MULTIPLE PATH DECOUPLING

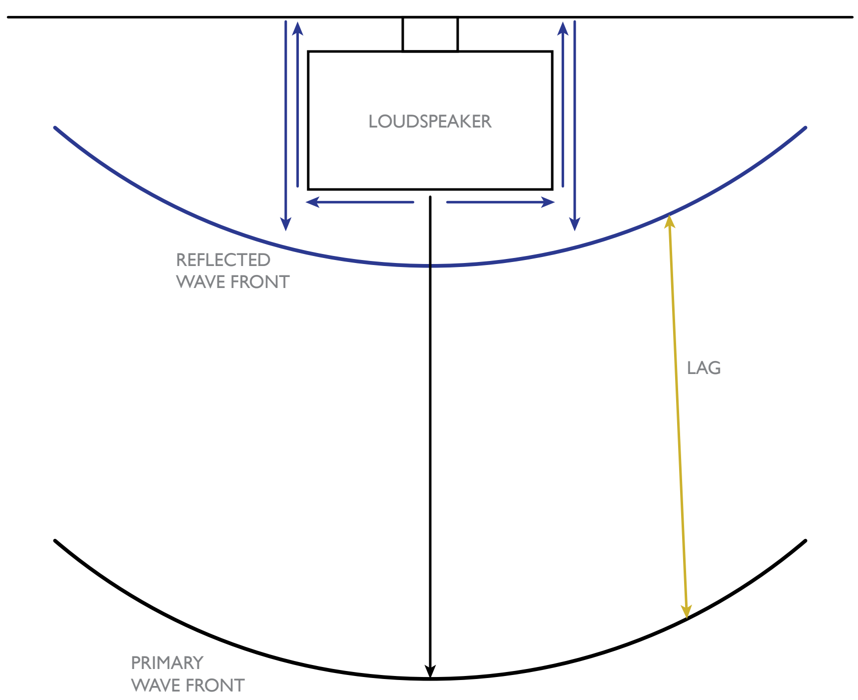
Multiple path acoustic wall coupling for suface mounted loudspeakers

An acoustic source radiates energy into its surroundings. If this source is an engineered loudspeaker, its radiated energy has an envelope shaped to present uniform energy to the audience. The ability of a loudspeaker to control its radiated energy in this way is diminished at lower frequencies, where wavelengths are larger than the loudspeaker itself, and acoustic energy radiates in all directions equally. In this case, the loudspeaker is said to be omnidirectional.

There are numerous situations that require loudspeakers to be surface mounted on a wall. For clarity, this does not refer to 'in-wall' loudspeakers which requires cutting into the wall and the loudspeaker effectively becoming part of the wall. The invention is specific to on-wall loudspeakers which are selfcontained and use some form of mount to secure them to the wall surface. The distance between the radiating opening of the loudspeaker and the wall itself becomes a critical dimension. In the frequency ranges where the loudspeaker radiation is omnidirectional, the acoustic interaction of the wall becomes a fundamental part of the loudspeaker characteristic behavior.

The detail of this can be explained as follows and is described in the graphic below – in general terms and at any given snapshot in time - ½ of the omnidirectional energy radiated from the loudspeaker is generally directed towards the audience, the other ½ radiates towards the wall. Typical wall construction forms an acoustic reflector for these frequencies (most absorption materials are not effective at low frequencies). The resulting energy contains two wave fronts, one direct and one reflected. They are near equal magnitude but with a time lag between them. This lag relates directly with the speed of soun transit time from the radiating opening of the loudspeaker around the perimeter of the loudspeaker to the wall and back. The nature of the reflected wave is a function of the loudspeaker and the acoustic characteristic of the wall.

For most wall mounted loudspeakers, the lag time between the two wave fronts is in a range between 1 – 5msec depending on mount size and loudspeaker size (corresponds to 14"- 68" pathlength delta). In these time ranges, the resulting sound experience is effected negatively with certain frequencies being canceled out and others being accentuated. In the case of the canceled frequencies, the problem is severe as electronic equalization cannot resolve the issue. The frequency response on the following page shows the resulting frequency response with a 3.7msec lag time reflected wave.



