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(54) **INTEGRATION OF ANTENNA STRUCTURES INTO BALLOON ENVELOPES**

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H01Q 1/12	(2006.01)
H04B 1/06	(2006.01)
H04B 1/38	(2015.01)

(52) **U.S. Cl.**
CPC ***H01Q 1/1292*** (2013.01); ***H04B 1/06*** (2013.01); ***H04B 1/38*** (2013.01)

(58) **Field of Classification Search**
CPC H01Q 1/243; H01Q 9/42; H01Q 1/38
See application file for complete search history.

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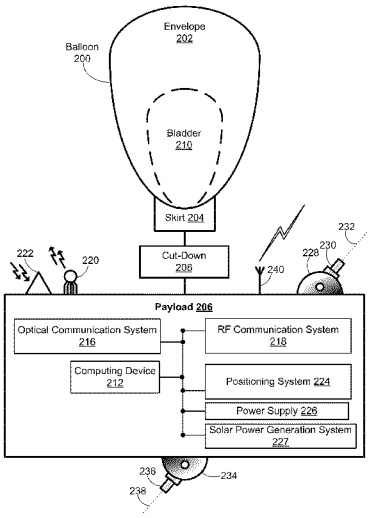
(57) **ABSTRACT**

Methods and apparatus are disclosed for receiving and transmitting signals at a balloon. Received signals can be received at the balloon, which can include a payload and an envelope. The envelope can include at least a first antenna section and a second antenna section. Both the first and second antenna sections are configured at least to receive the received signals and convey at least the received signals to the payload. The first antenna section can include a first metallization pattern to receive a first type of signal. The second antenna section can include a second metallization pattern to receive a second type of signal, with the first metallization pattern being different from the second metallization pattern.

20 Claims, 8 Drawing Sheets



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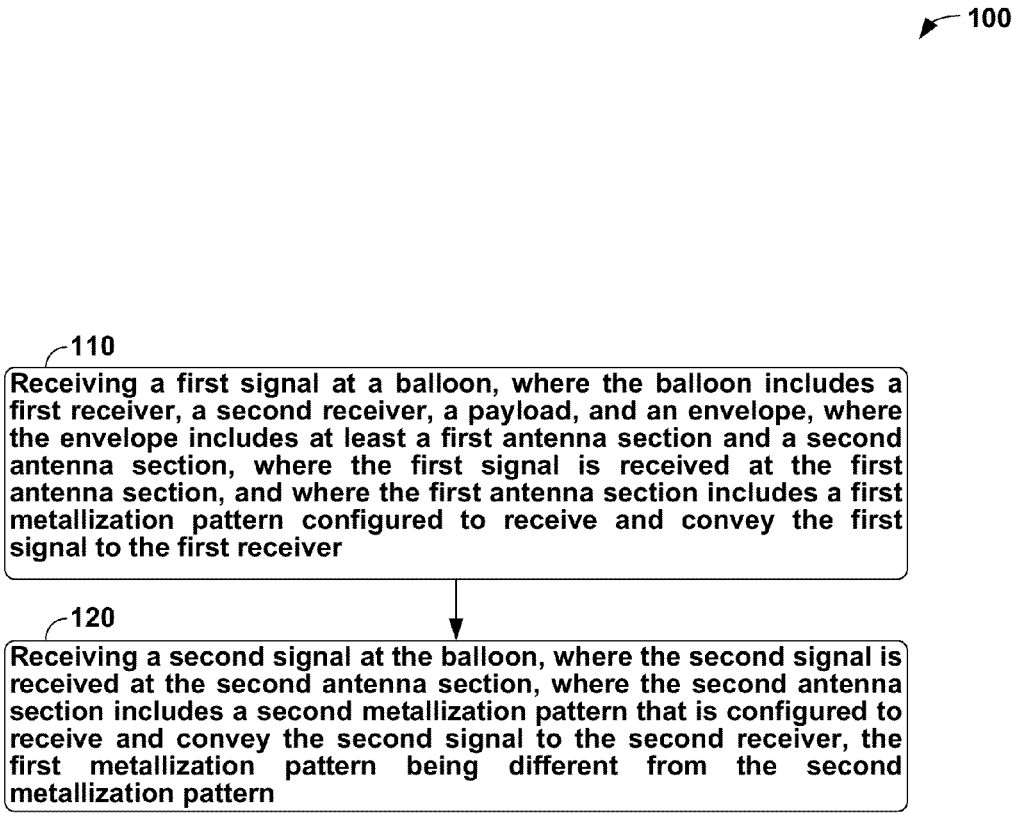
100
110
Receiving a first signal at a balloon, where the balloon includes a first receiver, a second receiver, a payload, and an envelope, where the envelope includes at least a first antenna section and a second antenna section, where the first signal is received at the first antenna section, and where the first antenna section includes a first metallization pattern configured to receive and convey the first signal to the first receiver
120
Receiving a second signal at the balloon, where the second signal is received at the second antenna section, where the second antenna section includes a second metallization pattern that is configured to receive and convey the second signal to the second receiver, the first metallization pattern being different from the second metallization pattern

FIGURE 1

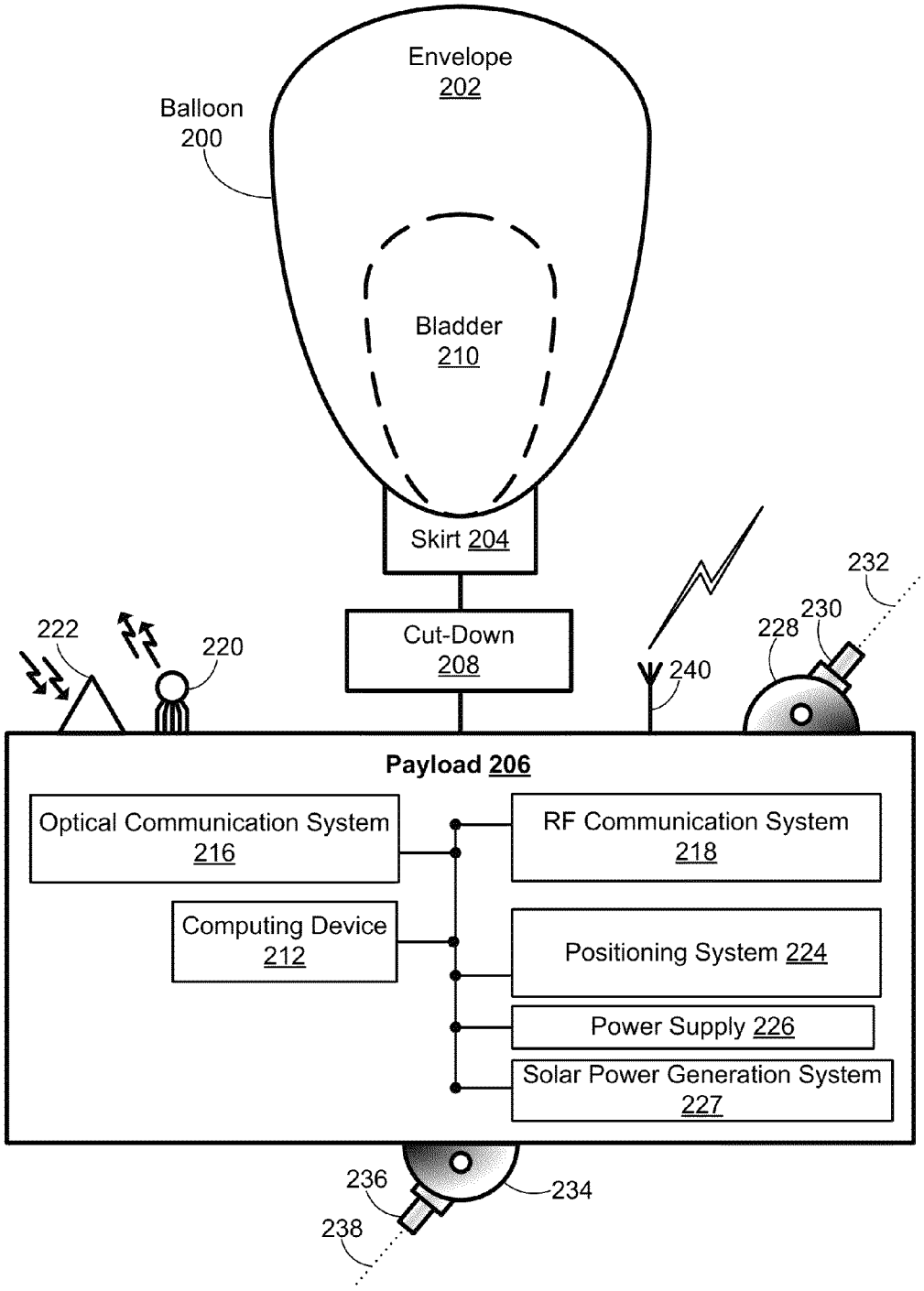
Envelope
202
Balloon
200
Bladder
210
Skirt 204
Cut-Down
208
222
220
240
232
230
228
Payload 206
Optical Communication System
216
RF Communication System
218
Computing Device
212
Positioning System 224
Power Supply 226
Solar Power Generation System
227
236
234
238

