Research Residency

Having gained some experience with parabolic and simple conic reflectors for sound focusing in previous research with ultrasound, I decided to use the opportunity of this research to explore two somewhat unusual sound-focusing techniques.

The first of these techniques is based on an aerodynamic model of sound propagation (rather than a wave model). Figure 1 is a photograph of the experimental prototype speaker I made to test this technique. The driver (an Altec 403A 8-inch speaker), housed in a wood enclosure, is loaded by a cylindrical baffle in which is suspended a glass bulb. Compression air fronts, produced by the driver, flow around the bulb and form a compression airstream at the mouth of the baffle. (This same technique is used to produce a directed, concentrated airstream at the tail of jet engines.) The enclosure is ducted to enhance low-frequency response of the system, and the duct and baffle are wrapped in sound-absorbing fiberglass to reduce diffraction around the lip. Figure 2 is a photograph of the prototype without the glass bulb and fiberglass, revealing the baffle and duct arrangement.

This model was subjected to frequency-response tests at 1 meter both on- and off-axis. With secondary calculations, I used the frequency-response plots to obtain figures for the ratio between the on-axis and off-axis levels across the audio spectrum; these figures give a good indication of the directivity of the prototype. Figure 3 is a plot of these directivity figures against frequency for both the test model (dotted line) and the driver alone in a ported enclosure (solid line). The plot shows that in the region from 800 to 3,000 Hz, the test model is significantly more directional than the driver alone -- on the average, over 3 times more directional. That indication was easily confirmed in subjective listening tests: the model produced, in that frequency range, a concentrated sound beam

the boundaries of which one could clearly hear when moving back and forth in front of the model.

The success of this prototype in this frequency range suggests to me that a similar unit, suitably proportioned and damped against physical resonance (which, in the prototype, produced a loss of low-frequency directivity), may be effective at low frequencies where other focusing techniques run into problems with size limitations.

The second technique I researched is the use of a resonant air chamber, in the form of a Helmholtz resonator, activated by a compression driver. Figure 4 is a photograph of the test model, showing the glass resonator and driver mounted for testing. Figure 5 is a directivity plot for this model, derived in the same manner as was the plot of Figure 3. The significant peak at about 3700 Hz, which is the resonant frequency of the air chamber, indicates that such a resonator is indeed very directional <u>at resonance</u>, that is, in a narrow band around a single frequency. The loss in directionality at about 360 Hz (the dip in the curve), which is the resonant frequency of the glass bulb itself, is similar to the loss of low-frequency directionality due to resonance of the baffle in the other test model, above; this suggests that such physical resonances must be damped out in instruments constructed on either of these models.

A Performance With A Directional Loudspeaker

In May of this year, during a separate residency at Media Study/Buffalo, I had the opportunity to make a performance using a directional loudspeaker in an unusual acoustic environment: an empty indoor Olympic-size swimming pool. Figure 6 is a photograph of the directional loudspeaker I constructed for this performance. It is a conventional horn-loaded compression driver working into a paraboloid reflector, producing a beam of sound with nominally flat wavefronts.

In the piece, "Dry Pool Soundings," I fed this speaker a continuous train of clicks (20 Hz pulses) and, holding and aiming the speaker, moved slowly through the pool area, scanning the walls, floor, and ceiling with the click beam. The reactions of the space to the excitation of the beam were quite complex. Among other phenomena, images of the clicking sound appeared localized in different parts of the room; soft melodies in harmonic intervals were audible not in the room, but localized in the ear of the listener. I used my movements in the space to "play" these melodies as I heard them.

Directions of Present and Future Work

At this point in the project, my main goal is to apply the knowledge gained thus far to the construction of an array of directional loudspeakers covering the entire audio range. To this end, I am now working with speaker designers at Meyer Sound Laboratories, a consulting firm in San Leandro, California, to develop:

1) a focused low-frequency speaker combining a resonant air column with an aerodynamic focusing device;

2) a low-mid frequency focused speaker using the aerodynamic principle;

3) a high-mid frequency focused speaker using the Helmholtz resonator principle;

4) a high-mid frequency focused speaker using a hybrid driver and corner reflector;

5) a high-frequency focused array using parabolic reflectors.

I anticipate, however, that these tools will evolve constantly in an ongoing research, much as have the instrumental loudspeakers used for "Rainforest."

We now have collected enough information to produce an initial grouping of directional and focusing loudspeakers of a variety of types, capable of various degrees and characters of sound focusing. The task which lies before us, the use of these

tools interacting in performance with each other and with an acoustical environment, is easily as complex as the development of the tools has been; it's apparent that these complex interactions must now be studied. That study, however, can't proceed in a conventional laboratory: it must involve a real performance space, and real, musical signals. Moreover, only general conclusions may be reached, and the primary goal of the research now is achievement of a degree of flexibility and adaptability: since the character of the interaction of a given sound beam with a space is fundamentally dependent on the characteristics of the space, the work or works we make must be remade for each space.

My experience indicates that the character of that interaction is also dependent on the type of focusing arrangement used, and the frequency range in which it is used. I think, therefore, that the adoption of a number of different focusing techniques in overlapping ranges can help us attain the necessary flexibility. Use of auxilliary signal processors such as phase shifters, analog delays, active crossovers, and so on will also increase our flexibility. A clearer picture of the effect of each of these variables will develop in practice.