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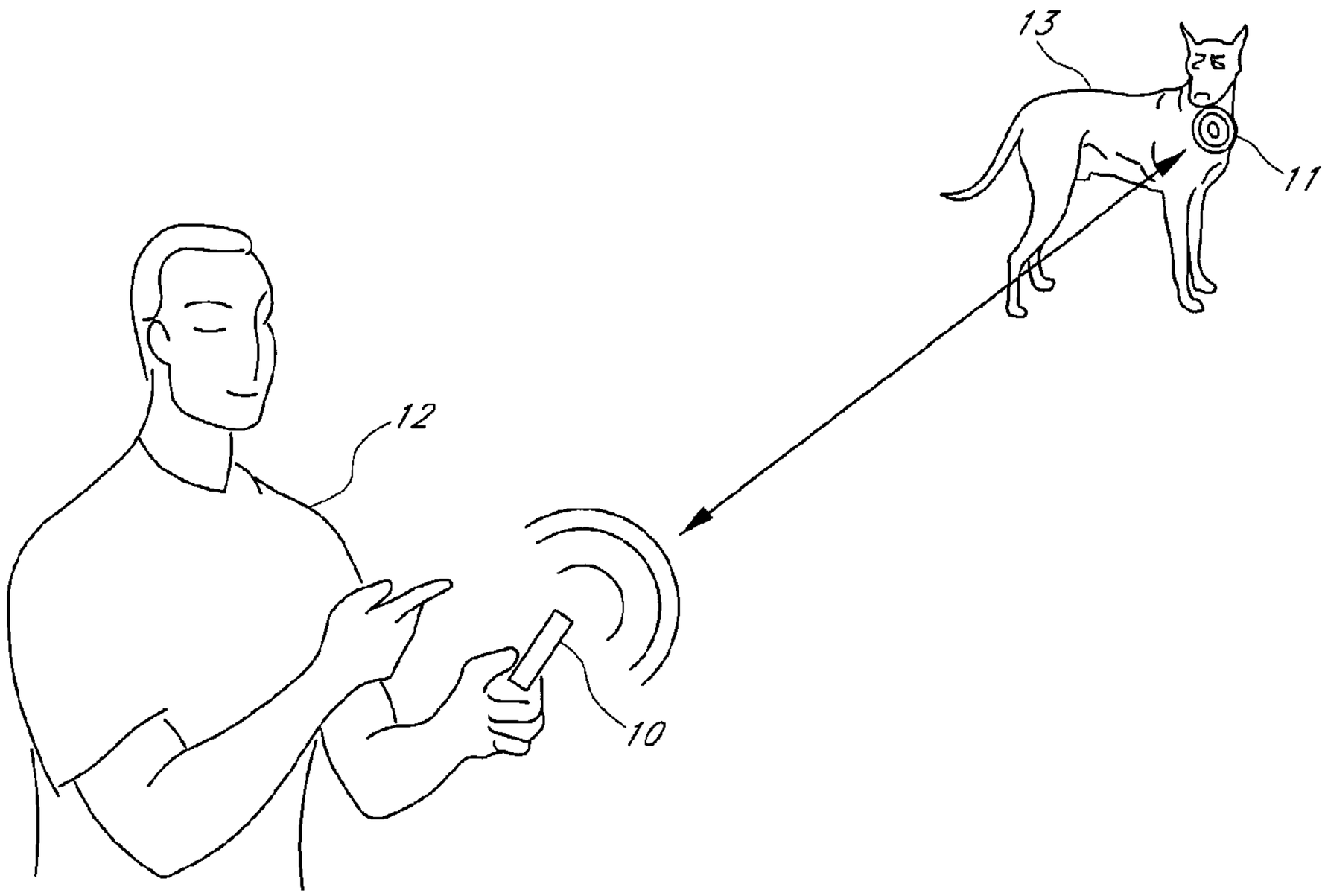

(57) Abrégé/Abstract:
A system and method for locating objects such as people, pets, and personal articles is described. A transceiver is attached to the person, animal, or item to be tracked and a handheld locator device is employed to transmit a locator signal containing an address code to the transceiver. Upon receipt of a signal, the transceiver compares the address code contained in the locator signal with an address code stored in the transceiver. If the two codes are same, the transceiver sends a return signal back to the locator device. The locator device uses this return signal to determine the distance and/or direction of the transceiver from the user's location. The system allows a user to select from a multiple number of items to locate and allows multiple users to search for different articles within the same general area without interference.

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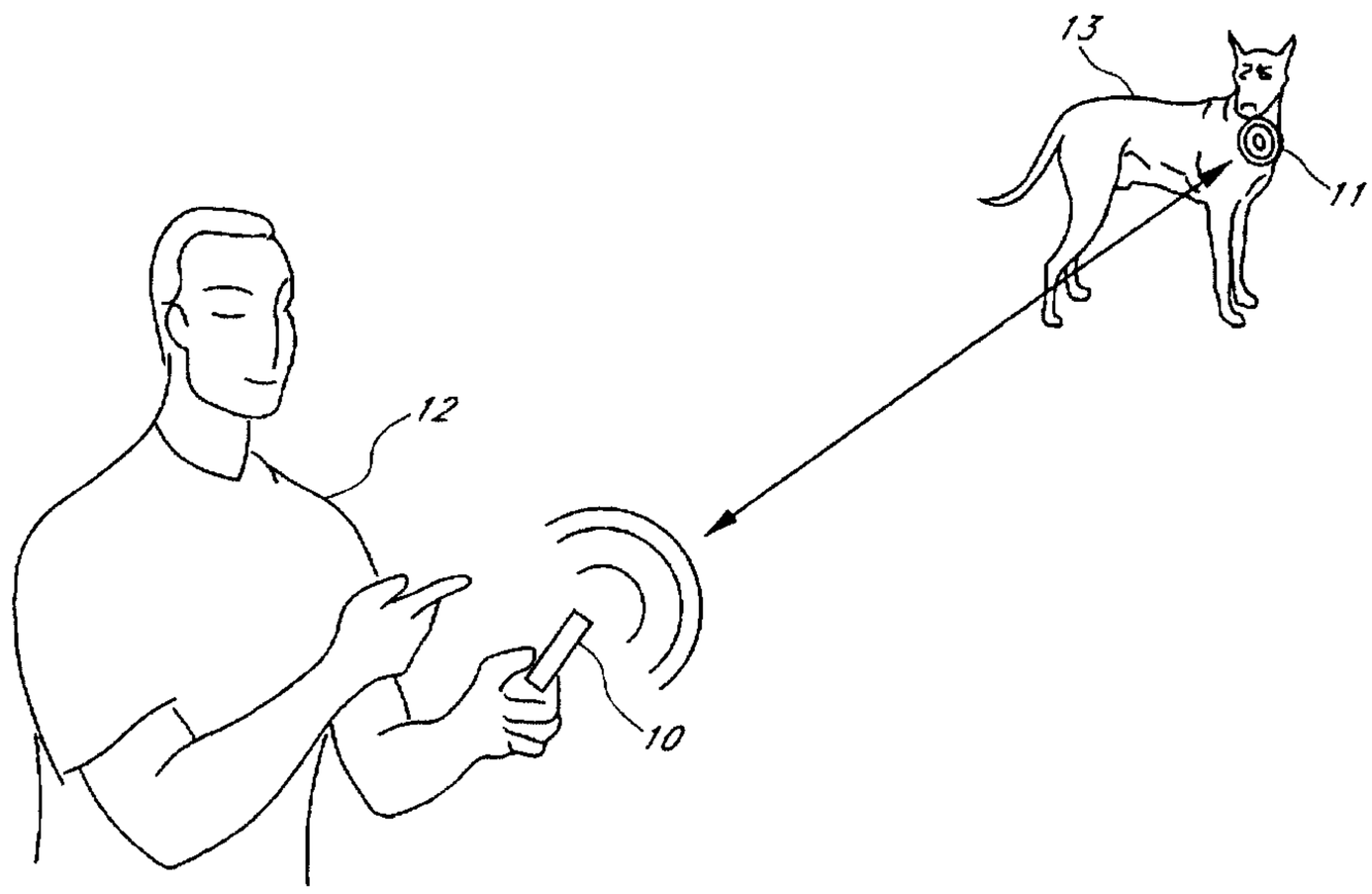

(57) Abstract: A system and method for locating objects such as people, pets, and personal articles is described. A transceiver is attached to the person, animal, or item to be tracked and a handheld locator device is employed to transmit a locator signal containing an address code to the transceiver. Upon receipt of a signal, the transceiver compares the address code contained in the locator signal with an address code stored in the transceiver. If the two codes are same, the transceiver sends a return signal back to the locator device. The locator device uses this return signal to determine the distance and/or direction of the transceiver from the user's location. The system allows a user to select from a multiple number of items to locate and allows multiple users to search for different articles within the same general area without interference.

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ARTICLE LOCATOR SYSTEM

Background

Field of the Invention

The present invention relates generally to a device for locating lost articles, and more particularly, to a portable locator device that communicates with a transceiver through radio frequency signals to determine the relative distance and/or direction of the transceiver from the locator unit.

Description of the Related Art

Many devices have been proposed for the location of various types of objects. Most of these devices are limited to tracking a certain type of object, such as a child or a set of keys, or are confined to only occasional uses. Many of these devices are also limited in their range of applications due to such limiting factors as operating range, battery life, or the inability to selectively locate large numbers of different articles.

For example, the inventions described by U.S. Pat. No. 5,289,163 issued Feb. 22, 1994 to Perez, U.S. Pat. No. 4,785,291 issued Nov. 15, 1988 to Hawthorne, U.S. Pat. No. 5,900,817 issued May 4, 1999 to Olmassakian, U.S. Pat. No. 5,652,569 issued July 29,1997 to Gerstenberger *et al.*, U.S. Pat. No. 6,127,931 issued Oct. 3, 2000 to Mohr, or U.S. Pat. No. 4,785,291 issued Nov. 15, 1988 to Hawthorne, generally relate to a form of an electronic leash for child monitoring.

These devices require the caregiver to activate the caregiver's monitoring device and child's transceiver device, and attach the transceiver to the child so that the child may be located if the parent and child become separated. While such devices may be useful in some circumstances, such as a shopping trip or a visit to the park, it is well known that children may wander away from their caregivers at any time without warning. If the child's transceiver device has not been activated before the child wanders away, the transceiver cannot be located by the caregiver's device.

Additionally, these systems rely on relatively constant communications between the child's transceiver device and the monitoring device. The need for constant communications between the transceiver and monitoring device disadvantageously requires the consumption of a large amount of power from the transceiver's battery. As a result, the transceiver may not have usable battery power at critical times in which the parent desires to locate the child.

Another class of locator devices is described, for example, in U.S. Pat. No. 5,939,981 issued Aug. 17,1999 to Renney, U.S. Pat. No. 5,294,915 issued Mar. 15, 1994 to Owen or U.S. Pat. No. 6,166,652 issued Dec. 26, 2000 to Benvenuti. In general, these locator devices include a radio transmitter that is used to activate a radio receiver attached to an article, such as a television remote control or set of keys. When the receiver is activated, it emits an audible signal that alerts the user to location of the article to which the receiver is attached. Unfortunately, these systems are only useful over a relatively small area due to the limited range of the audible signal.

Accordingly, there is still an unfulfilled need for an article locator system that is power efficient, able to selectively locate multiple articles, and able to accurately locate articles beyond the immediate area of the locator device.

Summary

The present invention solves these and other problems by providing an article locator system that includes a locator unit and one or more transceiver units. The transceiver, also referred to as a tag, is battery powered and relatively small in size so that it can be easily and non-obtrusively attached to an object that the user may need to locate at some time in the future. In one embodiment, a unique digital address code is stored in each transceiver.

The locator unit is capable of storing one or more digital address codes corresponding to the address codes stored in the receiver units. A user can search for a particular object by selecting the digital address code that corresponds to the code stored in the locator unit that is attached to the object the user desires to locate. The selected digital address code is then transmitted by wireless means from the locator unit to transceiver devices within range of the locator unit.

In one embodiment in order to conserve power, the transceiver does not always remain activated. Instead, the transceiver periodically activates its receiver in order to determine if a signal is being sent from a locator device. When an address code is transmitted by the locator unit, all of the transceivers within range of the transmission will, at their next receiver activation cycle, detect the wireless transmission from the handheld locator. Each transceiver decodes the digital address signal and compares it to the unique address stored within the transceiver. If the address code transmitted by the locator device matches the address code stored in the transceiver, the transceiver activates its wireless transmitter and transmits a short-duration response signal. The locator device includes a wireless receiver that detects the wireless signal response from the selected transceiver. From this response signal, the distance and/or relative direction of the selected transceiver from the locator can be determined. This information is then displayed to the user.

The present invention is particularly advantageous, because in one embodiment, it provides the user with a variety of methods by which to locate an object to which a transceiver has been attached. This allows the user to best select the

means that is most suited to the type of search the user is conducting. For instance, in various embodiments, the user may chose to locate a transceiver by measuring its bearing from the locator unit, its distance from the locator unit, or both its bearing and distance from the locator unit. Furthermore, in one embodiment, the user may chose to locate a transceiver by directing the transceiver to activate an indicator, such as an audible-tone or light, to alert the user as to the location of the transceiver.

The present invention is also particularly advantageous because, in various embodiments, it automatically selects the best search option for the user. For instance, in one embodiment, if the locator unit comes within a certain distance of the transceiver, the locator unit will instruct the transceiver to activate its indicator, such as a tone or light, to assist the user in locating the transceiver. In various embodiments, other functions can also be automated, thereby eliminating the need for the user to make decisions. For instance, in one embodiment, if the locator unit is experiencing interference in receiving a signal from a transceiver, the locator unit can request the user to move the locator unit to a different position. In a further embodiment, the locator system can automatically vary the signal strengths of the search and return signals, and can tune the receivers and transmitters of the locator unit and receiver to optimize performance. In these embodiments, the present invention presents the user with a wide range of search options, and can also select the options best suited to the environment in which the user is in. This eliminates the need for the user to make such decisions, thereby simplifying the search process for the user, while at the same time optimizing the search and locate performance.

In accordance with one aspect of the invention, there is provided an electronic system for locating an item, comprising a locator module. The locator module comprises a first memory unit operable to store one or more first address codes, a user control operable to allow a user to select one of the stored first address codes, a first transmitter operable to wirelessly transmit a locator signal, wherein the locator signal includes one of the selected first address codes, a first receiver operable to receive a return signal transmitted by a transceiver module, an antenna array operably connectable to the first transmitter and the first receiver and a first control unit operable to calculate a relative direction of the transceiver module from the locator module. The first control unit is linked to the first memory unit, the user control, the

first transmitter, and the first receiver. The transceiver module comprises a second memory unit operable to store a second address code, a second receiver operable to receive the locator signal transmitted from the locator module, a second transmitter operable to wirelessly transmit the return signal, a second control unit operable to compare the selected first address code transmitted by the locator module with the second address code, and activate the second transmitter to wirelessly transmit the return signal if the two codes are the same. The second control unit is linked to the second memory unit, the second receiver, and the second transmitter and a timer linked to the second receiver and the second control unit, the timer operable to activate the second receiver and second control unit at a specified time interval and for a specified time period.

The locator module may further comprise a second timer linked to the first control unit, the second timer operable to determine the time between when the locator signal is transmitted to when the return signal is received, and the first control unit may be operable to calculate a distance of the transceiver module from the locator module.

The locator unit may further comprise a real-time clock.

The locator module may be configured to allow the user to specify a known distance from the locator module to the transceiver module, use the known distance to determine an expected time period between when a locator signal is sent to the transceiver module to when the return signal should be received by the locator module, measure an actual time period from when the locator signal is sent to the transceiver module to when the return signal is received by the locator module, obtain an electronic system delay time by subtracting the actual time period from the expected time period, and store the electronic system delay time in the first memory unit.

The locator unit may further comprise a first sensor operable to measure a first temperature, and the transceiver may comprise a second sensor operable to measure a second temperature. The first and second temperatures may be used to calculate the system delay time.

Calculating the distance of the transceiver module from the locator module may comprise determining a total time elapsed from when the locator signal is sent to

when the return signal is received by the locator device, subtracting an electronic system propagation delay time, and dividing by two.

The locator module may determine distance to the transceiver module by switching between antennas in the antenna array according to a commutation frequency selected to minimize a tone output from the first receiver.

The locator module may determine distance to the transceiver module by switching between antennas in the antenna array according to a commutation frequency selected to minimize a tone output from the first receiver, wherein the commutation frequency is swept across a desired range of frequencies.

The locator module may be configured to measure a phase delay between a tone transmitted to the transceiver module and a tone received from the transceiver module.

The locator module may be configured to calibrate to the transceiver module, the locator module configured to measure a phase delay between a tone transmitted to the transceiver module and a tone received from the transceiver module when the transceiver module is relatively close to the locator module, convert the phase delay to a time delay and store the system delay time.

The first control unit may be further operable to measure and store a signal processing time delay through the electronic system.

The locator module may further comprise a switch to operably connect the first receiver to the antenna array.

The locator module may further comprise a switch to operably connect the first receiver to the antenna array, and the control unit may control a commutation rate of the switch.

The timer may be a real-time clock.

The real time clock may be programmable to activate the second receiver at specified times.

The real time clock may be operable to be programmed by the locator module.

The locator module may further comprise a conflict detection receiver, the conflict detection receiver linked to the first control unit and operable to detect a second locator signal transmitted from a second locator module.

The first control unit may be further operable to delay the transmission of the locator signal from the first transmitter unit when the conflict detection receiver detects the second locator signal.

The conflict detection receiver may be integral with the first receiver.

The second memory unit may be further operable to at least temporarily store a session identifier.

The transceiver module may further comprise a battery, the battery operable to power the second memory unit, the second receiver, the second transmitter, the second timer, and the second control unit.

The transceiver module may be powered by radio frequency energy.

The transceiver module may further comprise an outer housing.

The outer housing may be waterproof

The locator module may further comprise a display screen linked to the first control unit.

The antenna array may comprise two or more antennas coupled to the locator module and arranged in a circular path.

The two or more antennas may be pivotally coupled to the locator module.

There may be three or more antennas.

The first control unit may be further operable to determine the strength of the return signal received at each of the antennas, and is operable to select the antenna receiving a strongest return signal.

The first receiver may be only active for a limited period after the locator signal is sent.

The locator unit may further comprise an internal compass unit operable to convert a relative direction of the transceiver module to a magnetic bearing.

The system may further comprise a third transmitter operable to send a first signal to a second locator unit, and may further comprise a third receiver operable to receive a second signal from a second locator unit.

The system may further comprise one or more additional locator units, wherein the locator unit and the additional locator units may be connected by a communication path.

The communication path may comprise a computer network.

control unit controls a commutation rate of the switch. The locator module can also further include an internal compass unit operable to convert a relative direction of the transceiver module to a magnetic bearing. In one embodiment, the locator unit is operable to send commands to the transceiver.

The transceiver module includes a second receiver operable to receive the signal transmitted by the first transmitter, a second transmitter operable to transmit the return signal, and a second control unit operable to compare the first address code transmitted by the locator module with an address code stored in the transceiver module. If the two codes are the same, the second control unit activates the second transmitter to transmit the return signal. In one embodiment, the transceiver includes a timer operable to activate the second receiver and second control unit at a specified time interval and for a specified time period.

In one embodiment, the first control unit is further operable to calibrate and store a signal processing time delay through the transceiver module. In one embodiment, the distance from the locator module to the

The antenna array may comprise one or more monopole-type antennas.

The antenna array may comprise one or more dipole-type antennas.

The antenna array may comprise one or more patch-type antennas.

The first transmitter may transmit the first address code using frequency shift keying.

The locator module may determine bearing to the transceiver module by switching between antennas in the antenna array and using Doppler processing to determine a direction of a wireless signal received from the transceiver module.

The locator module may send commands to the transceiver module.

The transceiver may further comprise a sensor linked to the second control unit.

The sensor may be operable to measure temperature.

The transceiver may further comprise an indicator linked to the second control unit.

The locator signal may comprise a spread spectrum signal, an ultra wide band signal, a wideband FM signal, or a CDMA signal.

In accordance with another aspect of the invention, there is provided a method for locating an object. The method involves attaching a transceiver to the object, the transceiver comprising a first receiver operable to receive a locator signal that contains a first address code, a first transmitter operable to wirelessly transmit a return signal, a first control unit operable to compare a second address code stored in a first memory unit with the address code contained in the locator signal, and activate the first transmitter to wirelessly transmit the return signal if the two codes are the same, wherein the first control unit is linked to the first memory unit, the first receiver, and the first transmitter and a first timer linked to the first receiver and the first control unit, the first timer operable to activate the first receiver and first control unit at a specified time interval and for a specified time period, entering and storing the first address code in a locator unit. The locator unit comprises a second memory unit operable to store the first address code, a user control operable to allow a user to input the first address code and select the first address code after it has been entered and stored, a second transmitter operable to wirelessly transmit the locator signal, wherein the locator signal includes the selected first address code, a second receiver operable

to receive the return signal transmitted by the transceiver module, one or more antennas linked to the second receiver, a second control unit operable to calculate a relative direction of the transceiver module from the locator module, wherein the second control unit is linked to the second memory unit, the user control, the second transmitter, and the second receiver, selecting the first address stored in the locator unit and activating the locator unit to wirelessly transmit the first address code to the transceiver, wherein if the transceiver receives the locator signal containing the first address code and verifies that the first address code matches the second address code stored in the transceiver, the return signal is sent from the transceiver to the locator module, and the locator module analyzes the return signal to determine the relative direction of the transceiver.

The locator unit may further comprise a second timer operable to determine a time between when the locator signal is transmitted to when the return signal is received, wherein the second timer is linked to the second control unit, and wherein the second control unit is operable to calculate a distance of the transceiver module from the locator module.

The first timer may activate the first receiver and the first control unit for a period of time at regular intervals.

The first timer may be a real-time clock, and the user can program the real time clock to activate the first receiver and the first control unit at predetermined times.

In accordance with another aspect of the invention, there is provided a system, comprising a locator module comprising a first radio frequency transmitter operable to transmit a first address code, a first receiver configured to receive a return signal transmitted by a second transmitter, an antenna array operably connectable to the first transmitter and the first receiver by a switch and a first control unit operable to control the switch, the first control unit operable to determine a bearing of a transceiver module from the control unit. The transceiver module comprises a second receiver operable to receive the signal transmitted by the first transmitter, the second transmitter operable to transmit the return signal. The transceiver module further comprises a second control unit operable to compare the first address code transmitted by the locator module with an address code stored in the transceiver module and

activate the second transmitter to transmit the return signal if the two codes match and a timer operable to activate the second receiver and second control unit at a specified time interval and for a specified time period.

The first control unit may be further operable to determine a distance between the locator unit and the transceiver module.

The first control unit may be further operable to calibrate and store a signal processing time delay through the transceiver module.

Calculating the distance of the transceiver module from the locator module may comprise determining a phase delay between a transmitted tone frequency modulated onto a first carrier and a received tone frequency modulated onto a second carrier.