FIGURE 2

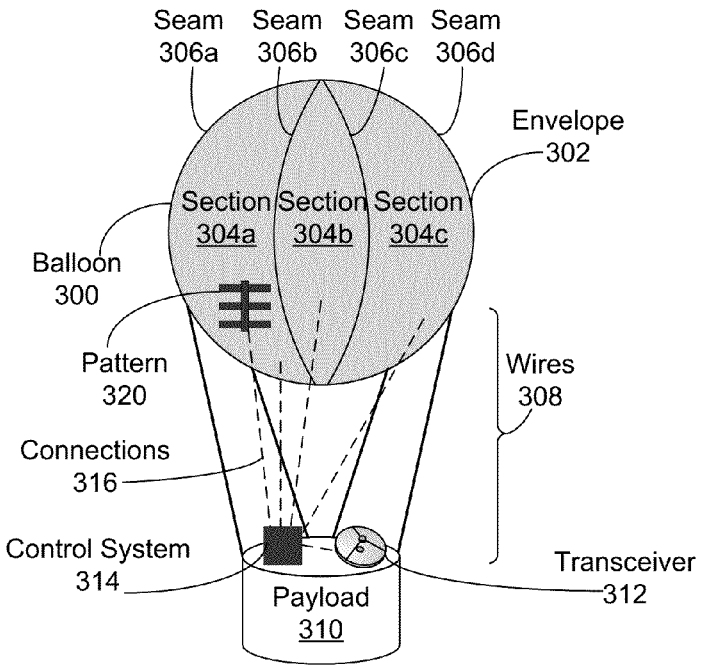

FIGURE 3

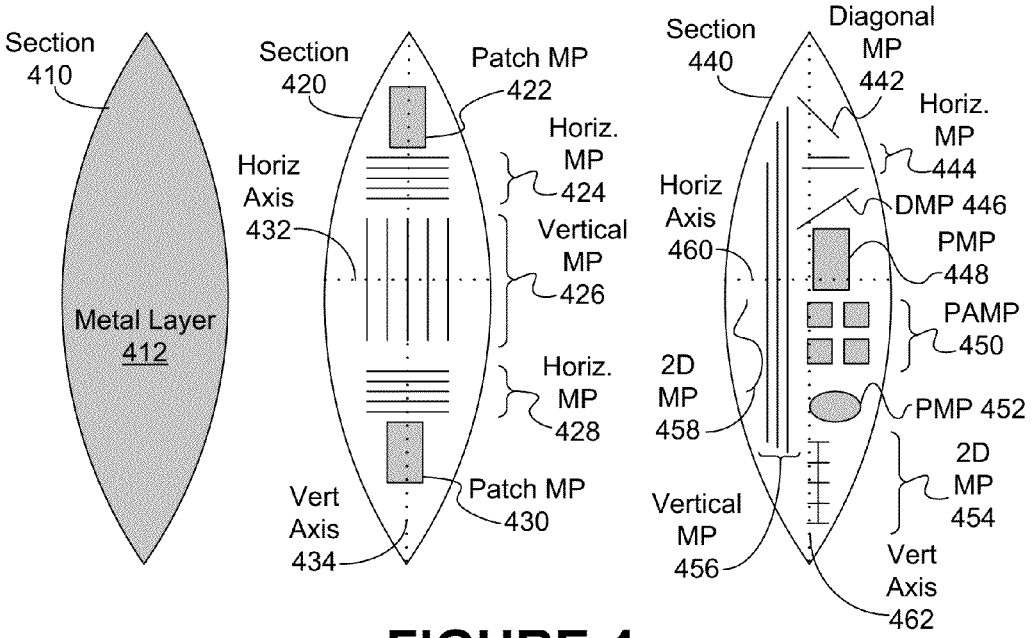

FIGURE 4

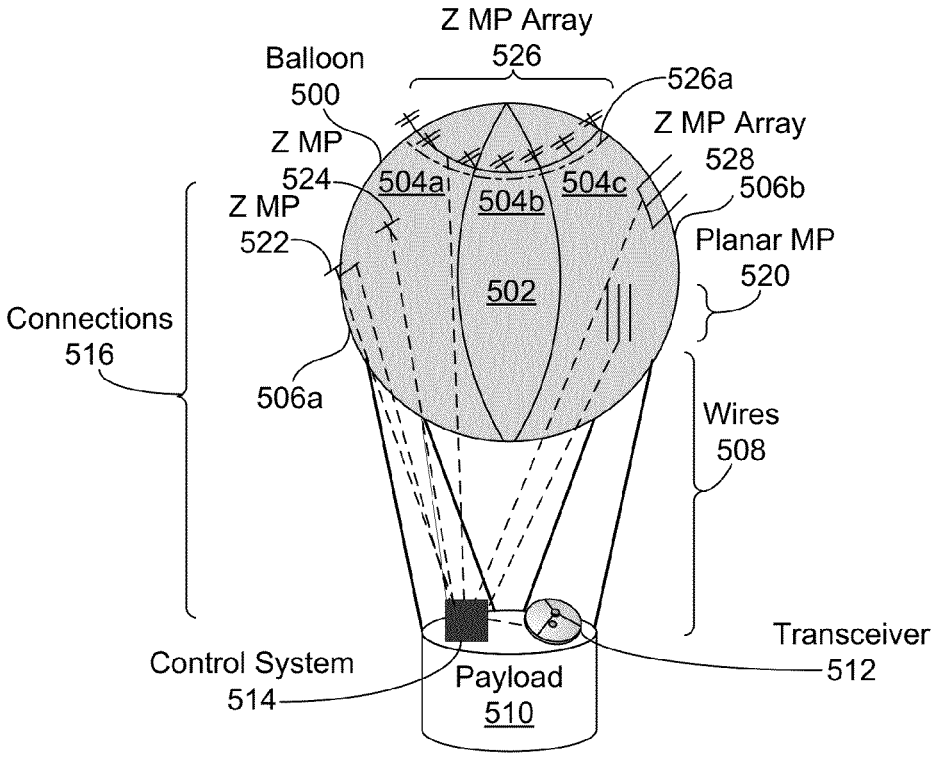

FIGURE 5A

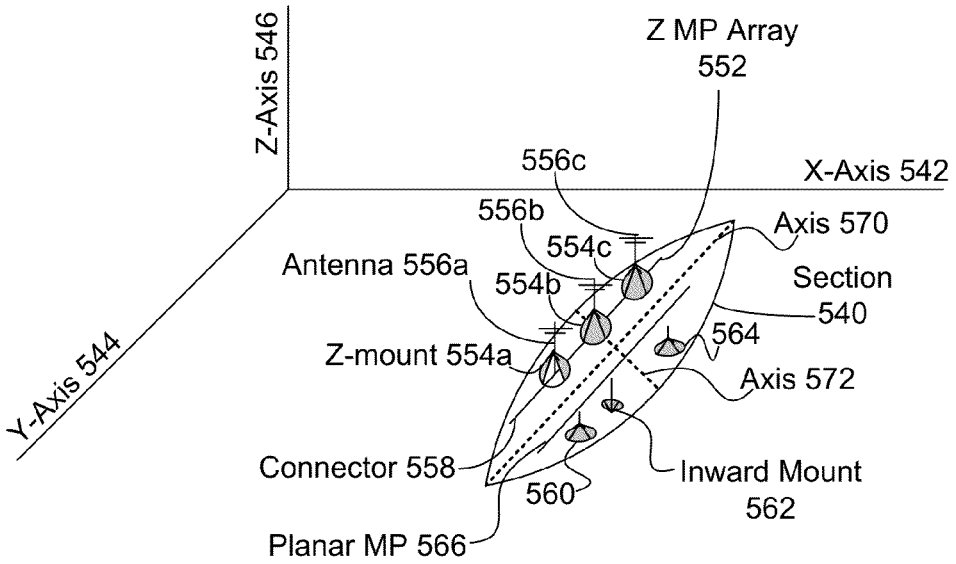

FIGURE 5B

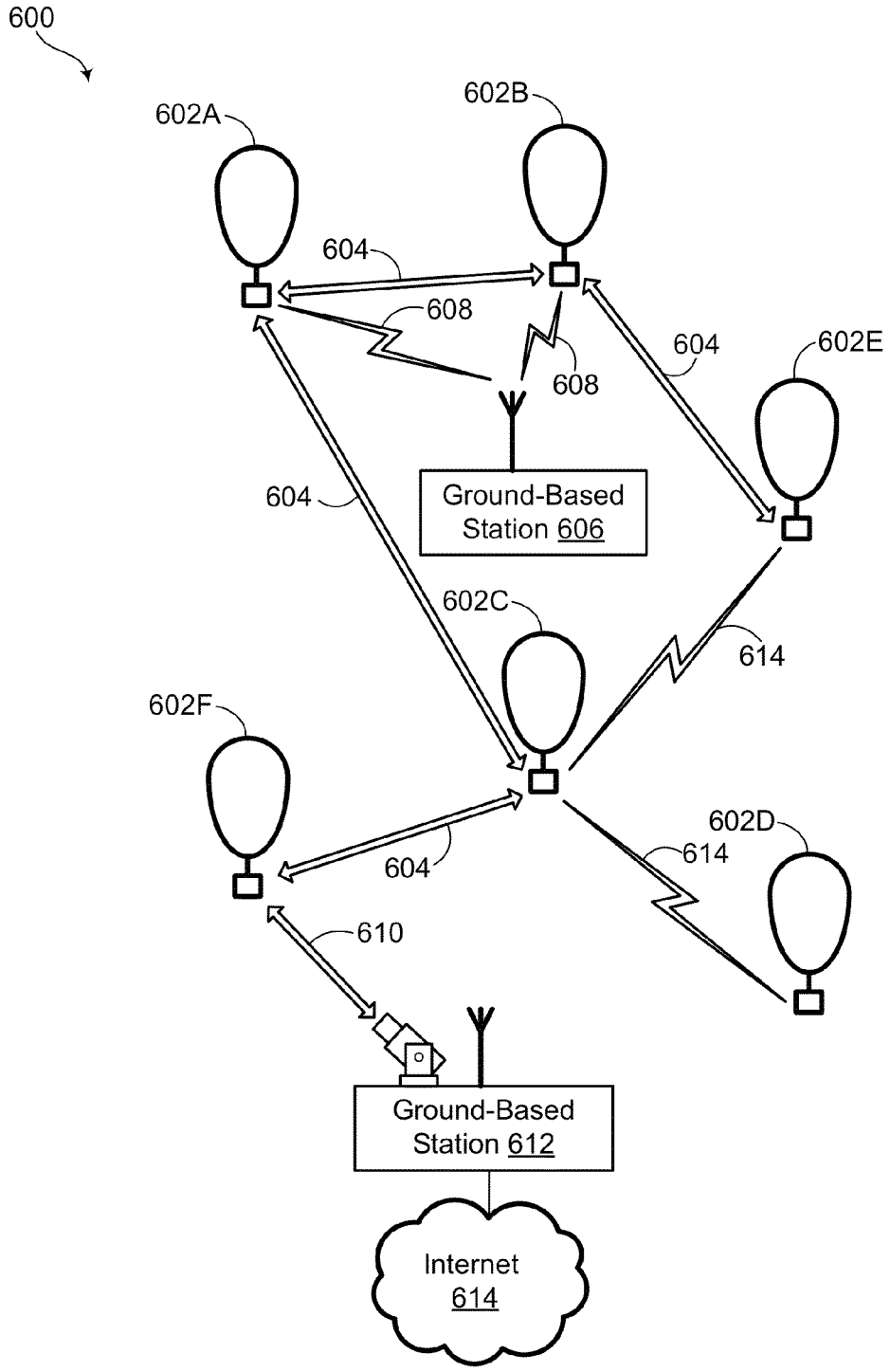
600
602A
602B
604
608
608
604
602E
604
Ground-Based Station 606
602C
614
602F
602D
604
614
610
Ground-Based Station 612
Internet 614

FIGURE 6A

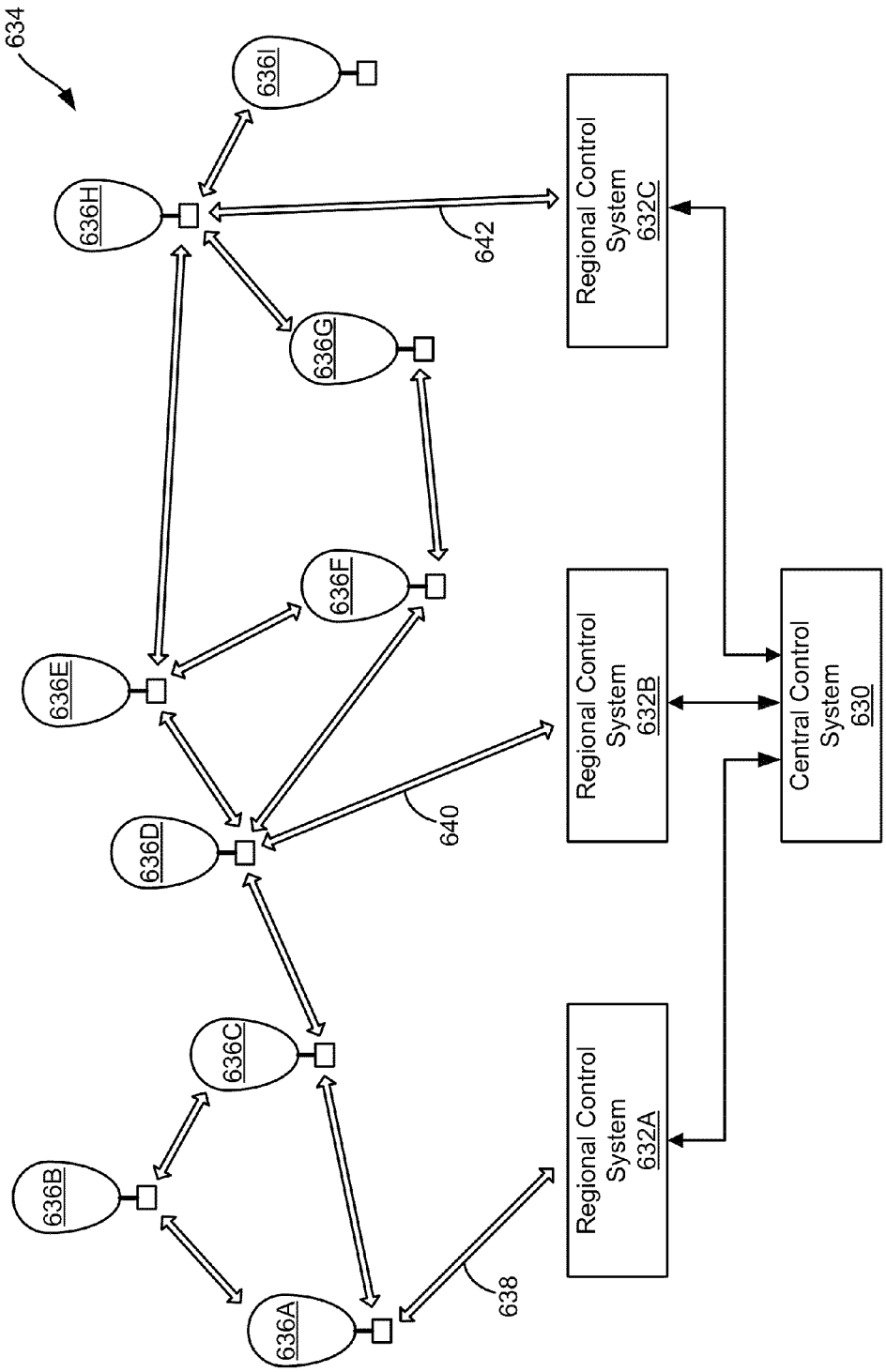
634
636I
636H
636G
636F
636E
636D
636C
636B
636A
642
640
638
Regional Control System 632C
Regional Control System 632B
Regional Control System 632A
Central Control System 630

