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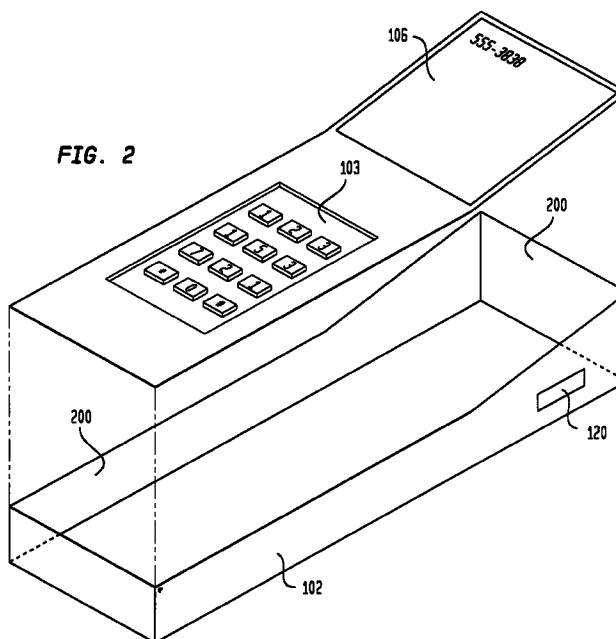
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(54) Antenna apparatus in wireless terminals

(57) A wireless terminal comprising a housing (102) that comprises an enclosed conductive element (200) that contains a radio has one or more openings (120) is used to provide both electromagnetic shielding and an integrated antenna. The openings (120) are excited to resonate, thereby forming a slot antenna for the radio. Multiple openings can be used to provide antenna diversity.



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Description

Field of the Invention

The present invention relates to telecommunications in general, and, more particularly, to antennas for wireless terminals.

Background of the Invention

A wireless terminal is a device that transmits and/or receives radio frequency signals. Examples of wireless terminals include televisions, radios, cellular telephones, pagers, personal digital assistants and satellites.

Many devices that formerly relied on wireline connections for transmitting and/or receiving signals are now wireless terminals. For example, devices such as telephones, scanners, data entry devices and point-of-sale terminals now use wireless techniques to transmit and/or receive signals representing information to/from a host system.

A point-of-sale terminal, for example, can transmit to a host system a signal indicating that a particular item is being sold. If the host system comprises a database that tracks inventory, the database can be updated to reflect the sale of the item. In addition, the host system can transmit a signal back to the wireless terminal that represents processed information (for example, the price of, and any tax on, the item). The wireless terminal can use that information to perform additional functions, such as printing a receipt for the purchase of the item. To enable a wireless terminal to be capable of transmitting and/or receiving signals, it needs an antenna.

A wireless terminal's antenna can be either mounted externally or integrated into the wireless terminal itself. Mounting an antenna externally has several disadvantages. For example, an externally mounted antenna (especially one that employs a telescoping structure) can poke the eyes of the wireless terminal's user or the eyes of someone near the user. In addition, an externally mounted antenna can mar the aesthetics of the wireless terminal. And furthermore, the mechanical provisions needed to externally mount an antenna increases the cost of the wireless terminal.

In comparison, an internal antenna is disadvantageous because of the need to extensively plan in advance the mechanical layout of the wireless terminal. For example, sufficient space must be reserved within the housing of the wireless terminal for the antenna. In addition, the design of the wireless terminal's electromagnetic shielding must consider the desired radiation pattern of the integrated antenna.

Summary of the Invention

Embodiments of the present invention are capable of providing an antenna for a wireless terminal without

many of the costs and restrictions associated with antennas in the prior art. In particular, in accordance with an embodiment of the present invention it is recognized that a conductive element in a wireless terminal can be used both as means of providing electrical protection to the electrical components within the wireless terminal and as component of an antenna for the wireless terminal.

