US010877157B2

(12) **United States Patent**
Murphy

(10) **Patent No.: US 10,877,157 B2**
(45) **Date of Patent: *Dec. 29, 2020**

(54) **AIRCRAFT DISTRESS TRACKING AND INTERFACE TO SEARCH AND RESCUE SYSTEM**

(71) Applicant: **The Boeing Company**, Chicago, IL (US)

(72) Inventor: **Timothy Allen Murphy**, Everett, WA (US)

(73) Assignee: **The Boeing Company**, Chicago, IL (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 190 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **16/142,555**

(22) Filed: **Sep. 26, 2018**

(65) **Prior Publication Data**

US 2019/0025436 A1 Jan. 24, 2019

Related U.S. Application Data

(63) Continuation of application No. 14/832,851, filed on Aug. 21, 2015, now Pat. No. 10,088,574.

(51) **Int. Cl.**
G01S 19/17 (2010.01)
G01S 1/68 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***G01S 19/17*** (2013.01); ***B64D 25/20*** (2013.01); ***G01S 1/68*** (2013.01); ***G01S 5/0231*** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC G01S 19/17; G01S 5/0231; G01S 1/68; B64D 25/20; B64D 2045/0065; B64D 45/00; B64D 45/0059
(Continued)

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,750,166 A * 7/1973 Dearth G01S 13/78 342/30
5,311,197 A 5/1994 Sorden et al.
(Continued)

FOREIGN PATENT DOCUMENTS

JP	H11263292	A	9/1998
JP	200340193	A	2/2003
WO	WO2012011825	A1	1/2012

OTHER PUBLICATIONS

The State Intellectual Property Office of the People's Republic of China, Notification of First Office Action with English Translation, dated Dec. 5, 2018, regarding Application No. 2016106976187, 15 pages.

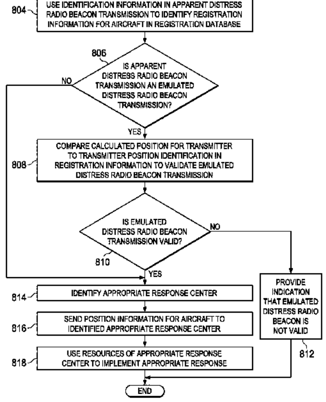
(Continued)

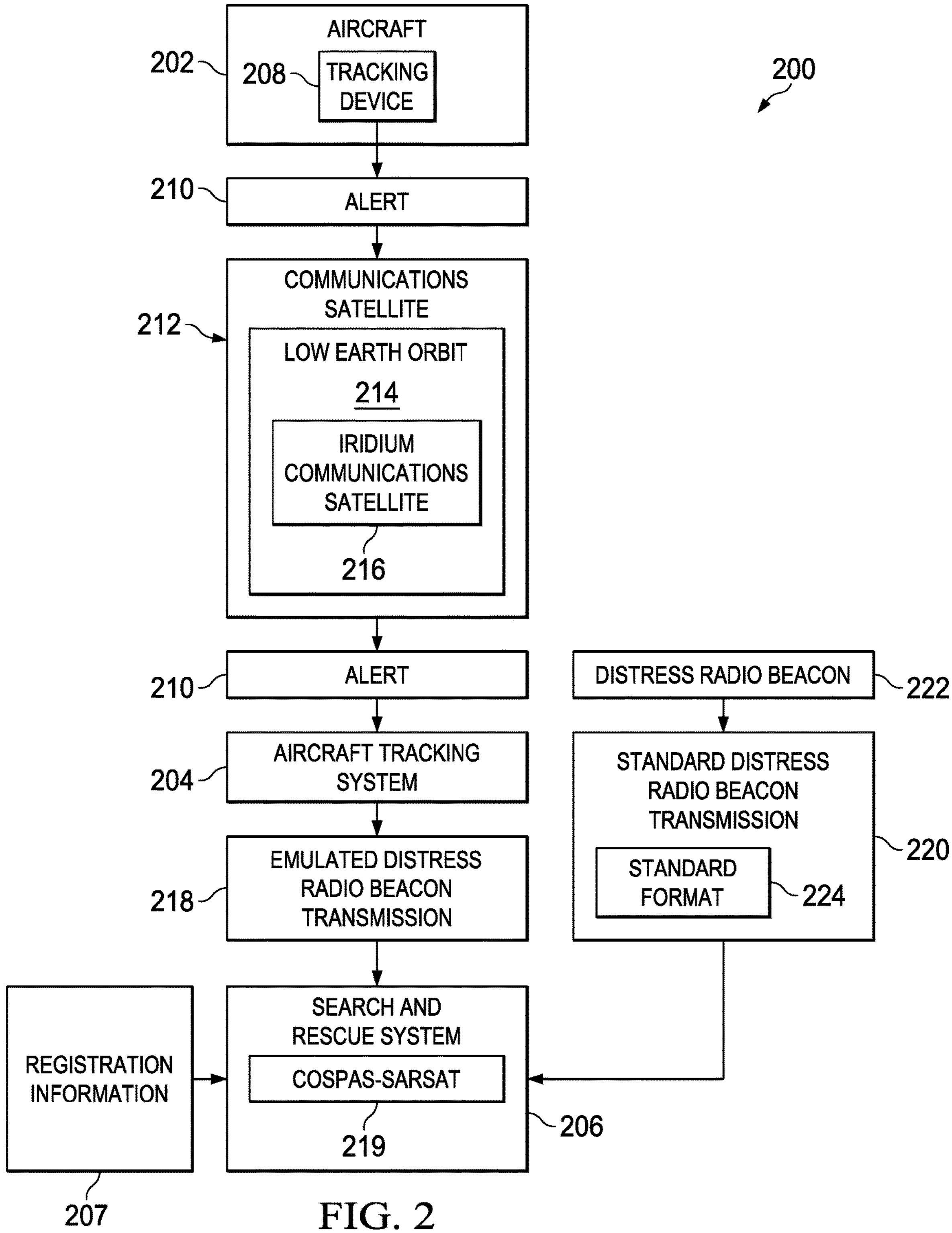
Primary Examiner — Chuong P Nguyen
(74) *Attorney, Agent, or Firm* — Yee & Associates, P.C.

(57) **ABSTRACT**

An apparatus and method of delivering an alert from an aircraft to a search and rescue system. An alert from an aircraft is received via a communications satellite. The alert comprises identification information identifying the aircraft and position information identifying the position of the aircraft. In response to receiving the alert, an emulated distress radio beacon signal is generated. The emulated distress radio beacon signal comprises the identification information and the position information in a standard format of a signal generated by a distress radio beacon. The emulated distress radio beacon signal is broadcast from a location other than the aircraft as an emulated distress radio beacon transmission that is configured to be received and processed by the search and rescue system.

20 Claims, 9 Drawing Sheets





AIRCRAFT
202
208
TRACKING DEVICE
200
210
ALERT
COMMUNICATIONS SATELLITE
212
LOW EARTH ORBIT
214
IRIDIUM COMMUNICATIONS SATELLITE
216
210
ALERT
DISTRESS RADIO BEACON
222
204
AIRCRAFT TRACKING SYSTEM
STANDARD DISTRESS RADIO BEACON TRANSMISSION
220
218
EMULATED DISTRESS RADIO BEACON TRANSMISSION
STANDARD FORMAT
224
REGISTRATION INFORMATION
SEARCH AND RESCUE SYSTEM
COSPAS-SARSAT
219
206
207

FIG. 2

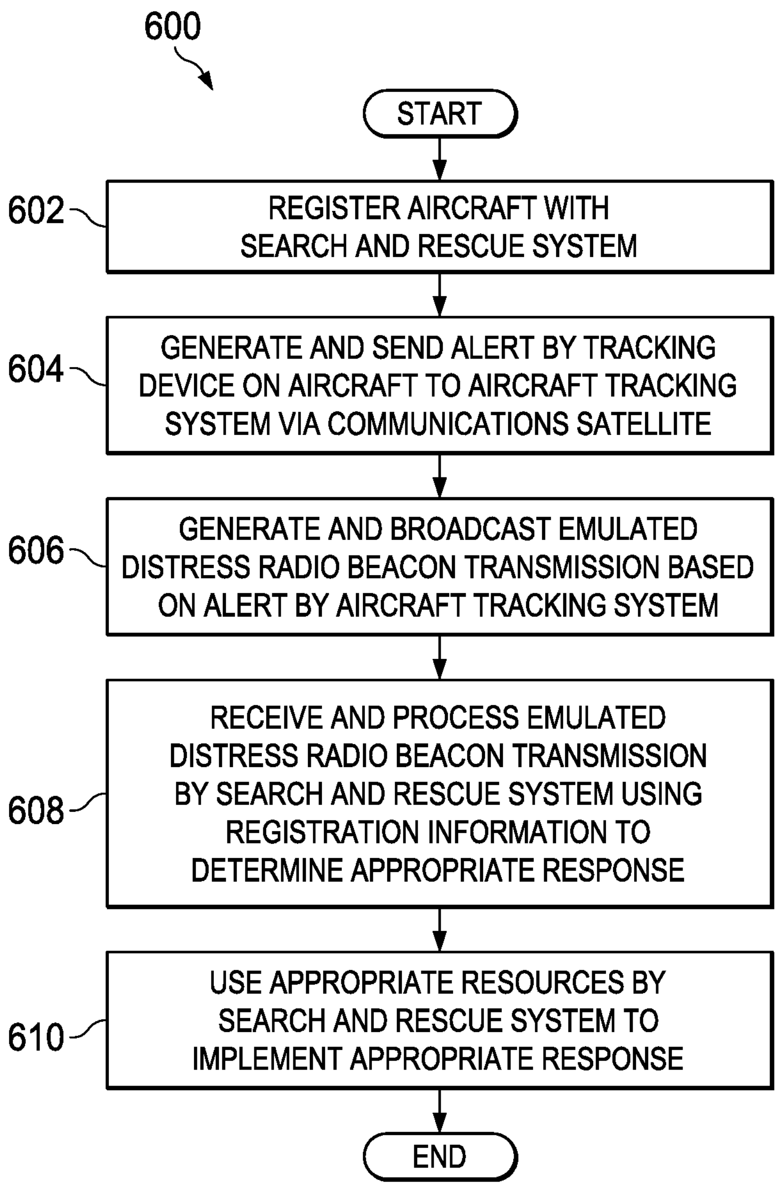

600
START
602
REGISTER AIRCRAFT WITH SEARCH AND RESCUE SYSTEM
604
GENERATE AND SEND ALERT BY TRACKING DEVICE ON AIRCRAFT TO AIRCRAFT TRACKING SYSTEM VIA COMMUNICATIONS SATELLITE
606
GENERATE AND BROADCAST EMULATED DISTRESS RADIO BEACON TRANSMISSION BASED ON ALERT BY AIRCRAFT TRACKING SYSTEM
608
RECEIVE AND PROCESS EMULATED DISTRESS RADIO BEACON TRANSMISSION BY SEARCH AND RESCUE SYSTEM USING REGISTRATION INFORMATION TO DETERMINE APPROPRIATE RESPONSE
610
USE APPROPRIATE RESOURCES BY SEARCH AND RESCUE SYSTEM TO IMPLEMENT APPROPRIATE RESPONSE
END

