

## BRIEF OVERVIEW OF CBT THEORY

Don Keele, Sept. 26, 2008

 Harman International

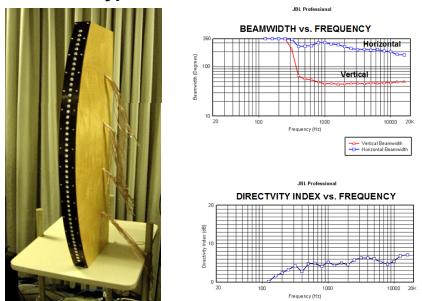
### 1.1.A Brief CBT History

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 - 3]. 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.

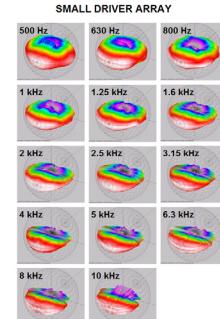
The theory was applied to loudspeaker arrays by Keele in 2000 [4] where he extended the concept to arrays based on circular-arc line arrays and toroidal-shaped curved surface arrays. Keele also extended the concept to straight-line and flat-panel CBT arrays with the use of signal delays [5]. The 3D sound-field of CBT circular-arc line arrays was analyzed by Keele in 2003 [6]. In 2003 Keele also described the practical implementation of CBT circular-arc line arrays [7].

### First Prototype of 2002

#### SMALL DRIVER ARRAY



#### 3D Polar Balloons Measured in JBL Arena



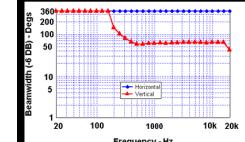
These line arrays provide incredibly even coverage with wide-band constant beamwidth and directivity! Right-left, up-down and near-far! These arrays essentially have no nearfield. The pattern is essentially independent of distance!

### Simulation Results

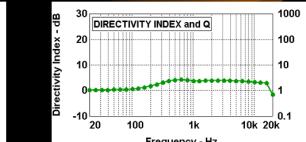
- Curved Line Source (Circular Wedge) *Cont.*

- 81 points, Legendre shading, 100°, 54° high (one wavelength at 250 Hz)

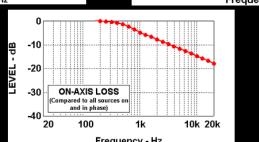
#### BEAMWIDTH



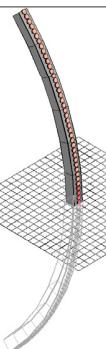
#### DIRECTIVITY



#### ON-AXIS LOSS

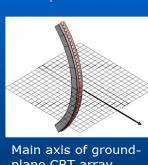


Applied to  
Ground-Plane  
Circular-Arc Line  
Arrays  
(Uses the ground  
plane to recreate  
the other half of  
the missing array!)



### Working Off the Side of the Pattern

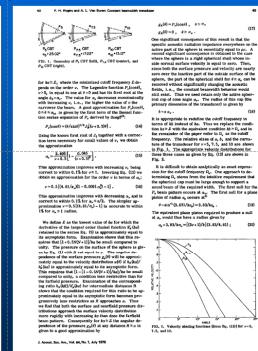
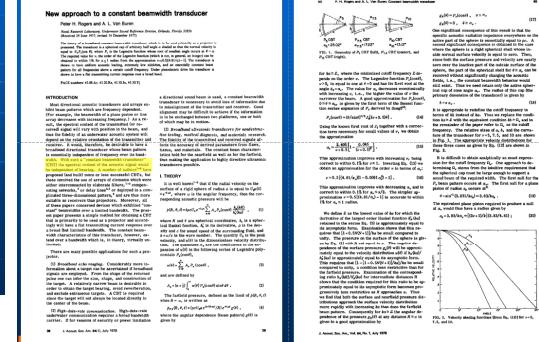
- At specific heights, the variation of near-far SPL is minimized because the trajectories approximately coincide with specific constant-pressure contours.



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.

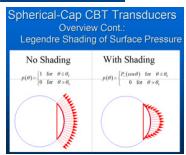
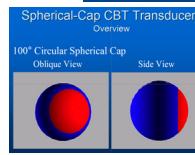
### Rogers & Van Buren 1978

(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."



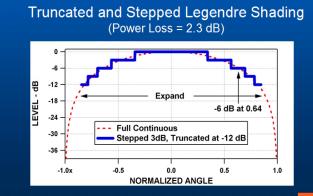
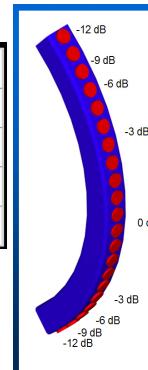
### Spherical-Cap CBT Transducers Overview Cont.: Observations

- Provides extremely uniform polaras above a certain frequency which are independent of distance
- Beamwidth =  $0.64 \times \text{Cap Angle}$
- Surface pressure distribution, fieldnear pressure pattern, and farfield pressure pattern are all essentially the same! No nearfield!
- Don't need the rest of the sphere!

### Applied to Circular-Arc Line Arrays

#### CBT Curved Line Source (Circular Wedge)

#### Truncated and Stepped Legendre Shading (Power Loss = 2.3 dB)



### 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 halve 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!