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**Margomenos**

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(54) **DUAL-BAND ANTENNA ARRAY AND RF FRONT-END FOR MM-WAVE IMAGER AND RADAR**

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343/700 MS, 700 R, 711–717, 793, 810,  
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See application file for complete search history.

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(63) Continuation of application No. 13/042,302, filed on Mar. 7, 2011, which is a continuation of application No. 12/429,470, filed on Apr. 24, 2009, now Pat. No. 8,022,861, which is a continuation-in-part of application No. 12/340,448, filed on Dec. 19, 2008, now Pat. No. 7,830,301, which is a continuation-in-part of application No. 12/098,283, filed on Apr. 4, 2008, now Pat. No. 7,733,265.

(57)

**ABSTRACT**

The radar includes a PCB having a top surface and a bottom surface, and a processor mounted on the bottom surface of the PCB. The radar includes a second liquid crystal polymer layer formed on the top surface of the printed circuit board, a second microstrip array printed on the second liquid crystal polymer layer, the second microstrip array having a patch, a first liquid crystal polymer layer formed on the second liquid crystal polymer layer, a first microstrip array printed on the first liquid crystal polymer layer, the first microstrip array having a perforated patch, an antenna positioned underneath the patch and connected to the second microstrip array, and a transmit/receive module connected to a bottom surface of the second liquid crystal polymer layer and configured to transmit a first frequency signal to the first microstrip array and a second frequency signal to the second microstrip array.

**20 Claims, 8 Drawing Sheets**

(51) **Int. Cl.**

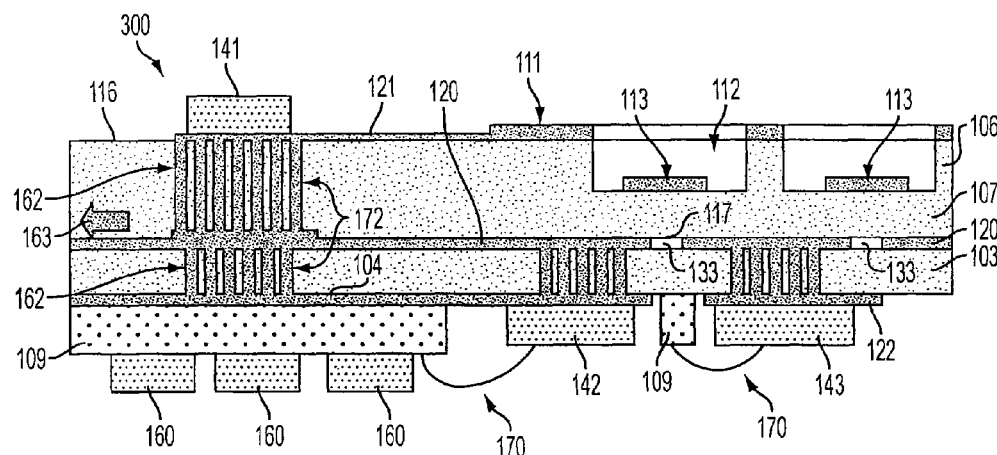
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**G01S 7/02** (2006.01)

**G01S 13/00** (2006.01)

(52) **U.S. Cl.** ..... **342/70**; 342/27; 342/175; 342/188; 342/195; 342/368; 343/700 R; 343/711; 343/872; 343/700 MS

(58) **Field of Classification Search** ..... 342/27, 342/28, 59, 70–72, 175, 195, 118, 128–133,



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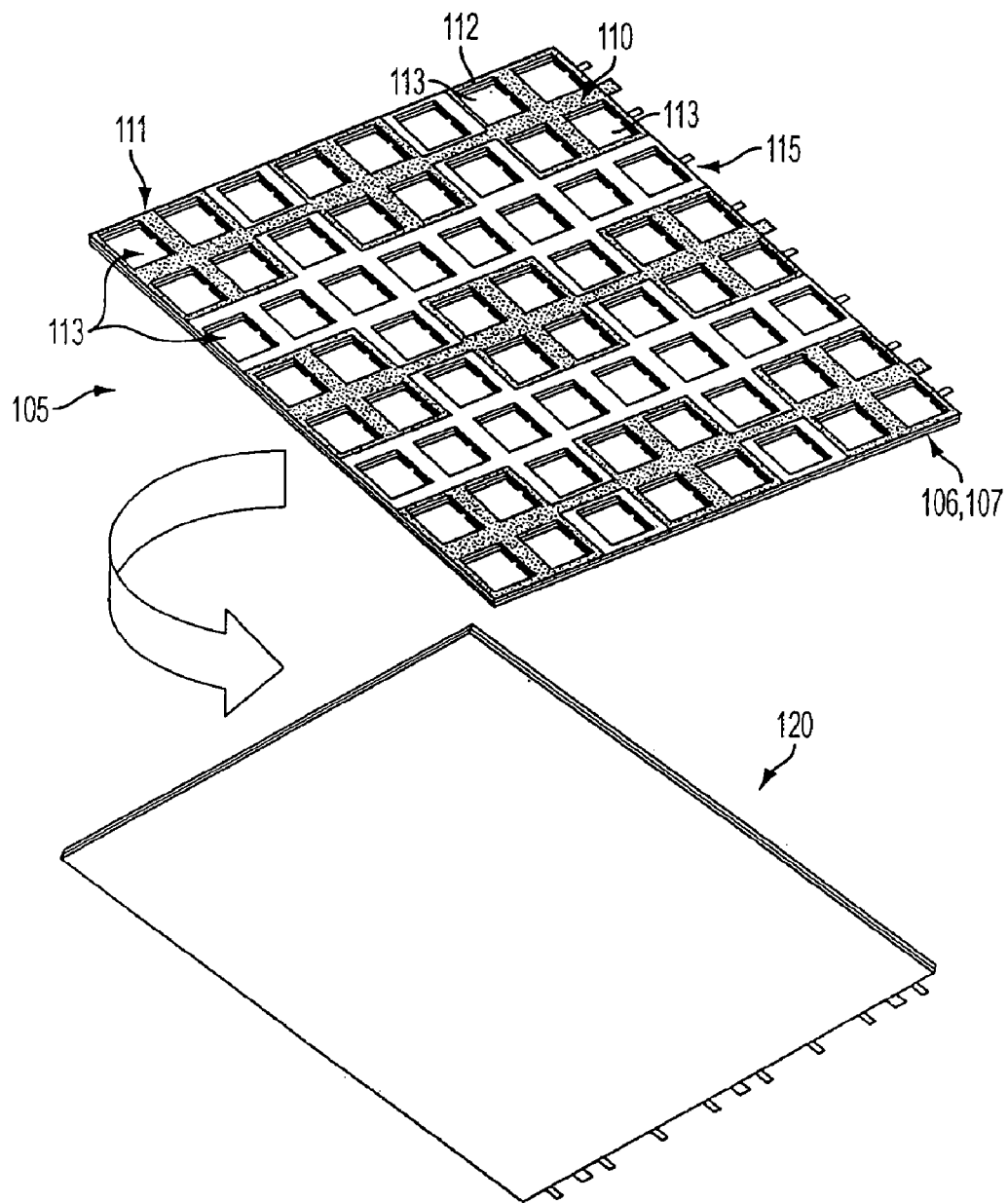


