[0533] As an illustrative example, consider the following choice of acoustic modes and substrate. The basin **2200** is formed of aluminum with a thickness of 1 mm which smoothly increases to a thickness of 3 mm within a centimeter of the arrays and transducers. The inside of the aluminum basin is enamel coated, with an appropriate type and thickness of enamel to support Love waves at about 5 MHz, e.g. 100 microns of lead (or other heavy metal) based enamel. For the acoustic paths across the touch region, the lowest order Love wave is used. Along the reflective arrays, e.g., a third order symmetric Lamb-type wave as modified by the presence of the enamel coating propagates. The array reflectors are formed as modulations in an otherwise smooth inside surface of the aluminum basin and may be fabricated by milling, scribing, chemical etching, photoetching, photoresist, or stamping before application of the enamel coating. The transducers (coupling to the Lamb-type waves) are wedge transducers and are bonding to the outside or convex surface of the aluminum basin. Thus, both the transducers and reflective arrays are protected from the environment in the basin **2200**.

[0534] Note that for this particular choice of modes and substrate, the basin **2200** can be partially or completely filled with water and still respond to and distinguish a touch due to a finger of similar perturbation that provides viscous damping at the touch surface.

[0535] From the perspective of perturbation analysis algorithm design, the drain pipe hole **2219** shown in **FIG. 22**(*b*) maybe regarded as a generalized "contaminant". In this regard, note that the sensor design of FIGS. **22**(*a*) and **22**(*b*) has sufficient redundancy to support anti-shadowing algorithms.

[0536] After a use of the wash basin or toilet is detected, a water flow or flush is manually or automatically initiated. In this case, the acoustic sensor may be used to determine when the bowl is emptied, and cease water flow when the contents are evacuated. In the case of a toilet, which operates according to a fixed cycle, a minimal cycle may be preprogrammed, detecting when such a cycle is necessary, with repetition as required to fully evacuate the bowl. Otherwise, a rate or duration of water flow may be modulated. Thus, a closed loop washing or flushing cycle control is possible.

[0537] Applications of acoustic sensors such as the above applications demand sensor designs of complex non-planar geometry as is enabled by the present invention.

Example 16

[0538] In some cases it may be advantageous to use the same spacing vector of the same reflective array for more than one sensor subsystem. This further extends the design options within the scope of this invention.

[0539] As an illustrative example, consider a reflective array along the X direction with a single set of uniformly spaced 45° reflectors on a soda-lime glass substrate. The array is illuminated by a transmit transducer which generates Rayleigh waves at either 5 MHz with or 2.5 MHz. The Rayleigh wavelength is 0.025" at 5 MHz and 0.050" at 2.5 MHz. The spacing of the reflectors along the axis of the array is 0.100", that is, four Rayleigh wavelengths at 5 MHz and two Rayleigh wavelengths at 2.5 MHz.

[0540] The spacing vector for this reflective array is S=(−0.050", 0.050"). This spacing vector supports 90° scattering of Rayleigh waves at 5 MHz, 90° scattering of Rayleigh waves at 2.5 MHz, and, as discussed below, for certain discrete thickness of the glass substrate, scattering of 5 MHz Rayleigh waves at 71.56° into a plate wave.

[0541] The incident wave vector for Rayleigh waves is $k_I=(2\pi/\lambda, 0)$ is evaluated as (251.3 inch^{-1}, 0) at 5 MHz and (125.7 inch^{-1}, 0) at 2.5 MHz. The corresponding 90° reflected wave vectors k_R are given by (0, 251.3 inch^{-1}) and (0, 125.7 inch^{-1}). In the spacing vector where V is the acoustic group velocity (assuming all modes the same) and t is the Y-to-X delay time. Similarly, if the 155 microsecond Y delay is combined with the 175 microsecond Y-to-X delay, the missing X coordinate can be determined by the following equation.

$$X=-W+(W/H)\times Y+\{W/[\sqrt{(H^2+W^2)}+H-W]\}\times V\times t$$

[0542] If the touch is in the zone covered by the X-to-Y sensor subsystem, then the corresponding equations are as follows.

$$Y=-H+(H/W)\times X+\{H/[\sqrt{(H^2+W^2)}+W-H]\}\times V\times t$$

$$X=+W+(W/H)\times Y-\{W/[\sqrt{(H^2+W^2)}+W-H]\}\times V\times t$$

[0543] The X-to-Y and the Y-to-X sensor subsystems are an example of sensor subsystems that do not have overlapping touch zones. The algorithm in **FIG. 25** does not attempt to pair up delay times from such pairs of sensor subsystems.

[0544] In many cases the redundancy-check algorithm of **FIG. 24**(*a*) and the anti-shadowing algorithm of **FIG. 25**(*a*) can be combined. For example, consider the X-Y-U-V sensor of **FIG. 14**, in which a touch is typically sensed by four sensor subsystems One coordinate measurement can be lost due to shadowing, and yet three coordinate measurements will remain to support an algorithm requiring a self-consistent triple of delay times.

[0545] The cylindrical sensor of **FIG. 19** also provides an application for this type of analysis. As is evident from inspection of **FIG. 19**(*b*), any or the following three coordinate pairs, (u,v), (u,ϕ), and (v,ϕ), is sufficient to determine the (r, ϕ) coordinates of the touch.

[0546] The spherical cap sensors of FIGS. **21**(*a*) and **21**(*b*) and FIGS. **21**(*c*) and **21**(*d*) provide other examples. In these cases, any of the three possible coordinate pairs (u, v), (u, ϕ), and (v, ϕ) is sufficient to determine the (Θ, ϕ) coordinates.

[0547] For the sensor of FIGS. **21**(*a*) and **21**(*b*), the anti-shadowing algorithm is essential to assure two-dimensional touch reconstruction for the entire touch surface. The v sensor subsystem has a blind region to between the hole and the transducers **R1** and **R2**; in this region (Θ,ϕ) coordinates are reconstructed from the (u,ϕ) sensor subsystem pair. Similarly the u sensor has a blind region between the hole and the transducers **T1** and **T1**; in this region (Θ,ϕ) coordinates are reconstructed from the (v,ϕ) sensor subsystem pair.

[0548] Similarly, the anti-shadowing algorithm of **FIG. 25**(*a*) can be used to optimize touch performance of polygonal sensors such as the hexagonal sensor of **FIG. 15**(*b*) and large sensors such as the large rectangular sensor of **FIG. 16**(*a*).