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(54) METHODS AND APPARATUSES FOR DETECTING AND NEUTRALIZING REMOTELY ACTIVATED EXPLOSIVES

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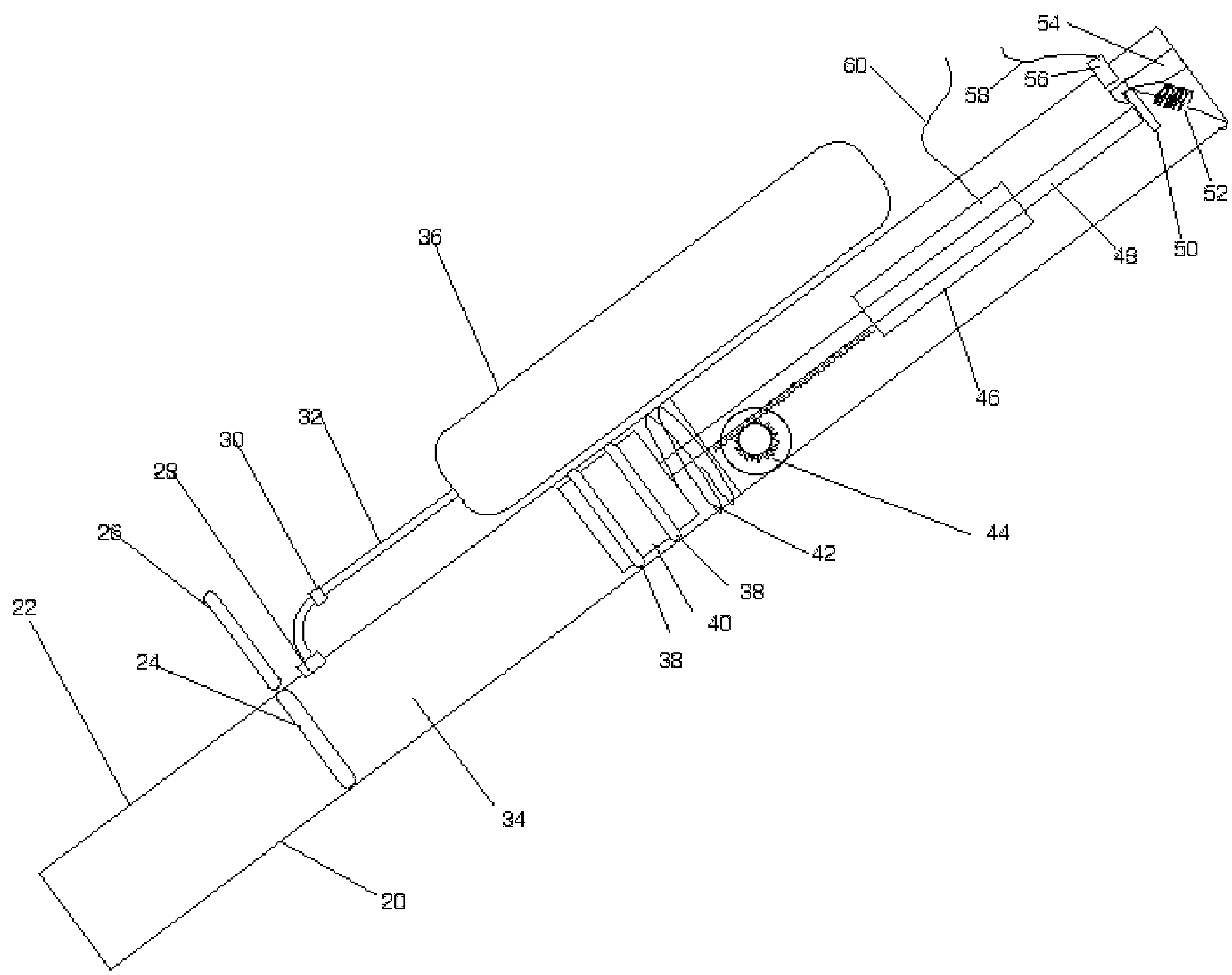
(57) **ABSTRACT**

A system and apparatus for detecting and neutralizing remotely activated explosive devices in a combat zone, especially one of relatively limited geographic area such as an urban setting. The apparatus is configured for mounting on or within an airborne drone and includes both transmitting and receiving circuits and antennas. The apparatus detects radio transmissions by analyzing received signals using standard RF direction finding techniques and a spectrum analyzer or other signal processing circuitry. Signals may be classified as threats using predetermined criteria, and the direction of threat signals may be assessed to allow for a determination of an enemy position from which an explosive is to be detonated. The apparatus also transmits a jamming signal which may serve to detonate devices within the dynamic RF footprint of the transmitting antenna. The drone also includes a highly directional low frequency audio device which is periodically directed randomly and at suspected enemy positions.