One embodiment of the present invention comprises: a radio; a housing; a conductive element in said housing having an opening, wherein said conductive element provides electrical protection to said radio, and a transmission line for coupling signals between said radio and said opening.

Brief Description of the Drawings

FIG. 1 depicts an isometric drawing of the exterior of wireless terminal 100, with which embodiments of the present invention can be practiced.

FIG. 2 depicts an exploded isometric drawing of wireless terminal 100.

FIG. 3 depicts a side view drawing of the interior of side element 115.

FIG. 4 depicts an exploded isometric drawing of wireless terminal 400, which comprises a bent-slot antenna.

FIG. 5 depicts an exploded isometric drawing of wireless terminal 500, which comprises two bent-slot antennas.

FIG. 6 depicts an exploded isometric drawing of wireless terminal 600, which comprises a bent-slot antenna that is partially comprised of a conductive partition within housing 602.

Detailed Description

FIG. 1 depicts an isometric drawing of the exterior of wireless terminal 100, with which embodiments of the present invention can be practiced. Wireless terminal 100 advantageously comprises: housing 102, keypad 103, display area 106, a radio within housing 102 (not shown) and other associated electronics (not shown). Keypad 103 can be used to enter information into wireless terminal 100 and display area 106 can be used to display information. It will be clear to those skilled in the art that wireless terminal 100 can comprise other input and output elements, such as, for example, a laser scanner, a microphone, a speaker, etc. Housing 102 advantageously comprises side element 115, which itself comprises opening 120. For the purposes of this specification, a radio is defined as a device that prepares electromagnetic signals for transmission via an antenna and/or processes signals that have been received via an antenna. It will be clear to those skilled in the art that as used in this specification the term radio includes devices that are capable of processing voice, data, video and other multimedia signals.

FIG. 2 depicts an exploded isometric drawing of wireless terminal 100 with the portion of housing 102 containing keypad 103 and display 106 elevated above the remainder. For pedagogical reasons, the radio and other associated electronics inside wireless terminal 100 are not shown so that a larger portion of the interior wall of housing 102 can be seen. The interior wall of housing 102 advantageously comprises conductive element 200. Conductive element 200 advantageously comprises a conductive coating that is applied to the interior walls of housing 102. For example, conductive element 200 can comprise a coating or spray of a conducting coating or paint as manufactured by W.L. Gore & Assoc. U.K. Ltd. or Chemitron Dev. Shinto Paint or as specified in electrical compliance handbooks. In accordance with the illustrative embodiment, conductive element 200 advantageously provides both: (1) electrical protection (e.g., electromagnetic compatibility, interference shielding and/or electrostatic discharge protection), and (2) a component of an antenna for wireless terminal 100.

FIG. 3 depicts a side view drawing of the interior of side element 115, all of which is coated with conductive element 200 except for a portion, opening 210, that corresponds with opening 120 in side element 115 (as shown in FIG. 1). To enable an antenna that will radiate effectively, opening 120 advantageously coincides with, and is at least as large as, opening 210. Opening 120 and opening 210 are advantageously both in the shape of a rectangle of width W and length L . Although opening 120 can be left "empty" or filled with ambient air, opening 120 can be filled with a dielectric material, such as ABS plastic. Dielectric materials can be used to keep outside contaminants from getting into housing 102 and can be used to make engineering trade-offs between the length required for the slot versus antenna efficiency in the design of the wireless terminal.

Opening 210 in conductive element 200 is excited so as to resonate at the frequency at which the wireless terminal is to operate, thereby forming an antenna. When the shape of opening 210 is a rectangle, the antenna is referred to as a slot antenna. The characteristics of slot antennas (including their structure and radiation patterns) are well known to those skilled in the art and are described in the following references, which are incorporated herein by reference: (1) Kai Fong Lee, Principles of Antenna Theory, pages 290-293, John Wiley & Sons, Chichester, 1984, ISBN 0471901679; and (2) Reference Data for Engineers: Radio, Electronics, Computer and Communications, chapter 32, 7th ed., Howard W. Sams & Co., Inc., Indianapolis, Indiana, 1985. As is well known to those skilled in the art, opening 210 can be excited either by conductive or inductive coupling. An example of conductive coupling includes a transmission line (e.g., a coaxial cable), which carries signals to be transmitted and received, that is mechanically attached (e.g., by soldering) to conductive element 200 near opening 210. In contrast, inductive coupling

can be achieved by placing a short, open radio frequency (RF) line, which acts as a short monopole antenna, in proximity to opening 210 so as to induce RF coupling.

