New trends in loudspeaker design for cinema applications

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It has long been known in audio circles that sound system performance in a closed space heavily depends on the acoustics of that particular space. The acoustics of that space depends in large part on the geometry of the room, materials, physical obstructions, and special design features. Even the "best" speaker system available may produce less than desirable results if the room acoustics are not acceptable. The major factor that concerns acousticians and sound system designers is room reflections; reflected sound energy from the surfaces (walls, ceilings, fixtures and furnishings, etc) in the room. Reflections can be good and bad; in a concert hall, for example, reflected energy significantly contributes to the overall sense of enjoyment of a live symphonic orchestra. In a movie theatre, however, a large percentage of reflections at the wrong frequencies can be detrimental to the enjoyment of the film.

The problem is *time*, or more specifically the *length* of time it takes for sound to travel from the loudspeaker to the listener. And since the loudspeaker is attempting to provide sound over a large listening area, it is nearly impossible to prevent sound from reaching interior surfaces first, from which the sound will reflect and reach a given listener a some time later than the direct sound from the loudspeaker. The two arrivals of the sound energy in the same frequency band can cause certain parts of that frequency band to "cancel" and certain parts to sum together – in both cases the original sound is altered by room acoustic if this happens to a significant degree.

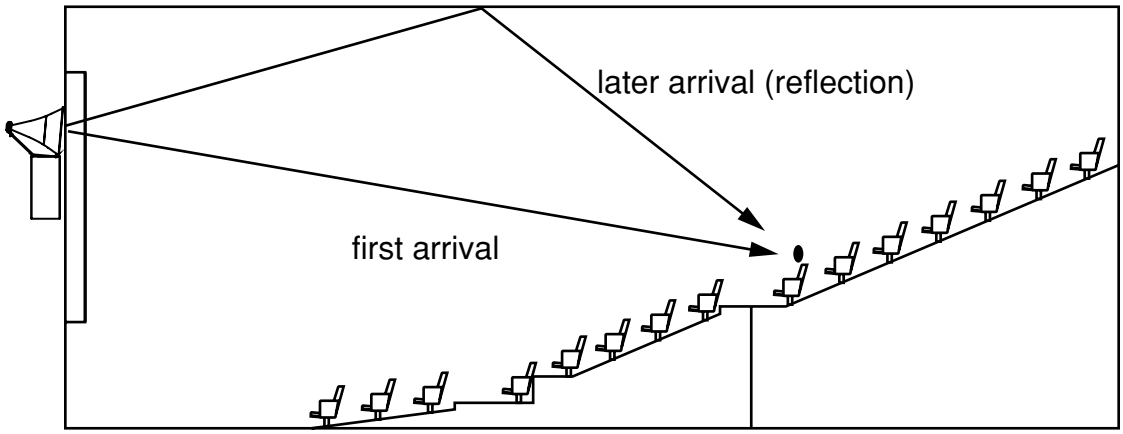

Fig. 1. Listener in seating area receives a combination of direct and reflected sound energy.

You might think the answer would be to create rooms that allowed no reflections (anechoic), but this tends to result in a very uncomfortable listening environment for a cinema experience. Perhaps this is because a "dead" room with no reflections takes away from the sense that we are in a big room, watching a larger than life image with other people – and this, many argue, defines the "movie experience". The attraction of this experience is why cinema exhibition thrives even in the face of the popularity of "home theatre".

So if the sound system must operate in a room that creates some degree of reflected energy, the obvious thing to do would be to design loudspeakers that controlled where the sound energy is directed – toward the listeners hopefully. But the history of sound systems in movie theatres did not necessarily follow this logic. Sound systems for cinemas evolved from loudspeakers designed for public address applications. Public address was typically speech only, and the environments in which these early systems were used ranged from outdoors to huge auditoriums and halls. In the early days there was not much thought given to controlling the directivity of a given speaker design. In later years, as the "constant directivity" horn developed in sound reinforcement, this same design was applied to cinema sound systems, and soon became "the standard". This standard still exists today. The horn pattern provided coverage over a range of 90 degrees in the horizontal plane, and 40 degrees in the vertical plane.

