"Rattletale™": Phase-coherent telekinetic imaging to detect tattletale signs of structural defects or potential failure

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***Abstract*—*(Tele)kinetic imaging* (e.g. kinetic sonar, radar, etc.) provides visuo-acoustic feedback in which subject matter undergoes vibrational or other acoustic stimulation and the response to the stimulation is imaged. Specifically, the imaging uses active sonar to cause microscopic vibrations in the subject matter, while a special kind of lock-in amplifier is used to image the effects of these microscopic vibrations. The effects of the vibrations are imaged using optical, radar, or sonar sensing. The method works in air (e.g. we can look at a wooden fence or circuit board and see which fence boards or components on the board are loose), or underwater (e.g. to look at ocean-going vessels underwater and see which of them are in danger of emminent failure). Kinetic imaging could be particularly useful in emergency preparedness, such as trying to navigate a safe path through a building or city just after an earthquake or terrorist attack.**

***Keywords*-active feedback metasensor imaging; telekinetic imaging; kinetic sonar; acoustic stimulation; lock-in amplifier; lock-in imaging; augmented reality; mediated reality; metasensing**

This paper introduces a new concept I call "kinetic imaging" in which a feedback loop is induced that gravitates toward (and therefore finds, or "rats out") natural resonances in loose objects or subject matter likely to be in danger of eminent failure, as illustrated in Fig 1.

I made this kinetic sonar prototype using the transducer I took from a *Toothtunes* Toothbrush head, which I connected to the MannLab/SYSU multiharmonic lock-in amplifier which is designed specifically to use the SWIM (Sequential Wave Imprinting Machine, as described in [2]). The newly invented lock-in amplifier is shown in Fig. 2. Wheras VR (virtual reality) concerns itself with fiction, this amplifier is mainly for "RR™(real reality)" which concerns itself with fact (truth).

The SWIM output device comprises an RGB LED, driven as described in Fig. 11. I affixed the LED directly to a a soft rubber ink roller (Speedball Deluxe 2-Inch Soft Rubber Brayer), so that it moves through space with the brayer. The result is an abakographic image [4] in which the trace of the RGB LED in the long-exposure image shows structural defects in the circuit board's components. This result is viewed through an EyeTap augmented reality eyeglass connected to the abakographic imaging system, showing the long exposure photograph of the light trails superimposed on visual reality.

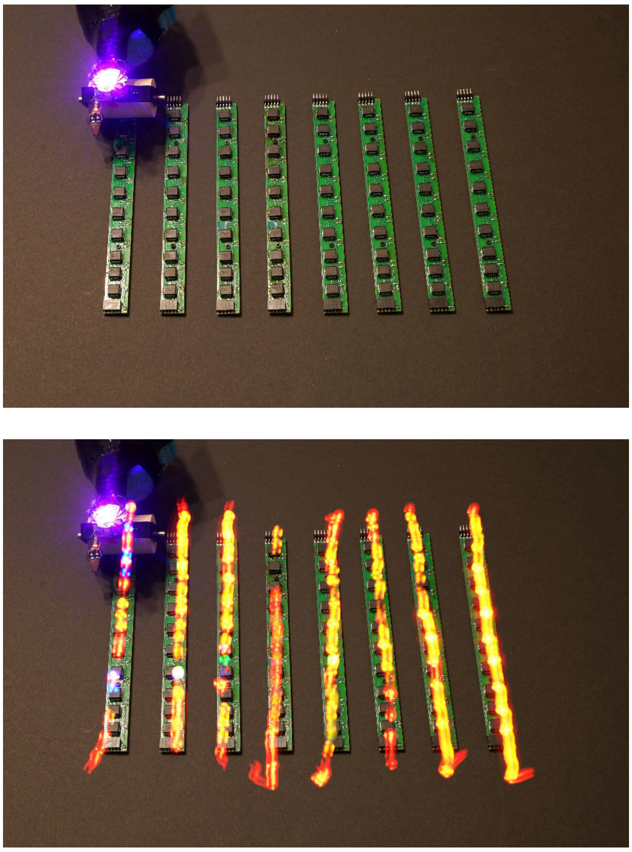

Figure 1: **Kinetic imaging the acoustic response of suface-mount circuit boards correctly identifies defective components.** *Note the lack of acoustic coupling from the 2nd and 3rd chips (integrated circuit packages) on the board 4th from left. Upon close inspection, both the 2nd and 3rd chips had defects in circuit board soldering.*

I. Introduction

Many sensing modes such as audiovisual recordings, and still photography, us passive measurement of subject matter. It is common to also include emissive components. For example, photographic cameras often use electronic flash lamps, or studio lighting. Modalities such as sonar are commonly used in both passive (receive-only) and active (transmit-receive) modes of operation. In active sensing systems such as sonar, radar, and lidar, ultrasound imaging (sonography), Computer Aided Tomography (CAT), and Magnetic

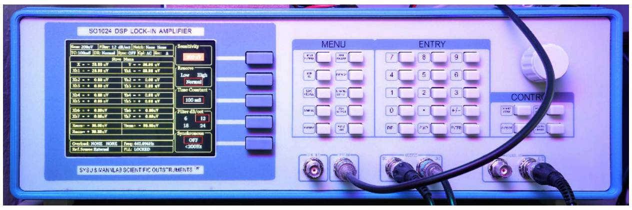

Figure 2: **SYSU Mannlab Scientific Outstrument™:** *A new kind of lock-in amplifier designed specifically for phenomenological augmented reality ("Real Reality™") such as rattletale.*

Resonance Imaging (MRI), the transmit signal is used to phase-coherently filter the received signal (e.g. in the homodyne receiver of a Doppler radar or sonar set).

