AUDIO ENGINEERING SOCIETY (AES) **PRESENTATION** [PowerPoint] [Acrobat]

OMNIVOX VERSUS SPHEROVOX COMPARISONS

MULTIPLE LOW-FREQUENCY CORNER FOLDED HORN DESIGNS

INTRODUCTION

Low-Frequency horn loaded systems for π/2 radiation are designed employing push-push operated dual membrane loudspeakers, closely mounted in parallel against each other. Tree Axis Symmetrical and efficient horn mouth loading is transformed to a symmetrical and uniform membrane cone loading. By doubling loudspeaker diaphragm, and respectively horn throat, lower horn cut-off frequency was achieved with the same extension rate, besides acoustic power doubling. Two such corner horn systems could be stacked together for quarter space π-loading, with important usage in front-of-stage subwoofer applications. Four horn systems are grouped together over the floor or on the ceiling for 2 π-radiation. Finally, 8 such systems could be united for full space low-frequency radiation.

Figure 1. Corner Horn Prototype

Placing reduced size horns in room corners for better driver loading at low frequencies has been known even before 1940s, when Paul Klipsch patented his Klipschhorn [1]. This horn is driven by a single loudspeaker and is by far the most copied design, probably still in production. Well known is also the double push-push loudspeaker structure [US Patent 4,923,031], which has also a double loudspeaker pair version.

Most developments, to our knowledge, have a common setback – the inability to achieve the necessary for many practical applications multiple arrangement capability, keeping at the same time spherical space radiation symmetry. A further drawback of most of the known low frequency horn loaded systems is that they don't exhibit symmetrical loudspeaker membrane loading, which vastly shortens the operational life of the horn systems.

CORNER HORN REALIZATION

The proposed design of the Low-Frequency Folded Corner Horn is based on a pair of membrane loudspeakers in push-push configuration, operated in parallel into a common radially expanding horn throat, comprising three individual, symmetrical and identical two-folded channel paths towards the horn output mouth. The twice folded horn provides a long path through, hence lower horn cut-off frequency, and smaller dimensions. This dual loudspeaker configuration further lowers cut-off frequency at equal system dimensions by doubling horn throat area at a given compression ratio Sd/St (Diaphragm to Throat area). Reduced to practice prototype installed into the measuring room corner is pictured on Fig.1. The partial cross-sectional view from Fig. 2 reveals the interior of the corner horn system, where two of the three folded channel paths are exposed.

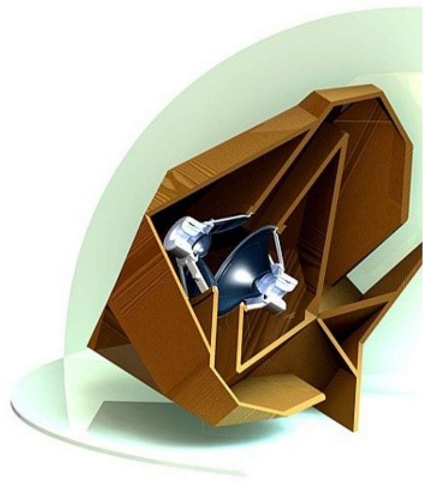

Figure 2. Corner Horn Partial Cross-Sectional View

Uniform loudspeaker membrane and suspension loading is achieved by a novel arrangement, wherein the membranes are placed parallel against each other and operate into a common, symmetrical, radially expanding horn throat, thus guaranteeing the membrane/voice coil stability under extreme displacement conditions.

Isometric symmetry is created in the physical horn realization, ensuring the same spatial spherical sound field symmetry. This is achieved by building three individual, identical two-folded sound propagating channels with isometric symmetry, operated in parallel and assuring symmetrical horn loading of the loudspeaker membranes from the room corner.

Special, suitable for radially expanding horns, single frame dual membrane loudspeaker driver is designed as an exotic High-End alternative, which strongly lowers overall horn system vibrations and weight, and considerably reduces front cavity volume, thus increasing the horn's upper cut-off frequency defined by that volume, an improving the system's symmetry. Partial cross-sectional view of this corner horn system is shown on Fig. 3.

