Microphone Beamforming

Syntronic Presentation For Chalmers DAT096

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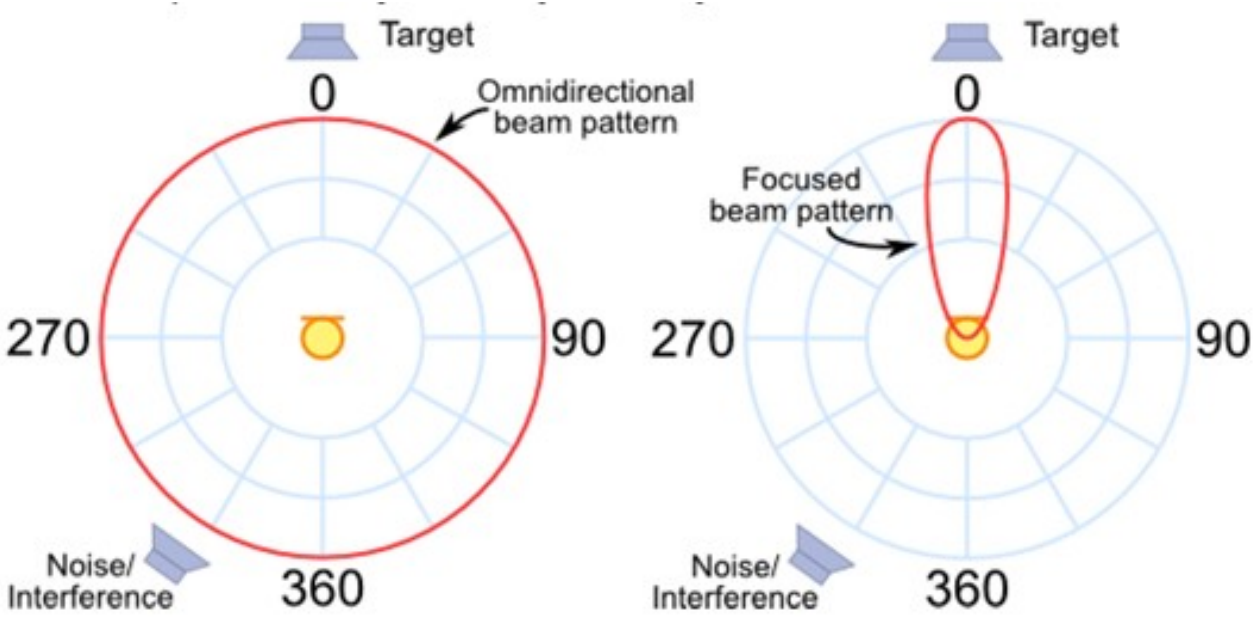
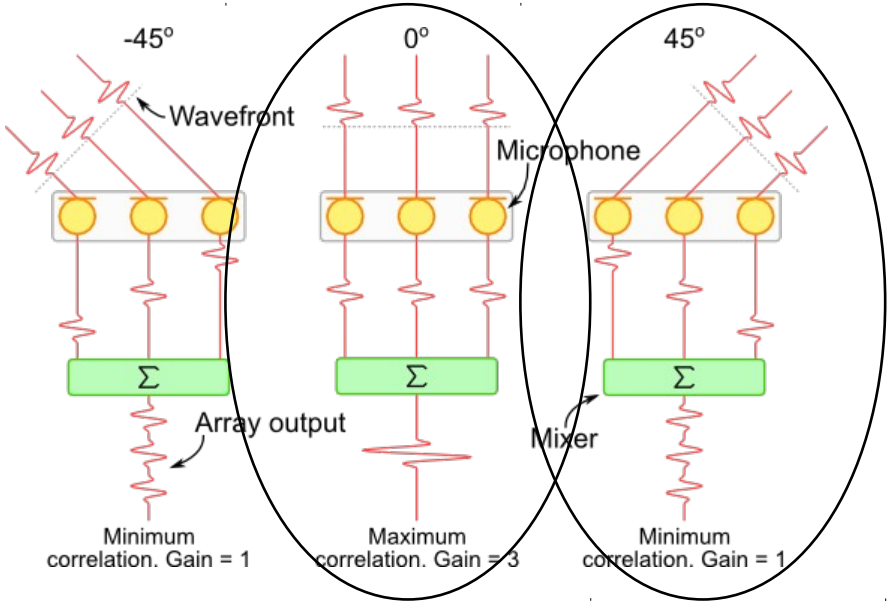
What is Beamforming?

- A technique to achieve directionality in signal transmission or **reception**



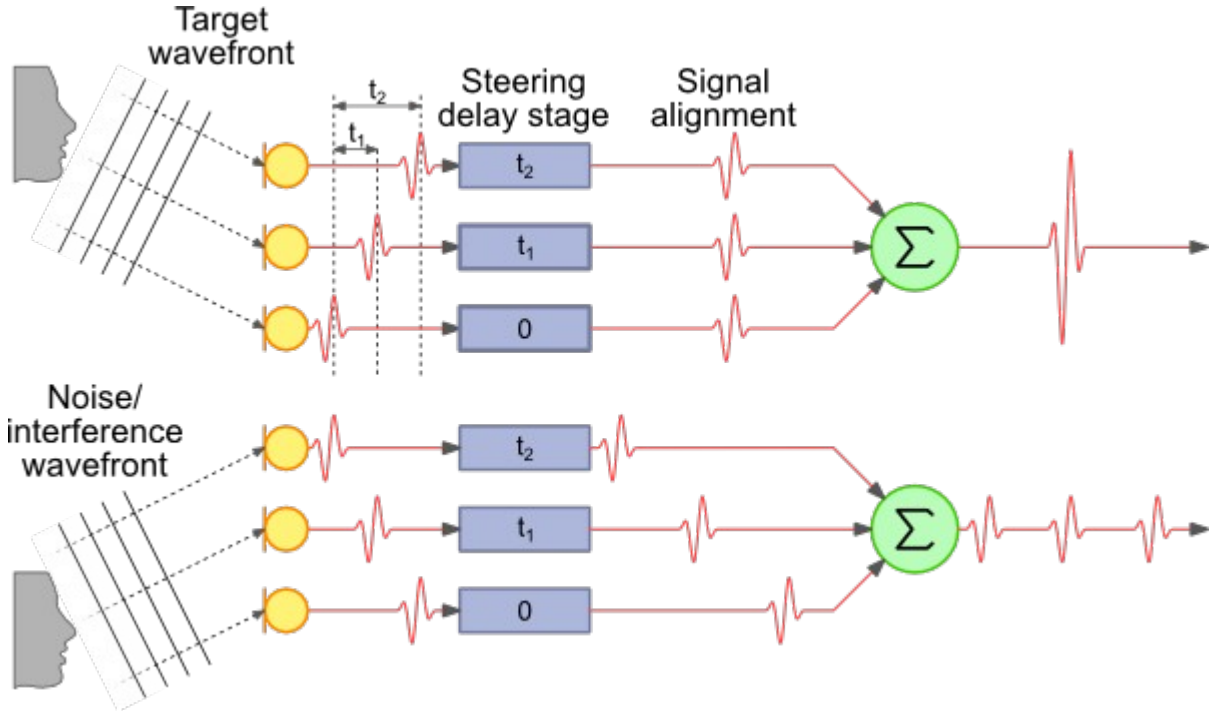
Beamforming Basics

- Directionality achieved by combining inputs from multiple sensors
- The signal coming from a desired angle is boosted compared to the signals coming from undesired angles

