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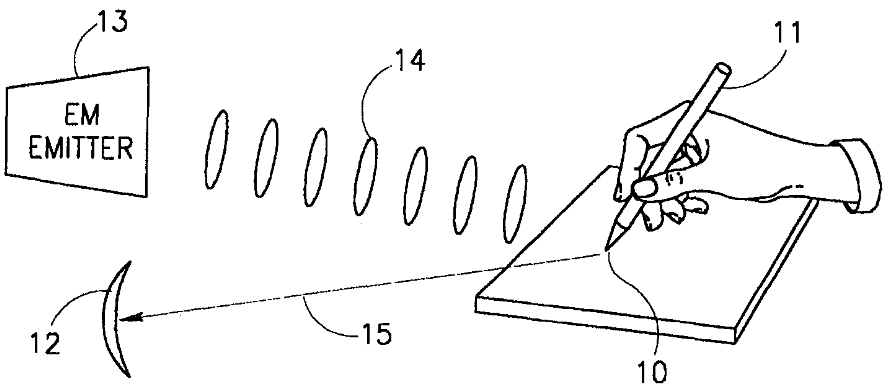

(57) Abstract

A method and system for measuring the distance from a piezoelectric substance (10) by transmitting an electromagnetic pulse (14) to the piezoelectric substance so as to generate an acoustic pulse (15) in response thereto. The acoustic pulse is sensed by an acoustic sensor (12) displaced from the piezoelectric substance by an unknown distance, and a time interval between initiation of the electromagnetic pulse and receipt of the acoustic pulse is measured. The distance between the piezoelectric substance and the acoustic sensor is computed by multiplying the measured time interval by the speed of sound, which is known. Upon striking the piezoelectric surface against a surface a modified echo characteristic of the acoustic pulse may be detected. This allows operation of one of a plurality of switches to be detected. By using multiple sensors, the spatial location of the switch can be computed and this allows the specific switch to be identified in a computer keyboard adapted for use with a computer but not physically connected thereto.

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Method and system for measuring the distance from a piezoelectric element

FIELD OF THE INVENTION

This invention relates to rangefinding using acoustic components.

BACKGROUND OF THE INVENTION

It is known to employ acoustics waves to measure relative location due to their relative low speed. Such a technique requires a power source to either transmit or receive the acoustical signal, for every object needed to be ranged. It is also known to employ Electromagnetic Waves (EM) to measure locations. But, since the speed at which the electromagnetic pulse propagates through air is very high (approximately $3x10^8$ ms^{-1}), the time taken for the electromagnetic pulse to travel distances of even several hundred meters is in the order of microseconds. Distances of up to one meter are traversed in several nanoseconds. Such time intervals must be measured very accurately because even a minute error in such a small time interval gives rise to a large error in the calculated displacement.

Time intervals of several nanoseconds can be measured accurately using relatively complicated electronics and signal processing, but this, of course, increases the measurement cost. For many low-cost applications the resulting cost may become prohibitive.

U.S. Patent No. 4,264,978 (Whidden) discloses a device for locating audio surveillance apparatus and is typical of prior art approached. An accessory utilized in association with a commercially available bug detector includes a pulse generator for transmitting an acoustic pulse which is sensed by an audio surveillance device and retransmitted as modulated electromagnetic information. Associated with the pulse generator is a timing arrangement and display. The timer is triggered into operation by the generation of the acoustic pulse. The operating speed of the timer is established to be a function of the speed of sound. Means are provided to stop the timer upon receipt of a demodulated signal representative of the retransmitted pulse whereby the display indicates the distance to the surveillance device. Such a device is based on the fact that the time involved for the acoustic pulse to be converted to electromagnetic energy and returned to the accessory is negligible as compared with the time for the acoustic pulse to travel from the accessory to the bug, the time measured by the timing arrangement essentially is a function of the range of the accessory from the bug.

SUMMARY OF THE INVENTION

It is therefore an object of the present invention to provide a low-cost method and system for measuring distance from a piezoelectric substance wherein the.

This object is realized in accordance with a first aspect of the invention by method for measuring the distance from a piezoelectric substance comprising:

(a) transmitting an electromagnetic pulse to said piezoelectric substance so as to generate an acoustic pulse in response thereto,

(b) sensing the acoustic pulse by an acoustic sensor displaced from the piezoelectric substance by an unknown distance,

(c) measuring a time interval between initiation of the electromagnetic pulse and receipt of the acoustic pulse, and

(d) calculating the distance between the piezoelectric substance and the acoustic sensor multiplying the measured time interval by the speed of sound.

It has further been found that striking the piezoelectric substance against a surface gives rise to a modified echo characteristic of the acoustic pulse. This is exploited in accordance with the invention in order to identify surface contact by the piezoelectric substance or by a carrier bearing the piezoelectric substance. For example, the piezoelectric substance may be attached to a person's finger whereby operation of a touch or pushbutton switch may be detected by virtue of a change in the echo characteristic of the acoustic pulse received by a remote acoustic sensor.

The approach according to the invention thus requires the generation of an electromagnetic pulse that initializes the timer and almost instantaneously produces an acoustic pulse upon striking the piezoelectric substance. The piezoelectric substance itself may be completely passive and may thus be provided as a miniature unit, suitable for mounting where space is at a premium and requiring no maintenance. In contrast thereto, in the arrangement described in U.S. Patent No. 4,264,978 (Whidden) discussed above, the acoustic pulse generator is active, requiring an external power source. This increases its complexity and cost and, most important, its bulk, such that it is not amenable to miniaturization. This militates against its use in the kind of varied applications to which the present invention is directed, in particular where an acoustic generator may be mounted at the tip of a user's finger as will be described in greater detail below.