Metavision or, more generally, metasensing, refers to sensing of sensors to determine their ability or capacity to sense. For example, a radar detector is a metasensor that senses whether a radar set is in use nearby. Radar detector detectors also exist and are used to sense metasensors. Another example of a metasensor is a "bug sweeper" which detects nearby sensors such as hidden cameras or microphones, known colloquially as "bugs". Recently, metasensing has been proposed as an imaging modality [1], through the use of phenomenological augmented reality. A special kind of lock-in amplifier has been developed specifically for phenomenological augmented reality. Specifically, the new kind of lock-in amplifier was developed to enable the visualization and aggregation of higher-order harmonics [2]. Such augmented reality lock-in amplifiers aggregate rather than isolate the phase-coherent response to various harmonics of a reference signal.

In this paper, these principles such as metasensing and Real Reality are developed as *active feedback metasensor based imaging*. This novel imaging modality gives rise to *telekinetic sonar imaging* or *telekinetic radar imaging* as an example. It was inspired by the "Doppler Danse" [3] system, wherein an X-band radar system was used to generate an acoustic representation of a subject matter's motion. In certain cases, the sound generated by movement could excite further motion, leading to a positive feedback loop – thus, the Doppler Danse system was restricted to use in locations with cement walls that did not exhibit this phenomenon. This feedback from rattling objects in the scene was detrimental to the original artistic goals of the Doppler Danse system. However, these mechanical vibrations induced by phase-coherent doppler radar being converted to kinetic sound waves can be put to a productive scientific and industrial use in order to detect loose components in manufacturing or construction. Possible use-cases include, for example, detection of loose ICs on a circuit, and imaging by degree of looseness, as shown in Fig. 1, or rattling rivets on the hull of a ship or aircraft.

Previous work on detection of loose components includes LPMS (Loose Parts Monitoring System) research [5]. Other related work includes "Vibration Response Imaging", i.e. response of subject matter to vibration (see [6] and [7]). Feedback-based sensing is also used in cognitive radio [8][9]. Lock-in imaging has been used in for Scanning Electrochemical Microscopy ([10]), Fluorescence Lifetime Imaging Microscopy ([11]), and in Lock-in Thermography (used for non-destructive evaluation of materials [12]).

The system I propose is novel in the following respects: (a) feedback-based active lock-in imaging that finds natural resonances in potentially defective structures; and (b) use of aggregated harmonics rather than isolated harmonics (hence the specially designed lock-in amplifier).

II. Phase-coherent wave visualization: SWIM (Sequential Wave Imprinting Machine)

Wearable computing and augmented reality enable humans to perceive otherwise invisible physical phenomena, visually superimposed upon where the phenomena is physically occuring. As an embodiment of HI (Humanistic Intelligence), this alignment between displayed content and physical reality occurs in the feedback loop of a computational process. In this way, alignment errors approach zero as the feedforward gain increases without bound. In practice, extremely high gain is possible with a special kind of phenomenological amplifier designed specifically to visualize telekinetic veillance.

Telekinetic imaging works well within the context of augmented reality, i.e. measuring the speed of wave propagation (e.g. the speed of light, speed of sound, etc.), and, more importantly, canceling the propagatory effects of waves by sampling them in physical space with an apparatus to which there is affixed an augmented reality display.

Whereas standing waves, as proposed by Melde in 1860, are well-known, and can be modeled as a sum of waves traveling in opposite directions, we shall now come to understand a new concept that we call "sitting waves", arising from a product of waves traveling in the same direction (Fig 5) as observed through a phenomenological augmented reality amplifier (Fig 3), in a time-integrated yet sparsely-sampled spacetime continuum. See also Fig. 4, where the latest version of the phenomenological augmented reality lock-in amplfier appears in the lower right hand corner.

A. *Visualizing the SONARadio Effect*

In this section, the "SONARadio Effect" is described, along with its practical use for imaging. In radar or lidar systems, the signal does not measurably move the target subject matter, whereas with sonar, sound waves can be used to create vibration in the target subject matter.