The locator module may determine range to the transceiver module by commutating between antennas in the antenna array according to a commutation frequency selected to minimize a tone output from the first receiver.

The locator module may determine range to the transceiver module by switching between antennas in the antenna array according to a commutation frequency selected to minimize a tone output from the first receiver, wherein the commutation frequency is swept across a desired range of frequencies.

The locator module may be configured to measure a phase delay between a tone transmitted to the transceiver module and a tone received from the transceiver module.

The locator module may be configured to calibrate to the transceiver module, the locator configured to measure a phase delay between a tone transmitted to the transceiver module and a tone received from the transceiver module when the transceiver module is relatively close to the locator module, convert the phase delay to a time delay and store the transceiver delay time.

The first control unit may control a commutation rate of the switch.

The first transmitter may send the first address code using frequency shift keying.

The locator module may further comprise an internal compass unit operable to convert a relative direction of the transceiver module to a magnetic bearing.

The antenna array may comprise two or more antennas coupled to the locator module along an approximately circular path.

The two or more antennas may be pivotally coupled to the locator module.

The antenna array may comprise one or more monopole-type antennas.

The antenna array may comprise one or more dipole-type antennas.

The antenna array may comprise one or more patch-type antennas.

The first transmitter may transmit the first address code using phase shift keying.

The locator module may determine bearing to the transceiver module by commutating between antennas in the antenna array and using Doppler processing to determine a direction of a wireless signal received from the transceiver module.

The locator module may send commands to the transceiver module.

The locator signal may comprise a spread spectrum signal, an ultra wide band signal, a wideband FM signal, or a CDMA signal.

In accordance with another aspect of the invention, there is provided a system, comprising a locator module comprising a first radio frequency transmitter operable to transmit a first address code, a first receiver configured to receive a return signal transmitted by a second transmitter, an antenna array operably connectable to the first transmitter and the first receiver by a switch and a first control unit operable to control the switch. The first control unit is operable to determine a distance of a transceiver module from the control unit. The transceiver module comprises a second receiver operable to receive the signal transmitted by the first transmitter, the second transmitter operable to wirelessly transmit the return signal, a second control unit operable to compare the first address code transmitted by the locator module with an address code stored in the transceiver module and activate the second transmitter to wirelessly transmit the return signal if the two codes match and a timer operable to activate the second receiver and second control unit at a specified time interval and for a specified time period.

In accordance with another aspect of the invention, there is provided a system, comprising a locator module comprising a first radio frequency transmitter operable to transmit a first address code, a first receiver configured to receive a return signal transmitted by a second transmitter, an antenna array operably connectable to the first

transmitter and the first receiver by a switch and a first control unit operable to control the switch. The first control unit is operable to determine a bearing of a transceiver module from the control unit and is operable to detect the presence of multipath by examining a second harmonic of a commutation frequency of the antenna array. The system further includes a transceiver module comprising a second receiver operable to receive the signal transmitted by the first transmitter. The second transmitter is operable to wirelessly transmit the return signal. The transceiver module further includes a second control unit operable to compare the first address code transmitted by the locator module with an address code stored in the transceiver module and activate the second transmitter to wirelessly transmit the return signal if the two codes match.

Brief Description of the Drawings

FIG. 1 is a perspective view showing one embodiment of the present invention.

FIG. 2 is a front view of a transceiver device with marked serial number.

FIGS. 3A and **3B** are schematic block diagrams illustrating the components of a transceiver device.

FIG. 4 is a front view of a locator device showing the transceiver selection display and controls.

FIG. 5 is a front view of a locator device showing the range and bearing display and controls.

FIG. 6 is a schematic block diagram illustrating the components of a locator device.

FIGS. 7A and **7B** are a view of the antenna array of one embodiment of the present invention.

FIG. 8 is a depiction of two locator units communicating to locate a transceiver.

FIG. 9 illustrates an array of antennas sampling an incoming wavefront a different points in space in a rotating pattern.

FIG. 10 illustrates the frequency spectrum of a Doppler tone signal when the sources of multipath reflections are absent.

FIG. 11 illustrates the frequency spectrum of a Doppler tone where the receiver was subject to strong multipath interference.

FIG. 12 shows relational features between a transceiver and locator unit that are useful in implementing the difference of sines algorithm.

FIG. 13 illustrates the signal levels at zero crossing for a selected antenna, A_0.

FIG. 14 is a block diagram of the locator and the tag emphasizing elements of that contribute to time delays in the distance measuring function of the locator.

FIG. 15 is a block diagram of the locator and the tag emphasizing elements of that contribute to time delays when an antenna array and diplexer are provided in the locator.

Detailed Description

A. Overview

The present invention is directed to a radio frequency location system in which a locator device is used to determine the distance and/or bearing from the user's location to one or more transceiver devices. One embodiment of this invention is illustrated in **FIGS. 1-6**.

FIG. 1 illustrates the general operation of one embodiment of the locator system of the present invention. A transceiver **11** has been previously attached to an object (in this case is a dog **13**) that a user **12** now wishes to locate. It will be understood that the application of the disclosed invention is not limited to the location of any particular type of object. The objects to be located using the disclosed invention include mobile objects such as a person, child, or pet, as well as stationary items of personal property such as wallets, keys, remote control devices, tools, parked vehicles and any other object which may from time to time need to be located by its owner or caregiver.

modulated radio frequency signal including the digital address code selected from the list of stored codes in the locator **10**. In one embodiment, the transceiver **11** periodically activates its radio frequency receiver and checks for the presence of transmissions of the form emitted from the locator **10**. If a transmission is detected, the transceiver **11** receives the digital address code transmitted by the locator **10** and compares the received address code with a stored address code within the transceiver **11**. In one embodiment, each transceiver **11** has a unique stored address code.

If the digital address code transmitted by the locator **10** matches the code stored in the transceiver **11**, the transceiver **11** will activate its transmitter and send a short duration RF signal back to the locator **10** to facilitate determining the distance and/or direction from the user's position to the selected transceiver **11**. Various embodiments of the present invention are contemplated. For example, in one embodiment, the locator unit **10** is operable to determine the distance of the transceiver **11** from the locator unit **10**. In another embodiment, the locator unit **10** is operable to determine the bearing of the transceiver **11** from the locator unit **10**. In yet another embodiment, the locator unit **10** is operable to determine both the distance and bearing of the transceiver **11** from the locator unit **10**. Other embodiments in addition to these are also described herein.

B. Transceiver

In one embodiment, the transceiver **11** is small in size such that it easily can be attached to a variety of objects, even if the objects are small. The transceiver **11** can be permanently affixed to the object, or it can be attached in such a way that it can be removed if desired. For example, the transceiver 11 can be attached to the object by an adhesive, a clip, or can be tied to the object. The transceiver **11** can also be designed such that it can be worn on a necklace, bracelet, or collar. The housing of the transceiver **11** can be made from a variety of material. The material is preferably durable in nature, and in the one embodiment, the housing is made from plastic.

FIG. 2 illustrates one embodiment of a transceiver **11** having an outer casing **20** preferably of waterproof and shock resistant design, an attachment mechanism **21** and a marking depicting an internally stored device address code **22**. In one embodiment, the transceiver **11** may have an antenna **23** protruding from the outer casing **20**. This embodiment is an example of one way the transceiver **11** can be made to attach to, for example, a dog collar or a key chain.

The relatively small size of the transceiver **11** allows it to remain virtually unnoticed even when attached to an object. Because the transceiver **11** is non-obtrusive when attached to an object, it can be permanently left on the object and cause little or no interference or inconvenience to the user of the object. Therefore, the transceiver **11** can be attached to the object many months, and even years, prior to the time the owner or caregiver wishes to locate the object. Although it is preferable to make the transceiver **11** small in size, those skilled in the art will realize that transceivers of varying larger sizes can also be constructed and utilized in situations where it is not necessary or desirable to have a small transceiver.

FIG. 3A illustrates a schematic block diagram of one embodiment of the transceiver **11** of the present invention. **FIG. 3B** illustrates another embodiment of the transceiver **11** in which the receiver **30** and

transmitter **33** are each coupled to a diplexer **36**. A receiver **30** and a control unit **32** are activated by a timer **31** at substantially regular time intervals for a period of time sufficient to determine if the locator device **10**, within the effective range of the RF signal, is transmitting a device address code. If a signal is detected during the activation period, the control unit **32** and receiver **30** will remain activated until a complete address code is received or the signal is no longer present. If the received address code matches the address code stored in the transceiver **11**, the control unit **32** activates a transmitter **33**. The transmitter **33** then sends a relatively short-duration RF return signal.

The transceiver **11** can be set to be activated at intervals that are best suited for the application in which the transceiver will be used. It should be noted that it is the receiver **30** and control unit **32** of the transceiver **11** that are activated at the determined intervals. The transmitter **33** is activated when an address code is received from a locator unit **10** that matches the address code stored in the transceiver **11**. For example, if the transceiver is being affixed to livestock, it will not be necessary for the user to receive a virtually continuous update of the position of the livestock. Therefore, the time intervals between the activation of the transceiver can be relatively long. For example, in one embodiment, the time interval between each activation can be from 5 to 15 minutes. If the user desires to be able to locate an object more quickly, the time interval between each activation of the transceiver **11** can be reduced. For example, in one embodiment, the time interval between each activation can be from 2 to 5 seconds. It will be apparent to those skilled in the art that the time intervals between each activation can readily be set to be any desired duration.

If no locator signal with a matching address code is detected within a predetermined period of time, the receiver **30** and control unit **32** will turn off, and the transceiver **11** will enter into stand-by mode. The receiver **30** and control unit **32** will be activated by timer **31** again at the next preset interval. In one embodiment, the transceiver **11** stays activated for between 5 and 10 msec once it has been activated. Those skilled in the art will realize that the transceiver **11** can be set to remain activated for varying lengths of time.

The timer can be preset during the manufacture of the transceiver **11**. In one embodiment, the timer **31** is a real-time clock that can activate the receiver **30** at intervals or at a specified time and date. In one embodiment, the real-time clock preferably operates on low power levels (*i.e.*, less than 3 microwatts). The presence of a real time clock allows the transceiver **11** to enter a low-power sleep mode until a specified time duration has elapsed or until a programmed time and date has been reached. When the programmed wakeup condition has been met, the real time clock has the ability to power up the RF receiver **30** and control unit **32** in the transceiver **11** to determine if a locator unit **10** is transmitting an address code.

Each transceiver **11** also has a memory unit that is operable to store a unique address code for that transceiver **11**. The memory unit can be any conventional memory means, such as non-volatile memory, volatile memory, programmed switches, wire jumpers, and the like. The memory unit can be linked to the control unit, and can be integral with the control unit **32** such that the control unit **32** also operates as the memory unit. In one embodiment, the address code is permanently stored in the memory unit. For example,

the address codes can be entered and permanently stored in the transceiver **11** during the manufacturing process.

In one embodiment, a session ID can also be temporarily stored in the memory unit. In this embodiment, the user can use the locator unit **10** to enter or remove addresses in the transceiver **11**. As discussed in more detail herein, this may be desirable when the user wishes to track a group of transceivers **11**. In this embodiment, the locator unit **10** can be used to send a temporary session ID to the transceiver **11**. This session ID is saved in the transceiver **11**, and contains less data than the unique ID that differentiates all transceivers **11** from one another and therefore can be more efficiently communicated. Preferably, the transceiver **11** utilizes non-volatile memory so that session ID's and other data set to the transceiver **11** from a locator unit **10** will be preserved during the low-power sleep intervals when power is removed from the processor circuitry. As discussed in more detail herein, this embodiment is particularly useful when a group of transceivers **11** is being tracked by the locator unit **10**.

Each transceiver **11** also includes at least one receiver **30**. The receiver **30** is used to receive an RF locator signal containing a digital address code that is sent by the locator unit **10**. Preferably, the receiver **30** is tuned to the frequency of the search signal that is sent by the control unit. When the receiver **30** receives the locator signal, the digital address code contained in the signal is output by the receiver **30** to a control unit **32**, which is linked to the receiver **30**.

In one embodiment, the control unit **32** includes a microprocessor. In one embodiment, the control unit **32** can also contain a filtering mechanism. In the case where a complete address code is received, the control unit **32** compares the received address code with the address code stored within the memory unit. If the address codes match, the control unit **32** activates the transmitter **33** that is linked to the control unit. The transmitter **33** then sends a relatively short-duration RF return signal to the locator unit **10**. The transmitter **33** is activated for a time interval of sufficient duration to allow the locator unit **10** that is the source of the transmission to determine the distance and bearing of the returned signal. In one embodiment, the duration of the signal transmitted is less than one second. In one embodiment, the duration is approximately 5 msec.

In one embodiment, the control unit **32** can be further operable to increase or decrease the time interval between activations of the receiver **30** depending on the usage history of the system. For example, if a signal has not been detected at the output of the receiver **30** by the control unit **32** after a predetermined amount of time, the time interval between activations can be increased to reduce the power consumption of the transceiver **11**, thereby increasing the life of the battery. Conversely, if an address code matching the stored address code has been received within a predetermined time period, the time interval between activations of the receiver **30** can be reduced to provide a faster response time for successive searches for that transceiver **11**.

Because only the transceiver **11** having an address code that matched the address code contained in the locator signal will transmit a response signal, and because each transceiver **11** can be manufactured with a permanently stored address code or can contain a temporarily stored address code, the signal sent back

from the transceiver **11** to the locator unit **10** need not include the address code in all embodiments. Thus, in one embodiment, the content of the RF signal transmitted from the transceiver **11** is substantially the same for every transceiver **11** device. The individual transceiver **11** devices are distinguished by transmitting an RF response signal within a narrowly defined time window after receipt of the digital address code, thereby eliminating the complications that would arise if the system design required the transceiver **11** device to transmit the stored digital address code back to the locator unit **10** as part of the response signal. In one embodiment the response signal preferably has a frequency between 902 MHz and 904 MHz, although those skilled in the art will realize that a variety of other higher and lower frequencies can readily be used.

The method of operation of the transceiver **11** offers a number of advantages. First, the transceiver **11** design can be simplified because there is no need for a digital code modulator. Thus, in one embodiment, the transceiver **11** is not required to send a digitally modulated signal back to the locator unit **10**. Second, the required RF receive level at the locator unit **10** is reduced because a digitally modulated signal need not be decoded thereby increasing the effective range of the system. Third, the power consumption in the transceiver **11** is reduced because the duration of the required transmission is reduced. The power consumption of the transceiver **11** is also reduced because the transceiver **11** can be made such that it has relatively few operational components. Additional advantages are also realized from making such a transceiver. For example, the transceiver **11** can be made with relatively minimal cost. If a transceiver **11** becomes broken or lost, the user can replace it with minimal expense.

In one embodiment the locator unit **10** transmits a digitally modulated locator signal using frequency shift keying. Those skilled in the art will realize that other methods, such as phase shift keying, may also be used. In one embodiment, the locator signal is sent at 1200 baud, although those skilled in the art will realize that other speeds may also be used. In one embodiment, the address code is transmitted from the locator unit **10** to the transceiver **11** at two frequencies, 902 MHz and 904 MHz. Higher and lower frequencies may also be used. Those of ordinary skill in the art will realize that frequency hopping schemes, spread spectrum, CDMA, pulsed communications systems such as Ultra Wideband, and wideband FM can also be used.

As previously stated, if the address code sent by the locator unit **10** matches the address code stored in the transceiver **11**, the transceiver **11** will send a response signal back to the locator unit **10**. In one embodiment, the transceiver **11** initially sends an unmodulated, continuous wave signal to the locator unit **10**. The locator unit **10** analyzes this signal to determine the relative bearing of the transceiver **11**, as discussed later herein. In one embodiment, after receiving the unmodulated signal from the transceiver **11**, the locator unit **10** directs the transceiver **11** to go into loop back mode. In another embodiment, the transceiver **11** can automatically enter loop back mode after it transmits the unmodulated signal for a determined time period. Upon entering loop back mode, the locator unit **10** sends a carrier signal that is FM modulated. In one embodiment, the carrier signal is sent at 902 MHz, and the carrier signal is FM modulated at 1800 Hz. Those skilled in the art will realize that other higher and lower frequencies may also be used.

After receiving the signal, the transceiver **11** demodulates it and extracts the 1800 Hz tone. A return FM modulated signal is then sent from the transceiver **11** back to the locator unit **10**. In one embodiment, the return signal is not independently generated in the transceiver **11**. Instead, the transceiver **11** simply loops back the signal received from the locator unit **10**. In one embodiment, the return signal is sent at 922 MHz and the signal is FM modulated at 1800 Hz. Those skilled in the art will realize that other higher and lower frequencies may also be used. The locator unit **10** can then determine the distance to the transceiver **11** by analyzing the return signal sent by the transceiver **11**. Specifically, distance between the locator unit **10** and the transceiver **11** is related to the shift in phase between the signal sent by the locator unit **10** and the signal received by the transceiver **11**. The locator unit **10** determines the change in phase between the signal it sent and the signal it received from the transceiver **11**, and from this change in phase it can determine the distance to the transceiver **11**.

This calculation is based on the assumption that there is not processing delay time in either the transceiver **11** or the locator unit **10**. In reality, there will be some processing delay. This delay will result in a larger change in phase between the signal sent by the locator unit **10** and the signal received from the transceiver **11**, thereby giving the appearance that the distance to the transceiver **11** is larger than it actually is. To compensate for this processing time delay, in one embodiment, a standard processing delay time may be entered into the locator unit **10**. The locator unit **10** can use this standard processing delay time when calculating the distance to the transceiver **11** in order to compensate for the actual processing delay time of the transceiver **11**. In another embodiment, the actual system delay time for each transceiver **11** can be determined through a calibration process. This calibration process is discussed in more detail herein.

In one embodiment, the transceiver **11** also includes a battery to provide power to the timer **31**, control unit **32**, receiver **30**, and transmitter **33**. In one embodiment, the battery is a sealed lithium battery, although those skilled in the art will realize that other types of batteries can also readily be used. The internal battery preferably is permanently mounted and provides a service life of several months to several years. In another embodiment, the transceiver **11** does not include a battery, but is instead derives its power from RF energy. This RF energy may come from the signals emitted by the locator unit **10** during a search, or may come from other sources, such as television or radio signals. In one embodiment, if the battery power of the transceiver **11** decreases to a predetermined point, the transceiver **11** can send a signal to the locator unit indicating that its battery level is low. In one embodiment, the transceiver **11** notifies the locator unit **10** that its battery level is low the next time the locator unit **10** addresses the transceiver **11**. The transceiver **11** can send the information in the interval after the loop back mode. In one embodiment, this information is transmitted using frequency shift keying. In yet another embodiment, the transceiver **11** may be connected to an external battery source. This would allow the transceiver **11** to remain constantly activated. In one embodiment, if the transceiver **11** was connected to an external power source, it would not be necessary for the transceiver **11** to have a timer, as it would not be necessary for the transceiver **11** to turn itself on at specified time intervals, as the transceiver **11** could always remain on.

The transceiver **11** can be constructed to meet the needs of the particular environment in which it is to be used. For instance, if the transceiver **11** will be attached to an object that is likely to remain in the user's home, the transceiver **11** will likely remain within a close range of the user. As a result, the transceiver **11** will only be required to transmit its return signal over a short range in order to be located by the nearby locator unit **10**. The absence of the need for relatively large components that transmit a high powered signal allows the transceiver **11** to be small in size. Such a transceiver **11** can be powered by a battery or it can lack a battery and instead derive its power from the RF energy.

Because in one embodiment the transceiver **11** can derive its power from RF energy, such as the energy emitted by the locator unit **10** during a search, it does not require any power when it is in "stand-by mode," that is, the periods when the transceiver **11** remains inactive (*i.e.* neither its receiver **30** nor transmitter **33** is active). The transceiver **11** can be activated when an RF signal is received within a certain frequency band. This RF energy is rectified and used to power the active circuitry which then awaits the reception of a coded address signal. If the transceiver **11** receives its unique address, it then activates its transmitter to reply with a generic, modulated RF signal that is common to all transceivers **11**. The system design allows enough time between interrogations for the transceiver **11** to build up enough energy to activate its transmitter. In this way, a locator unit **10** can repeatedly interrogate a transceiver **11** and update the range and bearing information to the user. This embodiment allows the user to attach the transceiver **11** to an article and search for it months or years later without having to worry about maintaining a battery.

Another embodiment of the transceiver **11** is particularly well adapted for outdoor use. This embodiment is characterized by a relatively long range of operation, but a limited battery life. In one embodiment, the transceiver **11** comprises a sealed battery that powers its receiver and transmitter. The transceiver **11** is approximately 25mm diameter and 12 mm thick. This size is of sufficient compactness that the transceiver **11** can easily be worn on a pet's collar or attached to a toddler. The transceiver **11** has a range of approximately 1 miles, which defines an area over 2000 acres, thereby providing search capabilities over an extended area such as a neighborhood or amusement park.

In this embodiment, the transceiver **11** draws a very small amount of power from its internal battery when it is in stand-by mode. This allows transceiver **11** to remain active for up to 5 years without needing to be replaced. In one embodiment, when the transceiver **11** receives a modulated preamble signal from the locator unit **10**, it powers up its decoding circuitry and awaits its coded address signal. Upon receiving its address signal the transceiver **11** will power up its transmitter and respond in the manner of the indoor transceiver **11**. The actual life of the outdoor transceiver **11** embodiment will depend on the number of times it has been searched for and the total duration of the searches. In one embodiment, if the outdoor transceiver **11** detects that its battery is nearly discharged, it will respond to the locator unit **10** with a different code or modulation frequency. This will allow the locator unit **10** to alert the user that the transceiver **11** is in need of replacement. Furthermore, if the transceiver **11** is to be used outdoors, it can be sealed in a weatherproof or waterproof casing to prevent it from becoming damaged by exposure to the elements. It will be readily

apparent that this embodiment of the transceiver **11** does not have to be limited to application outdoors, but can also be used indoors if desired.

In one embodiment, the transceiver **11** can also include one or more sensors **34** and one or more indicators **35** that are linked to the control logic unit **32**. The sensor **34** can be adapted to sense one or more of a number of conditions, such as moisture, temperature, user input, shock, acceleration, movement, other medical devices (*i.e.* monitors for heart rate, breathing rate, and the like), or the battery level of the transceiver **11**. For example, in one embodiment the user input may be a panic button. If the panic button is pressed, in one embodiment the transceiver **11** can activate the indicator **35** and/or send a signal to the locator unit **10** indicating that the panic button has been pressed. In one embodiment, this information is sent to the locator unit **10** the next time the locator unit **10** polls the transceiver **11**. In one embodiment, the moisture sensor **34** can measure the humidity in the surrounding air. The moisture sensor **34** can be further operable to determine if the transceiver **11** has fallen into water. This application may be particularly useful if the transceiver **11** is attached to a child. In a further embodiment, if the sensor **35** detects that it has become emerged in water, the transceiver **11** can activate the indicator **35** and/or send a signal to the locator unit **10**. In one embodiment, this information is sent to the locator unit **10** the next time the locator unit **10** polls the transceiver **11**. The temperature sensor **34** can be operable to measure the temperature around the transceiver **11**. In more particular embodiments, the temperature sensor **34** can be operable to measure the body temperature of the user of the transceiver **11**. The temperature sensor **34** can also be useful in determining if a fire is occurring near the transceiver **11**. In one embodiment, the locator unit **10** can also include sensors of the type discussed herein.

