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Attorney Docket No. 300177

TUNABLE PARALLEL PLATE ANTENNA

STATEMENT OF GOVERNMENT INTEREST

[0001] The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

CROSS REFERENCE TO OTHER PATENT APPLICATIONS

[0002] None.

BACKGROUND OF THE INVENTION

(1) Field of the Invention

[0003] The present invention relates to tunable antennas, and more particularly to a parallel plate antenna that is tunable.

(2) Description of the Prior Art

[0004] United States Patent No. 8,228,243 discloses a parallel plate antenna designed for use in a field-deployed shielded room. Specifically, the antenna is designed to determine a radio-frequency (RF) "leakiness" of a room. Such leakiness generally occurs at holes, ports, windows, etc., made in the walls or roof of the room. The disclosed antenna is placed in a room to be evaluated and measures RF energy associated with test pulses directed toward the room from a location outside the room.

[0005] The parallel plate antenna is compact and effective, but has a fixed resonant frequency thereby limiting the value of the antenna beyond specific applications.

SUMMARY OF THE INVENTION

[0006] Accordingly, it is an object of the present invention to provide a tunable antenna.

[0007] It is a further object of the present invention to provide a tunable parallel plate antenna.

[0008] In order to attain the objects of the present invention, a tunable antenna is provided which comprises a base and a support coupled to the base and extending perpendicular thereto. The antenna also comprises a hollow tube coupled to the base and extending perpendicular thereto. The support and hollow tube oppose one another and are spaced apart from one another.

[0009] The antenna also includes a plurality of plates spaced apart and parallel to one another. Each plate has a connected end and an unconnected end such that each plate is coupled only at the connected end to one of the supports and hollow tubes and extends out to the unconnected end thereof. One of the plates located furthest from the base extends past the hollow tube and is spaced apart therefrom.

[0010] A shaft has a first end coupled to the base, extends through the hollow tube and the one plate extending past the hollow tube such that the second end of the shaft is spaced apart from the one plate extending past the hollow tube. A tuning piston is coupled to the shaft and is adapted for movement along the shaft and within the hollow tube.

[0011] A tuning plate is coupled to the second end of the shaft. Each of the support, hollow tube, plates, shaft, tuning piston, and tuning plate are electrically conductive. The shaft, tuning piston, hollow tube, and tuning plate are also electrically coupled. The shaft is electrically isolated from the one plate extending past the hollow tube.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] Other objects, features and advantages of the present invention will become apparent upon reference to the following description of the preferred embodiments and to the drawings, wherein corresponding reference characters indicate corresponding parts throughout the several views of the drawings and wherein:

[0013] **FIG. 1** is a cross-sectional and side view of a tunable parallel plate antenna in accordance with the present invention;

[0014] **FIG. 2** is a plan view of the hollow tube and tuning piston taken along reference line **2-2** of **FIG. 1** and in accordance with the present invention;

[0015] **FIG. 3** is a cross-sectional view of the top plate, shaft, and tuning plate of the antenna in accordance with the present invention;

[0016] **FIG. 4** is a cross-sectional view of the hollow tube and tuning piston illustrating gears used to translate rotation of the shaft to linear movement of the tuning piston in accordance with the present invention;

[0017] **FIG. 5** is a side view of the tunable parallel plate antenna illustrating an electric field distribution of the antenna;

[0018] **FIG. 6** is a side view of the tunable parallel plate antenna illustrating a magnetic field distribution of the antenna; and

[0019] **FIG. 7** is a cross-sectional view taken along reference line **7-7** in **FIG. 6** illustrating the magnetic field distribution of the antenna.

DETAILED DESCRIPTION OF THE INVENTION

[0020] Referring now to the drawings and more particularly to **FIG. 1**, a parallel plate antenna in accordance with an embodiment of the present invention is shown and is referenced by numeral **10.** In the illustrated embodiment, three parallel plates are shown. However, it is to be understood that an antenna in accordance with the present invention could be constructed with additional parallel plates without departing from the scope of the present invention.

[0021] Unless otherwise stated herein, the various parts of the antenna **10** need to be electrically conductive. Such electrical conductivity can be achieved by using solid metals for the various parts, metal-coated non-conductive substrates for the various parts, etc., without departing from the scope of the present invention.

