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(74) Agents: **FORD, Stephen, S.** et al.; MARGER JOHNSON & MCCOLLOM, P.C., 210 SW Morrison Street, Suite 400, Portland, OR 97204 (US).

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(71) Applicant (*for all designated States except US*): **CY-PRESS SEMICONDUCTOR CORPORATION** [US/US]; 198 Champion Court, San Jose, CA 95134-1709 (US).

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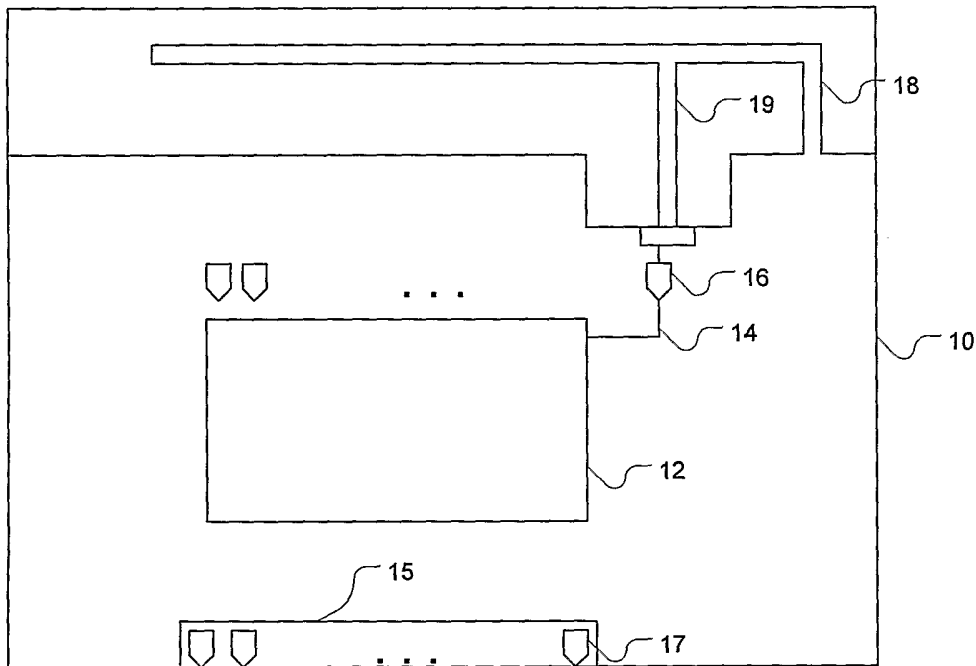
(72) Inventors; and

(75) Inventors/Applicants (*for US only*): **KWAN, Philip, Pak-Lin** [US/US]; 10340 SW Dunlin Place, Beaverton, OR 97007 (US). **BEARD, Paul** [GB/US]; 1657 Country Club Drive, Milpitas, CA 95035 (US).

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(54) Title: ANTENNA WITH MULTIPLE FOLDS



(57) Abstract: A wireless device has a module with a communications port and an antenna electrically coupled to the communications port, the antenna having multiple folds. The antenna has a shunt stub connected to a ground plane and a radiating portion that has multiple folds, or wiggles, allowing good electrical performance to be achieved with a minimal size.

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For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

ANTENNA WITH MULTIPLE FOLDS

BACKGROUND

Technical Field

5 This disclosure relates to wireless devices, more particularly to antenna used in wireless devices.

Background

 Wireless devices send and receive signals through an antenna. For transmission, the antenna converts electrical signals from a power amplifier to electro-magnetic fields and radiates those fields out in a desired manger. When receiving, the antenna receives radiated electro-magnetic fields and converts them back to electrical signal for interpretation and operation by the wireless device.

 Many different types of antenna are being used in wireless applications. A common one is an inverted 'F' antenna. It has two 'fingers' that provide electrical connection to the wireless device, and a long, straight arm that typically parallels an edge of the printed circuit board upon which the wireless device is mounted. The inverted F antenna provides good electrical performance, but has a rather large physical size. Another option is an antenna that is shaped similar to a 'question mark,' but the physical size is comparable to the inverted F antenna.

20 Wireless devices, because of their freedom from cables and wires, are particularly suited for small, portable implementations. One of the main physical constraints on making the device smaller is the size of the antenna. However, smaller antennas need to be able to match the electrical performance of the larger antenna.

SUMMARY

One embodiment of the invention is a wireless device has a module with a communications port and an antenna electrically coupled to the communications port, the antenna having multiple folds.

5 Another embodiment of the invention is an antenna having a shunt stub connected to a ground plane and a radiating portion that has multiple folds, or wiggles, allowing good electrical performance to be achieved with a minimal size.

