US 20090058731A1

(19) United States

(12) Patent Application Publication (10) Pub. No.: US 2009/0058731 A1

Geary et al. (43) Pub. Date: Mar. 5, 2009

(54) DUAL BAND STACKED PATCH ANTENNA

(75) Inventors: **Kevin Geary**, Los Angeles, CA (US); **James H. Schaffner**, Chatsworth, CA (US); **Hui-Pin Hsu**, Northridge, CA (US); **Joseph S. Colburn**, Malibu, CA (US); **Hyok J. Song**, Camarillo, CA (US)

Correspondence Address:
GENERAL MOTORS CORPORATION
LEGAL STAFF
MAIL CODE 482-C23-B21, P O BOX 300
DETROIT, MI 48265-3000 (US)

(73) Assignee: **GM GLOBAL TECHNOLOGY OPERATIONS, INC.**, DETROIT, MI (US)

(21) Appl. No.: **11/847,372**

(22) Filed: **Aug. 30, 2007**

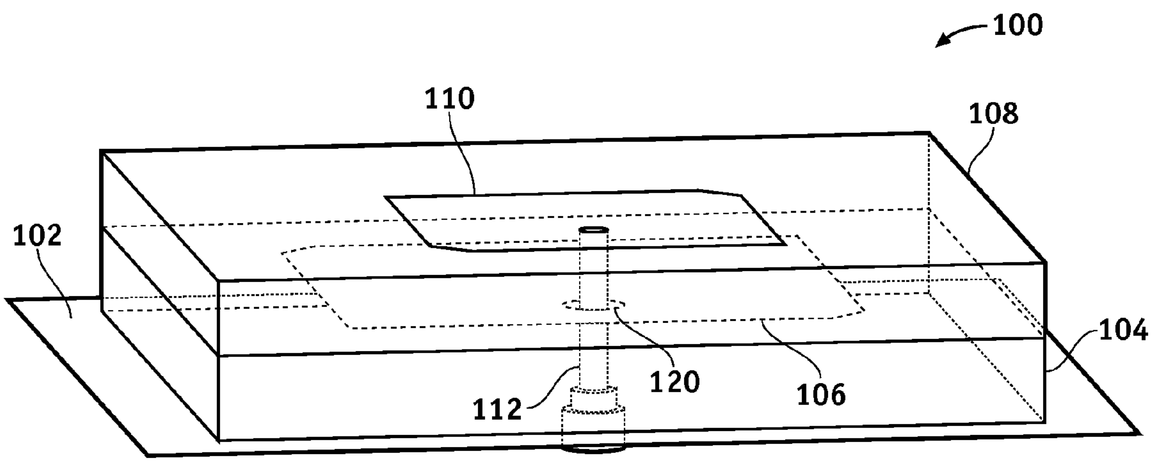
Publication Classification

(51) Int. Cl.
H01Q 9/04 (2006.01)

(52) U.S. Cl. .... 343/700 MS

(57) ABSTRACT

One or more of the embodiments of a dual band stacked patch antenna described herein employ an integrated arrangement of a global positioning system (GPS) antenna and a satellite digital audio radio service (SDARS) antenna. The dual band antenna receives right hand circularly polarized GPS signals in a first frequency band, left hand circularly polarized SDARS signals in a second frequency band, and vertical linear polarized SDARS signals in the second band. The dual band antenna includes a ground plane element, an upper radiating element (which is primarily utilized to receive SDARS signals), dielectric material between the ground plane element and the upper radiating element, and a lower radiating element (which is primarily utilized to receive GPS signals) surrounded by the dielectric material. The dual band antenna uses only one conductive signal feed to receive both GPS and SDARS signals.



