

METHOD AND SYSTEM FOR AUTHENTICATING USING A QUARTZ OSCILLATOR

FIELD OF THE INVENTION

[0001] The present invention relates to a method and system for authenticating using a quartz oscillator.

BACKGROUND OF THE INVENTION

[0002] Counterfeit consumer goods, commonly called knock-offs, are counterfeit or imitation products offered for sale. The spread of counterfeit goods has become global in recent years and the range of goods subject to counterfeiting has increased significantly.

[0003] Watches are vulnerable to counterfeiting, and have been counterfeited for decades. A counterfeit watch is an unauthorized copy of a part or all of an authentic watch. According to estimates by the Swiss Customs Service, there are some 30 to 40 million counterfeit watches put into circulation each year. It is a common cliché that visitors to New York City are approached on the street by vendors with a dozen such counterfeit watches inside their coats, offered at bargain prices. A counterfeit product may look genuine from the outside and contain sub-standard components. Extremely authentic looking, but very poor quality counterfeit watches can sell for as little as twenty dollars. The problem is becoming more and more serious, with the quality of the counterfeits constantly increasing.

[0004] Authentication solutions that have been used for protection of consumer goods from counterfeiting are often based on marking the item with a specific material, code, or marking, engraving, etc. However, these methods modify the nature and the appearance of the object, and this is often not acceptable in the watch (and other luxury items) industry, where the design of the object and its visual appearance are of paramount importance. Additionally, outer marks

may be exposed to copy and environmental factors (wear, dirt, etc.). Also, these methods require an active intervention at the time of manufacturing or distribution and, correspondingly an important change of the production process.

[0005] A quartz clock is a clock that uses an electronic oscillator that is regulated by a quartz crystal resonator to keep time. This crystal oscillator creates a signal with a very precise frequency, so that quartz clocks are at least an order of magnitude more accurate than mechanical clocks. The inherent accuracy and low cost of production has resulted in the proliferation of quartz clocks and watches. By the 1980s, quartz technology had taken over applications such as kitchen timers, alarm clocks, bank vault time locks, and time fuses on munitions, from earlier mechanical balance wheel movements, an upheaval known in watchmaking as the quartz crisis.

[0006] Quartz timepieces have dominated the wristwatch and clock market since the 1980s, Because of the high Q factor and low temperature coefficient of the quartz crystal they are more accurate than the best mechanical timepieces, and the elimination of moving parts makes quartz timepieces more rugged and eliminates the need for periodic maintenance.

[0007] It is desirable, when assessing the authenticity of a timepiece, to have as much information as possible not only on its outer appearance but also on its inner content. It is furthermore desirable not to have to open the timepiece when checking the authenticity, as the operation requires specialized equipment and procedures, which may impact the performance and/or integrity of the piece (e.g., water tightness), and which may invalidate the manufacturer's warranty.

[0008] It is, therefore, desirable to be able to authenticate a timepiece in a manner that is as non-invasive and as reliable as possible without having to open the timepiece.

SUMMARY OF EMBODIMENTS OF THE INVENTION

[0009] An aim of the invention is to provide a method for authenticating a timepiece that is non-invasive and reliable.

[0010] This aim is solved by the subject matter of the independent claims. Preferred embodiments are subject matter of the dependent claims.

[0011] Aspects of embodiments of the present invention are directed to a timepiece comprising at least one of at least one quartz oscillator, and at least one transducer.

[0012] In embodiments of the present invention, the at least one quartz oscillator is a quartz-based electronic oscillator.

[0013] In further embodiments of the present invention a respective quartz-based electronic oscillator comprises a quartz crystal, and electronic circuitry configured to drive the quartz crystal. When driven, the quartz crystal generates an oscillating electronic signal.

[0014] In additional embodiments of the present invention, the quartz crystal of at least one of the at least one quartz oscillators comprises a piezo-electric mechanical resonator having a resonant frequency serving as a time base for the timepiece.

[0015] In yet further embodiments of the present invention, the timepiece further comprises electronic and/or electromechanical circuitry configured to drive and/or operate the timepiece.

[0016] In embodiments of the present invention, the at least one of the at least one quartz oscillators; and the at least one transducer comprises a single quartz oscillator.

[0017] In further embodiments of the present invention, the quartz oscillator is structured and configured to perform a time-keeping for the timepiece.

[0018] In additional embodiments of the present invention, the quartz crystal and electronic circuitry driving the quartz crystal are not modified.

[0019] In yet further embodiments of the present invention, the at least one quartz oscillator comprises a modified quartz oscillator, which is modified so as to encode additional information in the acoustic signal the modified quartz resonator generates.

[0020] In embodiments of the present invention, wherein the modified quartz oscillator comprises a modified quartz crystal.

[0021] In further embodiments of the present invention, the modified quartz oscillator comprises at least one of a modified quartz crystal and a modified electronic circuitry configured to drive the quartz crystal and a modified electronic/electromechanical circuitry configured to drive and/or operate the timepiece.

[0022] In additional embodiments of the present invention, the modified quartz oscillator is one of amplitude modulated and frequency modulated.

[0023] In yet further embodiments of the present invention, the at least one of the at least one quartz oscillator; and the at least one transducer comprises a plurality of quartz oscillators.

[0024] In embodiments of the present invention, the plurality of quartz oscillators comprise a first quartz oscillator dedicated for time keeping purposes and at least a second quartz oscillator present in said timepiece and not used for time keeping purposes.

[0025] In further embodiments of the present invention, the first quartz oscillator and the at least one second quartz oscillator each have a different frequency domain.

[0026] In additional embodiments of the present invention, the at least one second quartz oscillator is operable to broadcast an encoded signal.

[0027] In yet further embodiments of the present invention, a frequency domain of the first quartz oscillator is in dependence upon a frequency domain of the at least one second quartz oscillator.

[0028] In embodiments of the present invention, a frequency domain of the at least one second quartz oscillator is in dependence upon a frequency domain of the first quartz oscillator.

[0029] In further embodiments of the present invention, the first quartz oscillator dedicated for time keeping purposes, the electronic circuitry driving the first quartz resonator, and the at least one second quartz oscillator present in said timepiece and not used for time keeping purposes are not modified.

[0030] In additional embodiments of the present invention, the at least one second quartz oscillator is structured and arranged to emit an acoustic signal having encoded information.

[0031] In yet further embodiments of the present invention, the one or more components whose resonance frequencies are detected comprise two or more components acting as a single resonator.

[0032] In embodiments of the present invention, the at least one of the at least one quartz oscillator; and the at least one transducer comprises the at least one quartz oscillator and the at least one transducer.

[0033] In further embodiments of the present invention, the at least one quartz oscillator and the at least one transducer comprises a quartz oscillator and a transducer.

[0034] In additional embodiments of the present invention, the at least one quartz oscillator is structured and arranged to generate a specific tone.

[0035] In yet further embodiments of the present invention, the timepiece is comprised in a mobile device.

[0036] In embodiments of the present invention, the timepiece is a watch.

[0037] In further embodiments of the present invention, the timepiece comprises a mobile device.

[0038] Additional aspects of embodiments of the present invention are directed to a method for authenticating a timepiece. The method comprises measuring acoustic vibrations emitted by the timepiece to obtain an electrical signal, performing a transform of said electrical signal into at least one domain, extracting identification information from the transformed electrical signal, comparing the extracted information with at least one reference information, and determining an authenticity of said timepiece based on the comparing.

[0039] In embodiments of the present invention, the timepiece comprises at least one of at least one quartz oscillator, and at least one transducer.

[0040] In further embodiments of the present invention, the at least one quartz oscillator comprises a first quartz oscillator dedicated for time keeping purposes and at least a second quartz oscillator present in said timepiece and not used for time keeping purposes.

[0041] In additional embodiments of the present invention, the electrical signal indicates magnitude information comprising a variation of a magnitude of the measured acoustic vibrations as a function of time, wherein said electrical signal comprises at least one specific tone associated with the presence of the quartz oscillator in the timepiece.

[0042] In yet further embodiments of the present invention, the performing the transform of said electrical signal into the at least one domain comprises transforming the electrical signal into

a frequency domain to obtain a frequency-domain power spectrum indicating a variation of a power of the electrical signal as a function of frequency.

[0043] In embodiments of the present invention, the method further comprises processing the frequency-domain power spectrum so as to reveal at least one narrow peak in the frequency-domain power spectrum corresponding to at least one specific tone associated with the presence of the quartz oscillator in the timepiece.

[0044] In further embodiments of the present invention, the method further comprises extracting at least one resonance frequency corresponding to said at least one narrow peak.

[0045] In additional embodiments of the present invention, the comparing the extracted information with at least one reference resonance information comprises comparing the extracted at least one resonance frequency with at least one reference resonance frequency.

[0046] In yet further embodiments of the present invention, the electrical signal is representative of the acoustic signal of the quartz oscillator.

[0047] In embodiments of the present invention, the electrical signal is representative of the acoustic signal of the quartz oscillator and the acoustic signal of one or more other elements of the timepiece.

[0048] In further embodiments of the present invention, the transform of said electrical signal into the frequency domain comprises a Fourier transform or a Fast Fourier transform.

[0049] In additional embodiments of the present invention, the frequency of a main peak in the frequency-domain power spectrum of the acoustic signal generated by the quartz oscillator is used for authentication purposes.

[0050] In yet further embodiments of the present invention, the frequency of a main peak and one or more less prominent peaks in the frequency-domain power spectrum of the acoustic signal generated by the quartz oscillator are used for authentication purposes.

[0051] In embodiments of the present invention, the frequency of a main peak in the frequency-domain power spectrum of the acoustic signal generated by the quartz oscillator and one or more peaks in a frequency-domain power spectrum of an acoustic signal generated by one or more other vibration-producing elements are used for authentication purposes.

[0052] In further embodiments of the present invention, a frequency of a main peak in a frequency-domain power spectrum of the acoustic signal generated by the at least one second quartz oscillator is used for authentication purposes.

[0053] In additional embodiments of the present invention, the method further comprises processing said electrical signal so as to attenuate one or more of a plurality of acoustic events of the measured acoustic vibrations represented in the electrical signal.

[0054] In yet further embodiments of the present invention, the processing the electrical signal so as to attenuate the plurality of events in said electrical signal comprises sampling said electrical signal (S), calculating an envelope (E) of said sampled electrical signal (S) by averaging an absolute value of a plurality of samples, and calculating a ratio of said sampled electrical signal (S) divided by said calculated envelope (E) of said sampled electrical signal (S).

[0055] In embodiments of the present invention, the processing the frequency-domain power spectrum so as to reveal at least one narrow peak in said frequency-domain power spectrum comprises filtering the frequency-domain power spectrum so as to reduce a background part and retain sharp peaks within the frequency-domain power spectrum.

[0056] In further embodiments of the present invention, the processing the frequency-domain power spectrum so as to reveal at least one narrow peak in the frequency-domain power spectrum comprises: calculating, for each frequency (F) of said frequency-domain power spectrum, a module (M(F)) of a complex number obtained in performing said transform of said processed electrical signal into a frequency domain; and multiplying said module (M(F)) of said complex number by an absolute value of a difference between said module (M(F)) of said complex number and a module (M(F-1)) of a complex number for an immediately preceding frequency and by an absolute value of a difference between said module (M(F)) of said complex number and a module (M(F+1)) of a complex number for an immediately following frequency.