Another embodiment of the invention is a method of manufacturing an antenna with multiple folds.

10 BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the invention may be best understood by reading the disclosure with reference to the drawings, wherein:

Figure 1 shows an inverted F antenna.

15 Figure 2 shows an embodiment of a substrate having a module and an antenna having multiple folds.

Figure 3 shows an embodiment of an antenna having multiple folds and a vertical shunt stub.

Figure 4 shows an embodiment of an antenna having multiple folds and a horizontal shunt stub.

20 Figure 5 shows a graph of antenna return loss versus frequency for different substrate thicknesses.

Figures 6a-6c shows a flowchart of an embodiment of a method to manufacture an antenna having multiple folds on a substrate.

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DETAILED DESCRIPTION OF THE EMBODIMENTS

An embodiment of an inverted F antenna is shown in Figure 1. The substrate 10 has mounted on it a module 12. The substrate may be a printed circuit board, or equivalent, such as a layered ceramic substrate. The substrate provides electrical connections for the module to allow it to be connected to power, communications and other types of traces in the substrate. For example, this substrate may have an edge connector 15 that allows the substrate to be inserted into a slot on a larger substrate, such as a mother board. The mother board provides power, ground and signals to the individual conductors such as 17 of the edge connector. These conductors are then connected through traces on the substrate to the module.

The substrate may also provide a conductor 14 between a connector 16 for the inverted F antenna 18. The shunt stub 19 provides the connection between the radiating portion of the antenna and the module 12. The connector 16 would comprise a communications port that allows the module 12 to provide signals to be radiated out of the antennas, and to allow the module 12 to receive signals from the antenna for conversion and operation.

As can be seen in Figure 1, the size of the substrate 10 is largely dependent upon the size of the inverted F antenna 18. This is due to the necessary size of the antenna to provide good electrical performance. As mentioned previously, it is generally desirable to reduce the size of wireless modules and the antenna is one of the main physical constraints on the size.

An alternative design is an antenna shaped much like a question mark, '?' However, the necessary size of this antenna is similar to that of the inverted F antenna, constraining the size of the unit to be of a larger-than-desirable size.

In Figure 2, an embodiment of an antenna having multiple folds is shown. This may be referred to as a 'wiggle' antenna. The actual sizes of the modules and antennas may vary,

but the comparative sizes between them can be seen by comparing Figures 1 and 2. In this embodiment, the two substrates have a similar vertical extent, but the folded antenna substrate shown in Figure 2 has less than half the horizontal extent of the inverted F antenna substrate.

5 In Figure 2, the substrate 20 has a module 22 with connectors such as 26. A conductor 24 connects the module 22 to the connector 26, although the actual conductor may not be seen if it is buried in the layers of the substrate. The conductor 24 provides a communications port for the module 22. In one embodiment the module 22 is a Universal Serial Bus (USB) module that communicates with other devices using the USB
10 communications protocol. The substrate 20 may or may not have other features, such as the edge connector of substrate 10 shown in Figure 1.

The antenna 28 has multiple folds, such as 32a and 32b. The embodiment of Figure 2 has a vertical shunt stub 30. The selection of a vertical shunt stub or a horizontal shunt stub is left up to the system designer, and the selection of a vertical shunt stub in this particular
15 embodiment is merely for demonstration purposes only.

Examples of horizontal and vertical shunt stub configurations are shown in Figures 3 and 4.

Figure 3 shows a vertical shunt stub wiggle antenna. The antenna is manufactured out of a substrate that has a bottom layer metal 40 and a top layer metal 44. The bottom layer metal is shown on the left. It has a width WG and a height HGB . A notch 42 having a height
20 $H5$ and a width $W3$ is shown in this embodiment as being in the upper left hand corner of the bottom layer metal. This is merely for demonstrative purposes and the notch can be provided in any position in the bottom layer metal that will allow proper connection of the antenna.

The antenna in this embodiment is formed out of the top layer metal 44 shown on the right. The top layer metal has a height HGT that may be less than that of the bottom layer
25 metal height HGB . The radiating portion of the antenna has a connecting arm 46 that

connects via a connector pad 54. The antenna has multiple folds such as 48, each spaced a distance G apart and having an interior height of $H1$, spaced from the bottom layer metal a distance $H2$.

The connecting arm and the width of the folds of the antenna are generally the same, shown here as width W . The exterior height of the antenna would therefore be the interior height $H1$ plus the width of the antenna itself at the top of the folds, W . The antenna has a tip 50, having a length L_{tip} . The individual selection of these dimensions is left up to the designer and the constraints of the module for which the antenna is being designed.

