LOW FREQUENCY WARNING TONE GENERATOR

BACKGROUND

[0001] Household fire and smoke detectors signal at about 3100 Hz. Most detector products have a 10-year useful life, and can be hardwired with a battery backup. In some examples, a detector is a sealed system with a 10-year battery backup, and can be hardwired to residential mains and can include an interconnect terminal. These units detect and signal smoke or carbon monoxide events, or other events. In some cases, two or more units can be connected (e.g., using a third wire).

[0002] Conventional or standard single-station detectors use an audio system that includes a small amplifier, a signal generator, and a piezoelectric speaker. The piezo speaker can be highly efficient and compact. The piezo speaker itself is generally a thin disk that is attached to the plastic housing of the detector.

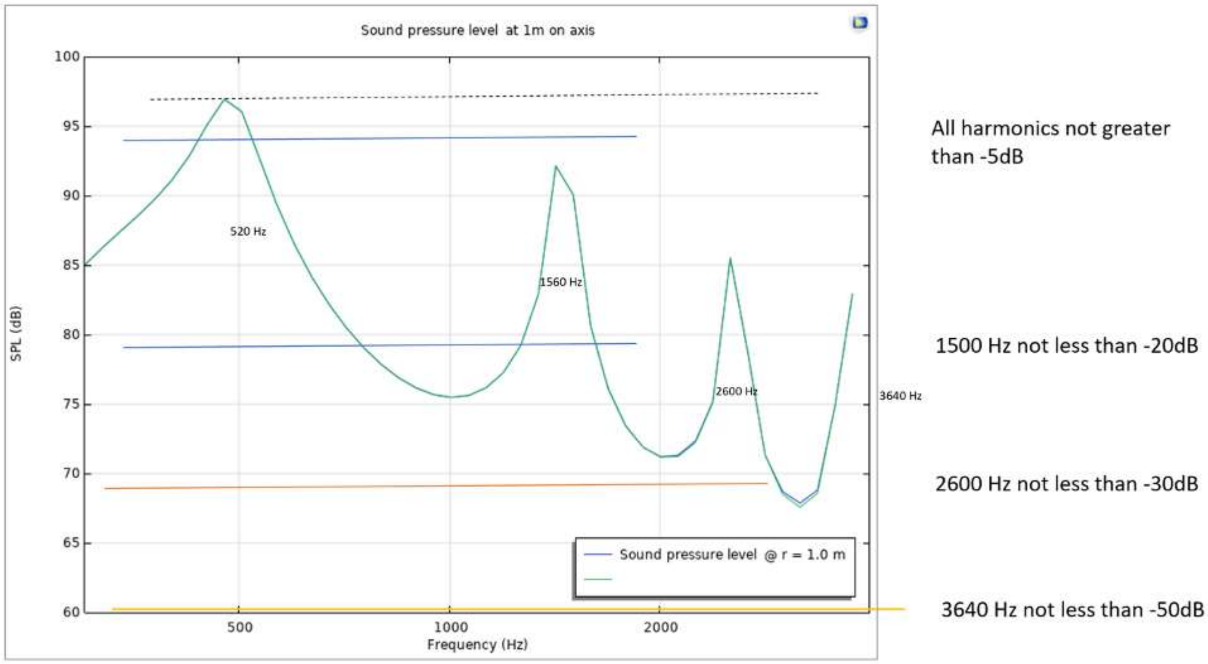
DETAILED DESCRIPTION

[0003] NFPA-72 (the 2022 edition of the National Fire Alarm and Signaling Code (R) from the National Fire Protection Association) provides the latest safety provisions to meet changing fire detection, signaling, and emergency communications demands. In addition to the core focus on fire alarm systems, the Code includes requirements for mass notification systems used for weather emergencies; terrorist events; biological, chemical, and nuclear emergencies; and other threats.

[0004] The Code was recently updated to require relatively lower frequency 520 Hz warning tones in newly constructed commercial sleeping areas. Examples of these areas are sleeping areas designated for occupants with hearing loss, such as senior living homes, hospital sleeping rooms where staff may rest or sleep, hotel sleeping rooms, dormitory sleeping rooms, and others. The new warning tone or signal requirement came about through testing conducted by fire safety agencies, universities, advocacy groups, and others. They found through this testing that people who are hard of hearing and/or who are slightly inebriated respond better to the lower 520 Hz tone than they do to higher pitched tones.

[0005] The 520 Hz signal is a square wave tone output that is pulsed in a temporal pattern, usually referenced as temporal 3, which means the signal includes 3 evenly-spaced tones then one long silent period, and then repeat. The latest version of the Code requires that the fundamental frequency is 520 Hz and that the signal includes the next 3 odd harmonics (F3, F5, F7). See the diagram below.

[0006]



[0007] One solution for the 520 Hz signaling problem can include or use a conventional loudspeaker and amplifier. The speaker can be a standard cone loudspeaker. Such a loudspeaker may be relatively inefficient and may not be operable at the required SPL using only a small amplifier and a battery housed in the housing of the detector. For example, using a sounder with a Gentex GHLF as an example, the power required to drive the sounder to the code required output is 3.98 Watts (24 Volts at 0.166 amps). For such sounders to operate at the required sound pressure levels, the sounder portion draws power from a main power panel (e.g., a 24 V panel). The main panel supplies a constant power source and a general alarm signal wire. This configuration works reasonably well but can be costly to install in terms of labor and materials, relies on an external power source, and can use a relatively large transducer and complex input signal. Furthermore, if a room is added or converted after the building is constructed, then the builder or contractor must find a way to run low voltage wiring back to the main panel. This can be an expensive proposition to add a detector to a room or building.

[0008] The present inventor has recognized that a problem to be solved includes providing an all-in-one sensor and sounder with a highly efficient sounder portion that can operate at the Code-mandated sound pressure levels using battery power and without relying on signals from a power main or centralized source or panel.

[0009] A solution can include or use a bandpass sounder. The bandpass sounder can include a tuned bandpass enclosure, such as a 4^{th} order bandpass woofer box and a pipe (e.g., in the style of an organ pipe). A bandpass box is a high efficiency system that favors single tuning. The pipe depends on the class and creates harmonic frequencies. A bandpass type 1 can include a two-chamber box with a transducer at the interface between the chambers. The first chamber can be a sealed box, and the second chamber can be a vented box. The tuning frequency of the system depends on the respective box volumes and the vent sizing.

