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(54) **Mobile wireless communications device with multiple-band antenna and related methods**

Drahtlose mobile Kommunikationsvorrichtung mit Mehrbandantenne und zugehörige Verfahren

Dispositif de communication mobile sans fil incluant une antenne multi-bande et procédés associés

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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.

[0005] US2008/165063 discloses a Handheld electronic devices are provided that contain wireless communications circuitry having at least first and second antennas. An antenna isolation element reduces signal interference between the antennas, so that the antennas may be used in close proximity to each other. A planar ground element may be used as a ground by the first and second antennas. The first antenna may be formed using a hybrid planar-inverted-F and slot arrangement in which a planar resonating element is located above a rectangular slot in the planar ground element. The second antenna may be formed from an L-shaped strip. The planar resonating element of the first antenna may have first and second arms. The first arm may resonate at a common frequency with the second antenna and may serve as the isolation element.; The second arm may resonate at approximately the same frequency as the slot portion of the hybrid antenna.

[0006] US2004/137950 discloses a build-in, multi band, multi antenna system (1) for a protable communicaiton device (10) has a first antenna (2, 4, 5), which is resonant in first an second frequency band. A secon antenna (3) is resonant in a fourth frequency bank. The first antenna, the papasitic element and the second antenna are provided on a common flexible substrate.

[0007] US7834809 discloses a multi-antenna integration module, which comprises a first antenna, a second antenna and a common unit. The first antenna further comprises a first feeder cable, a first feeder member, a coupling unit, which has a first and second coupling members, and an extension conductor. The second antenna further comprises a second feeder cable, a radiation conductor and a coupling conductor. The common unit further comprises a common conductor which has a first and second conductor, a common short-circuit member and a common ground member.; In the present invention, the design of the common unit integrates the radiation conductors, short-circuit members and ground members of different antenna systems into a single structure, whereby the isolation effect is promoted, and the signal interference among different antennae is decreased, and the space occupied by the antenna layout is reduced.

[0008] US2009/231200 discloses a multi-antenna module comprises a ground plane, a primary conductor, a secondary conductor and a plurality of coupling conductors, wherein the framework of the parallel primary radiation arm and secondary radiation arm can infinitely expand the number of antenna units in the same antenna structure. The capacitive coupling effect of parallel radiation arms and the inductance of the radiation arms themselves can effectively reduce the signal interference between antennae, whereby a plurality of antennae can be integrated to achieve antenna miniaturization. The primary conductor, the secondary conductor and the coupling conductors are all connected to the same ground plane, whereby the layout space is reduced, and the multi-antenna module is easy-to-assemble for various electronic devices.

[0009] The present invention is set out in the independent claims, with some optional features set out in the claims dependent thereto.

Brief Description of the Drawings

[0010]

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

FIG. 2 is a top plan view of an example embodiment of a multiple-band antenna from the mobile wireless communications device of FIG. 1.

FIG. 3 is a side elevation view of the multiple-band antenna of FIG. 2.

FIG. 4 is a top plan view of another example of a multiple-band antenna from the mobile wireless communications device of FIG. 1.

FIG. 5 is a side elevation view of the multiple-band antenna of FIG. 4.

FIG. 6 is a top plan view of yet another example of a multiple-band antenna from the mobile wireless communications device of FIG. 1 with the dielectric substrate removed.

FIG. 7 is a side elevation view of the multiple-band antenna of FIG. 6.

FIG. 8 is a current distribution diagram of an example embodiment of a secondary radiator in an antenna that excites mode 3.

FIG. 9A is a current distribution diagram of an example embodiment of a primary radiator in the mobile wireless communications device in a first mode.

FIGS. 9B-9D are far field patterns of an example embodiment of a primary radiator in the mobile wireless communications device in a first mode.

FIG. 10A is a current distribution diagram of an example embodiment of a primary radiator in the mobile wireless communications device in a second mode.

FIGS. 10B-10D are far field patterns of an example embodiment of a primary radiator in the mobile wireless communications device in a second mode.

FIG. 11A is a current distribution diagram of an example embodiment of a primary radiator in the mobile wireless communications device in a third mode.

FIGS. 11B-11D are far field patterns of an example embodiment of a secondary radiator in the mobile wireless communications device in a third mode.

FIG. 12 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

[0011] 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, and prime notation is used to indicate similar elements in alternative embodiments.

[0012] Generally speaking, a mobile wireless communications device may include a housing, at least one wireless transceiver carried by the housing and having a primary output, and a secondary output, and a multiple-band antenna carried by the housing and coupled to the at least one wireless transceiver. The multiple-band antenna may include a dielectric substrate and a pattern of electrically conductive traces thereon defining a primary radiator and a secondary radiator spaced apart from the primary radiator. The primary radiator may include a first elongate member having a primary feed coupled to the primary output, and a first reference member spaced from the first elongate member and at least partially laterally surrounding the first elongate member and coupled to a reference voltage. The secondary radiator may include a second elongate member having a secondary feed coupled to the secondary output.

[0013] More specifically, the first reference member may comprise a first arm, and a second arm coupled thereto. The first arm may have an L-shape, and the second arm may comprise a proximal portion coupled to the first arm and having an L-shape, and a distal portion extending away from the proximal portion.

[0014] Additionally, the first arm may extend along a bottom of the housing. The second elongate member may have a first arm, and a second arm coupled thereto. The secondary feed may be on the second arm, and the first arm may extend at least partially along a bottom edge of the housing. The dielectric substrate may have a non-planar shape. The dielectric substrate may be carried by a bottom of the housing, and the primary and secondary radiators may be carried by respective opposing first and second sides of the dielectric substrate. For example, the at least one wireless transceiver may comprise a Long Term Evolution (LTE) transceiver configured to operate the primary and secondary outputs in an

LTE carrier aggregation mode.

[0015] Another aspect is directed to a method of making a multiple-band antenna for a mobile wireless communications. The method may comprise forming a multiple-band antenna to comprise a dielectric substrate and a pattern of electrically conductive traces thereon defining a primary radiator and a secondary radiator spaced apart from the primary radiator. The primary radiator may comprise a first elongate member having a primary feed coupled to the primary output, and a first reference member spaced from the first elongate member and at least partially laterally surrounding the first elongate member and coupled to a reference voltage. The secondary radiator may comprise a second elongate member having a secondary feed coupled to the secondary output.

[0016] Referring initially to FIGS. 1-3, a mobile wireless communications device **20** according to the present disclosure is now described. The mobile wireless communications device **20** illustratively includes a housing **22,** a wireless transceiver **21** carried by the housing and having a primary and secondary outputs **55, 56,** and a multiple-band antenna **23** carried by the housing and coupled to the wireless transceiver. For example, the wireless transceiver **21** may comprise an LTE transceiver configured to operate the primary and secondary outputs **55, 56** in an LTE carrier aggregation mode. In the illustrated embodiment, the multi-band antenna **23** may operate the primary output **55** at: LTE Band 7, 3, 8, 20, Primary; Wideband Code Division Multiple Access (WCDMA) Band 1, 2, 5, 8, Primary; Global System for Mobile Communications (GSM) 850, 900, 1800, 1900; and operate the secondary output **56** at LTE Band 7, 3, 8, 20, Multiple Input Multiple Output (MIMO); WCDMA Band 1, 2, 5, 8 Diversity.

[0017] The multiple-band antenna **23** illustratively includes a dielectric substrate **24** and a pattern of electrically conductive traces thereon defining a primary radiator **26** and a secondary radiator **25** spaced apart from the primary radiator. The dielectric substrate **24** illustratively includes a non-planar shape, which illustratively fits the interior portions of the housing **22.** The dielectric substrate **24** may be carried by a bottom of the housing **22,** and the primary and secondary radiators **26, 25** may be carried by respective opposing first and second sides of the dielectric substrate.

[0018] The primary radiator **26** illustratively includes a first elongate member **32** having a primary feed **27** coupled to the primary output **55.** The primary radiator **26** illustratively includes a first reference member **33** (e.g. ground reference member) spaced from the first elongate member **32** and at least partially laterally surrounding the first elongate member and coupled to a reference voltage (e.g. ground). The secondary radiator **25** illustratively includes a second elongate member having a secondary feed **31** coupled to the secondary output **56.** More specifically, the first reference member **33** illustratively includes a first arm **35,** and a second arm **51** coupled thereto.

[0019] In detail, the first elongate member **32** has a substantially rectangular-shape, and extends in parallel with the first arm **35** of the first reference member **33** (bending upward slightly). The first elongate member **32** illustratively includes a top portion defining a recess **57,** and a protruding portion **58** partially extending across the recess and including the primary feed **27.**

[0020] The first arm **35** of the first reference member **33** is substantially rectangle-shaped, and illustratively includes a proximal portion **59,** and a distal portion **60** coupled thereto and having an enlarged width. The distal portion **60** also defines a notch **61** having parallel sides, and a curved end. Additionally, the first arm **35** extends along a bottom of the housing **22.**

[0021] The second arm **51** comprises a proximal portion **41** coupled to the first arm **35** and having an L-shape, and a distal portion **42** extending away from the proximal portion and having a rectangular-shape. The distal portion **42** illustratively includes a reference connection **28** (e.g. ground connection), and defines a recess **62** having a curved end. The proximal and distal portions **41, 42** have straight sides.