FIG. 1

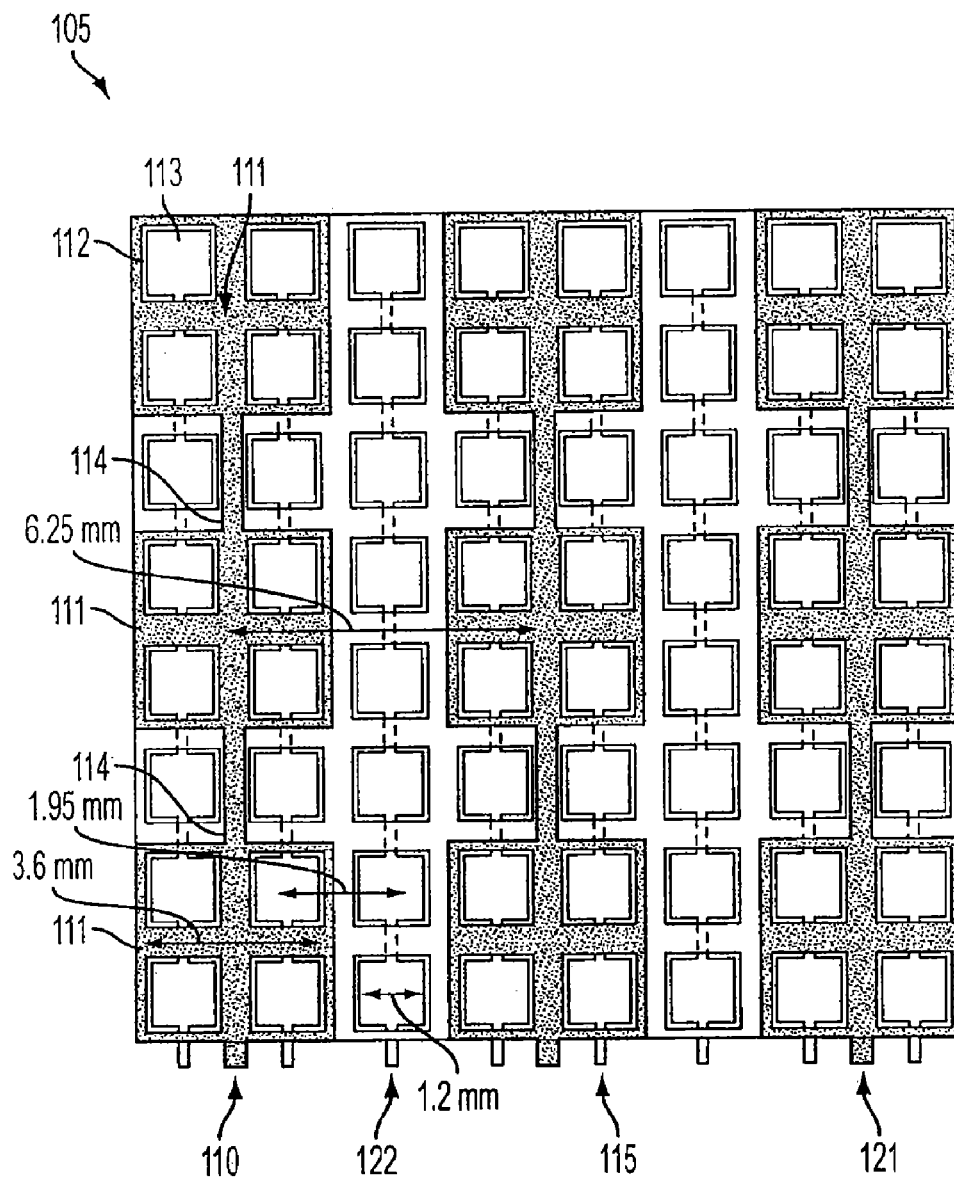


FIG. 2

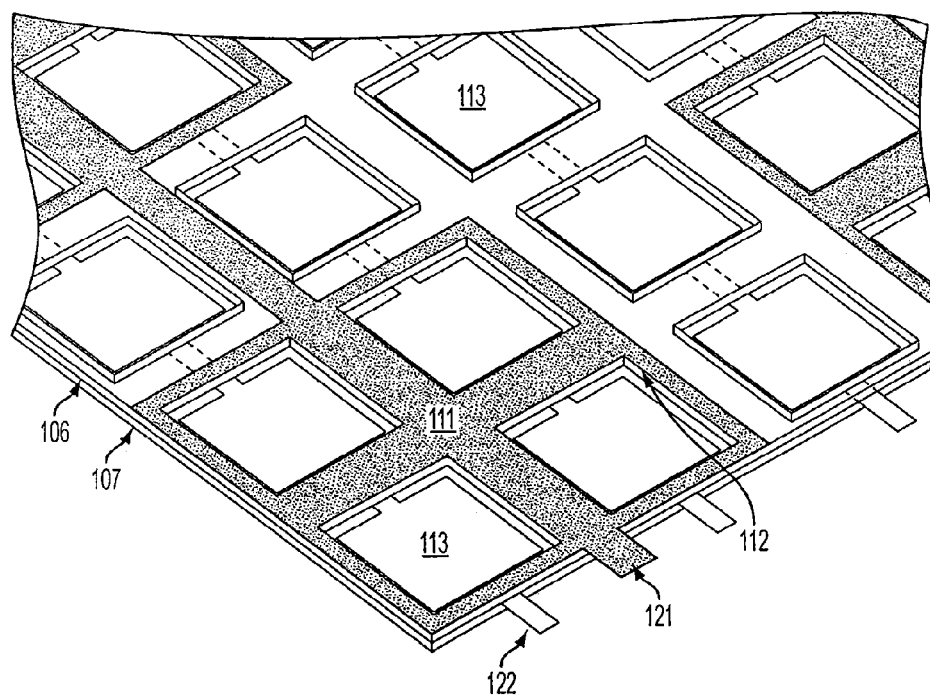


FIG. 3

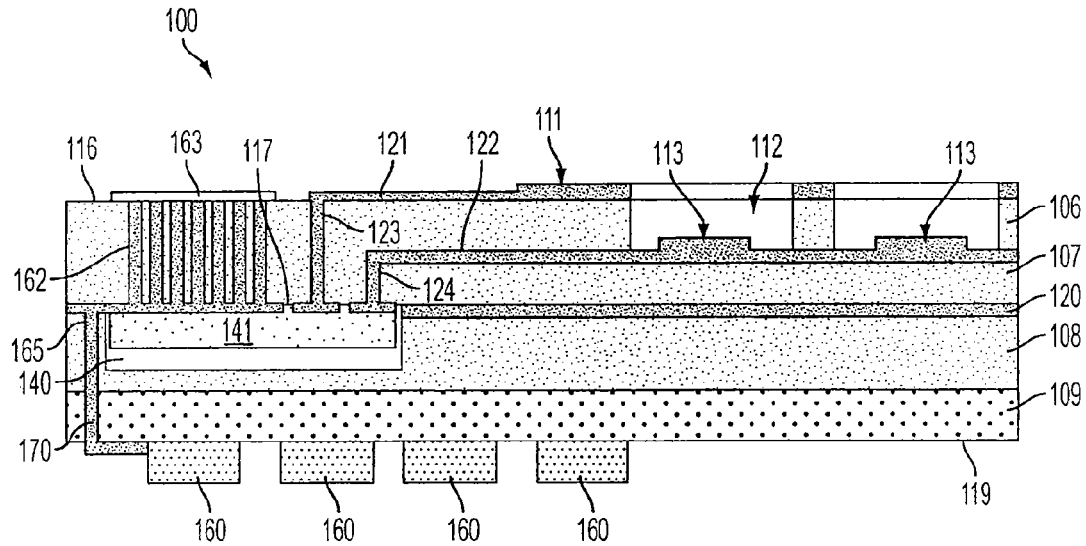


FIG. 4

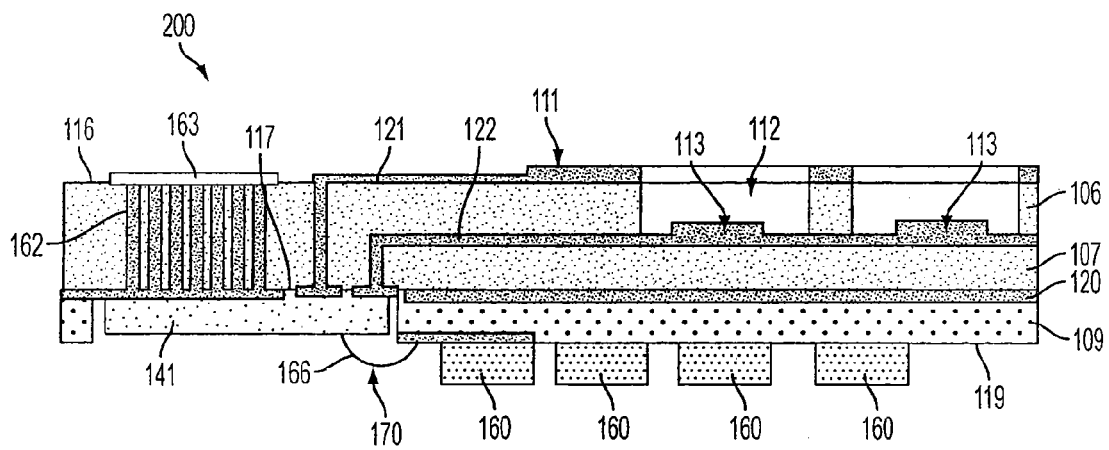


FIG. 5

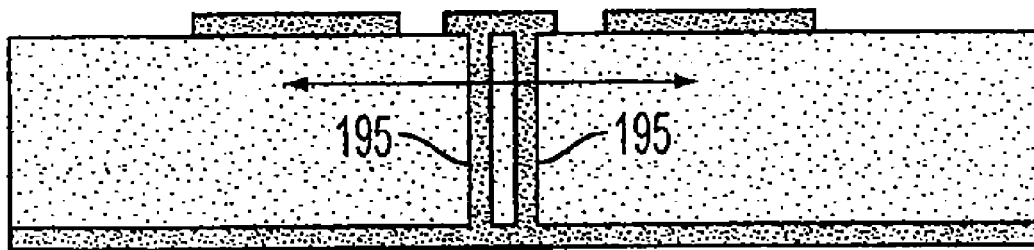


FIG. 6A

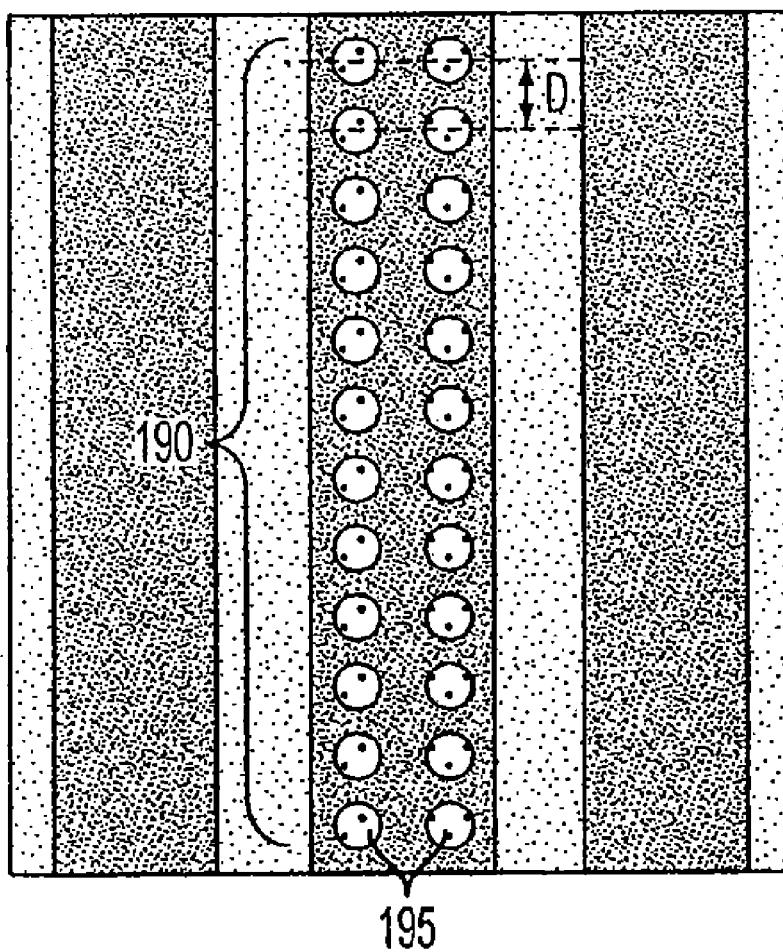


FIG. 6B



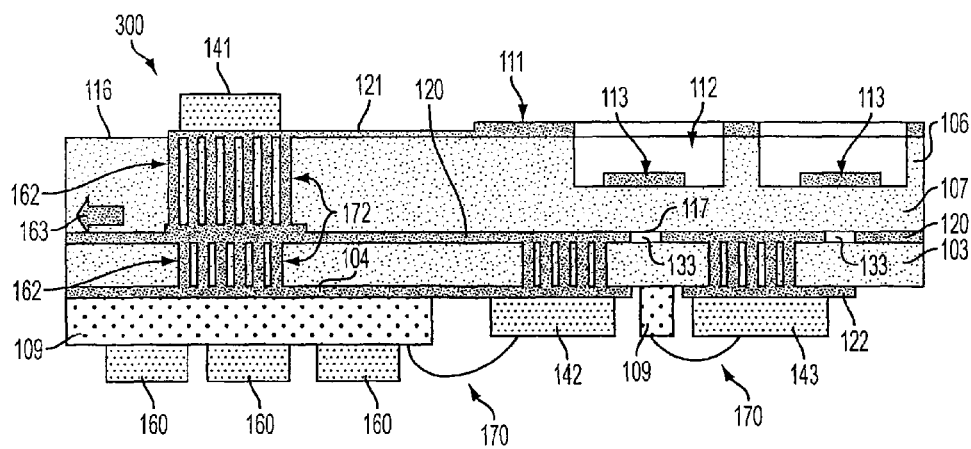


FIG. 7

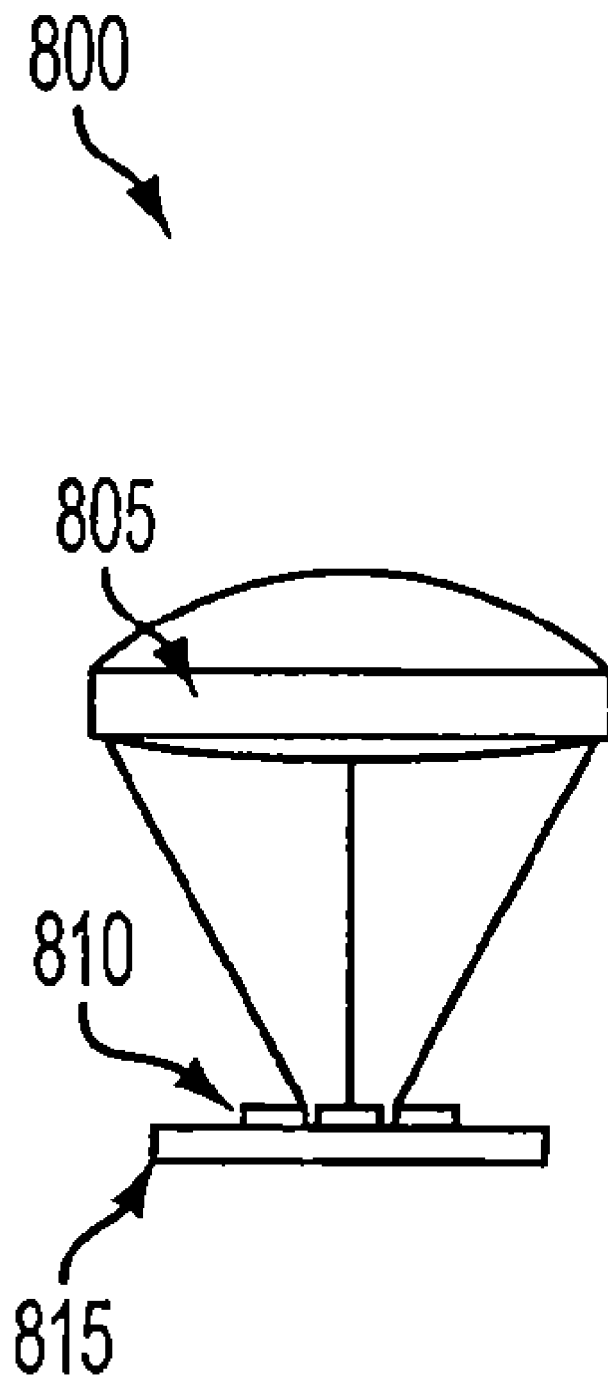


FIG. 8

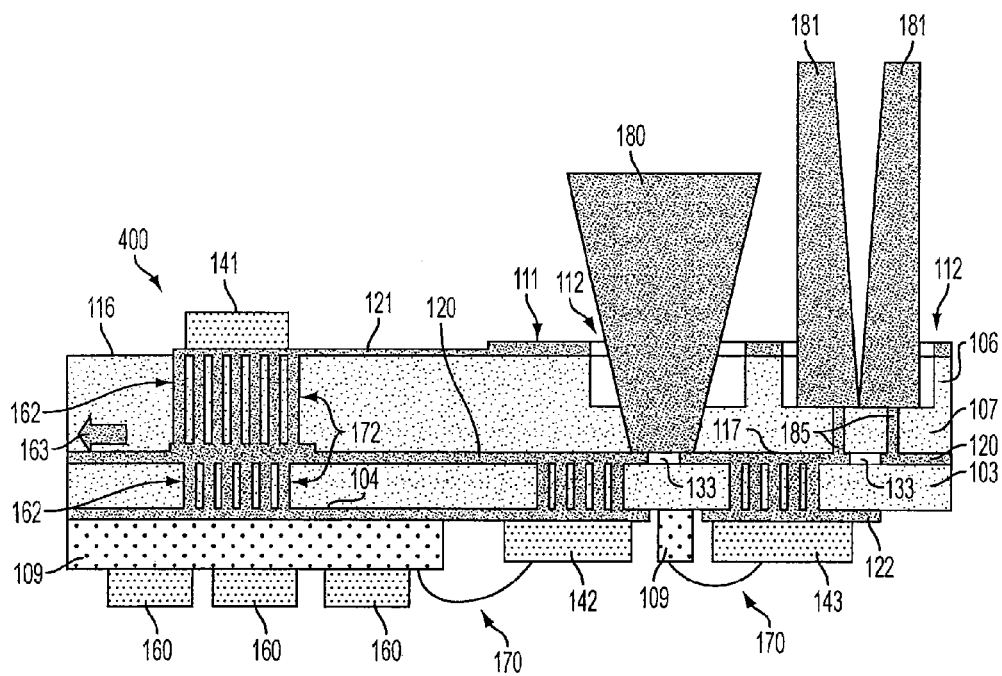


FIG. 9

# DUAL-BAND ANTENNA ARRAY AND RF FRONT-END FOR MM-WAVE IMAGER AND RADAR

CLAIM OF PRIORITY UNDER 35 U.S.C. §120

The present Application for Patent is a continuation of co-pending U.S. Patent application Ser. No. 13/042,302, entitled "Dual-Band Antenna Array and RF Front-End for MM-Wave Imager and Radar," filed Mar. 7, 2011, currently pending, which is a continuation of U.S. patent application Ser. No. 12/429,470, entitled "Dual-Band Antenna Array and RF Front-End for MM-Wave Imager and Radar," filed Apr. 24, 2009, now U.S. Pat. No. 8,022,861, which is a continuation-in-part application of U.S. patent application Ser. No. 12/340,448, entitled "Dual-Band Antenna Array and RF Front-End for Automotive Radars," filed Dec. 19, 2008, now U.S. Pat. No. 7,830,301 and U.S. patent application Ser. No. 12/098,283, entitled "Three Dimensional Integrated Automotive Radars and Methods of Manufacturing the Same," filed Apr. 4, 2008, now U.S. Pat. No. 7,733,265, the entire contents of which are incorporated herein by reference.

