Quantitative Beamforming Using Simulated Data and the ACAM 100 Array Design

Robert Dougherty, OptiNav, Inc.

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Setup

Synthetic Sources located 100 m from the ACAM 100. Three source configurations were studied:

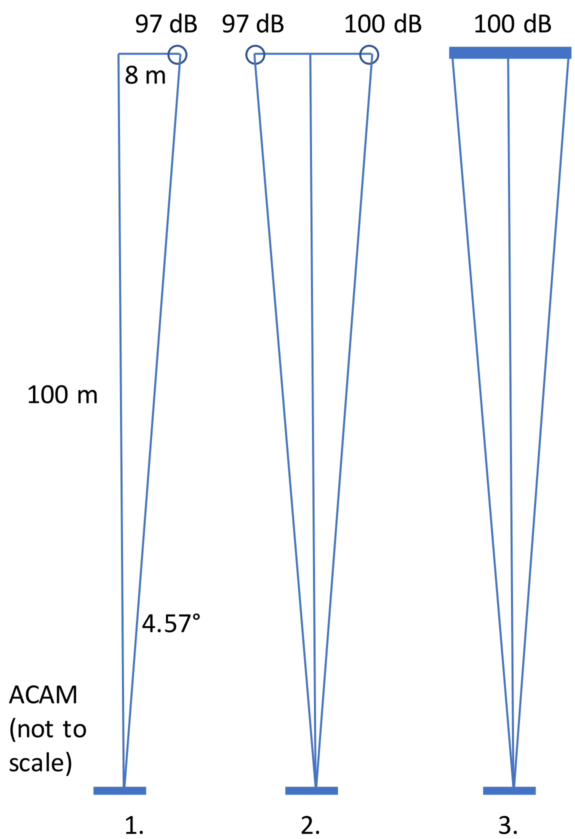
1. One 97 dB source at x = 8 m, z = 100 m. Angle from the array axis = 4.57° = 0.798 radians.

2. Two incoherent sources: 97 dB at (-8, 0, 100) m and 100 dB at (+8, 0, 100) m.

3. Incoherent line source extending from (-8, 0, 100) to (+8, 0, 100) m. Calibrated to produce an SPL of 100 dB at the array.

Results shown are 2D beamforming maps on a fixed color scale range of 75-105 dB and 1D line plots along (x, 0, 100), labeled according the horizontal angle, $\theta = \tan^{-1} \frac{x}{100\ \mathrm{m}}$.

Beamforming methods used are OptiNav Quantitative Beamforming (QB) and classical frequency domain beamforming (FDBF). Results from CLEAN-SC, Orthogonal Beamforming, and MUSIC are also shown for cases 2 and 3 at4 kHz,



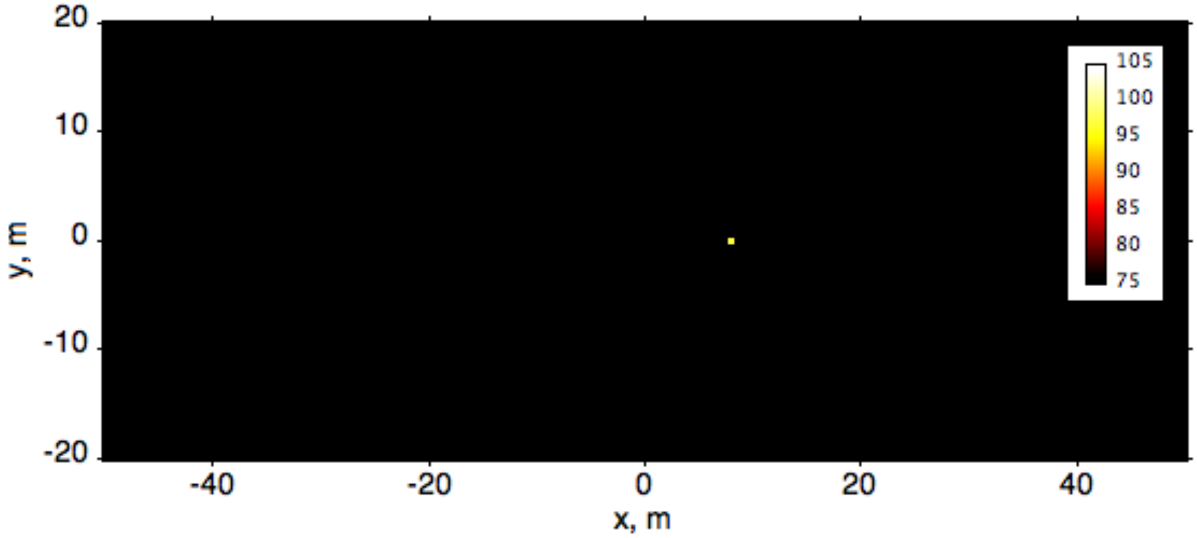
Setup for the three cases.

Results

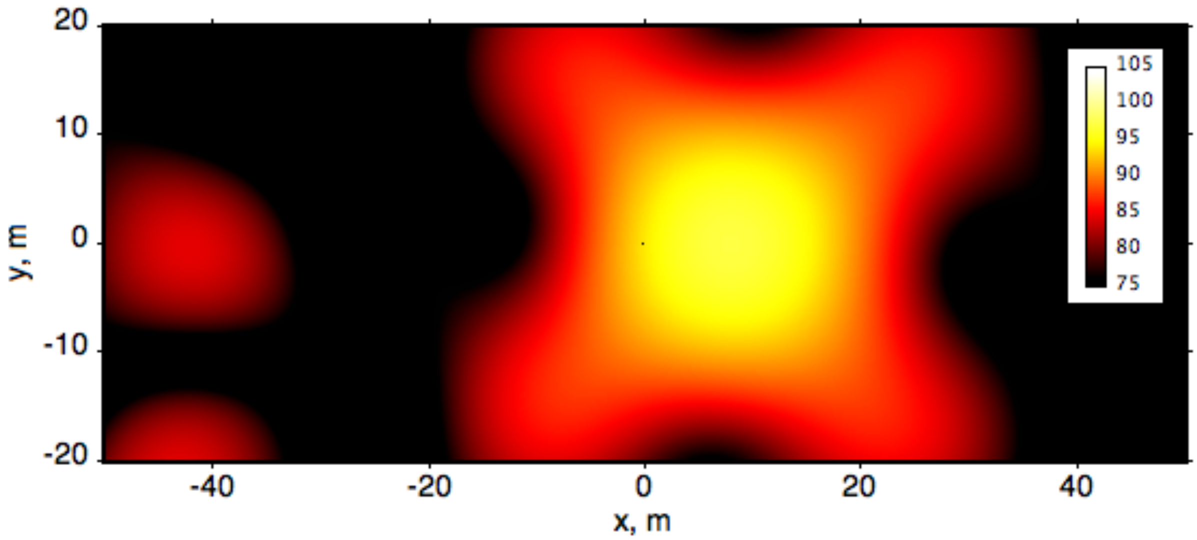
1. One source.

The angle from the array axis is 4.57° = 0.798 radians The SPL at the array was 97 dB for each of the narrow band frequencies. Two frequencies are shown: 8 kHz and 100 Hz.

