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Rabinovich et al.

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(54) **GPS, GSM, AND WIRELESS LAN ANTENNA FOR VEHICLE APPLICATIONS**

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H01Q 1/32 (2006.01)

(52) **U.S. Cl.** .... **343/713**; 343/700 MS; 343/895

(58) **Field of Classification Search** .... 343/700 MS, 343/711, 713, 876, 895
See application file for complete search history.

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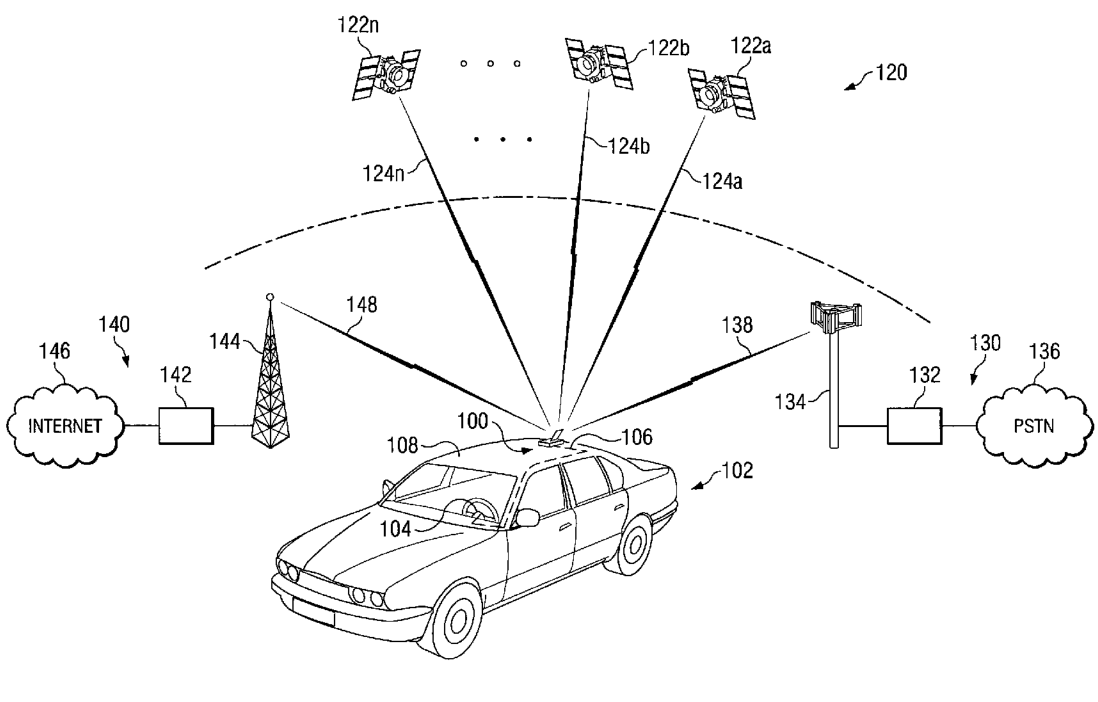
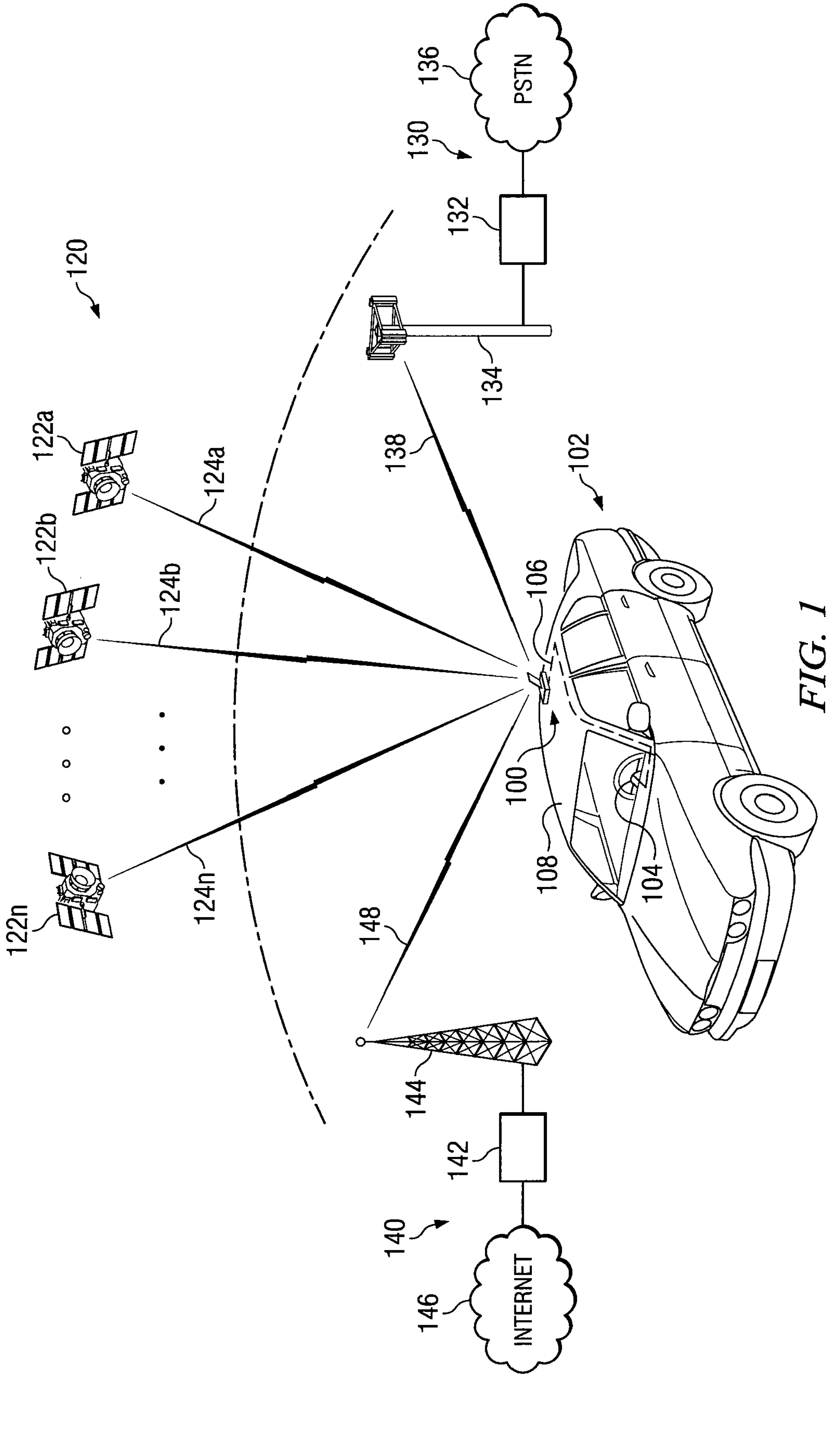
(74) *Attorney, Agent, or Firm* — Patton Boggs LLP

(57) **ABSTRACT**

A Global Positioning System (GPS), Global System for Mobile Communications (GSM), wireless local area network (WLAN) antenna, including a dielectric board including a ground plane; a first antenna trace line disposed on a first portion of the dielectric board and in electrical contact with the dielectric board, the first antenna trace line including at least one first meandered trace for transmitting and receive a WLAN radio frequency signal; a second antenna trace line disposed on a second portion of the dielectric board and in electrical contact with the dielectric board, the second antenna trace line including at least one second meandered trace for transmitting and receiving a GSM radio frequency signal; a GPS antenna for receiving radio frequency signals from at least one global positioning satellite; and a vehicle mountable housing for enclosing the dielectric board, the first antenna trace line, the second antenna trace line, and the GPS antenna.

26 Claims, 9 Drawing Sheets

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INTERNET
100
102
104
106
108
120
122a
122b
122n
124a
124b
124n
130
132
134
136
138
140
142
144
146
148

