CREATING SOUNDS AT A DISTANCE IN SPACE

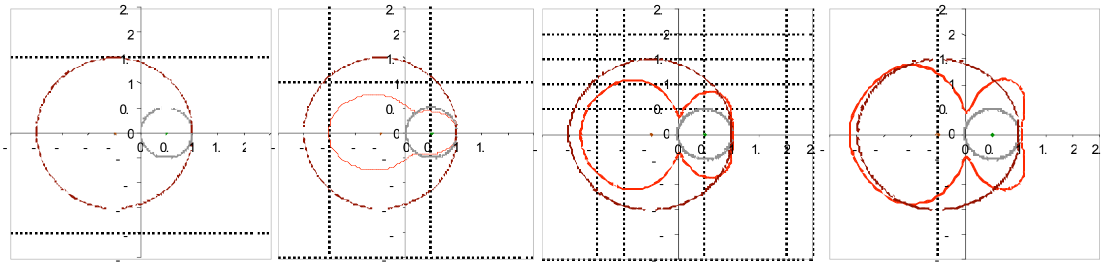
If we had a method to reproduce sound so that sound sources appeared to be placed or fixed in space, the reproduced sound would better match the original experience. The listener could then move and turn without destroying the experience. Ideally the method would be simple, cheap and backward-compatible with existing formats. Here is the background we need for one way to achieve this.

It is possible to create wave-fronts with controlled curvature by the use of multiple point sources if the signals fed to these sources are suitably processed. This will be explained using a simple example.

Figure 1 shows two point sources placed at two separate fixed locations. The first diagram shows the creation of wave-fronts from an acoustic impulse at these sources at an instant of time. The waves are expanding and the curvature of each circular (spherical) wave clearly tells you where the respective source is. If the wave front is viewed at a later instant of time, the curvature will be less because the wave has expanded more with distance (time).

It will have exactly scaled its increased divergence with the additional propagation time.

Launching of the wave from the right-most source has been delayed in time and so has not had time to expand as far or as much. The delay was selected such that the two wave-fronts arrive at a point on the right at the same time. If the observer was located to the right of the sources, the resulting wave-front measured (and heard) would be the sum of the two waves from the two sources. The intensity would be the sum of the two waves, but what about the wavefront curvature?



Two phase related sources in an array

Tighter curvature means closer than front loudspeaker

Parallel means way back at the vanishing point (horizon)

Beyond the horizon. Front-back confusion

FIGURE 1 VARIABLE DIVERGENCE WAVEFRONT

Put another way, where would we need to place a single equivalent point source so that the wave-front measured anywhere to the right was identical to the sum of the two waves?

The second diagram provides more clues. It shows the resulting sum of the two wave-fronts and indicates the effect of feeding a processed signal to the two sources that modifies the wave-front to “pinch it in” at the front in the direction of measurement (or listening). This wavefront now has a tighter curvature than the nearest source alone had, but only for the wave-front part propagating over a restricted angle to the right. This resultant wave-front would thus measure anywhere in this direction as if having been created by a source further forward than the closest loudspeaker location.

The third diagram shows a wave-front created by a different processing of the signals to produce a resultant parallel wavefront propagating to the right. This would behave as if it was created by a (potentially very loud) single source way back at the vanishing point or acoustic horizon behind the two sources.

Once the wavefront with a particular curvature has been created it will continue to diverge as if it came from a source location in space that is now not restricted to the locations of either of the actual sources contributing to recreating the wave, and in fact can place sources well away from the source locations. Each point on the wavefront will continue to propagate in the direction of the wavefront normal as if it were a freely expanding source in the medium [1].

The fourth diagram shows a situation that cannot occur with normal non-reflected point sound sources – the wavefront curves “inwards” and therefore represents a sound source “beyond the vanishing point”. An acoustic distance-measuring device seeing this wavefront curvature would be “front to back confused”, either interpreting the wave as a point source starting “back beyond the horizon” or “out-front behind it and getting louder”. The equipment would be front-to-back confused!

Placing sound sources at any distance along a line with two sources

The key point is that by using just two point sources (or two loudspeakers with carefully controlled polar responses) fed with suitably processed signals it is possible to place sound sources at will in a line at any distance from the furthermost distant limit (at the acoustic horizon) to appearing placed well in front of the nearest loudspeaker. The resulting wave-front, once created will propagate preserving the distance relationships for the apparent source. These placed sources will thus behave consistently for all observation (listeners) in the target observation area, including when off axis.

To generate the controlled curvature wave-fronts, electrical filters are used to process the signals fed to the two sources, the signal processing being relative to each other. These filters adjust the relative phase by the correct amount at each desired frequency to create the controlled divergence waves. The waves then expand out in the listening area as if created at a new point location in space.

Multiple sources can thus be placed using loudspeakers with appropriate polar response covering the desired observation area.

The design of these filters will take into account the nature of the loudspeaker radiation and the geometry of the array. The overall frequency response can be corrected independently with equalisation filters if required, as the phase control for source location can always be derived from one source signal to feed the other source loudspeaker.

The wavefront created by two loudspeakers in this manner will have restrictions on the extent of the listener area. More complex filtering and sectored loudspeaker geometries will be needed if extended listening areas are required. Examples will be described later.

The important point here is that this approach will enable the placement of sound sources that remain fixed in space as the observer turns and moves anywhere in the defined listening area.

Creating sounds placed at will in space is not restricted to single sound sources. Multiple placed sounds can be created simultaneously, and sound sources can be moved in space from the distant horizon or vanishing point up to being created well in front of the nearest loudspeaker of the array by controlling the phase of the signals fed to the array.

This approach has a second use. The method of placement adjustment would also allow sound sources placed at reproduction to apparently be moved away from the loudspeaker array used for reproduction.

This could be useful, for example, to correct the older surround formats where the loudspeakers cannot be physically placed ideally, or where the listener would like to shift the single sweet spot of these formats. The array correction would be fully independent of, and completely compatible with all source formats including stereo and surround.

It is hoped that correct sound field render and removal of all sweet spot constraints in the listening environment would be preferable to simply moving the sweet spot of the surround formats, but the compatibility issue is important.

No sweet spot in the listening area

We are now armed with the capability to place sounds at any desired distance in a straight line using frequency dependent phase controlled arrays. Whilst the source placement is restricted to being along a straight line, the listener location is not. The wave front divergence can be controlled over a wide range of listening angles. For example, the minimum radius divergent wave shown in the second graph of Figure 1 has consistent curvature (divergence) anywhere in the listening area defined by an angle in excess of 120 degrees centred on the closest source loudspeaker.

Listeners anywhere in the listener area forward of the second source would perceive the correct distance (and direction) of the created source location along the line. The sound sources created in this way would also behave consistently with listener head turning and movement - they would behave as real-life sound sources do.

This would be a significant improvement to the present day equi-distant surround sound formats.

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[1] Huygen's principle. Christian Huygens (1629-1695)