Once a predetermined sensor level has been met, the indicator **35** may be activated to alert the user. The indicator may be, for example, a light or a speaker operable to emit a sound. For example, if the temperature goes above or below a specified point, the indicator may be triggered, thereby alerting the user. In a further embodiment, the information obtained by the sensor **34** may be sent by the transceiver **11** to the locator unit **10**, thereby allowing the user of the locator unit **10** to monitor the conditions detected by the sensor **34**. In one embodiment, this information is sent to the locator unit **10** the next time the locator unit **10** polls the transceiver **11**.

This embodiment is also useful in regard to the calibration feature previously discussed. The propagation delay time of a signal through the transceiver **11** and the locator unit **10** may depend on factors such as humidity and temperature. The sensor **34** in the transceiver **11** can measure this information, the information can be sent to the locator unit **10**, and the locator unit **10** can use it in calculating changes in the system delay time.

In addition to the specific embodiments discussed herein, those skilled in the art will realize that transceivers **11** according to the present invention can readily be constructed to have varying sizes and transmission ranges to suit the particular need for which the transceiver **11** will be used.

C. Locator Unit

FIG. 4 illustrates one embodiment of the locator device **10** of the present invention. The housing **40** of the locator device **10** is preferably made of a durable material and is small in size so that the locator device **10** can easily be carried in the hand of the user. The locator unit **10** is typically battery powered. In one embodiment, the locator device **10** includes user controls **41, 42, 43, 44, 45** and a display screen **46**, such as an LCD screen with a backlight. Various display elements **47** and **48** are shown on the display screen **46**. The user controls allow a user to select from the different operational modes of the locator unit **10**, enter data and activate the location function.

Once the user has decided to attach a transceiver **11** to a particular object, the user can use the user controls **41, 42, 43, 44, 45** to enter the address code of the particular transceiver **11** into the memory of the locator unit **10**. In one embodiment, the memory is nonvolatile memory, such as electronically erasable programmable read only memory. The memory unit also can be any conventional memory means, such as non-volatile memory, volatile memory, programmed switches, wire jumpers, and the like.

The user can also enter an alphanumeric name to associate with that transceiver **11** which is easily remembered by the user. Once this is done, the user need not remember the device address code but can refer to the transceiver **11** by the alphanumeric name he or she has chosen. The user can scroll through the list of names using the cursor control **43,** once the desired object is selected from the list the user can press the search button **44** to begin the search. For instance, as shown on the display screen **46** in **FIG. 4**, the user has entered the address code "TR56H3" which appears in the serial number column **48**, and has entered the name "Dad's Glasses," which appears in the article name column **47**, to correspond with that particular address code. If the user wishes to search for the glasses, he can scroll down on the screen to select the name "Dad's Glasses" and begin a search by pressing the search button **44**. A search signal will then be sent that includes the corresponding address code, "TR56H3." In one embodiment, the first character of the address code is used to identify the RF channel to which the transceiver **11** has been assigned. This character is not transmitted to the transceiver **11**, but is used by the locator unit **10** to tune its transmitter **61** and receiver **62** frequencies to match the channel assignments of the selected transceiver **11**.

In one embodiment, the initial signal transmitted by the locator unit **10** has a frequency from 926 MHz to 928 MHz. In one embodiment, these frequencies are in 81 channels spaced at 25 KHz. Those skilled in the art will realize that higher or lower frequencies, different numbers of channels, and different channel spacing may be used. When the user directs the locator unit **10** to search for a specified transceiver **11**, the locator unit **10** will transmit a search signal on the channel on which the specified transceiver **11** is operating.

In one embodiment, the transceiver **11** will transmit a response signal that has a frequency from 902 MHz to 904 MHz. In one embodiment, these frequencies are in 81 channels spaced at 25 KHz. Those skilled in the art will realize that higher or lower frequencies, different numbers of channels, and different channel spacing may be used. Frequency plans for one embodiment of the present inventions are shown in table 1. Specifically, table 2 illustrates the frequency values for the first ten channels of this embodiment.

Channel #	Locator Unit Transmit Frequency (MHz)	Transceiver Transmit Frequency (MHz)
1	902.000	926.000
2	902.025	926.025
3	902.050	926.050
4	902.075	926.075
5	902.100	926.100
6	902.125	926.125
7	902.150	926.150
8	902.175	926.175
9	902.200	926.200
10	902.225	926.225

Table 1

Thus, if the transceiver **11** to be located was tuned to channel 1, the locator unit **10** would transmit a search signal at 902.000 MHz. The transceiver **11** would transmit a response signal at 926.000 MHz.

FIG. 5 illustrates the locator device **10** with the display screen **46** displaying the search mode screen. This screen is displayed once the user has initiated a search for a particular object. An object display element **50** verifies the name of the selected object. The range display element **51** indicates the distance from the locator's position to the transceiver **11** having the selected address code. A bearing display element **52** indicates the bearing of the signal received from the transceiver **11** having the selected address with respect to a center axis **53** of the locator unit **10**, with a bearing of 0 (zero) degrees indicating that the transceiver **11** having the selected address is directly in front of the locator unit **10** when the locator is held so that the top surface is parallel to the ground. Directional display element **54** provides a graphical representation of the bearing of the signal received from the transceiver **11** having the selected address. It will be readily apparent that other information useful to the user can also be displayed on the screen.

FIG. 6 is a block diagram of one embodiment of the locator unit **10**. The locator unit **10** includes a control unit **60**, which in one embodiment includes a microprocessor. The control unit **60** accepts input from the user input units **41, 42, 43, 44**, and **45**, processes the input, and produces the appropriate display on the display screen **46**. The user can enter the device address codes and the desired alphanumeric names as previously described, and this data will be stored in nonvolatile memory within the control unit. Alternatively, the memory unit can be external to the control unit **60**.

When the user selects a particular transceiver **11** that he or she wishes to locate and directs the locator unit **10** to begin searching, such as by pressing the search input control **44**, the control unit switches the display mode to the form shown in **FIG. 5** and activates a transmitter **61**, which is linked to the control unit **60**. The transmitter **61** then sends a modulated RF locator signal that includes the selected digital address code. In one embodiment, the locator signal has a frequency of approximately 926 MHz, although those skilled in the art will realize that higher and/or lower frequencies can also be used.

The locator signal is repetitively transmitted at intervals as long as the search input control **44** is activated. In one embodiment, the locator signal is transmitted continuously while the user is commanding the locator signal to be sent. In one embodiment, the locator may transmit the locator signal automatically at specified times or at specified intervals without the operator activating the search control **44**. The control unit **60** monitors the output of a direction finding receiver **62** which is connected to antenna array **65**. In one embodiment, a filter **67** may be interposed between the direction finding receiver **62** and the control logic unit **60**. In one embodiment, the filter **67** may be a band pass filter. In one embodiment, the locator unit **10** includes a switch **66** which controls the connection between the antenna array **65** and the transmitter **61**. The switch **66** may be integral with, or coupled to a diplexer. The switch **66** can also control the connection between the antenna array **65** and the receiver **62**.

In one embodiment, the antenna array has one or more antennas. In one embodiment, the antenna array **65** has 3 or more omni-directional antennas equally spaced around a circular path. The antennas can also be used for transmitting locator signals and command signals to the transceivers **11** and receiving digital response data back from the transceivers **11**. In one embodiment, the antennas can also be sued for receiving continuous wave signals or tone modulated signals back from the transceivers **11**. In one embodiment, each of the antennas can be independently switched to the RF receiver or the RF transmitter within the locator unit **10**. One embodiment of the antenna array **65** is shown in **FIGs. 7A** and **7B**. In this embodiment, the antenna array includes at least three antennas **70a**, **70b**, **70c** located along a circular path **71**. Each antenna **70a**, **70b**, **70c** is pivotally mounted to the locator unit **10**. **FIG. 7A** shows the antennas **70a**, **70b**, **70c** extended and in the operative position. When the user is finished using the locator unit **10**, he can then move the antennas **70a**, **70b**, **70c** to the stored position, shown in **FIG. 7B**. Because the antennas are pivotally connected to the locator unit **10**, the user can rotate the antennas such that they are parallel to the edges of the locator unit **10** as shown in **FIG. 7B**. This configuration allows the locator unit **10** to be conveniently stored, such as in the pocket of the user. Additionally, it prevents the antennas **70a**, **70b**, **70c** from being damaged when not in use. The antennas can be, for example, dipole antennas, patch antennas, slot antennas, or printed circuit antennas. Those skilled in the art will realize that many other antennas can also be used.

In the present invention, as is also true in other tracking systems using RF signals, the RF communications between the locator unit **10** and the transceivers **11** are subject to the effects of path fading in both directions. To mitigate these effects, one embodiment of the present invention uses a method to detect and reduce the fading losses for both the transmissions from the locator unit **10** to the transceiver **11** and the reception of the response from the transceiver **11** to the locator unit **10**.

During the polling process, where the locator unit **10** is attempting to establish communication with a selected transceiver **11**, the control unit **60** in the locator unit **10** attempts to establish communications using one of the antennas in the antenna array **65**. If that attempt is unsuccessful, the control unit **60** will select a different antenna in the antenna array **65** and repeat the polling sequence. The locator unit **10** will repeat this

polling operation. Because the individual antennas **70a, 70b, 70c** in the array **65** are on the circumference of the circle **71** which, in one embodiment, is approximately less than 1/3 wavelengths in diameter, at least one of the antennas will be in a favorable RF path position at all times.

In this embodiment, when receiving the RF signal response from the transceiver **11**, the locator unit **10** rapidly switches through the antenna array **65** in a circular fashion, sampling the received signal at each antenna preferably for approximately 1 msec before advancing to the next antenna in the array **65**. During the sampling interval, the relative phase of the received signal is measured to determine the bearing of the selected transceiver **11** with respect to the locator unit **10**. Also during each sampling interval, the control unit **60** reads the output of the wide dynamic range received signal strength (RSSI) circuitry that is within the RF receiver **62**, and stores the results for each antenna in the array **65**. Just before the transceiver's **11** preprogrammed switch from transmitting unmodulated carrier to transmission of the ranging tone and response data, the control unit **60** in the locator unit **10** selects the antenna having the most favorable RF path to the transceiver **11** and switches that antenna to the receiver **62**. This ensures the use of the antenna having the least RF fading and provides the highest signal level to the locator unit's **10** RF receiver **62**.

As previously described, when a transceiver **11** receives a locator signal that contains an address code matching the address code stored in the transceiver **11**, the transceiver **11** sends a response signal. The control unit **60** analyzes the response signal from the transceiver **11** at each of the receiving antennas **65** to determine the angle of arrival of the signal at the locator device **10**. From this information, the control unit **60** determines the distance and relative direction of the transceiver **11**. Those skilled in the art will realize that many standard techniques can be used to determine the relative direction of the transceiver **11** from the locator unit **10**. For instance, the Doppler principle for measuring the bearing of an RF transmission can be used, as taught by U.S. Patent No. 4,041,496 issued to Norris. Other improved methods for determining the distance and relative direction of the transceiver **11** are also discussed herein.

In one embodiment, the locator unit **10** also has a timer **63** that is operable to measure the time interval between the transmission of a control signal and the receipt

of a response signal by the receiver **62**. This time interval between the transmission of a control signal and the receipt of a response signal is equal to the sum of the propagation delay through the transceiver **11** and locator unit **10**, also referred to herein as the system delay, plus the propagation time of the RF signal from the locator device **10** to the selected transceiver **11** device and back. The measured time interval is read from the timer **63** by the control unit **60**, converted to an equivalent distance by subtracting out the system delay, dividing the result by 2 and displaying the calculated range on the display screen **46**.

A standard system delay for the transceiver **11** and locator unit **10** can be entered into the locator unit **10** for use in calculating the range in the manner previously described. However, in practice, the propagation delay of the control signal through an individual transceiver **11** will vary from device to device. Any such variation in the response time of the transceiver **11** will result in an error in the calculation of the distance from the locator unit **10** to the selected transceiver **11**. To minimize this error, in one embodiment

variation in the response time of the transceiver **11** will result in an error in the calculation of the distance from the locator unit **10** to the selected transceiver **11**. To minimize this error, in one embodiment the control unit **60** is further operable to calibrate the propagation delay though a selected transceiver **11** and locator unit **10**. It should be noted that the delays in the locator unit **10** are often no more constant that the delays in various transceivers **11**, and therefore in one embodiment the calibration function calibrates all the variances.

To perform the calibration, the user places a transceiver **11** that he or she wishes to calibrate a known distance from the locator unit **10**, and inputs the distance between the locator unit **10** and the transceiver **11** into the locator unit **10**. The user then activates the calibration mode. Once this mode is activated, a locator signal containing the address code of the selected transceiver **11** is sent by the locator unit **10**. As previously described, the transceiver **11** will receive this signal and send a return signal which will be received by the locator unit **10**. The control unit **60** reads the data from the timer **63** to determine the time elapsed from when the search signal was sent to when the return signal was received. Because the distance between the locator unit **10** and the transceiver **11** is known, the expected time it should take for a signal to travel to and back from the transceiver **11** (assuming a transceiver **11** and locator unit **10** propagation delay of zero) can be calculated. The expected time can then be subtracted from the time actually measured to yield the propagation delay for the selected transceiver **11** and locator unit **10**. This measured system delay time is then stored in the memory of the control unit **60** and associated with the particular transceiver **11**.

When subsequent searches are performed for this transceiver **11**, the control unit **60** will recall the stored system delay time associated with that transceiver **11** and use it when calculating the distance between the locator unit **10** and the transceiver **11**, thereby reducing error in the distance calculation due to delay time variations of the individual transceivers **11** or variations in the delay time of the individual locator unit **10**. If the selected address code does not have a measured delay time stored in the memory, a factory-stored, average delay time will be used in the distance calculation for that device.

Referring again to **FIG. 6**, in one embodiment the locator unit **10** also includes a conflict detection receiver **64** for detecting the presence of transmissions from a second locator unit operating within the RF reception range of the first locator unit. In this embodiment, when the user has initiated a search, the control unit **60** samples the output of the conflict detection receiver **64** prior to activating the transmitter **61**. If a transmission from a second locator device is detected, the control unit **60** will delay activating the transmitter **61** such time as the RF channel is free from interference, *i.e.* until the second locator unit is no longer transmitting a search signal. In one embodiment, the conflict detection receiver **64** can be the same unit as the direction finding receiver **62**. In another embodiment, a transceiver **11** can be placed in the locator unit **10**. The transceiver **11** can be used to detect any search signals being sent by other locator units **10**. This embodiment is further advantageous because it would allow another locator unit **10** to search for the embedded transceiver **11** and thereby find the locator unit **10**.

If two locators within RF signal range of each other are activated at the same time, the interfering signal will be detected and both locator devices will cease transmissions for a randomly selected time interval

in the art as Carrier Sense, Multiple Access/Collision Detect or CSMA/CD. The application of these techniques to RF transmitters sharing a common communication channel is taught by Patterson in U.S. Pat. No. 4,013,959. Using the method described above, any number of locator devices **10** and transceivers **11** of the present invention can be used simultaneously in the same general area without interference thereby overcoming a major limitation found in the prior art.

Additionally, in one embodiment, this situation is further addressed by only activating the receiver **62** for a limited period of time after each locator signal is sent. This helps to minimize the possibility that a return signal from a different transceiver **11** other than the particular one being searched for will be received by the locator unit **10**. When the search function is activated in a locator unit **10**, the transmitter **61** begins sending the selected transceiver **11** address at a standard repetition rate such as, for example, 10 interrogations per second. Each time the locator unit **10** transmits the transceiver **11** address code, a "gate" is opened in the locator's receiver **62** to receive the response. The locator unit **10** is only receptive to transceiver **11** transmissions during the time the receiver is gated "on," that is to say, the locator unit **10** is only receptive to transceiver **11** transmissions during the time the receiver **62** is activated. After the transmission interval, the process is repeated again until the user releases the search button **44**.

Specifically, if a locator signal is sent by the locator unit **10** at time t_0, the receiver **62** is turned on at time t_1, the minimum time it would take for a response from a transceiver **11** to be received by the locator unit **10** after a locator signal was sent at time t_0. The receiver **62** is then turned off at time t_2, the maximum time it would take for a response from a transceiver **11** to be received by the locator unit **10** once a locator signal has been sent at time t_0.

The control unit can also have other advantageous features in addition to those previously discussed. For instance, in one embodiment the control unit can display to the user an electronic compass that is constantly updated. This aids the user in locating an object for which he is searching. To conserve power in the transceiver **11** and to keep the RF channel free for use by other locator units **10** in the area, it is preferable to poll transceivers **11** for range and position information as infrequently as possible. For example, if a range and bearing has been established from the locator

unit **10** to the transceiver **11** and the range indication is several hundred feet, it is unnecessary to poll the transceiver's **11** position again until the user has time to move closer to the transceiver's **11** location.

However, it is seldom possible for the user to move in a straight-line path from his present location to the location of the transceiver **11**. Commonly there are objects in the path that must be circumvented or the user is forced to follow a trail or sidewalk that takes them off of the straight-line path. In these cases the user will invariably change the orientation of the locator unit **10** as they negotiate the best path to the transceiver **11**. This reorientation or rotation of the locator unit **10** may cause a static bearing display to indicate erroneous bearings to the transceiver's **11** location and may be confusing to the user.

To overcome this problem, without resorting to a high polling rate that would compromise other important system goals, an electronic compass can be incorporated into the locator unit **10**. The electronic compass displays the relative bearing to the selected transceiver **11** as an absolute magnetic bearing. Each

To overcome this problem, without resorting to a high polling rate that would compromise other important system goals, an electronic compass can be incorporated into the locator unit **10**. The electronic compass displays the relative bearing to the selected transceiver **11** as an absolute magnetic bearing. Each time the transceiver's **11** location is polled by the locator unit **10**, the output of the internal compass is also read. In this way the relative bearing of the transceiver **11** can be converted to an absolute compass heading from the user's present position.

As the user negotiates the best path to the transceiver's **11** location, the display is updated continuously from the locator unit's internal compass, thus giving the appearance that the transceiver's **11** bearing is being continuously updated as the locator unit **10** is rotated. It will be noted that as the user moves, in one embodiment of the present invention the bearing to the object indicated by the compass heading will become slightly incorrect.

For example, if after a polling the transceiver **11** and receiving a response, it is determined that the transceiver is in a direction due north of the user, the compass heading will read north. If the user moves to the east, the transceiver **11** will now be located north-west of the user. However, the compass heading will be continually updated to continue to display a northern direction. Thus, the compass heading will not be pointing to the exact location of the transceiver. This is not problematic because the compass heading will be updated to display an accurate directional bearing at the next polling cycle. In the present example, after the next polling event, the compass heading will be updated to show the transceiver is located in a north-west direction. Because the user will move only a limited distance between polling events, the compass will only display a slightly incorrect bearing for a relatively small duration of time as the user moves. Advantageously, the compass will point the user in the general direction of the transceiver. Additionally, the compass will give the appearance to the user that the direction to the transceiver is being continuously updated between polling cycles.

As previously mentioned, periodically, or at the discretion of the operator, the transceiver's **11** range and bearing with respect to the locator unit **10** is re-measured providing fresh data for the range and bearing display and compensating for any movement of the locator unit **10** or transceiver **11** with respect to one another. The relative bearing to the selected transceiver **11** can be displayed by the directional display element **54** of **FIG. 5**.

In one embodiment, the locator unit **10** is further operable to communicate with other locator units. This has a number of advantages. For instance, if a first locator unit searches for and is unable to locate a particular transceiver **11** because of unreliable readings or because the transceiver **11** is out of the search range, the locator unit can communicate with other locator units and direct them to also search for the transceiver **11**. If one of these locator units finds the transceiver **11**, the location of the transceiver **11** can be sent to the first locator unit. This capability may be useful, for example, in a warehouse setting in which dozens of locator units and thousands of transceivers **11** are being used.

As shown in **FIG. 8**, a first locator unit **80** is attempting to locate a transceiver **81**. However, the transceiver **81** is located outside a search rage **82** of the first locator unit **80**. The first locator unit **80** can then send a wireless signal to a second locator unit **83**, and request that it conduct a search for the transceiver **81**. Because the transceiver **81** is within a search range **84** of the second locator unit **83**, it can determine the range and bearing of the transceiver **81**.

In order to determine the range and bearing from the first locator unit **80** to the transceiver **81**, it is useful for the first locator unit **80** and second locator unit **83** to determine their range and bearing with respect to each other or with respect to a common point. This can be accomplished, for example, by constructing the locator units such that each locator unit functionally possesses the transceiver **11** of the kind previously described. Assuming the first and second locator units **80, 83** are within search range of each other, the first locator unit **80** can conduct a search for the transceiver contained in the second locator unit **83**, and thereby determine the range and bearing to the second locator unit **83**. Once the first locator unit **80** has obtained the range and bearing from it to the second locator unit **83**, and received from the second locator unit **83** the range and bearing of the transceiver **81** from the second locator unit **83**, the first locator unit **80** can determine the range and bearing of the transceiver **81** from itself.

Alternatively, the first and second locator **80, 83** could determine their location relative to a common point. This can be accomplished, for example, by each locator determining its range and bearing relative to a transceiver **11** that has been placed at a known location.

Locator units **10** can communicate with each other via several methods. In one embodiment, the locator unit **10** can transmit information to another locator unit using the same transmitter **61** it uses to send a locator signal when searching for a transceiver **11**, and can receive information using the same receiver **62** it uses to receive signals from a transceiver **11**. If it is necessary for two or more locator units located an extended distance apart to communicate, each locator unit can be connected to its own wireless modem. For example, the each locator unit **10** can be connected to a Palm Pilot ® or other personal data assistant device that has an attached wireless modem. Furthermore, multiple locator units **10** can be connected through other communication paths. The term "communication path" is intended to include communication medium such as wireless, Ethernet, the internet, and the like. If one locator unit **10** connected to the communication path locates the desired transceiver **11**, it may communicate to the locator unit **10** that initiated the search for the transceiver **11** that the transceiver **11** has been located. This will assist the user in locating the transceiver **11**.

In one embodiment, to ensure that security between locator units is obtained, and to prevent the locator unit **10** from responding to a request from an unauthorized locator unit to perform a search, locator units can be identified by group. In this embodiment, the locator unit only responds to search requests from other locator units in its same groups. This allows a user or supervisor to maintain policies and permissions on a group-wide level.

Multiple transceivers **11** can be tracked in a quick and efficient manner. The user can use the tracking information to determine the location of each transceiver **11** with respect to the user's location, or the

locator unit **10** can automatically compare the measured location with parameters set by the user. For instance, the user can enter a specified distance into the locator unit **10**, and if any of the transceivers **11** selected by the user to be tracked move further than this specified distance from the user, the locator unit **10** will alert the user. This may be desirable, for instance, when a teacher desires to track the students during a field trip.