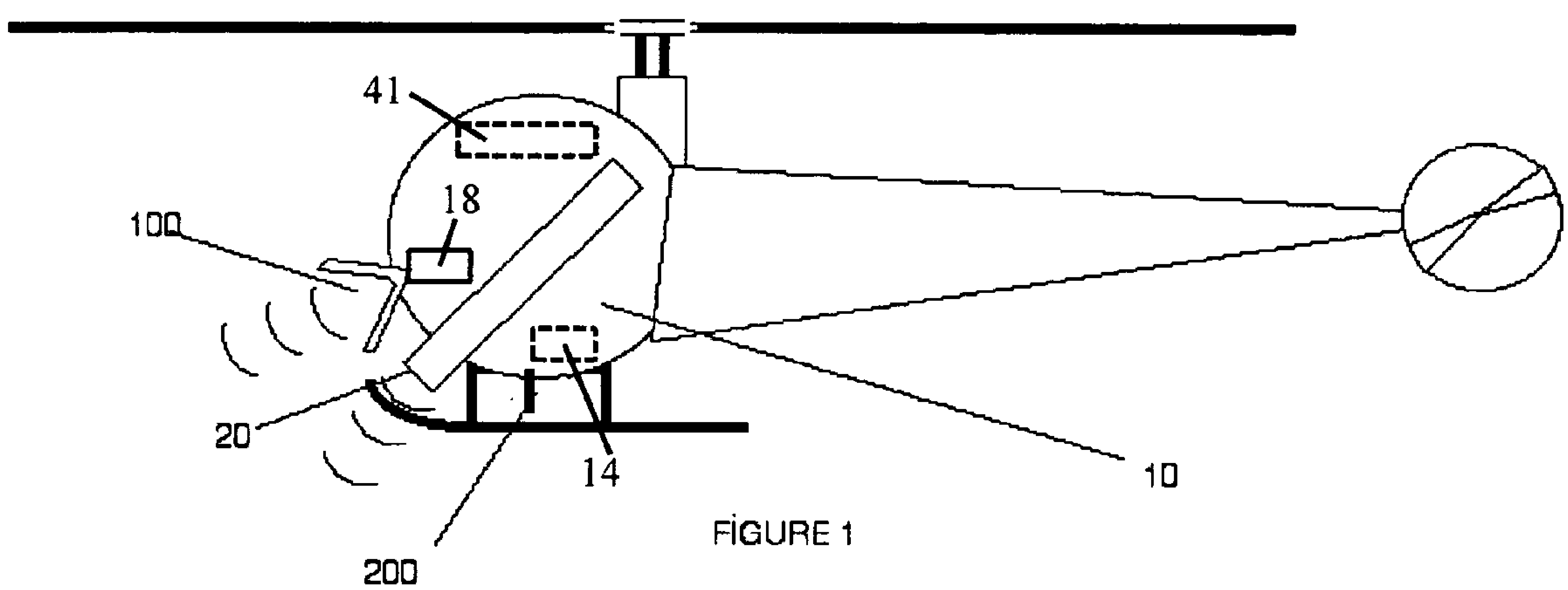


FIGURE 1

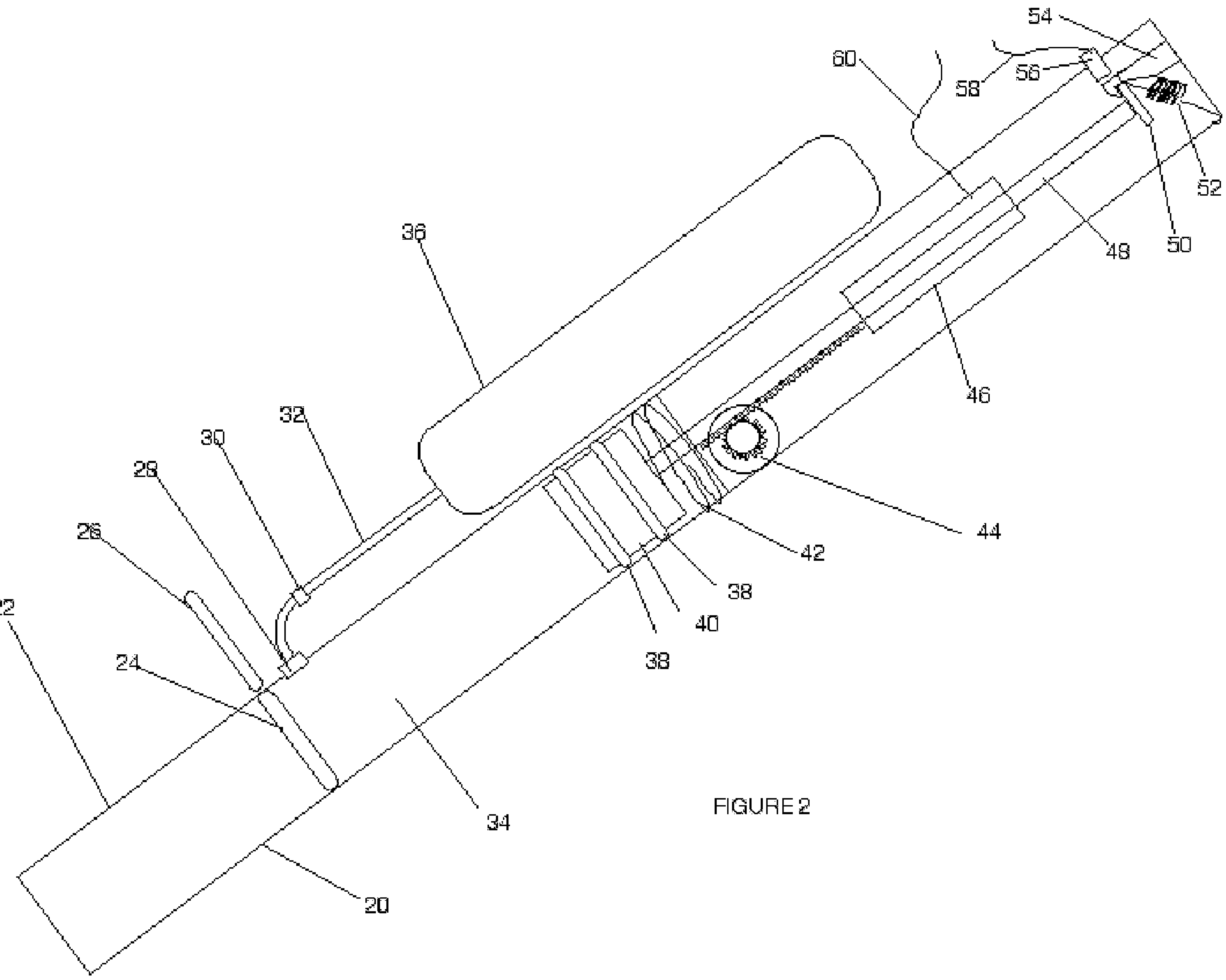


FIGURE 2