The invention also contemplates the use of two or more acoustic sensors mutually displaced by known distances, each of which receives a respective acoustic pulse at respective time intervals. By determining the distance of the piezoelectric substance to each of the acoustic sensors, the actual location in two– or three–dimensional space of the piezoelectric substance may be computed, depending on the number of acoustic receivers.

According to a second aspect of the invention there is provided a system for measuring the distance from a piezoelectric substance, the system comprising:

an electromagnetic transmitter for generating electromagnetic pulses,

said piezoelectric substance being connected to an electromagnetic receiver for receiving one of said electromagnetic pulses so as to generate in response thereto an acoustic pulse,

an acoustic sensor displaced from the piezoelectric substance for sensing said acoustic pulse,

a timer coupled to the acoustic sensor and to the electromagnetic transmitter for measuring a time interval between initiation of the electromagnetic pulse and receipt of the acoustic pulse, and

a processing unit coupled to the timer for calculating the distance between is the piezoelectric substance and the acoustic sensor multiplying the measured time interval by the speed of sound.

The piezoelectric substance may be a passive unit energized by received electromagnetic energy, thus allowing miniaturization thereof. The processing unit may be a personal computer and the acoustic sensor may be a microphone in which case it is preferably constituted by the computer microphone, thereby saving costs. The computer keyboard may be provided with a pair of piezoelectric elements at opposite diagonals thereof for allowing a spatial location of an origin point of the keyboard to be determined by means of a pair of mutually spaced apart acoustic sensors mounted, for example, on the computer monitor.

When an operator having a piezoelectric element attached to his or her finger presses on one of the keys of the keyboard, an acoustic pulse having a modified echo characteristic is produced and this serves as an indication that a key has been operated. At the same time, the actual key thus depressed may be identified by determining a spatial location of the operator's finger relative to the origin point of the keyboard by triangulating between the two mutually spaced acoustic sensors with respect to said acoustic pulse. This allows use of a keyboard that is not physically attached to the computer.

BRIEF DESCRIPTION OF THE DRAWINGS

In order to understand the invention and to see how it may be carried out in practice, a preferred embodiment will now be described, by way of non-limiting example only, with reference to the accompanying drawings, in which:

Figs. 1 and 2 are pictorial representations showing the principle of operation of a method for measuring the distance from a piezoelectric substance in accordance with the invention;

Fig. 3 is a flow diagram showing the principal operating steps associated is with the method according to the invention;

Fig. 4 is a schematic representation showing the use of triangulation for determining a spatial location of a piezoelectric substance using more than one acoustic sensor;

Fig. 5 is a pictorial representation depicting use of the invention in a computer keyboard;

Fig. 6 is a pictorial representation depicting use of the invention in an interactive book; and

Fig. 7 is a pictorial representation depicting use of the invention in a computer touch screen.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Figs. 1 to 3 illustrate the principles of the invention for measuring the distance between a piezoelectric substance 10 depicted by the tip of a pointing device 11 to an acoustic sensor 12. An electromagnetic emitter 13 transmits an electromagnetic pulse 14, which strikes the piezoelectric substance 10 and is reflected therefrom as an acoustic pulse 15. The acoustic pulse 15 diffracts and is detected by the acoustic sensor 12. By synchronizing the electromagnetic emitter 13, the time of emission of the electromagnetic pulse 14 may be determined. Since the electromagnetic pulse travels at the speed of light ($3x10^8$ ms^{-1}), for small distances the time taken for the electromagnetic pulse to reach the acoustic sensor 12 is negligible. On the other hand, the resulting acoustic pulse 15 travels at the speed of sound equal to 300 ms^{-1}, being one million times slower than the speed of the electromagnetic pulse. Therefore, the time of emission of the electromagnetic pulse is substantially coincident with the time of emission of the acoustic pulse. The time taken T for the acoustic pulse 15 to reach the acoustic sensor 12 starting from the emission of the electromagnetic pulse 14 is, for all practical purposes, the time taken for the acoustic pulse 15 to travel from the piezoelectric substance 10 to the acoustic sensor 12.

Since the time T and the speed of sound V are known, the distance D between piezoelectric substance 10 and the acoustic sensor 12 can be determined in accordance with the equation:

$$D = v \times T \qquad (1)$$

The electromagnetic (EM) waves generated by the electromagnetic emitter 13 are preferably strong, but they need not necessarily traverse large distances. The EM waves can therefore be produced using near field radiation or with coupled antennas.

If the transmitter is an inductor then it can be drawn with high oscillating voltage to achieve strong transmission. The inductor should preferably have high inductance and low capacitance, and be non-shielded. For stronger transmission, the inductor may be driven by a circuit that produces high amplitude signals, or it can be driven by a spike–producing circuit that utilizes the transient characteristics of an inductor – that is by switching the current driven into the inductor and thereby achieving a high dI/dt (where I is the current), and therefore a high induced voltage L*dI/dt. Inductors can be used in serial or in parallel to enhance the effect, or they can just be aligned in different directions, to cover well the geometry.