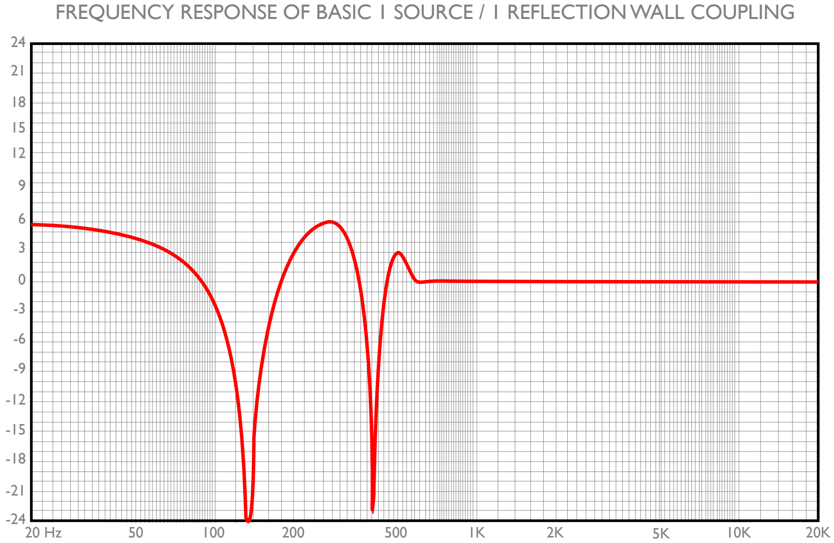
The graph below shows the cancelled frequencies near 150Hz and 400Hz. Near 300Hz, there is an energy peak. The primary wave front, without the reflection energy, would be an ideal flat line at 0dB in this simulation. Thus, the reflected energy creates both the cancellations and the peaks. For reference, all simulations are intentionally made 'flat' above 500Hz for simplicity in the discussion.

In contrast to the discussion above, there is benefit from the reflected energy when the lag times are small in comparison to the wavelengths involved. In this case, the effective output of the loudspeaker is nearly doubled as the audience now receives all of the omnidirectional energy. This is evident from the graph above for those frequencies below 60Hz. The invention utilizes this property to resolve the cancellation problem by breaking the energy into multiple arrivals. Instead of a singular source as with typical loudspeaker design, the invention uses multiple sources in strategic locations on the enclosure. There are no longer two wave fronts established as described earlier, but a series of wave fronts, both direct and reflected, with lag times between them strategically chosen to mitigate any discernible cancellations.

The technique used to achieve the stated goal can be executed in several different ways. The use of redirected energy from a single driver is one scenario. The use of multiple drivers is another. Both can achieve the same results with the driver scenario having the most design flexibility. The term 'source', for purposes of this description, can be either an acoustic exit or a separate driver.

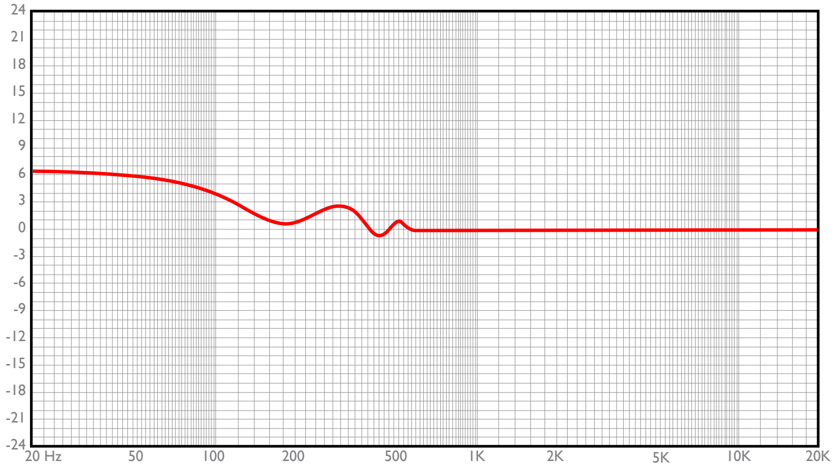
The energy arrival lag times and their individual energy magnitudes cannot be arbitrary for good performance. With mathematical similarities to diffusion number theory, only certain combinations actually smooth the response and avoid severe cancelations and peaks. Investigation is on-going to seek an analytical formula, however, this is not absolutely required as a computer optimizer routine also provides good results. Several simulations created using the optimizer routine and an actual product are shown to support the theory. Three simulation solutions are presented, each with different results and based on different design variables. The corresponding magnitudes and lag times for each source or reflection is shown adjacent to each graph. All simulations are based on the same enclosure as modeled in above. In each case, new sources (and their associated wall reflections) are added with optimized magnitudes and lag times to mitigate the cancellation notches. Therefore, the primary energy and its 3.7msec reflection are maintained in each solution.