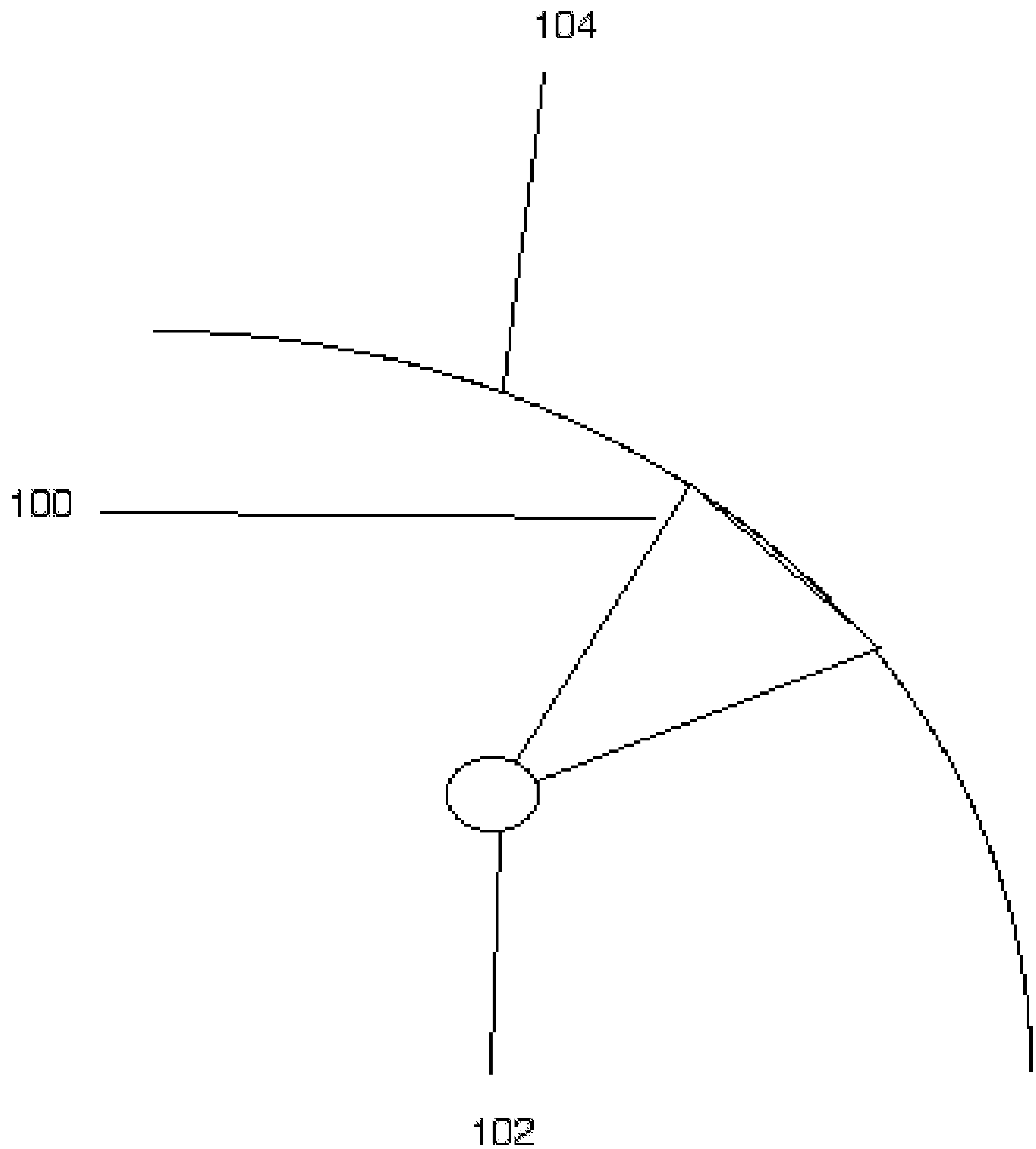


FIGURE 3

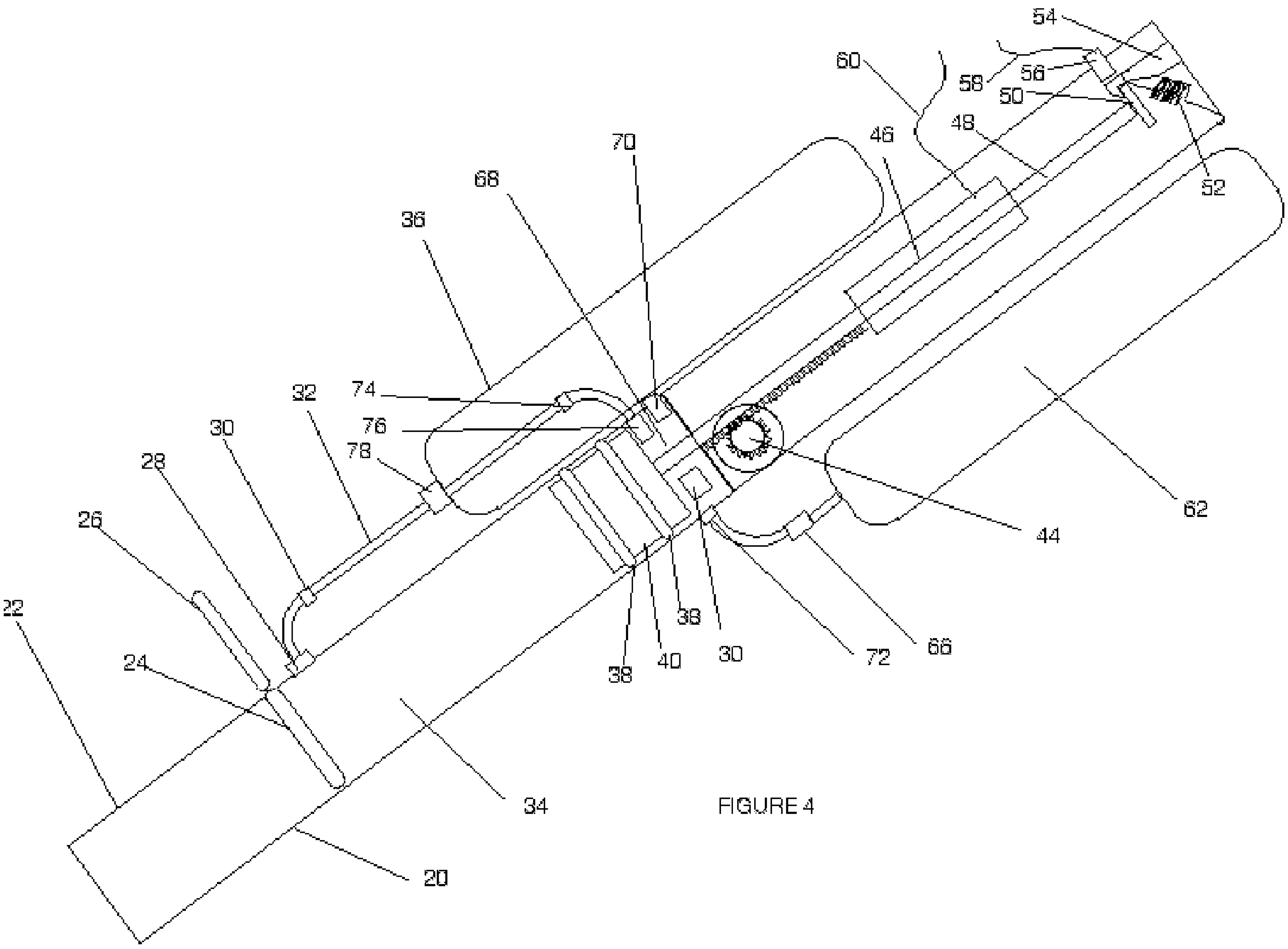

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