[0057] In additional embodiments of the present invention, the method further comprises repeating said calculating and multiplying a predetermined number of times; and determining, for each frequency (F) of said frequency-domain power spectrum, an average of results (V(F)) of said repeated calculating and multiplying.

[0058] In yet further embodiments of the present invention, the method further comprises extracting a width of said revealed at least one narrow peak.

[0059] In embodiments of the present invention, the method further comprises extracting a relative amplitude of said revealed at least one narrow peak.

[0060] In further embodiments of the present invention, the method further comprises recertifying the timepiece when timepiece maintenance is performed.

[0061] In additional embodiments of the present invention, a threshold for determining a positive authentication of a timepiece is configured in dependence upon an age of the timepiece.

[0062] In yet further embodiments of the present invention, the performing the transform of said electrical signal into the at least one domain further comprises performing a time-frequency domain transform of the electrical signal into a time-frequency domain.

[0063] In embodiments of the present invention, the performing the transform of said electrical signal into the at least one domain comprises performing a time-frequency domain transform of said electrical signal into a time-frequency domain.

[0064] In further embodiments of the present invention, the method further comprises processing electrical signal to reveal identification information.

[0065] In additional embodiments of the present invention, the transform comprises one of a Fourier transform, a short-time Fourier transform, a Gabor transform, a Wigner transform, and a wavelet transform.

[0066] In yet further embodiments of the present invention, the performing the time-frequency domain transform of said electrical signal into a time-frequency domain indicates a frequency of the electrical signal as a function of time, and the extracting further comprises extracting at least one of magnitude information, frequency information, and time information in the time-frequency representation of the electrical signal.

[0067] In embodiments of the present invention, the method further comprises utilizing at least one of the extracted magnitude information, time information and frequency information to create a unique identifier for the timepiece.

[0068] In further embodiments of the present invention, the method further comprises creating reference information for the timepiece based on the unique identifier, wherein the reference

information comprises at least one of reference magnitude information, reference time information and reference frequency.

[0069] In additional embodiments of the present invention, the method further comprises modulating the frequency of the at least one quartz oscillator to generate a set of additional peaks in the spectrum, wherein a respective frequency of one or more of the set of additional peaks is used for authentication purposes.

[0070] In yet further embodiments of the present invention, the frequency of the at least one quartz oscillator is modulated with a time-variable signal, the method further comprising demodulating the generated acoustic signal to recover a message signal.

[0071] Additional aspects of embodiments of the invention are directed to a method for authenticating a timepiece, the timepiece comprising at least one of: at least one quartz oscillator; and at least one transducer, wherein at least one of the quartz oscillator and electronic circuitry driving the quartz oscillator are modified so as to encode additional information in an acoustic signal the at least one quartz oscillator generates. The method comprises modulating a resonance frequency of the quartz to generate a set of additional peaks in a signal frequency spectrum, measuring acoustic vibrations emitted by the timepiece to obtain an electrical signal, extracting identification information from the electrical signal, comparing the extracted information with at least one reference resonance information, and determining an authenticity of said timepiece based on the comparing.

[0072] In embodiments of the present invention, a respective frequency of one or more of the set of additional peaks is used for authentication purposes.

[0073] In further embodiments of the present invention, the frequency of the quartz oscillator is modulated with a time-variable signal, and the method further comprises demodulating the generated acoustic signal is to recover a message signal.

[0074] In additional embodiments of the present invention, the method further comprises utilizing extracted magnitude information to create a unique identifier for the timepiece.

[0075] In embodiments of the present invention, a method comprises measuring acoustic vibrations emitted by the timepiece to obtain an electrical signal, performing a transform of said electrical signal into a domain, extracting identification information from the transformed electrical signal, comparing the extracted information with at least one reference information; and determining an authenticity of said timepiece based on the comparing.

[0076] In further embodiments of the present invention, a method comprises measuring acoustic vibrations emitted by the timepiece to obtain an electrical signal, said electrical signal indicating magnitude information comprising a variation of a magnitude of the measured acoustic vibrations as a function of time, wherein said electrical signal comprises at least one specific tone associated with the presence of an element in the timepiece, performing a transform of said electrical signal into a frequency domain to obtain a frequency-domain power spectrum indicating a variation of a power of the electrical signal as a function of frequency, processing the frequency-domain power spectrum so as to reveal at least one narrow peak in the frequency-domain power spectrum corresponding to the at least one specific tone, extracting at least one resonance frequency corresponding to said at least one narrow peak, comparing the extracted at least one resonance frequency with at least one reference resonance frequency, and determining an authenticity of said timepiece based on the comparing.

[0077] In additional embodiments of the present invention, a method comprises measuring acoustic vibrations emitted by the timepiece to obtain an electrical signal, said electrical signal indicating magnitude information comprising a variation of a magnitude of the measured acoustic vibrations as a function of time, wherein said electrical signal comprises at least one specific tone associated with the presence of the quartz oscillator in the timepiece, performing a transform of said electrical signal into a frequency domain to obtain a frequency-domain power spectrum indicating a variation of a power of the electrical signal as a function of frequency, processing the frequency-domain power spectrum so as to reveal at least one narrow peak in the frequency-domain power spectrum corresponding to the at least one specific tone, extracting at least one resonance frequency corresponding to said at least one narrow peak, comparing the extracted at least one resonance frequency with at least one reference resonance frequency, and determining an authenticity of said timepiece based on the comparing.

[0078] In yet further embodiments of the present invention, a method comprises measuring acoustic vibrations emitted by the timepiece to obtain an electrical signal, said electrical signal indicating magnitude information comprising a variation of a magnitude of the measured acoustic vibrations as a function of time, demodulating the electrical signal in the time domain, decoding the demodulated electrical signal to reveal a decoded message, comparing the decoded message with at least one reference message, and determining an authenticity of said timepiece based on the comparing.

[0079] In embodiments of the present invention, a method comprises measuring acoustic vibrations emitted by the timepiece to obtain an electrical signal, said electrical signal indicating magnitude information comprising a variation of a magnitude of the measured acoustic vibrations as a function of time, wherein said electrical signal comprises at least one specific tone

associated with the presence of the quartz oscillator in the timepiece, performing a time-frequency domain transform of said electrical signal into a time-frequency domain, processing electrical signal to reveal identification information, comparing the identification information with at least one reference information, and determining an authenticity of said timepiece based on the comparing.

[0080] In further embodiments of the present invention, a method comprises sending a detection signal, measuring acoustic vibrations emitted by the timepiece in response to the detection signal to obtain an electrical signal, said electrical signal indicating magnitude information comprising a variation of a magnitude of the measured acoustic vibrations as a function of time, wherein said electrical signal comprises at least one specific tone associated with the presence of the transducer in the timepiece, decoding the electrical signal to reveal a decoded message, comparing the decoded message with at least one reference message, and determining an authenticity of said timepiece based on the comparing.

[0081] Additional aspects of embodiments of the present invention are directed to a timepiece comprising at least two quartz oscillators, wherein a first quartz oscillator is dedicated for time keeping purposes and at least a second quartz oscillator is present in said timepiece and not used for time keeping purposes.

[0082] Additional aspects of embodiments of the present invention are directed to a timepiece, comprising at least one of at least one quartz oscillator comprising a quartz-based electronic oscillator having a quartz crystal piezo-electric mechanical resonator having a resonant frequency that serves as a time base for the timepiece and electronic circuitry configured to drive the quartz crystal and to generate an oscillating electronic signal, and at least one transducer.

[0083] In embodiments of the present invention, at least one of the at least one quartz oscillator and the at least one transducer is configured to emit an identification signal.

[0084] In further embodiments of the present invention, the timepiece further comprises electronic and/or electromechanical circuitry configured to drive and/or operate the timepiece.

[0085] Additional aspects of embodiments of the present invention are directed to a device, comprising at least one of at least one quartz oscillator comprising a quartz-based electronic oscillator having a quartz crystal piezo-electric mechanical resonator having a resonant frequency that serves as a time base for the timepiece and electronic circuitry configured to drive the quartz crystal and to generate an oscillating electronic signal and at least one transducer. At least one of the at least one quartz oscillator and the at least one transducer is configured to emit an identification signal.

[0086] In further embodiments of the present invention, the device comprises at least one of a timepiece, a watch, a mobile device, and a tablet.

BRIEF DESCRIPTION OF THE FIGURES

[0087] For a more complete understanding of the invention, as well as other objects and further features thereof, reference may be had to the following detailed description of the invention in conjunction with the following exemplary and non-limiting drawings wherein:

[0088] Fig. 1A shows exemplary normalized spectra of five different watches of the same model and manufacturer in accordance with embodiments of the invention;

[0089] Fig. 1B shows exemplary normalized spectra of the same watch taken at different times. with the spectra vertically offset vertically for clarity in accordance with embodiments of the invention;

[0090] Fig. 2 shows exemplary normalized spectra of the same watch taken at different times with the spectra offset vertically for clarity in accordance with embodiments of the invention;

[0091] Fig. 3 shows an exemplary and non-limiting overview of the signal spectra measured on three individual watches of the same make and models in accordance with embodiments of the invention;

[0092] Fig. 4 illustrates an exemplary and non-limiting detail of a discriminating feature of the spectra of Fig. 3 in accordance with aspects of embodiments of the present invention;

[0093] Fig. 5 shows exemplary spectra of a quartz oscillator with a natural frequency of about 32'768.5 Hz modulated at 1 Hz (bottom), 2 Hz (middle), and 4 Hz (top) in accordance with embodiments of the invention;

[0094] Fig. 6 shows an exemplary demodulated signal of the same quartz oscillator as in Fig 5, modulated, in successive 5s intervals, respectively at 1 Hz, 2 Hz, 3 Hz, 4 Hz, 5 Hz, 4 Hz, 3 Hz, 2 Hz, 1 Hz in accordance with embodiments of the invention;

[0095] Fig. 7 shows exemplary spectra of a device incorporating a quartz oscillator with a natural frequency f_o of about 32'768.39 Hz and a piezoelectric transducer which is excited with two sinusoidal waves of frequency $f_o - 100$ Hz and $f_o + 100$ Hz, respectively, in accordance with embodiments of the invention;

[0096] Fig. 8 shows exemplary normalized spectra of three mobile phones from of the same model and manufacturer in accordance with embodiments of the invention;

[0097] Fig. 9 shows exemplary normalized spectra of the same mobile phone taken at different times in accordance with embodiments of the invention;

[0098] Fig. 10 shows an illustrative environment for managing the processes in accordance with embodiments of the invention; and

[0099] Figs. 11, 12 and 13 show exemplary flows for performing aspects of embodiments of the present invention.

[0100] Reference numbers refer to the same or equivalent parts of the present invention throughout the various figures of the drawings.

DETAILED DESCRIPTION OF EMBODIMENTS OF THE INVENTION

[0101] In the following description, the various embodiments of the present invention will be described with respect to the enclosed drawings.

