



## SIG ACAM 100 with OptiNav BeamformX

Signal Interface Group’s (SIG) ACAM 100 is a microphone array for locating and analyzing sound sources in real time. Combined with OptiNav’s BeamformX software, it makes a powerful, compact, system at a breakthrough price.

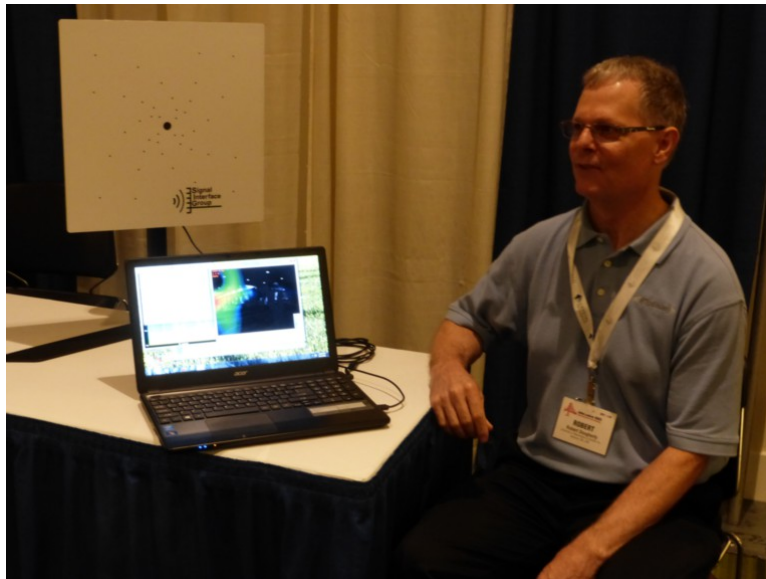


Figure 1. SIG ACAM 100 and OptiNav BeamformX at InterNoise 2015.

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## Overview

SIG ACAM 100 combines 40 digital MEMS microphones and a 5 megapixel optical camera in a planar, 40 x 40 cm array.

BeamformX is OptiNav's real time beamforming code. It has two frequency domain beamforming options: conventional beamforming and Robust Asymptotic Functional Beamforming (RAFB). The latter represents years of research in beamforming at OptiNav and is superior in speed, resolution, and dynamic range. The name is sufficiently complicated that it is sometimes also called "OptiNav beamforming". Functional Beamforming is patent pending and was described at the Berlin Beamforming Conference and the AIAA Aeroacoustics Conference in 2014. The Robust and Asymptotic modifications of Functional Beamforming have not yet been published.

## BeamformX features

BeamformX has three windows: Single Mic Spectrum, Spectrogram, and the beamforming Display (Fig 2).

The Single Mic Spectrum window shows the instantaneous narrowband spectrum from either a single microphone or the result of steering the array to a point selected on the Display window. In the case of steering, there is choice between a simple delay and sum combination or a more-sophisticated signal processing calculation. The single microphone or steered signal can also be played through the (Windows) computer's audio system.

The Spectrogram window shows the previous 30 seconds or so of data. Clicking on the Spectrogram pauses the acquisition and causes the Display window to be updated to the selected time and frequency and the Single Mic Spectrum window to adjust to the selected time. Clicking "Play buffer" (on the Display window) causes the Display and the Single Mic Spectrum windows to advance using the data in the spectrogram buffer. This playback can be at normal speed or slow motion.

The Display window gives the main beamforming result. The optical image and the acoustic beamforming color contour map are fused. Three choices for the acoustic lookup table are available: "Red hot" (thermal), "Rainbow", and "Fire". The top level of the color map autoscales to the highest beamforming result found, and the bottom level is lower than the top by the dynamic range setting. The normal setting for the dynamic range is 20 dB (High Dynamic Range, appropriate for RAFB), with a reduced range for frequencies lower than 4 kHz, as discussed below. Deselecting HDR divides the dynamic range by 2 to give a range that is more typical of a conventional system. The integration time is controlled by an adjustable exponential decay filter.