Consider a Doppler or pulse Doppler radar/lidar set (i.e. one that embodies a homodyne receiver, phase-coherent detector, or lock-in amplifier) in conjunction

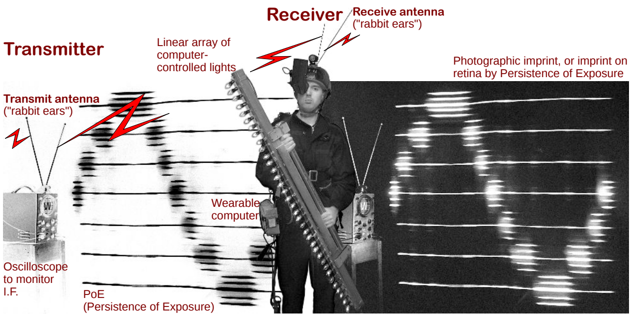

Figure 3: Photo illustration of SWIM (Sequential Wave Imprinting Machine) showing the process of generating long-exposure photographs that show radio waves from the original wearable computing system built in the 1970s and early 1980s. Photographic trails left by electric lights create an augmented reality overlay allowing radio waves to be visualized as "sitting waves". For an historical account of this work, see http://wearcam.org/par/

with physical observables such as sound and light. One such system is Mann's "Doppler Danse" apparatus of the 1970s which was used in various artistic endeavours in which human movement was rendered audible and visible by way of sound and light driven by an output from such a set. Radar sounds from body movement are presented through a loudspeaker responsive to an output of a Doppler radar set, as illustrated in Fig 6.

The ratio of the speed-of-light to the speed-of-sound is roughly equal to the ratio of radar frequencies to audio frequencies. Roughly speaking, the speed of light (i.e. the speed of electromagnetic radio wave propagation) is about a million times faster than the speed of sound, i.e. approxmiately 300,000,000 meters/second as compared with roughly 346 meters/second.

And moreover, audio frequencies are typically in the 20cps (Cycles Per Second) to 20 KCPS (Kilo Cycles Per Second) range, whereas radio waves are in the 20 MCPS (20 Mega Cycles Per Second) to 20 GCPS (20 Giga Cycles Per Second) range.

It so happens that normal human body movement of walking, running, or dancing, causes a Doppler shift on a typical 10 GCPS ("X-band") radar set that is in a nicely audible range, typically audible on a large woofer or subwoofer, thus forming the basis of Mann's "Doppler Danse" set. Typically sound and light are controlled as a form of artistic effect. A problem with the Doppler Danse system is that some objects in the scene, such as walls made of drywall, furniture made of thin veneer, cardboard boxes, etc., vibrate when struck with the sound waves from the woofer or subwoofer, and these vibrations are picked up by the radar set, amplified, and cause further vibrations.

In this sense the Doppler Danse setup causes feedback in the presence of objects that move when subjected to sound waves. Let us call this the "SONARadio effect", which is illustrated in Fig 7. Such an appartaus, using this discovered effect, gives rise to a new kind of imaging that allows us to see through or into walls, cardboard boxes, furniture, etc., in new ways. See Fig 8. Thus the flaw or defect in the Doppler Danse system is used as a desirable feature in a new form of imaging, i.e. a new imaging modality, where sound-responsive objects image brightly and objects that are less sound-responsive image darkly. Additionally, the colors of the light source indicate the nature of the sound vibrations.

B. Variations

More generally, any acoustic excitation may be applied geophonically, hydrophonically, microphonically, or ionophonically (i.e. in solid, liquid, gas, or plasma) to give rise to any measurable vibration or motion using any vibrometer, motion sensor, or the like, not just a radar motion sensor. The motion sensing can be done radiographically, photographically, videographically, or even sonographically, i.e. by another sonar set operating at another frequency. In the latter case, a satisfactory sonar set is a sonar Doppler burglar alarm running at 40 KCPS or simply two 40 KCPS transducers connected to a lock-in amplifier such as an SR510 or a MannLab/SYSU amplifier (the latter allowing multiple harmonics to be output simultaneously). In this case, sound waves are used to vibrate the subject matter in the scene, and sound waves are also used to "see" that vibration.

Alternatively, a lock-in camera can be used (i.e. each pixel behaves like a lock-in amplifier to "see" the change due to a known sound stimulus). To the extent that a camera can be used for seeing motion, e.g. through "motion magnification" or the like, some embodiments of the invention use a software-implemented image processing algorithm in place of the individual lock-in amplifier or homodyne receiver. Other embodiments use a hardware-based sonar vision system in which sound stimulus causes motion that is imaged directly in vision, no longer requiring the mechanical scanning. Other embodiments of the invention use an electronically-steered radar set in which an antenna array is used for beamforming to direct the motion-sensing beam along the target subject matter, while stimulating it with known sound.

Thus there are many embodiments of the SONARadio or more generally sonar-vision system. Such embodiments of the invention may have practical utility.

C. Applications

Suppose, for example, a police officer wishes to see and understand a residence, and in particular, the walls, windows, and door(s) to the residence. Consider the front door, and door-frame, and surrounding wall, for example.

The officer wishes to know where the door is strong or stiff, versus where it is weak or compliant or has more "give". Suppose, for example, the officer wishes to be able to see, in his EyeTap, if there are any loose panels in the door that have some "give" and could be easily pushed out with his fist or foot, or battering ram,

Figure 4: Phenomenological augmented reality using persistence-of-exposure. Leftmost: Persistence-of-exposure is motion-stabilized in the Metavision augmented reality glass, so that users can see and touch and interact with actual sound waves from the violin mounted at the end of the augmented reality desk. Rightmost: Persistence-of-exposure is presented on a large interactive augmented reality display viewable by a large group of users without them needing to wear any special eyewear. Here the actual radio waves from a new smartphone prototype are being visualized.