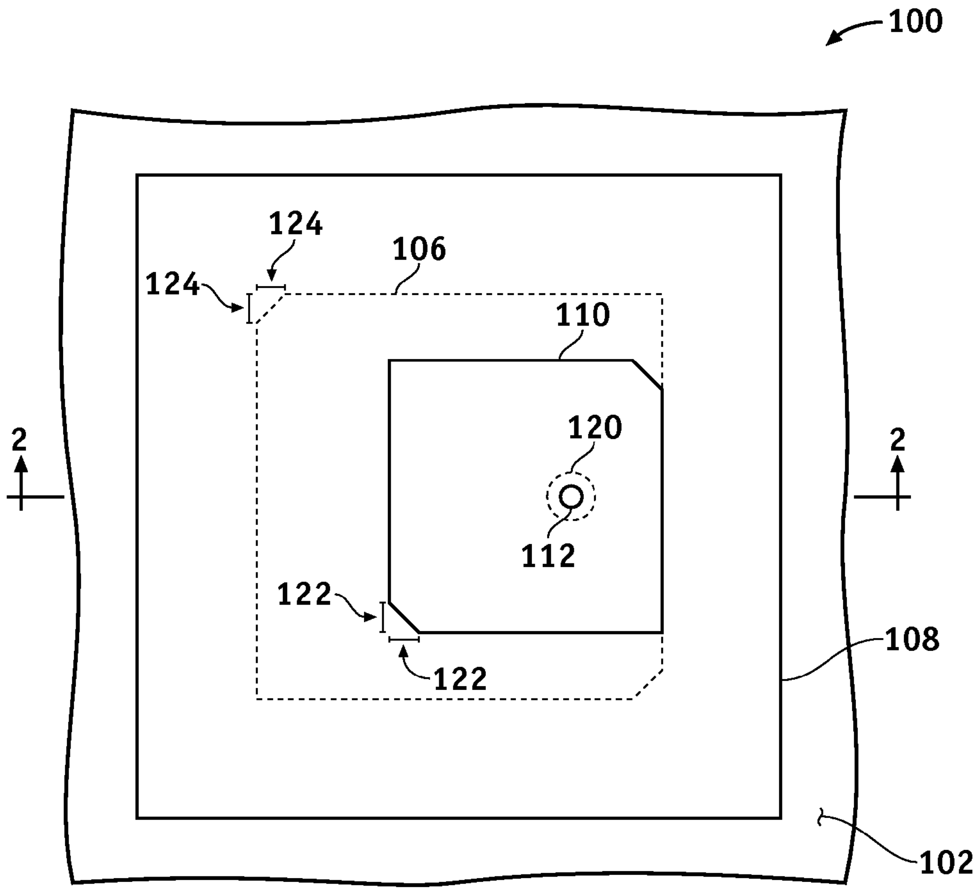

100
124
124
106
110
120
2
2
112
122
122
108
102

FIG. 1

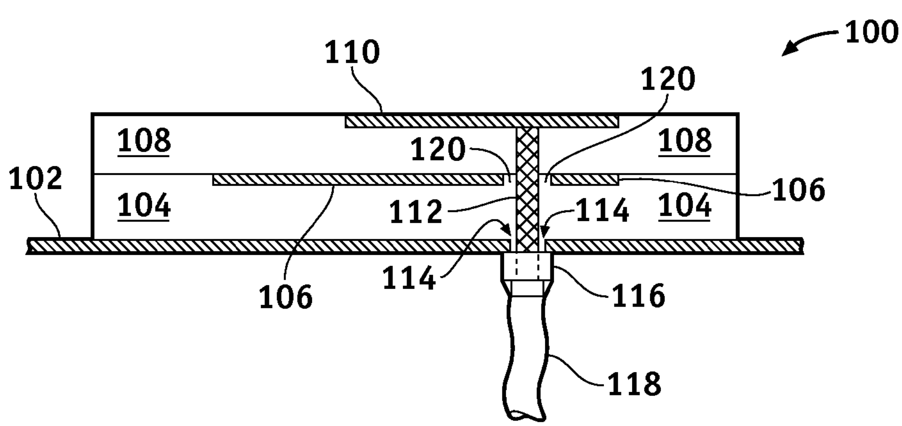

100
110
120
108
120
108
102
104
112
114
104
106
114
106
116
118

FIG. 2

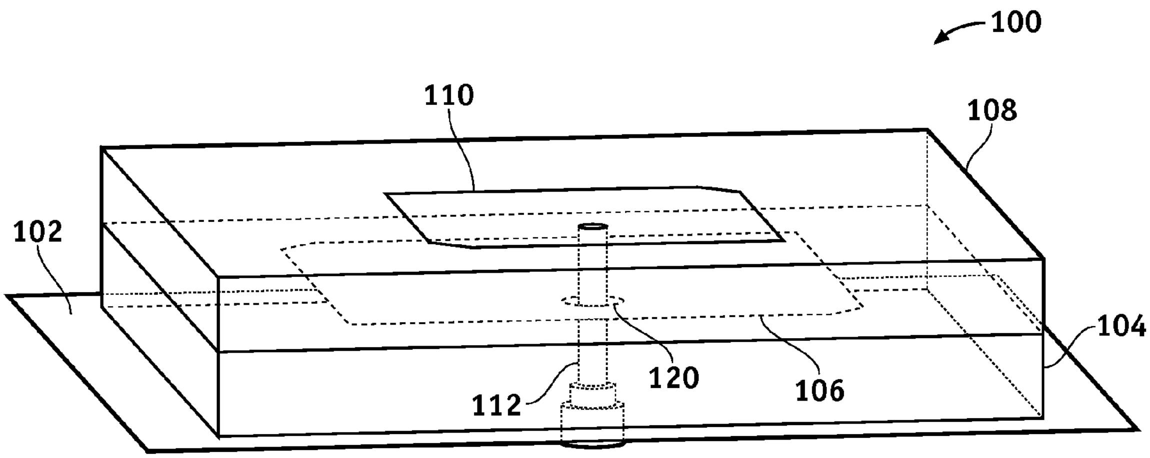

100
110
108
102
104
120
106
112

FIG. 3

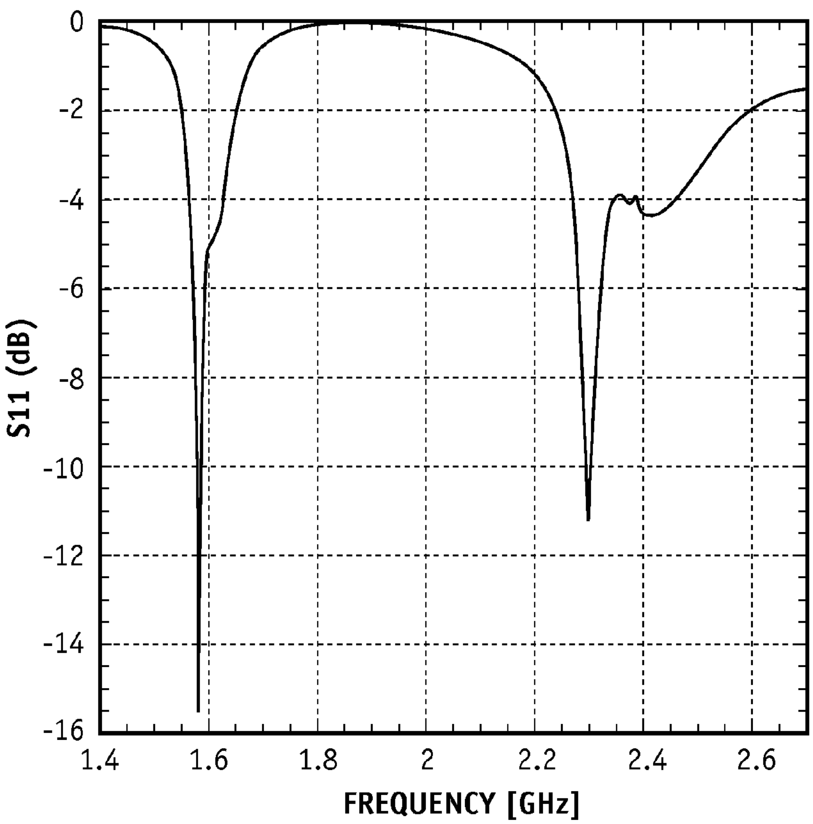

0
-2
-4
-6
-8
-10
-12
-14
-16
S11 (dB)
1.4
1.6
1.8
2
2.2
2.4
2.6
FREQUENCY [GHz]