In this embodiment the shunt stub 52 is a vertical shunt stub. The shunt stub 52 is spaced a distance $G3$ from the first of the antenna folds. The shunt stub 52 will typically be as wide as the folds of the antenna, for ease of manufacturing. In this embodiment, it can be seen that the bottom of the folds of the antenna are spaced a distance $H6$ from the top layer of metal 44. For comparative purposes, the distance $H6$ in Figure 3 is substantially equal to the distance $H3+W+H2$ of Figure 4.

In addition to the radiating portion of the antenna, the antenna has a shunt stub 52. In one embodiment the radiating portion and the shunt stub are manufactured out of the same layer. No limitation that these structures be manufactured separately should be inferred. As can be seen in Figure 3, the shunt stub 52 is connected to the bottom layer metal 40. This provides an extended ground plane for the antenna. The extended ground plane improves the antenna return loss and bandwidth control. Return loss is typically defined as the difference, usually expressed in decibels (dB), compared between the incident voltage or current on a transmission line and the reflected current or voltage as measured at a particular point. This will be discussed further with regard to Figure 5. The position and size of the shunt stub also assists in achieving the desired resonant behavior.

With regard to bandwidth control, the bandwidth control may be improved by the

distance between the top layer and the bottom layer of metal in the substrate. This distance is referred to as the offset. There is an optimum offset for a given frequency and a given substrate thickness. The ground offset acts as a tuning element for the antenna, similar to a tuning capacitor. The performance of a wiggle antenna at different board thicknesses is shown in Figure 5.

In Figure 4, an embodiment of an antenna with a horizontal shunt stub is shown. In this embodiment, the connecting arm of the antenna 46 is connected to the pad 54 and the folds of the antenna 48 are spaced apart a distance G , as in the horizontal embodiment shown in Figure 4. Shunt stub 52 is spaced above the top layer of metal 44 by a distance $H3$, and from the bottom of the folds of the antenna by a distance $H2$.

As discussed above with regard to Figure 4, the use of a wiggle antenna reduces the size of the antenna, while still providing good return loss performance. Figure 5 shows a graph of return loss versus frequency for four different thicknesses of substrates. In this graph, the substrates were printed circuit boards, but no limitation of the use of PCBs as the substrate is intended or implied.

On the graph, curve 60 is the performance specification for return loss. Curve 62 is the return loss performance for a wiggle antenna on a substrate thickness of 15 mils. It must be noted that the thickness of the substrate is the separation between the top layer metal and the bottom layer metal. Curve 64 is for a substrate that is 32 mils thick. Curve 66 is for a substrate that is 47 mils thick and curve 68 is for a substrate that is 63 mils thick. As can be seen by these results, the return loss is more than satisfactory for a wiggle antenna.

The wiggle antenna manufacture is not much more complicated than the manufacture of an inverted F antenna or similar construction, such as a question mark antenna. The process will be discussed relative to the bottom layer metal and the top layer metal shown in Figures 3 and 4.

In Figure 6a, bottom layer metal 40 is shown with the notch 42 in the upper left hand corner. As mentioned previously, the notch may be located at any position as desired by the system designer and for ease of manufacturing. In Figure 6a, the contact pad 54 is provided, adjacent the notch 42.

5 When top metal layer 44 is formed or otherwise provided, it results in the structure shown in Figure 6b. In one embodiment, where the antenna is formed out of the top layer metal, the top layer of metal may cover all the bottom layer of metal from this view. As discussed with regard to Figures 3 and 4, the dimensions of the folds of the antenna may be uniform. This allows the metal to be patterned and etched with fewer steps.

10 For example, assume a process where the metal is patterned with a UV-cured mask. The photoresist or other masking material is formed on the top layer of the metal. Using reticles to form the appropriate patterns, the photoresist is cured in a pattern such as the one shown in Figure 6c. The uniformity of the structure dimensions allows fewer reticles to be used and easier step-and-repeat processes to form the folds of the antenna.

15 In Figure 6d, the metal that is exposed is etched and the mask cleaned away, leaving the structures shown in Figure 3. The antenna 48 is connected to the conductor pad 54, and the vertical stub 52 is connected to the bottom layer metal 40. The process for the vertical stub antenna would be very similar. As mentioned above, the discussion of the antenna may refer to a radiating portion and a shunt stub as though they were separate structures.

20 However, in reality, these structures may be formed out of the same layer of metal at the same time.

 In this embodiment, the antenna was formed in the top layer of metal and the bottom layer of metal is used for the ground plane. However, the reverse could also be implemented. The basic process would be to form a layer of metal on a substrate and then pattern and etch
25 the metal to form the antenna with multiple folds. The metal layer from which the antenna is

formed could be the top layer or the bottom layer.

