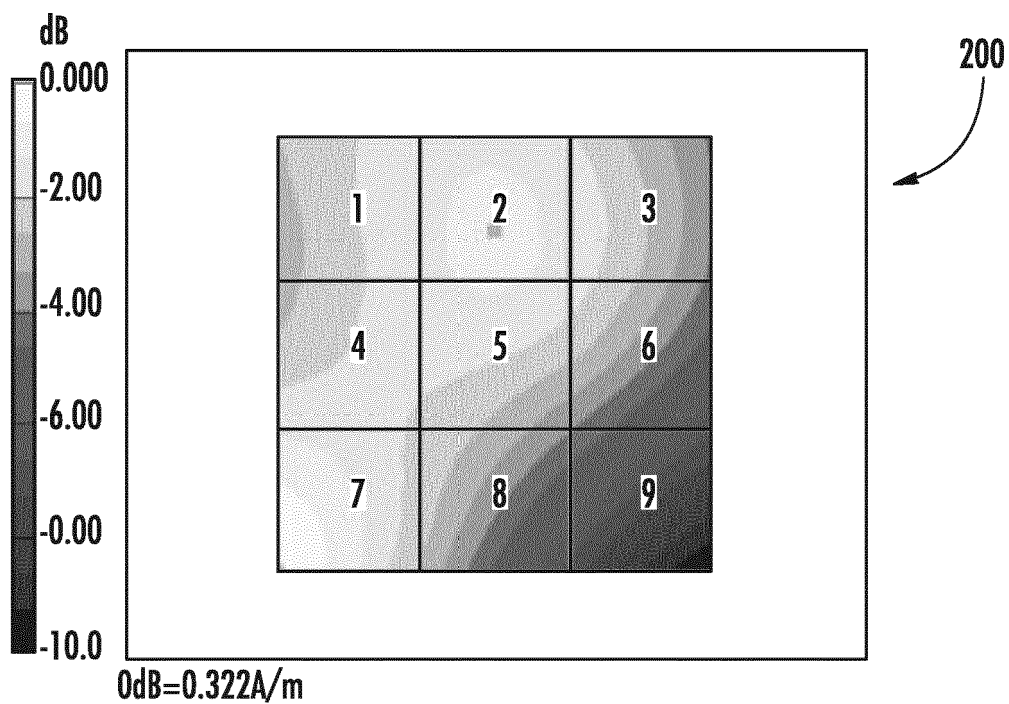


FIG. 25

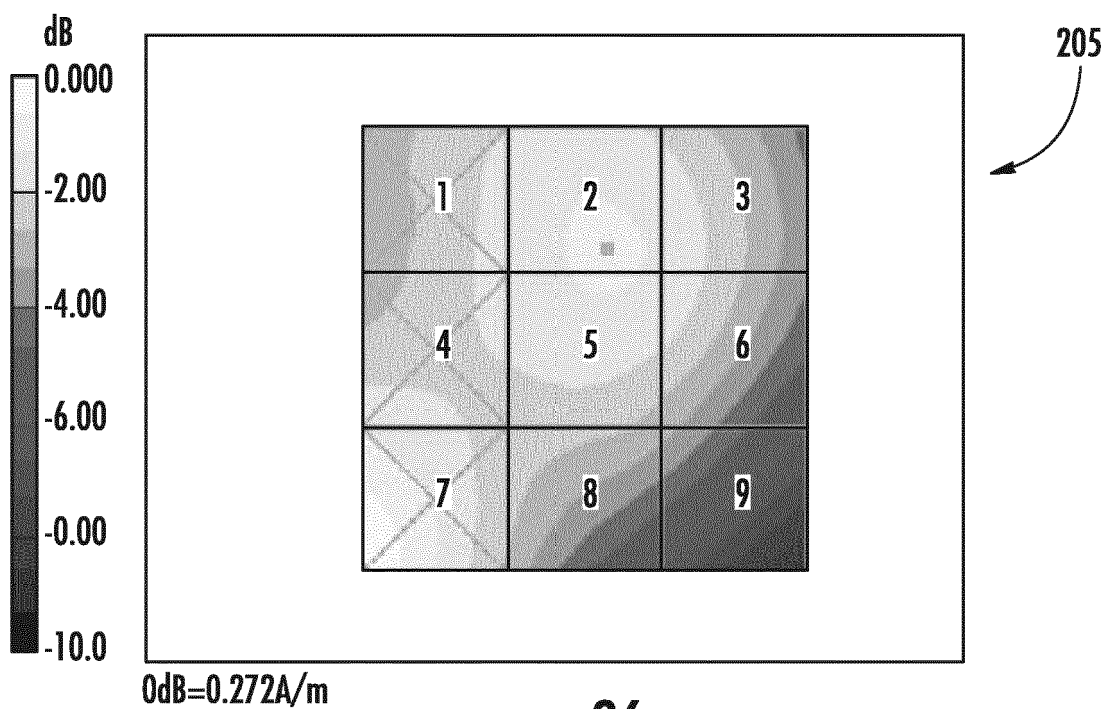


FIG. 26

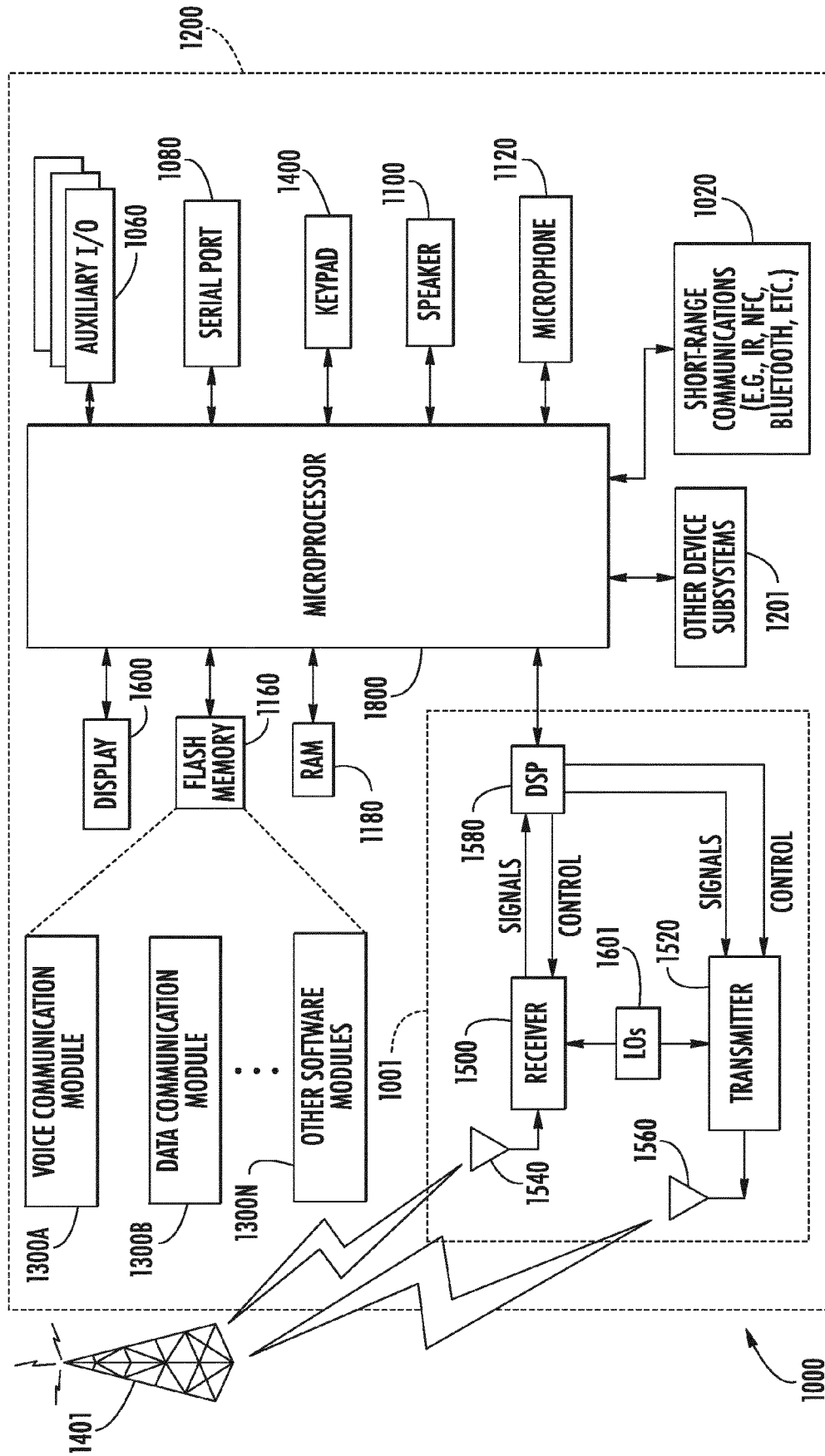


FIG. 27



EUROPEAN SEARCH REPORT

Application Number
EP 12 15 2968

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The present search report has been drawn up for all claims			TECHNICAL FIELDS SEARCHED (IPC)
			H01Q
Place of search		Date of completion of the search	Examiner
The Hague		20 June 2012	Fredj, Aziz
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EPO FORM 1503 03/82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
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