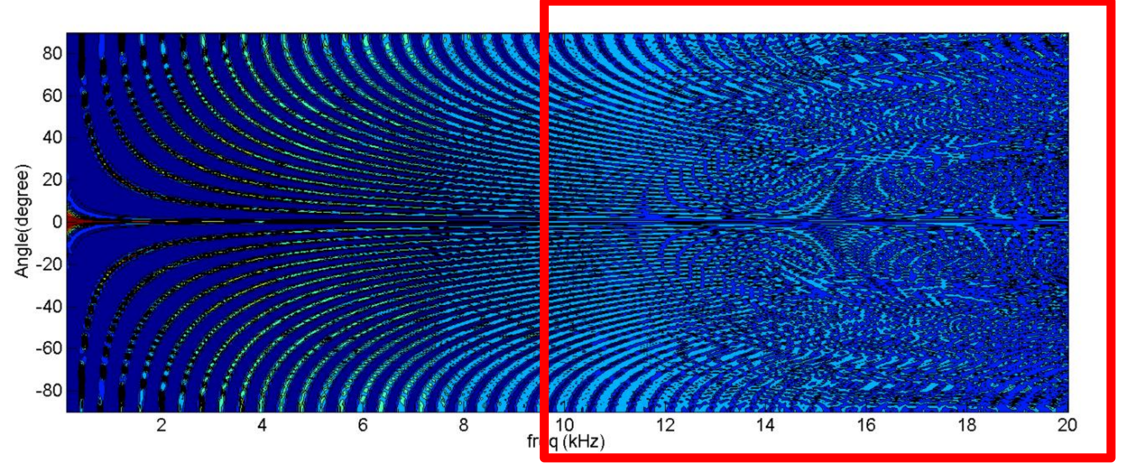
Frequency-Difference Beamforming with Sparse Arrays

Shima H. Abadi[1], Heechun Song[2], David R. Dowling[1]
1. Mechanical Engineering, University of Michigan
2. Scripps Institution of Oceanography, University of California at San Diego