FIGURE 6B

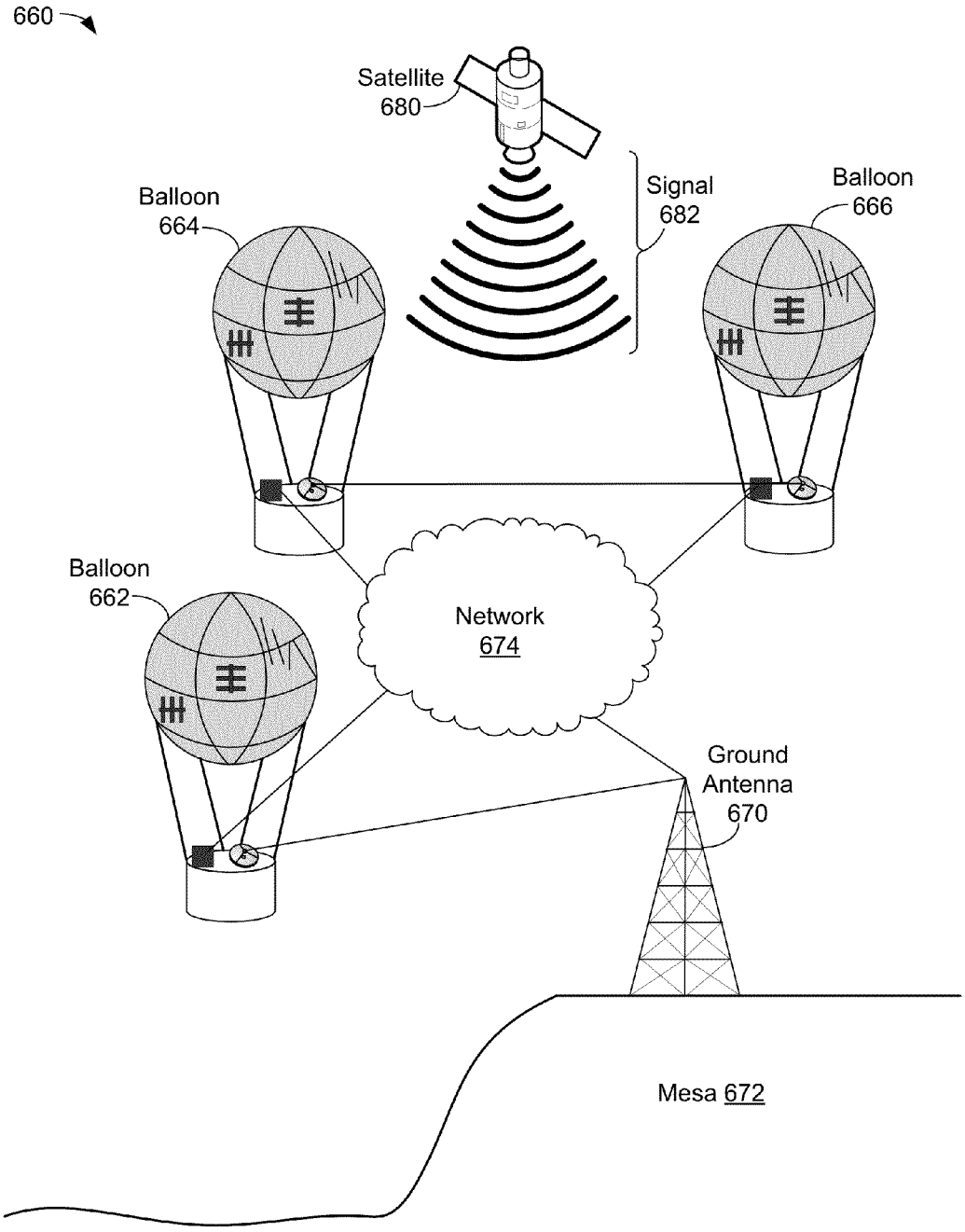
660
Satellite
680
Signal
682
Balloon
664
Balloon
666
Balloon
662
Network
674
Ground
Antenna
670
Mesa 672

FIGURE 6C

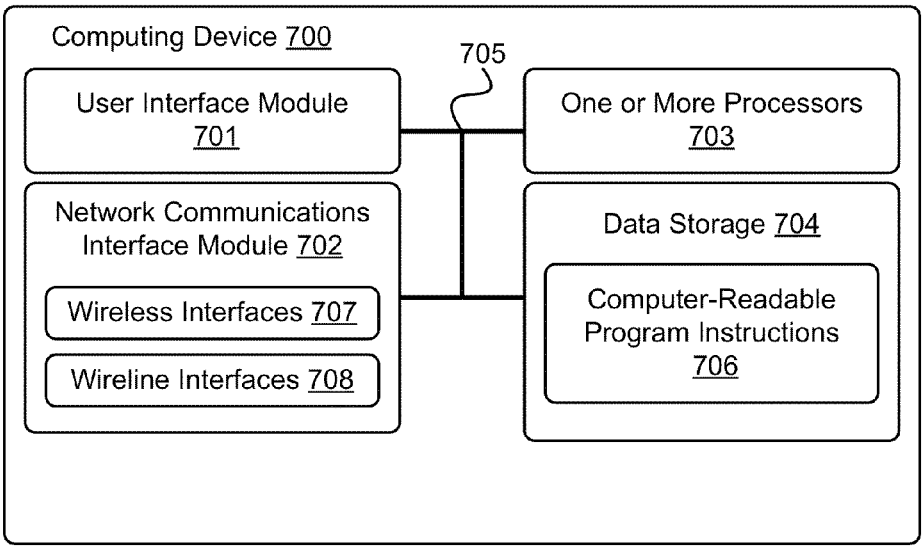

FIGURE 7A

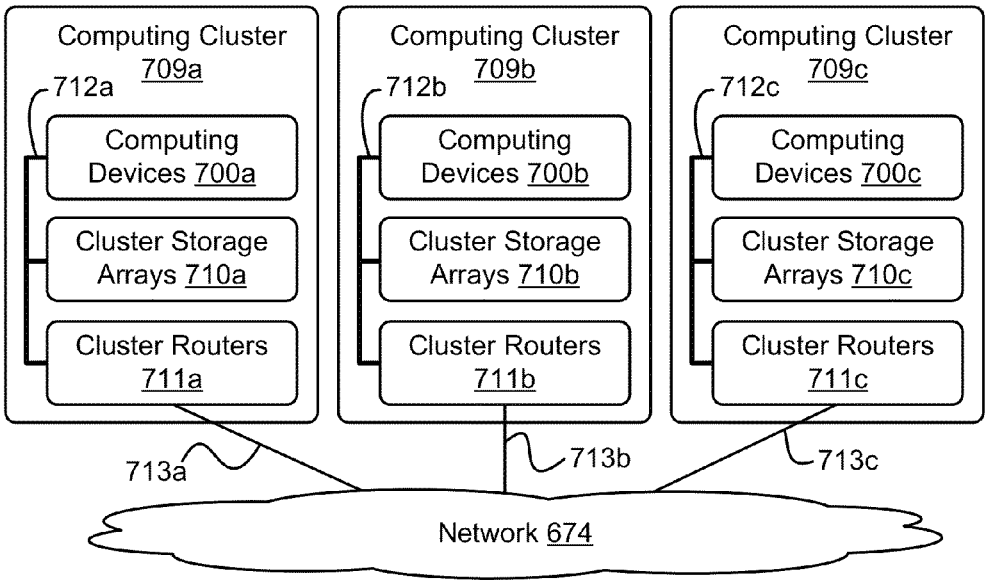

FIGURE 7B

INTEGRATION OF ANTENNA STRUCTURES INTO BALLOON ENVELOPES

BACKGROUND

Unless otherwise indicated herein, the materials described in this section are not prior art to the claims in this application and are not admitted to be prior art by inclusion in this section.

Current high-altitude balloons can include an envelope and a payload which are connected via wires. In some cases, the payload can include a communications receiver. The envelope can be made of a light-weight fabric, such as, but not limited to, nylon, silk, or polyester film, or combinations thereof, that can contain gases used to keep the balloon aloft. An example polyester film is Biaxially-oriented Polyethylene Terephthalate (boPET) a.k.a. Mylar™ Mylar™ is trademarked by E. I. DuPont De Nemours & Co. of Wilmington, Del.

Some communication receivers aboard current high-altitude balloons can require a clear upward view for communication. For example, a balloon's envelope can block communication signals, such as signals from satellites, from reaching a communication receiver.

SUMMARY

In a first aspect, a balloon is provided. The balloon includes a payload and an envelope. The envelope can include at least a first antenna section and a second antenna section. Both the first antenna section and the second antenna section are configured at least to receive signals and convey the received signals to the payload. The first antenna section includes a first metallization pattern to receive a first type of signal. The second antenna section includes a second metallization pattern to receive a second type of signal; the first metallization pattern being different from the second metallization pattern.

In another aspect, a method is provided. A first signal is received at a balloon. The balloon includes a first receiver, a second receiver, a payload, and an envelope. The envelope includes at least a first antenna section and a second antenna section. The first signal is received at the first antenna section of the plurality of antenna sections. The first antenna section includes a first metallization pattern configured to receive and convey the first signal to the first receiver. A second signal is received at the balloon. The second signal is received at the second antenna section. The second antenna section includes a second metallization pattern configured to receive and convey the second signal to the second receiver; the first metallization pattern being different from the second metallization pattern.

The foregoing summary is illustrative only and is not intended to be in any way limiting. In addition to the illustrative aspects, appearances, embodiments, and features described above, further aspects, appearances, embodiments, and features will become apparent by reference to the figures and the following detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a flow chart of a method, according to an example embodiment.

FIG. **2** shows an example balloon, in accordance with an example embodiment.

FIG. **3** shows another example balloon, in accordance with an example embodiment.

FIG. **4** shows example sections of a balloon, in accordance with an example embodiment.

FIG. **5**A shows another example balloon, in accordance with an example embodiment.

FIG. **5**B shows an example section of a balloon, in accordance with an example embodiment.

FIG. **6**A shows an example network, in accordance with an example embodiment.

FIG. **6**B shows another example network, in accordance with an example embodiment.

FIG. **6**C shows an example network scenario, in accordance with an example embodiment.

FIG. **7**A is a block diagram of a computing device, in accordance with an example embodiment.

FIG. **7**B depicts a network of computing clusters arranged as a cloud-based server system, in accordance with an example embodiment.

DETAILED DESCRIPTION

Overview

Example embodiments disclosed herein can generally relate to a data network formed by balloons, and in particular, to a mesh network formed by high-altitude balloons deployed in the stratosphere. In order that the balloons can provide a reliable mesh network in the stratosphere, where winds may affect the locations of the various balloons in an asymmetrical manner, the balloons in an exemplary network can be configured to move latitudinally and/or longitudinally relative to one another by adjusting their respective altitudes, so that winds aloft can carry the respective balloons to the respectively desired locations.

Further, in an exemplary balloon network, the balloons can communicate with one another using free-space optical communications. For instance, the balloons can be configured for optical communications using ultra-bright LEDs or possibly lasers for optical signaling (although regulations for laser communications can restrict laser usage). In addition, the balloons can communicate with ground-based station(s) using radio-frequency (RF) communications. Further, the balloons can be configured to communicate with one or more satellites. The one or more satellites can include but not limited to navigational satellites; e.g., Global Positioning System (GPS) satellites, communications satellites, broadcast television and/or radio satellites, and/or other satellites.