FIG. 6

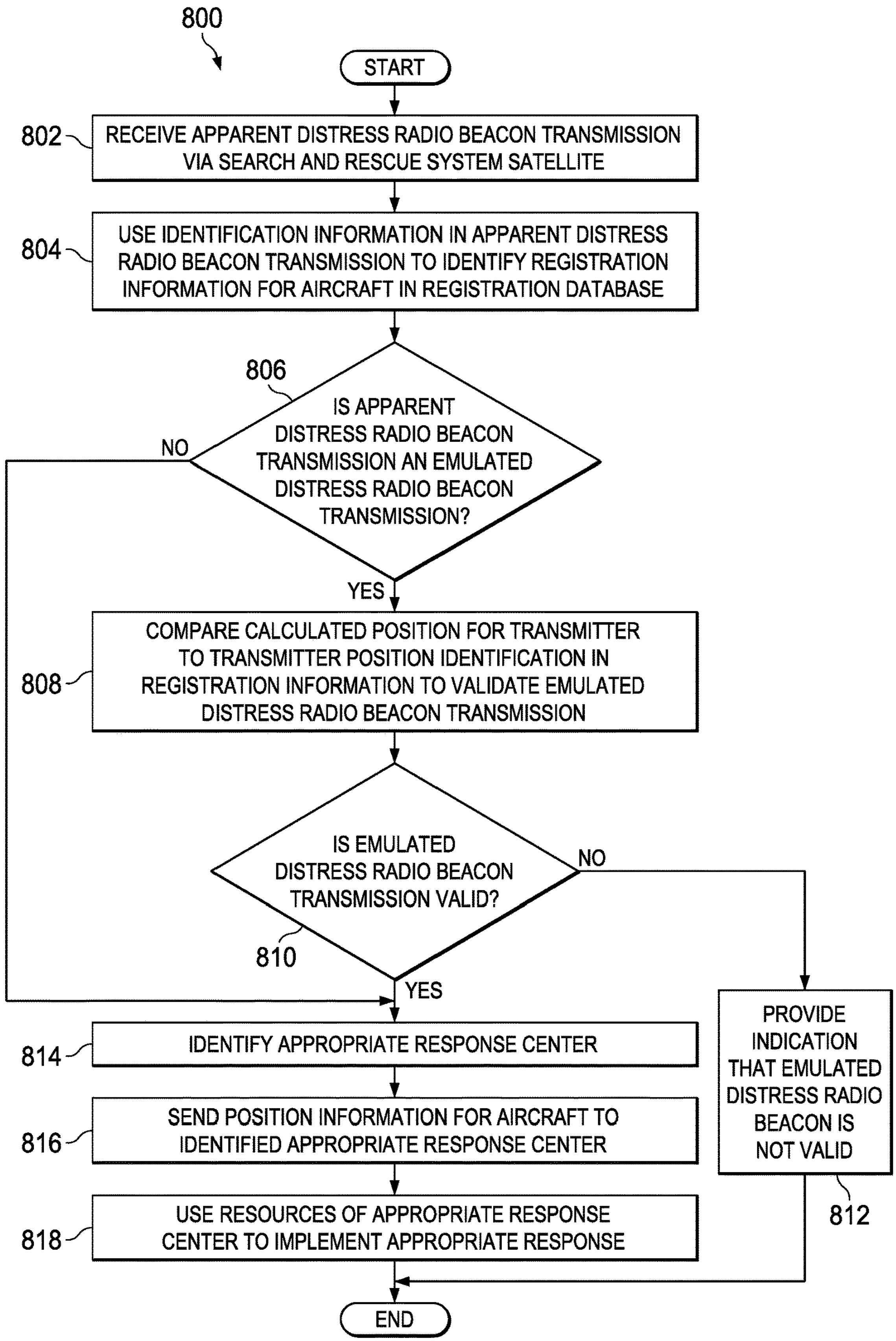

800
START
802
RECEIVE APPARENT DISTRESS RADIO BEACON TRANSMISSION VIA SEARCH AND RESCUE SYSTEM SATELLITE
804
USE IDENTIFICATION INFORMATION IN APPARENT DISTRESS RADIO BEACON TRANSMISSION TO IDENTIFY REGISTRATION INFORMATION FOR AIRCRAFT IN REGISTRATION DATABASE
806
IS APPARENT DISTRESS RADIO BEACON TRANSMISSION AN EMULATED DISTRESS RADIO BEACON TRANSMISSION?
NO
YES
808
COMPARE CALCULATED POSITION FOR TRANSMITTER TO TRANSMITTER POSITION IDENTIFICATION IN REGISTRATION INFORMATION TO VALIDATE EMULATED DISTRESS RADIO BEACON TRANSMISSION
IS EMULATED DISTRESS RADIO BEACON TRANSMISSION VALID?
810
NO
YES
814
IDENTIFY APPROPRIATE RESPONSE CENTER
816
SEND POSITION INFORMATION FOR AIRCRAFT TO IDENTIFIED APPROPRIATE RESPONSE CENTER
818
USE RESOURCES OF APPROPRIATE RESPONSE CENTER TO IMPLEMENT APPROPRIATE RESPONSE
PROVIDE INDICATION THAT EMULATED DISTRESS RADIO BEACON IS NOT VALID
812
END

FIG. 8

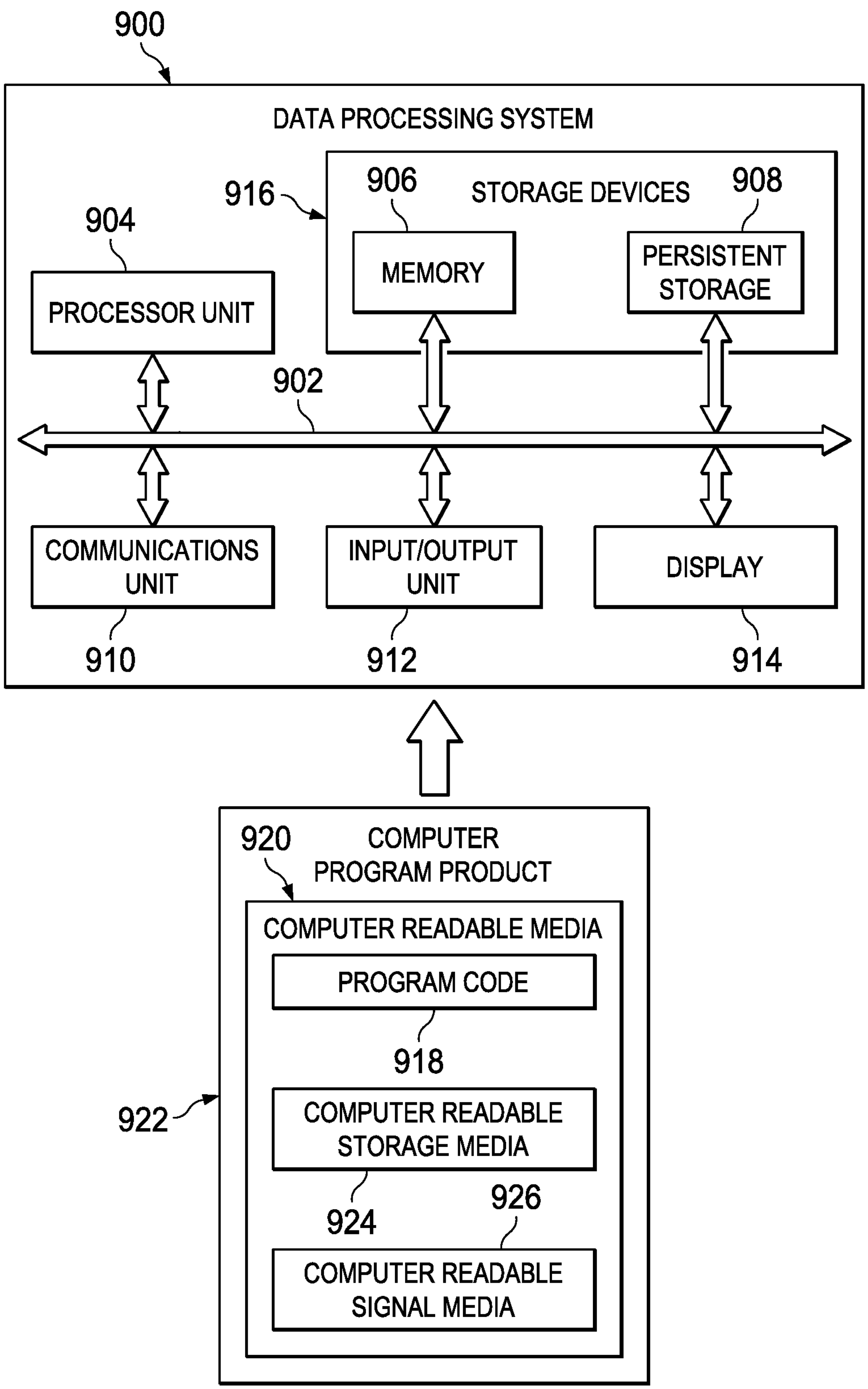

900
DATA PROCESSING SYSTEM
916
906
STORAGE DEVICES
908
904
MEMORY
PERSISTENT STORAGE
PROCESSOR UNIT
902
COMMUNICATIONS UNIT
INPUT/OUTPUT UNIT
DISPLAY
910
912
914
920
COMPUTER PROGRAM PRODUCT
COMPUTER READABLE MEDIA
PROGRAM CODE
918
922
COMPUTER READABLE STORAGE MEDIA
924
926
COMPUTER READABLE SIGNAL MEDIA

FIG. 9

Registration information **424** may include, for example, without limitation, identification information **428**, transmitter information **430**, and other information **432**.

Transmitter information **430** in registration information **424** may indicate that apparent distress radio beacon transmission **410** from an aircraft identified by identification information **428** is an emulated distress radio beacon transmission. Transmitter information **430** also may identify transmitter position **434** of the source of the emulated distress radio beacon transmission. Mission control center **406** may comprise validator **436** for validating a received emulated distress radio beacon transmission by comparing calculated position **420** for the transmission to transmitter position **434** as identified in registration information **424**.

Response center **408** may include resources **438** for performing search and rescue operations. Response center **408** may use information provided by mission control center **406** to use resources **438** in an appropriate manner to perform a search and rescue operation in response to the received emulated distress radio beacon transmission.

The illustrations of FIGS. **2-4** are not meant to imply physical or architectural limitations to the manner in which different illustrative embodiments may be implemented. Other components in addition to, in place of, or in addition to and in place of the ones illustrated may be used. Some components may be unnecessary in some illustrative embodiments. Also, the blocks are presented to illustrate some functional components. One or more of these blocks may be combined, divided, or combined and divided into different blocks when implemented in different illustrative embodiments.

Turning to FIG. **5**, an illustration of a block diagram of a tracking device is depicted in accordance with an illustrative embodiment. Tracking device **500** may be an example of one implementation of tracking device **112** on aircraft **102** in FIG. **1** or tracking device **208** on aircraft **202** in FIG. **2**. For example, without limitation, tracking device **500** may be attached to aircraft **501** on outside **502** of aircraft **501**.

Tracking device **500** comprises various electronics contained within housing **504**. Housing **504** may be made in any appropriate manner of any appropriate material such that the electronics contained inside housing **504** are protected to maintain proper operation of tracking device **500** when tracking device **500** is attached to aircraft **501** on outside **502** of aircraft **501**. For example, without limitation, the electronics may be hermitically sealed **506** within interior **508** of housing **504**. The electronics may be hermetically sealed **506** within interior **508** of housing **504** using any appropriate materials and structures to provide an airtight seal between interior **508** of housing **504** and outside **502** of aircraft **501** when tracking device **500** is attached to aircraft **501** on outside **502** of aircraft **501**. Electronics for tracking device **500** may include satellite navigation system receiver **510**, number of antennas **512**, satellite communications transceiver **514**, distress identifier **516**, and processor **518**.

Satellite navigation system receiver **510** may be configured to receive navigation signals from satellites in a satellite navigation system via number of antennas **512**. For example, without limitation, satellite navigation system receiver **510** may be configured to use satellite navigation system receiver antenna **519** in number of antennas **512** to receive the navigation signals. For example, without limitation, satellite navigation system receiver **510** may be configured to receive navigation signals from satellites in a global navigation satellite system such as the Global Positioning System (GPS), the Global Navigation Satellite System (GLONASS), another appropriate satellite navigations system, or from various combinations of satellite navigation systems. In accordance with an illustrative embodiment, the navigation signals received by satellite navigation system receiver **510** may be used to determine the position of aircraft **501**.

Satellite communications transceiver **514** may be configured to send and receive information via a satellite communications system. For example, without limitation, satellite communications transceiver **514** may be configured to send and receive information via communications satellites in low Earth orbit, such as satellites in the Iridium network, other appropriate communications satellites, or various communications satellites from various combinations of satellite communications systems.

In accordance with an illustrative embodiment, satellite communications transceiver **514** may be used to send position information **520** to a receiving station via a satellite. Position information **520** may include information identifying the position determined using the navigation signals received by satellite navigation system receiver **510**. In distinct embodiments, position information **520** may be augmented by additional information such as time stamps, and other aircraft navigation or aircraft state data.

Satellite communications transceiver **514** also may be used to send identification information **522**, alert **524**, other information **525**, or various combinations of appropriate information to a receiving station via a satellite. Identification information **522** may include information identifying aircraft **501**. Alert **524** may include information indicating that aircraft **501** is in distress.

Satellite communications transceiver **514** also may be configured to receive instructions **526** via a satellite. For example, without limitations, instructions **526** may include instructions for controlling operation of the electronics for tracking device **500**.

Satellite communications transceiver **514** may use satellite communications antenna **530** in number of antennas **512** to send and receive communications from a communications satellite. Alternatively, satellite communications transceiver **514** and satellite navigation system receiver **510** may share the use of shared antenna **532** in number of antennas **512**. In this case, diplexer **534** or another appropriate device may be used for separating and directing the appropriate signals from shared antenna **532** to satellite navigation system receiver **510** and satellite communications transceiver **514** and for directing any signals from satellite communications transceiver **514** to shared antenna **532**.

Distress identifier **516** may be configured to identify when aircraft **501** is in distress. The functions performed by distress identifier **516** may be implemented in hardware or in software running on hardware. For example, without limitation, the functions performed by distress identifier **516** may be implemented, in whole or in part, in software running on processor **518**. Alternatively, the functions performed by distress identifier **516** may be implemented entirely separately from processor **518**.

Distress may include any undesired condition of aircraft **501**. Distress identifier **516** may be configured to identify when aircraft **501** is in distress automatically in any appropriate manner. For example, without limitation, distress identifier **516** may determine that aircraft **501** is in distress when power for operation of electronics for tracking device **500** that is provided on power line **536** from power source **538** on inside **540** of aircraft **501** is interrupted.

In some distinct embodiments, a list or a matrix of indicators that aircraft **501** is in distress, or factors associated with aircraft **501** in distress, may be stored in storage **541** transmitter on the aircraft as an emulated emergency locator transmitter transmission from a location other than the aircraft.