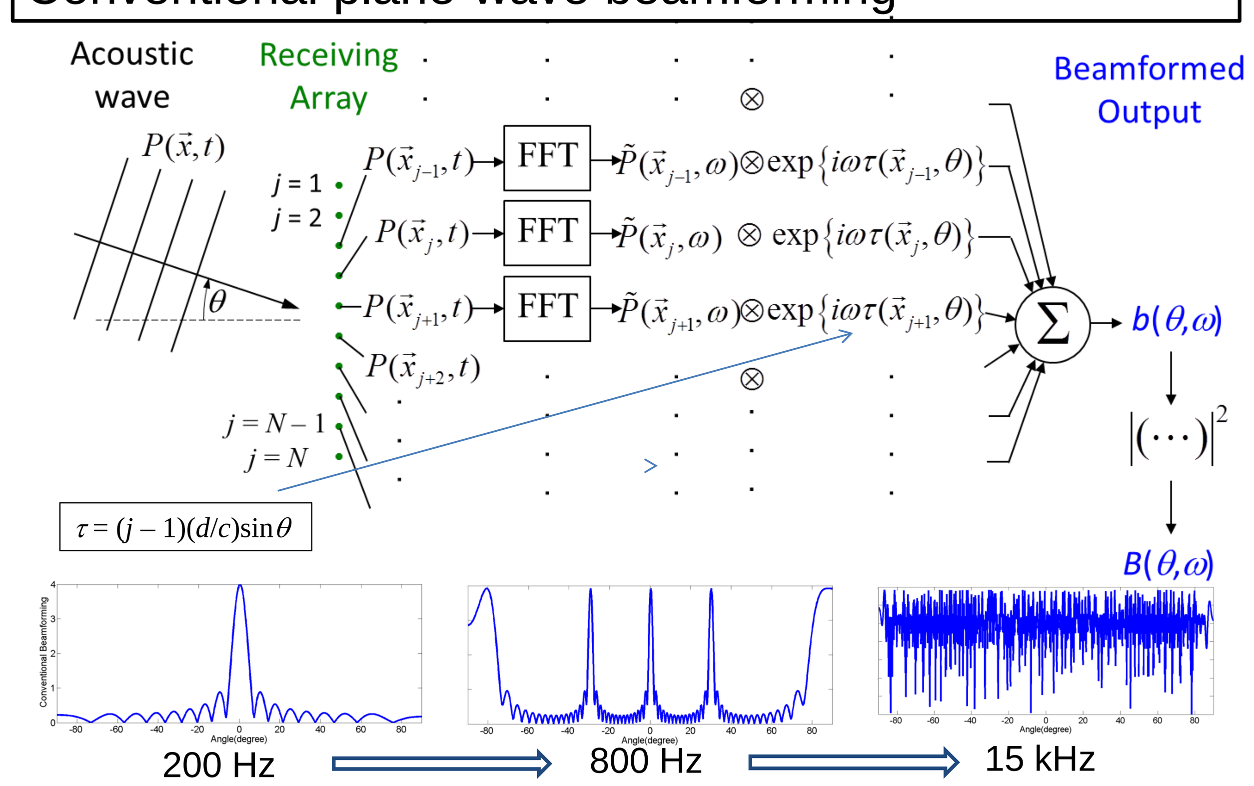
Introduction

When an acoustic signal is transmitted to a remote receiving array with sufficient aperture and transducer density, the arrival direction(s) of the ray paths linking the source and the array may be determined by beamforming the transducer recordings.