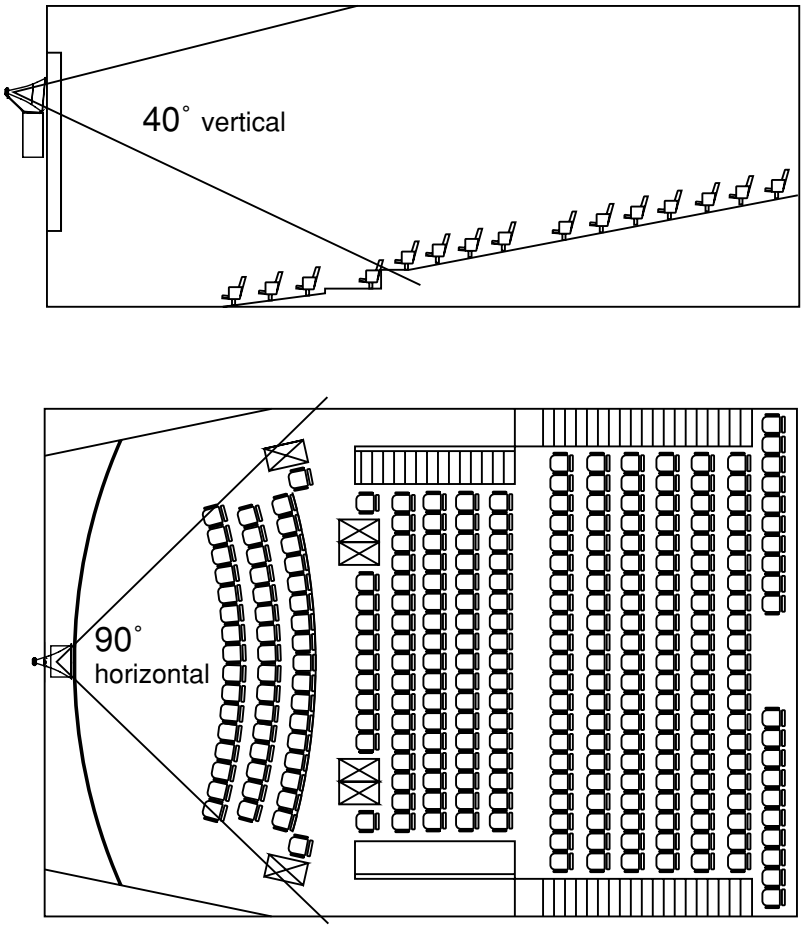

Fig. 2. Elevation and plan view of cinema, illustrating conventional 40 by 90 coverage pattern.

But beginning in the mid-90's a major theatre design trend began. Some will argue that "stadium seating" has really been around since the days of Greek theatre, and this is probably true. In any case, it is safe to say that new construction today is nearly 100% stadium seating, and many older theatres are retrofitting conventional slope floors to stadiums. This new steep rake floor is a change to the room geometry, and therefore, a change to the interior acoustics. Where the traditional 90 by 40 horn covered fairly well in moderately sloped theatres, the new room geometry presents new challenges to conventional speaker coverage.

Loudspeaker manufacturers have taken notice of this change in theatre design and have begun to offer a new category of horns to the cinema market to better address the new room geometry. Manufacturers such as JBL Professional, Electro-Voice (EVI), Sonics Associates, and Eastern

Acoustic Works (EAW) have all begun to offer three-way screen speaker systems with so-called "asymmetric" pattern horns. The main idea behind the asymmetric horn is that the pattern is no longer a perfectly symmetric 90 degrees (45 degrees laterally in each direction from a center point – "on axis") by 40 degrees (20 degrees above and below axis from the same center point). Now the horn's energy may be distributed directly on axis and downward, in the case of vertical asymmetry.