[0022] The antenna **10** includes a base **20**, a support **30** coupled to the base and extending perpendicularly therefrom. The antenna also includes a hollow tube **40** coupled to the base **20** and extending perpendicularly therefrom to an open end **42** and such that the support **30** and the hollow tube oppose one another in a spaced-apart fashion.

[0023] The antenna **10** also comprises a series of parallel plates **50** with each plate coupled to one of the supports **30** and with a hollow tube **40** extending perpendicularly away therefrom in a cantilevered fashion. That is, each plate **50** is connected on one end **50A** thereof to the support **30** or the hollow tube **40** and is unconnected on another end **50B** of the plate. Unless otherwise stated, the term "coupled" as used herein refers to mechanical and electrical coupling. It is to be understood that a variety of coupling or attachment schemes could be used without departing from the scope of the present invention.

[0024] The base **20** provides mechanical support for the support **30** and the hollow tube **40**. Furthermore, the base **20** serves as an attachment point to an electrical ground plane (not shown) for the antenna **10**. Each of the support **30** and the hollow tube **40** can have one or more plates **50** coupled thereto with the plates being alternately connected to the support or the hollow tube. The number of plates **50** shown in the figures is exemplary and is not to be considered as a limitation of the present invention. One of the plates **50** located closest to the base **20** defines a feed point **60** to which an antenna feed **62** is coupled. The antenna feed **62** can be conical (as shown), cylindrical, a plate, etc., without departing from the scope of the present invention.

[0025] The antenna **10** also includes a resonant frequency tuning mechanism that cooperates with the hollow tube **40** and one of the plates **50**. More specifically, the plate **50** that is part of the tuning mechanism is located furthest from the base **20**, and extends from the support **30** past the hollow tube **40** as the plate passes an open top **42** of the hollow tube in a spaced-apart fashion to define a gap region **70** defining the aperture of the antenna **10**.

[0026] The tuning mechanism includes a shaft **80** supported on one end **80A** thereof by the base **20** or another support mechanism (not shown) coupled to the base. A tuning piston **82** is coupled to the shaft **80** for movement within the hollow tube **40** while being electrically coupled to the hollow tube. A tuning plate **84** is coupled to the shaft **80** at an opposing end **80B**.

[0027] The tuning mechanism operates to move the tuning piston **82** along the shaft **80** and in the hollow tube **40** as indicated by arrows **86A** and **86B** to tune the resonant frequency of the antenna **10** at the aperture **70**. While a variety of tuning mechanism constructions can be used to generate and control movements in directions **86A** and **86B**, some non-limiting exemplary constructions will be described herein.

[0028] Referring now to **FIG. 2**, the hollow tube **40** can be rectangular with the tuning piston **82** being similarly shaped for movement within the tube. It is to be understood that the radial cross-sectional shapes of the hollow tube **40** and the tuning piston **82** could also be circular, triangular, or in the shape of other polygons without departing from the scope of the present invention. The tuning piston **82** can be electrically coupled to the hollow tube **40** by electrical contacts **88** such as leaf springs, brushes, etc. Such electrical conductivity between the hollow tube **40** and the tuning piston **82** can also be provided by mechanical linkage mechanisms as will be described below.

[0029] Referring additionally now to **FIG. 3**, the shaft **80** extends through the one plate **50** that extends over the open end **42** of the hollow tube **40**. The shaft **80** is electrically isolated from the plate **50** using a dielectric bushing **52** disposed between the shaft and the plate where the shaft passes through the plate. End **80B** of the shaft **80** is mechanically and electrically coupled to the tuning plate **84**.

[0030] By way of example, if the shaft **80** is a rotating shaft as indicated by a rotational arrow **81**, the tuning plate **84** can be coupled to the shaft for rotation in correspondence therewith. In such a case, the tuning plate **84** also functions as a flywheel to maintain smooth rotational movement of the shaft **80** which, in turn, translates to smooth the movements **86A** and **86B** of the tuning piston **82**.

[0031] As mentioned above, a variety of constructions can be used to bring about the movements **86A** and **86B** of the tuning piston **82**. With reference to **FIG. 4**, the shaft **80** and the tuning piston **82** can be in threaded engagement with one another. Mechanical and electrical coupling between the hollow tube **40** and the tuning piston **82** are provided by gears. In the illustrated embodiment, rack gears **90** are coupled to opposing side walls of the hollow tube **40**. Cooperating pinion gears **92** are disposed in opposing lateral edges of the tuning piston **82**. By virtue of this construction, when the shaft **80** experiences the rotational movement **81**, the tuning piston **82** experiences movement **86A** or **86B** depending on the direction of the rotational movement as the pinion gears **92** engage the rack gears **90**.

