FLOATING WAVEGUIDE TECHNOLOGY

‘Floating’ Waveguide

A direct radiator loudspeaker has primarily two regions of operation: the pistonic region and the adjacent upper decade of spectrum. The pistonic region is defined as the frequency range between the mechanical resonance of the loudspeaker (lower) to the spectrum region where wavelength equals the radiating surface of the loudspeaker (upper). The pistonic region is the optimum region of operation for a direct radiator. The adjacent upper decade of spectrum – where wavelength is smaller than the device – has efficient energy output but is flawed by mechanical cone breakup modes and erratic directivity behavior. This region, while flawed, is important in many designs and is the critical region of operation for the invention.

The majority of all loudspeaker designs are simple two-way, which means they include two radiating elements (called drivers) – a high frequency driver (HF) and a low frequency driver (LF). This design choice is popular due to: moderate cost, design simplicity, and moderate package size. This arrangement is also the minimum number of elements that can reproduce the musical spectrum effectively. Within the professional loudspeaker marketplace, larger LF’s (>10”) are often favored because of improved low frequency performance and overall acoustical output. In this case, the region above pistonic behavior has to be utilized.

The operating region that includes the transition frequencies between the HF and LF drivers is called the crossover region. Performance in this region is specifically a function of the acoustic summation of the two drivers. The distance between drivers is a major contributor in determining the stable operational radiation solid angle for the crossover region. A major design goal for the crossover region is for this solid angle to match the operational radiation envelope of the individual drivers (which should also match each other). A larger driver displacement translates to a smaller crossover operational angle with erratic behavior outside this solid angle. For a professional loudspeaker, whose primary design goal is to present uniform sound coverage to a large audience area, this is non-trivial because most of the audience is in the off-axis area and the crossover region occurs in the center of the sound spectrum. The result is missing and/or distorted audible content to a large portion of the audience with the problems typically in the speech region.

The invention presented greatly improves crossover region performance of two-way loudspeakers utilizing large LF drivers. The invention specifically aids in abating all three issues cited above.

These are stated again for clarity:
1) poor off-axis directivity in the crossover region due to displacement between drivers;
2) poor directivity from the LF in the region above pistonic behavior; and
3) poor LF performance due to cone breakup.

The invention, in short, forces a condensed geometry between the drivers and then ‘floats’ a midrange waveguide in front the LF as a means to mitigate the above mentioned issues. This design has some similarities with coaxial designs, but is specifically not coaxial. This is a hybrid design meant to benefit from the close proximity of acoustic centers without introducing a central axis obstruction for the LF driver. In addition, and specifically unique, the LF and HF waveguides and associated acoustic elements are used to redirect very low frequency energy not supported adequately by the LF waveguide to exit freely using other paths. The details of this are explained below and include several key functional steps.

Note: It is assumed the HF driver is coupled to the horn or waveguide, which is typical for professional two-way loudspeakers and necessary in this invention.

Step 1 - Condensed geometry between HF and LF

The typical and easiest placement of drivers in a loudspeaker is on a vertical line on a simple baffle. The displacement between drivers, in this case, is dependent on driver size. For two-way designs with large LF drivers, the displacement is prohibitive to good crossover behavior. Diagram 1 is a best case simplification to the actual acoustic result.

The diagram shows the foundation of the crossover summation equation. Each driver radiates acoustic energy, and if viewed instantaneously, this energy is in the form of individual pressure waves. Each wave has a propagation speed (speed of sound in air) and therefore has a time of flight to travel from driver to listener. For good crossover summation, the HF energy wave and the LF energy wave must align within ¼ wavelength. When drivers are displaced, an included angle develops where the waves are in alignment and the summation is positive. Outside this angle, summation is largely subtractive. The loudspeaker design goal is to align drivers such that the path length alignment angle encompasses the directivity angle (intended operational angle of the loudspeaker).