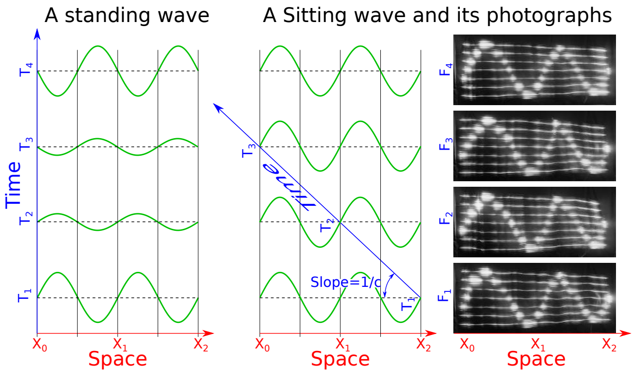

Figure 5: **Left:** *a standing wave at four points in time.* **Middle and Right:** *a sitting wave at four points in time. Whereas the standing wave stands still only at the nodal points, (e.g. elsewhere varying in amplitude between -1 and +1), the sitting wave remains approximately fixed throughout its entire spatial dimension, due to a sheared spacetime continuum with time-axis at slope* $1/c$*. The effect is as if we're moving along at the speed, c, of the wave propagation, causing the wave to, in effect, "sit" still in our moving reference frame.* **Right:** *four frames,* F_1 *...* F_4 *from a 36-exposure film strip of a 35-lamp Sequential Wave Imprinting Machine. Each of these frames arose from sparse sampling of the spacetime continuum after it was averaged over millions of periods of a periodic electromagnetic wave.*

so that he could reach in and turn the door handle, or otherwise compromise the door.

To accomplish this task, the officer may use a smart baton with a built-in Tactile SWIM (TSWIM) so that he can feel, and more generally, sense (see, hear, etc.) where the door is more or less complaint. The baton contains a tactor (vibrotactile transducer) which causes the door to vibrate when it is touched to the door. The lock-in amplifier of the invention picks up these vibrations and indicates their strength in a phase-coherent fashion, with the output of the LED fed to an RGBA LED inside the wand, such that the wand glows in proportion to the compliance of the door at the particular point in which the wand is touched. Alternatively, suppose a home inspector wishes to take a look at the condition of the insides of the walls of a

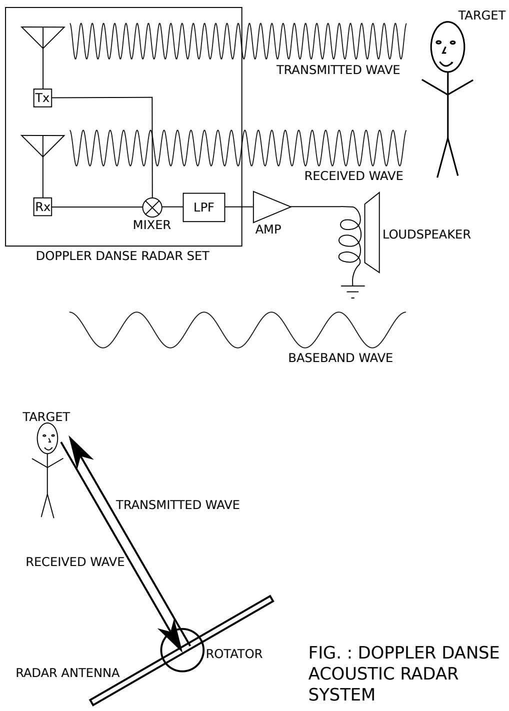

Figure 6: **Doppler Danse system.** *The system emits a transmitted wave from transmitter Tx to hit a target such as a person-in-motion; multiple persons may be scanned out by a radar antenna on a rotator. Suppose that the target is moving away from the Doppler Danse radar set. The received wave reflected off the target will contain frequency components that are shifted down in frequency. Some of the transmitted wave is used as a reference signal in a mixer with the output of a receiver Rx. The result is lowpass filtered by lowpass filter LPF, resulting in a baseband wave that is output to an amplified loudspeaker system. The baseband signal here is at a negative frequency which in some embodiments is made discernable by having two outputs, "real" and "imaginary". A loudspeaker allows the target person to hear his or her own Doppler signal. When the output is complex colored light is used to distinguish negative from positive freqencies.*

