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(54) **MANAGING UNMANNED AERIAL VEHICLE BROADCAST SIGNALS**

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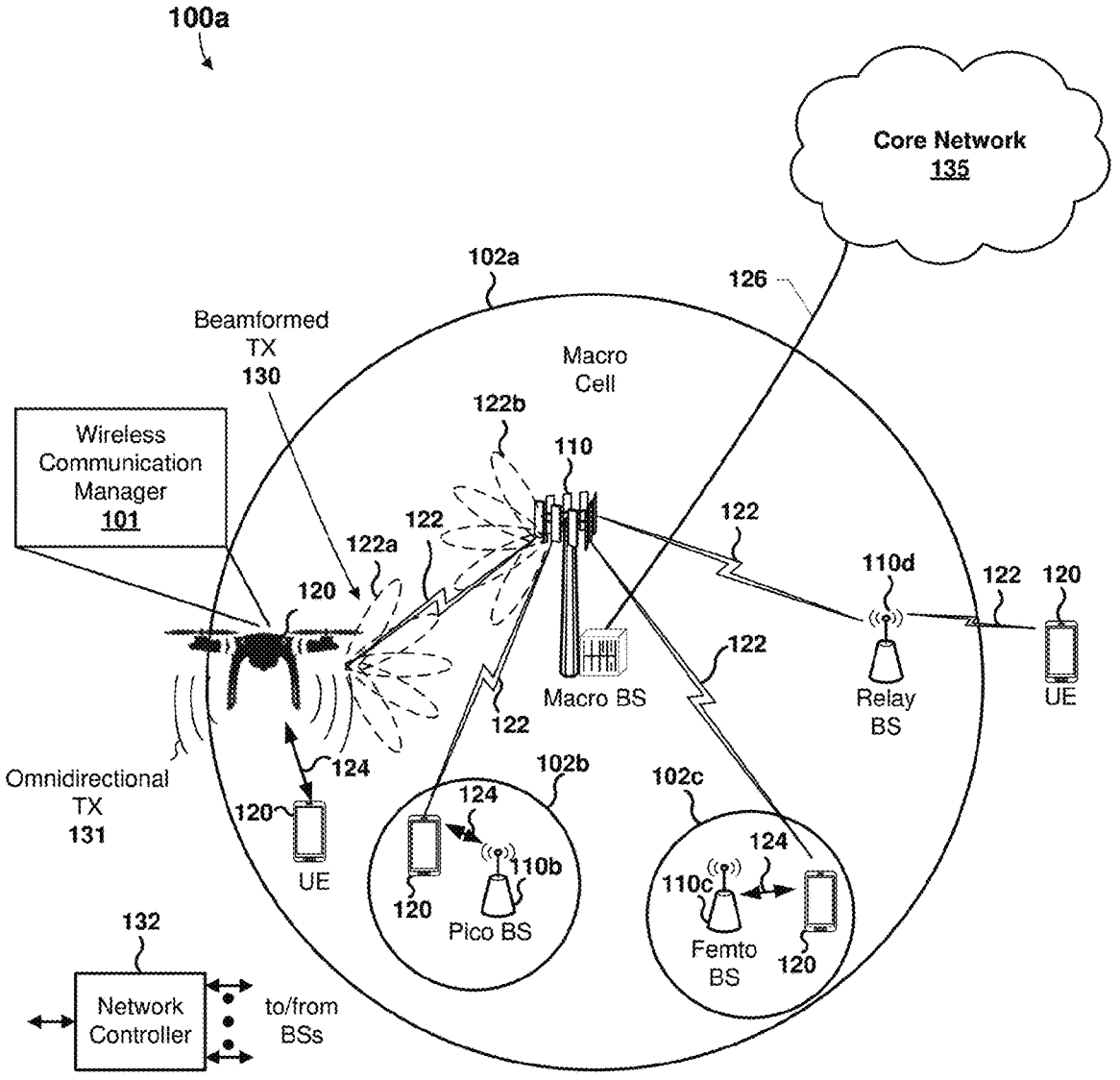
(57) **ABSTRACT**

Aspects include systems, methods, devices, and non-transitory processor readable storage mediums for managing a broadcast signal of an apparatus for wireless communication. Various aspects may enable an apparatus to send a message using either omnidirectional transmissions or beamformed transmission based on whether the altitude of the apparatus meets an altitude threshold. In some implementations and aspects, the processor of the apparatus may determine a type of the message and may select the altitude threshold based on the determined message type. In some implementations and aspects, the processor of the apparatus may send the message using beamformed transmissions in response to determining that the message is intended for reception by a certain type of second apparatus.



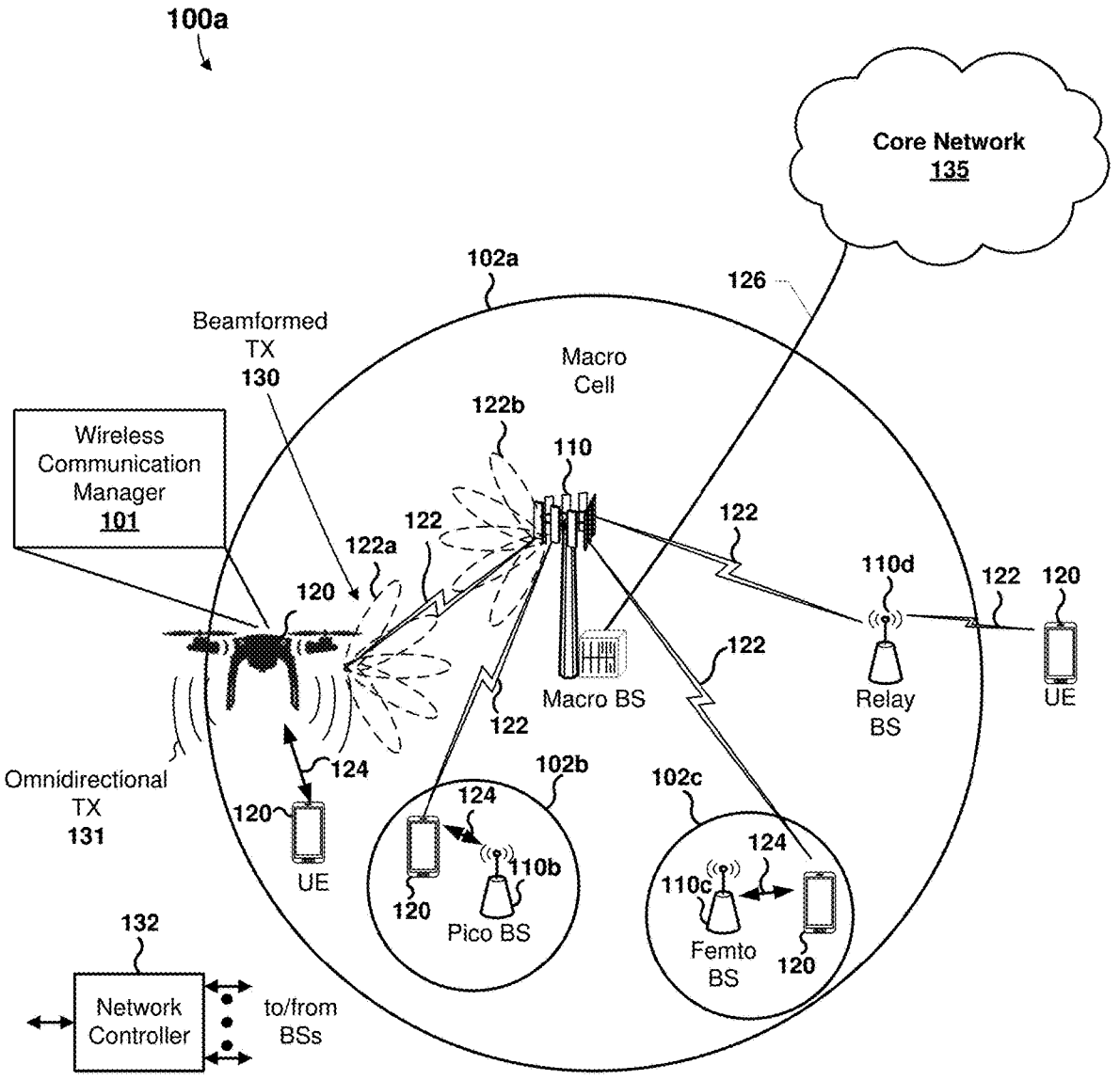

100a
Core Network
135
102a
126
Beamformed
TX
130
Macro
Cell
Wireless
Communication
Manager
101
122b
110
122
122a
120
122
110d
122
120
Macro BS
Relay
BS
UE
Omnidirectional
TX
131
124
120
UE
102b
102c
124
110b
120
Pico BS
124
110c
Femto
BS
120
132
Network
Controller
to/from
BSs

FIG. 1A

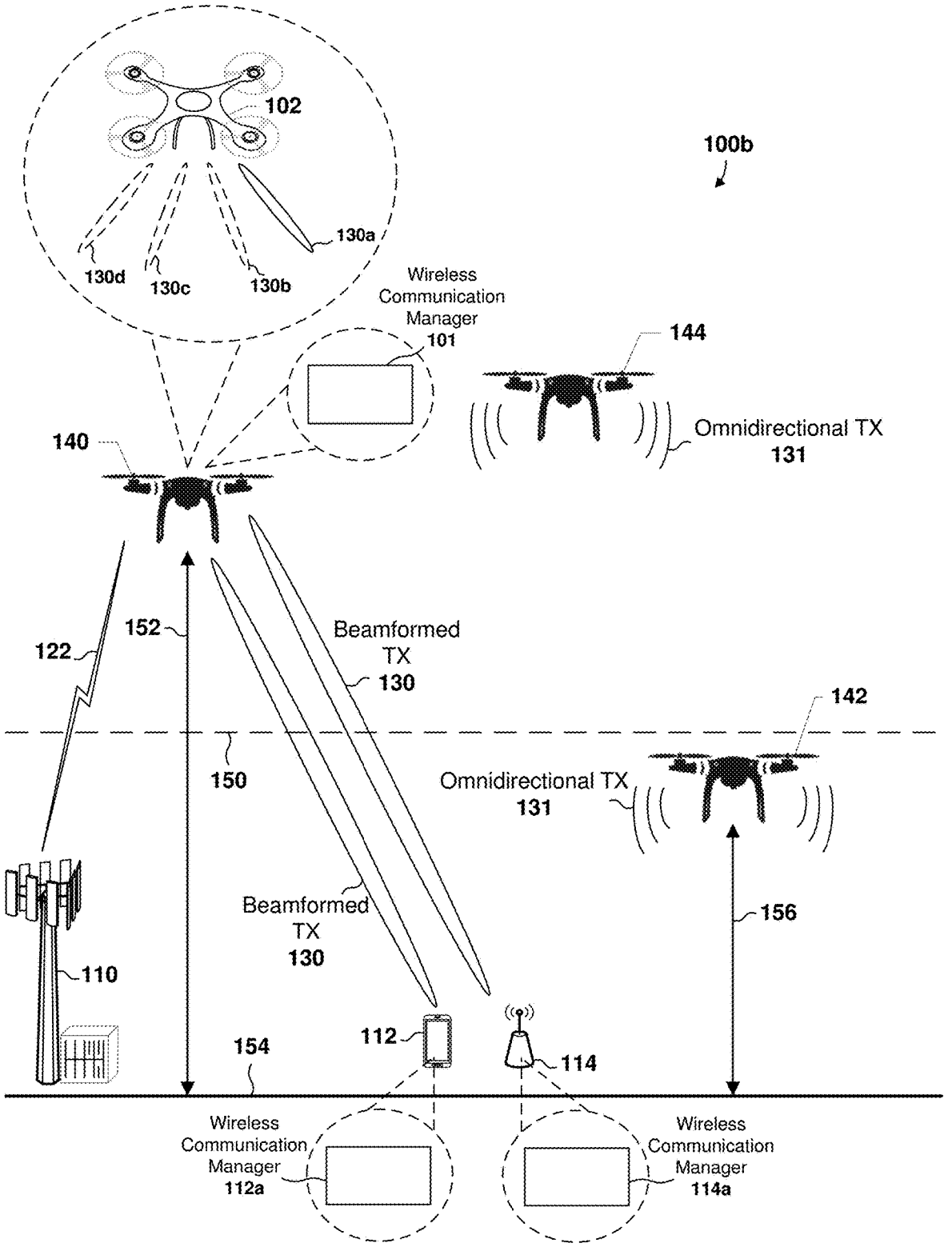

102
100b
130a
130d
130c
130b
Wireless
Communication
Manager
101
144
Omnidirectional TX
131
140
122
152
Beamformed
TX
130
142
150
Omnidirectional TX
131
156
Beamformed
TX
130
110
112
114
154
Wireless
Communication
Manager
112a
Wireless
Communication
Manager
114a

FIG. 1B

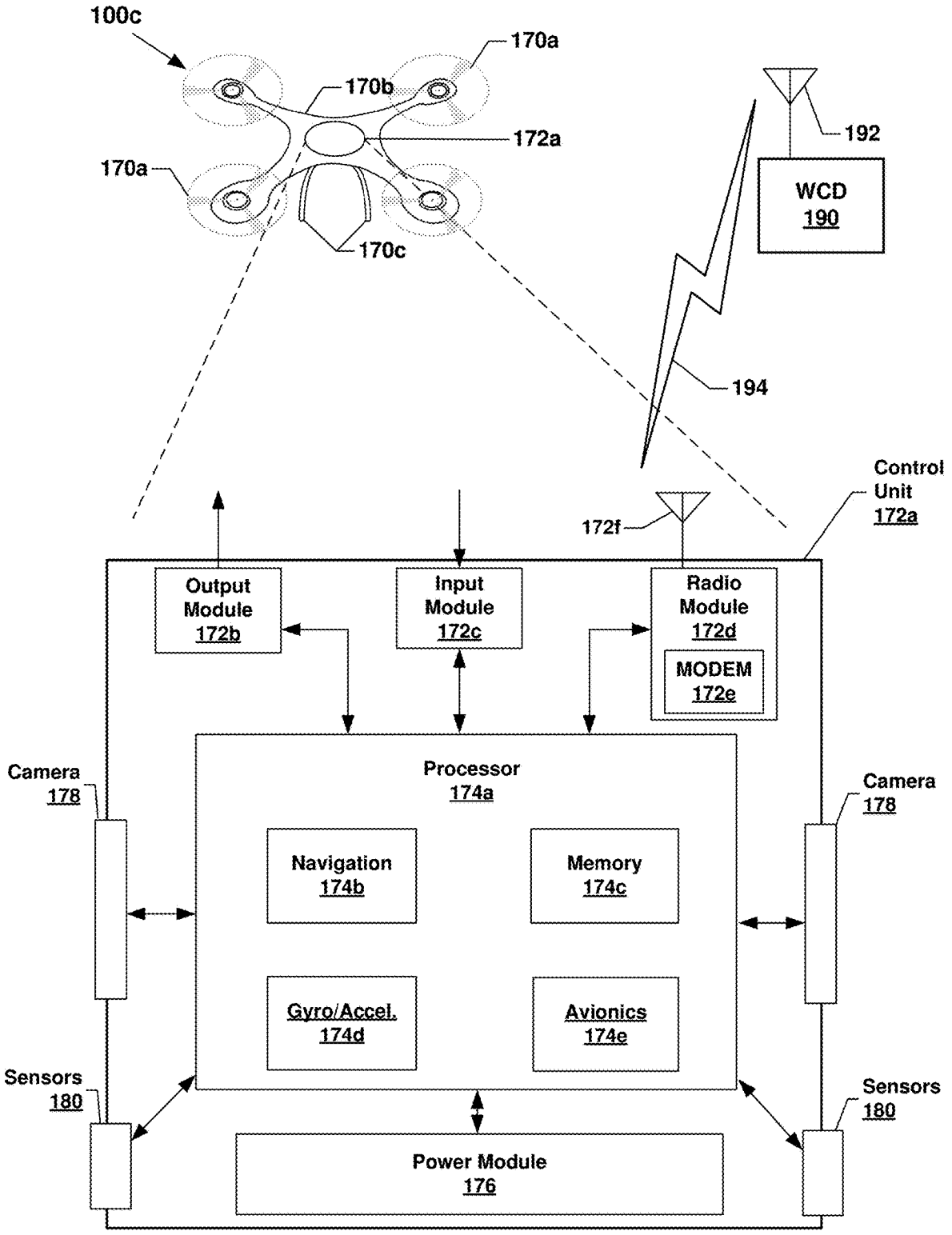

100c
170a
170b
172a
170a
170c
192
WCD
190
194
Control
Unit
172a
172f
Output
Module
172b
Input
Module
172c
Radio
Module
172d
MODEM
172e
Processor
174a
Camera
178
Navigation
174b
Memory
174c
Gyro/Accel.
174d
Avionics
174e
Camera
178
Sensors
180
Sensors
180
Power Module
176

FIG. 1C

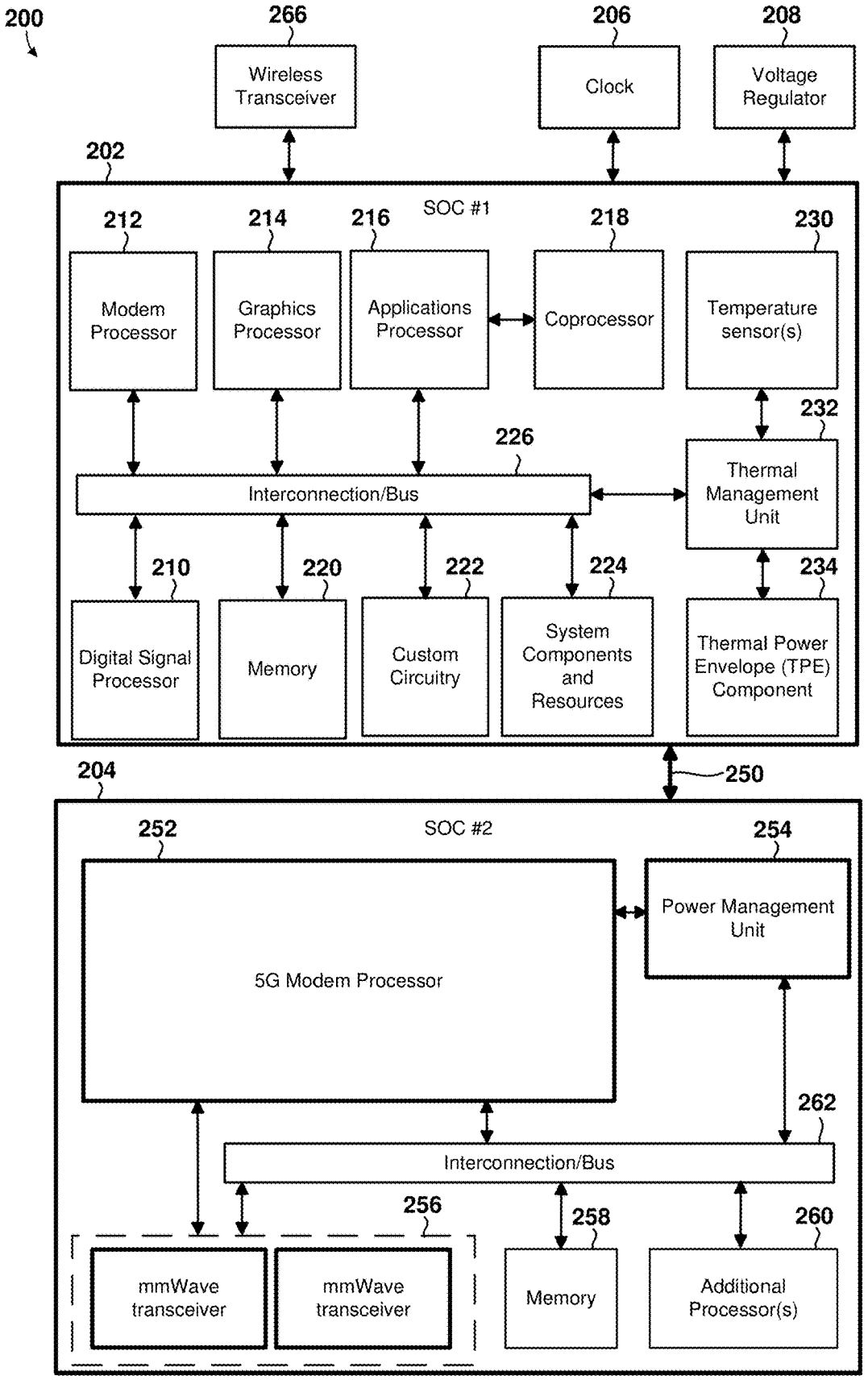

200
266
Wireless Transceiver
206
Clock
208
Voltage Regulator
202
SOC #1
212
Modem Processor
214
Graphics Processor
216
Applications Processor
218
Coprocessor
230
Temperature sensor(s)
232
226
Interconnection/Bus
Thermal Management Unit
210
Digital Signal Processor
220
Memory
222
Custom Circuitry
224
System Components and Resources
234
Thermal Power Envelope (TPE) Component
204
250
252
SOC #2
254
5G Modem Processor
Power Management Unit
262
Interconnection/Bus
256
258
260
mmWave transceiver
mmWave transceiver
Memory
Additional Processor(s)