While it is possible for a locator unit **10** to track a group of transceivers **11** by polling each transceiver **11** in a "round robin" fashion, this method may be undesirably slow for more than just a few transceivers **11** in a group. It may take an undesirable amount of time to poll multiple transceivers **11** in the manner previously described because a transceiver address must be transmitted to each transceiver **11**, and the locator unit **10** must repetitively transmit the transceiver address until the selected transceiver **11** activates its receiver **30**. As a result, it may require several seconds for each transceiver **11** to be tracked. To facilitate the efficient tracking of groups of transceivers **11** by one or more locator units **10**, one embodiment of the present invention allows communications between the locator unit **10** and each transceiver **11** to be streamlined.

As previously discussed, the transceiver **11** preferably contains a real-time clock that allows the transceiver **11** to be activated at times specified by the user. Additionally, as previously discussed, in one embodiment a temporary session ID can also be stored in the transceiver **11**. In one embodiment, the locator unit **10** also includes a real-time clock function at the application software level and has the ability to set the real time clock of individual transceivers **11** over the RF link. The application-level software of the locator unit **10** also preferably includes a database capable of storing and retrieving data pertaining to the total population of transceivers **11** associated with the individual locator unit **10**.

These capabilities can be used to efficiently track a group of transceivers **11** in the following way. The user first identifies the group of transceivers **11** to be tracked by selecting them from the database using any of the search and sort capabilities provided. The user can save a selected group of transceivers **11** and assign a name to the group for later recall. The user can then select alarm conditions which can be compared against the location of each transceiver **11** in the group. For instance, alarm conditions can include: no response received from transceiver **11**, transceiver **11** beyond a specified range, transceiver **11** outside specified range of bearings, change in location (movement) beyond a specified amount, low battery condition of transceiver **11**, or activation of an external switch (i.e. a panic button.). Alarm conditions can be the same or different for each transceiver **11** in the group.

Once the group-tracking mode is activated in the locator unit **10**, the selected transceivers **11** will be automatically assigned a session ID code for this group tracking session. The session ID code is a combination of a unique session identifier and a unique locator unit code such that multiple locator units **10** tracking groups of transceivers **11** within range of each other will assign unique session ID's to the transceivers **11** in their respective groups. Each transceiver **11** in the group will also have its real time clock set to match the one in the locator unit **10**. The locator unit **10** can then assign successive wakeup times to

each transceiver **11** in the group such that each transceiver **11** in the group will activate its receiver in turn to be polled by the locator unit **10**.

Using this method, the locator unit **10** can efficiently communicate with a group of transceivers **11** at predetermined intervals and collect range, bearing and other data from each transceiver **11** to display to the user and/or compare to specified alarm parameters. For example, a group of 30 transceivers **11** can be polled at one minute intervals and compared to the specified alarm conditions of no response or greater than 100 feet distance from the locator unit **10**. By contrast, a group of transceivers **11** which are activating their receivers at unsynchronized 5 second intervals could take as long as 2 ½ minutes to poll with each transceiver **11** in the group waking up 12 times as often and consuming proportionately more power from the internal battery. An added advantage is that each transceiver's receive cycle is significantly shortened by the use of the abbreviated session ID, reducing power consumption and reducing the likelihood of a data transmission error causing a missed response or an erroneous response from a transceiver **11**.

If a transceiver **11** violates a specified alarm condition the system software will notify the locator unit **10** user. If desired, the user can initiate a search for the transceiver **11** by programming the transceiver's wakeup interval to a shorter duration and activating the locator unit's search mode. In one embodiment, the locator unit **10** may also send a command to the transceiver **11** to cause the activation of its signaling device thereby alerting the wearer of the transceiver **11** or others close by that the transceiver **11** has violated a specified alarm condition.

As discussed, in one embodiment the locator unit **10** can instruct the transceiver **11** to turn on at specified times. By avoiding unnecessary wake up cycles in the transceiver **11**, and instead instructing the transceiver **11** to turn on at specified times, the transceiver **11** can communicate more often and at the same total power consumption level. For example, a transceiver **11** that wakes up once every ten seconds but only transmits infrequently uses about the same amount of power as a transceiver **11** that wakes up once every two minutes but transmits each time it wakes up.

Finally, as the previous discussion indicates, in one embodiment the locator unit **10** is operable to send various commands to the transceiver **11**, and the transceiver **11** is operable to send various responses back to the locator unit **10**. A listing of some of the commands are included in Table 2.

Command Function	Data	Response
Locate Transceiver	Tag ID, SAT Tone	Unmodulated Carrier, Tone Loop Back
Set Buzzer On/Off	Duration (1-255) Seconds, 0=Off	Ack/Nak
Set Wakeup Interval	1 to 65,535 seconds	Ack/Nak
Set Wakeup Date	YY:MM:DD 3-byte packed BCD	Ack/Nak
Set Wakeup Time	HH:MM:SS 3-byte packed BCD	
Set Wakeup Duration (Time to wait for data)	1-255 msec, 0=Auto (As fast as possible)	Ack/Nak
Set Tag Secondary ID (In addition to factory address)	16 to 28 bits, 0 clears secondary ID	Ack/Nak
Set Session ID (In addition to factory and secondary addresses)	8 bits, 0 clears session ID	Ack/Nak
Set Session ID Expiration	HH:MM:SS, 0= Active until cleared	Ack/Nak
Set Date	YY:MM:DD 3-byte packed BCD	Ack/Nak
Set Time	HH:MM:SS 3-byte packed BCD	Ack/Nak
Read Battery Status	None	Good/Bad/Nak
Read External Data, Port #	Input Port # (0-3)	Data/Nak
Write External Data, Port #	Output Data, Port # (0-3)	Ack/Nak
Set Transceiver Frequency Channel	Channel # (0-255)	Ack/Nak
Tune Transceiver Receiver Frequency	Value, 0 - 31	Ack/Nak
Tune Transceiver Transmit Frequency	Value, 0 - 31	Ack/Nak
Set Transceiver Unmodulated Response Duration	1-255 msec, 0= On Until Canceled	Ack/Nak
Set Transceiver Tone Loop Through Response Duration	1-255 msec, 0= On Until Canceled	Ack/Nak
Cancel Transceiver Response	None	None
Set Transceiver Transmitter Power Level	Level (1-15), 0 = OFF	Ack/Nak
Restore defaults	None	Ack/Nak

Table 2

In Table 2, "Ack" stands for acknowledge, and "Nak" stands for not acknowledge. In one embodiment, the "locate transceiver" command is the command followed when the locator unit **10** is attempting to find the transceiver **11**. The locator unit **10** sends a locator signal containing an address code, and then sends a single audible tone that is FM modulated. The transceiver **11** initially sends an unmodulated carrier signal, and then enters into loop back mode in which it responds with a modulated FM carrier signal.

In one embodiment, the transceiver **11** is operable to emit an audible tone. This will help the user to locate the transceiver **11**. For instance, once the user is relatively close to the transceiver **11**, the user can direct the transceiver **11** to emit an audible tone to help the user locate the transceiver **11**. In another

embodiment, if the signal strength of the locator signal or the return signal reaches a certain predetermined level, indicating that the locator unit **10** is relatively close to the transceiver **11**, the transceiver **11** can automatically emit an audible tone. This will assist the user in locating the transceiver **11**. In another embodiment, the user can instruct the control unit **10** to direct the transceiver **11** to emit an audible tone. This feature is particularly useful when the user knows the transceiver **11** is close by, such as when the user is searching for the transceiver **11** in the room of a house. The user can direct the transceiver **11** to emit an audible tone, thereby allowing the user to quickly locate the transceiver **11**. Those skilled in the art will realize that the transceiver **11** may include other indicators than the ability to emit an audible tone, such as the ability to activate a light coupled to the transceiver **11**, and the like.

With the "set buzzer on/off" command, the locator unit **10** can instruct the transceiver **11** to emit a tone for a specified duration. In one embodiment, the duration can be from 1-255 seconds, although other time periods may also be used. In one embodiment, the locator unit **10** can also command the transceiver **11** to stop emitting the tone.

As previously discussed, in one embodiment the locator unit **10** can set the time interval between activations of the transceiver **11**. The "set wakeup interval" command allows the locator unit **10** to set the time intervals between activations of the transceiver **11** to be from 1 to 65,535 seconds later, although other time durations may also be used.

In one embodiment, the locator unit **10** may also set the time at which the transceiver **11** will activate. The "set wakeup date" command allows the locator unit **10** to instruct the transceiver **11** to activate on a certain date. The "set wakeup time" command allows the locator unit **10** to instruct the transceiver **11** to activate at a certain time. In one embodiment, the wakeup date and time can each be sent as a 3-byte packed BCD, although other means may be used as well.

In one embodiment, the locator unit **10** can direct the transceiver **11** to stay activated for a specified duration, and wait for a locator signal or other data to be sent from the locator unit **10**. The "set wakeup duration" command allows the locator unit **10** to instruct the transceiver **11** to remain activated for a specified duration. In one embodiment, this duration can be between 1-255 msec, or the transceiver **11** can be set to remain activated for as little time as possible. Other durations may also be used.

In one embodiment, the transceiver **11** may be programmed to store a secondary address code. The secondary address code allows the user to supplement the primary address code assigned to the transceiver **11** (such as a factory assigned address code) with an address code that is more meaningful to the user, like an inventory control number or serial number. The transceiver **11** will respond to both the primary and secondary address codes. The secondary address code can be shorter than the primary stored address code, thereby expediting the rate at which multiple transceivers **11** can be polled. The "set transceiver secondary ID" command allows the locator unit **10** to direct the transceiver **11** to store a secondary address code. In one embodiment, the address codes can be between 16 and 28 bits, although other lengths may also be used. The locator unit **10** can also command the transceiver **11** to erase a stored secondary address code.

In one embodiment, the locator unit **10** can also send the transceiver **11** a session ID. This is useful when a group of transceivers **11** is being tracked during a particular time period, or session. The "set session ID" command allows the locator unit **10** to send the transceiver **11** a session ID that will be stored in the transceiver **11**. In one embodiment, the session ID can be 8 bits, although other data lengths may also be used. The locator unit **10** can also direct the transceiver **11** to erase a stored session ID. In one embodiment, the locator unit **10** can direct the transceiver **11** to erase a session ID at a specified time. If the user only wanted to track a group of transceivers **11** for a specified time, the user can use this command to set the time at which the tracking session will automatically terminate. The "set session ID expiration" allows the locator unit **10** to direct the transceiver **11** to erase a session ID at a specified time. The locator unit **10** can also direct the transceiver **11** to retain the session ID until it has been cleared by the user.

As previously stated, in one embodiment, the transceiver **11** includes a real time clock. In one embodiment, this clock can be set by the locator unit **10**. The "set date" command allows the locator unit **10** to send the date to the transceiver **11**. The "set time" command allows the control unit **10** to send the time to the transceiver **11**. The real time clock of the transceiver **11** can then be programmed using this information. In one embodiment, the date and time may each be sent as 3-byte packed BCD, although other data lengths may also be used.

In one embodiment, the transceiver **11** includes a battery. In a further embodiment, the transceiver **11** can check the status of the battery, and send the status to the locator unit **10**. The "read battery status" command allows transceiver **11** to send information to the locator unit **10** indicating that its battery level is acceptable, or that the battery power is low.

In one embodiment, the locator unit **10** may be operable to be coupled to an external device, such as a computer. The locator unit **10** can then receive information from the external device, such as transceiver **11** numbers, names, etc. Similarly, in one embodiment the transceiver **11** may also be operable to read and/or write data. The "read external data" command directs the transceiver **11** to receive information at a specified port on the transceiver **11**. For example, as previously stated, the transceiver may include a sensor **34**. The read external data command may be used to command the transceiver **11** to read information from the sensor **34**. In one embodiment, the transceiver **11** may also write data to an external device. The "write external data" command allows the transceiver **11** to write data to the external device through a specified port on the transceiver **11**. As previously discussed, the external device can be an indicator **35**. In one embodiment, the transceiver **11** has three ports, although those skilled in the art will realize that the transceiver **11** may have more or less ports.

In one embodiment, the locator unit **10** may communicate with the transceiver **11** on various frequency channels. This allows the user to switch to a different channel if interference exists on the current channel that is being used. The "set transceiver frequency channel" allows the control unit **10** to direct the transceiver **11** to receive data on a particular frequency channel. In one embodiment, between 0 and 255

channels may be used, although those skilled in the art will realize that more channels may be used if necessary.

In one embodiment, the locator unit **10** may also tune the receiver frequency of the transceiver **11**. This is useful to ensure that the transceiver **11** is properly tuned so that it will receive as strong a signal as possible from the locator unit **10**. The "tune transceiver receiver frequency" command allows the locator unit **10** to tune the receiver frequency of the transceiver **11**. Similarly, in one embodiment, the "tune transceiver transmit frequency" command allows the locator unit **10** to tune the transmitter frequency of the transceiver **11**. In one embodiment, the tuning of the receiver and transmitter may be done between 0 and 31 settings, although other values are possible.

As previously discussed, in one embodiment the transceiver **11** responds with an unmodulated, continuous wave tone once it has received an address code from a locator unit **10** that matches the address code stored in the transceiver **11**. In one embodiment, the locator unit **10** can use a "set transceiver unmodulated response duration" to instruct the transceiver **11** to emit the unmodulated tone for a specified period of time. In one embodiment, the duration can be set for between 1 and 255 msec, although other durations may also be used. In a further embodiment, the locator unit **10** can command the transceiver **11** to continue to emit the unmodulated tone until the locator unit **10** instructs it to stop.

In one embodiment, after the transceiver **11** receives an address code that matches the address code stored in the transceiver **11**, the transceiver **11** sends an unmodulated carrier signal, and then enters into loop back mode in which it sends a modulated FM signal back to the locator unit **10**. The "set transceiver tone loop though response duration" allows the locator unit **10** to direct the transceiver **11** to send the modulated FM signal for a specified duration. In one embodiment, the duration may be between 1 and 255 msec, although other durations may also be used. The locator unit **10** may also direct the transceiver **11** to continue to loop the modulated FM signal until the locator unit directs the transceiver **11** to stop.

In one embodiment, the locator unit **10** can cancel any response that is expected or being received from a transceiver **11**. The "cancel transceiver response" command allows the locator unit **10** to cancel a response from a specified transceiver **11**.

In one embodiment, the locator unit **10** can set the transmitter **33** power level of the transceiver **11**. For example, if the locator unit **10** determines that the transceiver **11** is relatively far away, it can instruct the transceiver **11** to increase its transmitter power so that the locator unit **10** will receive a stronger signal. If the transceiver **11** is relatively close to the locator unit **10**, the locator unit **10** can instruct the transceiver **11** to decrease its transmitter power level, thereby reducing the power consumption of the transceiver **11**. The locator unit **10** can use the "set transceiver transmitter power level" command to accomplish this. In one embodiment, the transmitter **33** of the transceiver **11** has between 1 and 15 power levels. Those skilled in the art will realize that more power levels may also be created. In a further embodiment, the "set transceiver transmitter power level" command may be used to turn off the transmitter **33** of the transceiver **11**.

In one embodiment, the transceiver **11** is provided with certain default settings that are preprogrammed. For instance, the transceiver **11** may be preprogrammed to activate at certain time intervals, and remain active for a specified period of time. If the user changes these settings, the "restore defaults" command can be used to restore the settings in the transceiver **11** to the ones that were originally present before being modified by the user. Similarly, if the user enters certain default values and later changes them, the "restore defaults" commands can be used to restore the values originally entered by the user.

D. Determination of Range and Bearing

The bearing from the locator unit **10** to the transceiver **11** can be determined according to the conventional methods, such as by utilizing well known Doppler techniques. The present invention also contemplates other improved methods for determining the range and bearing of the transceiver **11**.

FIG. 14 is a block diagram of the locator **10** and the transceiver **11** emphasizing elements of the locator **10** and the transceiver **11** that contribute to time delays in the distance measuring function of the locator **10**. For purposes of explanation, and not by way of limitation, in **FIG. 14**, the antenna array **65** is represented by a transmit antenna **165** and a receive antenna **166**. The control logic **60** instructs the transmitter **61** to send a distance measurement signal to the transceiver **11**. A transmitted tone output of the transmitter **61** is provided to a first input of the interval timer **63**. An RF output of the transmitter 61 is provided to the transmit antenna **165**. The transmitter **61** has a time delay d1. The transmit antenna **165** radiates electromagnetic waves to a receive antenna **167**. The path from the antenna **165** to the antenna **167** has a time delay p1. An output of the receive antenna **167** is provided to an input of the receiver **30**. The receiver **30** has a time delay d2. An output of the receiver **30** is provided to control logic and filtering module **32**. The module **32** has a time delay d3. An output of the module **32** is provided to the transmitter **33**. The transmitter **33** has a time delay d4. An output of the transmitter **33** is provided to a transmit antenna **168**. The transmit antenna **168** radiates electromagnetic waves to the receive antenna **166**. The path from the antenna **168** to the antenna **166** has a time delay p2. An output of the receive antenna **166** is provided to an input of the receiver **62**. The receiver **62** has a time delay d5. An output of the receiver **62** is provided to a bandpass filter **67**. A received tone output of the bandpass filter **67** is provided to a second input of the interval timer **63**.

In one embodiment, the range from the locator **10** to the transceiver **11** is calculated by measuring the time delay for a tone to propagate through the transmitter **61**, traverse the distance to the transceiver **11**, propagate through the receiver **30**, propagate through the module **32**, propagate through the transmitter **33**, traverse the distance back to the locator **10**, propagate through the receiver **62**, and propagate through the filter **67**. This total time interval is measured by the interval timer **63**, which compares the phase of the transmitted tone to the phase of the received tone. In one embodiment, the interval timer **63** begins counting a high-frequency reference clock at a zero crossing of the transmitted tone and stops counting at a zero crossing of the received tone.

The total delay time of the audio tone is:

$$total_delay = d1 + p1 + d2 + d3 + d4 + p2 + d5 + d6$$

The delays ($d1$ – $d6$), due to signal processing, are relatively constant and do not vary directly with the distance between the locator **10** and the transceiver **11**. This signal processing delay is treated as a constant and subtracted from the total measured time delay. The RF time-of-flight, represented by p1 and p2, is directly proportional to the distance the signal must travel though the air. The distance from the locator **10** to the transceiver **11** is then found by the equation:

$$distance = c\left(\frac{total_delay - signal_processing_delay}{2}\right)$$

where c is the speed of light in air.

Unfortunately, the round trip RF time-of-flight is typically relatively small when compared to the typical signal processing time. In one embodiment, the signal processing time is on the order of 250 microseconds. However, the time-of-flight is often less than 10 microseconds. In this situation, the measured quantity is about 4% of the total delay. In a more extreme case, where the distance to the transceiver **11** is 50 feet, the time-of-flight of the RF signal would be 100 nanoseconds or about .04% of the total delay. Therefore, a variation in signal processing delay of even .1% would be large with respect to the measured fight time. In some situations, variations with time, temperature, frequency offsets and varying signal levels may well introduce significant errors in the distance measurement.

Typically, the most signal processing delay is caused by the filter elements in the locator **10** and the transceiver **11**. In one embodiment, the receiver **62** is a triple heterodyne receiver with a relatively large delay resulting from the number of stages and filters in such a receiver (a typical triple heterodyne receiver has four or more filters). In one embodiment, the direct-conversion receiver in the transceiver **11** has only one filter element in the RF path. Thus eliminating the signal processing delays in the locator **10** will reduce the signal processing delays in the distance-measurement loop.

In one embodiment, the array **65** is used as a Doppler antenna array to form an RF inferometer to facilitate range measurement. In the case of a Doppler receiver, an array of antennas is used to sample the incoming wavefront at different points in space in a rotating pattern as depicted in **FIG. 9**.

As the antennas **65** are successively switched to the RF receiver **62** by the switch **66**, the phase of the signal will be shifted either positively or negatively depending on the angle of arrival of the incoming wavefront with respect to the array **65**. In the example shown in **FIG. 9**, a switch from antenna **90a** to **90b** will cause a negative shift in phase while a switch from **90c** to **90d** will cause a positive shift in phase. Switching from **90d** to **90a** or from **90b** to **90c** will have little impact on the phase of the signal. These changes in phase can be detected by a standard FM discriminator in the receiver **62**. If an antenna array could be built with an infinite number of antennas, the output of the FM discriminator would be a perfect sine wave with a period equal to the commutation rate (i.e., the switching rate) of the antenna array. This signal is often referred to as the “Doppler Tone”.

The same principles apply to a switched antenna array while transmitting. If the antennas are switched one at a time to a RF transmission source, the resulting RF emissions will be modulated in phase by the commutation of the antennas. **FIG. 16** is a block diagram of the locator **10** and the transceiver **11** emphasizing elements of the locator **10** and the transceiver **11** that contribute to time delays in the distance measuring function of the locator **10**. Unlike **FIG. 14**, **FIG. 16** shows the antenna array **65** and the diplexer switch **66** which controls the connection between the antenna array **65** and the transmitter **61**. The diplexer switch **66** also controls the connection between the antenna array **65** and the receiver **62**. In one embodiment, the transmitter **61** and the receiver **62** operate at different frequencies, thereby allowing full duplex operation. Since the locator **10** includes the RF diplexer **66**, the antenna array can be simultaneously used for transmission and reception in full duplex mode. As shown in **FIG. 16**, the selected transceiver **11** will receive the transmissions from the locator **10** and retransmit the received modulation at the transceiver transmit frequency.

The transmit modulation created by commutating the antenna array in the locator **10** will be received by the transceiver **11** and retransmitted back to the locator **10**, where it will again be modulated by the commutation of the antenna array **65**. The two modulation waveforms are summed in the receiver **62** and processed simultaneously through the various stages and filters in the receiver **62**. The two modulation signals are substantially identical in frequency, since they are both produced by the commutation of the antenna array, but shifted in phase by the external time delay p1+d2+d3+d4+p2. "External time delay" refers to the delay in the system that is external to the locator unit **10**. Note that delays in the locator **10** have been eliminated from the time delay calculation, resulting in a desirable reduction of delay due to signal processing and thereby achieving a corresponding reduction in errors due to variations in those processing delays.

Because the RF response from the transceiver **11** is summed in the receiver **62** with the modulation created by the antenna commutation, it is not possible to measure the delay of the signal through the transceiver **11** by timing the interval between the zero crossings of the two signals. Instead, the receiver **62** is used as an RF inferometer wherein the antenna commutation rate is adjusted until the external time delay produces a 180-degree phase shift between the two signals and the maximum cancellation of the commutation-rate frequency is achieved at the output of the receiver **62**. In one embodiment, the commutation rate is chosen to produce cancellation of the signals for any commutation rate satisfying the formula:

$$External_time_delay = m/2f$$

where *m* is a odd integer (i.e. 1, 3, 5, etc), *f* is the antenna commutation frequency in Hz, and the external time delay is given by p1+d2+d3+d4+p2 (as shown in **FIG. 16**). For example, when the external time delay is 500 microseconds, receiver output nulls will occur at the commutation rates of 1KHz, 3KHz, 5KHz, etc.