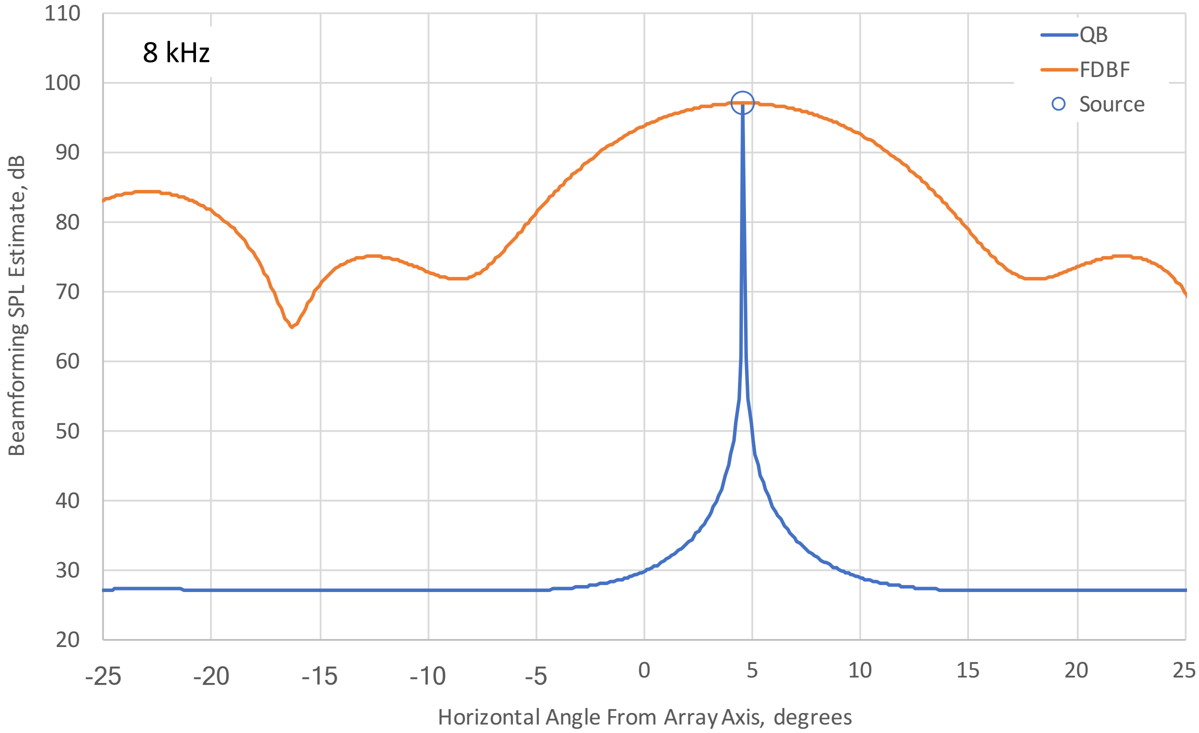
8 kHz



8 kHz, Quantitative Beamforming

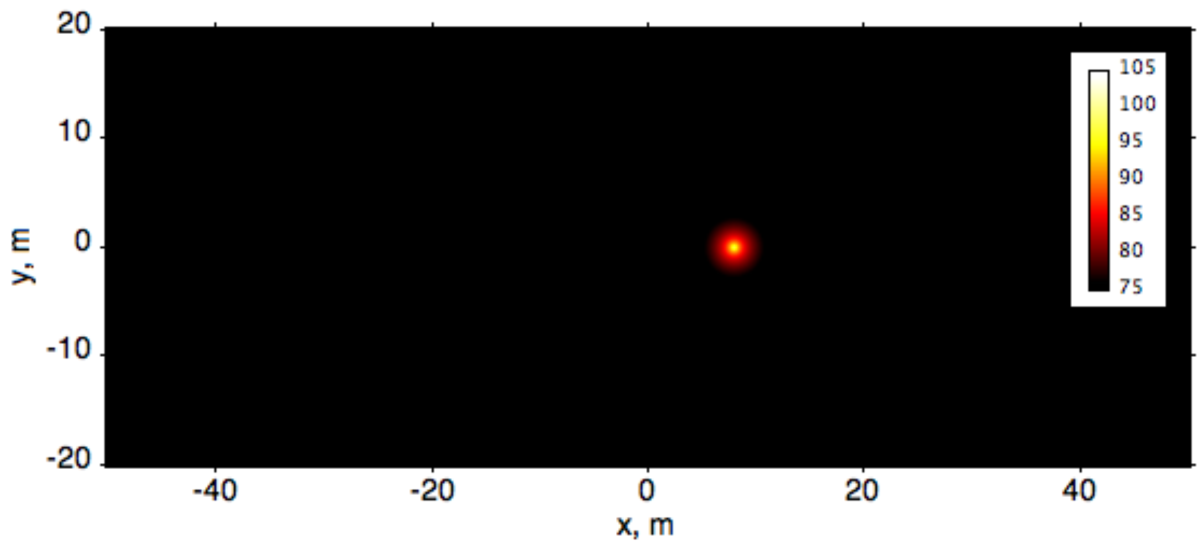


8 kHz, FDBF

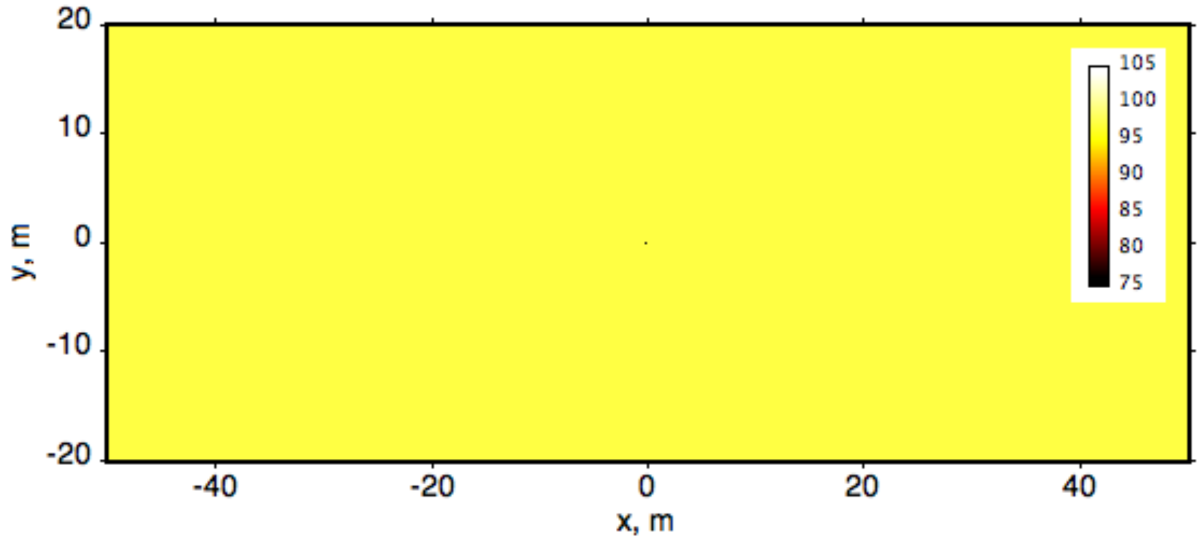


8 kHz 1D plot

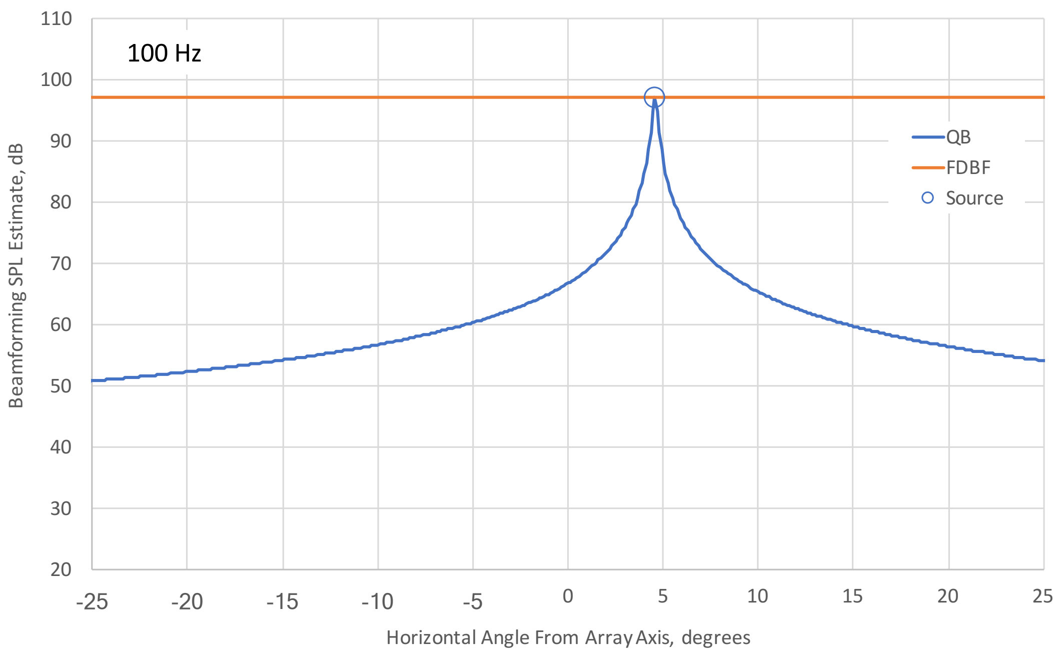
100 Hz



100 Hz, Quantitative Beamforming



100 Hz, FDBF

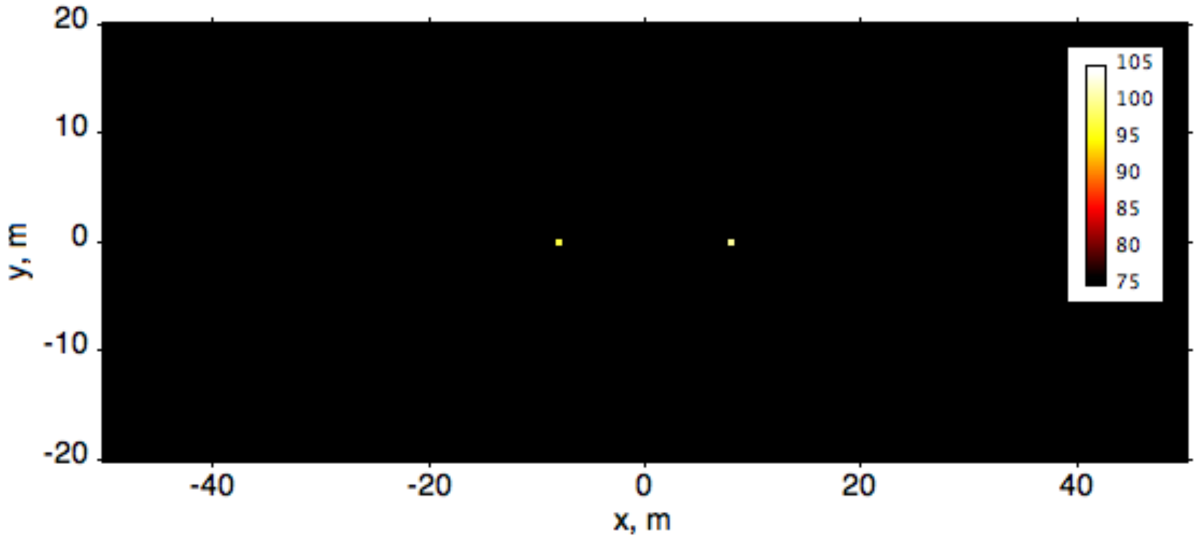


100 Hz 1D plot

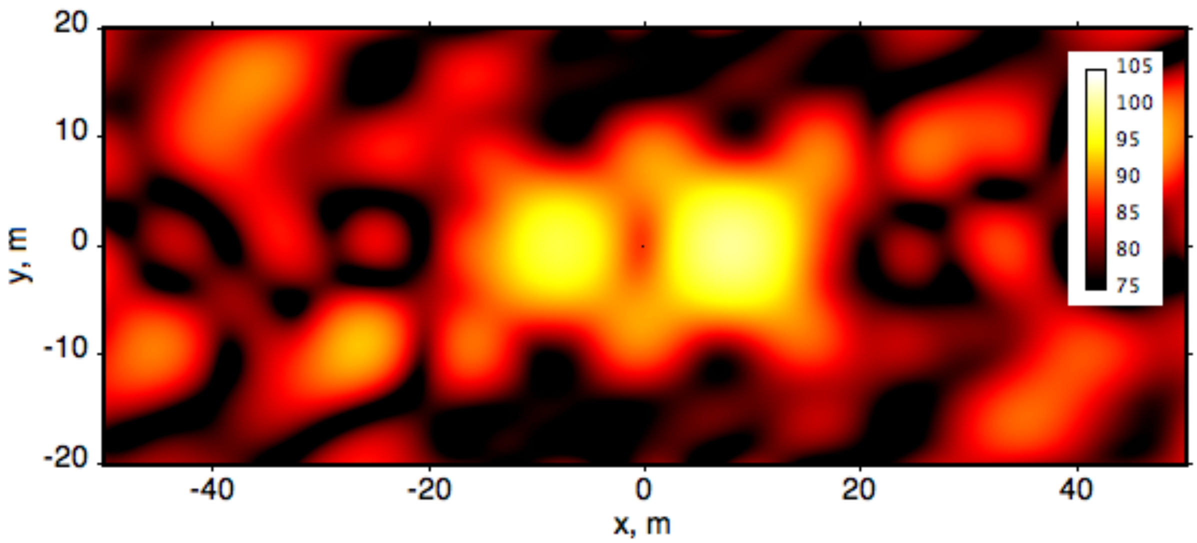
2. Two incoherent sources:

97 dB source at (-8, 0, 100) m and 100 dB source at (+8, 0, 100) m. The angular separation of the sources is 0.1596 radians. The frequency for which this equals the Rayleigh resolution limit, $\frac{1.22\,\lambda}{D}$, is 8118 Hz, where D was taken as 0.32 m. For frequencies below 8118 Hz, FDBF, CLEAN-SC, and Orthogonal Beamforming are not expected to be able to correctly separate the sources. The superresolution methods, Quantitative Beamforming and MUSIC are expected to be able to separate the sources for lower frequencies.