FIG. 1

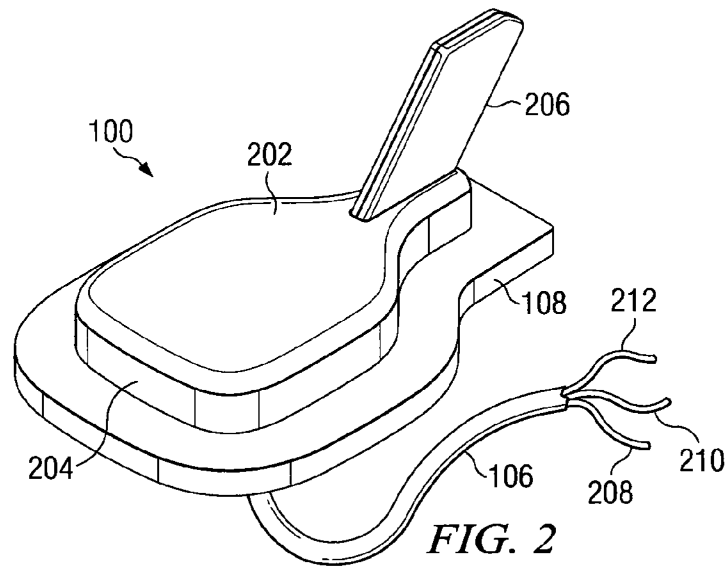


FIG. 2

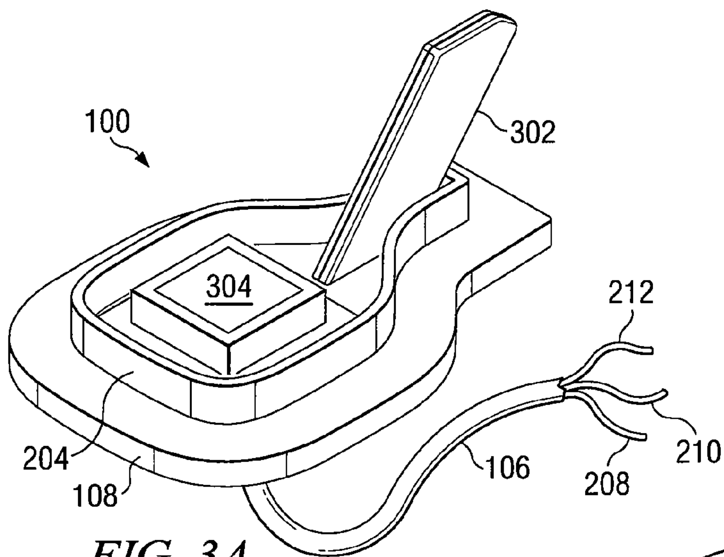


FIG. 3A

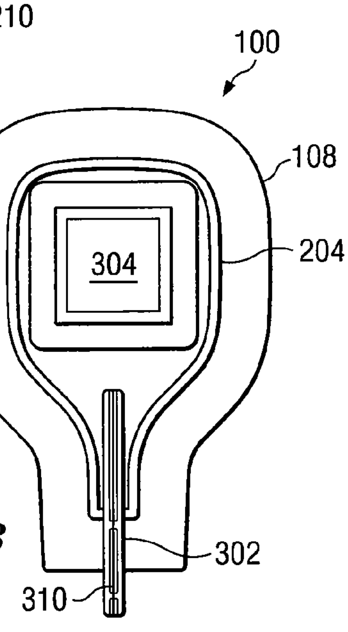


FIG. 3B

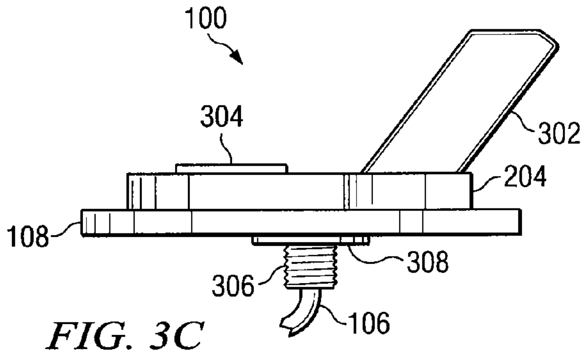


FIG. 3C

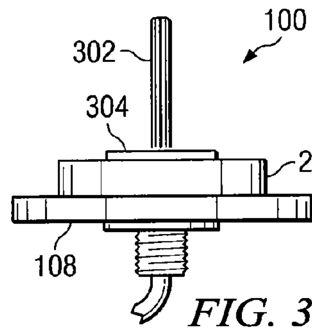


FIG. 3D

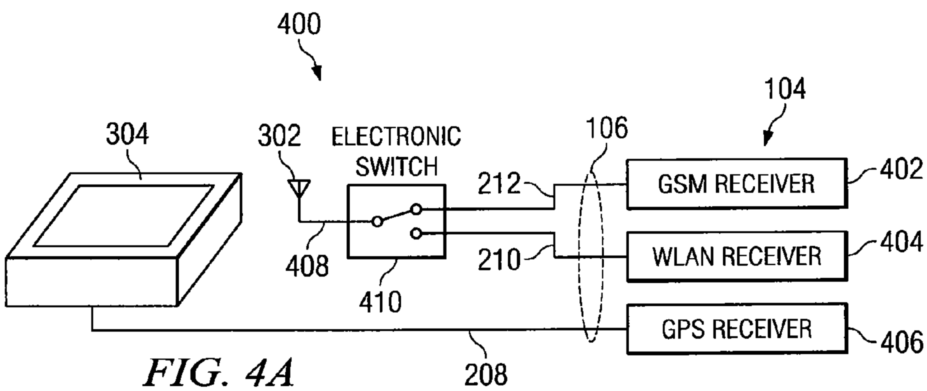


FIG. 4A

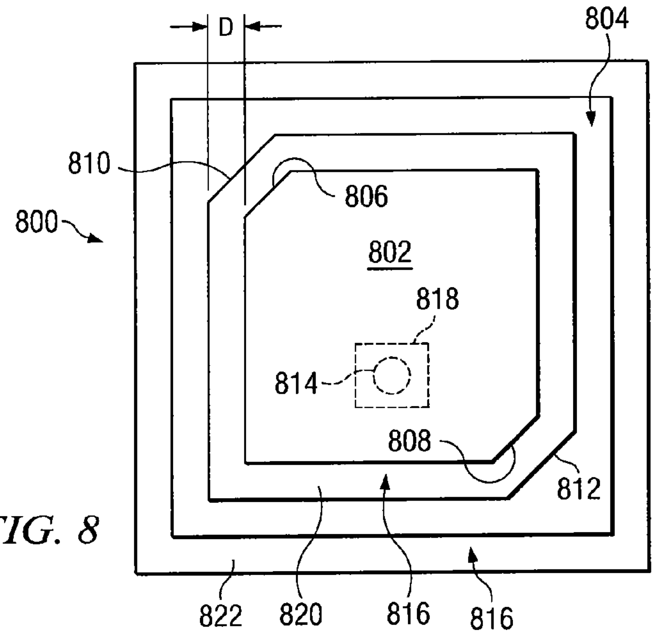
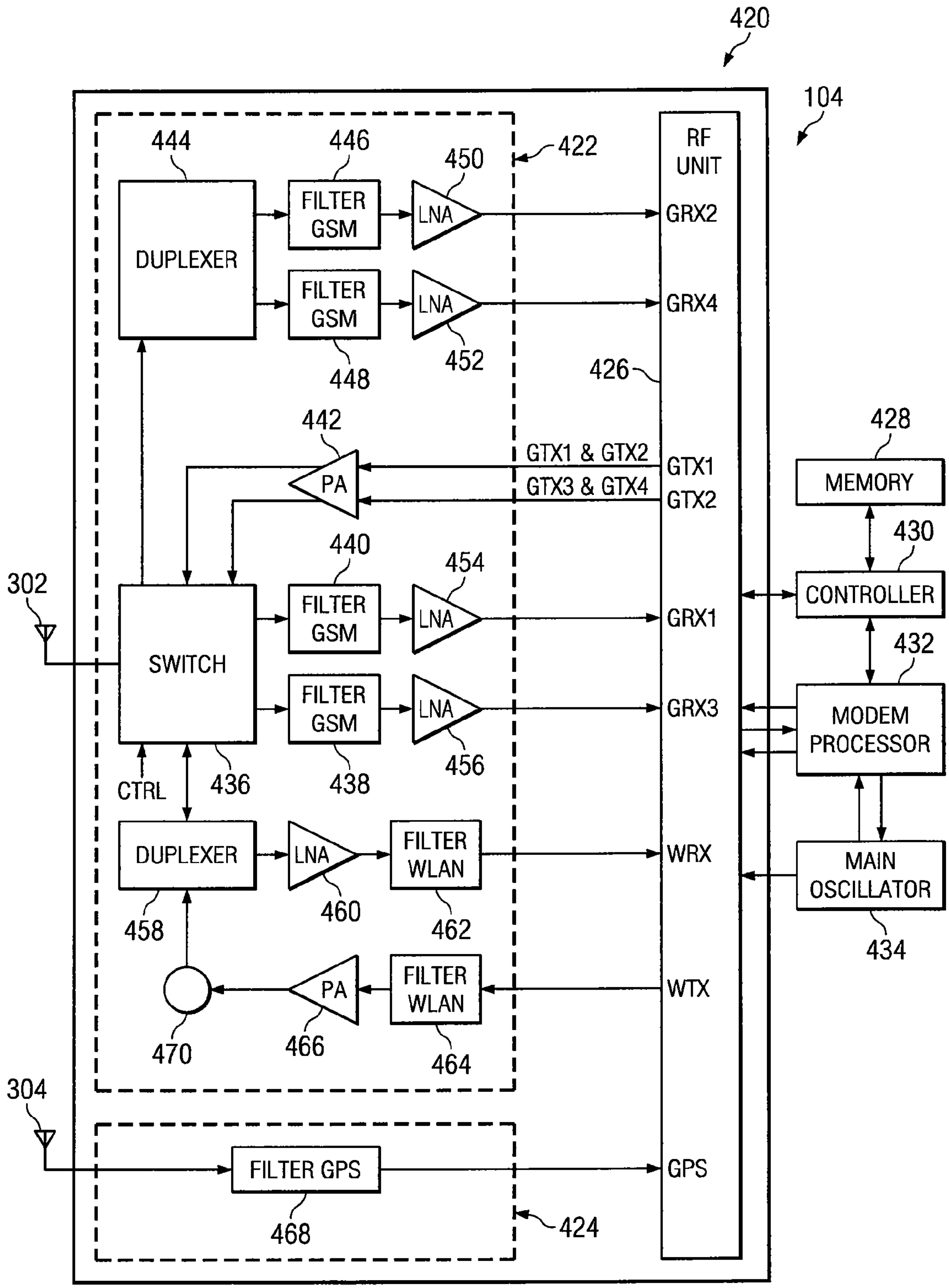


FIG. 8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104
444
446
450
422
RF UNIT
DUPLEXER
FILTER GSM
LNA
GRX2
FILTER GSM
LNA
GRX4
448
452
426
442
428
PA
GTX1 & GTX2
GTX1
MEMORY
GTX3 & GTX4
GTX2
440
454
430
302
SWITCH
FILTER GSM
LNA
GRX1
CONTROLLER
FILTER GSM
LNA
GRX3
432
MODEM PROCESSOR
CTRL
436
438
456
DUPLEXER
LNA
FILTER WLAN
WRX
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PA
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WTX
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466
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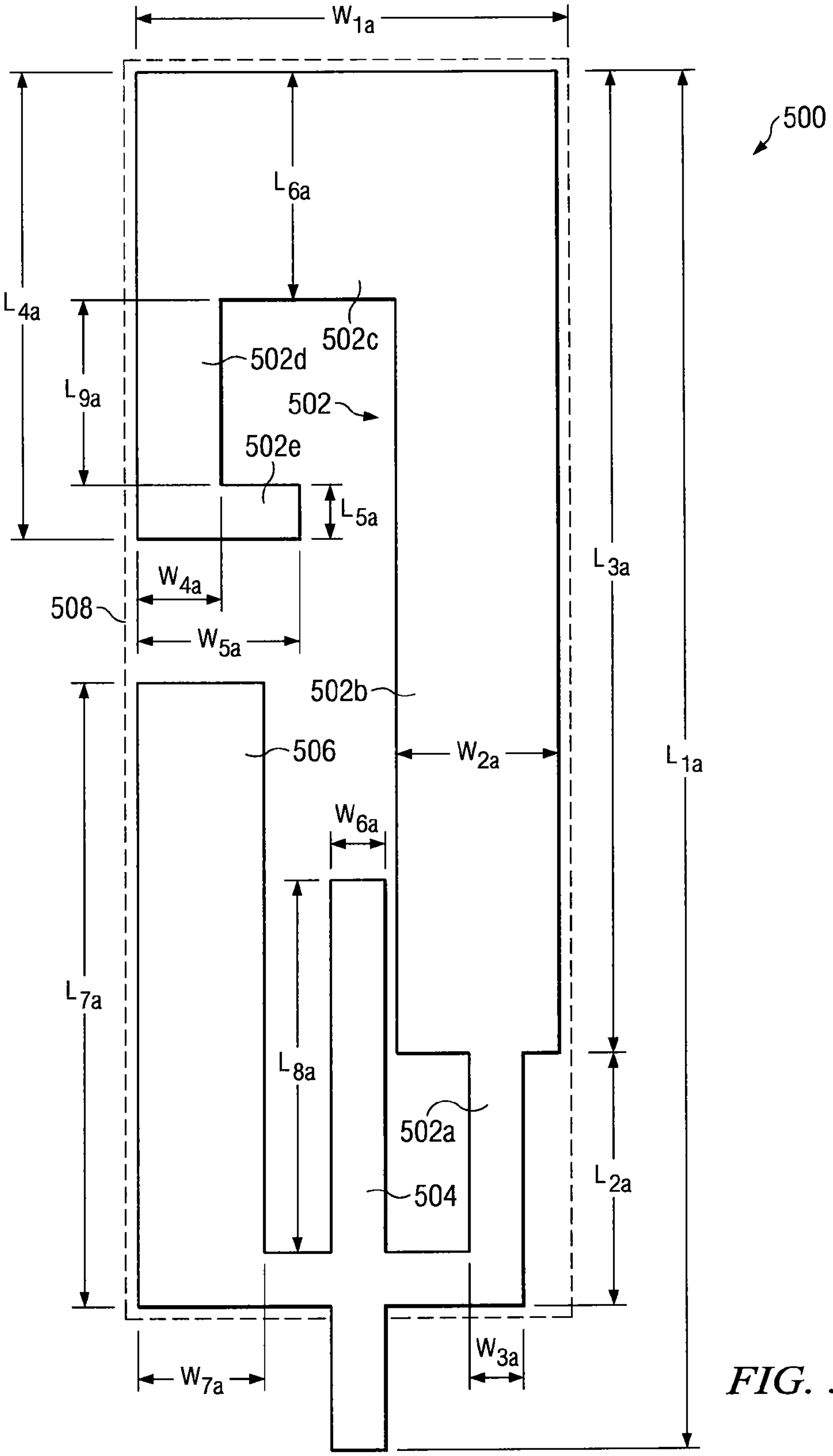
304
FILTER GPS
GPS
468
424

FIG. 4B



W1a
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L6a
L4a
502c
502d
L9a
502
502e
L5a
L3a
W4a
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L2a
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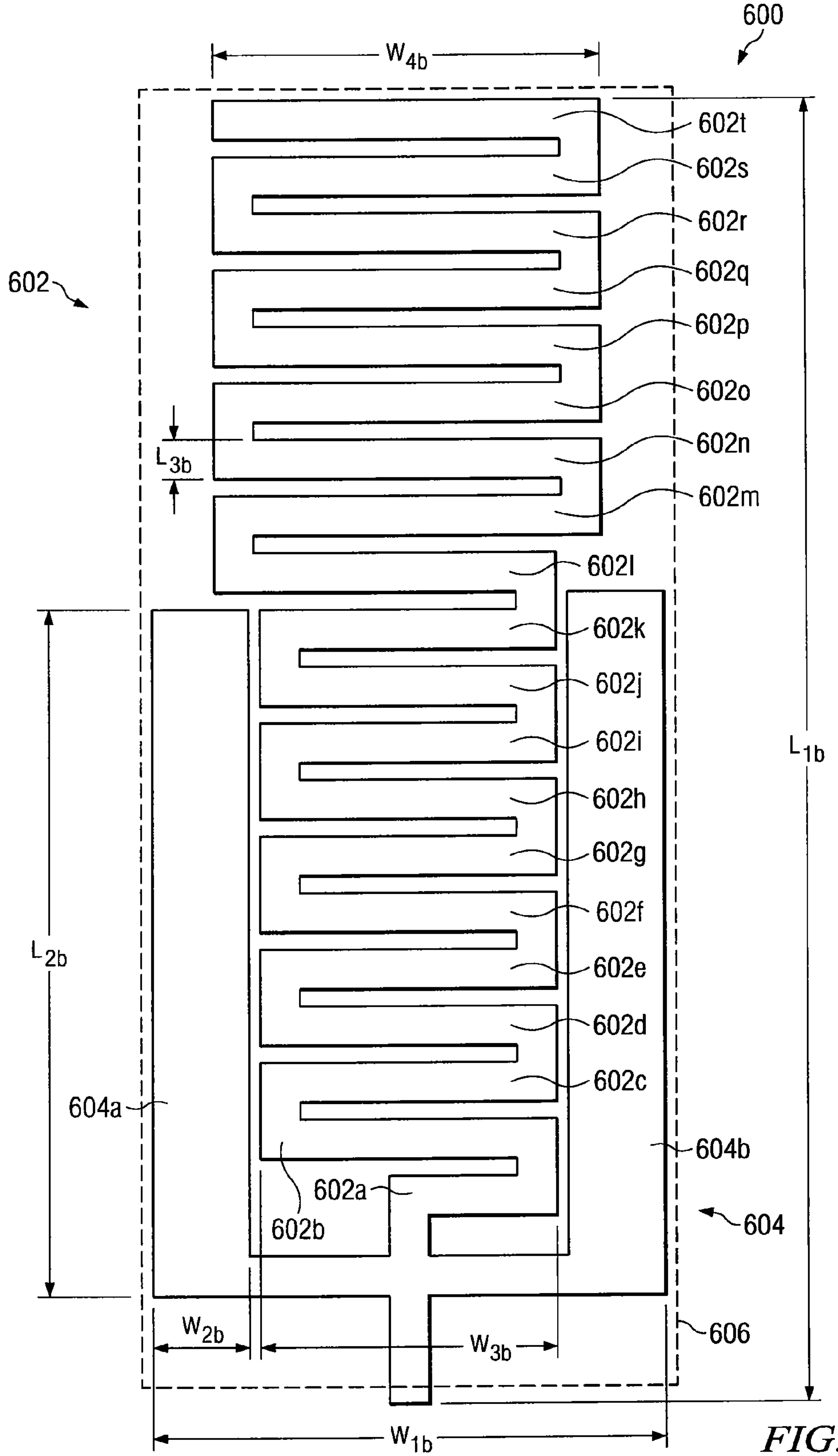
W3a
W7a