To compute the range to the selected transceiver **11**, the signal processing delay though the transceiver **11** must be known. This can be measured by a calibration procedure which involves placing the transceiver **11** at a known distance (*i.e.* relatively close) from the locator **10** and sweeping the commutation

frequency to find the null at the output of the receiver **62**. This calibration procedure allows variations in the transceiver signal processing delay due to component variations or other factors. In one embodiment, the transceiver calibration is done for each transceiver **11**. The signal processing delay for each transceiver is stored according to the transceiver id.

For example, assume a given transceiver **11** has a signal processing delay of 100 microseconds. If this transceiver **11** is placed relatively close to the locator **10** (e.g. within a few feet) and the commutation frequency is increased until a minimum signal level is observed at the receiver's output, then the first null would be observed at a commutation frequency of 5KHz. This is the "zero distance" reference frequency for this transceiver **11**. If the transceiver **11** is then moved to a position 1000 feet from the locator **10**, the total time delay would be 100+p1+p2 microseconds. Assuming an RF propagation velocity of 1 foot per nanosecond, the total flight time (p1+p2) of the signal would equal 2000 nanoseconds or 2 microseconds. Therefore the total delay in this example would be 102 microseconds. This delay would correspond to a first null commutation frequency of approximately 4.902 KHz. This provides a resolution of approximately 10 feet of range for each 1 Hz change in commutation frequency, or 200 ppm frequency deviation per 10 feet of distance change. This resolution is easily achievable with inexpensive components and compares favorably with the cost and complexity of the high-speed time-base and counter used to perform the interval measurement using the previous method.

In one embodiment, given the power constraints dictated by the FCC, a maximum range of operation of approximately one mile is typical. In the example above, this would correspond to a frequency deviation of approximately 480 Hz at the maximum range, or about 10% of the "zero range" commutation frequency. This allows a system design that sweeps the commutation frequency over a relatively small range (e.g. 4.0 KHz to 5.5 KHz) to find the null frequency. This speeds up the range measurement process and reduces false indications that could be caused by detecting secondary nulls in the signal. The lower end of the actual range of frequencies used in the commutation frequency sweep is controlled, at least in part, by the signal processing time delay expected in the transceiver **11**. The bandwidth of the range of frequencies used in the commutation frequency sweep is controlled, at least in part by the maximum allowed distance of the locator **10** and transceiver **11**.

1. Multipath Detection

As shown in **FIG. 9**, in the case of a traditional Doppler receiver, an array of antennas **90a-d**, is used to sample an incoming wavefront **91** at different points in space in a rotating pattern. As the antennas are successively switched to the RF receiver, the phase of the signal will be changed either positively or negatively depending on the approximate angle of arrival of the incoming wavefront with respect to the array. In the example shown in **FIG. 9**, a switch from antenna **90a** to antenna **90b** will cause a negative change in phase while a switch from antenna **90c** to antenna **90d** will cause a positive change in phase. Switching from antenna **90d** to antenna **90a** or from antenna **90b** to antenna **90c** will have little impact on the phase of the signal. These changes in phase can be detected by a standard FM discriminator on a receiver's output. If an

antenna array could be built with an infinite number of antennas, the output of the FM discriminator would be a perfect sine wave with a period equal to the commutation rate of the antenna array. This signal is often referred to as the "Doppler Tone" because it is generally in the audio band and may be heard on the output of the radio receiver. The phase of this output sine wave, relative to the start of the antenna commutation cycle (*i.e.* antenna **90a**), indicates the angle of arrival of the wavefront. In **FIG. 9**, the inflection point where the phase change goes from positive to negative is where the arrow on the circle is shown. So in this example, the phase of the receiver output would be advanced approximately 315 degrees from the antenna **90a** switch point, indicating the angle of arrival of the signal is 45 degrees to the left of antenna **90a**.

Of course, it is not practical to have an infinite number of antennas in the antenna array. Fortunately, the Nyquist Criterion states that only 2 sample points per cycle are needed to reconstruct a sampled sine wave. In one embodiment of the present invention, a minimum of 3 samples per cycle are used to avoid any 180-degree ambiguity in the determination of the angle of arrival of the signal. To reconstruct the sine wave from the discriminator output, the signal is passed through a relatively narrow band pass filter with a center frequency set to the commutation rate of the antenna array. In one embodiment, a switched capacitor filter is employed. A switched capacitor filter has an adjustable center frequency that is controlled by a clock signal at some multiple of the desired center frequency, for instance 100 times the center frequency. This design allows the center frequency of the filter to be precisely matched because the clock source is derived from the same time base as the control circuitry for the commutation of the antennas. In this way, a very narrow band pass filter can be employed, for instance a 10 Hz pass band, without regard to component accuracies or drift causing the Doppler tone to be outside the center frequency of the filter.

Because RF signals may reflect off nearby objects, it is often the case that an RF receiver will receive signals both directly from the transmitter and from the sources of the RF reflections. Such conditions are commonly referred to as "multipath" and are unavoidable in most typical operational environments. In extreme cases the reflected signals are stronger than the direct path signals because RF absorbing materials such as a hill or a building blocks the direct path from the transmitter to the receiver while the reflected path(s) are relatively free of obstructions. Any of these conditions can cause errors in the measurement of the angle of arrival of the RF signal.

FIG. 10 shows the frequency spectrum of a Doppler tone signal when the sources of multipath reflections are absent. The antenna commutation rate used in this test was approximately 500Hz. **FIG. 10** shows that while the odd harmonics of the commutation frequency are quite strong, the even harmonics are more than 20 dB below the level of the fundamental.

FIG. 11 shows the frequency spectrum of a Doppler tone where the receiver was subject to strong multipath interference. In the presence of multipath interference the second harmonic level is greatly increased and in the example shown in **FIG. 11**, is approximately 6 dB above the level of the fundamental. Measurement of the second harmonic of the commutation frequency is useful to the determination of an accurate bearing measurement as opposed to a potentially erroneous one. By measuring the effects of

multipath the system can ignore potentially confusing data and request the operator to relocate the receiver. For instance, if multipath interference is detected, a message would appear on the display screen **46** of the locator unit **10** requesting that the user move the control unit before another search is performed. In many cases, even small movements of the receiver can produce a large difference in the level of multipath interference, in other cases the source of the interference is moving, as in the case of a passing automobile, and the multipath conditions are changing rapidly with time.

One method of measuring the second harmonic level is to include a second band pass filter, as previously described, tuned to the second harmonic frequency and measure the signal level at the output of the filter. Unfortunately, switched capacitor filters or other types of narrow bandwidth filters are expensive components and adding a second filter for this purpose would have a negative impact on the systems cost and complexity.

Recognizing that the frequency of the Doppler tone is controlled by the commutation of the antenna array, the control electronics can position various frequency components of the tone within the band pass of a single filter. By setting the commutation rate to equal the center frequency of the filter, the fundamental frequency of the Doppler tone can be sampled. To check for the presence of multipath interference, the control electronics may reduce the commutation rate to one half the center frequency of the filter thereby allowing the measurement of the second harmonic level. If desired, the commutation rate can be swept over a range of frequencies as the output of the band pass filter is sampled to measure the complete amplitude versus frequency spectrum of the signal, as depicted in **FIGs. 10 and 11**. This can be accomplished without employing a digital signal processor using Fast Fourier Transforms (FFT) or other processor intensive techniques to analyze the signal.

2. Difference of Sines Algorithm

When a Doppler technique is used for measuring bearing, a processing element needs to analyze the output of multiple Doppler antennas. For low power applications, the processing element may not have much compute power. It is therefore important to reduce the computational expense associated with determining the bearing for the multiple antenna outputs.

Conventional processing methods involve the following steps. First, for each antenna in the antenna array: 1) switch to the antenna, 2) extract the sine wave from the antenna output using Fourier analysis or Sine wave fit algorithms, and 3) determine the phase offset of the sine wave relative to the antenna switch timing. Second, determine the bearing from the validated mean phase offset. Unfortunately, Fourier analysis and Sine wave fit algorithms are computationally expensive require floating point processing not available in low power applications.

In one embodiment, the control unit uses a difference of sines algorithm and integer math and table lookups to reduce the computational expense of determining the bearing. In this embodiment, the locator unit **10** has an antenna array consisting of four antennas, designated in **FIG. 12** as **120a, 120b, 120c, 120d**, that

are located in a square array having sides of length *a*. The Doppler carrier signal transmitted from the transceiver **11** to the antenna array has a wavelength, W where W/4 > *a*.

The bearing of the object relative to each antenna can be determined by knowing the values of t_1 and t_2, shown in **FIG. 12**. The antenna closest to the object is determined by detecting a negative going zero-crossing while all the other antennas read positive values. This determines which quadrant in which the transceiver **11** is located. In **FIG. 12**, the transceiver **11** is in the 270-360 degree quadrant. If t_1 is less than t_2 then the bearing can be further narrowed to a 45 degree range. The exact bearing can be determined trigonometrically.

The values of t_1 and t_2 can be determined by measuring the phase difference between the signal received at antenna **120b** and **120d** relative to antenna **120a**. Specifically, the following formulas can be used:

$$t_1 = T_1 - T_0$$

$$t_2 = T_2 - T_0$$

where T_0 is the time of the negative going zero crossing at antenna **120a** while antennas **120b, 120c, and 120c** are all positive, T_1 is the time of the negative going zero crossing at antenna **120b**, and T_2 is the time of the negative going zero crossing at antenna **120d**. **FIG. 13** illustrates the signal levels at zero crossing of antenna **120a**. In actuality, t_1 cannot be measured absolutely because the wavefront travels across the array in less than a nanosecond. Instead sampling the 2 adjacent antennas **120b** and **120d** at known intervals later and computing the times of their zero-crossings determine the phase difference. The following formulas can be used:

$$D1 = c \cdot t_1$$

$$D2 = c \cdot t_2$$

$$D1 = a \cdot \sin(\theta_1)$$

$$D2 = a \cdot \cos(\theta_2)$$

where c is the speed of light.

For objects far away θ_1 and θ_2 are almost equal. The bearing can be determined according to the following formula:

$$\text{ARCSIN}\,(t_1 \cdot c/a).$$

A search of a sine lookup table can compute this. It yields angle 0-90 degrees within the quadrant. Preferably, the sine lookup table could have 90 locations.

For closer objects, the following relation is true:

$$\theta = (\theta_1 + \theta_2)/2$$

The same table can be used for cosine if the resultant offset is subtracted from 90, wherein:

$$\theta = 45 + (\text{ARCSIN}(t_1 \cdot c/a) - \text{ARCSIN}(t_2 \cdot c/a))/2.$$

Therefore, the algorithm preferably has the following steps. First, for each antenna, determine the time, T_n, negative going zero crossing. Second, locate the nearest antenna **120a, 120b, 120c, 120d** with the earliest negative going zero crossing. Third, compute $t_1 = T_1 - T_0$. Fourth, compute, $t_2 = T_1 - T_0$. Fifth, look up

t_1 in the sine table. Sixth, look up t_2 is sine table using 90° offset. Seventh, compute theta. The sine table can be stored in the memory unit of the locator unit **10**, and the algorithm can be executed by the control unit **60** of the locator unit **10**.

The examples given above are provided to illustrate the application of the invention and are not intended to limit the scope of the invention. Various embodiments of the present invention can include different combinations of the described features. The scope of the invention is intended to be defined by the following claims.

THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. An electronic system for locating an item, comprising:

a locator module comprising:

a first memory unit operable to store one or more first address codes;

a user control operable to allow a user to select one of the stored first address codes;

a first transmitter operable to wirelessly transmit a locator signal, wherein the locator signal includes one of the selected first address codes;

a first receiver operable to receive a return signal transmitted by a transceiver module;

an antenna array operably connectable to the first transmitter and the first receiver; and

a first control unit operable to calculate a relative direction of the transceiver module from the locator module, wherein the first control unit is linked to the first memory unit, the user control, the first transmitter, and the first receiver; and

the transceiver module comprising:

a second memory unit operable to store a second address code;

a second receiver operable to receive the locator signal transmitted from the locator module;

a second transmitter operable to wirelessly transmit the return signal;

a second control unit operable to compare the selected first address code transmitted by the locator module with the second address code, and activate the second transmitter to wirelessly transmit the return signal if the two codes are the same, wherein the second control unit is linked to the second memory unit, the second receiver, and the second transmitter; and

a timer linked to the second receiver and the second control unit, the timer operable to activate the second receiver and second control unit at a specified time interval and for a specified time period.

2. The system of Claim **1**, wherein the locator module further comprises a second timer linked to the first control unit, the second timer operable to determine the time between when the locator signal is transmitted to when the return signal is received, and wherein the first control unit operable to calculate a distance of the transceiver module from the locator module.

3. The system of Claim **1**, wherein the locator unit further comprises a real-time clock.

4. The system of Claim **1**, wherein the locator module is configured to:

allow the user to specify a known distance from the locator module to the transceiver module;

use the known distance to determine an expected time period between when a locator signal is sent to the transceiver module to when the return signal should be received by the locator module;

measure an actual time period from when the locator signal is sent to the transceiver module to when the return signal is received by the locator module;

obtain an electronic system delay time by subtracting the actual time period from the expected time period, and

store the electronic system delay time in the first memory unit.

5. The system of Claim **4**, wherein the locator unit further comprises a first sensor operable to measure a first temperature, and the transceiver comprises a second sensor operable to measure a second temperature, and the first and second temperatures are used to calculate the system delay time.

6. The system of Claim **2**, wherein calculating the distance of the transceiver module from the locator module comprises determining a total time elapsed from when the locator signal is sent to when the return signal is received by the locator device, subtracting an electronic system propagation delay time, and dividing by two.

7. The system of Claim **1**, wherein the locator module determines distance to the transceiver module by switching between antennas in the antenna array according to a commutation frequency selected to minimize a tone output from said first receiver.

8. The system of Claim **1**, wherein the locator module determines distance to the transceiver module by switching between antennas in the antenna array according to a commutation frequency selected to minimize a tone output

from said first receiver, wherein said commutation frequency is swept across a desired range of frequencies.

9. The system of Claim **1**, wherein the locator module is configured to measure a phase delay between a tone transmitted to the transceiver module and a tone received from the transceiver module.

10. The system of Claim **1**, wherein the locator module is configured to calibrate to the transceiver module, the locator module configured to:

measure a phase delay between a tone transmitted to the transceiver module and a tone received from the transceiver module when said transceiver module is relatively close to the locator module;

convert the phase delay to a time delay; and

store the system delay time.

11. The system of Claim **1**, wherein the first control unit is further operable to measure and store a signal processing time delay through the electronic system.

12. The system of Claim **1**, wherein said locator module further comprises a switch to operably connect said first receiver to said antenna array.

13. The system of Claim **1**, wherein said locator module further comprises a switch to operably connect said first receiver to said antenna array, and wherein said control unit controls a commutation rate of said switch.

14. The system of Claim **1**, wherein the timer is a real-time clock.

15. The system of Claim **14**, wherein the real time clock is programmable to activate the second receiver at specified times.

16. The system of Claim **14**, wherein the real time clock is operable to be programmed by the locator module.

17. The system of Claim **1**, wherein the locator module further comprises a conflict detection receiver, the conflict detection receiver linked to the first control unit and operable to detect a second locator signal transmitted from a second locator module.

18. The system of Claim **17**, wherein the first control unit is further operable to delay the transmission of the locator signal from the first transmitter unit when the conflict detection receiver detects the second locator signal.

19. The system of Claim **17**, wherein the conflict detection receiver is integral with the first receiver.

20. The system of, Claim **1**, wherein the second memory unit is further operable to at least temporarily store a session identifier.

21. The system of Claim **1**, wherein the transceiver module further comprises a battery, the battery operable to power the second memory unit, the second receiver, the second transmitter, the second timer, and the second control unit.

22. The system of Claim **1**, wherein the transceiver module is powered by radio frequency energy.

23. The system of Claim **1**, wherein the transceiver module further comprises an outer housing.

24. The system of Claim **23**, wherein the outer housing is waterproof

25. The system of Claim **1**, wherein the locator module further comprises a display screen linked to the first control unit.

26. The system of Claim **1**, wherein the antenna array comprises two or more antennas coupled to the locator module and arranged in a circular path.

27. The system of Claim **26**, wherein the two or more antennas are pivotally coupled to the locator module.

28. The system of Claim **27**, wherein there are three or more antennas.

29. The system of Claim **26**, wherein the first control unit is further operable to determine the strength of the return signal received at each of the antennas, and is operable to select the antenna receiving a strongest return signal.

30. The system of Claim **1**, wherein the first receiver is only active for a limited period after the locator signal is sent.

31. The system of Claim **1**, wherein the locator unit further comprises an internal compass unit operable to convert a relative direction of the transceiver module to a magnetic bearing.

32. The system of Claim **1** further comprising a third transmitter operable to send a first signal to a second locator unit, and further comprising a third receiver operable to receive a second signal from a second locator unit.

33. The system of Claim **1**, further comprising one or more additional locator units, wherein the locator unit and the additional locator units are connected by a communication path.

34. The system of Claim **33**, wherein the communication path comprises a computer network.

35. The system of Claim **1**, wherein the antenna array comprises one or more monopole-type antennas.

36. The system of Claim **1**, wherein the antenna array comprises one or more dipole-type antennas.

37. The system of Claim **1**, wherein the antenna array comprises one or more patch-type antennas.

38. The system of Claim **1**, wherein the first transmitter transmits the first address code using frequency shift keying.

39. The system of Claim **1**, wherein the locator module determines bearing to the transceiver module by switching between antennas in the antenna array and using Doppler processing to determine a direction of a wireless signal received from the transceiver module.

40. The system of Claim **1**, wherein the locator module sends commands to said transceiver module.

41. The system of Claim **1**, wherein the transceiver further comprises a sensor linked to the second control unit.

42. The system of Claim **41**, wherein the sensor is operable to measure temperature.

43. The system of Claim **1**, wherein the transceiver further comprises an indicator linked to the second control unit.

44. The system of Claim **1**, wherein the locator signal comprises a spread spectrum signal, an ultra wide band signal, a wideband FM signal, or a CDMA signal.

45. A method for locating an object, the method comprising:

attaching a transceiver to the object, the transceiver comprising:

a first receiver operable to receive a locator signal that contains a first address code;

a first transmitter operable to wirelessly transmit a return signal;

a first control unit operable to compare a second address code stored in a first memory unit with the address code contained in the locator signal, and activate the first transmitter to wirelessly transmit the return signal if the two codes are the same, wherein the first control unit is linked to the first memory unit, the first receiver, and the first transmitter; and

a first timer linked to the first receiver and the first control unit, the first timer operable to activate the first receiver and first control unit at a specified time interval and for a specified time period;

entering and storing the first address code in a locator unit, the locator unit comprising:

a second memory unit operable to store the first address code;

a user control operable to allow a user to input the first address code and select the first address code after it has been entered and stored;

a second transmitter operable to wirelessly transmit the locator signal, wherein the locator signal includes the selected first address code;

a second receiver operable to receive the return signal transmitted by the transceiver module;

one or more antennas linked to the second receiver;

a second control unit operable to calculate a relative direction of the transceiver module from the locator module, wherein the second control unit is linked to the second memory unit, the user control, the second transmitter, and the second receiver;

selecting the first address stored in the locator unit; and

activating the locator unit to wirelessly transmit the first address code to the transceiver, wherein if the transceiver receives the locator signal containing the first address code and verifies that the first address code matches the second address code stored in the transceiver, the return signal is sent from the transceiver to the locator module, and the locator module analyzes the return signal to determine the relative direction of the transceiver.

46. The method of Claim **45**, wherein the locator unit further comprises a second timer operable to determine a time between when the locator signal is transmitted to when the return signal is received, wherein the second timer is

linked to the second control unit, and wherein the second control unit is operable to calculate a distance of the transceiver module from the locator module.

47. The method of Claim **45**, wherein the first timer activates the first receiver and the first control unit for a period of time at regular intervals.

48. The method of Claim **45**, wherein the first timer is a real-time clock, and the user can program the real time clock to activate the first receiver and the first control unit at predetermined times.

49. A system, comprising:

a locator module comprising:

a first radio frequency transmitter operable to transmit a first address code;

a first receiver configured to receive a return signal transmitted by a second transmitter;

an antenna array operably connectable to the first transmitter and the first receiver by a switch; and

a first control unit operable to control the switch, the first control unit operable to determine a bearing of a transceiver module from the control unit; and

the transceiver module comprising:

a second receiver operable to receive the signal transmitted by the first transmitter;

the second transmitter operable to transmit the return signal;

a second control unit operable to compare the first address code transmitted by the locator module with an address code stored in the transceiver module and activate the second transmitter to transmit the return signal if the two codes match; and

a timer operable to activate the second receiver and second control unit at a specified time interval and for a specified time period.

50. The system of Claim **49**, wherein the first control unit is further operable to determine a distance between the locator unit and the transceiver module.

51. The system of Claim **49**, wherein the first control unit is further operable to calibrate and store a signal processing time delay through the transceiver module.

52. The system of Claim **50**, wherein calculating the distance of the transceiver module from the locator module comprises determining a phase delay between a transmitted tone frequency modulated onto a first carrier and a received tone frequency modulated onto a second carrier.

53. The system of Claim **49**, wherein the locator module determines range to the transceiver module by commutating between antennas in the antenna array according to a commutation frequency selected to minimize a tone output from said first receiver.

54. The system of Claim **49**, wherein the locator module determines range to the transceiver module by switching between antennas in the antenna array according to a commutation frequency selected to minimize a tone output

from said first receiver, wherein said commutation frequency is swept across a desired range of frequencies.

55. The system of Claim **49**, wherein the locator module is configured to measure a phase delay between a tone transmitted to the transceiver module and a tone received from the transceiver module.

56. The system of Claim **49**, wherein the locator module is configured to calibrate to the transceiver module, the locator configured to:

measure a phase delay between a tone transmitted to the transceiver module and a tone received from the transceiver module when said transceiver module is relatively close to the locator module;

convert the phase delay to a time delay; and

store the transceiver delay time.

57. The system of Claim **49**, wherein the first control unit controls a commutation rate of said switch.

58. The system of Claim **49**, wherein said first transmitter sends said first address code using frequency shift keying.

59. The system of Claim **49**, wherein the locator module further comprises an internal compass unit operable to convert a relative direction of the transceiver module to a magnetic bearing.

60. The system of Claim **49**, wherein the antenna array comprises two or more antennas coupled to the locator module along an approximately circular path.

61. The system of Claim **49**, wherein the two or more antennas are pivotally coupled to the locator module.

62. The system of Claim **49**, wherein the antenna array comprises one or more monopole-type antennas.

63. The system of Claim **49**, wherein the antenna array comprises one or more dipole-type antennas.

64. The system of Claim **49**, wherein the antenna array comprises one or more patch-type antennas.

65. The system of Claim **49**, wherein the first transmitter transmits the first address code using phase shift keying.

66. The system of Claim **49**, wherein the locator module determines bearing to the transceiver module by commutating between antennas in the antenna array and using Doppler processing to determine a direction of a wireless signal received from the transceiver module.