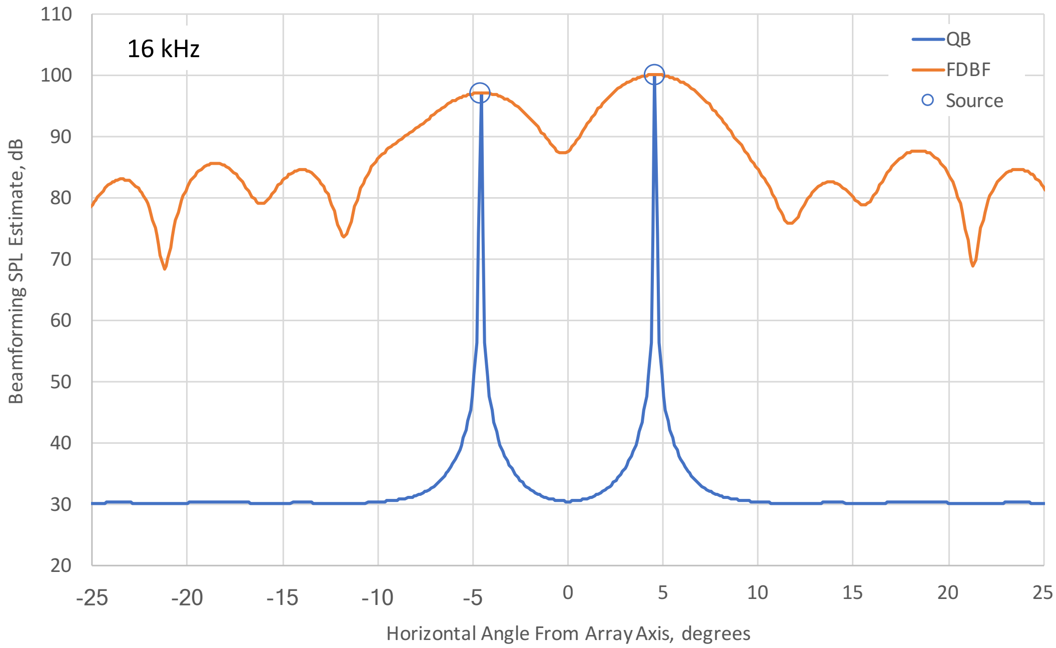
16 kHz



16 kHz, Quantitative Beamforming

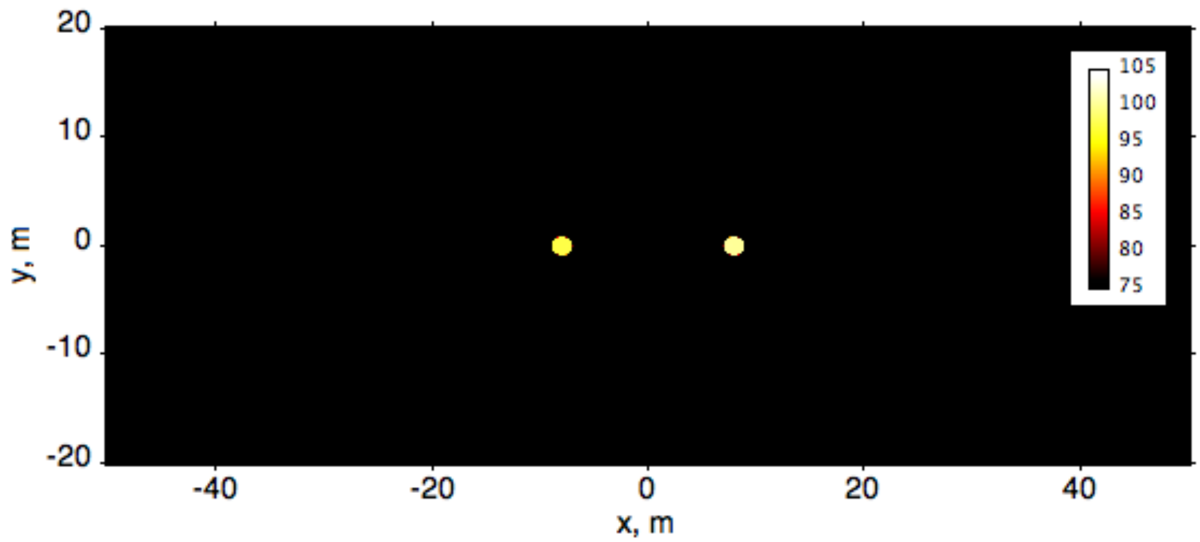


16 kHz, FDBF

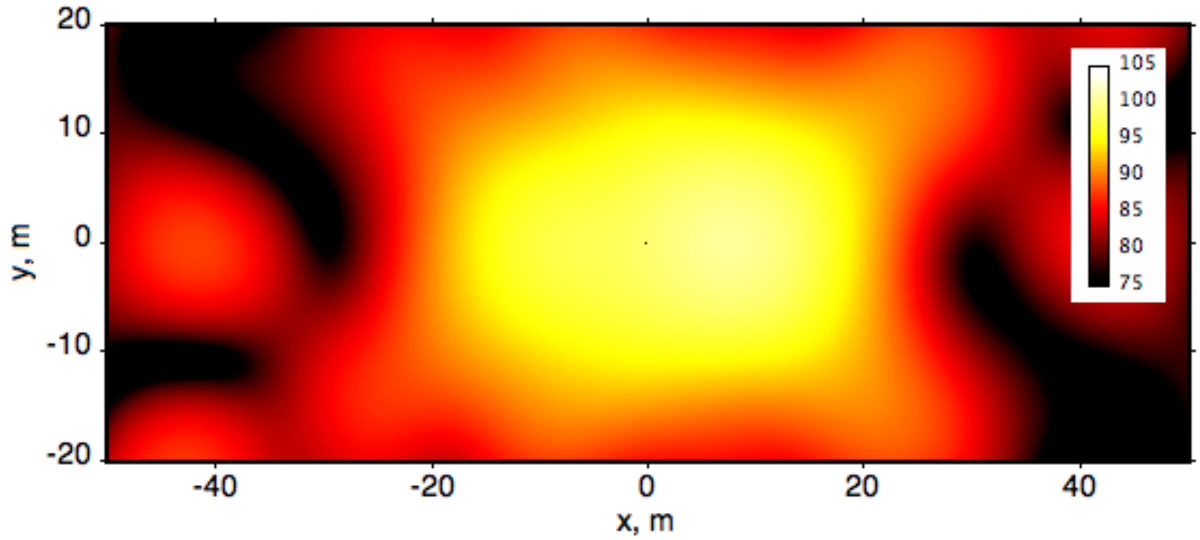


16 kHz 1D plot

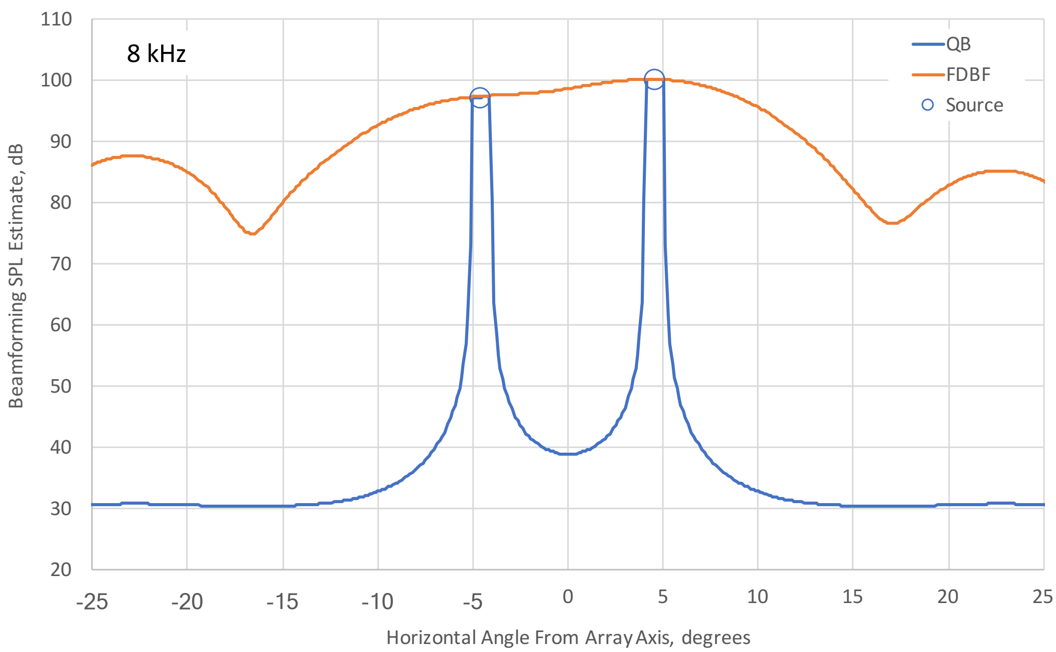
8 kHz



8 kHz, Quantitative Beamforming

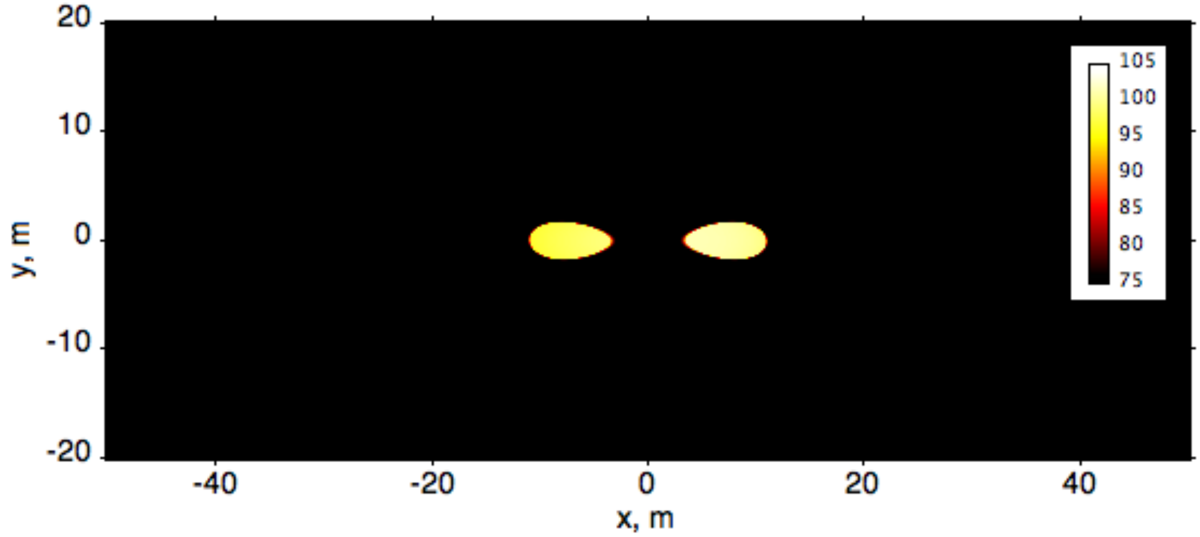


8 kHz FDBF

