(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
7 August 2003 (07.08.2003)

PCT

(10) International Publication Number
WO 03/065553 A2

(51) International Patent Classification[7]: H02K 33/16, G08B 6/00

(21) International Application Number: PCT/IB03/00180

(22) International Filing Date: 23 January 2003 (23.01.2003)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
02100087.2 30 January 2002 (30.01.2002) EP

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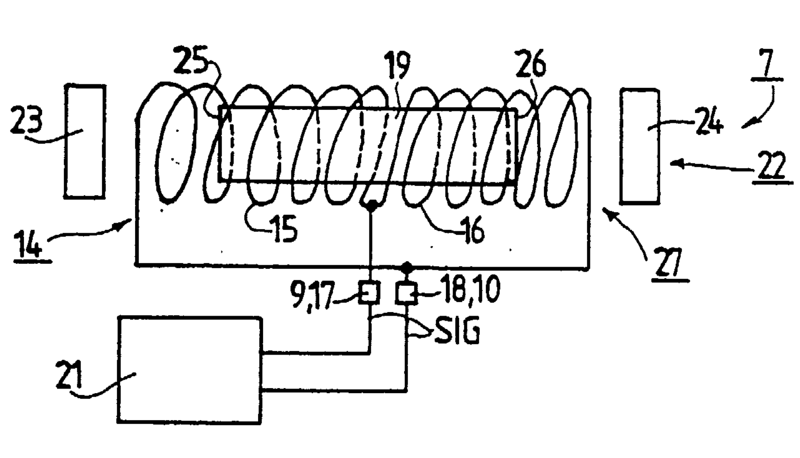
(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, OM, PH, PL, PT, RO, RU, SD, SE, SG, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZM, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PT, SE, SI, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *without international search report and to be republished upon receipt of that report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) **Title:** DEVICE FOR PRODUCING MECHANICAL VIBRATIONS



(57) Abstract: A device (7) for producing mechanical vibrations has a component (19) displaceable under the action of a magnetic field and drive means (14) driving the component (19) and energy supply means (21) for feeding energy in the form of an electrical supply signal (SIG) to the drive means (14), it being possible to set the component (19) in motion in accordance with a to-and-fro displacement movement with the aid of the drive means (14) and the energy supply means (21) being designed to produce a supply signal (SIG) that is variable in its frequency.

WO 03/065553 A2

Device for producing mechanical vibrations

The invention relates to a device for producing mechanical vibrations.

The invention furthermore relates to a communications device comprising a device for producing mechanical vibrations.

A communications device, namely a portable telephone and, to be specific, a so-called mobile telephone having a device for producing mechanical vibrations and, consequently, such a device for producing mechanical vibrations are disclosed, for example, in patent document US 5 379 032 A. As regards the energy supply means, patent document US 5 379 032 A only mentions that the energy supply means must be designed to produce and deliver a suitable electrical supply signal having a suitable waveform and a suitable current intensity in order to be able to drive a displaceable component formed by a permanent magnet in a suitable way with the aid of drive means formed by a coil.

In a device for producing mechanical vibrations as known from patent document US 5 379 032 A, an attempt is always made for the drive means to be supplied with an electrical supply signal whose frequency corresponds as exactly as possible to a certain frequency, in order to achieve the result that the drive means bring about a displacement movement of the displaceable component with a certain desired frequency, which desired frequency is determined by the mass of the displaceable component and by other factors in the known device. As a result of external effects, but also as a result of internal effects, an alteration in the frequency ratios in a known device may, however, occur, which then has the disadvantage that the energy supply means no longer delivers an optimum electrical supply signal with respect to the frequency to the drive means, which has the consequence that a less favorable supply of the drive means takes place, which in turn has an adverse effect in that a reduction occurs in the mechanical vibrations that can be produced.

It is an object of the invention to eliminate the above-cited difficulties and to provide an improved device for generating mechanical vibrations and an improved communications device.