[0022] The first reference member **33** illustratively includes a third arm **47** extending almost entirely across the bottom edge of the dielectric substrate **24.** The third arm **47** illustratively includes a proximal portion **62,** and a distal portion **63** coupled thereto. The proximal portion **62** is rectangle-shaped, and the distal portion **63** is also rectangle-shaped. The distal portion **63** illustratively includes a greater width than that of the proximal portion **62** and has a rectangle-shaped notch **64** adjacent a corner thereof. The distal portion **63** also illustratively defines a square-shaped opening **65.**

[0023] The second elongate member illustratively includes a first arm **46,** and a second arm **34** coupled thereto. The secondary feed **31** illustratively is on the second arm **34,** and the first arm **46** may extend at least partially along a bottom edge of the housing **22.** In particular, the first arm **46** illustratively includes rectangle-shaped proximal and distal portions **66, 67,** the distal portion defining a rectangle-shaped recess **68** on a side thereof. The second arm **34** illustratively includes a proximal portion **110,** a medial portion **111** coupled to the proximal portion, and a distal portion **112** coupled to the medial portion. The proximal portion **110** is rectangle-shaped, and the medial portion **111** is U-shaped. The distal portion **112** comprises an L-shaped portion coupled to the medial portion **111,** and a rectangle-shaped portion coupled to the L-shaped portion.

[0024] Another aspect is directed to a method of making a multiple-band antenna **23** for a mobile wireless communications **20.** The method may comprise forming a multiple-band antenna **23** to comprise a dielectric substrate **24** and a pattern of electrically conductive traces thereon defining a primary radiator **26** and a secondary radiator **25** spaced apart from the primary radiator. The primary radiator **26** may comprise a first elongate member having a primary feed **27** coupled to the primary output, and a first reference member **33** spaced from the first elongate member and at least partially laterally surrounding the first elongate member and coupled to a reference voltage. The secondary radiator **25** may comprise a second elongate member having a secondary feed **31** coupled to the secondary output.

[0025] Referring now additionally to FIGS. 4-5, another embodiment of the multiple-band antenna **23'** is now described. In this embodiment of the multiple-band antenna **23',** those elements already discussed above with respect to FIGS. 1-3 are given prime notation and most require no further discussion herein. This embodiment differs from the previous embodiment in that the first arm **35'** illustratively has an L-shape, and uniform width throughout. The first arm **35'** also does not include the recess from the embodiments of FIGS. 2-3. The third arm **47'** also does not include the notch of the prior embodiment, but does include an L-shaped turn **120'** in a medial portion thereof. The second arm **34'** of the secondary radiator **25'** illustratively includes a single L-shaped turn **121',** rather the multiple turns of the prior embodiments. In the illustrated embodiment, the multi-band antenna **23'** may operate the primary output **55'** at: LTE Band 4, 13 Primary; CDMA 1x Voice, EVDO Diversity; WCDMA Band 1, 2, 5, 8 Primary; GSM 850, 900, 1800, 1900; and operate the secondary output **56'** at: LTE Band 13 MIMO; CDMA 1x Voice Primary; and CDMA 1x EVDO Diversity.

[0026] Referring now additionally to FIGS. 6-7, another embodiment of the multiple-band antenna **23"** is now described. In this embodiment of the multiple-band antenna **23",** those elements already discussed above with respect to FIGS. 1-3 are given double prime notation and most require no further discussion herein. This embodiment differs from the previous embodiment in that the third arm **47"** includes the rectangle-shaped recess **64"** in a medial portion rather than the corner of the embodiment of FIGS. 2-3. Also, the secondary radiator **25"** has a general C-shape including the first and second arms **46", 34".** The first arm **46"** illustratively includes a pair of rectangle-shaped branches **115', 116'.** The second arm **34"** illustratively has an L-shape and is rectangle-shaped throughout. In the illustrated embodiment, the multi-band antenna **23"** may operate the primary output **55"** at: LTE Band 2, 4, 5, 17 Primary; WCDMA Band 1, 2, 5, 8 Primary; GSM 850, 900, 1800, 1900; and operate the secondary output **56"** at: LTE Band 2, 4, 5, 17 MIMO; WCDMA Band 1, 2, 5, 8 Diversity.

[0027] With regards to the operating bands of the embodiments of FIGS. 2-7, the operating frequencies are shown in Table 1 herein.

Band	Frequency Range (MHz)
LTE 17	704 – 746
LTE 13	746 – 777
LTE 20	791 – 862
LTE/WCDMA 5 GSM 850 CDMA 1x Cell	824 – 894
LTE/WCDMA 8 GSM 900	880 – 960
LTE 3 LTE/WCDMA 4 Tx GSM 1800	1710 – 1880
LTE/WCDMA 2 GSM 1900 CDMA 1x PCS	1850 – 1990
WCDMA 1	1920 – 2170
LTE 7	2500 – 2690

Table 1: Operating Frequencies

Theory of Operation

[0028] The basis of this multiple-band antenna **23** relies on exciting different characteristics modes in the chassis of the mobile wireless communications device **20.** Characteristics modes describe the current distribution and far field radiation that are unique to a given conducting body at a specific frequency. In theory, a metallic object could possess infinite number of characteristic mode for a given frequency, however not all modes are excitable in practice. Mathematically, characteristics modes on a metal object are precisely described by the following close boundary problem:

$$[L(J) - E] = 0;$$

where the operator L is defined as

$$L(J) = j\omega A(J) - \nabla\Phi(J);$$

and
A and Φ are the vector and scalar potentials due to a given current distribution respectively.

[0029] Since A and Φ are integrals defined over the closed surface, the problem can be rewritten in terms of impedances and arrive at the eigenvalues problem as

$$Z(J) = L(J);$$

and

$$Z(J) = vM(J);$$

where matrix M is a symmetric matrix that diagonalizes the matrix Z, *v* are the eigenvalues, and J are the eigenvectors. A characteristic mode refers to a given set of eigenvalue and eigenvector.

[0030] By definition, the eigenvectors associated with a particular conducting body are orthogonal to each other and must satisfy the orthogonality relationships $\langle J_m | Z J_n \rangle = 0$, for $m \neq n$.
In other words, the current distribution and radiation pattern of one mode is un-correlated to the current distribution and radiation pattern of another mode, even though there is only one radiating element. By exploiting this orthogonality principle of characteristic modes, the multiple-band antenna **23** can achieve low correlation at low frequencies despite having only one radiator and it is this particular property that enables this feature. More specifically, the first elongate member **32**
in N-series excites a dominant mode 1 (v_1,J_1) and the secondary radiator **25** excites a dominant mode 3 (v_3,J_3).

[0031] Referring now to FIGS. 8-11D, diagram **77** shows the current distribution, and diagrams **79, 81, 83** show the far field patterns for the mobile wireless communications device **20** while in mode 1 at 704 MHz. Diagram **85** shows the current distribution, and diagrams **87, 89, 91** show the far field patterns for the mobile wireless communications device **20** while in mode 2 at 704 MHz. Diagrams **93, 70** show the current distribution, and diagrams **95, 97, 99** show the far field patterns for the mobile wireless communications device **20** while in mode 3 at 704 MHz.

[0032] The multiple-band antenna **23** may exploit the natural resonances, known as characteristics modes, of an arbitrary metallic object to achieve low correlation between multiple antennas in a MIMO system. Typical MIMO systems may rely on an antenna array where the antenna elements are usually separated from each other by half of a wavelength. For low frequency LTE bands, such as Band 17 (704 MHz - 746 MHz) or Band 13 (746 MHz - 777 MHz), the half wavelength spatial separation may not be achievable in handheld devices, such as a smartphone where the overall dimension of the device is on the order of a quarter wavelength of the operating wavelength. Low frequency is particularly interesting because radiation at low frequencies is predominantly due to the mobile device's chassis and the antenna element serves as an excitation element. Consequently, the current distributions excited by each antenna element in a MIMO system share one radiator, i.e. the chassis of the device. This is in conflict to the multi-antenna requirement of MIMO because multiple antennas usually mean that there are multiple radiating elements, which may not be true in a handset. The multiple-band antenna **23** may relax this requirement and enable: high performance MIMO with a single radiating element; and systematic antenna element placement with minimal correlation and gain imbalance.

