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Karl KIEFER, *et al*
Vomit Beam

See also : RUBTSOV : Puke Ray

http://www.wired.com/2007/03/navy_researchin/

Navy Researching Vomit Beam (Updated)
by Noah Shachtman

You never know what's going to land in your mailbox. Last night, I found a weapon that shoots an invisible wall-penetrating beam that makes people so dizzy they fall over. (It can make them puke, too, but I'll get to that in a moment.)

Okay, okay… it was only a description of the device that I came across, going through my (mostly junk) mail. The less-lethal weapon was one of many novelties described in an invitation to the "Navy's 07 'Opportunity Forum" for small businesses.

Invocon, Inc., one of dozens of companies expected to showcase their wares at the forum, says it'll be there to display its "non-lethal, stand-off weapon for military and law enforcement personnel that could ultimately work through walls and other non-metallic structures."

They've even got a Navy contract to develop the thing. I looked up Invocon's contract in the Navy's Small Business Innovative Research database and found this slightly more detailed description of the work:

IVC proposes to investigate the use of beamed RF [radio frequency] energy to excite and interrupt the normal process of human hearing and equilibrium. The focus will be in two areas. (1) Interruption of the mechanical transduction process by which sound and position (relative to gravity) are converted to messages that are processed by the brain. (2) Interruption of the chemical engine which sustains the proper operation of the nerve cells that respond to the mechanical transduction mechanisms referenced in item (1). Interruption of either or both of these processes has been clinically shown to produce complete disorientation and confusion.

Wow! Through the walls? That even beats the Active Denial System — the pain ray that Noah wrote about the other day. Invocon even touts its device as a "Star Trek hand-held Phaser Weapon set on 'Stun'."

However, rather than causing intense pain, like the Active Denial System, Invocon is advertising a weapon that boasts the ability to go through walls and incapacitate everyone in a room by making them lose their balance. "Second order effects would be extreme motion sickness," the company notes.

Basically, you're safely in your house, an invisible beam hits you, you feel dizzy, and fall over (or puke). Or so goes the promotion:

The benefits of such a weapon would be that in areas of extreme risk to Marine Corps personnel, hostiles could be controlled without loss of life. The weapon effect would be helpful in urban combat where rooms could be subjected to the EPIC stimulus and then subdued without further risk to friendlies or hostiles. Similar technology could be applied to law enforcement operations especially in hostage situations where all the people in a room could be incapacitated without damage and subsequently sorted out as to which are the bad guys and which are the good guys.

Invocon claims they have already held the "first known demonstration" of this technology. You gotta wonder who that lucky employee was.

US7841989
Electromagnetic personnel interdiction control method and system

Inventor: KIEFER KARL / CHAMPAIGNE KEVIN

An electromagnetic personnel interdiction control (EPIC) non-destructive stun type weapon system and method utilizes beamed RF energy (Lorentz Force) to disrupt the normal mechanical transduction process and/or the chemical engine by which sound, position and other sensory input are converted to messages by nerve cells and processed by the brain to produce complete disorientation, confusion, and temporary incapacitation sufficient to temporarily and remotely render a human powerless to resist arrest or subjugation. Removal of the RF electromagnetic energy will leave the nerve cells and surrounding tissues with no damage and the second order effects of severe motion sickness and the psychological effects of "helplessness" remains until the body chemistry returns to normal.

BACKGROUND OF THE INVENTION

1. Field Of The Invention

This invention relates generally to non-destructive stun weapons, and, more particularly to a non-destructive stun type weapon that utilizes beamed electromagnetic RF energy (Lorentz Force) that disrupts the normal mechanical transduction process and/or the chemical engine by which sound, position and other sensory input are converted to messages by nerve cells and processed by the brain to produce complete disorientation and confusion to temporarily and remotely render a human powerless to resist arrest or subjugation.

2. Background Art

There is a long-felt need in the military and in law enforcement for a non-destructive stun type weapon that would remotely incapacitate a hostile war fighter, terrorist, or criminal suspect ineffective for a period of time without permanent damage.

The US military has achieved improved accuracy and the ability to target small objectives with precision that precludes widespread collateral damage. These improvements are in air-to-ground munitions as well as ground-to-ground weapons. This precise destruction of

"hostile military targets" while allowing adjacent personnel and structures to survive with no damage has broadened the ability of political decision makers to respond with "measured response" force to threats of terror and hostile military actions. These responses are more politically acceptable since innocent civil casualties are kept at a minimum. The desirability of waging bloodless war to counter threats to national security is virtually limitless since both military and civil authority could determine a priori when and if loss of human life is necessary.

Clinical evidence demonstrates that hearing and equilibrium disruption may result from disease and side effects from medication. Considerable efforts are being made to better understand the mechanics of the inner ear so that effective treatments may be made available to counter the debilitating effects of mechanical and chemical disruption of normal human functions. However, the existence of these debilitating effects prove that chemical interruption of inner ear processes can produce effects that are desirable for a stun type weapon if they are not permanent.

The human vestibular system is remarkably sturdy under a variety of conditions. Yet, it has been proven vulnerable. Most of the time, the vestibular loss is transient. However, in some cases the loss is recurring, escalating and, ultimately, permanent. There are several levels at which the vestibular function can be affected: interference with the function of the central nervous system components of balance and the interruption of the hair cell's transduction process. The means to interfere with the nervous system would be to emulate, for example, the stimuli of the motion sickness, which can be quite debilitating. Visual stimulations such as virtual reality or virtual simulator sickness are also classed as disruption at the level of the central nervous system.

Various chemicals and drugs are known that disrupt the function of vestibular hair cells themselves. Calcium channel blockers interfere with normal function at the hair bundle level. Other drugs disrupt the synaptic and post-synaptic process. Yet other drugs cause death of the hair cell itself. The vestibulotoxic medications are also used to suppress vestibular function to treat vestibular disorders, such as vertigo and vestibular migraine. However, inducing chemical changes in the body without contact is not an easy path.

The normal operation of the cells of the ear, vestibular system, and the eye can also be disrupted by increasing or decreasing the magnitude of the static charge on the particular cell membranes to adversely affect its attraction to calcium (Ca) and/or potassium (K) ions and thereby impact the rate of ion flow and the ultimate pulse rate of the cells. Uncorrelated data would then be fed to the brain and the brain would have no basis for decoding, thereby creating disorientation.

Altering the normal electromagnetic field and subsequent surfaces charges on the tissues of the ear, vestibular system and the eye can change the impedance of their conduction capabilities, disturb the ion flow, and subsequently impact the pulse output of the cells to the brain. This interruption of normal ion flow would cause pulse patterns to the brain that it cannot decode, thereby creating disorientation.

The normal electrochemical balance of substantially all of the cells of the human body relative to the rest of the body fluids can be disrupted by altering the relative charge level to cause the cells to activate the protein doors or cation channels in the cell wall that allow unidirectional passage of negative charge sodium (Na) ions and the opposite passage of positively charged calcium (Ca) ions, thereby causing hyperactive chemical exchanges that can negatively impact the system and disrupt normal smooth and striated muscular functions.