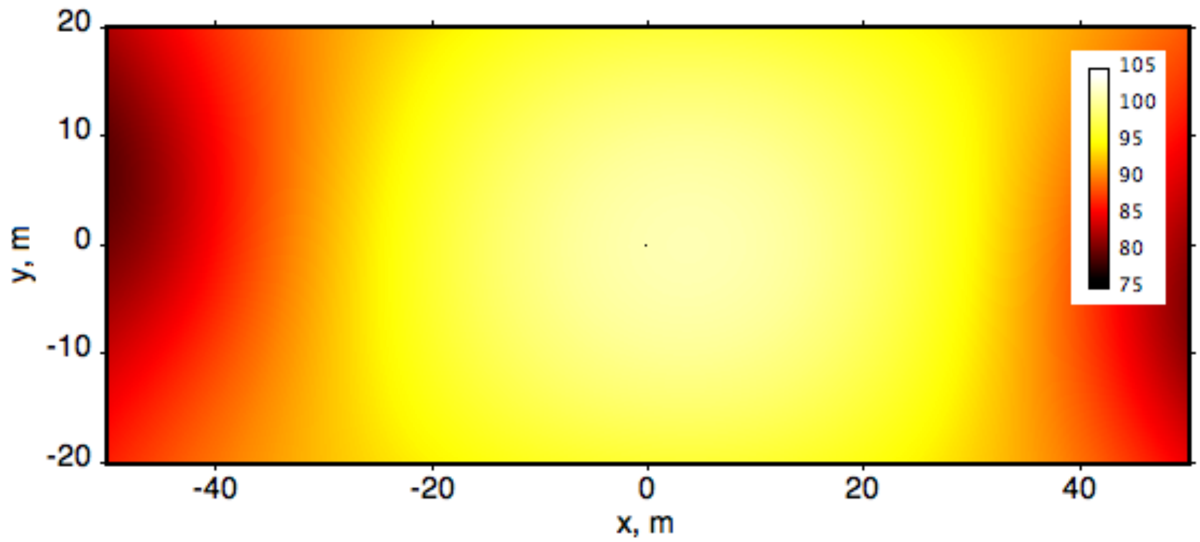


8 kHz 1D plot

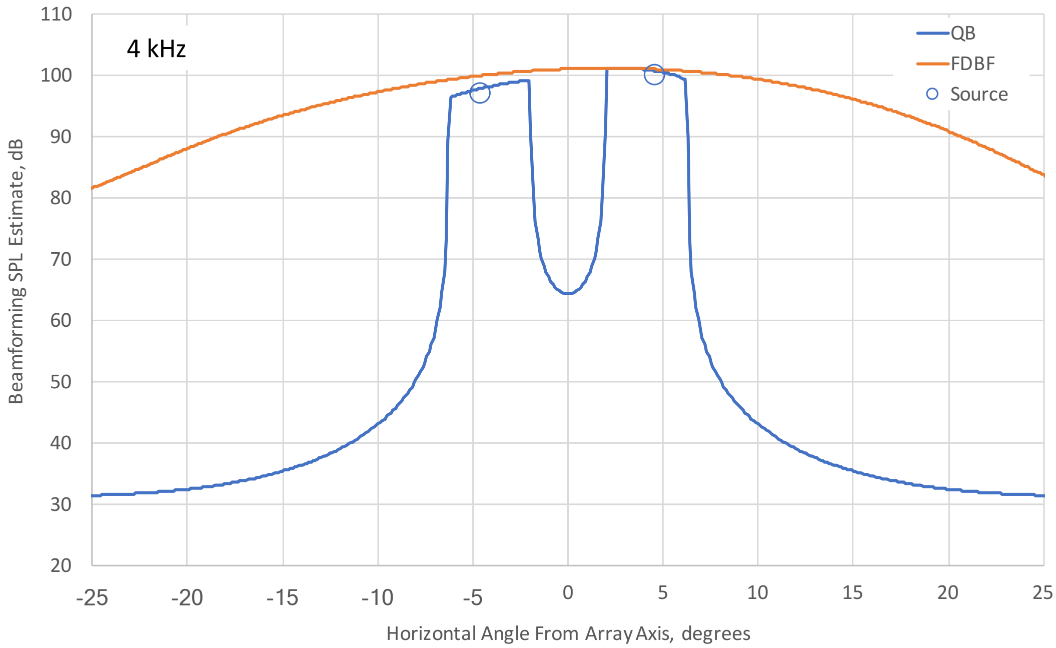
4 kHz



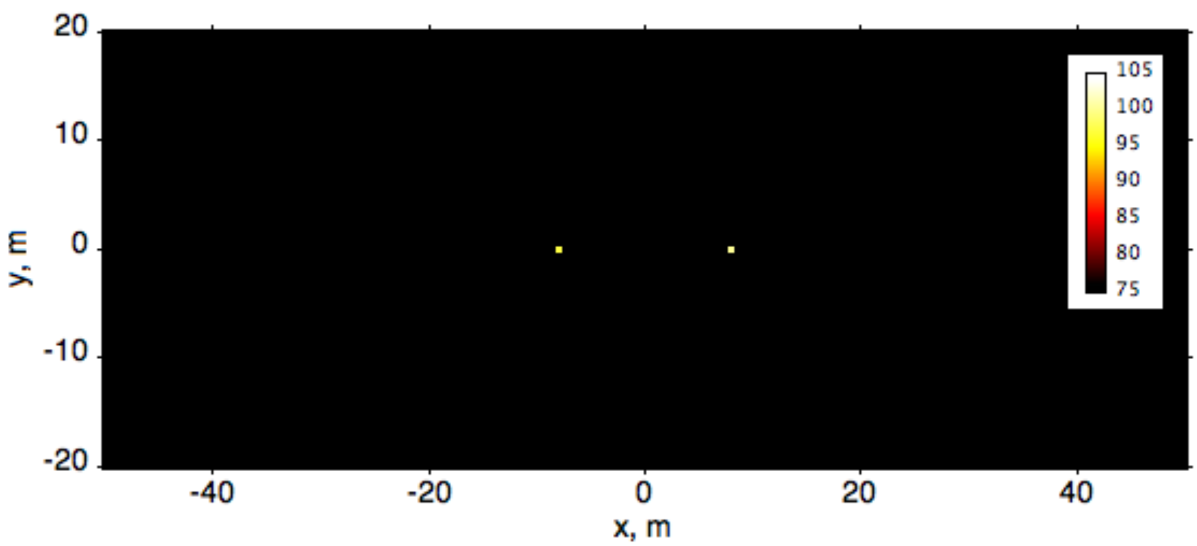
4 kHz, Quantitative Beamforming



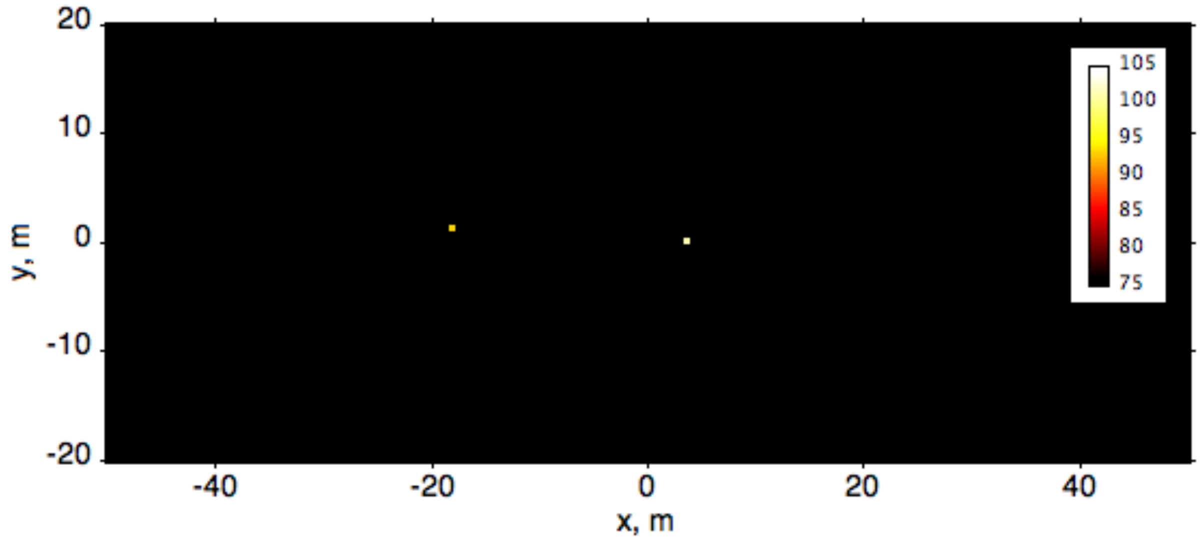
4 kHz FDBF



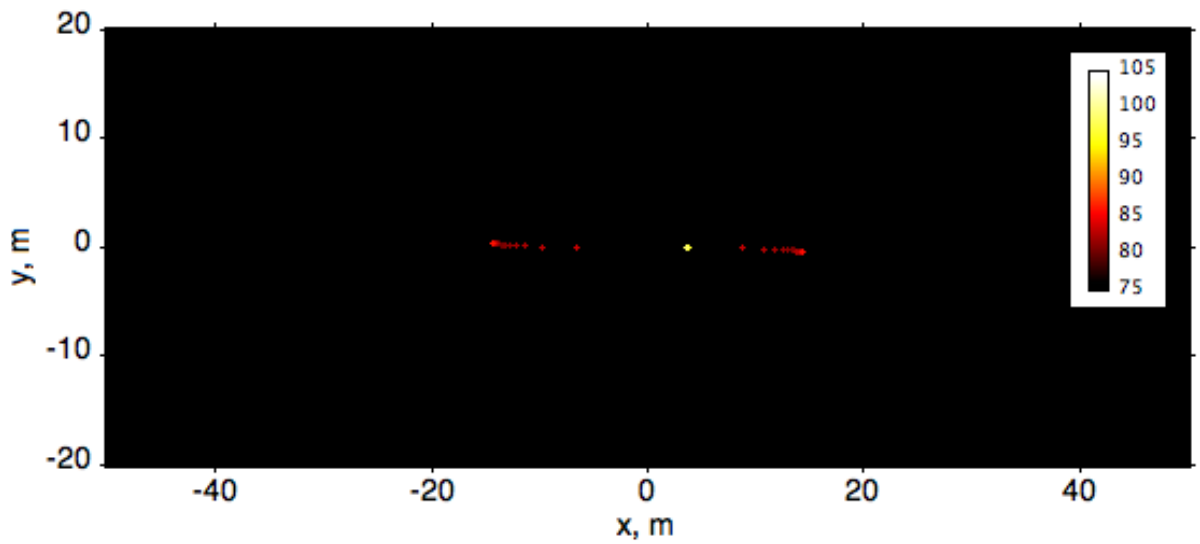
4 kHz 1D plot



4 kHz MUSIC

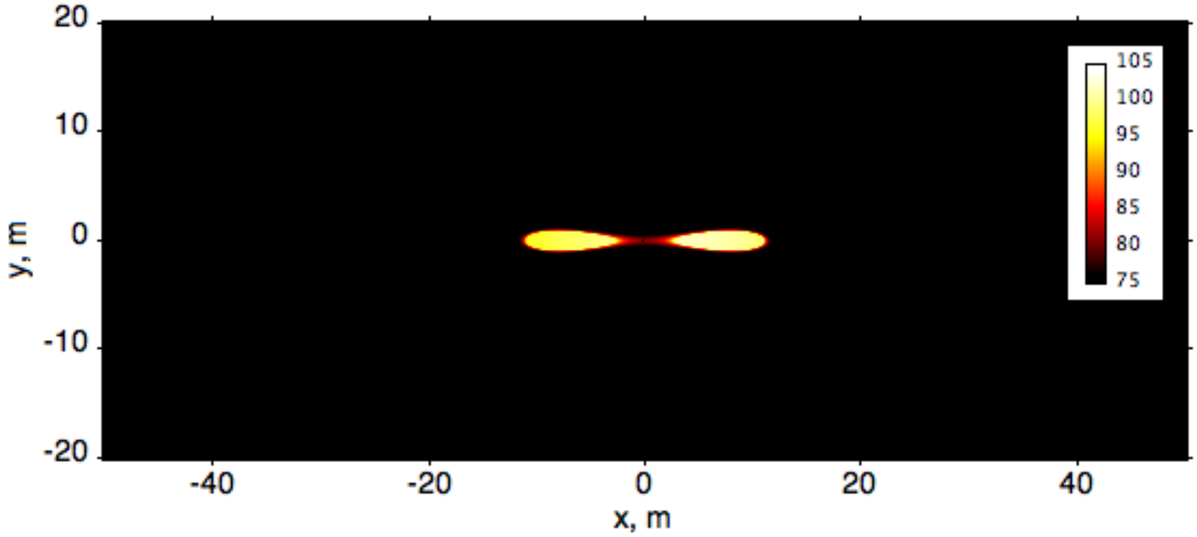