The piezoelectric substance 10 comprises of a piezoelectric material (film/ceramic or other) and has a different frequency response for transmission and reception. The piezoelectric material transmits most strongly at its resonant frequency. The EM radiation is received by a receiving antenna , which can be a simple inductor for a compact unit, or it can be any form of a wound coil that receives enough energy to drive the passive piezoelectric component. Such a coil antenna can be mounted on the piezoelectric component, without significantly increasing its bulk. The piezoelectric substance 10 typically exhibits capacitive electrical behavior, whilst the antenna is predominantly inductive. The antenna and the piezoelectric material thus form a resonant circuit when connected, and this effect is exploited to maximize the efficiency of the circuit, that is, to maximize the acoustic output for a given EM radiation. Moreover, the received energy may be used to supply energy to the piezoelectric material without requiring an external power source. Such techniques for obtaining the necessary energy from the received EM radiation are used in the contactless smart card industry and are described, for example, in U.S. Patent No. 5,241,160 (Bashan *et al.*) incorporated herein by reference.

Piezoelectric materials have diverse material properties, as well as electrical and mechanical specifications. When choosing a material, the electrical and mechanical efficiency and behavior as a function of frequency should be considered as well as its capacitance.

The acoustic sensor 12 includes a receiver circuit (not shown) that is preferably shielded to remove any EM effects that can be received from transmitter. After the signal is received, its start time should be measured. The longer the duration of the signal, the easier it is to detect its phase. However, since the start and finish times of the signal are of primary interest, it is possible to produce an intermittent signal having successive sections of varying durations and delays, such that the receiver can uniquely identify each section, thereby increasing the accuracy of the reading, or in addtion or separately the signal phase information can be used.

Acoustic sensors can have different resonant frequencies, such that when using multiple sensors, the sensors' reactions will be distinguishable. This effect can be achieved by means of impedance matching and filtering using different circuit elements like capacitors, as is well known in the art.

Fig 3 shows the principle of an electronic timer circuit employing an accurate time reference such as a quartz crystal for providing short clock pulses of known duration. On emission of an electromagnetic pulse, the timer is reset so that T is equal to zero. On each clock pulse, the received acoustic signal is analyzed to determine if a returned signal has been received, according to frequency and energy characteristics and, if so, what is the exact time of receipt. If a signal were not detected then the measured time interval T is incremented by the clock pulse ΔT. Receipt of an acoustic pulse by the acoustic sensor 12 is detected by the threshold comparator, and the current value of T is substituted into equation (1) to provide the distance D. The timer and processor may be constituted by a suitably programmed computer/microcontroller.

In the foregoing description, it will be appreciated that if only a single acoustic sensor is employed, then the piezoelectric substance can lie anywhere on a circle centered at the acoustic sensor and having a radius equal to the measured distance D. In practice, in order to determine the spatial location of the piezoelectric substance relative to the acoustic sensor, two or more mutually spaced acoustic sensors must be employed having known locations in space relative to a defined origin point. By measuring the respective distance of the piezoelectric substance from each acoustic sensor, the spatial location of the piezoelectric substance relative to the defined origin point can then be calculated by triangulation.

Fig. 4 shows schematically use of a pair of mutually spaced acoustic sensors for determining the spatial location of the piezoelectric substance relative to one of the acoustic sensors. A circle 20 is centered at a first acoustic sensor 21 and has a radius R1 equal to the range of the piezoelectric substance from the first acoustic sensor 21. Thus, the piezoelectric substance may lie anywhere on the circle 20. Likewise, a circle 22 is centered at a second acoustic sensor 23 and has a radius R2 equal to the range of the piezoelectric substance from the second acoustic sensor 23. Thus, the piezoelectric substance may lie anywhere on the circle 22. Therefore, the piezoelectric substance must lie on the point of intersection 24 of the two circles 20 and 22.

It will be clear that Fig. 4 is highly schematic and allows only the 2-d location of the piezoelectric substance to be determined within a plane containing the centers of the acoustic sensors and the piezoelectric substance. In practice, each acoustic sensor defines a sphere centered at the acoustic sensor and having a radius equal to the measured distance of the piezoelectric substance. The actual spatial location of the piezoelectric substance must then determined by the common point of intersection of at least three spheres derived from three mutually spaced acoustic sensors having known centers relative to a fixed origin.

Fig. 5 shows a computer keyboard 25 having a pair of piezoelectric elements 26 and 27 at opposite diagonals thereof. An electromagnetic pulse derived from a suitable electromagnetic emitter (not shown) is directed toward the piezoelectric elements 26 and 27 for reflecting respective acoustic pulses. A pair of mutually spaced apart acoustic sensors 29 and 30 are mounted, for example, on a computer monitor 31 for receiving the acoustic pulses thereby allowing a spatial location of an origin point 28 of the keyboard to be determined. The keyboard 25 is equipped with a plurality of keys of which only Q, W, E, R, T and Y are shown and each of which is mounted on the keyboard 25 at a known spatial displacement to the origin point 28.

A computer operator has a piezoelectric element 32 attached to one of his or her fingers 33 so that the spatial location of the finger 33 relative to the acoustic sensors 29 and 30 may be measured. Likewise, the location of the origin point 28 of the keyboard 25 relative to the acoustic sensors 29 and 30 may be measured. The relative location of the finger 33 to the origin point 28 of the keyboard 25 may thereby be calculated and this, in turn, allows the key closest to the finger 33 to be determined. When a key is pressed, the acoustic pulse emitted by the acoustic sensors 29 and 30 is subjected to a modified echo characteristic serving as an indication that the key identified as being closest to the finger 33 has been operated. This allows the keyboard 25 to be physically detached from the computer.

The same technique may equally be applied to other computer input devices such as a mouse, joystick or pointing device. The electromagnetic pulse may be derived from the computer directly without an external emitter since all computers and computer accessories emit a certain amount of stray electromagnetic emission, or it can be produced by all common electrical appliances such as fluorescent lamps, thereby obviating the need to provide an external transmitter of electromagnetic pulses. In some cases, the stray electromagnetic emission's characteristic can be controlled and programmed, such is the case in a speaker connected to a computer, a computer screen and even the computer processor can be controlled by issuing commands and changing power saving modes. In these cases the EM can contain information for controlling/downloading purposes, even in general applications that do not involve positioning.