[0032] The shapes of the plates **50** can all be rectangular as shown and described in the afore-mentioned U.S. Patent No. 8,228,243. However, the present invention is not so limited. For example, the plates **50** between the base **20** and the one plate extending over the hollow tube **40** can be T-shaped as described in United States Patent Application No. 16/143,593, filed September

27, 2018, the contents of which are incorporated herein by reference.

[0033] The ability to change the antenna's resonant frequency is now explained. The internal dimensions of the hollow tube **40**, the shaft **80**, and the tuning piston **82** are very small as compared to the operating wavelengths of the antenna **10** such that the tuning mechanism behaves as a lumped-element circuit.

[0034] To understand the behavior of the tuning mechanism behavior, one can temporarily ignore the elements of the tuning mechanism that are internal to the hollow tube **40**. In this state, a complex admittance of value Y_1 ($Y_1 = G_1 + jB_1$) appears across the aperture **70**.

[0035] The real part of the admittance (i.e., G_1), called the conductance, is a function of antenna geometry and frequency and describes the conversion of stored energy in the parallel plate region into radiation across the aperture **70** and into the surrounding space. The imaginary part of the admittance (i.e., B_1), also a function of geometry and frequency is called the susceptance. The susceptance describes the energy storage across the aperture **70**. The admittance therefore describes, in total, the imperfect "leakiness" of energy from the parallel plate cavity and into space and is responsible for generating current flow on the external surface of the antenna **10** to thereby form the radiated field.

[0036] Adding back the elements of the tuning mechanism that are internal to the hollow tube **40** adds another admittance Y_2 ($Y_2 = G_2 + jB_2$) in parallel with the admittance Y_1 to thereby yield a total admittance Y_t across the aperture **70** that is the sum of admittances Y_1 and Y_2. The movement **86A** or **86B** of the tuning piston **82** changes the value of Y_2, which when combined with Y_1, causes a shift in resonant frequency of the antenna **10.** The admittance Y_2 of the tuning mechanism is formed by the electrostatic coupling to the uppermost plate **50** by means of the tuning plate **84.**

[0037] The parallel plate region of the antenna **10** is a conveyor of radio-frequency power. In a transmission mode, the feed point **60** is energized with an alternating voltage and a propagating electromagnetic field is established in the region that is "leaked" across the aperture **70** (with an admittance Y_t) to generate an external surface distribution of current that, in turn, generates a radiated field. The same action occurs in reception, but in reverse order. When the spacing of the parallel plates **50** is small compared to the operating wavelength; power transfer to and from the aperture **70** is efficient because the fields in the parallel plate region are highly confined.

[0038] Referring now to **FIGs. 5-7**, the internal electric (**FIG. 5**) and magnetic field (**FIG. 6** and **FIG. 7**) distributions are illustrated for the antenna **10**. The illustrations are “snapshots” in an instant of time because the fields alternate rapidly in polarity when traveling towards the aperture **70** at nearly the speed of light. The electric and magnetic fields actually exist simultaneously, but are shown separately to avoid confusion.

[0039] The advantages of the present invention are numerous. The antenna **10** can be readily tuned to any resonant frequency in a design range of the antenna. Movement of the tuning piston **82** can be affected through a variety of manual, automated, and even remotely-controlled mechanisms.

[0040] It will be understood that many additional changes in the details, materials, steps and arrangement of parts, which have been herein described and illustrated in order to explain the nature of the invention, may be made by those skilled in the art within the principle and scope of the invention as expressed in the appended claims.

[0041] The foregoing description of the preferred embodiments of the invention has been presented for purposes of illustration and description only. It is not intended to be exhaustive nor to limit the invention to the precise form disclosed; and obviously many modifications and variations are possible in light of the above teaching. Such modifications and variations that may be apparent to a person skilled in the art are intended to be included within the scope of this invention as defined by the accompanying claims.