[0010] The pipe is primarily based on type (open end, closed end) and length characteristics. The volume of the vented portion of the type 1 bandpass box can be merged with the pipe. With the design volume for the vented chamber specified, a pipe can be tuned to the design frequency at, e.g., 520 Hz. The pipe section creates the needed harmonics F3, F5, F7. In an example, the pipe is a closed-end type or stopped-type pipe.

[0011] For a stopped pipe, the frequency of the nth harmonic Fn is (n*v)/(4*L)

[0012] Where:

- V = speed of sound (e.g., 343 m/s).
- n = the harmonic
- L = the length of pipe

[0013] Parameters of a sealed rear chamber and vented front chamber bandpass enclosure standard can be provided as follows:

[0014] Volume of the vented chamber (this is the vented side) Vf = (2*S * Qts)^2 * Vas

[0015] Volume of the sealed chamber Vr = Vas/((Qbp/Qts)^2 – 1)

[0016] Vent tuning frequency is fb = Qbp * (fs/Qts)

[0017] Vent length Lv = (1.463 * 10^7*R^2)/(fb^2 * Vf) -1.463 * R

[0018] Where:

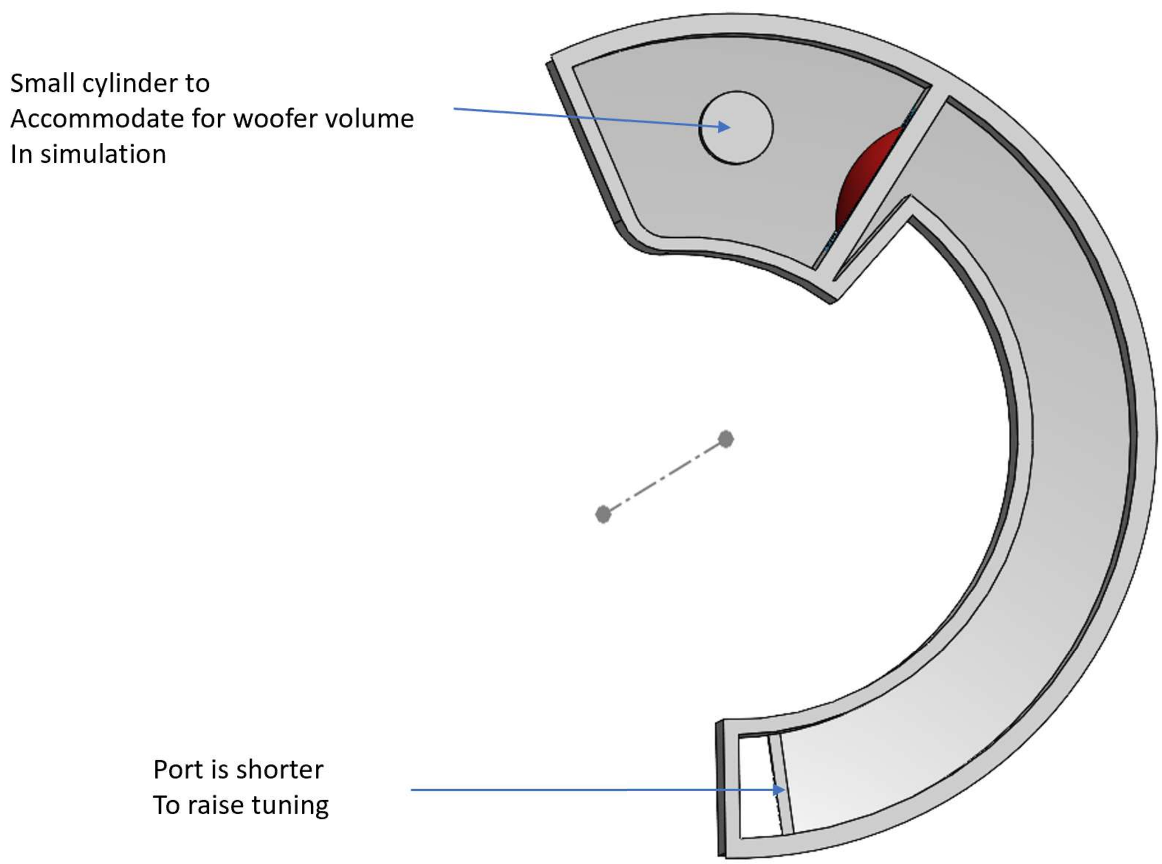
- Qbp = Q of the bandpass rear chamber
- Qts = Total Q of the driver
- fs = Driver free air resonance

- R = radius of the port
- S = bandpass ripple

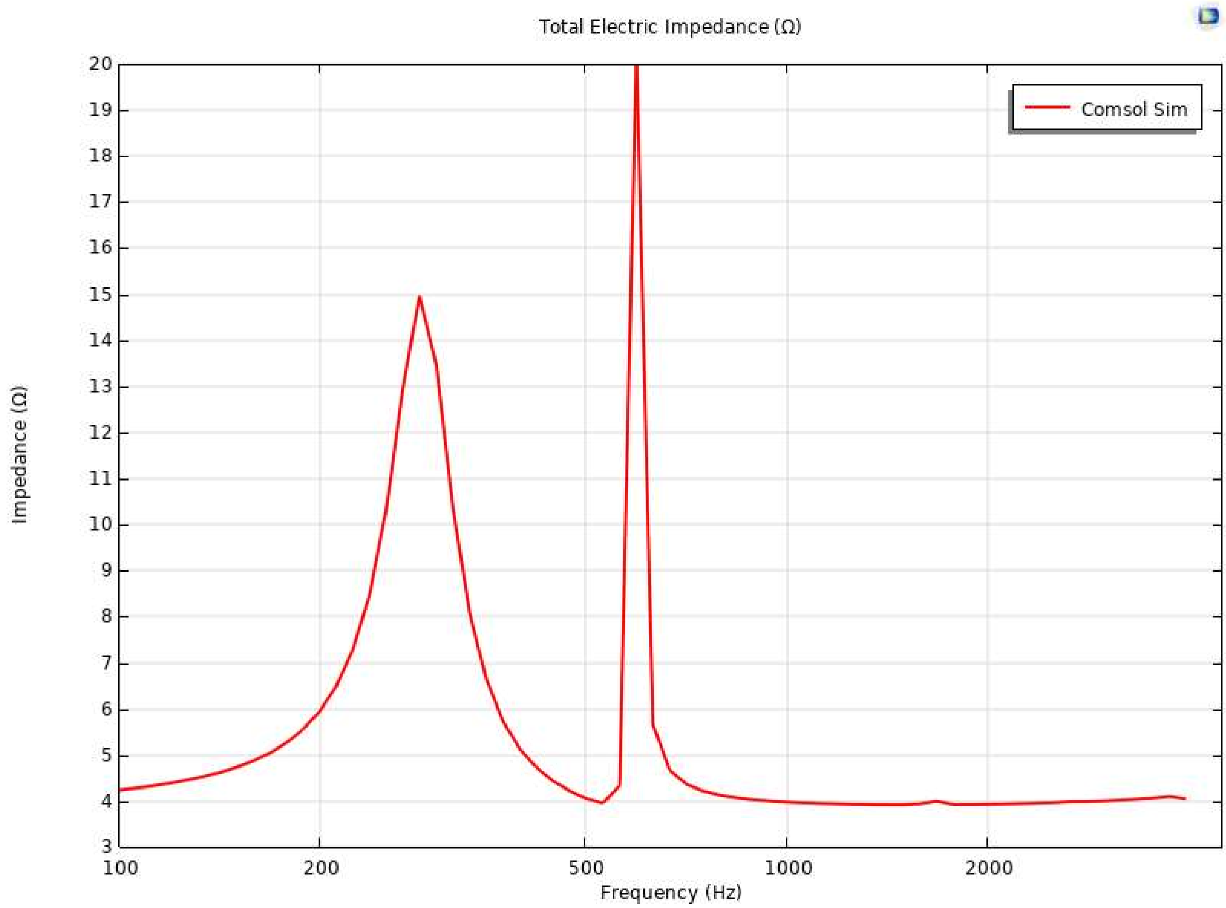
[0019] With the bandpass box and stopped pipe parameters determined, the length of the pipe can be determined based on the volume of the vented (front) chamber of the bandpass box. One dimension (e.g., the length) of the pipe can be fixed, and the two other dimensions can determine the pipe height and width.