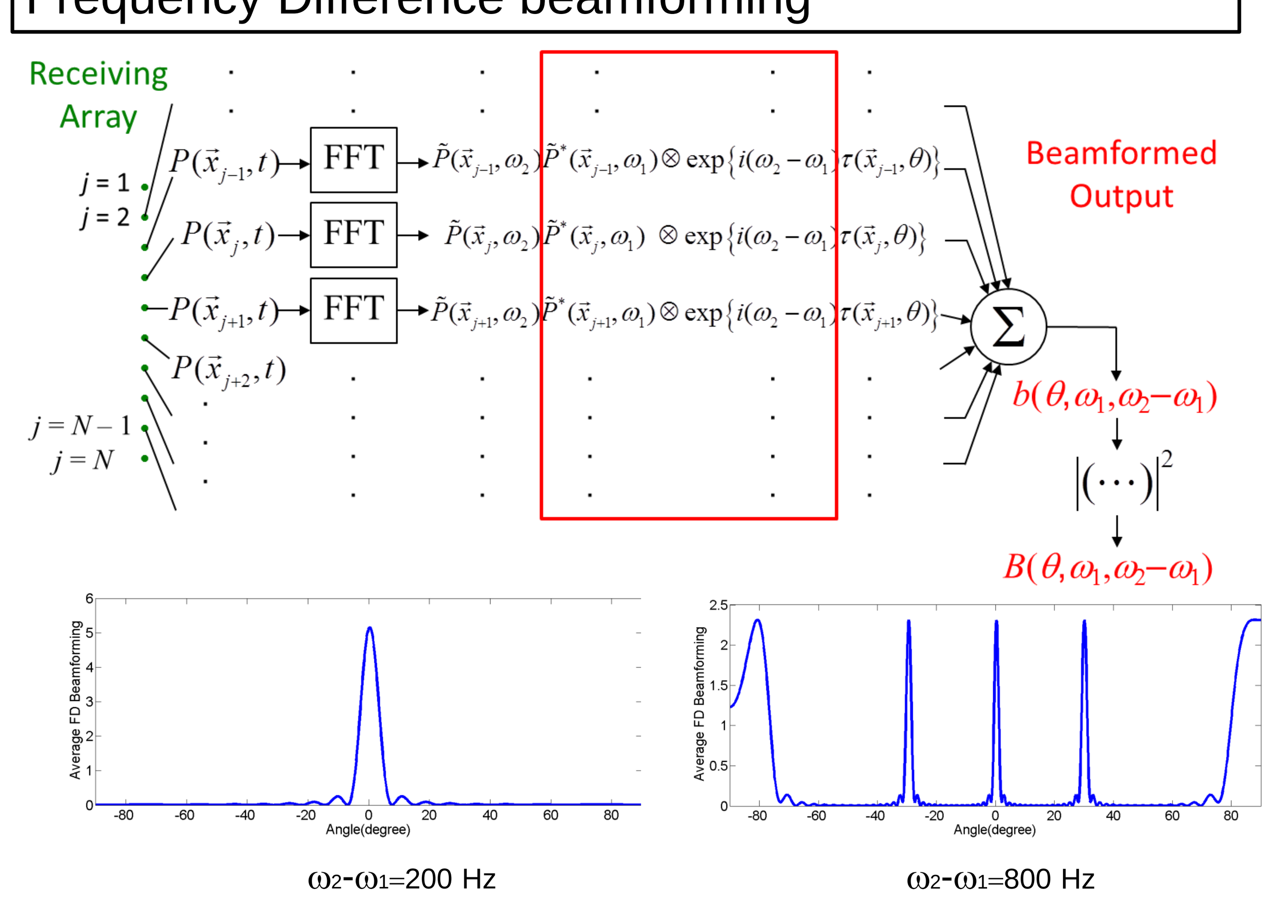
Methods and Materials

Conventional plane-wave beamforming



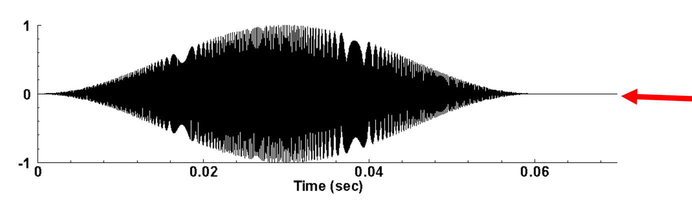
Can *lower frequency information* be manufactured from a *difference of higher frequency information*?