4 kHz Orthogonal Beamforming

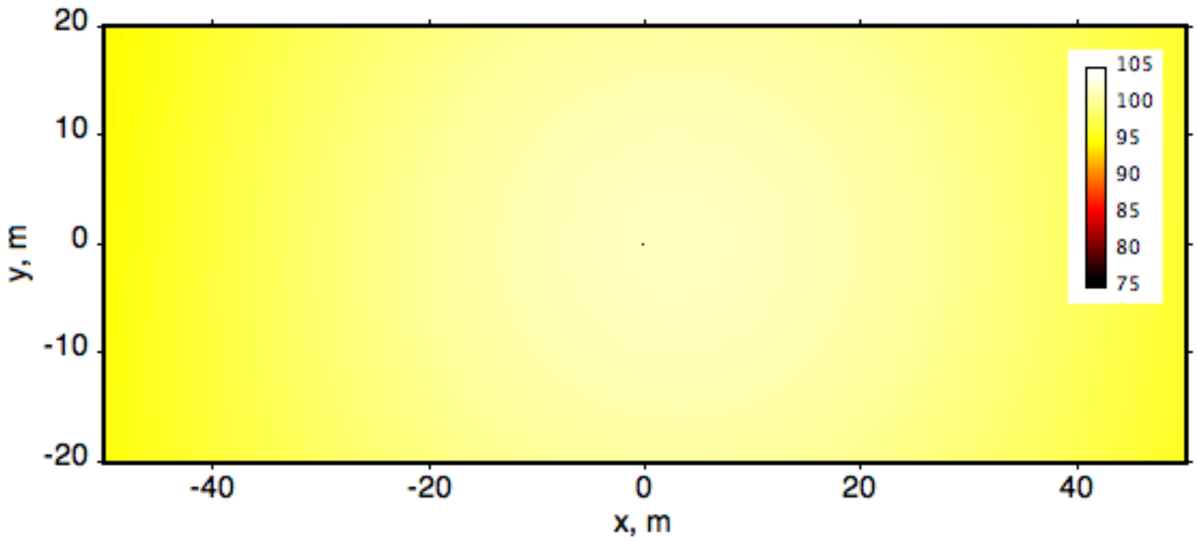


4 kHz CLEAN-SC

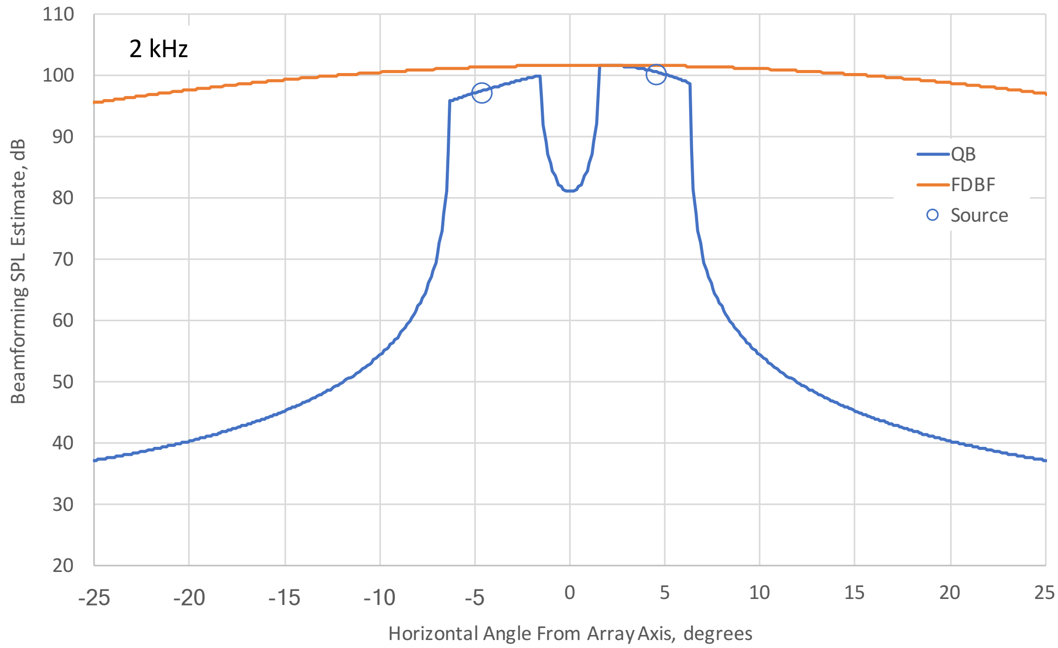
2 kHz



2 kHz, Quantitative Beamforming

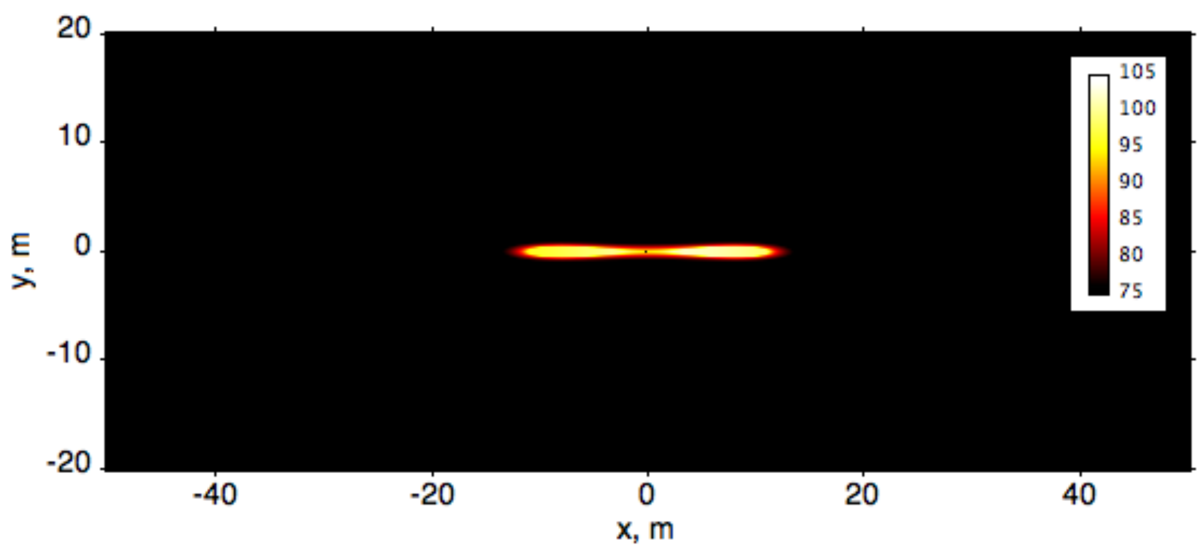


2 kHz FDBF

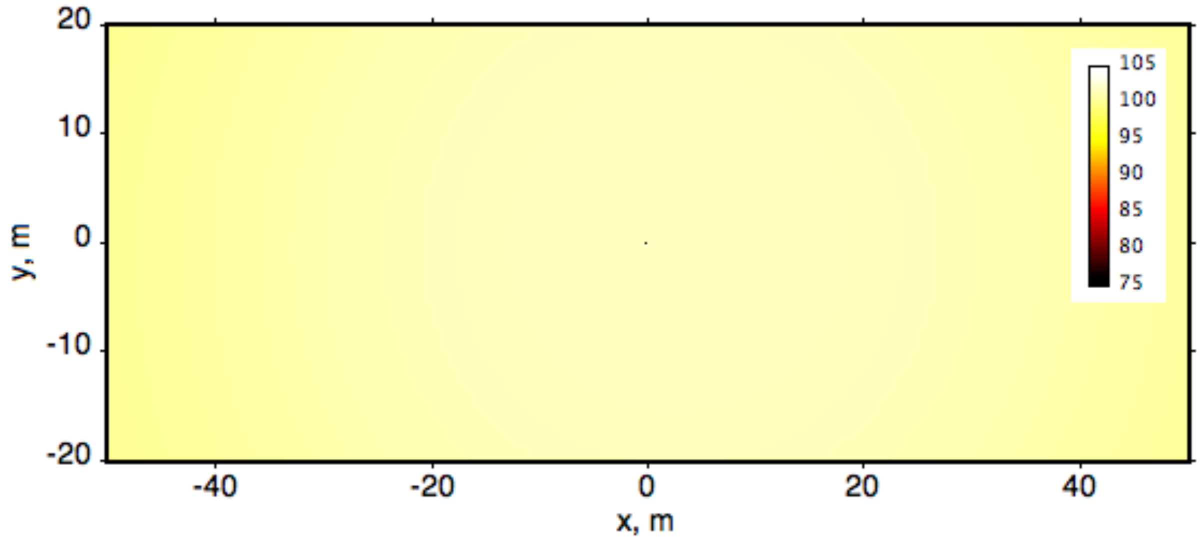


2 kHz 1D plot

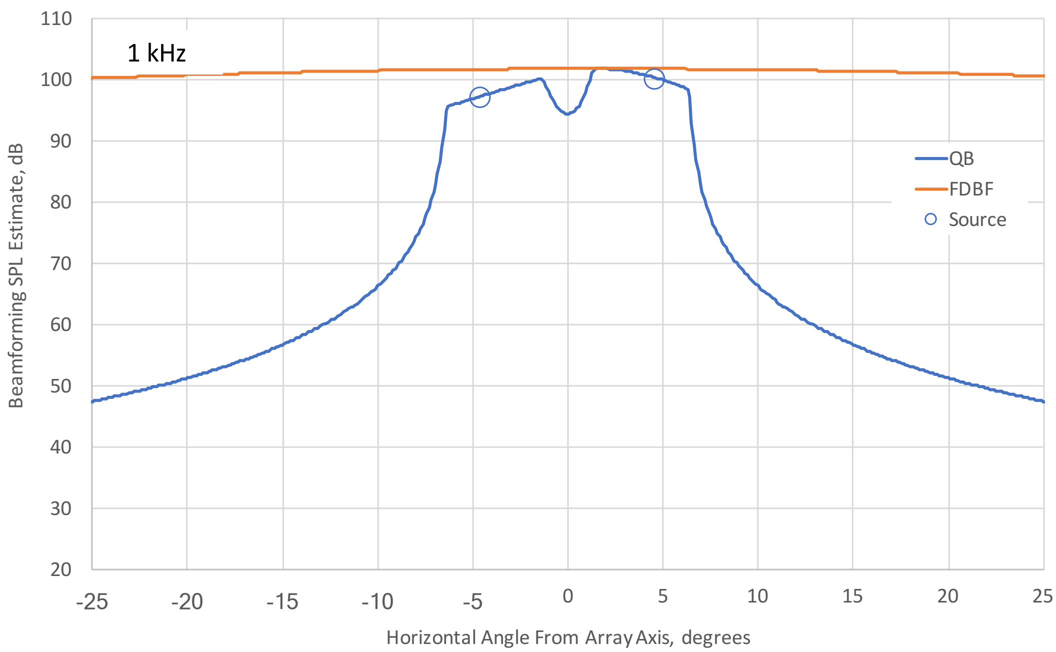
1 kHz



1 kHz, Quantitative Beamforming