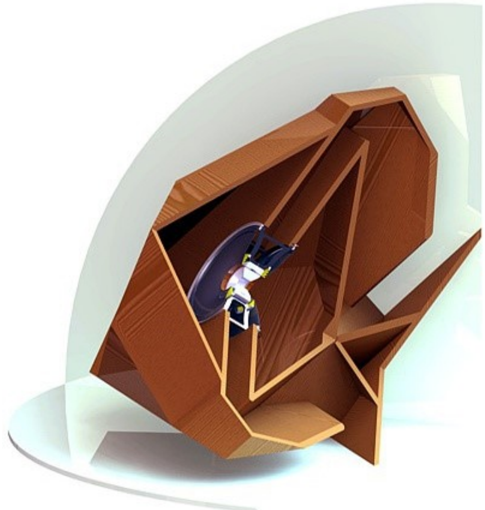

Figure 3. High-End Alternative with Single Frame Dual Membrane Loudspeaker

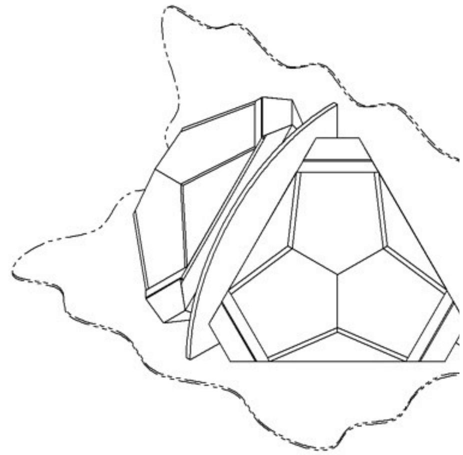

Figure 4. Corner Horn Multistacking Options a) Room Wedge π-Radiation

The corner horn is intended to operate in 3 surface room corners, yet able to be doubled and stacked for operation in 2 surface quadrupled for operation in half-space over a plane, or octupled to radiate in full 4π spherical octahedron space. All these mult options are shown schematically on Fig. 4.

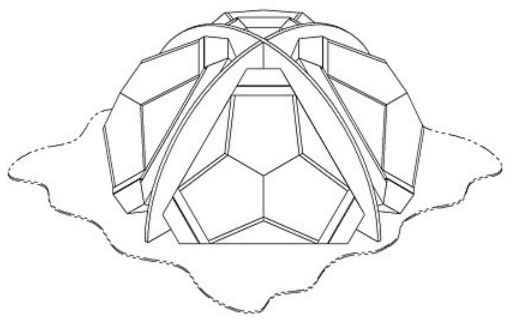

Figure 4. Corner Horn Multistacking Options b) On the Floor 2 π-Radiation

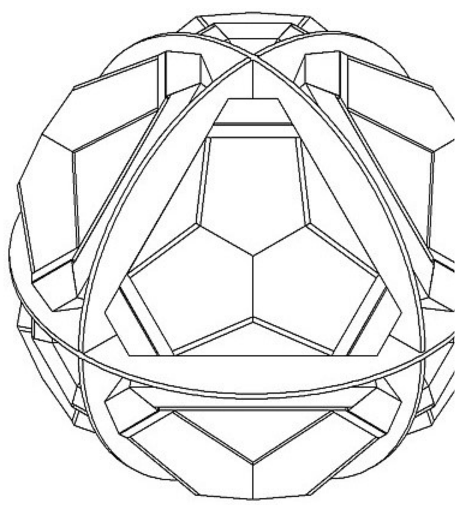

Figure 4. Corner Horn Multistacking Options c) Full Space 4 π-Radiation

OPERATION OF THE CORNER HORN

Both loudspeakers are driven in parallel by a single amplifier or by separate amplifiers, in both cases in-phase to one another, meaning both their membranes move towards one another during the positive sine wave half-cycle of the input signal, thus creating the compressing sound wave front, and opposite from one another during the negative sine wave half-cycle, thus completing the sound pressure wave form.
The sound pressure wave, created into the front cavity volume between the two loudspeaker membranes at the horn throat, propagates along the three input channels, whose input area collectively forms the horn throat. Each of these three individual sound propagating paths has substantially identical input area, substantially identical expansion rate, and they all have isometric symmetry in regards to the common embodiment and the corner axis.

For visualizing the actual sound wave front formation and spatial radiation, a typical software simulation program is used whose computational results are given on Fig. 5-7, showing 40Hz, 60Hz and 120 SPL radiation predictions. As an input data in the simulations, the actual SPL measured into the throat of the horn of Fig. 1 is entered as horn throat SPL in the 3-D model.

The horn system has a hyper-exponential expansion rate, with critical horn cut-off frequency of 30 Hz and constant T of expansion in the range between 0.5 ÷ 0.65. The latter figures result in efficient low frequency operation down to 30Hz. The horn system efficiency could vary within 35 ÷ 50 %, whereas the upper frequency limit and the actual efficiency figures depend on the Thiele/Small loudspeaker parameters. In the reduced to practice model, using specially designed loudspeakers with an effective peak displacement volume of around 2000 cm3, 1000 acoustic watts could be radiated with a 2400 watts PA in the frequency band between 30 Hz and 300 Hz, which is equivalent to about 42% efficiency.