FIGURE 4

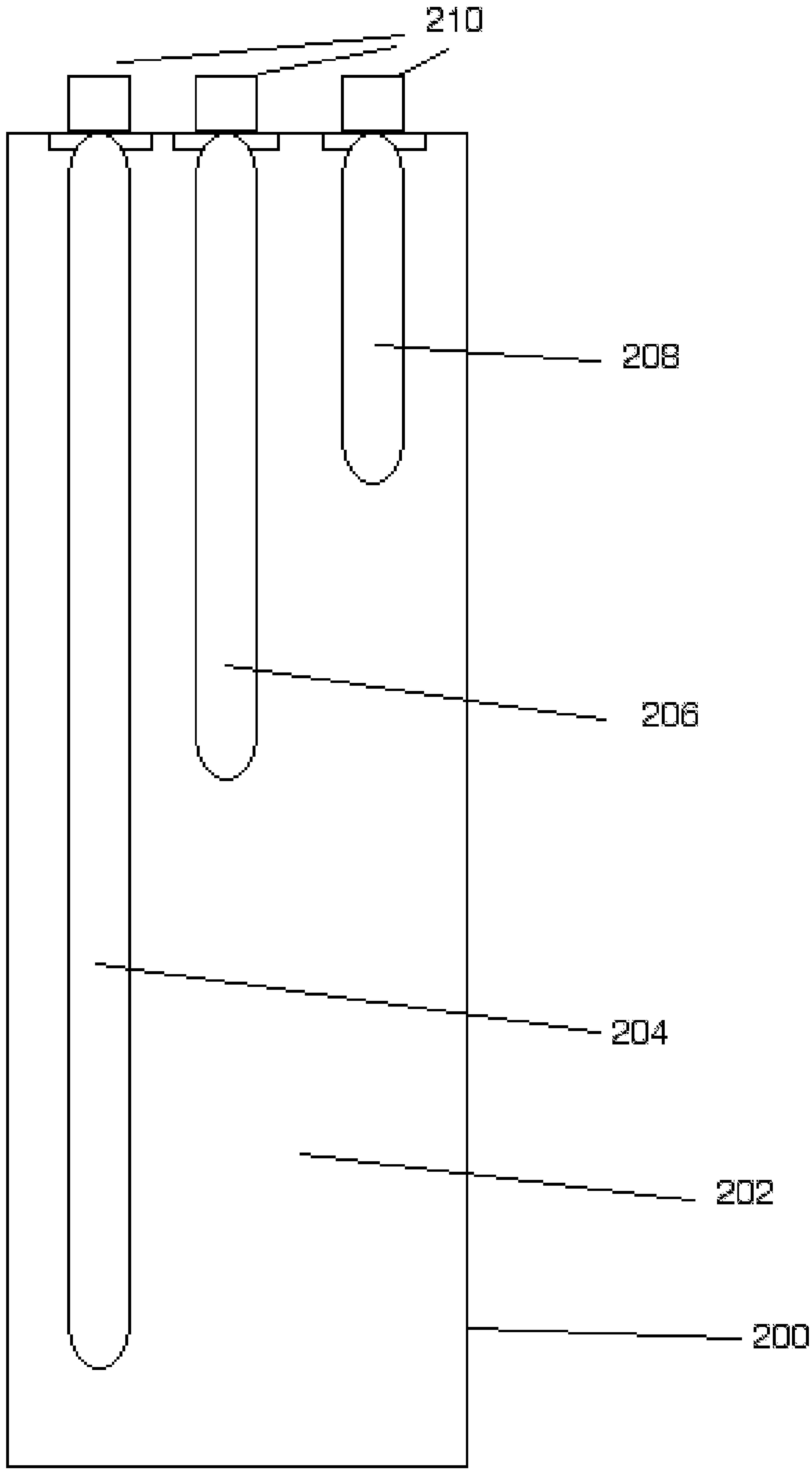

FIGURE 5

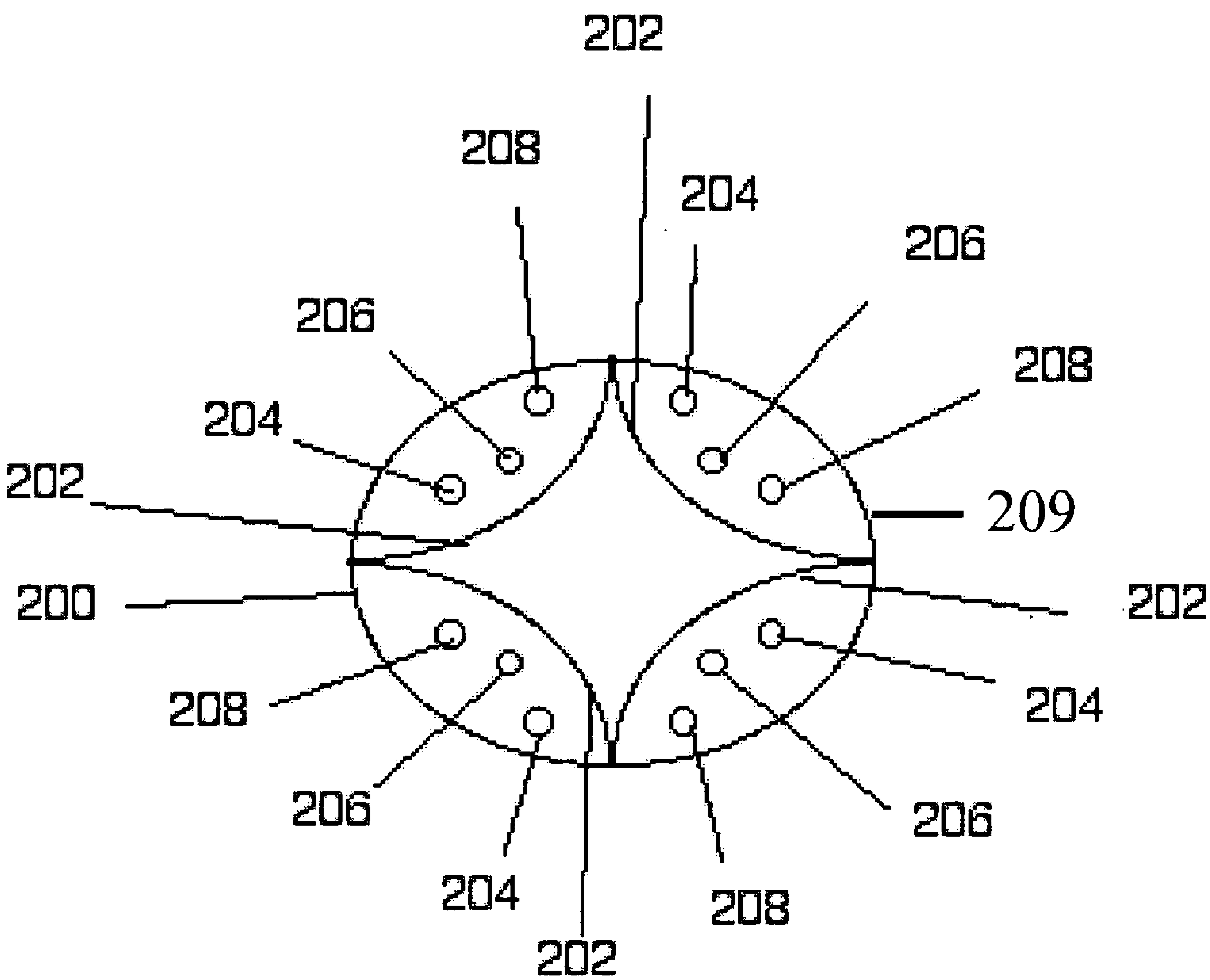