DIAGRAM 1

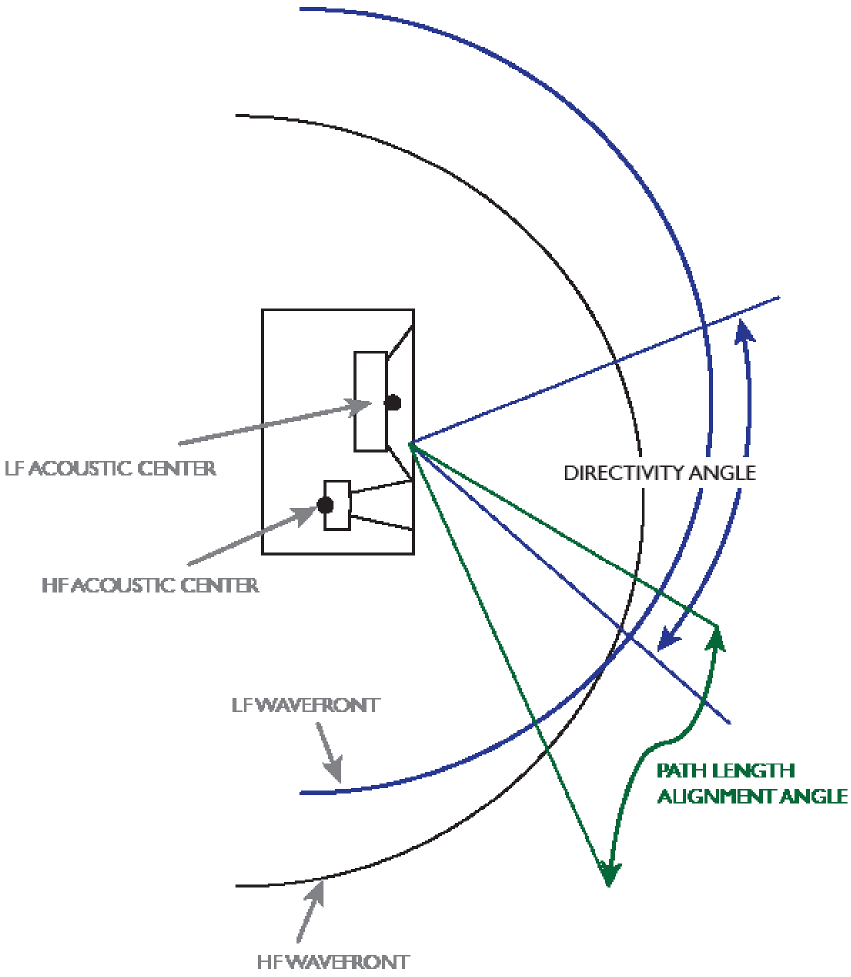
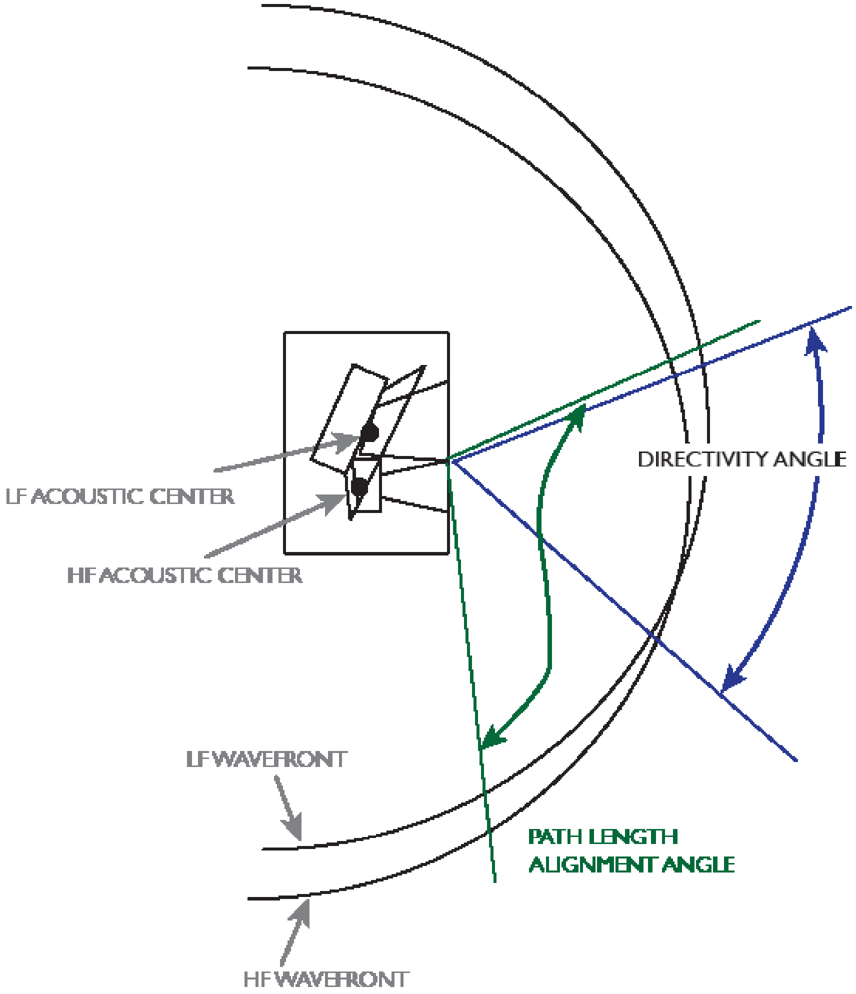