For example, the metal layer formed on the substrate could be the bottom metal layer formed directly on the substrate. Alternatively, the metal layer could be the top metal layer formed on the substrate overlying other layers, including the bottom metal layer. It seems to
5 result in a simpler manufacturing flow to use the top layer for the antenna and the bottom layer for the ground plane, but the process may be adjusted as necessary by the system designer.

The wiggle antenna has several advantages. The smaller size allows the overall unit to be smaller, as is desirable in wireless devices. The use of the extended ground plane on the
10 front (top layer) or back (bottom layer) of the substrate provides improved return loss performance. Similarly, the extended ground plane allows better bandwidth control. The position and size of the shunt stub can be manipulated to allow for a particular resonant behavior.

It should be appreciated that reference throughout this specification to "one
15 embodiment" or "an embodiment" means that a particular feature, structure or characteristic described in connection with the embodiment is included in at least one embodiment of the present invention. Therefore, it is emphasized and should be appreciated that two or more references to "an embodiment" or "one embodiment" or "an alternative embodiment" in various portions of this specification are not necessarily all referring to the same embodiment.
20 Furthermore, the particular features, structures or characteristics may be combined as suitable in one or more embodiments of the invention.

Similarly, it should be appreciated that in the foregoing description of exemplary
embodiments of the invention, various features of the invention are sometimes grouped together in a single embodiment, figure, or description thereof for the purpose of streamlining
25 the disclosure aiding in the understanding of one or more of the various inventive aspects.

This method of disclosure, however, is not to be interpreted as reflecting an intention that the claimed invention requires more features than are expressly recited in each claim. Rather, as the following claims reflect, inventive aspects lie in less than all features of a single foregoing disclosed embodiment.

WHAT IS CLAIMED IS:

1. A wireless device, comprising:
a module having a communications port; and
an antenna electrically coupled to the communications port, the antenna having
5 multiple folds.
2. The wireless device of claim 1, the module further comprising a Universal Serial Bus
module.
- 10 3. The wireless device of claim 1, the antenna further comprising a shunt stub.
4. The wireless device of claim 3, the shunt stub further comprising a vertical shunt stub.
5. The wireless device of claim 3, the shunt stub further comprising a horizontal shunt
15 stub.
6. The wireless device of claim 3, the shunt stub being connected to an extended ground
plane.
- 20 7. The wireless device of claim 1, the module and antenna being mounted on a printed
circuit board.
8. An antenna, comprising:
a shunt stub; and
25 a radiating portion, the radiating portion having multiple folds.

9. The antenna of claim 8, the multiple folds further comprising folds each being of a substantially equal height.
10. The antenna of claim 8, the multiple folds further comprising folds each being of a substantially equal distance from the other folds.
11. The antenna of claim 8, the multiple folds further comprising folds each having a substantially equal width.
12. The antenna of claim 8, the shunt stub further comprising a vertical shunt stub.
13. The antenna of claim 8, the shunt stub further comprising a horizontal shunt stub.
14. The antenna of claim 8, the radiating portion and the shunt stub being formed out of a same layer of metal.
15. The antenna of claim 8, the shunt stub being connected to an extended ground plane.
16. The antenna of claim 15, the radiating portion and the extended ground plane being offset a predetermined distance to provide bandwidth control.
17. A method of manufacturing an antenna, comprising:
forming a metal layer on a substrate; and
patterning the metal layer to form an antenna having a shunt stub and multiple folds.

18. The method of claim 17, forming a metal layer further comprising forming a top layer of metal.

19. The method of claim 17, forming the metal layer on the substrate further comprising
5 forming the metal layer on the substrate having a bottom layer of metal.