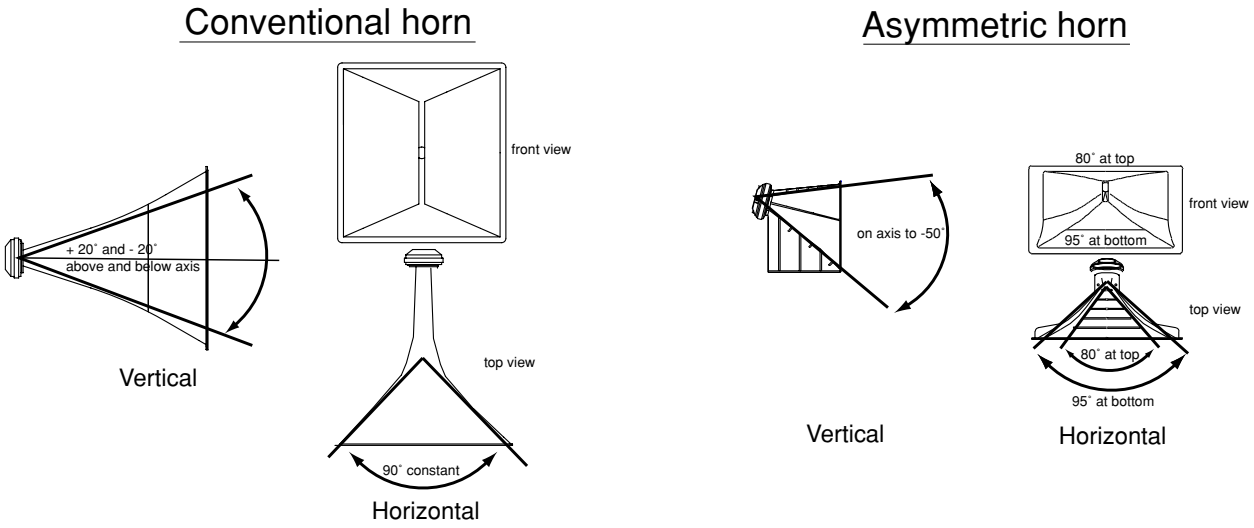

Fig.3. Comparison of vertical and horizontal coverage patterns of conventional and typical asymmetric HF horns.

The result is better coverage toward the back of a room and down the seating area, without sending energy to the ceiling, where reflections back into the seating might harm dialog intelligibility. Also, since the seats in the rear of the house are directly on axis but most distant, and the nearest seats are at the "edge" of the horn's pattern, the result is that the entire house is evenly covered with minimal variation in sound levels.

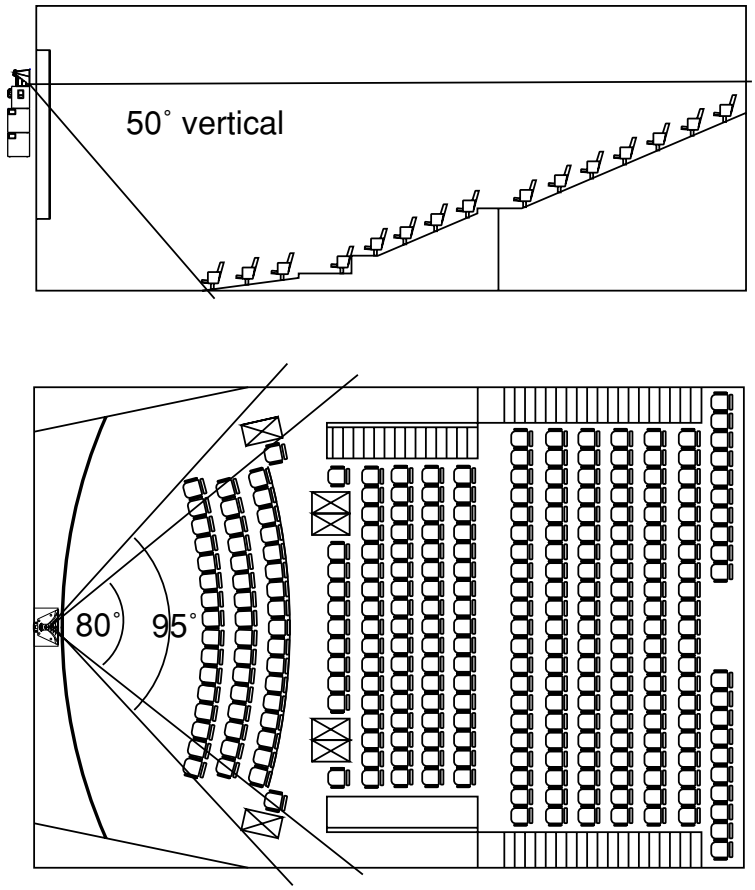

Fig. 4. Asymmetrical horn in a stadium seating theatre.