[0033] With regards to Table 2 below, the measured performance of the multi-band antenna **23** in varying operating frequencies is shown. Of particular interest is the LTE MIMO and Correlation section, which demonstrate the low correlation values achieved with the multi-band antenna **23.**

Verizon

LTE Rx are 10MHz BW

Voice	Conducted Power	TRP	Required Gain	Measured Gain			Conducted Sensitivity	TIS	Required Gain	Measured Gain		
Cell (FS)	24	18	-6	-4.6	-5.0	-5.4	-108	-101	-7	-5.4	-5.3	-5.2
			Margin	1.4	1.0	0.6			Margin	1.6	1.8	1.8
PCS (FS)	24	19	-5	-5.1	-4.8	-4.9	-107	-101	-6	-5.2	-5.7	-6.0
			Margin	-0.1	0.3	0.1			Margin	0.8	0.3	0.0

EVDO	Conducted Power	TRP	Required Gain	Measured Gain			Conducted Sensitivity	TIS	Required Gain	Measured Gain		
Cell (FS)	24	18	-6	-4.6	-5.0	-5.4	-109.5	-102.5	-7	-5.4	-5.3	-5.2
			Margin	1.4	1.0	0.6			Margin	1.6	1.8	1.8
PCS (FS)	24	19	-5	-5.1	-4.8	-4.9	-108.5	-102.5	-6	-5.2	-5.7	-6.0
			Margin	-0.1	0.3	0.1			Margin	0.8	0.3	0.0

LTE	Conducted Power	TRP	Required Gain	Measured Gain			Conducted Sensitivity	TIS	Required Gain	Measured Gain		
Band 13	23.5	18	-5.5	-5.2	-5.0	-5.5	-98.5	-91	-7.5	-6.6	-6.3	-5.8
			Margin	0.3	0.5	0.0			Margin	0.9	1.2	1.8
Band 4	23.5	19	-4.5	-4.3	-3.8	-3.8	-97	-91	-6	-4.1	-4.3	-4.7
			Margin	0.2	0.7	0.7			Margin	1.9	1.7	1.3

LTE MIMO	Conducted Sensitivity	TIS	Required Gain	Measured Gain			Delta with Primary		
Band 13	-98.7	-88	-10.7	-9.8	-9.7	-9.3	3.2	3.4	3.6
			Margin	0.9	1.0	1.4			
Band 4	-97	-88	-9.0	-9.0	-7.9	-7.3	4.9	3.6	2.6
			Margin	0.0	1.1	1.7			

Correlation	Required	Measured		
Band 13	0.5	0.33	0.32	0.32
	Margin	0.17	0.18	0.18
Band 4	0.5	0.06	0.07	0.06
	Margin	0.44	0.43	0.44

Diversity	Conducted Sensitivity	TIS	Required Gain	Measured Gain			Delta with Primary		
Cell (FS)	-108	-95	-13	-9.2	-9.3	-9.3	3.8	4.1	4.0
			Margin	3.8	3.7	3.7			
PCS (FS)	-107	-95	-12	-3.7	-3.9	-3.6	1.5	1.9	2.4
			Margin	8.3	8.1	8.4			

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.**

[0034] The housing **1200** may be elongated vertically, or may take on other sizes and shapes (including clamshell housing structures). The keypad may include a mode selection key, or other hardware or software for switching between text entry and telephony entry.

[0035] In addition to the processing device **1800,** other parts of the mobile device **1000** are shown schematically in FIG. 12. 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.

[0036] 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.**

[0037] 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.

[0038] 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 TAC™ 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.

[0039] 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.

[0040] 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.**

[0041] 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.**

[0042] 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.**

[0043] 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.

[0044] 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.

[0045] 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 multiple-band antenna (23) for a mobile wireless communications device (20) comprising a housing (22), and at least one wireless transceiver (21) carried by the housing, said multiple-band antenna comprising:

   a dielectric substrate and a pattern of electrically conductive traces thereon defining a primary radiator (26) and a secondary radiator (25) spaced apart from said primary radiator,
   said primary radiator comprising
   a first elongate member (32) comprising a protruding portion (58) having a primary feed (27) coupled to a primary output (55) and defining a recess (57), the protruding portion partially extending across the recess, and
   a first reference member (33) spaced from said first elongate member and at least partially laterally surrounding said first elongate member and coupled to a reference voltage,
   said secondary radiator comprising a second elongate member having a secondary feed (31) coupled to a secondary output (56);
   wherein said first reference member comprises a first arm (35), and a second arm (51) coupled thereto;
   the first arm (35) of the first reference member (33) is rectangular-shaped, and includes a proximal portion (59), and a distal portion (60) coupled thereto and **characterised in** having an enlarged width, in which the distal portion (60) defines a notch (61) having parallel sides, and a curved end.

2. The multiple band antenna of claim 1, when coupled by a housing (22) and coupled to a wireless transceiver (21), the wireless transceiver and housing forming part of a mobile wireless communications device.

3. The multiple band antenna of claim 1, wherein said first arm has an L-shape; and wherein said second arm comprises a proximal portion (41) coupled to said first arm and having an L-shape, and a distal portion (42) extending away from said proximal portion.

4. The multiple band antenna of claim 1, wherein said first arm extends along a bottom of said housing.

5. The multiple band antenna of claim 1, wherein said second elongate member has a first arm (46), and a second arm (34) coupled thereto.

6. The multiple band antenna of claim 5, wherein said secondary feed is on said second arm; and wherein said first arm extends at least partially along a bottom edge of said housing.

7. The multiple band antenna of claim 1, wherein said dielectric substrate has a non-planar shape.

8. The multiple band antenna of claim 1, wherein said dielectric substrate is carried by a bottom of said housing; and wherein said primary and secondary radiators are carried by respective opposing first and second sides of said dielectric substrate.

9. The multiple band antenna of claim 1, wherein said at least one wireless transceiver comprises a Long Term Evolution (LTE) transceiver configured to operate said primary and secondary outputs in an LTE carrier aggregation mode.

10. A method of making a multiple-band antenna (23) for a mobile wireless communications device (20) comprising:

   forming a multiple-band antenna to comprise a dielectric substrate and a pattern of electrically conductive traces thereon defining a primary radiator (26) and a secondary radiator (25) spaced apart from the primary radiator;
   the primary radiator comprising
   a first elongate member (32) comprising a protruding portion (58) having a primary feed (27) coupled to a primary output (55) and defining a recess (57), the protruding portion partially extending across the recess, and
   a first reference member (33) spaced from the first elongate member and at least partially laterally surrounding the first elongate member and coupled to a reference voltage;
   the secondary radiator comprising a second elongate member having a secondary feed (31) coupled to a secondary output (56);
   wherein said first reference member comprises a first arm (35), and a second arm (51) coupled thereto;
   the first arm (35) of the first reference member (33) is rectangular-shaped, and includes a proximal portion (59), and a distal portion (60) coupled thereto and having an enlarged width, in which the distal portion (60) defines a notch (61) having parallel sides, and a curved end.

11. The method of claim 10, wherein the first arm has an L-shape; and wherein the second arm comprises a proximal portion (41) coupled to the first arm and having an L-shape, and a distal portion (42) extending away from the proximal portion.

Patentansprüche

1. Eine Mehrbandantenne (23) für eine mobile drahtlose Kommunikationsvorrichtung (20), die ein Gehäuse (22) und zumindest einen drahtlosen Transceiver (21) aufweist, der von dem Gehäuse getragen wird, wobei die Mehrbandantenne aufweist:

ein dielektrisches Substrat und ein Muster aus elektrisch leitenden Bahnen darauf, die einen primären Radiator (26) und einen sekundären Radiator (25) definieren, der von dem primären Radiator beabstandet ist;
wobei der primäre Radiator aufweist
ein erstes längliches Element (32), das einen vorstehenden Teil (58) mit einer primären Zufuhr (27) aufweist, die mit einem primären Ausgang (55) gekoppelt ist und eine Aussparung (57) definiert, wobei sich der vorstehende Teil teilweise über die Aussparung erstreckt, und
ein erstes Referenzelement (33), das von dem ersten länglichen Element beabstandet ist und das erste längliche Element zumindest teilweise seitlich umgibt und mit einer Referenzspannung gekoppelt ist;
wobei der sekundäre Radiator ein zweites längliches Element aufweist mit einer sekundären Zufuhr (31), die mit einem sekundären Ausgang (56) gekoppelt ist;
wobei das erste Referenzelement einen ersten Arm (35) und einen zweiten Arm (51) aufweist, der damit gekoppelt ist;
wobei der erste Arm (35) des ersten Referenzelements (33) eine rechteckige Form hat und einen proximalen Teil (59) und einen distalen Teil (60) umfasst, der damit gekoppelt ist und **dadurch gekennzeichnet ist, dass** er eine vergrößerte Breite hat, in der der distale Teil (60) eine Kerbe (61) definiert mit parallelen Seiten und einem gebogenen Ende.

2. Die Mehrbandantenne gemäß Anspruch 1, wenn durch ein Gehäuse (22) gekoppelt und mit einem drahtlosen Transceiver (21) gekoppelt, der drahtlose Transceiver und das Gehäuse einen Teil einer mobilen drahtlosen Kommunikationsvorrichtung bilden.

