BRIEF OVERVIEW OF CBT THEORY

A Brief CBT History:

CBT or constant beamwidth transducer theory is based on un-classified military under-water transducer research done in the late 1970s and early 80s [1 - 2]. This research describes a curved-surface transducer in the form of a spherical cap with frequency-independent Legendre shading that provides wide-band extremely-constant beamwidth and directivity behavior with virtually no side lobes.

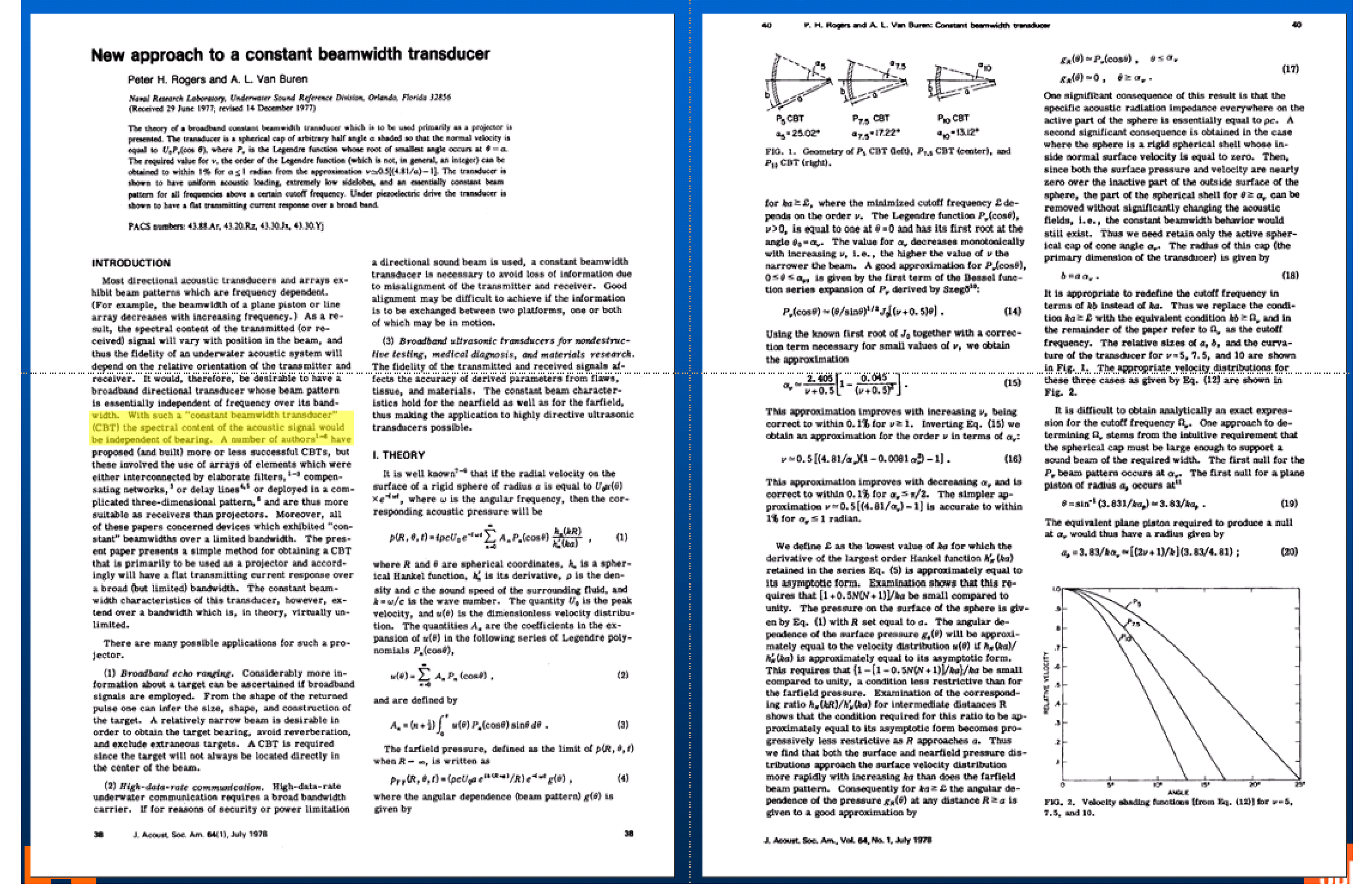
The theory was applied to loudspeaker arrays by Keele in 2000 [3] where he extended the concept to arrays based on circular-arc line arrays and toroidal-shaped curved surface arrays. Keele also extended the concept to straight-line and flat-panel CBT arrays with the use of signal delays [4]. The 3D sound-field of CBT circular-arc line arrays was analyzed by Keele in 2003 [5]. In 2003 Keele also described the practical implementation of CBT circular-arc line arrays [6]. In 2005 Keele and Button applied the theory to ground-plane versions of CBT arrays that are specifically designed to operate when placed against a planar reflective boundary [7]. Keele in 2010 showed the superiority of CBT arrays when compared to six other types of arrays [8].