FIG. 2

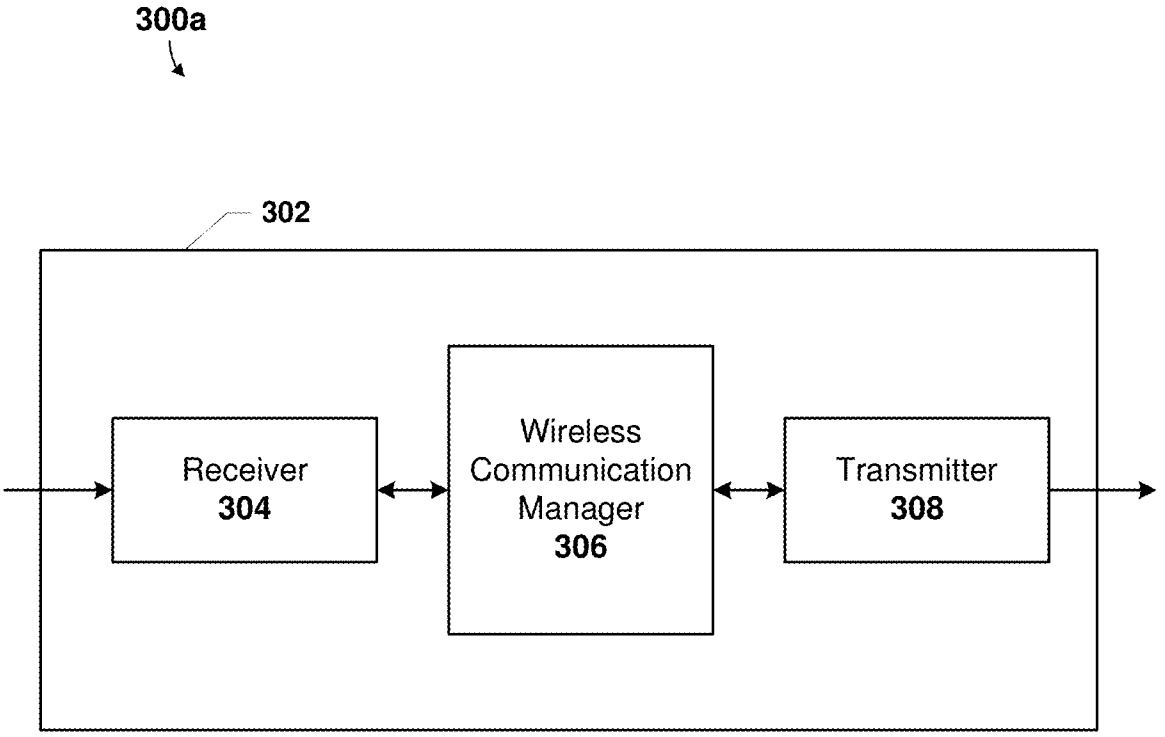

300a
302
Receiver
304
Wireless
Communication
Manager
306
Transmitter
308

FIG. 3A

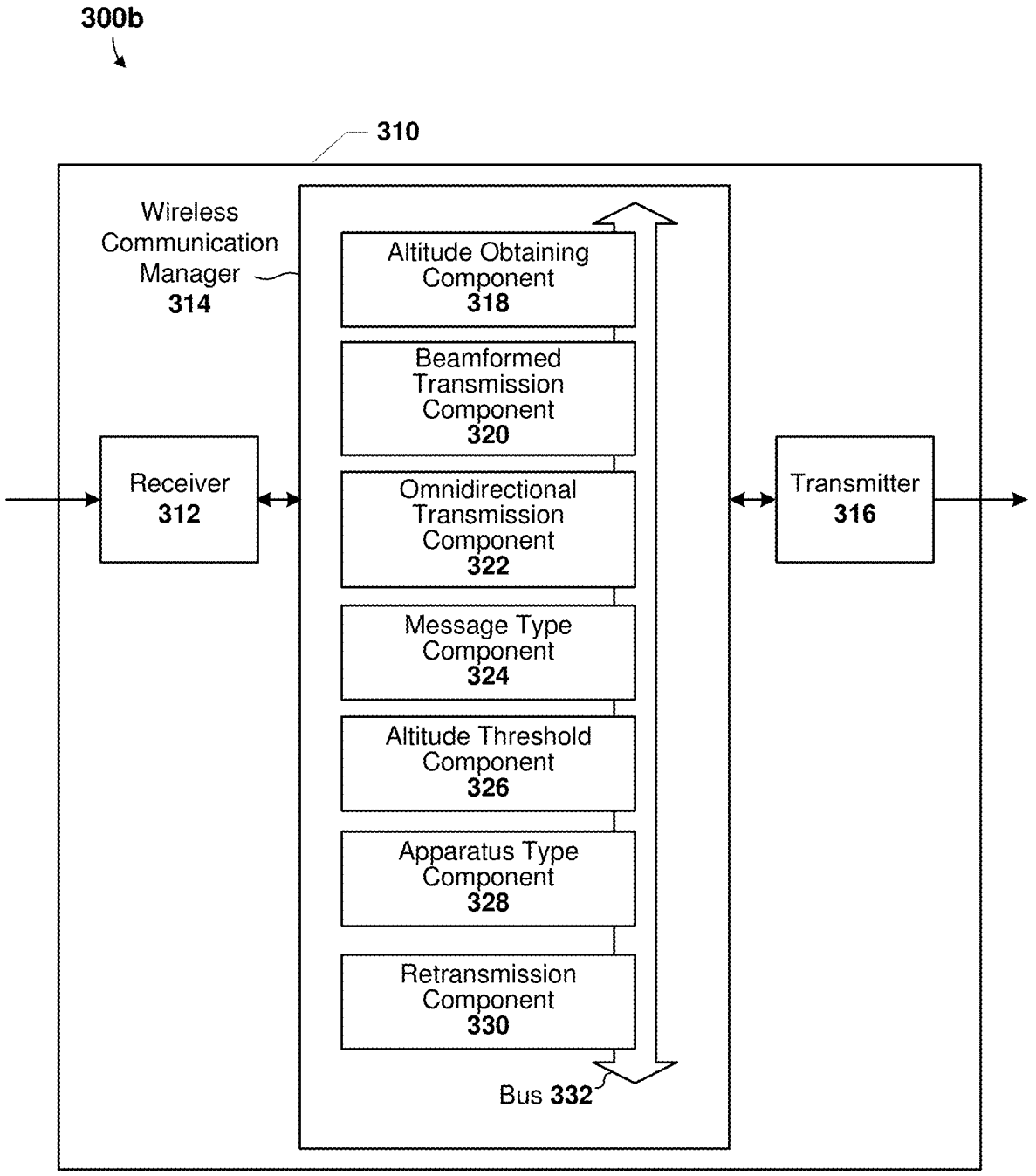

300b
310
Wireless Communication Manager 314
Receiver 312
Transmitter 316
Altitude Obtaining Component 318
Beamformed Transmission Component 320
Omnidirectional Transmission Component 322
Message Type Component 324
Altitude Threshold Component 326
Apparatus Type Component 328
Retransmission Component 330
Bus 332

FIG. 3B

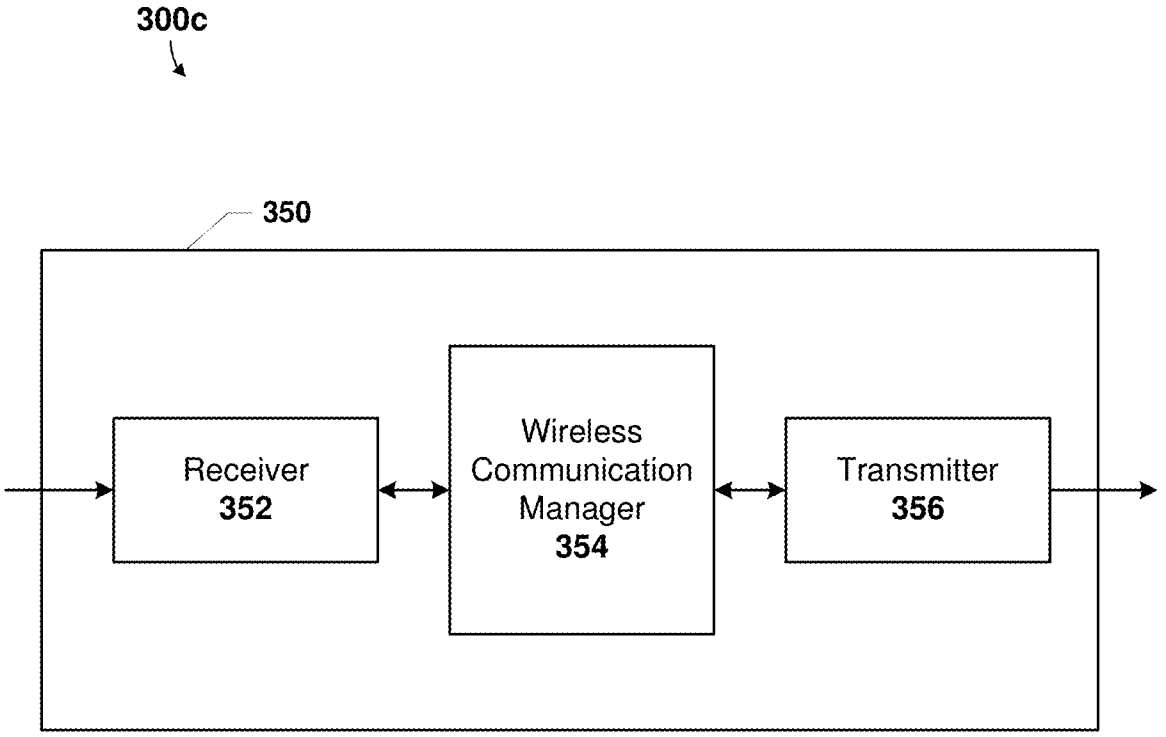

300c
350
Receiver
352
Wireless
Communication
Manager
354
Transmitter
356

FIG. 3C

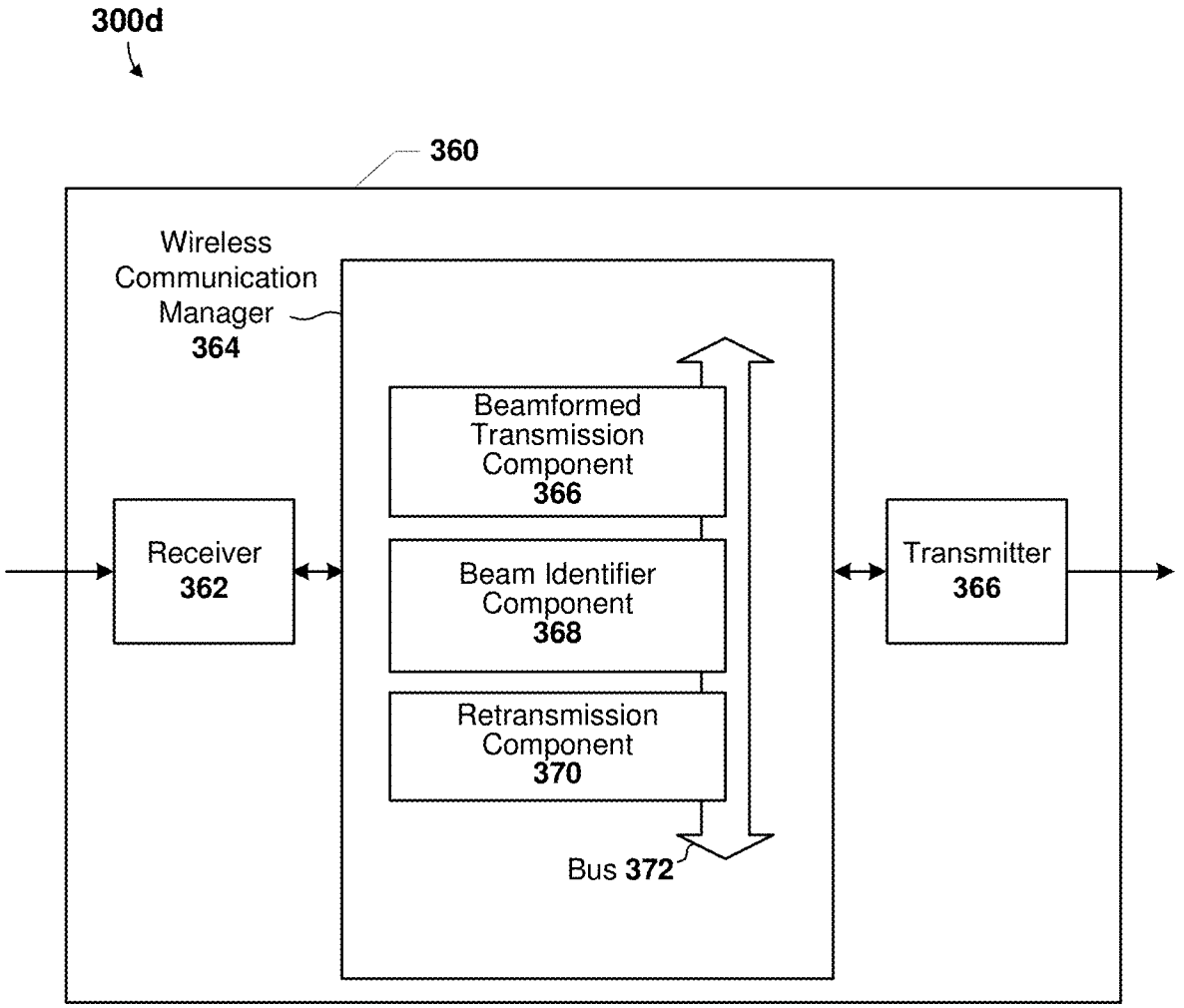

300d
360
Wireless Communication Manager 364
Beamformed Transmission Component 366
Receiver 362
Beam Identifier Component 368
Transmitter 366
Retransmission Component 370
Bus 372

FIG. 3D

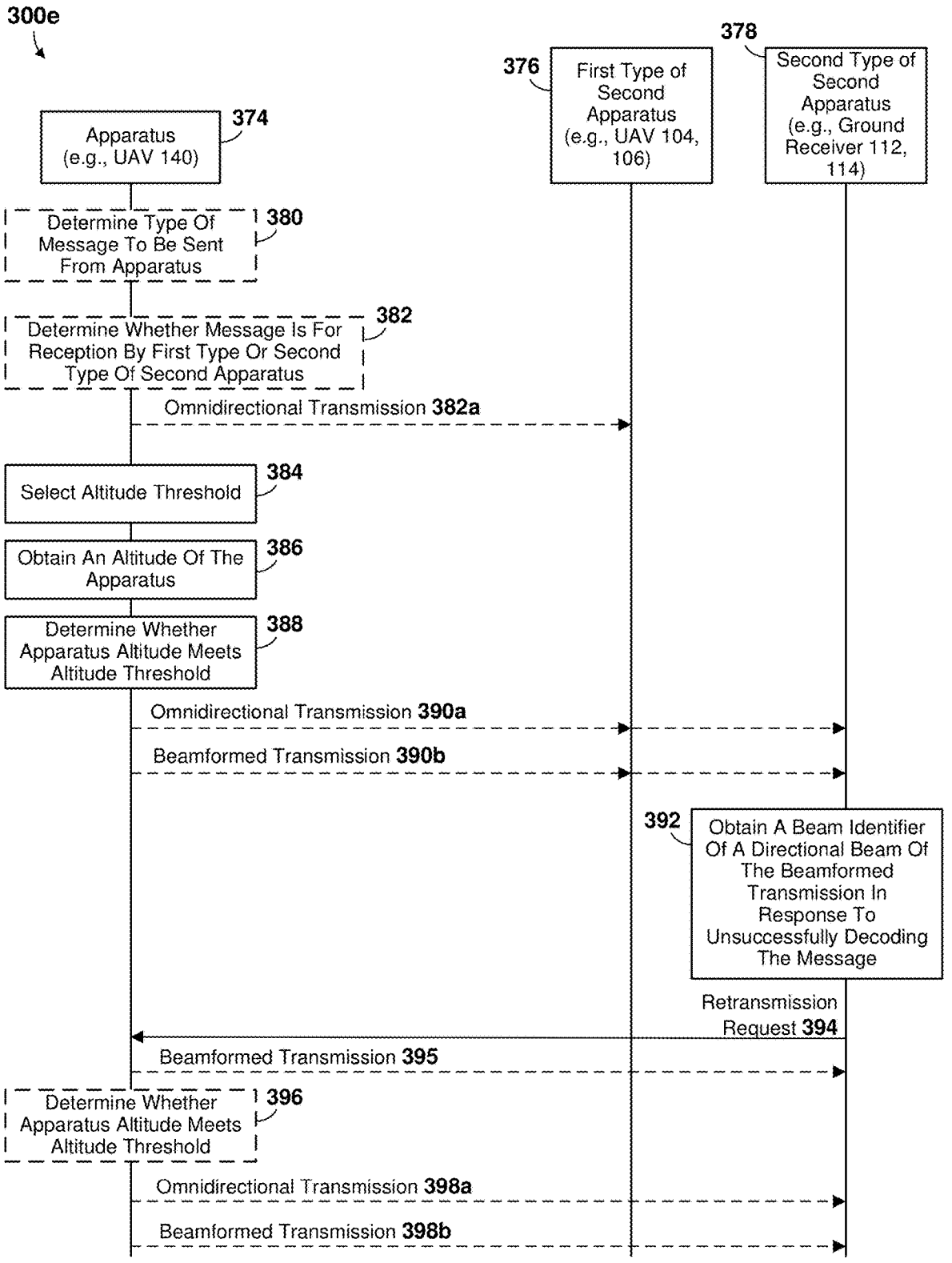

300e
Apparatus (e.g., UAV 140)
374
First Type of Second Apparatus (e.g., UAV 104, 106)
376
Second Type of Second Apparatus (e.g., Ground Receiver 112, 114)
378
Determine Type Of Message To Be Sent From Apparatus
380
Determine Whether Message Is For Reception By First Type Or Second Type Of Second Apparatus
382
Omnidirectional Transmission 382a
Select Altitude Threshold
384
Obtain An Altitude Of The Apparatus
386
Determine Whether Apparatus Altitude Meets Altitude Threshold
388
Omnidirectional Transmission 390a
Beamformed Transmission 390b
392
Obtain A Beam Identifier Of A Directional Beam Of The Beamformed Transmission In Response To Unsuccessfully Decoding The Message
Retransmission Request 394
Beamformed Transmission 395
Determine Whether Apparatus Altitude Meets Altitude Threshold
396
Omnidirectional Transmission 398a
Beamformed Transmission 398b