FIG. 4

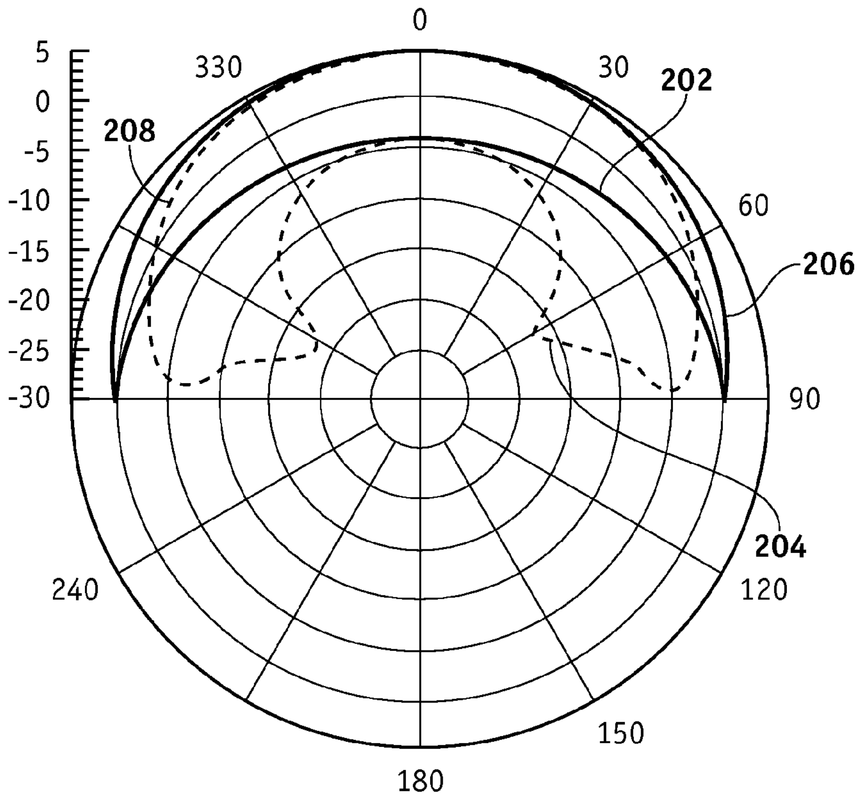

0
30
60
90
120
150
180
240
330
5
0
-5
-10
-15
-20
-25
-30
202
204
206
208

FIG. 5

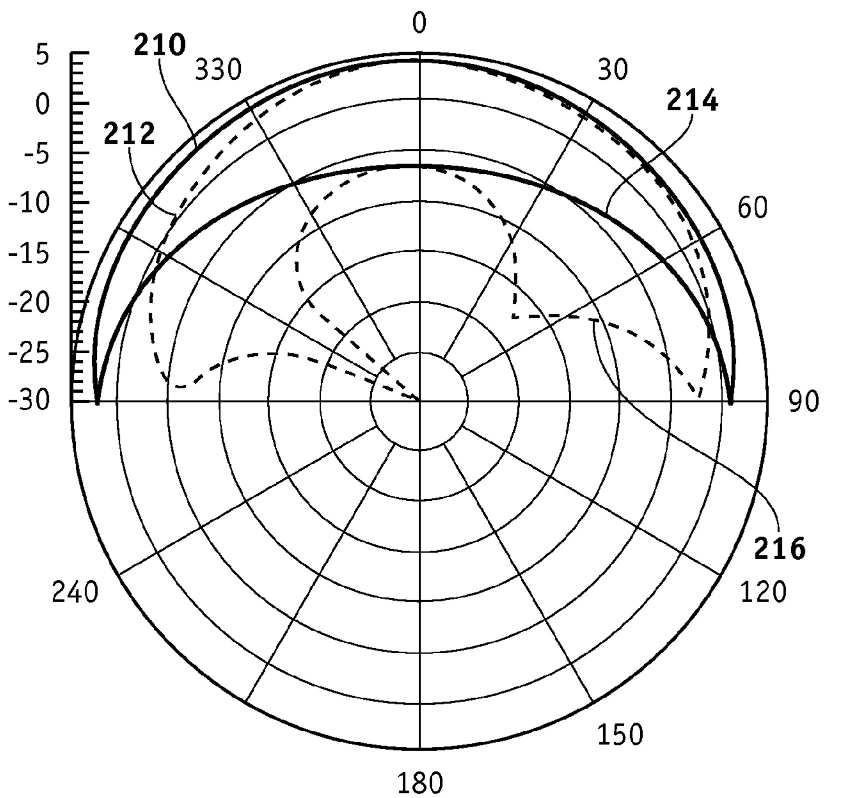

0
30
60
90
120
150
180
240
330
5
0
-5
-10
-15
-20
-25
-30
210
212
214
216

FIG. 6

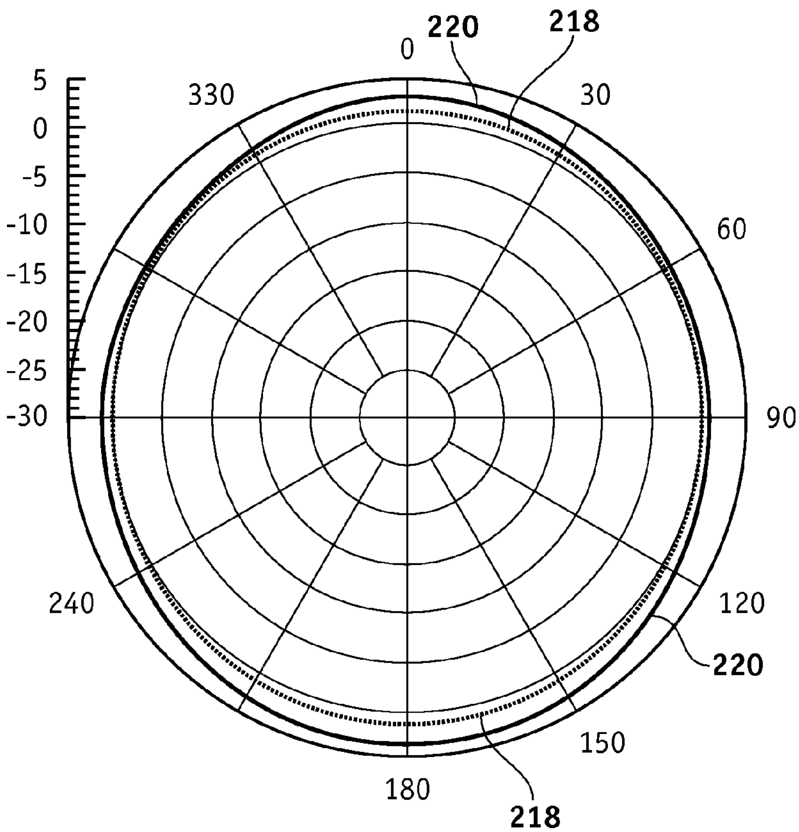

220
218
0
30
60
90
120
150
180
240
330
5
0
-5
-10
-15
-20
-25
-30
220
218

FIG. 7

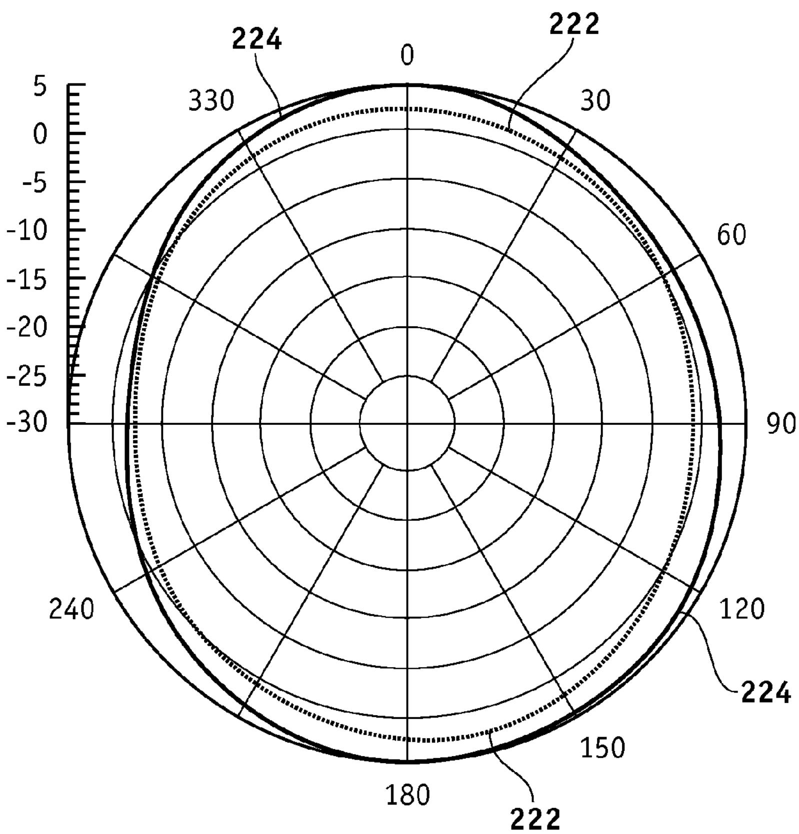

224
222
0
30
60
90
120
150
180
240
330
5
0
-5
-10
-15
-20
-25
-30
224
222

FIG. 8

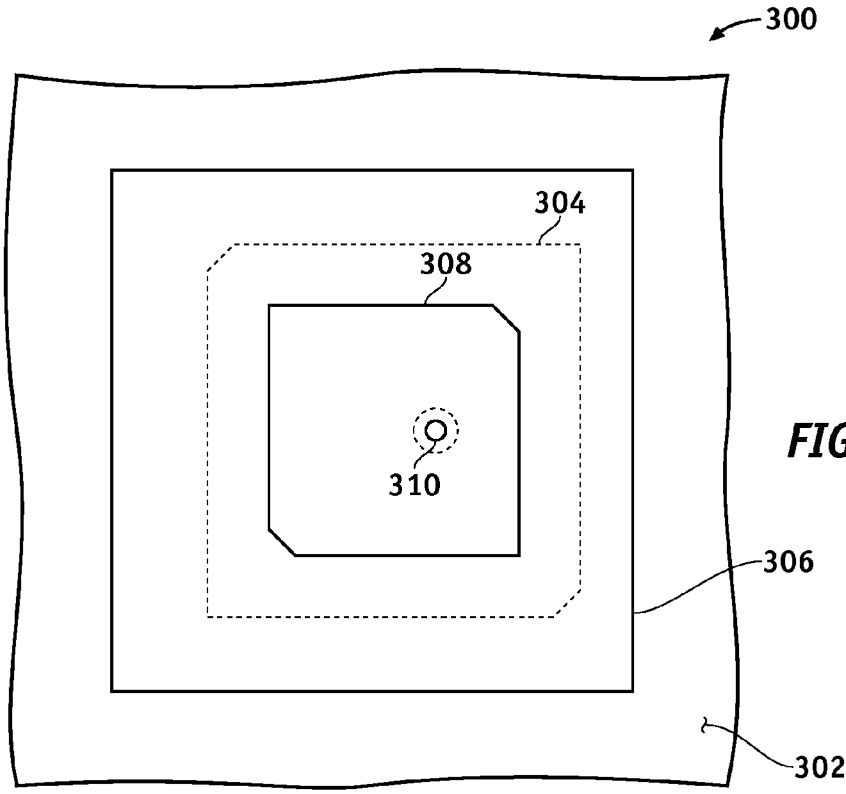


FIG. 9

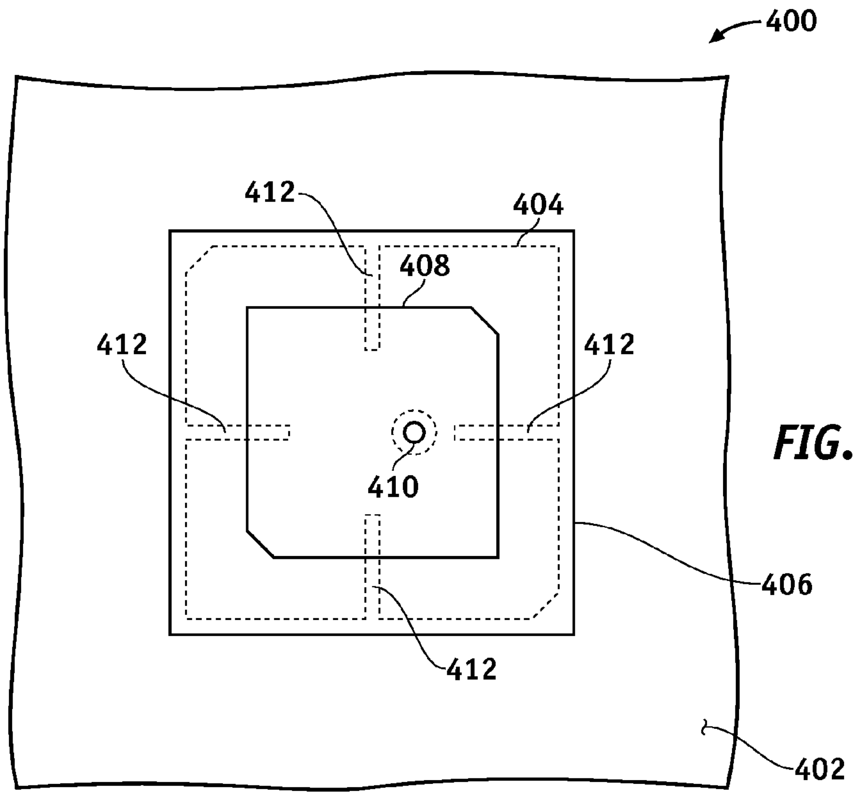


FIG. 10

DUAL BAND STACKED PATCH ANTENNA

TECHNICAL FIELD

[0001] The subject matter described herein generally relates to patch antennas, and more particularly relates to an integrated dual band stacked patch antenna that is suitable for use with both global positioning system (GPS) signals and satellite digital audio radio service (SDARS) signals.

BACKGROUND

[0002] The prior art is replete with radio frequency (RF) and microwave antenna designs, structures, and configurations. Such antennas are utilized in many different applications to wirelessly transmit and receive signals that convey information or data. For example, modern automobiles (and other vehicles) might utilize a number of antennas that receive signals throughout the RF spectrum. Indeed, a vehicle may include one or more of the following systems: an AM/FM radio; a satellite radio; a GPS based navigation system; and a mobile telecommunication system. Some vehicles may include antennas to receive SDARS signals and/or GPS signals. In this context, L1 GPS signals are used for commercial navigation and mapping systems. By definition, SDARS signals that originate from satellites are left hand circularly polarized (LHCP) signals in the frequency band of 2.320 GHz to 2.345 GHz, and L1 GPS signals that originate from satellites are right hand circularly polarized (RHCP) signals in the frequency band of 1.57442 GHz to 1.57642 GHz. Some satellite radio systems also utilize terrestrial repeaters that transmit SDARS signals with vertical linear polarization (VLP) in the frequency band of 2.320 GHz to 2.345 GHz. These repeaters are employed to improve terrestrial signal reception by transmitting the SDARS signals at low elevation angles.

[0003] The traditional approach for achieving both GPS and SDARS reception in a vehicle is to place two individual patch antennas on the roof of the vehicle, where one antenna is devoted to the GPS band and the other antenna is devoted to the SDARS band. The distinct GPS antenna is individually designed for enhanced gain of RHCP signals in the GPS band, while the separate and distinct SDARS antenna is individually designed for enhanced gain of LHCP signals (and terrestrial VLP signals) in the SDARS band. Unfortunately, undesirable coupling often occurs between the two antennas when they are placed close to one another, which is often the case in vehicle installations that strive to achieve a streamlined and clean appearance. Such coupling degrades the overall performance of each antenna, particularly the VLP terrestrial gain in the SDARS frequency band (in addition, typical standalone SDARS patch antennas do not provide adequate VLP gain for reliable quality of service).

[0004] Two types of integrated GPS/SDARS patch antennas are described in United States Patent Application Publication No. 2006/0097924 A1. A first design employs a single layer structure with both radiating elements residing on the same dielectric layer. This first design may not provide a desirable amount of VLP gain for terrestrial SDARS signals. A second design employs a stacked structure having two feeds—one for the GPS signals and one for the SDARS signals. In addition, this second design uses a shorting pin connected between one radiating element and the ground plane. This second design has the disadvantage of having a relatively complex configuration, and the further disadvantage of requiring two distinct feed elements, which increases the complexity and cost of final assembly onto a vehicle.

BRIEF SUMMARY

[0005] A dual band patch antenna as described herein includes a stacked arrangement of two radiating elements separated by dielectric material. Both radiating elements share the same conductive feed, which may simplify the construction, reduces manufacturing cost, and reduces final assembly time. In one embodiment suitable for use in vehicular deployments, the dual band patch antenna can be configured and tuned to receive RHCP GPS signals simultaneously with LHCP SDARS signals. This particular dual band patch antenna is at the same time also configured and tuned to provide enhanced gain for terrestrial VLP SDARS signals.