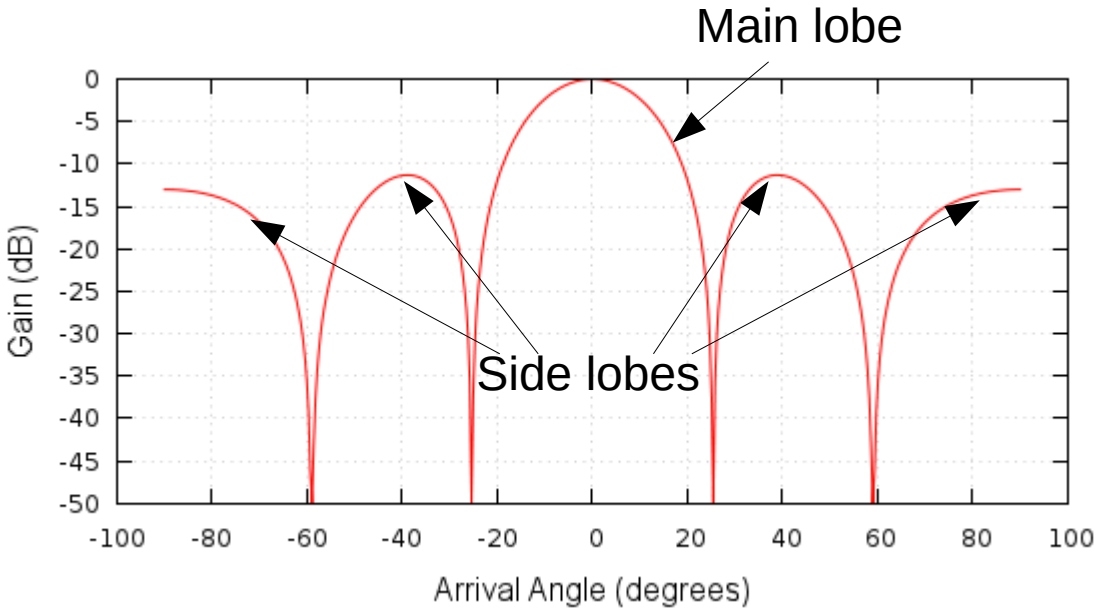


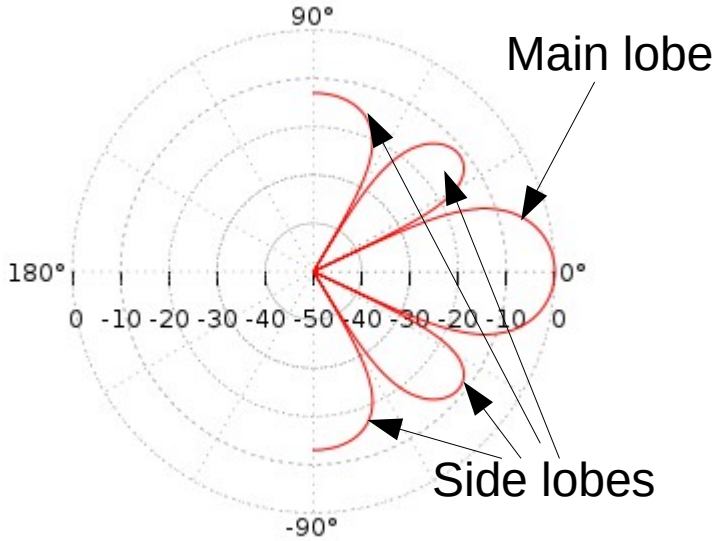
Beamforming Basics

- Simplest beamforming algorithm: Delay and sum

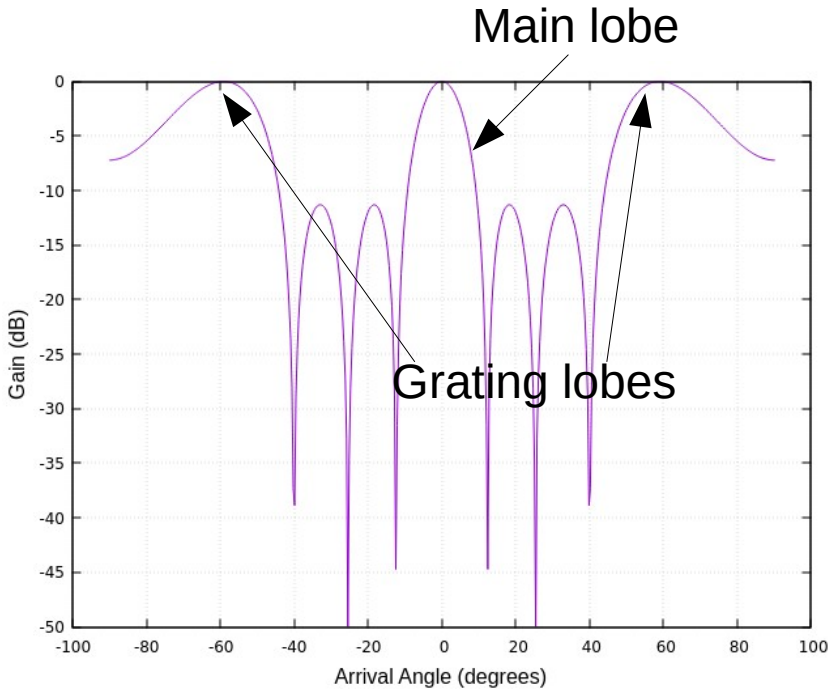


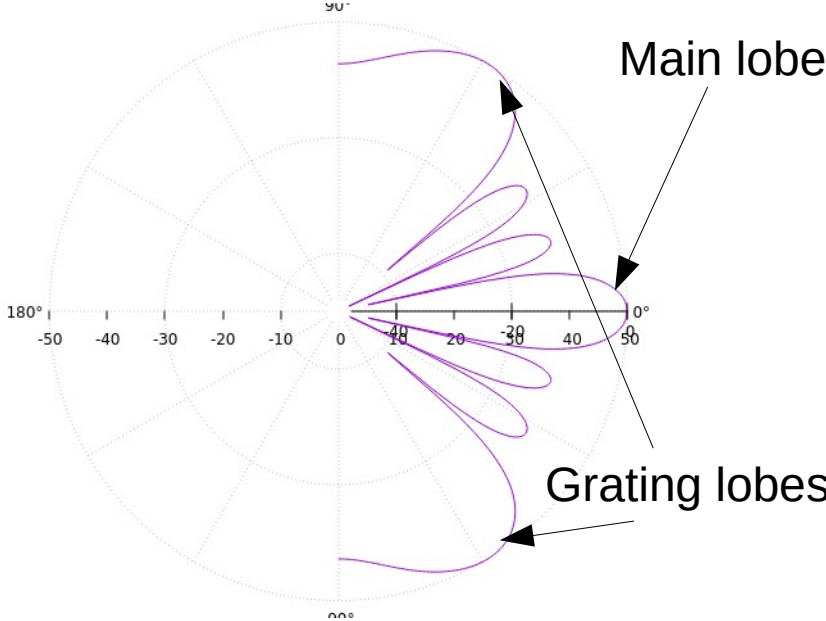
Delay and Sum Beamformer Beam Pattern





Delay and Sum Beamformer Beam Pattern

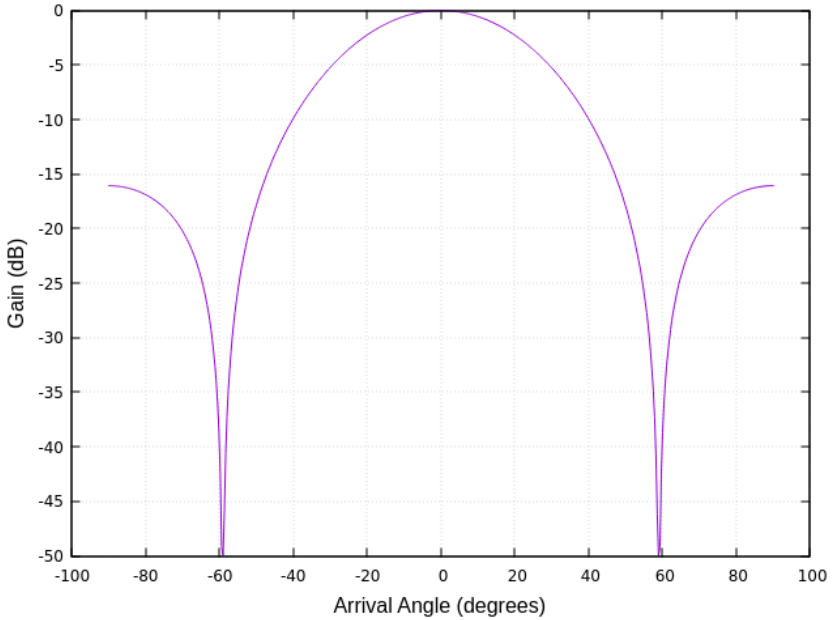