FIG. 5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602c
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L2b
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604b
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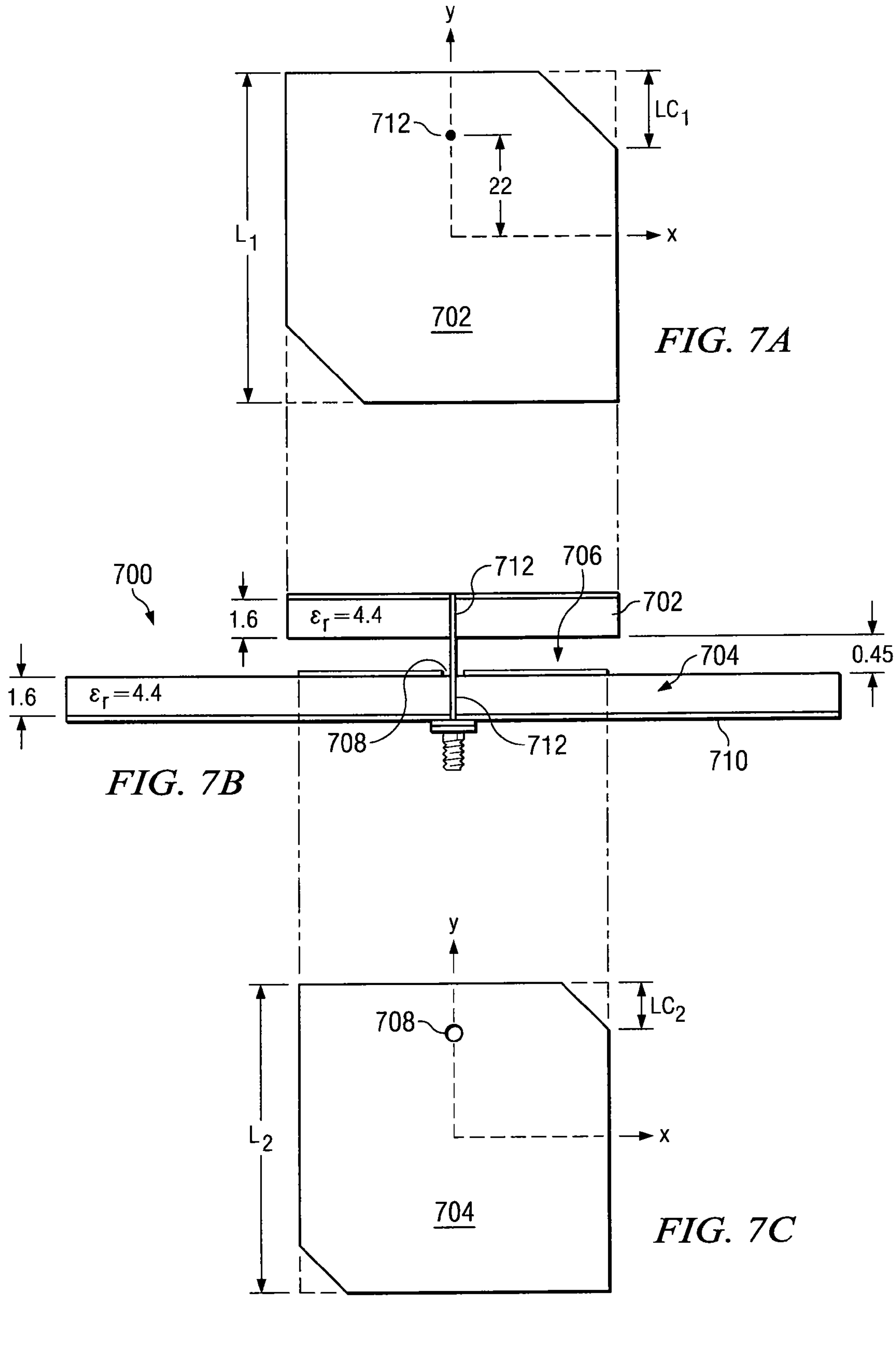
602b
604
606
W2b
W3b
W1b

FIG. 6


y
x
712
22
LC1
L1
702
FIG. 7A
700
1.6
εr=4.4
712
706
702
0.45
704
1.6
εr=4.4
708
712
710
FIG. 7B
y
x
708
LC2
L2
704
FIG. 7C

900

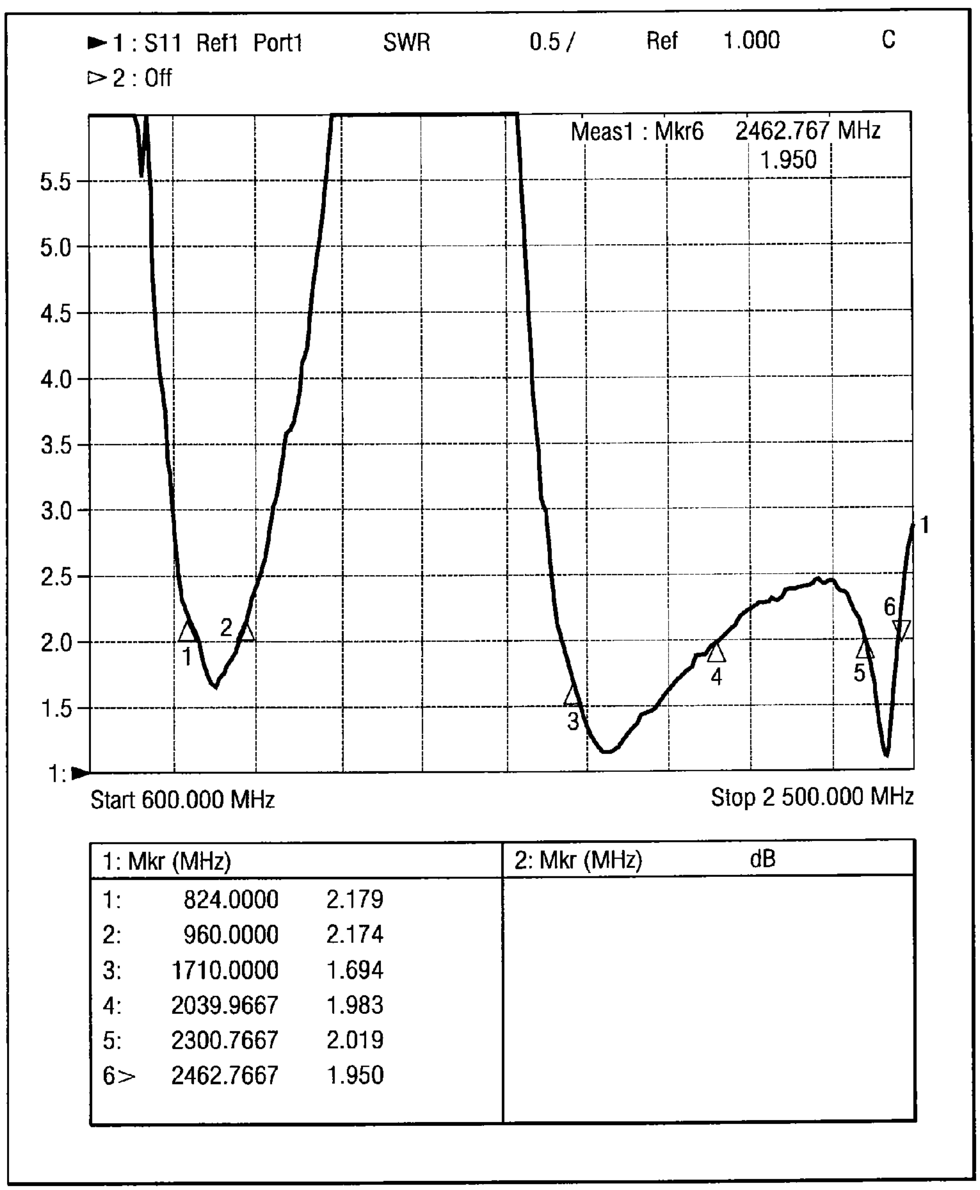
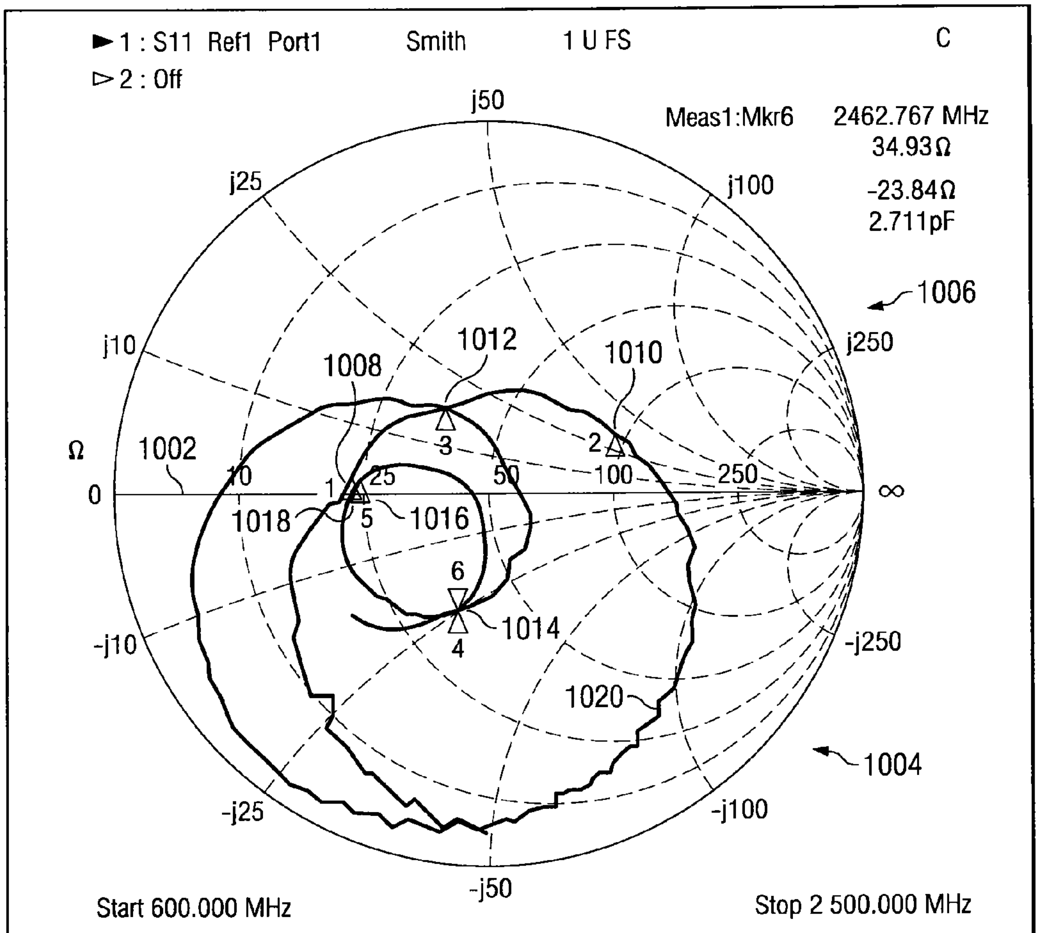

►1 : S11 Ref1 Port1 SWR 0.5 / Ref 1.000 C
▻2 : Off
Meas1 : Mkr6 2462.767 MHz
1.950
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1:►
1
2
3
4
5
6
Start 600.000 MHz
Stop 2 500.000 MHz
1: Mkr (MHz)
1: 824.0000 2.179
2: 960.0000 2.174
3: 1710.0000 1.694
4: 2039.9667 1.983
5: 2300.7667 2.019
6> 2462.7667 1.950
2: Mkr (MHz) dB

FIG. 9

1000



1: Mkr (MHz)	Ohm	Ohm	2: Mkr (MHz) dB
1: 824.000	22.96	2.600	
2: 960.000	91.45	33.62	
3: 1710.000	35.78	17.64	
4: 2039.967	34.73	-24.78	
5: 2380.767	24.90	1.584	
6: 2462.767	34.93	-23.84	

FIG. 10

GPS, GSM, AND WIRELESS LAN ANTENNA FOR VEHICLE APPLICATIONS

BACKGROUND

Without limiting the scope of the invention, its background will be described in relation to an antenna for a vehicle to communicate with a Global Positioning System ("GPS"), Global System for Mobile Communications ("GSM"), and wireless local area network ("WLAN") systems, as an example.