3. Die Mehrbandantenne gemäß Anspruch 1, wobei der erste Arm eine L-Form hat; und wobei der zweite Arm einen proximalen Teil (41) aufweist, der mit dem ersten Arm gekoppelt ist und eine L-Form hat, und einen distalen Teil (42), der sich weg von dem proximalen Teil erstreckt.

4. Die Mehrbandantenne gemäß Anspruch 1, wobei sich der erste Arm entlang einer Unterseite des Gehäuses erstreckt.

5. Die Mehrbandantenne gemäß Anspruch 1, wobei das zweite längliche Element einen ersten Arm (46) und einen damit gekoppelten zweiten Arm (34) hat.

6. Die Mehrbandantenne gemäß Anspruch 5, wobei die sekundäre Zufuhr an dem zweiten Arm ist; und wobei sich der erste Arm zumindest teilweise entlang eines unteren Rands des Gehäuses erstreckt.

7. Die Mehrbandantenne gemäß Anspruch 1, wobei das dielektrische Substrat eine nicht-planare Form hat.

8. Die Mehrbandantenne gemäß Anspruch 1, wobei das dielektrische Substrat durch eine Unterseite des Gehäuses getragen wird; und wobei die primären und sekundären Radiatoren durch jeweilige gegenüberliegende erste und zweite Seiten des dielektrischen Substrats getragen werden.

9. Die Mehrbandantenne gemäß Anspruch 1, wobei der zumindest eine drahtlose Transceiver einen LTE(Long Term Evolution)-Transceiver aufweist, der konfiguriert ist, um die primären und sekundären Ausgänge in einem LTE-Carrier-Aggregation-Modus zu betreiben.

10. Ein Verfahren zur Herstellung einer Mehrbandantenne (23) für eine mobile drahtlose Kommunikationsvorrichtung (20), das aufweist:

Bilden einer Mehrbandantenne, um ein dielektrisches Substrat und ein Muster aus elektrisch leitenden Bahnen

darauf aufzuweisen, die einen primären Radiator (26) und einen sekundären Radiator (25) definieren, der von dem primären Radiator beabstandet ist;
wobei der primäre Radiator aufweist
ein erstes längliches Element (32), das einen vorstehenden Teil (58) mit einer primären Zufuhr (27) aufweist, die mit einem primären Ausgang (55) gekoppelt ist und eine Aussparung (57) definiert, wobei sich der vorstehende Teil teilweise über die Aussparung erstreckt, und
ein erstes Referenzelement (33), das von dem ersten länglichen Element beabstandet ist und das erste längliche Element zumindest teilweise seitlich umgibt und mit einer Referenzspannung gekoppelt ist;
wobei der sekundäre Radiator ein zweites längliches Element aufweist mit einer sekundären Zufuhr (31), die mit einem sekundären Ausgang (56) gekoppelt ist;
wobei das erste Referenzelement einen ersten Arm (35) und einen zweiten Arm (51) aufweist, der damit gekoppelt ist;
wobei der erste Arm (35) des ersten Referenzelements (33) eine rechteckige Form hat und einen proximalen Teil (59) und einen distalen Teil (60) umfasst, der damit gekoppelt ist und eine vergrößerte Breite hat, in der der distale Teil (60) eine Kerbe (61) definiert mit parallelen Seiten und einem gebogenen Ende.

11. Das Verfahren gemäß Anspruch 10, wobei der erste Arm eine L-Form hat; und wobei der zweite Arm einen proximalen Teil (41) aufweist, der mit dem ersten Arm gekoppelt ist und eine L-Form hat, und einen distalen Teil (42), der sich weg von dem proximalen Teil erstreckt.

Revendications

1. Antenne à bandes multiples (23) pour un dispositif mobile de communications sans fil (20) comprenant un boîtier (22) et au moins un émetteur-récepteur sans fil (21) porté par le boîtier, ladite antenne à bandes multiples comprenant :

un substrat diélectrique et un motif de traces électriquement conductrices sur celui-ci définissant un élément rayonnant primaire (26) et un élément rayonnant secondaire (25) espacé dudit élément rayonnant primaire ;
ledit élément rayonnant primaire comprenant
un premier élément allongé (32) comprenant une partie en saillie (58) ayant une alimentation primaire (27) couplée à une sortie primaire (55) et définissant un évidement (57), la partie en saillie s'étendant partiellement à travers l'évidement, et
un premier élément de référence (33) espacé dudit premier élément allongé et au moins entourant de manière partiellement latérale ledit premier élément allongé et couplé à une tension de référence ;
ledit élément rayonnant secondaire comprenant un deuxième élément allongé ayant une alimentation secondaire (31) couplée à une sortie secondaire (56) ;
où ledit premier élément de référence comprend un premier bras (35) et un deuxième bras (51) couplé à celui-ci ;
le premier bras (35) du premier élément de référence (33) est de forme rectangulaire et comporte une partie proximale (59) et une partie distale (60) couplée à celle-ci et **caractérisé en ce qu'**il a une largeur agrandie, où la partie distale (60) définit une encoche (61) ayant des côtés parallèles et une extrémité incurvée.

2. Antenne à bandes multiples de la revendication 1, lorsqu'elle est couplée par un boîtier (22) et couplée à un émetteur-récepteur sans fil (21), l'émetteur-récepteur sans fil et le boîtier font partie d'un dispositif mobile de communications sans fil.

3. Antenne à bandes multiples de la revendication 1, dans laquelle ledit premier bras a une forme de L ; et dans laquelle ledit deuxième bras comprend une partie proximale (41) couplée audit premier bras et ayant une forme de L, et une partie distale (42) s'étendant loin de ladite partie proximale.

4. Antenne à bandes multiples de la revendication 1, dans laquelle ledit premier bras s'étend le long d'une partie inférieure dudit boîtier.

5. Antenne à bandes multiples de la revendication 1, dans laquelle ledit deuxième élément allongé a un premier bras (46) et un deuxième bras (34) couplé à celui-ci.

6. Antenne à bandes multiples de la revendication 5, dans laquelle ladite alimentation secondaire se trouve sur ledit deuxième bras ; et dans laquelle ledit premier bras s'étend au moins partiellement le long d'un bord inférieur dudit boîtier.

7. Antenne à bandes multiples de la revendication 1, dans laquelle ledit substrat diélectrique a une forme non plane.

8. Antenne à bandes multiples de la revendication 1, dans laquelle ledit substrat diélectrique est porté par une partie inférieure dudit boîtier ; et dans laquelle lesdits éléments rayonnants primaire et secondaire sont portés par les premier et deuxième côtés opposés respectifs dudit substrat diélectrique.

9. Antenne à bandes multiples de la revendication 1, dans laquelle ledit au moins émetteur-récepteur sans fil comprend un émetteur-récepteur d'Evolution à Long Terme (LTE) configuré pour faire fonctionner lesdites sorties primaire et secondaire dans un mode d'agrégation de porteuses LTE.

10. Procédé de fabrication d'une antenne à bandes multiples (23) pour un dispositif mobile de communications sans fil (20) comprenant le fait :

de former une antenne à bandes multiples pour comprendre un substrat diélectrique et un motif de traces électriquement conductrices sur celui-ci définissant un élément rayonnant primaire (26) et un élément rayonnant secondaire (25) espacé de l'élément rayonnant primaire ;
l'élément rayonnant primaire comprenant :

un premier élément allongé (32) comprenant une partie en saillie (58) ayant une alimentation primaire (27) couplée à une sortie primaire (55) et définissant un évidement (57), la partie en saillie s'étendant partiellement à travers l'évidement, et
un premier élément de référence (33) espacé du premier élément allongé et au moins entourant de manière partiellement latérale le premier élément allongé et couplé à une tension de référence ;
l'élément rayonnant secondaire comprenant un deuxième élément allongé ayant une alimentation secondaire (31) couplée à une sortie secondaire (56) ;
où ledit premier élément de référence comprend un premier bras (35) et un deuxième bras (51) couplé à celui-ci ;
le premier bras (35) du premier élément de référence (33) est de forme rectangulaire et comporte une partie proximale (59) et une partie distale (60) couplée à celle-ci et ayant une largeur agrandie, où la partie distale (60) définit une encoche (61) ayant des côtés parallèles et une extrémité incurvée.

11. Procédé de la revendication 10, dans lequel le premier bras a une forme de L ; et dans lequel le deuxième bras comprend une partie proximale (41) couplée au premier bras et ayant une forme de L et une partie distale (42) s'étendant loin de la partie proximale.