A tracking device on the aircraft then may generate and send an alert to an aircraft tracking system via a communications satellite (operation **604**). The aircraft tracking system then may generate and broadcast an emulated distress radio beacon transmission based on the alert received from the aircraft (operation **606**). The emulated distress radio beacon transmission may be received by a search and rescue system and processed by the search and rescue system to determine an appropriate response (operation **608**). The search and rescue system then may use appropriate resources to implement the appropriate response (operation **610**), with the process terminating thereafter.

Turning to FIG. **7**, an illustration of a flowchart of a process for delivering an alert from an aircraft to a search and rescue system is depicted in accordance with an illustrative embodiment. For example, without limitation, process **700** may be implemented by aircraft tracking system **300** in FIG. **3**.

Process **700** may begin with determining whether an alert, including aircraft identification information and position information, is received from a tracking device on an aircraft (operation **704**). Operation **704** may be repeated until an alert is received from an aircraft.

When it is determined in operation **704** that an alert is received from an aircraft, the alert may be evaluated (operation **706**). Evaluating the received alert may include determining whether the alert is a distress alert indicating that the aircraft is in distress (operation **708**). When the alert is not a distress alert, appropriate action may be taken (operation **710**). In this case, the appropriate action taken in operation **710** does not include alerting a search and rescue system.

When it is determined in operation **708** that the received alert is a distress alert, an emulated distress radio beacon signal including the identification information and the position information may be generated (operation **712**). The emulated distress radio beacon signal then may be broadcast (operation **714**), with the process terminating thereafter.

Turning to FIG. **8**, an illustration of a flowchart of a process of using an alert from an aircraft to perform a search and rescue operation is depicted in accordance with an illustrative embodiment. Process **800** may be performed, for example, by search and rescue system **400** in FIG. **4**.

Process **800** may begin with receiving an apparent distress radio beacon transmission via a search and rescue system satellite (operation **802**). Identification information in the apparent distress radio beacon transmission may be used to identify registration information for the aircraft in a registration database (operation **804**). The identified registration information then may be used to determine whether the apparent distress radio beacon transmission is an emulated distress radio beacon transmission (operation **806**). If it is determined at operation **806** that the apparent distress radio beacon transmission is an emulated distress radio beacon transmission, a calculated position for the transmitter may be compared to information identifying the transmitter position in the registration information (operation **810**).

It then may be determined whether the emulated distress radio beacon transmission is valid (operation **810**). If it is determined that the emulated distress radio beacon transmission is not valid, an indication that the emulated distress radio beacon is not valid may be provided (operation **812**), with the process terminating thereafter. If it is determined that the emulated distress radio beacon transmission is valid, an appropriate response center may be identified (operation **814**), position information for the aircraft may be sent to the identified appropriate response center (operation **816**), and resources may be used by the appropriate response center to implement an appropriate response (operation **818**), with the process terminating thereafter.

Turning to FIG. **9**, an illustration of a block diagram of a data processing system on which various functions may be implemented is depicted in accordance with an illustrative embodiment. In this illustrative example, data processing system **900** includes communications fabric **902**. Communications fabric **902** provides communications between processor unit **904**, memory **906**, persistent storage **908**, communications unit **910**, input/output (I/O) unit **912**, and display **914**.

Processor unit **904** serves to execute instructions for software that may be loaded into memory **906**. Processor unit **904** may be a number of processors, a multi-processor core, or some other type of processor, depending on the particular implementation. Further, processor unit **904** may be implemented using a number of heterogeneous processor systems in which a main processor is present with secondary processors on a single chip. As another illustrative example, processor unit **904** may be a symmetric multi-processor system containing multiple processors of the same type.

Memory **906** and persistent storage **908** are examples of storage devices **916**. A storage device is any piece of hardware that is capable of storing information, such as, for example, without limitation, data, program code in functional form, and/or other suitable information either on a temporary basis and/or a permanent basis. Storage devices **916** may also be referred to as computer-readable storage devices in these examples. Memory **906** may be, for example, a random access memory or any other suitable volatile or non-volatile storage device. Persistent storage **908** may take various forms, depending on the particular implementation.

For example, persistent storage **908** may contain one or more components or devices. For example, persistent storage **908** may be a hard drive, a flash memory, a rewritable optical disk, a rewritable magnetic tape, or some combination of the above. The media used by persistent storage **908** also may be removable. For example, a removable hard drive may be used for persistent storage **908**.

Communications unit **910**, in these examples, provides for communications with other data processing systems or devices. In these examples, communications unit **910** is a network interface card. Communications unit **910** may provide communications through the use of either or both physical and wireless communications links.

Input/output unit **912** allows for input and output of data with other devices that may be connected to data processing system **900**. For example, input/output unit **912** may provide a connection for user input through a keyboard, a mouse, and/or some other suitable input device. Further, input/output unit **912** may send output to a printer. Display **914** provides a mechanism to display information to a user.

Instructions for the operating system, applications, and/or programs may be located in storage devices **916**, which are in communication with processor unit **904** through communications fabric **902**. In these illustrative examples, the instructions are in a functional form on persistent storage **908**. These instructions may be loaded into memory **906** for execution by processor unit **904**. The processes of the different embodiments may be performed by processor unit **904** using computer-implemented instructions, which may be located in a memory, such as memory **906**.

system satellite and signal Doppler measurements for the apparent distress radio beacon transmission; and

comparing the location of the transmitter as identified in the registration information to the calculated position to determine whether the apparent distress radio beacon transmission is valid.

* * * * *

AIRCRAFT DISTRESS TRACKING AND INTERFACE TO SEARCH AND RESCUE SYSTEM

This application is a continuation of U.S. patent application Ser. No. 14/832,851, filed Aug. 21, 2015, now U.S. Pat. No. 10,088,574, the disclosure of which is incorporated by reference herein in its entirety.

BACKGROUND INFORMATION

1. Field

The present disclosure relates generally to identifying, locating, and responding to an aircraft in distress. More particularly, the present disclosure relates to a method and apparatus for delivering an alert from an aircraft to a search and rescue system for responding to the aircraft in distress.

2. Background

Many aircraft carry distress radio beacons. Distress radio beacons may be known as emergency beacons or by other names. For example, without limitation, many commercial passenger aircraft and other aircraft may carry a distress radio beacon known as an emergency locator transmitter, ELT.

An emergency locator transmitter on an aircraft is intended to aid in locating the aircraft after a crash. An emergency locator transmitter on an aircraft may be manually or automatically activated to send out a distress signal when the aircraft is in distress. For example, without limitation, an emergency locator transmitter may be activated to transmit a distress signal automatically upon immersion in water or when another condition indicating that the aircraft is in distress is detected.

A search and rescue system may detect a distress signal generated by an emergency locator transmitter or other distress radio beacon on an aircraft and respond in an appropriate manner. For example, COSPAS-SARSAT is an international humanitarian search and rescue system for locating and responding to aircraft, ships, or individuals in distress. The COSPAS-SARSAT system includes a network of satellites, ground stations, mission control centers, and rescue coordination centers.

COSPAS-SARSAT uses satellites to detect distress signal transmissions from emergency locator transmitters on aircraft. The signal from an emergency locator transmitter on an aircraft is received by a satellite in the COSPAS-SARSAT system and relayed to the nearest available ground station. The ground station, called a Local User Terminal, processes the signal and determines the position from which it originated. The primary means for determining the position of the transmission from the emergency locator transmitter is using satellite orbit information and signal Doppler measurements. In some cases, an emergency locator transmitter may be configured to determine its location using a satellite navigation system receiver that is either integrated into the emergency locator transmitter or fed by a satellite navigation system receiver that is not part of the emergency locator transmitter.

Information identifying the position of the emergency locator transmitter is transmitted from the ground station to a mission control center where it is joined with identification data and other information associated with the emergency locator transmitter. The mission control center then transmits an alert message to an appropriate rescue coordination

center based on the determined geographic location of the detected transmission from the emergency locator transmitter and other available information.

Current emergency locator transmitters may have several limitations. For example, position information provided by current emergency locator transmitters may not be sufficiently accurate or provided in a sufficiently reliable manner to locate an aircraft in distress effectively. The majority of currently fielded emergency locator transmitters do not provide position information directly. The location of the emergency locator transmitter is determined by radio frequency direction finding or multilateration through satellite links. This process may take an undesirably long time and may not be sufficiently reliable.

The weight of current emergency locator transmitters may be relatively high. Maintenance requirements for current emergency locator transmitters also may be relatively high. For example, most emergency locator transmitters fitted to aircraft today are powered by a non-rechargeable battery that is relatively heavy and must be maintained appropriately to ensure reliable operation and to prevent any undesired condition from occurring. It also may be relatively difficult to reduce or eliminate undesirable tampering with current emergency locator transmitters.

Accordingly, it would be beneficial to have a method and apparatus that take into account one or more of the issues discussed above, as well as possible other issues.

SUMMARY

The illustrative embodiments of the present disclosure provide a method of delivering an alert from an aircraft to a search and rescue system. An alert from the aircraft is received via a communications satellite. The alert comprises identification information identifying the aircraft and position information identifying a position of the aircraft. In response to receiving the alert, an emulated distress radio beacon signal is generated. The emulated distress radio beacon signal includes the identification information and the position information in a standard format of a signal generated by a distress radio beacon. The emulated distress radio beacon signal is broadcast from a location other than the aircraft as an emulated distress radio beacon transmission that is configured to be received and processed by the search and rescue system.

The illustrative embodiments of the present disclosure also provide an apparatus comprising a receiver, a formatter, and a transmitter. The receiver is configured to receive an alert from an aircraft via a communications satellite. The alert comprises identification information identifying the aircraft and position information identifying the position of the aircraft. The formatter is configured to generate an emulated distress radio beacon signal comprising the identification information and the position information in a standard format of a signal generated by a distress radio beacon. The transmitter is configured to broadcast the emulated distress radio beacon signal from a location other than the aircraft as an emulated distress radio beacon transmission that is configured to be received and processed by a search and rescue system.

The illustrative embodiments also provide a system comprising a tracking device on an aircraft, an aircraft tracking system, and a search and rescue system. The tracking device is configured to send an alert from the aircraft via a communications satellite, wherein the alert comprises identification information identifying the aircraft and position information identifying the position of the aircraft. The aircraft

tracking system is configured to receive the alert from the aircraft, generate an emulated distress radio beacon signal comprising the identification information and the position information in a standard format of a signal generated by a distress radio beacon, and broadcast the emulated distress radio beacon signal from a location other than the aircraft as an emulated distress radio beacon transmission. The search and rescue system is configured to receive the emulated distress radio beacon transmission as a standard distress radio beacon transmission via a search and rescue system satellite and use the identification information and the position information to conduct a search and rescue operation.

The illustrative embodiments of the present disclosure also provide a method of using an alert from an aircraft to perform a search and rescue operation. An apparent distress radio beacon transmission comprising identification information identifying the aircraft and position information identifying a position of the aircraft is received. The identification information is used to identify registration information for the aircraft indicating whether the apparent distress radio beacon transmission is an emulated distress radio beacon transmission transmitted from a transmitter that is not a distress radio beacon located on the aircraft. The identification information and the position information are used to perform a search and rescue operation in response to a determination that the apparent distress radio beacon transmission is an emulated distress radio beacon transmission transmitted from a transmitter that is not a distress radio beacon located on the aircraft.

Various features, functions, and benefits may be achieved independently in various embodiments of the present disclosure or may be combined in yet other embodiments in which further details can be seen with reference to the following description and drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

The novel features believed characteristic of the illustrative embodiments are set forth in the appended claims. The illustrative embodiments, however, as well as a preferred mode of use, further objectives, and benefits thereof, will best be understood by reference to the following detailed description of illustrative embodiments of the present disclosure when read in conjunction with the accompanying drawings, wherein:

FIG. **1** is an illustration of an aircraft operating environment in accordance with an illustrative embodiment;

FIG. **2** is an illustration of a block diagram of an aircraft operating environment in accordance with an illustrative embodiment;

FIG. **3** is an illustration of a block diagram of an aircraft tracking system in accordance with an illustrative embodiment;

FIG. **4** is an illustration of a block diagram of a search and rescue system in accordance with an illustrative embodiment;

FIG. **5** is an illustration of a block diagram of a tracking device in accordance with an illustrative embodiment;

FIG. **6** is an illustration of a flowchart of a process of using an alert from an aircraft to perform a search and rescue operation in accordance with an illustrative embodiment;

FIG. **7** is an illustration of a flowchart of a process for delivering an alert from an aircraft to a search and rescue system in accordance with an illustrative embodiment;

FIG. **8** is an illustration of a flowchart of a process for using an alert from an aircraft to perform a search and rescue operation in accordance with an illustrative embodiment; and

FIG. **9** is an illustration of a block diagram of a data processing system in accordance with an illustrative embodiment.

DETAILED DESCRIPTION

Different illustrative embodiments recognize and take into account a number of different considerations. "A number," as used herein with reference to items, means one or more items. For example, "a number of different considerations" are one or more different considerations.