Wireless communication systems are widely deployed in vehicles to provide various communication services such as voice, data, and so on. These wireless systems may be based on Code Division Multiple Access ("CDMA"), Time Division Multiple Access ("TDMA"), Frequency Division Multiple Access ("FDMA"), or some other multiple-access techniques. A wireless system may implement one or more standards adopted by a standards group or consortium, such as IS-2000, IS-856, IS-95, GSM, Wideband-CDMA ("W-CDMA"), and so on.

A vehicle equipped with wireless communication device (s), such as a cellular or mobile phone, may utilise a transceiver system to obtain two-way communications with a particular wireless system. The transceiver system may include a transmitter for data transmission and a receiver for data reception. On a transmit path, the transmitter may modulate a radio frequency ("RF") carrier signal with data to produce a RF modulated signal that is more suitable for transmission from the vehicle. Further, the transmitter may condition the RF modulated signal to generate an RF uplink signal and then transmit the RF uplink signal via a wireless channel to one or more base stations in a particular wireless system. On a receive path, the receiver may receive one or more RF downlink signals from one or more base stations, and condition and process the received signal to obtain data sent by the base station(s).

Some vehicles are equipped with a multi-mode wireless device, such as a dual-mode cellular phone, which may be capable of communicating with multiple wireless systems (e.g., GSM and CDMA systems). This capability allows the multi-mode device to receive communication services from more systems and enjoy greater coverage provided by these systems. A multi-mode transceiver may have many signal paths to support all of the frequency bands used by all of the wireless systems. Interconnecting all of these signal paths to the antenna may require a complicated transmitter/receiver ("T/R") switch with many input/output ("I/O") RF ports. Additionally, multi-mode wireless system have different and separate antennas for each wireless system it is communicating with, thus creating large and complex arrays of antennas housed together or separately that are not aesthetically pleasing.

SUMMARY

The above-described problems are solved and a technical advance is achieved by the GPS, GSM, and WLAN antenna for vehicle applications ("GPS, GSM, and WLAN antenna") disclosed in this application. The GPS, GSM, and WLAN antenna may be used for GPS positioning information, wireless cellular communications, and wireless internet data transmissions, for example. More specifically, the GPS, GSM, and WLAN antenna includes a housing for two different multiband antennas disposed on a single printed circuit board ("PCB") and a GPS antenna for use in vehicle applications.

In one embodiment, the present GPS, GSM, WLAN antenna includes a dielectric board including a ground plane; a first antenna trace line disposed on a first portion of the dielectric board and in electrical contact with the dielectric board, the first antenna trace line including at least one first meandered trace for transmitting and receiving a WLAN radio frequency signal; a second antenna trace line disposed on a second portion of the dielectric board and in electrical contact with the dielectric board, the second antenna trace line including at least one second meandered trace for transmitting and receiving a GSM radio frequency signal; a GPS antenna for receiving radio frequency signals from at least one global positioning satellite; and a vehicle mountable housing for enclosing the dielectric board, the first antenna trace line, the second antenna trace line, and the GPS antenna.

In one aspect, the GPS, GSM, WLAN antenna further includes a first output in contact with the first antenna trace line; a second output in contact with the second antenna trace line; and a third output in contact with the GPS antenna for outputting electrical signals to at least one transceiver via a RF cable. In another aspect, the GPS, GSM, WLAN antenna further includes a switch in contact with the first output and second output for switching between the GSM radio frequency signal and the WLAN radio frequency signal for providing the GSM radio frequency signal to a GSM transceiver and the WLAN radio frequency signal to a WLAN transceiver. In addition, the transmitting and receiving of GSM radio frequency may be time division multiple access. Also, the first antenna trace line may be capable of receiving 900 MHz, 1800 MHz, 850 MHz, and 1900 MHz radio frequency signals. Further, the second antenna trace line may be capable of receiving 2.4 GHz radio frequency signals.

In another aspect, the GPS antenna is capable of receiving one of 1.57542 GHz and 1.2276 GHz radio frequency signals. In yet another aspect, the second antenna trace line includes a first antenna trace line portion having a length of 10 mm and a width of 2 mm, the first antenna trace line portion extending laterally from a base of the housing; a second antenna trace line portion having a length of 40 min and a width of 7 mm, the second antenna trace line portion extending laterally from the first antenna trace line portion; a third antenna trace line portion having a length of 9 mm and a width of 17 mm, the third antenna trace line portion extending substantially longitudinally from the second antenna trace line portion; a fourth antenna trace line portion having a length of 8 mm and a width of 3 mm, the fourth antenna trace line portion extending laterally from the third antenna trace line portion towards the base of the housing; and a fifth antenna trace line portion having a length of 2 mm and a width of 3 mm, the fifth antenna trace line portion extending longitudinally from the fourth antenna trace line portion toward the first antenna trace line portion.

In still yet another aspect, the first antenna trace line has a length of 24 mm and a width of 5 mm, the second antenna trace line extending laterally from a base of the housing. Additionally, the first antenna trace line includes a first antenna trace line and a second antenna trace line spaced apart to define a GSM antenna portion between the first antenna trace line and the second antenna trace line, the first and second antenna trace line having a length of 36 mm and a width of 5 mm, the first and second antenna trace line extending laterally from a base of the housing. Further, the second antenna trace line includes a first plurality of meander trace antenna lines disposed between the first antenna trace line and the second antenna trace line; and a second plurality of meander antenna trace lines not disposed between the first antenna trace line and the second antenna trace line, wherein the first plurality of meander trace antenna lines have a width of 15 mm and a length 2 mm, and the second plurality of meander trace antenna lines have a width of 20 mm and a length of 2 mm. Also, the dielectric board may be a FR-4 dielectric substrate. In addition, the GPS, GSM, WLAN antenna may further include a satellite digital audio radio antenna.

In another embodiment, the present invention includes a vehicle having a GPS, GSM, WLAN antenna, including a vehicle body; a dielectric board including a ground plane; a first antenna trace line disposed on a first portion of the dielectric board and in electrical contact with the dielectric board, the first antenna trace line including at least one first meandered trace for transmitting and receiving a WLAN radio frequency signal; a second antenna trace line disposed on a second portion of the dielectric board and in electrical contact with the dielectric board, the second antenna trace line including at least one second meandered trace for transmitting and receiving a GSM radio frequency signal; a GPS antenna for receiving radio frequency signals from at least one global positioning satellite; and a housing mounted on the vehicle body for enclosing the dielectric board, the first antenna trace line, the second antenna trace line, and the GPS antenna.

In one aspect, the vehicle further includes a first output in contact with the first antenna trace line; a second output in contact with the second antenna trace line; and a third output in contact with the GPS antenna for outputting electrical signals to at least one transceiver via a RF cable. In another aspect, the vehicle further includes a switch in contact with the first output and second output for switching between the GSM radio frequency signal and the WLAN radio frequency signal for providing the GSM radio frequency signal to a GSM transceiver and the WLAN radio frequency signal to a WLAN transceiver. In yet another aspect, the transmitting and receiving of GSM radio frequency is time division multiple access. Also, the first antenna trace line is capable of receiving 900 MHz, 1800 MHz, 850 MHz, and 1900 MHz radio frequency signals. In another aspect, the second antenna trace line is capable of receiving one of 2.4 GHz radio frequency signals.

Preferably, the GPS antenna is capable of receiving one of 1.57542 GHz and 1.2276 GHz radio frequency signals. Also preferably, the second antenna trace line includes a first antenna trace line portion having a length of 10 mm and a width of 2 mm, the first antenna trace line portion extending laterally from a base of the housing; a second antenna trace line portion having a length of 40 mm and a width of 7 mm, the second antenna trace line portion extending laterally from the first antenna trace line portion; a third antenna trace line portion having a length of 9 mm and a width of 17 mm, the third antenna trace line portion extending substantially longitudinally from the second antenna trace line portion; a fourth antenna trace line portion having a length of 8 mm and a width of 3 mm, the fourth antenna trace line portion extending laterally from the third antenna trace line portion towards the base of the housing; and a fifth antenna trace line portion having a length of 2 mm and a width of 3 mm, the fifth antenna trace line portion extending longitudinally from the fourth antenna trace line portion toward the first antenna trace line portion.

In another aspect, the first antenna trace line has a length of 24 mm and a width of 5 mm, the second antenna trace line extending laterally from a base of the housing. In addition, the first antenna trace line includes a first antenna trace line and a second antenna trace line spaced apart to define a GSM antenna portion between the first antenna trace line and the second antenna trace line, the first and second antenna trace line having a length of 36 mm and a width of 5 mm, the first and second antenna trace line extending laterally from a base of the housing. Further, the second antenna trace line includes a first plurality of meander trace antenna lines disposed between the first antenna trace line and the second antenna trace line; and a second plurality of meander antenna trace lines not disposed between the first antenna trace line and the second antenna trace line, wherein the first plurality of meander trace antenna lines have a width of 15 mm and a length 2 mm, and the second plurality of meander trace antenna lines have a width of 20 mm and a length of 2 mm. In yet another aspect, the dielectric board is a FR-4 dielectric substrate. In addition, the vehicle may further include a satellite digital audio radio antenna.

BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the features and advantages of the GPS, GSM, and WLAN antenna, reference is now made to the detailed description of the invention along with the accompanying figures in which corresponding numerals in the different figures refer to corresponding parts and in which:

FIG. **1** is an illustration of an exemplary vehicle including a GPS, GSM, and WLAN antenna according to one embodiment;

FIG. **2** is an illustration of a perspective view of an exemplary GPS, GSM, and WLAN antenna with cover according to one embodiment;

FIG. **3**A is an illustration of a perspective view of the GPS, GSM, and WLAN antenna of FIG. **2** without cover according to one embodiment;

FIG. **3**B is an illustration of a plan view of the GPS, GSM, and WLAN antenna of FIG. **3**A according to one embodiment;

FIG. **3**C is an illustration of a side view of the GPS, GSM, and WLAN antenna of FIG. **3**A according to one embodiment;

FIG. **3**D is an illustration of a front view of the GPS, GSM, and WLAN antenna of FIG. **3**A according to one embodiment;

FIG. **4**A is an illustration of an exemplary circuit of a GPS, GSM, and WLAN antenna according to one embodiment;

FIG. **4**B is an illustration of an exemplary circuit of a GPS, GSM, and WLAN antenna according to another embodiment;

FIG. **5** is an illustration of a plan view of a combination printed GSM meander antenna and printed WLAN meander antenna according to one embodiment;

FIG. **6** is an illustration of a plan view of a combination printed GSM meander antenna and printed WLAN meander antenna according to another embodiment;

FIG. **7**A is an illustration of top view of a top patch of a dual band GPS antenna of FIG. **7**B according to one embodiment;

FIG. **7**B is an illustration of a cross-section view of a dual band GPS antenna according to one embodiment;

FIG. **7**C is an illustration of a top view of a bottom patch of the dual band GPS antenna according to one embodiment;

FIG. **8** is an illustration of a plan view of a GPS and satellite digital audio radio antenna according to one embodiment;

FIG. **9** illustrates a graph of the measurement of the combination printed GSM meander antenna and printed WLAN meander antenna of FIG. **5** according to one embodiment; and

FIG. **10** is a Smith chart used for displaying an exemplary impedance plot that shows the impedance of combination printed GSM meander antenna and printed WLAN meander antenna of FIG. **5** according to one embodiment.

DETAILED DESCRIPTION OF THE DRAWINGS

The term "exemplary" is used herein to mean "serving as an example, instance, or illustration." Any embodiment, aspect, or design described herein as "exemplary" is not necessarily to be construed as preferred or advantageous over other embodiments, aspects, or designs.