Delay and Sum Beamformer Characteristics

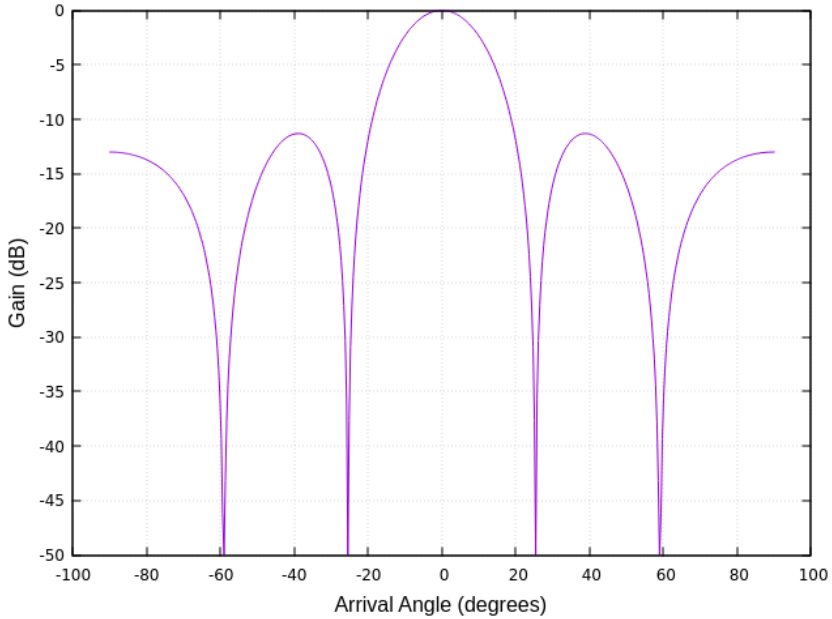
- The beam pattern depends upon following parameters:
  - Speed of sound (c)
  - Number of microphones (n)
  - Distance between microphones (d)
  - Frequency of the incoming signal (f)
- Spatial aliasing
  - Results in grating lobes
  - $f_{max} = c/d$
  - $d_{max} = c/f$