[0006] The above and other features can be provided by an embodiment of a dual band patch antenna that includes: a first patch antenna arrangement configured to receive signals in a first frequency band; a second patch antenna arrangement coupled to, and stacked on, the first patch antenna arrangement, the second patch antenna arrangement being configured to receive signals in a second frequency band; and only one signal feed shared by both the first patch antenna arrangement and the second patch antenna arrangement.

[0007] The above and other features can also be provided by an embodiment of a dual band patch antenna that includes: a first antenna arrangement comprising a ground plane element, a first radiating element, and a first dielectric layer coupled between ground plane element and the first radiating element; a second antenna arrangement coupled to the first antenna arrangement, the second antenna arrangement comprising a second radiating element and a second dielectric layer coupled to the second radiating element, and the second antenna arrangement being coupled to the first antenna arrangement such that the first radiating element is located between the first dielectric layer and the second dielectric layer; and a signal feed shared by both the first antenna arrangement and the second antenna arrangement.

[0008] The above and other features can also be provided by an embodiment of a dual band patch antenna that includes: a ground plane element having a signal port formed therein; an upper radiating element; dielectric material between the ground plane element and the upper radiating element; a lower radiating element located within the dielectric material, the lower radiating element comprising an aperture formed therein; and only one signal feed for both the upper radiating element and the lower radiating element, the signal feed being connected to the upper radiating element, and the signal feed extending through the dielectric material, through the aperture without contacting the lower radiating element, and through the signal port without contacting the ground plane element. The lower radiating element, the dielectric material, and the ground plane element cooperate to receive signals in a first frequency band, while the upper radiating element, the dielectric material, and the ground plane element cooperate to receive signals in a second frequency band.

[0009] This summary is provided to introduce a selection of concepts in a simplified form that are further described below in the detailed description. This summary is not intended to identify key features or essential features of the claimed subject matter, nor is it intended to be used as an aid in determining the scope of the claimed subject matter.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] One or more embodiments of the invention will hereinafter be described in conjunction with the following drawing figures, wherein like numerals denote like elements, and

[0011] FIG. **1** is a top view of an embodiment of a dual band patch antenna;

[0012] FIG. **2** is a cross sectional view of the dual band patch antenna, as viewed from line **2-2** of FIG. **1**;

[0013] FIG. **3** is a perspective phantom view of the dual band patch antenna shown in FIG. **1**;

[0014] FIG. **4** is a graph of return loss versus frequency for the dual band patch antenna shown in FIG. **1**;

[0015] FIG. **5** is a diagram of LHCP and RHCP gain patterns for the dual band patch antenna shown in FIG. **1**, for a single frequency within/near the L1 GPS frequency band;

[0016] FIG. **6** is a diagram of LHCP and RHCP gain patterns for the dual band patch antenna shown in FIG. **1**, for a single frequency within/near the SDARS frequency band;

[0017] FIG. **7** is a diagram of LHCP gain patterns for the dual band patch antenna shown in FIG. **1** and for a standalone SDARS single patch antenna at a single frequency within/near the SDARS frequency band;

[0018] FIG. **8** is a diagram of VLP gain patterns for the dual band patch antenna shown in FIG. **1** and for a standalone SDARS single patch antenna at a single frequency within/near the SDARS frequency band;

[0019] FIG. **9** is a top view of another embodiment of a dual band patch antenna; and

[0020] FIG. **10** is a top view of yet another embodiment of a dual band patch antenna.