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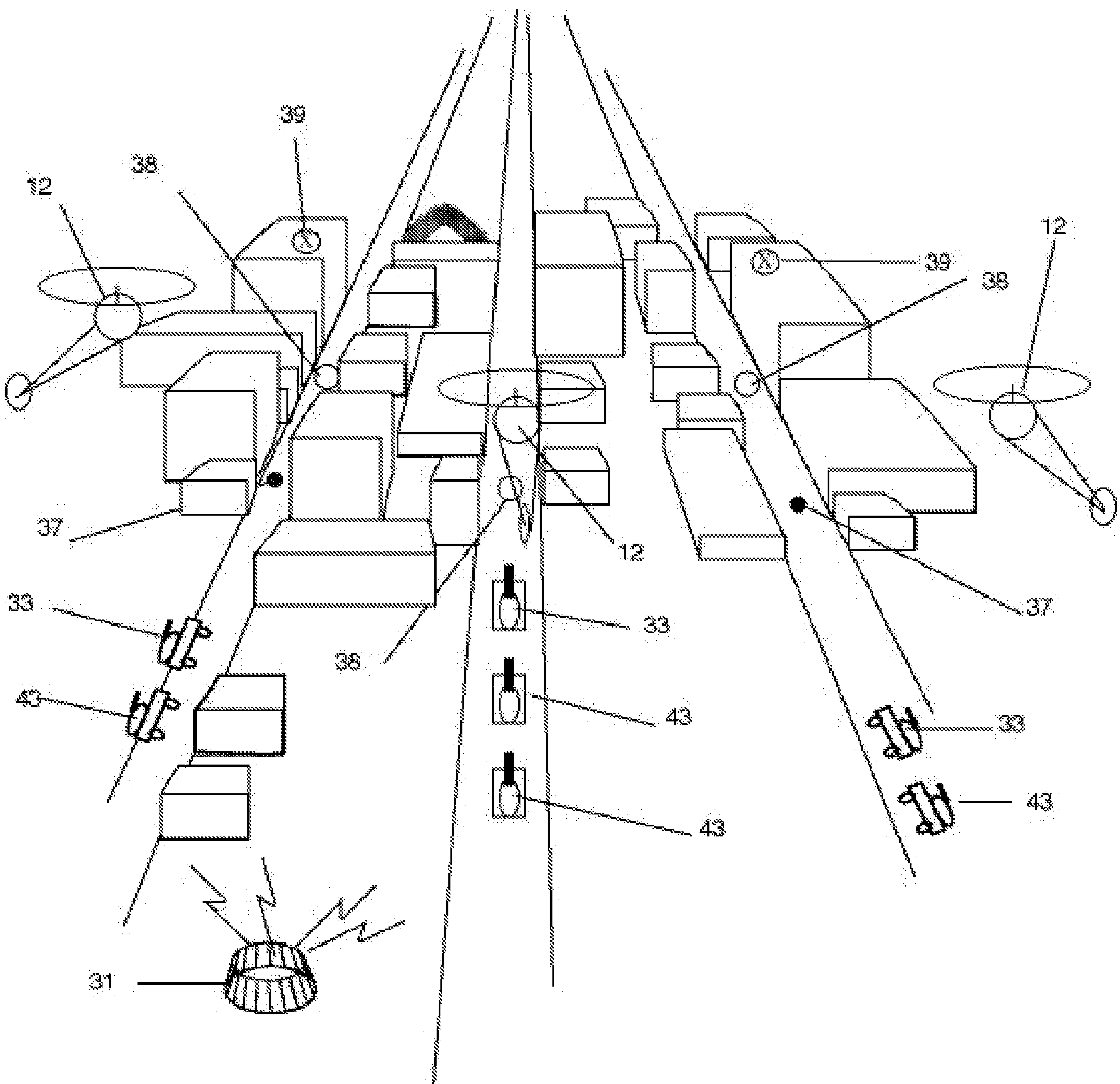
FIGURE 6