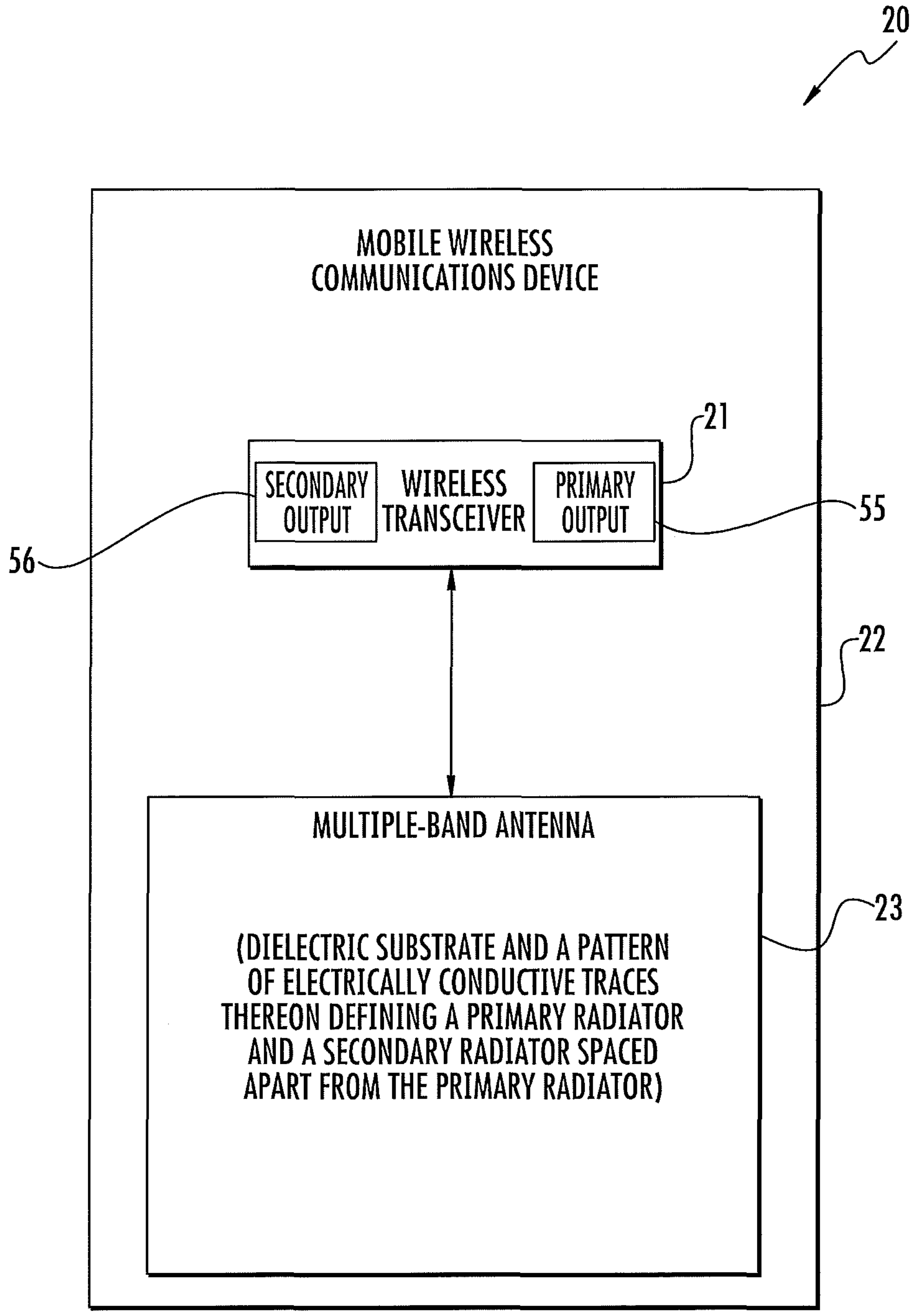
20
MOBILE WIRELESS
COMMUNICATIONS DEVICE
21
SECONDARY
OUTPUT
WIRELESS
TRANSCEIVER
PRIMARY
OUTPUT
55
56
22
MULTIPLE-BAND ANTENNA
23
(DIELECTRIC SUBSTRATE AND A PATTERN
OF ELECTRICALLY CONDUCTIVE TRACES
THEREON DEFINING A PRIMARY RADIATOR
AND A SECONDARY RADIATOR SPACED
APART FROM THE PRIMARY RADIATOR)

FIG. 1

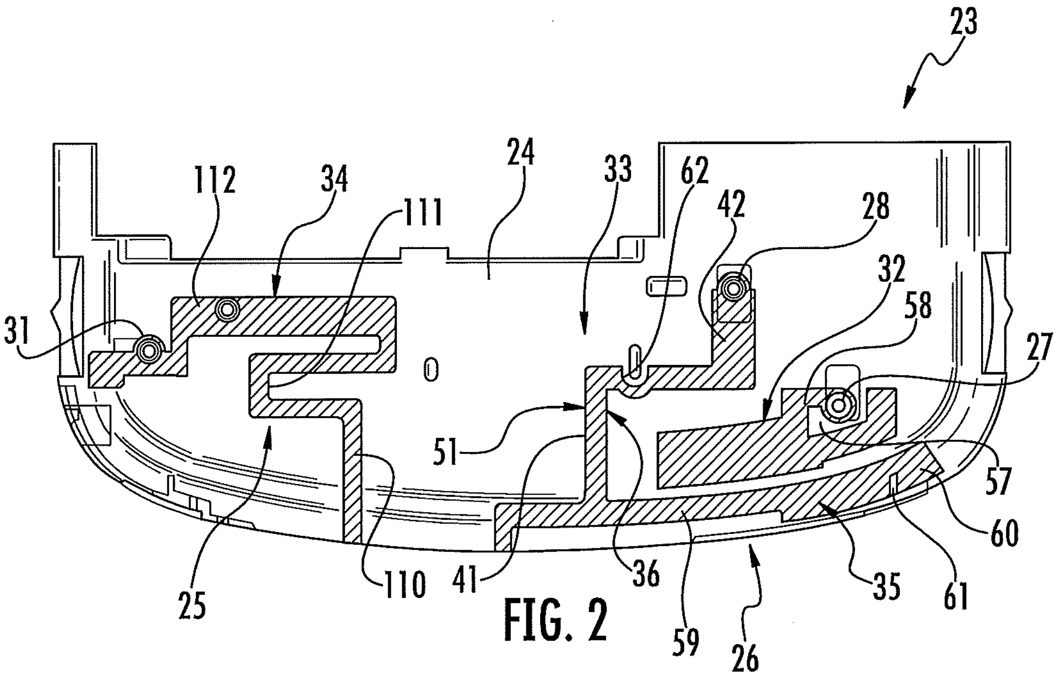
23
112
34
24
111
33
62
42
28
32
58
31
27
51
57
36
60
110
41
35
61
25
59
26