The application of pulses of voltage directly to nerve paths can also feed uncorrelated sensory input data to the brain that would ultimately produce some level of disorientation.

It is well known in the field of physics that electromagnetic radio frequency energy can actually excite physical movement in devices that are tuned to sympathetic resonance, and certain resonant structures can respond to and demodulate high frequency radio carrier energy.

The present invention is distinguished over the prior art in general by an electromagnetic personnel interdiction control (EPIC) non-destructive stun type weapon and method that utilizes beamed electromagnetic RF energy (Lorentz Force) to excite and interrupt the normal process of human hearing, equilibrium and other senses to produce complete disorientation and confusion. This is accomplished by: (1) interruption of the mechanical transduction process by which sound, position (relative to gravity) and other sensory input is converted to messages that are processed by the brain; and (2) interruption of the chemical engine which sustains the proper operation of nerve cells that respond to the mechanical transduction mechanisms. Interruption of either or both of these processes produces complete disorientation and confusion sufficient to temporarily and remotely render a human powerless to resist arrest or subjugation.

The present invention provides a minimum destruction weapon that can temporarily incapacitate a human threat as a point or area target and will operate through walls and other protective mediums that now provide cover for combatants in urban warfare situations. It provides an individual soldier or law enforcement officer with the ability to reduce an opponent to helplessness from a remote location while doing no permanent damage. Such a weapon has significant utility for use by military units in an assault situation, allowing them to remotely subdue and capture hostile war fighters, terrorists, and large numbers of prisoners that would result from the "stun and restrain" tactic. The damage of friendly fire mistakes would be minimized since no permanent damage would be done by the stun weapon. Used in "special operations" raid scenarios, the prisoner issues would not be critical since the raid would be in and out before the complete recovery of stunned combatants. It also has significant utility for use by law enforcement personnel, allowing them to remotely incapacitate criminal suspects or rioters from a remote location and render them ineffective for a period of time without permanent damage.

SUMMARY OF THE INVENTION

It is therefore an object of the present invention to provide an electromagnetic personnel interdiction control (EPIC) non-destructive stun type weapon apparatus and method that utilizes beamed RF energy (Lorentz Force) to remotely excite the human vestibular inner ear system and interrupt the normal process of human hearing and equilibrium and thereby produce complete disorientation, confusion, and temporary incapacitation sufficient to render a human powerless to resist arrest or subjugation.

It is another object of this invention to provide an electromagnetic personnel interdiction control (EPIC) non-destructive stun type weapon apparatus and method that utilizes electromagnetic waves to interfere with vestibular function by applying Lorentz Force on the ionic currents in the cilia of the human inner ear to cause extraneous motion of the entire ciliary bundle thereby creating disorienting input to the brain resulting in a reaction that produces complete disorientation and confusion and will render a person inoperable for the duration of the stimulus and for a short time thereafter.

Another object of this invention is to provide an electromagnetic personnel interdiction control (EPIC) non-destructive stun type weapon apparatus and method that produces complete disorientation and confusion utilizing electromagnetic waves to interfere with vestibular function by transmitting radio frequency transmissions having a frequency and modulation correlated to the physical and chemical structure of the human inner ear transduction process to: (1) interrupt the mechanical transduction process by which sound and position (relative to gravity) are converted to messages that are processed by the brain; and (2) interrupt the chemical engine which sustains the proper operation of the nerve cells that respond to the mechanical transduction mechanisms.

Another object of this invention is to provide a non-destructive stun type weapon for use by military and law enforcement personnel that will remotely incapacitate a hostile war fighter, terrorist, or criminal suspect from a remote location and render them ineffective for a period of time without permanent damage.

Another object of this invention is to provide a non-destructive stun type weapon for use by military and law enforcement personnel that provides a weapon that can temporarily incapacitate a human threat as a point or area target.

Another object of this invention is to provide a non-destructive stun type weapon for military personnel for use in an assault situation, allowing military units to remotely subdue, and capture, large numbers of prisoners that would result from the "stun and restrain" tactic, without shooting or gunfire.

Another object of this invention is to provide a non-destructive stun type weapon for use by military and law enforcement personnel that can operate through walls and other protective mediums that now provide cover for combatants to temporarily incapacitate the combatant threat.

Another object of this invention is to provide a non-destructive stun type weapon for use by military and law enforcement personnel that will disrupt the normal operation of the cells of the ear, vestibular system, and the eye by increasing or decreasing the magnitude of the static charge on the particular cell membranes to adversely affect its attraction to calcium (Ca) and/or potassium (K) ions and thereby impact the rate of ion flow and the ultimate pulse rate of the cells, such that uncorrelated data would then be fed to the brain and the brain would have no basis for decoding, thereby creating disorientation.

Another object of this invention is to provide a non-destructive stun type weapon for use by military and law enforcement personnel that will alter the normal electromagnetic field and subsequent surfaces charges on the tissues of the ear, vestibular system and the eye and change the impedance of their conduction capabilities, disturb the ion flow, and subsequently impact the pulse output of the cells to the brain to produce pulse patterns that it cannot decode, thereby creating disorientation.

Another object of this invention is to provide a non-destructive stun type weapon for use by military and law enforcement personnel that is capable of disrupting the normal electrochemical balance of various cells of the human body relative to the rest of the body fluids by altering the relative charge level to cause the cells to activate the protein doors or cation channels in the cell wall that allow unidirectional passage of negative charge sodium (Na) ions and the opposite passage of positively charged calcium (Ca) ions, thereby causing hyperactive chemical exchanges that can negatively impact the system and disrupt normal

smooth and striated muscular functions.

Another object of this invention is to provide a non-destructive stun type weapon for use by military and law enforcement personnel that is capable of remotely applying pulses of voltage directly to nerve paths to feed uncorrelated sensory input data to the brain that would produce disorientation.

A further object of this invention is to provide an electromagnetic personnel interdiction control (EPIC) apparatus and method for use in medical applications to correct or alleviate symptoms of dizziness, Benign Paroxysmal Positional Vertigo (BPPV), disorientation, lightheadedness, imbalance, nausea, and confusion, utilizing electromagnetic waves to enhance vestibular function by transmitting radio frequency transmissions having a frequency and modulation correlated to the physical and chemical structure of the human inner ear transduction process to: (1) normalize the mechanical transduction process by which sound and position (relative to gravity) are converted to messages that are processed by the brain; and/or (2) normalize the chemical engine which sustains the proper operation of the nerve cells that respond to the mechanical transduction mechanisms.

A still further object of this invention is to provide a non-destructive stun type weapon for use by military and law enforcement personnel that will remotely incapacitate a hostile human combatant that is inexpensive to manufacture, quick and easy to implement, and safe and reliable in operation.

Other objects of the invention will become apparent from time to time throughout the specification and claims as hereinafter related.