Effect of Distance between Microphones



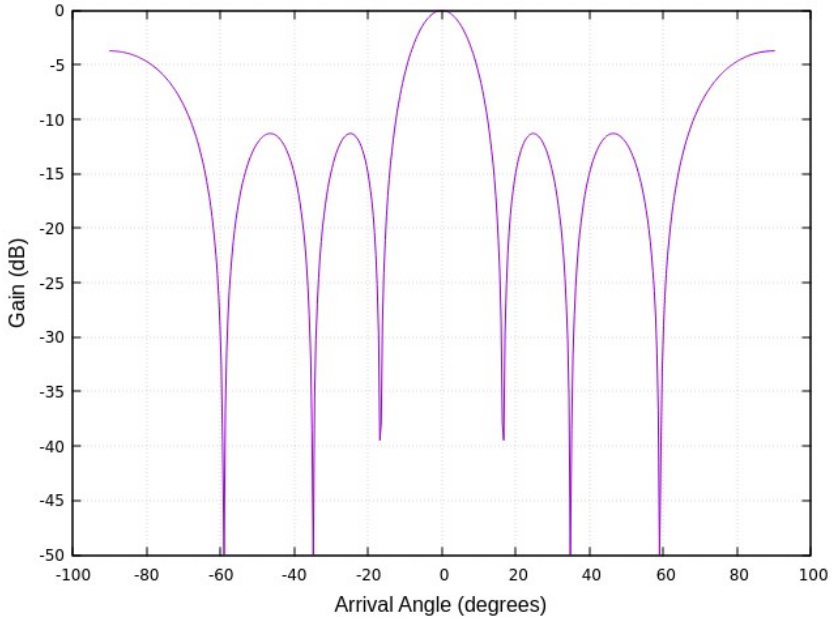
d = 100mm, n = 4, f = 1kHz

Effect of Distance between Microphones



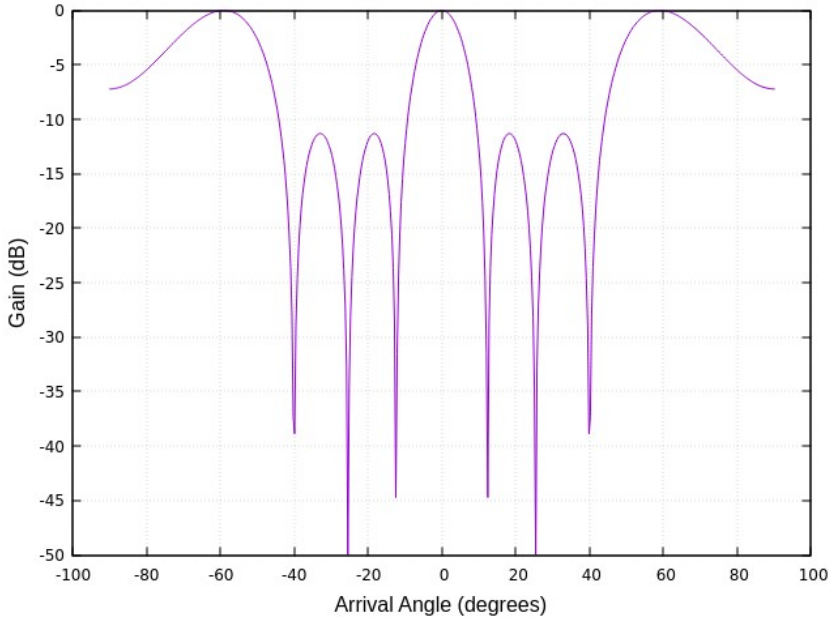
d = 200mm, n = 4, f = 1kHz

Effect of Distance between Microphones



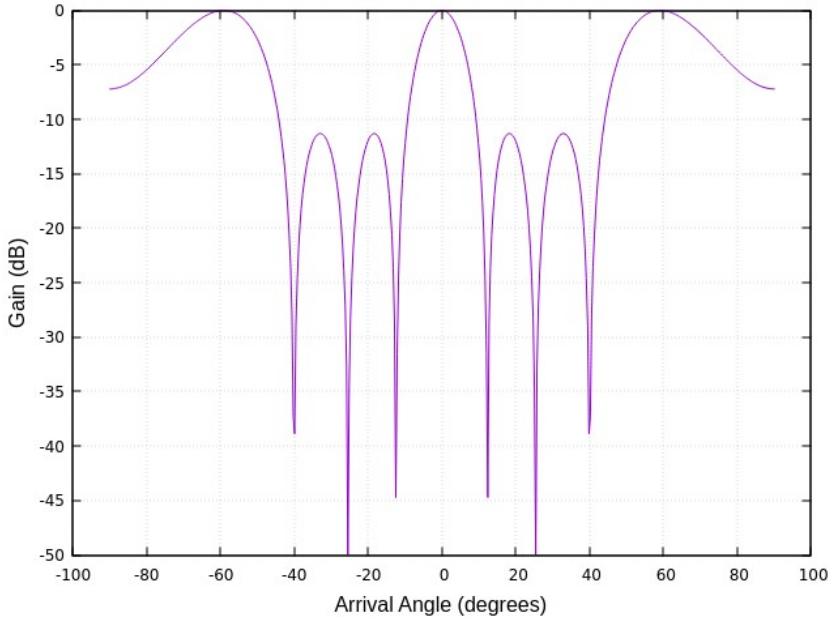
d = 300mm, n = 4, f = 1kHz

Effect of Distance between Microphones



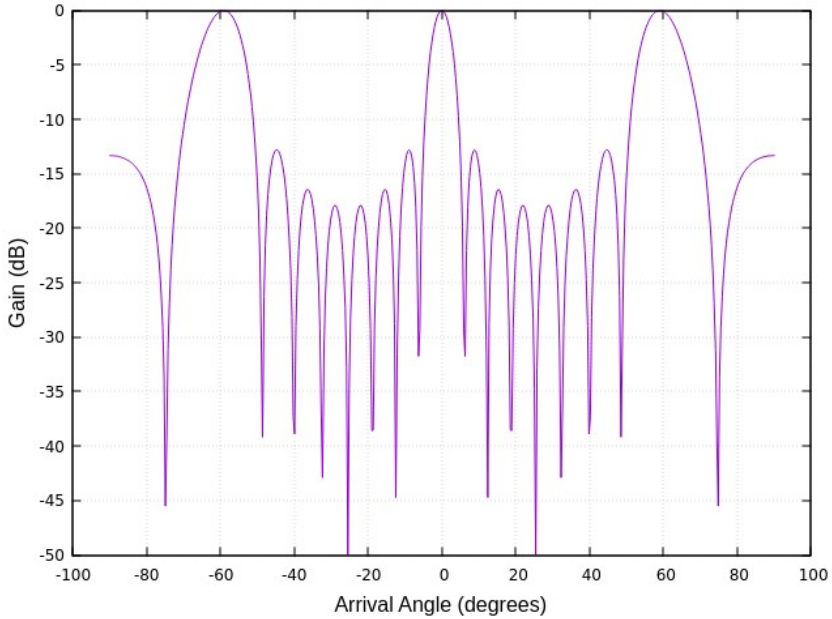
d = 400mm, n = 4, f = 1kHz

Effect of Number of Microphones



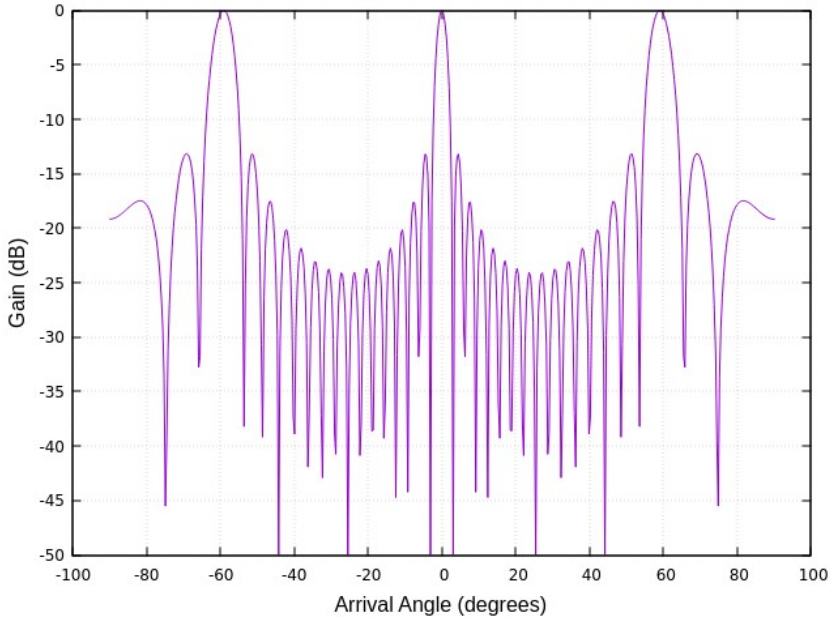
d = 400mm, n = 4, f = 1kHz

Effect of Number of Microphones



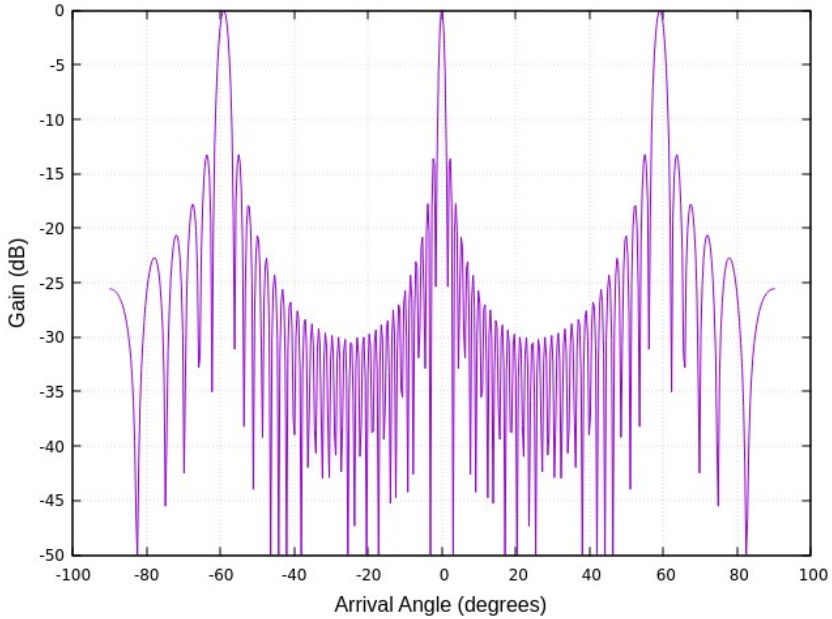