To better communicate with satellites and other overhead communication devices; e.g., communication devices aboard high-flying aircraft, a balloon can be configured with an envelope divided into sections. These sections can include one or more "antenna sections." Each antenna section of the envelope can be configured to send and/or receive signals, such as but not limited to signals from overhead communication source.

In some cases, the balloon can send communication signals. For example, the balloon can generate data, such as diagnostic data about the balloon or communications to other balloons in the network, that can be converted into communications signals for transmission. In other cases, the balloon can receive communications signals from other balloons in the network or signals that include navigational data from GPS or other navigational satellites. In yet other cases, the balloon can both send and receive communication signals. For example, the balloon can receive signals from one balloon in the network and relay the signals, perhaps after modification, to another balloon or communications device.

An example antenna section can be a "metallization section" with a thin layer of metallized material substantially or completely overlaying a fabric making up a section of the

envelope. Communication signals can be received at the thin layer of metallized material and transmitted from the antenna section to a control system in the payload of the balloon. Antenna sections can include "metallization patterns" (MPs) or patterns of metal embedded into and/or overlaying the fabric of the section. Example metallization patterns include, but are not limited, horizontal, diagonal, and vertical patterns that can act as dipole antennas, two-dimensional patches and/or arrays of patches of thin metal shaped as squares, rectangles, triangle, circles, ellipses, and/or in other shapes that can act as patch and/or other types of antenna, and "Z metallization patterns" that are configured to project an antenna out of a plane of the envelope of the balloon.

By using antenna sections for balloons, the balloon can gain and/or enhance the ability to communicate with overhead communications sources, such as satellites, other balloons in the network, and overhead aircraft. In some scenarios, overhead communications sources may not be directly overhead, and so antenna sections can receive communication signals from communication sources in other directions relative to the balloon, such as communication source(s) with higher, equal, and/or lower altitude(s) than the balloon. Such communications sources can include balloons, ground stations, mobile communications and/or computing devices, and other communications devices. By enhancing the ability of the balloon to communicate, the balloon can be able to increase performance via better navigation; i.e., using GPS, carrying out additional communications, and providing additional services; e.g., balloon/satellite communication.

As the envelope of the balloon is often a large object, the use of antenna sections that are part of balloon envelopes enables putting large antennas aloft whenever the balloon is launched. As putting large separate antennas aloft can be complicated and expensive, using antenna sections of balloon envelopes can save time and difficulty in comparison.

The use of multiple antenna sections can lead to increased communication throughput by enabling multiple simultaneous communications sessions, perhaps with each session using a different antenna section. Also, the multiple simultaneous communications sessions can involve simultaneous communications between the balloon and multiple communications devices, such as multiple satellites, balloons, ground stations, and/or other communication devices. In some scenarios, different types of signals can be received and/or transmitted using the multiple antenna sections; e.g. the balloon can receive a GPS signal from a GPS satellite and a balloon-RF signal from another balloon or the balloon can communicate with a ground station using RF signals that can have different protocol, frequency, encoding, and/or other characteristics than balloon-RF signals and/or GPS signals.

Example Operations

FIG. **1** is a flow chart of method **100**, according to an example embodiment. Method **100** begins at block **110**, where a first signal is received at a balloon. The balloon can include a first receiver, a second receiver, a payload, and an envelope. At least a portion of the envelope can include at least a first antenna section and a second antenna section. The first signal can be received at the first antenna section. The first antenna section can include a first metallization pattern configured to receive and convey the first signal to the first receiver.

At block **120**, a second signal is received at the balloon. The second signal can be received at the second antenna section. The second antenna section can include a second metallization pattern configured to receive and convey the second signal to the second receiver. The first metallization pattern can differ from the second metallization pattern.

In some embodiments, the balloon can initially operate in a first mode in which the balloon operates the first receiver to receive the first signal and does not operate the second receiver. In these embodiments, method **100** can further include: while the balloon is operating in the first mode, a trigger event can be detected; and in response to detecting the trigger event, the balloon can switch from operation in the first mode to operation in a second mode in which the balloon operates the second receiver to receive the second signal and does not operate the first receiver.

In other embodiments, method **100** can further include: in response to receiving the first signal, determining a transmittable signal; and transmitting the transmittable signal from the balloon using a transmitting antenna section of the plurality of antenna sections. The transmitting antenna section can include either the first antenna section or the second antenna section. In particular embodiments, determining the transmittable signals can include determining diagnostic information about the balloon. Then, the transmittable signals can be generated based on the diagnostic information. In other particular embodiments, the transmittable signals are based on the first signal. In still other particular embodiments, the balloon can also include a control system. Then, transmitting the transmittable signal can include: selecting the transmitting antenna section using the control system and transmitting the transmittable signals using the transmitting antenna section.

Example Balloons and Balloon Segments

Various types of balloon systems can be incorporated in an example balloon network. Some embodiments can utilize high-altitude balloons that may operate in an altitude range between 18 km and 22 km. FIG. **2** shows a high-altitude balloon **200**, according to an example embodiment. As shown, balloon **200** includes envelope **202**, skirt **204**, payload **206**, and cut-down system **208** attached between balloon **202** and payload **206**.

The envelope **202** and skirt **204** can take various forms, which can be currently well-known or yet to be developed. For instance, envelope **202** and/or skirt **204** can be made of metalized Mylar™ or boPET. Alternatively or additionally, some or all of envelope **202** and/or skirt **204** can be constructed from a highly-flexible latex material or a rubber material such as chloroprene. Other materials are also possible at least as discussed herein. Further, the shape and size of envelope **202** and skirt **204** can vary depending upon the particular implementation. Additionally, envelope **202** can be filled with various different types of gases, such as helium and/or hydrogen. Other types of gases are possible as well.

The payload **206** of balloon **200** can include a computing device **212**. In particular, computing device **212** can be configured to store instructions that can be accessed and executed by computing device **212** in order to carry out some or all the balloon functions described herein. Computing devices are described in more detail below in the context of FIGS. **7**A and **7**B.

Payload **206** of balloon **200** can also include various other types of equipment and systems to provide a number of different functions. For example, payload **206** can include optical communication system **216**, which can transmit optical signals via an ultra-bright LED system **220**, and which can receive optical signals via an optical-communication receiver; e.g., a photo-diode receiver system. Further, payload **206** can include RF communication system **218**, which can transmit and/or receive RF communications via an antenna system **240**.

Payload **206** can also include power supply **226** configured to supply power to the various components of balloon **200**.

Power supply **226** can include or take the form of a rechargeable battery. In other embodiments, power supply **226** can additionally or alternatively represent other means known in the art for producing power. In addition, balloon **200** can include solar power generation system **227**. Solar power generation system **227** can include solar panels and could be used to generate power that charges and/or is distributed by the power supply **226**.

Further, payload **206** can include various types of other systems and sensors **228**, **234**. For example, payload **206** can include one or more video and/or still cameras, a GPS system, various motion sensors (e.g., accelerometers, gyroscopes, and/or compasses), and/or various sensors for capturing environmental data. Further, some or all of the components within payload **206** can be implemented in a radiosonde, which can be operable to measure, e.g., pressure, altitude, geographical position (latitude and longitude), temperature, relative humidity, and/or wind speed and/or direction, among other information.

As noted, balloon **206** includes an ultra-bright LED system **220** for free-space optical communication with other balloons. As such, optical communication system **216** can be configured to transmit a free-space optical signal by modulating the ultra-bright LED system **220**. The optical communication system **216** can be implemented with mechanical systems and/or with hardware, firmware, and/or software. Generally, the manner in which an optical communication system is implemented can vary, depending upon the particular application.

In a further aspect, balloon **200** can be configured for altitude control. For instance, balloon **200** can include a variable buoyancy system, which is configured to change the altitude of balloon **200** by adjusting the volume and/or density of the gas in balloon **200**. A variable buoyancy system can take various forms, and can generally be any system that can change the volume and/or density of gas in envelope **202**.

In an exemplary embodiment, a variable buoyancy system can include a bladder **210** located inside of envelope **202**. Bladder **210** could be an elastic chamber configured to hold liquid and/or gas. Alternatively, bladder **210** need not be inside envelope **202**. For instance, bladder **210** can be a rigid bladder perhaps pressurized well beyond neutral pressure. The buoyancy of balloon **200** can therefore be adjusted by changing the density and/or volume of the gas in bladder **210**. To change the density of bladder **210**, balloon **200** can be configured with systems and/or mechanisms for heating and/or cooling the gas in bladder **210**. Further, to change the volume, balloon **200** can include pumps or other features for adding gas to and/or removing gas from bladder **210**. Additionally or alternatively, to change the volume of bladder **210**, balloon **200** can include release valves or other features that are controllable to allow gas to escape from bladder **210**. Multiple bladders **210** could be implemented within the scope of this disclosure. For instance, multiple bladders **210** could be used to improve balloon stability.

In an example embodiment, envelope **202** could be filled with helium, hydrogen or other lighter-than-air material. Envelope **202** could thus have an associated upward buoyancy force. In such an embodiment, air in the bladder **210** could be considered a ballast tank that can have an associated downward ballast force. In another example embodiment, the amount of air in bladder **210** could be changed by pumping air, perhaps using an air compressor, into and out of bladder **210**. By adjusting the amount of air in bladder **210**, the ballast force can be controlled. In some embodiments, the ballast force can be used, in part, to counteract the buoyancy force and/or to provide altitude stability.

In other embodiments, envelope **202** could be substantially rigid and include an enclosed volume. Air could be evacuated from envelope **202** while the enclosed volume is substantially maintained. In other words, at least a partial vacuum could be created and maintained within the enclosed volume. Thus, envelope **202** and the enclosed volume could become lighter than air and provide a buoyancy force. In yet other embodiments, air or another material could be controllably introduced into the partial vacuum of the enclosed volume in an effort to adjust the overall buoyancy force and/or to provide altitude control.

Further, balloon **200** can include a navigation system (not shown). The navigation system can implement station-keeping functions to maintain position within and/or move to a position in accordance with a desired topology. In particular, the navigation system can use altitudinal wind data to determine altitudinal adjustments that result in the wind carrying the balloon in a desired direction and/or to a desired location. The altitude-control system can then make adjustments the density of the balloon chamber in order to effectuate the determined altitudinal adjustments and cause the balloon to move laterally to the desired direction and/or to the desired location.

Alternatively, the altitudinal adjustments can be computed by a ground-based control system and communicated to balloon **200**. As another alternative, the altitudinal adjustments can be computed by a ground-based or satellite-based control system and communicated to balloon **200**. Furthermore, in some embodiments, specific balloons in a heterogeneous balloon network can be configured to compute altitudinal adjustments for other balloons and transmit the adjustment commands to those other balloons.

As shown, balloon **200** includes cut-down system **208**. The cut-down system **208** can be activated to separate the payload **206** from the rest of balloon **200**. This functionality can be utilized anytime the payload needs to be accessed on the ground, such as when it is time to remove balloon **200** from a balloon network, when maintenance is due on systems within payload **206**, and/or when power supply **226** needs to be recharged or replaced.

In an exemplary embodiment, the cut-down system **208** can include a connector, such as a balloon cord, connecting the payload **206** to the envelope **202** and a means for severing the connector (e.g., a shearing mechanism or an explosive bolt). In an example embodiment, the balloon cord, which can be nylon, is wrapped with a nichrome wire. A current could be passed through the nichrome wire to heat it and melt the cord, cutting the payload **206** away from the envelope **202**. Other types of cut-down systems and/or variations on the illustrated cut-down system **208** are possible as well.

In an alternative arrangement, a balloon may not include a cut-down system. In such an arrangement, the navigation system can be operable to navigate the balloon to a landing location, in the event the balloon needs to be removed from the network and/or accessed on the ground. Further, it is possible that a balloon can be self-sustaining, such that it theoretically does not need to be accessed on the ground. In yet other embodiments, balloons can be serviced in-flight by specific service balloons or another type of service aerostat or service aircraft.

