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(54) **RADAR-BASED GESTURE SENSING AND DATA TRANSMISSION**

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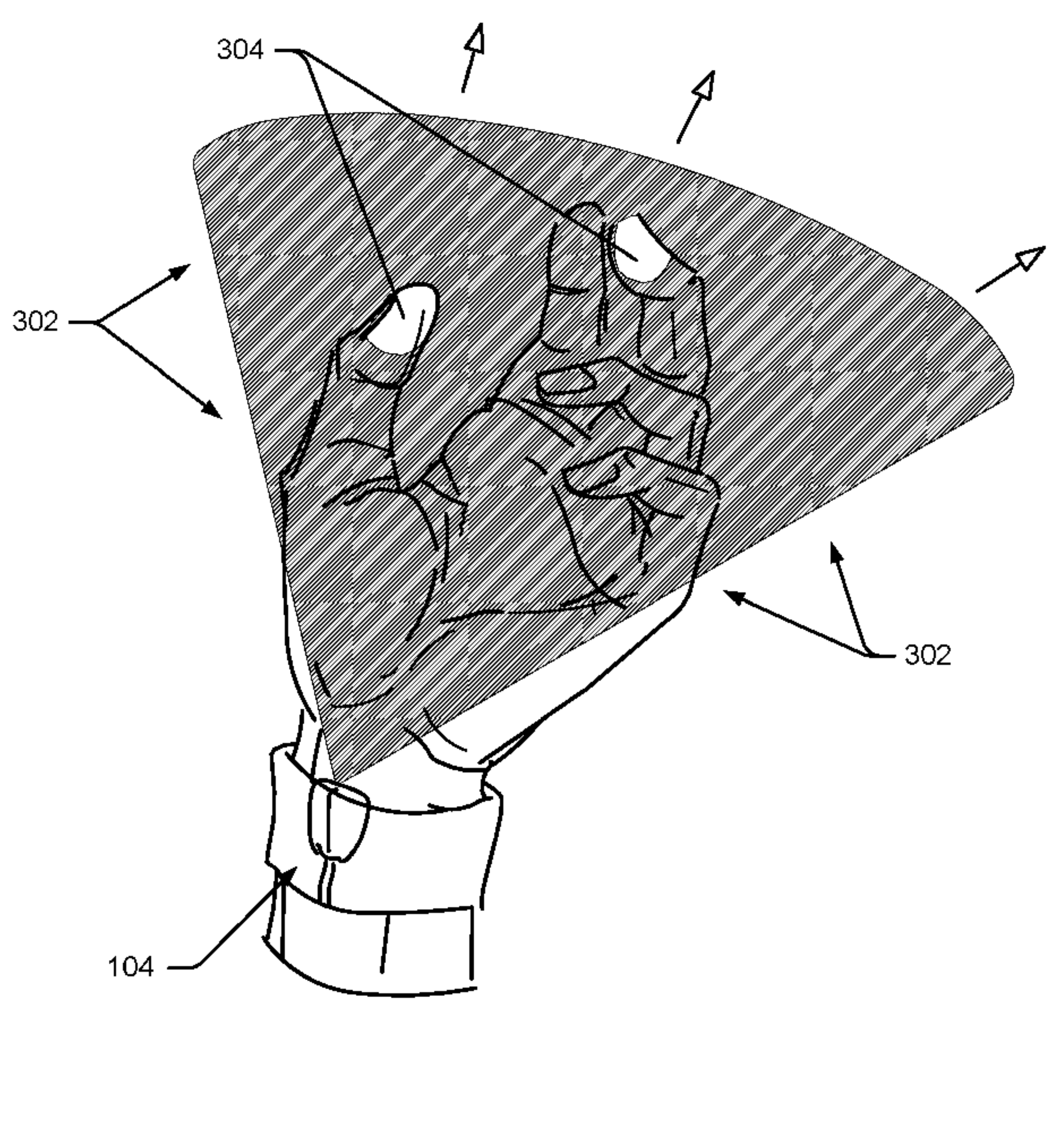
(57) **ABSTRACT**

This document describes techniques and devices for radar-based gesture sensing and data transmission. The techniques enable, through a radar system, seamless and intuitive control of, and data transmission between, computing devices. This radar system can both transmit data and sense gestures, thereby performing with a single system, control of many devices and data transmission with those devices. Not only can this provide control of many devices, from refrigerators to laptops, this radar system also allows high-bandwidth data transmission between devices.

20 Claims, 8 Drawing Sheets



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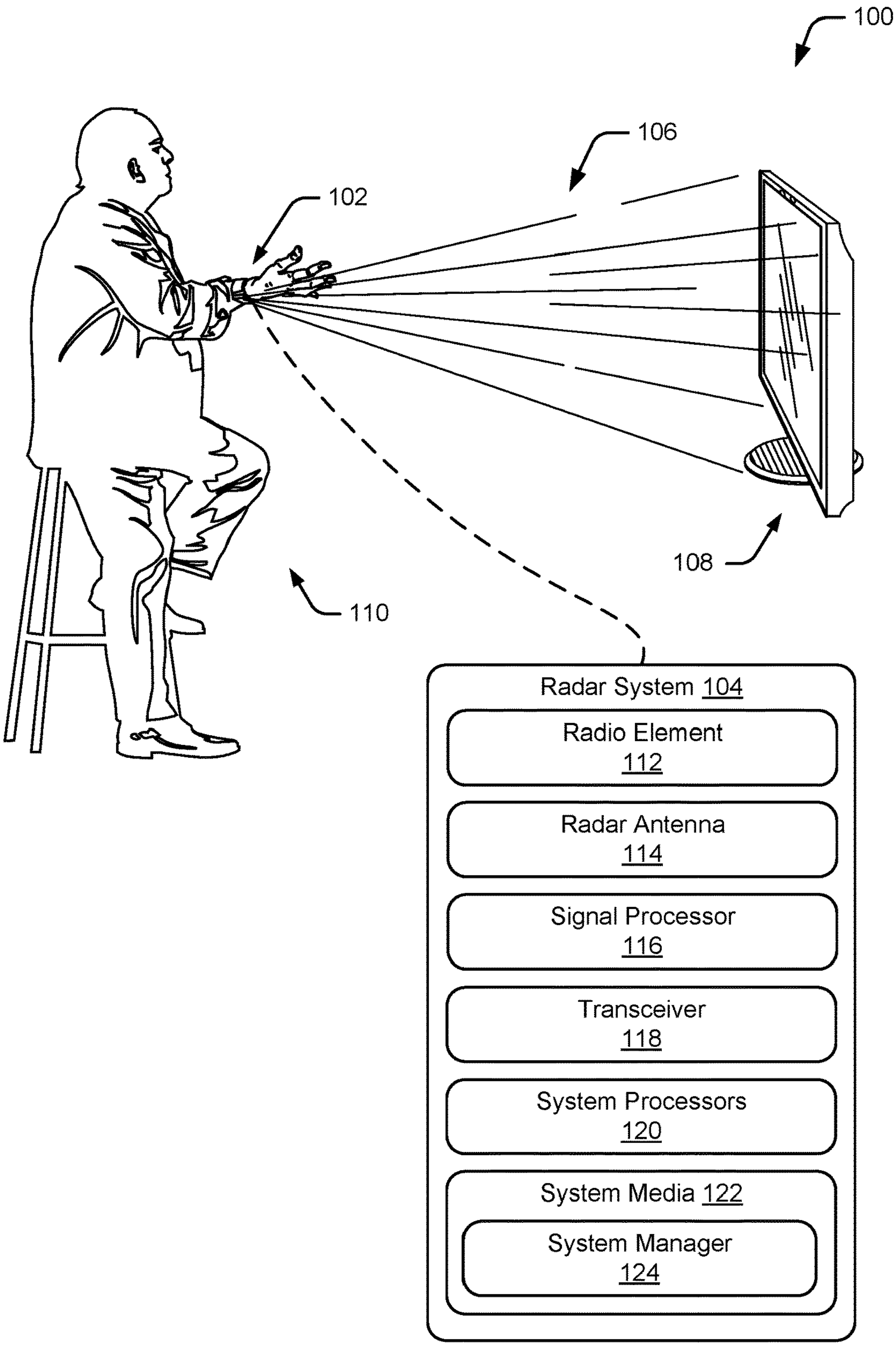

100
106
102
108
110
Radar System 104
Radio Element 112
Radar Antenna 114
Signal Processor 116
Transceiver 118
System Processors 120
System Media 122
System Manager 124