Frequency Difference beamforming

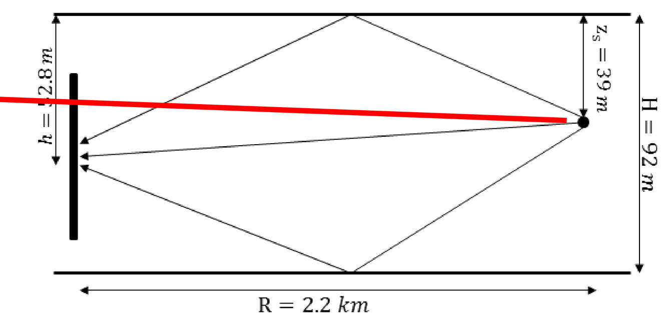


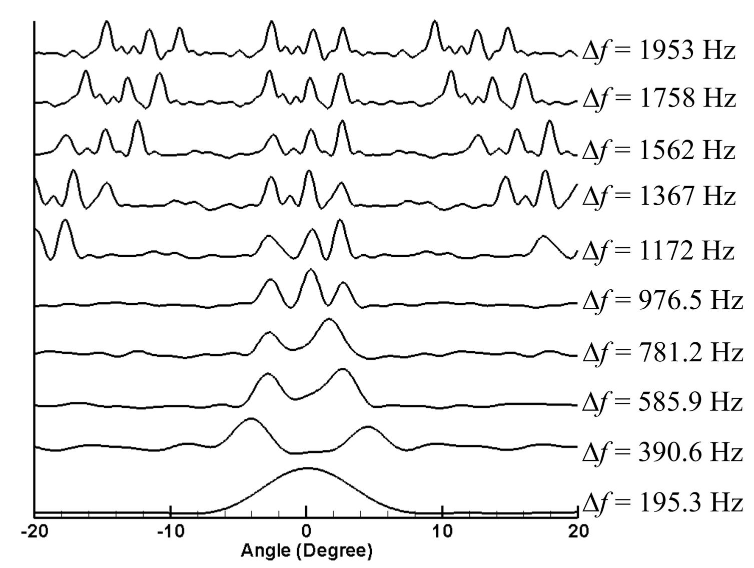
Results

Three-Path Simulation



Source Signal: 60 ms cosine-tapered LFM chirp, 11 kHz -19 kHz



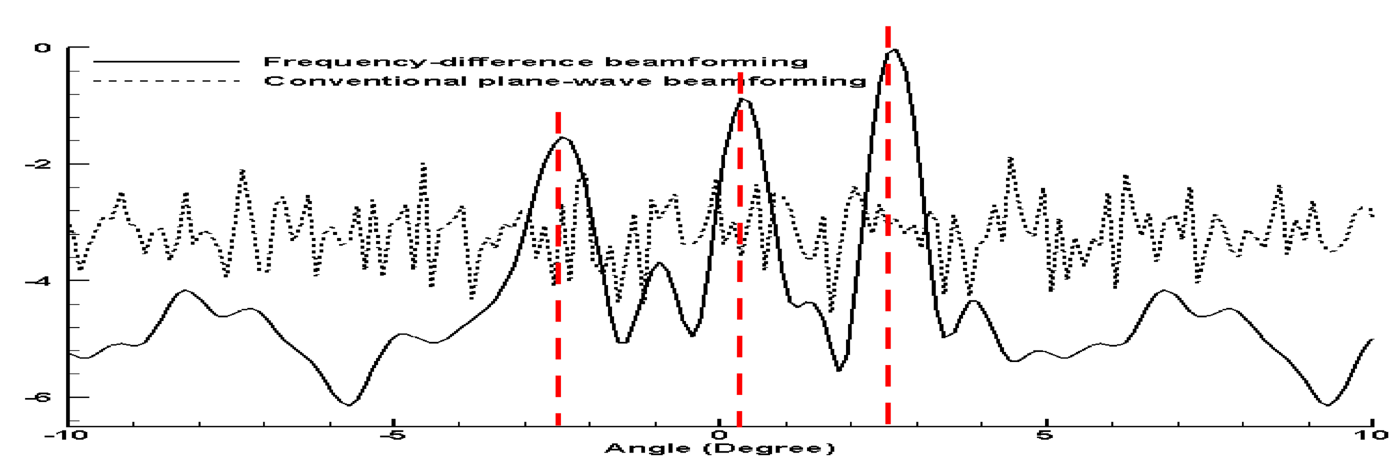