TUNABLE PARALLEL PLATE ANTENNA

ABSTRACT OF THE DISCLOSURE

A tunable antenna includes a base supporting a support and hollow tube opposing and spaced apart from one another, and spaced-apart and parallel plates. Each plate is coupled only at one end thereof to one of the support and hollow tube. One of the plates located furthest from the base extends past the hollow tube and is spaced apart therefrom. A shaft extends through the hollow tube and the one plate extending past the hollow tube. A tuning plate is coupled to the end of the shaft. A tuning piston is coupled to the shaft and is adapted for movement within the hollow tube where such movement changes the resonant frequency of the antenna.

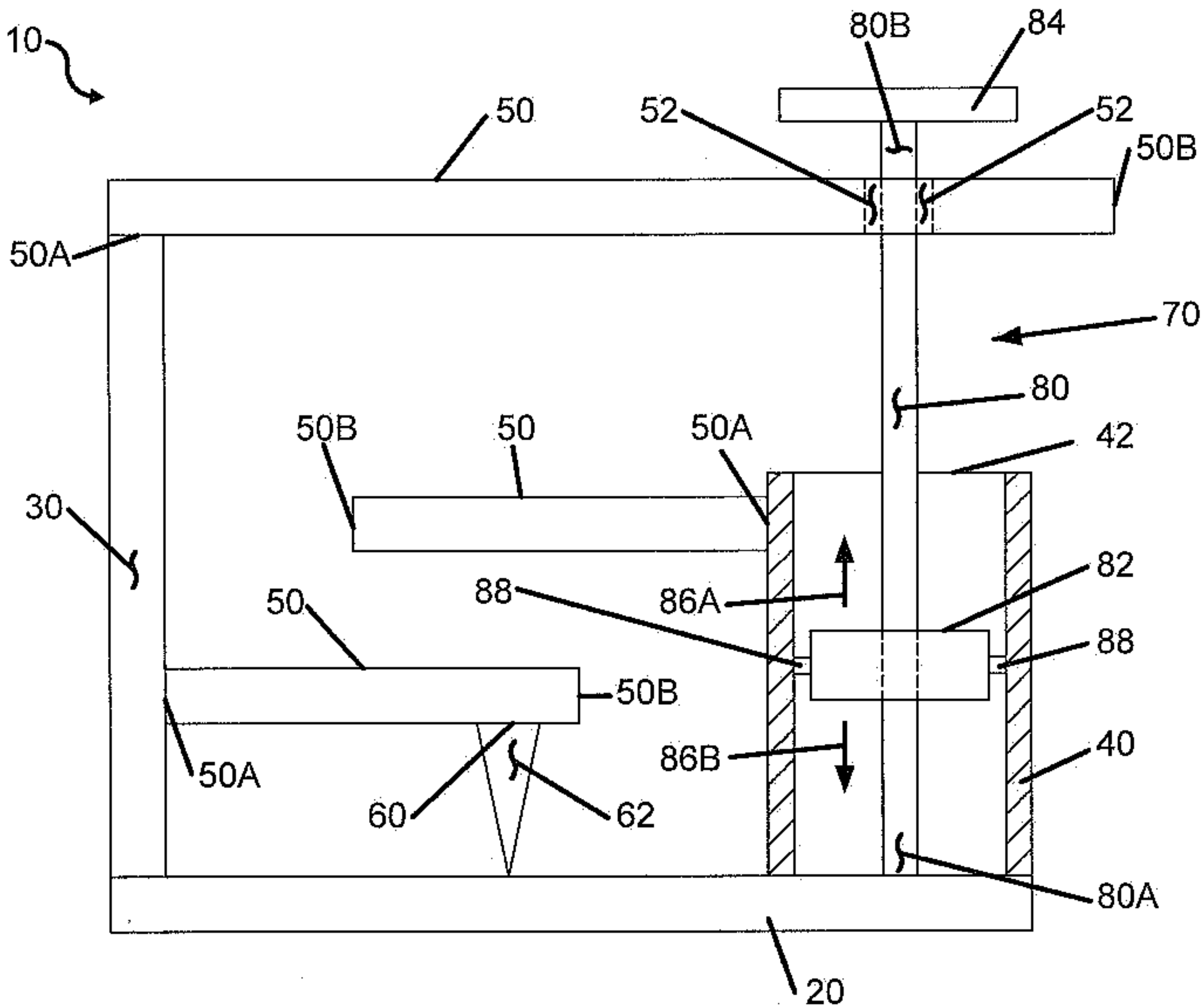
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FIG .1