CBT Technical Papers

- **CBT MILITARY PRIOR ART:** First formulated in JASA papers published in 1978 by the U.S. Navy describing shaded spherical-cap underwater (Sonar) transducers:
  - [1] P. H. Rogers, and A. L. Van Buren, **"New Approach to a Constant Beamwidth Transducer,"** J. Acous. Soc. Am., vol. 64, no. 1, pp. 38-43 (1978 July).
  - [2] J. Jarzynski, and W. J. Trott, **"Array Shading for a Broadband Constant Directivity Transducers,"** J. Acous. Soc. Am., vol. 64, no. 5, pp. 1266-1269 (1978 Nov.).
- **KEELE CBT PAPERS:** Applied to loudspeaker arrays in six AES technical papers by Keele between 2000 and 2010:
  - [3] D. B. Keele, Jr., **"The Application of Broadband Constant Beamwidth Transducer (CBT) Theory to Loudspeaker Arrays,"** 109th Convention of the Audio Engineering Society, Preprint 5216 (Sept. 2000).
  - [4] D. B. Keele, Jr., **"Implementation of Straight-Line and Flat-Panel Constant Beamwidth Transducer (CBT) Loudspeaker Arrays Using Signal Delays,"** 113th Convention of the Audio Engineering Society, Preprint 5653 (Oct. 2002).
  - [5] D. B. Keele, Jr., **"Full-Sphere Sound Field of Constant Beamwidth Transducer (CBT) Loudspeaker Line Arrays,"** J. Audio Eng. Soc., vol. 51, no. 7/8 (July/August 2003).
  - [6] D. B. Keele, Jr., **"Practical Implementation of Constant Beamwidth Transducer (CBT) Loudspeaker Circular-Arc Line Arrays,"** 115th Convention of the Audio Engineering Society, Preprint 5863 (Oct. 2003).
  - [7] D. B. Keele, Jr. and D. J. Button, **"Ground-Plane Constant Beamwidth Transducer (CBT) Loudspeaker Circular-Arc Line Arrays,"** 119th Convention of the Audio Engineering Society, Preprint 6594 (Oct. 2005).
  - [8] D. B. Keele, Jr., **"A Performance Ranking of Seven Different Types of Loudspeaker Line Arrays,"** 129th Convention of the Audio Engineering Society, Preprint 8155 (Nov. 2010).

Rogers & Van Buren 1978

(Lots of heavy-duty math!)