The different illustrative embodiments recognize and take into account that many of the limitations of an emergency locator transmitter may be overcome by replacing the emergency locator transmitter on an aircraft with an Iridium based tracking system. The different illustrative embodiments also recognize, however, that the current COSPAS-SARSAT search and rescue system is not configured to receive alerts from such a tracking system.

Illustrative embodiments provide a system and method for receiving alerts and position information from a tracking device on an aircraft and re-transmitting the alerts in an appropriate format for the current COSPAS-SARSAT system. In accordance with an illustrative embodiment, an alert received from the tracking device on an aircraft may be converted into an emulated emergency locator transmitter signal that may be broadcast using a transmitter that emulates a transmission from an emergency locator transmitter.

Turning to FIG. **1**, an illustration of an aircraft operating environment is depicted in accordance with an illustrative embodiment. Aircraft operating environment **100** may include any appropriate environment in which aircraft **102** may be operated in any appropriate manner.

Aircraft **102** may be any appropriate type of aircraft that may be configured to perform any appropriate operation or mission in aircraft operating environment **100**. For example, without limitation, aircraft **102** may be a commercial passenger aircraft or any other appropriate type of aircraft.

Aircraft operating environment **100** may include search and rescue system **104**. Search and rescue system **104** may comprise various systems and personnel for responding to an indication that aircraft **102** is in distress. For example, without limitation, search and rescue system **104** may comprise the COSPAS-SARSAT search and rescue system.

Search and rescue system **104** may comprise search and rescue system satellites **106** and ground facilities **108**. Search and rescue system satellites **106** may comprise satellites in low Earth orbit, satellites in geostationary orbits, or both. Search and rescues system satellites are configured to detect transmissions from distress radio beacons, such as emergency locator transmitters, and to rely such transmissions to ground facilities **108**.

Ground facilities **108** are configured to receive the relayed distress radio beacon transmissions from search and rescue system satellites **106**, process the distress radios beacon transmissions, and conduct appropriate search and rescue operations in response. For example, without limitation, ground facilities **108** may include multiple response centers having various resources for responding to various distress situations. Ground facilities **108** may be configured to process received distress radio beacon transmissions to identify and notify the appropriate response center or centers for responding to a particular distress situation.

In accordance with an illustrative embodiment, aircraft **102** may include tracking device **112**. For example, without limitation, tracking device **112** may be attached to the skin of aircraft **102** on the outside of aircraft **102**. In accordance with an illustrative embodiment, tracking device **112** may be configured to determine automatically the position of aircraft **102**, to determine when aircraft **102** is in distress, and to send an alert including position information identifying the position of aircraft **102** when aircraft **102** is determined to be in distress.

Tracking device **112** may be configured to identify the position of aircraft **102** using navigation signals **114** received from a number of navigation system satellites **116** in a known manner. Tracking device **112** may use navigation signals **114** received from more than three navigation system satellites **116** to determine the position of aircraft **102**. For example, without limitation, navigation system satellites **116** may include satellites in satellite navigation system **117** such as the Global Positioning System, GPS, the Global Navigation Satellite System, GLONASS, other appropriate satellite navigation systems, or various combinations of satellite navigation systems that may be used by tracking device **112** to determine the position of aircraft **102**.

In accordance with an illustrative embodiment, tracking device **112** on aircraft is not a conventional emergency locator transmitter or other conventional distress radio beacon. In accordance with an illustrative embodiment, tracking device **112** is configured to send an alert including position information to aircraft tracking system **118** via communications satellite **120**.

For example, without limitation, aircraft tracking system **118** may be a global aircraft tracking system. Aircraft tracking system **118** may be operated by any appropriate entity. For example, without limitation, when aircraft **102** is a commercial passenger aircraft, aircraft tracking system **118** may be operated by an airline. Alternatively, aircraft tracking system **118** may be operated by a third party for a number of airlines or other operators of aircraft **102**.

Communications satellite **120** may comprise any appropriate communications satellite or a plurality of communications satellites for establishing a communications link between tracking device **112** on aircraft **102** and aircraft tracking system **118**. Tracking device **112** may be configured to send alerts, including position information identifying the position of aircraft **102**, from tracking device **112** to aircraft tracking system **118** via the communications link established using communications satellite **120**. For example, without limitation, communications satellite **120** may be a communications satellite in low Earth orbit. A satellite in low Earth orbit is in orbit around the Earth with an altitude between approximately 160 kilometers and 2000 kilometers. For example, without limitation, communications satellite **120** may be an Iridium communications satellite in the Iridium satellite constellation operated by Iridium Communications.

Search and rescue system **104** may not be configured to receive an alert transmitted from tracking device **112** on aircraft **102**. In accordance with an illustrative embodiment, however, aircraft tracking system **118** may include appropriate facilities for receiving an alert transmission from tracking device **112** on aircraft **102**, evaluating the alert, and transmitting the alert in an appropriate format to be received and processed by search and rescue system **104**. For example, without limitation, aircraft tracking system **118** may be configured to evaluate an alert received from tracking device **112** on aircraft **102** to determine whether the alert indicates that aircraft **102** is in distress.

Appropriate action by search and rescue system **104** may be desired or required when aircraft **102** is in distress. If action from search and rescue system **104** is desired or required, aircraft tracking system **118** may generate emulated distress radio beacon signal **122**. Emulated distress radio beacon signal **122** may include identification information identifying aircraft **102** and position information identifying the position of aircraft **102** as provided in the alert received from tracking device **112** on aircraft **102**. Emulated distress radio beacon signal **122** may be in a standard format of a signal generated by a distress radio beacon. For example, without limitation, emulated distress radio beacon signal **122** may be in the standard format of a transmission from an emergency locator transmitter on an aircraft. Aircraft tracking system **118** may broadcast emulated distress radio beacon signal **122** as an emulated distress radio beacon transmission that is configured to be received and processed by search and rescue system **104**. Emulated distress radio beacon signal **122** may be broadcast from a location that is not on aircraft **102** using any appropriate transmitter **124** that is configured to emulate a transmission from a distress radio beacon on an aircraft. For example, without limitation, transmitter **124** may be located on the ground.

Emulated distress radio beacon signal **122** may be received by search and rescue system satellites **106** and relayed to ground facilities **108** for search and rescue system **104** in a normal manner. Search and rescue system **104** thus may be notified of and respond to an alert generated by tracking device **112** on aircraft **102** without significant changes to search and rescue system **104**.

Turning to FIG. **2**, an illustration of a block diagram of an aircraft operating environment is depicted in accordance with an illustrative embodiment. Aircraft operating environment **200** may be an example of one implementation of aircraft operating environment **100** in FIG. **1**. Aircraft operating environment **200** may comprise aircraft **202**, aircraft tracking system **204**, and search and rescue system **206**.

Aircraft **202** may be any appropriate type of aircraft that may be configured to perform any appropriate operation or mission in aircraft operating environment **200**. For example, without limitation, aircraft **202** may be a commercial passenger aircraft, a cargo aircraft, a military aircraft, or any other appropriate type of aircraft. Aircraft **202** may be a fixed wing aircraft, a rotary wing aircraft, or a lighter-than-air aircraft. Aircraft **202** may be a manned aircraft or an unmanned aircraft.

Before operating aircraft **202** in aircraft operating environment **200**, registration information **207** for aircraft **200** may be provided to search and rescue system. Registration information **207** may comprise the same type of information that would be needed by search and rescue system **206** to respond to a transmission from an actual emergency locator transmitter on an aircraft. For example, without limitation, registration information **207** may include information connecting aircraft identification information in a received distress radio beacon signal to the operator of the aircraft, appropriate contact information, an appropriate regulatory authority that should be contacted in an emergency situation, or other appropriate information. The aircraft position at the time of the distress signal reception may determine which Air Navigation Service Unit should be contacted as well.

For example, without limitation, registration information **207** may notify search and rescue system **206** that an apparent distress radio beacon transmission from aircraft **202** is not from a distress radio beacon on aircraft **202**, but is from aircraft tracking system **204**. Registration information is provided to search and rescue system **206** so that search and rescue system **206** may respond appropriately when an apparent distress radio beacon transmission from aircraft **202** is received by search and rescue system **206**.

Aircraft **202** includes tracking device **208**. Tracking device **208** may be configured to send alert **210** to aircraft tracking system **204** via communications satellite **212**. Communications satellite **212** may be a communications satellite in low Earth orbit **214**. For example, without limitation, communications satellite **212** may be Iridium communications satellite **216**

Alert **210** may indicate that aircraft **202** is in distress and may include position information identifying the position of aircraft **202**. Aircraft tracking system **204** may evaluate alert **210** and broadcast emulated distress radio beacon transmission **218**. Emulated distress radio beacon transmission **218** may include information identifying aircraft **202** and position information identifying the position of aircraft **202** and may be in the form of a transmission from a distress radio beacon that can be received and processed by search and rescue system **206**.

For example, without limitation, search and rescue system **206** may comprise the COSPAS-SARSAT **219** search and rescue system or another appropriate search and rescue system that may be configured to receive and process standard distress radio beacon transmission **220** from distress radio beacon **222** on an aircraft to perform a search and rescue operation. Signals in standard distress radio beacon transmission **220** from distress radio beacon **222** may be in standard format **224** of signals generated by distress radio beacon **222**.

Search and rescue system **206** may receive emulated distress radio beacon transmission **218** and use the information provided in emulated distress radio beacon transmission **218** along with registration information **207** for aircraft **202** to conduct an appropriate search and rescue operation. In accordance with an illustrative embodiment, emulated distress radio beacon transmission **218** may be in standard format **224** of standard distress radio beacon transmission **220** from distress radio beacon **222** on an aircraft. Therefore, search and rescue system **206** may receive and process emulated distress radio beacon transmission **218** to conduct an appropriate search and rescue operation in the same manner or a similar manner to which standard distress radio beacon transmission **220** from distress radio beacon **222** on an aircraft is received and processed by search and rescue system **206**.

Turning to FIG. **3**, an illustration of a block diagram of an aircraft tracking system is depicted in accordance with an illustrative embodiment. Aircraft tracking system **300** may be an example of one implementation of aircraft tracking system **118** in FIG. **1** and aircraft tracking system **204** in FIG. **2**. Aircraft tracking system **300** may include receiver **302**, evaluator **304**, and distress radio beacon emulator **306**.

Receiver **302** may include any appropriate communications system including a satellite communications receiver for receiving alert **308** from an aircraft via a communications satellite. Alert **308** may include identification information **310**, position information **312**, distress information **314**, and other information **318**. Distress information **314** may indicate that alert **308** is distress alert **316**. Alternatively, other information **318** may indicate that alert **308** is other alert **320** other than distress alert **316**.

Evaluator **304** may be configured to evaluate whether alert **308** is distress alert **316** or other alert **320**. The evaluation performed by evaluator **304** may be performed automatically by a computer system or by a computer system in combination with a human operator.

For example, without limitation, distress radio beacon emulator **306** may be emergency locator transmitter emulator **322**. Distress radio beacon emulator **306** may comprise formatter **324** and transmitter **326**. In response to alert **308** being determined to be distress alert **316** by evaluator **304**, formatter **324** may generate emulated distress radio beacon signal **328**. Formatter **324** may be configured to generate emulated distress radio beacon signal **328** in a standard format of a signal generated by a distress radio beacon. For example, without limitation, emulated distress radio beacon signal **328** may be emulated emergency locator transmitter signal **330** in a standard format of a signal generated by an emergency locator transmitter. Emulated distress radio beacon signal **328** may include identification information **332** identifying the aircraft from which alert **308** was received, position information **334** identifying the position of the aircraft as identified in alert **308**, and other information **336**.

Transmitter **326** may be configured to broadcast emulated distress radio beacon signal **328** as emulated distress radio beacon transmission **338**. For example, without limitation, transmitter **326** may be configured to broadcast emulated emergency locator transmitter signal **330** as emulated emergency locator transmitter transmission **340**. For example, without limitation, emulated emergency locator transmitter transmission **340** may be encoded by formatter **324** and broadcast by transmitter **326** in accordance with emergency locator transmitter standards for signal modulation, message format, repetition rate, power, other characteristics, or various combinations of characteristics of a transmission from a standard emergency locator transmitter. For example, without limitation, transmitter **326** may broadcast emulated emergency locator transmitter transmission **340** at approximately 406 MHz or at any other appropriate frequency to emulate a transmission from a standard emergency locator transmitter.

Turning to FIG. **4** an illustration of a block diagram of a search and rescue system is depicted in accordance with an illustrative embodiment. Search and rescue system **400** may be an example of one implementation of search and rescue system **104** in FIG. **1** and search and rescue system **206** in FIG. **2**. For example, without limitation, search and rescue system **400** may comprise search and rescue system satellites **402**, ground stations **404**, mission control center **406**, and response center **408**.

Search and rescue system satellites **402** are configured to detect apparent distress radio beacon transmission **410** and relay apparent distress radio beacon transmission **410** to ground stations **404**. Ground stations **404** are configured to receive and process apparent distress radio beacon transmission **410** from search and rescue system satellites **402**. Ground stations **404** may extract identification information **412**, position information **414**, and other information **416** from received apparent distress radio beacon transmission **410** and forward such information to mission control center **406**. Ground stations **404** also may include position calculator **418** for determining calculated position **420** of the transmission of apparent distress radio beacon transmission **410** using satellite orbit information and signal Doppler measurements in a known manner. Calculated position **420** also may be provided to mission control center **406**.