FIG. **3** shows a balloon **300** with a balloon envelope **302** having integrated antennas in sections **304***a*, **304***b*, **304***c* connected via wires **308** to payload **310**. Balloon **300** can be the same as or differ from balloon **200** described above in the context of FIG. **2** and/or balloon **500** described below in the context of FIG. **5**A. In embodiments not shown in the Figures, balloon **300** can include some or all of the components of

balloons **200** and **500** described that are not shown as components of balloon **300** in FIG. **3**. In specific embodiments not shown in the Figures, wires **308** can be replaced with and/or complemented by a skirt and/or cut-down, such as skirt **204** and cut-down **208** of balloon **200** discussed above in the context of FIG. **2**.

Envelope **302** is divided into antenna sections **304***a*, **304***b*, **304***c* that are separated by seams **306***a*, **306***b*, **306***c*, **306***d*. Payload **310** includes transceiver **312** configured to communicate with at least one or more satellites (not shown in FIG. **3**) and control system **314**. Control system **314** can be included as part of payload **310** as shown in FIG. **3** or, in other embodiments, placed elsewhere on balloon **300**. FIG. **3** shows communication pathways as connections **316** as dashed lines from control system **314** to transceiver **312**, sections **304***a*, **304***b*, **304***c*, and metallization pattern **320**.

Antenna sections **304***a*, **304***b*, **304***c* can be partially or completely covered one or more metallized materials. If the antenna section is nearly or completely covered by a metallized material, the antenna section can also be termed as a "metallized section." The metallized material can be, but is not limited to copper, silver, or aluminum, and can overlay part or all of a fabric making up the corresponding section of envelope **302**. In some embodiments, the metallized material need not be metallic in nature, but rather is any material suitable for conducting electrical, magnetic, and/or electromagnetic signals. Similarly, metallization patterns can utilize any material suitable for conducting electrical, magnetic, and/or electromagnetic signals.

Each antenna section **304***a*, **304***b*, **304***c* can be electrically isolated from one another by seams **306***a*, **306***b*, **306***c*, **306***d*. Seams **306***a*, **306***b*, **306***c*, **306***d* of envelope **302** can be made of an electrically isolating material such as boPET.

For signal reception, communication signals can be received at the thin layer of metallized material at an antenna section from one or more entities external to balloon **300** and transmitted from the antenna section to control system **314** via connection(s) **316**. For signal transmission, communication signals can be generated at control system **314** and sent via connection(s) **316** to the thin layer of metallized material to be transmitted from the antenna section to one or more entities external to balloon **300**.

For example, GPS signals can be received at antenna section **304***a* from a GPS satellite and transmitted via connections **316** to control system **314**. Then, control system **314** can, if necessary, communicate the received GPS signals to a GPS receiver (not shown) in balloon **300**; e.g., in payload **310**. For signal transmission from balloon **300** to another entity outside balloon **300**, communication signals destined for the other entity can be provided to and/or generated by control system **314** and communicated by connections **316** to an antenna section, such as section **304***b*. Then, antenna section **304***b* can send the communication signals as radio waves, which can be received by the other entity.

In some embodiments, two or more metallized sections can work together to act as one antenna. In other embodiments, each antenna section **304***a*, **304***b*, **304***c* can act as a separate antenna. For example, each antenna section can be designed with one or more material(s) and/or metallization pattern(s), such as metallization pattern **320** in section **304***a* of FIG. **3**, so that it operates as a different kind of antenna. A metallized pattern can be on an outer surface of the envelope and/or could be partially or wholly embedded within the envelope.

Control system **314** can be configured to switch between antenna sections **304***a*, **304***b*, **304***c*, and/or metallization pattern **320** to send and/or receive signals. Once received, signals can be provided by control system **314** to transceiver **312** and/or other components carried by balloon **300**; e.g., as part of payload **310**, that are connected to the control system **314** enabling multiple frequencies and/or types of signals to be received at and utilized by balloon **300**.

Similarly, transceiver **312** and/or other components of balloon **300**, perhaps in payload **310**, can be configured to send signals to control system **314**. Signals provided to control system **314** can be conveyed to one or more antenna sections **304***a*, **304***b*, **304***c*, and/or metallization pattern **310** for transmission. In this fashion, multiple frequencies and/or types of signals can be sent by balloon **300**.

FIG. **4** shows example sections **410**, **420**, and **440** of a balloon envelope, in accordance with an example embodiment. Section **410** is a balloon envelope section completely covered by metal layer **412** to act as an antenna section. In some embodiments, metal layer **412** can overlay a fabric layer of section **410**. The fabric layer (not shown in FIG. **4**) can be made of an airtight lightweight material, such as but not limited to, nylon, silk, or polyester (e.g., boPET), or combinations thereof. In other embodiments, metal layer **412** can be covered by the fabric layer. In still other embodiments, section **410** can be made solely of metal layer **412**. In even other embodiments, multiple metal and/or fabric layers can be used to construct section **410**.

Section **420** includes a symmetric series of metallization patterns; including patch metallization patterns (MPs) **422** and **430**, horizontal metallization patterns **424** and **428**, and vertical metallization pattern **426**. The symmetric series of metallization patterns is symmetric both about horizontal axis **432** and vertical axis **434** of section **420**. In some embodiments not shown, a series of metallization patterns can be symmetric about one axis of an antenna section and be asymmetric about another axis of the antenna section. Both axes **432**, **434** of section **420** are shown in FIG. **4** as dotted lines, while components of the symmetric series of metallization patterns of section **420** are shown using solid lines. Each type of metallization pattern—patch, horizontal, vertical, etc.—in section **420** can be used to send/receive the same or different signals than other metallization patterns.

Section **440** includes an asymmetric series of metallization patterns, including diagonal MPs (DMPs) **442** and **446**, horizontal metallization pattern **444**, patch metallization patterns **448**, **452**, patch array metallization pattern (PAMP) **450**, two-dimensional (2D) metallization patterns **454**, **458**, and vertical metallization pattern **456**. The series of metallization patterns for section **440** is classified as asymmetric as the series of metallization patterns for section **440** does not show symmetry about either horizontal axis **460** or vertical axis **462**. Both horizontal axis **460** and vertical axis **462** of section **440** are shown in FIG. **4** as dotted lines, while components of the symmetric series of metallization patterns of section **440** are shown using solid lines. Each type of metallization pattern—patch, horizontal, vertical, etc.—in section **440** can be used to send/receive the same or different signals than other metallization patterns.

In some embodiments, some or all of metallization patterns **320**, **422-430**, and **442-456** can be covered by fabric layer(s) and/or other layer(s) of respective sections **304***a*, **420**, or **440**, while in still other embodiments, some or all of metallization patterns **320**, **422-430**, and **442-456** can be uncovered by fabric layer(s) and/or other layer(s) respective sections **304***a*, **420**, or **440**. In even other embodiments, metallization patterns can be constructed as non-metallic "negative patterns" of a metal layer. A negative pattern can be a pattern of non-metallic material embedded in or overlaying the metal layer, a pattern of metal removed from the metal layer leaving a

pattern-shaped gap in the metal layer, or a pattern of non-metallic material inside of, formed in, and/or otherwise part of the metal layer.

FIG. **5**A shows balloon **500**, in accordance with an example embodiment. Balloon **500** can be the same as or differ from balloon **200** described above in the context of FIG. **2** and/or balloon **300** described above in the context of FIG. **3**. In embodiments not shown in the Figures, balloon **500** can include some or all of the components of balloons **200** and **300** that are not shown as components of balloon **500** in FIG. **5**. In specific embodiments not shown in the Figures, wires **508** can be replaced with and/or complemented by a skirt and/or cut-down, such as skirt **204** and cut-down **208** of balloon **200** discussed above in the context of FIG. **2**.

Balloon **500** includes envelope **502** made of antenna sections **504***a*, **504***b*, **504***c* separated by seams such as seams **506***a* and **506***b*. Envelope **502** is connected to payload **510** via wires **508**. FIG. **5** shows payload **510** with transceiver **512** and control system **514**. Transceiver **512** and control system **514** can perform the respective above-mentioned functions of transceiver **312** and control system **314** mentioned above in the context of FIG. **3**. For example, control system **514** is configured to communicate signals to metallization patterns **520**, **522**, **524**, **526**, and **528** of balloon **500** via connections **516**.

As with balloon **300**, balloon **500** has metallization patterns in antenna sections **504***a*, **504***b*, **504***c* including planar metallization pattern **520** that is in the plane of section **504***c*. Balloon **500** also includes Z metallization patterns **522**, **524**, **526**, and **528** that, at least in part, project out of the planes of sections **504***a*, **504***b*, and **504***c*. Z metallization pattern **522** includes two single pole antennas projecting out from the plane of section **504***a*. In some embodiments, the two antennas in pattern **522** can be electrically connected; e.g., by a metal layer of section **504***a* or by a conductor lying in the plane of section **504***a* connecting the two antennas. In other embodiments, the two antennas can be electrically isolated; e.g., the two antennas can be separated by a non-conducting layer of section **504***a* such as a non-metallic fabric layer.

Z metallization pattern **524** includes a single T shaped antenna projecting out from the plane of section **504***a*. Z metallization pattern **526** is shown in FIG. **5**A as a Z metallization pattern array **526** made up of seven double-crossed antennas extending out of the plane of envelope **502** connected via a conductor traveling in an arc from section **504***a* to section **504***c*. In some embodiments, Z metallization pattern **526** can be contained in a single section, such as circular section covering the top of balloon separated by a seam **526***a* shown in FIG. **5**A with a dotted and dashed line. Z metallization pattern array **528** is shown as three single pole antennas connected via a conductor in the plane of section **504***c*.

FIG. **5**B shows example section **540** of a balloon envelope, in accordance with an example embodiment. Section **540** is depicted in FIG. **5**B in an x-y plane outlined by X-axis **542** and Y-axis **544**, with Z-axis **546** as a vertical axis projecting from the x-y plane. Section **540** is shown with specific axes **570** and **572**.

Section **540** includes Z metallization array **552** made up of three antennas **556***a*, **556***b*, and **556***b* mounted in respective "Z-mounts" **554***a*, **554***b*, **554***c* and connected via connector **558**. Z-mounts **554***a*, **554***b*, **554***c* and antennas **556***a*, **556***b*, **556***c* project from the x-y plane in the direction of Z-axis **546**, while connector **558** lies in a plane of section **540**; e.g., in the x-y-plane.

Z-mount **554***a* is shown in a cutaway fashion to permit view of a bottom portion of antenna **556***a* in contact with connector **558**. Similar connections can be used to connect antennas **556***b* and **556***c* to connector **558** as well. In other embodiments not shown in FIG. **5**B, other connecting techniques can be used to connect antennas **556***a*, **556***b*, **556***c* via connector **558**; e.g., Z-mount **554***a* can include conducive elements that electrically connect both connector **558** and antenna **556***a* to Z-mount **554***a*. In these other embodiments, antennas **556***a*, **556***b*, **556***c* may not be directly connected to connector **558**; rather, antennas **556***a*, **556***b*, **556***c* could be indirectly connected to connector **558** via respective Z-mounts **554***a*, **554***b*, **554***c*.

FIG. **5**B shows section **540** configured planar metallization pattern **566** in the plane of section **540** and two single antennas **560** and **564** projecting in the direction of Z-axis **546**. Antennas **560** and **564** are configured using Z-mounts the same as or similar to Z-mounts **554***a*, **554***b*, **554***c*. Section **540** is also configured with an antenna projecting in the direction of Z-axis **546** using inward mount **562**. Inward mount **562** can include a cavity or hole in one or more layers of section **540** configured to support an antenna inserted into the cavity or hole. In other embodiments, inward mount **562** can be configured as "volcano-shaped mount" that protrudes from section **540** in the direction of Z-axis **546** with a (nearly) central cavity that is configured to support an antenna protruding from the x-y plane. Other Z-mounts are possible as well.

Example Balloon Networks

FIG. **6**A shows balloon network **600**, according to an example embodiment. As shown, balloon network **600** includes balloons **602**A to **602**F, which are configured to communicate with one another via free-space optical links **604**. Each of balloons **602**A to **602**F can be configured with some or all of the components of balloons **200**, **300**, and/or **500** discussed above regarding FIGS. **2**, **3**, and **5**. Configured as such, balloons **602**A to **602**F can collectively function as a mesh network for packet-data communications. Further, at least some of balloons **602**A and **602**B can be configured for RF communications with ground-based station **606** via respective RF links **608**. Yet further, some balloons, such as balloon **602**F, can be configured to communicate via optical link **610** with ground-based station **612**.