1 kHz FDBF

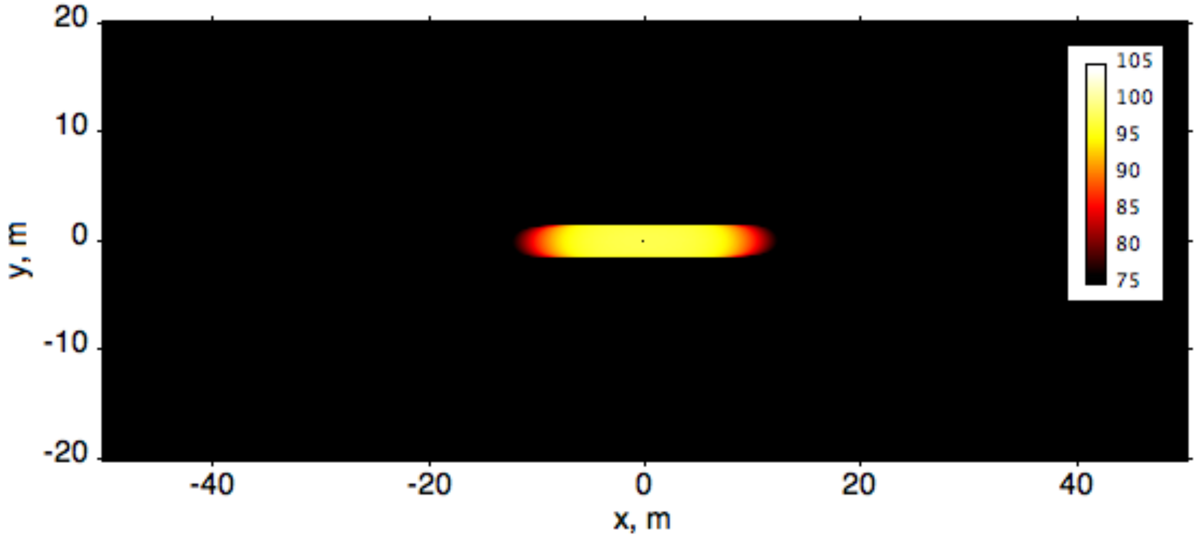


1 kHz 1D plot

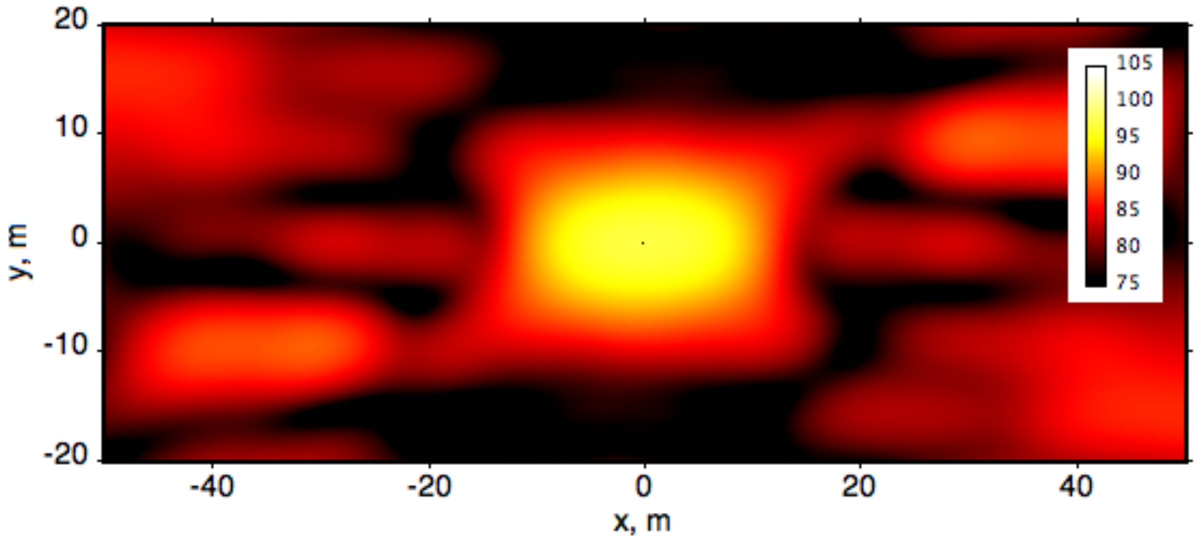
3. Incoherent line source

The source extends from (-8, 0, 100) to (+8, 0, 100) m. The simulated data was made from 1000 incoherent sources spaced along the line. The level at the array combining all of the sources was 100 dB. The