In those cases where the electromagnetic transmitter is not coupled to the timing unit, a detector must be provided for detecting the electromagnetic pulses and establishing a start time (T equals zero) at the start of the electromagnetic pulse.

Fig. 6 shows pictorially an interactive book or magazine 35 having predefined areas having piezoelectric elements 36 and 37 that a reader can "click" on with his finger 38 (constituting a "pointing device") so as to obtain an audio/visual response. For example, a user can read in a brochure, click a commercial, and his PC will go to the advertiser's web page or will display a video, or download more information to his PDA. The book or magazine has two or more piezoelectric elements 39, 40 and 41 located thereon, preferably spaced apart along edges or the inside spine of the book cover. The reader wears a piezoelectric element 42 on the tip of his finger. When the reader touches a location in the book, or a PC/PDA nearby, the reader's pointing location is measured using the localization technique according to the invention.

Specifically, an electromagnetic transmitter 43 transmits electromagnetic pulses to all the piezoelectric elements, thus generating respective acoustic pulses that are relayed to at least one acoustic sensor 44. A processor 45 is coupled to the electromagnetic transmitter 43 and to the acoustic sensor 44 and allows the respective distances from the acoustic sensor 44 to each of the piezoelectric elements to be computed, as explained above. The piezoelectric elements 39, 40 and 41 serve as reference points for defining the book's boundary. When the piezoelectric element 42 touches one of the piezoelectric elements 36 or 37, the processor 45 determines that the distance from the acoustic sensor 44 to both piezoelectric elements 36 or 37 is equal. This indicates that the user's finger 38 is within the specified areas. A vocalization unit 46 coupled to the processor 45 and is responsive to the user's finger 38 being within the specified areas for vocalizing a pre–recorded message or melody and playing it through a loudspeaker 47 coupled to the vocalization unit 46. Likewise, pre-recorded video messages may be displayed on a display unit (shown).

The special areas on the book can be marked in color or by means of an icon that signifies the area is "clickable". Locations having a similar x-y axis but on different pages are hard to identify (as are books with soft covers because soft cover books can bend, and then the relative locations of the units are changed). Therefore, even those locations on different pages should be spaced apart. Using a similar method, turning a page can be detected (if the unit is placed inside the book or on the page), and in response thereto a new message or melody could be played.

According to an alternative embodiment, the identification of the clicked points and turning of pages is achieved via identification rather the localization of the clicks. In this case, the clickable units can transmit an identifiable signal when touched by the user's finger. Preferably, an active element is placed on the user's finger, in order to send data characteristic of the clicked area to the vocalization unit or to the processor. This can be accomplished by means of magnetic materials, electronic components and even a barcode or other optically coded information instead of, or in addition to, the piezoelectric elements, providing the finger unit is adapted to read this information.

In accordance with yet another embodiment, clicking on the piezoelectric elements 36 or 37, transmits to the processor 45 an encoded pulse identifying the address of a respective Internet site. The resulting signal received by the processor 45 is decoded so as to extract the Internet site address, thus allowing the processor 45 to access the Internet site via a modem (not shown). Data downloaded from the Internet site to the processor 45 may be vocalized by the vocalization unit 46 and loudspeaker 47 and/or displayed on a display device (not shown).

Fig. 7 shows pictorially a regular computer screen operating as a touch screen 50. Location of a user's finger 51 on the touch screen can be measured using triangulation by placing units 52, 53 and 54 at several corners of the touch screen and a complementary unit 55 on the user's finger. This application can achieve better accuracy as more units are employed, but even one unit can give some knowledge of the location of the user's finger, and thus give enough information in some cases. It is also possible to use the computer built–in microphone to receive the returning signal and the PC to analyze them.

Although various embodiments have been described, it will be appreciated that many more applications of the invention are possible. For example, the acoustic sensor may be mounted in a toy having therein a processor responsive to the received acoustic pulse for operating the toy. Such a toy may be mobile and include a servo system for maintaining a substantially constant distance from a specified object having mounted therein the piezoelectric substance. The object may be a child and such an application allows the toy to chase the child. The acoustic sensor may be an integral component of the toy, many of which are, in any case, provided with microphones for other purposes. More generally, in all embodiments, the acoustic sensor may be integral with the processor.

Other applications of the invention include Virtual Reality, Virtual Presence, robotics, CAD/CAM, computer games, mobile toys that reacts to movements, remote controlled vehicles. The invention also allows operation of electrical products, such as switching on and off electric lights, air conditioning, and the like. Likewise, the invention is applicable to other computer input devices and peripherals, educational and medical software, input devices for the disabled and remote controllers for business applications and presentations.

It is further noted that a speaker or other equivalent transducer for converting electrical signals to mechanical vibrations simultaneously emits electromagnetic radiation, which effectively encodes the acoustic information produced by the transducer. This electromagnetic radiation, which constitutes "stray radiation" since it is a by-product of the device, may be transmitted to an electromagnetic receiver and subsequently decoded to extract the data. The decoded data can then be fed to another acoustic transducer, for example, to relay the original acoustic data in a different location, or it can be used for other purposes such as control, and so on.

Put generally, a signal capable of being reproduced acoustically can be conveyed by:

(a) driving an acoustic transducer so as to produce mechanical vibrations and to emit stray electromagnetic radiation simultaneously therewith,

(b) receiving said stray electromagnetic radiation, and

(c) decoding the received stray electromagnetic radiation so as to extract the signal.