FUGURE 7A

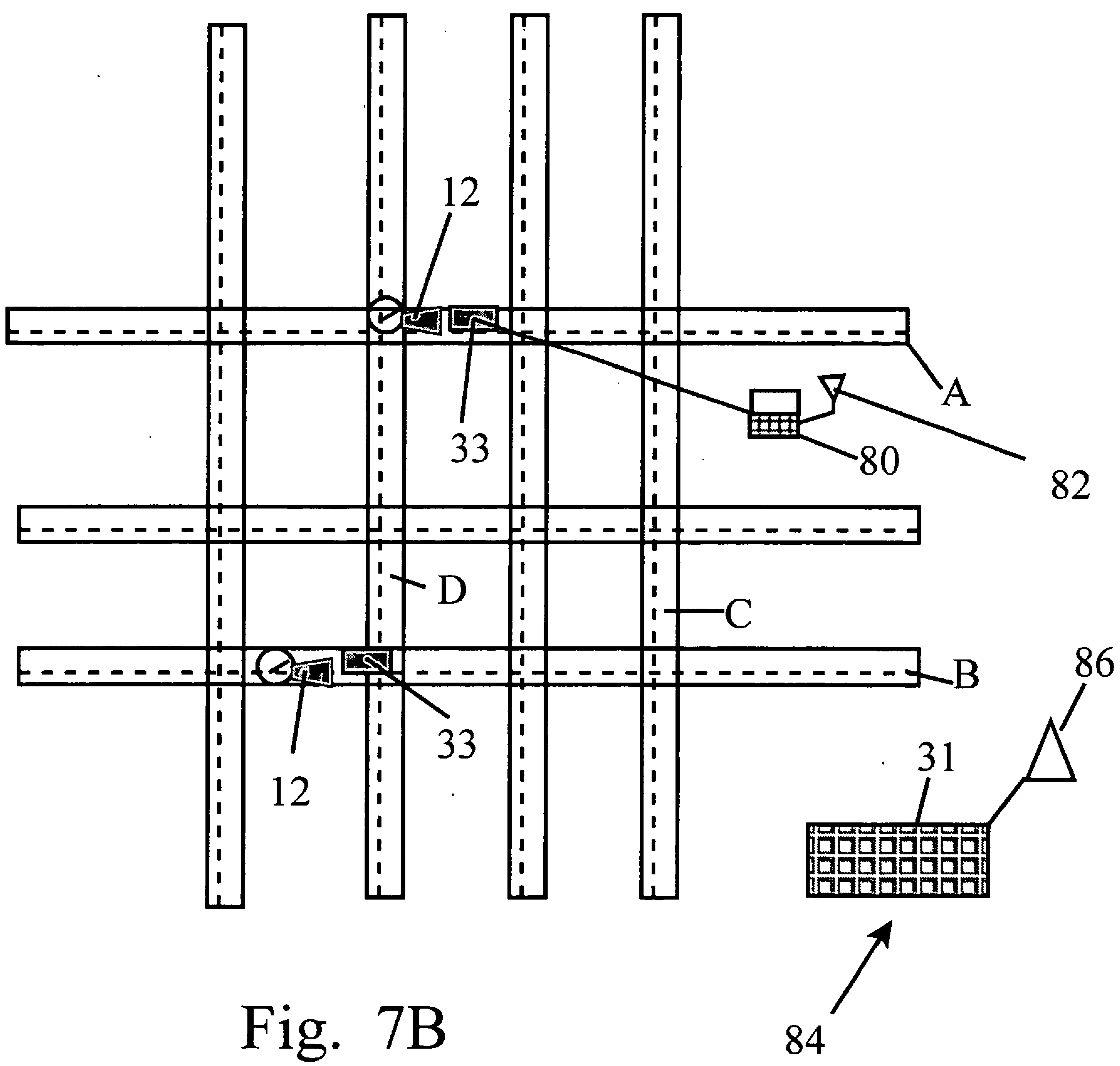


Fig. 7B

METHODS AND APPARATUSES FOR DETECTING AND NEUTRALIZING REMOTELY ACTIVATED EXPLOSIVES

BACKGROUND OF INVENTION

[0001] The present invention is directed to electronic and audio countermeasures for use in a wartime environment. More specifically, the invention concerns a device which can use both electronic and audio countermeasures to explode or deactivate various types of remotely controlled or condition responsive explosive devices such as IEDs and land mines.

[0002] Many types of devices, systems, and methods have been developed over the years to counter stationary explosive devices of the type configured for use in a wartime environment. These devices, which include land mines and radio controlled explosives are particularly effective in population dense environments such as those encountered in an urban warfare scenario. Of particular concern of late is the so called IED or improvised explosive device, which is relatively compact and may be remotely activated by e.g., an RF signal, and have even been known to be activated by cell phones connected to the IED so as to trigger an explosion upon the receipt of a call.

[0003] The techniques for dealing with these devices fall generally into two categories namely; a percussive technique which uses a transducer of some type to generate a shock wave which can trigger the device, the percussive type also including devices having parts designed for actual contact with the explosive device, and an electronic type which uses various electronic techniques for both finding and remotely detonating an explosive.

[0004] U.S. Pat. No. 6,487,950 issued to one Samland discloses a method of detecting and detonating land mines using microwave power at a first level for detection and a second level for detonation. While this method may be satisfactory for detonating passive condition responsive buried land mines, it does not address the issue of radio activated IEDs at all and thus cannot be used for that purpose.

[0005] U.S. Pat. No. 7,000,546 issued to Bender et al. Discloses a method of and device for detonating magnetic field responsive sea mines by generating a broad spectrum magnetic field extending about the perimeter of the vessel containing the device. Again, this device is only useful for detonating passive mine assemblies.

SUMMARY OF THE INVENTION

[0006] The present invention concerns a system and apparatus for detecting and neutralizing remotely activated explosive devices in a combat zone, especially one of relatively limited geographic area such as an urban setting. The apparatus is configured for mounting on or within an airborne drone and includes both transmitting and receiving circuits and antennas. The apparatus detects radio transmissions by analyzing received signals using standard RF direction finding techniques and a spectrum analyzer or other signal processing circuitry. Signals may be classified as threats using predetermined criteria, and the direction of threat signals may be assessed to allow for a determination of an enemy position from which an explosive is to be detonated. The apparatus also transmits a jamming signal which may serve to detonate devices within the dynamic RF footprint of the transmitting antenna. The drone also includes a highly directional low frequency audio device which is periodically directed randomly and at suspected enemy positions. A plurality of drones deployed within a given geographical area may transmit data to a base station, which can then transmit positional data in real time, which in combination with stored data may be used to optimize operational efficiency of the apparatus and allow for planning and altering troop movements.

[0007] In accordance with the above, it is an object of the invention to provide a system and apparatus for detecting and neutralizing remotely activated explosive devices in a combat zone.

[0008] It is another object of the invention to provide a system and apparatus for detecting and neutralizing remotely activated explosive devices in a combat zone having both transmitting and receiving circuits.

[0009] It is another object of the invention to provide a system and apparatus for detecting and neutralizing remotely activated explosive devices in a combat zone having one or more antennas configured for transmitting and receiving RF signals in accordance with the method of the invention.

[0010] It is another object of the invention to provide a system and apparatus for detecting and neutralizing remotely activated explosive devices which employs a remotely controlled and/or programmable drone aircraft.

[0011] It is another object of the invention to provide a system and apparatus for detecting and neutralizing remotely activated explosive devices in a combat zone which employs acoustic means to detonate explosive devices and disrupt enemy positions.

[0012] These and other objects of the present invention will become readily apparent upon further review of the following specification and drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] FIG. **1** is a side view of an apparatus for electronic and acoustic explosive detection and neutralization formed in accordance with the technique of the invention positioned on a drone aircraft.

[0014] FIG. **2** is a side view, partly in cross section of the audio transducer portion of the apparatus.

[0015] FIG. **3** is a side view of an antenna used with the RF receiving and transmitting portion of the apparatus.

[0016] FIG. **4** is an alternative embodiment of the audio transducer portion of the apparatus.

[0017] FIG. **5** is a side view of one quadrant showing a three-antenna arrangement.

[0018] FIG. **6** is a top view showing an alternate embodiment of an antenna arrangement for the apparatus.

[0019] FIG. **7**A is a simulation of an aerial view of a scenario where the system of the invention is deployed.

[0020] FIG. **7**B is a plan view of a scenario where the system of the invention is deployed.

DETAILED DESCRIPTION OF THE INVENTION

[0021] Referring now to FIGS. **1-7**B, a system for detecting and neutralizing concealed explosive devices positioned in a combat zone, is shown. The system, generally indicated by the numeral **10**, is configured for use in a wartime environment, and particularly an urban setting. The apparatus used with the system **10** is configured to detect, neutralize, and/or destroy various types of explosive devices as may be deployed ay an enemy in a warfare scenario, and is particularly useful against the so called improvised explosive devices or IEDs, the weapon of choice for enemy soldiers and terrorists engaged in war with traditional standing or occupying armed forces. The system **10** may also be deployed to defeat traditional hidden explosive devices such as land mines.

[0022] Of particular concern for armies dealing with guerilla activities is the remotely controlled IED which may be hidden virtually anywhere but is most often used on or near roads to disrupt troop movements and discourage the normal functioning of a large urban area. These IEDs are especially difficult to neutralize because they are often hidden in other vehicles and may be detonated by a simple RF transmitter or even a cell phone. The apparatus **10** may be divided into two sections, operated in accordance with the system of the invention to detect, neutralize, and destroy all explosive devices of the condition responsive or remotely activated type. Preferably, the system **10** includes electronic and electrical systems mounted on a remotely controlled drone **12** such as a remotely controlled helicopter, but may alternatively be operated on an armored vehicle which may optionally be manned. The advantage of a drone aircraft **12** is that the device is not as susceptible to damage from the explosive devices regardless of whether it finds them or not. Also, the drone **12** can be operated only a few feet above the road surface unlike traditional drones which are operated high above the target area and thus incapable of employing all of the techniques of the invention. Also, the RF footprint of the drone **12** can be kept small so as not to interfere with normal, e.g., cell phone communications, within the target community.