Diagram 1 is a best case simplification to the actual acoustic result. First, there is a 3dB differential between coherence and ¼ wavelength summation (i.e, there is 3dB variance within the alignment angle). Second, the actual phase waves of the drivers are much more complex (and frequency dependent) than the simple equal path length circles drawn from the acoustic centers. The diagram shows the foundation of the summation equation, but the actual alignment angle will always be smaller than shown.

There are several design manipulations (all with corresponding design penalties) that can center the alignment angle inside the directivity angle. This is helpful, but does not enlarge the alignment angle. The only way to expand the alignment angle is to bring the HF and LF acoustic centers closer together and have the phase wave of each driver be similar in shape.

The invention utilizes a condensed geometry between the HF and LF elements. This can be accomplishied in numerous ways (including use of phase plugs) and the exact technique is not critical to the invention. The first product utilizing this invention (JBL 9350 cinema surround) uses a geometry similar to the one shown in Diagram 2.

DIAGRAM 2



Step 2 - Midrange horn on LF driver

The motivation for the condensed geometry should be clear. This means, however, the LF is no longer a simple direct radiator. It now has acoustical obstructions in the form of the HF device near the LF radiating surface that impedes the crossover region frequencies. This gets to the foundation of the invention – how to achieve a condensed geometry while maintaining good acoustic behavior from the LF at all operating frequencies.

One major element in the invention is the use of an LF waveguide with a specific size – much smaller than a traditional low frequency horn. In fact, the size must be chosen carefully to mate with the HF horn since it must align to it. Further, to mitigate the effects of cone breakup and narrowing directivity, the LF waveguide throat (coupling to the driver) must be considerably smaller than the LF driver radiation surface. The waveguide mouth (coupling to free air) is then sized appropriate to waveguide design practice and to support the directivity criteria. The design specifics for the waveguide can vary as long as these two criteria are met: 1) the waveguide mouth area is larger than the LF radiating surface area and 2) the waveguide length and shape is strategically chosen to mate with the HF waveguide to maintain proper phase wave relationships.

Typical LF waveguide/horn design follows two methods. One is meant to support low frequencies. In this case, the horn couples to all of the LF radiating surface and must be large enough to support lower frequencies. The second method is meant to support the midrange frequencies and follows compression driver techniques (i.e, the driver fires into a compression chamber (– with or without a phase plug) – and then couples to the horn). This can significantly improve the high frequency performance but greatly diminishes low frequency performance (effective radiating surface is diminished and the compression chamber introduces a new compliance to the system).