To achieve the above-cited object, features according to the invention are provided in a device according to the invention so that a device in accordance with the invention can be characterized in the way specified as follows, namely:

A device for producing mechanical vibrations that has at least one component held so as to be displaceable along a movement path and has drive means for driving the component with whose aid the component can be set in motion in accordance with a to and fro movement, which movement is intended to take place with a certain desired frequency, and that has energy supply means for supplying energy in the form of an electrical supply signal to the drive means, wherein the energy supply means are designed to produce a supply signal that is variable in its frequency.

To achieve the above-cited object, in a communications device according to the invention, features according to the invention are provided so that a communications device according to the invention can be characterized in the way specified as follows, namely:

A communications device including a device for producing mechanical vibrations, that has at least one component held so as to be displaceable along a movement path and includes the drive means for driving the component with whose aid the component can be set in motion in accordance with a to and fro displacement movement, which displacement movement is intended to take place with a certain desired frequency, and that has energy supply means for feeding energy in the form of an electrical supply signal to the drive means, wherein the energy supply means are designed to produce a supply signal that is variable in its frequency.

As a result of the features provided according to the invention, the result is achieved with simple circuitry means and therefore in an inexpensive way that, during the operation of a device for producing mechanical vibrations according to the invention, an optimum electrical supply signal with respect to the frequency is delivered by the energy supply means to the drive means at least during a part of the total operating time so that, at least during said part of the total operating time, an optimum supply of energy to the drive means exists and, consequently, an optimum production of mechanical vibrations is achieved. A further advantage of the design according to the invention is that, in a device according to the invention for producing mechanical vibrations, in which because of the structural design an alteration in the targeted desired frequency for the displacement movement of the component held so as to be displaceable, arises during the operation of the device, an optimum supply of the drive means and, consequently, an optimum production of mechanical vibrations is achieved by a systematic alteration of the frequency of the variable electrical supply signal virtually during the entire operating time of the device.

In a device according to the invention or in a communications device according to the invention, it has been found advantageous if the features as claimed in Claims 2 to 5 or as claimed in Claims 7 to 10 are provided in addition. These designs have proved advantageous as regards production of mechanical vibrations that is as free as possible of interfering signals and is reliable in operation and has as high an amplitude as possible, and, consequently, as good a perceptibility as possible.

These and other aspects of the invention are apparent from and will be elucidated with reference to the embodiments described hereinafter.

The invention is disclosed further by reference to exemplary embodiments shown in the drawings, but to which the invention is not restricted.

Fig. 1 shows an oblique view of a communications device and, to be specific, a mobile telephone according to an exemplary embodiment of the invention that contains a device for producing mechanical vibrations according to an exemplary embodiment of the invention..

Fig. 2 shows an oblique view of the device for producing mechanical vibrations of the mobile telephone according to Fig. 1.

Fig. 3 shows a longitudinal section of the device for producing mechanical vibrations according to Fig. 2.

Fig. 4 shows schematically the device for producing mechanical vibrations according to Figs. 2 and 3 in the form of a block circuit diagram.

Fig. 5 shows a diagram that illustrates an electrical supply signal occurring in a device according to Figs. 2 to 4.

Fig. 6 shows a diagram in which a part of the electrical supply signal according to Fig. 5 is shown on a larger time-scale.

Fig. 1 shows a mobile telephone 1. The mobile telephone 1 has a casing 2 that comprises a casing front wall 3 with a sound-permeable cover 4, behind which a microphone and a loudspeaker, which are not shown, are disposed, and a display device 5 and keyset 6. Accommodated in the casing 2 is a device 7, shown only schematically in Fig. 1, for producing mechanical vibrations. In the event of an incoming call, the device 7 serves to produce vibrations that signal to a user of the mobile telephone 1 in a noticeable way that a call can be or is to be accepted. The device 7 is shown in detail in Figs 2 to 4.

The device 7 for producing mechanical vibrations has a casing 8 that comprises two mutually coaxially disposed, pot-type sleeves 9 and 10 made of metal and, to be specific, made of brass in the present case. Instead of brass, non-magnetic iron or magnetic iron may also be used, a particularly good magnetic screening being achieved in the latter case. Each of the two sleeves 9 and 10 has four air passage holes 11 in the region of their sealed-off end.