[0102] The particulars shown herein are by way of example and for purposes of illustrative discussion of the embodiments of the present invention only and are presented in the cause of providing what is believed to be the most useful and readily understood description of the principles and conceptual aspects of the present invention. In this regard, no attempt is made to show structural details of the present invention in more detail than is necessary for the fundamental understanding of the present invention, the description is taken with the drawings making apparent to those skilled in the art how the forms of the present invention may be embodied in practice.

[0103] As used herein, the singular forms “a,” “an,” and “the” include the plural reference unless the context clearly dictates otherwise. For example, reference to “a magnetic material” would also mean that mixtures of one or more magnetic materials can be present unless specifically excluded.

[0104] Except where otherwise indicated, all numbers expressing physical quantities, such as frequency, time, and so forth used in the specification and claims are to be understood as being modified in all instances by the term “about.” Accordingly, unless indicated to the contrary, the numerical parameters set forth in the specification and claims are approximations that may vary depending upon the desired properties sought to be obtained by the present invention. At the very least, and not to be considered as an attempt to limit the application of the doctrine of equivalents to the scope of the claims, each numerical parameter should be construed in light of the number of significant digits and ordinary rounding conventions.

[0105] Additionally, the recitation of numerical ranges within this specification is considered to be a disclosure of all numerical values and ranges within that range. For example, if a range is from about 1 to about 50, it is deemed to include, for example, 1, 7, 34, 46.1, 23.7, or any other value or range within the range.

[0106] The various embodiments disclosed herein can be used separately and in various combinations unless specifically stated to the contrary.

[0107] A quartz clock is a clock that uses an electronic oscillator that is regulated by a quartz crystal to keep time. This crystal oscillator creates a signal with a very precise frequency. Generally, some form of digital logic counts the cycles of this signal and provides a numeric time display, usually in units of hours, minutes, and seconds.

[0108] Quartz has an advantage in that its size does not change much as temperature fluctuates. For example, fused quartz is often used for laboratory equipment that must not change shape along with the temperature, because a quartz plate's resonance frequency, based on its size, will not significantly rise or fall. Similarly, since its resonator does not change shape, a quartz clock will remain relatively accurate as the temperature changes.

[0109] The frequency at which the crystal oscillates depends on its shape, size, and the crystal plane on which the quartz is cut. The positions at which electrodes are placed can slightly change the tuning, as well. If the crystal is accurately shaped and positioned, it will oscillate at a desired frequency. For example, a 15-bit binary digital counter driven by the frequency will overflow once per second, creating a digital pulse once per second. The pulse-per-second output can be used to drive many kinds of clocks.

[0110] The crystal planes and tuning of a clock crystal may be designed to operate best at 25 °C, the normal temperature of the inside of a watch on a human wrist. A correctly designed watch case forms an expedient crystal oven that uses the stable temperature of the human body to keep the crystal in its most accurate temperature range.

[0111] In embodiments of the present invention, the quartz crystal resonator may be in the shape of a small tuning fork, laser-trimmed or precision lapped to vibrate at a specific frequency generally between approximately 30,000 Hz and 40,000 Hz, (e.g., at 32,768 Hz). In most clocks, the resonator may be in a small can or flat package, e.g., about 4 mm long. The range of frequencies between approximately 30,000 Hz and 40,000 Hz represent a compromise between the large physical size of low frequency crystals for watches and the large current drain of high frequency crystals, which reduces the life of the watch battery.

[0112] In accordance with aspects of embodiments of the invention, it has been found that a number of electrically operated devices emit vibrations which are characteristic of their inner content. Notable examples of electrically operated devices include quartz watches and mobile devices (e.g., mobile telephone). Mobile telephones, for example, do not rely upon the microprocessor to maintain proper time, but instead utilize a quartz clock. The emitted vibration can be measured without opening the device, and in accordance with embodiments of the present

invention, the vibration's characteristics can be used for authentication and/or identification purposes. Further, in accordance with embodiments of the invention, a device may be tailored to emit a vibration which encodes a specified piece of information (e.g., an identifier).

Single Existing Quartz

[0113] In embodiments of the present invention, a quartz is already present and existing inside the item (e.g., the timepiece) to perform a specific function (e.g., for time-keeping purposes). In accordance with aspects of embodiments of the invention, the already present quartz may also be utilized to provide an identifier (e.g., a unique identifier) for the item.

Non-modified device

[0114] In accordance with aspects of embodiments of the invention, the quartz and/or the electronic circuitry driving the quartz is not modified (e.g., the quartz and/or the electronic circuitry driving the quartz is taken as is).

Main Peak Frequency

[0115] In accordance with aspects of embodiments of the invention, a frequency of a main peak in a frequency-domain power spectrum of the acoustic signal generated by the quartz oscillator may be used for identification and/or authentication purposes.

[0116] In embodiments of the invention, a transducer is used to convert the vibration of the item under inspection into a measurable signal, which may then be further processed, recorded, analyzed, stored, and/or compared with a reference signal.

[0117] Exemplary transducers include a microphone, an accelerometer, or a vibrometer, which are operable to convert the vibration into an electrical signal. A contact microphone of the

piezoelectric type is well suited for the purpose, as this kind of device can be inexpensive, sensitive to the target vibration and insensitive to airborne acoustic environment (e.g., ambient) noise. Once the signal is captured, the signal is processed to extract information from the signal.

[0118] After the acoustic vibrations emitted by the timepiece to be authenticated have been measured, in embodiments of the present invention, the obtained electrical signal may be processed so as to attenuate the plurality of acoustic events in the electrical signal. According to an exemplary and non-limiting embodiment of the present invention, this attenuation of the plurality of events in the electrical signal may be achieved by carrying out the following steps. First, the electrical signal S is sampled at a predetermined sampling frequency, e.g., 96 kHz, to obtain a digital signal, e.g., a 16-bit signal. An envelope E of the obtained sampled signal is calculated by averaging an absolute value of the plurality of samples, e.g., the last 200 samples. Then, a ratio A of the sampled electrical signal S divided by the calculated envelope E of the sampled electrical signal S is calculated. The calculation of this ratio $A = S/E$ allows for attenuating the loud vibrations, thereby revealing the weak vibrations during the quiet zone.

[0119] In embodiments of the present invention, after processing the electrical signal so as to attenuate the plurality of acoustic events in the electrical signal, further processing may include, for example, analog-to-digital conversion, amplifying, filtering (analog/digital), and/or mathematical transforms to and/or from time domain, frequency domain and/or time-frequency domain.

[0120] For example, in embodiments, a transform of the processed electrical signal into a frequency domain is performed, in order to obtain a frequency-domain power spectrum indicating a variation of the power of the processed electrical signal as a function of frequency. According to a preferred embodiment of the present invention, the frequency-domain transform

is a Fourier transform, preferably a Fast Fourier transform. However, other frequency-domain transforms could also be utilized.

[0121] Reverting to the exemplary values mentioned above with respect to the attenuation of the acoustic events in the electrical signal, a Fast Fourier transform of the ratio A signal is carried out on a number (e.g., a large number) of consecutive values. With a non-limiting exemplary embodiment, the Fast Fourier transform of the ratio A signal, which has been sampled at 130 kHz, was performed on 655,360 consecutive values thereof. This analysis allows for obtaining a frequency-domain spectrum until 65 kHz with a resolution of 0.2 Hz. Generally, it must be understood that the values indicated herewith are only meant for exemplary purposes and are not limiting the principles of the present invention. Further, various analysis durations may be selected, which may range, e.g., from 2 seconds to 2 minutes. The person skilled in the art will immediately understand that an extremely fine frequency analysis of the ratio A signal can be performed, which will permit a spectrum having easily recognizable peaks.

[0122] After the transform of the processed electrical signal into the frequency domain has been performed to obtain a frequency-domain power spectrum, the frequency-domain power spectrum is processed so as to reveal a narrow peak (or a plurality of narrow peaks) in the frequency-domain power spectrum. This narrow peak corresponds to the resonance frequency of the quartz within the timepiece to be authenticated. The plurality of narrow peaks may also include resonance frequencies of a mechanical part or a plurality of mechanical parts within the timepiece to be authenticated. Embodiments of the present invention present a way of extracting the information on the resonance frequencies of the quartz (and, in embodiments, mechanical parts), wherein the obtained resonance frequency information can be used for authentication purposes.

[0123] According to an embodiment of the invention, the processing of the frequency-domain power spectrum so as to reveal at least one narrow peak in the frequency-domain power spectrum comprises filtering the frequency-domain power spectrum so as to reduce the background noise signal and keep the sharp peaks, e.g., by performing a derivative of the spectrum with respect to frequency, or by wavelet de-noising of the spectrum.

[0124] According to another embodiment, a fast and convenient method to carry out the processing step of processing the frequency-domain power spectrum so as to reveal at least one narrow peak in the frequency-domain power spectrum comprises the following steps. First, for each frequency F of the frequency-domain power spectrum, a module $M(F)$ of a complex number obtained in performing the transform of the processed electrical signal into the frequency domain is calculated. Then, a value $V(F)$ of $M(F)$ multiplied by the double derivative in frequency is calculated. This multiplication allows for revealing the narrow peak(s) in the frequency-domain power spectrum, and thus, reveals the resonance frequency of quartz. The module $M(F)$ of the complex number is multiplied by an absolute value of a difference between the module $M(F)$ of the complex number and a module $M(F-1)$ of a complex number for an immediately preceding frequency ($F-1$). The obtained number is further multiplied by an absolute value of a difference between the module $M(F)$ of the complex number for frequency F and the module $M(F+1)$ of the complex number for an immediately following frequency ($F+1$). This calculation is summarized by the following equation (1):

$$V(F) = M(F) \times \text{abs}(M(F) - M(F-1)) \times \text{abs}(M(F) - M(F+1)) \quad (1)$$

where $\text{abs}(X)$ represents the absolute value of X .

[0125] According to an embodiment of the present invention, the resonance frequency corresponding to the identified narrow peak in the frequency-domain power spectrum (or a

plurality of such resonance frequencies) is extracted. In embodiments, the frequency-power spectrum of the measured acoustic vibrations of the timepiece to be authenticated may reveal several peaks in the power spectrum representation at several frequencies attributable to the quartz and one or more mechanical components.

[0126] With an exemplary and non-limiting embodiment, eight peaks can be identified in the power spectrum, the power spectrum value of which is larger than 600 on the logarithmic scale. These peaks in the power spectrum can be identified at frequencies f_0 to f_7 , which are comprised in the range between 0 and about 40 kHz. It must be noted that these values are given for illustrative purposes only and are not limiting. In particular, even though the particular example of a threshold set at 600 for identifying peaks in the power spectrum has been given, the person skilled in the art will immediately understand that another threshold may be set, depending on the amount of frequency peaks desired as frequency information. For instance, the threshold could be set at 1000, so that only a few peaks can be identified.

[0127] The respective frequencies f_0 to f_7 corresponding to peaks in the frequency-domain power spectrum of the measured acoustic vibrations of the timepiece to be authenticated can be extracted from the frequency-domain power spectrum.