Waveguides are frequency-selective devices. The invention mitigates this property by not forcing all frequencies through the waveguide. By proper positioning and size, the LF waveguide in the invention must be optimized for crossover frequencies understanding these are also outside pistonic behavior.

Step 3 - Floating waveguide

The condensed geometry is the primary motivation and the smaller LF horn is a means to mitigate poor driver behavior in the crossover region. The unique element of the invention, however, is allowing the LF waveguide to 'float' in front of the LF driver.

Allowing the LF waveguide to float provides a means to effectively extract the higher frequencies from the radiating surface directly into the LF waveguide (designed to support these frequencies) without the use of a compression chamber and forcing all frequencies into the horn. Therefore, frequencies not optimum for the LF horn are allowed a different radiation path. For best design, several paths are necessary for good performance. These paths are created using numerous acoustical elements and are primarily formed to address different frequency regions.

The example method will be used to describe the technique. The 9350 cinema surround has two internal chambers. The rear chamber houses the LF driver in a vented box design. The front chamber is formed by enclosing the space directly in front of the LF driver and behind the two waveguides. The front chamber includes 7 exit paths for LF energy. The primary exit is the LF waveguide itself, which is the critical exit for the crossover frequencies.

As described earlier, the LF waveguide throat is smaller than the LF driver diaphragm. Floating the waveguide does not force all LF energy into it, therefore, a portion of energy is divided between LF waveguide and other exits. Energy will follow the path of least resistance and the invention utilizes this property to optimize performance. Placement of the LF waveguide throat near the center of the diaphragm creating a close coupling to the voice coil promotes the higher crossover frequencies to enter the waveguide. Crossover frequencies that are generated by the outer portions of the diaphragm are, in general, the energy that produces the erratic behavior outside the pistonic region of operation. Therefore, this energy is not allowed to exit other paths. The use of extensive absorption treatment inside the front chamber and dividing the outer rim energy into different paths is important in this regard.

The use of multiple paths now requires the energy from these paths to acoustically sum back together at the listener. The same ¼ wavelength alignment requirement is true for this energy as it was described for the crossover energy. Thus, each secondary exit will have a path length requirement and a frequency dependency critical to this alignment.

The frequency region just below the effective operation of the LF waveguide is the most difficult to maintain in the design. These wavelengths are small enough to be greatly affected by the obstructions in the front chamber and also have difficulty aligning to the LF waveguide energy. In the 9350, three exits are primary for these frequencies and include a direct opening above the LF waveguide and the two slender openings on the side walls. The top opening provides a very direct path out for the energy on the upper edges of the diaphragm. This exit meets the ¼ wavelength requirement for all frequencies produced by the LF. The slender exits are very specific to a small portion of energy from the left and right rim portions of the diaphragm.

A critical element in the design is the use of a driver load plate. This element accomplishes several important functions. The first is to provide a safe landing for acoustical treatment between the waveguides and the driver critical to suppressing crossover energy trapped in the front chamber. The second is to prevent energy from directly pressurizing the rear surface of the waveguides. In concert with the rear wall exits, the load plates provide a direct path out of the front chamber from the bottom portion of the diaphragm.

The 9350 design allows the rear chamber vents to radiate into the front chamber. This was actually a compromise in the design to meet certain manufacturing processes. Ideally, these ports would have radiated directly into free air. This requirement and other aesthetic requirements dictated a certain front chamber size requiring the rear and bottom exits to be optimized to mitigate internal standing wave modes.

A front chamber is not a necessity for the invention, but very useful. Rim energy from the diaphragm must be broken into separate paths and not allowed identical symmetric paths back into free air. Crossover energy from the diaphragm rim must be largely absorbed.

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