Lecture Summary – Chapter 8 (Chapter 10 in 3rd Ed.)
Cancellation (LF Delay Steering)

- cancellation effects

**Cancellation effects: Polarity and delay**

<table>
<thead>
<tr>
<th>Effect Description</th>
<th>Polarity and Delay</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 units: Matched polarity</td>
<td>&gt;270°</td>
</tr>
<tr>
<td>2 units: 1 reverse polarity</td>
<td>31.5 Hz</td>
</tr>
<tr>
<td>2 units: 1 @ 8 ms delay</td>
<td>270°</td>
</tr>
</tbody>
</table>

All frequencies move forward.
Coverage falls with frequency.

1/24th octave, 20 x 40 m

- coverage shape and angle

**Coverage shape vs angle: The myth of the omnidirectional subwoofer**

A single subwoofer: All frequencies would be rated at 360° by the protractor method (no -6dB is found).

Do they look the same to you?

- AR = 1
  - FAR = .55
  - 31.5 Hz
  - Forward aspect ratio = .55 (345°)
  - Aspect ratio (including the rear) = 1
  - Omnidirectional

- AR = 1.08
  - FAR = .62
  - 63 Hz
  - Forward aspect ratio = .62 (330°)
  - Aspect ratio (including the rear) = 1.08
  - Nearly omnidirectional

- AR = 1.22
  - FAR = .72
  - 125 Hz
  - Forward aspect ratio = .72 (270°)
  - Aspect ratio (including the rear) = 1.22
  - NOT omnidirectional

These differences will multiply when these elements are combined into highly overlapped arrays.
- quantity effects – “steering” (more like focusing) a coupled line source arrays of subs

![Steering effects: Quantity](image1)

- spacing effects – “steering” (more like focusing) a coupled line source arrays of subs

![Steering effects: Quantity](image2)
• radial effects – “steering” a coupled point source sub array (but...the beamwidth of the subwoofer array rarely needs to be made wider!)

- cardioid subwoofer arrays
  - reduce stage leakage ($\geq 20$ dB front/back ratio)
  - rear/side control reduces early house reflections
  - steering reduces horizontal coverage in addition to rear coverage
  - price is efficiency loss (reduced maximum SPL), compared with all subwoofers in phase acting as a block
  - extra space/special rigging required
  - not always applicable (no need to cancel rear if speakers are against a wall)
  - potential compromise in transient response (“tightness”)
  - two cardioid configurations are in common use
    - end-fire (front-steered)
    - gradient (rear-steered)
- **forward steering**
  - **end-fire cardioid subwoofer array**
    - **log-staggered end-fire cardioid subwoofer array**
    - **(compact) gradient in-line cardioid subwoofer array**
- gradient inverted stack cardioid subwoofer array

2 wide, 4 element end-fire array outdoors
- lateral steering of line source sub array

![Lateral steering: subwoofer array delay tapering](image)

- delay (beam) steering – not a “new idea”… (discussion in text limited to subwoofer arrays)

The angle $\theta$, the angle by which the wavefront is shifted by the delay system, is given by

$$\theta = \sin^{-1} \frac{x}{d}$$  \hspace{1cm} 2.26

where $d =$ distance between the units, in centimeters.

Phase shifting can be used in many other ways besides beam tilting. For example, practically any wavefront shape can be obtained by introducing the appropriate phase shift in the sound sources.

![Fig. 2.5. A delay system for tilting the directional characteristic of a line of sound sources.](image)
- note potential problems with **back lobes** (Ref: *DSP Beam Steering with Modern Line Arrays*, Meyer Sound White Paper) – the back lobes get “steered down” too (but that assumes a certain degree of “silliness” in wanting to “fly” an array like this!)

Tilting the cone up to look underneath…
- **application: electronically steered arrays**

- **virtual loudspeaker aiming**
- Renkus-Heinz ICONYX
• Meyer (no relation) Sound Steerable CAL Column Array Loudspeaker
• "CAL is a digitally steerable column array product in which all high-frequency and low-frequency drivers are tight-packed in a bi-amped configuration and are individually amplified and processed."

Features & Benefits

• Variable vertical coverage from 5° to 30°
• 60° of vertical beam steering, ±30° *
• Custom-built drivers and tweeters designed and optimized for beam steering
• Every driver and tweeter has dedicated amplifier channel and processing
• The best algorithms utilized based on years of research into sound field synthesis
• Low profile, discreet aesthetics, custom colors and weather protection
• AVnu Alliance certification ensures seamless interoperability with other certified AVB devices