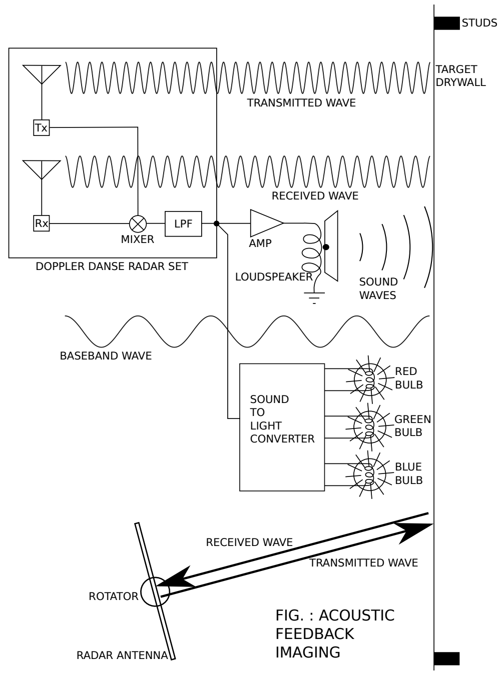

Figure 7: **Acoustic feedback imaging.** *Based on the SONARadio feedback effect, here a span of target drywall between two studs is subjected to sound waves from a loudspeaker such as a woofer or subwoofer or sonar sending device. The target drywall is set in motion by the sound waves, and that motion causes a Doppler shift of the transmitted wave that manifests itself in the received wave received from the transmitted wave being reflected off the target drywall. The output of the Doppler Danse radar set is also fed to a sound to light converter driving three light bulbs (red, green, and blue). These bulbs shine on the target drywall and render it in a color and light level associated with the degree and nature of acoustic feedback present in the overall system. By building this apparatus into a wand, the wand may be waved back and forth across a wall, and will light up the wall in areas that don't have studs behind them. The resulting image of a long-exposure photograph will show the studs as dark, and the target drywall as brightly colored. Additionally, if there is black mould growing behind the drywall, or if there are places where rats and mice have damaged the wall inside, these areas show up in different colors. Alternatively, as is more typical of a radar set, the set spins on a rotator and the light bulbs are replaced by a pinspot or colored lasers, to "paint" the wall with light in a color and quantity indicative of what is hidden inside the wall.*

home. Fig. 9 depicts a phenomenological augmented reality system made using low cost technology of a common musical toothbrush available in department stores. This is a good teaching project for students and hobbyists, as we (my children and I) discovered that the low-cost toothtunes toothbrushes can be used to stimulate walls and other surfaces into vibration. The toothbrush was designed to vibrate the teeth so that a person can hear music through bone conduction. As such it makes a good acoustic impedance match to other solid materials like walls, and building materials such as drywall.

A camera, shown as "CAM." in Fig 9 is setup on a tripod or placed on the bathroom counter facing the wall where the black mold is forming at the edge of the drywall that adjoins the SHOWER STALL. This part of the BATHROOM WALL is made of DRYWALL and

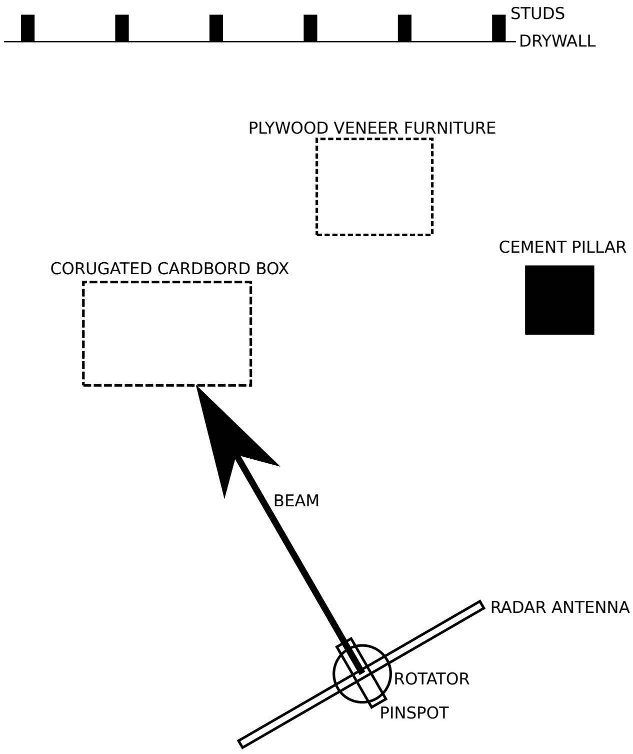

Figure 8: **Imaging of variously acoustically-responsive objects and subject matter.** *A pinspot lights up objects according to the nature of their acoustic feedback, using the SONARadio feedback effect. The cement pillar shows up dark (black or almost black) because it responds very little to the sound stimulus. The corrugated cardboard box shows up brightly, especially in areas of the box that are weak or loose, versus the reinforced corners that show up a little darker. The plywood veneer furniture also shows up brightly since it feeds back strongly. The wall in the background shows up brightly where the drywall is free to vibrate, and darker where the drywall is secured by studs. The entire scene is visible in this way to everyone looking at it without the need for special eyeglasses or other devices. Thus we have a true phenomenological augmented reality (i.e. a "Real Reality").*

has WOOD STUDS, some of which are of ROTTED WOOD.