[0128] Then, the extracted resonance frequency or frequencies of the identified peaks in the frequency-domain power spectrum is/are compared with a reference resonance frequency or frequencies. The reference resonance frequencies have been stored previously and correspond to the values obtained when performing the above method steps on a particular timepiece model (or an individual item). By storing the resonance frequency values for a timepiece model (or an individual item), reference resonance frequency information is stored, which can be used for

comparison with a timepiece to be authenticated. The comparison results give information on an authenticity of the timepiece to be authenticated.

[0129] It has been observed by the inventors of the present invention that the reliability and degree of precision of the invention are such that it is possible to even identify differences between the timepieces of an identical model. Indeed, timepieces that are manufactured by hand are unique, so that two timepieces of an identical model differ from each other with differences that at first glance are merely imperceptible. When applying the principles underlined in the present invention to different timepieces from the same series and the same company, it can be seen that the corresponding acoustic measurements are different and the extracted relevant respective pieces of frequency information, which characterize the fingerprint of the respective timepiece, are different. Hence, an identifier can be defined for a timepiece without having to open the timepiece.

[0130] According to an embodiment of the invention, the processing steps for revealing the narrow peaks in the frequency-domain power spectrum are repeated and, for each frequency F of the frequency-domain power spectrum, an average of the results $V(F)$ of the repeated calculating and multiplying steps is calculated. This average value is then represented on a graph, wherein a plurality of narrow peaks can be identified. By performing the method steps described with respect to the embodiments of the present invention, the contribution of the acoustic vibrations emitted by the timepiece to be authenticated in the quiet zone between acoustic events is, so to say, highlighted or “amplified.” On the other hand, the contribution of the loud acoustic events is attenuated by processing the electrical signal according to the embodiments of the present invention. Hence, by performing the steps according to the embodiments of the present invention, a frequency-domain power spectrum is obtained in which clearly recognizable narrow

peaks can be extracted which correspond to the acoustic vibrations of the mechanical parts within the timepiece to be authenticated. These acoustic vibrations are comparatively weak, when compared with the loud acoustic events taking place during the events or sub-events, but are comparatively long-lived, in comparison with these events or sub-events.

[0131] According to a variant of an embodiment of a method for authenticating a timepiece according to the present invention, the processing of the electrical signal for attenuating the plurality of events in the electrical signal obtained by measuring acoustic vibrations of the timepiece to be authenticated may be replaced by another processing step. Indeed, another possibility to attenuate the loud acoustic events is to divide the electrical signal by its average signal amplitude, where the average amplitude is found by taking the absolute value of the signal and filtering it with a low-pass filter. Another possibility would be to multiply the electrical signal by zero, wherever its average signal amplitude is larger than a given threshold. Finally, still another possibility would be to multiply the electrical signal by zero in a given time interval after the beginning of the acoustic event.

[0132] According to another variant of an embodiment of a method for authenticating a timepiece according to the present invention, a time-frequency transform of the acoustic vibrations emitted by the timepiece to be authenticated into a time-frequency domain can be used instead of a frequency-domain transform as described above. Unlike a transform into a frequency domain, which only gives information on the frequencies that are present in the transformed signal, a time-frequency representation gives information on which frequencies are present at which time.

[0133] According to this variant, the time-frequency transform to be used may be one among the several time-frequency transforms available and known to the person skilled in the art. In

particular, only to cite a few possible transforms, the transform into a time-frequency representation may be one of the windowed Fourier transform and a wavelet transform.

[0134] The wavelet transform is described, for example, in C. Torrence and G.P. Compo, *Bulletin of the American Meteorological Society*, 79, 1998. The continuous wavelet transform takes a time-domain signal $s(t)$, the electrical signal of the measured acoustic vibrations emitted by the timepiece to be authenticated, the electrical signal indicating a variation of the magnitude of the measured acoustic vibrations as a function of time, and transforms this time-domain signal into a time-frequency representation $W(f, t)$, which is defined by the following equation (2):

$$W(f, t) = \sqrt{\frac{2\pi f}{c}} \int_{-\infty}^{\infty} s(t') \psi^* \left(\frac{2\pi f(t' - t)}{c} \right) dt' \quad (2)$$

where:

- ψ is the wavelet function (there are several types to choose from); and
- c is a constant which depends on the chosen wavelet function.

[0135] By using the time-frequency information, which is obtained from a time-frequency representation of the electrical signal obtained by measuring acoustic vibrations emitted by the timepiece to be authenticated, information on an authenticity of the timepiece can be derived. In order to do so, the time-frequency information is extracted from the time-frequency representation and compared with reference time-frequency information, which has been previously stored for the timepiece model. By comparing the time-frequency information extracted for the timepiece to be authenticated with the reference time-frequency information for the timepiece model, it can be derived whether the timepiece is authentic or not.

[0136] In one exemplary embodiment, the transducer is a stand microphone model 13.1720 supplied by Witschi Electronic, Ltd. The signal from the microphone is sampled at 16 bit, 96 kHz using a sound card, and a length of about 45 seconds of the signal is recorded in digital form. The digital signal is then further transformed to time domain using a Fast Fourier Transform algorithm.

[0137] Fig. 1A shows exemplary normalized spectra of five different watches of the same model and manufacturer in accordance with embodiments of the invention. As shown in Fig. 1A, it is apparent that each of the spectra displayed has a prominent peak around 37,770 Hz, but also that each of the peaks has a slightly different frequency. Fig. 1A illustrates the fact that clearly recognizable narrow peaks can be extracted, which allow for uniquely identifying different timepieces. It is apparent that the peaks identified for the respective timepieces differ from those identified for the other timepieces, thereby allowing for differentiating them from each other.

[0138] In accordance with embodiments of the invention, the first information (i.e., the prominent peak around approximately 37,770 Hz) can be used for a generic authentication test of a watch, based on the fact that all of the tested watches display a peak in the range of approximately 32,769.5-32,770.5 Hz. In accordance with embodiments of the invention, the same approach may be used for all the watches from a given class (e.g., model, manufacturer, type, etc.).

[0139] In accordance with embodiments of the invention, the second information (i.e., the slightly different frequency of each of the peaks) may be used for authentication of the individual watch, based on the fact that a given individual is expected to have a peak at a specific

frequency. Hence, a counterfeit with the same serial number having a peak at a different frequency would be immediately identified as such, and disqualified as an authentic item.

[0140] In embodiments of the invention, the position of the peak may be conveniently defined by the center frequency, the peak frequency, and/or the weighted frequency. Additionally, the position of the peak may be conveniently defined using other methods known to the skilled person, such as, for example, by least square fitting of the appropriate function (Lorentzian, Gaussian, etc.) to the data.

[0141] In the example given, the peak in the frequency domain is quite sharp, and the signal-to-noise ratio quite high. Both of these features have a favorable impact on the precision with which the position of the peak can be located (down to 1/100 Hz or better). This, in turn has a favorable impact on the discriminating power of the measurement.

[0142] Fig. 1B shows exemplary normalized spectra of the same watch taken at different times in accordance with embodiments of the invention. As shown in Fig. 1B, the spectra are vertically offset for clarity. As shown with the repeated measurements of the same watch in Fig. 1B, the peak position is also quite stable and can be reproducibly measured. The frequency peak is consistently and reliably found at the same position in all measurements.

[0143] When quartz is used for time-keeping purposes, with an exemplary and non-limiting embodiment, the specific frequency of the quartz may range from approximately 30,000 Hz - 40,000 Hz. As such, in embodiments, different items may each have different specific peak frequencies so as to serve as an identifier for the item. However, as there may only be a total frequency range of 10,000 Hz in which to distinguish a number of items, the inventors contemplate that, if the total number of items is high (e.g., 1,000,000) the 10,000 Hz range may

not provide enough spectrum to achieve unique identifiers for each of the items based only on the peak frequency of the existing quartz. As such, in accordance with aspects of embodiments of the invention, the main peak frequency of the item may be combined with additional information of the item so as to provide a higher level of identification and/or authentication for the item.

Main and Less Prominent Peak Frequencies

[0144] With additional embodiments of the present invention, less prominent peaks in the spectrum of the acoustic signal generated by the quartz may be used together with the main peak in the spectrum. That is, the quartz may generate frequencies in a main domain and other smaller domains. In accordance with aspects of embodiments of the invention, by utilizing both the main peak and one or more less prominent peaks in the spectrum of the acoustic signal, the amount of discriminating information obtained from the item (e.g., the timepiece) may be increased, thus providing a higher level of identification and/or authentication.

[0145] For example, as shown in Fig. 1A, each of the time pieces generates additional (e.g., less prominent) frequency peaks that are distinguishable from one another. As such, by utilizing both the main peak and one or more less prominent peaks in the spectrum of the acoustic signal, the amount of discriminating information obtained from the item (e.g., the timepiece) is increased, which provides a higher level of identification and/or authentication for the item.

Main Peak Frequency and Other Acoustic Signals

[0146] In accordance with further aspects of embodiments of the invention, other acoustic signals generated by the item may be analyzed, in order to increase the amount of discriminating information. For example, in embodiments, the vibrations generated by one or more mechanical components of the timepiece, for example, the motor driving the watch hands, the ticking noises emitted when the hands move, or any other vibration produced by the item, etc. may be measured, and used together with the main peak frequency to provide a higher level of identification and/or authentication for the item.

[0147] As noted above, the plurality of narrow peaks may also include resonance frequencies of a mechanical part or a plurality of mechanical parts within the timepiece to be authenticated. With an exemplary embodiment, additional frequencies in the spectrum of the measured acoustic signal that originate from parts of the device other than the quartz itself are taken into account. In the case of a watch, these may include the vibrations generated by the motor driving the hands, the ticking noise (e.g., “tick-tock”) emitted when the hands move, and other operations related to the functioning of the watch. In embodiments of the present invention, information on the resonance frequencies of the quartz and one or more mechanical parts are extracted, wherein the combined resonance frequency information can be used for authentication and/or identification purposes.

[0148] In accordance with aspects of embodiments of the invention, by utilizing the combined resonance frequency information, the amount of discriminating information obtained from the item (e.g., the timepiece) may be increased, thus providing a higher level of identification and/or authentication.

[0149] Fig. 2 shows an exemplary and non-limiting overview of the signal spectra measured on three individual watches (1); (2); and (3) of the same make and models in accordance with

embodiments of the invention. For each watch, two measurements taken at different times are shown, in order to illustrate the reproducibility of the measurement. In order to more clearly illustrate aspects of embodiments of the present invention, the spectra have been offset vertically for clarity.

[0150] In accordance with aspects of embodiments of the invention, the signal may be pre-processed, before extracting the spectrum, in order to suppress less certain features and enhance others. For example, Fig. 3 shows an overview of the spectrum obtained when the signal shown in Fig. 2 is pre-processed so as to suppress the louder sound, e.g. associated with the hands movement, and enhance the faint noise remaining after the movement is complete (e.g., in the “quiet zone” spectrum), as the main contribution comes from the comparatively long intervals of time when the hands are not moving, in-between the comparatively short time intervals when the hands are moving.