Fig. 1

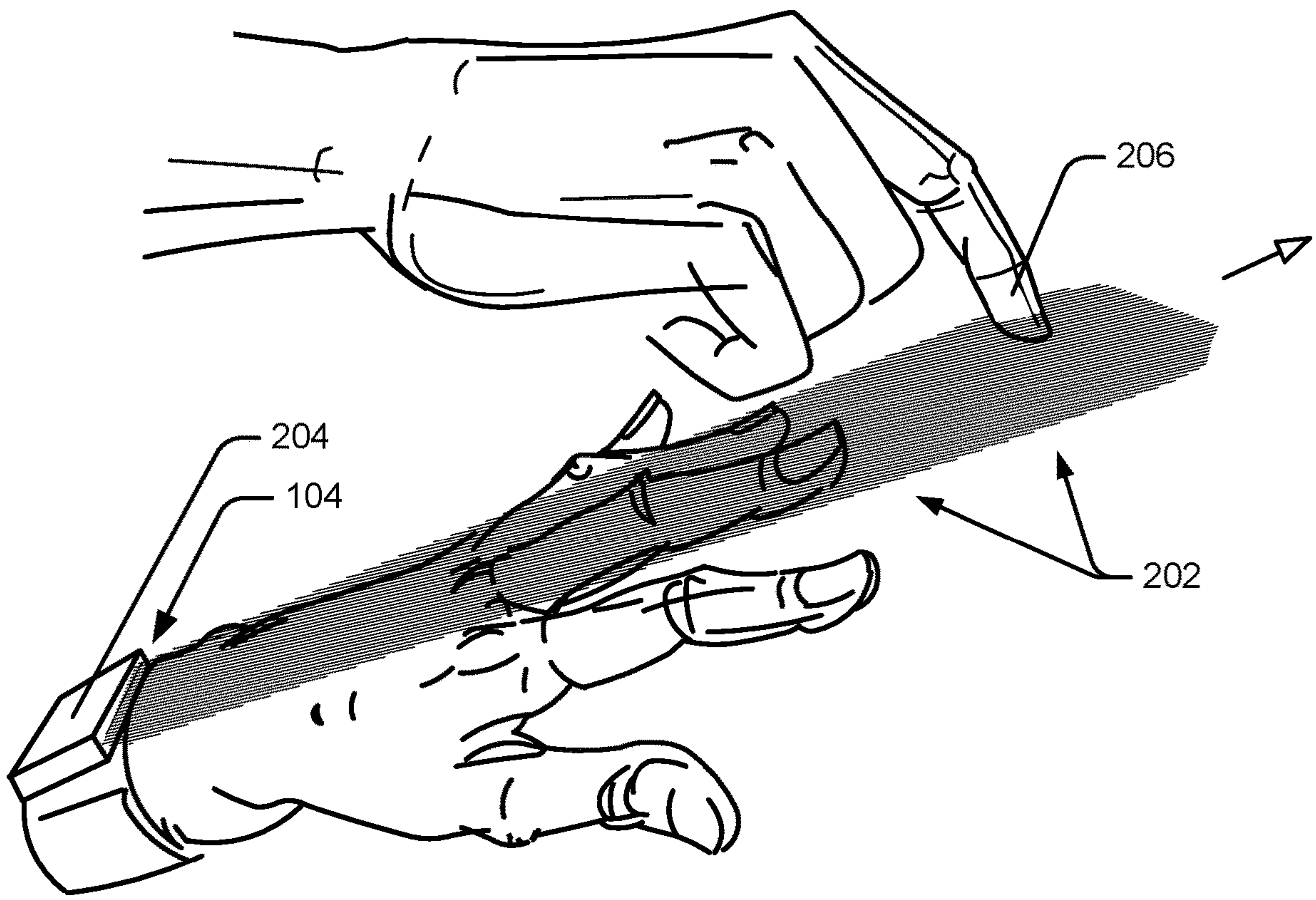


Fig. 2

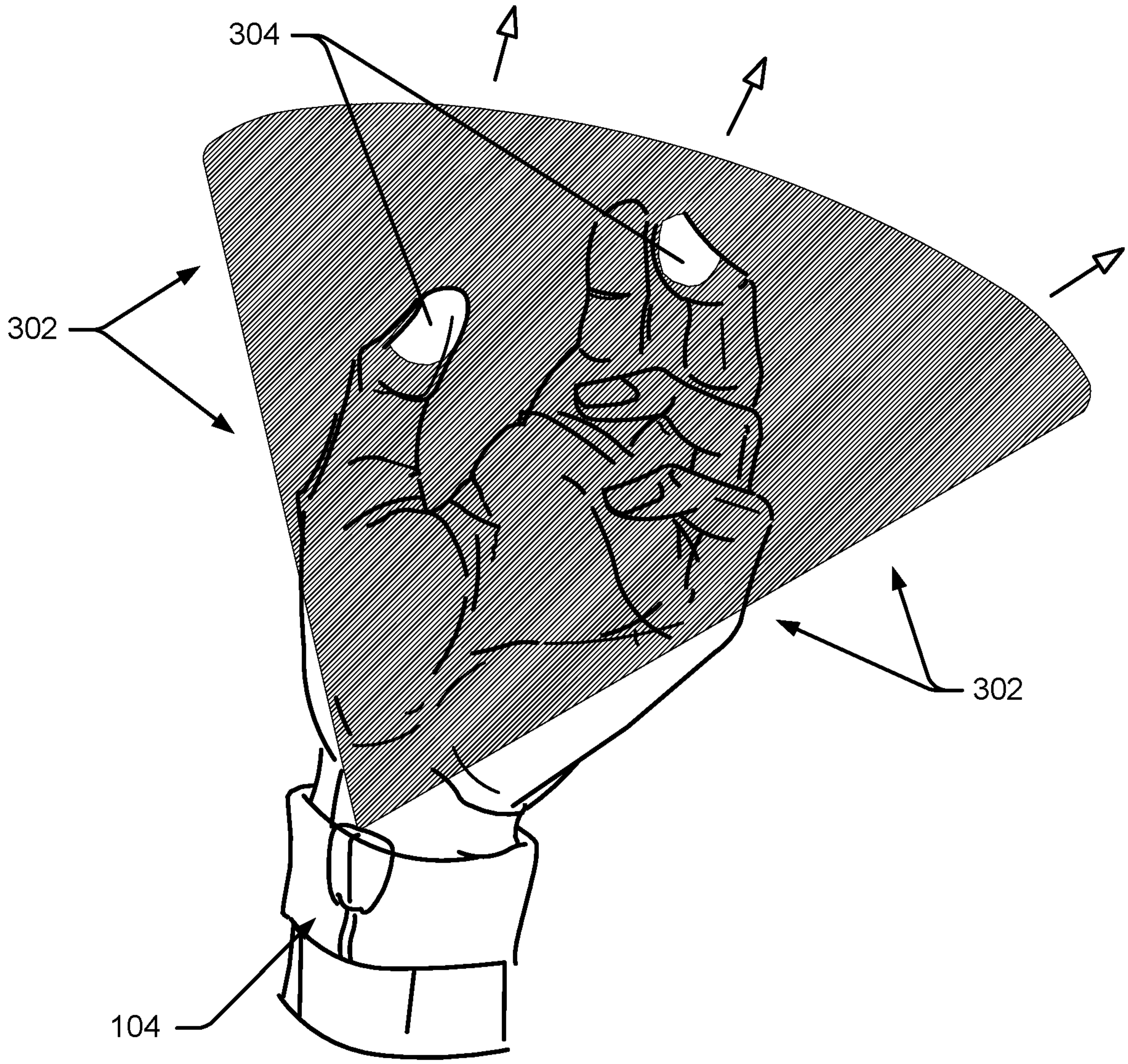
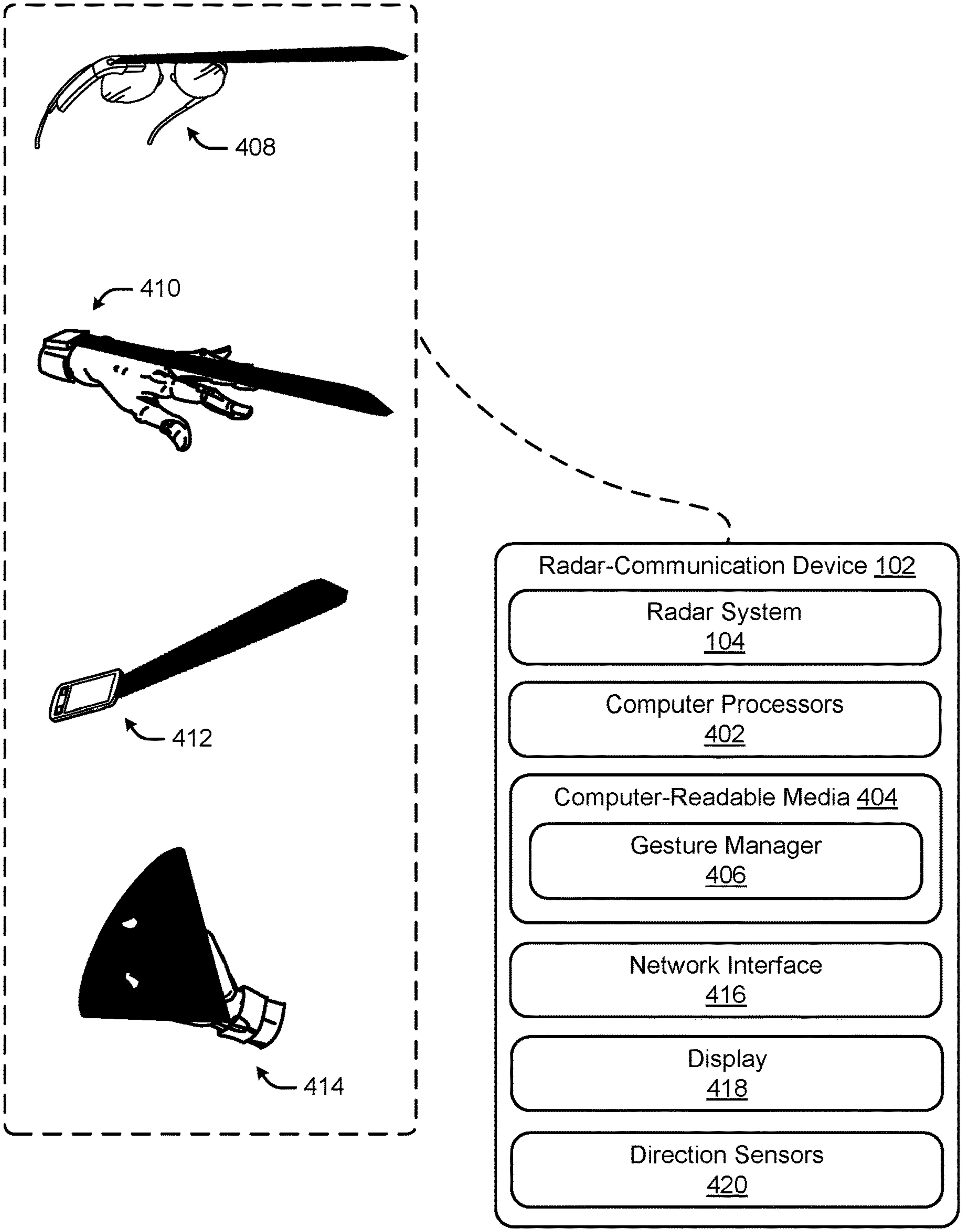