DETAILED DESCRIPTION

[0021] The following detailed description is merely exemplary in nature and is not intended to limit the invention or the application and uses of the invention. Furthermore, there is no intention to be bound by any expressed or implied theory presented in the preceding technical field, background, brief summary or the following detailed description.

[0022] For the sake of brevity, conventional techniques and aspects related to GPS systems, SDARS systems, RF/microwave antenna design, and RF/microwave signal propagation may not be described in detail herein. In addition, those skilled in the art will appreciate that embodiments of the dual band patch antennas described herein may be practiced in conjunction with any number of applications and installations at any set of two or more frequency bands, and that the vehicular deployment described herein is merely one suitable example.

[0023] The following description refers to elements or nodes or features being “connected” or “coupled” together. As used herein, unless expressly stated otherwise, “connected” means that one element/node/feature is directly joined to (or directly communicates with) another element/node/feature, and not necessarily mechanically. Likewise, unless expressly stated otherwise, “coupled” means that one element/node/feature is directly or indirectly joined to (or directly or indirectly communicates with) another element/node/feature, and not necessarily mechanically.

[0024] A dual band patch antenna configured in the manner described herein can be used to receive signals in a first frequency band and to receive signals in a second frequency band. In practice, the antenna has a reciprocal operating nature, and the same antenna structure may be used both in receive mode and in transmit mode. In certain embodiments, the first frequency band and the second frequency band are non-overlapping, i.e., there are no shared frequencies in the two bands. The reception of the different signals may occur simultaneously, concurrently, or at different times. Although an antenna as described herein can be suitably configured and tuned to receive signals in any two frequency bands (within practical and economical limits), the following non-limiting examples relate to a vehicular implementation that is intended to support the L1 GPS band and the SDARS band, where the L1 GPS band is normally utilized for navigation messages, coarse-acquisition data, and encrypted precision code. More specifically, the antenna embodiments described herein are suitably configured to receive right hand circularly polarized L1 GPS signals in the 1.57442 GHz to 1.57642 GHz frequency band, to receive left hand circularly polarized SDARS signals in the 2.320 GHz to 2.345 GHz frequency band, and to receive vertical linear polarized SDARS signals in the 2.320 GHz to 2.345 GHz frequency band. This allows the antenna embodiments to be used with common satellite radio and GPS-based onboard navigation systems.

[0025] Again, the dual band capability of the embodiments described herein is not limited to GPS and SDARS frequency bands. Generally, such antenna embodiments can be configured and tuned to support any two bands, thus providing a compact, low cost, high performance, single feed, stacked patch antenna, regardless of polarization or gain pattern dependence.

[0026] FIG. **1** is a top view of an embodiment of a dual band patch antenna **100**, FIG. **2** is a cross sectional view of dual band patch antenna **100**, as viewed from line **2-2** of FIG. **1**, and FIG. **3** is a perspective phantom view of dual band patch antenna **100**. Antenna **100** generally includes a first patch antenna arrangement configured to receive signals in a first frequency band (e.g., GPS signals), and a second patch antenna arrangement configured to receive signals in a second frequency band (e.g., SDARS signals), where the second patch antenna arrangement is coupled to and stacked on the first patch antenna arrangement. As described in more detail below, the first patch antenna arrangement can be formed as one separate component (for example, a first ceramic substrate with metallization areas, or a first printed circuit board with metallization areas) and the second patch antenna arrangement can be fabricated independently as another separate component (for example, a second ceramic substrate with metallization areas, or a second printed circuit board with metallization areas) and then attached to the first patch antenna arrangement.

[0027] In operation, the radiating element for the first (lower) patch antenna arrangement will have some effect on the performance of the second (upper) patch antenna arrangement and, analogously, the radiating element for the second (upper) patch antenna arrangement will have some impact on the performance of the first (lower) patch antenna arrangement. In practice, a complex RF coupling interaction takes place with antenna **100** to obtain the desired overall performance for both frequency bands of interest.

[0028] The illustrated embodiment of antenna **100** includes a ground plane element **102**, a first dielectric layer **104** (obscured from view in FIG. **1**), a first radiating element **106**, a second dielectric layer **108**, a second radiating element **110**, and a signal feed **112**. In certain embodiments, ground plane element **102**, first dielectric layer **104**, and first radiating element **106** form part of a first antenna arrangement that is fabricated as a first substrate, while second dielectric layer **108** and second radiating element **110** form part of a second antenna arrangement that is fabricated as a second substrate. In this regard, first dielectric layer **104** can be one substrate that is coupled between ground plane element **102** and first radiating element **106**, and second dielectric layer **108** can be another substrate coupled to second radiating element **110**. Although fabricated as separate components, the two substrates can be coupled together during a subsequent process step (using lamination, bonding, or any suitable technique) such that first radiating element **106** is located between first dielectric layer **104** and second dielectric layer **108** as depicted in FIG. **2**.

[0029] In practice, the first antenna arrangement may be fabricated by forming thin metal layers on the top and bottom exposed surfaces of dielectric layer **104**. The thickness of the metal layers will depend upon the particular dielectric material, the type of metal used, the substrate fabrication technique, and desired performance characteristics. For example, the thickness of the metal layers in practical embodiments may within the range of about 8 to 35 micrometers. Thereafter, the metal layers can be selectively removed or patterned using well known techniques (such as masking, photolithography, and etching) to create the desired size, shape, and features of ground plane element **102**, first radiating element **106**, and aperture **120** (described below). Likewise, the second antenna arrangement may be fabricated by forming a thin metal layer on the top exposed surface of dielectric layer **108**, followed by selective removal of the metal to create the desired size, shape, and features of second radiating element **110**. The thickness of the metal layers for the second antenna arrangement will depend upon the particular dielectric material, the type of metal used, the substrate fabrication technique, and desired performance characteristics. For example, the thickness of the metal layers in practical embodiments may be within the range of about 8 to 35 micrometers.

[0030] In preferred embodiments, the same dielectric material is used to form both dielectric layers **104/108**. In one exemplary embodiment, dielectric layers **104/108** are formed from a ceramic material such as alumina, and the metallization on dielectric layers **104/108** is formed from copper cladding, gold coated copper cladding, using commercial thin film processes, typically specified as 100-150 microinches, or the like. For such an embodiment, the antenna arrangements are suitably configured to cooperate with the dielectric constant (approximately nineteen in this particular embodiment) exhibited by the ceramic dielectric material. In another exemplary embodiment, dielectric layers **104/108** are formed from a dielectric material that is commonly used in printed circuit boards, such as FR-4 or other laminates, and the metallization on dielectric layers **104/108** is formed from copper, aluminum, or the like. The dielectric layers in such an embodiment can be formed from a class of materials including a composite polytetrafluoroethylene (PTFE) with glass or ceramic, and a composite hydrocarbon with ceramic (such as the TMM materials available from Rogers Corp.), with dielectric constants in the range of approximately 2.8 to 10.2. An embodiment that leverages printed circuit board techniques and technologies represents a relatively low cost alternative. For such an embodiment, the antenna arrangements are suitably configured to cooperate with the relatively low dielectric constant (approximately ten or less) exhibited by the laminate dielectric material. Of course, a dual band patch antenna as described herein can be realized using other dielectric materials and metallization materials.