Highlighted Text

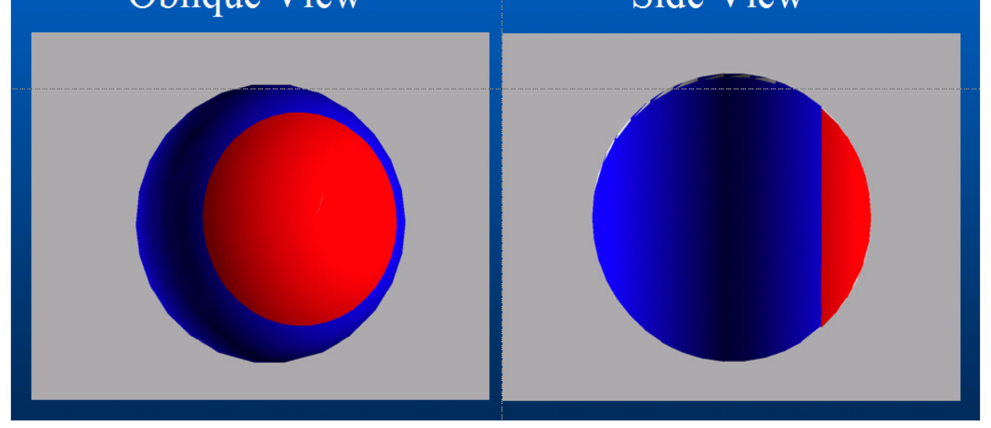
- "With such a 'constant beamwidth transducer' (CBT) the spectral content of the acoustic signal would be independent of bearing."

These arrays require no complex DSP processing! Just frequency-independent shading (attenuation) applied to the speakers which are mounted on a circular arc.

Spherical-Cap CBT Transducers

Overview

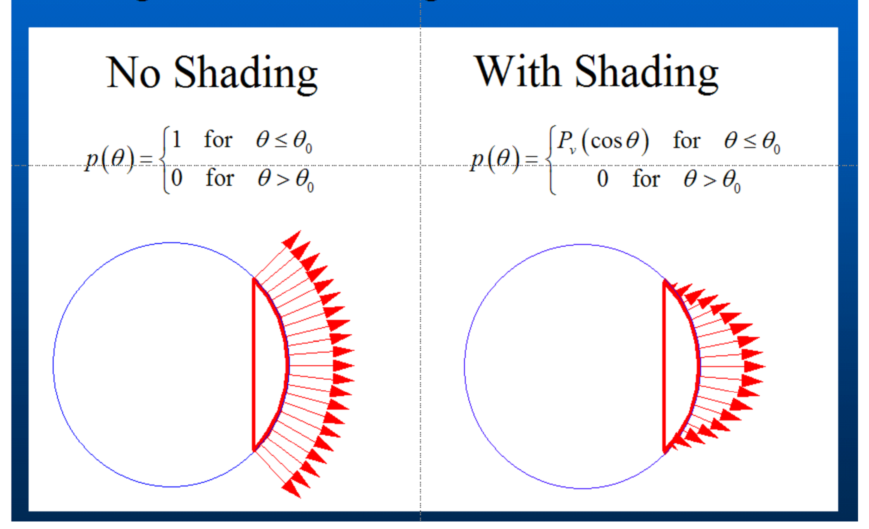
100° Circular Spherical Cap



Spherical-Cap CBT Transducers

Overview Cont.:

Legendre Shading of Surface Pressure

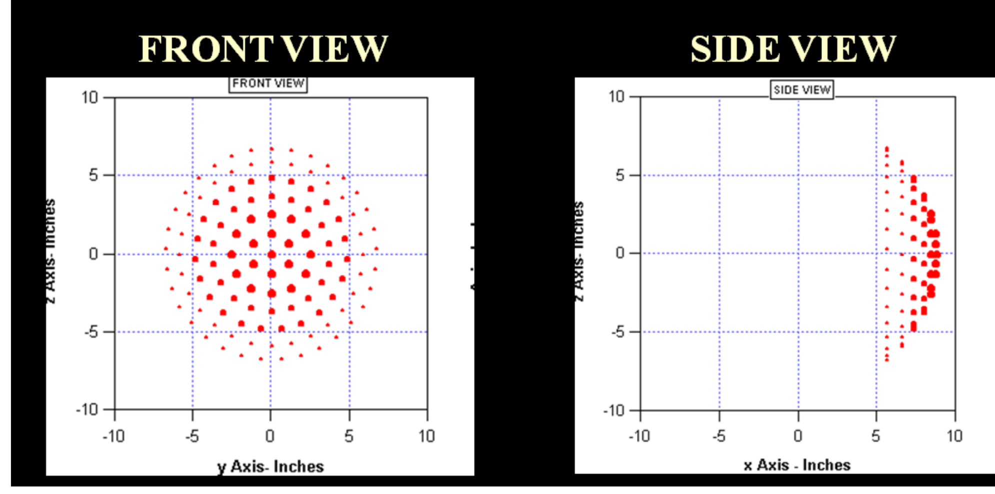


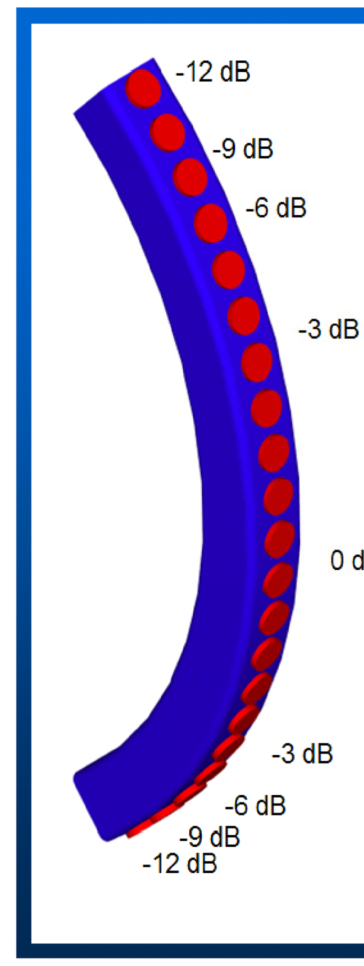
Spherical-Cap CBT Transducers Overview Cont.: Observations

- Provides extremely uniform polars above a certain frequency which are independent of distance
- Beamwidth = 0.64 x Cap Angle
- Surface pressure distribution, nearfield pressure pattern, and farfield pressure pattern are all essentially the same! No nearfield!
- Don't need the rest of the sphere!

Application to Point-Source Arrays

- Circular Spherical Cap
  - Example: 121-Point 100° Circular Spherical Cap Array with Legendre Shading



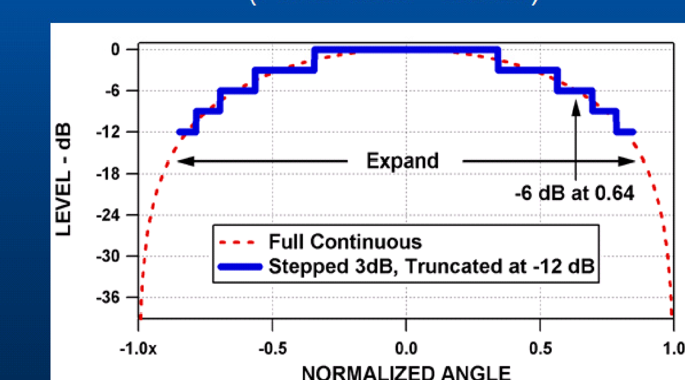


Applied to Circular-Arc Line Arrays

CBT Curved Line Source (Circular Wedge)