The picture seen-through-the-drywall-darkly, as shown in Fig. 10 is captured in a darkened room, e.g. by turning off the bathroom lights, while moving the toothbrush that has colored lights attached to it. The colored lights indicate the strength of the return from the lock-in amplifier, according to the XY to RGB converter illustrated in Fig. 11. The complex outputs (X = augmented reality, and Y = augmented imaginality), of any phase-coherent detector, lock-in amplifier, homodyne receiver, or the like, are therefore used to overlay a phenomenologically augmented reality upon a field of vision or view, thus showing a degree of acoustic response as a visual overlay.

D. Kinetic Sonar with roller

In order to make a smooth motion over the surface, a roller system was developed. In this way, acoustic energy is transferred to a soft rubber roller, specifically the Speedball Deluxe 2-Inch Soft Rubber Brayer as

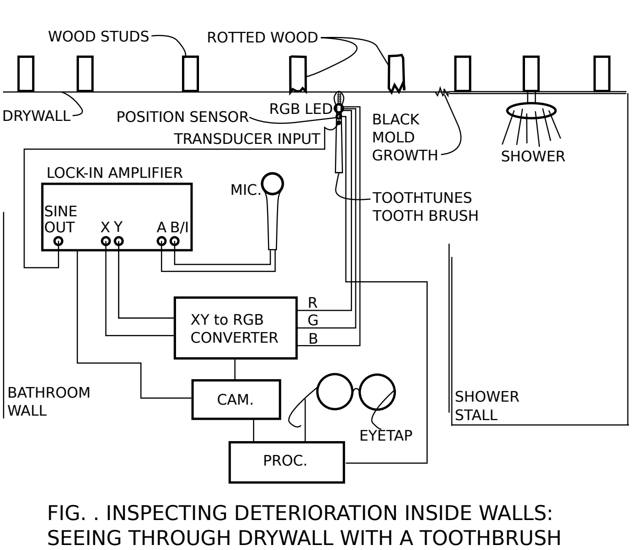

Figure 9: **Seeing through drywall with a toothbrush.** *"Toothtunes" toothbrushes have been mass-produced, giving rise to a low-cost source of vibration transducers. A small hole is drilled into the brush to access the two wires going to the transducer. A long flexible wire is attached thereto, and connected to the sine out of a lock-in amplifier. A suitable lock-in amplifier is the one designed by author Mann (representing Mannlab) in collaboration with SYSU, which is the only lock-in amplifier capable of outputting multiple harmonics at the same time. Here the hard part of the brush (not the soft bristles) is pressed against the wall, causing it to vibrate. A microphone picks up these vibrations and is connected to the signal input of the lock-in amplifier, through inputs A and B/I, where the lock-in amplifier is set to the "A-B" setting. The output of the lock-in amplifier is converted to RGB colors using an XY to RGB converter to drive an RGB LED (Light Emitting Diode) that is mounted onto the "toothtunes tooth brush". The brush is slid along the wall in a systematic fashion and the LED color and light output varies in a way that shows differences in material properties within the wall, making visible the wood studs behind the drywall, and also their condition, e.g. showing differences between studs in good condition and those that are rotting out from water getting in behind and to the left of the bathroom shower.*

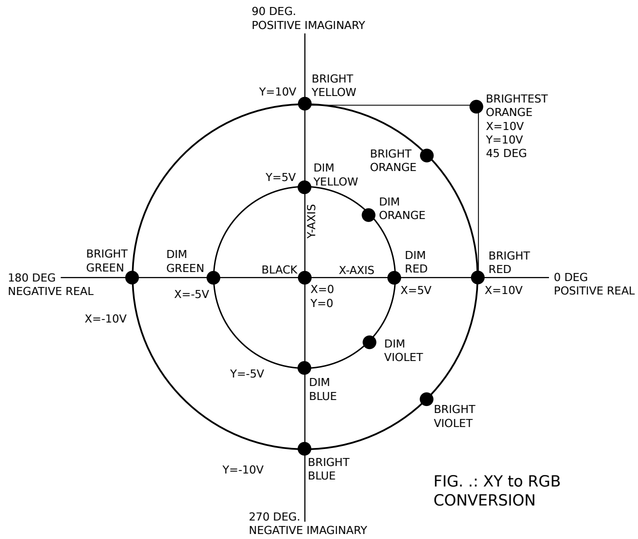

Figure 11: **Complex color-mapper**. *The complex color-mapper converts from a complex-valued quantity, typically output from a homodyne receiver or lock-in amplifier or phase-coherent detector of the invention, into a colored light source. Typically more light is produced when the magnitude of the signal is greater. The phase affects the hue of the colour. For example, a strong positive real signal (i.e. when X=+10 volts) is encoded as bright red. A weakly positive real signal, i.e. when X=+5 volts, is encoded as a dim red. Zero output ($X = 0$ and $Y = 0$) presents itself as black. A strong negative real signal (i.e. $X = -10$ volts) is green, whereas weakly negative real ($X = -5$ volts) is dim green. Strongly imaginary positive signals ($Y = 10v$) are bright yellow, and weakly positive-imaginary ($Y = 5v$) are dim yellow. Negatively imaginary signals are blue (e.g. bright blue for $Y = -10v$ and dim blue for $Y = -5v$). More generally, the quantity of light produced is approximately proportional to a magnitude, $R_{XY} = \sqrt{X^2 + Y^2}$, and the color to a phase, $\Theta = \arctan(Y/X)$. So a signal equally positive real and positive imaginary (i.e. $\Theta = 45$ degrees) is dim orange if weak, bright orange of strong (e.g. X=7.07 volts, Y=7.07 volts), and brightest orange of very strong, i.e. X=10v and Y=10v, in which case the R (red) and G (green) LED components are on full. Similarly a signal that is equally positive real and negative imaginary renders itself as purple or violet, i.e. with the R (red) and B (blue) LED components both on together. This produces a dim violet or bright violet, in accordance with the magnitude of the signal.*