FIG. 3E

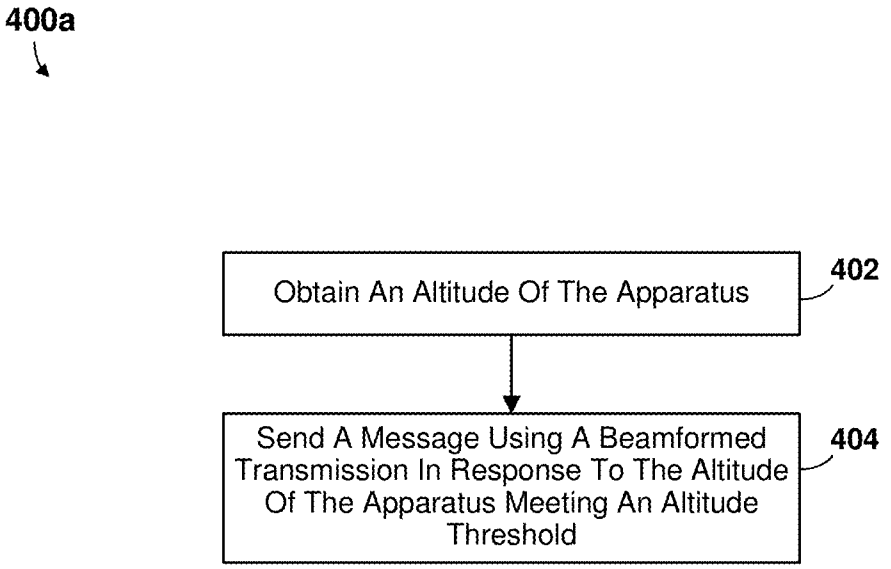

400a
Obtain An Altitude Of The Apparatus
402
Send A Message Using A Beamformed Transmission In Response To The Altitude Of The Apparatus Meeting An Altitude Threshold
404

FIG. 4A

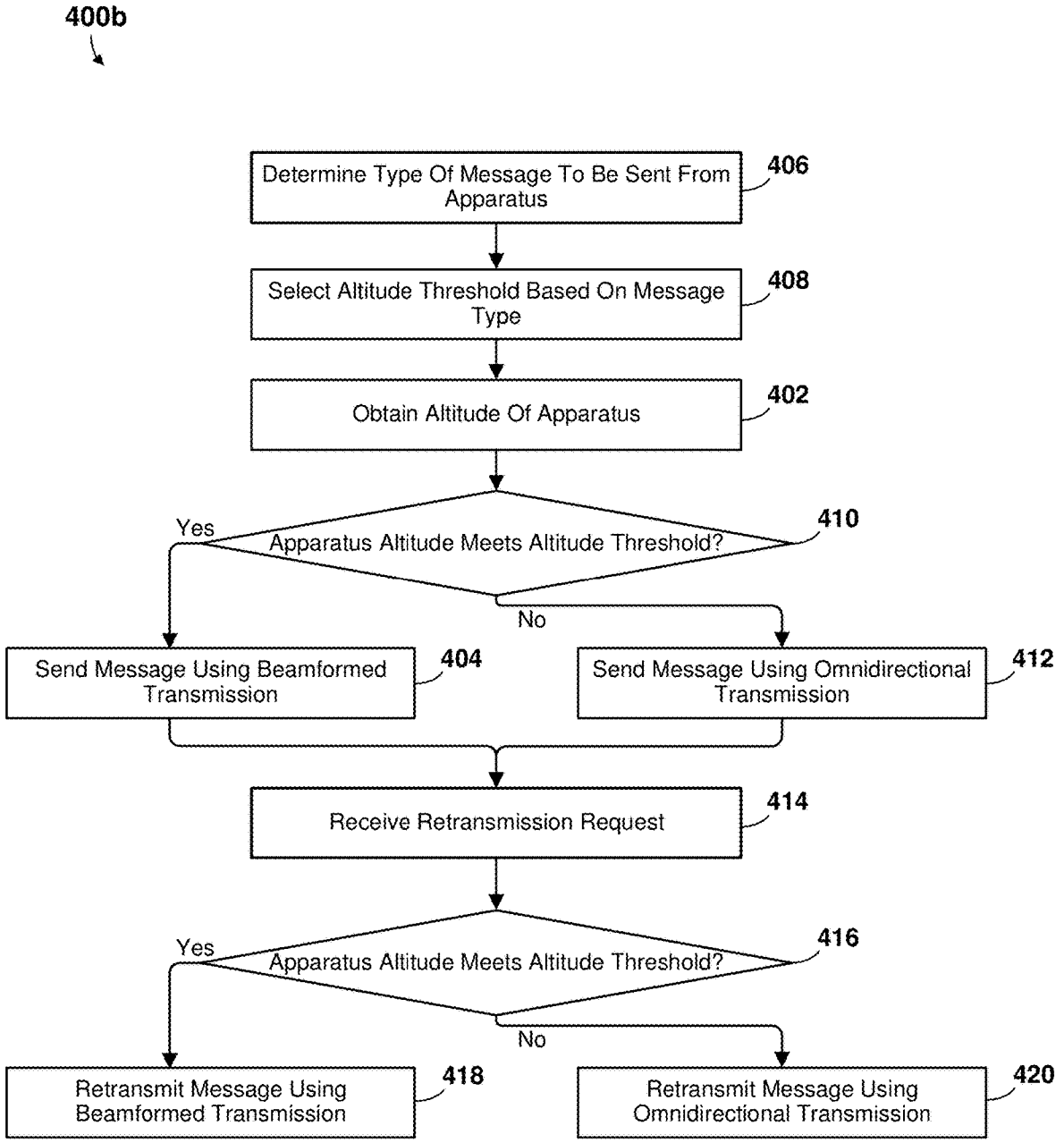

400b
Determine Type Of Message To Be Sent From Apparatus
406
Select Altitude Threshold Based On Message Type
408
Obtain Altitude Of Apparatus
402
Yes
Apparatus Altitude Meets Altitude Threshold?
410
No
Send Message Using Beamformed Transmission
404
Send Message Using Omnidirectional Transmission
412
Receive Retransmission Request
414
Yes
Apparatus Altitude Meets Altitude Threshold?
416
No
Retransmit Message Using Beamformed Transmission
418
Retransmit Message Using Omnidirectional Transmission
420

FIG. 4B

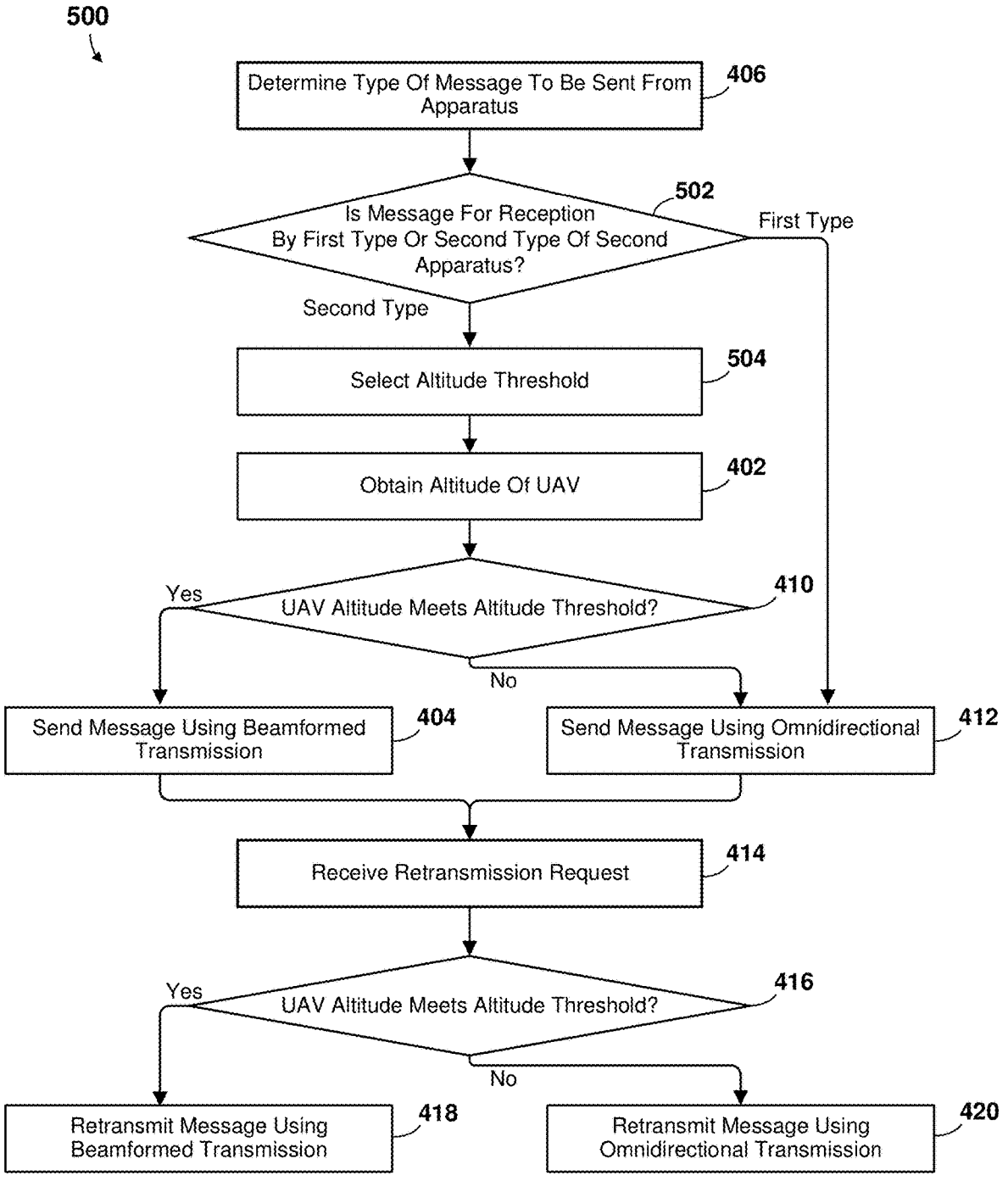

500
Determine Type Of Message To Be Sent From Apparatus
406
Is Message For Reception By First Type Or Second Type Of Second Apparatus?
502
First Type
Second Type
Select Altitude Threshold
504
Obtain Altitude Of UAV
402
Yes
UAV Altitude Meets Altitude Threshold?
410
No
Send Message Using Beamformed Transmission
404
Send Message Using Omnidirectional Transmission
412
Receive Retransmission Request
414
Yes
UAV Altitude Meets Altitude Threshold?
416
No
Retransmit Message Using Beamformed Transmission
418
Retransmit Message Using Omnidirectional Transmission
420

FIG. 5

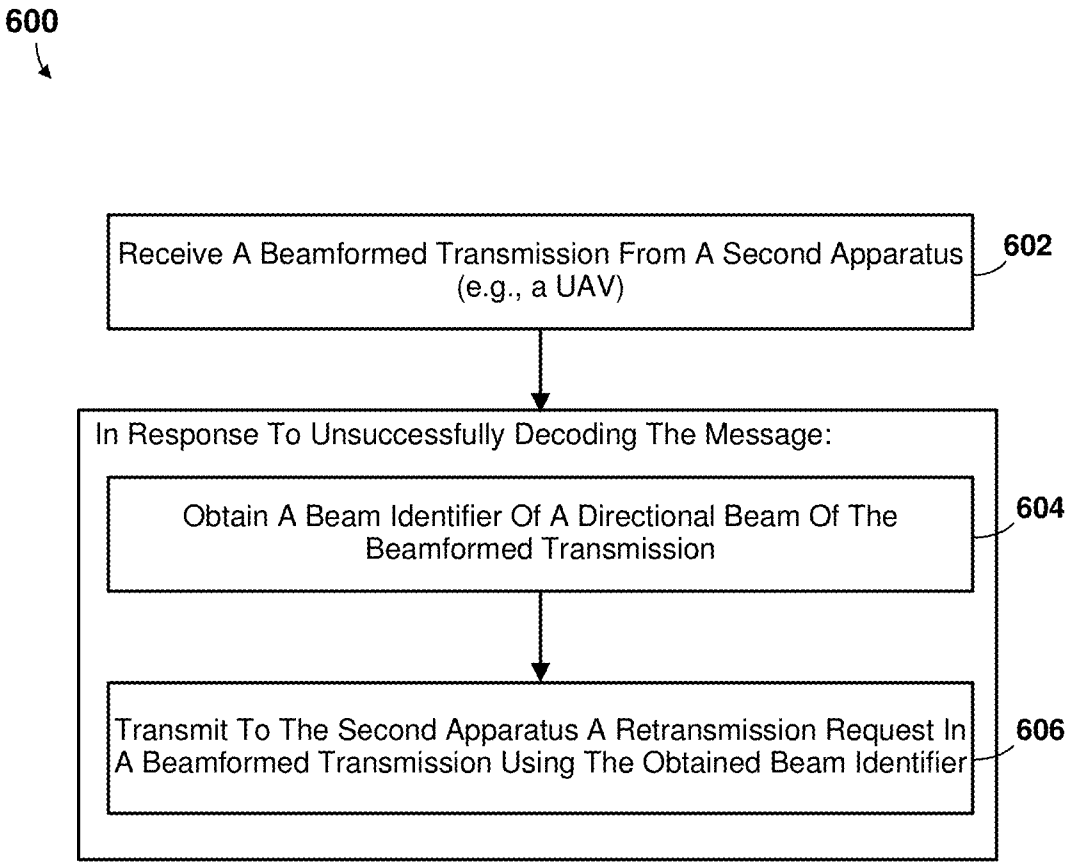

600
Receive A Beamformed Transmission From A Second Apparatus (e.g., a UAV)
602
In Response To Unsuccessfully Decoding The Message:
Obtain A Beam Identifier Of A Directional Beam Of The Beamformed Transmission
604
Transmit To The Second Apparatus A Retransmission Request In A Beamformed Transmission Using The Obtained Beam Identifier
606