Simulation Ray-Path Angles: – 2.4°, 0.3°, +2.6°

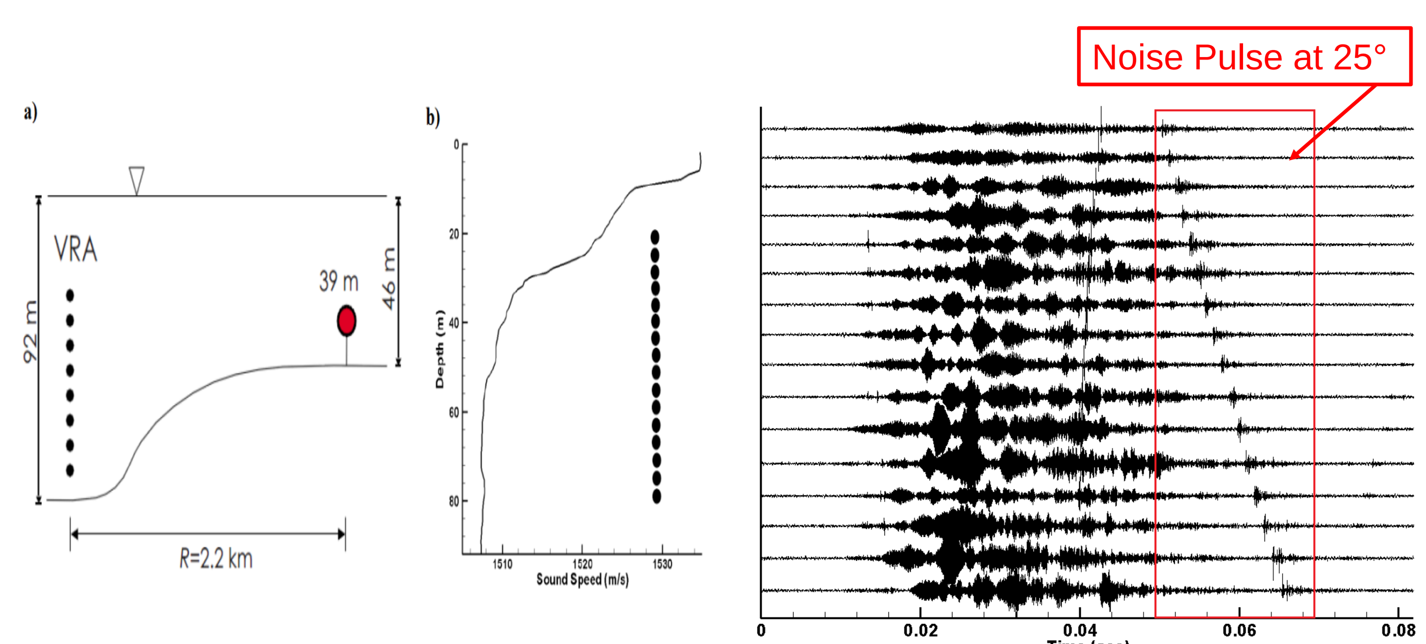
Side lobes appear at 20° as expected at:

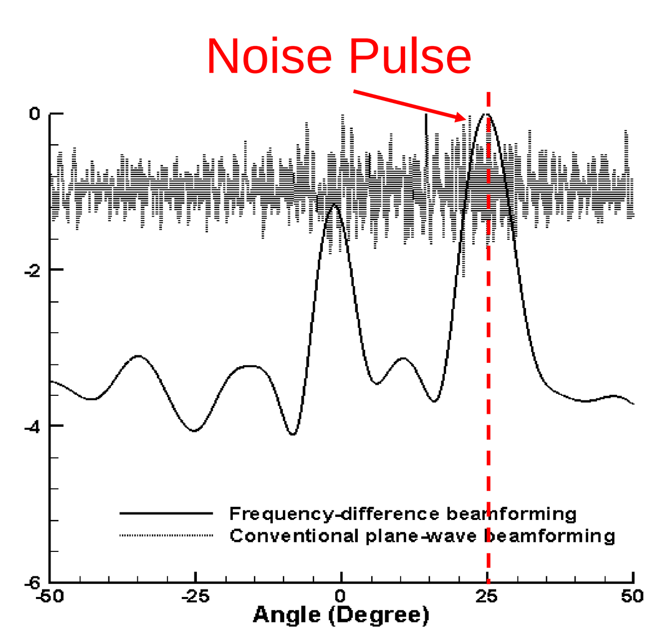
$$"f" = \frac{1500m/s}{(3.75m)\sin 20°} @170Hz$$