FIG. 2

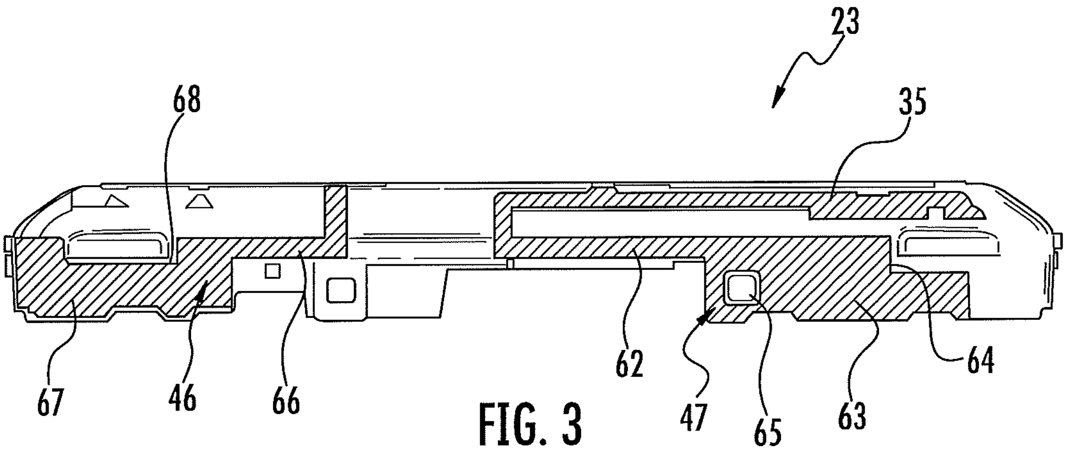
23
68
35
67
46
66
62
47
65
63
64

FIG. 3

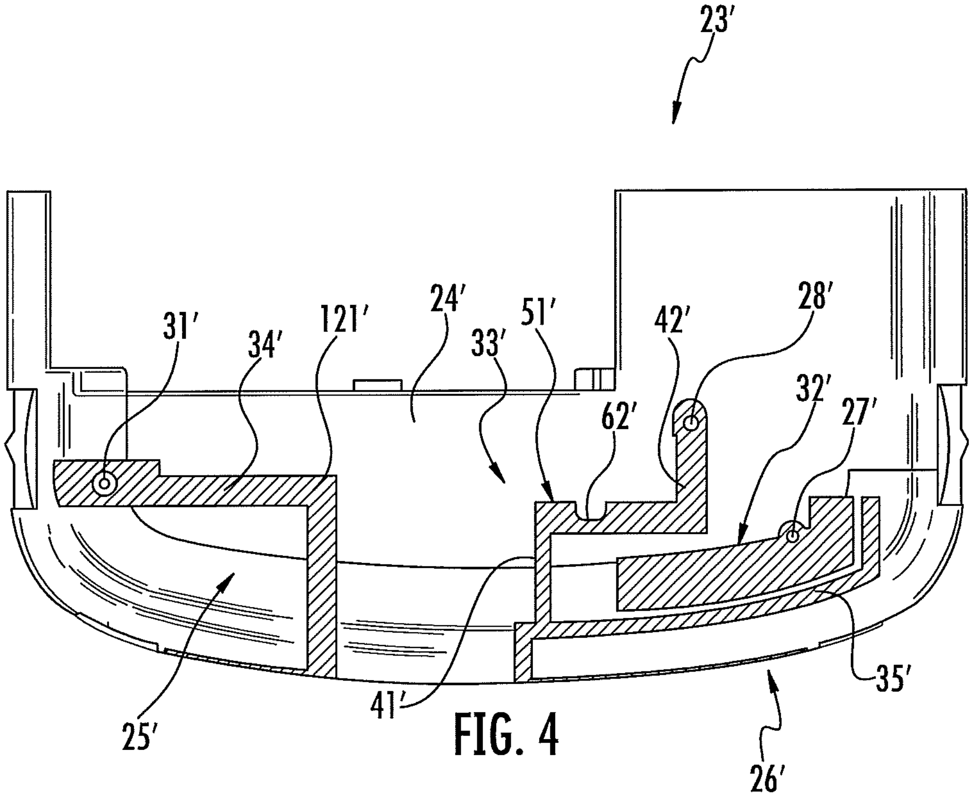

FIG. 4

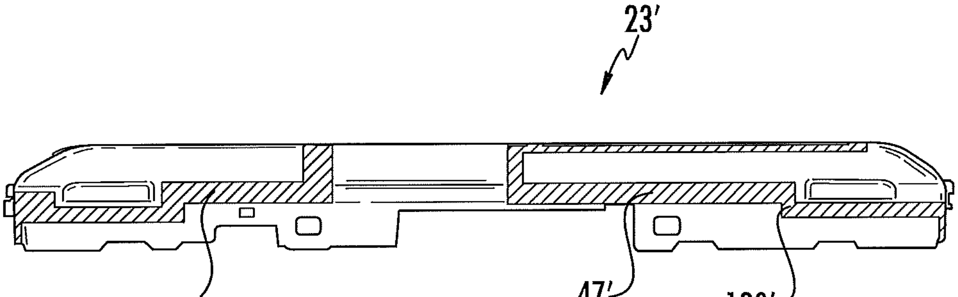

FIG. 5

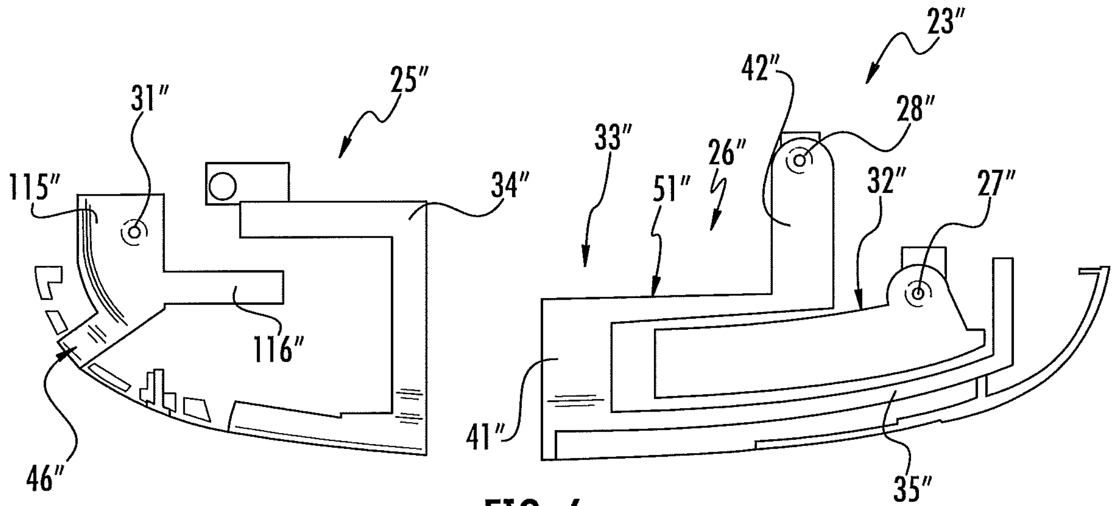
25"
31"
115"
34"
116"
46"
23"
42"
28"
33"
26"
51"
32"
27"
41"
35"

FIG. 6

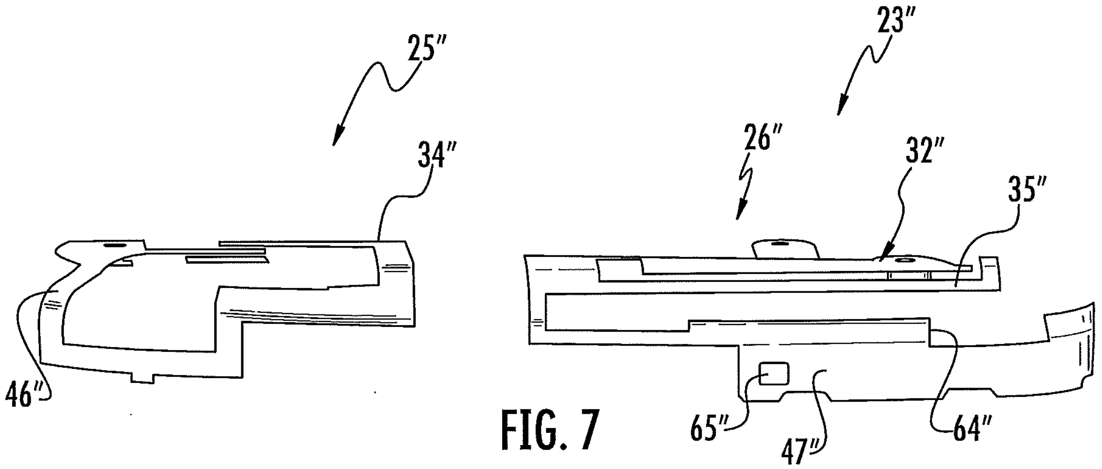
25"
34"
46"
23"
26"
32"
35"
65"
47"
64"

