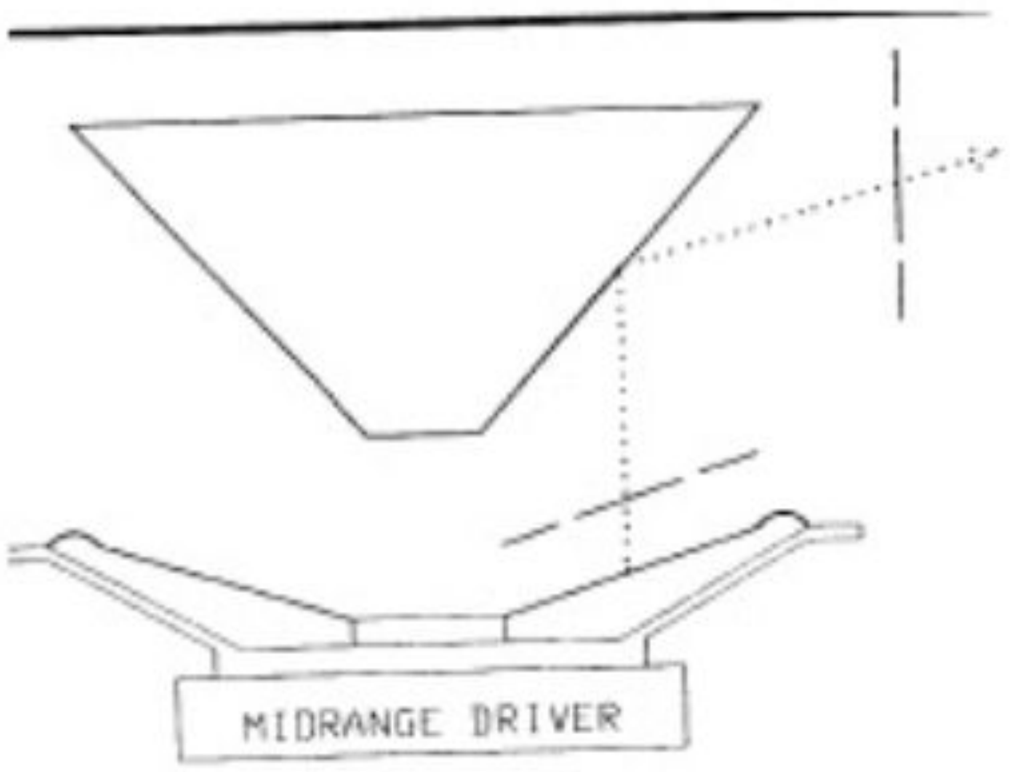

FIGURE 2: A vertically aligned phase front.

FIGURE 3: The lens angles.