## BACKGROUND

### 1. Field

The invention relates to three dimensional integrated automotive radars and passive mm-wave imagers. More particularly, the invention relates to a dual-band antenna array and RF front-end that can be used for creating a three dimensional integrated automotive radar and passive mm-wave imager.

### 2. Background

Automotive radar systems are currently being provided in many luxury automobiles. Over the past few years, automotive radar systems have been used with intelligent cruise control systems to sense and adjust the automobile's speed depending on traffic conditions. Today, automotive radar systems are being used with active safety systems to monitor the surroundings of an automobile for collision avoidance. Current automotive radar systems are divided into long range (for adaptive cruise control and collision warning) and short range (for pre-crash, collision mitigation, parking aid, blind spot detection, etc.). Two or more separate radar systems, for example, a 24 GHz short range radar system and a 77 GHz long range radar system, which are typically each 15×15×15 centimeters in dimensions, are used to provide long and short range detection. The long range radar systems are used to track vehicles in front of the automobile at long distances (e.g., 20 to 150 meters) and accordingly adjust the speed of the automobile.

Prior art automotive radar systems have several drawbacks. For example, since multiple prior art radar systems are separately mounted on a vehicle, significant space is needed and can be wasteful. The cost for packaging, assembling, and mounting each radar system increases due to the additional number of radar systems. In order for each radar system to work properly, the materials placed on top of each radar system needs to be carefully selected so that the materials are RF transparent. The cost for multiple radar systems is further increased because multiple areas of RF transparency are needed on the front, sides, and rear of the vehicle. Thus, increasing the number of radar systems increases the packaging, assembly, mounting, and materials costs.

Therefore, a need exists in the art for three dimensional integrated automotive radars having a dual-band antenna array and RF front-end for automotive radars and imagers.

## SUMMARY

The invention relates to a dual-band antenna array and RF front-end that can be used for creating a three dimensional (3-D) integrated automotive radar and passive millimeter (mm)-wave imager. The 3-D integrated automotive radar can be used for both 77 GHz long range radar and mm-wave imaging applications. The 3-D integrated automotive radar significantly reduces manufacturing, assembling, and mounting costs. In addition, the 3-D integrated automotive radar is compact, thus reducing the space needed for mounting sensors on the vehicle (e.g., front and rear bumpers), wiring, and RF transparent materials in multiple locations on the front of the vehicle.

Millimeter wave imagers form an image based on receiving mm-wave radiation that is emitted from a scene. Millimeter wave imagers have the ability to sense objects through fog, dust, haze, sandstorms, etc. during both nighttime and daytime. Millimeter wave imagers advantageously do not radiate any signals thus making them very safe to operate and difficult to detect.

In one embodiment, the invention includes a method for creating a dual-band antenna array and RF front-end for automotive radars and imagers. The invention combines a 220 GHz mm-wave passive imager RF front-end with a 77 GHz radar antenna RF front-end on a single chip/system based on 3-D RF integration techniques. Combining the imager and the radar provides advantages in manufacturing, assembly, and testing costs. The combined imager and radar allow for a smaller size and for the packaging, assembly, and mounting to be together inside the vehicle (e.g., within the bumper). Also, data transfers between the imager and the radar can be accomplished more rapidly, efficiently, and with a reduced number of connections and wires. Data is used from both the imager and the radar to create an image of the environment.

In another embodiment, an automotive radar comprises a printed circuit board having a top surface, a bottom surface, and a cavity, a lower layer having a plurality of patches, the lower layer being positioned on the top surface of the printed circuit board, and a lower microstrip feed connected to the plurality of patches and positioned on the lower layer. The automotive radar also comprises an upper layer having a patch with a plurality of perforations that expose the plurality of patches, the upper layer being positioned on the lower layer, an upper microstrip feed connected to the patch and positioned on the upper layer, and a transmit module positioned in the cavity of the printed circuit board and configured to transmit a first signal having a first frequency to the upper microstrip feed and a second signal having a second frequency to the lower microstrip feed. The automotive radar also comprises an antenna positioned underneath the perforated patch or underneath the patch and connected to the first microstrip array or the second microstrip array.

## BRIEF DESCRIPTION OF THE DRAWINGS

The features, objects, and advantages of the invention will become more apparent from the detailed description set forth below when taken in conjunction with the drawings, wherein:

FIGS. 1, 2, and 3 are perspective, top, and exploded views, respectively, of a low-cost, compact radar and imager that utilizes a three-dimensional integrated architecture having a dual band array made of at least two bonded layers positioned on a common ground plane according to an embodiment of the invention;

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FIG. 4 is a cross-sectional view of a 3-D integrated dual-band RF front end of a radar and imager formed on a printed circuit board (PCB) according to an embodiment of the invention;

FIG. 5 is a cross-sectional view of a 3-D integrated dual-band RF front end of a radar and imager where the second layer is directly mounted to the PCB and a packaged T/R module is flip-chip mounted to a bottom surface of the second layer according to another embodiment of the invention;

FIGS. 6A and 6B are cross-sectional and top views, respectively, of via fences that are used to provide isolation between the first patch array and the second patch array according to an embodiment of the invention;

FIG. 7 is a cross-sectional view of a 3-D integrated dual-band RF front end of a radar and imager having a 220 GHz aperture feed array that is positioned under the 77 GHz patch array according to another embodiment of the invention;

FIG. 8 is a block diagram of a passive mm-wave imager according to an embodiment of the invention; and

FIG. 9 is a cross-sectional view of a 3-D integrated dual-band RF front end of a radar and imager having different 220 GHz antennas according to another embodiment of the invention.

#### DETAILED DESCRIPTION

Apparatus, systems and methods that implement the embodiments of the various features of the invention will now be described with reference to the drawings. The drawings and the associated descriptions are provided to illustrate some embodiments of the invention and not to limit the scope of the invention. Throughout the drawings, reference numbers are re-used to indicate correspondence between referenced elements. For purposes of this disclosure, the term “patch” may be used synonymously with the term “antenna.”