Fig. 3



408
410
412
414
Radar-Communication Device 102
Radar System
104
Computer Processors
402
Computer-Readable Media 404
Gesture Manager
406
Network Interface
416
Display
418
Direction Sensors
420

Fig. 4

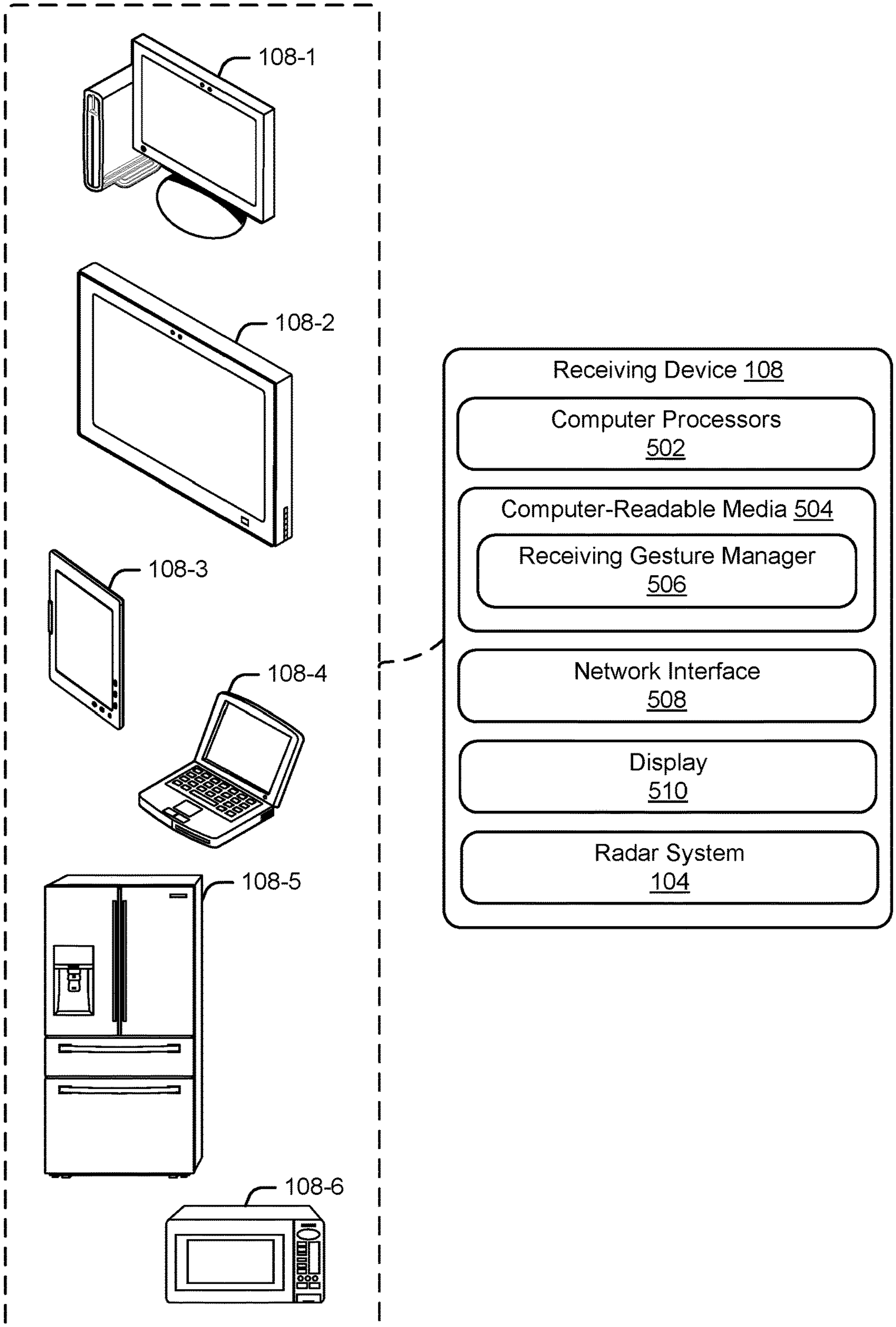

108-1
108-2
108-3
108-4
108-5
108-6
Receiving Device 108
Computer Processors 502
Computer-Readable Media 504
Receiving Gesture Manager 506
Network Interface 508
Display 510
Radar System 104