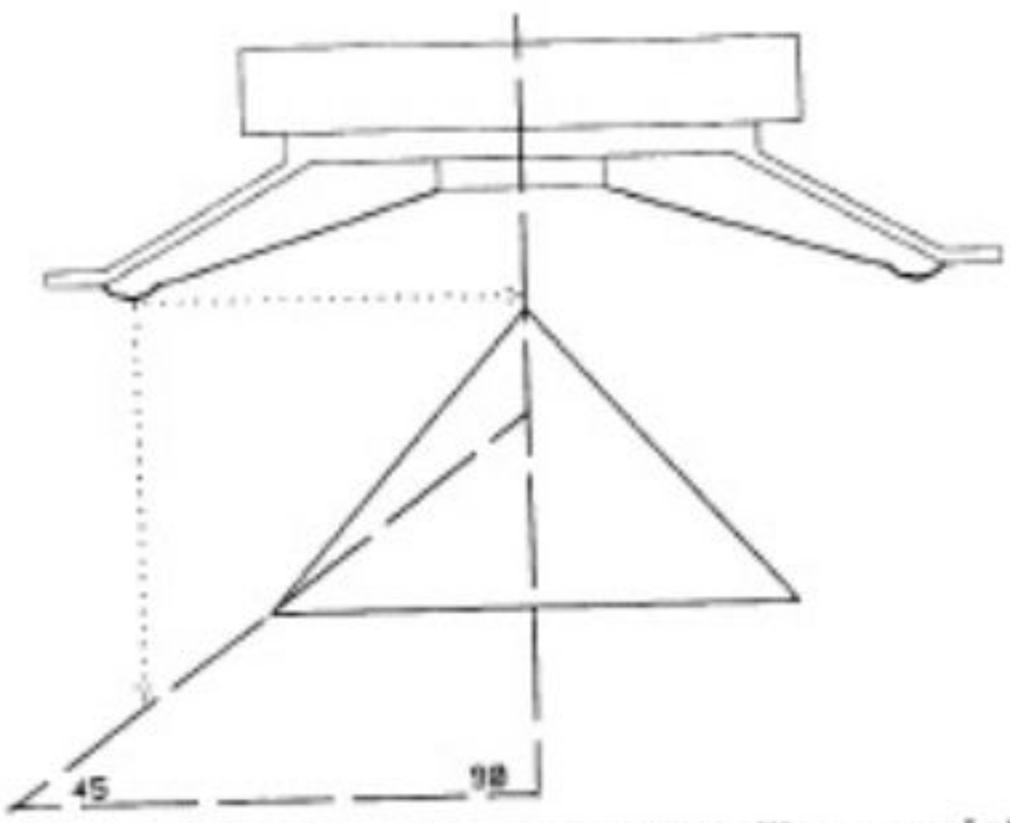

FIGURE 4: The driver radiates like a point source at the outer edge.

My thoughts strayed toward simply damping the undesired output off the cone with an absorbent material. I quickly abandoned this idea because it was wasteful. I tried to imagine a cone that would not only radiate the anterior portion of the output into the room, but would also redirect the posterior portion away from the wall and toward the extremities of the room.

Other factors would also decide the final shape of the lens: it should radiate without any phase cancellation and the surface had to be intricately designed to match the driver. Should the lens be designed around the reflecting wave front or the phase front, and from what could the lens be constructed?

I tried to design a mathematical model for the shape. It would be a simple matter of applying Huygens' Principle to every point on the driver cone, transforming the wave vectors at the lens, and deriving the final shape from this information. Needless to say it turned out to be quite a project. I am still working on it and probably will be for some time.

While I was laying the foundation for a mathematical model, however, an intuitive model started to take shape. Even so, I was still deciding how to meet the two constraints: radiating without phase cancellation and redirecting the posterior portion of the drivers' output. I examined a typical driver more closely for a solution and discovered the wave front and phase front are at an angle to each other.

Why a difference exists between them has to do with how the driver is oscillating. In most cases, the driver is moving in and out, sending the wavefront down the speaker's axis. Since the sound is created at the same instant at the back, inside portion of the driver surface as it is at the outer portion, and since both waves are moving at the same speed, they stay the same distance from one another. Therefore, the phase front is at an angle to the driver's axis, but is moving down that axis (*Fig. 1*).

For calculations, it is easier to use the normals for the fronts. These normals are perpendicular to the fronts and, from the forementioned information, you know that the phase vector is at a constant angle to the wave vector.

Since phasing causes interference patterns, I chose to design the lens around the phase vector. If the phase of the output were controlled and coherent, would this minimize destructive interference? I believed if the phase front were vertically aligned as it left the driver-lens combination, it would help keep interference to a minimum. What "vertically phase coherent" means is that if a vertical line is drawn next to the driver-lens combination, all output on that line was created by the driver at the same moment in time. This can be seen in *Fig. 2*.

CALCULATING SLOPES. I calculated the lens slope from the characteristics of the driver surface. The simplest driver to use is one with a flat cone, mostly found in midrange or bass drivers. Before calculating the slope of the lens, it is necessary to find the slope of the driver surface. I did this by measuring the angle between the surface of the cone and the horizontal. An angle of 30° is common for a midrange driver, so I will use that to illustrate my calculations. If the driver surface is at 30° with the horizon then, from simple trigonometry, the vector for the phase front has an angle of:

$$180° - (30° + 90°) = 60°$$

Since the phase front will strike the lens and reflect at the angle of incidence, the normal to the lens surface must bisect the angle of the phase front (60°), while also reflecting the phase front parallel to the ground.