[0020] In an example, to approximate a stopped organ pipe, the walls of the vented (front) chamber should be substantially parallel, but need not be linear. The parallel wall configuration will produce strong harmonics at F3, F5, and F7. Finally, vent length can be as calculated from the bandpass calculations. In an example, the vent can be located at the end of the stopped pipe such as can be similar to a standard organ pipe.

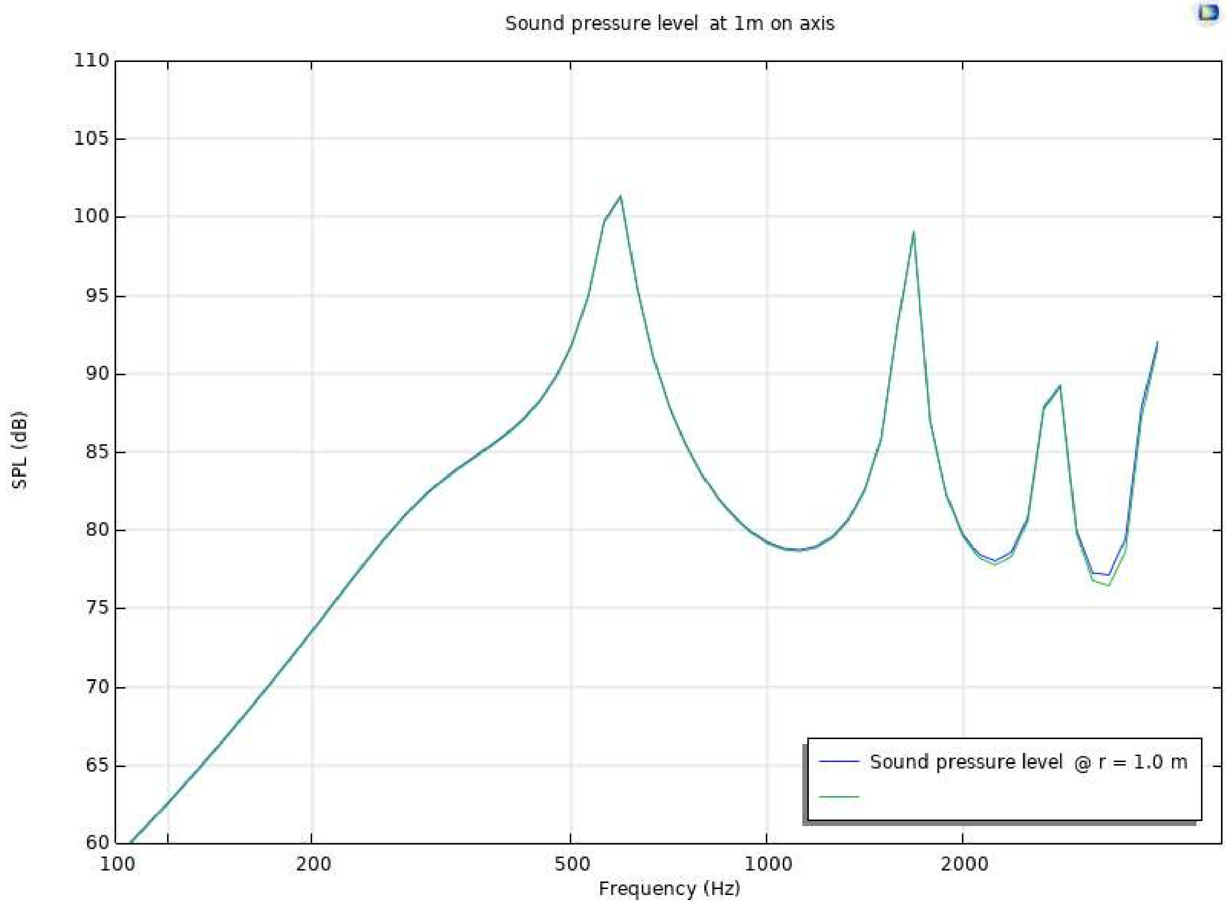
[0021] **Data -** Simulation in COMSOL Revision 1.1



