METHOD AND APPARATUS FOR SENSORY STIMULATION

This Nonprovisional application claims priority under 35 U.S.C. §119(e) on U.S. Provisional Application Nos. 60/960,899 filed on Oct. 18, 2007, this application also claims priority under 35 U.S.C. §119(a) on Patent Application No(s). 20075651, 20080213, 20085475 and 20085472 filed in Finland on Sep. 18, 2007, Mar. 14, 2008, May 19, 2008, and May 19, 2008, respectively, the entire contents of which are hereby incorporated by reference.

BACKGROUND OF THE INVENTION

The present invention relates to an apparatus and method for sensory stimulation. The invention is particularly applicable for stimulating the sense of touch.

Manual input devices, such as joysticks and mice, are frequently complemented by means for providing tactile sensations such that the manual input devices provide tactile feedback to their users. There are hundreds of U.S. patents for tactile feedback devices. In most or all of the prior art devices the tactile stimulation is generated by means of moving or vibrating mechanical members. A problem shared by most such devices is that such moving mechanical members tend to be bulky, unreliable and/or difficult to control.

BRIEF DESCRIPTION OF THE INVENTION

An object of the present invention is to provide a method and apparatus for alleviating at least one of the problems identified above.

The object of the invention is achieved by features which are disclosed in the attached independent claims. The dependent claims and the present patent specification disclosed additional specific embodiments and non-essential features of the invention.

The invention is based on the surprising discovery that subcutaneous Pacinian corpuscles can be stimulated by means of a capacitive electrical coupling and an appropriately dimensioned control voltage, either without any mechanical stimulation of the Pacinian corpuscles or as an additional stimulation separate from such mechanical stimulation. An appropriately dimensioned high voltage is used as the control voltage. In the present context a high voltage means such a voltage that direct galvanic contact must be prevented for reasons of safety and/or user comfort. This results in a capacitive coupling between the Pacinian corpuscles and the apparatus causing the stimulation, wherein one side of the capacitive coupling is formed by at least one galvanically isolated electrode connected to the stimulating apparatus, while the other side, in close proximity to the electrode, is formed by the body member, preferably a finger, of the stimulation target, such as the user of the apparatus, and more specifically the subcutaneous Pacinian corpuscles.

Without committing themselves to any particular theory, the inventors find it likely that the invention is based on a controlled formation of an electric field between an active surface of the apparatus and the body member, such as a finger, approaching or touching it. The electric field tends to give rise to an opposite charge on the proximate finger. A local electric field and a capacitive coupling can be formed between the charges. The electric field directs a force on the charge of the finger tissue. By appropriately altering the electric field a force capable of moving the tissue may arise, whereby the sensory receptors sense such movement as vibration.

A benefit of the invention is independence from mechanical vibration and its associated problems in the prior art.

An aspect of the invention is an apparatus for generating an electrosensory stimulus to at least one body member. The apparatus comprises one or more conducting electrodes each of which is provided with an insulator. When the body member is proximate to the conducting electrode, the insulator prevents flow of direct current from the conducting electrode to the body member. A capacitive coupling over the insulator is formed between the conducting electrode and the body member. The apparatus also comprises a high-voltage source for applying an electrical input to the one or more conducting electrodes, wherein the electrical input comprises a low-frequency component in a frequency range between 10 Hz and 1000 Hz. The capacitive coupling and electrical input are dimensioned to produce an electrosensory sensation which is produced independently of any mechanical vibration of the one or more conducting electrodes or insulators.

Another aspect of the invention is a method for causing an electrosensory sensation to a body member. The method comprises providing one or more conducting electrodes. Each conducting electrode is provided with an insulator wherein, when the body member is proximate to the conducting electrode, the insulator prevents flow of direct current from the conducting electrode to the body member. A capacitive coupling over the insulator is formed between the conducting electrode and the body member. A high-voltage source is provided for applying an electrical input to the one or more conducting electrodes. The electrical input comprises a low-frequency component in a frequency range between 10 Hz and 1000 Hz, while the capacitive coupling and electrical input are dimensioned to produce an electrosensory sensation. The electrosensory sensation is produced independently of any mechanical vibration of the one or more conducting electrode(s) or insulator(s).

It is beneficial to vary the capacitive coupling such that the variation comprises one or more frequency components in a range wherein the Pacinian corpuscles exhibit their maximal sensitivity. This frequency range is roughly 10 to 1000 Hz and in most humans 100 to 500 Hz. The capacitive coupling can be varied by varying the control voltage and/or parameters of the capacitive coupling.

By way of example, the high-voltage charge applied to the electrode can have a voltage of at least 750, 1000, 1500 or 2000 V and at most 20, 50 or 100 kV (no-load measurements). In the present context, voltage values may refer to voltage in direct current or effective (RMS) voltages in alternating current. The high-voltage current applied may be direct current or alternating current. When alternating current is being used, the frequency of the current may be high, such as at least 1 kHz, 10 kHz, 20 kHz or 30 kHz and at most 100 kHz, 500 kHz tai 1 MHz, provided that the signal also exhibits a low-frequency component, for example such that high-frequency signal has an envelope whose frequency stimulates the desired sensory cells. The high-frequency alternating current can be modulated by means of a control signal having a low-frequency component, for example.

When high-voltage direct current is being used, the electrode may be embodied as a MEMS component (micro electromechanical system), which comprises a set of rotating, preferably individually controllable tiny electrodes. The strength of the capacitive coupling formed by the electrode can be adjusted by adjusting these tiny electrodes. In this case the strongest coupling is achieved when the tiny electrodes are oriented such that they collectively form a plane. In the inventive technique, by measuring the characteristics of the capacitive coupling, for example the capacitance of its varia-