d = 400mm, n = 8, f = 1kHz

Effect of Number of Microphones



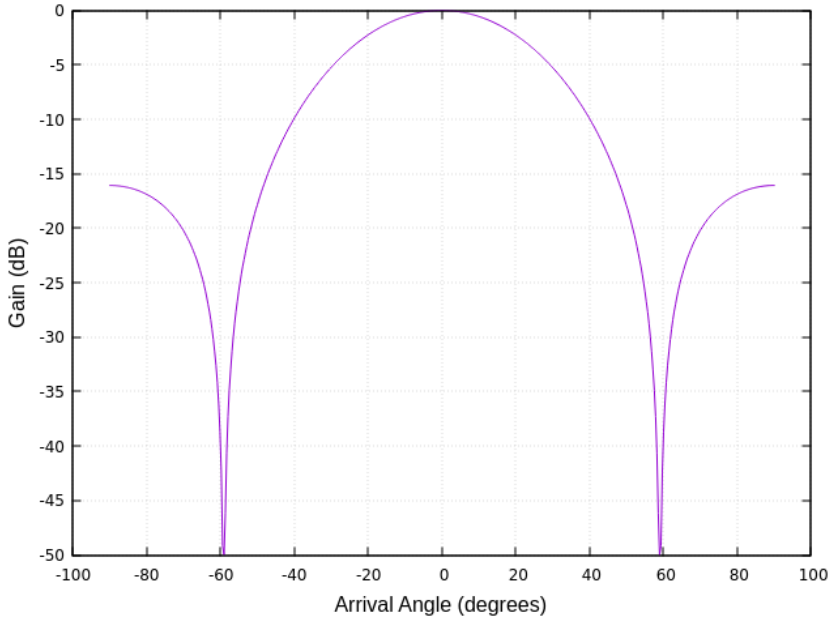
d = 400mm, n = 16, f = 1kHz

Effect of Number of Microphones



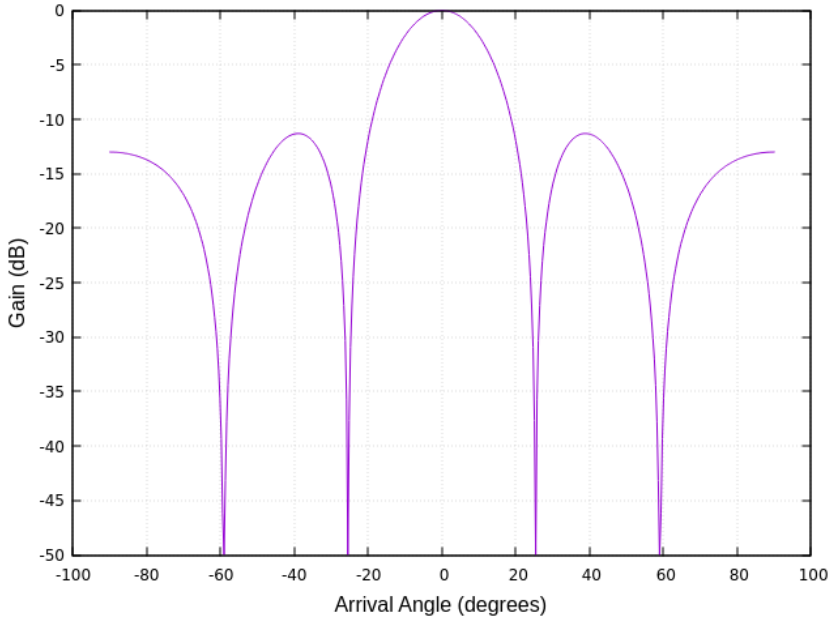
d = 400mm, n = 32, f = 1kHz

Effect of Input Frequency



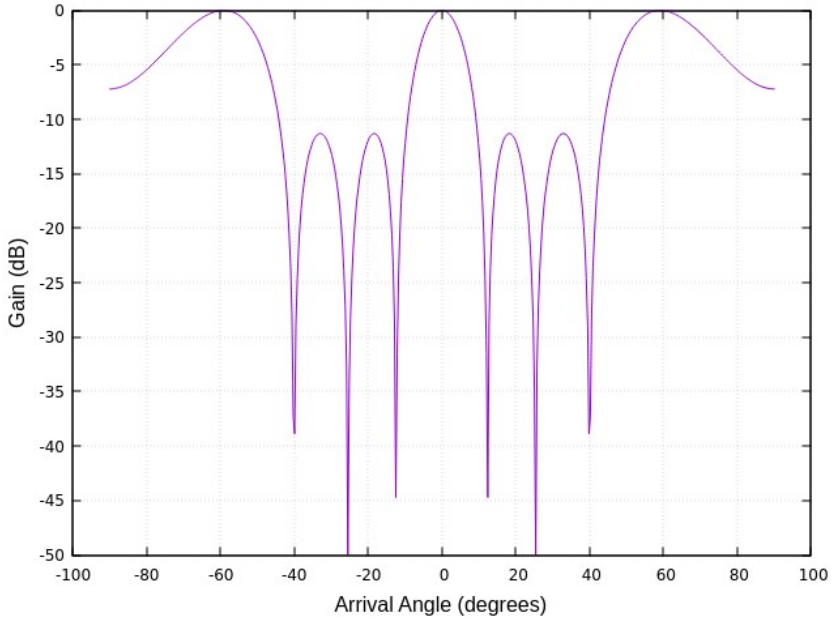
d = 100mm, n = 4, f = 1kHz

Effect of Input Frequency



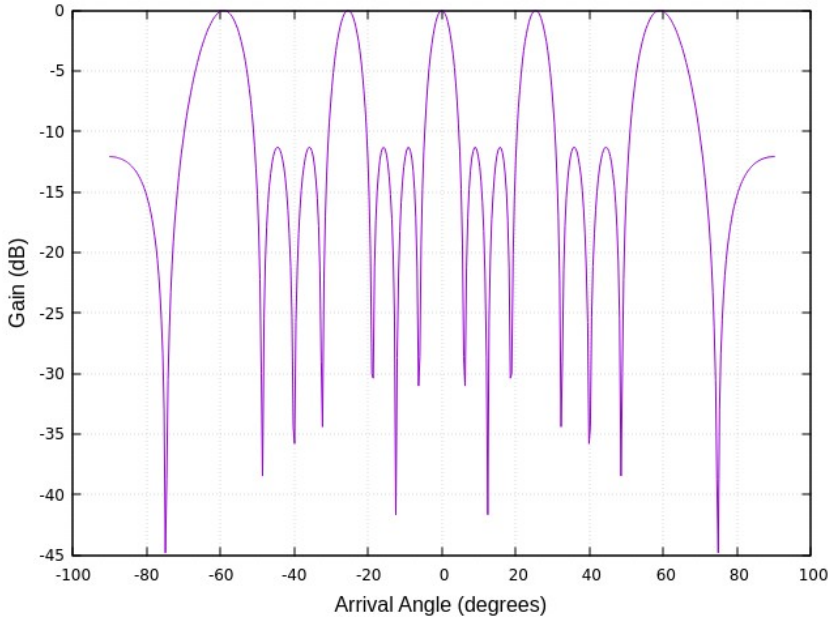
d = 100mm, n = 4, f = 2kHz

Effect of Input Frequency



d = 100mm, n = 4, f = 4kHz

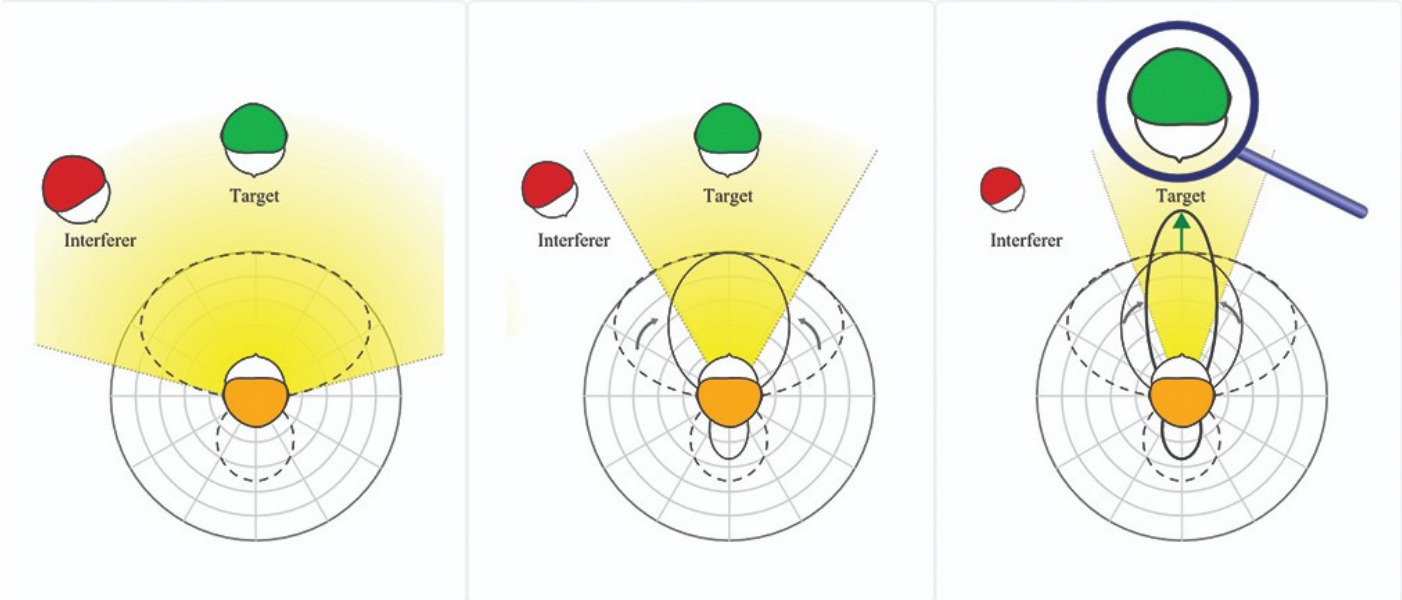
Effect of Input Frequency



d = 100mm, n = 4, f = 8kHz

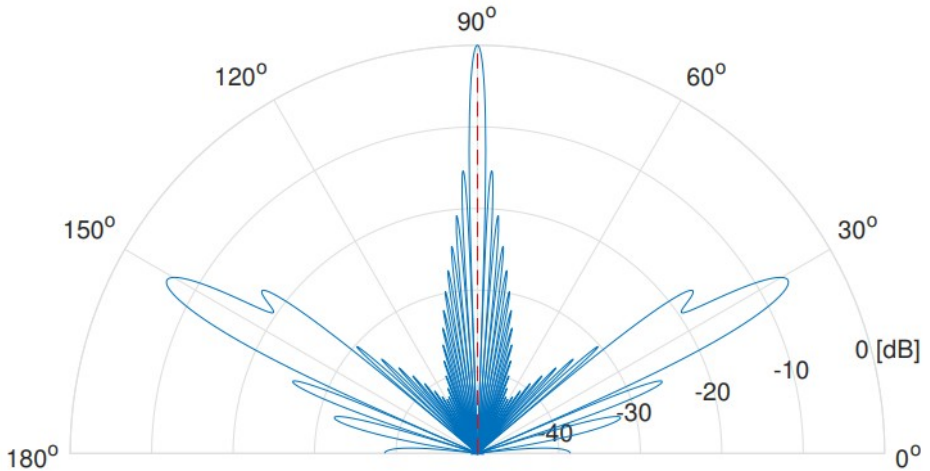