FIG. **1** is an illustration of an exemplary vehicle **102** including a GPS, GSM, and WLAN antenna **100** disposed on the roof **108** of vehicle **102** capable of communicating with multiple systems. Preferably, GPS, GSM, and WLAN antenna **100** is capable of communicating with a GPS **120**, a GSM **130**, and a WLAN system **140**. Additionally, GPS, GSM, and WLAN antenna **100** includes a transceiver **104** via a conductor **106** for communicating signals between GPS, GSM, and WLAN antenna **100** and transceiver **104**. Transceiver **104** may be incorporated within GPS, GSM, and WLAN antenna **100** or it may be located in a separate location of vehicle **102**, such as that shown in FIG. **1**

GPS **120** includes a plurality of GPS satellites **122***a*-**122***n* (collectively **122**) that may be in orbit around the earth. A GPS antenna **304** (FIG. **3**) has line-of-sight to one or more GPS satellites **122** from any location on Earth unless blocked by objects (e.g., buildings, trees, mountains, and so on). A GPS receiver **406** (FIG. **4**) may obtain a three-dimensional ("3-D") position fix based on measurements for at least three GPS satellites **122** or a two-dimensional ("2-D") position fix based on measurements for three GPS satellites **122**. A position fix is an estimate of the location of GPS antenna **304** and/or GPS receiver **406**. GPS receiver **406** may determine a time of arrival ("TOA") for each GPS satellite **122**, which is a measure of the time it takes for GPS signals **124***a*-**124***n* (collectively **124**) to travel from GPS satellites **122** to GPS receiver **406**. GPS receiver **406** may then calculate the distance to each GPS satellite **122** based on the TOA for GPS satellites **122**. GPS receiver **406** may then triangulate the position of vehicle **102** on Earth based on accurate distances to three GPS satellites **122** and the known locations of these satellites. Since GPS receiver **406** is typically not synchronized with GPS satellites **122**, an additional measurement for either a fourth GPS satellite **122** or an Earth-bound base station is used to account for ambiguity in the timing of GPS receiver **406**.

GSM **130** may be a TDMA system that may implement one or more TDMA standards such as, e.g., GSM. GSM **130** may include one or more Node B **134** and a radio network controller ("RNC") **132**. Node B **134** provides over-the-air communication of GSM RF signals for GPS, GSM, and WLAN antenna **100** of vehicle **102** under its coverage area. RNC **132** couples to Node Bs in GSM **130** and provides coordination and control for one or more Node B **134**. In general, Node B **134** is a fixed station that provides communication coverage for GPS, GSM, and WLAN antenna **100** of vehicle **102** and may also be referred to as base station(s) or some other terminology as would be understood by one of ordinary skill in the art. RNC **132** are network entities that provide coordination and control for the base stations and may also be referred to by some other terminology. Additionally, RNC **132** may also be in communication with a public switched telephone network ("PSTN") **136**. Generally, GSM **130** is a cellular network and may include a plurality of Node B **134** and RNC **132** located in cells where vehicle **102** may travel. Node B **134** may transmit to and receive modulated RF signals **138** from GPS, GSM, and WLAN antenna **100** of vehicle **102**.

WLAN system **140** includes one or more access points **144**, such as an omni-directional antenna, multi-directional antenna, and/or directional antenna, for transmitting RF signals **148** to GPS, GSM, and WLAN antenna **100** of vehicle **102**. Generally, access point **144** is in communication with a router **142** that is in communication with Internet **146** for transmitting and receiving data via RF signals **148** to GPS, GSM, and WLAN antenna **100** of vehicle **102**. It should be noted that one of ordinary skill in the art will understand that WLAN system **140** has been simplified to better illustrate features of GPS, GSM, and WLAN antenna **100**. Well-known elements have not been shown, but are nonetheless part of a network embodying features of GPS, GSM, and WLAN antenna **100**. For example, one embodiment of WLAN system **140** may include amplifiers, power supplies, maintenance systems, gateways, additional routers, bridges, firewalls, and the like.

Referring now to FIG. **2**, an embodiment of GPS, GSM, and WLAN antenna **100** is shown with a cover **202**, a housing or base **204**, and a GSM/WLAN antenna housing **206**, all preferably in sealing arrangement for protecting the electronics and antennas contained within as further described herein from the elements and weather. Generally, cover **202**, base **204**, and GSM/WLAN antenna housing **206** have a size, form, and/or shape sufficient to enclose the electronics and antennas contained within them. In one embodiment, base **204** has a size and shape sufficient to enclose GPS antenna **304** (FIG. **3**) and the base portion of a GSM/WLAN antenna **302** (FIG. **3**) as described herein. Additionally, GSM/WLAN antenna housing **206** has a size and shape sufficient to enclose the all or a portion of GSM/WLAN antenna **302** as described herein. In another embodiment, cover **202**, base **204**, and GSM/WLAN antenna housing **206** are a unified single piece and not separate individual pieces. Preferably, base **204** has a lower surface that joins in a sealing arrangement with the upper surface of roof **108** of vehicle **102**. Additionally, conductor **106** may exit the lower surface of base **204** and be disposed through roof **108** as it is routed to transceiver **104**, in one embodiment. In another embodiment, GPS, GSM, and WLAN antenna **100** may be affixed or attached to other portions of vehicle **102**, such as pillars, windows, trunks, bodies, etc. Cover **202**, base **204**, and GSM/WLAN antenna housing **206** may be made out of a material that is weatherproof and dustproof while allowing the GPS antenna **304** and GSM/WLAN antenna **302** contained within GPS, GSM, and WLAN antenna **100** to operate without providing unnecessary interference with RF signals.

In one aspect, conductor **106** may include one or more separate conductors, wires, or cables, such as a radio frequency ("RF") cable **208**, a RF cable **210**, and a RF cable **212**. RF cable **208** is for conducting signals between GPS receiver **406** (FIG. **4**) and GPS, GSM, and WLAN antenna **100**. RF cable **210** is for conducting signals between a WLAN receiver **404** (FIG. **4**) and GPS, GSM, and WLAN antenna **100** and RF cable **212** is for conducting signals between a GSM receiver **402** (FIG. **4**) and GPS, GSM, and WLAN antenna **100**.

Referring now to FIGS. **3A-3D**, an embodiment of GPS, GSM, and WLAN antenna **100** is shown with cover **202** and GSM/WLAN antenna housing **206** removed from base **204**. A GSM/WLAN antenna **302** and GPS antenna **304** are disposed and/or positioned within base **204** of GPS, GSM, and WLAN antenna **100**. Preferably, GSM/WLAN antenna **302** is a substantially planar PCB antenna having a combination GSM antenna and WLAN antenna traced on one or both sides of PCB antenna as further described below in FIGS. **5** and **6**. Preferably, GSM/WLAN antenna **302** has one end that is secured to base **204** such that GSM/WLAN antenna **302** extends in an upward position to enable incident RF signals between GSM **130** and WLAN system **140** and GSM/WLAN antenna **302** of GPS, GSM, and WLAN antenna **100** to be effectively communicated. Also, GPS antenna **304** is positioned within base **204** such as in a substantially horizontal position such that it enables incident RF signals between GPS **120** and GPS antenna **304** of GPS, GSM, and WLAN antenna **100** to be effectively communicated.

In one embodiment, roof **108** has a hole or aperture therethrough (not shown) for receiving a threaded member **306** of base **204** for securing GPS, GSM, and WLAN antenna **100** to vehicle **102**. In one aspect, a fastener, such as a nut or threaded washer **308** may be used with threaded member **306** for securing GPS, GSM, and WLAN antenna **100** to roof **108** of vehicle **102**. Other types of fasteners, adhesives, and the like may be used to secure GPS, GSM, and WLAN antenna **100** to vehicle **102**, as would be commonly known to those skilled in the art.

Referring now to FIG. **4**A, an embodiment of an exemplary circuit **400** is shown that includes conductor **106** including RF cable **208**, RF cable **210**, and RF cable **212** in communication with GSM/WLAN antenna **302** and GPS antenna, respectively. RF cable **210** and RF cable **212** may be one RF cable **408** instead of two separate RF cables. In one embodiment, a switch **410** may switch the signals carried in conductor **408** to RF cable **210** and RF cable **212** to WLAN receiver **404** and GSM receiver **402**, respectively. GSM receiver **402**, WLAN receiver **404**, and GPS receiver **406** may be part of transceiver **104** or they may be located separately or in different locations within vehicle **102**. In another embodiment, one or more of RF cables **408**, RF cable **208**, switch **410**, RF cable **210**, and RF cable **212** may be housed fully or partially within GPS, GSM, and WLAN antenna **100**. In yet another embodiment, one or more of switch **410**, conductor **408**, RF cable **208**, RF cable **210**, and RF cable **212** may be located fully or partially located within transceiver **104**.

In general, GPS, GSM, and WLAN antenna **100** may be capable of communicating with any number of wireless systems of different wireless technologies, such as code division multiple access ("CDMA"), TDMA, GSM, GPS, WLAN, and the like. In one embodiment, the following describes the GPS, GSM, and WLAN antenna **100** communicating with GPS **120**, GSM **130**, and WLAN system **140**. GPS, GSM, and WLAN antenna **100** may receive signals from one or more transmitting entities at any given moment, where a transmitting entity may be a base station, satellite, and the like; each transmitting entity may be received by each of the GSM/WLAN antenna **302** and GPS antenna **304** of GPS, GSM, and WLAN antenna **100**, albeit at different amplitudes and/or phases.

Referring now to FIG. **4**B, another embodiment of an exemplary circuit **420** of transceiver **104** is described. As discussed above, GSM **130** and WLAN system **140** may operate on various frequency bands. For example, WLAN receiver **404** and GSM/WLAN antenna **302** may operate at 2.4 GHz range and GSM receiver **402** and GSM/WLAN antenna **302** may operate at 900 MHz and 1800 MHz; 850 MHz and 1900 MHz; and/or 2100 MHz range. GPS receiver **406** and GPS antenna **304** may operate at 1.57542 and/or 1.2276 GHz for example. For each frequency band, except for the GPS frequency band, one frequency range may be used for the downlink (i.e., forward link) from access point **144** and/or Node B **134** to GPS, GSM, and WLAN antenna **100**, and another frequency range may be used for the uplink (i.e., reverse link) from GPS, GSM, and WLAN antenna **100** to access point **144** and Node B **134**. As an example, for the GSM850/cellular band range (824-849 MHz) may be used for the uplink, and the 869 to 894 MHz range may be used for the downlink.

GPS, GSM, and WLAN antenna **100** may support one or multiple frequency bands for each of GPS **120**, GSM **130**, and WLAN system **140**. In one embodiment, GPS, GSM, and WLAN antenna **100** communicates with one wireless system at a time, and in another embodiment, GPS, GSM, and WLAN antenna **100** communicates with more than one wireless system at a time. Various embodiments of circuit **420** of transceiver **104** of GPS, GSM, and WLAN antenna **100** are described.

Generally, GPS, GSM, and WLAN antenna **100** includes transceiver **104** that may support four frequency bands with receiving ("RX") diversity for TDMA for GSM and support four frequency bands with transmitting ("TX") diversity for TDMA for GSM. The quad GSM bands may include first, second, third, and fourth GSM transmit bands ("GTX**1**," "GTX**2**," "GTX**3**," "GTX**4**") and first, second, third, fourth GSM receive bands ("GRX**1**," "GRX**2**," "GRX**3**," "GRX**4**"). In addition, to these four frequency bands, transceiver **104** may support a WLAN frequency transmit band ("WTX") and a WLAN frequency receive band ("WRX"). Transceiver **104** may include a GSM/WLAN portion **422** that is in communication with GSM/WLAN antenna **302**. In addition, transceiver **104** may include a GPS portion **424** that is in communication with GPS antenna **304**. Additionally, GSM/WLAN portion **422** of transceiver **104** may include a switch **436** that may be switch **410** or another switch in addition to switch **410**. GSM/WLAN portion **422** and GPS portion **424** may be in communication with a RF unit **426**, which may condition signals for GSM/WLAN portion **422**. Switch **436** may be a transmit/receive T/R switch that has one or more common RF port in communication with GSM/WLAN antenna **302**.

Further, switch **436** may be in communication with a duplexer **458** for the WRX and WTX paths. Switch **436** may further include two input RF ports for the four GSM transmit paths, GTX**1**-GTX**4**. Switch **436** may also include two output RF ports for the GMS receive paths, GRX**1** and GRX**2**. Switch **436** couples the common RF port to one of the I/O RF ports at any given moment based on a control signal ("CTRL"), which may be a single-bit or multi-bit signal. For GSM, which may be a time division duplex ("TDD") system, uplink and downlink transmissions occur in different non-overlapping time intervals or time slots, and only the transmit path or the receive path may be active at any given moment. Switch **436** performs switching to allow GSM/WLAN portion **422** to process either GSM or WLAN signals. Additionally, switch **436** further performs switching between the GSM transmit and receive paths when GSM/WLAN portion **422** is processing GSM.

