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(54) **VIBRATOR TUBE**

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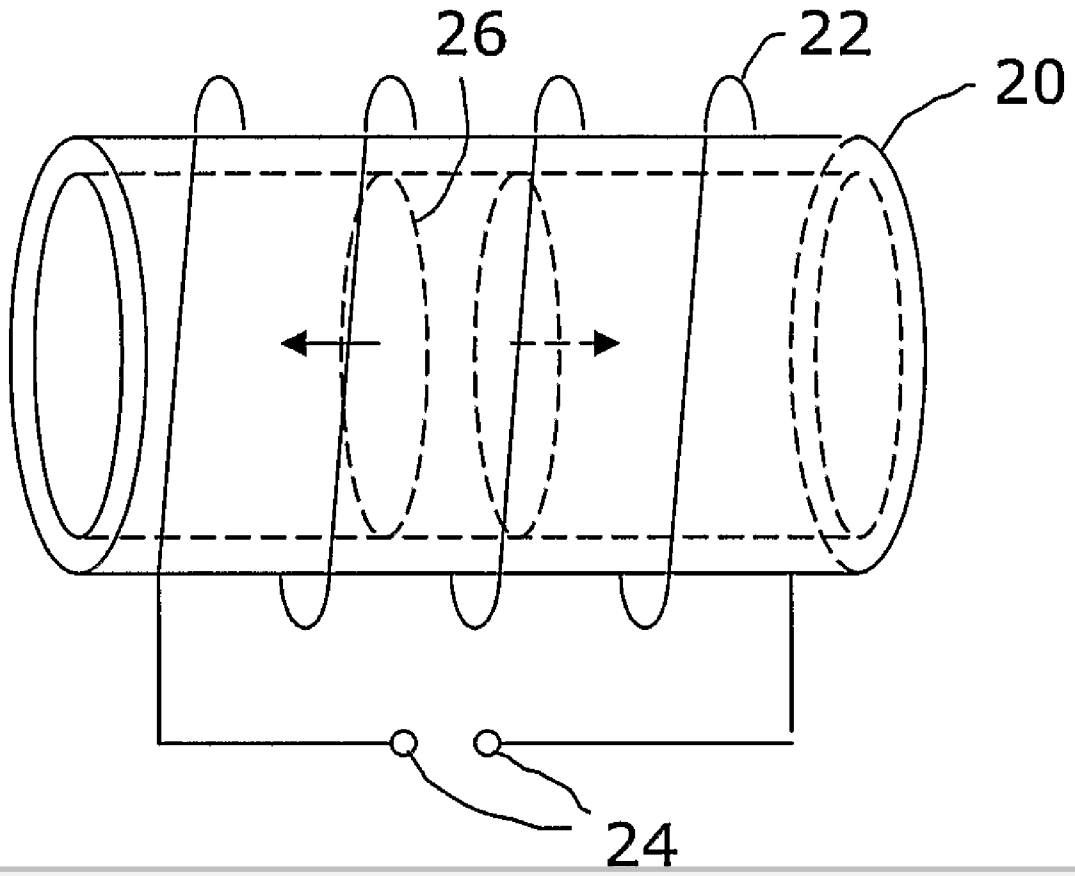
(57) **ABSTRACT**

An electromagnetic vibrator for use in a portable communication device (**90**) comprising a housing (**20**,**30**,**40**,**50**,**60**,**70**,**80**) comprising a track directed in a first dimension, a coiling (**22**,**82**) comprising at least one coil turn, oriented in a second dimension essentially perpendicular to the first dimension, coiled around the track and being arranged to receive an electric voltage, a permanent magnet assembly (**26**,**32**,**34**,**42**,**52**,**62**,**72**,**84**) arranged for motion along the track to which said permanent magnet assembly is tightly fitted, and a ferrofluid mixture placed between the track and the permanent magnet assembly (**26**,**32**,**34**,**42**,**52**,**62**,**72**,**84**), allowing motion of the permanent magnet assembly (**26**,**32**,**34**,**42**,**52**,**62**,**72**,**84**) in the first dimension in dependence of the electric voltage as supplied to the coiling (**22**,**82**).