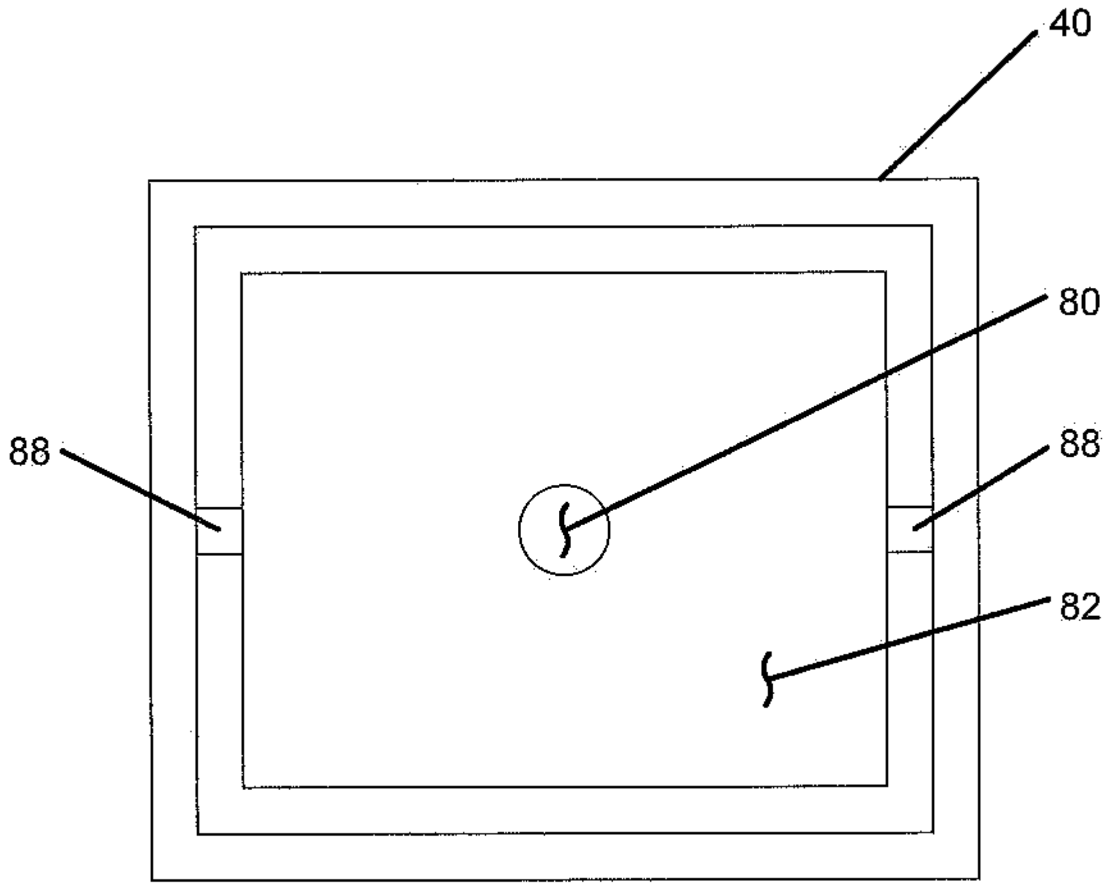

FIG .2

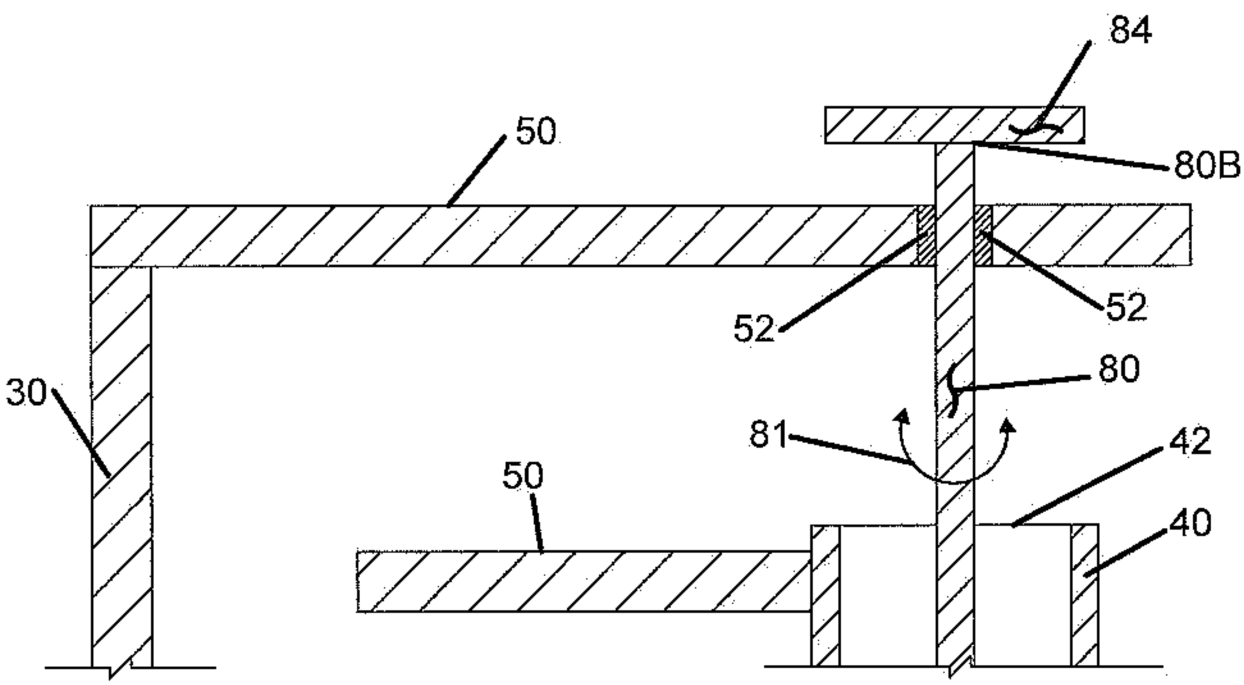