[0031] Ground plane element **102** functions as the ground plane for both first radiating element **106** and second radiating element **110**. In a typical vehicle installation, ground plane element **102** can be electrically coupled to a conductive sheet or component of the vehicle, such as the roof, a fender, or the trunk lid. In practice, ground plane element **102** may terminate at the boundary of dielectric layer **104** or it may extend beyond the boundary as depicted in FIG. **1** and FIG. **2**. In the illustrated embodiment, ground plane element **102** includes a signal port **114** formed therein. Signal port **114** may be realized as a hole or aperture formed in ground plane element **102**, and signal port **114** is configured to receive signal feed **112** such that signal feed **112** does not contact ground plane element **102**.

[0032] Signal port **114** enables the received GPS and SDARS signals to be propagated from dual band patch antenna **100** to the system or systems of interest. In this regard, signal port **114** may include, accommodate, or cooperate with a suitably configured connector **116** for signal feed **112**. Connector **116** isolates signal feed **112** from ground plane element **102** using well known principles. Connector **116** may be, for example, a male or female SMA connector or any RF/microwave component. Antenna **100** may also include or be coupled to a system connection cable **118** via connector **116**, where system connection cable **118** is configured to propagate signals having frequencies in either of the two bands supported by antenna **100**. Notably, antenna **100** utilizes only one connector **116** and only one system connection cable **118** to propagate the dual band signals; this simplifies the installation of antenna **100** and reduces cost.

[0033] As shown in FIG. **2**, first dielectric layer **104** is located between, and physically separates, ground plane element **102** and first radiating element **106**. Similarly, second dielectric layer **108** is located between, and physically separates, first radiating element **106** and second radiating element **110**. When deployed, second radiating element **110** will be the upper radiating element of antenna **100**, and first radiating element **106** will be the lower radiating element of antenna **100**. In this embodiment, first radiating element **106** is sandwiched within the dielectric material, and no portion of first radiating element **106** is exposed. As mentioned above, first dielectric layer **104** and second dielectric layer **108** are preferably formed from a common dielectric material. Notably, although this exemplary embodiment is fabricated by bonding or laminating two patch antenna arrangements together, an alternate embodiment may instead embed or form first radiating element **106** in dielectric material such that the dielectric material contains no seams, junctions, or discontinuities.

[0034] Dual band patch antenna **100** utilizes only one signal feed **112**, which is shared by both patch antenna arrangements. In other words, signal feed **112** is used for first radiating element **106** and for second radiating element **110**. Signal feed **112** may be realized as a solid conductor, a conductive post or wire, a standard sized RF connector pin, or a conductive tube. Notably, signal feed **112** physically contacts only one of the two radiating elements; in the exemplary embodiment signal feed **112** is in electrical contact with second radiating element **110**, and signal feed **112** has no direct physical contact with first radiating element **106**. Here, signal feed **112** is connected to the lower surface of second radiating element **110**, signal feed **112** extends through dielectric layers **104/108**, and signal feed **112** extends through signal port **114**.

[0035] To accommodate signal feed **112**, first radiating element **106** includes an aperture **120** formed therein. Aperture **120** may be realized as a hole, a slot, or an opening formed in first radiating element **106**, and aperture **120** is configured to receive signal feed **112** such that signal feed **112** does not contact first radiating element **106**. During fabrication, a properly sized hole can be drilled through the dielectric material, either stopping at second radiating element **110** or through second radiating element **110**. This drilled hole may or may not be plated with metal. Thereafter, signal feed **112** (which may be realized as a standard SMA pin) can be inserted into the hole into contact with second radiating element **110**. After installation, signal feed **112** is preferably flush against the dielectric material although a slight gap may exist between the dielectric material and the outer surface of signal feed **112**. In practice, signal feed **112** may be soldered or otherwise affixed to second radiating element **110**.

[0036] Signal feed **112**, the dielectric material, and aperture **120** cooperate to function as an aperture coupler for first radiating element **106**. In other words, signal feed **112** is coupled to first radiating element **106** via aperture coupling, and absent any physical contact with first radiating element **106** itself. For the illustrated embodiment, the diameter of aperture **120** is influenced by the diameter of signal feed **112**, the type of dielectric material, the output impedance of antenna **100**, the desired amount of coupling, and the frequencies of the signals to be coupled. Thus, signals received by first radiating element **106** are aperture coupled to signal feed **112**, while signals received by second radiating element **110** are directly coupled to signal feed **112**. Accordingly, first radiating element **106**, the dielectric material, signal feed **112**, and ground plane element **102** cooperate to receive signals in the L1 GPS band, while second radiating element **110**, the dielectric material, signal feed **112**, and ground plane element **102** cooperate to receive signals in the SDARS band.

[0037] In practice, the aperture coupling mechanism is arranged to minimize sensitivity to manufacturing and assembly inconsistencies. In particular, large aperture diameters tend to be less sensitive to both the exact feed placement within the aperture and to variations in the dimensions of the feed.

[0038] Moreover, antenna **100** lacks any intervening interconnects or shorting pins between ground plane element **102**, first radiating element **106**, and second radiating element **110**. As illustrated in FIG. **2**, ground plane element **102** is physically isolated from first radiating element **106** and from second radiating element **110**, and first radiating element **106** is physically isolated from second radiating element **110**. This relatively simple structure is therefore easy to manufacture and assemble.

[0039] The actual size, shape, and arrangement of elements in dual band patch antenna **100** will vary depending upon the particular application, packaging constraints, desired materials, manufacturing considerations, and other practical influences. The embodiment described below with reference to FIG. **1** and FIG. **2** is merely one suitable implementation.

[0040] Referring to FIG. **1**, both dielectric layers **104/108** are formed from a ceramic material such as alumina, and both dielectric layers **104/108** are approximately 35 mm by 35 mm square. First dielectric layer **104** is 4 mm thick, while second dielectric layer is 3 mm thick. Second radiating element **110** is formed as a 13 mm by 13 mm square with truncated opposing corners as depicted in FIG. **1**. The cut corners are utilized to achieve LHCP operation for SDARS frequencies. The dimension **122** for these cut corners is 1.75 mm in this embodiment.

[0041] FIG. **1** depicts first radiating element **106** in dashed lines because it is actually hidden from view and sandwiched between the dielectric layers **104/108**. First radiating element **106** is formed as a 17 mm by 17 mm square with truncated opposing corners as depicted in FIG. **1**. Notably, the truncated corners of first radiating element **106** correspond to the non-truncated corners of second radiating element **110**. The cut corners of first radiating element **106** are utilized to achieve RHCP operation for L1 GPS signals. The dimension **124** for these cut corners is 1.75 mm in this embodiment. In this particular embodiment, first radiating element **106** is not centered relative to dielectric layers **104/108**. Rather, one side of first radiating element **106** corresponds to one side of second radiating element **110**, resulting in an offset positioning of first radiating element **106**. In general, first radiating element **106** and second radiating element **110** will not be centered with respect to one another or the dielectric substrates. Rather, their position with respect to the feed placement is chosen in order to achieve a good input impedance match at both frequency bands of interest.

[0042] Signal feed **112** may also be offset relative to second radiating element **110**. In this regard, the central longitudinal axis of signal feed **112** is positioned about 3.7 mm from the right edges of first radiating element **106** and second radiating element **110**. For this embodiment, aperture **120**, which is formed in first radiating element **106** and is concentric with signal feed **112**, has a radius of approximately 1.7 mm.

[0043] Given the physical dimensions of first radiating element **106** and second radiating element **110**, the dielectric material for dielectric layers **104/108** is selected to obtain the appropriate center frequencies of operation. Conversely, given the dielectric constants of the materials chosen for dielectric layers **104/108**, the physical dimensions could then be selected to obtain the appropriate center frequencies of operation. As mentioned previously, the same dielectric material may, but need not, be chosen for both dielectric layers **104/108**. The physical dimensions described above are suitable for ceramic substrates where the dielectric constant for both dielectric layers **104/108** is 19.0. The selection of the same dielectric material is desirable to minimize material costs and to simplify the manufacturing process. This design also uses a particularly wide aperture coupler for the feeding mechanism for first radiating element **106** in an effort to minimize the sensitivity of the structure to feed pin placement. Of course, fine tuning of the various physical parameters (such as the corner truncation dimensions, overall size of the metallization areas, overall size of dielectric layers **104/108**, the offset of radiation elements **106/110** relative to signal feed **112**, and the dimensions of aperture **120**) may be employed to achieve the desired performance for the designated frequency bands.