Applications

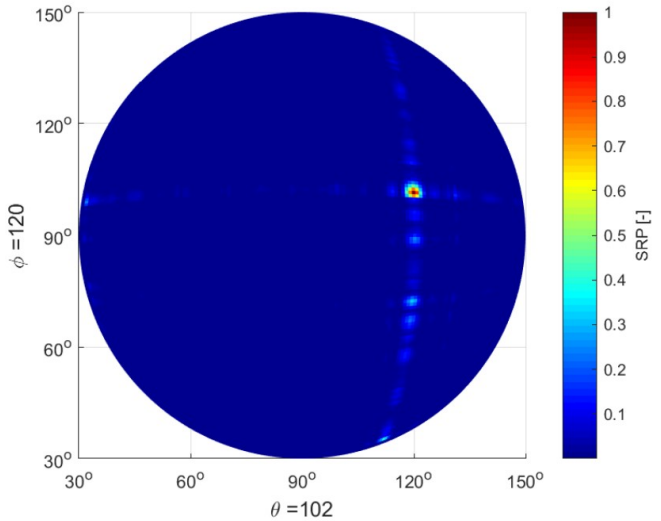
-Directional Speech enhancement



Applications

-Sound source localization (Direction of Arrival)





Arrays

-Represent how you sample signals “in space”. Can be in 1, 2 or 3 dimensions and consist of 2 or more sensors

-Shape of an array will affect how to solve for the directionality of the array.

-The set of delays which maximally add together the wavefront of an incoming wave at a certain angle is the current “viewing” direction of the array.

-Distance between microphones will dictate what frequencies the array can be optimized for.