The GSM transmit path includes a power amplifier ("PA") module **442** that receives and amplifies a GSM transmit signal (GTX**1**-GTX**4**) from RF unit **426** and provides a GSM uplink signal for transmission via GSM/WLAN antenna **302**. PA module **442** may have a variable gain that may be adjusted based on a gain control signal, which may come from a modem processor **432**. The gain control signal may ramp-up or ramp-down the gain of PA module **442**. The amplitude of the GSM uplink signal may also be controlled by the gain control signal and the phase of the GSM uplink signal may be controlled by modem processor **432** to achieve any modulation, such as Gaussian minimum-shift keying ("GMSK"), phase-shift keying ("PSK"), offset quadrature phase-shift keying ("OQPSK"), quadrature amplitude modulation

("QAM"), and the like. The GSM transmit and receive paths may be designed to be compliant with GSM system requirements described in 3GPP TS 51.010, which is publicly available, for example.

The first and third GSM receive paths, GRX**1** and GRX**3**, may each include a GMS filter **440** and **438**, respectively, that filters a received signal from GSM/WLAN antenna **302** and a low noise amplifier ("LNA") **454** and **456**, respectively, that amplifies the filtered signal from filters **440** and **438** and provides GSM received signals (GRX**1** and GRX**3**) to RF unit **426**. GSM filters **440** and **438** may be bandpass filters that are implemented with a surface acoustic wave ("SAW") filter having a bandwidth equal to the first or second GSM receive signals (GRX**1** and GRX**3**). Also, GSM filters **440** and **438** may filter out large amplitude undesired signals (or "jammers") and other out-of-band signals transmitted by other wireless systems.

The WLAN transmit path includes a filter **464**, a power amplifier **466**, and an isolator **470**. Filter **464** filters a WTX from RF unit **426** and provides a filtered WLAN signal. Filter **464** may be implemented with a SAW filter having a bandwidth equal to the WLAN transmit band. Power amplifier **466** amplifies the filtered WLAN signal and provides a WLAN uplink signal. Isolator **470** couples the WLAN uplink signal to duplexer **458** and prevents the signal from duplexer **458** from coming back to power amplifier **466**, and provides an impedance load for power amplifier **466**. Duplexer **458** routes the WLAN uplink signal from isolator **470** to switch **436** for transmission via GSM/WLAN antenna **302**.

Duplexer **458** also receives, via switch **436**, the received signal from GSM/WLAN antenna **302** and routes the received signal to the WLAN receive path. Duplexer **458** provides isolation between the transmit path and the main receive path for WLAN, filters out undesired signal components for each of these two paths, and supports simultaneous operation of these two signal paths for full-duplex communication. The WRX path includes a LNA **460** and a filter **462**. LNA **460** amplifies the received signal from GSM/WLAN antenna **302** and provides an amplified received signal. Filter **462** filters the amplified received signal and provides a WRX to RF unit **426**. Filter **462** may be implemented with a SAW filter having a bandwidth equal to the WLAN receive band, WRX. Duplexer **458** performs filtering to preselect the WRX band and filter **462** provides additional filtering to remove leakage of the WLAN uplink signal coming from the WLAN transmit path.

RF unit **426** performs signal conditioning for GSM and WLAN signals for all of the transmit and receive paths. For each GSM received signal and each WLAN received signal, RF unit **426** may perform frequency down-conversion, demodulation, filtering, amplification, and gain control. For each GSM transmit signal and each WLAN transmit signal, RF unit **426** may perform filtering, amplification and gain control, modulation, and frequency up-conversion. RF unit **426** may utilize a super-heterodyne architecture or a direct-conversion architecture. The super-heterodyne architecture may use multiple stages, such as frequency down-conversion from RF to an intermediate frequency ("IF") in one stage, and (e.g., quadrature) demodulation from IF to baseband in another stage. The direct-conversion architecture uses a single stage to perform demodulation and frequency down-conversion from RF directly to baseband. Similarly, modulation and frequency up-conversion are performed in multiple stages for the super-heterodyne architecture and in a single stage for the direct-conversion architecture. RF unit **426** also performs modulation and demodulation for each wireless system based on the modulation scheme employed by that system and using techniques known in the art. For example, modulation for GSM may be performed with an offset phase locked loop ("OPLL") or a polar modulation scheme.

Additionally, GSM/WLAN portion **422** may include a diplexer **444** that couples to GSM/WLAN antenna **302**, obtains the received signal from GSM/WLAN antenna **302**, provides first and second diplexer output signals to the second and fourth GSM receive paths (GRX**2** and GRX**4**), respectively. The second GSM receive path includes a filter **446** and an LNA **450** that filter and amplify the first diplexer output signal and provide a second GSM received signal (GRX**2**) to RF unit **426**. The fourth GSM receive path (GRX**4**) includes a filter **448** and an LNA **452** that filter and amplify the second diplexer output signal and provide a fourth GSM received signal (GRX**4**) to RF unit **426**. Filters **446** and **448** may be SAW filters having bandwidths equal to the second and fourth GSM receive bands, respectively.

A modulator/demodulator ("modem") processor **432** performs baseband modem processing for GSM and WLAN. For each transmit path, modem processor **432** encodes, interleaves, and modulates data to obtain data symbols, which are modulation symbols for data. Modem processor **432** further performs physical layer processing on the data symbols and pilot symbols, which are modulation symbols for a pilot, in accordance with the wireless system. For example, modem processor **432** may channelize (or "cover") and spectrally spread (or "scramble") the data and pilot symbols to obtain data chips. For each receive path, modem processor **432** performs the complementary physical layer processing (e.g., spectral despreading and dechannelization) to obtain received symbols, and further demodulates, deinterleaves, and decodes the received symbols to obtain decoded data. The modem processing for GSM is described in 3GPP TS 05 documents, and the modem processing for WLAN is dependent on the WLAN standard being implemented, such as IEEE 802.11a/b/g/n. Modem processor **432** also performs analog-to-digital conversion for each receive path and digital-to-analog conversion for each transmit path. Although not shown in FIG. **4**B, modem processor **432** may also interface with a memory unit **428**, multimedia units (e.g., a camera), I/O units (e.g., a touch screen, a display unit, a keypad, a speaker, and/or a microphone), and the like. Modem processor **432** may be implemented with one or more application specific integrated circuits ("ASICs").

A main oscillator **434** provides a reference oscillator signal (at a predetermined frequency) to RF unit **426** and modem processor **432**. Main oscillator **434** may be implemented with a voltage-controlled temperature-compensated crystal oscillator ("VCTCXO") or some other types of oscillator known in the art. RF unit **426** may include built-in voltage-controlled oscillators ("VCOs") and phase locked loops ("PLLs"). One set of VCO and PLL may be used for each signal path that may be "tuned" (i.e., adjusted in frequency) independently. Each set of VCO and PLL receives the reference oscillator signal from main oscillator **434** and generates a local oscillator ("LO") signal at the desired frequency. A controller **430** controls the operation of modem processor **432** and possibly RF unit **426**. Memory **428** provides storage for controller **430** and modem processor **432**.

Additionally, transceiver **104** may include a GPS portion **424** that supports GPS signals. GPS portion **424** includes a filter **468** that is in communication with GPS antenna **304** for GPS, filters a received signal from GPS antenna **304**, and provides a GPS received signal to RF unit **426**. GPS antenna **304** may be designed for one or more GPS bands, such as 1.227 GHz and/or 1.575 GHz, as further described below with reference to FIG. **7**. Filter **468** may be implemented with a SAW filter having a bandwidth equal to the GPS band, for example.

Referring now to FIG. **5**, an illustration of a plan view of an embodiment of a GSM/WLAN printed meander antenna **500** having different widths and lengths are shown. In one aspect, GSM/WLAN printed meander antenna **500** is printed on a PCB **508**. In FIG. **5**, GSM/WLAN printed meander antenna **500** is shown with a GSM printed meander antenna portion **502**, **506**, and WLAN printed meander antenna portion **504**. GSM printed meander antenna portion **502**, **506** and WLAN printed meander antenna portion **504** may be connected to transceiver **104** via conductor **106**. GSM printed meander antenna portion **502**, **506** and WLAN printed meander antenna portion **504** are printed on one side or both sides of PCB **508**. GSM printed meander antenna portion **502**, **506** and WLAN printed meander antenna portion **504** may further include an inductor (not shown) disposed between them for additional impedance tuning of GSM/WLAN printed meander antenna **500**. In one embodiment, GSM/WLAN printed meander antenna **500** may further include a resistor (not shown) for providing additional frequency bandwidth.

In one embodiment, GSM printed meander antenna portion **502** may include a antenna trace line antenna trace line **502***a*, antenna trace line **502***b*, antenna trace line **502***c*, antenna trace line **502***d*, and antenna trace line **502***e* (collectively **502**). Antenna trace lines **502***a* and **502***b* may have a length L_{1a} from about 84 millimeters ("mm") to about 28 mm. In another aspect, antenna trace lines **502***a* and **502***b* may have a length L_{1a} from about 70 mm to about 42 mm. Preferably, antenna trace lines **502***a* and **502***b* may have a length L_{1a} of 56 mm. Antenna trace line **502***a* may have a length L_{2a} from about 15 mm to about 5 mm. In another aspect, antenna trace line **502***a* may have a length L_{2a} from about 13 mm to about 8 mm. Preferably, antenna trace line **502***a* may have a length L_{2a} of 10 mm. Additionally, antenna trace line **502***a* may have a width W_{3a} from about 3 mm to about 1 mm. In another aspect, antenna trace line **502***a* may have a width W_{3a} from about 3 mm to about 2 mm. Preferably, antenna trace line **502***a* may have a width W_{3a} of 2 mm.

In one aspect, antenna trace line **502***b* has a length L_{3a} of from about 60 mm to about 20 mm. In another aspect, antenna trace line **502***b* has a length L_{3a} of from about 50 mm to about 30 mm. Preferably, antenna trace line **502***b* has a length L_{3a} of 40 mm. Antenna trace line **502***b* has a width W_{2a} of from about 10 mm to about 3 mm. In one aspect, antenna trace line **502***b* has a width W_{2a} of from about 8 mm to about 5 mm. Preferably, antenna trace line **502***b* has a width W_{2a} of 7 mm.

In one aspect, antenna trace line **502***c* has a length L_{6a} of from about 13 mm to about 4 mm. In another aspect, antenna trace line **502***c* has a length L_{6a} of from about 11 mm to about 7 mm. Preferably, antenna trace line **502***c* has a length L_{6a} of 9 mm. Antenna trace line **502***c* has a width W_{1a} of from about 26 mm to about 9 mm. In one aspect, antenna trace line **502***c* has a width W_{1a} of from about 21 mm to about 13 mm. Preferably, antenna trace line **502***c* has a width W_{1a} of 17 mm. Additionally, the combined length of antenna trace line **502***d* and antenna trace lines **502***e* has a length L_{4a} of from about 29 mm to about 10 mm. In another aspect, the combined length of antenna trace line **502***d* and antenna trace lines **502***e* has a length L_{4a} of from about 24 mm to about 14 mm. Preferably, antenna trace line **502***d* and antenna trace lines **502***e* has a length L_{4a} is 19 mm.

In one aspect, antenna trace line **502***d* has a length L_{9a} of from about 12 mm to about 4 mm. In another aspect, antenna trace line **502***d* has a length L_{9a} of from about 10 mm to about 6 mm. Preferably, antenna trace line **502***d* has a length L_{3a} of 8 mm. Antenna trace line **502***d* has a width W_{4a} of from about 5 mm to about 2 mm. In one aspect, antenna trace line **502***d* has a width W_{4a} of from about 4 mm to about 3 mm. Preferably, antenna trace line **502***d* has a width W_{4a} of 3 mm.

In one aspect, antenna trace line **502***e* has a length L_{5a} of from about 3 mm to about 1 mm. In another aspect, antenna trace line **502***e* has a length L_{5a} of from about 3 mm to about 2 mm. Preferably, antenna trace line **502***e* has a length L_{3a} of 2 mm. Antenna trace line **502***e* has a width W_{5a} of from about 9 mm to about 3 mm. In one aspect, antenna trace line **502***e* has a width W_{5a} of from about 8 mm to about 5 mm. Preferably, antenna trace line **502***e* has a width W_{5a} of 6 mm.