FIG. 7

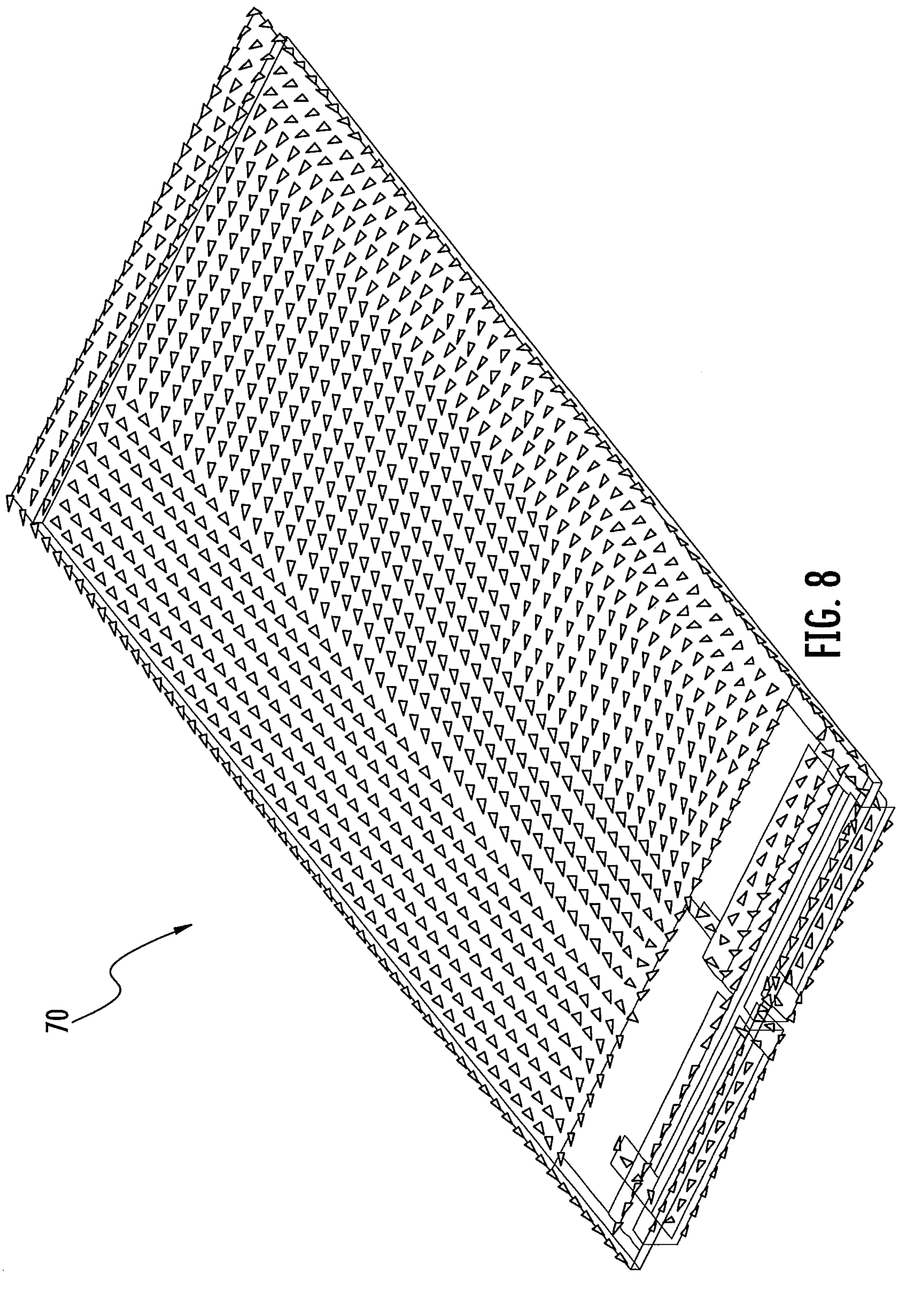

FIG. 8

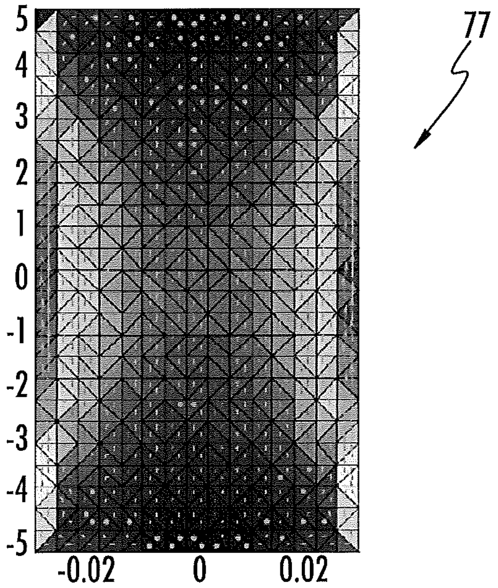

FIG. 9A

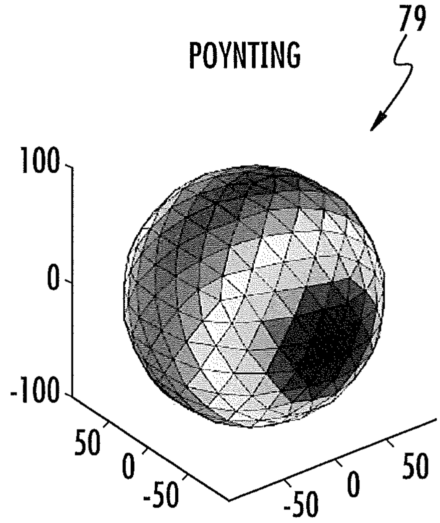

FIG. 9B

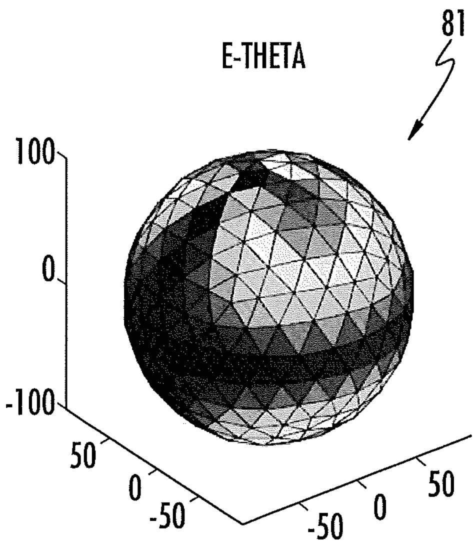

FIG. 9C

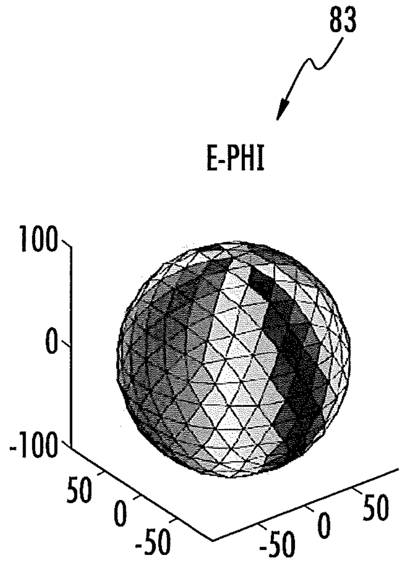

FIG. 9D

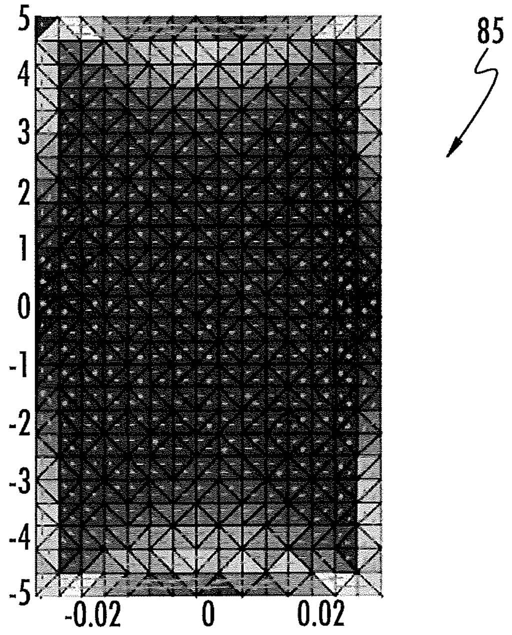

FIG. 10A

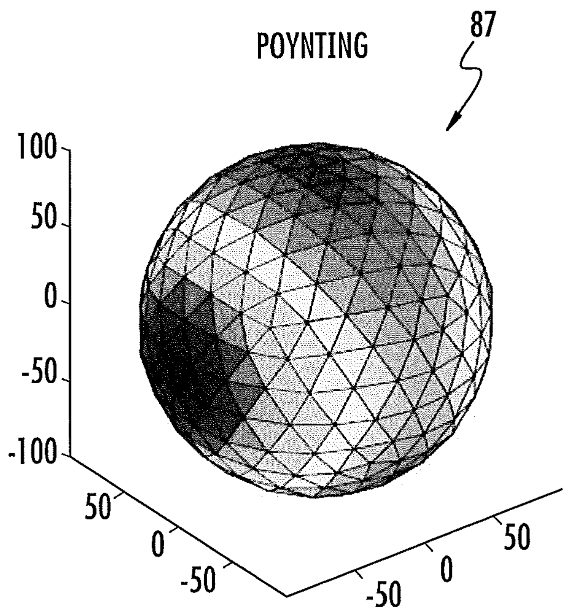

FIG. 10B

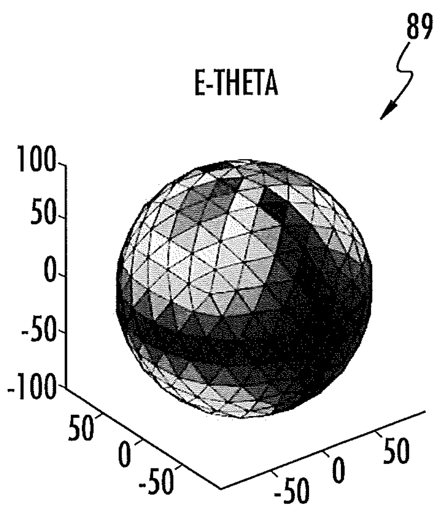

FIG. 10C

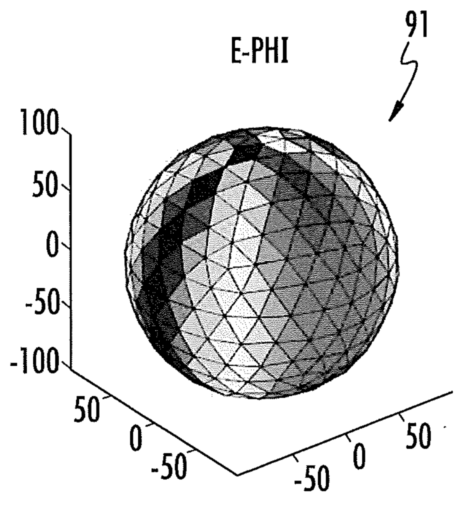

FIG. 10D

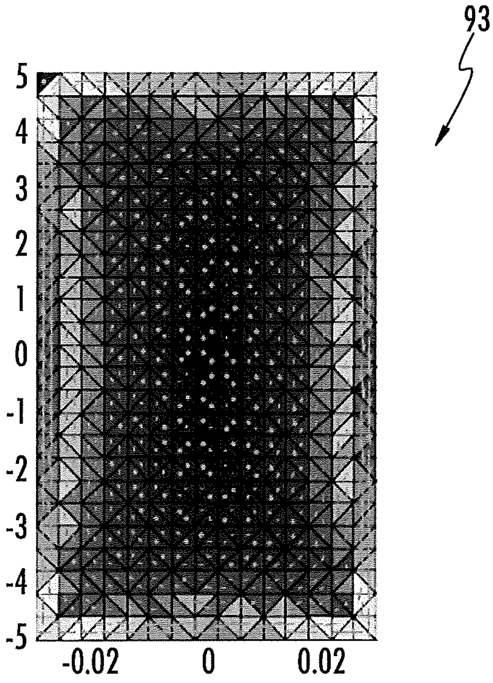

FIG. 11A

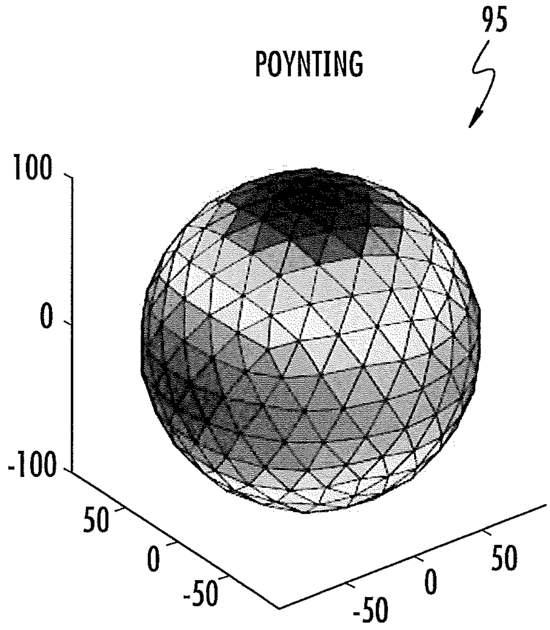

FIG. 11B

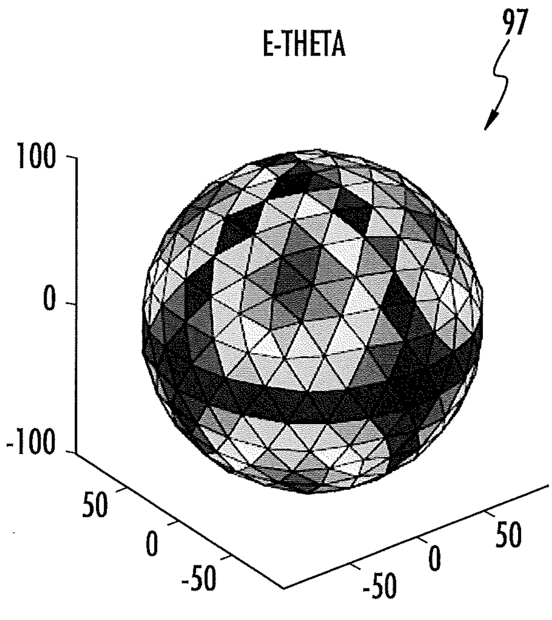

FIG. 11C

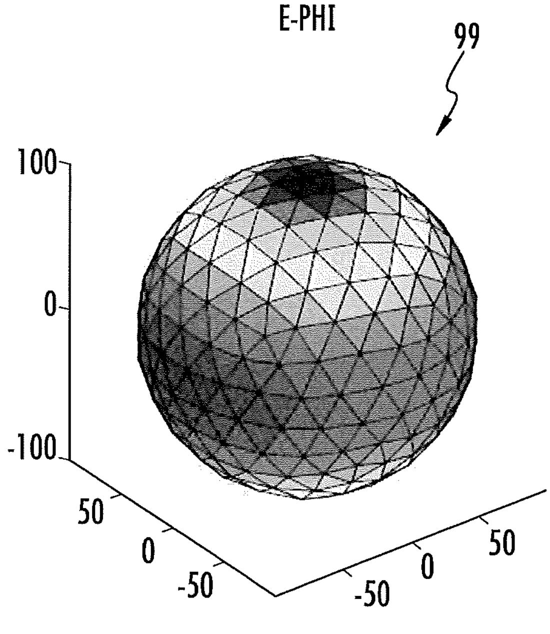