As is well known to those skilled in the art, to improve the efficacy of the antenna the surface area of conductive element 200 is advantageously large with respect to the area of opening 210. When the wavelength at which the wireless terminal operates to transmit and/or receive signals is λ , the length L of opening 210 is advantageously between approximately 0.25λ and 0.5λ and the width W of opening 210 is advantageously 0.10λ or less. The surface area of conductive element 200 is advantageously λ^2 or larger. For example, if the frequency of operation of wireless terminal 100 is 2.4 GHz, then λ is approximately 12 centimeters, L is advantageously between approximately 3 to 6 centimeters, W is advantageously 1.2 centimeters or less and the total surface area of conductive element 200 is advantageously 144 square centimeters or greater.

FIG. 4 depicts an isometric drawing of an alternative embodiment of the present invention in which the openings in the housing and the conductive element are instead "bent" or "wrapped" around a corner of housing 402 of wireless terminal 400. This provides a more omnidirectional radiation pattern than does embodiments of the present invention that have planar openings. As shown in FIG. 4, when the opening is a bent rectangle, this embodiment is known as a "bent-slot" antenna. From the above description, it will be clear to those skilled in the art how to make and use embodiments of present invention using bent-slot antennas. The reference A. Kumoyama et al., "UHF Bent-Slot Antenna System for Portable Equipment - I," IEEE Trans. On Vehicular Tech., vol. VT-36, No. 2, pp. 78-85, Can 1987, provides background on bent-slot antennas and is incorporated by reference.

FIG. 5 depicts an isometric drawing of yet another embodiment of the present invention that comprises two bent-slot antennas in adjacent corners so as to provide antenna diversity. Such antenna diversity can be used to increase link reliability for a given operating range or to increase the transmission range for a given level of link reliability. From the above description, it will be clear to those skilled in the art how to make and use embodiments of present invention that use two or more bent-slot antennas to achieve antenna diversity.

FIG. 6 depicts an exploded isometric drawing of another embodiment of the present invention. Again, for pedagogical reasons, the radio and most of the associated components of wireless terminal 600 are not shown so that the placement of the certain components are more clearly visible.

According to this embodiment, the inside of housing 620 is divided into two compartments by a conductive partition, such as printed circuit board 630: the first compartment includes opening 655, and the second compartment does not. The conductive partition can

comprise a sheet of metal or other conductor, or a printed circuit board that comprises a conductive plane. The interior wall of housing 620 within the first compartment advantageously comprises conductive element 611. In contrast, the interior walls of housing 620 within the second compartment do not comprise conductive element 611.

Advantageously, opening 655 in one wall of housing 620 forms a portion of a bent-slot antenna. Another portion of the bent-slot antenna is formed by opening 650 in printed circuit board 630. Printed circuit board 630 advantageously comprises a conductive element, such as a layer of metal, and is positioned so that the conductive element of printed circuit board 630 is electrically and mechanically connected to conductive element 611 within the first compartment, thereby forming a larger conducting element. For example, such an electrical and mechanical connection can be made by sliding printed circuit board 630 into recessed grooves of housing 620 (not shown).

Advantageously, the size of printed circuit board 630 is 0.25λ or larger by 0.25λ or larger. As described above, printed circuit board 630 comprises opening 650. The vertices of opening 650 and opening 655 advantageously abut, thereby forming a single, continuous larger opening, suitable for excitation as a bent-slot antenna with the length and width of the slot chosen as explained above.

