APPARATUS AND METHOD FOR SOUND REPRODUCTION

TECHNICAL FIELD

[0001] The exemplary and non-limiting embodiments of this invention relate generally to audio transducers/loudspeakers combined with a graphical display panel, such as may be present in a portable music device or wireless radio as well as larger consumer electronics devices such as televisions and desktop/laptop personal computers.

BACKGROUND

[0002] This section is intended to provide a background or context to the invention that is recited in the claims. The description herein may include concepts that could be pursued, but are not necessarily ones that have been previously conceived or pursued. Therefore, unless otherwise indicated herein, what is described in this section is not prior art to the description and claims in this application and is not admitted to be prior art by inclusion in this section.

[0003] The consumer products industry is driven, particularly for portable products like mobile phones, toward thinner designs and larger displays which enable more information to be viewed. Traditionally this resulted in reducing loudspaker size to enable a larger display, in accord with general costomer preferences. There appears to be short term technology stagnation in electroacoustics. Further size reduction of existing loudspeaker types is seen to be at the cost of performance, which in many current products is adequate only for speech.

[0004] In developed countries hand-portable devices are being used for music applications and so there is a desire for greater dynamic response from the loudspeaker (IHF mode). Additionally, mixed media communication in which one party sends the other visual information while discussing it verbally on the phone drives a need for better sound fidelity in IHF mode, since placing the handset against one's ear prevents the user from simultaneously viewing the display. Many users do not routinely carry an earpiece or headphones.

[0005] In developing countries the mobile phone is typically used in IHF mode so that whole families can simultaneously converse with friends and relatives over a single phone or listen to music through its IHF speaker. External loudspeakers such as in a docking station are often impractical in some developing countries since sometimes there is no main power available and mobile phones are recharged using solar panels or hand cranked generators. The various considerations outlined above show there is a motivation to achieve good sound quality from mobile phones in IHF mode without increasing phone size, and without drawing excessive battery power.

[0006] Integrating a loudspeaker into a handheld electronic product is usually difficult because loudspeakers are not modular. A good quality sound emitter in current technologies requres size and space, which often conflicts with miniaturization trends in portable consumer electronics. Different models will allow resonant cavities of varying sizes and shapes and so there is little if any design re-use across different products. Consumers favor the largest possible display screen which often results in the end product exhibiting a compromised audio quality, for example where sound is routed through the back or out of the side of the housing to avoid the large LCD screen. Many current mobile phone models exhibit acoustical efficiency less than 0.1%.

[0007] There are certain prior art approaches for integrating a visual display with a loudspeaker. For example, one approach by NXT uses an optically transparent speaker having a clear panel driven from the edge by piezo-electric actuators. This approach is seen to work only with large panels where the vibration modes are so dense that in theory the listener does not notice them. In mobile products, the panel is small and so frequency response is poor while distortion is high. The NXT approach uses a piezo-electric shaker that also appears too large for portable product designers. One small-screen adaptation of the NXT approach is "TechJapan: Casio 2.5 LCD with Integrated Speaker" (http://techjapan.com/modules.
php?op=modload&name=News&file=articel&sid=1132, last visited Mar. 18, 2010).

[0008] Other references that detail other techniques and/or background information that might be relevant to these teachings include:

- **[0009]** Self Assembled Inorganic Micro-Display on Plastic, by Ehsan Saeedi, Samuel S. Kim, and Babak A. Parviz (*MEMS* 2007, Kobe Japan, 21-25 Jan. 2007);
- **[0010]** International publication numbers WO 2009/017278 and WO 2006/038176;
- **[0011]** European Patent Applications EP 1912469 and 1827057;
- **[0012]** Japanese Patent Publication numbers 2007-300578 and 2-76400;
- **[0013]** UK Patent Application GB 2360901; and
- **[0014]** U.S. Pat. No. 7,372,110 and US Patent Application Publication number US 2005/0226455.

SUMMARY

[0015] The foregoing and other problems are overcome, and other advantages are realized, by the use of the exemplary embodiments of this invention.

[0016] In a first aspect thereof the exemplary embodiments of this invention provide an apparatus comprising a graphical display panel and a loudspeaker. The graphical display panel comprises a display layer for displaying images, and defines a plurality of apertures penetrating through at least the display layer. The loudspeaker comprises a diaphragm arranged substantially parallel to the display layer.

[0017] In a second aspect thereof the exemplary embodiments of this invention provide a method for making apertures or holes in the graphical display panel noted above. In this second aspect of the exemplary embodiment of the invention the method comprises: determining a desired acoustic resistance; using physical parameters of a graphical display panel and the desired acoustic resistance to determine a surface area of the graphical display panel to be occupied by a plurality of holes and to determine a radius of the holes. Further, the method comprises controlling a computer to form the holes, in each of a plurality of graphical display panels that each define the physical parameters, such that the formed holes define the determined radius and occupy the determined surface area of the graphical display panel.

[0018] In a third aspect thereof the exemplary embodiments of this invention provide a computer readable memory storing a program of computer readable instructions that when executed cause the computer to perform actions comprising: determining a desired acoustic resistance; using physical parameters of a graphical display panel and the desired acoustic resistance to determine a surface area of the graphical display panel to be occupied by a plurality of holes