Accommodated in the casing 8 is a coil holder 12 that is of tubular design in accordance with a hollow cylinder and from which a separating ring 13 projects in its middle region. The coil holder 12 together with the separating ring 13 comprises an electrically insulating material, namely plastic. The coil holder 12 is provided to hold a coil configuration 14. The coil configuration 14 comprises two coil segments 15 and 16 that are connected to one another in parallel, as can be inferred from Fig. 4. The design of the two coil segments 15 and 16 and, to be specific, the winding direction of said two coil segments 15 and 16, in particular, is chosen in such a way that the magnetic fields produced with the aid of the two coil segments 15 and 16 at a certain time instant are directed oppositely to one another. As a result, one coil segment acts attractively and the other coil section acts repulsively in each case on a component that is held so as to be displaceable in the interior of the coil configuration 14 and that is dealt with in still greater detail later. The coil configuration 14 consequently forms drive means for said component. The two coil segments 15 and 16 are connected in an electrically conducting manner to two terminal lugs 17 and 18. The terminal lugs 17 and 18 are of electrically conducting design and are each connected mechanically and in an electrically conducting manner to one of the sleeves 9 and 10, likewise comprising electrically conducting material. This achieves the result that the two sleeves 9 and 10 can be utilized as electrical terminal pieces for the electrically conducting connection and serve for this purpose.

The device 7 furthermore has a component 19 that is displaceable under the action of a magnetic field. In the device 7, said component 19 is formed by a permanent magnet 19 that is of hollow cylindrical design and is held inside the tubular coil holder 12 of hollow cylindrical design along a movement path indicated by a double arrow 20 and linear in the present case.

The device 7 furthermore has energy supply means 21 as is evident from Fig. 4. The energy supply means 21 are provided for feeding energy in the form of an electrical supply signal SIG to the coil configuration 14 and are formed by an electrical signal generator. In the present case, the energy supply means 21 are provided on a printed circuit board, which is not shown, in the communications device 1 with positional separation from the casing 8 of the device 7. The energy supply means 21 may, however, be directly connected to the casing 8. For this purpose, the energy supply means 21 are connected in an electrically conducting manner to the two sleeves 9 and 10 and, consequently, to the two terminal lugs 17 and 18. As a result of feeding energy to the coil configuration 14, it is possible to produce, with the aid of said coil configuration 14, magnetic fields that occur successively in an alternating manner with at least one alternating frequency f_A and act in opposite directions on the permanent magnet 19 and thereby cause the permanent magnet 19 to be displaced to and fro. This achieves that, as a consequence of feeding the supply signal SIG to the coil configuration 14, the permanent magnet 19 is displaced to and fro parallel to the movement path 20, which has the consequence that mechanical vibrations are produced with the aid of the device 7. In executing such a to-and-fro movement, the permanent magnet 19 moves an air cushion in each case in the region of its two ends 25 and 26, as a result of which air flows occur through the air passage holes 11 so that no undesirable air-cushion damping occurs for the permanent magnet 19.

The device 7 furthermore contains counterforce means 22 that are designed and provided in a particularly advantageous way in the present case for the continuous application of a counterforce in each case that counteracts the displacement of the permanent magnet 19 under the action of the magnetic fields. In the device 7, the counterforce means 22 have two additional magnets 23 and 24 of which one additional magnet 23 is disposed opposite one end 25 of the permanent magnet 19 held so as to be displaceable and the other additional magnet 24 is disposed opposite the other end 26 of the permanent magnet 19 held so as to be displaceable. The magnetization of the permanent magnet 19 and of the additional magnets 23 and 24 and, consequently, the magnetic polarity of the permanent magnet 19 and of the additional magnets 23 and 24 are chosen, as can be inferred from Fig. 3, in such a way that each additional magnet 23 or 24 permanently exerts a repulsive force on the permanent magnet 19 held so as to be displaceable. The additional magnets 23 and 24 are firmly held in the respective sleeve 9 and 10 of the casing 8 with the aid of an adhesive joint in each case.