FIG. 11D

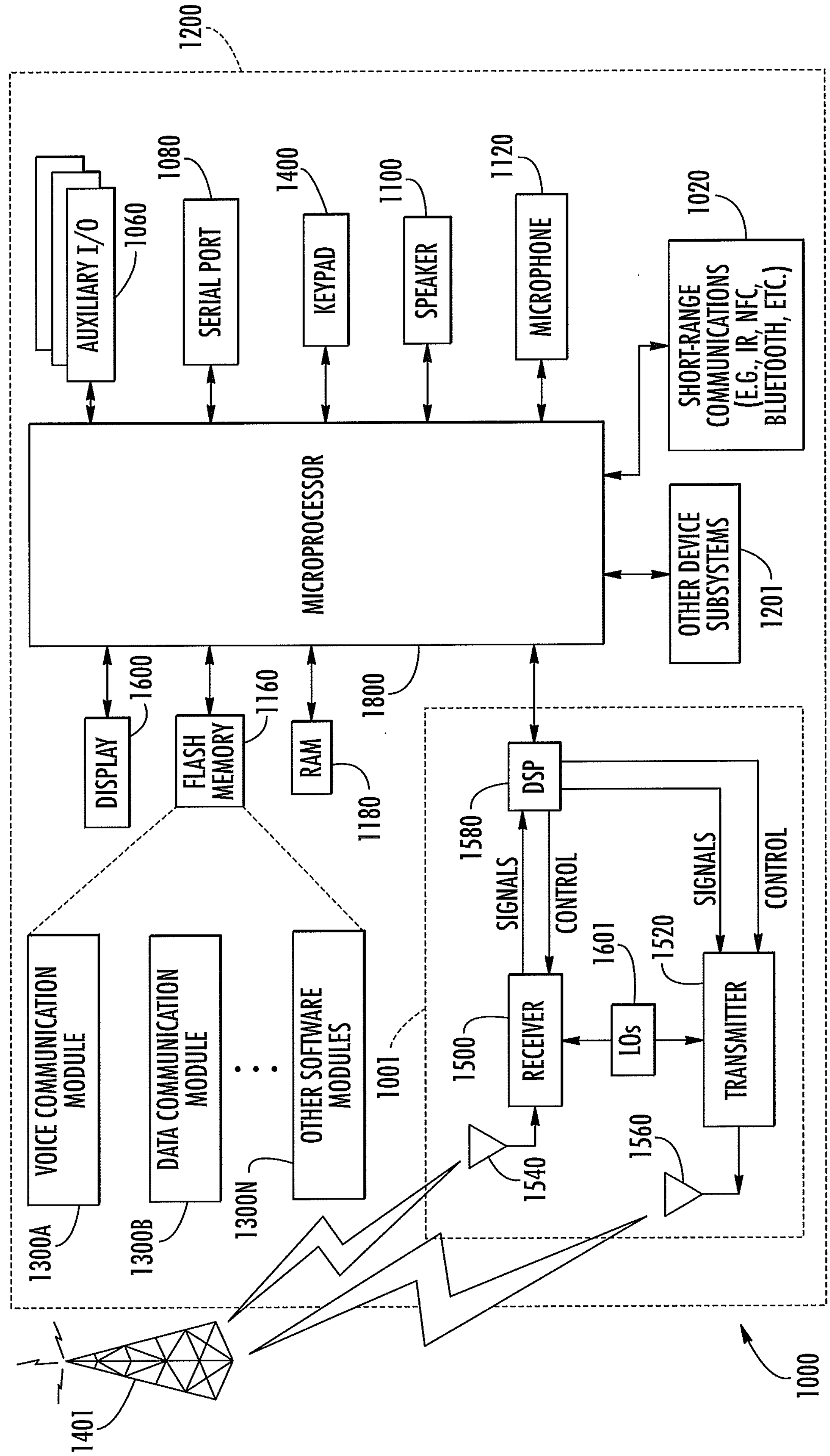
1200
AUXILIARY I/O
1060
SERIAL PORT
1080
KEYPAD
1400
SPEAKER
1100
MICROPHONE
1120
SHORT-RANGE COMMUNICATIONS (E.G., IR, NFC, BLUETOOTH, ETC.)
1020
MICROPROCESSOR
OTHER DEVICE SUBSYSTEMS
1201
DISPLAY
1600
FLASH MEMORY
1160
RAM
1180
1800
VOICE COMMUNICATION MODULE
1300A
DATA COMMUNICATION MODULE
1300B
OTHER SOFTWARE MODULES
1300N
DSP
1580
SIGNALS
CONTROL
SIGNALS
CONTROL
RECEIVER
1500
LOs
1601
TRANSMITTER
1520
1001
1540
1560
1401
1000

FIG. 12

REFERENCES CITED IN THE DESCRIPTION

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- US 2004137950 A **[0006]**
- US 7834809 B **[0007]**
- US 2009231200 A **[0008]**