[0023] In accordance with a key aspect of the invention, real time and stored data from past and current deployments of the drones **12** is used to control, and alter as necessary, the operation of the various sub-components of the drone **12**, and to plan and/or alter routes taken by convoys using the drones **12** as will be explained in more detail later.

[0024] Referring now particularly to FIG. **1**, the first section of the electronic systems mounted on the drone **12** is the RF transmitting/receiving section which consists of an electronic transmitter and receiver circuit section **14**, the transmitting/receiving section **14** operably connected to transmitting and receiving antennas. The transmitting/receiving section **14** is preferably digital and programmable in order to more efficiently coordinate with the various other aspects of the system **10** as will be described in more detail below. The transmitter/receiver circuit **14** should have separate outputs for the transmitting and receiving antennas. Transmitting antenna **100** consists of a primary transmitting element **102** which receives an output directly from the transmitter section of the transmitter/receiver circuit **14**. A parabolic reflector **104** focuses the output of the element into a narrow beam to create a relatively narrow footprint to allow for linear movement of the drone **12**, combined optionally with side to side sweeping movement of the antenna to scan an area having a width slightly wider than e.g., a road to be swept for IEDs. Movement of the antenna **100**, which may be accomplished by a small microprocessor controlled motor **18** attached thereto, may be done under program control to allow for adjusting the area scanned particularly the width of the scan pattern. The electronic counter measure signal emitted from the transmitting/receiving section **14** is frequency shifted in accordance with an adjustable predetermined algorithm to ensure that any IEDs in the area of the scan are irradiated with a signal approximating a detonation signal. The changing frequencies are designed to both detonate and/or interrupt detonation signals intended for the IED. Preferably, at least one microprocessor device **41** is used to coordinate the various electronic systems of the invention, the microprocessor **41** capable of transmitting operational data as well as receiving and storing data associated with previous and current movements of all drones **12** deployed within a given geographical area as will be described in more detail below.

[0025] The receiving antenna **200** is of the direction finding type and may be formed of several elements as is known in the art. As shown in FIGS. **5** and **6**, the antenna **200** has four groups of three dipole elements **204**, **206**, and **208** radially spaced and positioned within a housing **209** having terminals **210** for electrical connection to the receiving circuit **14**. The dipole elements **204**, **206**, and **208** are of varying lengths and arranged from shortest to longest. An isolation reflector **202** extends lengthwise within the housing **209** and has four sides with concave surfaces for isolating the antenna groups.

[0026] Referring now to FIG. **2**, second section of the apparatus **10** is the sonic disrupter **20** which uses a high powered low frequency audio pulse to detonate land mines. The energy of the audio pulse is sufficient to detonate pressure or impact triggered explosive devices as is known in the art. The disrupter **20** is housed within a cylindrical muzzle **22** which contains a pressure diaphragm **24** capable of withstanding four atmospheric pressures. Compressed air or nonflammable gas is forced into compressed air or nonflammable gas chamber **34** from a source of compressed air or nonflammable gas contained within canister **36** through the compressed air or nonflammable gas line **32** and through the compressed air or nonflammable gas control valve **35**. When the compressed air or nonflammable gas pressure in the compressed air or nonflammable gas chamber reaches three atmospheric pressures, the compressed air or nonflammable gas control valve **35** closes. At this point, the disruptor **20**, is armed for firing.

[0027] Firing of the audio sound blast cannon, device **20**, is initiated by applying power to the plunger shaft release trigger solenoid **56** and pulling the plunger shaft release trigger **54** pulled away from the plunger shaft stopper **50**. At this point the plunger spring **42**, with the assistance of the plunger shaft thrust solenoid **46** as power is applied over the plunger shaft solenoid control wires **60**, accelerate the plunger **40** to sufficient speed to overcome the restraining force of the pressure diaphragm **24** forcing the compressed air or nonflammable gas out the muzzle **22**. The plunger motor/gears **44** drive the plunger shaft **48** rearward to be locked into the firing position by the plunger shaft release trigger **54** locking onto the plunger shaft stopper **50**. The plunger shaft trigger release spring **52** holds the plunger shaft release trigger **54** in place. Once the plunger shaft **48** is locked in place, the plunger motor/gear **44** is lifted slightly, clearing the plunger shaft gears and allowing the plunger shaft **48** to slide forward unimpeded. Concurrent with this action, a secondary pressure diaphragm **26** is automatically placed in the cannon muzzle **22**.

[0028] Information gathered from drones **12** operated in a given area can be transmitted in network fashion to continually indicate to a base station, as well as all troops deploying the drones, of actual or potential enemy IED deployment, thus several drones **12** operated by a plurality of troop convoys can provide real time troop data to enhance transport safety. Referring now specifically to FIGS. **7**A and B, a typical scenario involving two drones **12** and two accompanying convoys which will include a lead vehicle **33** and optionally additional vehicles **43**. The lead vehicle **33** will include control means **80** for programming and real time control of the drone **12** preferably in the form of a laptop computer **80** with pre-loaded software and a transmitting/receiving antenna **82** connected thereto. The control means **80** software may include GPS data, local map information, etc. as required to provide a two dimensional map or grid from which the operator of the drone **12** can assess the relative positions of threats, other drones **12**, topography, etc., as needed to navigate a preferred route and effect course changes as needed. It should be noted that the drones **12** are pre-programmed with a set of default instructions, stored on microprocessor **41**, for operating the various sub-components as described above, which instructions may be readily modified by control means **80** in accordance with the deployment conditions. Additionally, the control means **80** may include a menu driven software interface which forces the operator to select the various parameters such as detonation signal frequency and scan area upon initialization to ensure optimal deployment of the drone **12**. As the convoys **33**, **43** proceed, real time information is transmitted to the base station **31** which correlates the data from each convoy **33**, **43** and transmits data received from all convoys **33**, **43** so that the information is stored and displayable in a useful fashion on all computers **80**. The base station **31** includes a computer **84** having an antenna **86** operatively connected thereto for receiving data from the convoys **33**, **43**. The data received from all of the convoys **33**, **43** is stored on the base computer **84**, the combined data then broadcasted from the base computer via antenna **86**, where it can be displayed on all control means **80** in a useful format. If, for example, a "bogey" **37**, **38** (e.g., anti-personnel mine, land mine, IED, etc.) is detected, data concerning the bogey **37** such as position, whether or not detonated, frequency of detonation, etc. is transmitted back to the base station **31** (either automatically by drone **12** or by an operator entering data at the control means **80**) and re-transmitted to all control means **80** currently operating to allow the user (e.g., the driver of a lead vehicle **33**) to effect course changes etc. as needed. By way of an example, if convoys **33**, **43** are proceeding along roads A and B without incident, then the portions of roads A and B traversed may be indicated as clear on all active control means **80** for subsequent convoys **33**, **43**. Data concerning cross roads C and D may have been already transmitted to the base station **31** by previous convoys **33**, **43** so that the current convoys **33**, **43** can have information useful should an immediate course change be needed.