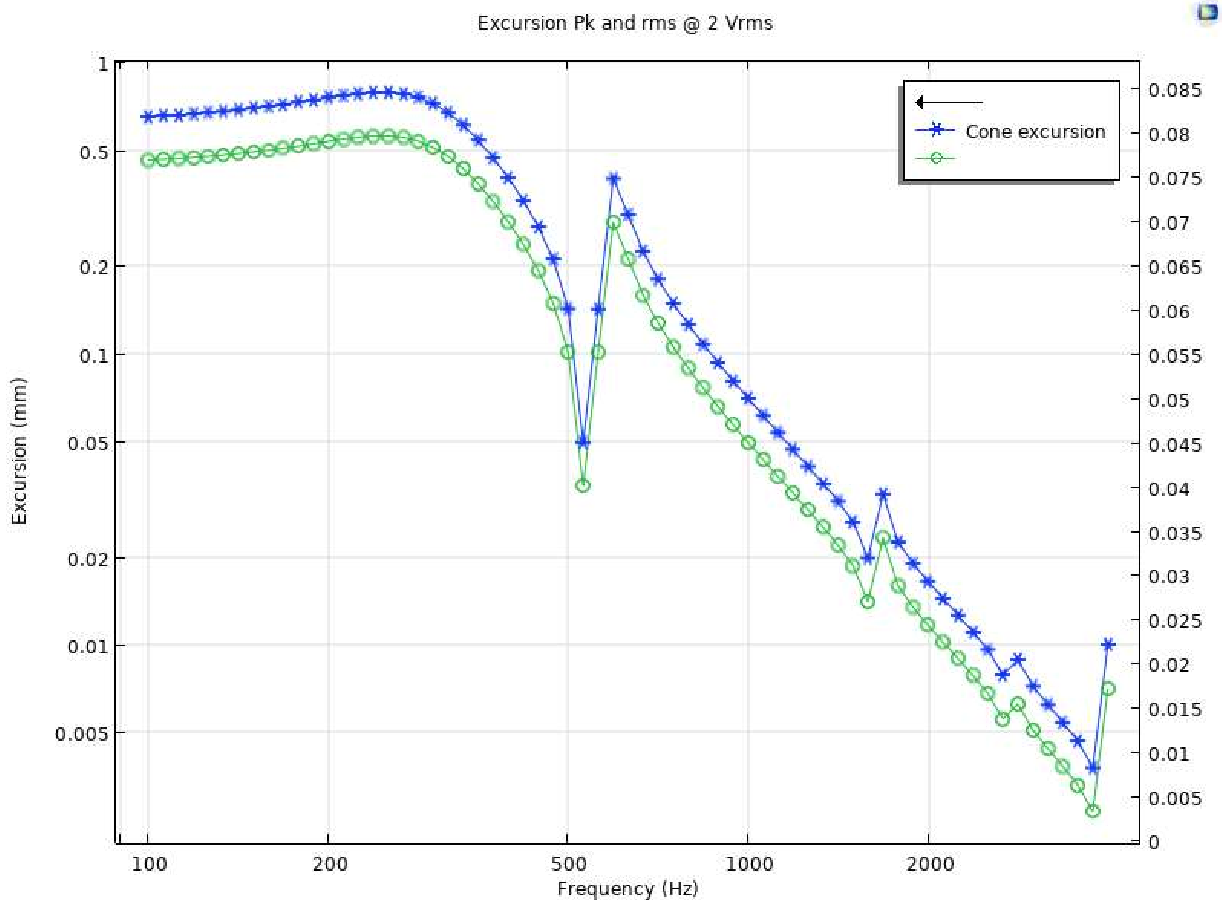
Model for simulation



Impedance from simulation

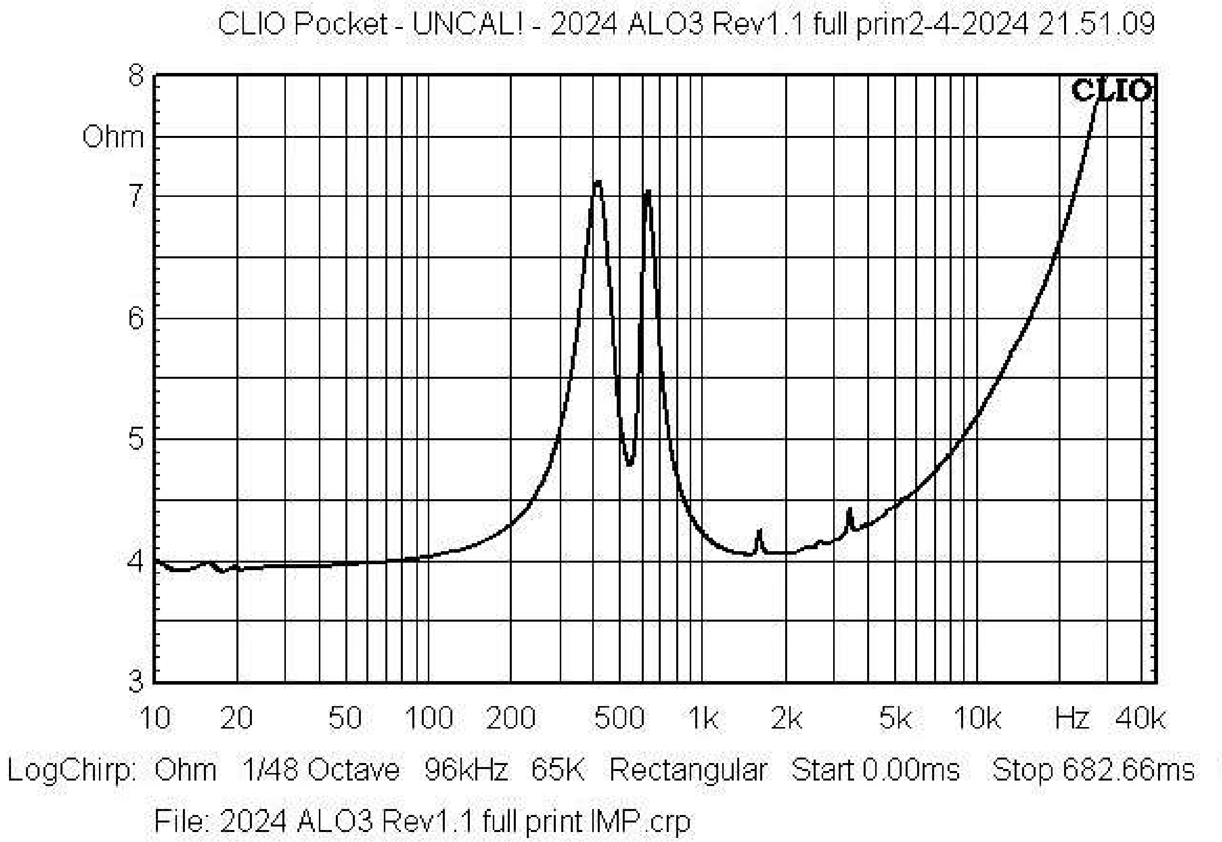


Frequency response from simulation

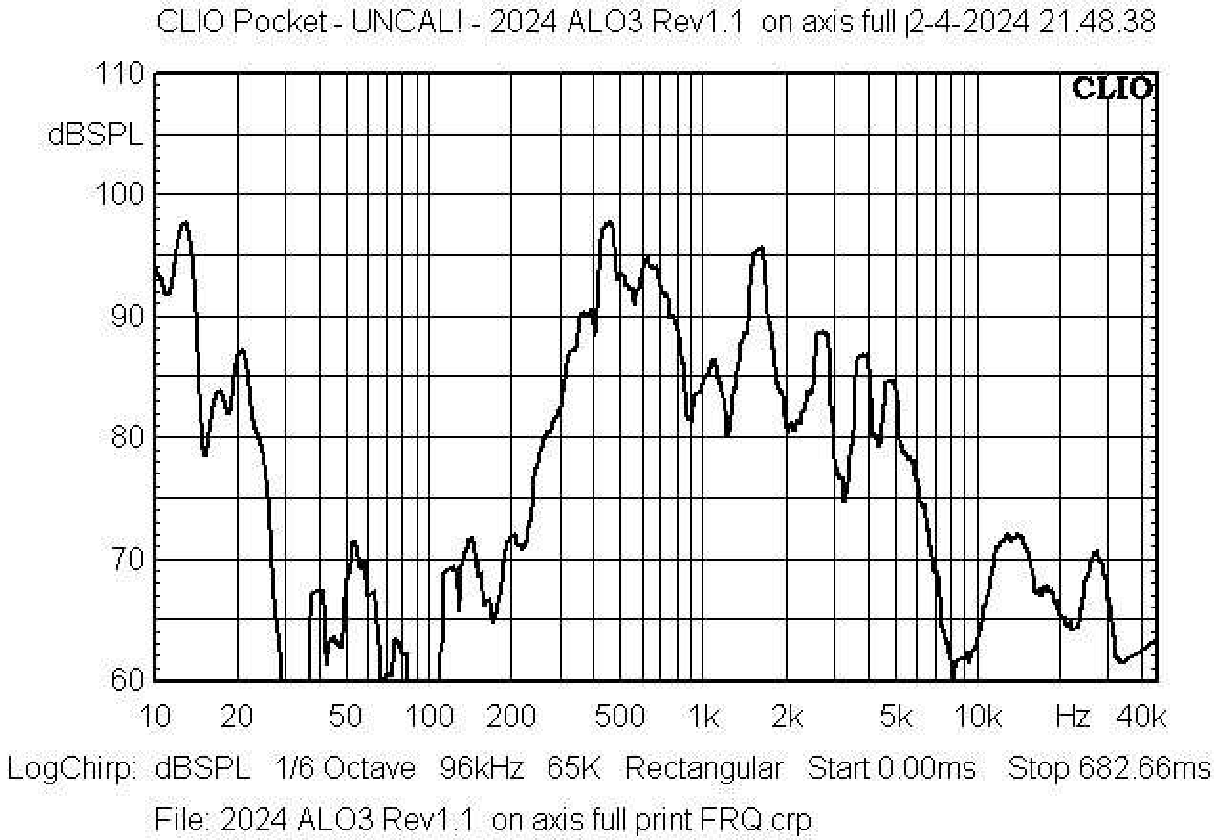


Cone excursion from simulation

Measurements

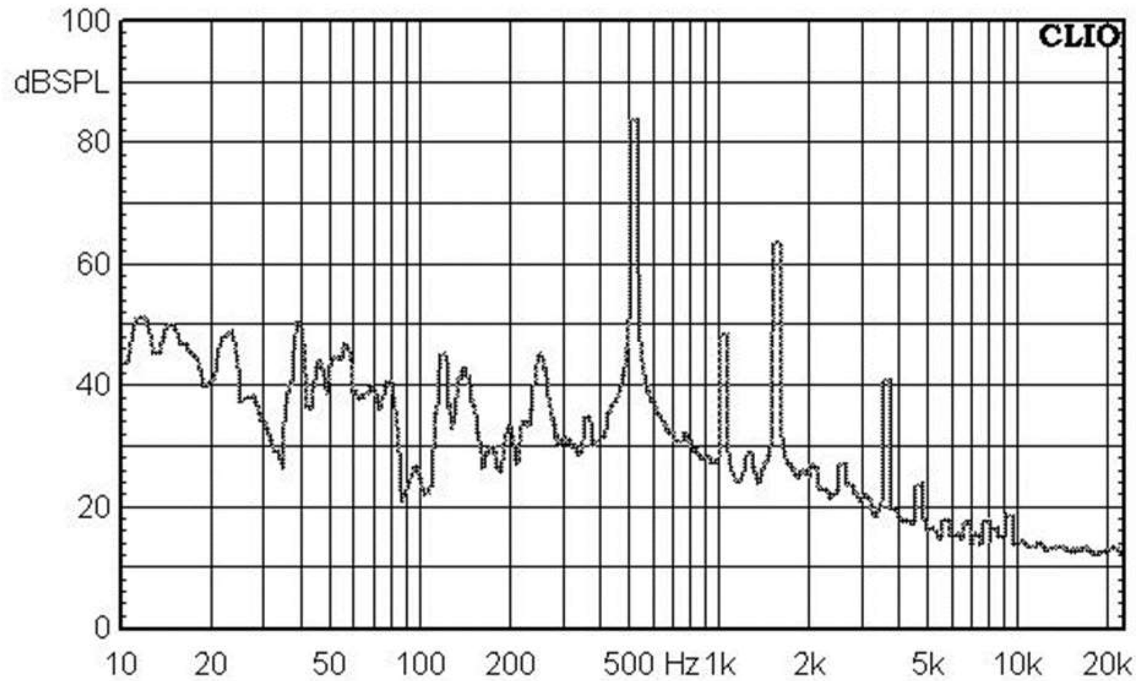


Input = Swept sine wave



Input = 520 Hz continuous sine wave

CLIO Pocket - UNCAL! - Rev 1.1 full print 15%covered RTA 2-4-2024 22.04.12



FFT: dBSPL 96kHz 65536 1.46Hz Rectangular 1/12 Octave
File: Rev 1.1 full print 15%covered RTA on axis 520 in.ffp

[0022] Note: This measurement is uncorrected for level.