An advantage of this embodiment is that it is typically easier, mechanically, to connect a transmission line (*i.e.*, a path for carrying signals from the radio to excite the antenna to resonance and vice versa) to printed circuit board 630 than to a conductive coating. For example, a stripline on printed circuit board 630 can be used as a conductive coupling to opening 650 and opening 655. As described above, there is advantageously no conductive coating between openings 650 and 655 and the exterior of wireless terminal 660 so that signals can radiate.

This embodiment of the invention is particularly advantageous for use with wireless terminals such as laser scan bar code readers and infrared low speed data link couplings. In particular, in such applications, printed circuit board 630 is typically positioned behind window 680 in housing 620 through which the laser scans or through which wireless terminal 660 establishes an infrared communications link. In such applications, window 680 forms a portion of the wireless terminal which is not shielded and through which signals can propagate from the bent-slot antenna. Those skilled in the art will recognize that other materials (*e.g.*, pieces of gold or copper), suitable for conducting electrical signals, can be used in place of printed circuit board 630.

The apparatus disclosed herein has been described without reference to specific hardware. Instead, the method has been described in such a way that those skilled in the art can readily adapt such hardware

as can be preferable or available. While the above teaching of the present invention has been in terms of an integrated antenna for a hand-held wireless terminal, those skilled in the art will recognize the applicability of these teachings to other contexts, as for example in satellite communications.

In particular, those skilled in the art will recognize that other embodiments of the present invention can be constructed without departing from the spirit and scope of the invention. For example, the opening need not be in the shape of a slot, *e.g.*, opening 210 can be a zigzag pattern or in a "V" shaped pattern or can bend around more than one edge of the wireless terminal. As was shown in the embodiments discussed above, the length of the opening is advantageously chosen in relation to the size of the conducting element and the operating frequency of the wireless terminal.

Further, those skilled in the art will recognize that techniques used in general antenna design to excite resonance at particular frequencies on small sized antennas (less than 0.25λ in length) can be used. Embodiments of the present invention can also incorporate multiple antennas thereby providing antenna diversity.

Claims

1. A wireless terminal comprising:

a radio;
a housing containing said radio, CHARACTERIZED BY
a conductive element in said housing having an opening, wherein said conductive element provides electrical protection to said radio; and
a transmission line for carrying signals between said radio and said opening.

2. The wireless terminal of claim 1 wherein said opening is rectangular in shape and has a width W and a length L .

3. The wireless terminal of claim 2 wherein said opening has a length L of between 0.25λ and 0.5λ , where λ is the wavelength at which the wireless terminal is designed to operate.

4. The wireless terminal of claim 1 wherein said opening is filled with air.

5. The wireless terminal of claim 1 wherein said opening is filled with a dielectric material.

6. A wireless terminal comprising:

a housing, CHARACTERIZED BY
an enclosed conductive element in said housing having a first opening and a second opening

ing, wherein said conductive element encloses a radio and provides electrical protection to said radio;

a first transmission line in said enclosed conductive element for carrying signals between said radio and said first opening; and
a second transmission line in said enclosed conductive element for carrying signals between said radio and said second opening.

7. The wireless terminal of claim 6 wherein said first opening and said second opening are excited as bent-slot antennas.

8. The wireless terminal of claim 6 wherein said first opening and said second opening provide antenna diversity for said wireless terminal.

9. The wireless terminal of claim 6 wherein said first opening and said second opening are rectangular in shape and have a width W and a length L .

10. The wireless terminal of claim 9 wherein said opening has a length L of between 0.25λ and 0.5λ , where λ is the wavelength at which the wireless terminal is designed to operate.