Fig. 5

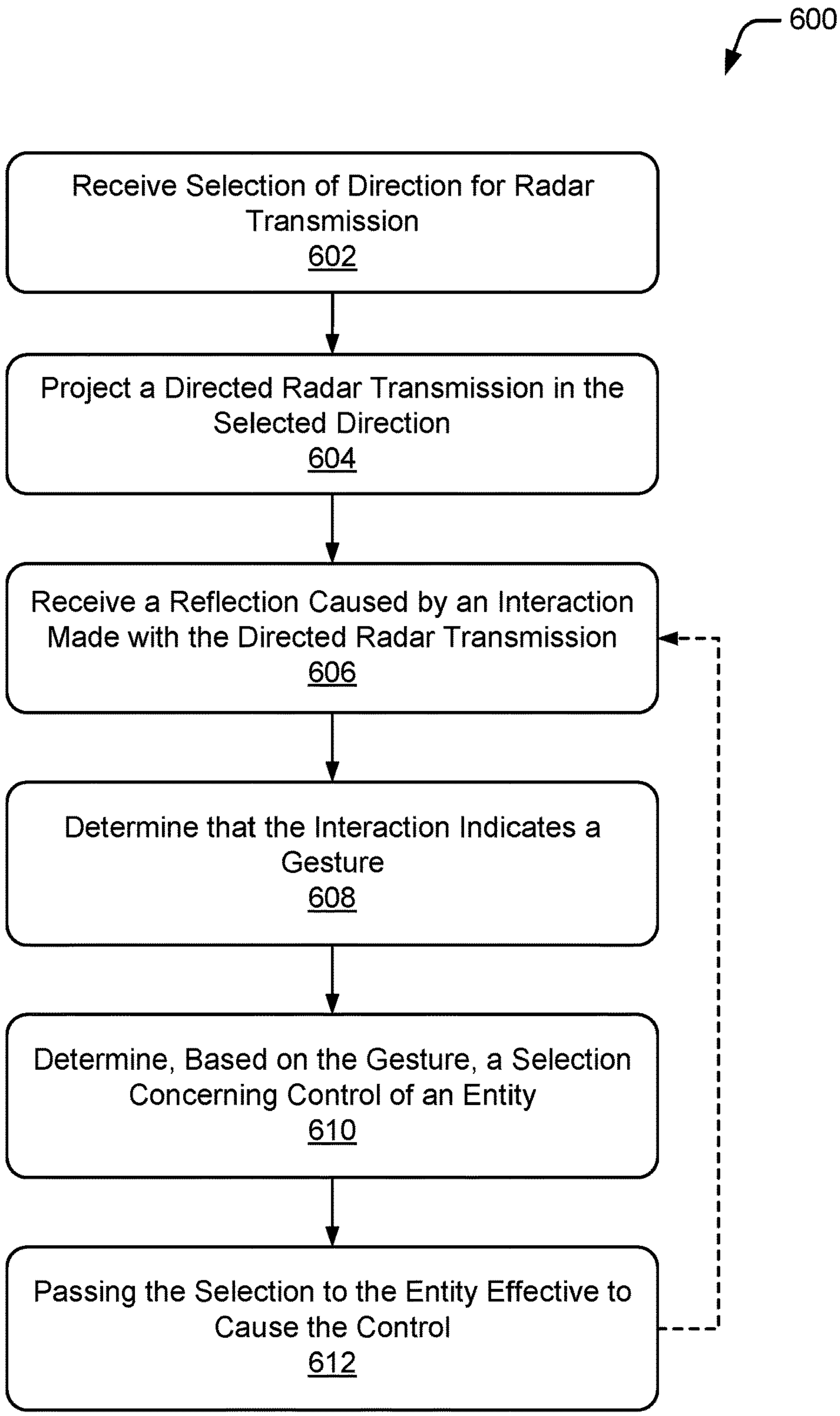

600
Receive Selection of Direction for Radar Transmission
602
Project a Directed Radar Transmission in the Selected Direction
604
Receive a Reflection Caused by an Interaction Made with the Directed Radar Transmission
606
Determine that the Interaction Indicates a Gesture
608
Determine, Based on the Gesture, a Selection Concerning Control of an Entity
610
Passing the Selection to the Entity Effective to Cause the Control
612

Fig. 6

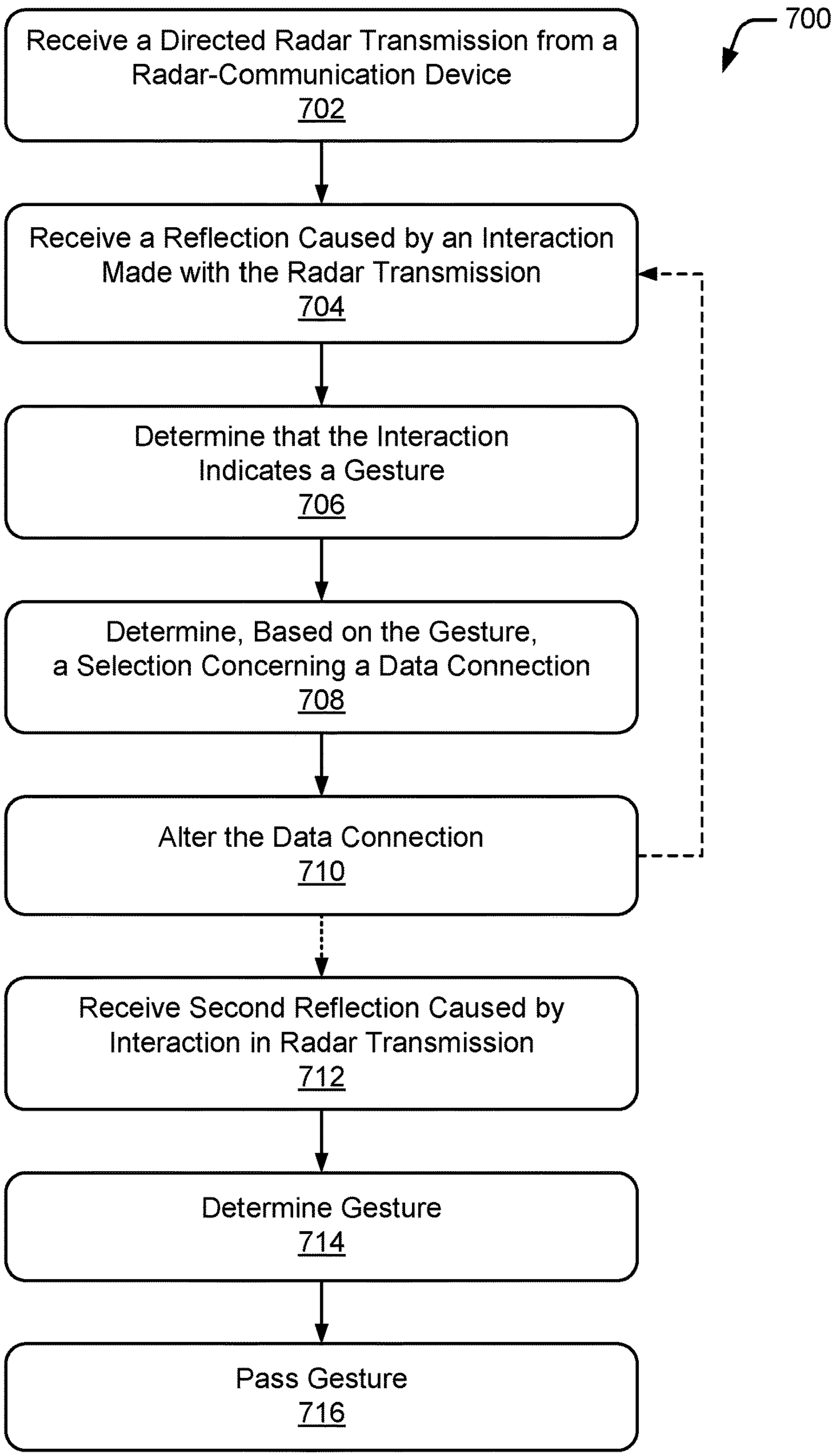

700
Receive a Directed Radar Transmission from a Radar-Communication Device 702
Receive a Reflection Caused by an Interaction Made with the Radar Transmission 704
Determine that the Interaction Indicates a Gesture 706
Determine, Based on the Gesture, a Selection Concerning a Data Connection 708
Alter the Data Connection 710
Receive Second Reflection Caused by Interaction in Radar Transmission 712
Determine Gesture 714
Pass Gesture 716