Figure 10: **SONEMAR (SONar/ElectroMagnetic radAR).** *Moving a light and sound transducer back and forth allows us to see the acoustical material properties of the wall. The studs and other materials inside the wall are visible by way of reduced light output because the wall vibrates less when stimulated by sound. Areas where the drywall is attached to the rotted out stud exhibit a phase-shift in the complex-valued signal quantity, and this phase shift is visible as a color change from blue to green. Thus areas of rot show up as green.*

described in Fig. 1 caption. The energy was transferred to the roller using the transducer salvaged from a ToothTunes toothbrush. The transducer was mounted on a cantilever so that it would transmit vibrational energy to the metal mount of the roller. This helps to facilitate exploration of rough surfaces such as wooden doors. See the results in Fig. 12 second from the left.

E. Telekinetic Sonar at-a-distance

In some applications, e.g. where we wish to inspect buildings from a distance away, without having to touch the subject matter directly, a directional metasensing sonar system is proposed. A powerful yet portable (wearable or carryable) subwoofer such as a battery-powered lightweight tubular subwoofer, together with a directional sonar, is used to both stimulate, and sense, the subject matter. See Fig. 13.

This kind of system is not limited to phase-coherent detection, i.e. the system can also operate quite nicely without phase-coherent detection, e.g. using

Figure 12: Leftmost: a wooden door. Next: results of rolling the RGB LED, microphone, transducer assembly back and forth across the door. Note that we can see the otherwise hidden heavy metal lock mechanism of the door, but we don't see so well the details of the fine structure. Next: results of a non-contact version of the new imaging modality which will be described in the next subsection. Here we can clearly see the various vibrational modes of the door, especially the lower portion which is very loose and rattles a lot. Rattling produces higher harmonics. The apparatus finds the natural resonant frequencies of each part of the door. The lower part of the door resonated around 55 CPS (Cycles Per Second). The left part resonanted around 100 CPS, and the right part around 130 CPS. Rightmost: the true structure behind the door, showing the other side of the door (inside). Image is left-right reversed to match the other side of the door.