In one aspect, antenna trace line of WLAN printed meander antenna portion **504** ("antenna trace line **504**") has a length L_{8a} of from about 23 mm to about 8 mm. In another aspect, antenna trace line **504** has a length L_{8a} of from about 19 mm to about 11 mm. Preferably, antenna trace line **504** has a length L_{8a} of 15 mm. Antenna trace line **504** has a width W_{6a} of from about 7 mm to about 2 mm. In one aspect, antenna trace line **504** has a width W_{6a} of from about 6 mm to about 4 mm. Preferably, antenna trace line **504** has a width W_{6a} of 5 mm.

In one aspect, GSM printed meander antenna portion **506** ("antenna trace line **506**") has a length L_{7a} of from about 37 mm to about 12 mm. In another aspect, antenna trace line **506** has a length L_{7a} of from about 31 mm to about 19 mm. Preferably, antenna trace line **506** has a length L_{7a} of 25 mm. Antenna trace line **506** has a width W_{7a} of from about 8 mm to about 3 mm. In one aspect, antenna trace line **506** has a width W_{7a} of from about 6 mm to about 4 mm. Preferably, antenna trace line **506** has a width W_{7a} of 5 mm.

In one embodiment, antenna trace line **502***a* and antenna trace line **502***b* extend laterally or vertically from the lower end of PCB **508** to the upper end of PCB **508**. In this embodiment, antenna trace line **502***c* may extend longitudinally or horizontally from one side of antenna trace line **502***c* towards the other side of PCB **508** as shown. Further, antenna trace line **502***d* may extend laterally or vertically from the upper end of PCB **508** towards the lower end of PCB **508**. Antenna trace line **502***e* may extend longitudinally or horizontally from one end of antenna trace line **502***d* towards antenna trace line **502***b*. In one embodiment, WLAN printed meander antenna portion **504** extends laterally or vertically from the lower end of PCB **508** toward the upper end of PCB **508**, although it preferably terminates prior to antenna trace line **502***e*. Additionally, GSM printed meander antenna portion **506** also extends laterally or vertically from the lower end of PCB **508** toward the upper end of PCB **508**, although it also preferably terminates prior to antenna trace line **502***e*.

In the representative embodiments described herein, terms such as "above," "below," "upper," "lower," etc., are used for convenience in referring to the accompanied drawings. In general, "above," "upper," "upward" and similar terms refer to a direction that is commonly thought of as vertically upward and the terms "below," "lower," and "downward" and similar terms refer to a direction in the opposite direction or vertically downward as commonly known. For purposes of this discussion, the relativity of these terms may be thought of in the context of the use and operation of the present GPS, GSM, and WLAN antenna **100**. In one embodiment, the term "lower" may refer to the lower end of GPS, GSM, and WLAN antenna **100** that affixes to roof **108** of GPS, GSM, and WLAN antenna **100**. Thus, the term "upper" may refer to the upper end of GPS, GSM, and WLAN antenna **100** that extends away from roof **108** of GPS, GSM, and WLAN antenna **100**.

Referring to FIG. **6**, an illustration of a plan view of another embodiment of a GSM/WLAN printed meander antenna **600** having different widths and lengths are shown. In one aspect, GSM/WLAN printed meander antenna **600** is printed on a PCB **606**. In FIG. **6**, GSM/WLAN printed meander antenna **600** is shown with a printed meander antenna portion **602** and printed meander antenna portions **604***a*, **604***b*. Printed meander antenna portion **602** and printed meander antenna portions **604***a*, **604***b* may be connected to transceiver **104** via conductor **106**. Printed meander antenna portion **602** and printed meander antenna portion **604***a*, **604***b* are printed on one side or both sides of PCB **606**. Printed meander antenna portion **602** and printed meander antenna portion **604***a*, **604***b* may further include an inductor (not shown) disposed between them for additional impedance tuning of GSM/WLAN printed meander antenna **600**. In one embodiment, GSM/WLAN printed meander antenna **600** may further include a resistor (not shown) for providing additional frequency bandwidth.

In one embodiment, GSM printed meander antenna portion **602** may each include 20 longitudinal or horizontal antenna trace lines of GSM printed meander antenna portion **602**, **602***a*-**602***t* (collectively **602**). In one embodiment, antenna trace lines **602** may have a length L_{1b} from about 104 mm to about 35 mm. In another aspect, antenna trace lines **602** may have a length L_{1b} from about 86 mm to about 52 mm. Preferably, antenna trace lines **602** may have a length L_{1b} from about 86 mm is 69 mm. The length L_{1b} includes all the bends of the antenna trace lines **602**. In one aspect, printed meander antenna portion **602** and printed meander antenna portions **604***a*, **604***b* may have a width W_{1b} from about 39 mm to about 13 mm. In another aspect, printed meander antenna portion **602** and printed meander antenna portions **604***a*, **604***b* may have a width W_{1b} from about 32 mm to about 20 mm. Preferably, printed meander antenna portion **602** and printed meander antenna portions **604***a*, **604***b* may have a width W_{1b} of 26 mm.

In one aspect, antenna trace lines **604***a* and **604***b* may have a length L_{2b} from about 54 mm to about 18 mm. In another aspect, antenna trace lines **604***a* and **604***b* may have a length L_{2b} from about 45 mm to about 27 mm. Preferably, antenna trace lines **604***a* and **604***b* have a length L_{2b} of 36 mm. Antenna trace lines **604***a* and **604***b* may have a width W_{2b} from about 8 mm to about 3 mm. Antenna trace lines **604***a* and **604***b* have a width W_{2b} from about 6 mm to about 4 mm. Preferably, antenna trace lines **604***a* and **604***b* have a length L_{2b} is 5 mm.

The individual antenna trace lines **602***a*-**602***t* may have a length L_{3b} from about 3 mm to about 1 mm. Further, individual antenna trace lines **602***a*-**602***t* may have a length L_{3b} from about 2 mm to about 1 mm. Preferably, individual antenna trace lines **602***a*-**602***t* may have a length L_{3b} of 2 mm. It may be common to consider L_{3b} as a width of the entire printed meander antenna portion **602** in one embodiment although its dimensions are being provided as a length. As can be seen from FIG. **6**, the widths of the individual antenna trace lines **602***a*-**602***t* may vary. For example, the upper portion of printed meander antenna portion **602** is shown having a slightly wider width of individual antenna trace lines **602***a*-**602***t* than the lower portion of printed meander antenna portion **602**. In one aspect, the width W_{3b} of individual antenna trace lines **602***a*-**602***t* may be from 23 mm to about 8 mm. In another aspect, the width W_{3b} of individual antenna trace lines **602***a*-**602***t* may from about 19 mm to about 12 mm. Preferably, the width W_{3b} of individual antenna trace lines **602***a*-**602***t* is 15 mm. Further, the width W_{4b} of individual antenna trace lines **602***a*-**602***t* may be from 30 mm to about 10 mm. Also, the width W_{4b} of individual antenna trace lines **602***a*-**602***t* may be from 25 mm to about 15 mm. Preferably, the width W_{4b} of individual antenna trace lines **602***a*-**602***t* is 20 mm. As shown, the upper portion of printed meander antenna portion **602** may have the width W_{4b} and the lower portion of printed meander antenna portion **602** may have the width of W_{3b}.

In one embodiment, antenna trace lines **602***a*-**602***t* may extend longitudinally or horizontally from the lower end of PCB **606** and meander back and forth substantially adjacent to each other as the entire length of printed meander antenna portion **602** extends towards the upper end of PCB **606**. The printed meander antenna portions **604***a*, **604***b* may extend vertically or laterally from the lower end of PCB **606** towards the upper end of PCB **606** and may end at a point where the widths of **602***a*-**602***t* increase in width. In one aspect, any or all of the trace lines described herein may be made from a conducting material, such as copper.

In one embodiment, symmetrical printed meander dipole antennas **600** and **700** may further include a ground spot that may be located on the bottom side of PCB **508** and **606**, respectively, that may be used as a ground for the amplifier circuit when using GSM/WLAN printed meander antennas **500** and **600** in an active receiving embodiment. In one aspect, the lengths and number of bends of antenna trace lines **602***a*-**602***t* may be chosen using electromagnetic software, such as IE3D, to provide a desirable resistance, such as 50 Ohms input impedance for a particular application. Additionally, impedance tuning may further be optimized by using inductors in addition to the additional cutting of the trace lines as described herein.

PCBs **508** and **606** may be a width that is desirable for a particular application. The width of the printed antenna trace lines may be any desired width for a particular application. PCBs **508** and **606** may further include a ground plane (not shown) with a dielectric board (not shown) disposed thereon. In one embodiment, the dielectric board of PCBs **508** and **606** may be composed of FR-4 material and have a thickness of approximately 1.6 mm and a relative permittivity of 4.4. It should be understood in the art that the configuration of the outputs of PCBs **508** and **606** may have alternative configurations and the dielectric board may be composed of another material and have a different thickness and provide an operable antenna solution. In one embodiment, ground pads are used as the second "arm" on each of these GSM/WLAN printed meander antenna **500** and GSM/WLAN printed meander antenna **600**; the pads serve concomitantly as LNA grounds. The LNA located at the antenna trace line side may increase the sensitivity of a particular receiver as described herein, for example.

As further understood in the art, physical parameters of GSM/WLAN printed meander antennas **500** and **600** may be used for adjusting bandwidth to receive signals, such as RF signals, over a frequency band for tuning impedance of the antenna over the frequency band, and for adjusting gain over the bandwidth. If the output of the GSM/WLAN printed meander antennas **500** and **600** has a certain impedance that includes only resistive component (reactive component value is equal to), then if the RF circuit has the same input impedance, a voltage standing wave ratio ("VSWR") will have a value of 1.0 and the RF signal will be completely input into the RF circuit (i.e., no part of the RF signal will reflect back from the RF circuit). If the output impedance of GSM/WLAN printed meander antennas **500** and **600** and the input impedance of the RF circuit do not match, the VSWR increases to a multiple of 1.0, where the higher the ratio, the higher the VSWR and the lower the input of the RF input impedance of the RF circuit. In one embodiment, these fundamental RF principles may drive the configuration of GSM/WLAN printed meander antennas **500** and **600**. Because slight differences in the configuration of GSM/WLAN printed meander antennas **500** and **600** can have large effects in tuning over the frequency range of a desired application(s), many configurations of the basic structure of GSM/WLAN printed meander antennas **500** and **600** may be used to provide RF output to any of the receivers described herein at a certain resistance (e.g., 50 Ohms) to match a resistance of an RF circuit (e.g., 50 Ohms).

In one embodiment, GPS antenna **304** is a single feed antenna that operates at 1.227 GHz frequency, and in another embodiment, GPS antenna **304** is a single feed antenna that operates at 1.575 GHz frequency. In another embodiment, GPS antenna **304** may be single feed dual band GPS antenna, which operates at both 1.227 GHz and 1.575 GHz frequencies. In both of these embodiments, GPS antenna **304** may be a single patch antenna or double patch antenna, for example.

Referring now to FIGS. **7A-7C**, an embodiment of a single feed dual band GPS antenna **700** is shown. Dual band GPS antenna **700** includes a top patch antenna **702** and a bottom patch antenna **704**. Dual band GPS antenna **700** is a single feed low-profile circularly polarized ("CP") microstrip antenna. Dual band GPS antenna **700** may be in place of GPS antenna **304** or in addition to GPS antenna **304** in GPS, GSM, and WLAN antenna **100**. Dual band GPS antenna **700** operates in both the 1.227 GHz and 1.575 GHz frequencies. Top patch antenna **702** is substantially a square patch that is printed on FR4 substrate of thickness of 1.6 mm with a relative permittivity of 4.4. Top patch antenna **702** further includes a contact feed or probe feed **712** that excites top patch antenna **702** through a via **708** located in bottom patch antenna **704**. Additionally, bottom patch antenna **704** may have a ground plane **710** disposed on the lower side of bottom patch antenna **704**. In one aspect, ground plane **710** may have dimension of 100 mm by 100 mm. Probe feed **712** may be connected to RF cable **208** for providing signals to GPS receiver **406**.

Located between top patch antenna **702** and bottom patch antenna **704** is a thin air layer **706**. By varying the thickness of air layer **706**, the frequency ratio of top patch antenna **702** and bottom patch antenna **704** can be varied. In one aspect, the resonant lengths L_1 and L_2, of top patch antenna **702** and bottom patch antenna **704**, respectively, may about the same, but not quite equal. They generally will depend on the lower CP frequency at 1.227 GHz. In one embodiment, to excite top patch antenna **702** at 1.227 GHz, it is preferred that the resonant L_1 be slightly larger than L_2. In one embodiment, L_1 is approximately 60 mm and is a square with opposing corners with a truncated side length LC_1, of 8.5 mm. Then another CP operation at the desired frequency of 1.575 GHz, bottom patch antenna **704** preferably has a resonant L_2 of approximately 59 mm and is square with opposing corners with a truncated side length LC_2 of 7.5 mm. Air layer **706** is preferably 0.45 mm. For bottom patch antenna **704**, the obtained impedance bandwidth, determined from 10-db return loss, is 53 MHz, or about 4.3% with respect to 1.227 GHz. For top patch antenna **702**, impedance bandwidth is 44 MHz, or about 2.8% referenced to 1.575 GHz.