The lens angle calculations are as follows. From *Fig. 3*, X = 30° and Y = 60°. Since the phase vector reflected from the lens is parallel to the horizontal, the angle between incidence and reflection is also 60°. The bisector of this angle must be perpendicular to the lens surface, such that the calculation for the lens surface is:

$$Z = 90° + Y/2 = 120°$$

These calculations ignore Huygens' Principle to some extent. Since the face of the driver is flat and oscillating uniformly across its surface, the outer edge is the

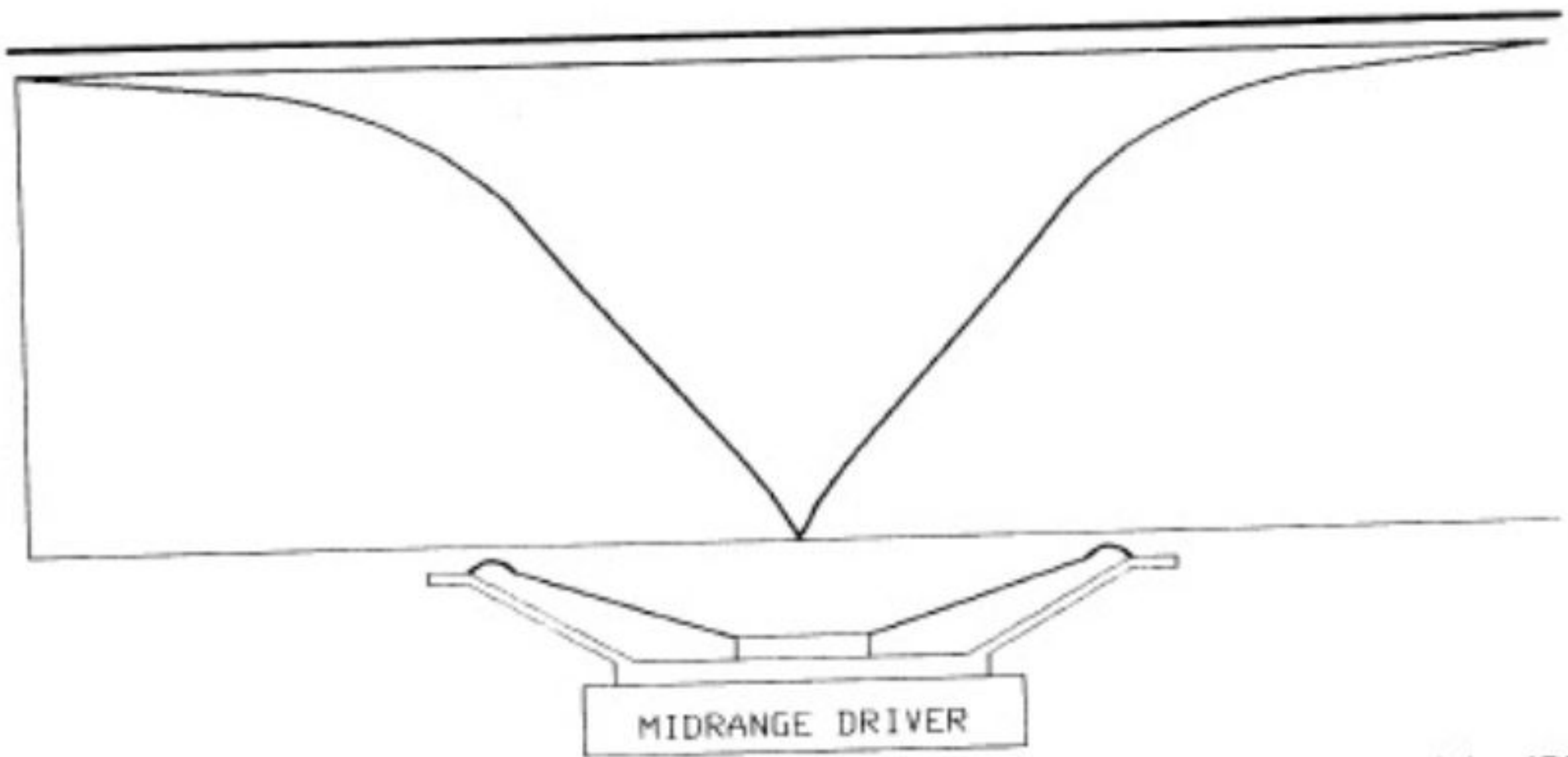

FIGURE 5: Approximating a lens curve from the calculated slope, the 90° slope, and the 45° slope.