In the method claims that follow, alphabetic characters used to designate claim steps are provided for convenience only and do not imply any particular order of performing the steps.

CLAIMS:

1. A method for measuring the distance from a piezoelectric substance (10) comprising:

(a) transmitting an electromagnetic pulse (14) to said piezoelectric substance so as to generate an acoustic pulse (15) in response thereto,

(b) sensing the acoustic pulse by an acoustic sensor (12) displaced from the piezoelectric substance by an unknown distance,

(c) measuring a time interval between initiation of the electromagnetic pulse and receipt of the acoustic pulse, and

(d) calculating the distance between the piezoelectric substance and the acoustic sensor multiplying the measured time interval by the speed of sound.

2. The method according to Claim 1, further including the steps of:

(e) sensing the acoustic pulse at at least two acoustic sensors (21, 23) that are spatially displaced by a known distance so as to determine respective distances between the piezoelectric substance and each of said acoustic sensors, and

(f) determining a location of the piezoelectric substance by triangulation.

3. The method according to Claim 1, further including the steps of:

(g) identifying surface contact by the piezoelectric substance or by a carrier bearing the piezoelectric substance by detecting a modified echo characteristic of the acoustic pulse.

4. The method according to Claim 2, further including the steps of:

(h) identifying surface contact by the piezoelectric substance or by a carrier bearing the piezoelectric substance by detecting a modified echo characteristic of the acoustic pulse.

5. The method according to Claim 4 for identifying operation of a specific switch in a device (25) having at least two mutually spaced switches each having a respective known location relative to an origin point of the device, said method further including the steps of:

- **(i)** mounting the piezoelectric substance (32) on a switch operator (33),
- **(j)** determining a spatial location of the origin point of the device,
- **(k)** identifying surface contact with said specific switch consequent to operation thereof by said switch operator,
- **(l)** determining a spatial location relative to said origin point of said switch operator by triangulating between two mutually spaced acoustic sensors with respect to an acoustic pulse having said modified echo characteristic, and
- **(m)** determining from said spatial location an identity of said specific switch.

6. The method according to Claim 1, wherein the acoustic sensor is mounted in a toy and there is further including the step of:

- **(n)** mounting in association with the toy a processor responsive to said acoustic pulse for operating the toy.

7. The method according to Claim 6, wherein the toy is mobile and further including the step of:

- **(o)** affixing in the toy a servo system for maintaining a substantially constant distance from a specified object, and
- **(p)** affixing the piezoelectric substance in said specified object so that movement thereof causes the toy to chase the object.

8. A method for identifying surface contact by a piezoelectric substance or by a carrier bearing the piezoelectric substance, the method comprising the steps of:

(a) transmitting an electromagnetic pulse to said piezoelectric substance so as to generate an acoustic pulse in response thereto, and

(b) detecting a modified echo characteristic of the acoustic pulse consequent to surface contact of the piezoelectric substance.

9. A system for measuring the distance from a piezoelectric substance (10, 26, 27), the system comprising:

an electromagnetic transmitter (13) for generating electromagnetic pulses (14),

said piezoelectric substance being connected to an electromagnetic receiver for receiving one of said electromagnetic pulses so as to generate in response thereto an acoustic pulse (15),

an acoustic sensor (12, 29, 30) displaced from the piezoelectric substance (10, 26, 27) for sensing said acoustic pulse,

a timer (45) coupled to the acoustic sensor and to the electromagnetic transmitter for measuring a time interval between initiation of the electromagnetic pulse and receipt of the acoustic pulse, and

a processing unit (45) coupled to the timer for calculating the distance between is the piezoelectric substance and the acoustic sensor multiplying the measured time interval by the speed of sound.

10. The system according to Claim 9, further including at least two acoustic sensors that are spatially displaced by a known distance, wherein:

the processing unit is responsively coupled to each of the at least two acoustic sensors (21, 23, 29, 30) so as to determine respective distances between the piezoelectric substance and each of said acoustic sensors, and to determine a location of the piezoelectric substance by triangulation.

11. The system according to Claim 9, including a computer touch screen (50) supporting respective piezoelectric substances (52, 53, 54).

12. The system according to Claim 9, further including:

a detector for detecting a modified echo characteristic of the acoustic pulse consequent to surface contact by the piezoelectric substance or by a carrier bearing the piezoelectric substance.

13. The system according to Claim 10, further including:

a detector for detecting a modified echo characteristic of the acoustic pulse consequent to surface contact by the piezoelectric substance or by a carrier bearing the piezoelectric substance.

14. The system according to Claim 13 for identifying operation of a specific switch in a device having at least two mutually spaced switches having respective known locations relative to an origin point of the device, said system further including:

means for determining a spatial location of the origin point of the device,

two mutually spaced apart acoustic sensors (29, 30) each for sensing an acoustic pulse generated by an piezoelectric substance (32) mounted in association with a switch operator (33), and

means responsive to an acoustic pulse having said modified echo characteristic for determining a spatial location relative to said origin point of said switch operator by triangulating between said two mutually spaced acoustic sensors with respect to said acoustic pulse, thereby allowing determination from said spatial location of an identity of said specific switch.

15. The system according to Claim 14, wherein:

the device is a keyboard (25) for use with a computer or similar machine, and

the switch operator is a finger (33) having the piezoelectric substance (32) mounted in association therewith.

16. The system according to Claim 9, wherein the processing unit is a computer and the acoustic sensor is integral therewith.