FIG. 6

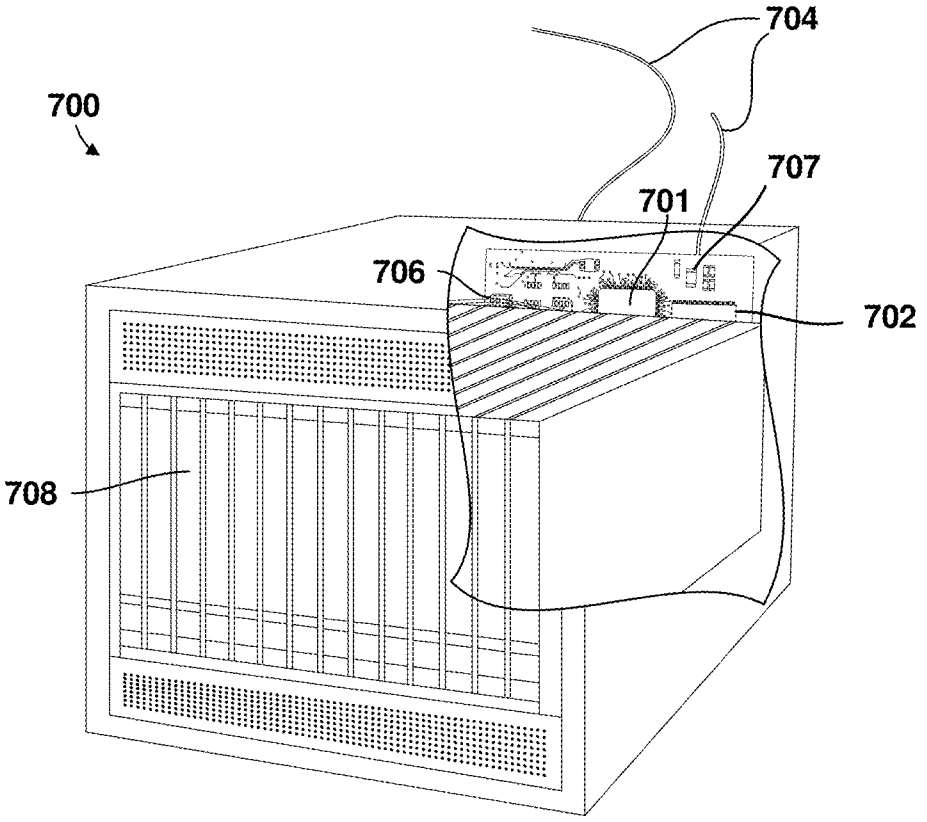


FIG. 7

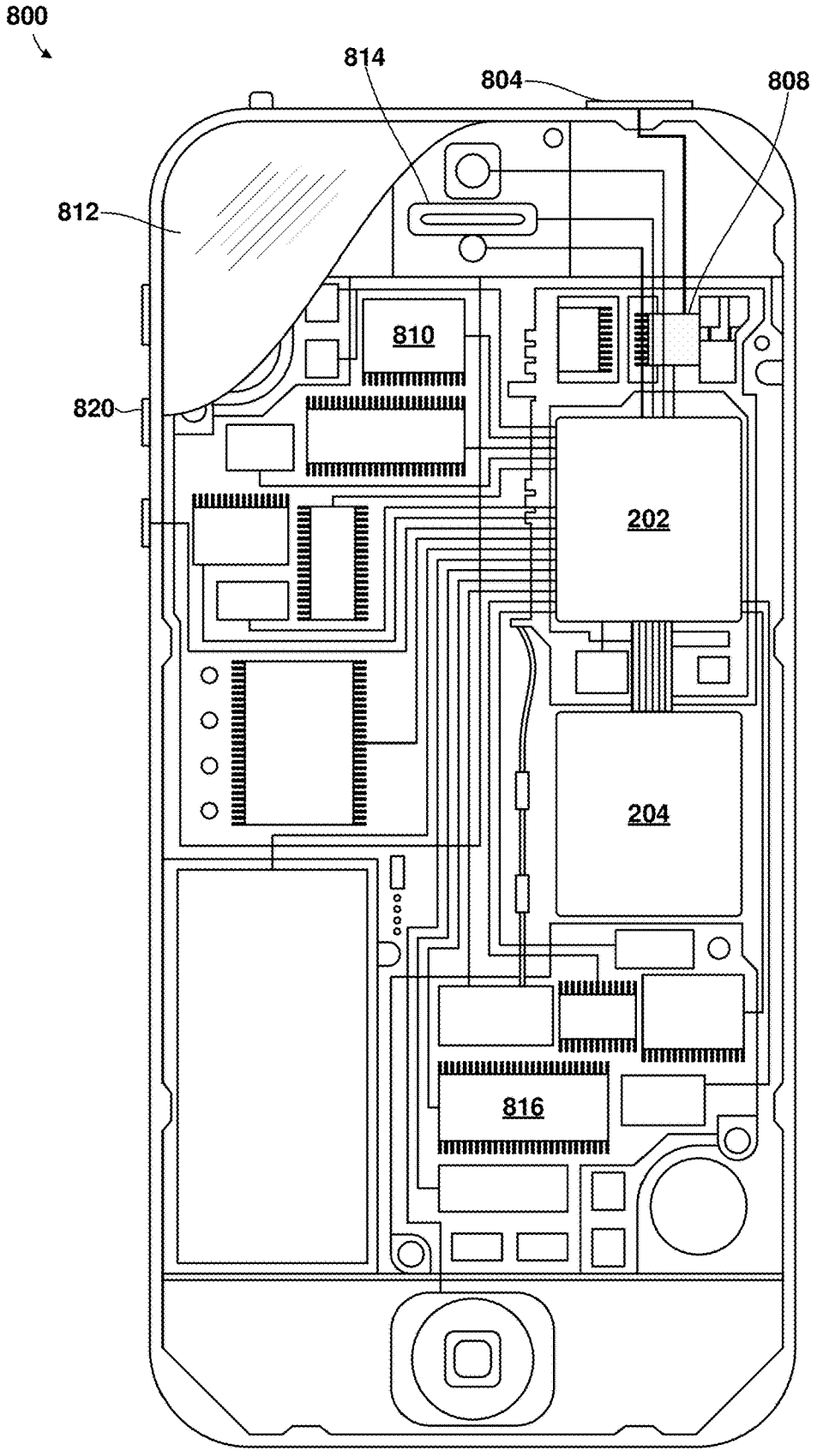


FIG. 8

MANAGING UNMANNED AERIAL VEHICLE BROADCAST SIGNALS

INTRODUCTION

[0001] The following relates generally to wireless communications, and more specifically to managing wireless communications of an apparatus based at least in part on the altitude of the apparatus.

[0002] Apparatuses configured for wireless communication, for example, unmanned aerial vehicles (UAV), may transmit various messages to support a variety of functions. Different messages may be subject to different requirements for communications, such as range and latency. There exists a need for further improvements in wireless communication by such apparatuses.

SUMMARY

[0003] This summary is a simplified summation of one or more aspects presented to provide a basic understanding of such aspects. This summary is not an extensive overview of all aspects contemplated, is not intended to identify key or critical elements of all aspects, and is not meant to delineate the scope of any or all aspects. This summary's sole purpose is to present some aspects in a simplified form as a prelude to the more detailed description that is presented later.

[0004] Various aspects may include a method performed for managing a broadcast signal. The method may include obtaining an altitude of the apparatus, and sending a message using beamformed transmissions in response to the altitude of the apparatus meeting an altitude threshold.

[0005] Another apparatus for wireless communication is described. The apparatus may include a memory and a processor, the memory and the processor configured to obtain an altitude of the apparatus, and send a message using beamformed transmissions in response to the altitude of the apparatus meeting an altitude threshold.

[0006] Some examples of the method, apparatuses, and non-transitory processor readable storage medium described herein may include operations, features, means, or instructions for sending the message using omnidirectional transmissions in response to the altitude of the apparatus failing to meet the altitude threshold.

[0007] Some examples of the method, apparatuses, and non-transitory processor readable storage medium described herein may include obtaining the altitude of the apparatus from one or more of an altitude sensor, apparatus barometer information, a global navigation satellite system receiver, or a network element that provides the altitude of the apparatus.

[0008] Some examples of the method, apparatuses, and non-transitory processor readable storage medium described herein may include determining a type of the message, and selecting the altitude threshold based on the determined type of the message.

[0009] Some examples of the method, apparatuses, and non-transitory processor readable storage medium described herein may include sending the message using omnidirectional transmissions in response to the message being for reception by a first type of second apparatus, and sending the message using beamformed transmissions in response to the message being for reception by the second type of second apparatus.

[0010] In some examples of the method, apparatuses, and non-transitory processor readable storage medium described herein, sending the message using beamformed transmissions in response to the message being for reception by the second type of second apparatus may include sending the message using beamformed transmissions in response to the message being for reception by the second type of second apparatus and the altitude meeting the altitude threshold.

[0011] In some examples of the method, apparatuses, and non-transitory processor readable storage medium described herein the message for reception by the first type of second apparatus may include a maneuvering safety message and the message for reception by the second type of second apparatus may include an identification message.

[0012] Some examples of the method, apparatuses, and non-transitory processor readable storage medium described herein may include sending the message using beamformed transmissions in directional beams in at least two different directions.

[0013] Some examples of the method, apparatuses, and non-transitory processor readable storage medium described herein may include sending the message using beamformed transmissions in directional beams in at least two different directions within a latency constraint of the message.

[0014] Some examples of the method, apparatuses, and non-transitory processor readable storage medium described herein may include sending the message using beamformed transmissions in directional beams in at least two different directions via a sidelink communication link.

[0015] Some examples of the method, apparatuses, and non-transitory processor readable storage medium described herein may include including in beamformed transmissions a beam identifier that enables a receiver device to obtain the beam identifier of a directional beam used to transmit a received beamformed transmission.

[0016] Some examples of the method, apparatuses, and non-transitory processor readable storage medium described herein may include receiving from a second apparatus a retransmission request including the beam identifier of the received beamformed transmission, and retransmitting the message using beamformed transmissions associated with the beam identifier.

[0017] Some examples of the method, apparatuses, and non-transitory processor readable storage medium described herein may include receiving from a second apparatus a retransmission request, and retransmitting the message using omnidirectional transmissions when the altitude of the apparatus fails to meet the altitude threshold.

[0018] Some examples of the method, apparatuses, and non-transitory processor readable storage medium described herein may include retransmitting the message using beamformed transmissions when the altitude of the apparatus meets the altitude threshold.

[0019] An apparatus is described. The apparatus may include memory, and a processor, the memory and the processor configured to receive beamformed transmissions from a second apparatus, obtain a beam identifier of a directional beam of beamformed transmissions in response to unsuccessfully decoding the message, and transmit to the second apparatus a retransmission request in beamformed transmissions using the obtained beam identifier.

[0020] A method for managing a broadcast signal is described. The method may include obtaining an altitude of the apparatus, and sending a message using beamformed transmissions in response to the altitude of the apparatus meeting an altitude threshold.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021] The accompanying drawings, which are incorporated herein and constitute part of this specification, illustrate exemplary implementations and aspects of the claims, and together with the general description given above and the detailed description given below, serve to explain the features of the claims.

[0022] FIG. **1**A is a system block diagram illustrating an example communication system suitable for implementing any of the various aspects.

[0023] FIG. **1**B is a conceptual diagram illustrating aspects of a system for managing a broadcast signal of an apparatus suitable for implementing various implementations and aspects.

[0024] FIG. **1**C is a component block diagram illustrating examples component of an apparatus suitable for implementing various implementations and aspects.

[0025] FIG. **2** is a component block diagram illustrating an example computing and wireless modem system suitable for implementing various implementations and aspects.

[0026] FIG. **3**A illustrates a block diagram of a device that supports managing a broadcast signal according to various aspects.

[0027] FIG. **3**B illustrates a block diagram of a device that supports managing a broadcast signal according to various aspects.

[0028] FIG. **3**C illustrates a block diagram of a device that supports managing a broadcast signal according to various aspects.

[0029] FIG. **3**D illustrates a block diagram of a device that supports managing a broadcast signal according to various aspects.

[0030] FIG. **3**E illustrates example operations of a process flow that supports that supports managing a broadcast signal according to various aspects.

[0031] FIG. **4**A is a process flow diagram illustrating a method that may be performed by a processor of an apparatus for managing a broadcast signal according to various implementations and aspects.

[0032] FIG. **4**B is a process flow diagram illustrating a method that may be performed by a processor of an apparatus for managing a broadcast signal according to various implementations and aspects.

[0033] FIG. **5** is a process flow diagram illustrating operations that may be performed by a processor of an apparatus as part of the methods for managing a broadcast signal according to various implementations and aspects.

[0034] FIG. **6** is a process flow diagram illustrating a method that may be performed by a processor of an apparatus for managing a broadcast signal of a second apparatus according to various implementations and aspects.

[0035] FIG. **7** is a component block diagram of a network computing device suitable for use with various implementations and aspects.

[0036] FIG. **8** is a component block diagram illustrating an example apparatus suitable for use with various implementations and aspects.

DETAILED DESCRIPTION

[0037] Apparatuses configured for wireless communication, for example, unmanned aerial vehicles (UAVs), may transmit various messages to support a variety of functions. For example, an apparatus may broadcast a "maneuvering safety message," such as a Detect and Avoid message (e.g., UAV-to-Everything Detect and Avoid (U2X-DAA)) to enable other apparatuses (e.g., other UAVs) to detect and avoid collisions. As another example, an apparatus may broadcast identification and location information, for example, for use by law enforcement or other official agencies. Other examples of wireless communications to or from another apparatus (e.g., a UAV) include data messages such as camera or other sensor information, maneuvering messages such as swarm behavior messages, and other suitable apparatus-to-apparatus communications. One example of wireless communications to or a from another apparatus (e.g., a ground receiver) is a message including identity information and/or location information of the apparatus (referred to herein as an "identification message"), which may be used by automated or semi-automated air traffic control systems, governmental agencies such as law enforcement, and the like. An example of an identification message is a U2X-ID message.

[0038] In some situations, different types of messages may be subject to varying parameters regarding their transmissions. For example, certain maneuvering safety messages by regulation should be transmitted to terrestrial devices of law enforcement or other official agencies. As another example, a maneuvering safety message and an identification message may be subject to different latency requirements by regulation. For instance, a maneuvering safety message may be required by regulation to be transmitted more frequently than an identification message. As another example, a longer transmission range may be required by regulation of an identification message (which may be required for ground receiving apparatuses) than a transmission range for a maneuvering safety message. As another example, maneuvering safety messages may be required by regulation to be transmitted more frequently than identification messages.

[0039] Various aspects include systems methods, devices, and non-transitory processor readable storage mediums for managing broadcast signals transmitted by an apparatus. In various aspects, based on whether an altitude of an apparatus meets an altitude threshold, the apparatus may transmit (or configure a message for transmission by the apparatus) as either omnidirectional transmissions or as beamformed transmissions. In some aspects, based on a type of message to be transmitted and whether an altitude of an apparatus meets an altitude threshold, the apparatus may transmit (or configure a message for transmission by the apparatus) as either omnidirectional transmissions or as beamformed transmissions. In some aspects, the apparatus may transmit beamformed transmissions in a plurality of directions from the apparatus, such as in four quadrants, or in a plurality of directions from the apparatus in response to the altitude of the apparatus meeting the altitude threshold.

[0040] Wireless communications between apparatuses (e.g., UAVs) that operate at varying altitudes and/or distances from other apparatuses (e.g., other UAVs, ground stations, controllers, and the like) may experience various effects due to separation distances. For example, UAVs operating at high altitude may experience signal attenuation in omnidirectional wireless transmissions with ground stations. For battery-powered apparatuses (e.g., UAVs), increasing transmit power to overcome distance-related attenuation may be impractical. Communicating using beam-formed transmissions may increase gain along the beam axis, and thus extend the range at which such trans-

missions may be received. However, the use of beamforming in communications may not be suitable in all operating situations. Various implementations and aspects address these communication tradeoffs by selecting beamforming or omnidirectional transmission methods for apparatus communications based on altitude and/or type of communication. Selecting between omnidirectional and beamforming transmission techniques based on altitude and/or communication type may improve the communication performance of apparatuses (e.g., UAVs) while conserving power.

[0041] While the description refers at times to a UAV, it will be understood that a UAV is merely one type of apparatus according to various implementations and aspects. Further, a UAV may include one of various types of vehicles including an onboard computing device configured to provide some autonomous or semi-autonomous capabilities. Examples of such vehicles include but are not limited to: aerial vehicles, such as UAVs; ground vehicles (e.g., an autonomous or semi-autonomous car, a vacuum robot, etc.); water-based vehicles (i.e., vehicles configured for operation on the surface of the water or under water); and/or some combination thereof. In some implementations and aspects, the vehicle may be manned. In other implementations and aspects, the vehicle may be unmanned. In implementations and aspects in which the vehicle is autonomous, the vehicle may include an onboard computing device configured to maneuver and/or navigate the vehicle without remote operating instructions (i.e., autonomously), such as from a human operator (e.g., via a remote computing device). In implementations and aspects in which the vehicle is semi-autonomous, the vehicle may include an onboard computing device configured to receive some information or instructions, such as from a human operator (e.g., via a remote computing device), and autonomously maneuver and/or navigate the vehicle consistent with the received information or instructions. In some implementations and aspects, the vehicle may be an aerial vehicle (unmanned or manned), which may be a rotorcraft or winged aircraft. For example, a rotorcraft (also referred to as a multirotor or multicopter) may include a plurality of propulsion units (e.g., rotors/propellers) that provide propulsion and/or lifting forces for the vehicle. Non-limiting examples of rotorcraft include tricopters (three rotors), quadcopters (four rotors), hexacopters (six rotors), and octocopters (eight rotors). However, a rotorcraft may include any number of rotors. A vehicle may include a variety of components and/or payloads that may perform a variety of functions. The term "components" when used with respect to a vehicle includes vehicle components and/or vehicle payloads.

[0042] Various aspects will be described in detail with reference to the accompanying drawings. Wherever possible, the same reference numbers will be used throughout the drawings to refer to the same or like parts. References made to particular examples and implementations and aspects are for illustrative purposes, and are not intended to limit the scope of the claims.

[0043] The term "system on chip" (SOC) is used herein to refer to a single integrated circuit (IC) chip that contains multiple resources or processors integrated on a single substrate. A single SOC may contain circuitry for digital, analog, mixed-signal, and radio-frequency functions. A single SOC also may include any number of general purpose or specialized processors (digital signal processors, modem processors, video processors, etc.), memory blocks (such as ROM, RAM, Flash, etc.), and resources (such as timers, voltage regulators, oscillators, etc.). SOCs also may include software for controlling the integrated resources and processors, as well as for controlling peripheral devices.

[0044] The term "system in a package" (SIP) may be used herein to refer to a single module or package that contains multiple resources, computational units, cores or processors on two or more IC chips, substrates, or SOCs. For example, a SIP may include a single substrate on which multiple IC chips or semiconductor dies are stacked in a vertical configuration. Similarly, the SIP may include one or more multi-chip modules (MCMs) on which multiple ICs or semiconductor dies are packaged into a unifying substrate. A SIP also may include multiple independent SOCs coupled together via high speed communication circuitry and packaged in close proximity, such as on a single motherboard or in a single wireless device. The proximity of the SOCs facilitates high speed communications and the sharing of memory and resources.

[0045] As used herein, the terms "network," "system," "wireless network," "cellular network," and "wireless communication network" may interchangeably refer to a portion or all of a wireless network of a carrier associated with a wireless device and/or subscription on a wireless device. The techniques described herein may be used for various wireless communication networks, such as Code Division Multiple Access (CDMA), time division multiple access (TDMA), FDMA, orthogonal FDMA (OFDMA), single carrier FDMA (SC-FDMA) and other networks. In general, any number of wireless networks may be deployed in a given geographic area. Each wireless network may support at least one radio access technology, which may operate on one or more frequency or range of frequencies. For example, a CDMA network may implement Universal Terrestrial Radio Access (UTRA) (including Wideband Code Division Multiple Access (WCDMA) standards), CDMA2000 (including IS-2000, IS-95 and/or IS-856 standards), etc. In another example, a TDMA network may implement GSM Enhanced Data rates for GSM Evolution (EDGE). In another example, an OFDMA network may implement Evolved UTRA (E-UTRA) (including LTE standards), Institute of Electrical and Electronics Engineers (IEEE) 802.11 (WiFi), IEEE 802.16 (WiMAX), IEEE 802.20, Flash-OFDM, etc. Reference may be made to wireless networks that use LTE standards, and therefore the terms "Evolved Universal Terrestrial Radio Access," "E-UTRAN" and "eNodeB" may also be used interchangeably herein to refer to a wireless network. However, such references are provided merely as examples, and are not intended to exclude wireless networks that use other communication standards. For example, while various Third Generation (3 G) systems, Fourth Generation (4G) systems, and Fifth Generation (5G) systems are discussed herein, those systems are referenced merely as examples and future generation systems (e.g., sixth generation (6G) or higher systems) may be substituted in the various examples.

[0046] As used herein, "beam" refers to a signal formed at a transmitting device through the use of a beamforming or beam steering technique applied via a combination of physical equipment and signal processing variously referred to as a beamforming function, a mapping function, or a spatial filter. Beam reception by a receiving device may involve configuring physical equipment and signal processing of the receiving device to receive signals transmitted in a beam by

the transmitting device. In some situations, beam reception by a receiving device also may involve configuring physical equipment and signal processing of the receiving device via a beamforming function, a mapping function, or a spatial filter so as to preferentially receive signals (e.g., with enhanced gain) from a particular direction (e.g., in a direction aligned with a transmitting device).

[0047] The term "beamforming" is used herein to refer to antenna array design and signal processing techniques used for directional signal communications and/or to achieve spatial selectivity of radio frequency (RF) signal reception. Beamforming on the transmitter end of communications may be accomplished by selective delaying (known as "phase shifting") of signals coupled to different elements in an antenna array so that RF signals emitted by the antenna array at a particular angle (relative to the antenna array) are enhanced through constructive interference while RF signals emitted by the antenna array at other angles (relative to the antenna) exhibit lower signal strength due to destructive interference. Beamforming on the receiver end of communications may be accomplished by processing signals received by elements in an antenna array through phase shifting circuits so that RF signals received at particular angles relative to the receiving antenna array are enhanced through constructive interference while RF signals received at other angles relative to the wireless device are reduced in perceived signal strength through destructive interference. Using beamforming techniques, RF signals may be transmitted (e.g., by a base station or wireless device) in one or more directional "beams" within the millimeter band for ultra-wideband communications. Each of such directional beams may be controlled by the transmitter using beamforming techniques to sweep in one or two dimensions (i e, azimuth and elevation directions). Beamforming in both transmitters and receivers may be accomplished using analog (e.g., phase shifter) circuits and digital processing techniques. To encompass both techniques, reference is sometimes made herein to "analog/RF beamforming" techniques and equipment.