20. The method of claim 17, forming the metal layer further comprising forming a bottom layer of metal.

Figure 1

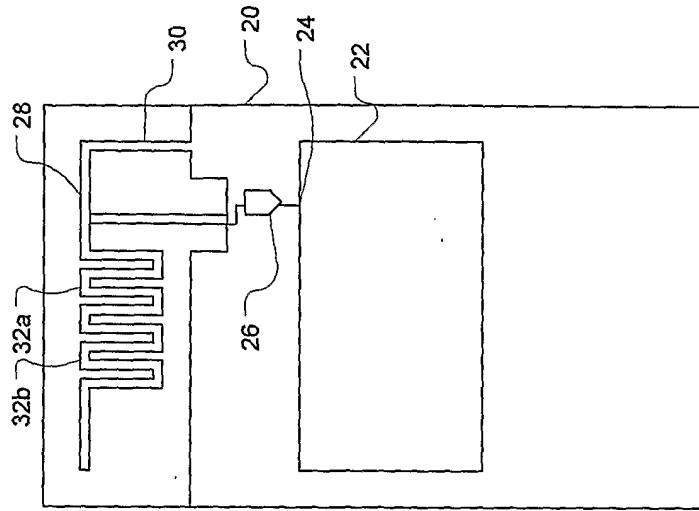
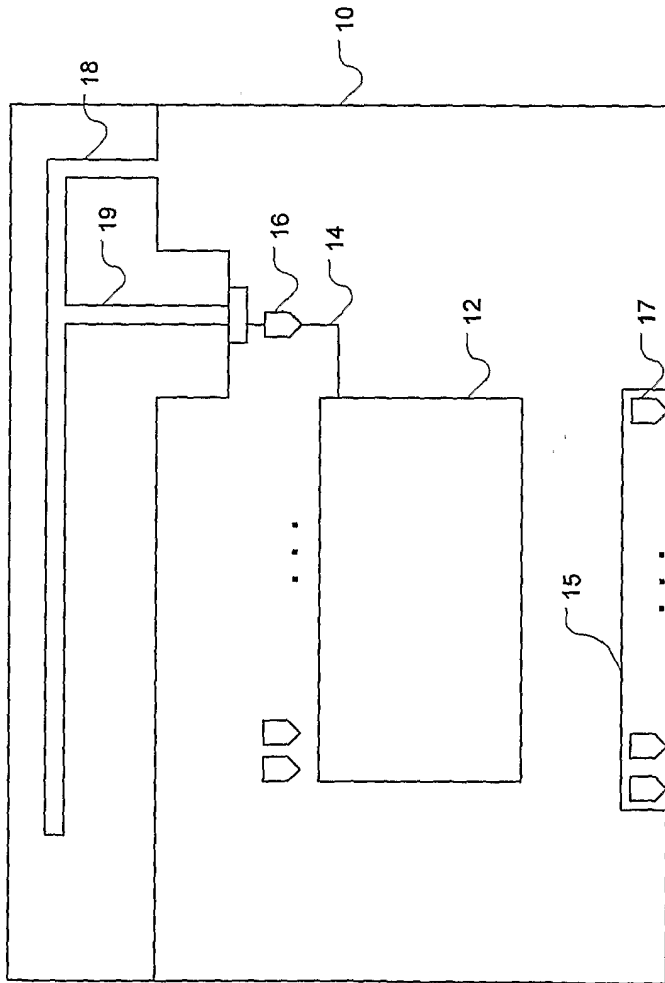