17. The system according to Claim 9, further including:

a toy (35) for affixing therein the acoustic sensor, the toy having therein a processor (45) responsive to said acoustic pulse for operating the toy.

18. The system according to Claim 17, wherein the toy is mobile and includes a servo system for maintaining a substantially constant distance from a specified object having mounted therein the piezoelectric substance.

19. The system according to Claim 17, wherein the acoustic sensor is an integral component of the toy.

20. The system according to Claim 9 or 10, being an interactive talking book (35), having respective piezoelectric substances (39, 40, 41) fixedly attached thereto for defining a reference frame of the book.

21. The system according to Claim 20, including at least one predetermined area defined by a respective piezoelectric substance (36, 37) and an acoustic sensor (44) responsively coupled thereto for identifying contact of a pointing device therewith.

22. The system according to Claim 21, wherein:

the piezoelectric substance (36, 37) is adapted to emit a signal encoding therein a respective Internet address, and

the processing unit is responsive to the received signal for decoding the respective Internet address and connecting thereto.

23. The system according to any one of Claims 9 to 22, wherein the electromagnetic pulses encode modulated data that is received by the electromagnetic receiver.

24. The system according to Claim 9, wherein the electromagnetic transmitter (13) is a source of stray electromagnetic emission.

25. The system according to any one of Claims 9 to 24, wherein the electromagnetic receiver is a passive unit energized by received electromagnetic energy.

26. A system for identifying surface contact by a piezoelectric substance (10) or by a carrier bearing the piezoelectric substance and emitting an acoustic pulse (15) in response to a received electromagnetic pulse (14), the system comprising:

an acoustic sensor (12) displaced from the piezoelectric substance (10) for sensing a modified echo characteristic of the acoustic pulse consequent to surface contact of the piezoelectric substance.

27. The system according to Claim 26, wherein the electromagnetic pulse is derived from a stray electromagnetic emission.

28. A method for conveying a signal capable of being reproduced acoustically, said method comprising the steps of:

(a) driving an acoustic transducer so as to produce mechanical vibrations and to emit stray electromagnetic radiation simultaneously therewith,

(b) receiving said stray electromagnetic radiation, and

(c) decoding the received stray electromagnetic radiation so as to extract the signal.