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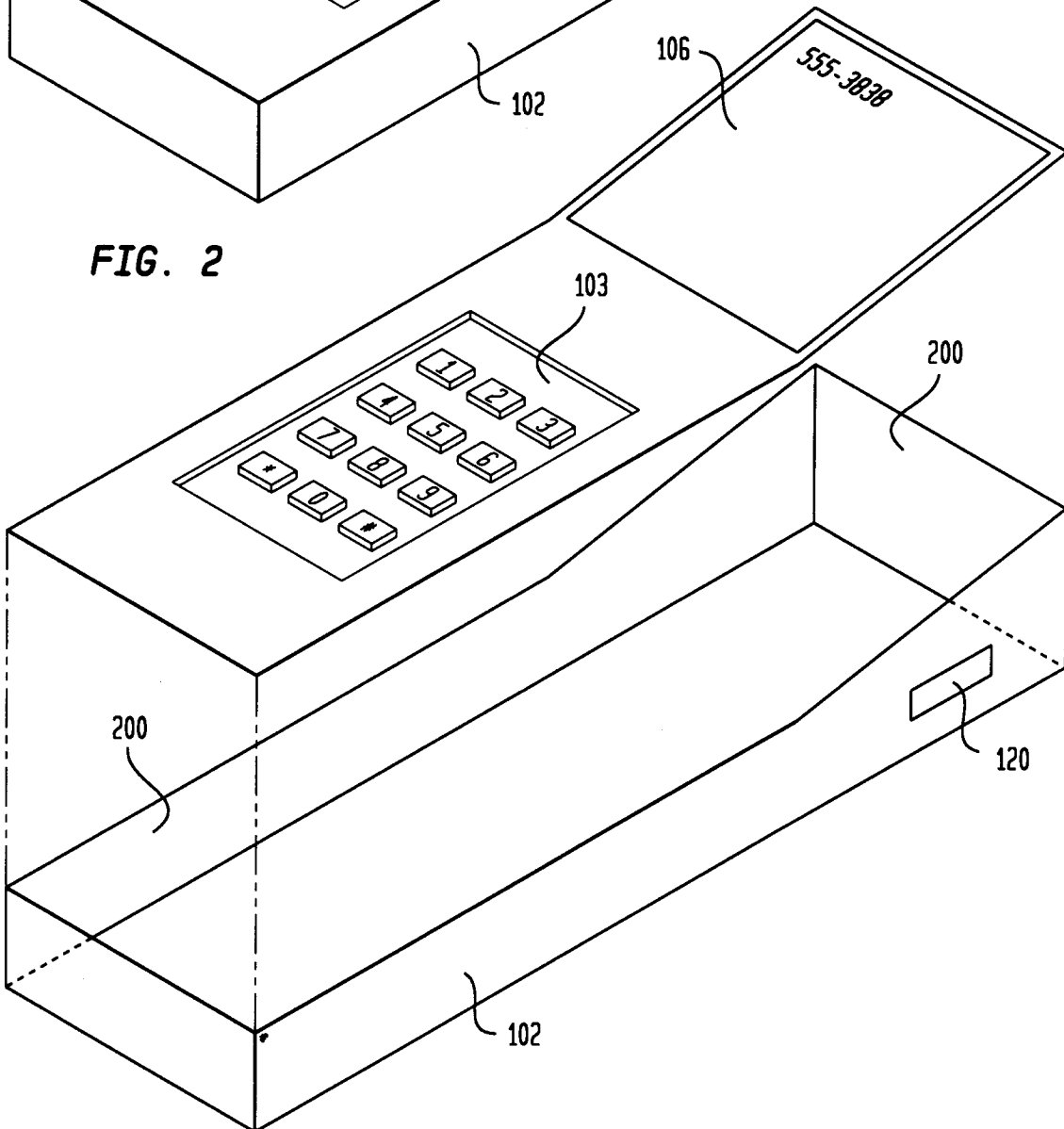
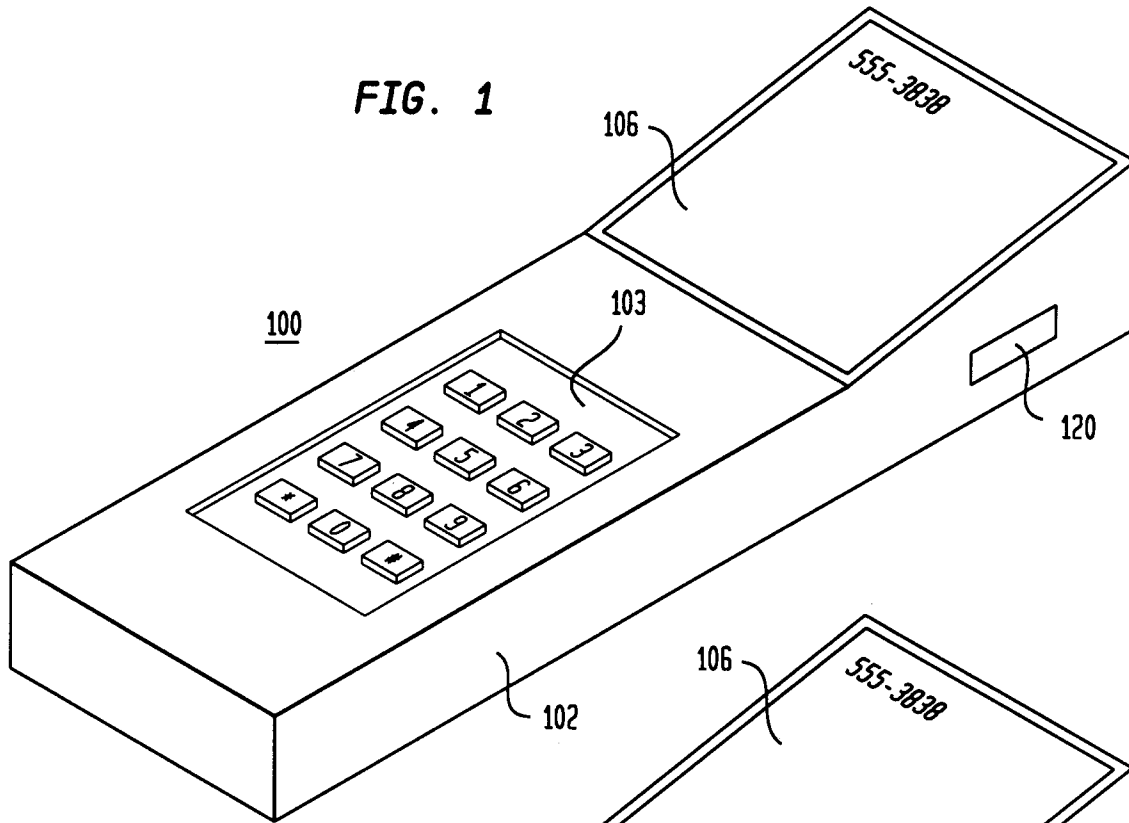