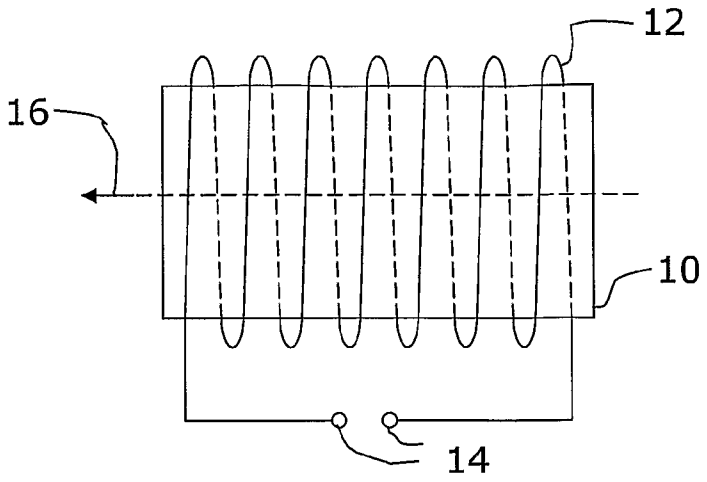


FIG. 1

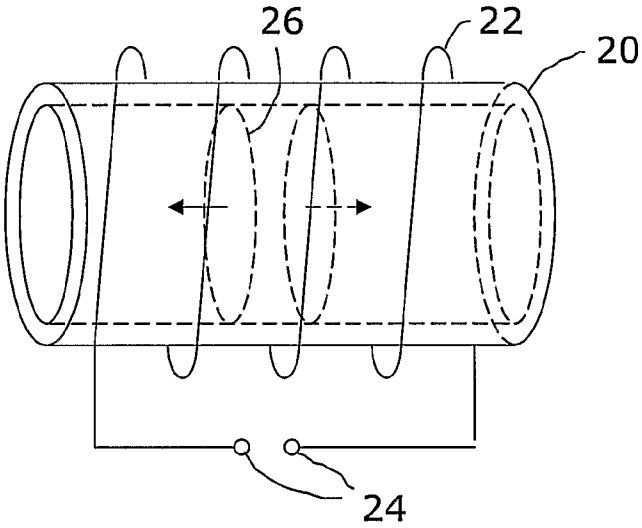


FIG. 2

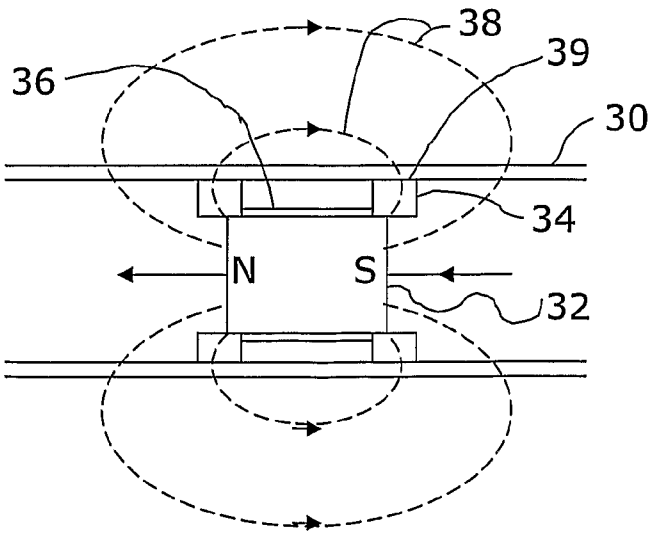


FIG. 3

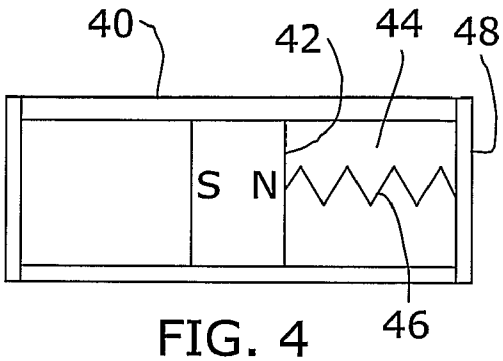


FIG. 4

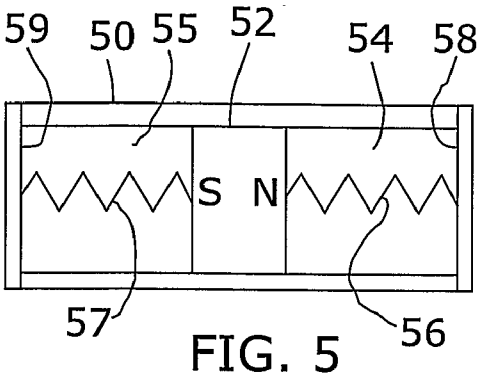


FIG. 5

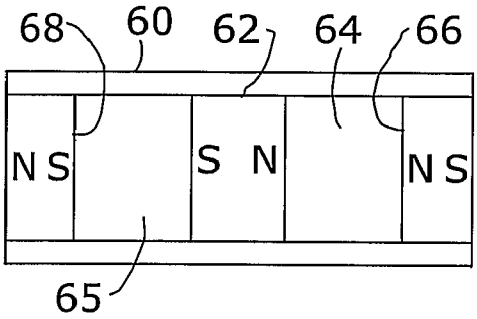


FIG. 6

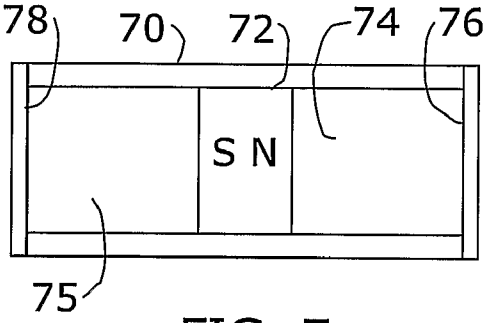


FIG. 7

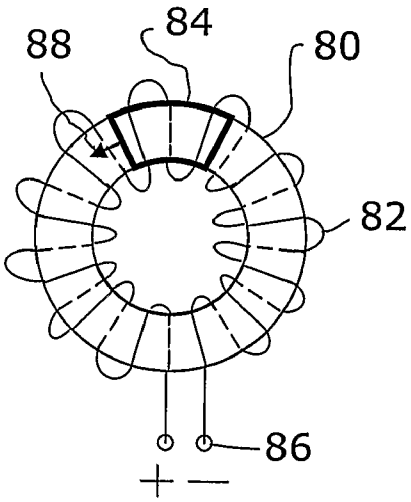


FIG. 8

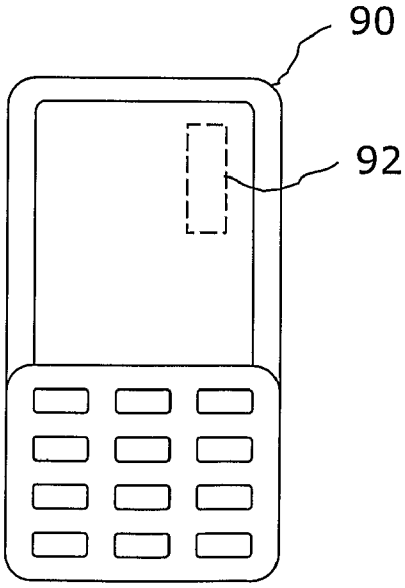


FIG. 9

VIBRATOR TUBE

[0001] The present invention relates to providing tactile stimuli to a user of a portable communication device.

DESCRIPTION OF RELATED ART

[0002] Vibrators within small communication devices are most commonly designed as direct current (DC) motors where a counter weight is mounted off-center on the rotating axis. Upon rotation of the axis, the counter weight causes the vibrator to vibrate as a function of the rotational frequency.

[0003] There is also another type of vibrators, linear motor type vibrators, which comprise a magnet and a coil system that are driven by an alternating current (AC) electric source. Linear motor type vibrators typically have a metal spring attached to a top or a bottom of a housing in order to provide support to the magnet system. One example of such a linear vibrator is described in JP2004-174309.

[0004] Until today the best performance has been achieved by the DC-motor type vibrators. However, there are disadvantages with this type of vibrators. The first disadvantage is that the response time is too long to enable a quick vibration response required in, for example, gaming. A second disadvantage is that the counter weight is not protected against dust and mechanical damage to the same degree as the interior of the motor itself.

[0005] A drawback of the linear motor type vibrator is that the efficiency in terms of vibration is only about 25-50% of that of a DC-motor type vibrator.