Truncated and Stepped Legendre Shading

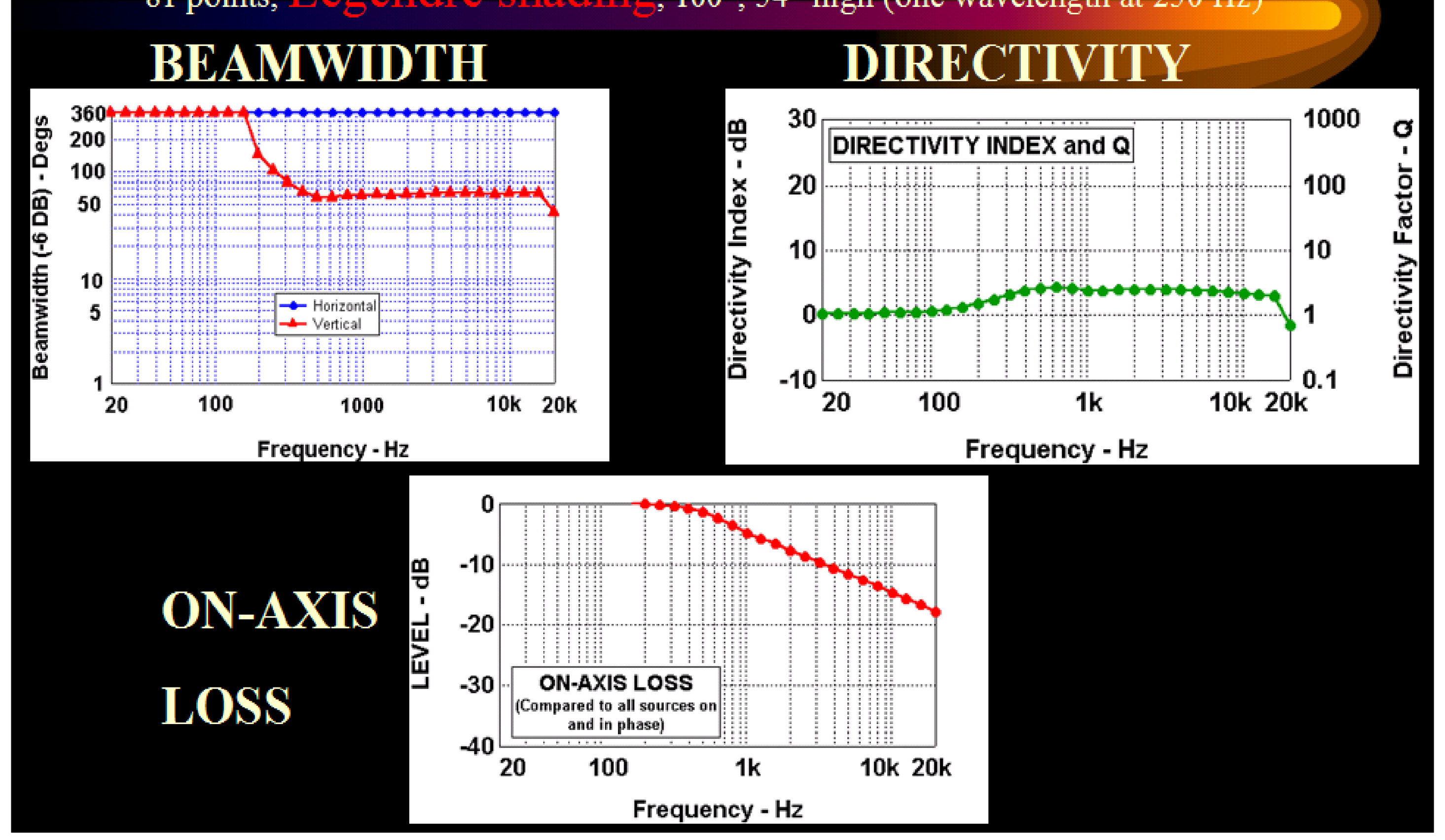
(Power Loss = 2.3 dB)



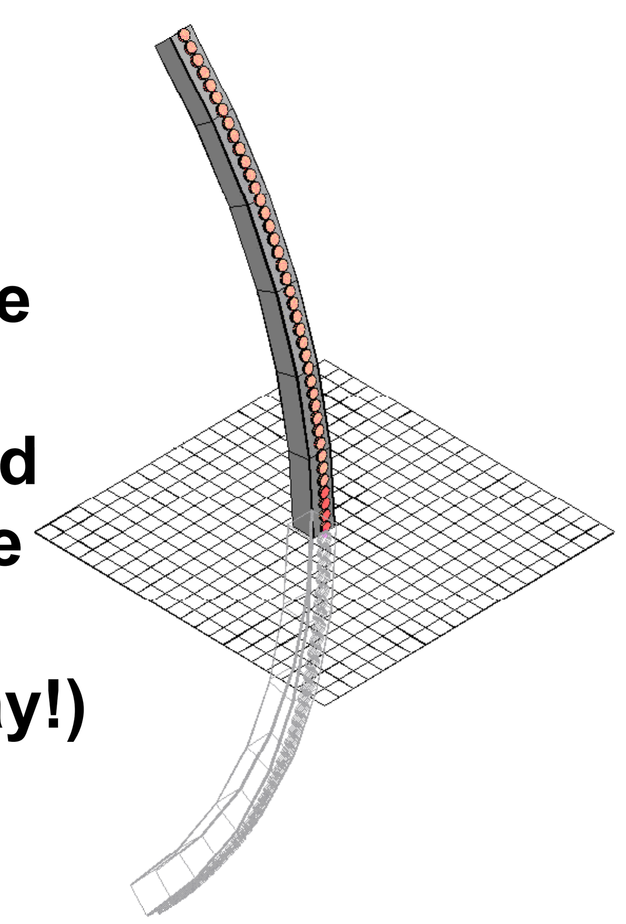
These line arrays provide incredibly even coverage with wide-band constant beamwidth and directivity! Right-left, up-down and near-far! These arrays essentially have no near-field. The pattern is essentially independent of distance!