The above noted objects and other objects of the invention are accomplished by an electromagnetic personnel interdiction control (EPIC) non-destructive stun type weapon apparatus and method that utilizes beamed RF energy (Lorentz Force) to excite and interrupt the normal process of human hearing, equilibrium and other senses to produce complete disorientation and confusion. This is accomplished by: (1) interruption of the mechanical transduction process by which sound, position (relative to gravity) and other sensory input is converted to messages that are processed by the brain; and (2) interruption of the chemical engine which sustains the proper operation of nerve cells that respond to the mechanical transduction mechanisms. Interruption of either or both of these processes produces complete disorientation and confusion sufficient to temporarily and remotely render a human powerless to resist arrest or subjugation. Removal of the RF excitation of the targeted structure will leave the organs and surrounding tissues with no damage. The second order effects of severe motion sickness and the psychological effects of "helplessness" remains until the body chemistry returns to normal.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an illustration of the human membranous labyrinth with cochlea and vestibular system.

FIG. 2 is a schematic illustration of the otolith organs showing the details of the utricle, ococonia, endolymph, cupula, macula, hair cell filaments, and saccular nerve.

FIG.3 is a schematic cross section through the cochlea.

FIGS. 4, 5 and 6 are schematic illustrations of the ciliary hair bundle showing the hair

cell directional polarization, ciliary transduction mechanism, and the deflection of the ciliary hair bundle toward and away from the kinocilium and the resultant change in conductivity.

FIG. 7 is a schematic illustration of the electromagnetic wave.

FIG. 8 is a graph illustrating an example of a signal modulation scheme.

FIG. 9 is a graph showing the magnetic field strength required to create a 15 nm displacement of a ciliary hair bundle.

FIG. 10 is a block diagram illustrating a typical electromagnetic personnel interdiction control (EPIC) system.

FIG. 11 is a schematic illustration showing a person aiming the antenna of the electromagnetic personnel interdiction control (EPIC) system at an attacker.