FIG .3

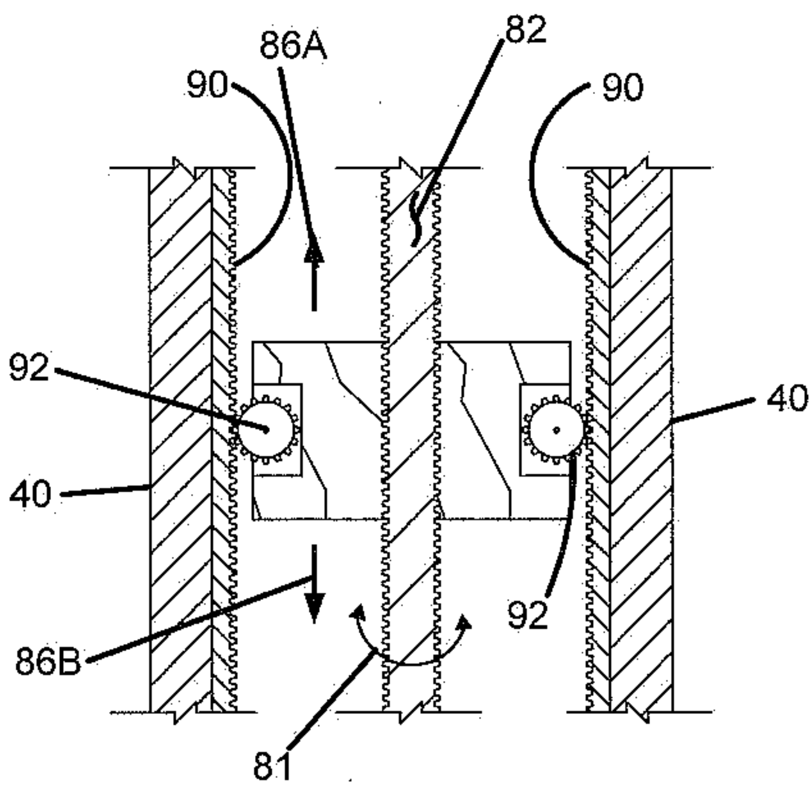

FIG .4