Referring to FIG. **8**, an embodiment of a combination GPS and satellite digital audio radio antenna ("GPS SDAR antenna") **800**. As noted above with respect to dual band GPS antenna **700**, GPS SDAR antenna **800** may be used in place of GPS antenna **304** or in addition to GPS antenna **304**. GPS signals **124** are right hand circular polarization ("RHCP") signals and SDARS are left hand circular polarization ("LHCP") signals, they may be operated at the same time without interfering with each other's passive performance. GPS SDAR antenna **800** may include a first top metallization element **802** and a second top metallization element **804** disposed over top surface of a dielectric material **14**. First top metallization element **802** includes opposing cut corners **806**, **808**, which results in a LHCP polarized antenna element, and second top metallization element **804** includes straight-edge interior corners **810**, **812** (i.e. non-perpendicular corners), which results in a RHCP polarized antenna element. A feed pin **814** is in direct contact with first top metallization element **802** and extends perpendicularly through the dielectric material **816** through an opening **818** formed in a substantially rectangular bottom metallization element (not shown). As illustrated, dielectric material **816** isolates the feed pin **814** from contacting the bottom metallization element.

Second top metallization **804** element is shaped as a substantially rectangular ring of material that encompasses a substantially rectangular sheet of material that defines first top metallization element **802**. Each first and second top metallization elements **802**, **804** may be separated by a ring **820** of dielectric material that may be integral with the dielectric material **816**, which supports first and second top metallization elements **802**, **804**. Although first and second top metallization elements **802**, **804** include a thickness, T, and are shown disposed in the top surface of dielectric material **816**, first and second metallization elements **802**, **804** may be placed over a top surface of dielectric material **816** and, as such, a separate ring **822** of dielectric material may be placed over the top surface of the dielectric material **816**. In one aspect, an outer ring of dielectric material **822** may be placed over top surface to encompass an outer periphery of the second top metallization element **804**. Additional disclosure relating to one embodiment of GPS SDAR antenna **800** are described in U.S. Pat. No. 7,253,770 issued Aug. 7, 2007 to Yegin et al; U.S. Pat. No. 7,405,700 issued Jul. 29, 2008 to Duzdar et al.; and U.S. Pat. No. 7,164,385 issued Jan. 16, 2007 to Duzdar et al.; which are all incorporated herein by reference in their entirety. GPS SDAR antenna **800** may be connected to GPS antenna **304** and satellite digital audio radio receiver (not shown) via RF cable **208** or other conductor means as commonly know to those skilled in the art.

Referring to FIG. **9**, a graph **900** shows a GSM/WLAN printed meander antenna **500** with resistance equal to 0 Ohms. As can be seen from graph **900**, the measurement of the frequency bandwidth is approximately 1638.77 MHz, beginning at 824.0000 MHz and ending at 2462.7667 MHz. Referring to FIG. **10**, a Smith chart **1000** is shown that is used for displaying an exemplary impedance plot **1020** for GSM/WLAN printed meander antenna **500**. In designing a RF signal path, for example, a network analyzer that is capable of generating the Smith chart **1000** may be used to analyze impedances over a frequency range for operating GSM/WLAN printed meander antenna **500**. As shown on the Smith chart **1000**, the input impedance plot **1020** shows input impedances of GSM/WLAN printed meander antenna **500** having an impedance of 50 Ohms. Because GSM/WLAN printed meander antenna **500** and circuits **400** and **420** may be mismatched in impedance, a VSWR value is greater than 1 results. A Smith chart has a normalized impedance plane **1002** defining an inductive impedance (positive imaginary parts) **1006** above the normalized impedance plane **1002** and a capacitive impedances (negative imaginary parts) **1004** below the normalized impedance plane **1002**. In Smith chart **1000**, a marker **1008** shows an impedance or resistance of 22.96 Ohms at 824.000 MHz; a marker **1010** shows an impedance of 91.45 Ohms at 960.000 MHz; a marker **1012** shows an impedance of 35.78 Ohms at 1710.000 MHz; a marker **1014** shows an impedance of 34.73 Ohms at 2039.967 MHz; a marker **1016** shows an impedance of 24.90 Ohms at 2380.767 MHz; and a marker **1018** shows an impedance of 34.93 Ohms at 2462.767 MHz.

The previous detailed description is of a small number of embodiments for implementing the GPS, GSM, WLAN antenna and is not intended to be limiting in scope. One of skill in this art will immediately envisage the methods and variations used to implement this invention in other areas than those described in detail. The following claims set forth a number of the embodiments of the GPS, GSM, WLAN antenna disclosed with greater particularity.

What is claimed:

1. A Global Positioning System (GPS), Global System for Mobile Communications (GSM), wireless local area network (WLAN) antenna, comprising:

a dielectric board including a ground plane;

a first antenna trace line disposed on a first portion of the dielectric board and in electrical contact with the dielectric board, the first antenna trace line comprising:

at least one first meandered trace for transmitting and receiving a WLAN radio frequency signal;

a second antenna trace line disposed on a second portion of the dielectric board and in electrical contact with the dielectric board, the second antenna trace line comprising:

at least one second meandered trace for transmitting and receiving a GSM radio frequency signal;

a GPS antenna for receiving radio frequency signals from at least one global positioning satellite; and

a vehicle mountable housing for enclosing the dielectric board, the first antenna trace line, the second antenna trace line, and the GPS antenna.

2. The GPS, GSM, WLAN antenna according to claim **1**, further comprising:

a first output in contact with the first antenna trace line;

a second output in contact with the second antenna trace line; and

a third output in contact with the GPS antenna for outputting electrical signals to at least one transceiver via a RF cable.

3. The GPS, GSM, WLAN antenna according to claim **2**, further comprising:

a switch in contact with the first output and second output for switching between the GSM radio frequency signal and the WLAN radio frequency signal for providing the GSM radio frequency signal to a GSM transceiver and the WLAN radio frequency signal to a WLAN transceiver.

4. The GPS, GSM, WLAN antenna according to claim **1**, wherein the transmitting and receiving of GSM radio frequency is time division multiple access.

5. The GPS, GSM, WLAN antenna according to claim **1**, wherein the first antenna trace line is capable of receiving 900 MHz, 1800 MHz, 850 MHz, and 1900 MHz radio frequency signals.

6. The GPS, GSM, WLAN antenna according to claim **1**, wherein the second antenna trace line is capable of receiving 2.4 GHz radio frequency signals.

7. The GPS, GSM, WLAN antenna according to claim **1**, wherein the GPS antenna is capable of receiving one of 1.57542 GHz and 1.2276 GHz radio frequency signals.

8. The GPS, GSM, WLAN antenna according to claim **1**, wherein the second antenna trace line comprises:

a first antenna trace line portion having a length of 10 mm and a width of 2 mm, the first antenna trace line portion extending laterally from a base of the housing;

a second antenna trace line portion having a length of 40 mm and a width of 7 mm, the second antenna trace line portion extending laterally from the first antenna trace line portion;

a third antenna trace line portion having a length of 9 mm and a width of 17 mm, the third antenna trace line portion extending substantially longitudinally from the second antenna trace line portion;

a fourth antenna trace line portion having a length of 8 mm and a width of 3 mm, the fourth antenna trace line portion extending laterally from the third antenna trace line portion towards the base of the housing; and

a fifth antenna trace line portion having a length of 2 mm and a width of 3 mm, the fifth antenna trace line portion extending longitudinally from the fourth antenna trace line portion toward the first antenna trace line portion.

9. The GPS, GSM, WLAN antenna according to claim **1**, wherein the first antenna trace line has a length of 24 mm and a width of 5 mm, the second antenna trace line extending laterally from a base of the housing.

10. The GPS, GSM, WLAN antenna according to claim **1**, wherein the first antenna trace line comprises:

a first antenna trace line and a second antenna trace line spaced apart to define a first antenna portion between the first antenna trace line and the second antenna trace line, the first and second antenna trace line having a length of 36 mm and a width of 5 mm, the first and second antenna trace line extending laterally from a base of the housing.

11. The GPS, GSM, WLAN antenna according to claim **10**, wherein the second antenna trace line comprises:

a first plurality of meander trace antenna lines disposed between the first antenna trace line and the second antenna trace line; and

a second plurality of meander antenna trace lines not disposed between the first antenna trace line and the second antenna trace line, wherein the first plurality of meander trace antenna lines have a width of 15 mm and a length 2 mm, and the second plurality of meander trace antenna lines have a width of 20 mm and a length of 2 mm.

12. The GPS, GSM, WLAN antenna according to claim **1**, wherein the dielectric board is a FR-4 dielectric substrate.

13. The GPS, GSM, WLAN antenna according to claim **1**, further comprising:

a satellite digital audio radio antenna.

14. A vehicle having a Global Positioning System (GPS), Global System for Mobile Communications (GSM), wireless local area network (WLAN) antenna, comprising:

a vehicle body;

a dielectric board including a ground plane;

a first antenna trace line disposed on a first portion of the dielectric board and in electrical contact with the dielectric board, the first antenna trace line comprising:

at least one first meandered trace for transmitting and receiving a WLAN radio frequency signal;

a second antenna trace line disposed on a second portion of the dielectric board and in electrical contact with the dielectric board, the second antenna trace line comprising:

at least one second meandered trace for transmitting and receiving a GSM radio frequency signal;

a GPS antenna for receiving radio frequency signals from at least one global positioning satellite; and a housing mounted on the vehicle body for enclosing the dielectric board, the first antenna trace line, the second antenna trace line, and the GPS antenna.

15. The vehicle according to claim **14**, further comprising:

a first output in contact with the first antenna trace line;

a second output in contact with the second antenna trace line; and

a third output in contact with the GPS antenna for outputting electrical signals to at least one transceiver via a RF cable.

16. The vehicle according to claim **15**, further comprising:

a switch in contact with the first output and second output for switching between the GSM radio frequency signal and the WLAN radio frequency signal for providing the GSM radio frequency signal to a GSM transceiver and the WLAN radio frequency signal to a WLAN transceiver.

17. The vehicle according to claim **14**, wherein the transmitting and receiving of GSM radio frequency is time division multiple access.

18. The vehicle according to claim **14**, wherein the first antenna trace line is capable of receiving 900 MHz, 1800 MHz, 850 MHz, and 1900 MHz radio frequency signals.

19. The vehicle according to claim **14**, wherein the second antenna trace line is capable of receiving 2.4 GHz radio frequency signals.

20. The vehicle according to claim **14**, wherein the GPS antenna is capable of receiving one of 1.57542 GHz and 1.2276 GHz radio frequency signals.

21. The vehicle according to claim **14**, wherein the second antenna trace line comprises:

a first antenna trace line portion having a length of 10 mm and a width of 2 mm, the first antenna trace line portion extending laterally from a base of the housing;

a second antenna trace line portion having a length of 40 mm and a width of 7 mm, the second antenna trace line portion extending laterally from the first antenna trace line portion;

a third antenna trace line portion having a length of 9 mm and a width of 17 mm, the third antenna trace line portion extending substantially longitudinally from the second antenna trace line portion;

a fourth antenna trace line portion having a length of 8 mm and a width of 3 mm, the fourth antenna trace line portion extending laterally from the third antenna trace line portion towards the base of the housing; and

a fifth antenna trace line portion having a length of 2 mm and a width of 3 mm, the fifth antenna trace line portion extending longitudinally from the fourth antenna trace line portion toward the first antenna trace line portion.

22. The vehicle according to claim **14**, wherein the first antenna trace line has a length of 24 mm and a width of 5 mm, the second antenna trace line extending laterally from a base of the housing.

23. The vehicle according to claim **14**, wherein the first antenna trace line comprises:

a first antenna trace line and a second antenna trace line spaced apart to define a first antenna portion between the first antenna trace line and the second antenna trace line, the first and second antenna trace line having a length of 36 mm and a width of 5 mm, the first and second antenna trace line extending laterally from a base of the housing.

24. The vehicle according to claim **23**, wherein the second antenna trace line comprises:

a first plurality of meander trace antenna lines disposed between the first antenna trace line and the second antenna trace line; and

a second plurality of meander antenna trace lines not disposed between the first antenna trace line and the second antenna trace line, wherein the first plurality of meander trace antenna lines have a width of 15 mm and a length 2 mm, and the second plurality of meander trace antenna lines have a width of 20 mm and a length of 2 mm.

25. The vehicle according to claim **14**, wherein the dielectric board is a FR-4 dielectric substrate.

26. The vehicle according to claim **14**, further comprising: a satellite digital audio radio antenna.

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