beamforming levels shown are independent for each point. They have not yet been normalized by “integration” to reproduce the total level at the array.

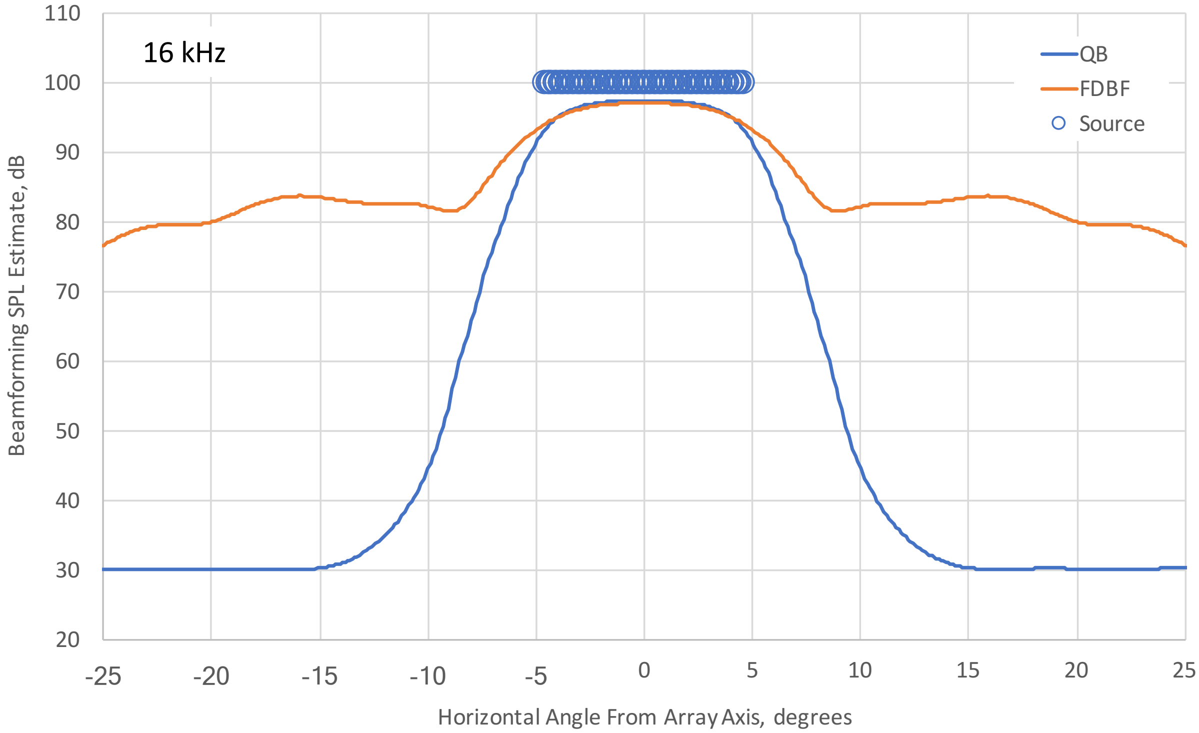
16 kHz



16 kHz, Quantitative Beamforming

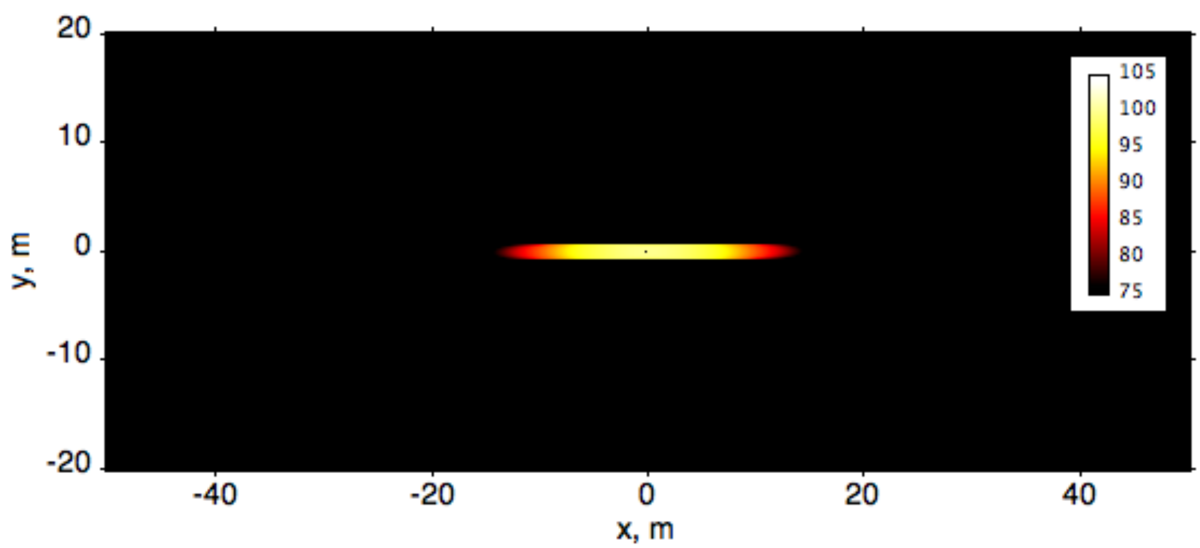


16 kHz FDBF

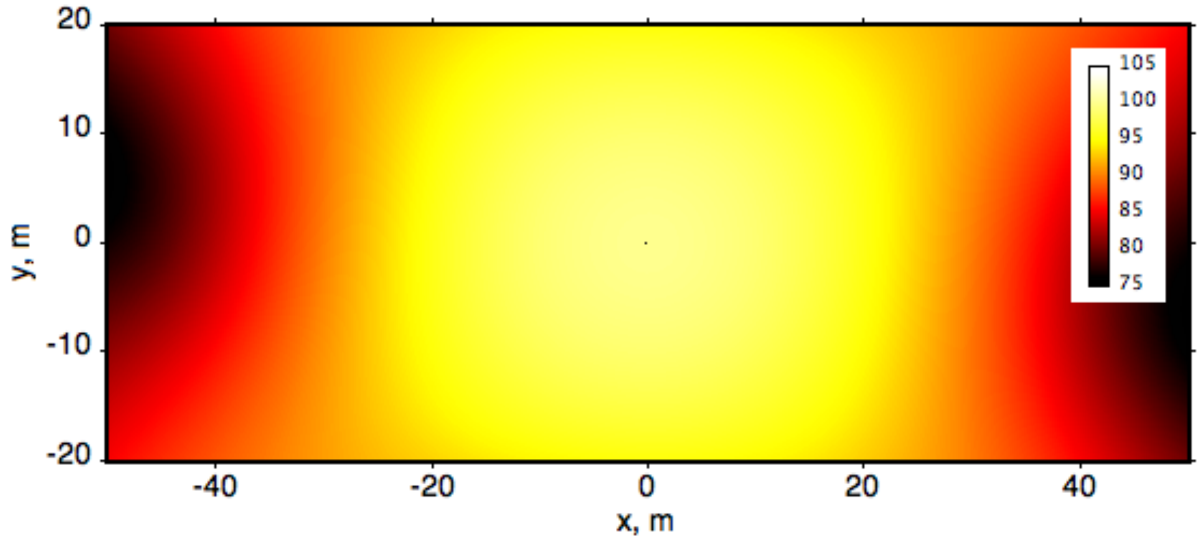


16 kHz 1D plot.