[0023] **Meeting the code requirements**

[0024] Based on measured performance characteristics, the prototype can exceed the Temporal 3 (Loudness) requirement of 79.8 dBa with a low-power amplifier using battery power.

[0025] Several corrections can be applied to reach the exact NFPA 72 code specification. For example:

[0026] Axial Sensitivity at 1Watt/1Meter as measured: 98.0 dBspl

[0027] Distance correction (1Meter to 10 ft): -9.68 dB

[0028] A-Weighting correction: -3.00 dBa

[0029] Final: 85.32 dBa

[0030] Thus the prototype exceeds the SPL requirement at 1-Watt output.

[0031] If the output of the amp is reduced to 0.25 Watts, then the code-required 79.8 dBa output is produced.

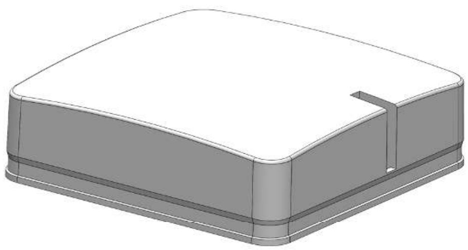
[0032] Decibel(power) = 10 Log(P1/P0) : Where P0 = 1 Watt

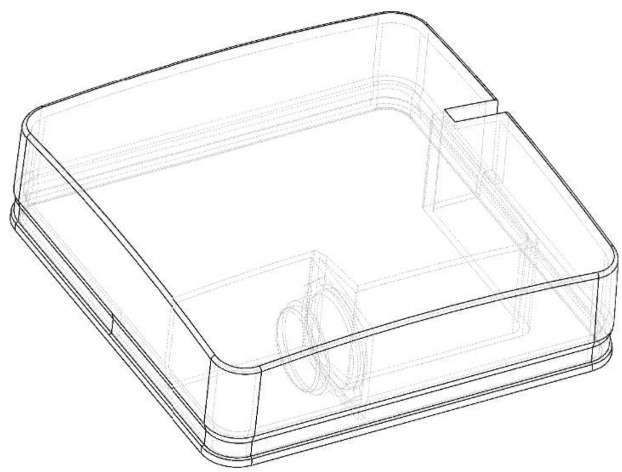
[0033] Consequently, with the amplifier at 1 Watt output, the sounder output meets the Temporal 4 (Loudness) requirement.

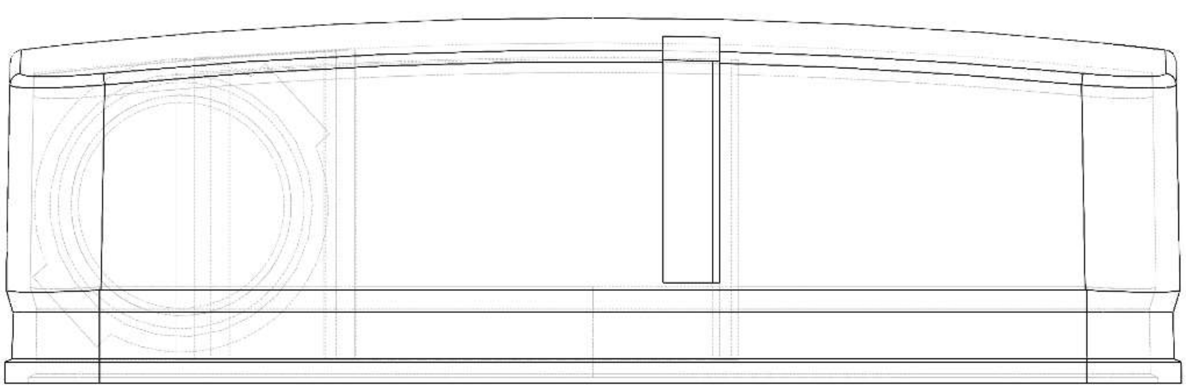
[0034] The systems disclosed herein, such as can include or use a type 1 band pass box, provide an efficiency improvement over a conventional speaker-in-box configuration. The prototype uses a 30 mm speaker rated for 78.5dB 1Watt/1Meter in a standard speaker box. The prototype provides 91.5dB 1Watt/1Meter for the same speaker in a bandpass type 1 box with tuning optimized or tuned for 520 Hz.

[0035] The bandpass sounder introduced herein can comprise various shapes, sizes, and form factors. In some examples, at least a portion of one or more of the enclosures of the bandpass sounder can be integrated with, or can comprise a portion of, a sidewall of a housing for a detector system (e.g., a smoke detector, fire detector, heat detector, gas detector, and the like).

[0036] In an example, the bandpass sounder can comprise a portion of a substantially rectangular enclosure as shown in the example below.