FREQUENCY RESPONSE OF BASIC 1 SOURCE / 1 REFLECTION WALL COUPLING



MAG	LAG	
1.0	0	USEC
1.0	3,700	USEC

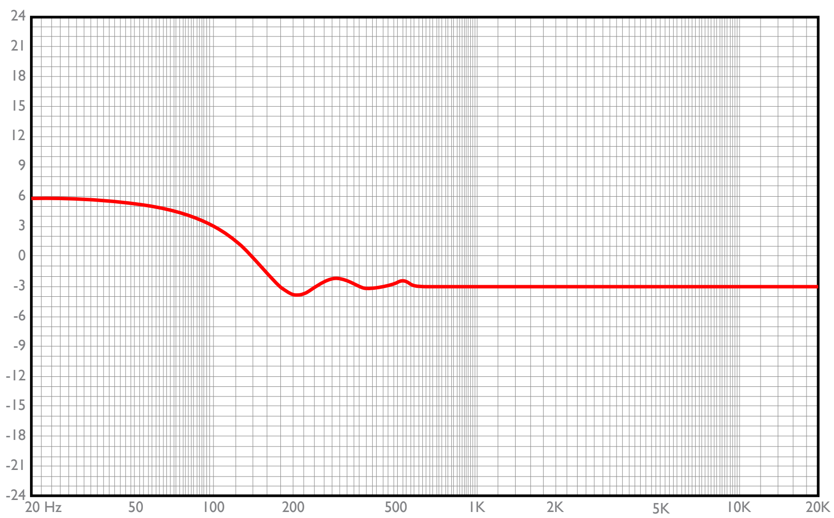
FREQUENCY RESPONSE OF 4 SOURCE/4 REFLECTION SOLUTION



MAG	LAG	
1.0	0	USEC
1.0	107	USEC
1.0	229	USEC
1.0	251	USEC
1.0	316	USEC
1.0	880	USEC
1.0	2,123	USEC
1.0	3,714	USEC

The first solution shown above includes a design with four sources (and their reflections) each with equal energy magnitude. This solution has the desirable property there is only 6dB differential between coherent summation and incoherent summation, which is the best case scenario. This solution is a mathematical possibility but not practical. Executing a design with four sources and reflections with the level of precision required would be very difficult, but not impossible. Solutions 2-3 are simpler in nature and assume two sources, a primary and a secondary, which are considered practical and effective.

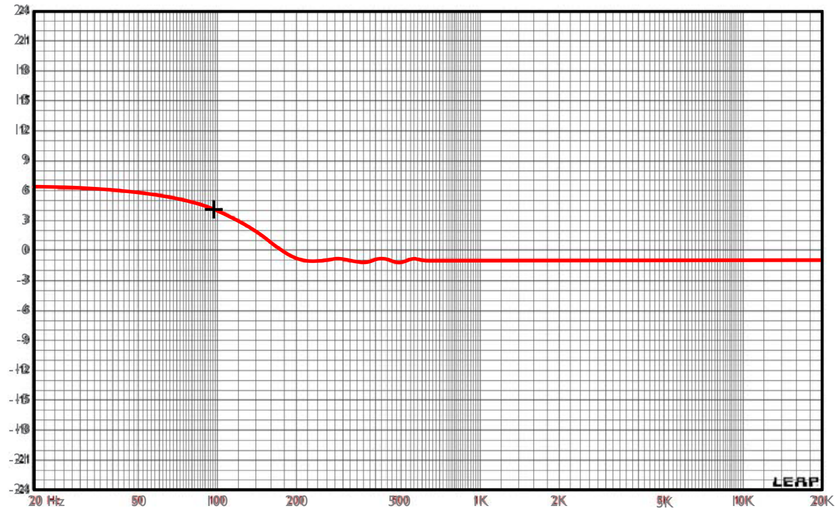
FREQUENCY RESPONSE OF 2 SOURCE/2 REFLECTION WALL SOLUTION



MAG	LAG	
0.70	0	USEC
0.90	1,104	USEC
0.60	1,720	USEC
0.60	3,730	USEC

The second solution shown above includes two sources and two reflections. The lag times are achievable if one source is on the face of the loudspeaker and the second is on the rear of the loudspeaker. This solution has 9dB differential between coherency and incoherent summation, which could be usefulin some designs.