[0151] Fig. 4 illustrates an exemplary and non-limiting detail of a discriminating feature of the spectra of Fig. 3 on a part of the respective frequency-domain power spectra obtained for the two timepieces (1), (2) and (3) represented in Fig. 3. in accordance with aspects of embodiments of the present invention.

[0152] Figs. 2 - 4 illustrate the fact that clearly recognizable narrow peaks can be extracted, which allow for uniquely identifying different timepieces. It is apparent that the peaks identified for the timepiece (1) differ from those identified for the timepieces (2) and (3), and timepieces (2) and (3) differ from each other, thereby allowing for differentiating each of the timepieces from each other.

Modified device

[0153] In additional embodiments of the invention, the quartz and/or the electronic circuitry driving the quartz may be modified, so as to encode additional information in the acoustic signal the quartz generates.

Quartz Oscillation Modulated to Generate Set of Additional Peaks

[0154] In accordance with aspects of the invention, the oscillation of the quartz may be modulated (e.g., amplitude modulation and/or frequency modulation) in order to generate a set of additional peaks in the frequency spectrum. The respective frequencies of these additional peaks may be used for authentication and/or identification purposes. In embodiments, for example, the frequencies of these additional peaks may be linked to a serial number for the item, such that the item can be authenticated.

[0155] For example, with an embodiment of the invention, a device may be tailored to emit a vibration that encodes, for example, a specified piece of information, which can be used as an identifier. In an exemplary embodiment, the frequency of the quartz oscillator may be modulated about its natural frequency by an electronic circuit, with a modulating signal $v(t)$. The same microphone and sound card as in the previous examples may be used to acquire the signal $S_{\text{out}}(t)$ corresponding to the generated vibration. This vibration and the corresponding signal $S_{\text{out}}(t)$ encode the modulating signal $v(t)$, which can be recovered with an appropriate signal processing, as known to the skilled person.

[0156] Fig. 5 shows exemplary spectra 500 of a quartz oscillator, in which the main frequency of the quartz is modulated in order to generate a set of additional peaks in the frequency spectrum. For example, as shown in Fig. 5, the quartz oscillator has a natural frequency 510 of

about 32'768.5 Hz, which is modulated at 1 Hz (bottom), 2 Hz (middle), and 4 Hz (top) in accordance with embodiments of the invention, to provide additional peaks 515. As shown in Fig. 5, three results are obtained using a sinusoidal wave of 1, 2, and 4 Hz, respectively, as a modulating signal $v(t)$, and taking the Fourier transform of the signal $S_{out}(t)$. In a non-limiting example, the three different spectra can be defined to encode, respectively, the numbers 1, 2, and 4. In embodiments, for example, the frequencies of these additional peaks may be linked to a serial number for the item, such that the item can be authenticated.

Quartz Oscillation Modulated With Time-Variable Signal

[0157] In accordance with aspects of embodiments of the invention, the oscillation of the quartz may be modulated (e.g., amplitude modulation and/or frequency modulation) with a time-variable signal (for example, as in a radio transmission). The generated signal may then be demodulated to recover the modulating signal.

[0158] Fig. 6 shows an exemplary demodulated signal 600 of the same quartz oscillator as in Fig 5, modulated, in successive 5s intervals, respectively at 1 Hz, 2 Hz, 3 Hz, 4 Hz, 5 Hz, 4 Hz, 3 Hz, 2 Hz, 1 Hz in accordance with embodiments of the invention. Figure 6 shows the result obtained using a sinusoidal wave of 1, 2, 3, 4, 5, 4, 3, 2, and 1 Hz, respectively, as a modulating signal $v(t)$ during successive time intervals 605, 610, 615, 620, 625, 630, 635, 640, 645 of approximately 5s length. The signal $S_{out}(t)$ is then numerically demodulated multiplying it by a sinusoidal wave at the natural frequency of the oscillator (32,768.5178 Hz) in accordance with aspects of embodiments of the invention. In a non-limiting example, the signal can be defined to encode the sequence 123454321.

Other Schemes for Modifying Quartz and/or Electronic Circuitry

[0159] In accordance with further embodiments of the present invention, other schemes may be used for modifying the quartz and/or the electronic circuitry driving the quartz so as to encode additional information in the acoustic signal the quartz generates. For example, without limiting the embodiments of the present invention other schemes for modifying the quartz and/or the electronic circuitry driving the quartz may include frequency modulation (FM); amplitude modulation (AM), and phase modulation (PM). Additionally, in embodiments, the modulation may further be analog (i.e. the modulation signal is an analog signal), or digital (i.e. the modulation signal is a digital signal). With embodiments of the present invention, digital modulation schemes may include those based on keying: frequency shift-keying, amplitude-shift keying, and phase-shift keying

Added Quartz (or Other Transducer)

[0160] In accordance with further embodiments of the present invention, a second element capable of generating acoustic vibrations (e.g., one or more quartz elements and/or another transducer) is added to the device for the purpose of authentication. In embodiments, the item may or may not already contain a first quartz and possibly an additional quartz used for other purposes (typically time-keeping). If the item does include a first quartz and an additional quartz for other purposes (e.g., time-keeping), the signal of the transducer (or a further additional quartz) may be linked to the first quartz and/or the additional quartz. In embodiments, specific information is encoded in the vibration generated by this second element. In embodiments, the second element may be, for example, a second quartz or a specific piezoelectric element.

[0161] According to embodiments of the present invention, by choosing the material, the thickness and the width of the quartz (or other transducer) and selecting a particular arrangement within the timepiece, the resonance frequency characteristics of the quartz, such as the frequency, resonance width and quality factor, may be precisely configured. By introducing this quartz with predetermined resonance frequency characteristics into a timepiece, the authentication of the timepiece can be tremendously improved, since the method steps described with respect to the embodiments of the present invention can be applied to a timepiece to be authenticated and the authentication comprises searching for the predetermined known resonance frequencies within the frequency-domain power spectrum. Since the principles mentioned above allow for a frequency-domain power spectrum having easily recognizable narrow peaks, an authentication of a timepiece comprising a quartz having predetermined resonance frequency characteristics includes extracting the resonance frequency or frequencies of the narrow peaks within the frequency-domain power spectrum and comparing these extracted resonance frequencies with the predetermined known resonance frequencies of the quartz. Hence, the added quartz allows for introducing a kind of signature into a timepiece, which can then be used for authenticating a timepiece.

[0162] However, even if one quartz is determined and created, it still remains that the production of the timepiece is subject to manufacturing tolerances, so that, even if a frequency is known, it remains that for two quartz elements, which seem to be the same, there will most likely be a small difference which could be determined in an efficient manner using the method according to the present invention. However, as already outlined above, it has been observed by the inventors of the present invention that the reliability and degree of precision of the invention are such that it is possible to identify such small differences. This, therefore, enhances the

strength of the protection for the timepieces such as luxury watches, where reproducing exactly a specific watch will be merely impossible.

Non-modified device

[0163] In accordance with aspects of embodiments of the invention, the quartz and/or the electronic circuitry driving the quartz is not modified (e.g., the quartz and/or the electronic circuitry driving the quartz is taken as is). In this case, however, as the added quartz is not used for time-keeping purposes, the characteristics of the added quartz (or other transducer) may be chosen more freely.

Main Peak Frequency

[0164] As similarly described above, in accordance with aspects of embodiments of the invention, a frequency of a main peak in the spectrum of the acoustic signal generated by the added quartz may be used for identification and/or authentication purposes.

Main and Less Prominent Peak Frequencies

[0165] With additional embodiments of the present invention, one or more less prominent peaks in the spectrum of the acoustic signal generated by the added quartz (or other transducer) may be used together with the main peak in the spectrum. In accordance with aspects of embodiments of the invention, by utilizing both the main peak and one or more less prominent peaks in the spectrum of the acoustic signal, the amount of discriminating information obtained

from the item (e.g., the timepiece) may be increased, thus providing a higher level of identification and/or authentication.

Specifically-Configured Quartz (or Other Transducer)

[0166] In additional embodiments of the invention, the quartz or other transducer may be configured (e.g., engineered) to emit an acoustic signal that encodes a message. In embodiments, the signal may be arbitrarily long and/or complex, for example, to encode a serial number, a message, etc.

[0167] Fig. 7 shows exemplary spectra 700 of a device incorporating a quartz oscillator with a natural frequency f_0 705 of about 32,768.39 Hz and a piezoelectric transducer that is excited with two sinusoidal waves of frequency $f_0 - 100$ Hz and $f_0 + 100$ Hz, respectively, in accordance with embodiments of the invention. Fig. 7 shows an exemplary and non-limiting result obtained using as an excitation signal $u(t)$ of the second element two sinusoidal waves of frequency $f_0 - 100$ Hz and $f_0 + 100$ Hz, respectively, and taking the Fourier transform of the signal $S_{\text{out}}(t)$. In a non-limiting example, the three spectra 705, 710, 715 can be defined to encode, respectively, the numbers -100 and 100. The examples given here should not be taken as limiting. Other signals can be used as modulation and/or excitation, and the invention contemplates other encoding schemes.

[0168] In embodiments, a timepiece may include two quartz elements, wherein the first quartz element is dedicated to time-keeping purposes, and the second quartz element is dedicated to identification purposes. In embodiments, the second quartz element may be designed to broadcast a predetermined message or an arbitrary message.

[0169] In embodiments, in a timepiece having two quartz elements, the first quartz element may be linked to the second quartz element. With an exemplary and non-limiting embodiment, the first quartz element may be correlated to the second quartz element (e.g., mathematically correlated). With a further exemplary and non-limiting embodiment, the second quartz element may be designed based on the first quartz element.

[0170] In further embodiments, a timepiece may include more than two (e.g., three) quartz elements, wherein the first quartz element is dedicated to time-keeping purposes, and the remaining (e.g., two) quartz elements are dedicated to identification purposes. In embodiments, the second quartz element may be designed to broadcast a predetermined message or an arbitrary message.

[0171] In embodiments, the quartz may be manufactured to produce a range of variability (e.g., narrow variability), wherein the peak frequencies of the quartz of respective devices is close (e.g., within range of variability) but not exactly the same (e.g., unique). In accordance with aspects of the invention, quartz manufactured to produce a range of variability provides for both the “general” make and/or model level of identification, and the “specific” individual authentication

[0172] In further embodiments of the invention, a timepiece may include a single quartz element dedicated to both time-keeping purposes and identification purposes. For example the single quartz may be designed to emit a first frequency to generate the pulse (for timekeeping), and, e.g., simultaneously emitting a second frequency used to encode the authentication message.

[0173] In additional embodiments, a timepiece may include a single quartz element dedicated to time-keeping purposes and a transducer dedicated to identification purposes.

[0174] It has been observed by the inventors of the embodiments of the present invention that the reliability and degree of precision of the embodiments of the invention are such that it is possible to even identify differences between the timepieces of an identical model. Indeed, because of manufacturing tolerances, even two timepieces of an identical model differ from each other. When applying the principles underlined in the present invention to different timepieces from the same series and the same manufacturer, it can be seen that the corresponding acoustic measurements are different and the extracted relevant respective pieces of frequency information, which characterize the fingerprint of the respective timepiece, are different. Hence, an identifier (e.g., a unique identifier) can be defined for a timepiece without having to open the timepiece.