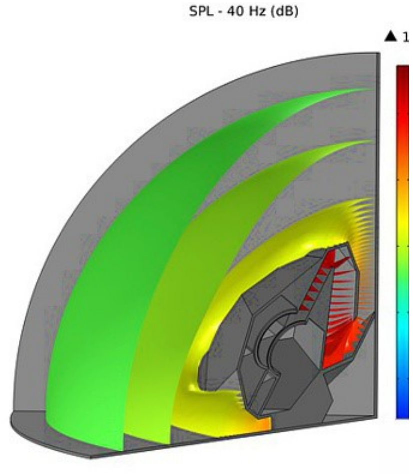

Figure 5. Simulated SPL Field – 40Hz

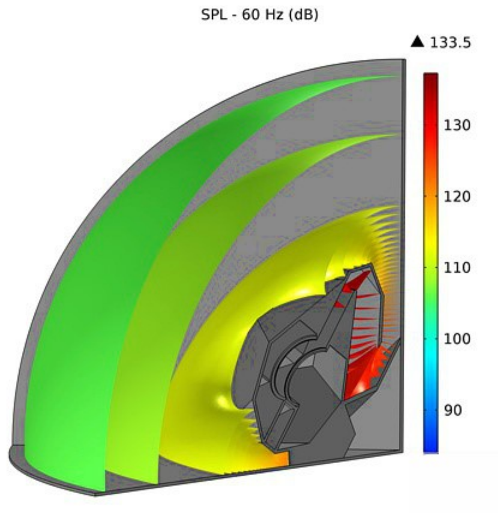

Figure 6. Simulated SPL Field – 60Hz

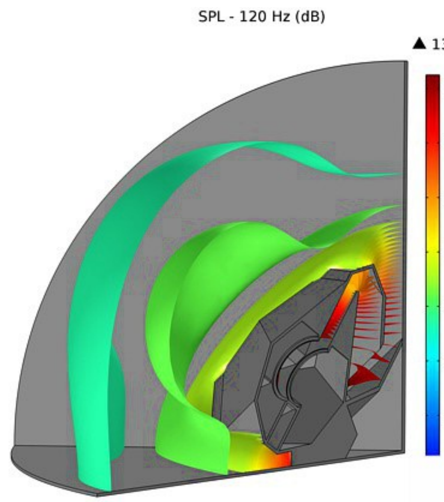

Figure 7. Simulated SPL Field – 120Hz

MEASUREMENT RESULTS

Measuring low frequency corner horn parameters is a very challenging thing, no matter outside or inside. Both cases insist on having symmetrical hard corner and lack of any reflections down to sub-30Hz frequency. Such conditions are not available in any anechoic and can hardly be found outside. Measuring inside the room is more sensible, as the most real usages of the horn will be there.

As the current corner horn design is intended to be used for both PA applications in big houses and for High-End applications in smaller rooms, the measuring procedure might be accomplished under either of these two conditions. As long as standardized sound power measurements are carried out either in free field or in relatively small reverberation rooms, this determined our choice to use a small room and to define corner horn sound power level frequency response as precisely as possible. Real free field measurements will soon follow outside, which is a matter of acceptable weather conditions and proper corner place availability, where the maximum SPL, SWL and distortion performance could be defined with much greater precision.

What we found readily available and pretty suitable as a room for our corner horn measurement, was a rectangular room with equal length and width of 4.6m and a height of 3m. This is a typical office room which has been lightly equipped and having a hard empty corner suitable for accommodating the horn, and uniform reverberation RT60 of 0.4 - 0.5 sec down to the lowest frequencies.

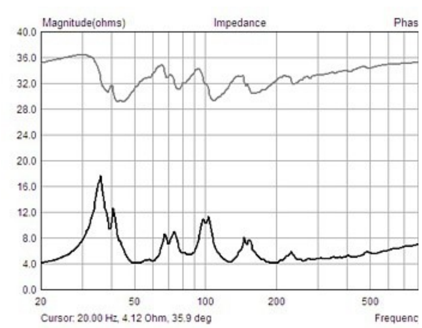

Figure 8. LF Corner Horn Complex Impedance

The measuring procedure is based on a P.V.Bruel [2] publication, defining SWL as dependable on averaged SPL level, defined by time a averages from a large number of microphone positions, and equally dependable on the room parameters RT, V, St and frequency. Th formula is:

$$L_W = L_P + 10\log\frac{V}{V_0} - 10\log\frac{T}{T_0} - 14 + 10\log\left(1+\frac{cS}{f8V}\right) \qquad (1)$$

where Vo and To are reference values of 1m3 and RT=1sec, while V, T and S are the actual room volume (65m3), measured RT fo frequency f (Hz) and the total room area (100m2).