Fig. 7

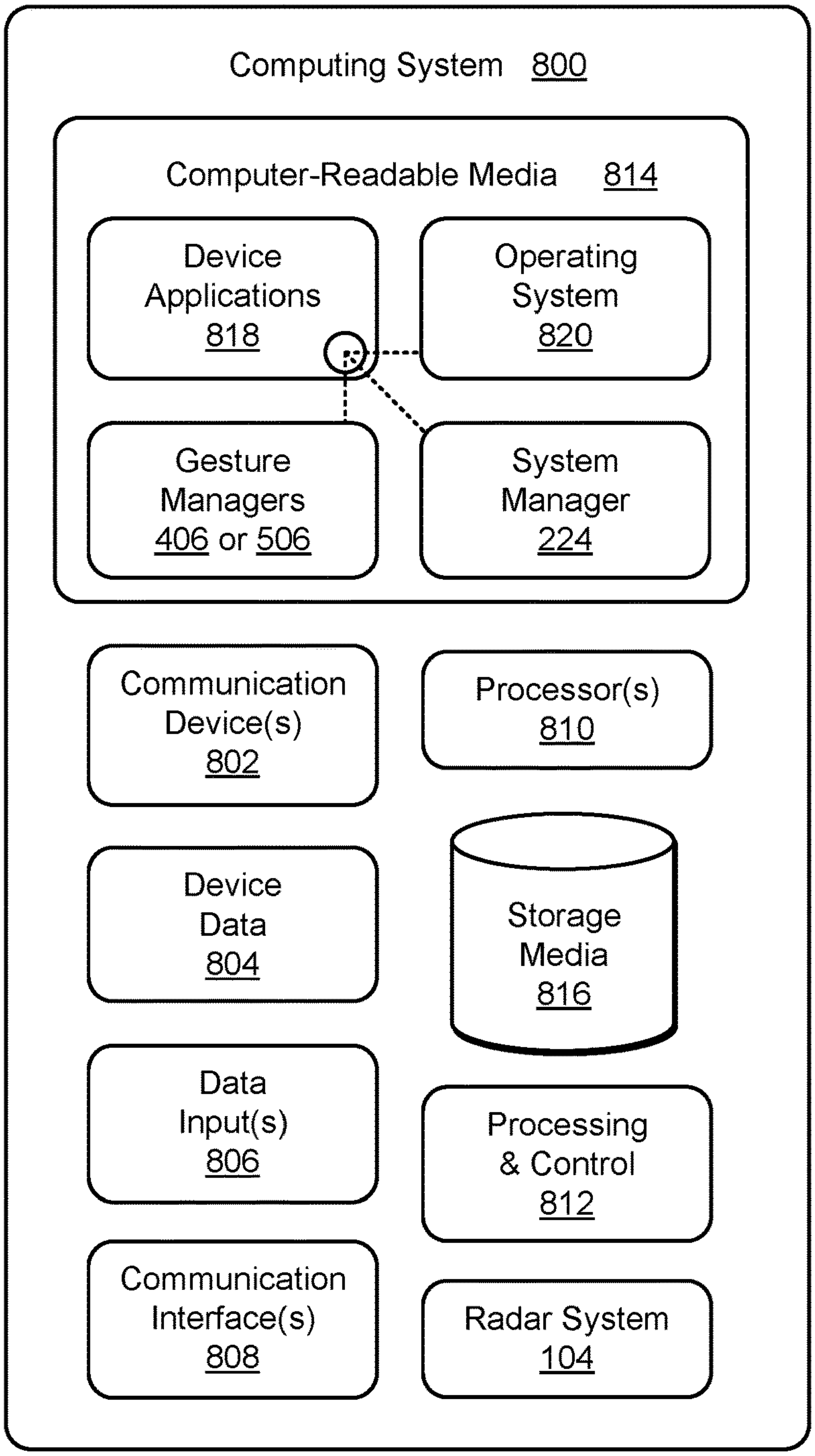

Computing System 800
Computer-Readable Media 814
Device Applications 818
Operating System 820
Gesture Managers 406 or 506
System Manager 224
Communication Device(s) 802
Processor(s) 810
Device Data 804
Storage Media 816
Data Input(s) 806
Processing & Control 812
Communication Interface(s) 808
Radar System 104

Fig. 8

RADAR-BASED GESTURE SENSING AND DATA TRANSMISSION

PRIORITY APPLICATION

This application is a continuation of and claims priority to U.S. patent application Ser. No. 14/513,875 filed Oct. 14, 2014 entitled "Radar-Based Gesture Sensing and Data Transmission", which, in turn, claims priority under 35 U.S.C. § 119(e) to U.S. Provisional Patent Application No. 62/034,560, entitled "Radar-Based Gesture Sensing and Data Transmission" and filed on Aug. 7, 2014, the disclosure of which is incorporated in its entirety by reference herein.

BACKGROUND

With the proliferation of computing devices in nearly every aspect of modern life—from automobiles to home appliances—users increasingly desire seamless and intuitive ways to control these many devices. Because of this need, control devices have proliferated for these computing devices, such as a television's remote, a gaming system's gesture-sensing camera, a tablet computer's touch screen, a desktop computer's keyboard, a smart-phone's audio-based controller, or a microwave oven's button control pad. This conventional use of many control devices is expensive and fails to provide seamless and intuitive control desired by users.

This proliferation of computing devices has also increased many user's desire to integrate communication between these devices, such as to pass a song from a smart phone with limited audio capabilities to a home stereo system or a television program from a tablet computer with a small screen to a large-screen television.

SUMMARY

This document describes techniques and devices for radar-based gesture sensing and data transmission. The techniques enable, through a radar system, seamless and intuitive control of, and data transmission between, computing devices. This radar system can both transmit data and sense gestures, thereby performing with a single system, control of many devices and data transmission with those devices. Not only can this provide control of many devices, from refrigerators to laptops, this radar system also allows high-bandwidth data transmission between devices.

This summary is provided to introduce simplified concepts concerning radar-based gesture sensing and data transmission, which are further described below in the Detailed Description. This summary is not intended to identify essential features of the claimed subject matter, nor is it intended for use in determining the scope of the claimed subject matter.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of techniques and devices for radar-based gesture sensing and data transmission are described with reference to the following drawings. The same numbers are used throughout the drawings to reference like features and components:

FIG. **1** illustrates an example environment in which radar-based gesture sensing and data transmission can be implemented.

FIG. **2** illustrates an example radar transmission emitted by a radar system of a wearable computing device.

FIG. **3** illustrates an example radar transmission emitted by a radar system and interacted with by a finger of a user.

FIG. **4** illustrates an example radar communication device having the radar system of FIG. **1**.

FIG. **5** illustrates an example receiving device having the radar system of FIG. **1**.

FIG. **6** illustrates an example method enabling radar-based gesture sensing and data transmission from a radar-communication device.

FIG. **7** illustrates another example method enabling radar-based gesture sensing and data transmission performed at a receiving device.

FIG. **8** illustrates an example device embodying, or in which techniques may be implemented that enable use of, a radar-based gesture sensing and data transmission.

DETAILED DESCRIPTION

Overview

This document describes techniques and devices enabling radar-based gesture sensing and data transmission. These techniques and devices enable users to control and transmit data with a radar system rather than multiple different kinds of control devices, thereby permitting users to learn one simple system rather than many different systems to control their devices. Further, these techniques and devices also enable data transmission with this radar system, thereby reducing costs not only by reducing the number and type of control devices, but also by replacing other data transmission systems.

Consider, for example, a user that wishes to transmit a playlist of songs from her smartphone to her stereo system. Assume that, in one room of her home, she has three radar-sensitive devices, the stereo system, a television, and a thermostat to control her apartment's heating and cooling. She may simply point her smartphone in the direction of her stereo system and then make a hand gesture between her smartphone and her stereo system, such as a hand-swipe from her smartphone toward her stereo system. The techniques can determine, based on this pointing and gesture, to transmit the playlist of songs from her smartphone through the radar system and to her stereo system. The radar system may also enable her to continue to control her stereo system by sensing gestures in a radar field (even the radar field transmitting data to the stereo system), such as to pause a song or turn up the stereo system's volume.

Example Environment

FIG. **1** is an illustration of an example environment **100** in which techniques using, and an apparatus including, a radar system for gesture sensing and data transmission may be embodied. Environment **100** includes a radar-communication device **102** having a radar system **104**, a radar transmission **106** provided by radar system **104**, and a receiving device **108**, which receives radar transmission **106**. As shown, a user **110** points his radar-communication device **102** in a direction of receiving device **108**. With this direction and a gesture that interacts with radar transmission **106** (described below), the techniques establish communication with, or control of, receiving device **108**.

Radar system **104** is configured to transmit data and to sense gestures. To enable this, radar system **104** includes a radio element **112**, a radar antenna **114**, a signal processor **116**, a transceiver **118**, system processors **120**, system media **122**, and a system manager **124**.

Generally, radio element **112** is configured to provide a radar transmission capable of transmitting data. Radio element **112** can be configured to emit continuously modulated radiation, ultra-wideband radiation, and/or sub-millimeter-frequency radiation. Radio element **112**, in some cases, is configured to form radiation in beams, the beams aiding a receiving device, and/or radar antenna **114** and signal processor **116**, to determine which of the beams are interrupted, and thus locations of interactions within a field having the radar transmission. In some cases, radio element **112** is configured to transmit radar that penetrates fabric or other obstructions and reflect from human tissue. These fabrics or obstructions can include wood, glass, plastic, cotton, wool, nylon and similar fibers, and so forth, while reflecting from human tissues, such as a person's hand, thereby potentially improving gesture recognition as clothing or other obstructions can be overcome.

In more detail, radio element **112** can be configured to emit microwave radiation in a 1 GHz to 300 GHz range, a 3 GHz to 100 GHz range, and narrower bands, such as 57 GHz to 63 GHz. This frequency range affects radar antenna **114**'s ability to receive interactions, such as to track locations of two or more targets to a resolution of about two to about 25 millimeters. Radio element **112** can be configured, along with other entities of radar system **104**, to have a relatively fast update rate, which can aid in resolution of the interactions.

By selecting particular frequencies, radar system **104** can operate to substantially penetrate clothing while not substantially penetrating human tissue. Further, radar antenna **114** or signal processor **116** can be configured to differentiate between interactions in the radar field caused by clothing from those interactions in the radar field caused by human tissue. Thus, a person wearing gloves or a long sleeve shirt that could interfere with sensing gestures with some conventional techniques, can still be sensed with radar system **104**.