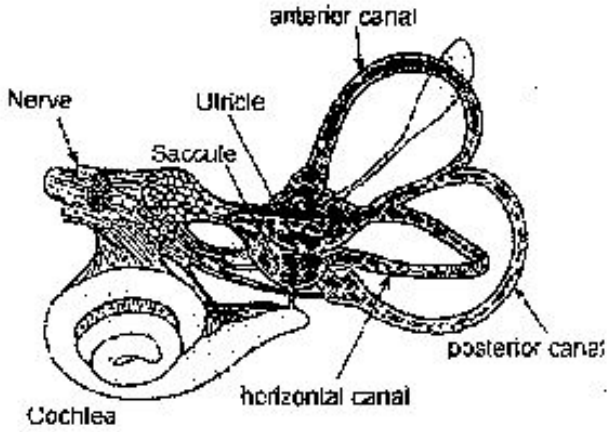


Fig. 1

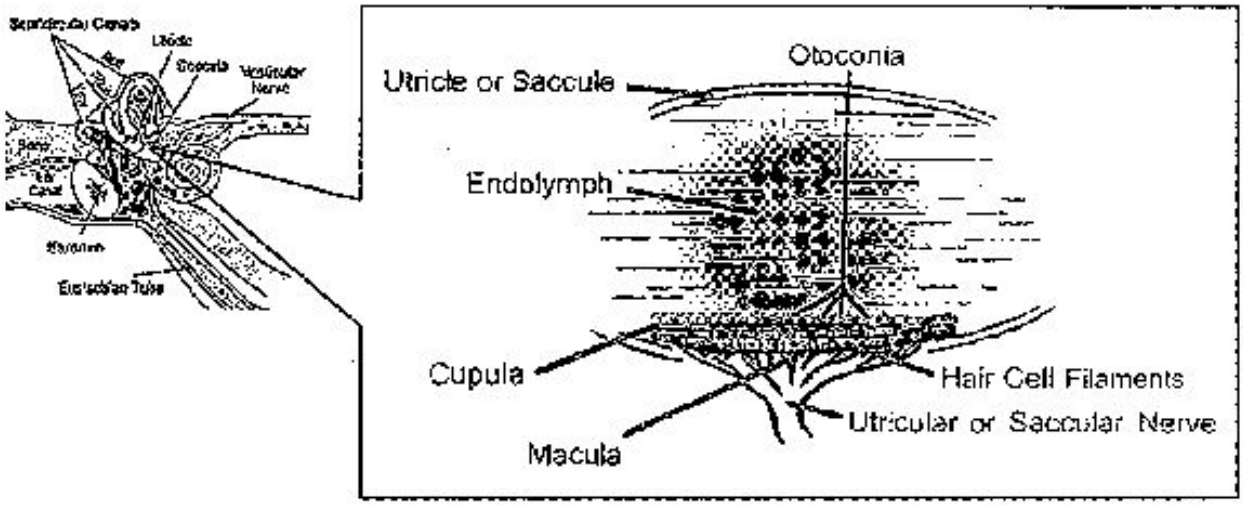


Fig. 2

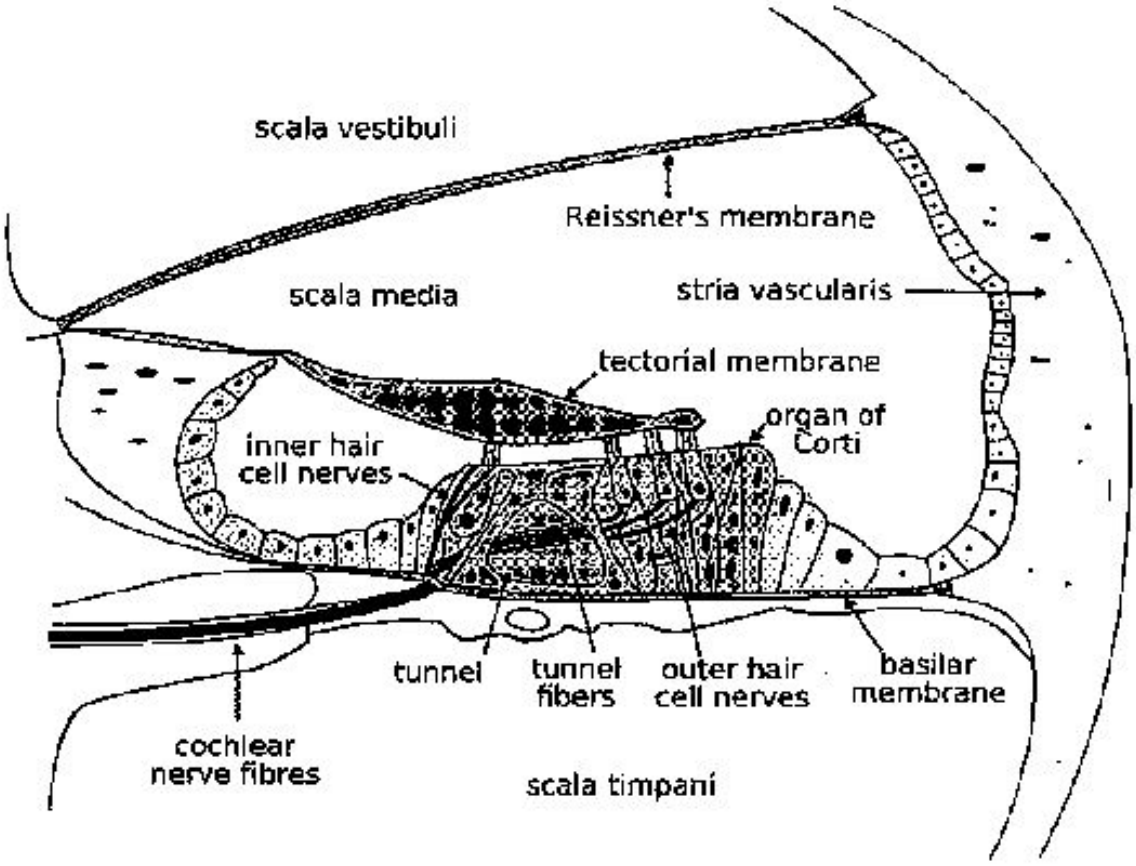


Fig. 3

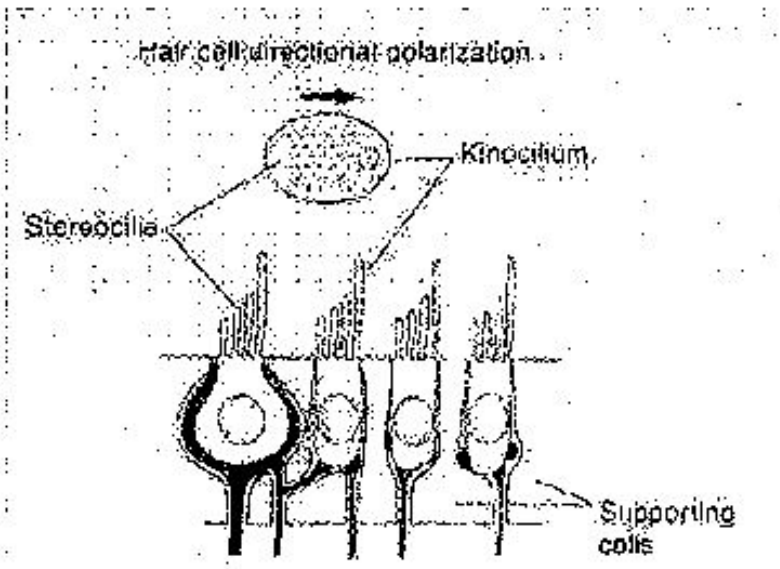


Fig. 4

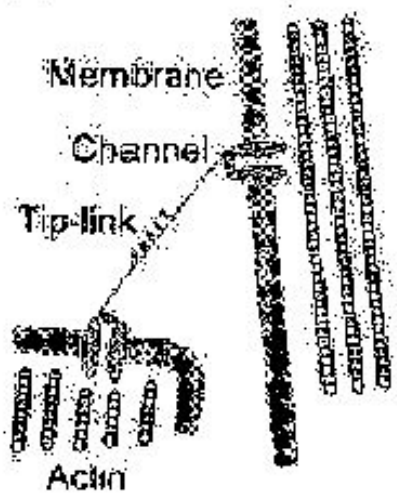
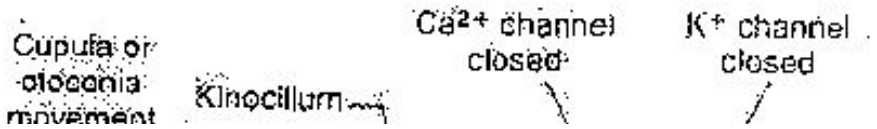


Fig. 5



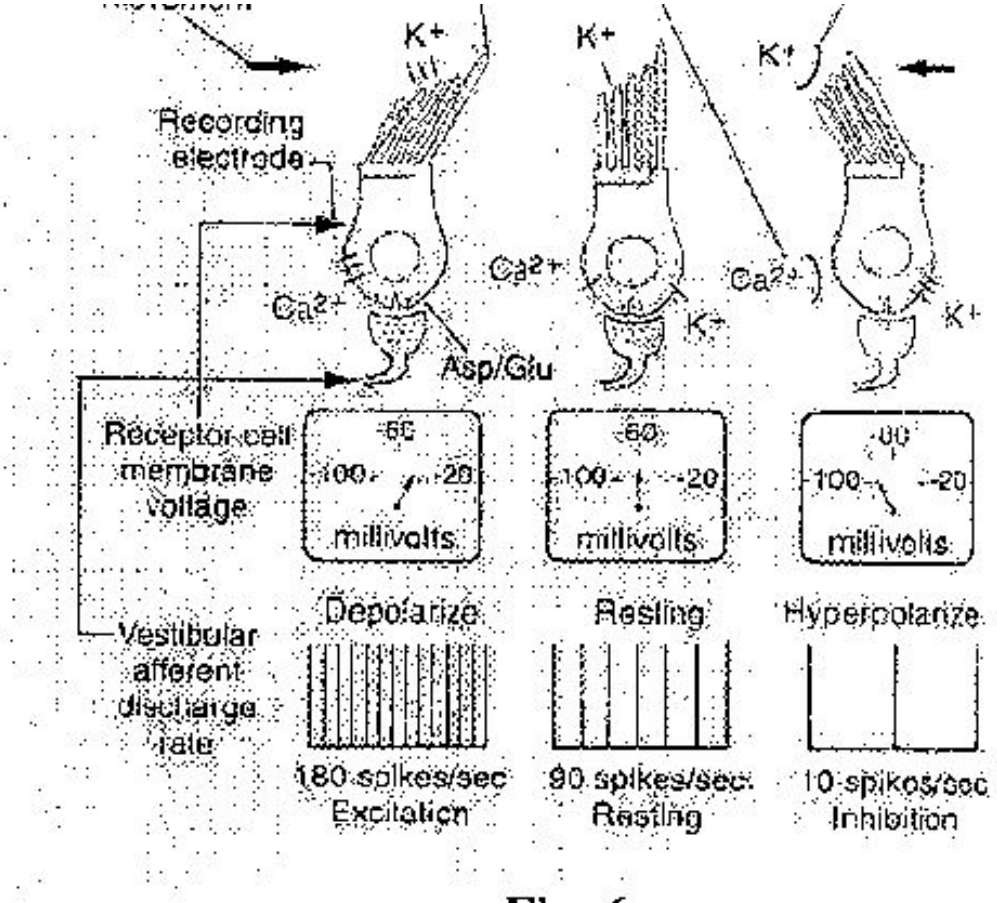

K+
K+
K+
Recording electrode
Ca2+
Ca2+
Ca2+
K+
K+
Asp/Glu
Receptor cell membrane voltage
-60
-100
-20
millivolts
-60
-100
-20
millivolts
-60
-100
-20
millivolts
Depolarize
Resting
Hyperpolarize
Vestibular afferent discharge rate
180 spikes/sec Excitation
90 spikes/sec Resting
10 spikes/sec Inhibition