[0029] The data obtained at the base station **31** may also be correlated to allow for a determination of terrorist **39** position, e.g., activity centered around a given position. It should be noted that some data, particularly detonation of bogeys **37**, **38**, or visual confirmation of enemy position will have to be manually entered into control means **80** before it can be transmitted to the base station **31**. Other data such as RF signals transmitted from the drones **12** in response to a threat condition and received by the receiving antenna **82** is automatically stored on control means **80**, where it may be transmitted to the base station **31** for further analysis.

[0030] In an alternative embodiment of the disruptor **20** a volatile fuel system is used for activating the plunger to expel the compressed air **34**. Compressed air must be used with this system. A quantity of fuel is contained within a container **62**. When the plunger **40** and plunger shaft **48** are moved to its cocking position, fuel is passed through the fuel spray nozzle **66** into the fuel chamber **68** behind the plunger. When the system is ready to fire, the trigger solenoid **56** is activated approximately 0.10 seconds prior to the fuel igniter **70** system being initiated. This will allow the plunger **40** and the plunger shaft **48** to move unimpeded. The fuel igniter **70** is then activated and the fuel is ignited causing the plunger **40** to press forward moving the compressed air **34** to expel it at sonic speed towards its objective. As the plunger is returned to the cocking position and the plunger shaft stopper **50** is latched by the plunger shaft release trigger **54**, a one-way spent fuel exhaust valve **72** is opened to release spent fuel. This exhaust valve **72** is closed before the injecting of raw fuel into the firing chamber **68**. After the compressed air is forced into the compressed air chamber **34** to approximately three atmospheres, through the compressed air inlet valve **28**, the compressed air control valve **30** closes. As this action is completed, air is forced into the firing chamber **68** by way of the compressed air distributor **78**, the compression check valve and **74**, and the air injection nozzle **76**. The compression check valve **74** closes to obtain a compression ration of approximately 11 to 1. All other action is identical to the spring firing system.

[0031] An alternative embodiment of the frequency directional finding antenna system device **200** may consist of four each, quadrant located, siamesed antennas consisting of three independently tuned dipole antennas with a isolation reflector. Each antenna wavelength may be tuned to a low frequency band **204**, mid frequency band **206**, and a high frequency band **208**. These bands will be the expected frequencies that would be a compilation of frequencies nominally used for remotely controlled bombs and bomb detonators. The isolation reflector **202** would be designed to minimize interference to the other independent antenna systems. The four antenna systems may be contained within a nonconductive material. The antennas will be connected to the transmitter receiver section **14** which may optionally contain independent frequency analyzers for each antenna group and signal strength electronics thereby providing a general direction from which a suspected frequency is being generated. This information will then be processed by the transmitter receiver section **14** to aid in further defining the suspected frequency location.

[0032] In operation, the drone **12** is released by the user, e.g., a soldier in convoy lead vehicle **33** traversing a combat zone with a high risk of hidden IEDs etc. The drone **12** will sweep a predetermined area as programmed by the user, the area typically being linear and overlapping the intended route. For example, If the road is 25 meters wide, transmitting antenna **100** is oscillated so as to sweep an area 30 meters wide as the drone progresses linearly approximately centrally of the road. The oscillation rate of the antenna **100** would be selected and perhaps modified based upon response time and other parameters as would become apparent depending upon effectiveness over time. The detonation signals broadcast by the transmitting antenna **100** may be narrowed down by intelligence gathered at the base station **31** and broadcast to all the drones **12** to ensure a more effective scan (i.e., to more reliably detonate devices within the scan area of the transmitting antenna) and to reduce the amount of time the directional RF beam is focused on a particular area to allow for a quicker scan and faster troop movement. Receiving antenna **200** will receive and transmitter/receiver circuitry **14** process local RF transmissions to determine the direction and intensity of RF transmissions which may be intended to detonate an IED. Transmitter/receiver circuitry **14** on the drone **12** can adaptively change the RF jamming signal transmitted by antenna **100** in response to a received threat so that a broadband jamming signal is not mandated, and also to minimize unintended interference with local (non threat) RF signals. The information obtained from receiving antenna **200** can then be used to assess potential enemy positions, by e.g. triangulation or other well known techniques. Sonic disrupter **20** is also swept over the target area in much the same pattern as the transmitting antenna to detonate any hidden sub surface IEDs such as mines. All threats encountered by drone **12**/convoy **33**, **43** are noted by the drone **12** operator and entered into the system using device **80**, for transmission back to the base station **31**, so that the data gathered from all drones **12** deployed over a period of time can be used to assess enemy positions and plan convoy **33**, **43** routes. Thus, the drones **12** used in accordance with the system can be used to gather data which, as previously mentioned, can be transmitted to the base station **31** which includes data processing means **84** for storing and coordinating threat data. The combined threat data obtained from all previously and currently active drones **12** can then be continuously transmitted from the base station **31** to control means **80** so that any active drone **12** can access all current and previous data.

What is claimed is:

1-11. (canceled)

12. A system for locating and destroying explosive devices comprising:

a remotely controllable mobile support element including transmitter, receiver, and disrupter sections;

said transmitter section including a transmitting antenna configured to broadcast a detonation signal over a predetermined area;

said receiver section including a receiving antenna array configured to receive RF signals over a wide bandwidth;

said disruptor section including an acoustic device for emitting a pressure wave;

a microprocessor positioned within said mobile support element and connected to send control signals to, and receive operating data from said transmitter, receiver, and disruptor sections;

a control means associated with said mobile support element and adapted for receiving said operating data, said control means also adapted for sending said control signals to said transmitter, receiver, and disruptor sections; and,

a base station including means for receiving and storing said operating data from said control means.

13. The system of claim **12** wherein said system includes at least two of said remotely controllable mobile support elements, each of said mobile support elements associated with a corresponding one of said control means;

said receiving and storing means at the base station adapted for receiving and storing combined operating data from said at least two remotely controllable mobile support elements, said base station including means for broadcasting said combined operating data to each of said corresponding control means.

14. The system of claim **13** wherein said pressure wave is of sufficient energy to detonate pressure or impact sensitive explosive devices.

15. The system of claim **13** wherein said detonation signal is broadcast over a predetermined range of frequencies, said predetermined range of frequencies modified in accordance with said combined operational data.

16. The system of claim **1** wherein said control means is positioned within a vehicle, said control means adapted for manual entry of operational data.

* * * * *