FIG. 3

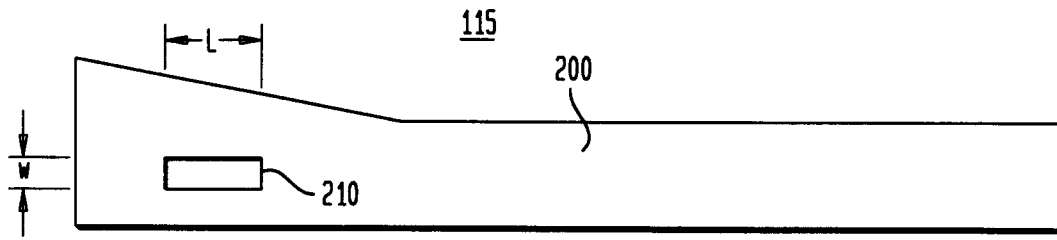


FIG. 4

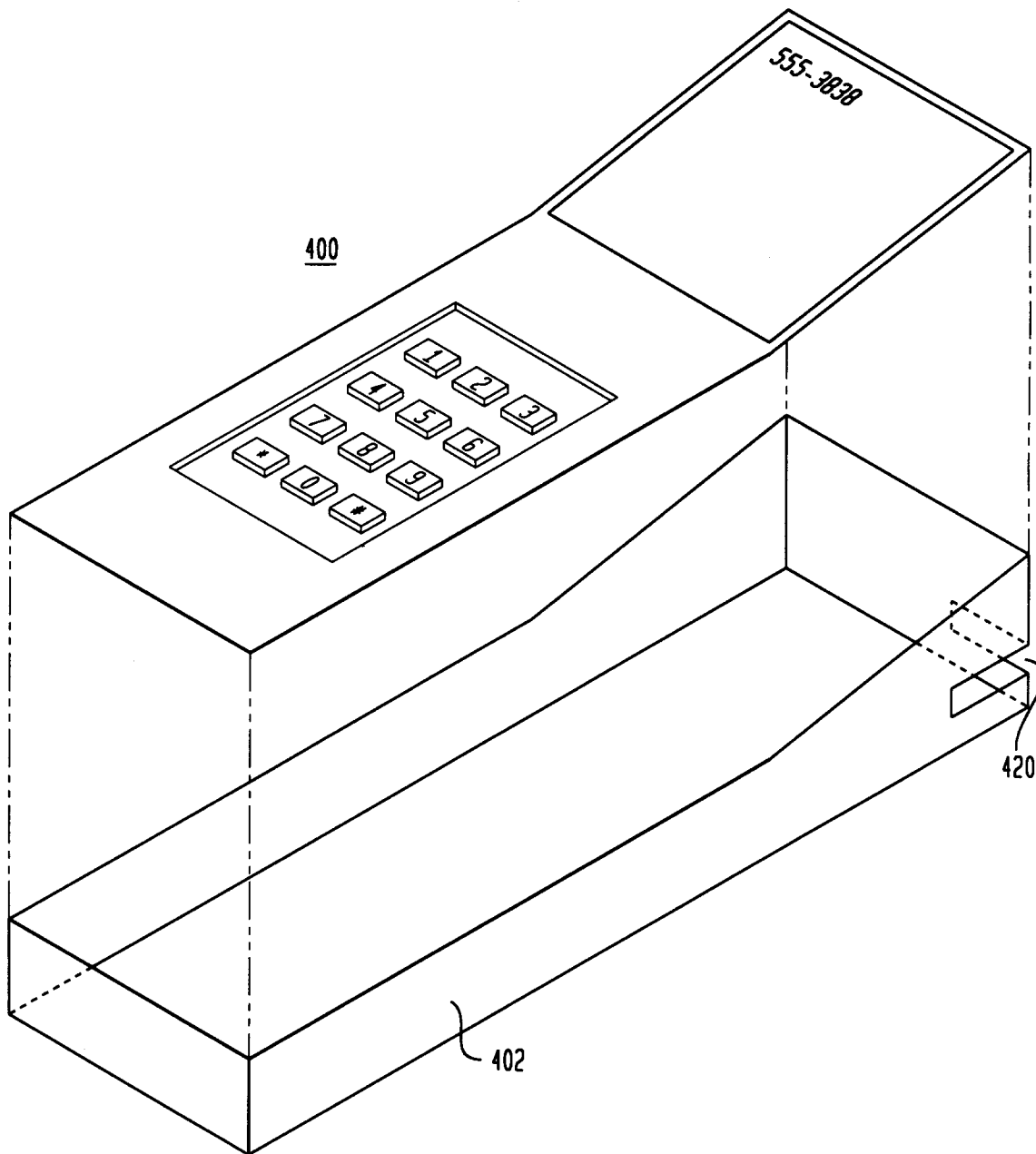