Fig. 6

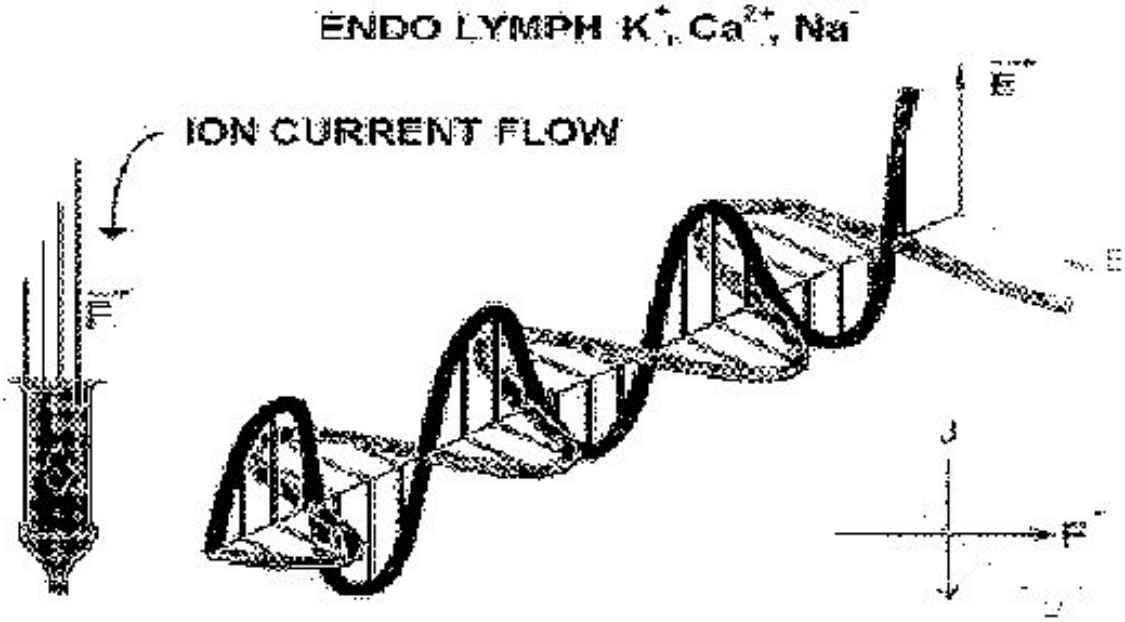

ENDO LYMPH K+, Ca2+, Na+
ION CURRENT FLOW

Fig. 7

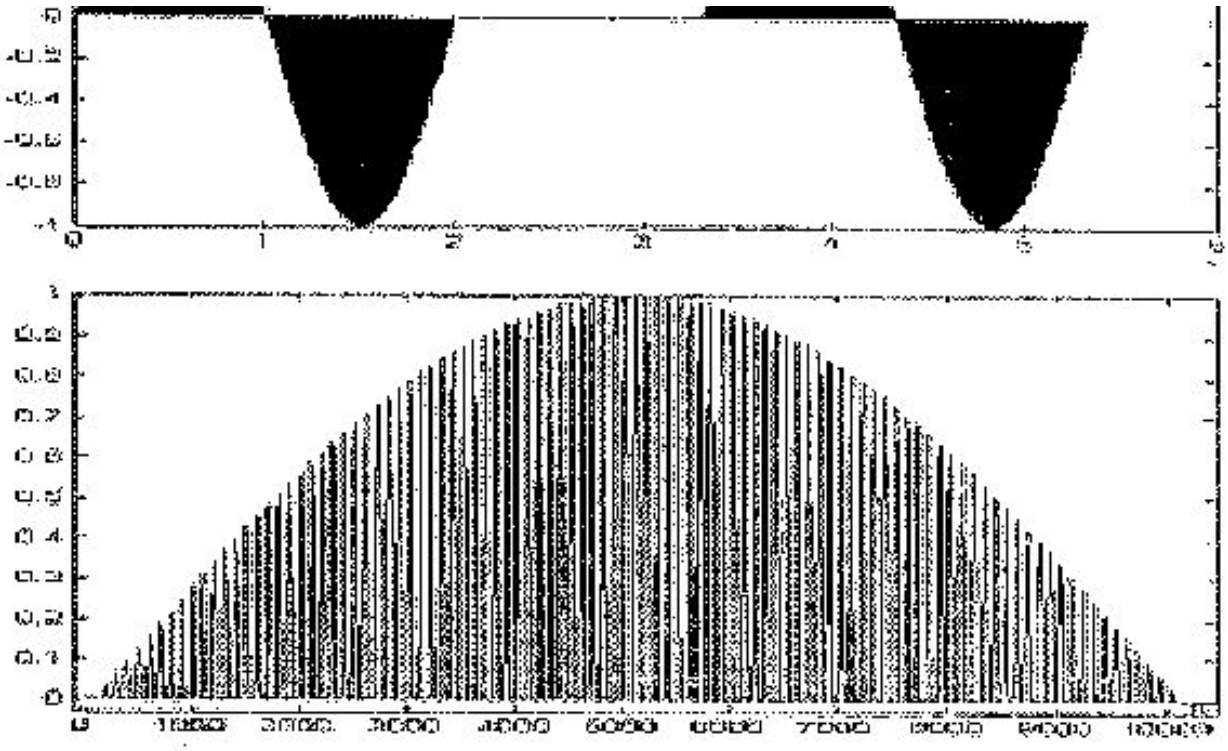


Fig. 8 Modulation scheme for EPIC signal. Upper panel shows a signal with two consequent pulses. Lower panel is a zoom into the first half-wave of the pulse.