[0044] For the vehicular application described herein, the first patch antenna arrangement is configured to receive signals in a GPS frequency band (e.g., the L1 GPS frequency band of 1.57442 GHz to 1.57642 GHz), while the second patch antenna arrangement is configured to receive signals in the SDARS frequency band (i.e., the 2.320 GHz to 2.345 GHz band). As mentioned previously, the first patch antenna arrangement is suitably configured to receive RHCP signals (such as L1 GPS signals), while the second patch antenna arrangement is suitably configured to receive LHCP signals (such as SDARS signals that originate from satellites). Notably, the second patch antenna arrangement is also configured to effectively receive VLP SDARS signals in the 2.320 GHz to 2.345 GHz frequency band—such signals originate from terrestrial repeaters used by some satellite radio providers. The placement of the SDARS patch antenna arrangement above the GPS patch antenna arrangement results in improved low angle performance for SDARS signals. Moreover, the physical configuration of antenna **100** (e.g., the type and thickness of dielectric material, type and the thickness of the metallization layers) may be designed to increase or reduce the overall height of the SDARS patch antenna, according to the desired gain characteristics for terrestrial VLP SDARS signals.

Proof Of Concept

[0045] A dual band stacked patch antenna having the dimensions and characteristics described above was validated using an electromagnetic modeling application. The simulations assumed an infinite ground plane. The return loss (S**11**) is depicted in FIG. **4**, which is a graph of the return loss versus frequency for the dual band patch antenna. FIG. **4** shows that the return loss within the two frequency windows near the L1 GPS and SDARS frequency bands is less than −10 dB. FIG. **5** is a diagram of LHCP and RHCP gain patterns for the dual band patch antenna (at a frequency within/near the L1 GPS band), and FIG. **6** is a diagram of LHCP and RHCP gain patterns at a frequency within/near the SDARS band. In FIG. **5**, plot **202** represents the LHCP gain pattern at an azimuth angle (θ) of zero degrees, plot **204** represents the LHCP gain pattern at an azimuth angle of ninety degrees, plot **206** represents the RHCP gain pattern at an azimuth angle of zero degrees, and plot **208** represents the RHCP gain pattern at an azimuth angle of ninety degrees. In FIG. **6**, plot **210** represents the LHCP gain pattern at an azimuth angle of zero degrees, plot **212** represents the LHCP gain pattern at an azimuth angle of ninety degrees, plot **214** represents the RHCP gain pattern at an azimuth angle of zero degrees, and plot **216** represents the RHCP gain pattern at an azimuth angle of ninety degrees. Within each frequency window, high gain is achieved over a wide elevation angle. Approximately 10 dB of gain suppression of the opposite handed circular polarization at zenith (θ=zero degrees) is achieved within each frequency band. This demonstrates that very little coupling can be achieved between the lower and upper patch antenna arrangements.

[0046] For comparison, FIG. **7** is a diagram of LHCP gain patterns for the dual band patch antenna shown in FIG. **1** and for a currently known standalone SDARS single patch antenna. FIG. **7** compares the LHCP gain patterns of the standalone, single band, SDARS patch antenna (plot **218**) and the dual band stacked patch antenna (plot **220**) at an elevation angle of sixty degrees down from zenith, i.e., thirty degrees up from horizon. Here it can be seen that in all azimuth directions the stacked patch antenna outperforms the standalone SDARS patch antenna in terms of LHCP gain. FIG. **8** also depicts a comparison of the standalone SDARS antenna versus the dual band stacked patch antenna; FIG. **8** is a diagram of VLP gain patterns for the dual band patch antenna shown in FIG. **1** and for the standalone SDARS single patch antenna at an elevation angle of ninety degrees down from zenith, i.e., at horizon. In FIG. **8**, plot **222** represents the VLP gain pattern at horizon for the standalone SDARS patch antenna, while plot **224** represents the VLP gain pattern at horizon for the dual band stacked patch antenna. Again, the dual band stacked patch antenna outperforms the isolated standalone SDARS patch antenna in all directions, providing anywhere from −2.2 dB to more than 5.0 dB of VLP gain. The minimum of −2.2 dB represents a 1.3 dB improvement in the minimum VLP gain at horizon when compared to the isolated standalone SDARS patch antenna. In practice, overall system performance should see an even greater improvement because the VLP gain performance of the standalone SDARS single patch antenna is known to degrade in the presence of other radiating sources, such as a standalone single patch GPS antenna. These results clearly highlight the advantages of the dual GPS/SDARS stacked patch antenna presented herein.

[0047] FIG. **9** is a top view of another embodiment of a dual band patch antenna **300**. Antenna **300** is similar to antenna **100** in many ways, and common features, elements, and characteristics will not be redundantly described here in the context of antenna **300**. Antenna **300** generally includes a ground plane element **302**, a first dielectric layer (hidden from view), a first radiating element **304**, a second dielectric layer **306**, a second radiating element **308**, and a signal feed **310**.

[0048] Antenna **300** employs a circuit board material having a relatively low dielectric constant (about 9.8), for example, TMM10i or alumina. These materials are relatively inexpensive and, therefore, antenna **300** represents a low-cost realization of a dual band stacked patch configuration. The overall dimensions of the first dielectric layer (35 mm by 35 mm, 4 mm thick) and second dielectric layer **306** (35 mm by 35 mm, 3 mm thick) are as described above for antenna **100**. First radiating element **304** is formed as a 27 mm by 27 mm square with truncated opposing corners, and second radiating element **308** is formed as a 19 mm by 19 mm square with truncated opposing corners that correspond to the non-truncated corners of first radiating element **304**. As mentioned above in connection with antenna **100**, both radiating elements **304**/**308** are offset (off-axis) from signal feed **310**. In contrast to antenna **100**, first radiating element **304** does not “share” a side with second radiating element **308**. As depicted in FIG. **9**, the outer boundary of second radiating element **308** as projected onto first radiating element **304** resides within the outer boundary of first radiating element **304**. In other words, from the perspective of FIG. **9**, the outline of second radiating element **308** completely fits within the outline of first radiating element **304**. Simulations of antenna **300** show that it provides more than a 3 dB improvement in the minimum VLP gain when compared to a conventional standalone SDARS patch antenna.

[0049] FIG. **10** is a top view of yet another embodiment of a dual band patch antenna **400**. Antenna **400** is similar to antenna **100** in many ways, and common features, elements, and characteristics will not be redundantly described here in the context of antenna **400**. Antenna **400** generally includes a ground plane element **402**, a first dielectric layer (hidden from view), a first radiating element **404**, a second dielectric layer **406**, a second radiating element **408**, and a signal feed **410**.

[0050] Antenna **400** employs a circuit board material having an even lower dielectric constant (about 6.0), for example, TMM6 or other Duroid materials. The overall dimensions of the first dielectric layer (35 mm by 35 mm, 4 mm thick) and second dielectric layer **306** (35 mm by 35 mm, 3 mm thick) are as described above for antenna **100**. First radiating element **404** is generally formed as a 33 mm by 33 mm square with truncated opposing corners. Notably, first radiating element **404** incorporates slits **412** in order to make the overall package more compact while benefiting from the very low dielectric constant (without slits **412**, the dimensions of first radiating element **404** would extend beyond the 35 mm by 35 mm form factor boundary). Here, each slit **412** extends 9.0 mm inward from the outside edge of first radiating element **404**, and each slit **412** is 1.0 mm wide. Moreover, a portion of each slit **412** extends beneath second radiating element **408** (as shown in the projected view of FIG. **10**). As shown in FIG. **10**, each slit **412** extends perpendicularly from the respective edge of first radiating element **404**, and each slit **412** is centrally located along the respective edge. In operation, although current exists along the edges of first radiating element **404** (including along the edges of slits **412** that extend beneath second radiating element **408**), essentially all of the electromagnetic energy is still radiated along the outer edges of first radiating element **404** that reside beyond the physical dimensions of second radiating element **408**, which is located above first radiating element **404**. Thus, minimal interference takes place between the radiating elements **404**/**408**.