FIG. 5

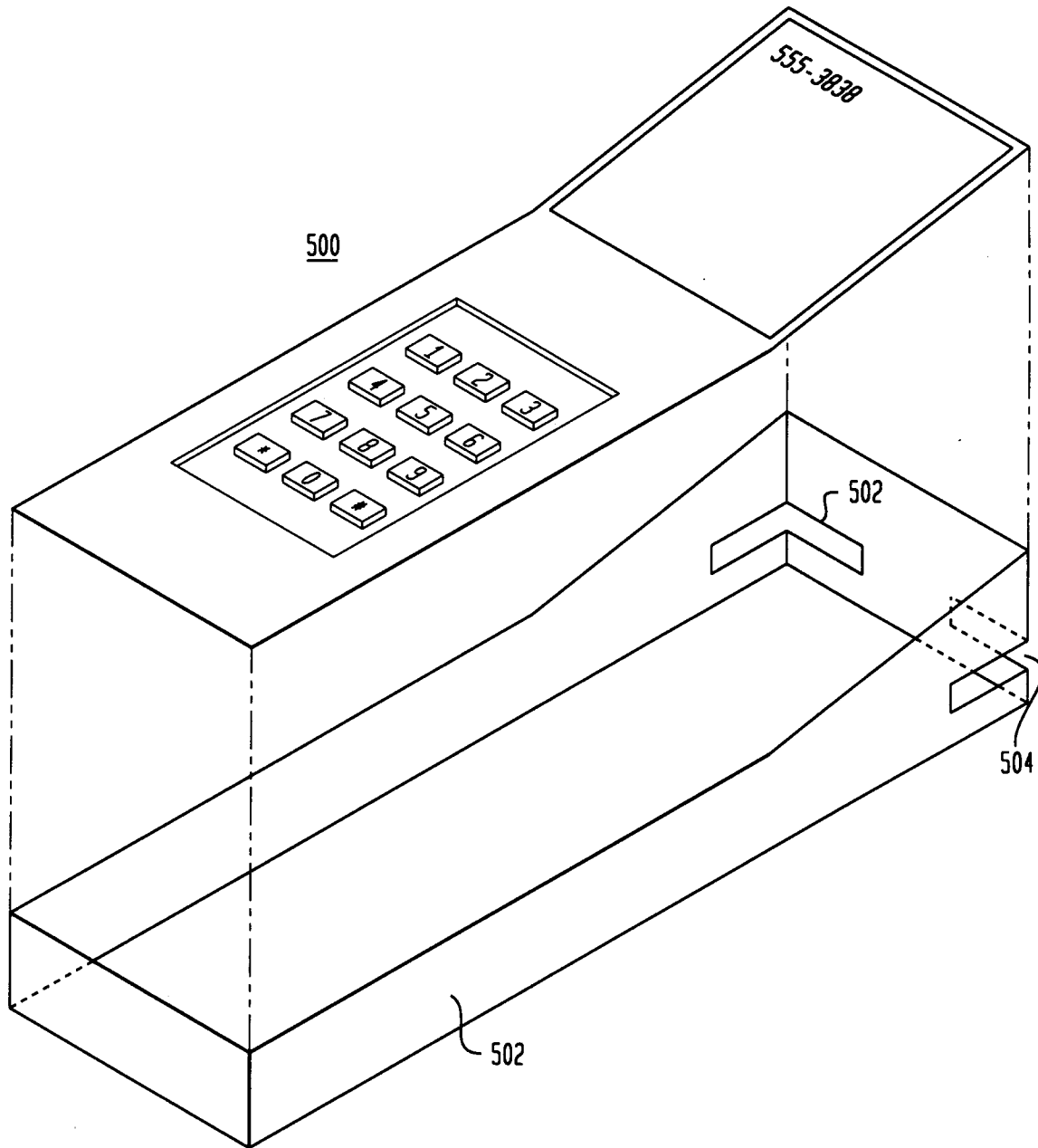


FIG. 6