67. The system of Claim **49**, wherein the locator module sends commands to said transceiver module.

68. The system of Claim **49**, wherein the locator signal comprises a spread spectrum signal, an ultra wide band signal, a wideband FM signal, or a CDMA signal.

69. A system, comprising:

a locator module comprising:

a first radio frequency transmitter operable to transmit a first address code;

a first receiver configured to receive a return signal transmitted by a second transmitter;

an antenna array operably connectable to the first transmitter and the first receiver by a switch; and

a first control unit operable to control the switch, the first control unit operable to determine a distance of a transceiver module from the control unit; and

the transceiver module comprising:

a second receiver operable to receive the signal transmitted by the first transmitter;

the second transmitter operable to wirelessly transmit the return signal;

a second control unit operable to compare the first address code transmitted by the locator module with an address code stored in the transceiver module and activate the second transmitter to wirelessly transmit the return signal if the two codes match; and

a timer operable to activate the second receiver and second control unit at a specified time interval and for a specified time period.

70. A system, comprising:

a locator module comprising:

a first radio frequency transmitter operable to transmit a first address code;

a first receiver configured to receive a return signal transmitted by a second transmitter;

an antenna array operably connectable to the first transmitter and the first receiver by a switch; and

a first control unit operable to control the switch, the first control unit operable to determine a bearing of a transceiver module from the control unit and operable to detect the presence of multipath by examining a second harmonic of a commutation frequency of the antenna array; and

the transceiver module comprising:

a second receiver operable to receive the signal transmitted by the first transmitter;

the second transmitter operable to wirelessly transmit the return signal;

a second control unit operable to compare the first address code transmitted by the locator module with an address code stored in the transceiver module and activate the second transmitter to wirelessly transmit the return signal if the two codes match.

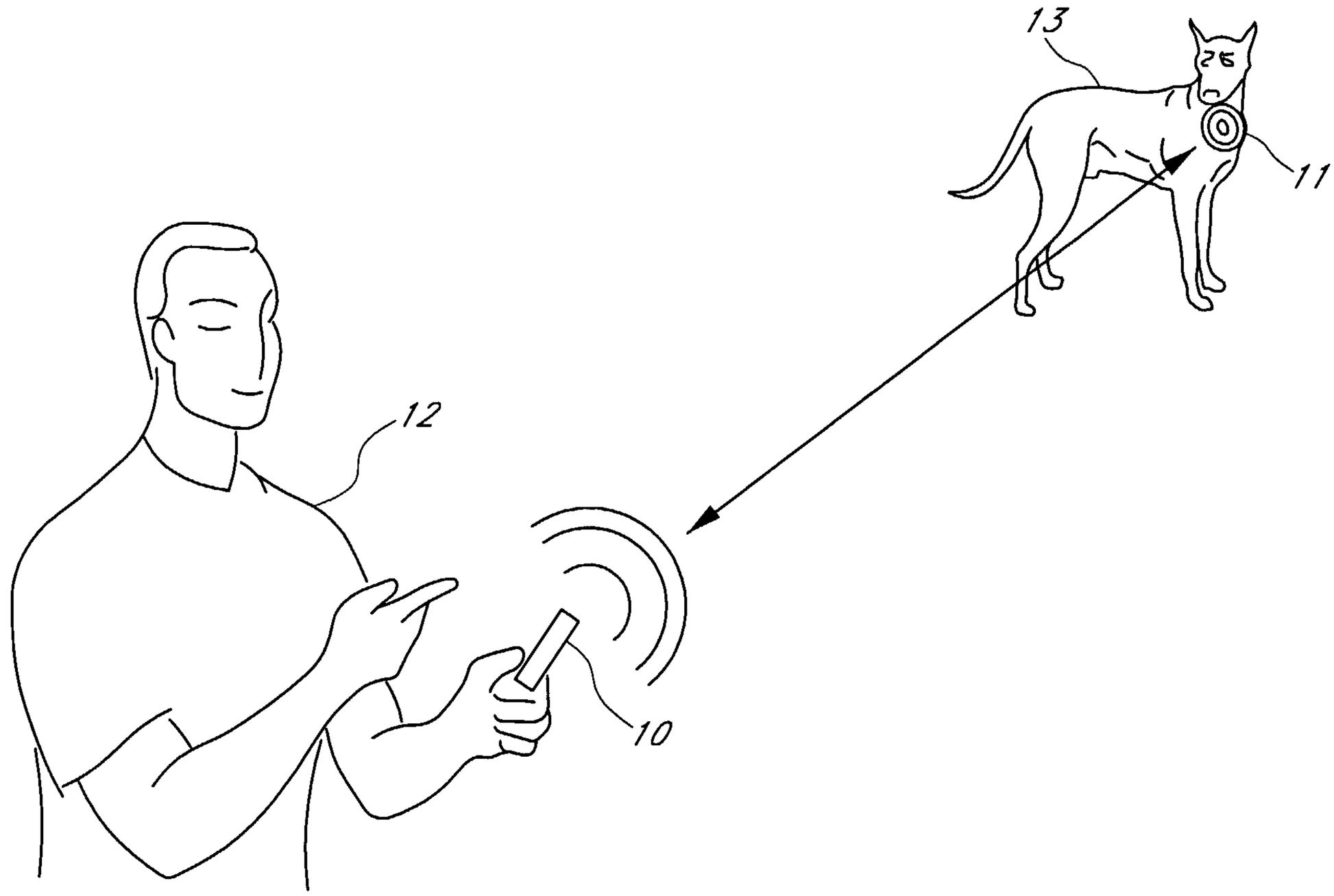


FIG. 1

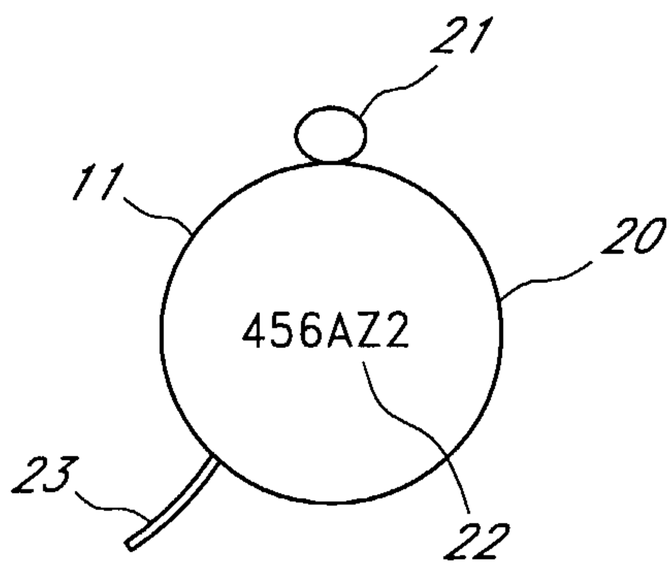


FIG.2

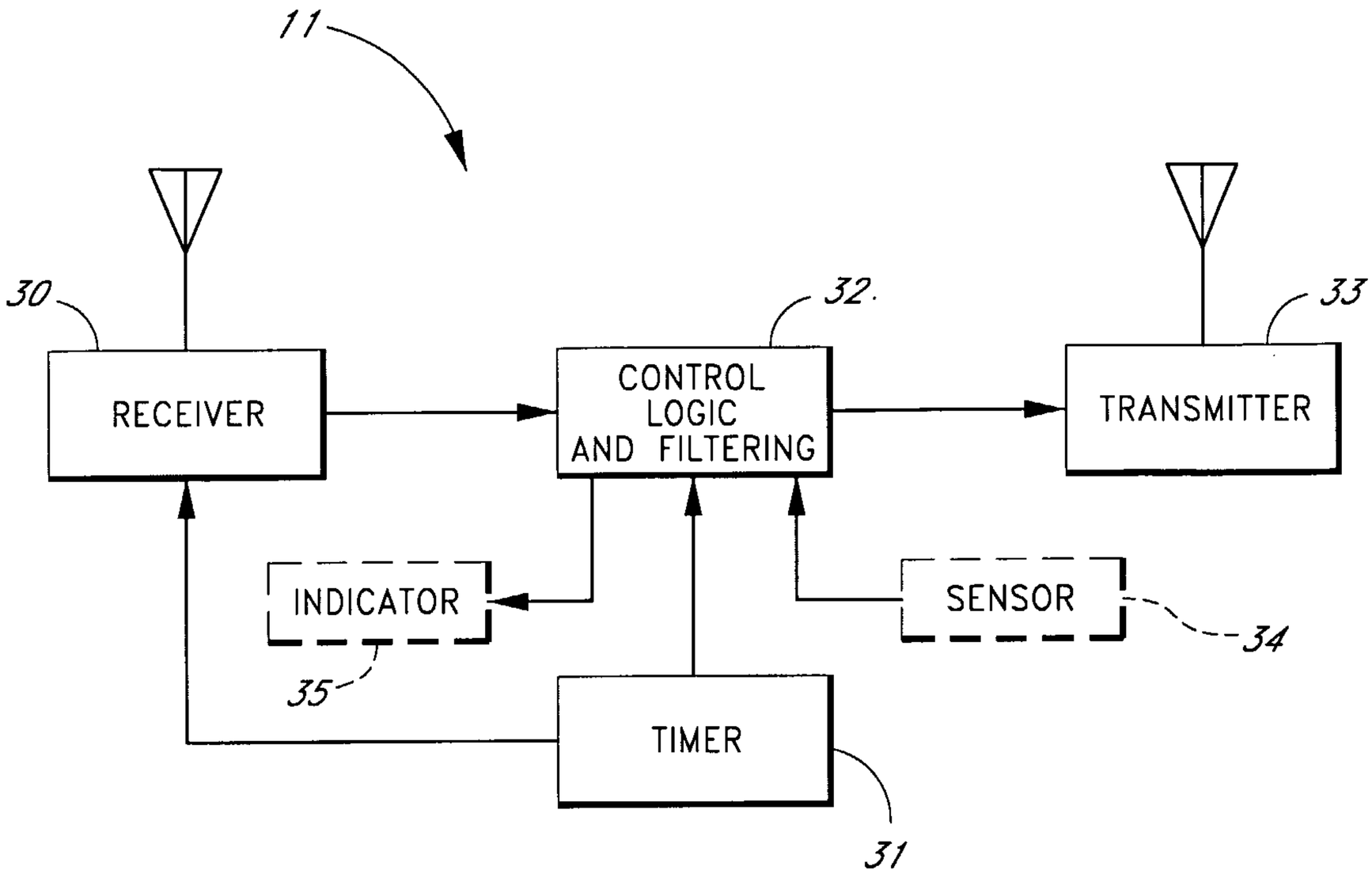

11
30
RECEIVER
32
CONTROL LOGIC AND FILTERING
33
TRANSMITTER
INDICATOR
35
SENSOR
34
TIMER
31

FIG. 3A

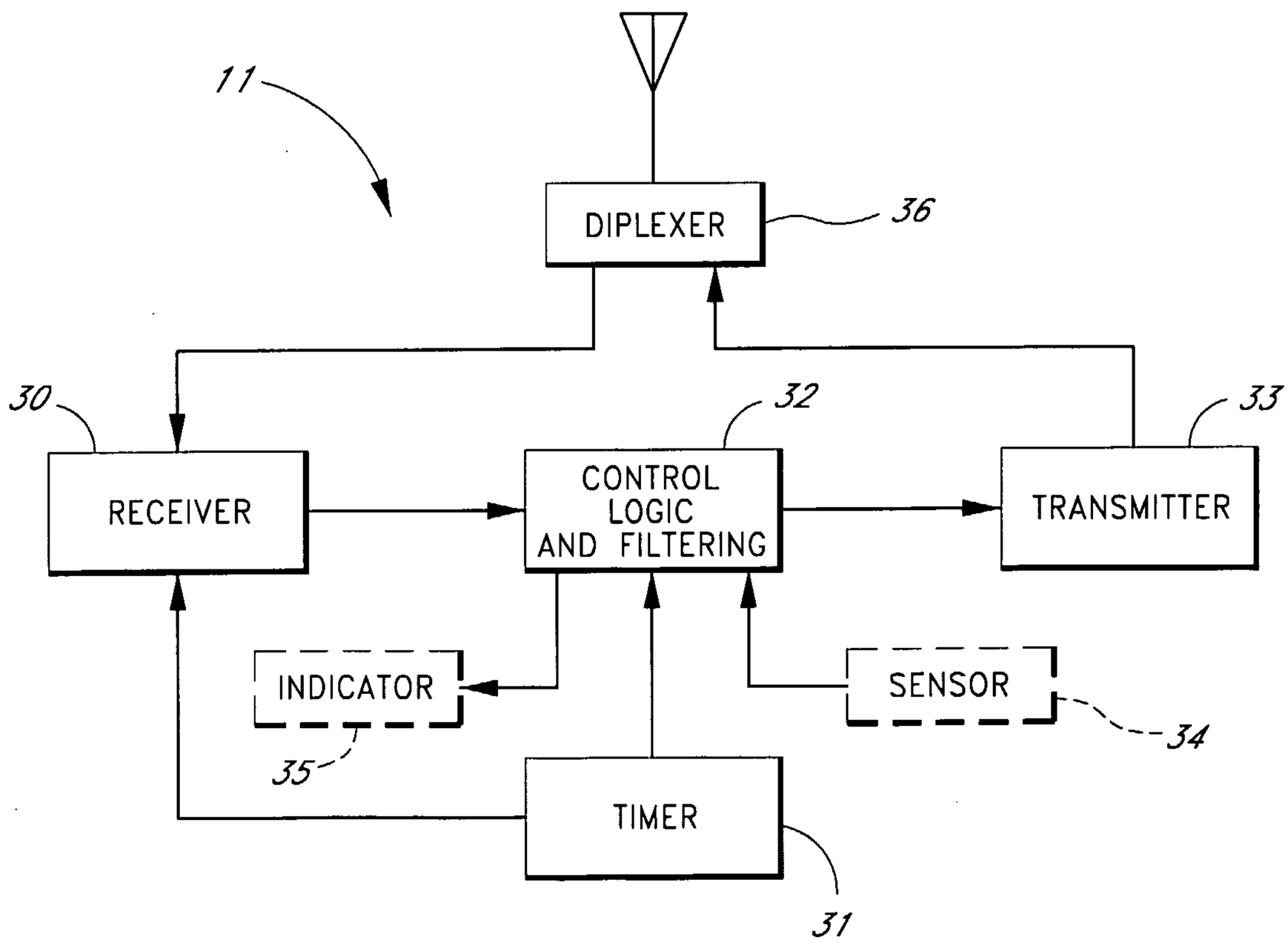

11
DIPLEXER
36
30
RECEIVER
32
CONTROL LOGIC AND FILTERING
33
TRANSMITTER
INDICATOR
35
SENSOR
34
TIMER
31

FIG. 3B

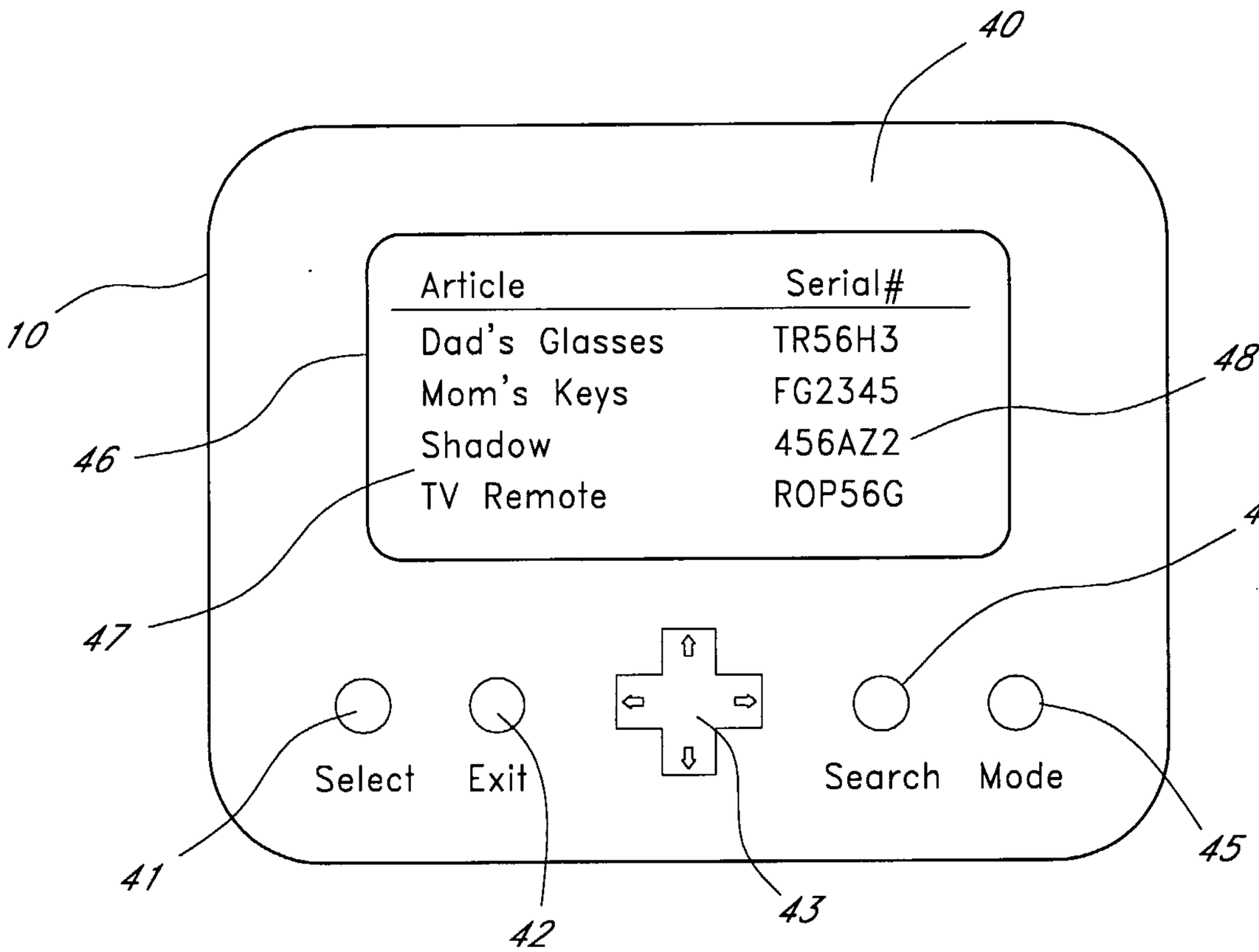

40
10
Article
Serial#
Dad's Glasses
TR56H3
Mom's Keys
FG2345
Shadow
456AZ2
TV Remote
ROP56G
48
46
44
47
Select
Exit
Search
Mode
41
42
43
45

FIG. 4

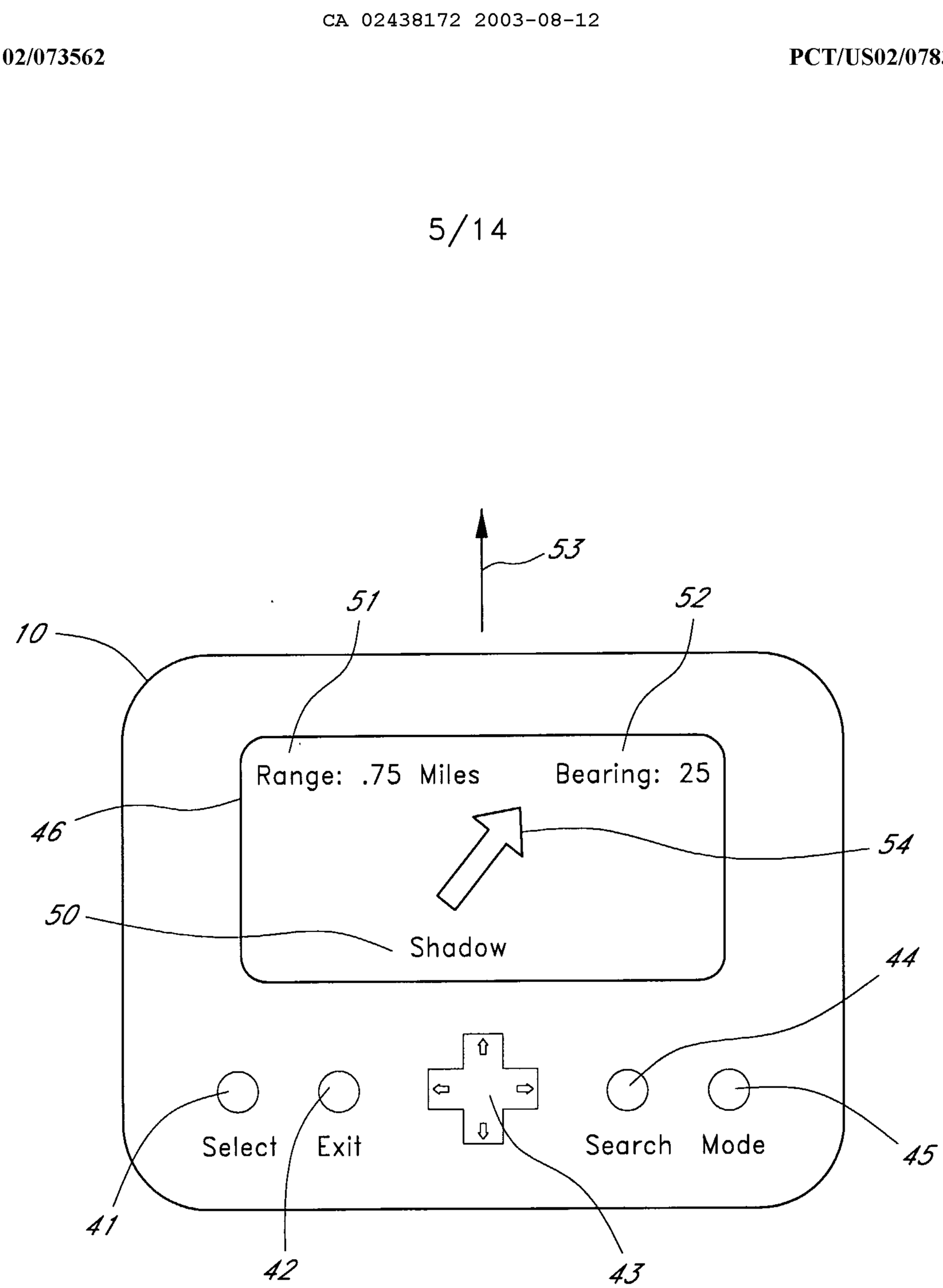

53
51
52
10
Range: .75 Miles
Bearing: 25
46
54
50
Shadow
44
Select
Exit
Search
Mode
45
41
42
43