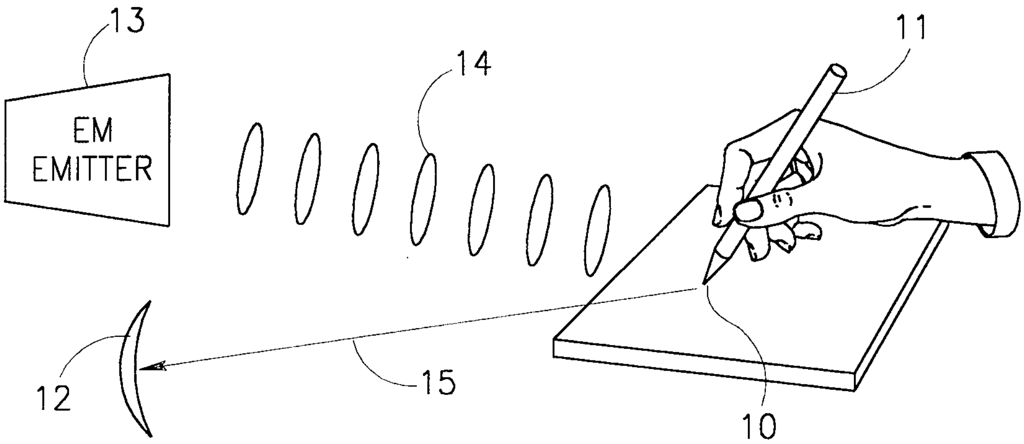

FIG.1

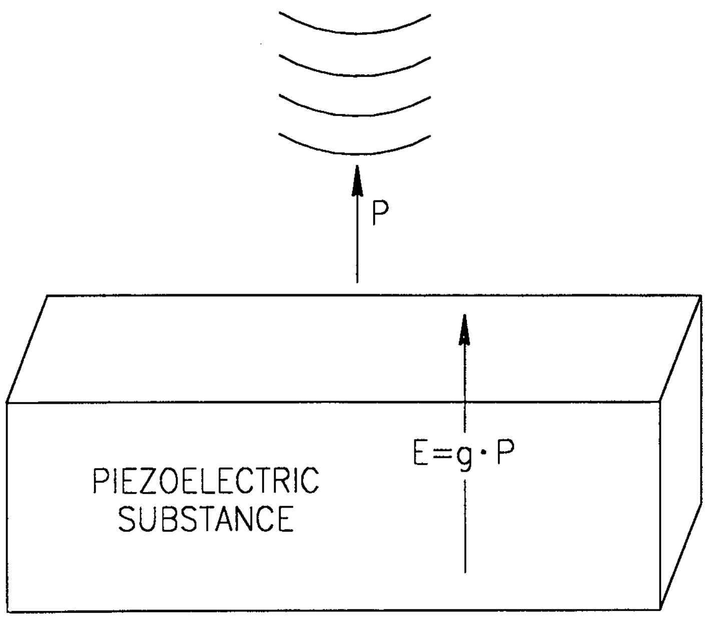

FIG.2

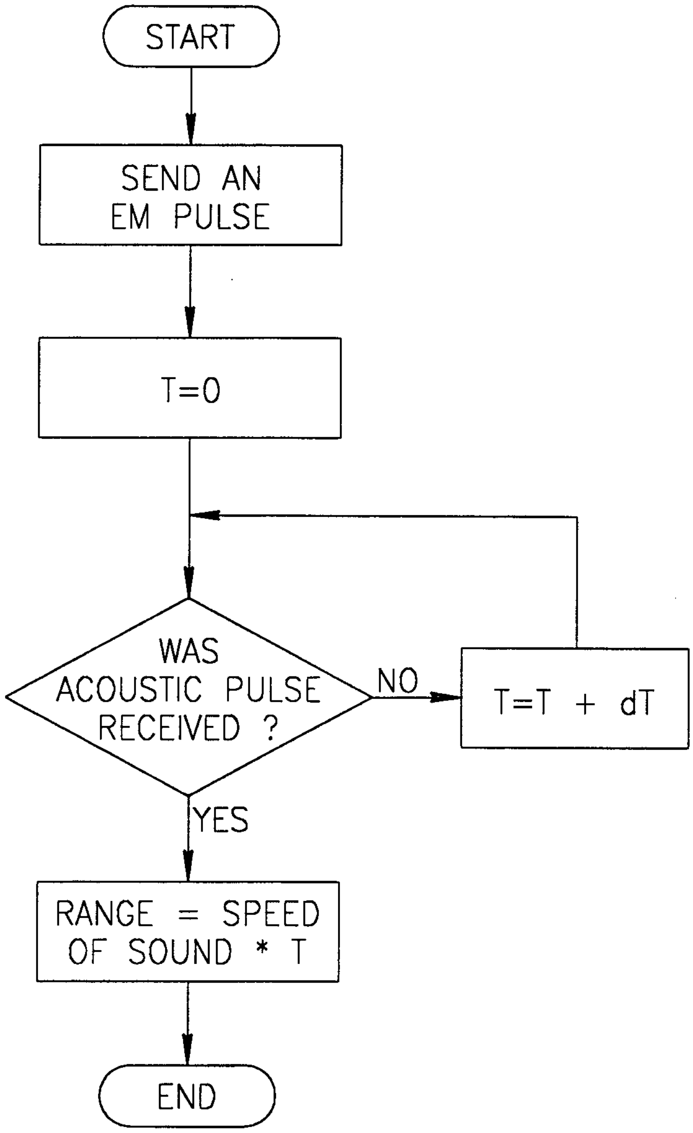
START
SEND AN EM PULSE
T=0
WAS ACOUSTIC PULSE RECEIVED ?
NO
T=T + dT
YES
RANGE = SPEED OF SOUND * T
END