In an exemplary embodiment, balloons **602**A to **602**F are high-altitude balloons, which are deployed in the stratosphere. At moderate latitudes, the stratosphere includes altitudes between approximately 10 kilometers (km) and 50 km altitude above the surface. At the poles, the stratosphere starts at an altitude of approximately 8 km. In an exemplary embodiment, high-altitude balloons can be generally configured to operate in an altitude range within the stratosphere that has relatively low wind-speeds (e.g., between 5 and 20 miles per hour (mph)).

More specifically, in a high-altitude-balloon network, balloons **602**A to **602**F can generally be configured to operate at altitudes between 18 km and 25 km (although other altitudes are possible). This altitude range can be advantageous for several reasons. In particular, this layer of the stratosphere generally has relatively low wind speeds (e.g., winds between 5 and 20 mph) and relatively little turbulence. Further, while the winds between 18 km and 25 km can vary with latitude and by season, the variations can be modeled in a reasonably accurate manner. Additionally, altitudes above 18 km are typically above the maximum flight level designated for commercial air traffic. Therefore, interference with commercial flights is not a concern when balloons are deployed between 18 km and 25 km.

To transmit data to another balloon, a given balloon **602**A to **602**F can be configured to transmit an optical signal via optical link **604**, **610**. In an exemplary embodiment, a given balloon **602**A to **602**F can use one or more high-power light-

emitting diodes (LEDs) to transmit an optical signal. Alternatively, some or all of balloons **602**A to **602**F can include laser systems for free-space optical communications over optical links **604**, **610**. Other types of free-space optical communication are possible. Further, in order to receive an optical signal from another balloon via optical link **604**, **610**, a given balloon **602**A to **602**F can include one or more optical receivers. Additional details of example balloons are discussed in greater detail above, with reference to FIGS. **2**, **3**, and **5**.

In a further aspect, balloons **602**A to **602**F can utilize one or more of various different RF air-interface protocols for communication with ground-based station **606** via respective RF links **608**. For instance, some or all of balloons **602**A to **602**F can be configured to communicate with ground-based stations **606** using protocols described in IEEE 802.11 (including any of the IEEE 802.11 revisions), various cellular protocols such as GSM, CDMA, UMTS, EV-DO, WiMAX, and/or LTE, and/or one or more propriety protocols developed for balloon-ground RF communication, among other possibilities.

In a further aspect, there can be scenarios where RF links **608** do not provide a desired link capacity for balloon-ground communications. For instance, increased capacity can be desirable to provide backhaul links from a ground-based gateway and in other scenarios as well. Accordingly, an exemplary network can also include downlink balloons, which provide a high-capacity air-ground link.

For example, in balloon network **600**, balloon **602**F is configured as a downlink balloon. Like other balloons in an exemplary network, downlink balloon **602**F can be operable for optical communication with other balloons via optical links **604**. However, downlink balloon **602**F can also be configured for free-space optical communication with ground-based station **612** via optical link **610**. Optical link **610** can therefore serve as a high-capacity link (as compared to an RF link, such as link **608**) between balloon network **600** and ground-based station **612**.

Note that in some implementations, downlink balloon **602**F can additionally be operable for RF communication with ground-based station **606**. In other cases, downlink balloon **602**F can only use an optical link for balloon-to-ground communications. Further, while the arrangement shown in FIG. **6**A includes just one downlink balloon **602**F, example balloon networks can also include multiple downlink balloons. On the other hand, a balloon network can also be implemented without any downlink balloons.

In other implementations, a downlink balloon can be equipped with a specialized, high-bandwidth RF communication system for balloon-to-ground communications, instead of, or in addition to, a free-space optical communication system. The high-bandwidth RF communication system can take the form of an ultra-wideband system, which can provide an RF link with substantially the same capacity as optical links **604**, **610**. Other forms are also possible.

Ground-based stations, such as ground-based stations **606** and/or **612**, can take various forms. Generally, a ground-based station can include components such as transceivers, transmitters, and/or receivers for communication via RF links and/or optical links with a balloon network. Further, ground-based station **606** can use various air-interface protocols in order to communicate with a balloon **602**A to **602**F over RF links **608**. As such, ground-based station **606** can be configured as an access point via which various devices can connect to balloon network **600**. Ground-based station **606** can have other configurations and/or serve other purposes without departing from the scope of this disclosure.

In a further aspect, some or all of balloons **602**A to **602**F can be configured to establish a communication link with space-based satellites in addition to, or as an alternative to, a ground-based communication link. In some embodiments, a balloon can communicate with a satellite via an optical link. However, other types of satellite communications are also possible. See FIG. **6**C discussed below for an example scenario regarding balloon/satellite communication.

Further, some ground-based stations, such as ground-based station **612**, can be configured as gateways between balloon network **600** and one or more other networks, such as Internet **614**. Thus, ground-based station **612** can serve as an interface between the balloon network **600** and Internet **614**, a cellular service provider's network, and/or other types of networks. Variations on this configuration and other configurations of ground-based station **614** are also possible.

As noted, balloons **602**A to **602**F can collectively function as a mesh network. More specifically, since balloons **602**A to **602**F can communicate with one another using free-space optical links, the balloons can collectively function as a free-space optical mesh network.

In a mesh-network configuration, each balloon **602**A to **602**F can function as a node of the mesh network, which is operable to receive data directed to it and to route data to other balloons. As such, data can be routed from a source balloon to a destination balloon by determining an appropriate sequence of optical links between the source balloon and the destination balloon. These optical links can be collectively referred to as a "lightpath" for the connection between the source and destination balloons. Further, each of the optical links can be referred to as a "hop" on the lightpath.

To operate as a mesh network, balloons **602**A to **602**F can employ various routing techniques and self-healing algorithms. In some embodiments, balloon network **600** can employ adaptive or dynamic routing, where a lightpath between a source and destination balloon is determined and set-up when the connection is needed, and released at a later time. Further, when adaptive routing is used, the lightpath can be determined dynamically depending upon the current state, past state, and/or predicted state of the balloon network.

In addition, the network topology can change as the balloons **602**A to **602**F move relative to one another and/or relative to the ground. Accordingly, balloon network **600** can apply a mesh protocol to update the state of the network as the topology of the network changes. For example, to address the mobility of balloons **602**A to **602**F, balloon network **600** can employ and/or adapt various techniques that are employed in mobile ad hoc networks (MANETs). Other examples are possible as well.

In some implementations, balloon network **600** can be configured as a transparent mesh network. More specifically, in a transparent balloon network, the balloons can include components for physical switching that is entirely optical, without any electrical components involved in the physical routing of optical signals. Thus, in a transparent configuration with optical switching, signals travel through an entirely optical multi-hop lightpath.

In other implementations, the balloon network **600** can implement a free-space optical mesh network that is opaque. In an opaque configuration, some or all balloons **602**A to **602**F can implement optical-electrical-optical (OEO) switching. For example, some or all balloons can include optical cross-connects (OXCs) for OEO conversion of optical signals. Other opaque configurations are also possible.

In a further aspect, balloons in an exemplary balloon network **600** can implement wavelength division multiplexing (WDM), which can help to increase link capacity. When

WDM is implemented with transparent switching, physical lightpaths through the balloon network can be subject to the "wavelength continuity constraint." More specifically, because the switching in a transparent network is entirely optical, it can be necessary to assign the same wavelength for all optical links on a given lightpath.

An opaque configuration, on the other hand, can avoid the wavelength continuity constraint. In particular, balloons in an opaque balloon network can include the OEO switching systems operable for wavelength conversion. As a result, balloons can convert the wavelength of an optical signal at each hop along a lightpath.

Further, various routing algorithms can be employed in an opaque configuration. For example, to determine a primary lightpath and/or one or more diverse backup lightpaths for a given connection, exemplary balloons can apply or consider shortest-path routing techniques such as Dijkstra's algorithm and k-shortest path, and/or edge and node-diverse or disjoint routing such as Suurballe's algorithm, among others. Additionally or alternatively, techniques for maintaining a particular quality of service (QoS) can be employed when determining a lightpath. Other techniques are also possible.

In some embodiments, balloon network **600** can implement station-keeping functions to help provide a desired network topology. For example, station-keeping can involve each balloon **602**A to **602**F maintaining and/or moving into a certain position relative to one or more other balloons in the network (and possibly in a certain position relative to the ground). As part of this process, each balloon **602**A to **602**F can implement station-keeping functions to determine its desired positioning within the desired topology, and if necessary, to determine how to move to the desired position.

The desired topology can vary depending upon the particular implementation. In some cases, balloons can implement station-keeping to provide a substantially uniform topology. In such cases, a given balloon **602**A to **602**F can implement station-keeping functions to position itself at substantially the same distance (or within a certain range of distances) from adjacent balloons in balloon network **600**.

In other cases, balloon network **600** can have a non-uniform topology. For instance, exemplary embodiments can involve topologies where balloons are distributed more or less densely in certain areas, for various reasons. As an example, to help meet the higher bandwidth demands that are typical in urban areas, balloons can be clustered more densely over urban areas. For similar reasons, the distribution of balloons can be denser over land than over large bodies of water. Many other examples of non-uniform topologies are possible.

In a further aspect, the topology of an exemplary balloon network can be adaptable. In particular, station-keeping functionality of exemplary balloons can allow the balloons to adjust their respective positioning in accordance with a change in the desired topology of the network. For example, one or more balloons could move to new positions to increase or decrease the density of balloons in a given area. Other examples are possible.

In some embodiments, balloon network **600** can employ an energy function to determine if and/or how balloons should move to provide a desired topology. In particular, the state of a given balloon and the states of some or all nearby balloons can be input to an energy function. The energy function can apply the current states of the given balloon and the nearby balloons to a desired network state; e.g., a state corresponding to the desired topology. A vector indicating a desired movement of the given balloon can then be determined by determining the gradient of the energy function. The given balloon can then determine appropriate actions to take in order to effectuate the desired movement. For example, a balloon can determine an altitude adjustment or adjustments such that winds will move the balloon in the desired manner.

In some embodiments, mesh networking and/or station-keeping functions can be centralized. For example, FIG. **6**B is a block diagram illustrating a balloon-network control system, according to an example embodiment. In particular, FIG. **2** shows a distributed control system, which includes central control system **630** and a number of regional control-systems **632**A to **632**C to coordinate certain functionality for balloon network **634**. As such, the distributed control system can be configured to control and/or coordinate certain functions for balloons **636**A to **636**I. Each of balloons **636**A to **636**I can be configured with some or all of the components of balloons **200**, **300**, and/or **500** discussed above regarding FIGS. **2**, **3**, and **5**.

In the illustrated embodiment, central control system **630** can be configured to communicate with balloons **636**A to **636**I via regional control systems **632**A to **632**C. Regional control systems **632**A to **632**C can be configured to receive communications and/or aggregate data from balloons in the respective geographic areas that they cover, and to relay the communications and/or data to central control system **630**. Further, regional control systems **632**A to **632**C can be configured to route communications from central control system **630** to the balloons in their respective geographic areas. For instance, as shown in FIG. **6**B, regional control system **632**A can relay communications and/or data between balloons **636**A to **636**C and central control system **630**, regional control system **632**B can relay communications and/or data between balloons **636**D to **636**F and central control system **630**, and regional control system **632**C can relay communications and/or data between balloons **636**G to **636**I and central control system **630**.

In order to facilitate communications between the central control system **630** and balloons **636**A to **636**I, certain balloons can be configured as downlink balloons, which are operable to communicate with regional control systems **632**A to **632**C. Accordingly, each regional control system **632**A to **632**C can be configured to communicate with the downlink balloon or balloons in the respective geographic area it covers. For example, in the illustrated embodiment shown in FIG. **6**B, balloons **636**A, **636**D, and **636**H are configured as downlink balloons. As such, regional control systems **632**A to **632**C can respectively communicate with balloons **636**A, **636**D, and **636**H via optical links **638**, **640**, and **642**, respectively.