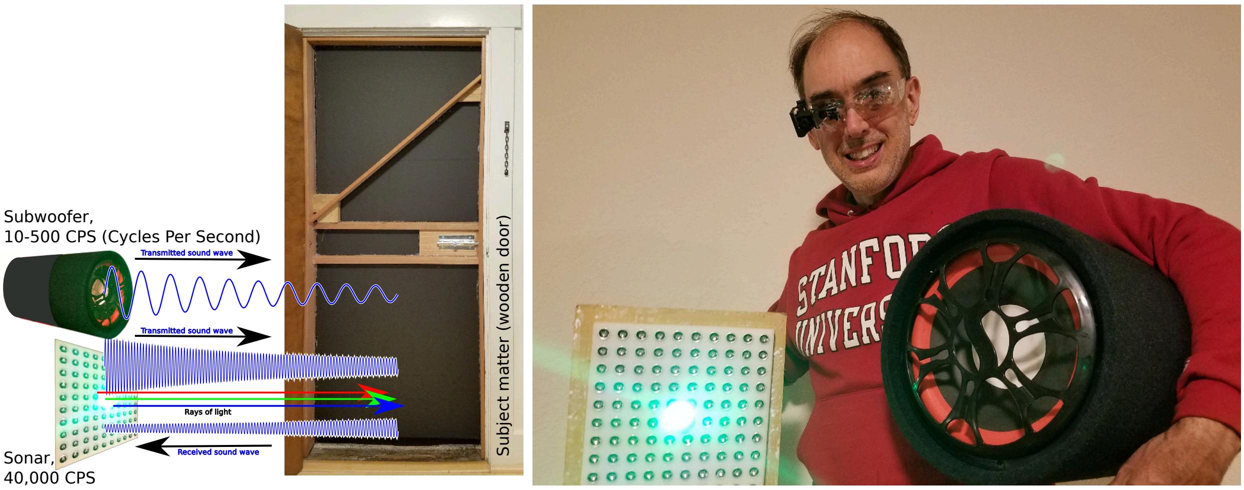

Figure 13: Telekinetic meta-sonar: A handheld directional sonar transmits and receives at 40,000 cycles per second, while at the same time a subwoofer transmits at a much lower frequency range. The sonar senses the effect of the subwoofer on the subject matter. The sonar has 100 elements arranged in a 10 by 10 grid. A very sensitive lock-in amplifier allows the system to pull out a very weak signal effect of the subwoofer on the subject matter, and this effect feeds back. The frequency from the subwoofer is thus adaptive and depends on what the sonar is pointed at. Although the subwoofer is not very directional, its effect is highly directional because it operates within the feedback loop of the highly directional sonar. An output from the lock-in amplifier drives a very narrow beam (highly directional) spotlight, which is aligned exactly with the very narrow beam of the sonar. Thus the apparatus can be used to sweep the beam back-and forth while the beam "paints out" a pattern of light on the subject matter. EyeTap eyeglass is used to see a stabilized persistence-of-exposure, for augmented reality overlay. Thus the apparatus can be used to inspect objects by way of their acoustic properties. See the results in Fig. 12 third from the left.

magnitude-only detection, or using feedback, as in some of the earlier mentioned implementations. More generally, alternative embodiments may construct images in a variety of different ways, which may be combined into a single image of multiple channels. For example, in one embodiment, a first image plane may arise from an acoustic feedback, a second image plane from a magnitude response, a third and fourth image plane from a phase-coherent complex-valued detection at one stimulus frequency, a fifth and sixth plane at another frequency, and so on. In essence, we sense and compute a visuacoustic transfer function of the subject matter, over a certain impulse or step response is measured in response to a transient acoustic disturbance. In other situations, where there is significant nonlinearity, a different response is measured and computed for a variety of different amplitude and frequency reference waveforms, waveshapes, and wave spectra. Additionally, the capabilities of the Mannlab/SYSU amplifier can be fully put to use here, in characterizing harmonic responses arising from nonlinearities and distoritions of waveforms, such as when stimulating

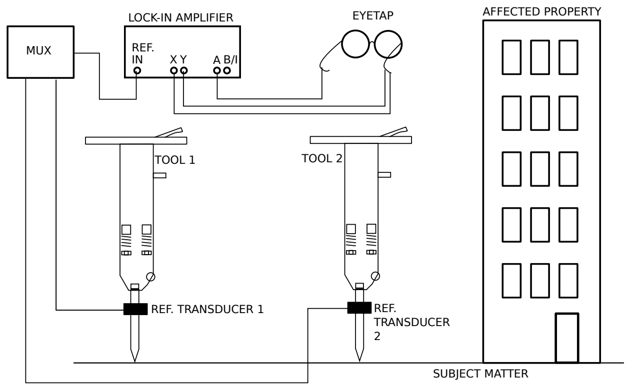

FIG. . VISUALIZING ENVIROMENTAL IMPACT OF INDUSTRIAL NOISE AND MECHANICAL DISTURBANCE

Figure 14: **Jackhammer vision.** *Various tools, such as "jackhammer" pneumatic impact drills TOOL 1 and TOOL 2 affect SUBJECT MATTER including surrounding buildings, such as an AFFECTED PROPERTY. Using EyeTap Digital Eye Glass, the effects on the AFFECTED PROPERTY due to each tool can be visualized. A multiplexer, MUX sequentially selects to be responsive to each of the tools. While switching to TOOL 1 the AFFECTED PROPERTY is visualized through a lock-in camera in the EyeTap. Upon the EyeTap's display screen is displayed a video magnified view of the vibrations in the AFFECTED PROPERTY that are caused by TOOL 1. The AFFECTED PROPERTY is vibrated by many things including some of the tools, but what we want to see is the vibrations due specifically to TOOL 1, as made visible by selecting TOOL 1's pickup REF. TRANSDUCER 1 for the reference input REF IN to the LOCK-IN AMPLIFIER that is the basis of the lock-in camera of the EYETAP. Subsequently we select through the multiplexer MUX, TOOL 2, specifically, through connecting REF. TRANSDUCER 2, to the lock-in amplifier REF. IN. This forms the basis of the lock-in camera in the EyeTap to display the vibrations in the AFFECTED PROPERTY that are due to TOOL 2. Thus we can see selectively or superimposed the affects of individual tools on the surrounding landscape and environment.*

subject matter at higher amplitudes where objects that "buzz", can be distinguished from those that don't. In this way, we can see loose objects as distinct from firm but still easily vibrated objects. Harmonic imaging using the Mannlab/SYSU amplifier makes visible, for example, loose fence boards, when looking out across the fence in our back yard. Moreover, we can selectively image responses due to different inputs, as illustrated in Fig. 14.

III. Conclusion

A novel imaging and sensing modality has been proposed, based on feedback-based active lock-in imaging, and specifically phase-coherent telekinetic imaging. Subject matter is imaged in conjunction with sound bombardment. The imaging can, for example, also be by way of sound, e.g. subject matter is bombarded by low-frequency sounds while being imaged by high frequency sonar, which, through the design and realization of a special kind of lock-in amplifier, is fed back to the production of the low-frequency sound. In this way, the system "finds" the natural resonances in subject matter. Telekinetic sonar may find application in manufacturing (e.g. inspecting circuitboards or other parts), physical security, building inspection, and emergency response.

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