[0048] FIG. **1**A is a system block diagram illustrating an example communication system **100***a* suitable for implementing any of the various aspects or implementations. The communications system **100***aa* may be a 5G New Radio (NR) network, or any other suitable network such as an LTE network, 5G network, etc. While FIG. **1**A illustrates a 5G network, later generation networks may include the same or similar elements. Therefore, the reference to a 5G network and 5G network elements in the following descriptions is for illustrative purposes and is not intended to be limiting.

[0049] The communications system **100***a* may include a heterogeneous network architecture that includes a core network **135** and a variety of wireless devices (illustrated as UEs **120** in FIG. **1**A). In various implementations and aspects, the wireless devices **120** may include apparatuses such as UAVs. The communications system **100***a* may also include a number of base stations (illustrated as the BS **110**, the BS **110***b*, the BS **110***c*, and the BS **110***d*) and other network entities. A base station is an entity that communicates with wireless devices, and also may be referred to as a Node B, an LTE Evolved nodeB (eNodeB or eNB), an access point (AP), a Radio head, a transmit receive point (TRP), a New Radio base station (NR BS), a 5G NodeB (NB), a Next Generation NodeB (gNodeB or gNB), or the like. Each base station may provide communication coverage for a particular geographic area. In 3GPP, the term "cell" can refer to a coverage area of a base station, a base station Subsystem serving this coverage area, or a combination thereof, depending on the context in which the term is used. The core network **135** may be any type core network, such as an LTE core network (e.g., an Evolved Packet Core (EPC) network), 5G core network, etc.

[0050] A base station **110**-**110***d* may provide communication coverage for a macro cell, a pico cell, a femto cell, another type of cell, or a combination thereof. A macro cell may cover a relatively large geographic area (for example, several kilometers in radius) and may allow unrestricted access by mobile devices with service subscription. A pico cell may cover a relatively small geographic area and may allow unrestricted access by mobile devices with service subscription. A femto cell may cover a relatively small geographic area (for example, a home) and may allow restricted access by mobile devices having association with the femto cell (for example, mobile devices in a closed subscriber group (CSG)). A base station for a macro cell may be referred to as a macro BS. A base station for a pico cell may be referred to as a pico BS. A base station for a femto cell may be referred to as a femto BS or a home BS. In the example illustrated in FIG. **1**A, a base station **110** may be a macro BS for a macro cell **102***a*, a base station **110***b* may be a pico BS for a pico cell **102***b*, and a base station **110***c* may be a femto BS for a femto cell **102***c*. A base station **110** **110***d* may support one or multiple (for example, three) cells. The terms "eNB", "base station", "NR BS", "gNB", "TRP", "AP", "node B", "5G NB", and "cell" may be used interchangeably herein.

[0051] In some examples, a cell may not be stationary, and the geographic area of the cell may move according to the location of a mobile base station. In some examples, the base stations **110**-**110***d* may be interconnected to one another as well as to one or more other base stations or network nodes (not illustrated) in the communications system **100***a* through various types of backhaul interfaces, such as a direct physical connection, a virtual network, or a combination thereof using any suitable transport network

[0052] The base station **110**-**110***d* may communicate with the core network **135** over a wired or wireless communication link **126**. The wireless devices **120** may communicate with the base station **110**-**110***d* over a wireless communication link **122**. In some implementations and aspects, the base station **110** may be a non-mmW cell (e.g., LTE cell, Sub-6 GHz cell, etc.). In some implementations and aspects, the base station **110** may be a mmW cell (e.g., a gNB operating at mmW frequencies). In scenarios in which the base station **110** is a mmW cell, the base station **110** may utilize beamforming for communications with the wireless device **120**. In a similar manner, the wireless device **120** (e.g., an apparatus such as a UAV) may utilize beamforming for communications with the base station **110**. The base station **110** may transmit a beamformed signal, such as a mmW beam, in one or more transmit directions **122***b*. The wireless device **120** may receive the beamformed signal from the base station **110** in one or more receive directions **122***a*. The wireless device **120** may transmit a beamformed signal, such as a mmW beam, in one or more transmit directions. The base station **110** may receive the beamformed signal from the wireless device in one or more receive directions. The base station **110** and/or wireless device **120** may perform beam training and configuration operations to select receive

and/or transmit beam directions for each of the base station **110** and/or wireless device **120**. The transmit and receive directions for the base station **110** and/or wireless device **120** may be the same or the transmit and receive directions for the base station **110** and/or wireless device **120** may be different.

[0053] The wired communication link **126** may use a variety of wired networks (e.g., Ethernet, TV cable, telephony, fiber optic and other forms of physical network connections) that may use one or more wired communication protocols, such as Ethernet, Point-To-Point protocol, High-Level Data Link Control (HDLC), Advanced Data Communication Control Protocol (ADCCP), and Transmission Control Protocol/Internet Protocol (TCP/IP).

[0054] The communications system **100***a* also may include relay stations (e.g., relay BS **110***d*). A relay station is an entity that can receive a transmission of data from an upstream station (for example, a base station or a mobile device) and transmit the data to a downstream station (for example, a wireless device or a base station). A relay station also may be a mobile device that can relay transmissions for other wireless devices. In the example illustrated in FIG. **1**A, a relay station **110***d* may communicate with macro the base station **110** and the wireless device **120** in order to facilitate communication between the base station **110** and the wireless device **120**. A relay station also may be referred to as a relay base station, a relay base station, a relay, etc.

[0055] The communications system **100***a* may be a heterogeneous network that includes base stations of different types, for example, macro base stations, pico base stations, femto base stations, relay base stations, etc. These different types of base stations may have different transmit power levels, different coverage areas, and different impacts on interference in communications system **100***a*. For example, macro base stations may have a high transmit power level (for example, 5 to 40 Watts) whereas pico base stations, femto base stations, and relay base stations may have lower transmit power levels (for example, 0.1 to 2 Watts).

[0056] A network controller **132** may couple to a set of base stations and may provide coordination and control for these base stations. The network controller **132** may communicate with the base stations via a backhaul. The base stations also may communicate with one another, for example, directly or indirectly via a wireless or wireline backhaul.

[0057] The wireless devices **120** may be dispersed throughout communications system **100***a*, and each wireless device may be stationary or mobile. A wireless device also may be referred to as an access terminal, a terminal, a mobile station, a subscriber unit, a station, user equipment (UE), etc.

[0058] A macro base station **110** may communicate with the communication network **135** over a wired or wireless communication link **126**. The wireless devices **120** may communicate with a base station **110-110***d* over a wireless communication link **122**.

[0059] The wireless communication links **122**, **124** may include a plurality of carrier signals, frequencies, or frequency bands, each of which may include a plurality of logical channels. The wireless communication links **122** and **124** may utilize one or more Radio access technologies (RATs). Examples of RATs that may be used in a wireless communication link include 3GPP LTE, 3G, 4G, 5G (e.g., NR), GSM, CDMA, WCDMA, Worldwide Interoperability for Microwave Access (WiMAX), Time Division Multiple Access (TDMA), and other mobile telephony communication technologies cellular RATs. Further examples of RATs that may be used in one or more of the various wireless communication links **122**, **124** within the communication system **100***a* include medium range protocols such as Wi-Fi, LTE-U, LTE-Direct, LAA, MuLTEfire, and relatively short range RATs such as ZigBee, Bluetooth, and Bluetooth Low Energy (LE).

[0060] Certain wireless networks (e.g., LTE) utilize orthogonal frequency division multiplexing (OFDM) on the downlink and single-carrier frequency division multiplexing (SC-FDM) on the uplink. OFDM and SC-FDM partition the system bandwidth into multiple (K) orthogonal subcarriers, which are also commonly referred to as tones, bins, etc. Each subcarrier may be modulated with data. In general, modulation symbols are sent in the frequency domain with OFDM and in the time domain with SC-FDM. The spacing between adjacent subcarriers may be fixed, and the total number of subcarriers (K) may be dependent on the system bandwidth. For example, the spacing of the subcarriers may be 15 kHz and the minimum Resource allocation (called a "resource block") may be 12 subcarriers (or 180 kHz). Consequently, the nominal Fast File Transfer (FFT) size may be equal to 128, 256, 512, 1024 or 2048 for system bandwidth of 1.25, 2.5, 5, 10 or 20 megahertz (MHz), respectively. The system bandwidth may also be partitioned into subbands. For example, a subband may cover 1.08 MHz (i.e., 6 Resource blocks), and there may be 1, 2, 4, 8 or 16 subbands for system bandwidth of 1.25, 2.5, 5, 10 or 20 MHz, respectively.

[0061] While descriptions of some aspects may use terminology and examples associated with LTE technologies, some aspects may be applicable to other wireless communications systems, such as a new Radio (NR) or 5G network. NR may utilize OFDM with a cyclic prefix (CP) on the uplink (UL) and downlink (DL) and include support for half-duplex operation using time division duplex (TDD). A single component carrier bandwidth of 100 MHz may be supported. NR Resource blocks may span 12 sub-carriers with a sub-carrier bandwidth of 75 kHz over a 0.1 millisecond (ms) duration. Each Radio frame may consist of 50 subframes with a length of 10 ms. Consequently, each subframe may have a length of 0.2 ms. Each subframe may indicate a link direction (i.e., DL or UL) for data transmission and the link direction for each subframe may be dynamically switched. Each subframe may include DL/UL data as well as DL/UL control data. Beamforming may be supported and beam direction may be dynamically configured. Multiple Input Multiple Output (MIMO) transmissions with precoding may also be supported. MIMO configurations in the DL may support up to eight transmit antennas with multi-layer DL transmissions up to eight streams and up to two streams per wireless device. Multi-layer transmissions with up to two streams per wireless device may be supported. Aggregation of multiple cells may be supported with up to eight serving cells. Alternatively, NR may support a different air interface, other than an OFDM-based air interface.

[0062] Some mobile devices may be considered machine-type communication (MTC) or Evolved or enhanced machine-type communication (eMTC) mobile devices. MTC and eMTC mobile devices include, for example, robots, remote devices, sensors, meters, monitors, location tags, etc., that may communicate with a base station, another

device (for example, remote device), or some other entity. A wireless node may provide, for example, connectivity for or to a network (for example, a wide area network such as Internet or a cellular network) via a wired or wireless communication link. Some mobile devices may be considered Internet-of-Things (IoT) devices or may be implemented as NB-IoT (narrowband internet of things) devices. A wireless device **120** may be included inside a housing that houses components of the wireless device, such as processor components, memory components, similar components, or a combination thereof.

[0063] In general, any number of communication systems and any number of wireless networks may be deployed in a given geographic area. Each communications system and wireless network may support a particular Radio access technology (RAT) and may operate on one or more frequencies. A RAT also may be referred to as a Radio technology, an air interface, etc. A frequency also may be referred to as a carrier, a frequency channel, etc. Each frequency may support a single RAT in a given geographic area in order to avoid interference between communications systems of different RATs. In some cases, 4G/LTE and/or 5G/NR RAT networks may be deployed. For example, a 5G non-standalone (NSA) network may utilize both 4G/LTE RAT in the 4G/LTE RAN side of the 5G NSA network and 5G/NR RAT in the 5G/NR RAN side of the 5G NSA network. The 4G/LTE RAN and the 5G/NR RAN may both connect to one another and a 4G/LTE core network (e.g., an evolved packet core (EPC) network) in a 5G NSA network. Other example network configurations may include a 5G standalone (SA) network in which a 5G/NR RAN connects to a 5G core network.

[0064] In some aspects, two or more wireless devices **120** may communicate directly using one or more sidelink channels **124** (for example, without using a base station **110**-**110***d* as an intermediary to communicate with one another). For example, wireless devices **120** may communicate using peer-to-peer (P2P) communications, device-to-device (D2D) communications, a vehicle-to-everything (V2X) protocol (which may include a vehicle-to-vehicle (V2V) protocol, a vehicle-to-infrastructure (V2I) protocol, or similar protocol), a mesh network, or similar networks, or combinations thereof. In this case, the wireless devices **120** may perform scheduling operations, resource selection operations, as well as other operations described elsewhere herein as being performed by the base station **110**.

[0065] In the example illustrated in FIG. **1**A, wireless devices **120** (e.g., an apparatus, such as a UAV) may include a wireless communication manager **101**. In various implementations and aspects, the wireless communication manager **101** may be configured to perform operations for managing wireless communications by the apparatus (e.g., a UAV), such as described with reference to FIGS. **3**A, **3**B, **3**E, **4**A, **4**B, and **5**. In various implementations and aspects, the wireless communication manager **101** may be configured to obtain an altitude of the apparatus (e.g., a UAV), send a message using beamformed transmissions **132***a* in response to the altitude of the apparatus meeting an altitude threshold. In various implementations and aspects, the wireless communication manager **101** may be further configured to send the message using omnidirectional transmissions **134** in response to the altitude of the apparatus failing to meet the altitude threshold.

[0066] FIG. **1**B is a conceptual diagram illustrating aspects of a system **100***b* for managing a broadcast signal of an apparatus (e.g., a UAV) suitable for implementing various implementations and aspects. Apparatuses (e.g., UAVs **140**, **142**, **144**) may send wireless communications to and receive wireless communications from other devices for a variety of purposes. Such wireless communications may be to or from another apparatus (e.g., between or among UAVs **140**, **142**, and **144**), or to or from a device on the ground (e.g., a user equipment (UE) such as a mobile device **112**, a base station **114**, and the like, collectively referred to herein as a "ground receiver"). One example of wireless communications received from or transmitted to another apparatus is a message indicating the apparatus's current and planned behavior such as its path, altitude, velocity, maneuvers, and the like, generally referred to herein as a "maneuvering safety message." An example of a maneuvering safety message is a UAV-to-Everything Detect and Avoid (U2X-DAA) message. Other examples of wireless communications to or from another apparatus include data messages such as camera or other sensor information, maneuvering messages such as swarm behavior messages, and other suitable apparatus-to-apparatus (e.g., UAV-to-UAV) communications. One example of wireless communications received from or transmitted to a ground receiver is a message including identity information and/or location information of the apparatus (referred to herein as an "identification message"). In some aspects, an identification message may be used by automated or semi-automated air traffic control systems, governmental agencies such as law enforcement, and the like. An example of an identification message is a U2X-ID message. Maneuvering safety messages and identification messages typically are subject to different requirements for latency, range of transmission, rate of generation and transmission (e.g., to update information in a message), and are intended for different receiving devices. In some implementations and aspects, the apparatus **140**, **142**, **144** may be configured to transmit the maneuvering safety message or the identification message over a sidelink communication link.

[0067] In some aspects, the apparatus (e.g., **140**, which may be a UAV) may include the wireless communication manager **101**. In various aspects, the wireless communication manager **101** may be configured to perform operations for managing the transmission of maneuvering safety messages or identification messages as described herein, such as described with reference to FIGS. **3**A, **3**B, **3**E, **4**A, **4**B, and **5**. In various aspects, the wireless communication manager **101** may be configured to obtain an altitude of the apparatus. In various aspects, the wireless communication manager **101** may be configured to send a message using beamformed transmissions in response to the altitude of the apparatus meeting an altitude threshold. In various aspects, the wireless communication manager **101** may be configured to send the message using omnidirectional transmissions in response to the altitude of the apparatus failing to meet the altitude threshold.

[0068] In various implementations and aspects, an apparatus (e.g., **140**, **142**, **144**, which may be a UAV) may be configured to configure and transmit a message as omnidirectional transmissions or beamformed transmissions based on various factors, including a type of message to be sent, a direction of transmission, an altitude of the apparatus, beam width, multi subframe allocation, and beam sweep. In this

manner, the apparatus may configure a transmission at a physical (PHY) layer based on the various factors.

[0069] In some implementations and aspects, the apparatus may send a message using either omnidirectional transmissions (e.g., **131**) or beamformed transmission (e.g., **130**) based on whether the altitude of the apparatus meets an altitude threshold. For example, the altitude **152** of the apparatus (e.g., UAV) **140** (i.e., above the ground **154**) meets (e.g., is greater than, or is greater than or equal to) an altitude threshold **150**. As another example, the altitude **156** of the apparatus (e.g., UAV) **142** fails to meet (does not meet) the altitude threshold **150**. In some implementations and aspects, the apparatus **140**, **142**, **144** may obtain its altitude from various sources, for example from an altitude sensor aboard the apparatus, such as barometer information, from a global navigation satellite system receiver, such altitude derived from three-dimensional global coordinates. In some implementations and aspects, the apparatus **140**, **142**, **144** may obtain its altitude from a network element that provides the altitude of the apparatus, for example, via a communication link **122** with a base station **110**, which may be an element of a communication network (e.g., communications system **110***a*).

[0070] In some implementations and aspects, the apparatus **140**, **142**, **144** may determine the altitude threshold dynamically. For example, the apparatus **140**, **142**, **144** may determine a type of a message to be transmitted (e.g., a maneuvering safety message or an identification message) and may select the altitude threshold based on the determined message type. For example, in response to determining that message is of a type for reception by a ground receiver **112**, **114** (e.g., an identification message), the apparatus may **140**, **142**, **144** select the altitude threshold **150**. As another example, in response to determining that the message is for reception by other apparatuses, the apparatus may **140**, **142**, **144** select an altitude threshold that is very low, or zero. In some implementations and aspects, the apparatus may configure or select the altitude threshold using a setting or parameter, which may be referred to for example, as a "Beamforming_HeightThreshold" parameter or another suitable parameter.

[0071] In some implementations and aspects, the apparatus may select the altitude threshold based on capabilities of various devices of the apparatus and/or environmental conditions. For example, the apparatus may select the altitude threshold based on a transmit power capability of a transmit chain or a radio module of the apparatus. As another example, the apparatus may select the altitude threshold based on a stored power level in a battery or power module of the apparatus. As another example, the apparatus may select the altitude threshold based on beamforming capabilities of a transmission device of the apparatus. In some implementations and aspects, the apparatus may determine a level or an amount of radio frequency interference proximate to the apparatus, and may select the altitude threshold based on the level or amount of radio frequency interference. In some implementations and aspects, the apparatus may determine a level or an amount of communication link congestion or network congestion, and may select the altitude threshold based on the level or amount of communication link congestion or network congestion. The apparatus may also determine other factors and consider such factors in selecting the altitude threshold.

[0072] In some implementations and aspects, the apparatus may send a message using either omnidirectional transmissions (e.g., **131**) or beamformed transmission (e.g., **130**) based on whether the message includes a message for reception by a first type of other (second) apparatuses (e.g., other UAVs) or a message for reception by a second type of other (second) apparatuses (e.g., a ground receiver). For example, the apparatus **142** may send the message using omnidirectional transmission **131** in response to determining that the message is for reception by a first type of other apparatuses. As another example, the apparatus **144** may send the message using omnidirectional transmissions **131** in response to determining that the message is for reception by a second type of other apparatuses. In some implementations and aspects, the apparatus **144** may send the message using the message using omnidirectional transmission **131** even though the apparatus **144** meets the altitude threshold **150**.