Mission control center **406** may receive information from ground stations **404** and exchange information with other mission control centers **422**. Mission control center **406** may use registration information **424** in registration database **426** to determine whether apparent distress radio beacon transmission **410** is an emulated distress radio beacon and to determine the appropriate response center **408** to notify.

and used by distress identifier **516** to automatically determine that aircraft **501** is in distress. Examples of indicators that aircraft **501** is in distress may include abnormal position changes, abnormal deviations from flight plans, and abnormal commanded changes to the configuration of aircraft **501** that may put the aircraft in harm.

Alternatively, or in addition, distress identifier **516** may be configured to identify when aircraft **501** is in distress in response to the operation of manual actuator **542** by a human operator. Manual actuator **542** may comprise any appropriate actuation or signaling device that may be operated manually by a human operator inside **540** aircraft **501**. For example, without limitation, distress identifier **516** may determine that aircraft **501** is in distress in response to manual activation of a switch or other appropriate manual actuator **542** by a human operator inside **540** aircraft **501**. In this case, the switch or other appropriate one of manual actuator **542** may be connected to provide an appropriate signal to indicate distress to distress identifier **516** either by a wire or wirelessly in any appropriate manner.

Preferably, no interface or other capability is provided for a human operator inside **540** aircraft **501** to inhibit or cancel any such indication of distress that is provided to or determined by distress identifier **516**. Limiting interfaces for controlling operation of tracking device **500** from inside **540** aircraft **501** in this manner may reduce or eliminate accidental or intentional tampering with the desirable operation of tracking device **500**.

Distress identifier **516** may provide an appropriate indication to processor **518** in response to automatic or manual identification of distress by distress identifier **516**. An indication that aircraft **501** is in distress may be provided from distress identifier **516** to processor **518** in any appropriate manner and form.

Processor **518** may be configured to control the operation of tracking device **500** including satellite navigation system receiver **510** and satellite communications transceiver **514**. For example, processor **518** may be configured to use satellite navigation system receiver **510** to determine the position of aircraft **501** and to generate position information **520** identifying the position of aircraft **501** as identified using satellite navigation system receiver **510**. Processor **518** may be configured to use satellite communications transceiver **514** to send position information **520** to a receiver station via a satellite. Processor **518** may be configured to generate and send position information **520** automatically at rate **544** while aircraft **501** is in flight.

Rate **544** may be defined by fixed intervals. Alternatively, processor **518** may be configured to change rate **544** for generating and sending position information **520** based on various conditions. For example, processor **518** may be configured to change rate **544** for generating and sending position information **520** based on the geographic location of aircraft **501**. For example, without limitation, processor **518** may be configured to send updates for position information **520** more frequently when aircraft **501** is in flight over the ocean or in another remote location. Processor **518** may be configured to send position information updates less frequently when aircraft **501** is in flight in a location where aircraft **501** may be in sight of an air traffic control radar system or in another less remote location. Processor **518** also may be configured to generate and send position information **520** more frequently when it is determined that aircraft **501** is in distress.

Processor **518** also may be configured to generate and send alert **524** when it is determined that aircraft **501** is in distress. For example, alert **524** may be generated and sent by processor **518** to a receiving station via a satellite along with or in addition to position information **520** transmitted using satellite communications transceiver **514**. For example, without limitation, alert **524** may include or be associated with position information **520** identifying the position of aircraft **501** when the distress started. For example, without limitation, alert **524** may include information identifying various characteristics of the distress, such as the condition or event that triggered the indication of distress or any other appropriate information or various combinations of information about the distress.

Processor **518** also may be configured to take appropriate action in response to instructions **526** received via a satellite and satellite communications transceiver **514**. For example, without limitation, processor **518** may be configured to generate and send position information **520**, change rate **544** for generating and sending position information **520**, or take other appropriate actions or various combinations of actions in response to instructions **526** received via satellite communications transceiver **514**.

Electronics for tracking device **500** may include power supply **546**. Power supply **546** may be implemented in any appropriate manner to provide appropriate electrical power for operation of the various electronic components in tracking device **500** from electrical power provided to power supply **546** on power line **536**. For example, without limitation, in the case where tracking device **500** is attached to aircraft **501** on outside **502** of aircraft **501**, power line **536** may be connected to provide electrical power to power supply **546** from power source **538** on inside **540** of aircraft **501**. Power source **538** may comprise any appropriate source of electrical power for operation of tracking device **500**.

Power line **536** may be implemented in any appropriate manner to provide electrical power from an appropriate power source **538** to power supply **546** in tracking device **500**. Various undesirable conditions on power line **536** may cause inconsistencies in power supply **546** or other electronics in tracking device **500**. For example, without limitation, power line **536** may include circuit breaker **548**. Circuit breaker **548** may be implemented in any known and appropriate manner to prevent undesirable conditions on power line **536** from reaching power supply **546** or other electronics in tracking device **500**. For example, without limitation, circuit breaker **548** may be implemented in a known and appropriate manner to prevent excessive current, excessive voltage, excessive power, or any other undesirable condition or combination of undesirable conditions on power line **536** from reaching power supply **546** and other electronics for tracking device **500**.

Electrical power for operation of tracking device **500** may include battery **549**. Battery **549** may be contained in housing **504** along with the other electronic components of tracking device **500**. Battery **549** may include any appropriate type and number of batteries for providing appropriate electrical power for operation of various electronic components in tracking device **500**. Power for operation of tracking device **500** may be provided by battery **549** as an alternative or in addition to providing power for operation of tracking device **500** from power source **538** via power line **536**. For example, without limitation, when power for operation of tracking device **500** is available from both battery **549** and from power source **538** via power line **536**, battery **549** may be used to provide back-up power for operation of tracking device **500** when power on power line **536** is interrupted. For example, without limitation, when tracking device **500** is attached to aircraft **501** on outside **502** of aircraft **501**, providing battery **549** for powering tracking device **500** may prevent accidental or intentional disabling of the operation of tracking device **500** from inside **540** of aircraft **501** by disrupting power for tracking device **500** that is provided on power line **536** from power source **538** located inside **540** of aircraft **501**.

The different components illustrated for tracking device **500** are not meant to provide architectural limitations to the manner in which different embodiments may be implemented. The different illustrative embodiments may be implemented in a system including components in addition to or in place of those illustrated for tracking device **500**. Other components shown in FIG. **5** can be varied from the illustrative examples shown.

For example, without limitation, processor **518** may also be configured to receive information identifying the position of aircraft **501** from other aircraft systems **550** on inside **540** of aircraft **501**. Information provided by other aircraft systems **550** may be used for back-up, calibration, testing, or in comparison with the position of aircraft **501** identified using satellite navigation system receiver **510**.

Electronics for tracking device **500** may be implemented in any appropriate manner using any appropriate hardware or hardware in combination with software. For example, without limitation, processor **518** may be configured to execute instructions for software that may be loaded or otherwise stored in storage **541**. Processor **518** may be a number of processors, a multi-processor core, or some other type of processor, depending on the particular implementation. Further, processor **518** may be implemented using a number of heterogeneous processor systems in which a main processor is present with secondary processors on a single chip. As another illustrative example, processor **518** may be a symmetric multi-processor system containing multiple processors of the same type.

Storage **541** may include memory, persistent storage, or any other appropriate storage devices or various combinations of storage devices. Storage **541** may comprise any piece of hardware that is capable of storing information, such as, for example, without limitation, data, program code in functional form, and/or other suitable information either on a temporary basis and/or a permanent basis. Storage **541** may also be referred to as a computer readable storage device in these examples. Storage **541**, in these examples, may be, for example, a random access memory or any other suitable volatile or non-volatile storage device. Storage **541** may take various forms, depending on the particular implementation. For example, storage **541** may be implemented, in whole or in part, as part of processor **518**. Alternatively, storage **541** may be implemented entirely separate from processor **518**.

In any case, instructions for the operating system, applications, and/or programs may be located in storage **541**, which is in communication with processor **518** in any appropriate manner. The processes of the different embodiments may be performed by processor **518** using computer-implemented instructions, which may be located in storage **541**. These instructions may be referred to as program instructions, program code, computer usable program code, or computer-readable program code that may be read and executed by processor **518**. The program code in the different embodiments may be embodied on different physical or computer-readable storage media.

In these examples, storage **541** may be a physical or tangible storage device used to store program code rather than a medium that propagates or transmits program code. In this case, storage **541** may be referred to as a computer-readable tangible storage device or a computer-readable physical storage device. In other words, storage **541** is embodied in a medium that can be touched by a person.

Alternatively, program code may be transferred to processor **518** using computer-readable signal media. Computer-readable signal media may be, for example, a propagated data signal containing program code. For example, computer-readable signal media may be an electromagnetic signal, an optical signal, and/or any other suitable type of signal. These signals may be transmitted over communications links, such as wireless communications links, optical fiber cable, coaxial cable, a wire, and/or any other suitable type of communications link. In other words, the communications link and/or the connection may be physical or wireless in the illustrative examples. In some illustrative embodiments, program code may be downloaded over a network to storage **541** from another device or data processing system through computer-readable signal media for use within processor **518**.

The different embodiments may be implemented using any hardware device or system capable of running program code. As one example, electronics for tracking device **500** may include organic components integrated with inorganic components and/or may be comprised entirely of organic components excluding a human being. For example, storage **541** may be comprised of an organic semiconductor.

In another illustrative example, processor **518** may take the form of a hardware unit that has circuits that are manufactured or configured for a particular use. This type of hardware may perform operations without needing program code to be loaded in storage **541** to be configured to perform the operations.

For example, when processor **518** takes the form of a hardware unit, processor **518** may be a circuit system, an application-specific integrated circuit (ASIC), a programmable logic device, or some other suitable type of hardware configured to perform a number of operations. With a programmable logic device, the device is configured to perform the number of operations. The device may be reconfigured at a later time or may be permanently configured to perform the number of operations. Examples of programmable logic devices include a programmable logic array, programmable array logic, a field programmable logic array, a field programmable gate array, and other suitable hardware devices. With this type of implementation, program code may be omitted, because the processes for the different embodiments are implemented in a hardware unit.

In still another illustrative example, processor **518** may be implemented using a combination of processors found in computers and hardware units. Processor **518** may have a number of hardware units and a number of processors that are configured to run program code. With this depicted example, some of the processes may be implemented in the number of hardware units, while other processes may be implemented in the number of processors.

Turning to FIG. **6**, an illustration of a flowchart of a process of using an alert from an aircraft to perform a search and rescue operation is depicted in accordance with an illustrative embodiment. Process **600** may be implemented, for example, in aircraft operating environment **100** in FIG. **1** or in aircraft operating environment **200** in FIG. **2**.

Process **600** may begin with registering an aircraft with a search and rescue system (operation **602**). For example, without limitation, operation **602** may include providing appropriate registration information to the search and rescue system so that the search and rescue system may identify what is apparently a transmission from an emergency locator

(51) **Int. Cl.**

B64D 25/20	(2006.01)
G01S 5/02	(2010.01)
B64D 45/00	(2006.01)

(52) **U.S. Cl.**

CPC *B64D 45/00* (2013.01); *B64D 45/0059* (2019.08); *B64D 2045/0065* (2013.01)

(58) **Field of Classification Search**

USPC 342/357.32, 385; 340/981

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,355,140	A *	10/1994	Slavin	G01S 5/0009 342/357.31
5,367,306	A	11/1994	Hollon et al.	
5,969,673	A *	10/1999	Bickley	H04B 7/18504 342/357.59
6,324,393	B1 *	11/2001	Doshay	G01C 21/26 340/436
6,799,094	B1	9/2004	Vaida et al.	
7,158,053	B2	1/2007	Crank	
7,196,621	B2	3/2007	Kochis	
7,215,282	B2 *	5/2007	Boling	G08B 25/016 340/539.13
7,218,227	B2	5/2007	Davis et al.	
7,245,899	B2	7/2007	Carle et al.	
7,564,404	B2	7/2009	Katz	
7,898,425	B2	3/2011	Nagy et al.	
7,948,401	B2	5/2011	Wartofsky et al.	
8,674,853	B2 *	3/2014	Gorabi	B63B 43/00 340/984
9,031,497	B1	5/2015	Hoffman et al.	
9,049,585	B1	6/2015	Hoffman et al.	
9,178,601	B1	11/2015	Hoffman et al.	
9,330,554	B2	5/2016	Calvar Anton et al.	
10,002,519	B2	6/2018	Bekanich	
10,036,813	B2 *	7/2018	Nyikos	G01S 19/24
10,088,574	B2	10/2018	Murphy	
10,163,328	B2 *	12/2018	Bekanich	G08B 25/009
10,585,160	B2 *	3/2020	Polynin	G08G 5/0013
2003/0130771	A1	7/2003	Crank	
2008/0024365	A1	1/2008	Holmes et al.	
2008/0174484	A1	7/2008	Katz	
2008/0191863	A1	8/2008	Boling et al.	
2009/0224966	A1 *	9/2009	Boling	G08B 25/016 342/357.31
2011/0122019	A1	5/2011	Lee et al.	
2011/0194629	A1	8/2011	Bekanich	
2012/0098699	A1	4/2012	Calmettes et al.	
2013/0093625	A1	4/2013	Smith	
2014/0354481	A1	12/2014	Holmes et al.	
2016/0003933	A1	1/2016	Calmettes et al.	
2016/0047880	A1 *	2/2016	Helfrick	G01S 5/0231 340/981
2016/0176538	A1	6/2016	Bekanich	
2017/0052259	A1	2/2017	Murphy	
2017/0106997	A1 *	4/2017	Bekanich	H04B 7/18506
2017/0155763	A1	6/2017	Bekanich	
2017/0247118	A1	8/2017	Adler et al.	
2018/0240324	A1	8/2018	Bekanich	
2018/0247519	A1	8/2018	Bekanich	

OTHER PUBLICATIONS

Maqsood Ahmed, "Satellite-aided Search and Rescue (SAR) System," Advances in Space Technologies, 2006, International Conference on Sep. 1, 2006, pp. 43-48.