Radar antenna **114** is configured to sense interactions in the radar transmissions and signal processor **116** is configured to process the sensed interactions sufficient to provide gesture data usable to determine a gesture from the sensed interactions. In some cases interactions are also or instead sensed by a receiving device, which is described later below. Radar antenna **114** can include one or many sensors, such as an array of radiation sensors, the number in the array based on a desired resolution and the type or types of radar being transmitted. Radar antenna **114** is configured to receive reflections of the radar transmission, including those caused by two or more targets (e.g., fingers), and signal processor **116** is configured to process the sensed interactions sufficient to provide data usable to determine gestures.

An example of a radar transmission and a gesture interaction within that radar transmission is illustrated in FIG. **2**, which shows radar transmission **202** emitted by radar system **104** of a wearable computing device. In this particular example, the wearable computing device is illustrated as wearable computing bracelet **204**, though any suitable computing device, wearable or otherwise, may implement the techniques described herein. Radar transmission **202** is interacted with by a person's finger **206**, which causes a refection (not shown) in radar transmission **202**. This reflection, as noted, can be received and processed to provide data from which a gesture is determined.

By way of a second example, consider FIG. **3**, which illustrates a radar transmission **302** (the transmission shown truncated) emitted by radar system **104**, which here is not part of a computing device. This radar transmission **302** is shown interacted with by fingers **304**, which again causes reflections in radar transmission **302**.

A user may perform complex or simple gestures with a hand or fingers (or a device like a stylus) that interrupts the radar transmission. Example gestures include the many gestures usable with current touch-sensitive displays, such as swipes, two-finger pinch and spread, tap, and so forth. Other gestures are enabled that are complex, or simple but three-dimensional, examples include many sign-language gestures, e.g., those of American Sign Language (ASL) and other sign languages worldwide. A few of these include an up-and-down fist, which in ASL means "Yes", an open index and middle finger moving to connect to an open thumb, which means "No", a flat hand moving up a step, which means "Advance", a flat and angled hand moving up and down, which means "Afternoon", clenched fingers and open thumb moving to open fingers and an open thumb, which means "taxicab", an index finger moving up in a roughly vertical direction, which means "up", and so forth. These are but a few of many gestures that can sensed by radar system **104**.

Returning to FIG. **1**, radar system **104** may include transceiver **118**, which in some cases aids in communicating in manners other than through radar. In cases where radar system **104** is included with a computing device, transceiver **118** may not be used. As noted gesture data can be transmitted through radio element **112** or transceiver **118**. This gesture data can be provided in a format usable by a receiving device sufficient for the receiving device to determine the gesture in those cases where the gesture is not determined by radar system **104** or a computing device into which radar system **104** is integrated.

Radar system **104** may include one or more system processors **120** and system media **122** (e.g., one or more computer-readable storage media). System media **122** includes system manager **124**, which can perform various operations, including determining a gesture based on gesture data from signal processor **116**, mapping the determined gesture to a pre-configured control gesture associated with a control input associated with a receiving device, and causing radio element **112** or transceiver **118** to transmit the control input to the receiving device effective to enable control of the device. This is but one of the ways in which the above-mentioned control through radar system **104** can be enabled. Operations of system manager **224** are described in greater detail as part of methods **600** and **700** below.

Radar system **104** can be used with, or embedded within, many different garments, accessories, and computing devices. Consider, for example, FIG. **4**, which illustrates radar-communication device **102** in greater detail. Radar-communication device **102** includes radar system **104**, one or more computer processors **402**, and computer-readable media **404**, which includes memory media and storage media. Applications and/or an operating system (not shown) embodied as computer-readable instructions on computer-readable media **404** can be executed by processors **402** to provide some of the functionalities described herein. Computer-readable media **404** also includes gesture manager **406** (described below). Example radar-communication devices **102** include computing devices, such as computing spectacles **408**, a computing bracelet **410** (e.g., smart watch), and a smart phone **412**. Devices having little or no computing may also be used, including radar transmitter **414**, which includes a network interface **416**, but may or may not include computer processors **402**, gesture manager **406**, display **418**, and direction sensors **420**.

Direction sensors **420** are capable of sensing a user's directional selection through various input manners and devices, which range from buttons, capacitive sensors, radar fields, and touch screens to orientation sensors capable of determining an orientation or orientation change of radar-communication device **102**. Further, direction can be sensed without movement of radar-communication device **102**, such as through gestures made within a radar transmission or other non-directional selection. For a radar transmission that can be received by multiple devices, selection of the receiving device can be made without changing the direction but instead making a gesture in the radar field that indicates selection of the intended receiving device. This gesture can be directional to the device—such as movement from radar-communication device **102** toward receiving device **108**, or be a gesture associated with the particular device.

Buttons, capacitive sensors, and touch screens enable a user to select receiving devices or controls of a receiving device, such as to increase a volume or pause a program with a button associated with that control on radar-communication device **102** (e.g., a button on radar-communication device **102** for altering volume can be used to control receiving device **108**). Touch screens or pads enable a user to select controls and devices with visual controls similar to the buttons but also through zooming gestures, such as a pinch gesture to zoom out or a spread gesture to zoom in. Cameras and orientation sensors can determine selections that tilt, turn, move in, move out, move up, move left, move right, and move down radar-communication device **102**, to name just a few.

Direction sensors **420** may also include orientations sensors, which can include micromachined accelerometers, which may also be referred to as microelectromechanical system (MEMS) based accelerometers. These micromachined accelerometers, depending on the types, are configured to measure, in multiple axes, magnitude and direction of proper acceleration (e.g., G-force) as a vector quantity. By so doing, the micromachined accelerometers can sense orientation, coordinate acceleration, vibration, shock, and falling. For use as orientation sensors, these micromachined accelerometers can sense six degrees of freedom of radar-communication device **102**, including three degrees of freedom in translation (X, Y, and Z) and three in rotation (pitch, yaw, and roll). Cameras can be used to track a device's location, such as relative to a user viewing the display, by tracking imaged objects (e.g., a book pictured by the camera can be used to determine, based on the book changing size or location in an image captured by the camera, an orientation or location in three dimensions of the display) or objects that relate to the viewer, such as by tracking a user's facial features (e.g., eyes, cornea, irises).

Radar-communication device **102** may implement little or no computer software, such as when configured as radar transmitter **414**. In addition to the example device shown, radar-communication device **102** may also be implemented as other small wearable devices, such as a ring, bracelet, or broach or small handheld remote controllers and so forth.

As noted above, radar-communication device **102**, using radar system **104**, communicates with a receiving device, such as receiving device **108** of FIG. **1**. In more detail, consider FIG. **5**, which illustrates an example receiving device **108**. Receiving device **108** is illustrated with various non-limiting example devices, desktop computer **108-1**, a television **108-2**, a tablet **108-3**, a laptop **108-4**, a refrigerator **108-5**, and a microwave **108-6**, though other devices may also be used, such as home automation and control systems, entertainment systems, audio systems, other home appliances, security systems, netbooks, smartphones, and e-readers.

Receiving device **108** includes one or more computer processors **502** and computer-readable storage media (storage media) **504**. Storage media **504** includes applications and/or an operating system (not shown) embodied as computer-readable instructions executable by computer processors **502** to provide, in some cases, functionalities described herein. Storage media **504** also includes receiving gesture manager **506** (described below).

Receiving device **108** may also include network interfaces **508** for communicating data over wired, wireless, or optical networks. By way of example and not limitation, network interface **508** may communicate data over a local-area-network (LAN), a wireless local-area-network (WLAN), a personal-area-network (PAN), a wide-area-network (WAN), an intranet, the Internet, a peer-to-peer network, point-to-point network, a mesh network, and the like. Receiving device **108** includes a display **510**, which can be touch-sensitive, though this is not required.

Receiving gesture manager **506** is capable of interacting with applications and devices associated with or through which receiving device **108** is able to communicate and radar system **104** effective to control and/or alter data communications between various devices or applications.

Receiving device **108** is also shown including radar system **104**, which can be included in whole or in part. In some cases, receiving device **108** receives reflections from gesture interactions in radar transmissions (e.g., radar transmissions of other devices), and thus can sense gestures within the radar field of the radar transmissions. In such cases, receiving device **108** includes radar antenna **114** and signal processor **116** as described above. Further, receiving device **108** may receive and transmit data using radar, in such cases radio element **112** is also included in receiving device **108**. In conjunction with these and/or other elements of radar system **104** operating at receiving device **108**, receiving gesture manager **506** is capable of determining gestures based on interactions to radar transmission **106**.

As will be described in greater detail below, radar transmissions can enable data communication between (e.g., one-way or bi-directional transmissions) radar-communication device **102** and receiving device **108**, as well as sensing of gestures made within the radar transmissions.