Even though this technique for SWL measurement is actually offered for smaller sound power sources placed at a number of room po: will be used as the only one, to our knowledge, well-documented procedure. The influence of the low frequency modal room behavi corner horn impedance, loading and radiation performance might differ to some extent from that of much bigger houses or from field conditions, but as it is pointed out in [2] free field loading on the sound source radiation impedance is better at lower frequen the room loading. The real free field condition measurements are expected to show a bit better low-frequency loading and hi capabilities.

The complex impedance of the corner horn is shown on Fig. 8 and the room modal interferences are clearly visible.

Figure 9 shows the measured SPL values averaged over time and space for any 1/3 octave band center frequency between 25Hz and 315Hz, together with the calculated sound power level SWL using the actual room parameters and Equation 1. These measurement levels are obtained from 1W(4-Ohms) power applied to both loudspeakers, which might be used for direct reading of sensitivity or power level of the corner horn. Theoretical maximum sound power level of the corner horn system by using 2400W power amplifier should be 33.8dB higher than the SWL documented. The measured thermal compression of the loudspeaker components of less than 2dB at 600WRMS would bring about the same compression at full power excitation with sine sweep signal, not much longer than 5sec. So maximum SWL about 32 dB higher than shown on the current figures are realistic, which means radiated acoustic power approaching 1000W within the useful frequencies bandwidth.

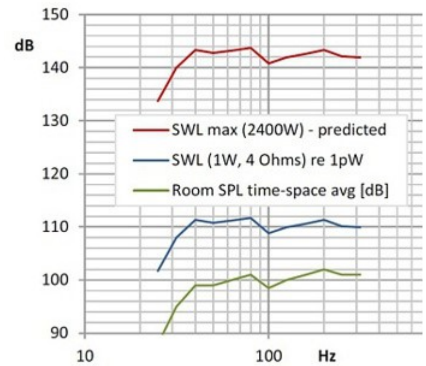

Figure 9. Corner Horn Sound Power Level - calculated f measured Room SPL time/space averages

As long as our room has typical small living room dimensions, it is very suitable to analyze room mode influence on the horn performance and to make suggestions for room-horn mutual operation optimization. The corner horn design should be made either for a concrete well-evaluated room (acoustically) in advance, or both room-horn combinations should be designed together.

This room modal behavior is the worst one possible, having two first modes coinciding with each other and their third mode coinciding with the second vertical mode at about 120Hz. This modal dist however, very well illustrates the importance of the room dimensional properties (ratios) on the frequency response evenness b Schroeder frequency, in the discrete standing wave (DSW) region.

SUMMARY AND CONCLUSIONS

This paper doesn't attempt to offer any new method of LF corner horn analyses design or construction. It only offers three nove which make the current design very practical and attractive for both PA and High-End markets:

• Doubling the membrane area Sd not just to double radiated power, but to increase extension rate (reduce the size) at the same hor frequency at the same time,

• Symmetrical opposing loudspeaker positioning, ensuring uniform membrane loading, symmetrical horn throat loading by the corner spherical radiation into π/4 space,

• Multiple stacking possibility by design, ensuring pure spherical π/2 radiation of two horn arrangements at the wall/floor boundary o of the stage operation in big concert halls, the same 4-fold operation at the middle of big arena floors or on the ceilings, and 8 spherical radiation in the form of a hanged cluster of eight horn systems.

Utilizing the three adjacent to the corner walls as part of themselves, the offered designs dramatically reduce their dimensional weights, and by clustering two, four or eight systems, the total weight might be kept low, because the artificial boards between horns are symmetrically enforced on both sides, and might be relatively thick and lightweight.

Comparative analyses against grouped bass reflex systems for big venue sub-woofer applications, revealed a much better weight/e ratio. The same price performance advantage ratio could be expected from multiple horn systems with a shorter and better def bottom and more uniform audience coverage with less on-stage interferences.

For high-end application, the current design revealed the possibility of obtaining 100dB SPL in a typical room of 65m3 volume, ar reverberation time from a 1W power amplifier, which might be an extremely exotic single ended class-A amplifier with the same sub evaluated purist bass performance.