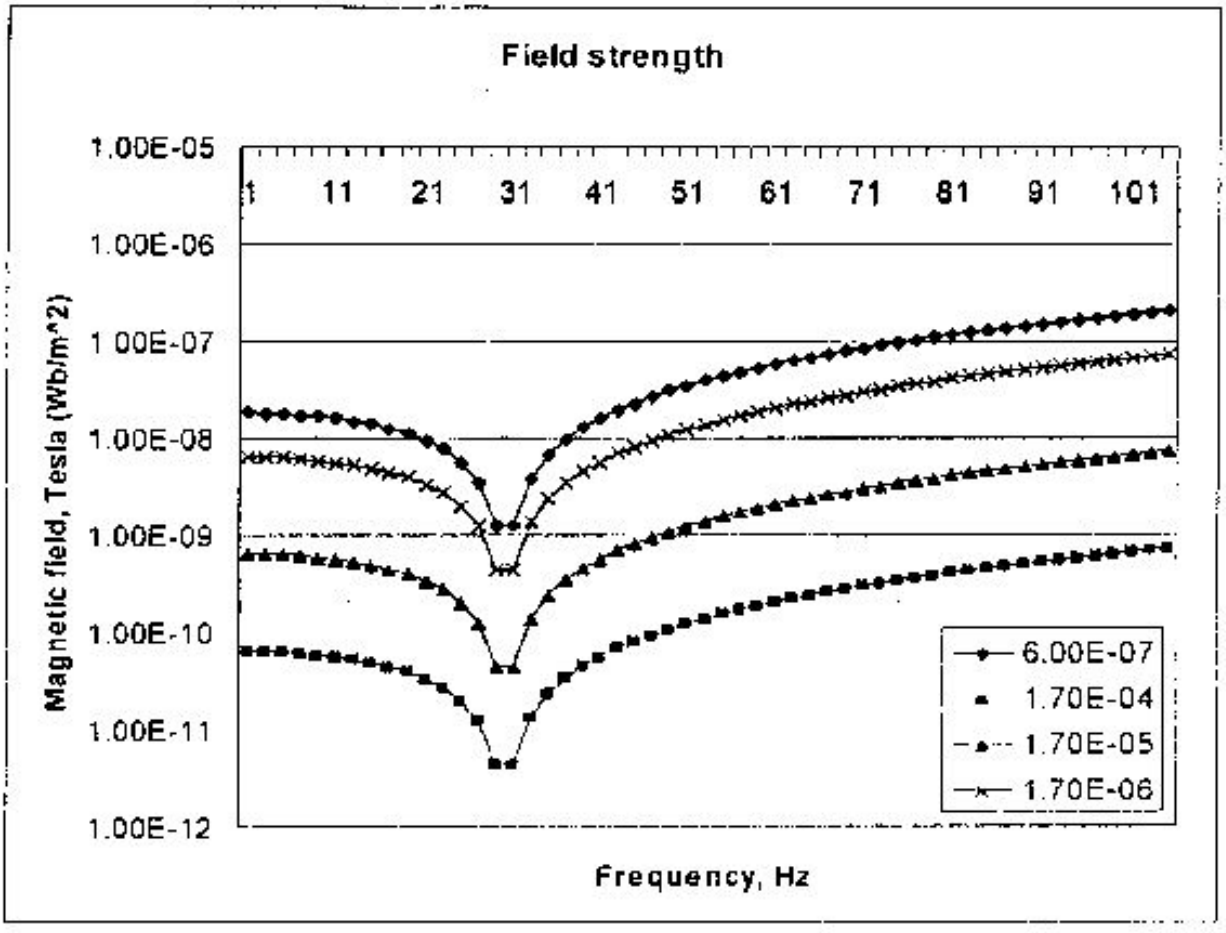


Fig. 9 Magnetic field strength required to create 15 nm displacement. Field is plotted as a function of driving frequency at various values of resting current.

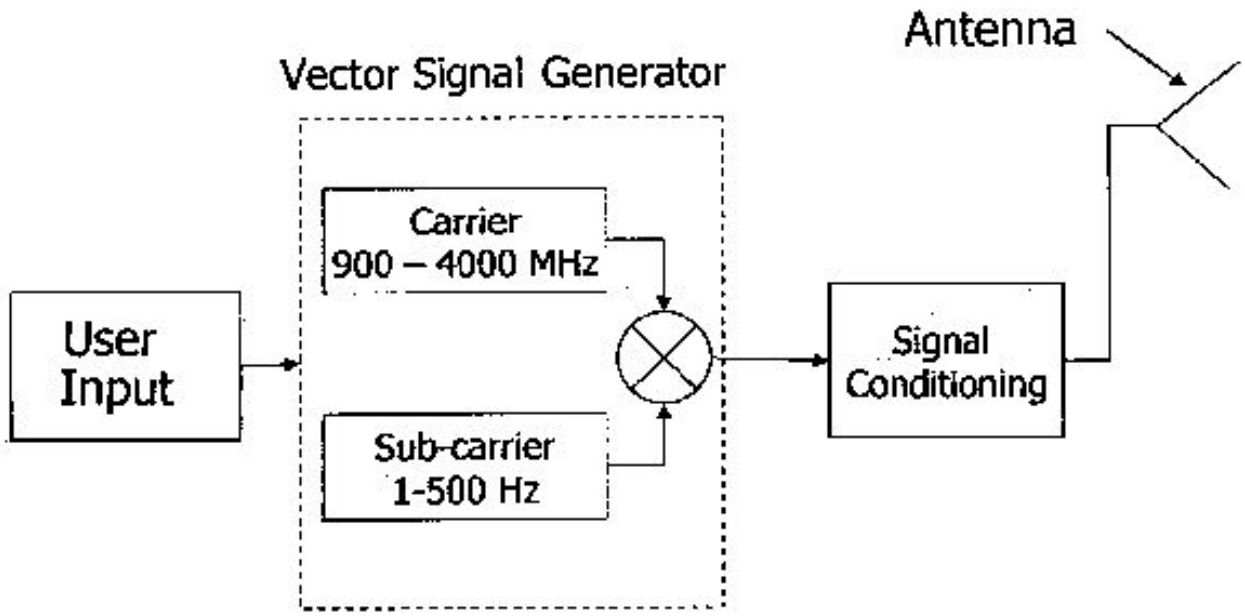


Fig. 10

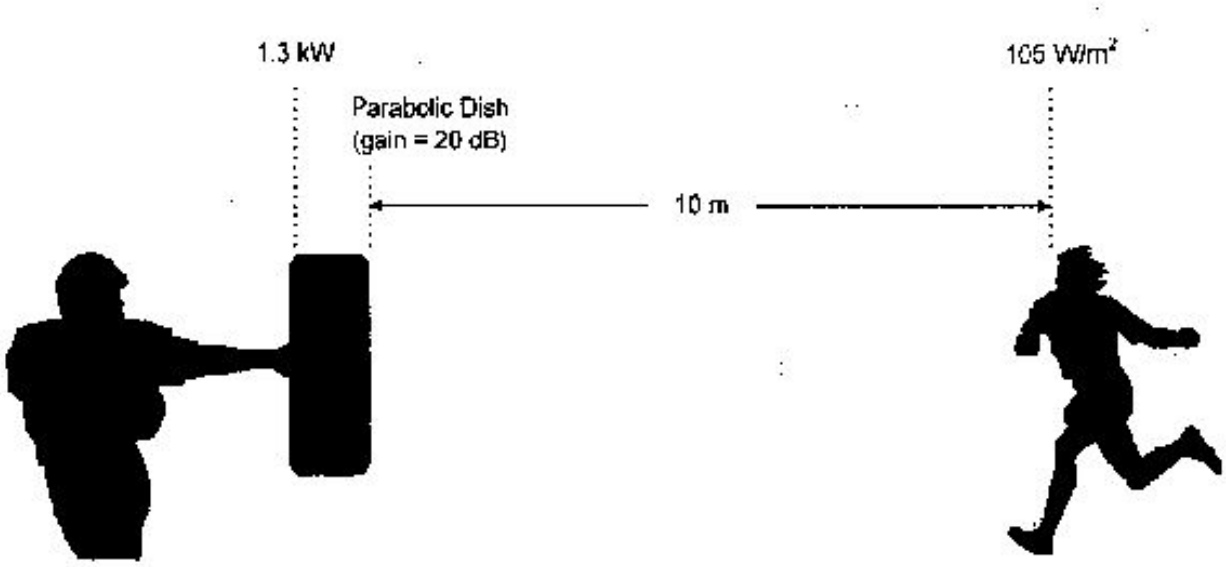


Fig. 11

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Human perception depends on the classical five senses of hearing, sight, smell, taste and touch. Along with these there are at least four other senses: equilibrioception (balance), proprioception (body awareness), thermoception (heat) and nociception (pain). Vestibluar System