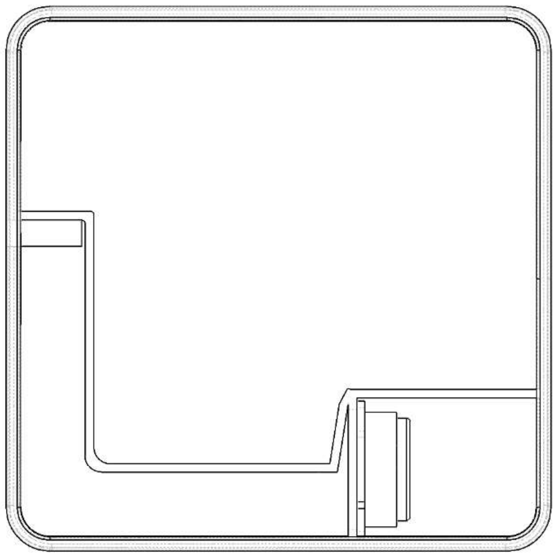




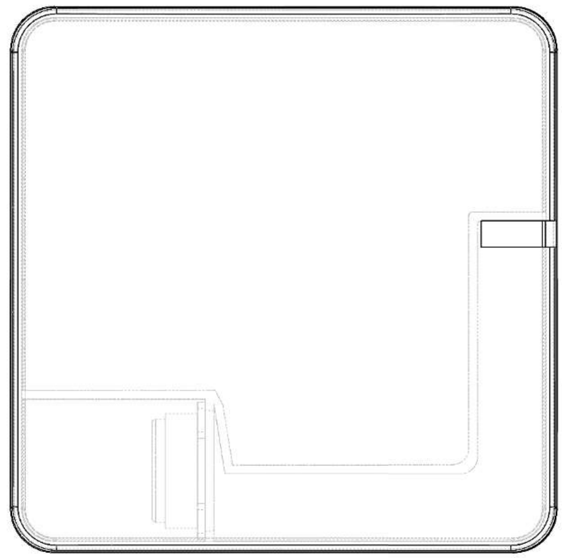


Side

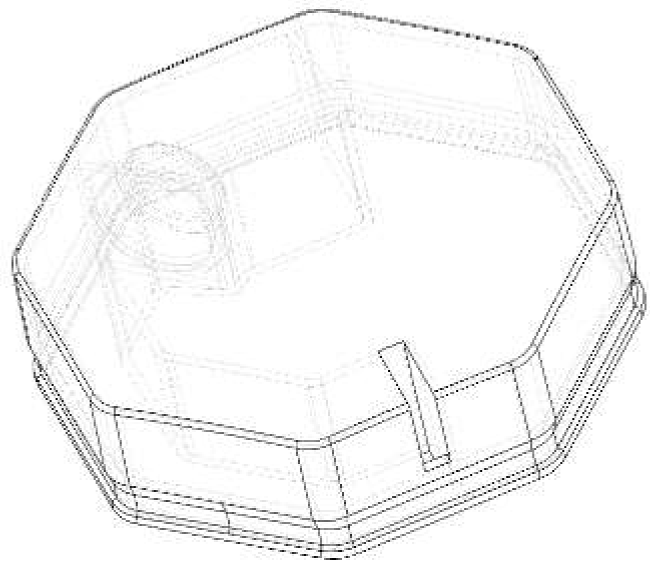
Underside

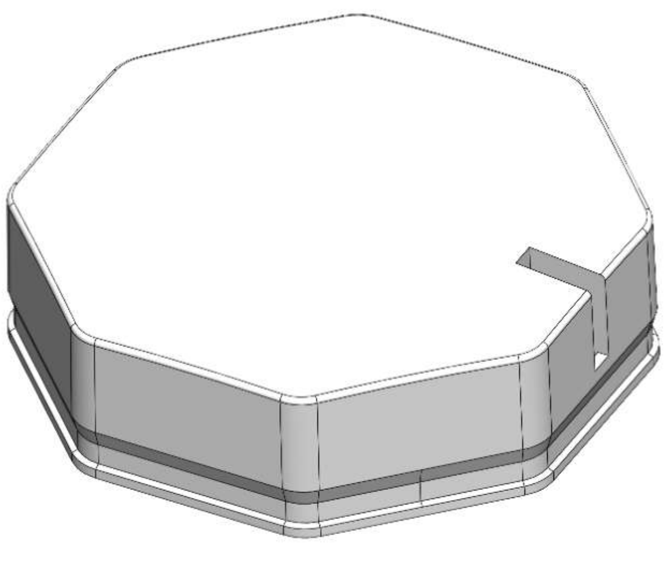


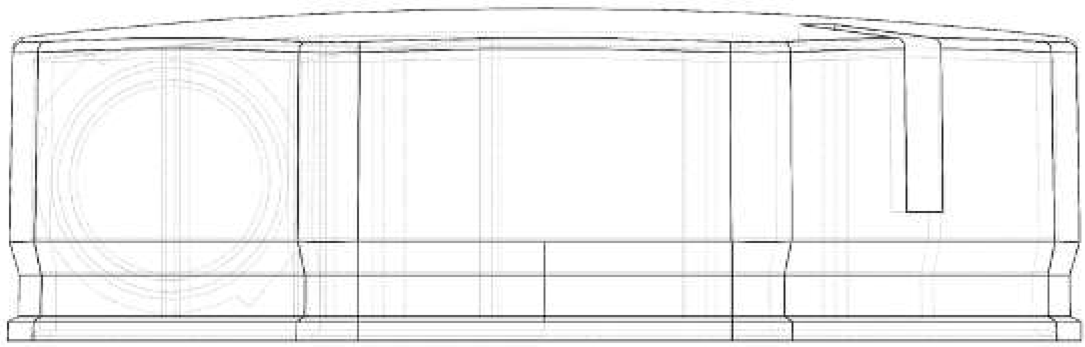
Top side

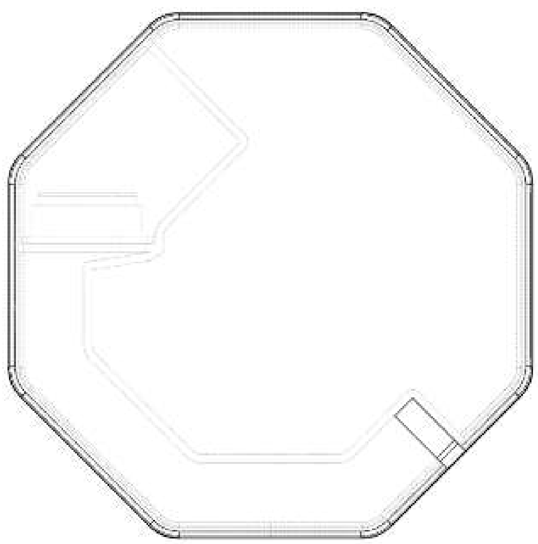


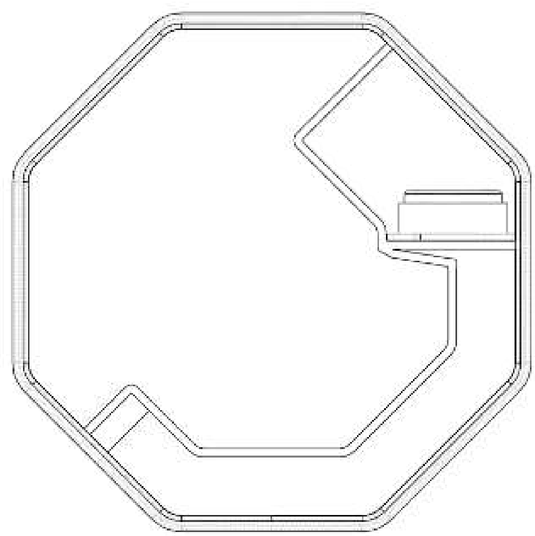
[0037] In an example, the bandpass sounder can comprise a portion of a substantially octagonal enclosure as shown in the example below.