FIGS. 1, 2, and 3 are perspective, top, and exploded views, respectively, of a low-cost, compact radar and imager 100 that utilizes a three-dimensional integrated architecture having a dual band array 105 made of at least two bonded layers 106 and 107 positioned on a common ground plane 120 according to an embodiment of the invention. The radar and imager 100 includes a 77 GHz automotive radar and a 220 GHz passive mm-wave imager. The dual band array 105 includes a first layer 106 (e.g., a top or upper layer) and a second layer 107 (e.g., a lower layer). In one embodiment, the first layer 106 and the second layer 107 are bonded together, made of a low-cost mm-wave substrate and each approximately 4 mils thick. A number of different substrates can be used, each having their own fabrication tolerances and electrical and mechanical properties. The first layer 106 and the second layer 107 can be made of an Arlon CLTE-XT (PTFE ceramic), a Rogers RT 5880/RO 3003 (PTFE glass fiber), a Rogers Liquid Crystal Polymer (LCP), a low temperature cofired ceramic (LTCC), a Parylene N dielectric, a polytetrafluoroethylene (PTFE) ceramic, a PTFE glass fiber material, a Silicon material, a Gallium Arsenite (GaAs) material, an Alumina material, a PTFE material sold under the trademark TEFLON, a PTFE material sold under the trademark DUROID or any other material that can produce thin (about 2-4 mils in thickness) metallized layers which can be stacked to form multi-layer architectures. The radar and imager 100 may be implemented using hardware, software, firmware, middleware, microcode, or any combination thereof. One or more elements can be rearranged and/or combined, and other radars/imagers can be used in place of the radar and imager 100 while still maintaining the spirit and scope of the invention. Elements may be added to the radar and imager 100 and

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removed from the radar and imager 100 while still maintaining the spirit and scope of the invention.

The first layer (i.e., top layer) 106 has a series microstrip patch array 110 for 77 GHz operation. The patch array 110 includes one or more perforated patches 111 (i.e., antennas) where each hole or opening 112 is an approximately 1.4 millimeter square opening which uncovers a 220 GHz patch 113 (i.e., an antenna) located at or on the second layer (i.e., bottom layer) 107, which has a series microstrip patch array 115 for 220 GHz operation. The 220 GHz series microstrip patch array 115 may be printed on the second layer 107. In one embodiment, each perforated patch 111 is an approximately 3.6 millimeter square and each patch 113 is an approximately 1.2 millimeter square. The patches 111 are connected to one another via connectors 114. The size of each opening 112 is optimized to have minimum effects on the radiation performance of the patches 111 and 113. In one embodiment, the openings 112 on the first layer 106 allow unhindered radiation to be emitted from the 220 GHz patches 113. Furthermore, the openings 112 may be formed as a small horn-type of opening to further improve the radiation performance of the patches 111 and 113.

In order to ensure no grating lobes and low side lobe level, the spacing between the first patch array 110 and the second patch array 115 is  $\lambda_0/2$ , where  $\lambda_0$  is the free space wavelength at 220 GHz and 77 GHz, respectively. Due to the ratio between the two frequencies ( $220/77 \approx 3$ ), two 220 GHz patches 113 are placed inside or within the outer boundaries of one 77 GHz patch 111. In addition, two 220 GHz patches 113 are placed between two adjacent 77 GHz patches 111.

FIG. 4 is a cross-sectional view of a 3-D integrated dual-band RF front end of a radar and imager 100 formed on a printed circuit board (PCB) 109 according to an embodiment of the invention. In one embodiment, a packaging layer 108 is formed on the PCB 109. The packaging layer 108 is made of LCP and is used for packaging the T/R module 141. For example, the packaging layer 108 may have a cavity 140 for holding the T/R module 141. In addition, IF filters may be embedded in or fabricated on the packaging layer 108. In one embodiment, the T/R module 141 may be used for both or multiple frequencies.

The second layer 107 may be formed between the 220 GHz array 113 and the T/R module ground 120. The array of second patches 113 are formed on top of or are part of the second layer 107. The microstrip feed 122 connects the array of second patches 113 to the T/R module 141. The microstrip feed 122 is transitioned through a second via 124 to the T/R module 141. The first layer 106 may be formed on top of the microstrip feed 122 and/or the second layer 107. An array of first perforated patches 111 (e.g., 77 GHz patches) are formed on top of or are part of the first layer 106. The perforations 112 on the first layer 106 allow relatively unhindered radiation to pass from the array of second patches 113 (e.g., 220 GHz patches). In one embodiment, each perforation 112 is a horn-shaped opening (i.e., a lower portion of the horn is smaller in circumference than an upper portion of the horn), which improves the radiation performance of each patch 113. The microstrip feed 121 connects the array of first patches 111 to the T/R module 141. The microstrip feed 121 is transitioned through a first via 123 to the T/R module 141 and may be formed on or may be part of the first layer 106. The first layer 106 may contain the 77 GHz series patch array 110 and the microstrip feed 121. The microstrip feed 121 and the microstrip feed 122 may include a network of feed connectors or lines.

The first layer 106 has one or more microstrip feeds 121 and the second layer 107 has one or more microstrip feeds

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**122.** The microstrip feeds **121** and **122** are used as connections to the first and second layers **106** and **107**, respectively. In one embodiment, the patch arrays **110** and **115** are comprised of microstrip patch antennas.

A plurality of chips and/or components **160** (e.g., two Silicon-Germanium (SiGe) BiCMOS chips) may be mounted on a bottom surface **119** of the PCB **109**. The plurality of chips and/or components **160** may include one or more of the following: a digital signal processor (DSP), a digital clock, a temperature controller, a memory, a microprocessor, dynamic link libraries, a DC port, a data port, a voltage controlled oscillator, a PLL, etc. The plurality of chips and/or components **160** may be connected to one another via wireless links or via connectors, traces or wires on the PCB **109**. The output signals **170** (e.g., digital, DC, IF or RF signals) from the T/R module **141** may be directly connected using through-vias **165** (or may be wirelessly connected) to the plurality of chips and/or components **160**.

The T/R module **141** may be flip-chip bonded or mounted on a bottom surface **117** of the second layer **107**. The flip-chip transition provides significantly less parasitic inductance and lower loss compared to conventional wirebonds. A plurality of thermal vias **162** are directly connected to the T/R modules **141** and pass through the first and second layers **106** and **107**. The plurality of thermal vias **162** are used to remove the heat from the T/R module **141** and transfer the heat to a heat rejection area **163** that is located on a top surface **116** of the first layer **106**.

FIG. **5** is a cross-sectional view of a 3-D integrated dual-band RF front end of a radar and imager **200** where the second layer **107** is directly mounted to the PCB **109** and a packaged T/R module **141** is flip-chip mounted to a bottom surface **117** of the second layer **107** according to another embodiment of the invention. The output signals **170** (e.g., digital, DC, IF or RF signals) from the packaged T/R module **141** may be directly connected using wirebonds **166** (or may be wirelessly connected) to the plurality of chips and/or components **160**. In this embodiment, the T/R module **141** is pre-packaged so no additional LCP layer (such as **108** in FIG. **4**) is needed.