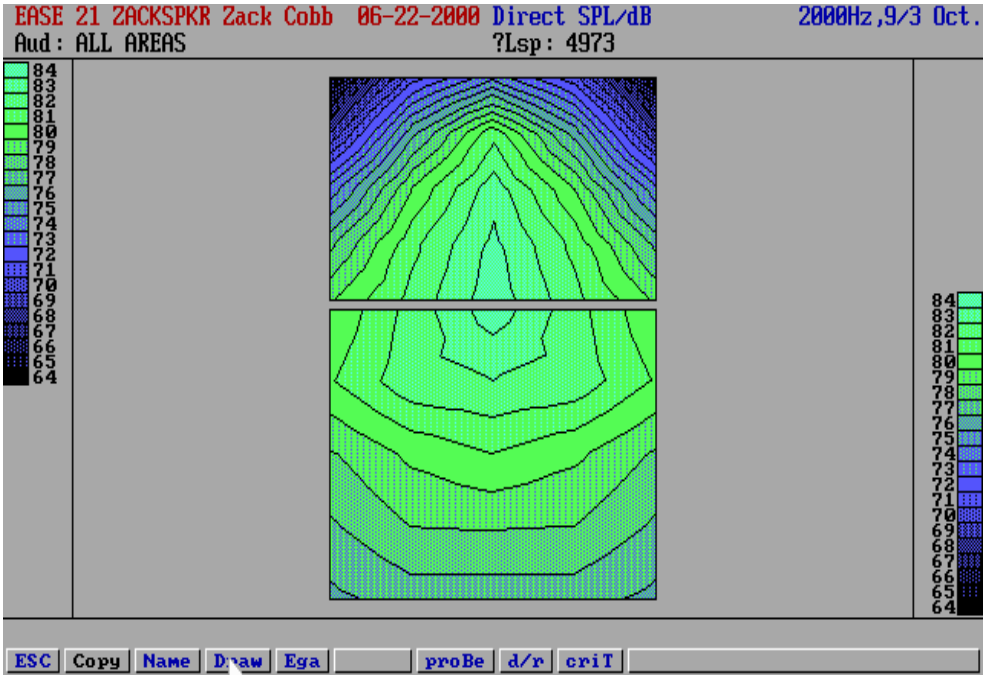

Fig.5. Coverage map simulation of conventional 90 x 40 horn, center channel only at 2 kHz. Note darker areas in front corners and variation of level from front to back.