In the illustrated configuration, only some of balloons **636**A to **636**I are configured as downlink balloons. The balloons **636**A, **636**F, and **636**I configured as downlink balloons can relay communications from central control system **630** to other balloons in the balloon network, such as balloons **636**B-E and **636**G-H. However, it should be understood that it in some implementations, it is possible that all balloons can function as downlink balloons. Further, while FIG. **6**B shows multiple balloons configured as downlink balloons, it is also possible for a balloon network to include only one downlink balloon, or possibly even no downlink balloons.

Note that a regional control system **632**A to **632**B can be a ground-based station configured to communicate with downlink balloons; e.g., ground-based station **612** of FIG. **6**A. Thus, while not shown in FIG. **6**B, a control system can be implemented in conjunction with other types of ground-based stations; e.g., access points, gateways, etc.

In a centralized control arrangement, such as that shown in FIG. **6**B, central control system **630**, and perhaps regional control systems **632**A to **632**C as well, can coordinate certain

mesh-networking functions for balloon network **634**. For example, balloons **636**A to **636**I can send central control system **630** state information, which the central control system **630** can utilize to determine a state of balloon network **634**. The state information from a given balloon can include location data, communication-link information such as, but not limited to, the identity of other balloons with which the balloon has established an optical, RF, or other type of communication link, the bandwidth of the link, wavelength usage and/or availability on a link, etc., wind data collected by the balloon, and/or other types of information. Accordingly, central control system **630** can aggregate state information from some or all of balloons **636**A to **636**I in order to determine an overall state of balloon network **634**.

The overall state of balloon network **634** can then be used to coordinate and/or facilitate certain mesh-networking functions such as determining lightpaths for connections. For example, the central control system **630** can determine a current topology based on the aggregate state information from some or all of balloons **636**A to **636**I. The topology can provide a picture of the current optical links that are available in balloon network and/or the wavelength availability on the links. This topology can then be sent to some or all of the balloons so that a routing technique can be employed to select appropriate lightpaths (and possibly backup lightpaths) for communications through balloon network **634**.

In a further aspect, central control system **630** (and possibly regional control systems **632**A to **632**C as well) can also coordinate certain station-keeping functions for balloon network **634**. For example, central control system **630** can provide state information received from balloons **636**A to **636**I to an energy function, which can effectively compare the current topology of the network to a desired topology, and provide a vector indicating a direction of movement (if any) for each balloon, such that the balloons can move towards the desired topology. Further, central control system **630** can use altitudinal wind data to determine respective altitude adjustments that can be initiated to achieve the movement towards the desired topology. Central control system **630** can provide and/or support other station-keeping functions as well.

FIG. **6**B shows a distributed arrangement that provides centralized control, with regional control systems **632**A to **632**C coordinating communications between central control system **630** and balloon network **634**. Such an arrangement can be useful to provide centralized control for a balloon network that covers a large geographic area. In some embodiments, a distributed arrangement can even support a global balloon network that provides coverage everywhere on earth. Of course, a distributed-control arrangement can be useful in other scenarios as well.

Further, it should be understood that other control-system arrangements are also possible. For instance, some implementations can involve a centralized control system with additional layers (e.g., sub-region systems within the regional control systems, and so on). Alternatively, control functions can be provided by a single, centralized, control system, which communicates directly with one or more downlink balloons.

In some embodiments, control and coordination of a balloon network can be shared by a ground-based control system and a balloon network to varying degrees, depending upon the implementation. In fact, in some embodiments, there can be no ground-based control systems. In such an embodiment, all network control and coordination functions can be implemented by the balloon network itself. For example, certain balloons can be configured to provide the same or similar functions as central control system **630** and/or regional control systems **632**A to **632**C. Other examples are also possible.

Furthermore, control and/or coordination of a balloon network can be de-centralized. For example, each balloon can relay state information to, and receive state information from, some or all nearby balloons. Further, each balloon can relay state information that it receives from a nearby balloon to some or all nearby balloons. When all balloons do so, each balloon can be able to individually determine the state of the network. Alternatively, certain balloons can be designated to aggregate state information for a given portion of the network. These balloons can then coordinate with one another to determine the overall state of the network.

Further, in some aspects, control of a balloon network can be partially or entirely localized, such that it is not dependent on the overall state of the network. For example, individual balloons can implement station-keeping functions that only consider nearby balloons. In particular, each balloon can implement an energy function that takes into account its own state and the states of nearby balloons. The energy function can be used to maintain and/or move to a desired position with respect to the nearby balloons, without necessarily considering the desired topology of the network as a whole. However, when each balloon implements such an energy function for station-keeping, the balloon network as a whole can maintain and/or move towards the desired topology.

As an example, each balloon A in a balloon network can receive distance information d_1 to d_k with respect to each of its k closest neighbors. Each balloon A can treat the distance to each of the k balloons as a virtual spring with vector representing a force direction from the first nearest neighbor balloon i toward balloon A and with force magnitude proportional to d_i. The balloon A can sum each of the k vectors and the summed vector is the vector of desired movement for balloon A. Balloon A can attempt to achieve the desired movement by controlling its altitude.

Alternatively, this process could assign the force magnitude of each of these virtual forces equal to $d_i \times d_j$, for instance. Other algorithms for assigning force magnitudes for respective balloons in a mesh network are possible.

In another embodiment, a similar process could be carried out for each of the k balloons and each balloon could transmit its planned movement vector to its local neighbors. Further rounds of refinement to each balloon's planned movement vector can be made based on the corresponding planned movement vectors of its neighbors. It will be evident to those skilled in the art that other algorithms could be implemented in a balloon network in an effort to maintain a set of balloon spacings and/or a specific network capacity level over a given geographic location.

FIG. **6**C shows an example network scenario **660**, in accordance with an example embodiment. Scenario **660** shows balloons **662**, **664**, and **666** aloft and connected with each other and with ground antenna **670** on mesa **672** via network **674**. Balloons **662**, **664**, **666**, ground antenna **670**, network **674**, and/or satellite **680** can include and/or be part of balloon network **600** shown in FIG. **6**A and/or balloon network **634** shown in FIG. **6**B. Each of balloons **662**, **664**, **666** can be configured with some or all of the components of balloons **200**, **300**, and/or **500** discussed above regarding FIGS. **2**, **3**, and **5**.

As shown in FIG. **6**C, envelopes of each of balloons **662**, **664**, and **666** are divided into both vertical and horizontal antenna sections, with each vertical antenna section depicted in FIG. **6**C having a metallization pattern. During scenario **660**, signals emitted by ground antenna **670** are received by one or more antenna sections of balloons **662**, **664**, and **666**.

Scenario **660** includes some entities with direct connections that bypass network **674**; e.g., balloons **664** and **666**, and balloon **662** and ground antenna **670**. In some other scenarios not shown in FIG. **6**C, all connections between entities utilize network **674**.

Scenario **660** continues with satellite **680** emitting signal **682** received by one or more antenna sections of each of balloons **664** and **666**. Initially during scenario **660**, signal **682** is not received by balloon **662**. Upon detecting a lack of communication with satellite **680**, balloon **662** can request balloons **664**, **666** and/or ground antenna **670** to route part or all of signal **682** from satellite **680** to balloon **662**. During scenario **660**, balloon **664** agrees to route the requested portion or the entirety of signal **682** to balloon **662** via network **674**.

Later, balloon **662** regains connectivity with satellite **680**. In that event, balloon **662** can request balloon **664** stop sending signal **682** via network **674** both to preserve bandwidth on network **674** and as the copy of signal **682** sent from balloon **664** is now redundant to balloon **662**.

Computing Device Architecture

FIG. **7**A is a block diagram of computing device **700**, in accordance with an example embodiment. In particular, computing device **700** shown in FIG. **7**A can be configured at least to perform one or more functions of method **100**, computing device **214**, communication systems **216**, **218**, positioning system **224**, ground-based stations **606**, **612**, and/or control systems **314**, **514**, **630**, **632**A, **632**B, and **632**C. Computing device **700** can include a user interface module **701**, a network-communication interface module **702**, one or more processors **703**, and data storage **704**, all of which can be linked together via a system bus, network, or other connection mechanism **705**.

User interface module **701** can be operable to send data to and/or receive data from external user input/output devices. For example, user interface module **701** can be configured to send and/or receive data to and/or from user input devices such as a keyboard, a keypad, a touch screen, a computer mouse, a track ball, a joystick, a camera, a voice recognition module, and/or other similar devices. User interface module **701** can also be configured to provide output to user display devices, such as one or more cathode ray tubes (CRT), liquid crystal displays (LCD), light emitting diodes (LEDs), displays using digital light processing (DLP) technology, printers, light bulbs, and/or other similar devices, either now known or later developed. User interface module **701** can also be configured to generate audible output(s), such as a speaker, speaker jack, audio output port, audio output device, earphones, and/or other similar devices.

Network-communications interface module **702** can include one or more wireless interfaces **707** and/or one or more wireline interfaces **708** that are configurable to communicate via a network, such as networks **600**, **630**, and **674** respectively shown in FIGS. **6**A, **6**B, and **6**B. Wireless interfaces **707** can include one or more wireless transmitters, receivers, and/or transceivers, such as a Bluetooth transceiver, a Zigbee transceiver, a Wi-Fi transceiver, a WiMAX transceiver, transceiver(s) for various cellular protocols such as GSM, CDMA, UMTS, EV-DO, WiMAX, and/or LTE, and/or other similar type of wireless transceiver configurable to communicate via a wireless network. Wireline interfaces **708** can include one or more wireline transmitters, receivers, and/or transceivers, such as an Ethernet transceiver, a Universal Serial Bus (USB) transceiver, or similar transceiver configurable to communicate via a twisted pair wire, a coaxial cable, a fiber-optic link, or a similar physical connection to a wireline network.

In some embodiments, network communications interface module **702** can be configured to provide reliable, secured, and/or authenticated communications. For each communication described herein, information for ensuring reliable communications (i.e., guaranteed message delivery) can be provided, perhaps as part of a message header and/or footer (e.g., packet/message sequencing information, encapsulation header(s) and/or footer(s), size/time information, and transmission verification information such as CRC and/or parity check values). Communications can be made secure (e.g., be encoded or encrypted) and/or decrypted/decoded using one or more cryptographic protocols and/or algorithms, such as, but not limited to, DES, AES, RSA, Diffie-Hellman, and/or DSA. Other cryptographic protocols and/or algorithms can be used as well or in addition to those listed herein to secure (and then decrypt/decode) communications.

Processors **703** can include one or more general purpose processors and/or one or more special purpose processors (e.g., digital signal processors, application specific integrated circuits, etc.). Processors **703** can be configured to execute computer-readable program instructions **706** that are contained in the data storage **704** and/or other instructions as described herein.

Data storage **704** can include one or more computer-readable storage media that can be read and/or accessed by at least one of processors **703**. The one or more computer-readable storage media can include volatile and/or non-volatile storage components, such as optical, magnetic, organic or other memory or disc storage, which can be integrated in whole or in part with at least one of processors **703**. In some embodiments, data storage **704** can be implemented using a single physical device (e.g., one optical, magnetic, organic or other memory or disc storage unit), while in other embodiments, data storage **704** can be implemented using two or more physical devices.

Data storage **704** can include computer-readable program instructions **706**, and perhaps additional data. In some embodiments, data storage **704** can additionally include storage required to perform at least part of the herein-described methods and techniques and/or at least part of the computer-based functionality of the herein-described devices and networks.

Cloud-Based Servers

FIG. **7**B depicts a network **674** of computing clusters **709***a*, **709***b*, **709***c* arranged as a cloud-based server system, in accordance with an example embodiment. Computing device **212** and control systems **314**, **514** can be cloud-based devices that store program logic and/or data of cloud-based applications and/or services. In some embodiments, computing device **212**, control system **314**, **514**, **630**, **632**A, **632**B, or **632**C can be a single computing device residing within a single payload or computing center. In other embodiments, computing device **212**, control systems **314**, **514**, **630**, **632**A, **632**B and/or control system **632**C can include multiple computing devices in a single payload or computing center, or even multiple computing devices located diverse geographic locations.