Extended European Search Report and Search Opinion, dated Feb. 21, 2017, regarding Application No. 16184606.8, 8 pages.

Office Action, dated Oct. 4, 2017, regarding U.S. Appl. No. 14/832,851, 28 pages.

Notice of Allowance, dated May 24, 2018, regarding U.S. Appl. No. 14/832,851, 13 pages.

Japan Patent Office Notice of Reasons for Rejection and English Translation, dated Nov. 12, 2019, regarding Application No. 2016-156164, 6 pages.

The State Intellectual Property Office of the People's Republic of China, Notification of the Second Office Action with English Translation, dated Mar. 4, 2019, regarding Application No. 2016106976187, 17 pages.

Canadian Intellectual Property Office Communication and Search Report, dated Apr. 3, 2020, regarding Application No. 2935837, 4 pages.

National Institute of Industrial Property Ministry of Economy (INPI) Written Opinion and Search Report with English Translation, dated Aug. 29, 2020, regarding Application No. BR102016018511, 6 pages.

* cited by examiner

These instructions are referred to as program instructions, program code, computer-usable program code, or computer-readable program code that may be read and executed by a processor in processor unit **904**. The program code in the different embodiments may be embodied on different physical or computer-readable storage media **924**, such as memory **906** or persistent storage **908**.

Program code **918** is located in a functional form on computer-readable media **920** that is selectively removable and may be loaded onto or transferred to data processing system **900** for execution by processor unit **904**. Program code **918** and computer-readable media **920** form computer program product **922** in these examples. In one example, computer-readable media **920** may be computer-readable storage media **924** or computer-readable signal media **926**.

Computer-readable storage media **924** may include, for example, an optical or magnetic disk that is inserted or placed into a drive or other device that is part of persistent storage **908** for transfer onto a storage device, such as a hard drive, that is part of persistent storage **908**. Computer-readable storage media **924** also may take the form of a persistent storage, such as a hard drive, a thumb drive, or a flash memory, that is connected to data processing system **900**. In some instances, computer-readable storage media **924** may not be removable from data processing system **900**.

In these examples, computer-readable storage media **924** is a physical or tangible storage device used to store program code **918** rather than a medium that propagates or transmits program code **918**. Computer-readable storage media **924** is also referred to as a computer-readable tangible storage device or a computer-readable physical storage device. In other words, computer-readable storage media **924** is a medium that can be touched by a person.

Alternatively, program code **918** may be transferred to data processing system **900** using Computer-readable signal media **926**. Computer-readable signal media **926** may be, for example, a propagated data signal containing program code **918**. For example, computer-readable signal media **926** may be an electromagnetic signal, an optical signal, and/or any other suitable type of signal. These signals may be transmitted over communications links, such as wireless communications links, optical fiber cable, coaxial cable, a wire, and/or any other suitable type of communications link. In other words, the communications link and/or the connection may be physical or wireless in the illustrative examples.

In some illustrative embodiments, program code **918** may be downloaded over a network to persistent storage **908** from another device or data processing system through computer-readable signal media **926** for use within data processing system **900**. For instance, program code stored in a computer-readable storage medium in a server data processing system may be downloaded over a network from the server to data processing system **900**. The data processing system providing program code **918** may be a server computer, a client computer, or some other device capable of storing and transmitting program code **918**.

The different components illustrated for data processing system **900** are not meant to provide architectural limitations to the manner in which different embodiments may be implemented. The different illustrative embodiments may be implemented in a data processing system including components in addition to or in place of those illustrated for data processing system **900**. Other components shown in FIG. **9** can be varied from the illustrative examples shown. The different embodiments may be implemented using any hardware device or system capable of running program code. As one example, the data processing system may include organic components integrated with inorganic components and/or may be comprised entirely of organic components excluding a human being. For example, a storage device may be comprised of an organic semiconductor.

In another illustrative example, processor unit **904** may take the form of a hardware unit that has circuits that are manufactured or configured for a particular use. This type of hardware may perform operations without needing program code to be loaded into a memory from a storage device to be configured to perform the operations.

For example, when processor unit **904** takes the form of a hardware unit, processor unit **904** may be a circuit system, an application-specific integrated circuit (ASIC), a programmable logic device, or some other suitable type of hardware configured to perform a number of operations. With a programmable logic device, the device is configured to perform the number of operations. The device may be reconfigured at a later time or may be permanently configured to perform the number of operations. Examples of programmable logic devices include, for example, a programmable logic array, programmable array logic, a field programmable logic array, a field programmable gate array, and other suitable hardware devices. With this type of implementation, program code **918** may be omitted, because the processes for the different embodiments are implemented in a hardware unit.

In still another illustrative example, processor unit **904** may be implemented using a combination of processors found in computers and hardware units. Processor unit **904** may have a number of hardware units and a number of processors that are configured to run program code **918**. With this depicted example, some of the processes may be implemented in the number of hardware units, while other processes may be implemented in the number of processors.

In another example, a bus system may be used to implement communications fabric **902** and may be comprised of one or more buses, such as a system bus or an input/output bus. Of course, the bus system may be implemented using any suitable type of architecture that provides for a transfer of data between different components or devices attached to the bus system.

Additionally, communications unit **910** may include a number of devices that transmit data, receive data, or transmit and receive data. Communications unit **910** may be, for example, a modem or a network adapter, two network adapters, or some combination thereof. Further, a memory may be, for example, memory **906**, or a cache, such as those found in an interface and memory controller hub that may be present in communications fabric **902**.

The flowcharts and block diagrams in the different depicted embodiments illustrate the architecture, functionality, and operation of some possible implementations of apparatuses and methods in illustrative embodiments. In this regard, each block in the flowcharts or block diagrams may represent a module, segment, function, and/or a portion of an operation or step. For example, one or more of the blocks may be implemented as program code, in hardware, or a combination of program code and hardware. When implemented in hardware, the hardware may, for example, take the form of integrated circuits that are manufactured or configured to perform one or more operations in the flowcharts or block diagrams.

In some alternative implementations of an illustrative embodiment, the function or functions noted in the blocks may occur out of the order shown in the figures. For example, in some cases, two blocks shown in succession may be executed substantially concurrently, or the blocks may sometimes be performed in the reverse order, depending upon the functionality involved. Also, other blocks may be added in addition to the blocks illustrated in a flowchart or block diagram.

The description of the different illustrative embodiments has been presented for purposes of illustration and description, and is not intended to be exhaustive or to limit the embodiments in the form disclosed. Many modifications and variations will be apparent to those of ordinary skill in the art. Further, different illustrative embodiments may provide different benefits as compared to other illustrative embodiments. The embodiment or embodiments selected are chosen and described in order to best explain the principles of the embodiments, the practical application, and to enable others of ordinary skill in the art to understand the disclosure for various embodiments with various modifications as are suited to the particular use contemplated.

What is claimed is:

1. A method of delivering an alert from an aircraft to a search and rescue system, comprising:

receiving the alert by a receiver in an aircraft tracking system from a tracking device on the aircraft via a communications satellite, wherein the alert comprises identification information identifying the aircraft and position information identifying a position of the aircraft;

in response to receiving the alert, generating an emulated distress radio beacon signal by a formatter in the aircraft tracking system, wherein the emulated distress radio beacon signal comprises the identification information and the position information in a format of a signal generated by a distress radio beacon;

broadcasting the emulated distress radio beacon signal by a transmitter in the aircraft tracking system from a location other than the aircraft as an emulated distress radio beacon transmission that is configured to be received and processed by the search and rescue system; and

sending registration information by the aircraft tracking system to the search and rescue system before broadcasting the emulated distress radio beacon signal, wherein the registration information indicates that an apparent distress radio beacon transmission that identifies the aircraft is the emulated distress radio beacon transmission, wherein the registration information includes transmitter position information that the search and rescue system can compare to a calculated position of the apparent distress radio beacon transmission to validate the apparent distress radio beacon transmission.

2. The method of claim **1**, wherein:

generating the emulated distress radio beacon signal comprises generating an emulated emergency locator transmitter signal in a format of a signal generated by an emergency locator transmitter; and

broadcasting the emulated distress radio beacon signal comprises broadcasting the emulated emergency locator transmitter signal from the location other than the aircraft as an emulated emergency locator transmitter transmission that is configured to be received and processed by the search and rescue system.

3. The method of claim **2**, wherein broadcasting the emulated emergency locator transmitter signal comprises broadcasting the emulated emergency locator transmitter signal at approximately 406 MHz to emulate a transmission from an emergency locator transmitter.

4. The method of claim **1**, wherein the registration information comprises transmitter information identifying the location other than the aircraft of the transmitter for broadcasting the emulated distress radio beacon signal.

5. The method of claim **1** further comprising:

evaluating the alert from the aircraft by an evaluator in the aircraft tracking system to determine whether the alert is a distress alert indicating that the aircraft is in distress; and

generating and broadcasting the emulated distress radio beacon signal in response to a determination that the alert is the distress alert.

6. The method of claim **1**, wherein the alert is received from the aircraft via the communications satellite in low Earth orbit.

7. The method of claim **6**, wherein the alert is received from the aircraft via an Iridium communications satellite.

8. The method of claim **1**, wherein the alert is generated by the tracking device on the aircraft comprising:

a satellite navigation system receiver configured to identify the position of the aircraft using navigation signals received from a satellite navigation system;

a satellite communications transceiver;

a number of antennas for the satellite navigation system receiver and the satellite communications transceiver;

a distress identifier configured to identify when the aircraft is in distress;

a processor configured to generate the position information identifying the position of the aircraft as identified by the satellite navigation system receiver, generate the alert, and send the alert via the communications satellite using the satellite communications transceiver in response to a determination by the distress identifier that the aircraft is in distress; and

a housing attached to the aircraft on an outside of the aircraft and containing the satellite navigation system receiver, the satellite communications transceiver, the number of antennas, the distress identifier, and the processor.

9. An apparatus, comprising:

a receiver configured to receive an alert from an aircraft via a communications satellite, wherein the alert comprises identification information identifying the aircraft and position information identifying a position of the aircraft;

a formatter configured to generate an emulated distress radio beacon signal comprising the identification information and the position information in a format of a signal generated by a distress radio beacon; and

a transmitter configured to broadcast the emulated distress radio beacon signal from a location other than the aircraft as an emulated distress radio beacon transmission that is configured to be received and processed by a search and rescue system; and

wherein the apparatus is further configured to send registration information to the search and rescue system before the emulated distress radio beacon signal is broadcast, wherein the registration information indicates that an apparent distress radio beacon transmission that identifies the aircraft is the emulated distress radio beacon transmission, wherein the registration information includes transmitter position information that the search and rescue system can compare to a calculated position of the apparent distress radio beacon transmission to validate the apparent distress radio beacon transmission.

10. The apparatus of claim 9, wherein:
the formatter is configured to generate the emulated distress radio beacon signal as an emulated emergency locator transmitter signal in a format of a signal generated by an emergency locator transmitter; and
the transmitter is configured to broadcast the emulated emergency locator transmitter signal from the location other than the aircraft as an emulated emergency locator transmitter transmission that is configured to be received and processed by the search and rescue system.

11. The apparatus of claim 10, wherein the transmitter is configured to broadcast the emulated emergency locator transmitter signal at approximately 406 MHz to emulate a transmission from an emergency locator transmitter.

12. The apparatus of claim 9, wherein the alert comprises distress information indicating whether the aircraft is in distress.

13. The apparatus of claim 12 further comprising:
an evaluator configured to evaluate the distress information in the alert from the aircraft to determine whether the alert is a distress alert indicating that the aircraft is in distress; and
wherein the formatter is configured to generate the emulated distress radio beacon signal in response to a determination that the alert is the distress alert.