[0073] As another example, the apparatus **140** may send the message using beamformed transmissions **130** based on the message being for reception by the second type of second apparatus (e.g., to a ground receiver **112** or to a ground receiver **114**). In some implementations and aspects, the apparatus **140** may send the message using beamformed transmissions **130** in directional beams (e.g., **130***a*, **130***b*, **130**, and **130***d*) aimed in at least two different directions. In some implementations and aspects, the apparatus **140** may transmit the directional beams from the apparatus in four quadrants, or in more directions from the apparatus.

[0074] In some implementations and aspects, the apparatus may transmit the directional beams (e.g., aimed, directed) in at least two different directions within a latency constraint of the message. For example, an identification message may have a latency requirement of transmission once per second. In this example, the apparatus may transmit all of the directional beams (e.g., **130***a*-**130***d*) within the latency requirement (e.g., 1 second). In some implementations and aspects, the apparatus may allocate communication link resources over multiple time slots and/or multiple subframes to transmit the directional beams. In some implementations and aspects, the apparatus may allocate frequency resources and subframes as part of a Semi-Persistent Scheduling (SPS) process. In some implementations and aspects, the apparatus may utilize an SPS parameter (which may be referred to as a "MultiSubframeAllocation" parameter) that indicates that the apparatus should allocate frequency resources, and an SPS parameter (which may be referred to as a "NumSubframe_BeamSweep" parameter) that indicates a number of subframes in which the apparatus should allocate frequency resources. In some implementations and aspects, the apparatus may configure the subframes close enough in time to comply with a latency requirement of a message or signal. In some implementations and aspects, the apparatus specify parameters for the type of message to be sent, an identification of the direction (s) of beamformed signals and/or the number of beamformed transmissions to be send, and a beam width of each beamformed transmission.

[0075] In some implementations and aspects, the apparatus may include in beamformed transmissions a beam identifier that is configured to enable a receiver device (e.g., the ground receiver **112**, **114**) to obtain the beam identifier of the direction beam used to transmit the beamformed transmissions. In some implementations and aspects, the receiver

device may use the beam identifier to send a signal back to the apparatus, e.g., by a beamformed transmission, requesting retransmission of a message or packet (e.g., in the event that the receiver device was unable to properly decode a message or packet received from the apparatus). In some implementations and aspects, the receiver device may include the beam identifier in the retransmission request. In some implementations and aspects, the apparatus may receive the retransmission request from the receiver device, and may retransmit the message using beamformed transmissions associated with the beam identifier. In this manner, the apparatus may efficiently retransmit the message only in the direction of the requesting receiver device, without retransmitting other beamformed transmissions in other directions. Further, the apparatus may dynamically determine whether to retransmit a message or signal based on the apparatus's altitude, which may change from time to time. In some implementations and aspects, the apparatus may receive a retransmission request from the receiver device, and may retransmit the message using omnidirectional transmissions when the altitude of the apparatus does not meet the altitude threshold. In some implementations and aspects, the apparatus may retransmit the message using beamformed transmissions when the altitude of the apparatus meets the altitude threshold.

[0076] FIG. **1**C is a component block diagram illustrating example components of an apparatus **100***c* (which may be, for example, a UAV) suitable for implementing various implementations and aspects. With reference to FIGS. **1**A-**1**C, the apparatus **100***c* (e.g., a UAV) may include a number of rotors **170***a*, a frame **170***b*, and landing columns **170***c* or skids. The frame **170***b* may provide structural support for the motors associated with the rotors **170***a*. The landing columns **170***c* may support the maximum load weight for the combination of the components of the apparatus **100***c* and, in some cases, a payload. For ease of description and illustration, some detailed aspects of the apparatus **100***c* are omitted such as wiring, frame structure interconnects, or other features that would be known to one of skill in the art. For example, while the apparatus **100***c* is shown and described as having a frame **170***b* having a number of support members or frame structures, the apparatus **100***c* may be constructed using a molded frame in which support is obtained through the molded structure. While the illustrated apparatus **100***c* has four rotors **170***a*, this is merely exemplary and various implementations and aspects may include more or fewer than four rotors **170***a*.

[0077] The apparatus **100***c* may further include a control unit **172***a* that may house various circuits and devices used to power and control the operation of the apparatus **100***c*. The control unit **172***a* may include a processor **174***a*, a power module **176**, sensors **180**, one or more cameras **178**, an output module **172***b*, an input module **172***c*, and a radio module **172***d*.

[0078] The processor **174***a* may be configured with processor-executable instructions to control travel and other operations of the apparatus **100***c*, including operations of various implementations and aspects. The processor **174***a* may include or be coupled to a navigation unit **174***b*, a memory **174***c*, a gyro/accelerometer unit **174***d*, and an avionics module **174***e*. The processor **174***a* and/or the navigation unit **174***b* may be configured to communicate with a server through a wireless connection (e.g., a cellular data network) to receive data useful in navigation, provide real-time position reports, and assess data.

[0079] The avionics module **174***e* may be coupled to the processor **174***a* and/or the navigation unit **174***b*, and may be configured to provide travel control-related information such as altitude, attitude, airspeed, heading, and similar information that the navigation unit **174***b* may use for navigation purposes, such as dead reckoning between Global Navigation Satellite System (GNSS) position updates. The gyro/accelerometer unit **174***d* may include an accelerometer, a gyroscope, an inertial sensor, or other similar sensors. The avionics module **174***e* may include or receive data from the gyro/accelerometer unit **174***d* that provides data regarding the orientation and accelerations of the apparatus **100***c* that may be used in navigation and positioning calculations, as well as providing data used in various implementations and aspects for processing images.

[0080] The processor **174***a* may further receive additional information from the sensors **180**, such as an image sensor or optical sensor (e.g., a sensor capable of sensing visible light, infrared, ultraviolet, and/or other wavelengths of light). The sensors **180** may also include a radio frequency (RF) sensor, a barometer, a humidity sensor, a sonar emitter/detector, a radar emitter/detector, a microphone or another acoustic sensor, a lidar sensor, a time-of-flight (TOF) 3-D camera, or another sensor that may provide information usable by the processor **174***a* for movement operations, navigation and positioning calculations, and determining environmental conditions. The sensors **180** may also include one or more sensors configured to detect temperatures generated by one or more components of the robotic vehicle, such as thermometers, thermistors, thermocouples, positive temperature coefficient sensors, and other sensor components.

[0081] The power module **176** may include one or more batteries that may provide power to various components, including the processor **174***a*, the sensors **180**, the one or more cameras **178**, the output module **172***b*, the input module **260**, and the radio module **172***d*. In addition, the power module **176** may include energy storage components, such as rechargeable batteries. The processor **174***a* may be configured with processor-executable instructions to control the charging of the power module **176** (i.e., the storage of harvested energy), such as by executing a charging control algorithm using a charge control circuit. Alternatively or additionally, the power module **176** may be configured to manage its own charging. The processor **174***a* may be coupled to the output module **172***b*, which may output control signals for managing the motors that drive the rotors **170***a* and other components.

[0082] The apparatus **100***c* may be controlled through control of the individual motors of the rotors **170***a* as the apparatus **100***c* progresses toward a destination. The processor **174***a* may receive data from the navigation unit **174***b* and use such data in order to determine the present position and orientation of the apparatus **100***c*, as well as the appropriate course towards the destination or intermediate sites. In various implementations and aspects, the navigation unit **174***b* may include a GNSS receiver system (e.g., one or more global positioning system (GPS) receivers) enabling the apparatus **100***c* to navigate using GNSS signals. Alternatively or in addition, the navigation unit **174***b* may be equipped with radio navigation receivers for receiving navigation beacons or other signals from radio nodes, such as

navigation beacons (e.g., very high frequency (VHF) omni-directional range (VOR) beacons), Wi-Fi access points, cellular network sites, radio station, remote computing devices, other robotic vehicles, etc.

[0083] The radio module **172***d* may be configured to receive navigation signals, such as signals from aviation navigation facilities, etc., and provide such signals to the processor **174***a* and/or the navigation unit **174***b* to assist in robotic vehicle navigation. In various implementations and aspects, the navigation unit **174***b* may use signals received from recognizable RF emitters (e.g., AM/FM radio stations, Wi-Fi access points, and cellular network base stations) on the ground.

[0084] The navigation unit **174***b* may include a planning application that may perform calculations to plan a path of travel for the robotic vehicle within a volumetric space ("path planning"). In some implementations and aspects, the planning application may perform path planning using information including information about aspects of a task to be performed by the robotic vehicle, information about environmental conditions, an amount of heat that may be generated by one or more components of the robotic vehicle in performing the task, as well as one or more thermal constraints.

[0085] The radio module **172***d* may include a modem **172***e* and a transmit/receive antenna **172***f*. The radio module **172***d* may be configured to conduct wireless communications via a variety of wireless communication devices (e.g., a wireless communication device (WCD) **190**), examples of which include a wireless telephony base station or cell tower (e.g., a base station **126**), a network access point (e.g., an access point **114**), a beacon, a smartphone, a tablet, or another computing device with which the apparatus **100***c* may communicate. The processor **174***a* may establish a bi-directional wireless communication link **194** via the modem **172***e* and the antenna **172***f* of the radio module **172***d* and the WCD **190** via a transmit/receive antenna **192**. In some implementations and aspects, the radio module **172***d* may be configured to support multiple connections with different wireless communication devices using different radio access technologies.

[0086] In various implementations and aspects, the WCD **190** may be connected to a server through intermediate access points. In an example, the WCD **190** may be a server of a robotic vehicle operator, a third-party service (e.g., package delivery, billing, etc.), or a site communication access point. The apparatus **100***c* may communicate with a server through one or more intermediate communication links, such as a wireless telephony network that is coupled to a wide area network (e.g., the Internet) or other communication devices. In some implementations and aspects, the apparatus **100***c* may include and employ other forms of radio communication, such as mesh connections with other robotic vehicles or connections to other information sources (e.g., balloons or other stations for collecting and/or distributing weather or other data harvesting information).

[0087] In various implementations and aspects, the control unit **172***a* may be equipped with an input module **172***c*, which may be used for a variety of applications. For example, the input module **172***c* may receive images or data from an onboard camera **178** or sensors **180**, or may receive electronic signals from other components (e.g., a payload).

[0088] While various components of the control unit **172***a* are illustrated as separate components, some or all of the components (e.g., the processor **174***a*, the output module **172***b*, the radio module **172***d*, and other units) may be integrated together in a single device or module, such as a system-on-chip module.

[0089] FIG. **2** is a component block diagram illustrating an example computing and wireless modem system **200** suitable for implementing various implementations and aspects. Various implementations and aspects may be implemented on a number of single processor and multiprocessor computer systems, including a system-on-chip (SOC) or system in a package (SIP).

[0090] With reference to FIGS. **1A-2**, the illustrated example computing system **200** (which may be a SIP in some implementations and aspects) includes a two SOCs **202**, **204** coupled to a clock **206**, a voltage regulator **208**, and a wireless transceiver **266** configured to send and receive wireless communications via an antenna (not shown) to/from wireless devices, such as a base station **126**. In some implementations and aspects, the first SOC **202** may operate as central processing unit (CPU) of the wireless device that carries out the instructions of software application programs by performing the arithmetic, logical, control and input/output (I/O) operations specified by the instructions. In some implementations and aspects, the second SOC **204** may operate as a specialized processing unit. For example, the second SOC **204** may operate as a specialized 5G processing unit responsible for managing high volume, high speed (such as 5 Gbps, etc.), or very high frequency short wave length (such as 28 GHz millimeter wave (mmWave) spectrum, etc.) communications.

[0091] The first SOC **202** may include a digital signal processor (DSP) **210**, a modem processor **212**, a graphics processor **214**, an application processor **216**, one or more coprocessors **218** (such as vector co-processor) connected to one or more of the processors, memory **220**, custom circuitry **222**, system components and resources **224**, an interconnection/bus module **226**, one or more temperature sensors **230**, a thermal management unit **232**, and a thermal power envelope (TPE) component **234**. The second SOC **204** may include a 5G modem processor **252**, a power management unit **254**, an interconnection/bus module **262**, a plurality of mmWave transceivers **256**, memory **258**, and various additional processors **260**, such as an applications processor, packet processor, etc.

[0092] Each processor **210**, **212**, **214**, **216**, **218**, **252**, **260** may include one or more cores, and each processor/core may perform operations independent of the other processors/cores. For example, the first SOC **202** may include a processor that executes a first type of operating system (such as FreeBSD, LINUX, macOS, etc.) and a processor that executes a second type of operating system (such as Microsoft Windows). In addition, any or all of the processors **210**, **212**, **214**, **216**, **218**, **252**, **260** may be included as part of a processor cluster architecture (such as a synchronous processor cluster architecture, an asynchronous or heterogeneous processor cluster architecture, etc.).

[0093] The first and second SOC **202**, **204** may include various system components, resources and custom circuitry for managing sensor data, analog-to-digital conversions, wireless data transmissions, and for performing other specialized operations, such as decoding data packets and processing encoded audio and video signals for rendering in a web browser. For example, the system components and resources **224** of the first SOC **202** may include power

amplifiers, voltage regulators, oscillators, phase-locked loops, peripheral bridges, data controllers, memory controllers, system controllers, access ports, timers, and other similar components used to support the processors and software clients running on a wireless device. The system components and resources **224** or custom circuitry **222** also may include circuitry to interface with peripheral devices, such as cameras, electronic displays, wireless communication devices, external memory chips, etc.

[0094] The first and second SOC **202**, **204** may communicate via interconnection/bus module **250**. The various processors **210**, **212**, **214**, **216**, **218**, may be interconnected to one or more memory elements **220**, system components and resources **224**, and custom circuitry **222**, and a thermal management unit **232** via an interconnection/bus module **226**. Similarly, the processor **252** may be interconnected to the power management unit **254**, the mmWave transceivers **256**, memory **258**, and various additional processors **260** via the interconnection/bus module **262**. The interconnection/bus module **226**, **250**, **262** may include an array of reconfigurable logic gates or implement a bus architecture (such as CoreConnect, AMBA, etc.). Communications may be provided by advanced interconnects, such as high-performance networks-on chip (NoCs).

[0095] The first or second SOCs **202**, **204** may further include an input/output module (not illustrated) for communicating with resources external to the SOC, such as a clock **206** and a voltage regulator **208**. Resources external to the SOC (such as clock **206**, voltage regulator **208**) may be shared by two or more of the internal SOC processors/cores.

[0096] In addition to the example computing system **200** discussed above, some implementations and aspects may be implemented in a wide variety of computing systems, which may include a single processor, multiple processors, multicore processors, or any combination thereof.

[0097] FIG. **3**A illustrates a block diagram **300***a* of a device **302** that supports managing a broadcast signal according to various aspects. With reference to FIGS. **1**-**3**A, the device **302** is an example of aspects of an apparatus **140**, **142**, **144** (e.g., a UAV). Device **302** may include a receiver **304**, a wireless communication manager **306**, and a transmitter **308**.

[0098] The receiver **304** may receive information, such as packets, control information, etc., associated with RF communications. The receiver **304** may be an example of aspects of radio module **172***d*, or transceiver **256** or **266**. The transmitter **308** may send information, such as packets, control information, etc., associated with RF communications. The transmitter **308** may be an example of aspects of radio module **172***d*, or transceiver **256** or **266**.

[0099] The wireless communication manager **306** may be an example of aspects of wireless communication manager **101** and processor **174***a*. The wireless communication manager **306** may obtain an altitude of the apparatus, and send a message using beamformed transmissions in response to the altitude of the apparatus meeting an altitude threshold. The wireless communication manager **306** may send the message using omnidirectional transmissions in response to the altitude of the apparatus failing to meet the altitude threshold. The wireless communication manager **306** may obtain the altitude of the apparatus from one or more of an altitude sensor, apparatus barometer information, a global navigation satellite system receiver, or a network element that provides the altitude of the apparatus (e.g., **172***d*, **172***f*, **174***b*, **174***d*, **174***e*, **178**, **180**). The wireless communication manager **306** may determine a type of the message, and select the altitude threshold based on the determined type of the message.

[0100] The wireless communication manager **306** may determine whether the message includes a message for reception by a first type of second apparatus or a message for reception by a second type of second apparatus, and send the message using beamformed transmission in response to determining that the message is for reception by the second type of second apparatus and the altitude meets the altitude threshold. The wireless communication manager **306** may send and/or receive a maneuvering safety message and/or an identification message.

[0101] The wireless communication manager **306** may send the message using beamformed transmissions in directional beams in at least two different directions. The wireless communication manager **306** may send the message using beamformed transmissions in directional beams in at least two different directions within a latency constraint of the message. The wireless communication manager **306** may send the message using beamformed transmissions in directional beams in at least two different directions via a sidelink communication link. The wireless communication manager **306** may include in beamformed transmissions a beam identifier that enables a receiver device to obtain the beam identifier of a directional beam used to transmit a received beamformed transmission.

[0102] The wireless communication manager **306** may receive from a second apparatus a retransmission request including the beam identifier of the received beamformed transmission, and retransmit the message using beamformed transmissions associated with the beam identifier. The wireless communication manager **306** may receive from a receiver device a retransmission request, and retransmit the message using omnidirectional transmissions when the altitude of the apparatus fails to meet the altitude threshold. The wireless communication manager **306** may retransmit the message using beamformed transmissions when the altitude of the apparatus meets the altitude threshold.

[0103] FIG. **3**B illustrates a block diagram **300***b* of a device **310** that supports managing a broadcast signal according to various aspects. With reference to FIGS. **1**-**3**B, device **310** may be an example of aspects of an apparatus **140**, **142**, **144** (e.g., UAV). Device **310** may include a receiver **312**, a wireless communication manager **314**, and a transmitter **316**. Device **310** may also include a processor. Each of the components of device **310** may be in communication with one another such as via one or more buses or other suitable connections.

[0104] The receiver **312** may receive information, such as packets, control information, etc., associated with RF communications. The receiver **312** may be an example of aspects of radio module **172***d*, or transceiver **256** or **266**. The transmitter **316** may send information, such as packets, control information, etc., associated with RF communications. The transmitter **316** may be an example of aspects of radio module **172***d*, or transceiver **256** or **266**.

[0105] The wireless communication manager **314** may be an example of aspects of wireless communication manager **101**, **112***a*, **114***a*, and processor **174***a*. The wireless communication manager **314** also may include an altitude component **318**, a beamformed transmission component **320**, an omnidirectional transmission component **322**, a message

type component **324**, an altitude threshold component **326**, an apparatus type component **328**, and a retransmission component **330**. Each of the components of the wireless communication manager **314** may be in communication with one another (e.g., via one or more buses **332** or other suitable connections).