FIGS. **6A** and **6B** are cross-sectional and top views, respectively, of via fences **190** (i.e., a number of vias **195** positioned along a line) that are used to provide isolation between the first patch array **110** and the second patch array **115** according to an embodiment of the invention. The via fences **190** are used to ensure high isolation between the two frequencies. The vias **195** can also be spaced apart a distance **D**, where **D** can be varied in order to form bandgap filters. In addition to vias **195**, periodic structures can be etched on the ground plane **120** in order to create bandgap effects. The result of these bandgap effects is that we can filter out the 77 GHz signals on the 220 GHz transmission line and vice versa.

FIG. **7** is a cross-sectional view of a 3-D integrated dual-band RF front end of a radar and imager **300** having a 220 GHz aperture feed array **113** that is positioned under the 77 GHz patch array **111** according to another embodiment of the invention. The 220 GHz array **113** is aperture fed. In particular, a plurality of apertures **133** are formed on the ground plane **120** and each aperture **133** is formed below or under a 220 GHz patch **113** and the 220 GHz microstrip line **122** is formed or printed on the backside of the third layer **103**.

In one embodiment, the first layer **106** includes the array of 77 GHz perforated patches **111** along with the microstrip feeding network **121**. The first layer **106** also includes a heat rejection area **163** for removing the heat generated at the SiGe or CMOS 77 GHz T/R module **141**. The ground plane **120** is formed or positioned on or adjacent to a third layer **103**. The third layer **103** may be similar to the first and second layers

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**106** and **107**. Therefore, the ground plane **120** separates the 77 GHz patch array **111** and the chips **160** from the 220 GHz components (e.g., 220 GHz receiver modules **142** and **143**), thus minimizing or reducing the crosstalk between the 77 GHz lines or systems and the 220 GHz lines or systems. The plurality of chips and/or components **160** are connected or mounted to the PCB **109**. Typically, one 220 GHz receiver module (e.g., SiGe, InP, GaAs or CMOS chip) is positioned behind each pixel, therefore there is no distribution network for the 220 GHz focal plane array **810**.

The microstrip feed **121** is used to connect the first layer **106** to a first (e.g., 77 GHz) transmit/receive (T/R) module **141** and the microstrip feed **122** is used to connect the second layer **107** to a second (e.g., 220 GHz) T/R module **142**. The first T/R module **141** may be formed or positioned on a top surface **116** of the first layer **106** and connected to the first microstrip feed **121**. The second T/R module **142** may be formed or positioned on a bottom surface **104** of the third layer **103** and connected to the second microstrip feed **122**. The first T/R module **141** is connected to the plurality of chips and/or components **160** using vias **172** and the first and second receive modules **142** and **143** are connected to the plurality of chips and/or components **160** using wired or wireless signals **170**.

Packaged module **141** for 77 GHz operation is mounted on the top surface **116** of the first layer **106** and packaged modules **142** and **143** for 220 GHz operation is mounted on the third layer **103**. The first and second T/R modules **141** and **142** may be a T/R monolithic microwave integrated circuit (MMIC) or a Silicon-Germanium (SiGe) BiCMOS chip that may include one or more of the following: a T/R switch, a low noise amplifier (LNA), a variable gain amplifier (VGA), a power amplifier (PA), a phase shifter, a mixer, an intermediate frequency (IF) amplifier, and an analog-to-digital (A/D) converter. The first T/R module **141** may generate first frequency signals (e.g., 77 GHz signals) and the first and second modules **142** and **143** may receive second frequency signals (e.g., 220 GHz signals).

The three mm-wave substrate layers **106**, **107** and **103** are mounted on the PCB **109** such that the third layer **103** is directly mounted on the PCB **109**. The PCB hosts all the digital circuitry. The interconnections between the T/R module **141** and the PCB **109** are achieved through vias **162** (for the 77 GHz module) and between the receive modules **142** and **143** and the PCB **109** are achieved through wirebonds **170** (for the 220 GHz modules). In both cases, the interconnections are at a very low Intermediate Frequency or DC. Therefore, limited parasitic effects exist from the interconnections to the PCB **109**. The heat rejection area **163** is on the side of the array and appropriate thermal straps are used to remove heat from under the T/R module **141** and the receive modules **142** and **143**.

FIG. **8** is a block diagram of a passive mm-wave imager **800** according to an embodiment of the invention. The mm-wave imager **800** includes a lens **805** that focuses a plurality of received mm-wave rays at a specific focal plane. On the specific focal plane, a focal plane array (FPA) of a plurality of sensitive receivers detects the plurality of received mm-wave rays and reconstructs the signal using read out integrated circuits. The 77 GHz radar does not require a lens for its operation. In one embodiment, a lens may be used only for beam correction and side lobe level reduction, however, the lens is not necessary. The radar and imager **300** can utilize a lens positioned over the patches **111** and **113** that is completely transparent at 77 GHz and operates at 220 GHz. Alter-

natively, the radar and imager **300** can utilize a lens positioned over the patches **111** and **113** that operates at both 77 GHz and 220 GHz.

FIG. 9 is a cross-sectional view of a 3-D integrated dual-band RF front end of a radar and imager **400** having different 220 GHz antennas according to another embodiment of the invention. For example, for the 220 GHz antennas a microstrip patch antenna may be used. Another example is to use the perforations at the 77 GHz patches and form a 220 GHz horn antenna **180**. Another example is to fabricate endfire antenna **181** for 220 GHz operation. The endfire antenna **181** can be attached vertically inside the hole **112** of the 77 GHz perforated patches **111**. The endfire antenna **181** can be Yagi-Uda or any form of a tapered slot antenna (e.g., Vivaldi, Fermi, etc.). As an example, FIG. 9 shows one 220 GHz horn antenna **180** and one 220 GHz tapered slot antenna **181**. A waveguide-to-microstrip transition is used to feed the 220 GHz horn antenna **180**. A coplanar waveguide to coplanar strip transition is used to feed the 220 GHz tapered slot antenna **181**.

A low cost substrate (such as LCP) is used to reduce the costs associated with printing the antennas, mounting the SiGe, InP, GaAs or CMOS chips, creating thermal management systems, packaging the chips. Hence, the overall cost of the radars and imagers disclosed herein is significantly reduced. The 3-D integration techniques also improve the performance of the radar and imager since they significantly reduce the number of necessary RF transitions from the antennas to the low noise amplifiers on the receiver chips and also improves the insertion loss. This reduces the overall system noise and improves the radar and imager sensitivity (i.e., range and minimum detectable target radar cross section). By combining the 220 GHz imager and the 77 GHz radar, the space on the vehicle needed to install mm-wave sensors is reduced, since only one mounting bracket can be used for both systems. Furthermore, the costs for packaging, assembly, and mounting of the mm-wave sensors are reduced. Also, by combining the 220 GHz imager and the 77 GHz radar, the need for wiring for data fusion between sensors and the use of mm-wave transparent materials is reduced.