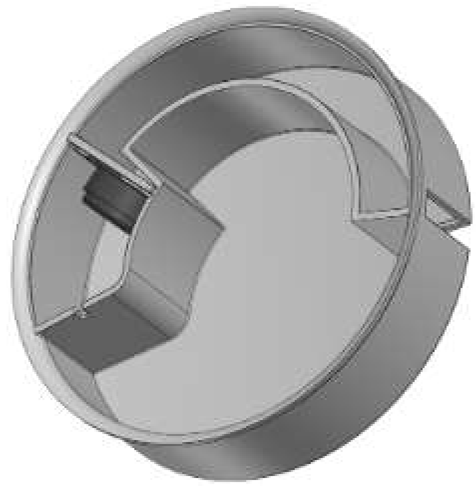


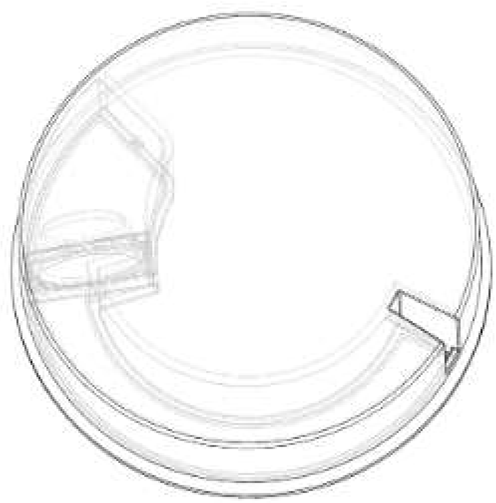


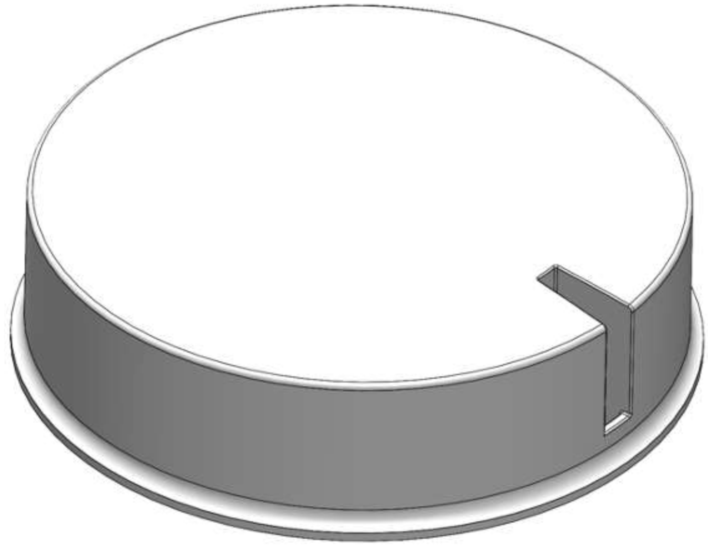


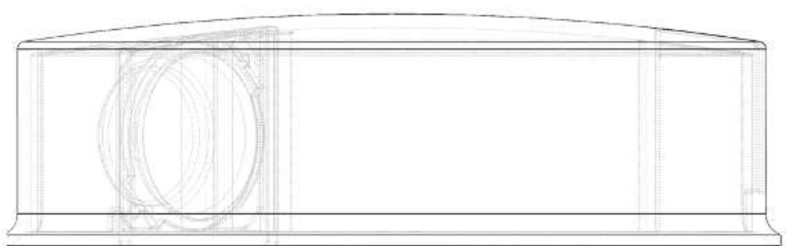


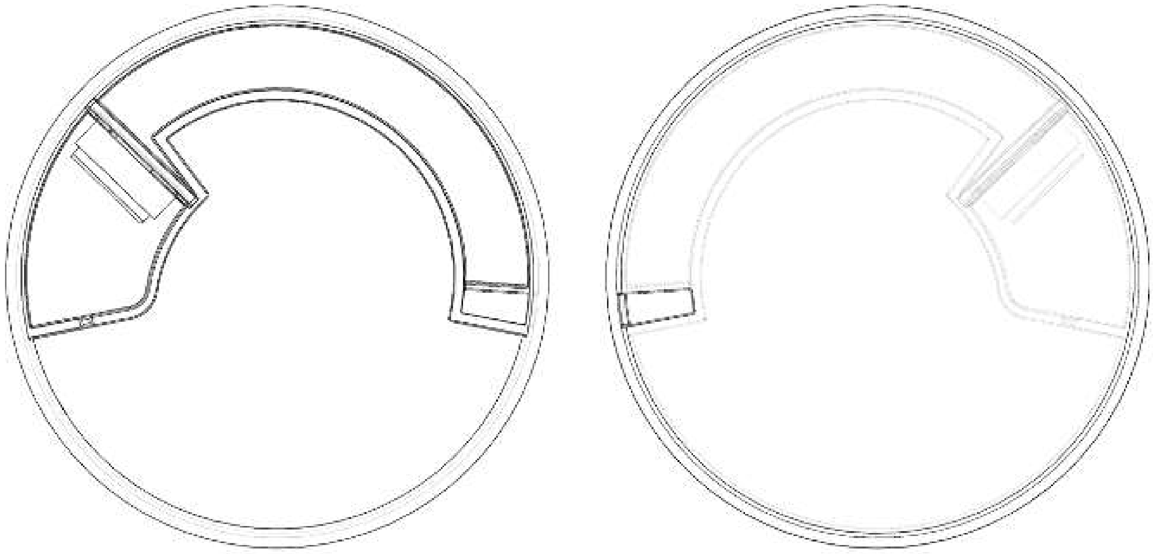
[0038] In an example, the bandpass sounder can comprise a portion of a substantially circular enclosure as shown in the example below.











[0039] Other configurations can similarly be used.

CLAIMS

What is claimed is:

1. A system as shown and described.

2. A detector with integrated acoustic sounder as shown and described.

3. The detector of claim 2, wherein the acoustic sounder comprises a driver coupled between a first enclosure and a second enclosure, wherein the first enclosure is sealed, and wherein the second enclosure is an elongated enclosure.

4. The detector of claim 3, wherein the second enclosure includes a port.

5. The detector of claim 4, wherein the port comprises an opening in a housing of the detector.

6. A smoke or fire detector system comprising:

a housing;

a detector portion inside the housing; and

a sounder portion inside the housing, wherein the sounder portion includes a loudspeaker driver, a first sealed enclosure, and a second elongate enclosure.

7. The fire detector system of claim 6, wherein the second elongate enclosure includes a port.

8. The fire detector system of claim 7, wherein the port comprises an opening in the housing.