[0051] Second radiating element **408** is formed as a 23 mm by 23 mm square with truncated opposing corners that correspond to the non-truncated corners of first radiating element **404**. As depicted in FIG. **10**, the outer boundary of second radiating element **408** as projected onto first radiating element **404** resides within the overall outer boundary of first radiating element **404**. In other words, from the perspective of FIG. **10**, the footprint of second radiating element **408** completely fits within the outer 33 mm by 33 mm footprint of first radiating element **404**. As mentioned above in connection with antenna **100**, both radiating elements **404**/**408** are offset (off-axis) from signal feed **410**. In contrast to antenna **100**, first radiating element **404** does not "share" a side with second radiating element **408**. In an alternate embodiment of antenna **400**, second radiating element **408** may include slits as described above for first radiating element **404**, thus resulting in a smaller patch footprint. Moreover, either or both radiating elements **404**/**408** could employ alternate compact design methodologies that are currently known, or those that might be developed in the future.

[0052] To summarize, embodiments of a dual band stacked patch antenna described herein are capable of simultaneously receiving both RHCP satellite signals within the L1 GPS frequency band and LHCP satellite signals within the SDARS frequency band. In addition, embodiments of the antenna described herein provide improved SDARS vertical linear polarization gain for terrestrial signal reception at low elevation angles as compared to current state of the art SDARS patch antennas. This improved VLP gain is achieved in part by placing an SDARS patch antenna element above a GPS patch antenna element, thereby raising the SDARS radiating element further above the ground plane, relative to conventional standalone SDARS patch antennas. Moreover, the compact, low profile, stacked patch design of the antenna reduces the overall size of the antenna module, which in turn decreases the rooftop surface area required to mount the antenna on a vehicle. Furthermore, the antenna employs a single feed that is utilized to propagate signals in both the GPS band and the SDARS band. This single feed approach reduces design complexity, manufacturing costs, cabling costs, and assembly time.

[0053] While at least one exemplary embodiment has been presented in the foregoing detailed description, it should be appreciated that a vast number of variations exist. It should also be appreciated that the exemplary embodiment or exemplary embodiments are only examples, and are not intended to limit the scope, applicability, or configuration of the invention in any way. Rather, the foregoing detailed description will provide those skilled in the art with a convenient road map for implementing the exemplary embodiment or exemplary embodiments. It should be understood that various changes can be made in the function and arrangement of elements without departing from the scope of the invention as set forth in the appended claims and the legal equivalents thereof.

What is claimed is:

1. A dual band patch antenna comprising:

a first patch antenna arrangement configured to receive signals in a first frequency band;

a second patch antenna arrangement coupled to, and stacked on, the first patch antenna arrangement, the second patch antenna arrangement being configured to receive signals in a second frequency band; and

only one signal feed shared by both the first patch antenna arrangement and the second patch antenna arrangement.

2. The dual band patch antenna of claim **1**, wherein:

the first patch antenna arrangement is configured to receive signals in a global positioning system (GPS) frequency band; and

the second patch antenna arrangement is configured to receive signals in a satellite digital audio radio service (SDARS) frequency band.

3. The dual band patch antenna of claim **2**, wherein:

the first patch antenna arrangement is configured to receive right hand circularly polarized L1 GPS signals in the 1.57422 GHz to 1.5762 GHz frequency band; and

the second patch antenna arrangement is configured to receive left hand circularly polarized SDARS signals in the 2.320 GHz to 2.345 GHz frequency band.

4. The dual band patch antenna of claim **3**, wherein the second patch antenna arrangement is configured to receive vertical linear polarized SDARS signals in the 2.320 GHz to 2.345 GHz frequency band.

5. The dual band patch antenna of claim **1**, wherein the first frequency band and the second frequency band are non-overlapping.

6. The dual band patch antenna of claim **1**, wherein:

the first patch antenna arrangement comprises a first radiating element;

the second patch antenna arrangement comprises a second radiating element and a second dielectric layer that separates the second radiating element from the first radiating element;

the signal feed is connected to the second radiating element; and

the signal feed is coupled to the first radiating element via aperture coupling and absent physical contact with the first radiating element.

7. The dual band patch antenna of claim **6**, further comprising:

a first dielectric layer of the first patch antenna arrangement; and

a ground plane element, the first dielectric layer separating the first radiating element from the ground plane element.

8. The dual band patch antenna of claim **7**, further comprising a signal port formed in the ground plane element, the signal port being configured to receive the signal feed.

9. The dual band patch antenna of claim **7**, wherein the first dielectric layer and the second dielectric layer are formed from a common dielectric material.

10. A dual band patch antenna comprising:

a first antenna arrangement comprising a ground plane element, a first radiating element, and a first dielectric layer coupled between the ground plane element and the first radiating element;

a second antenna arrangement coupled to the first antenna arrangement, the second antenna arrangement comprising a second radiating element and a second dielectric layer coupled to the second radiating element, and the second antenna arrangement being coupled to the first antenna arrangement such that the first radiating element is located between the first dielectric layer and the second dielectric layer; and

a signal feed shared by both the first antenna arrangement and the second antenna arrangement.

11. The dual band patch antenna of claim **10**, wherein:

the first antenna arrangement is formed from a first printed circuit board; and

the second antenna arrangement is formed from a second printed circuit board.

12. The dual band patch antenna of claim **10**, wherein:

the first antenna arrangement is formed from a first ceramic material having a high dielectric constant; and

the second antenna arrangement is formed from a second ceramic material having a high dielectric constant.

13. The dual band patch antenna of claim **10**, wherein the signal feed physically contacts only one of the first radiating element or the second radiating element.

14. The dual band patch antenna of claim **13**, wherein:

the signal feed physically contacts the second radiating element; and

the signal feed is coupled to the first radiating element via aperture coupling.

15. The dual band patch antenna of claim **10**, wherein the first radiating element includes a number of slits formed therein, and wherein a portion of each of the slits extends beneath the second radiating element.

16. The dual band patch antenna of claim **10**, wherein:

the first radiating element cooperates with the signal feed and the ground plane element to receive signals in a first frequency band; and

the second radiating element cooperates with the signal feed and the ground plane element to receive signals in a second frequency band.

17. A dual band patch antenna comprising:

a ground plane element having a signal port formed therein;

an upper radiating element;

dielectric material between the ground plane element and the upper radiating element;

a lower radiating element located within the dielectric material, the lower radiating element comprising an aperture formed therein; and

only one signal feed for both the upper radiating element and the lower radiating element, the signal feed being connected to the upper radiating element, and the signal feed extending through the dielectric material, through the aperture without contacting the lower radiating element, and through the signal port without contacting the ground plane element; wherein

the lower radiating element, the dielectric material, the signal feed, and the ground plane element cooperate to receive signals in a first frequency band; and

the upper radiating element, the dielectric material, the signal feed, and the ground plane element cooperate to receive signals in a second frequency band.

18. The dual band patch antenna of claim **17**, wherein:

the lower radiating element, the dielectric material, the signal feed, and the ground plane element are configured to receive right hand circularly polarized L1 global positioning system (GPS) signals in the 1.57422 GHz to 1.5762 GHz frequency band; and

the upper radiating element, the dielectric material, and the ground plane element are configured to receive left hand circularly polarized satellite digital audio radio service (SDARS) signals and vertical linear polarized SDARS signals in the 2.320 GHz to 2.345 GHz frequency band.

19. The dual band patch antenna of claim **17**, wherein the signal feed is coupled to the lower radiating element via aperture coupling.

20. The dual band patch antenna of claim **17**, further comprising:

a connector for the signal feed; and

only one system connection cable coupled to the connector, the system connection cable being configured to propagate signals in the first frequency band and signals in the second frequency band.

* * * * *