Referring to FIGS. 1 and 2, the auditory system is the sensory system for the sense of hearing. On its path from the outside world to the forebrain, sound information is preserved and modified in many ways. It changes media twice, first from air to fluid, then from fluid to "action potentials". Together with the cochlea and numerous liquid containing vesicles, the vestibular labyrinth forms the membranous labyrinth of the inner ear. It contains five separate specialized sensory receptors: three semicircular canals, and two otolith organs that complement each other in function. The semicircular canals (horizontal, anterior, and posterior) transduce rotational head movements (angular accelerations). The otolith organs (utricle and saccule) respond to translational head movements (linear accelerations) or to the orientation of the head relative to gravity. Each semicircular canal and otolith organ is spatially aligned to be most sensitive to movements in specific planes in three-dimensional space.

The vestibular system sends signals primarily to the neural structures that control our eye movements, and to the muscles that keep us upright. The projections to the former provide the anatomical basis of the vestibulo-ocular reflex, which is required for clear vision; and the projections to the muscles that control our posture are necessary to keep us upright.

As shown schematically in FIGS. 3, 4, 5 and 6, "hair cells" are the sensory receptor cells of the auditory system in all vertebrates. In mammals, the hair cells are located within the cochlea's organ of Corti (FIG.3). They derive their name from the tufts of stereocilia that protrude from the apical surface of the cell, a structure known as the hair bundle. Each hair cell contains 60 to 100 hexagonally arranged stereocilia and a single longer kinocilium (FIG. 4). Mammalian hair cells come in two anatomically and functionally distinct types: the outer and inner hair cells (FIG.3). Damage to these hair cells results in decreased hearing sensitivity, i.e. sensorineural hearing loss. Research of the past decades has shown that outer hair cells are motile and mechanically amplify low-level sound that enters the cochlea. The inner hair cells transform the sound vibrations in the fluids of the cochlea into electrical signals that are then relayed via the auditory nerve to the auditory brainstem and to the auditory cortex.

In the utricle and saccule hair cells, the otolithic membrane covers the stereocilia and its displacement excites the hair cells in unison. In the semicircular canals, the stereocilia are embedded in the gelatinous cupula that helps translate the motion of the endolymph that fills the canals into the unified motion of the hair cells residing in the cupula. In normal circumstances, the motion of the membranes will lag the head movements, creating a shearing distortion upon the underlying gel with cilia embedded in it.

As described above, the stereocilia are coupled to nerves. Excitation of these hairs activates nerve impulses that the brain interprets as sound or position relative to gravity. The nerves that connect the hairs and produce electrical impulses to the brain operate on the exchange of ionized calcium (Ca) and potassium (K) through semi-permeable cell membranes. Random and/or simultaneous excitation of all the hair/nerve combinations and the upset of the normal ionic chemistry produce sensations of intense wideband sound and complete disorientation which the brain has little or no hope of decoding.

The hair cell transduction mechanism is depicted schematically in FIGS. 5 and 6. The deflection of the ciliary (hair) bundle towards or away from the kinocilium causes change in conductivity of the cilia. Variation of ciliary current in turn causes change in the membrane potential of the hair cell, which leads to variation in the firing rate of the neuron, associated with this hair cell. The axis along which the motion has the most effect is a polarization line.

To disrupt the vestibular function, the present electromagnetic wave (described in greater detail hereinafter) impinges on the vestibular organs. Interaction of the alternating magnetic field with the current in hair bundles perpendicular to wave propagation will create an alternating sideways force on the cilia containing the current, and therefore on the entire ciliary bundle. Swaying of the bundle will produce periodic hyperpolarization-depolarization pattern at the cellular membrane leading to the increased decreased-increased firing rate of the cells.

The generic action and the representation of the electromagnetic wave (EMW) are illustrated schematically in FIGS. 6 and 7. The EMW has the electric field (heavier dark sinusoid) and the magnetic field (lighter sinusoid) alternating in phase in mutually perpendicular directions that are also perpendicular to the direction of the wave propagation. To begin, let us assume for an instant that magnetic field B is constant, and directed away from the reader, into the page. Positive potassium K<+> and calcium Ca<2+> ions flow down from outer end of the cilia towards cell body, and ciliary current J is also directed downwards according to the convention that current is directed along the motion of the positive charges. With the current directed down, and the magnetic field B directed into the page, the Lorentz force on the cilium F points to the right. Now, if the field changes the direction, the force will change the sign, too, pushing the cilium to the left. This will happen if the wave approaches the ciliary bundle from the right. The electric field now alternates in the vertical direction, whereas magnetic component sinusoidally oscillates in the direction perpendicular to the page, exerting horizontal (sideways) Lorentz force on the bundle.

Depending on the polarization and direction of the electromagnetic wave (EMW), different vestibular organs will be affected. The three cupulae, stretched across the ampullated end of each of the semicircular canals that act as transducers of angular accelerations, will be affected in their entirely. The sensory membranes in the saccule and utricle that transduce linear accelerations and static displacements have complex topology with several distinct excitation regions that are thought to be instrumental in distinguishing acceleration from head tilt by distinguishing the excitation patterns. Whatever is the excitation area, the stimulation will produce coherent input from the affected region, similar to what happens in normal circumstances. The effect of partial stimulation of either vestibular organ would be twofold: (1) as a result from the mismatch between the visual and vestibular sensory clues presented to the brain (vestibular system reports extraneous acceleration or motion that the eyes do not perceive); and (2) as a result of the unusual nature of the stimulus experienced by the vestibular system. The first action mechanism plays an up tight interconnection between visual and vestibular functions. Vestibular system inputs are used to steady the gaze during walking-a problem in early camcorders that lacked image stabilization filtration, when jumpy movies caused nausea in the viewers. This relation is amply demonstrated by the nausea associated with motion sickness when the brain cannot cope with mismatch between the visual clues of rest (no motion) and the vestibular clues of acceleration as happen on a ship or an airplane.