[0175] While described above in the context of timepieces (e.g., watches), in accordance with further embodiments of the invention, a mobile device (e.g., a mobile phone) may utilize the same identification/authentication approach. As shown in Figs. 8 and 9, a number of mobile phones of the same model and manufacturer were analyzed, with similar results to the watches, discussed above.

[0176] Fig. 8 shows exemplary normalized spectra of three mobile phones of the same model and manufacturer in accordance with embodiments of the invention. As shown in Fig. 8, it is apparent that each of the spectra displayed has a prominent peak around approximately 32,768.5 Hz - 32,769.0 Hz, but also that each of the peaks has a slightly different frequency.

[0177] Fig. 9 shows exemplary normalized spectra of the same mobile phone taken at different times in accordance with embodiments of the invention. As shown with the repeated measurements of the same mobile phone in Fig. 9, the peak position is also quite stable and can

be reproducibly measured. The frequency peak is consistently and reliably found at the same position in all measurements.

[0178] As shown in Figs. 1 and 8, different models of products (e.g., timepieces and mobile phones, respectively) will have different characteristic frequency representations. Consequently, by comparing the frequency representation of a timepiece to be authenticated with a reference frequency representation, which is expected for this particular timepiece model, authenticity information on the timepiece to be authenticated can be derived. Hence, it can be derived whether a timepiece to be authenticated is an authentic product or a counterfeit product. Additionally, as shown in Fig. 1, the same model of watch may exhibit different time-frequency representations, such that the time-frequency representation may be used as a unique identifier for a particular timepiece.

[0179] The above-described measurements of a particular timepiece should not change over time (i.e., remain stable). For example, as long as components of the watch are not touched or manipulated, the above-described measurements of a particular timepiece should not change. Of course, with maintenance of the timepiece (e.g., when the timepiece is opened), the above-described measurements may be affected. As such, when timepiece maintenance is performed (e.g., when the timepiece is opened), the timepiece should be recertified (e.g., the peak frequency of the quartz of the timepiece should be recaptured, and the results of the one or more the above-described measurements should be identified and stored). In embodiments, once the timepiece is recertified, the results of the one or more the above-described measurements may also be linked with the timepiece ID (e.g., the timepiece serial number), for example, in a database.

[0180] While the above-described measurements of a timepiece should not change over time, the embodiments of the invention contemplate that some of the above-described measurements

of respective timepiece may change (e.g., slightly) over time. Thus, in accordance with embodiments of the invention, a threshold for determining a positive authentication of a timepiece may be configured (e.g., lowered) in dependence upon an age of the timepiece. That is, in embodiments, an older timepiece may be subjected to a lower threshold for a positive authentication via comparison with stored time measurements, frequency measurements, and/or magnitude measurements (or stored identifiers based upon the measurements). In embodiments, the timepiece may be recertified on a regular basis (e.g., yearly) to account for the evolution (e.g., any property changes) of the timepiece over time.

[0181] With further contemplated embodiments, the analysis of a timepiece may be in two levels (e.g., a less intense first level and a more intense second level). For example, with a first level of analysis (e.g., an initial assessment), the timepiece may be identified by a make and model (e.g., using a peak within a range of frequencies), to determine if the timepiece is authentic (i.e., verified as a particular make and model). With this first level of analysis, an assessment may determine, for example, that the timepiece is in fact a particular make and/or model. A second level of analysis may include a deeper analysis of the emitted sounds, to identify a unique “finger print” for the timepiece (e.g., using a specific peak or a peak within a range of frequencies). This unique “finger print” may be stored in a database and/or compared with previously stored finger prints to positively identify the timepiece. In embodiments, either or both of the first and second levels of analysis may be done with a new timepiece, or with used timepieces that have not been previously analyzed.

[0182] In embodiments, the quartz oscillator may be arranged in a mechanical watch as a passive oscillator, e.g., without electrical power. Without electrical power, the quartz crystal comprised in the oscillator is capable of resonating at a frequency, and may resonate when

activated by another source of energy (e.g., an impact). In contrast, with an active oscillator, electrical power (e.g., from a battery used) is used, and a signal is sent to the quartz with electrodes to generate oscillation for timekeeping purposes. With an active oscillator, the battery and a microprocessor are used to drive the quartz oscillator. While the active oscillator emits sound, its primary function is to act as a time base. The invention contemplates that in some embodiments, an active oscillator may be utilized in a mechanical watch. Such an embodiment would include, for example, a power source (e.g., a battery) and a microprocessor to drive the quartz; however the quartz oscillator would not be utilized for timekeeping purposes, as the mechanical watch relies upon the mechanical movement for timekeeping purposes. With this exemplary embodiment, the quartz oscillator would be used for identification and authentication purpose in accordance with embodiments of the present invention.

[0183] While described above with regard to watches and mobile devices (e.g., mobile telephones), the present invention may be applied to other electrical equipment or devices. Instead of utilizing a quartz vibration, embodiments of the present invention may utilize, for example, a refresh rate of a screen, or some frequency of operation of repetitive activities within the electrical equipment or devices.

SYSTEM ENVIRONMENT

[0184] As will be appreciated by one skilled in the art, the present invention may be embodied as a timepiece, a system, a method or a computer program product. Accordingly, the present invention may take the form of an entirely hardware embodiment, an entirely software (excluding the transducers and A/D converters) embodiment (including firmware, resident software, micro-code, etc.) or an embodiment combining software and hardware aspects that may all generally be referred to herein as a “circuit,” “module” or “system.” Furthermore, the

present invention may take the form of a computer program product embodied in any tangible medium of expression having computer-usable program code embodied in the medium.

[0185] Any combination of one or more computer usable or computer readable medium(s) may be utilized. The computer-usable or computer-readable medium may be, for example but not limited to, an electronic, magnetic, optical, electromagnetic, infrared, or semiconductor system, apparatus, device, or propagation medium. More specific examples (a non-exhaustive list) of the computer-readable medium would include the following:

- an electrical connection having one or more wires,
- a portable computer diskette,
- a hard disk,
- a random access memory (RAM),
- a read-only memory (ROM),
- an erasable programmable read-only memory (EPROM or Flash memory),
- an optical fiber,
- a portable compact disc read-only memory (CDROM),
- an optical storage device,
- a transmission media such as those supporting the Internet or an intranet,
- a magnetic storage device
- a usb key,
- a certificate,

- a perforated card, and/or
- a mobile phone.

[0186] In the context of this document, a computer-usable or computer-readable medium may be any medium that can contain, store, communicate, propagate, or transport the program for use by or in connection with the instruction execution system, apparatus, or device. The computer-usable medium may include a propagated data signal with the computer-usable program code embodied therewith, either in baseband or as part of a carrier wave. The computer usable program code may be transmitted using any appropriate medium, including but not limited to wireless, wireline, optical fiber cable, RF, etc.

[0187] Computer program code for carrying out operations of the present invention may be written in any combination of one or more programming languages, including an object oriented programming language such as Java, Smalltalk, C++ or the like and conventional procedural programming languages, such as the "C" programming language or similar programming languages. The program code may execute entirely on the user's computer, partly on the user's computer, as a stand-alone software package, partly on the user's computer and partly on a remote computer or entirely on the remote computer or server. In the latter scenario, the remote computer may be connected to the user's computer through any type of network. This may include, for example, a local area network (LAN) or a wide area network (WAN), or the connection may be made to an external computer (for example, through the Internet using an Internet Service Provider). Additionally, in embodiments, the present invention may be embodied in a field programmable gate array (FPGA).

[0188] Fig. 10 shows an illustrative environment 1900 for managing the processes in accordance with the invention. To this extent, the environment 1900 includes a server or other

computing system 1905 that can perform the processes described herein. In particular, the server 1905 includes a computing device 1910. The computing device 1910 can be resident on a network infrastructure or computing device of a third party service provider (any of which is generally represented in Fig. 10).

[0189] In embodiments, the computing device 1910 includes a measuring tool 1945, an attenuating tool 1950, a transform tool 1955, a peak identification tool 1960, an extraction tool 1965, an identification tool 1970, a comparison tool 1975, and an authenticity determination tool 1980, which are operable to measure one or more detected sounds, attenuate portions of the one or more detected sounds, transform the signal, identify peaks in a signal, extract at least one resonance frequency, e.g., extract from an electrical signal or from a representation of said electrical signal in a time, frequency or time-frequency domain at least one of: magnitude information on a magnitude of one of said plurality of acoustic events, time information on said one of said plurality of acoustic events, and frequency information on a frequency of said one of said plurality of acoustic events, create an identifier based on the extracted information, compare the extracted information with stored information (e.g., compare the at least one resonance frequency), and determine an authenticity, e.g., the processes described herein. The measuring tool 1945, the attenuating tool 1950, the transform tool 1955, the peak identification tool 1960, the extraction tool 1965, the identification tool 1970, the comparison tool 1975, and the authenticity determination tool 1980 can be implemented as one or more program code in the program control 1940 stored in memory 1925A as separate or combined modules.

[0190] The computing device 1910 also includes a processor 1920, memory 1925A, an I/O interface 1930, and a bus 1926. The memory 1925A can include local memory employed during actual execution of program code, bulk storage, and cache memories which provide temporary

storage of at least some program code in order to reduce the number of times code must be retrieved from bulk storage during execution. In addition, the computing device includes random access memory (RAM), a read-only memory (ROM), and an operating system (O/S).

[0191] The computing device 1910 is in communication with the external I/O device/resource 1935 and the storage system 1925B. For example, the I/O device 1935 can comprise any device that enables an individual to interact with the computing device 1910 or any device that enables the computing device 1910 to communicate with one or more other computing devices using any type of communications link. The external I/O device/resource 1935 may be for example, a handheld device, PDA, handset, keyboard, smartphone, etc. Additionally, in accordance with aspects of the invention, the environment 1900 includes a measuring device 1985 for measuring sound vibrations (e.g., sonic emissions) from one or more timepieces.

[0192] In general, the processor 1920 executes computer program code (e.g., program control 1940), which can be stored in the memory 1925A and/or storage system 1925B. Moreover, in accordance with aspects of the invention, the program control 1940 having program code controls the measuring tool 1945, the attenuating tool 1950, the transform tool 1955, the peak identification tool 1960, the extraction tool 1965, the identification tool 1970, the comparison tool 1975, and the authenticity determination tool 1980. While executing the computer program code, the processor 1920 can read and/or write data to/from memory 1925A, storage system 1925B, and/or I/O interface 1930. The program code executes the processes of the invention. The bus 1926 provides a communications link between each of the components in the computing device 1910.

[0193] The computing device 1910 can comprise any general purpose computing article of manufacture capable of executing computer program code installed thereon (e.g., a personal

computer, server, etc.). However, it is understood that the computing device 1910 is only representative of various possible equivalent-computing devices that may perform the processes described herein. To this extent, in embodiments, the functionality provided by the computing device 1910 can be implemented by a computing article of manufacture that includes any combination of general and/or specific purpose hardware and/or computer program code. In each embodiment, the program code and hardware can be created using standard programming and engineering techniques, respectively.