Beamforming Algorithms - Adaptive

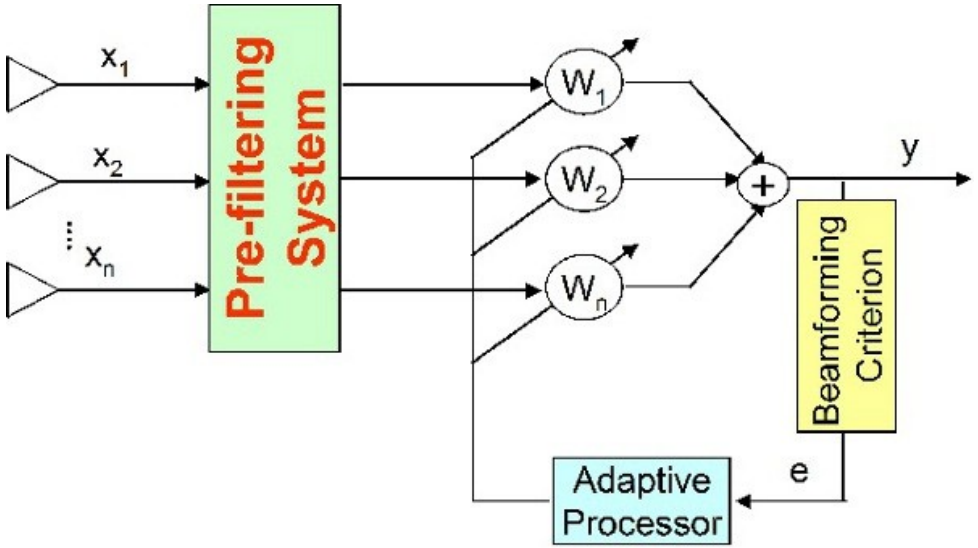
-Adaptively modify the delay and weights of the beam to achieve optimal result

-Adjust the beam to cancel interference in comparison to target, ie nulling.

-Generally more complex

Examples:

Least-Mean-Squares
Recursive-Mean-Square
Generalised SideLobe Canceler



Algorithm differences between applications

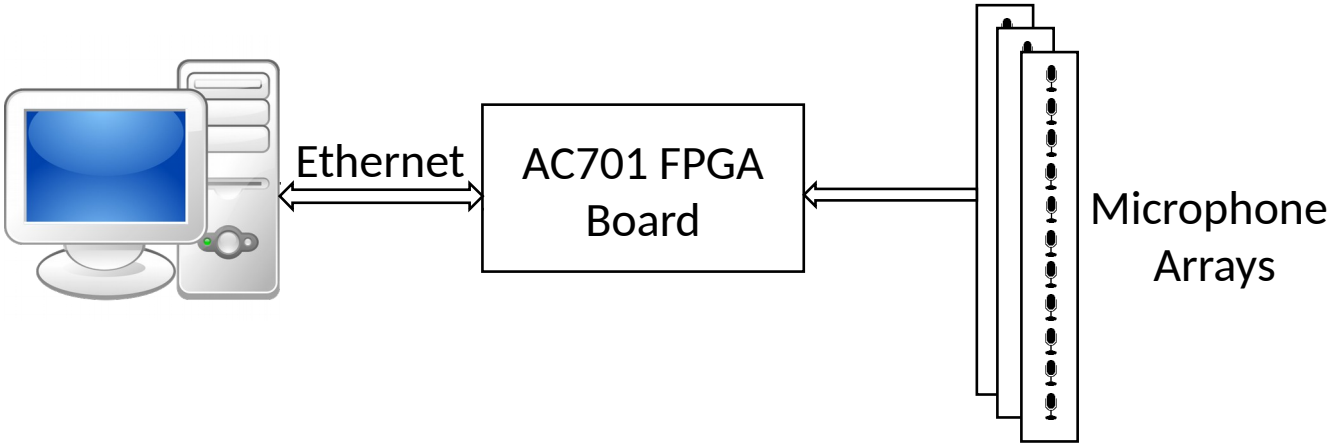
-Speech enhancement and isolation involves more around selecting weights/delays to constructively and destructively add waveforms together to either enhance certain sources over others or separate sources.