In the device 7, the design is such that the permanent magnet 19 and the counterforce means 22, that is to say the two additional magnets 23 and 24, are components of a vibration system 27 in which a mechanical resonance frequency f_R is dependent on the mass of the permanent magnet 19 and of a counterforce characteristic of the counterforce means 22, in the present case therefore of the magnetic repulsive force of each of the additional magnets 23 and 24. In this connection, said reference frequency f_R is a desired frequency with which the to-and-fro movement of the permanent magnet 19 is to take place. In the present case, said mechanical resonant frequency f_R is not constant and, to be specific, because the mechanical resonant frequency f_R is dependent on the travel of the permanent magnet 19 and, to be specific, in such a way that, for a relatively small travel of the permanent magnet 19 a relatively small counterforce is exerted on the permanent magnet 19 by the additional magnets 23 and 24, whereas, for a relatively large travel of the permanent magnet 19, the additional magnets 23 and 24 exert a relatively large counterforce on the permanent magnets 19, the variation in the increase between the small counterforce and the large counterforce are nonlinear and, to be specific, increases progressively. When the device 7 is first put into operation, the permanent magnet 19 first executes a relatively small travel and relatively small counterforces therefore act on the permanent magnet 19. With increasing operating time, the travel of the permanent magnet 19 increases, which results in progressively increasing counterforces. This fact has an effect such that a relatively low resonant frequency f_R of the vibration system 27 exists for the device 7 at the beginning of being put into operation and that the mechanical resonant frequency f_R increases with increasing operating time.

To take the above-described state of affairs into account, in the device 7 the design of the energy supply means 21 is advantageously such that the supply of energy to the coil configuration 14 causes the magnetic fields acting on the permanent magnet 19 to occur alternately in succession at least at such alternating frequency f_A that the at least one alternating frequency f_A is situated in a frequency range containing the mechanical resonant frequency f_R. In other words, this means that the energy supply means 21 are designed to produce a supply signal SIG that has a variable frequency. The supply signal SIG is shown schematically in Figs. 5 and 6. As is evident from Figs. 5 and 6, the supply signal SIG contains a pulse-shaped signal having oppositely polarized amplitude values, which signal occurs in a periodically recurring manner during a time interval T1, the occurrence phases being interrupted by signal-free segments with the duration T2. An energy saving is achieved by the provision of the signal-free segments in the supply signal SIG. Fig. 6 shows a signal segment having the duration T1 on an enlarged scale. As is evident from Fig. 6, the supply signal SIG has a lower alternating frequency f_A at the beginning of the time interval T1 than at the end of the time interval T1.

In a device 7 provided for experimental purposes, the design of the device 7 was such that the time interval T1 had a value of about 200 msec and the time interval T2 had a value of 400 msec. Within the time interval T1 there are a total of twenty one (21) pulses with alternating polarity, as can be inferred from Fig. 6. The alternating frequency f_A of the supply signal SIG had in this case a value of about 95 Hz at the beginning of the time interval T1 and a value of about 135 Hz at the end of the time interval T1.

In the case of the mobile telephone 1 and its device 7 for producing mechanical vibrations, the result has been achieved in a particularly advantageous way that mechanical vibrations are produced in a way that produces as little mechanical load as possible and, consequently, in an aging-resistant, operationally reliable and interference-signal-free way, and that very readily noticeable and perceptible mechanical vibrations are produced because the alternating frequency f_A for the magnetic fields acting on the permanent magnet 19 that can be displaced to and fro is not kept constant but is varied and, to be specific, is increased and, to be specific in such a way that the alternating frequency f_A is always equal as precisely as possible to the resonant frequency f_R of the vibration system 27 containing the permanent magnets 19 and the additional magnets 23 and 24, as a result of which a so-called resonance boost is achieved that produces advantageously strong mechanical vibrations.