Simulation Results Cont.

- Curved Line Source (Circular Wedge)
  - 81 points, Legendre shading, 100°, 54" high (one wavelength at 250 Hz)

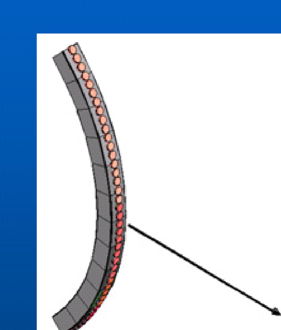


Applied to Ground-Plane Circular-Arc Line Arrays (Uses the ground plane to recreate the other half of the missing array!)

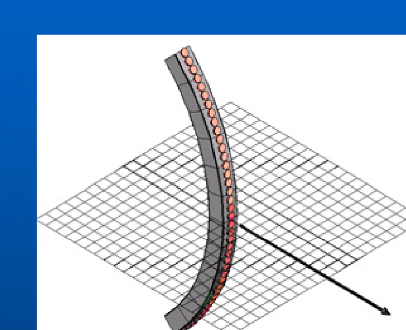


Working Off the Side of the Pattern

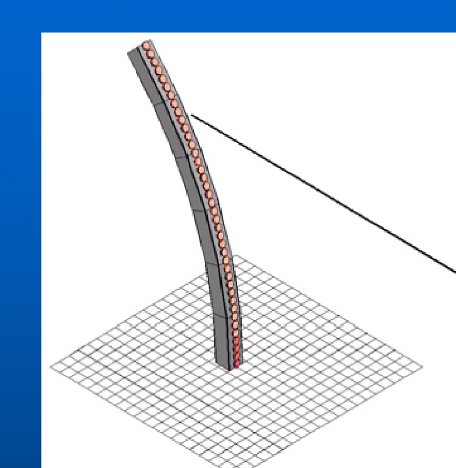
- At specific heights, the variation of near-far SPL is minimized because the trajectories approximately coincide with specific constant-pressure contours.



Main axis of free-standing CBT array.



Main axis of ground-plane CBT array. Axis grazes the ground-plane!



Typical listening axis for a ground-plane CBT array. The listener listens on an axis that is offset from the main axis of the array.

Conclusions: Advantages of CBT Ground-Plane Array

- Minimizes/eliminates detrimental floor reflections.
- Extremely uniform coverage: up-down, right-left, and near-far.
- Can be implemented without DSP, passive speaker-level shading can be used.
- Minimizes near-far variation of SPL at certain heights.
- The beneficial effects of the ground-plane can be taken advantage of in two ways:
  - Increase Effective Size:
    - Doubles effective array height.
    - Doubles array sensitivity (+6 dB).
    - Doubles array maximum sound pressure level (SPL) capability (+6 dB).
    - Extends operating bandwidth down by an octave (or two depending on how the beamwidth is defined).
  - Decrease Physical Size:
    - Can half the physical height of the array but maintain the same performance as the full-size free-standing array when a ground plane is available.
  - Or a combination of the two!