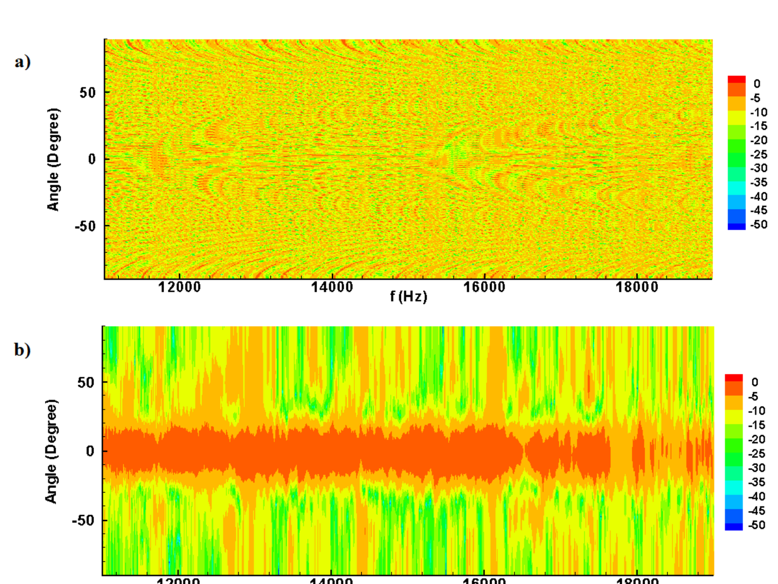
d/λ_c = 37.5; the array is sparse!



Focused Acoustic Field 2006 (FAF06) Experiment







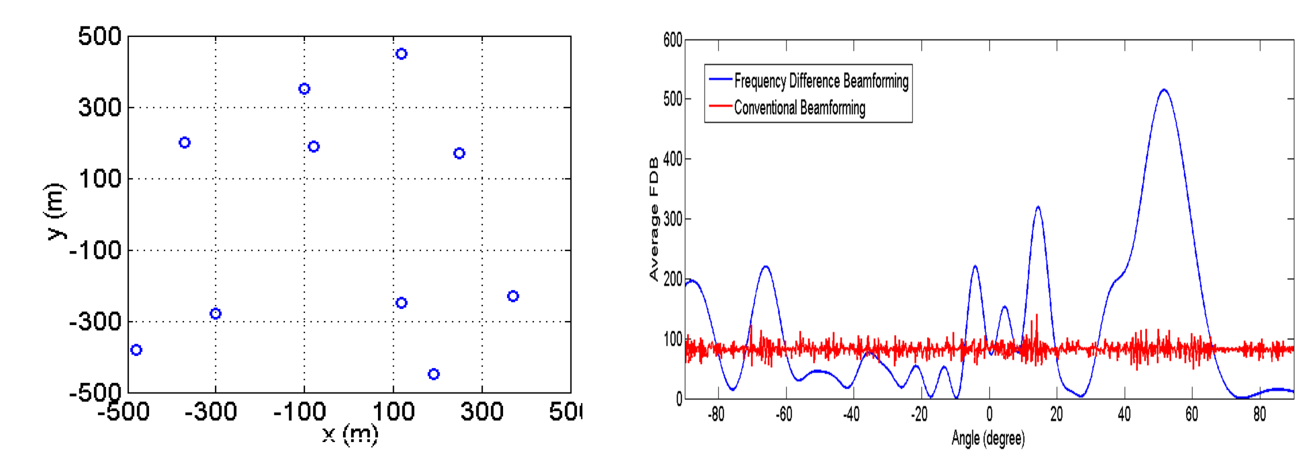
Conclusions

when the receiving array is sparse, i.e. there are many signal wavelengths between transducers, the utility of conventional beamforming is degraded because of spatial aliasing. Yet, when the signal has sufficient bandwidth, such aliasing may be mitigated or eliminated through use of an unconventional nonlinear beamforming technique that manufactures a desired frequency difference from the recorded signals. When averaged through the signal's frequency band, the output of frequency-difference beamforming is similar to that of conventional beamforming evaluated at the desired difference frequency.

Simulation and experiment results in this research study show that when the recording array is sparse, conventional delay-and-sum beamforming results in the signal's frequency band are featureless, but received ray-path directions are successfully determined using frequency differences that are well below the broadcast signal's frequency band.

Future Work

Directions of ray-paths recorded from a random array can be determined by frequency difference beamforming.



Acknowledgements

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References

S. H. Abadi, H. Song, D. R. Dowling, "Broadband sparse-array blind deconvolution using frequency-difference beamforming", Journal of the Acoustical Society of America, Vol. 132, Issue 5

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