14. A system, comprising:
a tracking device on an aircraft configured to send an alert from the aircraft via a communications satellite, wherein the alert comprises identification information identifying the aircraft and position information identifying a position of the aircraft;
an aircraft tracking system configured to receive the alert from the aircraft, generate an emulated distress radio beacon signal comprising the identification information and the position information in a format of a signal generated by a distress radio beacon, and broadcast the emulated distress radio beacon signal from a location other than the aircraft as an emulated distress radio beacon transmission; and
a search and rescue system configured to receive the emulated distress radio beacon transmission as an apparent distress radio beacon transmission via a search and rescue system satellite, receive registration information before receiving the emulated distress radio beacon transmission, wherein the registration information indicates that that the apparent distress radio beacon transmission that identifies the aircraft is the emulated distress radio beacon signal, wherein the registration information includes transmitter position information that the search and rescue system can compare to a calculated position of the apparent distress radio beacon transmission to validate the apparent distress radio beacon transmission, and use the identification information and the position information to conduct a search and rescue operation.

15. The system of claim 14, wherein the tracking device on the aircraft comprises:
a satellite navigation system receiver configured to identify the position of the aircraft using navigation signals received from a satellite navigation system;
a satellite communications transceiver;
a number of antennas for the satellite navigation system receiver and the satellite communications transceiver;
a distress identifier configured to identify when the aircraft is in distress;
a processor configured to generate the position information identifying the position of the aircraft as identified by the satellite navigation system receiver, generate the alert, and send the alert via the communications satellite using the satellite communications transceiver in response to a determination by the distress identifier that the aircraft is in distress; and
a housing attached to the aircraft on an outside of the aircraft and containing the satellite navigation system receiver, the satellite communications transceiver, the number of antennas, the distress identifier, and the processor.

16. The system of claim 15, wherein the processor is configured to change a rate for generating and sending position information according changing conditions, wherein the processor is configured to generate and send position information more frequently when the aircraft is in distress than when the aircraft is not in distress.

17. The system of claim 14, wherein the aircraft tracking system comprises:
a receiver configured to receive the alert from the aircraft via the communications satellite, wherein the communications satellite is in a low Earth orbit;
a formatter configured to generate the emulated distress radio beacon signal as an emulated emergency locator transmitter signal in a format of a signal generated by an emergency locator transmitter; and
a transmitter configured to broadcast the emulated distress radio beacon signal as an emulated emergency locator transmitter transmission.

18. The system of claim 14, wherein the search and rescue system comprises the COSPAS-SARSAT search and rescue system.

19. A method of using an alert from an aircraft to perform a search and rescue operation, comprising:
receiving, by a search and rescue system, an apparent distress radio beacon transmission comprising identification information identifying the aircraft and position information identifying a position of the aircraft;
using the identification information, by the search and rescue system, to identify registration information for the aircraft indicating whether the apparent distress radio beacon transmission is an emulated distress radio beacon transmission transmitted from a transmitter that is not a distress radio beacon located on the aircraft, wherein the registration information includes transmitter position information that the search and rescue system can compare to a calculated position of the apparent distress radio beacon transmission to validate the apparent distress radio beacon transmission; and
using the position information, by the search and rescue system, to perform the search and rescue operation in response to a determination that the apparent distress radio beacon transmission is the emulated distress radio beacon transmission transmitted from the transmitter that is not the distress radio beacon located on the aircraft.

20. The method of claim 19, wherein:
receiving the apparent distress radio beacon transmission comprises receiving the apparent distress radio beacon transmission via a search and rescue system satellite; and
the registration information comprises transmitter information identifying a location of the transmitter; and further comprising:
determining a calculated position of the transmitter using orbit information for the search and rescue

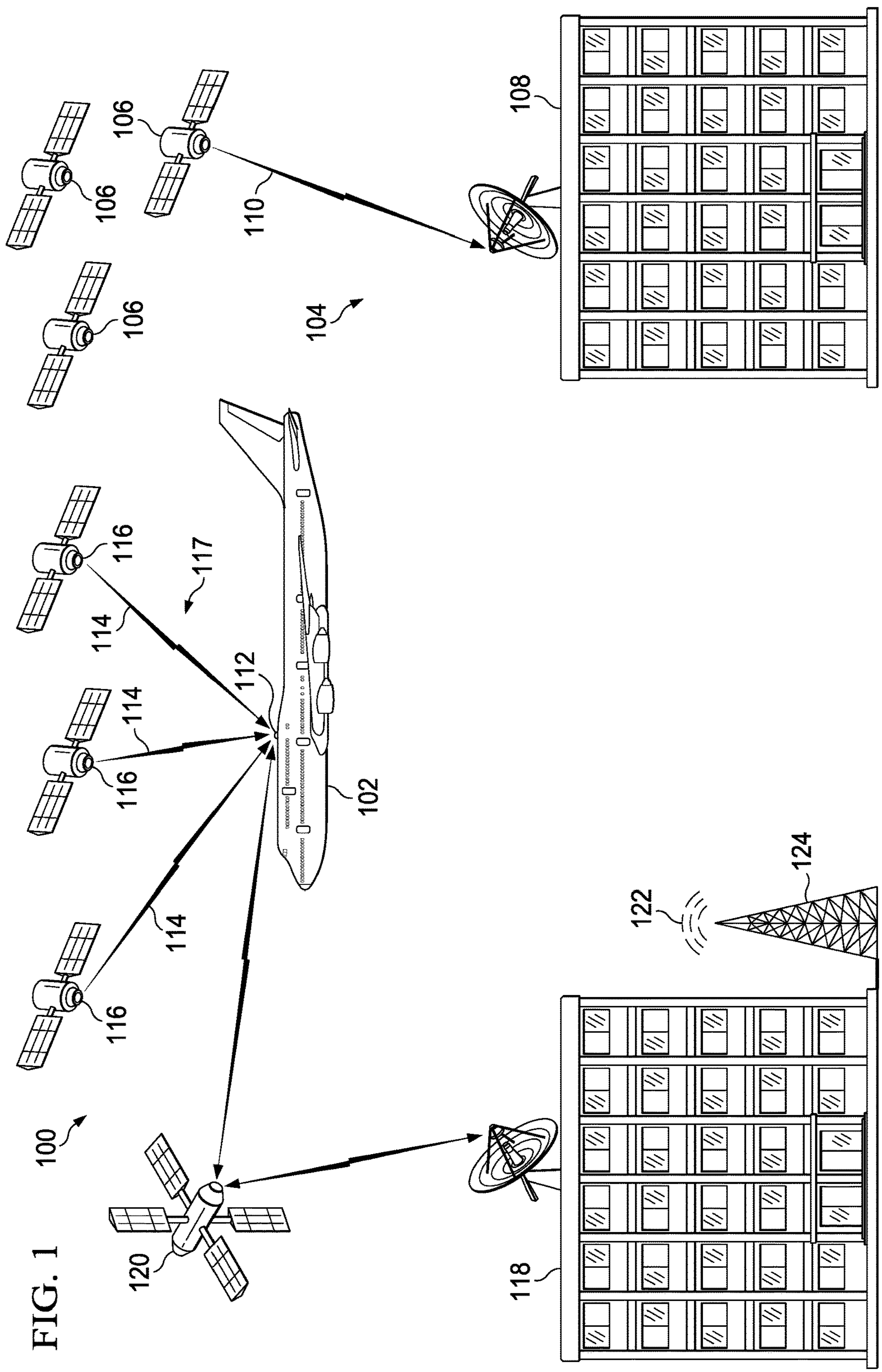
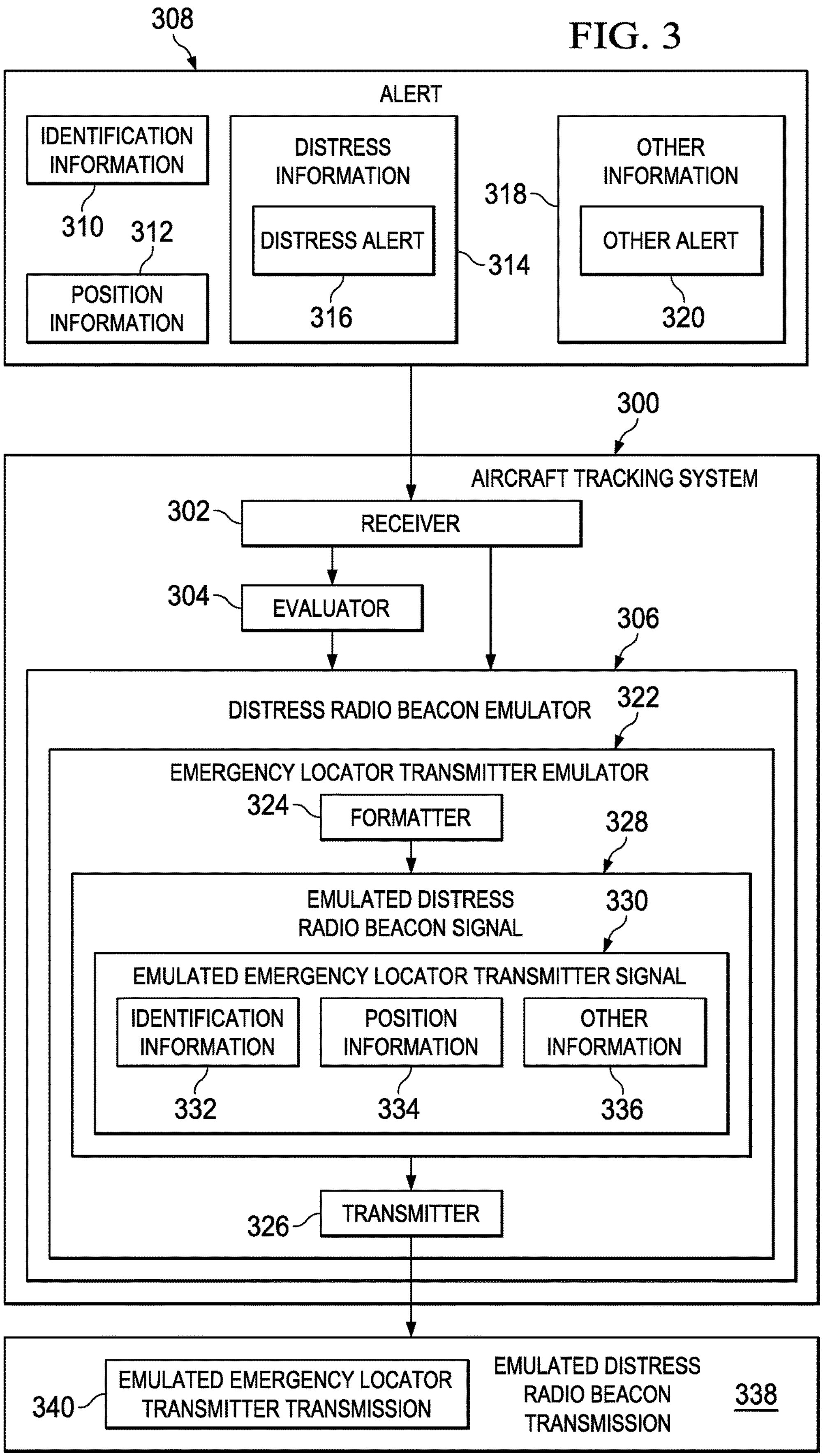

100
102
104
106
106
106
108
110
112
114
114
114
116
116
116
117
118
120
122
124

FIG. 1

FIG. 3


308
ALERT
IDENTIFICATION INFORMATION
310
312
POSITION INFORMATION
DISTRESS INFORMATION
DISTRESS ALERT
316
314
318
OTHER INFORMATION
OTHER ALERT
320
300
AIRCRAFT TRACKING SYSTEM
302
RECEIVER
304
EVALUATOR
306
DISTRESS RADIO BEACON EMULATOR
322
EMERGENCY LOCATOR TRANSMITTER EMULATOR
324
FORMATTER
328
EMULATED DISTRESS RADIO BEACON SIGNAL
330
EMULATED EMERGENCY LOCATOR TRANSMITTER SIGNAL
IDENTIFICATION INFORMATION
POSITION INFORMATION
OTHER INFORMATION
332
334
336
TRANSMITTER
326
340
EMULATED EMERGENCY LOCATOR TRANSMITTER TRANSMISSION
EMULATED DISTRESS RADIO BEACON TRANSMISSION
338