Those of ordinary skill would appreciate that the various illustrative logical blocks, modules, and algorithm steps described in connection with the examples disclosed herein may be implemented as electronic hardware, computer software, or combinations of both. To clearly illustrate this interchangeability of hardware and software, various illustrative components, blocks, modules, circuits, and steps have been described above generally in terms of their functionality. Whether such functionality is implemented as hardware or software depends upon the particular application and design constraints imposed on the overall system. Skilled artisans may implement the described functionality in varying ways for each particular application, but such implementation decisions should not be interpreted as causing a departure from the scope of the disclosed apparatus and methods.

The various illustrative logical blocks, modules, and circuits described in connection with the examples disclosed herein may be implemented or performed with a general purpose processor, a digital signal processor (DSP), an application specific integrated circuit (ASIC), a field programmable gate array (FPGA) or other programmable logic device, discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform the functions described herein. A general purpose processor may be a microprocessor, but in the alternative, the processor may be any conventional processor, controller, microcontroller, or state machine. A processor may also be implemented as a combination of computing devices, e.g., a combination of a

DSP and a microprocessor, a plurality of microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration.

The steps of a method or algorithm described in connection with the examples disclosed herein may be embodied directly in hardware, in a software module executed by a processor, or in a combination of the two. A software module may reside in RAM memory, flash memory, ROM memory, EPROM memory, EEPROM memory, registers, hard disk, a removable disk, a CD-ROM, or any other form of storage medium known in the art. An exemplary storage medium is coupled to the processor such that the processor can read information from, and write information to, the storage medium. In the alternative, the storage medium may be integral to the processor. The processor and the storage medium may reside in an Application Specific Integrated Circuit (ASIC). The ASIC may reside in a wireless modem. In the alternative, the processor and the storage medium may reside as discrete components in the wireless modem.

The previous description of the disclosed examples is provided to enable any person of ordinary skill in the art to make or use the disclosed methods and apparatus. Various modifications to these examples will be readily apparent to those skilled in the art, and the principles defined herein may be applied to other examples without departing from the spirit or scope of the disclosed method and apparatus. The described embodiments are to be considered in all respects only as illustrative and not restrictive and the scope of the invention is, therefore, indicated by the appended claims rather than by the foregoing description. All changes which come within the meaning and range of equivalency of the claims are to be embraced within their scope.

What is claimed is:

1. A radar for an automobile comprising:
  - a printed circuit board having a first surface and a second surface;
  - a processor coupled to the second surface of the printed circuit board, the processor configured to generate a first frequency signal and a second frequency signal;
  - a first substrate layer coupled with the first surface of the printed circuit board, the first substrate layer having a first patch having an opening therein;
  - a second substrate layer positioned between the first substrate layer and the first surface of the printed circuit board, the second substrate layer having a first patch disposed adjacent the opening of the first patch of the first substrate layer; and
  - a transmit module connected to the processor and coupled with first patch of the first substrate layer and the first patch of the second substrate layer, the transmit module configured to transmit the first frequency signal to the first patch of the first substrate layer and the second frequency signal to the first patch of the second substrate layer.
2. The radar of claim 1 wherein the first substrate layer and the second substrate layer are bonded together.
3. The radar of claim 1 wherein the transmit module comprises a transmit and receive module.
4. The radar of claim 1 wherein the first patch of the second substrate layer is positioned directly beneath the opening of the first patch of the first substrate layer.
5. The radar of claim 1 wherein:
  - the first substrate layer has a second patch having an opening therein, the second patch of the first substrate layer connected to the first patch of the first substrate layer; and

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the second substrate layer has a second patch, the second patch of the second substrate layer connected to the first patch of the second substrate layer and disposed adjacent to the opening of the second patch of the first substrate layer.

6. The radar of claim 1 wherein the opening of the first patch of the first substrate layer is formed with a first portion being smaller in perimeter than a second portion to further improve radiation performance of the opening of the first patch of the first substrate layer.

7. The radar of claim 1 further comprising a packaging layer positioned between the second substrate layer and the first surface of the printed circuit board, the packaging layer having a cavity for holding the transmit module.

8. The radar of claim 7 further comprising an Intermediate Frequency filter embedded in or fabricated on the packaging layer.

9. A radar for an automobile comprising:

a printed circuit board having a first surface and a second surface;

a processor coupled to the second surface of the printed circuit board, the processor configured to generate a first frequency signal and a second frequency signal;

a packaging layer coupled with the first surface of the printed circuit board;

a first liquid crystal polymer layer coupled with the first surface of the printed circuit board;

a first patch array printed on the first liquid crystal polymer layer, the first patch array including a first patch with a perforation, the first patch configured to radiate the first frequency signal;

a second liquid crystal polymer layer positioned between the first liquid crystal polymer layer and the first surface of the printed circuit board;

a second patch array printed on the second liquid crystal polymer layer, the second patch array including a second patch, the second patch configured to radiate the second frequency signal through the perforation of the first patch;

a ground plane positioned between the first liquid crystal polymer layer and the second liquid crystal polymer layer; and

a transmit module in communication with the processor and configured to transmit the first frequency signal to the first patch.

10. The radar of claim 9 wherein the transmit module is further configured to transmit the second frequency signal to the second patch.

11. The radar of claim 9 further comprising a second transmit module in communication with the processor, the second transmit module configured to transmit the second frequency signal to the second patch.

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12. The radar of claim 9 further comprising a thermal via positioned adjacent to the transmit module for removing heat from the transmit module.

13. The radar of claim 9 further comprising periodic structures etched on the ground plane for creating bandgap filter effects.

14. The radar of claim 9 further comprising a lens positioned over the first patch or the second patch for focusing a received mm-wave ray.

15. The radar of claim 14 wherein the lens is transparent at one of the first frequency signal or the second frequency signal.

16. The radar of claim 14 wherein the lens operates for both the first frequency signal and the second frequency signal.

17. The radar of claim 9 wherein the packaging layer comprises a liquid crystal polymer.

18. A method for communicating a plurality of signals via a dual-band antenna comprising the steps of:

providing a first antenna disposed in a first plane and a second antenna disposed in a second plane substantially parallel with the first plane, the first antenna having a first patch having a first perforation, the second antenna having a second patch exposed by the first perforation of the first patch of the first antenna;

generating a first signal having a first frequency and a second signal having a second frequency;

emitting the first signal from the first patch of the first antenna; and

emitting the second signal from the second patch of the second antenna, the second signal emitted through the first perforation of the first patch of the first antenna.

19. The method of claim 18 further comprising the steps of: receiving a third signal having the first frequency by the first patch of the first antenna; and

receiving a fourth signal having the second frequency by the second patch of the second antenna, the fourth signal received through the first perforation of the first patch of the first antenna.

20. The method of claim 19 further comprising the steps of: providing a lens positioned adjacent the first patch of the first antenna or the second patch of the second antenna; focusing a plurality of millimeter waves through the lens to a focal plane, the focal plane substantially parallel with the first plane of the first antenna and the second plane of the second antenna;

detecting the plurality of millimeter waves; and reconstructing the third signal or the fourth signal from the plurality of millimeter waves.

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