In the above-described device 7 for producing mechanical vibrations, the component 19 that is displaceably guided to and fro and can be made to vibrate is displaceably guided along a linear movement path. Such a component may, however, be displaceably guided along a movement path extending in the shape of an arc. In the above-described device 7 for producing mechanical vibrations, permanent magnet 19 having a circular-cylindrical shape is provided in each case as a displaceable component 19. Such a permanent magnet may, however, also be of block-shaped design with a rectangular cross section, in which case a particularly flat design can be achieved.

In the above-described device 7 for producing mechanical vibrations, the coil configuration 14 has two coil segments 15 and 16. Such a coil configuration may, however, also contain only a single coil that is supplied in an oppositely polarized way or more than two coil segments may also be provided.

In the above-described device 7 for producing mechanical vibrations, the coil configuration 14 is kept stationary and the component 19 interacting with the coil configuration 14 is held so as to be displaceable. In such an arrangement for producing mechanical vibrations, however, the component may also be kept stationary and the coil configuration may be guided displaceably.

Such a device for producing mechanical vibrations does not have to be based on the electrodynamic or on the electromagnetic principle, but it can also be based on the piezoelectric principle.

CLAIMS:

1. A device (7) for producing mechanical vibrations that has at least one component (19) held so as to be displaceable along a movement path (20) and has drive means (14) for driving the component (19) with whose aid the component (19) can be set in motion in accordance with a to and fro displacement movement, which displacement movement is intended to take place with a certain desired frequency (f_R), and that has energy supply means (21) for supplying energy in the form of an electrical supply signal (SIG) to the drive means, wherein the energy supply means (21) are designed to produce a supply signal (SIG) that is variable in its frequency.

2. A device (7) as claimed in claim 1, wherein the component (19) is formed by a component (19) displaceable under the action of a magnetic field and wherein the drive means (14) are formed by a coil configuration (14) that surrounds the component (19), and wherein, as a result of feeding energy to the coil configuration (14), it is possible to produce, with the aid of said coil configuration (14), magnetic fields that occur successively in an alternating manner with at least one alternating frequency (f_A) and act in opposite directions on the component (19) and thereby effect a to and fro displacement of the component (19), and wherein counterforce means (22) are provided that are designed and provided for the continuous application of a counterforce counteracting in each case the displacement of the component (19) under the action of the magnetic fields, and wherein the component (19) and the counterforce means (22) are components of a vibration system (27) in which a mechanical resonant frequency (f_R) is dependent on the mass of the component (19) and on a counterforce characteristic of the counterforce means (22).

3. A device (7) as claimed in claim 2, wherein the energy supply means (21) are designed in such a way that, as a result of feeding energy to the coil configuration (14), an alternatingly successive occurrence of the magnetic fields acting on the component (19) exists with at least one alternating frequency (f_A) situated in a frequency range containing the mechanical resonant frequency (f_R).

4. A device (7) as claimed in claim 2, wherein the component (19) is formed by a permanent magnet (19).

5. A device (7) as claimed in claim 4, wherein the counterforce means (22) have two additional magnets (23, 24) of which one additional magnet (23) is disposed opposite one end (25) of the permanent magnet (19) held so as to be displaceable and the other additional magnet (24) is disposed opposite the other end (26) of the permanent magnet (19) held so as to be displaceable and of which each additional magnet (23, 24) continuously exerts a repulsive force on the permanent magnet (19) held so as to be displaceable.

6. A communications device (1) including a device (7) for producing mechanical vibrations, that has at least one component (19) held so as to be displaceable along a movement path (20) and includes the drive means (14) for driving the component with whose aid the component (19) can be set in motion in accordance with a to and fro displacement movement, which displacement movement is intended to take place with a certain desired frequency (f_R), and that has energy supply means (21) for feeding energy in the form of an electrical supply signal (SIG) to the drive means, wherein the energy supply means (21) are designed to produce a supply signal (SIG) that is variable in its frequency.