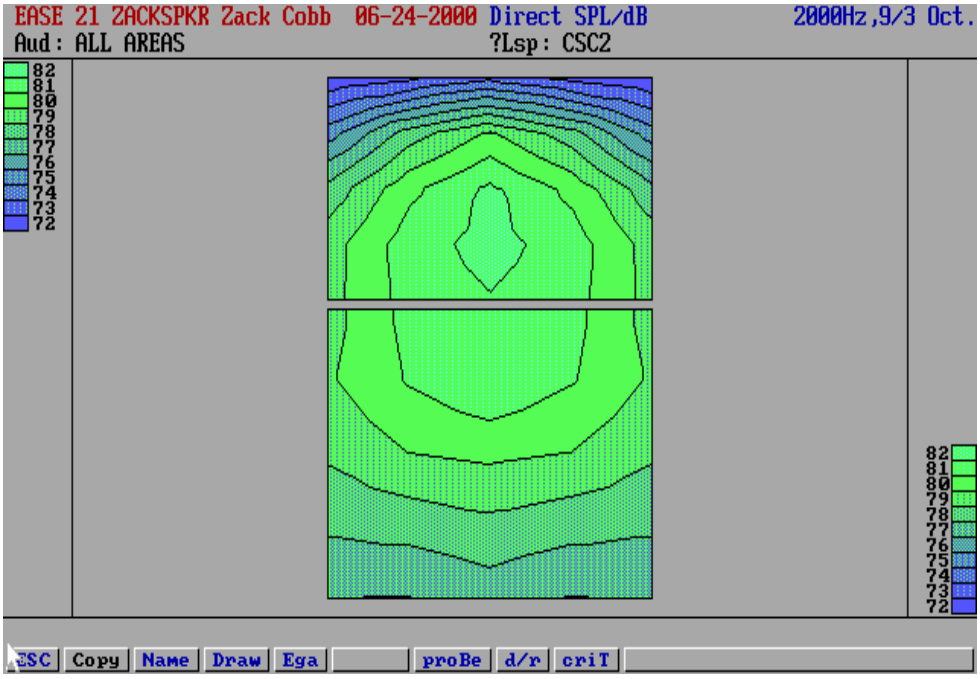

Fig. 6. Coverage map simulation of typical asymmetric horn, center channel only at 2 kHz. Note fewer variations front to back, and improved lateral coverage.

Asymmetric horns are not new in the world of loudspeakers. Altec Lansing began offsetting the compression driver on horn mount in the 1970's, which resulted in skewing the coverage pattern. JBL's model 4660, introduced in the mid-1980's, was a scaled down version of a larger asymmetric horn concept, and was targeted at rectangular room sound reinforcement applications, where the speaker could be mounted at the front of the room, on the ceiling. Electro-Voice's patented "Vari Intense®" horn design was implemented in a range of models targeted for small to medium fixed installation sound systems. It was not until the mid-1990's when the concept of asymmetric horns was adapted for use in cinema applications. The concept really began to make sense as the floor slopes increased with the rapid adoption of stadium seating plans.

The first product to feature the new (for cinema) design was the Electro-Voice "Variplex™" three-way screen system, introduced in 1997. The horn design uses the same basic concepts as their earlier "Vari Intense" system, but is adapted for both the midrange and high frequency

section in a THX-Approved system, and produces and asymmetric pattern in both the vertical and horizontal planes. In 1999, JBL introduced its "Screen Array" series of screen channel speakers, also featuring asymmetric mid and high frequency horns in a three-way system design. The screen array series includes models 3632 (for smaller rooms) and the model 4632 (for larger rooms and THX applications). That same year, Sonics Associates from Birmingham, Alabama introduced its S4 theatre system. Sonics has been the exclusive sound system provider for IMAX Corporation, but now has begun marketing their systems to the general exhibition industry. Their S4 system includes the model S4-500T (THX-Approved), S4-500, and S4-200 screen speakers, all of which feature a coaxially-mounted asymmetric high frequency horn inside a cone-loaded midrange horn. At CineExpo 2000, Eastern Acoustic Works (EAW) introduced its CSC Series screen speakers, featuring the THX-Approved model CSC923 for large rooms and CSC723 for medium sized rooms. Each of EAW's new CSC Series uses two-dimension (vertical and horizontal) asymmetric horns for both the midrange cone driver and the high frequency compression driver.

Fig.7. EAW s CSC923 and JBL s 4632 systems, featuring asymmetric mid and high frequency horn designs.

All manufacturers agree that, while the move to asymmetric horns was initially prompted by the steep-raked stadium style floor plan, even conventional moderately sloped houses are better covered by these "new" horn designs. The key advantage in both cases is that the on-axis (but distant) rear seats receive almost the same sound pressure level as the near (to the speaker position) but off-axis seats, without unnecessarily sending energy to the ceiling or side walls. Thus the front to back balance is improved, and potentially harmful ceiling reflections are minimized.

Although it has taken several years, major loudspeaker manufacturers are now developing and adapting horn designs that specifically address the needs of changing cinema designs. Ideally, advances in loudspeaker design should coincide with architectural and design trends, but interestingly there is no formal dialog between these two segments of the exhibition industry. Through such forums at the International Theatre Equipment Association, it is hoped that such advances can begin to move concurrently, and meaningful (and timely) improvements in the exhibition industry can continue far into the second century of cinema.