FREQUENCY RESPONSE OF 2 SOURCE/1 REFLECTION WALL SOLUTION



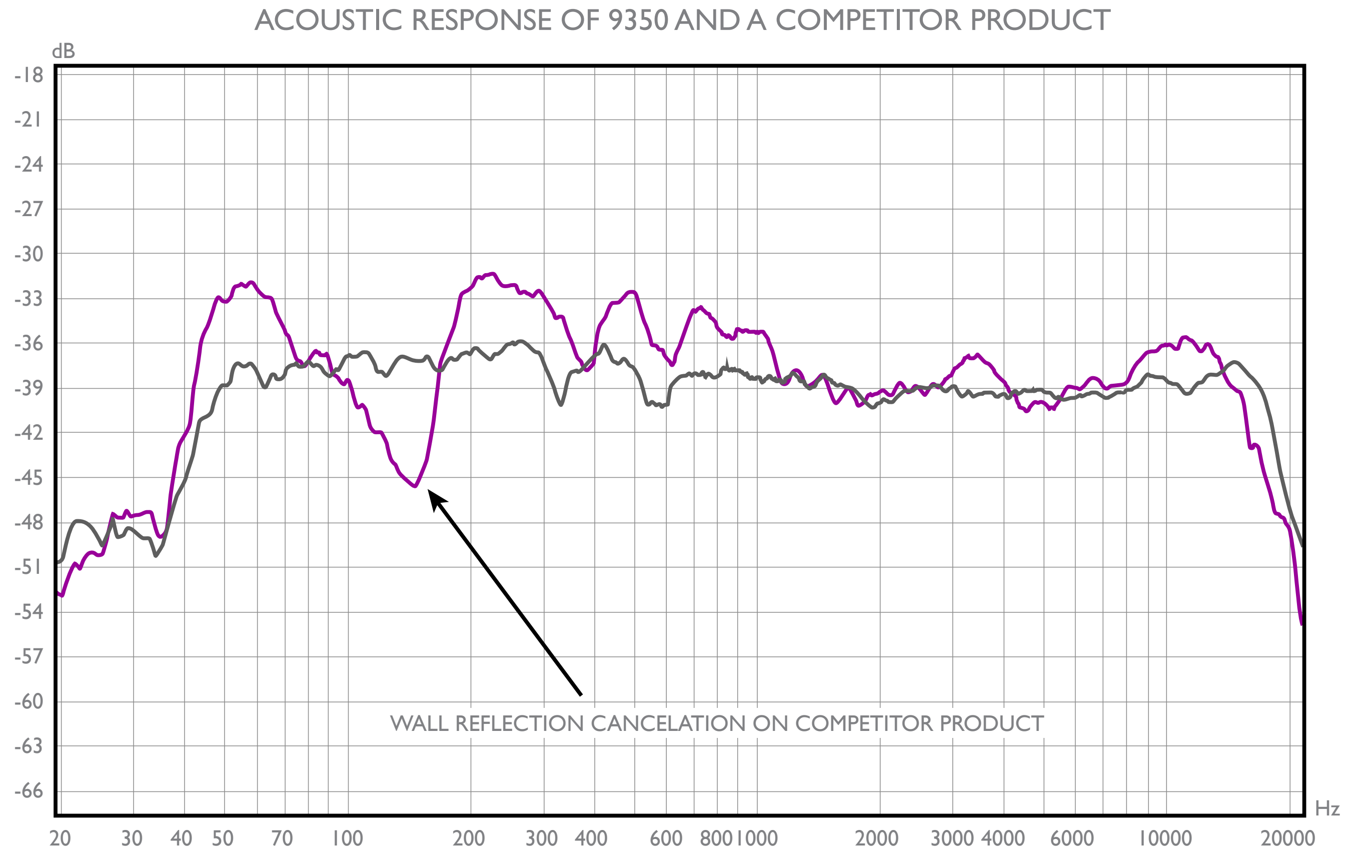
MAG	LAG	
0.80	0	USEC
1.65	1,354	USEC
0.50	3,700	USEC

This solution is the most intriguing of all and the easiest to implement. This includes two sources and one reflection. This is achievable with one source on the face and one on the rear. In this case, the mount distance and location of the rear source are such the direct energy and its reflection are indistinguishable (<100usec lag time in this example). The summation of the direct and reflected will naturally be a factor 2x if they are truly coherent, which tracks with the magnitude shown. The overall response is very smooth and the 7dB differential between coherency and incoherent summation is very good.