-Localization involves more around scanning and searching. With focus on finding the beam orientation with maximum input signal power

Real time suitability of algorithms

- Not all algorithms are suitable for real time systems.
- Complex mathematics difficult to implement on FPGA
- Cross correlation algorithms grow exponentially with number of sensors in array (grid search localization).
- FPGAs have limited resources.

Hardware Design for DAT096



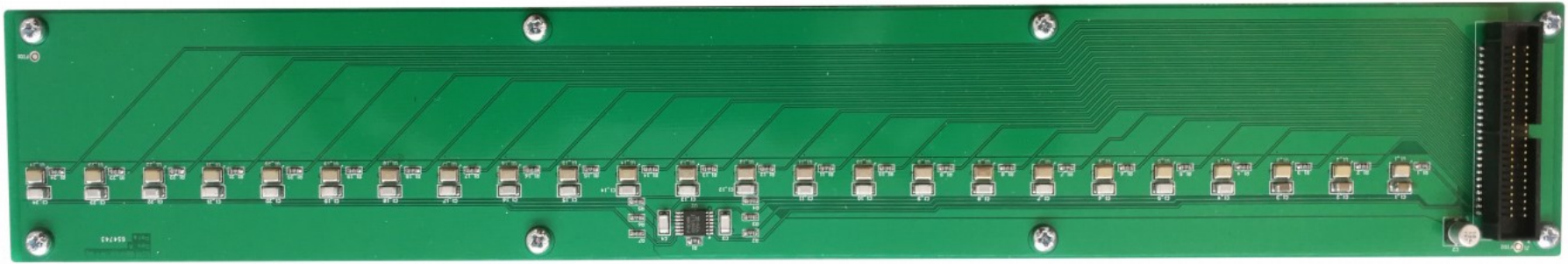
Syntronic Hardware - Linear Arrays

-Linear array of 24 MEMS microphones.

-Good for testing and development, but may not be optimal for speech.

-D=11.43mm

-You can make your own! We have schematics and guidelines on how to best achieve this.

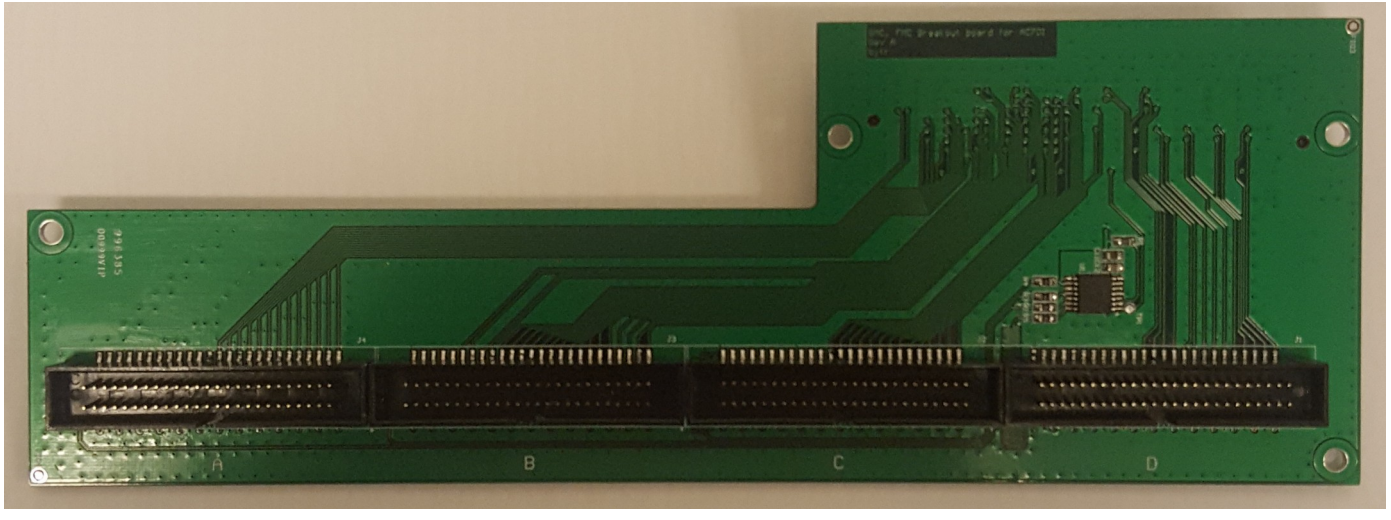


Syntronic Hardware - FMC Breakout

-FMC Breakout board for AC701

-Support for up to 4 separate panels with 24 microphones each, or one with 96

-Breaks out FPGA signals on FMC connector and propagates clock to all MEMS microphones

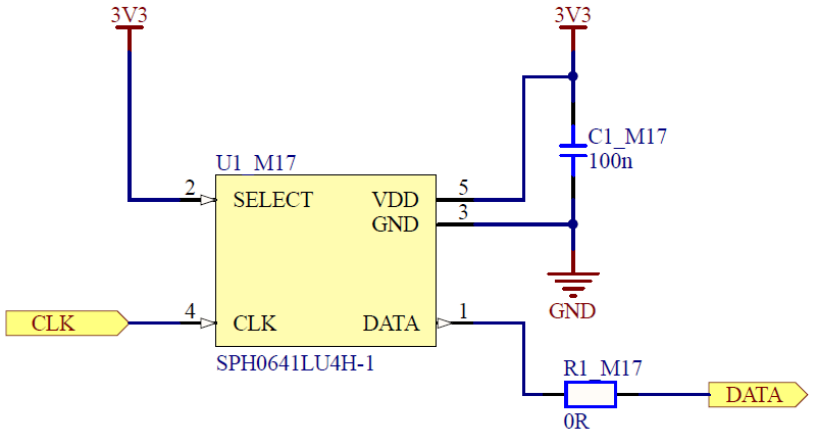


Syntronic Hardware - Microphone

-The Syntronic Array uses an Ultrasonic microphone SPH0641LU4H-1.

-Can be clocked at different frequencies to get different bandwidth. 20Hz to ~80Khz @ 4.8Mhz

-Oversampled output in PDM format,
Needs to be filtered to get PCM format



Microphone Channel

Thank you for having us!

Questions ?