In some embodiments, data and services at computing device **212**, control systems **314**, **514**, **630**, **632**A, **632**B and/or control system **632**C can be encoded as computer readable information stored in non-transitory, tangible computer readable media (or computer readable storage media) and accessible by other computing devices. In some embodiments, data at computing device **212**, control systems **314**, **514**, **630**, **632**A, **632**B and/or control system **632**C can be stored on a single disk drive or other tangible storage media, or can be

implemented on multiple disk drives or other tangible storage media located at one or more diverse geographic locations.

FIG. 7B depicts a cloud-based server system in accordance with an example embodiment. In FIG. 7B, the functions of computing device **212**, control systems **314**, **514**, **630**, **632**A, **632**B and/or control system **632**C can be distributed among three computing clusters **709***a*, **709***b*, and **709***c*. Computing cluster **709***a* can include one or more computing devices **700***a*, cluster storage arrays **710***a*, and cluster routers **711***a* connected by a local cluster network **712***a*. Similarly, computing cluster **709***b* can include one or more computing devices **700***b*, cluster storage arrays **710***b*, and cluster routers **711***b* connected by a local cluster network **712***b*. Likewise, computing cluster **709***c* can include one or more computing devices **700***c*, cluster storage arrays **710***c*, and cluster routers **711***c* connected by a local cluster network **712***c*.

In some embodiments, each of the computing clusters **709***a*, **709***b*, and **709***c* can have an equal number of computing devices, an equal number of cluster storage arrays, and an equal number of cluster routers. In other embodiments, however, each computing cluster can have different numbers of computing devices, different numbers of cluster storage arrays, and different numbers of cluster routers. The number of computing devices, cluster storage arrays, and cluster routers in each computing cluster can depend on the computing task or tasks assigned to each computing cluster.

In computing cluster **709***a*, for example, computing devices **700***a* can be configured to perform various computing tasks of computing device **212**, control systems **314**, **514**, **630**, **632**A, **632**B and/or control system **632**C. In one embodiment, the various functionalities of computing device **212**, control systems **314**, **514**, **630**, **632**A, **632**B and/or control system **632**C can be distributed among one or more of computing devices **700***a*, **700***b*, and **700***c*. Computing devices **700***b* and **700***c* in computing clusters **709***b* and **709***c* can be configured similarly to computing devices **700***a* in computing cluster **709***a*. On the other hand, in some embodiments, computing devices **700***a*, **700***b*, and **700***c* can be configured to perform different functions.

In some embodiments, computing tasks and stored data associated with computing device **212**, control systems **314**, **514**, **630**, **632**A, **632**B and/or control system **632**C can be distributed across computing devices **700***a*, **700***b*, and **700***c* based at least in part on the processing requirements of computing device **212**, control systems **314**, **514**, **630**, **632**A, **632**B and/or control system **632**C, the processing capabilities of computing devices **700***a*, **700***b*, and **700***c*, the latency of the network links between the computing devices in each computing cluster and between the computing clusters themselves, and/or other factors that can contribute to the cost, speed, fault-tolerance, resiliency, efficiency, and/or other design goals of the overall system architecture.

The cluster storage arrays **710***a*, **710***b*, and **710***c* of the computing clusters **709***a*, **709***b*, and **709***c* can be data storage arrays that include disk array controllers configured to manage read and write access to groups of hard disk drives. The disk array controllers, alone or in conjunction with their respective computing devices, can also be configured to manage backup or redundant copies of the data stored in the cluster storage arrays to protect against disk drive or other cluster storage array failures and/or network failures that prevent one or more computing devices from accessing one or more cluster storage arrays.

Similar to the manner in which the functions of computing device **212**, control systems **314**, **514**, **630**, **632**A, **632**B and/or control system **632**C can be distributed across computing devices **700***a*, **700***b*, and **700***c* of computing clusters **709***a*, **709***b*, and **709***c*, various active portions and/or backup portions of these components can be distributed across cluster storage arrays **710***a*, **710***b*, and **710***c*. For example, some cluster storage arrays can be configured to store the data of control system **630**, while other cluster storage arrays can store data of control system **632**A, **632**B, and/or **632**C. Additionally, some cluster storage arrays can be configured to store backup versions of data stored in other cluster storage arrays.

The cluster routers **711***a*, **711***b*, and **711***c* in computing clusters **709***a*, **709***b*, and **709***c* can include networking equipment configured to provide internal and external communications for the computing clusters. For example, the cluster routers **711***a* in computing cluster **709***a* can include one or more internet switching and routing devices configured to provide (i) local area network communications between the computing devices **700***a* and the cluster storage arrays **701***a* via the local cluster network **712***a*, and (ii) wide area network communications between the computing cluster **709***a* and the computing clusters **709***b* and **709***c* via the wide area network connection **713***a* to network **674**. Cluster routers **711***b* and **711***c* can include network equipment similar to the cluster routers **711***a*, and cluster routers **711***b* and **711***c* can perform similar networking functions for computing clusters **709***b* and **709***b* that cluster routers **711***a* perform for computing cluster **709***a*.

In some embodiments, the configuration of the cluster routers **711***a*, **711***b*, and **711***c* can be based at least in part on the data communication requirements of the computing devices and cluster storage arrays, the data communications capabilities of the network equipment in the cluster routers **711***a*, **711***b*, and **711***c*, the latency and throughput of local networks **712***a*, **712***b*, **712***c*, the latency, throughput, and cost of wide area network links **713***a*, **713***b*, and **713***c*, and/or other factors that can contribute to the cost, speed, fault-tolerance, resiliency, efficiency and/or other design goals of the moderation system architecture.

The above detailed description describes various features and functions of the disclosed systems, devices, and methods with reference to the accompanying figures. In the figures, similar symbols typically identify similar components, unless context dictates otherwise. The example embodiments described herein and in the figures are not meant to be limiting. Other embodiments can be utilized, and other changes can be made, without departing from the spirit or scope of the subject matter presented herein. It will be readily understood that the aspects of the present disclosure, as generally described herein, and illustrated in the figures, can be arranged, substituted, combined, separated, and designed in a wide variety of different configurations, all of which are explicitly contemplated herein.

With respect to any or all of the ladder diagrams, scenarios, and flow charts in the figures and as discussed herein, each block and/or communication can represent a processing of information and/or a transmission of information in accordance with example embodiments. Alternative embodiments are included within the scope of these example embodiments. In these alternative embodiments, for example, functions described as blocks, transmissions, communications, requests, responses, and/or messages can be executed out of order from that shown or discussed, including substantially concurrent or in reverse order, depending on the functionality involved. Further, more or fewer blocks and/or functions can be used with any of the ladder diagrams, scenarios, and flow charts discussed herein, and these ladder diagrams, scenarios, and flow charts can be combined with one another, in part or in whole.

A block that represents a processing of information can correspond to circuitry that can be configured to perform the specific logical functions of a herein-described method or technique. Alternatively or additionally, a block that represents a processing of information can correspond to a module, a segment, or a portion of program code (including related data). The program code can include one or more instructions executable by a processor for implementing specific logical functions or actions in the method or technique. The program code and/or related data can be stored on any type of computer readable medium such as a storage device including a disk or hard drive or other storage medium.

The computer readable medium can also include non-transitory computer readable media such as computer-readable media that stores data for short periods of time like register memory, processor cache, and random access memory (RAM). The computer readable media can also include non-transitory computer readable media that stores program code and/or data for longer periods of time, such as secondary or persistent long term storage, like read only memory (ROM), optical or magnetic disks, compact-disc read only memory (CD-ROM), for example. The computer readable media can also be any other volatile or non-volatile storage systems. A computer readable medium can be considered a computer readable storage medium, for example, or a tangible storage device.

Moreover, a block that represents one or more information transmissions can correspond to information transmissions between software and/or hardware modules in the same physical device. However, other information transmissions can be between software modules and/or hardware modules in different physical devices.

The particular arrangements shown in the figures should not be viewed as limiting. It should be understood that other embodiments can include more or less of each element shown in a given figure. Further, some of the illustrated elements can be combined or omitted. Yet further, an example embodiment can include elements that are not illustrated in the figures.

While various aspects and embodiments have been disclosed herein, other aspects and embodiments will be apparent to those skilled in the art. The various aspects and embodiments disclosed herein are for purposes of illustration and are not intended to be limiting, with the true scope and spirit being indicated by the following claims.

What is claimed is:

1. A balloon, comprising:

a payload; and

an envelope, comprising a plurality of antenna sections disposed symmetrically about a longitudinal axis of the balloon;

wherein a first antenna section of the plurality of antenna sections is different from a second antenna section of the plurality of antenna sections, the first antenna section is configured to receive a first type of signal, the second antenna section is configured to receive a second type of signal different from the first type of signal, and both the first antenna section and the second antenna section are configured at least to receive signals and to convey the received signals to the payload;

wherein the first antenna section comprises a first metallization pattern to receive the first type of signal; and

wherein the second antenna section comprises a second metallization pattern to receive the second type of signal, the first metallization pattern being different from the second metallization pattern.

2. The balloon of claim **1**, wherein the first antenna section comprises a metallized section.

3. The balloon of claim **1**, wherein the first metallization pattern comprises a symmetric metallization pattern.

4. The balloon of claim **1**, wherein the first metallization pattern comprises an asymmetric metallization pattern.

5. The balloon of claim **1**, wherein the first metallization pattern comprises a patch metallization pattern.

6. The balloon of claim **5**, wherein the patch metallization pattern comprises a patch array.

7. The balloon of claim **1**, wherein the first metallization pattern comprises a horizontal metallization pattern.

8. The balloon of claim **1**, wherein the first metallization pattern comprises a vertical metallization pattern.

9. The balloon of claim **1**, wherein the first metallization pattern comprises a two-dimensional (2D) metallization pattern.

10. The balloon of claim **1**, wherein the first metallization pattern comprises a Z metallization pattern.

11. The balloon of claim **1**, wherein the first antenna section and the second antenna section are separated by a seam, and wherein the seam comprises an insulating material.

12. The balloon of claim **1**, wherein the payload further comprises:

a control system, configured to receive signals and switch between the antenna sections such that when the control system is switched to a receiving antenna section, the received signals are received at the control system from the receiving antenna section.

13. The balloon of claim **12**, wherein the control system is further configured to transmit transmittable signals, and wherein when the control system is switched to a transmitting antenna section, the control system is configured to provide the transmittable signals to the transmitting antenna section for transmission.

14. The balloon of claim **1**, wherein at least one section of the plurality of sections is not an antenna section.

15. A method, comprising:

receiving a first signal of a first type at a balloon, wherein the balloon comprises a first receiver, a second receiver, a payload, and an envelope, wherein the envelope comprises a plurality of antenna sections disposed symmetrically about a longitudinal axis of the balloon, wherein a first antenna section of the plurality of antenna sections is different from a second antenna section of the plurality of antenna sections, wherein the first signal is received at the first antenna section, and wherein the first antenna section comprises a first metallization pattern configured to receive and convey the first signal to the first receiver; and

receiving a second signal of a second type different from the first type at the balloon, wherein the second signal is received at the second antenna section, and wherein the second antenna section comprises a second metallization pattern configured to receive and convey the second signal to the second receiver, the first metallization pattern being different from the second metallization pattern.

16. The method of claim **15**, wherein the balloon is initially operating in a first mode in which the balloon operates the first receiver to receive the first signal and does not operate the second receiver, the method further comprising:

while the balloon is operating in the first mode, detecting a trigger event; and

in response to detecting the trigger event, the balloon switching from operation in the first mode to operation in a second mode in which the balloon operates the second receiver to receive the second signal and does not operate the first receiver.

17. The method of claim **15**, further comprising:

in response to receiving the first signal, determining a transmittable signal; and

transmitting the transmittable signal from the balloon using a transmitting antenna section, wherein the transmitting antenna section comprises either the first antenna section or the second antenna section.

18. The method of claim **17**, wherein determining the transmittable signal comprises:

determining diagnostic information about the balloon; and

generating the transmittable signal based on the diagnostic information.

19. The method of claim **17**, wherein the transmittable signal is based on the first signal.

20. The method of claim **17**, wherein the balloon further comprises a control system, and wherein transmitting the transmittable signal comprises:

selecting the transmitting antenna section using the control system; and

transmitting the transmittable signals using the transmitting antenna section.

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