[0194] Similarly, the computing infrastructure 1905 is only illustrative of various types of computer infrastructures for implementing the invention. For example, in embodiments, the server 1905 comprises two or more computing devices (e.g., a server cluster) that communicate over any type of communications link, such as a network, a shared memory, or the like, to perform the process described herein. Further, while performing the processes described herein, one or more computing devices on the server 1905 can communicate with one or more other computing devices external to the server 1905 using any type of communications link. The communications link can comprise any combination of wired and/or wireless links; any combination of one or more types of networks (e.g., the Internet, a wide area network, a local area network, a virtual private network, etc.); and/or utilize any combination of transmission techniques and protocols.

FLOW DIAGRAMS

[0195] Figs. 11, 12, and 13 show exemplary flows for performing aspects of the present invention. The steps of Figs. 11, 12, and 13 may be implemented in the environment of Fig. 10, for example. The flow diagrams may equally represent high-level block diagrams of embodiments of the invention. The flowcharts and/or block diagrams in Figs. 11, 12, and 13

illustrate the architecture, functionality, and operation of possible implementations of systems, methods and computer program products according to various embodiments of the present invention. In this regard, each block in the flowcharts or block diagrams may represent a module, segment, or portion of code, which comprises one or more executable instructions for implementing the specified logical function(s). It should also be noted that, in some alternative implementations, the functions noted in the block may occur out of the order noted in the figures. For example, two blocks shown in succession may, in fact, be executed substantially concurrently, or the blocks may sometimes be executed in the reverse order, depending upon the functionality involved. Each block of each flowchart, and combinations of the flowchart illustrations can be implemented by special purpose hardware-based systems that perform the specified functions or acts, or combinations of special purpose hardware and computer instructions and/or software, as described above. Moreover, the steps of the flow diagrams may be implemented and executed from either a server, in a client server relationship, or they may run on a user workstation with operative information conveyed to the user workstation. In an embodiment, the software elements include firmware, resident software, microcode, etc.

[0196] Furthermore, the invention can take the form of a computer program product accessible from a computer-usable or computer-readable medium providing program code for use by or in connection with a computer or any instruction execution system. The software and/or computer program product can be implemented in the environment of Fig. 10. For the purposes of this description, a computer-usable or computer readable medium can be any apparatus that can contain, store, communicate, propagate, or transport the program for use by or in connection with the instruction execution system, apparatus, or device. The medium can be an electronic, magnetic, optical, electromagnetic, infrared, or semiconductor system (or apparatus or device) or

a propagation medium. Examples of a computer-readable storage medium include a semiconductor or solid state memory, magnetic tape, a removable computer diskette, a random access memory (RAM), a read-only memory (ROM), a rigid magnetic disk and an optical disk. Current examples of optical disks include compact disk – read only memory (CD-ROM), compact disc – read/write (CD-R/W) and DVD.

[0197] Fig. 11 illustrates an exemplary flow 2000 for creating and storing an identification code for a timepiece. At step 2005, the measuring tool measures acoustic vibrations to obtain an electrical signal. As shown in Fig. 11, at step 2010, the attenuating tool attenuates a plurality of acoustic events in said electrical signal. At step 2015, the transform tool obtains a frequency-domain power spectrum indicating a variation of a power of said processed electrical signal as a function of frequency. At step 2020, the peak identification tool identifies at least one narrow peak. At step 2025, the extraction tool extracts at least one resonance frequency. For example, the extraction tool extracts from said electrical signal or from a representation of said electrical signal in a time, frequency or time-frequency domain at least one of: magnitude information on a magnitude of one of said plurality of acoustic events including at least one specific tone associated with the presence of an element in the time piece (e.g., a quartz resonance frequency and/or a mechanical part resonance frequency), time information on said one of said plurality of acoustic events, and frequency information on a frequency of said one of said plurality of acoustic events. At step 2030, the identification tool creates an identification code based on said at least one resonance frequency (e.g. based on at least one of the magnitude information, the time information, and the frequency information). At step 2035, the identification tool stores the identification code in a storage system, e.g., a database.

[0198] Fig. 12 illustrates an exemplary flow 2100 for authentication and/or identification of a timepiece. As shown in Fig. 12, at step 2105, the measuring tool measures acoustic vibrations to obtain an electrical signal. At step 2110, the attenuating tool attenuates a plurality of acoustic events in said electrical signal. At step 2115, the transform tool obtains a frequency-domain power spectrum indicating a variation of a power of said processed electrical signal as a function of frequency. At step 2120, the peak identification tool identifies at least one narrow peak. At step 2125, the extraction tool extracts at least one resonance frequency. For example, the extraction tool extracts from said electrical signal or from a representation of said electrical signal in a time, frequency or time-frequency domain at least one of: magnitude information on a magnitude of one of said plurality of acoustic events, time information on said one of said plurality of acoustic events, and frequency information on a frequency of said one of said plurality of acoustic events. At step 2130, the identification tool creates an obtained identification code based on said at least one resonance frequency (e.g., based at least one of the magnitude information, the time information, and the frequency information). At step 2135, the comparison tool compares the obtained code with stored identification codes. At step 2140, the authentication determination tool determines whether the obtained code matches a stored identification code. If, at step 2140, the authentication determination tool determines that the obtained code matches a stored identification code, at step 2145, the timepiece is determined to be authentic. If, at step 2140, the authentication determination tool determines that the obtained code match does not match a stored identification code, at step 2150, the timepiece is determined to be un-authentic.

[0199] Fig. 13 illustrates an exemplary flow 2200 for authentication and/or identification of a timepiece. Fig. 13 utilizes abbreviations that are explained as follows. QC1, or quartz crystal 1,

is a piezo-electric mechanical resonator whose resonant frequency serves as a time-base for the timepiece. EIO1, or electronic circuitry, is used to drive the QC1 in order to generate an oscillating electronic signal, which serves as time base for the timepiece. QO1 is the quartz based electronic oscillator composed of QC1+EIO1. EID1, or electronic/electro-mechanical circuitry, is used to drive and/or operate the watch: e.g., counting the oscillations of the reference, advancing the hands of an analog watch, driving the display of a digital watch, etc. EMT, or electro mechanical transducer, is an element capable of emitting an acoustic vibration when driven with an appropriate electrical signal. In embodiments, the EMT may or may not be a quartz crystal (e.g., QC2).

[0200] In embodiments, the timepiece may include a single quartz crystal resonator (e.g., a single existing quartz). In embodiments, the single quartz crystal resonator may be non-modified (e.g., a non-modified device). In additional embodiments, the single quartz crystal resonator may be modified (e.g., a modified device). With embodiments of a modified device; the quartz main frequency may be modulated to generate a set of additional peaks. With additional embodiments of a modified device; the quartz main frequency may be modulated with a time-variable signal.

[0201] In further embodiments, the timepiece may include multiple quartz crystal resonators (or other transducers) (e.g., added quartz or other transducer). In embodiments, the multiple quartz crystal resonators may be non-modified (e.g., a non-modified device). In additional embodiments, the multiple quartz crystal resonators may be modified (e.g., a modified device). With embodiments of a modified device; the quartz main frequency may be modulated to generate a set of additional peaks. With additional embodiments of a modified device; the quartz main frequency may be modulated with a time-variable signal. With additional embodiments of

a modified device; the quartz (or other transducer) may be configured (e.g., engineered) to emit an acoustic signal that encodes a message (e.g., specifically-configured quartz or other transducer).

[0202] As shown in Fig. 13, at step 2205, a timepiece is presented. At step 2210, an acoustic signal is acquired. At step 2215, a determination of whether the timepiece includes one or more additional transducers is made. If, at step 2215, it is determined that the timepiece does not include an extra transducer (i.e., the time piece includes a single transducer or quartz resonator), at step 2220, a determination of whether the quartz resonator (or quartz-based electronic oscillator) (or “QO1”), which is composed of the quartz crystal (or “QC1”) and the electronic circuitry (or “EI01”) used to drive the quartz crystal, is modified. If, at step 2220, it is determined that the quartz-based electronic oscillator is not modified, at step 2225, a determination is made as to whether only the quartz based electronic oscillator acoustic signal is used. If, at step 2225, it is determined that only the quartz based electronic oscillator acoustic signal is used, at step 2230, a Fourier transform of the acoustic signal is performed to obtain a frequency domain spectrum (e.g., having at least one peak). At step 2235, a determination is made as to whether only the main frequency is used for the timepiece identifying characteristics. If, at step 2235, it is determined that only the main frequency is used, at step 2240, the main frequency is stored and/or compared with one or more reference values (e.g., for authentication and/or identification). If, at step 2235, it is determined that additional frequencies are used, at step 2245 the main and additional frequencies are stored and/or compared with one or more reference values.

[0203] If, at step 2225, it is determined that the identifying characteristics of the timepiece are based not only on the quartz based electronic oscillator acoustic signal, but additional acoustic

signals, at step 2250, a determination of whether only frequency information is used. If, at step 2250, it is determined that only frequency information is used, at step 2255, a Fourier transform of the acoustic signal is performed to obtain a frequency domain spectrum (e.g., having main and additional peaks). At step 2260, the main and additional frequencies are stored and/or compared with one or more reference values. If, at step 2250, it is determined that frequency information is not exclusively used (e.g., additional information is used in conjunction with frequency information or additional information is used without frequency information), at step 2265, another transform (e.g., time-frequency domain transform, such as, wavelet, spectrogram, etc.) is used to obtain a time-frequency domain. At step 2270, the identification information for the timepiece is stored and/or compared with one or more reference values.

[0204] If, at step 2220, it is determined that the quartz based electronic oscillator is modified, at step 2275, a determination is made as to whether only the quartz crystal itself is modified. If, at step 2275, it is determined that only the quartz crystal itself is modified, the process continues at step 2225. If, at step 2275, it is determined that more than the quartz crystal itself is modified (e.g., the electronic circuitry used to drive the quartz crystal (e.g., “EI01”) and/or the electronic/electromechanical circuitry used to drive and operate the watch (e.g., “EID1”) is also modified, at step 2285, a determination as to whether the quartz based electronic oscillator (e.g., “QO1”) is AM or FM modulated. If, at step 2285, it is determined that the quartz based electronic oscillator (e.g., “QO1”) is AM or FM modulated, at step 2290, a determination is made as to whether only frequency information is used. If, at step 2290, it is determined that only frequency information is used, at step 2295, a Fourier transform of the acoustic signal is performed to obtain a frequency domain spectrum revealing at least one peak frequency. At step

2300, the main peak frequency and additional peak frequencies are stored and/or compared with one or more reference values.

[0205] If, at step 2290, it is determined that frequency information is not exclusively used (e.g., additional information (for example, time domain information) is used in conjunction with frequency information or additional information is used without frequency information), at step 2305, the signal (e.g., the AM or FM modulated signal) is demodulated into a time domain. In embodiments, the demodulation may be done, for example, by nonlinear mixing (analog and/or digital) with a signal at the carrier frequency, for example, as done in AM/FM radio transmission. At step 2310, the demodulated signal is decoded to reveal an identification message, and compared with one or more reference values (e.g. expected identification messages). Alternatively, if at step 2290, it is determined that frequency information is not exclusively used (e.g., additional information (for example, time-frequency domain information) is used in conjunction with frequency information or additional information is used without frequency information), at step 2315, a time-frequency transform of the signal may be performed. In embodiments, the time-frequency transform may include, for example, a wavelet, a spectrogram, or a short-time Fourier transform, amongst other contemplated time-frequency transforms.