[0006] The american patent document U.S. Pat. No. 6,768,230 discloses a device for electrical generation comprising multiple magnets in polar opposition to each other, arranged horizontally respecting a very critical angle of displacement, to induce an electrical signal in one or more surrounding coils. Moreover a lubricant, preferably being a ferrofluid, that establishes a static coefficient of friction less than about 0.02. This document hence describes a horizontally restricted electrical generation device, a narrow application, wherein a ferrofluid is being used.

[0007] There is hence still a need to overcome the deficiencies of the vibrators as presented above, to achieve an efficient vibrator, having a short response time without comprising any mechanical parts that can be damaged from outside influences.

SUMMARY OF THE INVENTION

[0008] The invention is directed towards solving the problem of overcoming slow and inefficient provision of tactile stimuli to a user of a portable communication device.

[0009] This is achieved by providing quick and efficient vibrations of a portable communication device.

[0010] A first object of the present invention is to provide a device for providing quick and efficient vibrations of a portable communication device.

[0011] According to one aspect of this invention, this object is achieved by an electromagnetic vibrator for use in a portable communication device comprising:

[0012] a housing comprising a track directed in a first dimension,

the first dimension, coiled around the track and being arranged to receive an electric voltage,

[0014] a permanent magnet assembly arranged for motion along the track to which said permanent magnet assembly is tightly fitted, and

[0015] a ferrofluid mixture placed between the track and the permanent magnet assembly,

[0016] allowing motion of the permanent magnet assembly in the first dimension in dependence of the electric voltage as supplied to the coiling.

[0017] A second aspect of the present invention is directed towards an electromagnetic vibrator including the features of the first aspect, wherein the ferrofluid is a low friction ferrofluid mixture comprising magnetic or magnetizable nano particles, and a carrier fluid, in which the magnetic or magnetizable nano particles are dispersed.

[0018] A third aspect of the present invention is directed towards an electromagnetic vibrator including the features of the second aspect, wherein the nano particles comprise ferrite particles and the carrier fluid comprises an organic carrier fluid.

[0019] A fourth aspect of the present invention is directed towards an electromagnetic vibrator including the features of the first aspect, wherein the track comprises a tubular cavity directed in the first dimension and in which tubular cavity the first permanent magnet assembly is arranged to move.

[0020] A fifth aspect of the present invention is directed towards an electromagnetic vibrator including the features of the fourth aspect, wherein the tubular cavity has a circular cross section.

[0021] A sixth aspect of the present invention is directed towards an electromagnetic vibrator including the features of the fourth aspect, wherein the tubular cavity is linear in shape.

[0022] A seventh aspect of the present invention is directed towards an electromagnetic vibrator including the features of the fifth aspect, wherein the vibrator comprises at least a first centering element located on a first side of the permanent magnet assembly along the first dimension, for exerting an alternating attracting and repelling force directed in the first dimension on the permanent magnet assembly.

[0023] An eighth aspect of the present invention is directed towards an electromagnetic vibrator including the features of the seventh aspect, wherein the vibrator comprises a second centering element located on a second side of the permanent magnet assembly along the first dimensions for exerting a centering force directed in the first dimension on the permanent magnet assembly.

[0024] A ninth aspect of the present invention is directed towards an electromagnetic vibrator including the features of the seventh aspect, wherein the first centering element comprises a first spring of which a first end is attached to a first end of the permanent magnet assembly, and of which a second end is attached to an inner side of a first end stop of the tubular cavity.

[0025] A tenth aspect of the present invention is directed towards an electromagnetic vibrator including the features of the eighth aspect, wherein the first and second centering elements comprise a first and a second spring, respectively, attached on either side of the permanent magnet assembly, for exerting centering forces directed in the first dimension on the permanent magnet assembly.

features of the ninth aspect, wherein the first and second springs are non-linear in the first dimension.

[0027] A twelfth aspect of the present invention is directed towards an electromagnetic vibrator including the features of the eighth aspect, wherein the first and second centering elements comprise a second and a third permanent magnet, respectively, oriented in opposite direction in relation to one another in the first dimension, for exerting centering forces directed in the first dimension on the permanent magnet assembly.

[0028] A thirteenth aspect of the present invention is directed towards an electromagnetic vibrator including the features of the eighth aspect, wherein the first and second centering elements each comprise an essentially gas tight compartment and wherein there is an essentially gas tight fit at the contact surface between the permanent magnet assembly and the surface wall of the tubular cavity.