FIG. 5

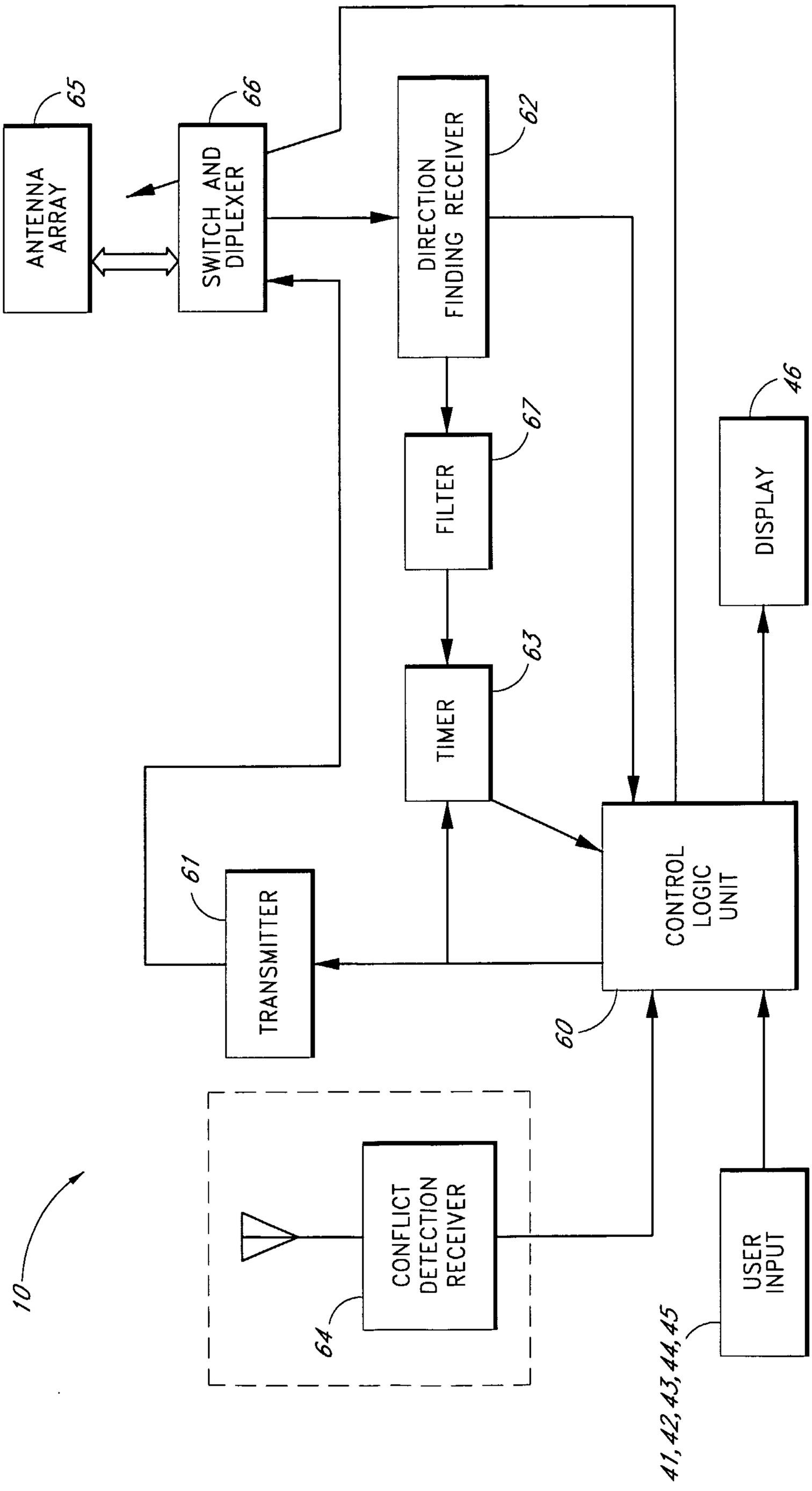

ANTENNA ARRAY
65
SWITCH AND DIPLEXER
66
DIRECTION FINDING RECEIVER
62
FILTER
67
TIMER
63
TRANSMITTER
61
CONTROL LOGIC UNIT
60
DISPLAY
46
CONFLICT DETECTION RECEIVER
64
USER INPUT
41, 42, 43, 44, 45
10