FIG.3

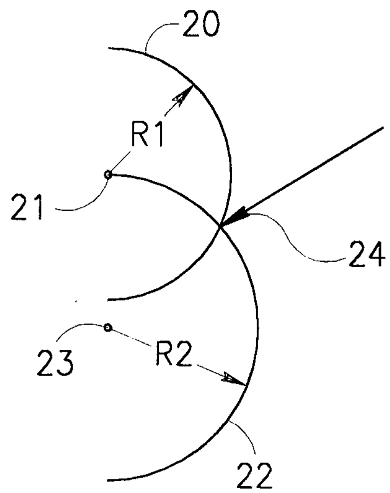

FIG.4

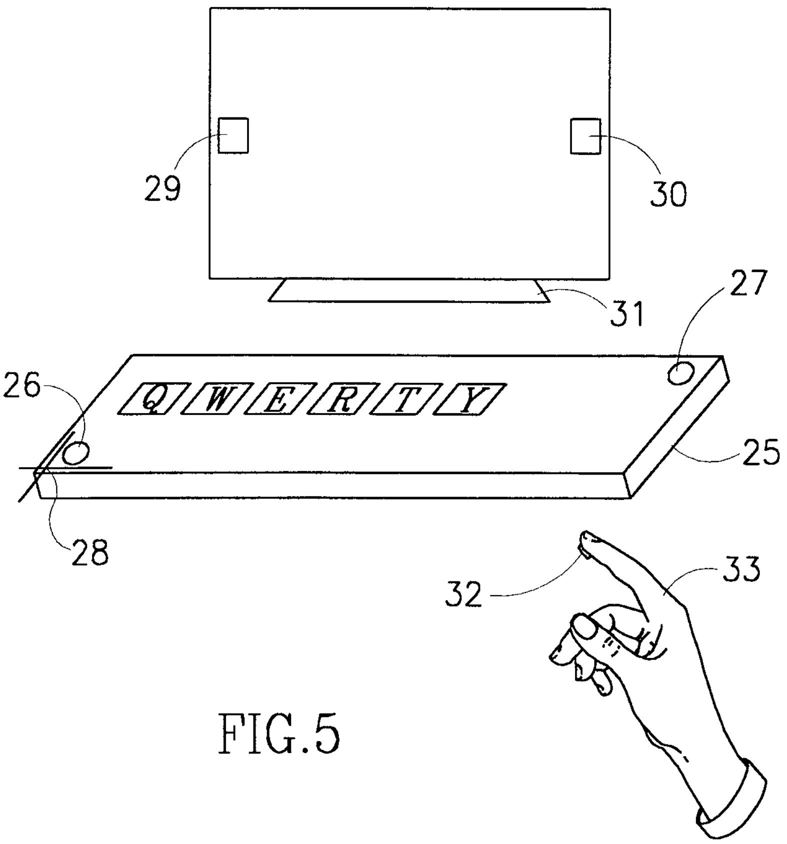

FIG.5

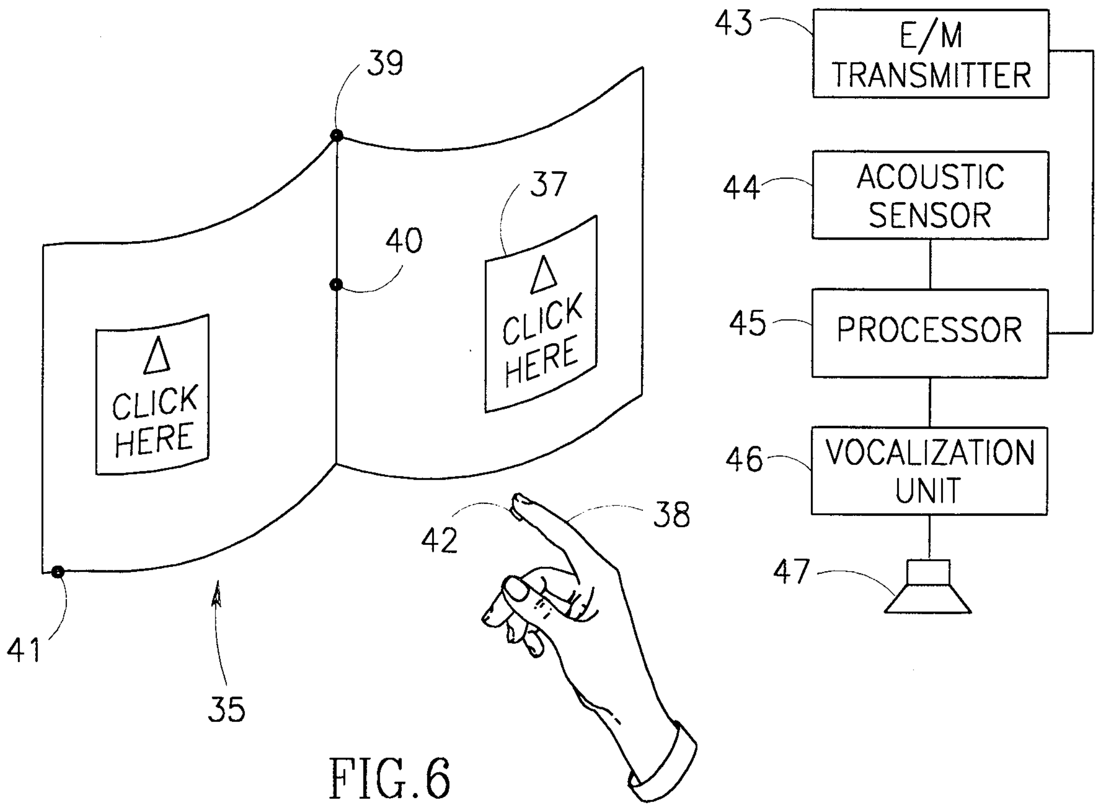
43
E/M TRANSMITTER
44
ACOUSTIC SENSOR
45
PROCESSOR
46
VOCALIZATION UNIT
47
39
37
40
CLICK HERE
CLICK HERE
42
38
41
35

FIG.6

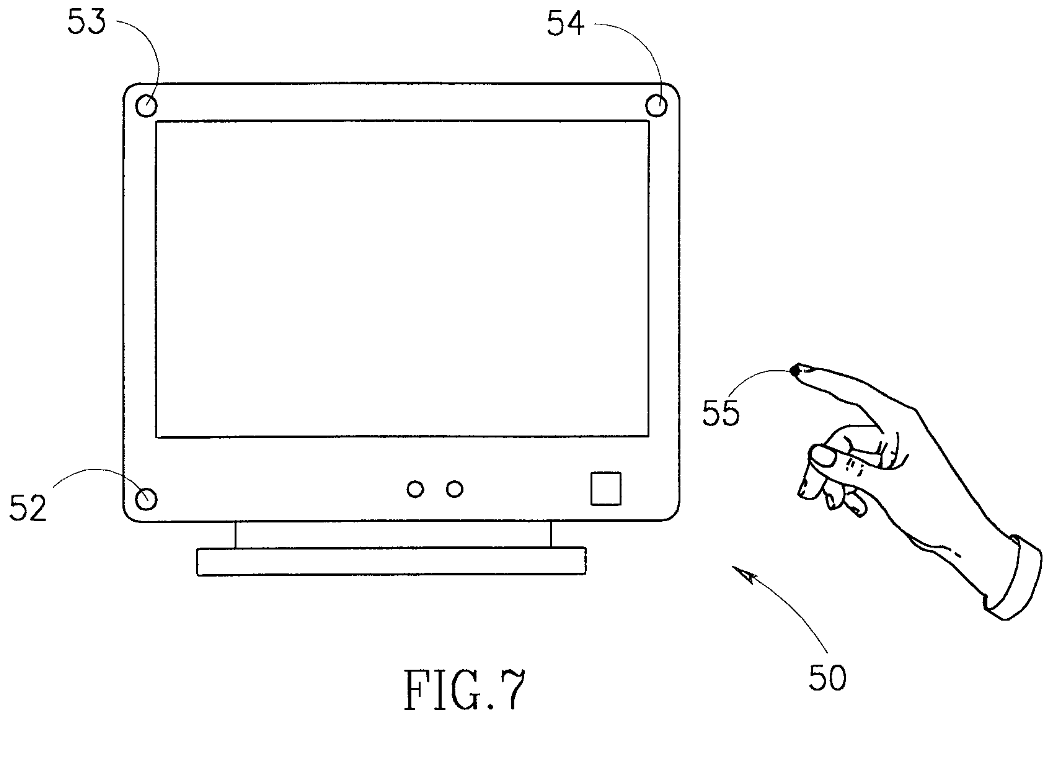
53
54
55
52
50

FIG.7