[0206] If, at step 2215, it is determined that the timepiece does include one or more additional transducers (e.g., additional quartz crystal and/or electromechanical transducer), at step 2325, a determination is made as to whether the additional transducer is a quartz-based electronic oscillator (e.g., comprising a quartz crystal and electronic circuitry used to drive the quartz crystal). If, at step 2325, it is determined that the additional transducer is a quartz-based electronic oscillator, the process continues at step 2220, wherein, in non-limiting embodiments,

analysis may be performed, for example, for both first quartz oscillator QO1 and the second quartz oscillator QO2, only the second quartz oscillator QO2, or the second quartz oscillator QO2 and a third quartz oscillator QO3.

[0207] If, at step 2325, it is determined that the additional transducer is not a quartz based electronic oscillator, at step 2335, an identification signal (e.g., appropriate electrical signal, e.g. upon pressing of a button),) may be sent to the additional transducer(s) to elicit an identification signal from the transducer, which may be an arbitrarily long signal. In embodiments, any identification signal that is supported by the transducer and the detection system may be sent. For example, in a non-limiting embodiment, the identification signal may utilize spread spectrum techniques (such as, frequency hopping), frequency shift keying, etc. At step 2340, the identification signal is decoded to identify message, and compared with one or more reference values (e.g., expected messages).

[0208] While the invention has been described with reference to specific embodiments, those skilled in the art will understand that various changes may be made and equivalents may be substituted for elements thereof without departing from the true spirit and scope of the invention. In addition, modifications may be made without departing from the essential teachings of the invention.

CLAIMS

What is claimed is:

1. A timepiece, comprising at least one of:

at least one quartz oscillator; and

at least one transducer.

2. The timepiece of claim 1, wherein the at least one quartz oscillator is a quartz-based electronic oscillator.

3. The timepiece of claim 2, wherein a respective quartz-based electronic oscillator comprises:

a quartz crystal; and

electronic circuitry configured to drive the quartz crystal,

wherein, when driven, the quartz crystal generates an oscillating electronic signal.

4. The timepiece of claim 3, wherein the quartz crystal of at least one of the at least one quartz oscillators comprises a piezo-electric mechanical resonator having a resonant frequency serving as a time base for the timepiece.

5. The timepiece of claim 2, further comprising electronic and/or electromechanical circuitry configured to drive and/or operate the timepiece.

6. The timepiece of claim 1, wherein the at least one of the at least one quartz oscillator; and the at least one transducer comprises a single quartz oscillator.

7. The timepiece of claim 6, wherein the quartz oscillator is structured and configured to perform a time-keeping for the timepiece.

8. The timepiece of claim 3, wherein the quartz crystal and electronic circuitry driving the quartz crystal are not modified.

9. The timepiece of claim 1, wherein the at least one quartz oscillator comprises a modified quartz oscillator, which is modified so as to encode additional information in the acoustic signal the modified quartz oscillator generates.

10. The timepiece of claim 9, wherein the modified quartz oscillator comprises a modified quartz crystal.

11. The timepiece of claim 9, wherein the modified quartz oscillator comprises at least one of a modified quartz crystal, a modified electronic circuitry configured to drive the quartz crystal and a modified electronic/electromechanical circuitry configured to drive and/or operate the timepiece.

12. The timepiece of claim 9, wherein the modified quartz oscillator is one of amplitude modulated and frequency modulated.

13. The timepiece of claim 1, wherein the at least one of the at least one quartz oscillator; and the at least one transducer comprises a plurality of quartz oscillators.

14. The timepiece of claim 13, wherein the plurality of quartz oscillators comprise a first quartz oscillator dedicated for time keeping purposes and at least a second quartz oscillator present in said timepiece and not used for time keeping purposes.

15. The timepiece of claim 14, wherein the first quartz oscillator and the at least one second quartz oscillator each have a different frequency domain.

16. The timepiece of claim 14, wherein the at least one second quartz oscillator is operable to broadcast an encoded signal.

17. The timepiece of claim 14, wherein a frequency domain of the first quartz oscillator is in dependence upon a frequency domain of the at least one second quartz oscillator.

18. The timepiece of claim 14, wherein a frequency domain of the at least one second quartz oscillator is in dependence upon a frequency domain of the first quartz oscillator.

19. The timepiece of claim 14, wherein the first quartz oscillator dedicated for time keeping purposes, the electronic circuitry driving the first quartz oscillator, and the at least one second quartz oscillator present in said timepiece and not used for time keeping purposes are not modified.

20. The timepiece of claim 14, wherein the at least one second quartz oscillator is structured and arranged to emit an acoustic signal having encoded information.

21. The timepiece of claim 1, wherein the one or more components whose resonance frequencies are detected comprise two or more components acting as a single resonator.

22. The timepiece of claim 1, wherein the at least one of the at least one quartz oscillator; and the at least one transducer comprises the at least one quartz oscillator and the at least one transducer.

23. The timepiece of claim 1, wherein the at least one quartz oscillator and the at least one transducer comprises a quartz oscillator and a transducer.

24. The timepiece of claim 1, wherein the at least one quartz oscillator is structured and arranged to generate a specific tone.

25. The timepiece of claim 1, wherein the timepiece is comprised in a mobile device.

26. The timepiece of claim 1, wherein the timepiece is a watch.

27. The timepiece of claim 1, wherein a quartz crystal and electronic circuitry driving the quartz crystal are not modified.

28. A method for authenticating a timepiece, the method comprising:

measuring acoustic vibrations emitted by the timepiece to obtain an electrical signal;

performing a transform of said electrical signal into at least one domain;

extracting identification information from the transformed electrical signal;

comparing the extracted information with at least one reference information; and

determining an authenticity of said timepiece based on the comparing.

29. A method for authenticating a timepiece, the timepiece comprising at least one of: at least one quartz oscillator; and at least one transducer, wherein at least one of the quartz oscillator and

electronic circuitry driving the quartz oscillator are modified so as to encode additional information in an acoustic signal the at least one quartz oscillator generates, the method comprising:

modulating a resonance frequency of the quartz to generate a set of additional peaks in a signal frequency spectrum,

measuring acoustic vibrations emitted by the timepiece to obtain an electrical signal;

extracting identification information from the electrical signal;

comparing the extracted information with at least one reference resonance information;

and

determining an authenticity of said timepiece based on the comparing.

30. A method for authenticating the timepiece of claim 7, the method comprising:

measuring acoustic vibrations emitted by the timepiece to obtain an electrical signal;

performing a transform of said electrical signal into a domain;

extracting identification information from the transformed electrical signal;

comparing the extracted information with at least one reference resonance information;

and

determining an authenticity of said timepiece based on the comparing.

31. A method for authenticating the timepiece of claim 9, the method comprising:

measuring acoustic vibrations emitted by the timepiece to obtain an electrical signal, said electrical signal indicating magnitude information comprising a variation of a magnitude of the measured acoustic vibrations as a function of time, wherein said electrical signal comprises at least one specific tone associated with the presence of an element in the timepiece;

performing a transform of said electrical signal into a frequency domain to obtain a frequency-domain power spectrum indicating a variation of a power of the electrical signal as a function of frequency,

processing the frequency-domain power spectrum so as to reveal at least one narrow peak in the frequency-domain power spectrum corresponding to the at least one specific tone;

extracting at least one resonance frequency corresponding to said at least one narrow peak;

comparing the extracted at least one resonance frequency with at least one reference resonance frequency; and

determining an authenticity of said timepiece based on the comparing.

32. A method for authenticating the timepiece of claim 11, the method comprising:

measuring acoustic vibrations emitted by the timepiece to obtain an electrical signal, said electrical signal indicating magnitude information comprising a variation of a magnitude of the measured acoustic vibrations as a function of time, wherein said electrical signal comprises at least one specific tone associated with the presence of the quartz oscillator in the timepiece;

performing a transform of said electrical signal into a frequency domain to obtain a frequency-domain power spectrum indicating a variation of a power of the electrical signal as a function of frequency,

processing the frequency-domain power spectrum so as to reveal at least one narrow peak in the frequency-domain power spectrum corresponding to the at least one specific tone;

extracting at least one resonance frequency corresponding to said at least one narrow peak;

comparing the extracted at least one resonance frequency with at least one reference resonance frequency; and

determining an authenticity of said timepiece based on the comparing.

33. A method for authenticating the timepiece of claim 11, the method comprising:

measuring acoustic vibrations emitted by the timepiece to obtain an electrical signal, said electrical signal indicating magnitude information comprising a variation of a magnitude of the measured acoustic vibrations as a function of time;

demodulating the electrical signal in the time domain;

decoding the demodulated electrical signal to reveal a decoded message;

comparing the decoded message with at least one reference message; and

determining an authenticity of said timepiece based on the comparing.

34. A method for authenticating the timepiece of claim 11, the method comprising:

measuring acoustic vibrations emitted by the timepiece to obtain an electrical signal, said electrical signal indicating magnitude information comprising a variation of a magnitude of the measured acoustic vibrations as a function of time, wherein said electrical signal comprises at least one specific tone associated with the presence of the quartz oscillator in the timepiece;

performing a time-frequency domain transform of said electrical signal into a time-frequency domain. processing electrical signal to reveal identification information

comparing the identification information with at least one reference information; and

determining an authenticity of said timepiece based on the comparing.

35. A method for authenticating the timepiece of claim 14, the method comprising:

sending a detection signal;

measuring acoustic vibrations emitted by the timepiece in response to the detection signal to obtain an electrical signal, said electrical signal indicating magnitude information comprising a variation of a magnitude of the measured acoustic vibrations as a function of time, wherein said electrical signal comprises at least one specific tone associated with the presence of the transducer in the timepiece;

decoding the electrical signal to reveal a decoded message;

comparing the decoded message with at least one reference message; and

determining an authenticity of said timepiece based on the comparing.

36. A timepiece comprising at least two quartz oscillators, wherein a first quartz oscillator is dedicated for time keeping purposes and at least a second quartz oscillator is present in said timepiece and not used for time keeping purposes.

37. A timepiece, comprising at least one of:

at least one quartz oscillator comprising a quartz-based electronic oscillator having a quartz crystal piezo-electric mechanical resonator having a resonant frequency that serves as a time base for the timepiece and electronic circuitry configured to drive the quartz crystal and to generate an oscillating electronic signal; and

at least one transducer.

38. A device, comprising at least one of:

at least one quartz oscillator comprising a quartz-based electronic oscillator having a quartz crystal piezo-electric mechanical resonator having a resonant frequency that serves as a time base for the timepiece and electronic circuitry configured to drive the quartz crystal and to generate an oscillating electronic signal; and

at least one transducer,

wherein at least one of the at least one quartz oscillator and the at least one transducer is configured to emit an identification signal.