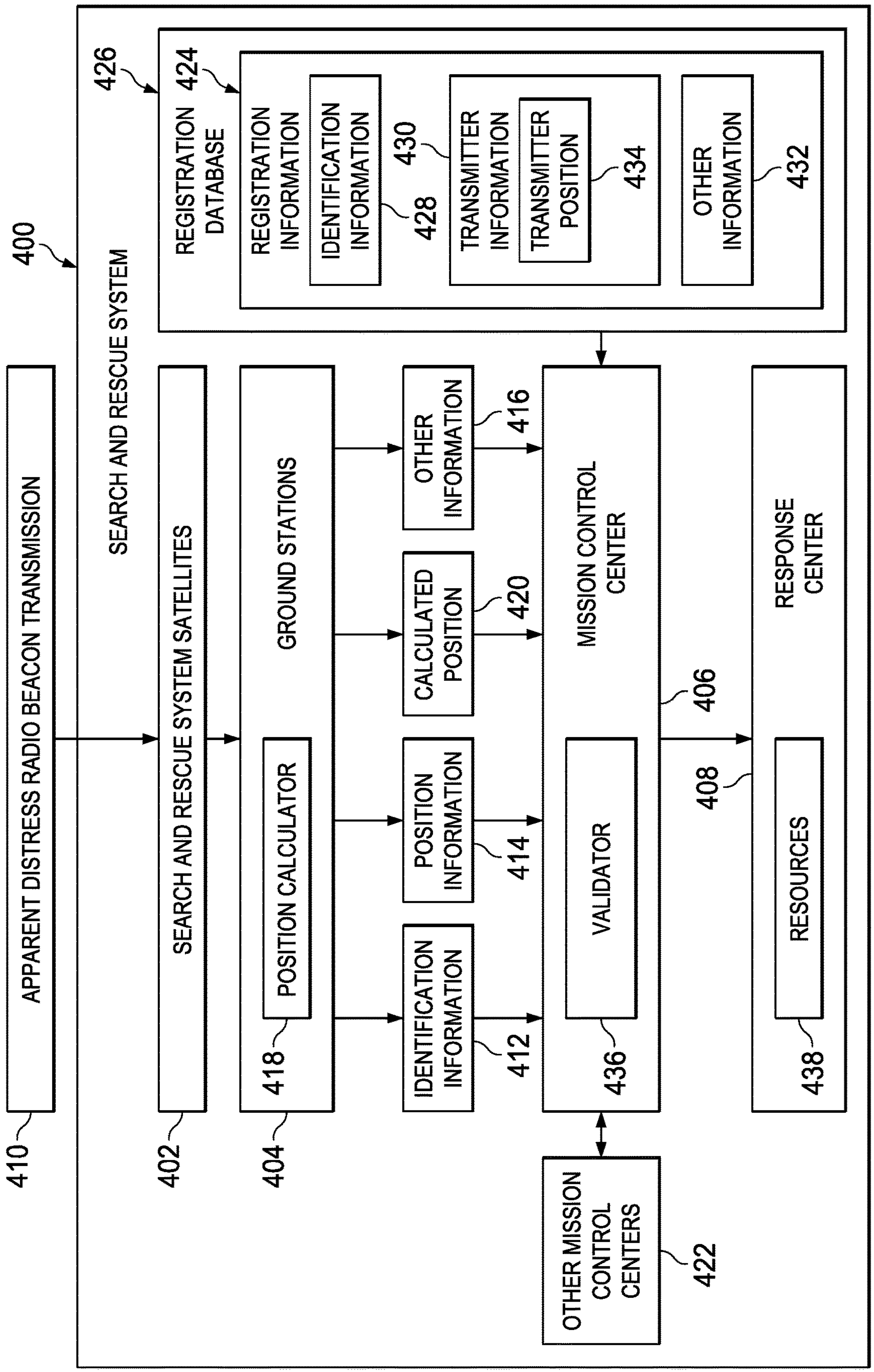

400
SEARCH AND RESCUE SYSTEM
410
APPARENT DISTRESS RADIO BEACON TRANSMISSION
402
SEARCH AND RESCUE SYSTEM SATELLITES
404
GROUND STATIONS
418
POSITION CALCULATOR
412
IDENTIFICATION INFORMATION
414
POSITION INFORMATION
420
CALCULATED POSITION
416
OTHER INFORMATION
406
MISSION CONTROL CENTER
436
VALIDATOR
422
OTHER MISSION CONTROL CENTERS
408
RESPONSE CENTER
438
RESOURCES
426
REGISTRATION DATABASE
424
REGISTRATION INFORMATION
428
IDENTIFICATION INFORMATION
430
TRANSMITTER INFORMATION
434
TRANSMITTER POSITION
432
OTHER INFORMATION

FIG. 4

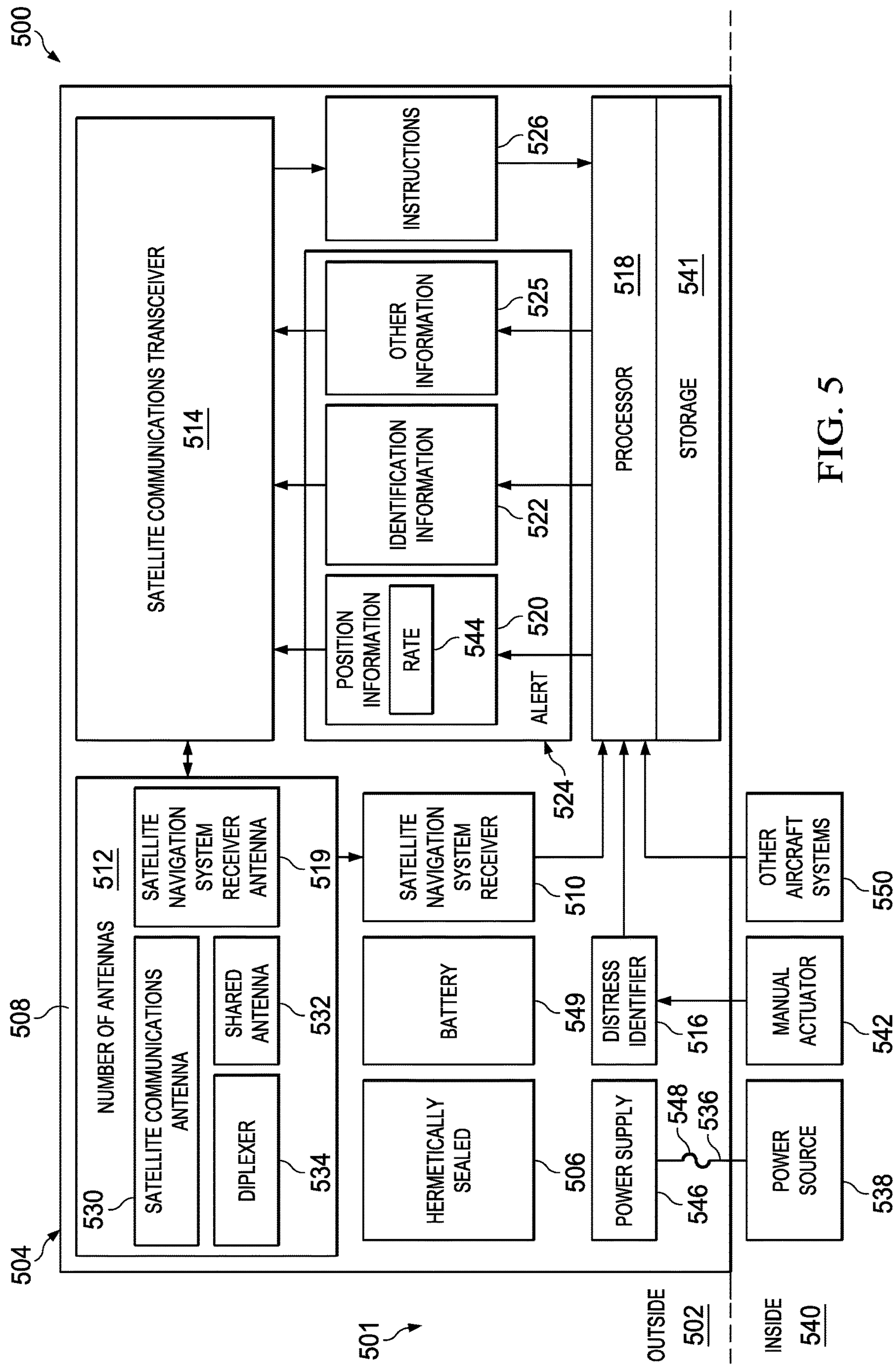

500
504
508
NUMBER OF ANTENNAS 512
530
SATELLITE COMMUNICATIONS ANTENNA
DIPLEXER
534
SHARED ANTENNA
532
SATELLITE NAVIGATION SYSTEM RECEIVER ANTENNA
519
SATELLITE COMMUNICATIONS TRANSCEIVER 514
INSTRUCTIONS
526
POSITION INFORMATION
RATE
544
520
ALERT
IDENTIFICATION INFORMATION
522
OTHER INFORMATION
525
524
PROCESSOR 518
STORAGE 541
HERMETICALLY SEALED
506
BATTERY
549
SATELLITE NAVIGATION SYSTEM RECEIVER
510
POWER SUPPLY
546
548
536
DISTRESS IDENTIFIER
516
POWER SOURCE
538
MANUAL ACTUATOR
542
OTHER AIRCRAFT SYSTEMS
550
501
OUTSIDE 502
INSIDE 540

FIG. 5

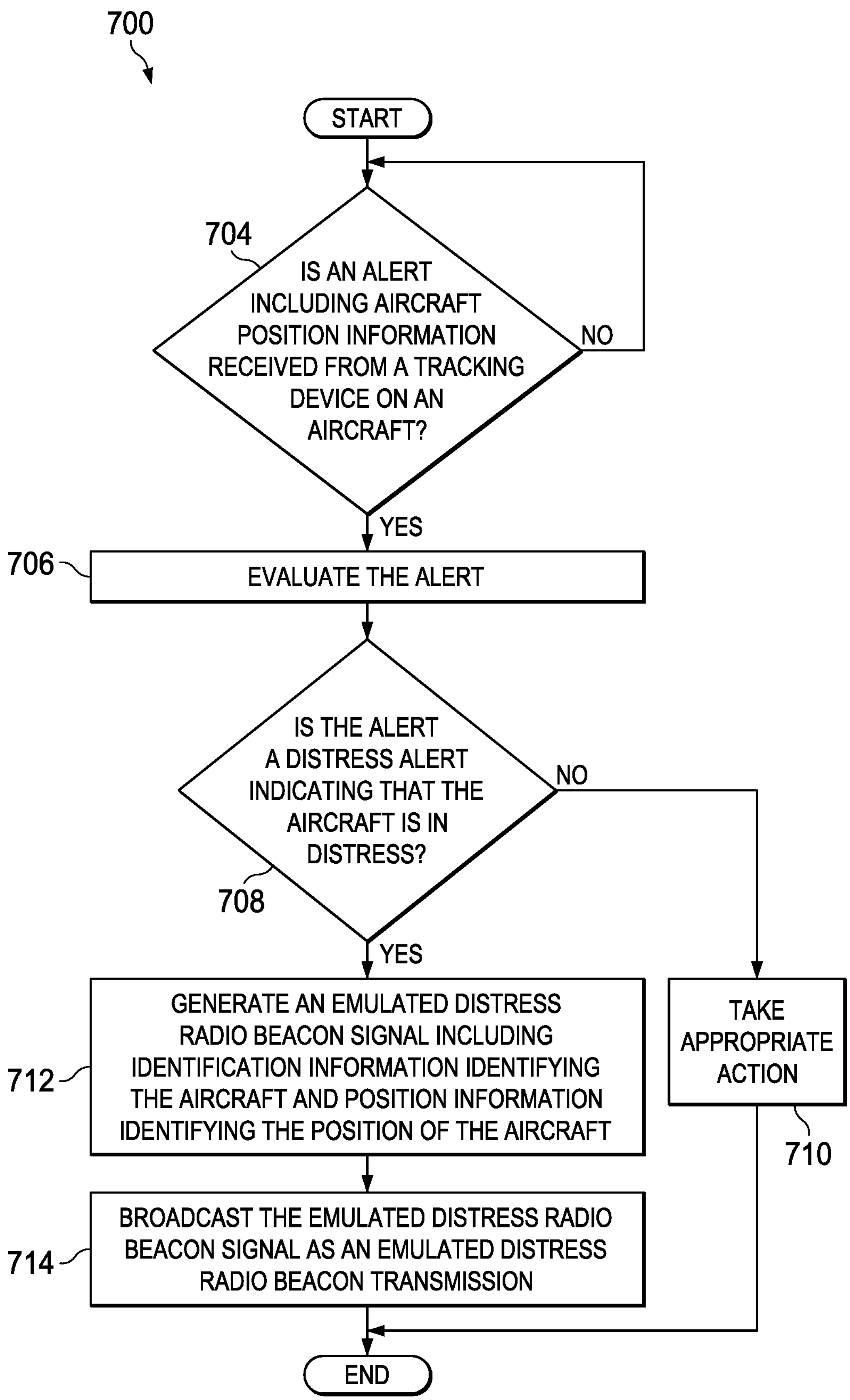

700
START
704
IS AN ALERT INCLUDING AIRCRAFT POSITION INFORMATION RECEIVED FROM A TRACKING DEVICE ON AN AIRCRAFT?
NO
YES
706
EVALUATE THE ALERT
IS THE ALERT A DISTRESS ALERT INDICATING THAT THE AIRCRAFT IS IN DISTRESS?
708
NO
YES
712
GENERATE AN EMULATED DISTRESS RADIO BEACON SIGNAL INCLUDING IDENTIFICATION INFORMATION IDENTIFYING THE AIRCRAFT AND POSITION INFORMATION IDENTIFYING THE POSITION OF THE AIRCRAFT
TAKE APPROPRIATE ACTION
710
714
BROADCAST THE EMULATED DISTRESS RADIO BEACON SIGNAL AS AN EMULATED DISTRESS RADIO BEACON TRANSMISSION
END

FIG. 7