Figure 2

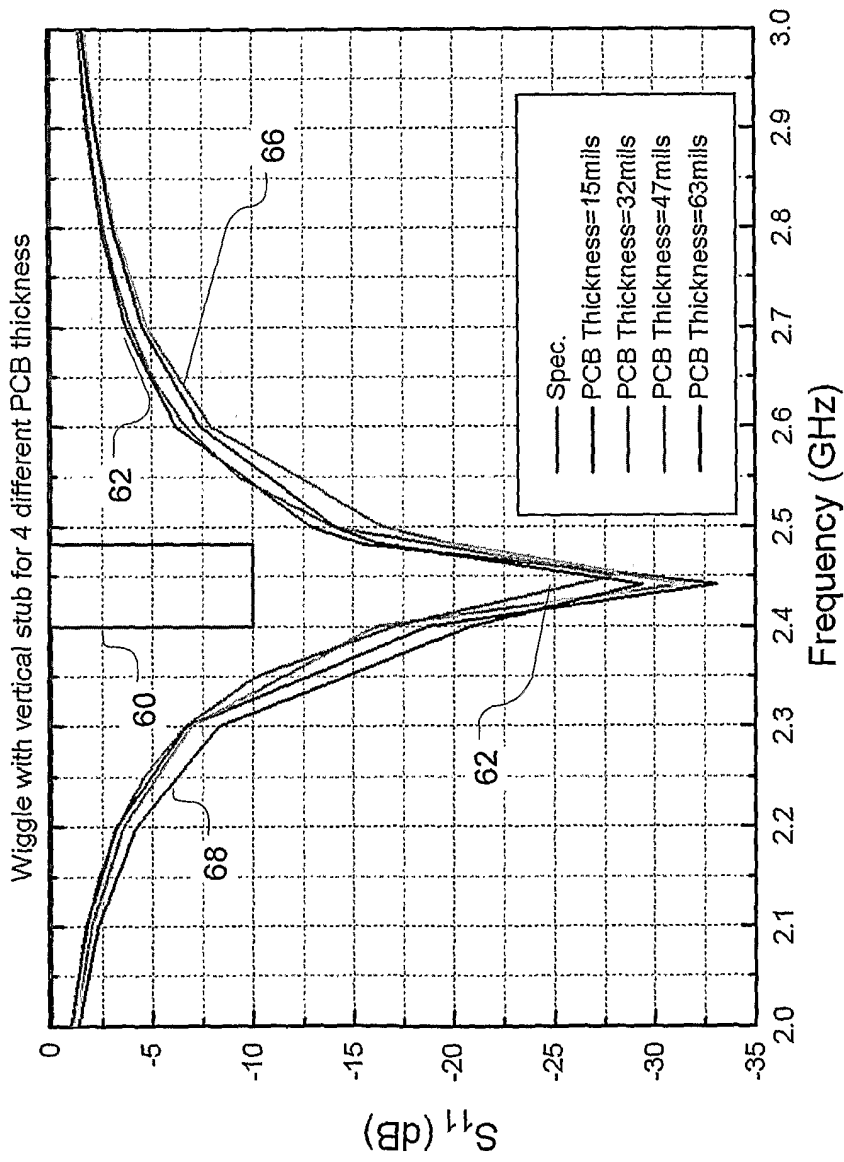


Figure 5

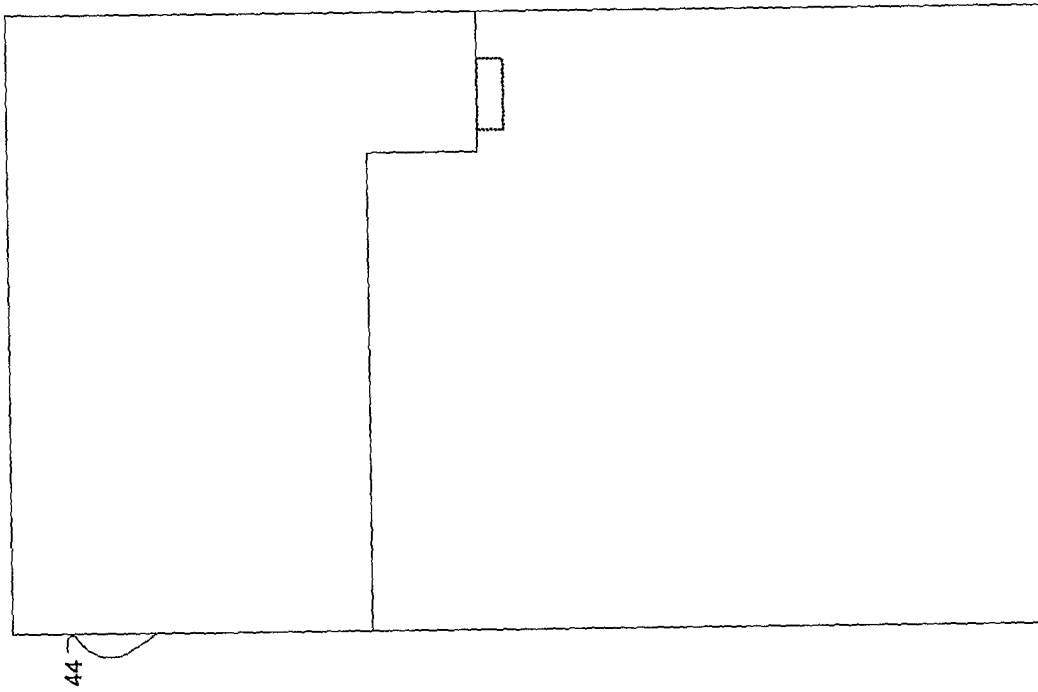


Figure 6a

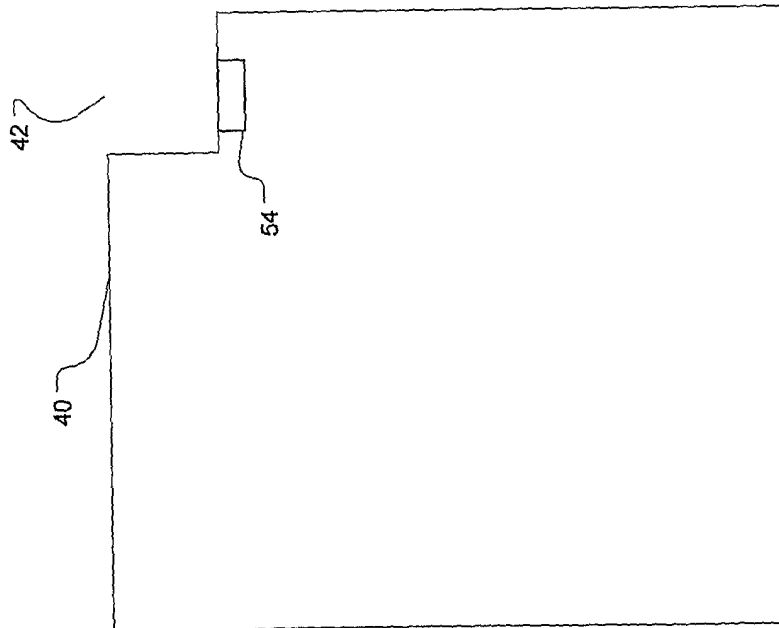


Figure 6b

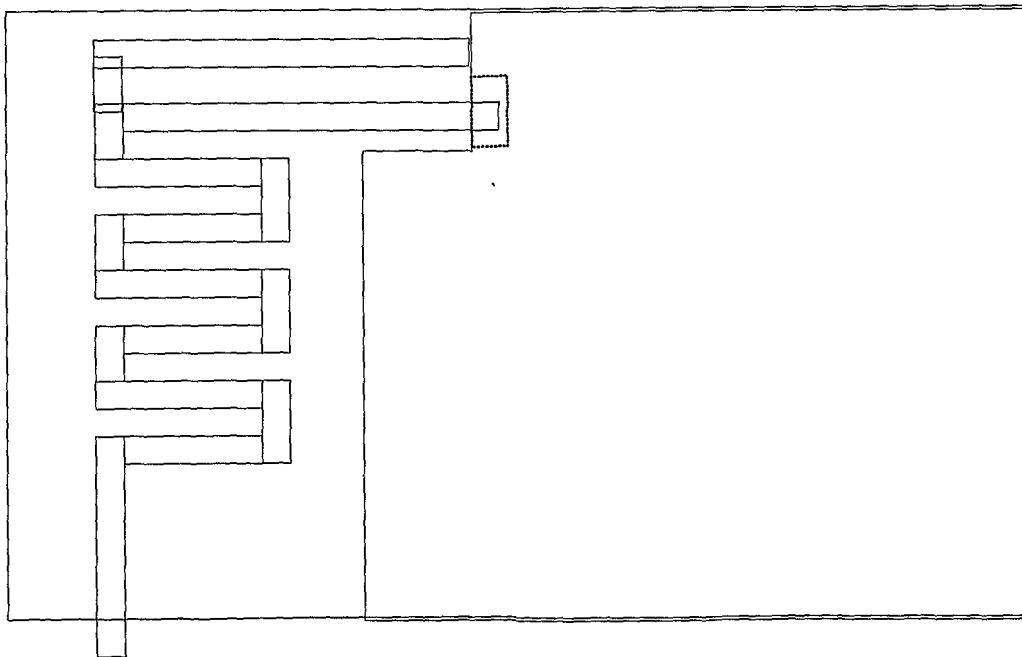


Figure 6c

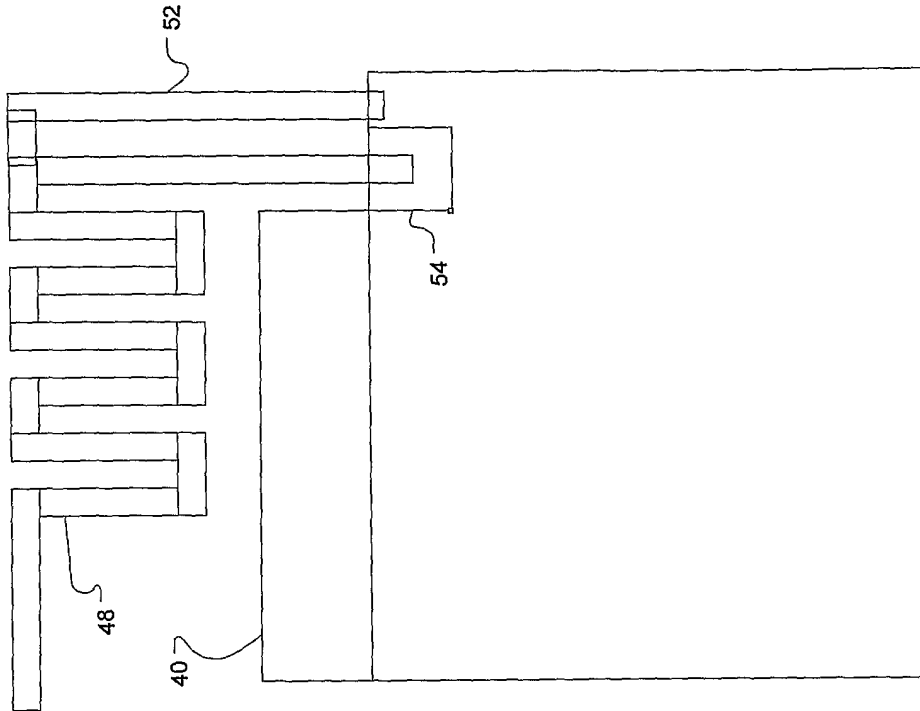


Figure 6d

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US06/03653

<p>A. CLASSIFICATION OF SUBJECT MATTER IPC: H01Q 1/24(2006.01)</p> <p>USPC: 343/702 According to International Patent Classification (IPC) or to both national classification and IPC</p>																				
<p>B. FIELDS SEARCHED</p> <p>Minimum documentation searched (classification system followed by classification symbols) U.S. : 343/702, 700, 803, 804</p> <p>Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched NONE</p> <p>Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) Please See Continuation Sheet</p>																				
<p>C. DOCUMENTS CONSIDERED TO BE RELEVANT</p> <table border="1"> <thead> <tr> <th>Category *</th> <th>Citation of document, with indication, where appropriate, of the relevant passages</th> <th>Relevant to claim No.</th> </tr> </thead> <tbody> <tr> <td>X --- Y</td> <td>US 2004/0075613 A1 (JARMUSZEWSKI et al) 22 April 2004 (22.04.2004), Fig. 4, column 2, lines [0020] to lines [0024]; column 1, lines [0015] to lines [0017] to lines [0018].</td> <td>1-4, 7-16 ----- 17-20</td> </tr> <tr> <td>Y</td> <td>US 6,424,299 B1 (CHA et al) 23 July 2002 (23.07.2002), Figs. 1-2, column 2, lines 8-67.</td> <td>17-20</td> </tr> <tr> <td>A</td> <td>US 5,668,560 A (EVANS et al) 16 September 1997 (16.09.1997), see entire document.