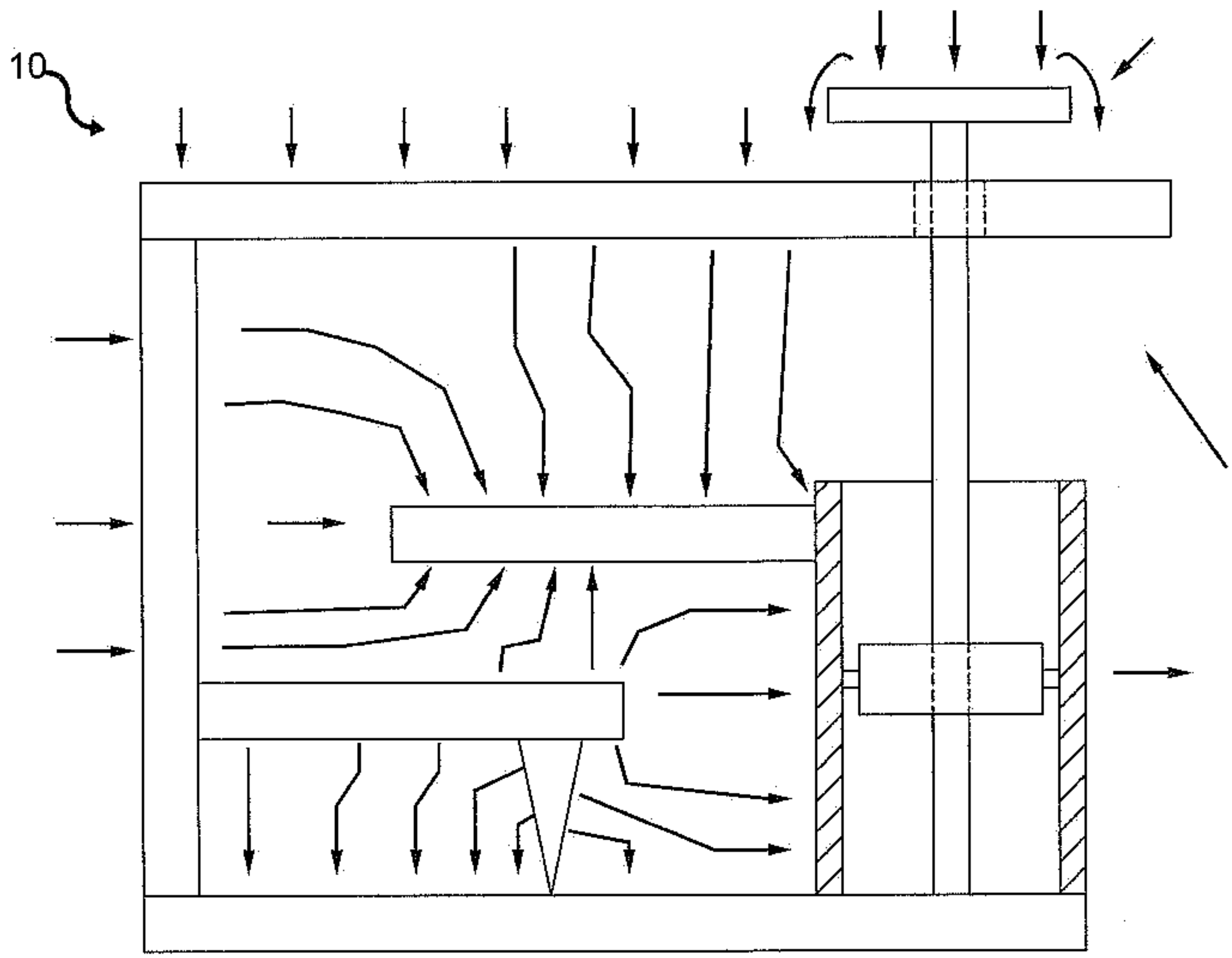

FIG .5

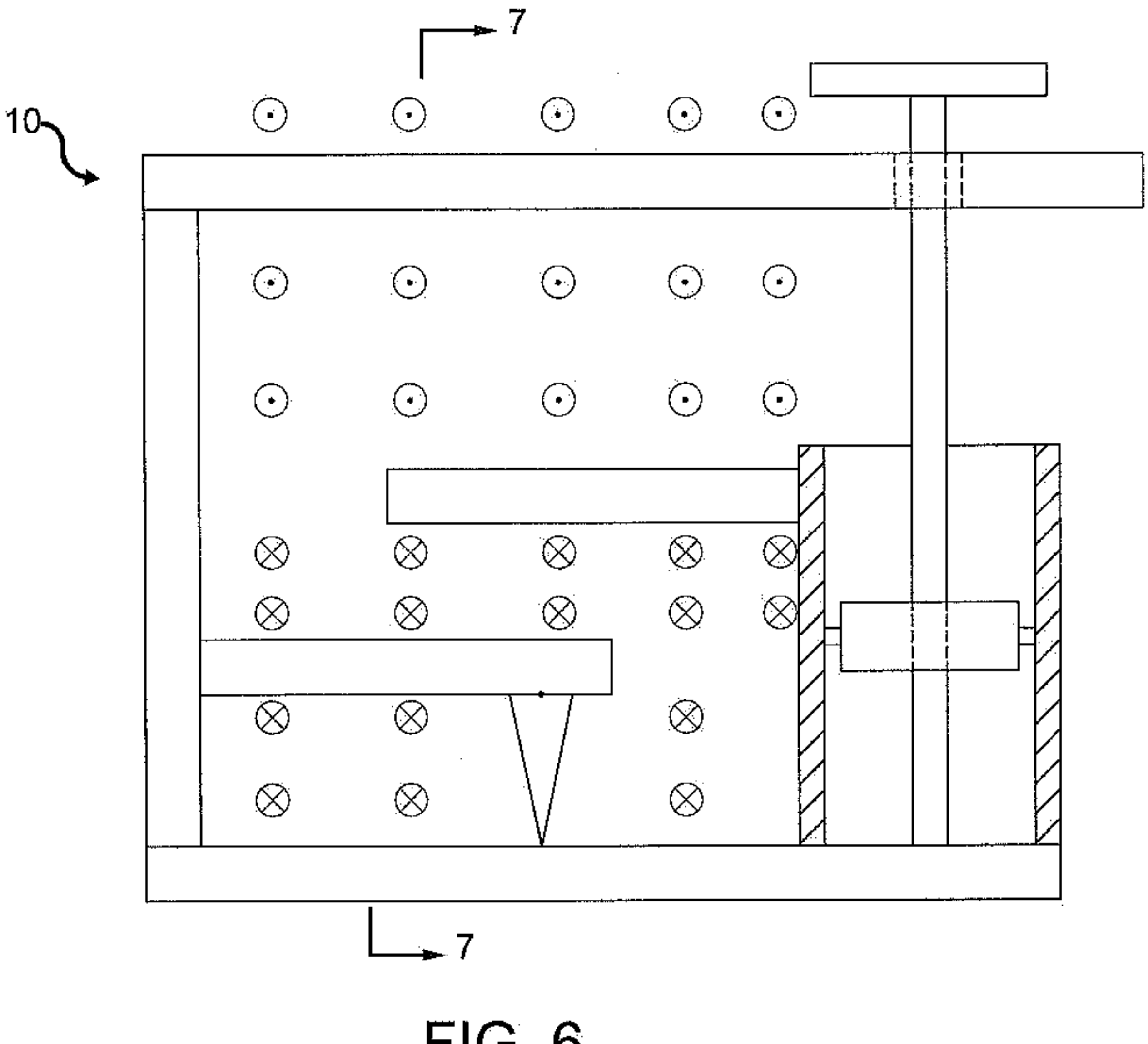