These and other capabilities and configurations, as well as ways in which entities of FIGS. **1-5** act and interact, are set forth in greater detail below. These entities may be further divided, combined, and so on. The environment **100** of FIG. **1** and the detailed illustrations of FIGS. **2-5** illustrate some of many possible environments and devices capable of employing the described techniques.

Example Methods

FIGS. **6** and **7** depict methods enabling radar-based gesture sensing and data transmission. These methods and other methods herein are shown as sets of blocks that specify operations performed but are not necessarily limited to the order or combinations shown for performing the operations by the respective blocks. In portions of the following discussion reference may be made to environment **100** of FIG. **1** and entities detailed in FIGS. **2-5**, reference to which is made for example only. The techniques are not limited to performance by one entity or multiple entities operating on one device.

At **602**, selection of a direction for projection of a radar transmission is received. This selection can be, as noted, through a physical orienting of a radar element of a radar-communication device toward a radar antenna associated with a computing device. Selection can made by a user, such as user **110** of FIG. **1**, to point or otherwise select a direction for the radar transmission. As shown in FIG. **1**, user **110** points radar-communication device **102** toward receiving device **108**. This selection can be sensed by radar-communication device **102** through various manners, such as through direction sensors **420** to sense an orientation of radar-communication device **102** as noted above.

At **604**, a directed radar transmission is projected to an entity in the selected direction. This is shown at FIG. **1**, where radar-communication device **102** emits radar transmission **106** via radar system **104** to receiving device **108**. This entity to which the directed radar transmission is directed can include various devices, but can also be a specific application or peripheral device of a receiving device, such as an application on a computing device.

In more detail, the directed radar transmission can be a directed-beam narrow field. In such a case, a simple or even no gesture need be made to the radar transmission to begin communication between radar-communication device **102** and receiving device **108**, as receiving device **108** may determine that communication is desired through the direction of the directed-beam narrow field. While the gesture interacting with the radar transmission, or direction (e.g., pointing) of the radar transmission to receiving device **108**, is described in the context of establishing communication, and in some other portions herein control of an entity, various other actions can be triggered. Thus, these example actions are not limited to selecting an entity to control or device with which to alter communication.

At **606**, a reflection caused by an interaction made with the directed radar transmission is received, such as at radar antenna **114** of radar system **104**. This reflection can be received at radar antenna **112**. The type of reflection depends on the frequency as well as other characteristics of radar transmission **106**. Thus, when the directed radar field includes time-split radar transmissions, one of the time-split radar transmissions transmits data and the other of the time-split radar transmissions can reflect radar from human tissue. In this case receiving the reflection caused by the interaction receives the reflection from human tissue from the other of the time-split radar transmissions, thereby permitting data to be communicated with less interaction from the interaction.

Another example radar transmission **106** includes directed beams, where some of the beams are interrupted by an interaction and others are not, thereby enabling data transmission by un-interrupted beams while sensing gestures with the interrupted beams.

In still other cases, the radar transmission is interrupted by the interaction, such as for radar transmissions having a single type of transmission. This single type of transmission, however, can reduce costs in producing radar system **104** and still enable data transmission and gesture sensing.

At **608**, a gesture made within the directed radar transmission and indicated by the interaction is determined. The determination of the gesture based on the interaction can be performed by system manager **124** and/or gesture manager **406**. The determined gesture can be as simple as an interruption or a complex, multi-target, moving three-dimensional gesture. With more-complex gestures mentioned above, gesture manager **406** can map particular gestures or types of gestures to particular devices or applications or peripherals associated with those devices. Thus, one particular gesture may map to control or communication with laptop **108-4**, another may map to microwave **108-6**, and so forth.

At **610**, a selection concerning control of an entity is determined based on the gesture. As noted, these selections can include starting or ceasing communication and various types of control of the entity—from initiating a stream of content from a smart phone **412** to a television **108-2**, to dispensing water from refrigerator **108-5**, to flipping through pages or images on desktop computer **108-1**, to controlling playback of media on television **108-2**.

At **612**, the selection is passed to the entity effective to cause the control. This passing of the selection (e.g., control gesture) can be through the same radar transmission, though this is not required. For example, any suitable network interface may be used to communicate the selection or other information between radar-communication device **102** and receiving device **108**. Following operation **612**, methods **600** may return to operation **606** to continue to receive gestures to control receiving device **108** (or radar-communication device **102**).

FIG. **7** depicts method **700**, which enables radar-based gesture sensing and data transmission with operations from a perspective of a receiving device.

At **702**, a directed radar transmission is received from a radar-communication device. This directed radar transmission can be through a physical orienting of a radar element of a radar-communication device toward a radar antenna (e.g., radar system **104** of radar-communication device **102** to radar antenna **114** of receiving device **108**).

In some cases, the directed radar transmission is a broad field having different characteristics at a center of the broad field than at a periphery of the broad field. In such a case, a receiving device (e.g., radar system **104** of receiving device **108**) determines, based on characteristics of radar received, that the directed radar transmission is directed to a computing device on which the method is performed.

In some other cases, the directed radar transmission is a directed-beam narrow field. In such a case, the receiving device the determination can be simply based on receiving the radar transmission.

At **704**, a reflection caused by an interaction made with the directed radar transmission is received. This interaction can interfere or not interfere with the radar transmission. In cases where the directed radar transmission includes time-split radar transmissions, one of the time-split radar transmissions can send data and the other, which is configured to reflect radar from human tissue rather than pass through human tissue as is with the other radar transmission, can receive the reflection caused by the interaction from human tissue.

At **706**, a gesture made within the directed radar transmission is determined based on the interaction. This gesture can be to begin a data connection, in which case a handshake protocol to begin a new data connection with a computing device associated with the radar-communication device can be performed. Alternately, this gesture can instead be to cease a current data connection, in which case the data connection is shut down.

At **708**, a selection concerning a data connection is determined based on the gesture. As noted, this can be to start or cease communications. The data connection may communicate any suitable type data, such as user files, images, music, video, streaming content, and so on. As such, the selection can be to initiate a stream of content (or media) between devices, terminate the stream of content, or select another device as a destination for the stream of content. In some cases, a state of the data connection or data being communicated thereby is determined. For example, if media is being streamed via the data connection, a point at which media playback ceases may be determined to enable subsequent media playback to resume at that point when a data connection is established at another device.

At **710**, the data connection is altered based on the selection. The data connection is not required to be between a receiving device and a computing device with which the radar-communication device may be integral. Thus, the data connection can be from the receiving device to a third device connected with or associated with the radar-communication device, such as in a case where radar transmitter **414** is acting as a transmitter to set up or pass data with another device, such as a user's tablet **108-3** to a television **108-2**.

Following a data connection being made at operation **710**, method **700** may proceed to operations **712**, **714**, and **716**. At **712**, a second reflection caused by a second interaction made with the directed radar transmission is received. As noted above, a reflection from an interaction can be received at a transmitting device or a receiving device, such as antenna **112** at receiving device **108**.

At **714**, a second gesture made within the directed radar transmission is determined based on the second interaction. This can be accomplished similarly to as noted in method **600** above. For example, receiving gesture manager **506** can determine the gesture to be of a particular type or unique, and map it to a desired control, device function, and/or entity (e.g., to control a particular application of receiving device **108**).

At **716**, the second gesture is passed to an application, an operating system, or a device effective control the application, the operating system, or the device. As noted above, the passed gesture can control or invoke any suitable function of the application, operating system, or device. For example, the passed gesture may pause playback, advance playback, or skip playback of media tracks being presented by a device.

As shown with dashed lines in FIG. **7**, method **700** may perform some mix of operations, excluding some and repeating others. Thus, after a data connection is established, other controls can be received, thereby performing operations **712**, **714**, and **716** (e.g., to control the same or other entities of receiving device **108**) or repeating operations **704**, **706**, and **710** (e.g., to cease the data connection).

The preceding discussion describes methods relating to radar-based gesture sensing and data transmissions. Aspects of these methods may be implemented in hardware (e.g., fixed logic circuitry), firmware, software, manual processing, or any combination thereof. These techniques may be embodied on one or more of the entities shown in FIGS. **1-5** and **8** (computing system **800** is described in FIG. **8** below), which may be further divided, combined, and so on. Thus, these figures illustrate some of the many possible systems or apparatuses capable of employing the described techniques. The entities of these figures generally represent software, firmware, hardware, whole devices or networks, or a combination thereof.

Example Computing System

FIG. **8** illustrates various components of example computing system **800** that can be implemented as any type of client, server, and/or computing device as described with reference to the previous FIGS. **1-7** to implement a radar-based gesture sensing and data transmission. In embodiments, computing system **800** can be implemented as one or a combination of a wired and/or wireless wearable device, System-on-Chip (SoC), and/or as another type of device or portion thereof. Computing system **800** may also be associated with a user (e.g., a person) and/or an entity that operates the device such that a device describes logical devices that include users, software, firmware, and/or a combination of devices.