FIG. 6

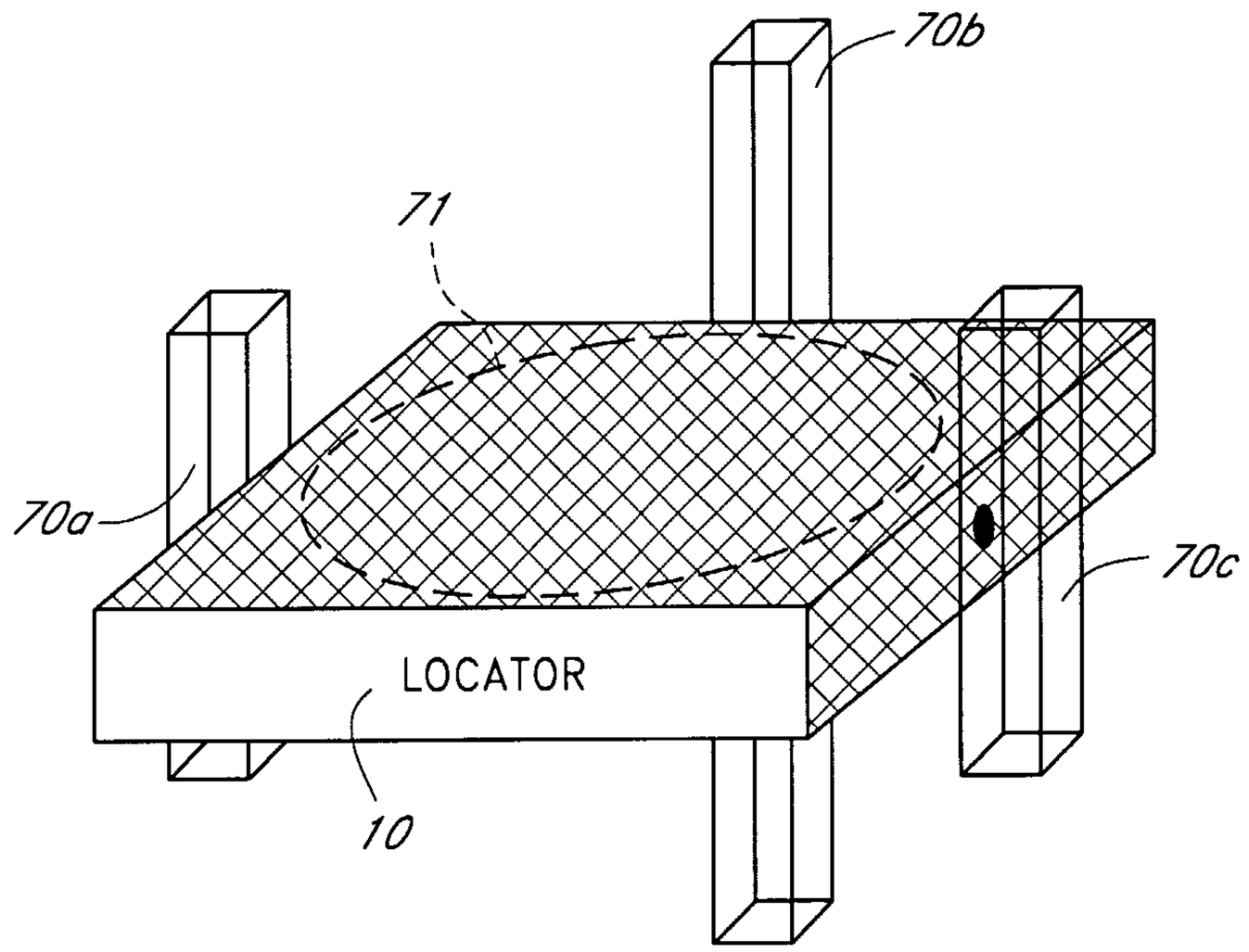


FIG. 7A

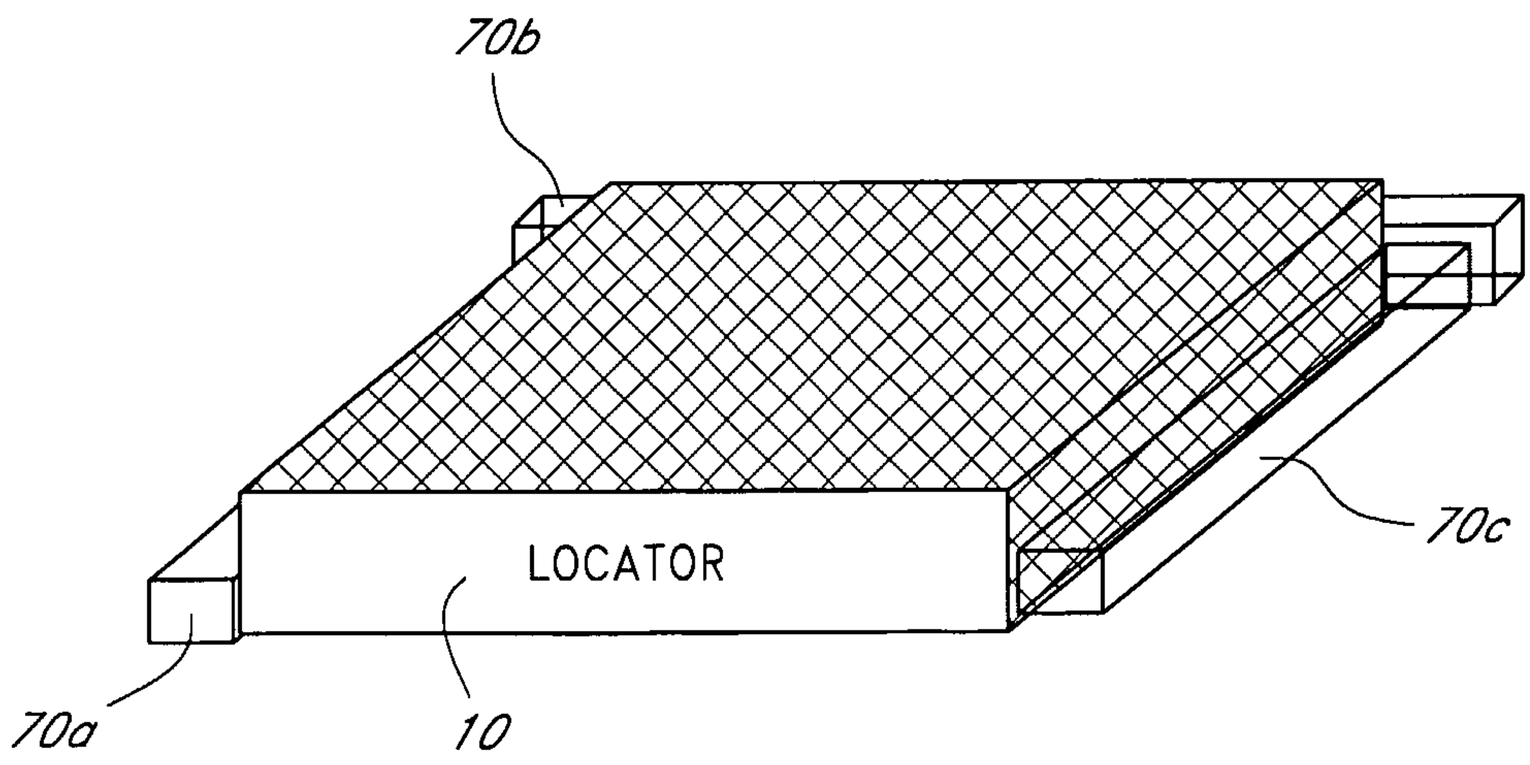


FIG. 7B

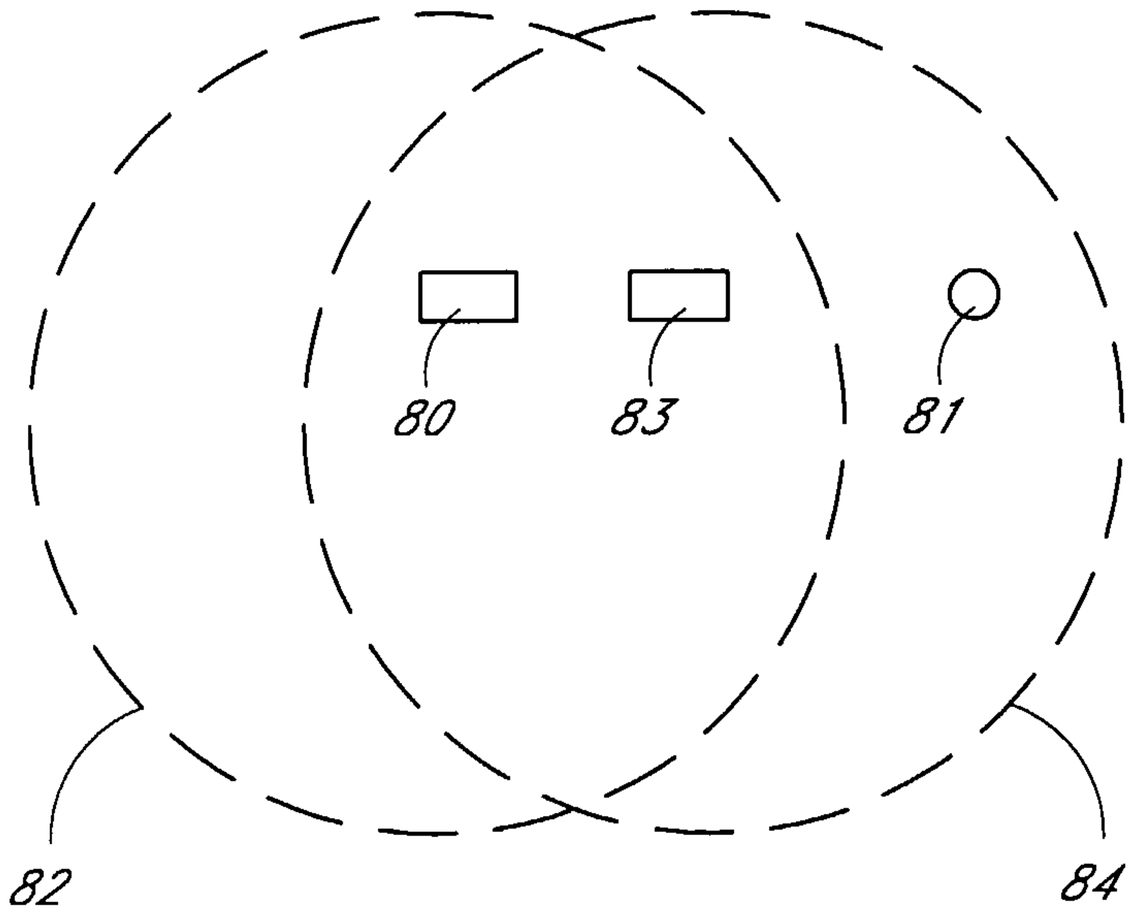


FIG. 8

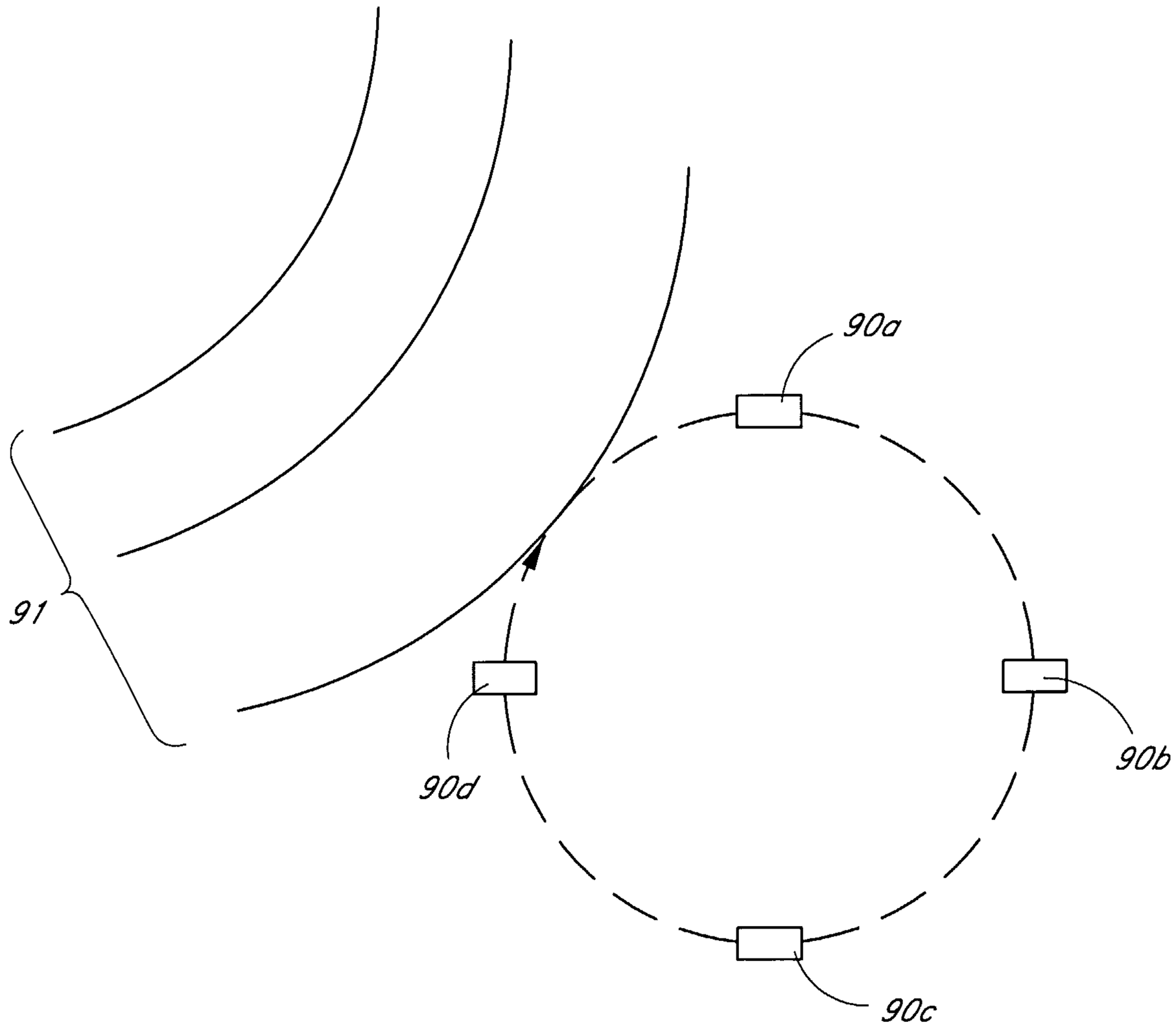


FIG. 9

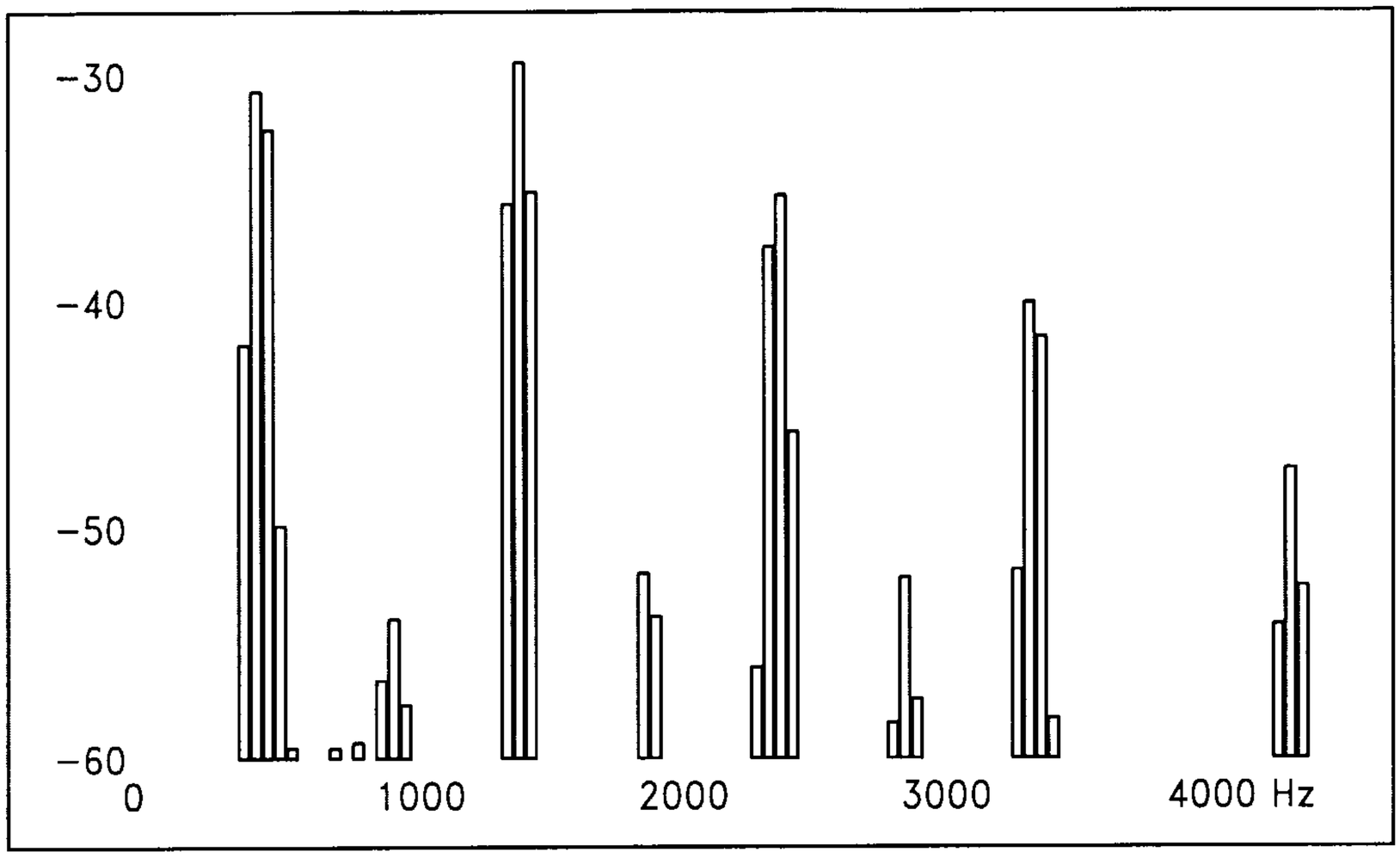

-30
-40
-50
-60
0
1000
2000
3000
4000 Hz

FIG. 10

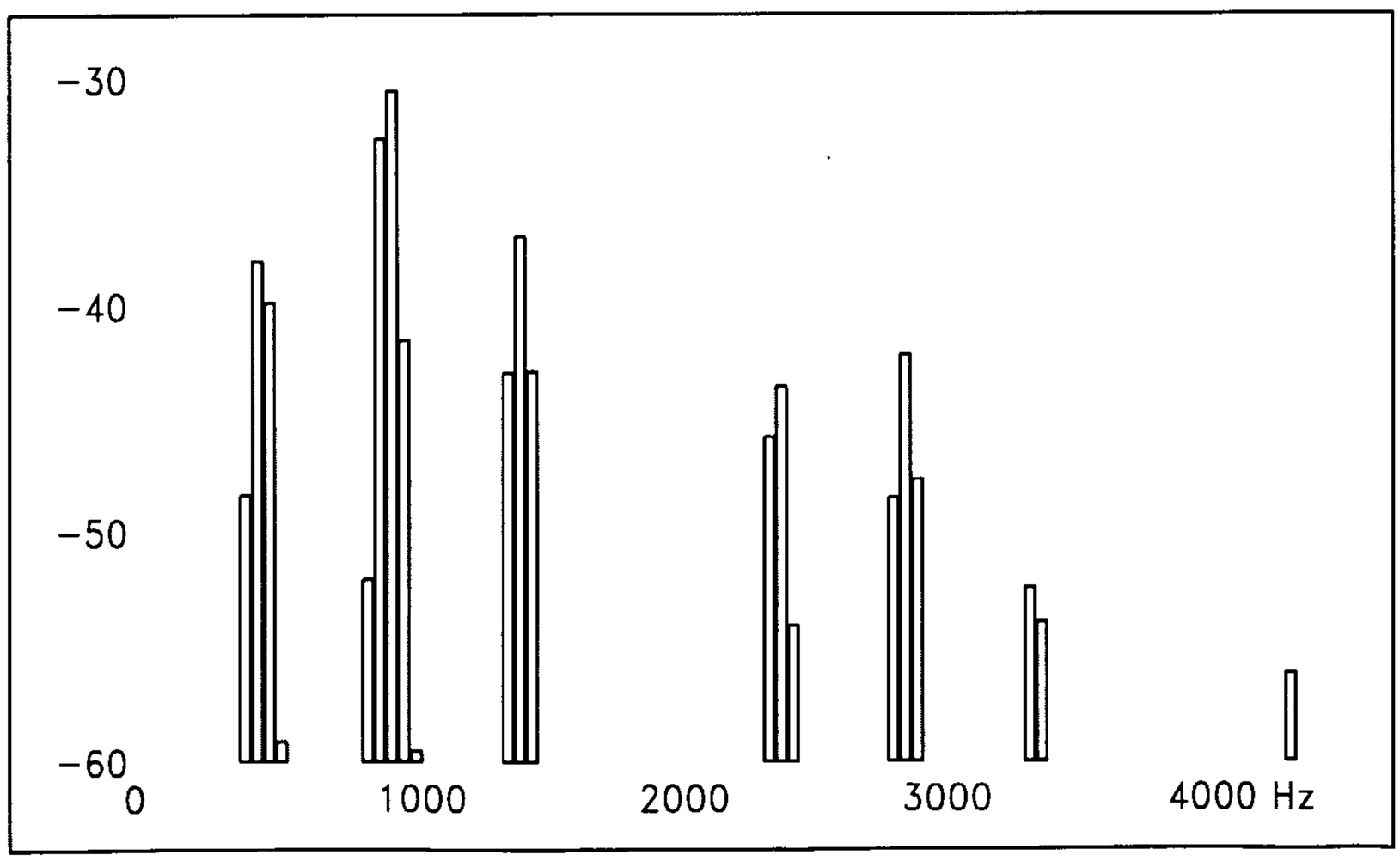

-30
-40
-50
-60
0
1000
2000
3000
4000 Hz

FIG. 11

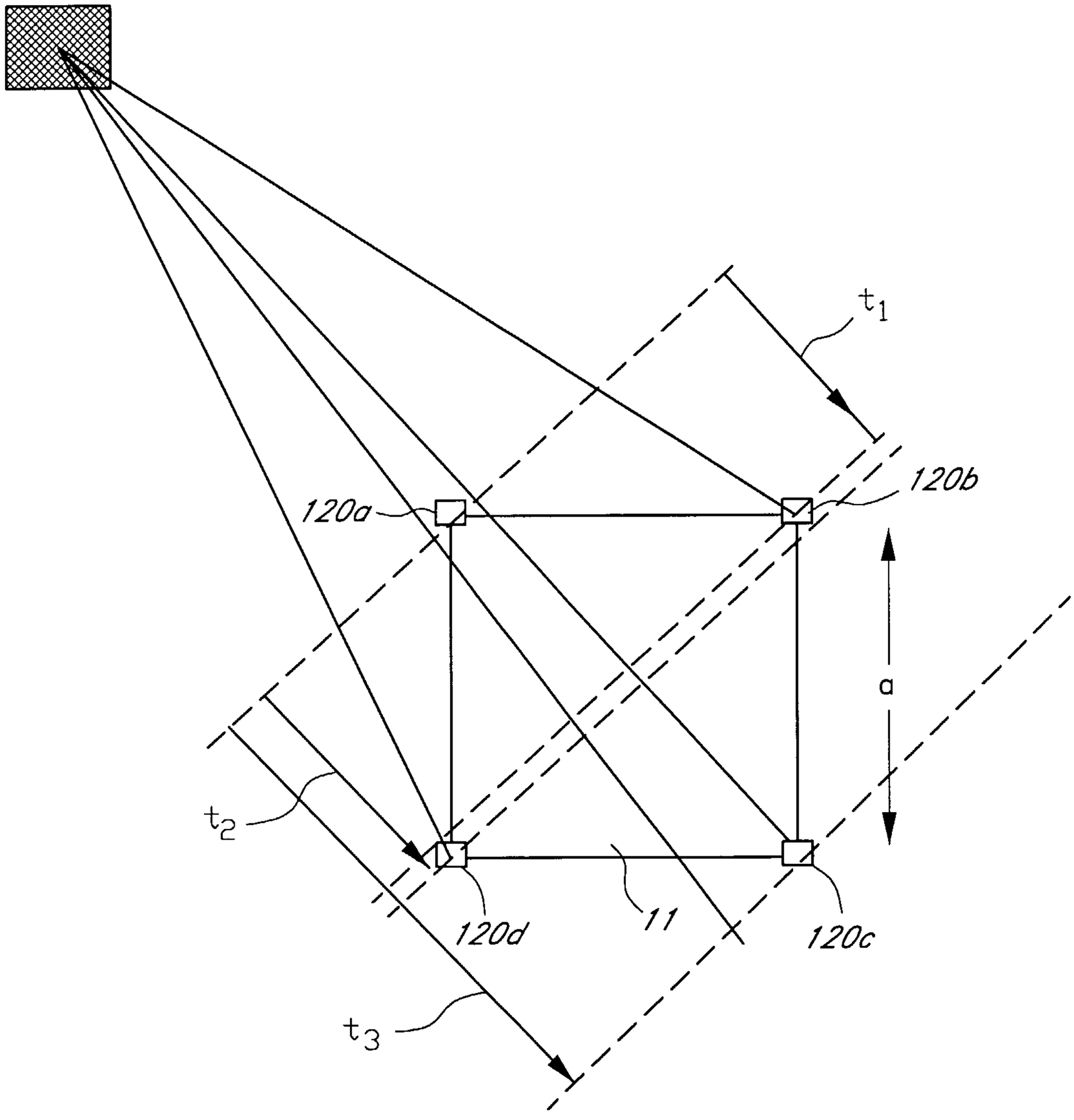


FIG. 12

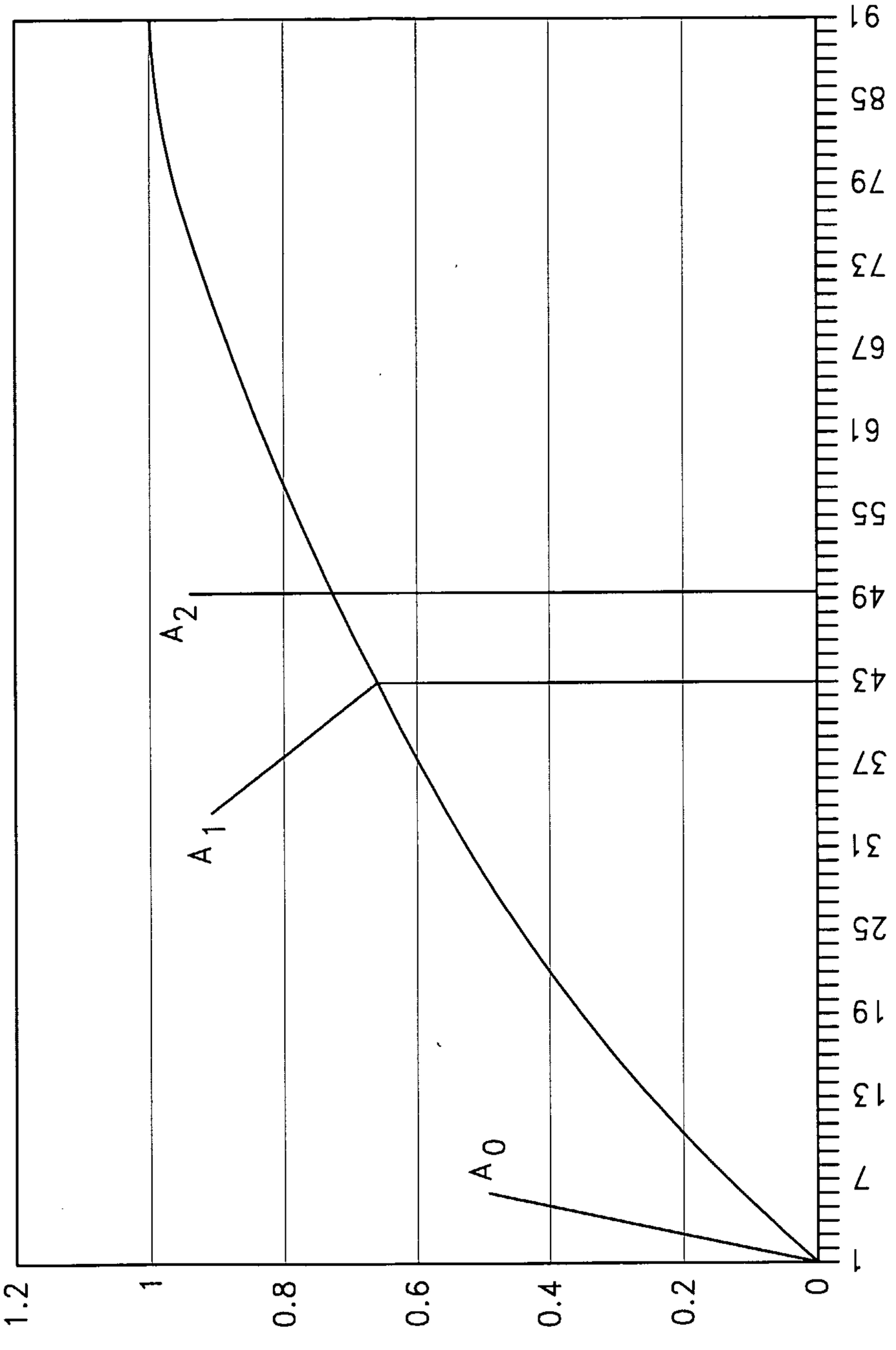


FIG. 13

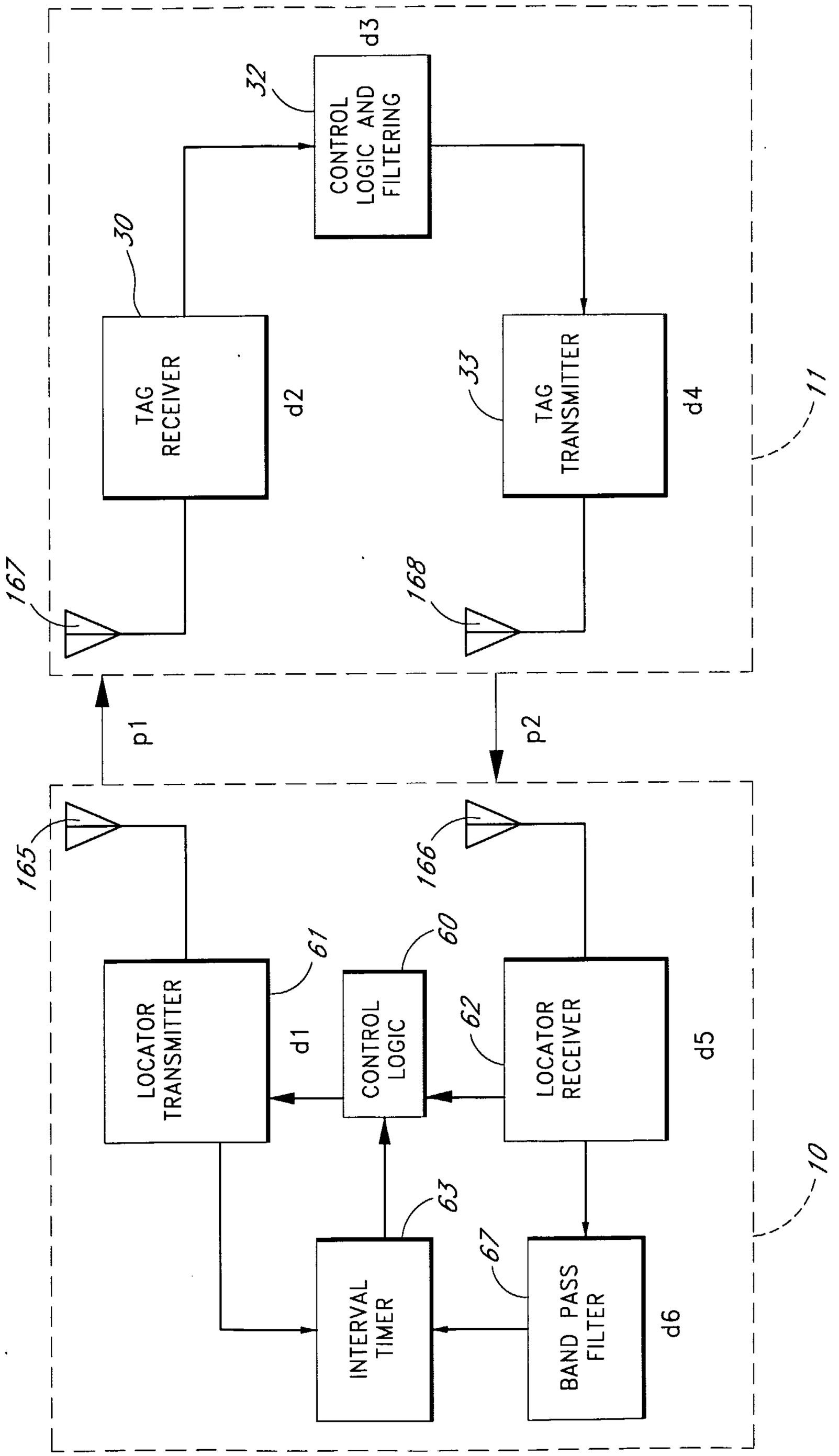

d3
32
CONTROL LOGIC AND FILTERING
30
TAG RECEIVER
d2
33
TAG TRANSMITTER
d4
11
167
168
p1
p2
165
166
LOCATOR TRANSMITTER
61
60
d1
CONTROL LOGIC
62
LOCATOR RECEIVER
d5
10
63
67
INTERVAL TIMER
BAND PASS FILTER
d6

FIG. 14

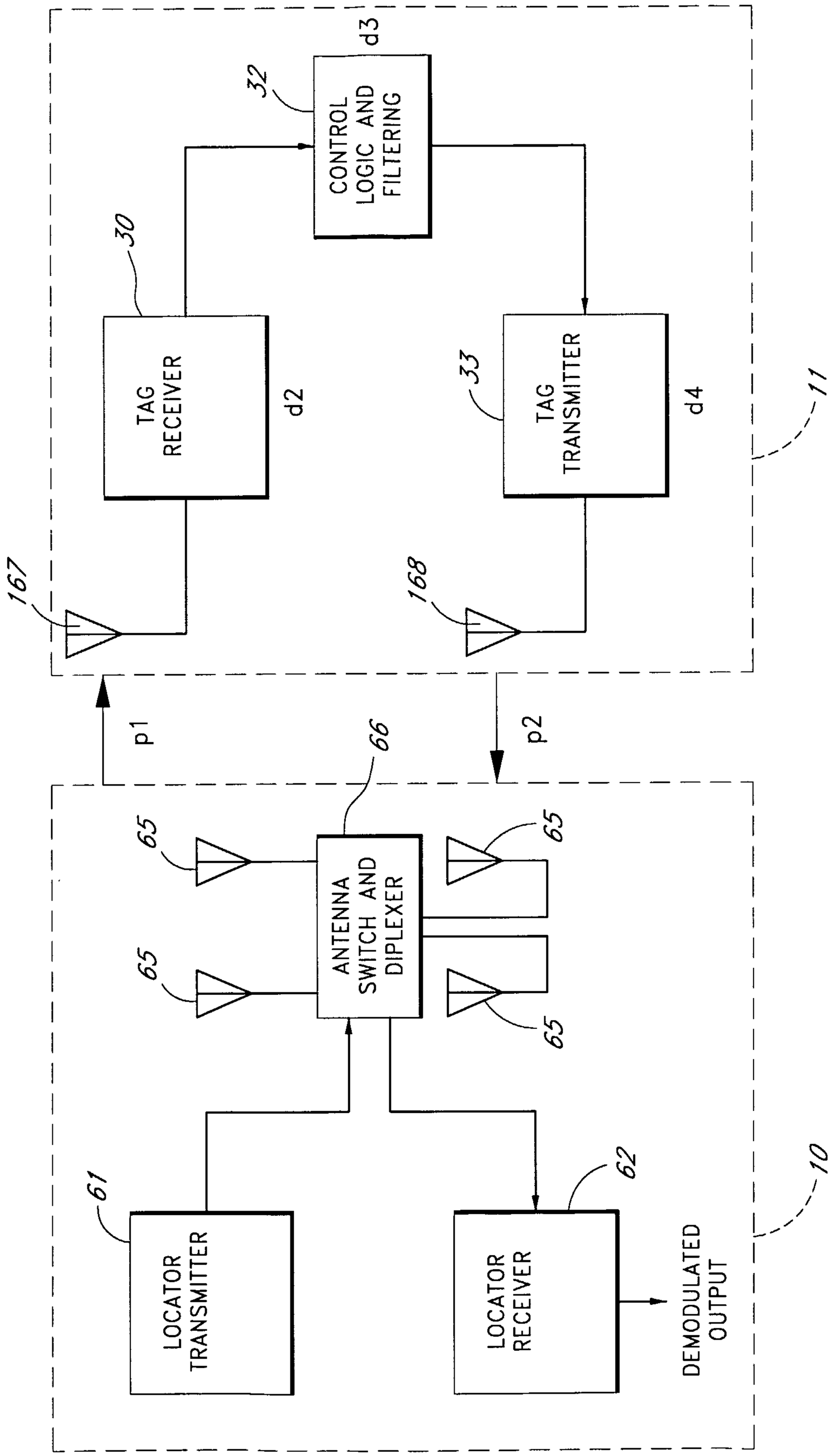
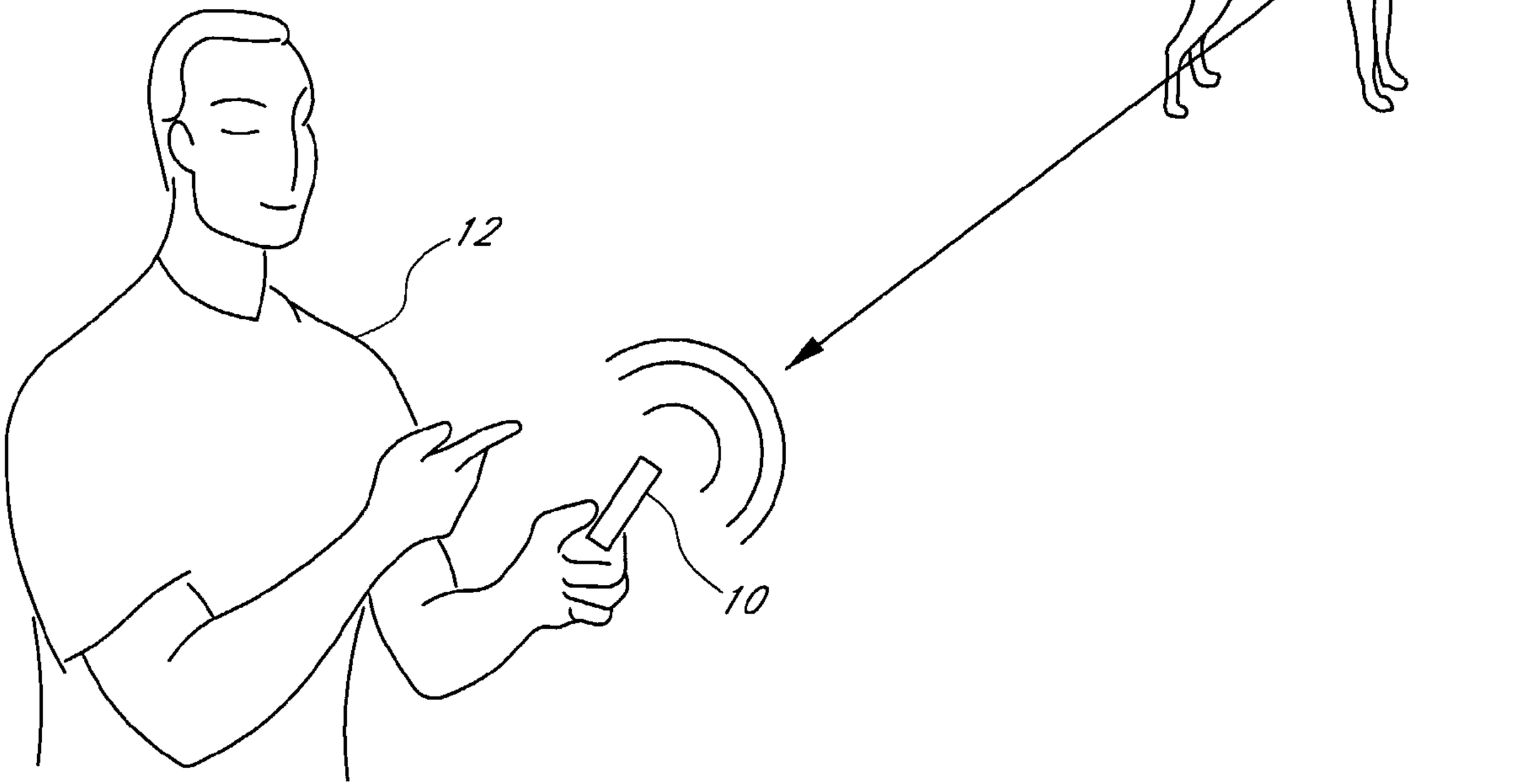

CONTROL LOGIC AND FILTERING
32
d3
TAG RECEIVER
30
d2
TAG TRANSMITTER
33
d4
11
167
168
p1
p2
66
ANTENNA SWITCH AND DIPLEXER
65
65
65
65
LOCATOR TRANSMITTER
61
LOCATOR RECEIVER
62
DEMODULATED OUTPUT
10

FIG. 15


13
26
11
12
10