7. A communications device (1) as claimed in claim 6, wherein the component (19) is formed by a component (19) displaceable under the action of a magnetic field and wherein the drive means (14) are formed by a coil configuration (14) that surrounds the component (19), and wherein, as a result of feeding energy to the coil configuration (14), it is possible to produce with the aid of said coil configuration (14) magnetic fields that occur successively in an alternating manner with at least one alternating frequency (f_A) and act in opposite directions on the component (19) and thereby effect a to-and-fro displacement of the component (19), and wherein counterforce means (22) are provided that are designed and provided for the continuous application of a counterforce counteracting in each case the displacement of the component (19) under the action of the magnetic fields, and wherein the component (19) and the counterforce means (22) are components of a vibration system (27) in which a mechanical resonant frequency (f_R) is dependent on the mass of the component (19) and of a counterforce characteristic of the counterforce means (22).

8. A communications device (1) as claimed in claim 7, wherein the energy supply means (21) are designed in such a way that, as a result of supplying energy to the coil configuration (14) an alternatingly successive occurrence of the magnetic fields acting on the component (19) exists with at least one alternating frequency (f_A) situated in a frequency range containing the mechanical resonant frequency (f_R).

9. A communications device (1) as claimed in claim 7, wherein the component (19) is formed by a permanent magnet (19).

10. A communications device (1) as claimed in claim 9, wherein the counterforce means (22) have two additional magnets (23, 24) of which one additional magnet (23) is disposed opposite one end (25) of the permanent magnet (19) held so as to be displaceable and the other additional magnet (24) is disposed opposite the other end (26) of the permanent magnet (19) held so as to be displaceable and of which each additional magnet (23, 24) continuously exerts a repulsive force on the permanent magnet (19) held so as to be displaceable.