Computing system **800** includes communication devices **802** that enable wired and/or wireless communication of device data **804** (e.g., received data, data that is being received, data scheduled for broadcast, data packets of the data, etc.). Device data **804** or other device content can include configuration settings of the device, media content stored on the device, and/or information associated with a user of the device. Media content stored on computing system **800** can include any type of audio, video, and/or image data. Computing system **800** includes one or more data inputs **806** via which any type of data, media content, and/or inputs can be received, such as human utterances, interactions with a localized radar field, user-selectable inputs (explicit or implicit), messages, music, television media content, recorded video content, and any other type of audio, video, and/or image data received from any content and/or data source.

Computing system **800** also includes communication interfaces **808**, which can be implemented as any one or more of a serial and/or parallel interface, a wireless interface, any type of network interface, a modem, and as any other type of communication interface. Communication interfaces **808** provide a connection and/or communication links between computing system **800** and a communication network by which other electronic, computing, and communication devices communicate data with computing system **800**.

Computing system **800** includes one or more processors **810** (e.g., any of microprocessors, controllers, and the like), which process various computer-executable instructions to control the operation of computing system **800** and to enable techniques for, or in which can be embodied, a radar-based gesture sensing and data transmission. Alternatively or in addition, computing system **800** can be implemented with any one or combination of hardware, firmware, or fixed logic circuitry that is implemented in connection with processing and control circuits which are generally identified at **812**. Although not shown, computing system **800** can include a system bus or data transfer system that couples the various components within the device. A system bus can include any one or combination of different bus structures, such as a memory bus or memory controller, a peripheral bus, a universal serial bus, and/or a processor or local bus that utilizes any of a variety of bus architectures.

Computing system **800** also includes computer-readable media **814**, such as one or more memory devices that enable persistent and/or non-transitory data storage (i.e., in contrast to mere signal transmission), examples of which include random access memory (RAM), non-volatile memory (e.g., any one or more of a read-only memory (ROM), flash memory, EPROM, EEPROM, etc.), and a disk storage device. A disk storage device may be implemented as any type of magnetic or optical storage device, such as a hard disk drive, a recordable and/or rewriteable compact disc (CD), any type of a digital versatile disc (DVD), and the like. Computing system **800** can also include a mass storage media device **816** and radar system **104**, including one or more or multiples of each of radar system **104**'s elements or components noted in FIG. **1** above.

Computer-readable media **814** provides data storage mechanisms to store device data **804**, as well as various device applications **818** and any other types of information and/or data related to operational aspects of computing system **800**. For example, an operating system **820** can be maintained as a computer application with computer-readable media **814** and executed on processors **810**. Device applications **818** may include a device manager, such as any form of a control application, software application, signal-processing and control module, code that is native to a particular device, a hardware abstraction layer for a particular device, and so on.

Device applications **818** also include any system components, entities, or managers to implement radar-based gesture sensing and data transmission. In this example, device applications **818** include gesture manager **406** or receiving gesture manager **506** and system manager **124**.

CONCLUSION

Although embodiments of techniques using, and apparatuses including, radar-based gesture sensing and data transmission have been described in language specific to features and/or methods, it is to be understood that the subject of the appended claims is not necessarily limited to the specific features or methods described. Rather, the specific features and methods are disclosed as example implementations of radar-based gesture sensing and data transmission.

What is claimed is:

1. A computer-implemented method comprising:
- projecting, by a radar system of a radar-communication device, a radar transmission;
- receiving, by the radar system, a first reflection caused by a first interaction made within the radar transmission;
- determining, by the radar-communication device, that the first interaction indicates first gesture data associated with a first gesture made within the radar transmission;
- determining, by the radar-communication device and based on the first gesture data, the first gesture, the first gesture indicating a remote entity;
- receiving, by the radar system, a second reflection caused by a second interaction made within the radar transmission;
- determining, by the radar-communication device, that the second interaction indicates second gesture data associated with a second gesture made within the radar transmission;
- determining, by the radar-communication device and based on the second gesture data, the second gesture;
- determining, by the radar-communication device and based on the second gesture, a selection concerning one of a plurality of controls of the remote entity; and
- passing the selection to the remote entity effective to cause the control.

2. The computer-implemented method of claim **1**, wherein passing the selection to the remote entity comprises transmitting the selection via the radar transmission.

3. The computer-implemented method of claim **1**, wherein passing the selection to the remote entity comprises transmitting the selection over a local area network, a personal area network, a wide area network, a point-to-point network, or a mesh network.

4. The computer-implemented method of claim **1**, wherein passing the selection to the remote entity comprises passing the selection to a network interface device, the network interface device configured to communicate the selection to the remote entity.

5. The computer-implemented method of claim **1**, further comprising initiating a data connection between the radar-communication device and the remote entity, the initiating comprising a handshake protocol to begin the data connection.

6. The computer-implemented method of claim **1**, wherein the selection comprises an instruction to cease a connection between the radar-communication device and the remote entity.

7. The computer-implemented method of claim **1**, wherein the first gesture or the second gesture comprises a complex, multi-target, or moving three-dimensional gesture.

8. An apparatus comprising:
- a radar system configured to:
  - provide radar transmissions; and
  - receive reflections within the radar transmissions;
- one or more computer processors; and
- one or more non-transitory computer-readable storage media having instructions stored thereon that, responsive to execution by the one or more computer processors, cause the one or more computer processors to perform operations comprising:
  - causing the radar system to provide a radar transmission;
  - receiving first reflections for a first interaction in the radar transmission;
  - processing the first received reflections to provide first gesture data for the first interaction;
  - determining, based on the provided first gesture data for the first interaction, remote entity;
  - receiving second reflections for a second interaction in the radar transmission;
  - processing the second received reflections to provide second gesture data for the second interaction;
  - determining, based on the provided second gesture data for the second interaction, a selection concerning one of a plurality of controls of the remote entity; and
  - passing the selection to the remote entity effective to cause the control.

9. The apparatus of claim **8**, wherein passing the selection to the remote entity comprises transmitting the selection via the radar transmission.

10. The apparatus of claim **1**, wherein passing the selection to the entity comprises transmitting the selection over a local area network, a personal area network, a wide area network, a point-to-point network, or a mesh network.

11. The apparatus of claim **8**, wherein passing the selection to the remote entity comprises passing the selection to a network interface device, the network interface device configured to communicate the selection to the remote entity.

12. The apparatus of claim **8**, further comprising initiating a data connection between the radar-communication device and the remote entity, the initiating comprising a handshake protocol to begin the data connection.

13. The apparatus of claim **8**, wherein the first gesture or the second gesture comprises a complex, multi-target, or moving three-dimensional gesture.

14. An apparatus comprising:
- a radar system configured to:
  - provide radar transmissions, the radar transmissions capable of transmitting data and capable of interacting with human tissue; and
  - receive reflections from interactions by the human tissue in the radar transmissions;

an orientation sensor configured to sense orientations of the apparatus relative to one or more remote computing devices;

one or more computer processors; and

one or more non-transitory computer-readable storage media having instructions stored thereon that, responsive to execution by the one or more computer processors, cause the one or more computer processors to perform operations comprising:

establishing an orientation of the apparatus relative to the one or more remote computing devices based on a sensed orientation from the orientation sensor;

determining one of the one or more remote computing devices based on the determined orientation of the apparatus relative to the one or more remote computing devices;

causing the radar system to provide a radar transmission towards the one of the one or more remote computing devices;

receiving reflections for an interaction in the radar transmission;

processing the received reflections in the radar transmission sufficient to determine the received reflections in the radar transmission comprise gesture data associated with a gesture, the gesture indicating a selection concerning one of a plurality of controls of the remote computing device; and

passing the indication of the control between the radar system and the one of the one or more computing devices.

15. The apparatus of claim **14**, wherein the determining the orientation of the apparatus is further based on the reflections from the interaction in the radar transmission.

16. The apparatus of claim **14**, wherein the orientation sensor comprises a camera.

17. The apparatus of claim **16**, wherein the camera senses tilt, turn, move in, move out, move up, move down, move left, or move right motions of the apparatus.

18. The apparatus of claim **16**, wherein the sensed orientation of the apparatus is based on tracked facial features of a user.

19. The apparatus of claim **14**, wherein the orientation sensor comprises a direction sensor, and wherein the direction sensor comprises a micromachined accelerometer.

20. The apparatus of claim **19**, wherein the micromachined accelerometer is configured to measure, in multiple axes, a magnitude or direction of acceleration.

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