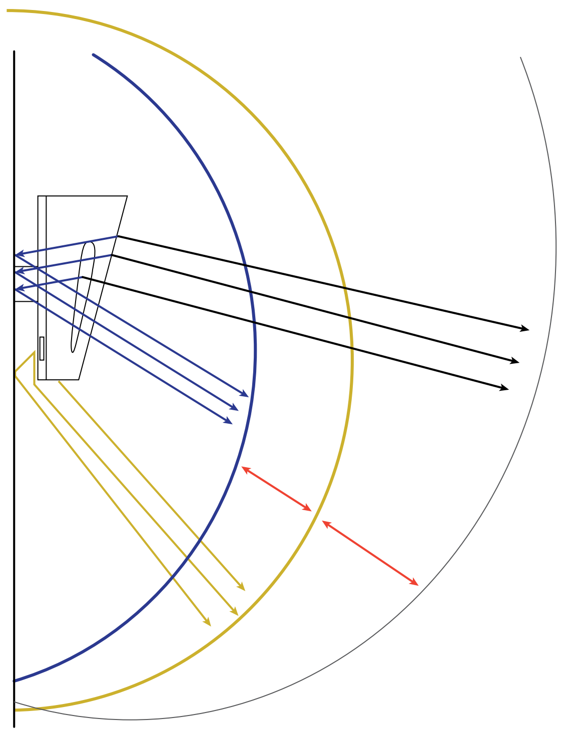
JBL 9350 Premium Cinema Surround

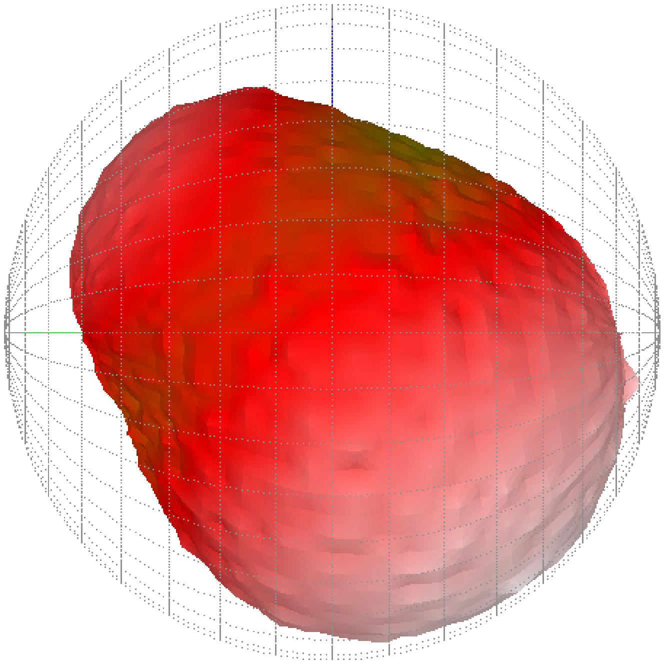
The first product using the invention is the JBL 9350 premium cinema surround. Typical of professional cinema surrounds, it surface mounts to a theater wall with a mount holding it between 4-8" off the wall. Drawings of the overall design are included and details the redirect mechanisms (load plate, triple horn body, and enclosure front cavity). The enclosure uses 7 exits for release of the low frequency energy (LF horn, top exit, bottom exit, 2x side exits, 2x rear exits).

The application for the product is such that the acoustical energy below the loudspeaker is the most important (towards audience) and therefore, the target 'axis' of the loudspeaker is approximately 30° down. In this orientation and particularly at angles between 30° and 60° down, the loudspeaker exit lag times are similar to Solution #3 above. The LF horn, top, and side exits are within 100usec and act as one arrival. Their reflections, likewise, act as a second unified arrival. The two rear and bottom exits and their reflections are close enough in time to also act as one arrival. Therefore, there exists three major wave front arrivals at these target angles with favorable lag times, mitigating the cancellation notching which occurs in the competitive products shown in the overlay graphic below.



The graphics below compare a simple interpretive view of the wave front arrivals of the 9350 next to the actual 200Hz radiation balloon of the 9350.





Further evidence of the two source arrangement within the 9350 is the radiation pattern of the loudspeaker shown above. The downward tilt in the pattern is not possible with one omnidirectional source. The radiation pattern is a result of the combination of sources presenting two wave fronts which sum together on the downward angles.

Note: The radiation balloon was measured with no wall interaction present but indicates the presence of two sources.

8500 Balboa Boulevard, P.O. Box 2200
Northridge, California 91329 U.S.A.