The second action mechanism borrows from the clinical observation of patients with Benign (Paroxysmal) Positional Vertigo (BPPV or BPV). Vertigo and syncope are the most common symptoms of BPPV, which are brought on by the contamination of the endolymph (liquid that fills semicircular canals responsible for detection of the angular accelerations) with otoconia crystals that have separated from otolith. Presence of the otoconia in the affected semicircular canal makes it gravity-sensitive, which results in the inappropriate input from the aforesaid semicircular canals. It is believed that it is the novelty of the stimulus that causes debilitating loss of balance that lasts from 30 to 60 seconds. Relaxation time is most probably a result of the viscous deceleration of the otoconia by surrounding endolymph liquid, rather than an

indication of brain's capability for adaptation. Therefore, the system mimicking symptoms associated with BPPV would be a very satisfactory means of temporary incapacitation.

The present electromagnetic personnel interdiction control (EPIC) system and method seeks affect changes at the cellular level by applying a Lorentz force to the bundles with the aim to overdrive the hair bundle oscillating under a normal stimulus or to excite an oscillation of the hair bundle producing in both cases an extraneous, unanticipated signal that is not matched by any other senses. The external motion of the hair bundles causes a hair cell to generate corresponding ciliary current that results in the change of membrane potential. In their animal studies of the cilia motion under transepithelial (through the membrane) electrical stimulation, Hudspeth et al. found that at the frequencies above the hair bundle's natural frequency (35 and 8 Hz for two saccular hair cell bundles of the bullfrog studied), the bundles' oscillations were a superposition of the driving and natural frequencies. Bozovic D, Hudspeth, A. J., "Hair-bundle movements elicited by transepithelial electrical stimulation of hair cells in the sacculus of the bullfrog", Proc Natl Acad Sci USA. 2003 Feb 4; 100(3):958-63.

These findings show the reciprocal nature of the mechano-chemical properties of the hair cells: the stimulation of the bundle causes changes on the membrane and vice versa. In the present system, we reciprocate these findings to conclude that if the ciliary bundle is driven at some frequency, there will be a response at the membrane, creating the desired neuronal activity that will be presented to the vestibular center in the brain.

Current knowledge of BPPV supports long-term effectiveness of the system. The fact that patients suffering from BPPV are usually instructed to relieve the symptoms by a series of controlled movements and absence of reports about the familiarization with the stimulus corroborate the argument that brain cannot learn and adapt to the stimulus within the timeframe of weapon usage and frequency of exposure. Moreover, from the chronic nature of the affliction, we deduce the potential to use the system repeatedly without losing its effectiveness.

The present system can also be modified to act at a more complex level. The vestibular system does not have the dynamic feedback of the cochlea, which lends so much complexity to the latter. There is no active processing and no continuous adaptation that makes our hearing so versatile. On the contrary, for secure functioning of the balance system, the vestibular inputs must always be the same, predictable and repeatable. The only "vestibular adaptation" is observed under continuous or frequent exposure to a stimulus. Researchers have described it as a "semi-premanent change of perception or perceptual-motor coordination that serves to reduce or eliminate a registered discrepancy between or within sensory modalities or the errors in behavior induced by this discrepancy". Return to original environment causes a renewed error, or aftereffect. Thus, repeated exposures to altered environment generally result in faster "adaptation". However, the learning applies only to that particular kind of stimulus. Therefore, the present system can act either by creating unusual sensations or by using more typical excitation in an on-off scheme.

The responses from all the hair cells in a cupula or a macula are coherent, and the brain has learned to recognize excitation patterns for various parts of the membrane, thus, varying the excitation patterns by only few hair cells may sufficient by itself to create a "panic" reaction in the brain, incapacitating the normal function.

The hair cell design is an amazing sensing mechanism with incredible dynamic range and equally incredible resolution throughout most of the dynamic range. The fundamental design

of a hair cell has proven to be evolutionary stable. The hair cells of frogs, turtles and mammals are all very similar. Most easily observable differences between the hair cells of different species are the geometric factors (size, overall bundle height, step height, number of cilia, and packing of cilia) of the bundle. There are also differences in the adaptation process timescales as well as the magnitude of the adaptation observed in various species. This divergence is a result of evolutionary adjustment to the stimuli experienced by a given species. Radio Frequency (RF) signal

FIG. 8 is a graph illustrating an example of a signal modulation scheme that was tested which fully utilizes the mechanical properties of the ciliary bundle. For the baseline power level estimate, we chose the average parameters for the hair cells measured and reported in published studies of various animal species. It is assumed that parameters of the mouse and human vestibular hair cells will not vary so much as to affect the power estimates by more than one order of magnitude. A higher radio frequency carrier is non-symmetrically modulated by a slower driving frequency for the hair bundles. This modulation scheme provides necessary permeability through most obstacles while maintaining good signal range. Displacement step and force step measurements show that the hair bundle acts as a low-pass filter integrating over high frequencies present in the input. Therefore, the hair bundle will act as an integrator for the higher frequency carrier, while fully responding to the modulation signal. Testing has shown that a carrier frequency in the 900 MHz Industrial, Scientific and Medical (ISM) band as defined by Federal Communications Commission, which is safely used by cellular phone operators, can reduce expected (non-existent) health concerns, and a driving frequency selected to be above most of the known natural frequencies of individual hair bundles (few to tens of Hz), and below the frequency of the utricular or saccular sensory system as a whole (few hundreds Hz), would avoid damage to the hair bundles by avoiding resonance where the bundle may be driven into too great an oscillation, and thereby maintain the non-lethal nature of the present system. Every other half-wave portion may be inverted to maximize the force on, and thus the displacement of, the hair bundle. This also lessens the signal power needed to achieve the same effect on the bundle.

Bundle Modeling and RF Power Level Current research indicates that the mechanical properties of the ciliary bundles yield similar order of magnitude figures for the dynamic properties of the hair bundles of outer hair cells of various species. The major source of differences can be ascribed to the evolutionary differences (i.e. frequency selectivity) in the hair cell morphology between the species. Moreover, most of the current research concentrates on the outer hair cells of the cochlea, as spontaneous activity of the latter is thought to give rise to spontaneous acoustic emissions from human ears. Two types of adaptation that alter dynamic properties of the hair bundles upon the stimulus have been observed; Fast and Slow. Slow adaptation happens within the time scales for neuronal processes, whereas fast adaptation occurs before the cellular membrane has changed polarization. Fast adaptation is believed to be meditated by the molecular motors involved in the mechano-transduction process. Most interestingly, it not only causes undesirable decrease in transduction current (at constant deflection), it also causes decrease in dynamic stiffness of the ciliary bundles. Although a decrease in the transduction current, occurring in the millisecond time scales (well below the intended stimulus) may hinder the influence of the present system; a decrease in dynamic stiffness after initial stimulation may contribute to the efficacy of present system.

The following equations are a simplified model of the hair bundle that has been used for the estimates of the frequency and the field strength of the electromagnetic wave (EMW) required to achieve certain displacement of the hair bundle. In this model, the hair bundle is treated as one point mass at the center of mass of the bundle, and idealization of the bundle

was manifest in the equal spacing between the bundles, equal density distribution among the cilia and along the length of each individual cilium. This model also assumes equal relative transducer efficiency at each cilium, and equal Lorentz force density among the cilia.