[0106] The altitude obtaining component **318** may obtain an altitude of the apparatus, such as from one or more of an altitude sensor, apparatus barometer information, a global navigation satellite system receiver, or a network element that provides the altitude of the apparatus. The beamformed transmission component **320** may send a message using beamformed transmissions in response to the altitude of the apparatus meeting an altitude threshold. The beamformed transmission component **320** may send the message using beamformed transmission in response to determining that the message is for reception by the second type of second apparatus and the altitude meets the altitude threshold. The beamformed transmission component **320** may send the message using beamformed transmissions in directional beams in at least two different directions. The beamformed transmission component **320** may send the message using beamformed transmissions in directional beams in at least two different directions within a latency constraint of the message. The beamformed transmission component **320** may send the message using beamformed transmissions in directional beams in at least two different directions via a sidelink communication link. The beamformed transmission component **320** may include in beamformed transmissions a beam identifier that enables a receiver device to obtain the beam identifier of a directional beam used to transmit a received beamformed transmission. The omnidirectional transmission component **322** may send the message using omnidirectional transmissions in response to the altitude of the apparatus failing to meet the altitude threshold.

[0107] The message type component **324** may determine a type of the message, such as a maneuvering safety message, an identification message, and/or another type of message. The message type component **324** may determine whether the message includes a message for reception by a first type of second apparatus or a message for reception by a second type of second apparatus. The message type component **324** may determine that the message for reception by the first type of second apparatus is a maneuvering safety message and/or the message for reception by the second type of second apparatus is an identification message. The altitude threshold component **326** may select the altitude threshold based on the determined type of the message.

[0108] The retransmission component **330** may receive from a second apparatus a retransmission request. The retransmission component **330** may receive from a second apparatus a retransmission request including the beam identifier of the received beamformed transmission. The beamformed transmission component **320** may retransmit the message using beamformed transmissions associated with the beam identifier. The beamformed transmission component **320** may retransmit the message using beamformed transmissions when the altitude of the apparatus meets the altitude threshold. The omnidirectional transmission component **322** may retransmit the message using omnidirectional transmissions when the altitude of the apparatus fails to meet the altitude threshold.

[0109] FIG. **3**C illustrates a block diagram **300***c* of a device **350** that supports managing a broadcast signal according to various aspects. With reference to FIGS. **1**-**3**C, device **350** is an example of aspects of an apparatus **112**, **114** (e.g., a ground receiver). Device **350** may include a receiver **352**, a wireless communication manager **354**, and a transmitter **356**.

[0110] The receiver **352** may receive information, such as packets, control information, etc., associated with RF communications. The receiver **352** is an example of aspects of radio module **172***d*, or transceiver **256** or **266**. The transmitter **356** may send information, such as packets, control information, etc., associated with RF communications. The transmitter **356** may be an example of aspects of radio module **172***d*, or transceiver **256** or **266**.

[0111] The wireless communication manager **354** is an example of aspects of wireless communication manager **112***a* and **114***a*. The wireless communication manager **354** may receive beamformed transmissions from a second apparatus, obtain a beam identifier of a directional beam of beamformed transmissions in response to unsuccessfully decoding the message, and transmit to the second a retransmission request in beamformed transmissions using the obtained beam identifier.

[0112] FIG. **3**D illustrates a block diagram **300***d* of a device **360** that supports managing a broadcast signal according to various aspects. With reference to FIGS. **1**-**3**D, device **302** is an example of aspects of an apparatus **112**, **114** (e.g., a ground receiver). Device **360** may include a receiver **362**, a wireless communication manager **364**, and a transmitter **366**. Device **360** may also include a processor. Each of the components of device **360** may be in communication with one another (e.g., via one or more buses or other suitable connections).

[0113] The receiver **362** may receive information, such as packets, control information, etc., associated with RF communications. The receiver **362** may be an example of aspects of radio module **172***d*, or transceiver **256** or **266**. The transmitter **366** may send information, such as packets, control information, etc., associated with RF communications. The transmitter **366** is an example of aspects of radio module **172***d*, or transceiver **256** or **266**.

[0114] The wireless communication manager **364** is an example of aspects of wireless communication manager **112***a*, **114***a*. The wireless communication manager **364** also may include beamformed transmissions component **366**, a beam identifier **368**, and a retransmission component **370**. Each of the components of the wireless communication manager **364** may be in communication with one another (e.g., via one or more buses **372** or other suitable connections).

[0115] The beamformed transmission component **366** may receive beamformed transmissions from a second apparatus (e.g., a UAV **140**, **142**, **144**). The beam identifier component **368** may obtain a beam identifier of a directional beam of beamformed transmissions in response to unsuccessfully decoding the message. The retransmission component may transmit to the second a retransmission request in beamformed transmissions using the obtained beam identifier.

[0116] FIG. **3**E illustrates example operations of a process flow **300***e* that supports that supports managing a broadcast signal according to various implementations and aspects. With reference to FIGS. **1**A-**3**E, process flow **300***e* includes a first apparatus **374** (e.g., UAV **140**), a first type of second apparatus **376** (e.g., UAV **104**, **106**), and a second type of second apparatus **378** (e.g., ground receiver **112**, **114**).

[0117] At **380**, the apparatus **374** (e.g., a UAV) optionally may determine a type of message to be sent from the apparatus. For example, the apparatus may determine that the message to be sent is a maneuvering safety message or an identification message. At **382**, the apparatus **374** optionally may determine whether the message is for reception by the first type of second apparatus **376** or the second type of apparatus **378**. In some implementations and aspects, the apparatus **374** may send the message using omnidirectional transmission **382***a* in response to determining that the message is for reception by the first type of second apparatus **376**.

[0118] At **384**, the apparatus **374** (e.g., a UAV) may select an altitude threshold. In some implementations and aspects, the apparatus **374** may select the altitude threshold based on the determined type of the message. In some implementations and aspects, the apparatus **374** may select an altitude threshold in response to determining that the message is intended for the first type of second apparatus **376**.

[0119] At **386**, the apparatus **374** (e.g., a UAV) may obtain an altitude of the apparatus. In various implementations and aspects, the apparatus **374** may obtain the altitude from one or more of a variety of sources, such as from an altitude sensor, apparatus barometer information, a global navigation satellite system receiver, a network element that provides the altitude of the apparatus, or another suitable source.

[0120] The apparatus **374** (e.g., a UAV) may send the message using omnidirectional transmissions **390***a* in response to the altitude of the apparatus failing to meet the altitude threshold (e.g., the altitude of the apparatus is less than the altitude threshold). The apparatus may send the message using beamformed transmissions **390***b* in response to the altitude of the apparatus meeting the altitude threshold (e.g., the altitude of the apparatus is greater than or equal to the threshold). In some implementations and aspects, the apparatus **374** may send the message using beamformed transmissions in response to the message being for reception by the second type of second apparatus and the altitude meeting the altitude threshold.

[0121] In some implementations and aspects, the apparatus **374** (e.g., a UAV) may send the message using beamformed transmissions **390***b* in directional beams in at least two different directions. In some implementations and aspects, the apparatus **374** may send the message using beamformed transmissions **390***b* in directional beams in at least two different directions within a latency constraint of the message. In some implementations and aspects, the apparatus **374** may send the message using beamformed transmissions **390***b* in directional beams in at least two different directions via a sidelink communication link. In some implementations and aspects, the apparatus **374** (e.g., a UAV) may include in beamformed transmissions **390***b* a beam identifier that enables a receiver device such as the first type of second apparatus **376** (e.g., a UAV) and/or the second type of second apparatus **378** (e.g., a ground receiver) to obtain the beam identifier of a directional beam used to transmit the received beamformed transmission.

[0122] At **392**, the second type of second apparatus **378** (e.g., a ground receiver) may obtain the beam identifier of the directional beam of the beamformed transmission **390***b* in response to unsuccessfully decoding the message. At **394**, the second type of second apparatus **378** may transmit to the first apparatus **374** (e.g., a UAV) a retransmission request **394**. In some implementations and aspects, the second type of second apparatus **378** may transmit the retransmission request **394** in a beamformed transmission using the obtained beam identifier.

[0123] At **395**, the apparatus **374** (e.g., a UAV) may retransmit the message using the beamformed transmission **395** associated with the beam identifier (e.g., in response to receiving the retransmission request **394**). In some implementations and aspects, the apparatus **374** optionally may retransmit the message using the beamformed transmission **395** without re-determining the altitude of the apparatus **374**.

[0124] At **396**, the apparatus **374** (e.g., a UAV) optionally may determine whether the altitude of the apparatus **374** meets the altitude threshold (e.g., in response to receiving the retransmission request **394**). In this manner, the apparatus **374** may account for a possible change in the altitude of the apparatus **374**.

[0125] The apparatus **374** (e.g., a UAV) may retransmit the message using omnidirectional transmissions **398***a* when the altitude of the apparatus **374** fails to meet the altitude threshold (e.g., the altitude of the apparatus **374** is less than the altitude threshold). The apparatus **374** may send the message using beamformed transmissions **398***b* when the altitude of the apparatus **374** meets the altitude threshold (e.g., the altitude of the apparatus **374** is greater than or equal to the threshold).

[0126] FIG. **4**A is a process flow diagram illustrating a method **400***a* that may be performed by a processor of an apparatus (e.g., a UAV) for managing a broadcast signal according to various implementations and aspects. With reference to FIGS. **1**-**4**B, the operations of the method **400***b* may be performed by a processor (such as the processor **210**, **212**, **214**, **216**, **218**, **252**, **260**, **274***a*) of an apparatus (such as the apparatus **100***c*, **140**, **142**, **144**, e.g., a UAV).

[0127] In block **402**, the processor may obtain an altitude of the apparatus. In some implementations and aspects, the processor may obtain the altitude of the apparatus from one or more of an altitude sensor, barometer information (which may, for example, enable the processor to infer the altitude of the apparatus), a global navigation satellite system receiver, or a network element that provides the altitude of the apparatus (e.g., via the base station **126**). Means for performing operations of block **404** may include the processor **210**, **212**, **214**, **216**, **218**, **252**, **260** and **274***a*, the wireless transceiver **266**, the radio module **172***d*, sensors **280**, the avionics module **274***e*, the wireless communication manager **101**, **306**, **314**, and the altitude obtaining component **318**.

[0128] In block **404**, the processor may send a message using beamformed transmissions in response to the altitude of the apparatus meeting an altitude threshold. In some implementations and aspects, the processor may send the message using beamformed transmissions in response to determining that the message is for reception by a ground receiver and the altitude meets the altitude threshold. In some implementations and aspects, the processor may send the beamformed transmission in directional beams aimed in at least two different directions (e.g., the directional beams **130***a*-**130***d*). In some implementations and aspects, the processor may send the directional beams aimed in at least two different directions within a latency constraint of the message. In some implementations and aspects, the processor may send the directional beams aimed in at least two different directions via a sidelink communication link. In some implementations and aspects, the processor may

include in the beamforming transmission a beam identifier configured to enable a receiver device (e.g., the apparatus **112**, **114**, such as a ground receiver) to obtain the beam identifier of the directional beam (e.g., **130***a*-**130***d*) used to transmit beamformed transmissions. Means for performing the operations of block **404** include the processor **210**, **212**, **214**, **216**, **218**, **252**, **260** and **274***a*, the wireless transceiver **266**, the radio module **172***d*, the wireless communication manager **101**, **306**, **314**, and the beamformed transmission component **320**.

[0129] FIG. **4**B is a process flow diagram illustrating a method **400***b* that may be performed by a processor of an apparatus (e.g., a UAV) for managing a broadcast signal according to various implementations and aspects. With reference to FIGS. **1**-**4**B, the operations of the method **400***b* may be performed by a processor (such as the processor **210**, **212**, **214**, **216**, **218**, **252**, **260**, **274***a*) of an apparatus (such as the apparatus **100***c*, **140**, **142**, **144**, e.g., a UAV).

[0130] In block **406**, the processor may determine a type of message to be sent from the apparatus. In some implementations and aspects, the processor may determine whether the message type is a message for reception by other apparatuses or a message for reception by a ground receiver. In some implementations and aspects, the message for reception by other apparatuses may be a maneuvering safety message and the message for reception by a ground receiver may be an identification message. Means for performing the operations of block **406** include the processor **210**, **212**, **214**, **216**, **218**, **252**, **260** and **274***a*, the wireless communication manager **101**, **306**, **314**, and the message type component **324**.

[0131] In block **408**, the processor may select the altitude threshold based on the determined type of the message. For example, the processor may select the altitude threshold based on whether the message is of a type for reception by a ground receiver, or the message is of a type for reception by other apparatuses. In some implementations and aspects, the processor may select the altitude threshold based on one or more additional factors. For example, the processor may select the altitude threshold based on one or more of a transmit power capability of a transmit chain or a radio module (e.g., **172***d*) of the apparatus, a stored power level in a battery or power module of the apparatus (e.g., **276**), beamforming capabilities of a transmission device of the apparatus (e.g., **172***d*, **172***f*), a level or an amount of radio frequency interference proximate to the apparatus, and a level or an amount of communication link congestion or network congestion Means for performing the operations of block **408** include the processor **210**, **212**, **214**, **216**, **218**, **252**, **260** and **274***a*, the wireless transceiver **266**, the radio module **172***d*, the antenna **172***f*, the power module **276**, the wireless communication manager **101**, **306**, **314**, and the altitude threshold component **326**.

[0132] In block **402**, the processor may obtain the altitude of the apparatus as described.

[0133] In determination block **410**, the processor may determine whether the altitude of the apparatus meets the altitude threshold. Means for performing the operations of determination block **410** include the processor **210**, **212**, **214**, **216**, **218**, **252**, **260** and **274***a*, the wireless communication manager **101**, **306**, **314**, and the altitude threshold component **326**.

[0134] In response to determining that the apparatus altitude meets the altitude threshold (i.e., determination block **410**="Yes"), the processor may send the message using beamformed transmissions in block **404** as described.

[0135] In response to determining that the apparatus altitude fails to meet (does not meet) the altitude threshold (i.e., determination block **408**="No"), the processor may send the message using omnidirectional transmissions in block **412**. Means for performing the operations of block **412** include the processor **210**, **212**, **214**, **216**, **218**, **252**, **260**, and **274***a*, the wireless transceiver **266**, the wireless communication manager **101**, **306**, **314**, and the omnidirectional transmission component **322**.

[0136] In block **414**, the processor may receive from a second apparatus (e.g., a receiving device) a retransmission request (e.g., a non-acknowledgment (NACK) message). In some implementations and aspects, the retransmission request may include the beam identifier of the received beamformed transmission. Means for performing the operations of block **414** include the processor **210**, **212**, **214**, **216**, **218**, **252**, **260**, **274***a*, the radio module **172***d*, the wireless communication manager **101**, **306**, **314**, and the retransmission component **330**.

[0137] In determination block **416**, the processor may determine whether the altitude of the apparatus meets the altitude threshold. Means for performing the operations of determination block **416** include the processor **210**, **212**, **214**, **216**, **218**, **252**, **260** and **274***a*, the wireless communication manager **101**, **306**, **314**, and the altitude threshold component **326**.

[0138] In response to determining that the apparatus altitude meets the altitude threshold (i.e., determination block **416**="Yes"), the processor may transmit the message using beamformed transmissions in block **418**. In some implementations and aspects, to retransmit the message the processor may perform one or more operations similar to those described above with respect to block **410**. Means for performing the operations of block **418** include the processor **210**, **212**, **214**, **216**, **218**, **252**, **260** and **274***a*, the wireless transceiver **266**, the radio module **172***d*, the wireless communication manager **101**, **306**, **314**, and the beamformed transmission component **320**.

[0139] In response to determining that the apparatus altitude does not meet the altitude threshold (i.e., determination block **416**="No"), the processor may retransmit the message using omnidirectional transmissions in block **420**. In some implementations and aspects, to retransmit the message the processor may perform one or more operations similar to those described above with respect to block **412**. Means for performing the operations of block **420** include the processor **210**, **212**, **214**, **216**, **218**, **252**, **260** and **274***a*, the wireless transceiver **266**, the radio module **172***d*, the wireless communication manager **101**, **306**, **314**, and the omnidirectional transmission component **320**.

[0140] FIG. **5** is a process flow diagram illustrating operations **500** that may be performed by a processor of an apparatus (e.g., a UAV) as part of the methods **400***a* and **400***b* for managing a broadcast signal according to various implementations and aspects. With reference to FIGS. **1**-**5**, the operations **500** may be performed by a processor (such as the processor **210**, **212**, **214**, **216**, **218**, **252**, **260**, **274***a*) of an apparatus (such as the apparatus **100***c*, **140**, **142**, **144**, e.g., a UAV).

[0141] In block **406**, the processor may determine a type of a message to be sent from the apparatus as described.

[0142] In determination block **502**, the processor may determine whether the message is intended for reception by a first type of second apparatus (e.g., UAV **142**, **144**) or a second type of second apparatus (e.g., ground receiver **112**, **114**). Means for performing the operations of determination block **502** include the processor **210**, **212**, **214**, **216**, **218**, **252**, **260** and **274***a*, the wireless communication manager **101**, **306**, **314**, and the apparatus type component **328**.

[0143] In response to determining that the message is intended for the first type of second apparatus (i.e., determination block **502**="First Type") (e.g., UAV **142**, **144**), the processor may send the message using omnidirectional transmissions in block **412** as described.

[0144] In response to determining that the message is intended for the first type of second apparatus (i.e., determination block **502**="Second Type") (e.g., ground receiver **112**, **114**), the processor may select an altitude threshold in block **504**. In some implementations and aspects, the processor may obtain the altitude of the apparatus from one or more of an altitude sensor, a barometer information (which may, for example, enable the processor to infer the altitude of the apparatus), a global navigation satellite system receiver, or a network element that provides the altitude of the apparatus (e.g., via the base station **126**). Means for performing the operations of block **504** include the processor **210**, **212**, **214**, **216**, **218**, **252**, **260**, and **274***a*, the wireless transceiver **266**, the radio module **172***d*, sensors **280**, the avionics module **274***e*, the wireless communication manager **101**, **306**, **314**, and the altitude threshold component **326**.

[0145] In blocks **402**, **404**, and **410-420**, the processor may perform the operations of corresponding blocks of the methods **400***a* and **400***b* as described.

[0146] FIG. **6** is a process flow diagram illustrating a method **600** that may be performed by a processor of an apparatus (e.g., a ground receiver) for managing a broadcast signal of a second apparatus (e.g., a UAV) according to various implementations and aspects. With reference to FIGS. **1-6**, operations of the method **600** may be performed by a processor (such as the processor **210**, **212**, **214**, **216**, **218**, **252**, **260**) of a an apparatus (e.g., ground receiver **112**, **114**).

[0147] In block **602**, the processor may receive beamformed transmissions from a second apparatus (e.g., UAV **140**, **142**, **144**). Means for performing the operations of block **602** include the processor **210**, **212**, **214**, **216**, **218**, **252**, **260**, the wireless transceiver **266**, the wireless communication manager **354**, **364**, and the beamformed transmission component **366**.

[0148] In response to unsuccessfully decoding the message, the processor may obtain a beam identifier of a directional beam of beamformed transmissions in block **604**. Means for performing the operations of block **604** include the processor **210**, **212**, **214**, **216**, **218**, **252**, **260**, the wireless communication manager **354**, **364**, and the beam identifier component **368**.

[0149] In block **606**, the processor may transmit to the second apparatus a retransmission request in beamformed transmissions using the obtained beam identifier. Means for performing the operations of block **606** include the processor **210**, **212**, **214**, **216**, **218**, **252**, **260**, the wireless transceiver **266**, the wireless communication manager **354**, **364**, and the retransmission component **370**.

