Subwoofer Array Directivity
Directivity as a Result Source Size

The acoustical size of a source, or array, is relative to the wavelength which it is radiating.

A source is acoustically small when its is smaller than a given wavelength.

A source is acoustically large when it is approximately the same size or larger than a given wavelength.

80 Hz polar graph of dual 18” subwoofer

The dimension of the subwoofer is approximately 0.6 m (2 ft). This about 1/7 of a wavelength at 80 Hz. No directivity control.
Directivity as a Result of Source Size

As the size of the array increases in a particular dimension, so does the directivity control in the plane of that dimension.
Directivity as a Result of Source Size

When the array size is one wavelength or greater there is substantial directivity control.

80 Hz polar graph of 8x dual 18” subwoofers

80 Hz polar graph of 16x dual 18” subwoofers
Steering the Main Lobe

Mechanical Steering – the array is tilted

Note that the rear lobe also follows the orientation of the array. It points in the opposite direction of the front lobe.
Steering the Main Lobe

Electrical Steering – the same incremental delay is applied to each box

Note that the rear lobe is pointing in the same direction as the front lobe.
Steering the Main Lobe

Electrical Steering – the same incremental delay is applied to each box

Note that as the steering increases the front and rear lobes begin to merge.
Steering the Main Lobe

End-Fire Array – when the inter-box delay is equal to the inter-box spacing

Each individual box is delayed back to the rear box so that, on-axis, all of the energy arrives at the same time.
Wave Front Shaping – Broadening the Main Lobe

Curving the array will decrease the directivity and broaden the coverage pattern.

Often there may not be sufficient space for a curved subwoofer array or time to accurately position each box in the array.
Wave Front Shaping – Broadening the Main Lobe

Huygens’ Principle
A wave front can be represented by a collection of point sources on that wave front. These point sources can be thought of as radiating secondary wave fronts. The propagation of the original wave front can be constructed from the superposition of the propagation of the secondary wave fronts.
Wave Front Shaping – Broadening the Main Lobe

The array can be curved electrically, instead of mechanically, by using delay.

The boxes farther from the center must be delayed progressively more. The curve is symmetrical so one delay output can drive two boxes.
Wave Front Shaping – Broadening the Main Lobe

The array is configured mechanically as a straight line.

The amount of delay can be varied to yield any amount of curvature from 0° to 90°.
Wave Front Shaping – Broadening the Main Lobe

Comparison of straight array with various amounts of curvature via delay

16 Box Straight Array, No Delay Curvature

16 Box Straight Array, Curved 90° with Delay
Wave Front Shaping – Broadening the Main Lobe

Comparison of straight array with various amounts of curvature via delay

16 Box Straight Array, Curved 45° with Delay

16 Box Straight Array, Curved 30° with Delay
Wave Front Shaping – Broadening the Main Lobe

Comparison of straight array with various amounts of curvature via delay

Polar Response at 80 Hz

On-Axis Magnitude Response

16 Box Straight Array, Curved with Delay
Wave Front Shaping – Broadening the Main Lobe

Directivity map – SPL as a function of both frequency and off-axis angle

Note the beamwidth narrowing as frequency increases.
Wave Front Shaping – Broadening the Main Lobe

Directivity map – SPL as a function of both frequency and off-axis angle

Note the slight increase in beamwidth compared to the straight array.

16 Box Straight Array, Curved 15° with Delay
Wave Front Shaping – Broadening the Main Lobe

Directivity map – SPL as a function of both frequency and off-axis angle

The beamwidth continues to increase as the virtual curve of the array increases.

16 Box Straight Array, Curved 30° with Delay
Wave Front Shaping – Broadening the Main Lobe

Directivity map – SPL as a function of both frequency and off-axis angle

The beamwidth is almost a constant 90° from 20 – 80 Hz.
Wave Front Shaping – Broadening the Main Lobe

Directivity map – SPL as a function of both frequency and off-axis angle

The beamwidth is almost a constant 180° from 20 – 80 Hz, with only slight narrowing around 30 Hz.

16 Box Straight Array, Curved 90° with Delay
Recap

Directivity control is directly related to the wavelength (frequency) being radiated and also the size of the source, or array, radiating it.

Steering of the main lobe can be done mechanically or electrically.

Wave front shaping can be used to broaden the directivity, or coverage pattern, and can yield fairly constant directivity.

Wave front shaping can be done mechanically or electrically.