[0029] A fourteenth aspect of the present invention is directed towards an electromagnetic vibrator including the features of the first aspect, wherein the coiling is arranged to receive an alternating current electric voltage.

[0030] A fifteenth aspect of the present invention is directed towards an electromagnetic vibrator including the features of the first aspect, wherein the tubular cavity has a toroidal shape.

[0031] A sixteenth aspect of the present invention is directed towards an electromagnetic vibrator including the features of the fifteenth aspect, wherein the coiling is arranged to receive a direct current electric voltage.

[0032] A second object of the present invention is to provide a portable communication device providing quick and efficient vibrations to its user.

[0033] A seventeenth aspect of the present invention is to provide a portable communication device comprising an electromagnetic vibrator comprising:

[0034] a housing comprising a track directed in a first dimension,

[0035] a coiling comprising at least one coil turn, oriented in a second dimension essentially perpendicular to the first dimension, around the track and being arranged to receive an electric voltage,

[0036] a permanent magnet assembly arranged for motion along the track, and

[0037] a ferrofluid mixture placed between the track and the permanent magnet assembly,

allowing motion of the permanent magnet assembly in the first dimension in dependence of the electric voltage as supplied to the coiling, and wherein the portable communication device is a mobile phone.

[0038] The present invention has thus the following overall advantages:

[0039] Firstly, the electromagnetic vibrator is more efficient due to the application of a ferrofluid mixture subjected to a magnetic field.

[0040] Secondly, the electromagnetic vibrator also achieves a shorter response time as the friction between the magnet assembly and the housing or track, is minimized.

[0041] Thirdly, the electromagnetic vibrator is also void of any mechanical parts that can be damaged from outside influences.

[0042] It should be emphasized that the term "comprises/ components, but does not preclude the presence or addition of one or more other features, integers, steps, components or groups thereof.

BRIEF DESCRIPTION OF THE DRAWINGS

[0043] The present invention will now be described in more detail in relation to the enclosed drawings, in which:

[0044] FIG. **1** schematically shows a housing-coil system,

[0045] FIG. **2** schematically shows housing-coil-magnet system according to one embodiment of the present invention,

[0046] FIG. **3** schematically shows a more detailed housing-magnet arrangement according to one embodiment of the present invention,

[0047] FIG. **4** schematically shows a housing-magnet arrangement according to one embodiment of the present invention,

[0048] FIG. **5** schematically shows a housing-magnet arrangement according to one embodiment of the present invention,

[0049] FIG. **6** schematically shows a housing-magnet arrangement according to one embodiment of the present invention,

[0050] FIG. **7** schematically shows a housing-magnet arrangement according to one embodiment of the present invention,

[0051] FIG. **8** schematically shows a housing-coil-magnet arrangement according to one embodiment of the present invention, and

[0052] FIG. **9** schematically shows a portable communication device according to one embodiment of the present invention.

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0053] The invention is directed towards solving the problem of overcoming slow and inefficient provision of tactile stimuli to a user of a portable communication device.

[0054] Electromagnetic vibrators utilizes the influence on a magnet by a magnetic field, which field generally is created by letting an electric current flow through a coiling. Dependent on the design of such magnet-coil system either a direct current (DC) electric voltage or an alternating current (AC) electric voltage is supplied to the coil, enabling an AC electric current and a DC electric current to flow through the coil.

[0055] FIG. **1** schematically shows an elongated hollow housing **10** around which a coiling is wound. An electric voltage is applied to the connections **14**, creating a magnetic field **16** that is directed along the long axis of the housing. The direction of the magnetic field is dependent on the polarity of the applied electric voltage.

[0056] As is shown in FIG. **2** a housing is designed to have a circular cross section, forming a hollow straight cylinder. A coiling **22** is would around the circular housing, which coiling is supplied with an electric voltage over the connectors **24**. A magnet **26** is positioned within the housing **20**. On supplying an electric voltage over the coiling **22** at the connectors **24**, a magnetic field is created within and around the coiling **22**. The magnet **26** is preferably oriented so that the magnetic axis of the magnet is parallel with the symmetry axis of the cylindrical housing, and most preferably that the directions of the

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