FIG .6

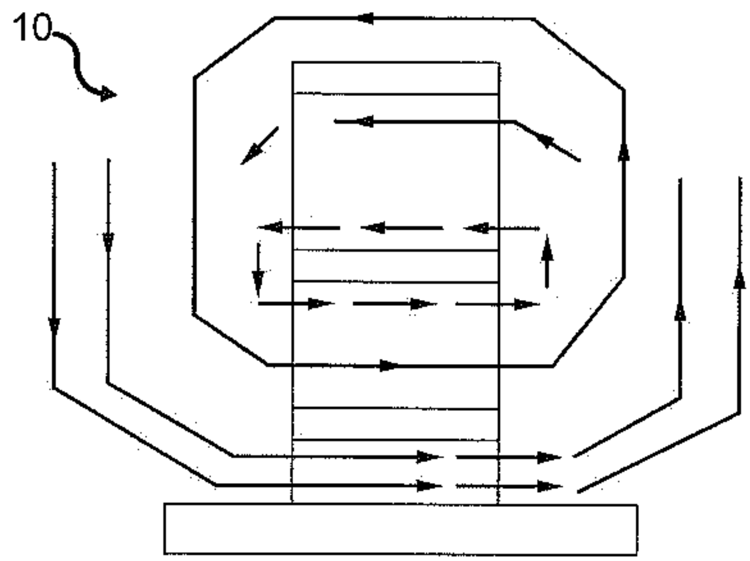

FIG .7