[0150] FIG. **7** is a component block diagram of a network computing device **700** suitable for use with various implementations and aspects. Such network computing devices may include at least the components illustrated in FIG. **7**. With reference to FIGS. **1-7**, the network computing device **700** may typically include a processor **701** coupled to volatile memory **702** and a large capacity nonvolatile memory, such as a disk drive **708**. The network computing device **700** also may include a peripheral memory access device **706** such as a floppy disc drive, compact disc (CD) or digital video disc (DVD) drive coupled to the processor **701**. The network computing device **700** also may include network access ports **704** (or interfaces) coupled to the processor **701** for establishing data connections with a network, such as the Internet or a local area network coupled to other system computers and servers. The network computing device **700** may include one or more antennas **707** for sending and receiving electromagnetic radiation that may be connected to a wireless communication link. The network computing device **700** may include additional access ports, such as USB, Firewire, Thunderbolt, and the like for coupling to peripherals, external memory, or other devices.

[0151] The processor of the network computing device **700** may be any programmable microprocessor, microcomputer or multiple processor chip or chips that can be configured by software instructions (applications) to perform a variety of functions, including the functions of some implementations and aspects described below. In some wireless devices, multiple processors may be provided, such as one processor within an SOC (e.g., **204**) dedicated to wireless communication functions and one processor within an SOC (e.g., **202**) dedicated to running other applications. Software applications may be stored in the memory **702** before they are accessed and loaded into the processor. The processors may include internal memory sufficient to store the application software instructions.

[0152] FIG. **8** is a component block diagram illustrating an example wireless device **800** suitable for use with various implementations and aspects. With reference to FIGS. **1-8**, the wireless device **800** (such as the receiver devices **112**, **114**) may be a device suitable for use in various implementations and aspects, such as a mobile device. The wireless device **800** may include a first SOC **202** (such as a SOC-CPU) coupled to a second SOC **204** (such as a 5G capable SOC). The first and second SOCs **202**, **204** may be coupled to internal memory **816**, a display **812**, and to a speaker **814**. Additionally, the wireless device **800** may include an antenna **804** for sending and receiving electromagnetic radiation that may be connected to a wireless data link or cellular telephone transceiver **808** coupled to one or more processing systems in the first or second SOCs **202**, **204**. The wireless device **800** may include menu selection buttons or rocker switches **820** for receiving user inputs.

[0153] The wireless device **800** also may include a sound encoding/decoding (CODEC) circuit **810**, which digitizes sound received from a microphone into data packets suitable for wireless transmission and decodes received sound data packets to generate analog signals that are provided to the speaker **814** to generate sound. One or more of the processing systems in the first and second SOCs **202**, **204**, wireless transceiver **808** and CODEC **810** may include a digital signal processor (DSP) circuit (not shown separately).

[0154] The processing systems of the network computing device **800** and the wireless device **800** may be any programmable microprocessor, microcomputer or multiple processor chip or chips that can be configured by processor-

executable instructions to perform a variety of functions, including the functions of the various implementations and aspects described herein. In some mobile devices, multiple processing systems may be provided, such as one processing system within an SOC **204** dedicated to wireless communication functions and one processing system within an SOC **202** dedicated to running other applications. Software applications may be stored in the memory **816** before they are accessed and loaded into the processing system. The processing systems may include internal memory sufficient to store the application software instructions.

[0155] Implementation examples are described in the following paragraphs. While some of the following implementation examples are described in terms of example methods, further example implementations and aspects may include: the example methods discussed in the following paragraphs implemented by an apparatus including a processor configured with processor-executable instructions to perform operations of the methods of the following implementation examples; the example methods discussed in the following paragraphs implemented by an apparatus including means for performing functions of the example methods; and the example methods discussed in the following paragraphs implemented as a non-transitory processor-readable storage medium having stored thereon processor-executable instructions configured to cause a processor of an apparatus to perform the operations of the example methods.

[0156] Example 1. A method performed by an apparatus for managing a broadcast signal, including obtaining an altitude of the apparatus, and sending a message using beamformed transmissions in response to the altitude of the apparatus meeting an altitude threshold.

[0157] Example 2. The method of example 1, further including sending the message using omnidirectional transmissions in response to the altitude of the apparatus failing to meet the altitude threshold.

[0158] Example 3. The method of either of examples 1 or 2, in which obtaining an altitude of the apparatus includes obtaining the altitude of the apparatus from one or more of an altitude sensor, apparatus barometer information, a global navigation satellite system receiver, or a network element that provides the altitude of the apparatus.

[0159] Example 4. The method of any of examples 1-3, further including determining a type of the message, and selecting the altitude threshold based on the determined type of the message.

[0160] Example 5. The method of any of examples 1-4, further including sending the message using omnidirectional transmissions in response to the message being for reception by a first type of second apparatus, and sending the message using beamformed transmissions in response to the message being for reception by the second type of second apparatus.

[0161] Example 6. The method of example 5, in which sending the message using beamformed transmissions in response to the message being for reception by the second type of second apparatus includes sending the message using beamformed transmissions in response to the message being for reception by the second type of second apparatus and the altitude meeting the altitude threshold.

[0162] Example 7. The method of example 5, in which the message for reception by the first type of second apparatus includes a maneuvering safety message and the message for reception by the second type of second apparatus includes an identification message.

[0163] Example 8. The method of any of examples 1-7, further including sending the message using beamformed transmissions in directional beams in at least two different directions.

[0164] Example 9. The method of any of examples 1-8, further including sending the message using beamformed transmissions in directional beams in at least two different directions within a latency constraint of the message.

[0165] Example 10. The method of any of examples 1-9, further including sending the message using beamformed transmissions in directional beams in at least two different directions via a sidelink communication link.

[0166] Example 11. The method of any of examples 1-10, further including in beamformed transmissions a beam identifier that enables a receiver device to obtain the beam identifier of a directional beam used to transmit a received beamformed transmission.

[0167] Example 12. The method of example 9, further including receiving from a second apparatus a retransmission request including the beam identifier of the received beamformed transmission, and retransmitting the message using beamformed transmissions associated with the beam identifier.

[0168] Example 13. The method of example 12, further including receiving from a second apparatus a retransmission request, and retransmitting the message using omnidirectional transmissions when the altitude of the apparatus fails to meet the altitude threshold.

[0169] Example 14. The method of example 13, further including retransmitting the message using beamformed transmissions when the altitude of the apparatus meets the altitude threshold.

[0170] Example 15. An apparatus including means for performing operations of the methods of any of examples 1-14.

[0171] Example 16. An apparatus including a memory; and at least one processor coupled to the memory, the memory and the at least one processor to perform operations of the methods of any of examples 1-14.

[0172] Example 17. A non-transitory processor readable storage medium having processor-executable instructions stored thereon configured to cause a processor of an apparatus to perform operations of the methods of any of examples 1-14.

[0173] Example 18. A method performed by an apparatus for managing a broadcast signal of a second apparatus, including receiving in beamformed transmissions from the second apparatus, obtaining a beam identifier of a directional beam of beamformed transmissions in response to unsuccessfully decoding the message, and transmitting to the second apparatus a retransmission request in beamformed transmissions using the obtained beam identifier.

[0174] Example 19. An apparatus comprising means for performing operations of the method of example 18.

[0175] Example 20. An apparatus comprising a memory; and at least one processor coupled to the memory, the memory and the at least one processor to perform operations of the method of example 18.

[0176] Example 21. A non-transitory processor readable storage medium having processor-executable instructions stored thereon configured to cause a processor of an apparatus to perform operations of the method of example 18.

[0177] As used in this application, the terms "component," "module," "system," and the like are intended to include a

computer-related entity, such as, but not limited to, hardware, firmware, a combination of hardware and software, software, or software in execution, which are configured to perform particular operations or functions. For example, a component may be, but is not limited to, a process running on a processor, a processor, an object, an executable, a thread of execution, a program, or a computer. By way of illustration, both an application running on a wireless device and the wireless device may be referred to as a component. One or more components may reside within a process or thread of execution and a component may be localized on one processor or core or distributed between two or more processors or cores. In addition, these components may execute from various non-transitory computer readable media having various instructions or data structures stored thereon. Components may communicate by way of local or remote processes, function or procedure calls, electronic signals, data packets, memory read/writes, and other known network, computer, processor, or process related communication methodologies.

[0178] A number of different cellular and mobile communication services and standards are available or contemplated in the future, all of which may implement and benefit from the various implementations and aspects. Such services and standards include, e.g., third generation partnership project (3GPP), long term evolution (LTE) systems, third generation wireless mobile communication technology (3G), fourth generation wireless mobile communication technology (4G), fifth generation wireless mobile communication technology (5G) as well as later generation 3GPP technology, global system for mobile communications (GSM), universal mobile telecommunications system (UMTS), 3GSM, general packet radio service (GPRS), code division multiple access (CDMA) systems (e.g., cdmaOne, CDMA1020™), enhanced data rates for GSM evolution (EDGE), advanced mobile phone system (AMPS), digital AMPS (IS-136/TDMA), evolution-data optimized (EV-DO), digital enhanced cordless telecommunications (DECT), Worldwide Interoperability for Microwave Access (WiMAX), wireless local area network (WLAN), Wi-Fi Protected Access I & II (WPA, WPA2), and integrated digital enhanced network (iDEN). Each of these technologies involves, for example, the transmission and reception of voice, data, signaling, and/or content messages. It should be understood that any references to terminology and/or technical details related to an individual telecommunication standard or technology are for illustrative purposes only, and are not intended to limit the scope of the claims to a particular communication system or technology unless specifically recited in the claim language.

[0179] Various implementations and aspects illustrated and described are provided merely as examples to illustrate various features of the claims. However, features shown and described with respect to any given implementation are not necessarily limited to the associated implementation and may be used or combined with other implementations and aspects that are shown and described. Further, the claims are not intended to be limited by any one example implementation. For example, one or more of the methods and operations **400***a*, **400***b*, **500**, and **600** may be substituted for or combined with one or more operations of the methods and operations **400***a*, **400***b*, **500**, and **600**.

[0180] The foregoing method descriptions and the process flow diagrams are provided merely as illustrative examples and are not intended to require or imply that the operations of various implementations and aspects must be performed in the order presented. As will be appreciated by one of skill in the art the order of operations in the foregoing implementations and aspects may be performed in any order. Words such as "thereafter," "then," "next," etc. are not intended to limit the order of the operations; these words are used to guide the reader through the description of the methods. Further, any reference to claim elements in the singular, for example, using the articles "a," "an," or "the" is not to be construed as limiting the element to the singular.

[0181] Various illustrative logical blocks, modules, components, circuits, and algorithm operations described in connection with the implementations and aspects disclosed herein may be implemented as electronic hardware, computer software, or combinations of both. To clearly illustrate this interchangeability of hardware and software, various illustrative components, blocks, modules, circuits, and operations have been described above generally in terms of their functionality. Whether such functionality is implemented as hardware or software depends upon the particular application and design constraints imposed on the overall system. Skilled artisans may implement the described functionality in varying ways for each particular application, but such implementation decisions should not be interpreted as causing a departure from the scope of the claims.

[0182] The hardware used to implement various illustrative logics, logical blocks, modules, and circuits described in connection with the implementations and aspects disclosed herein may be implemented or performed with a general purpose processor, a digital signal processor (DSP), an application specific integrated circuit (ASIC), a field programmable gate array (FPGA) or other programmable logic device, discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform the functions described herein. A general-purpose processor may be a microprocessor, but, in the alternative, the processor may be any conventional processor, controller, microcontroller, or state machine. A processor may also be implemented as a combination of receiver smart objects, e.g., a combination of a DSP and a microprocessor, a plurality of microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration. Alternatively, some operations or methods may be performed by circuitry that is specific to a given function.

[0183] In one or more implementations and aspects, the functions described may be implemented in hardware, software, firmware, or any combination thereof. If implemented in software, the functions may be stored as one or more instructions or code on a non-transitory computer-readable storage medium or non-transitory processor-readable storage medium. The operations of a method or algorithm disclosed herein may be embodied in a processor-executable software module or processor-executable instructions, which may reside on a non-transitory computer-readable or processor-readable storage medium. Non-transitory computer-readable or processor-readable storage media may be any storage media that may be accessed by a computer or a processor. By way of example but not limitation, such non-transitory computer-readable or processor-readable storage media may include RAM, ROM, EEPROM, FLASH memory, CD-ROM or other optical disk storage, magnetic disk storage or other magnetic storage smart objects, or any other medium that may be used to store desired program

code in the form of instructions or data structures and that may be accessed by a computer. Disk and disc, as used herein, includes compact disc (CD), laser disc, optical disc, digital versatile disc (DVD), floppy disk, and Blu-ray disc where disks usually reproduce data magnetically, while discs reproduce data optically with lasers. Combinations of the above are also included within the scope of non-transitory computer-readable and processor-readable media. Additionally, the operations of a method or algorithm may reside as one or any combination or set of codes and/or instructions on a non-transitory processor-readable storage medium and/or computer-readable storage medium, which may be incorporated into a computer program product.

[0184] The preceding description of the disclosed implementations and aspects is provided to enable any person skilled in the art to make or use the claims. Various modifications to these implementations and aspects will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other implementations and aspects without departing from the scope of the claims. Thus, the present disclosure is not intended to be limited to the implementations and aspects shown herein but is to be accorded the widest scope consistent with the following claims and the principles and novel features disclosed herein.

What is claimed is:

1. An apparatus for wireless communication, comprising:
memory; and
a processor, the memory and the processor configured to:
obtain an altitude of the apparatus; and
send a message using beamformed transmissions in response to the altitude of the apparatus meeting an altitude threshold.

2. The apparatus of claim **1**, wherein the memory and the processor are further configured to send the message using omnidirectional transmissions in response to the altitude of the apparatus failing to meet the altitude threshold.

3. The apparatus of claim **1**, wherein the memory and the processor are further configured to obtain the altitude of the apparatus from one or more of an altitude sensor, apparatus barometer information, a global navigation satellite system receiver, or a network element that provides the altitude of the apparatus.

4. The apparatus of claim **1**, wherein the memory and the processor are further configured to:
determine a type of the message; and
select the altitude threshold based on the determined type of the message.

5. The apparatus of claim **1**, wherein the memory and the processor are further configured to:
send the message using omnidirectional transmissions in response to the message being for reception by a first type of second apparatus;
send the message using beamformed transmissions in response to the message being for reception by a second type of second apparatus.

6. The apparatus of claim **5**, wherein the memory and the processor are further configured to send the message using beamformed transmissions in response to the message being for reception by the second type of second apparatus and the altitude meeting the altitude threshold.

7. The apparatus of claim **5**, wherein the memory and the processor are further configured such that the message for reception by a first type of second apparatus comprises a maneuvering safety message and the message for reception by a second type of second apparatus comprises an identification message.

8. The apparatus of claim **1**, wherein the memory and the processor are further configured to send the message using beamformed transmissions in directional beams in at least two different directions.

9. The apparatus of claim **1**, wherein the memory and the processor are further configured to send the message using beamformed transmissions in directional beams in at least two different directions within a latency constraint of the message.

10. The apparatus of claim **1**, wherein the memory and the processor are further configured to send the message using beamformed transmissions in directional beams in at least two different directions via a sidelink communication link.

11. The apparatus of claim **1**, wherein the memory and the processor are further configured to include in beamformed transmissions a beam identifier that enables a receiver device to obtain the beam identifier of a directional beam used to transmit a received beamformed transmission.

12. The apparatus of claim **11**, wherein the memory and the processor are further configured to:
receive from a second apparatus a retransmission request including the beam identifier of the received beamformed transmission; and
retransmit the message using beamformed transmissions associated with the beam identifier.

13. The apparatus of claim **12**, wherein the memory and the processor are further configured to:
receive from a second apparatus a retransmission request; and
retransmit the message using omnidirectional transmissions when the altitude of the apparatus fails to meet the altitude threshold.

14. The apparatus of claim **12**, wherein the memory and the processor are further configured to retransmit the message using beamformed transmissions when the altitude of the apparatus meets the altitude threshold.

15. A method performed by an apparatus for managing a broadcast signal, comprising:
obtaining an altitude of the apparatus; and
sending a message using beamformed transmissions in response to the altitude of the apparatus meeting an altitude threshold.

16. The method of claim **15**, further comprising sending the message using omnidirectional transmissions in response to the altitude of the apparatus failing to meet the altitude threshold.

17. The method of claim **15**, wherein obtaining an altitude of the apparatus comprises obtaining the altitude of the apparatus from one or more of an altitude sensor, apparatus barometer information, a global navigation satellite system receiver, or a network element that provides the altitude of the apparatus.

18. The method of claim **15**, further comprising:
determining a type of the message; and
selecting the altitude threshold based on the determined type of the message.

19. The method of claim **15**, further comprising:
sending the message using omnidirectional transmission in response to the message being for reception by a first type of second apparatus; and

sending the message using beamformed transmission in response to the message being for reception by the second type of second apparatus.

20. The method of claim **19**, wherein sending the message using beamformed transmission in response to the message being for reception by the second type of second apparatus comprises sending the message using beamformed transmission in response to the message being for reception by the second type of second apparatus and the altitude meeting the altitude threshold.

21. The method of claim **19**, wherein the message for reception by the first type of second apparatus comprises a maneuvering safety message and the message for reception by the second type of second apparatus comprises an identification message.

22. The method of claim **15**, further comprising sending the message using beamformed transmissions in directional beams in at least two different directions.

23. The method of claim **15**, further comprising sending the message using beamformed transmissions in directional beams in at least two different directions within a latency constraint of the message.

24. The method of claim **15**, further comprising sending the message using beamformed transmissions in directional beams in at least two different directions via a sidelink communication link.

25. The method of claim **15**, further comprising including in beamformed transmissions a beam identifier that enables a receiver device to obtain the beam identifier of a directional beam used to transmit a received beamformed transmission.

26. The method of claim **25**, further comprising:

receiving from a second apparatus a retransmission request including the beam identifier of the received beamformed transmission; and

retransmitting the message using beamformed transmissions associated with the beam identifier.

27. The method of claim **25**, further comprising:

receiving from a second apparatus a retransmission request; and

retransmitting the message using omnidirectional transmissions when the altitude of the apparatus fails to meet the altitude threshold.

28. The method of claim **27**, further comprising retransmitting the message using beamformed transmissions when the altitude of the apparatus meets the altitude threshold.

29. An apparatus, comprising:

memory; and

a processor, the memory and the processor configured to:

receive beamformed transmissions comprising a message from a second apparatus; and

in response to unsuccessfully decoding the message:

obtain a beam identifier of a directional beam of beamformed transmissions; and

transmit to the second apparatus a retransmission request in beamformed transmissions using the obtained beam identifier.

30. A method performed by a processor of an apparatus for managing a broadcast signal of a second apparatus, comprising:

receiving in beamformed transmissions from the second apparatus; and

in response to unsuccessfully decoding the message:

obtaining a beam identifier of a directional beam of beamformed transmissions; and

transmitting to the second apparatus a retransmission request in beamformed transmissions using the obtained beam identifier.

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