</td> <td>1-20</td> </tr> <tr> <td>A</td> <td>US 6,518,937 B2 (FANG) 11 February 2003 (11.02.2003), see entire document.</td> <td>1-20</td> </tr> <tr> <td>A</td> <td>US 6,738,023 B2 (SCOTT et al) 18 May 2004 (18.05.2004), see entire document.</td> <td>1-20</td> </tr> </tbody> </table>			Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.	X --- Y	US 2004/0075613 A1 (JARMUSZEWSKI et al) 22 April 2004 (22.04.2004), Fig. 4, column 2, lines [0020] to lines [0024]; column 1, lines [0015] to lines [0017] to lines [0018].	1-4, 7-16 ----- 17-20	Y	US 6,424,299 B1 (CHA et al) 23 July 2002 (23.07.2002), Figs. 1-2, column 2, lines 8-67.	17-20	A	US 5,668,560 A (EVANS et al) 16 September 1997 (16.09.1997), see entire document.	1-20	A	US 6,518,937 B2 (FANG) 11 February 2003 (11.02.2003), see entire document.	1-20	A	US 6,738,023 B2 (SCOTT et al) 18 May 2004 (18.05.2004), see entire document.	1-20
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<p>* Special categories of cited documents:</p> <table border="0"> <tr> <td>"A" document defining the general state of the art which is not considered to be of particular relevance</td> <td>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</td> </tr> <tr> <td>"E" earlier application or patent published on or after the international filing date</td> <td>"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone</td> </tr> <tr> <td>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</td> <td>"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art</td> </tr> <tr> <td>"O" document referring to an oral disclosure, use, exhibition or other means</td> <td>"&" document member of the same patent family</td> </tr> <tr> <td>"P" document published prior to the international filing date but later than the priority date claimed</td> <td></td> </tr> </table>			"A" document defining the general state of the art which is not considered to be of particular relevance	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention	"E" earlier application or patent published on or after the international filing date	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone	"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art	"O" document referring to an oral disclosure, use, exhibition or other means	"&" document member of the same patent family	"P" document published prior to the international filing date but later than the priority date claimed									
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"P" document published prior to the international filing date but later than the priority date claimed																				
<p>Date of the actual completion of the international search 23 March 2006 (23.03.2006)</p>		<p>Date of mailing of the international search report 07 APR 2006</p>																		
<p>Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US Commissioner for Patents P.O. Box 1450 Alexandria, Virginia 22313-1450 Facsimile No. (571) 273-3201</p>		<p>Authorized officer Jose Dees <i>J. Dees</i> Telephone No. 571-272-1604</p>																		

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US06/03653

Continuation of B. FIELDS SEARCHED Item 3:

US-PGPUB; USPAT; USOCR; EPO; JPO; DERWENT; EAST

Search Terms: (wireless or F with antenna or wiggle wiht antenna); module with (USB or universal near\$2 serial near\$3 bus near\$2 module)