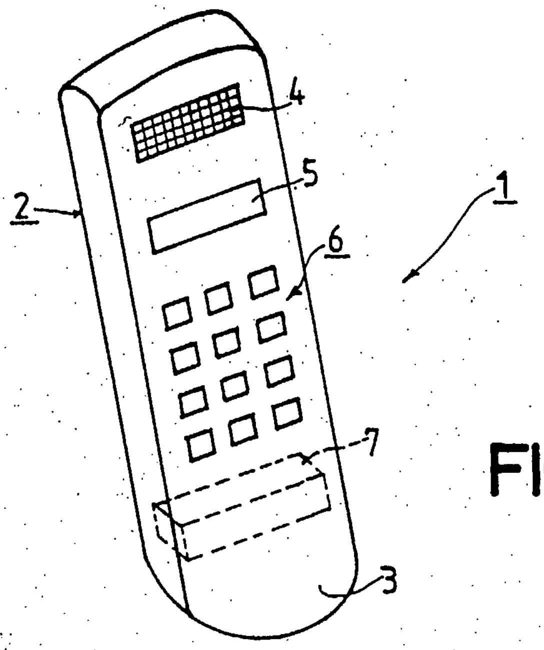


FIG.1

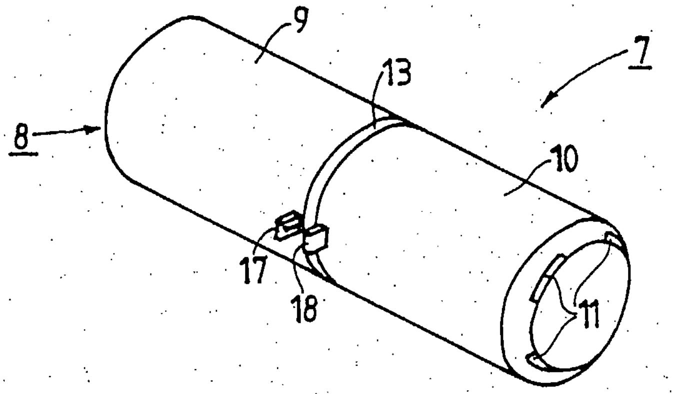


FIG.2

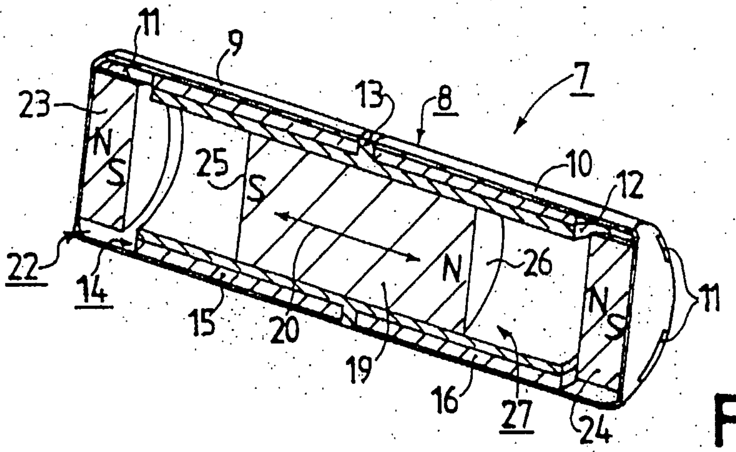


FIG.3

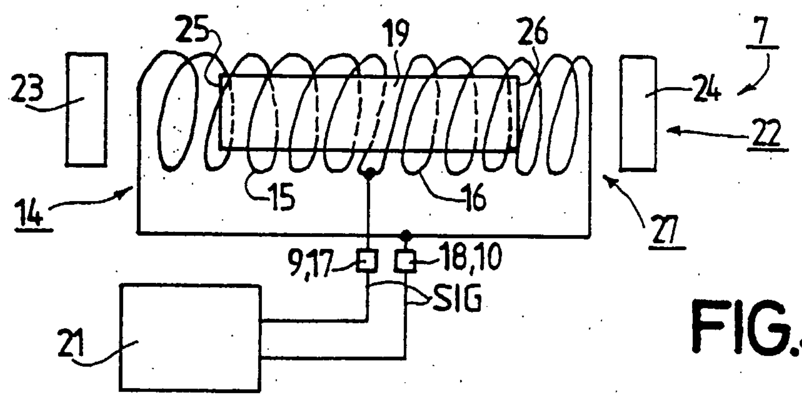


FIG.4

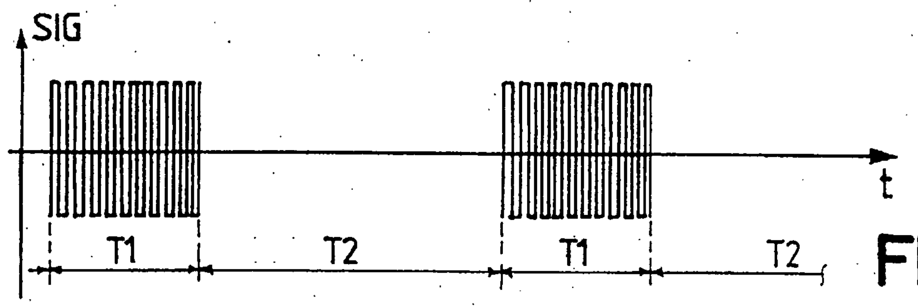


FIG.5

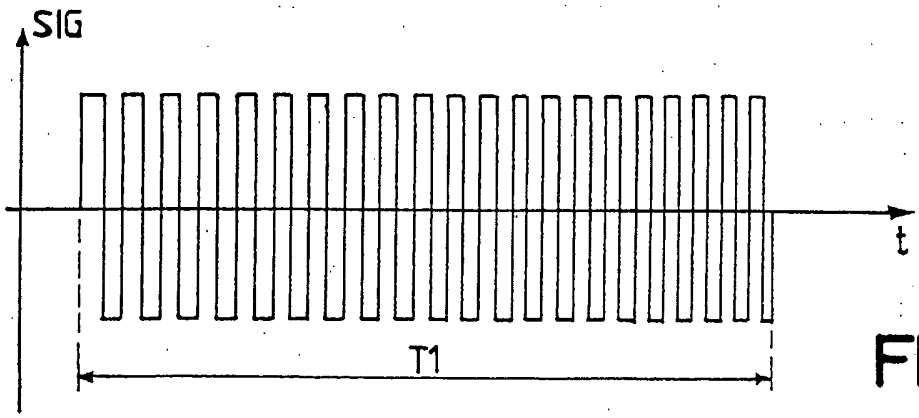


FIG.6