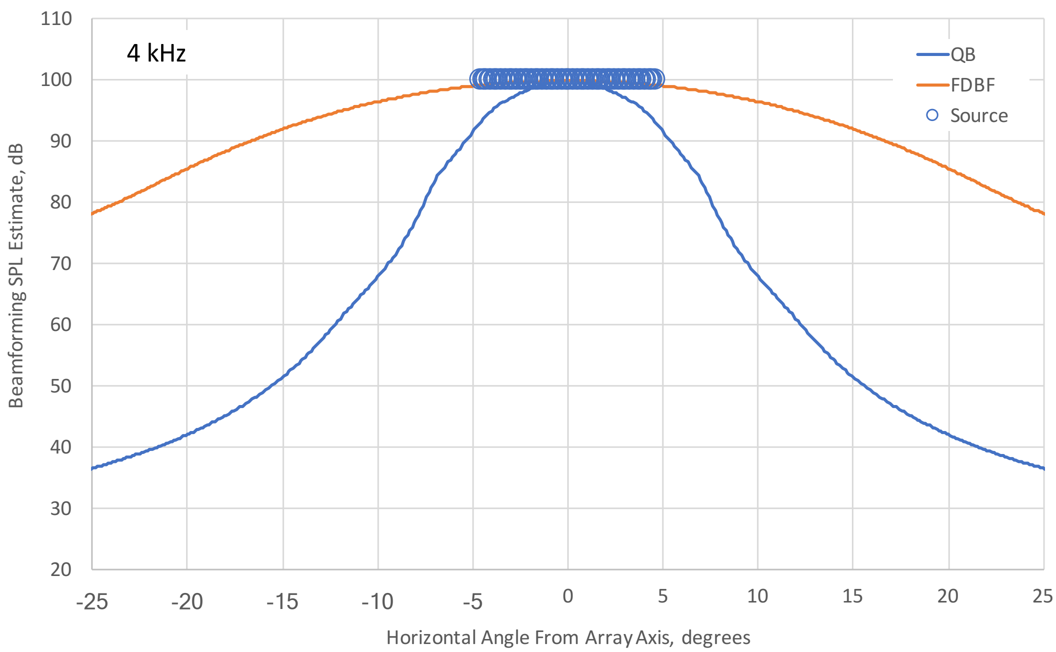
4 kHz



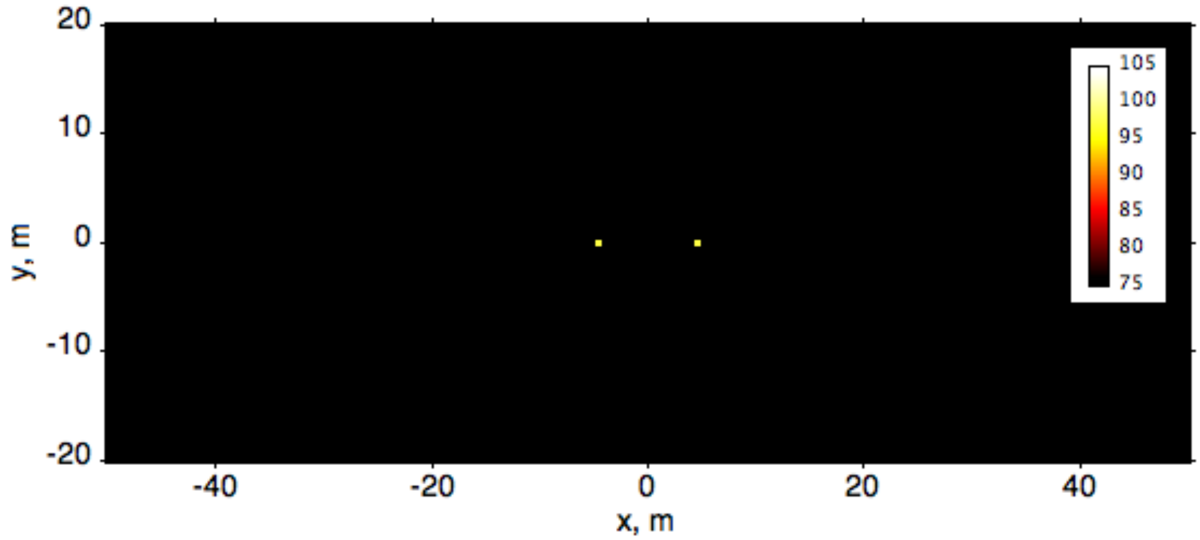
4 kHz, Quantitative Beamforming



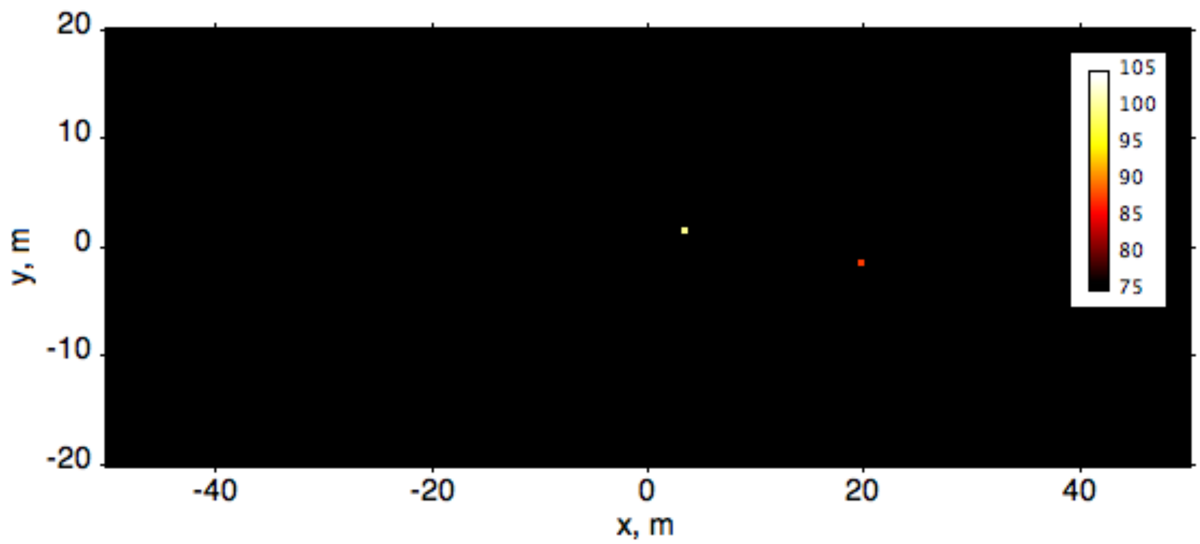
4 kHz FDBF



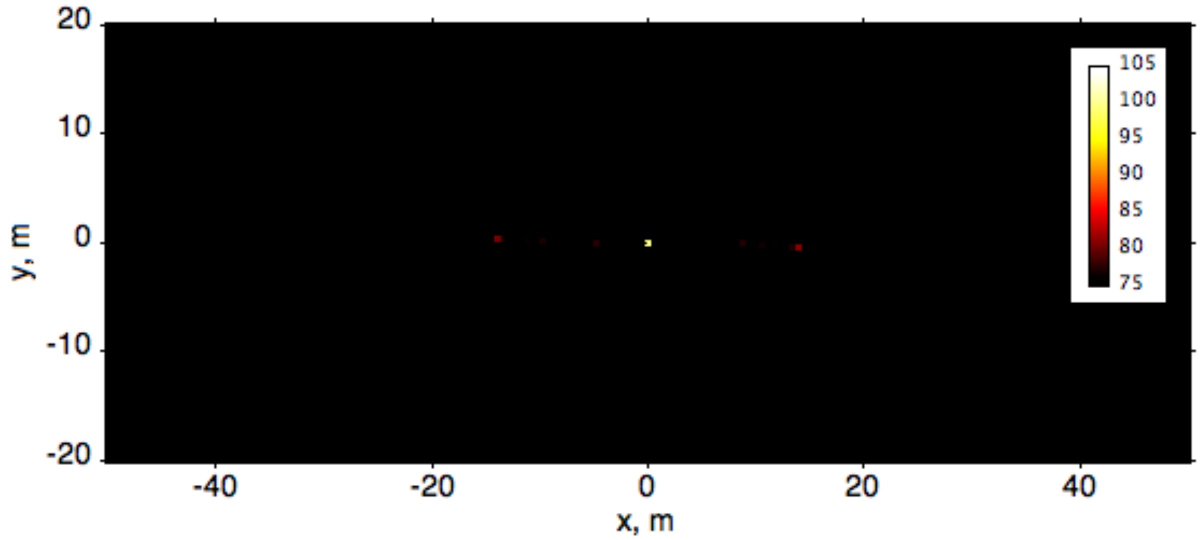
4 kHz 1D plot



4 kHz MUSIC



4 kHz Orthogonal Beamforming



4 kHz CLEAN-SC

Conclusions

Quantitative Beamforming (QB) has better resolution than FDBF, Orthogonal Beamforming, and CLEAN-SC. For isolated sources, it gives the correct levels for the source locations. For extended, incoherent sources, QB has the best performance, followed by FDBF. The other methods give very wrong results for extended sources.