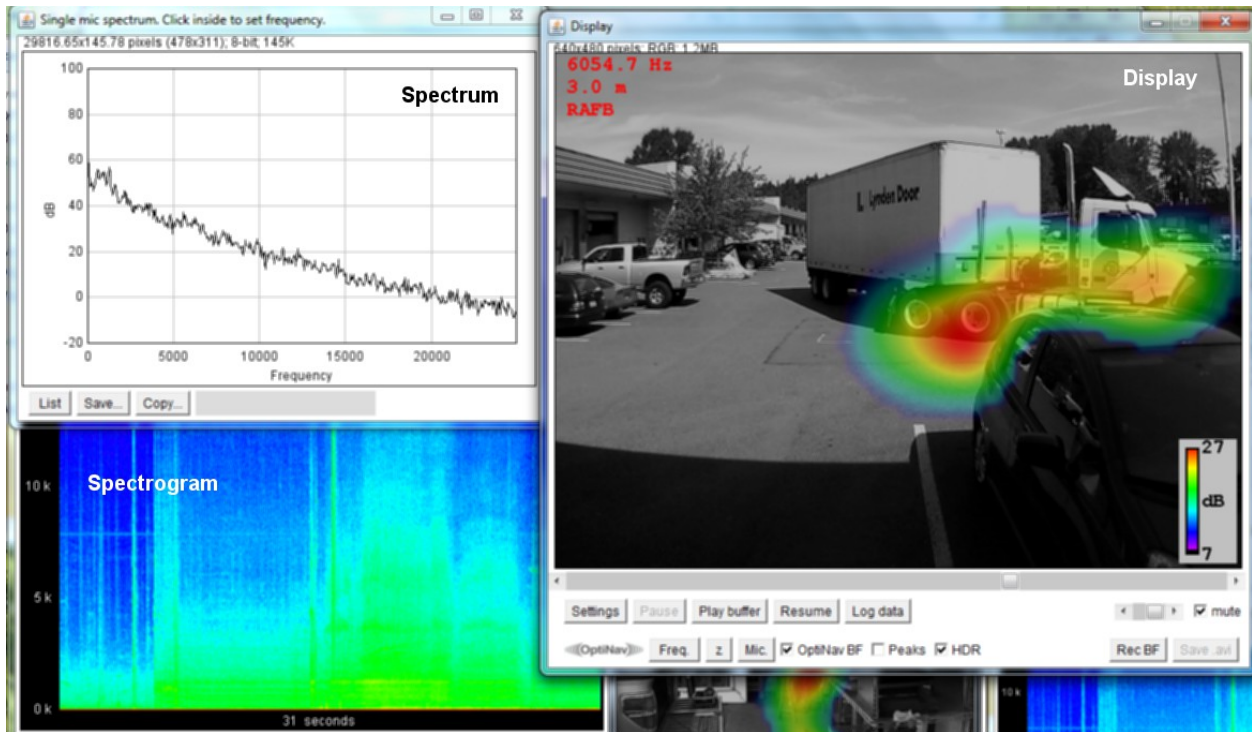


Figure 2. Windows of BeamformX.

## FAQ

**What sets this system apart from the competition?**

**How much does it cost?**

**Is this a product or a prototype?**

**What is the frequency range?**

**How far away can the source be?**

**Can you save an image?**

**What sets this system apart from the competition?**

1. Single cable array. The USB cable carries the acoustic data and the optical camera images to the computer and also powers the array.
2. Uniquely powerful beamforming software. BeamformX has exceptional speed, resolution, and dynamic range to show true sources over a wide dynamic range and not show spurious sidelobes. Examples are given in Figs. 3-5.
3. Low price makes the array much more affordable than competing systems.

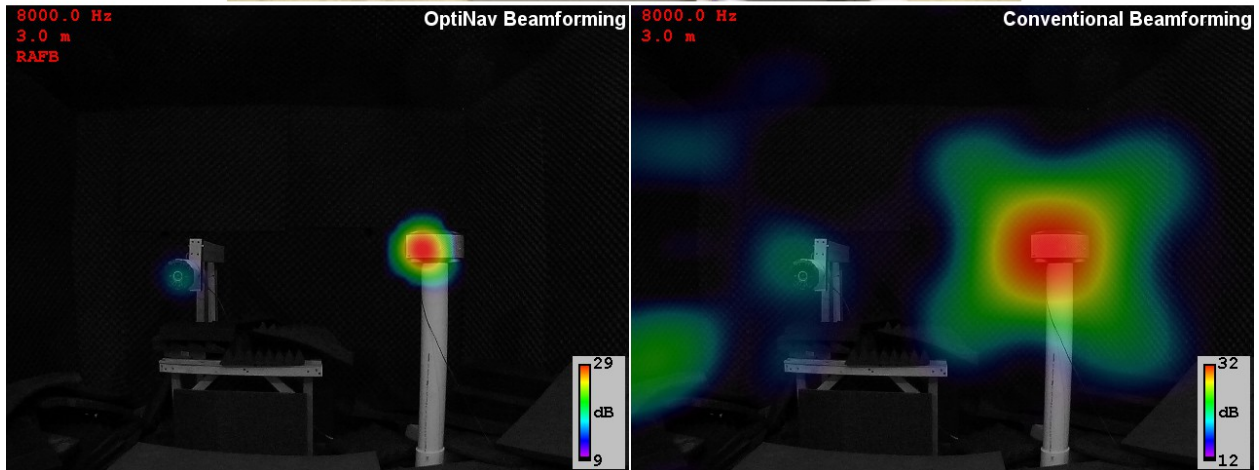
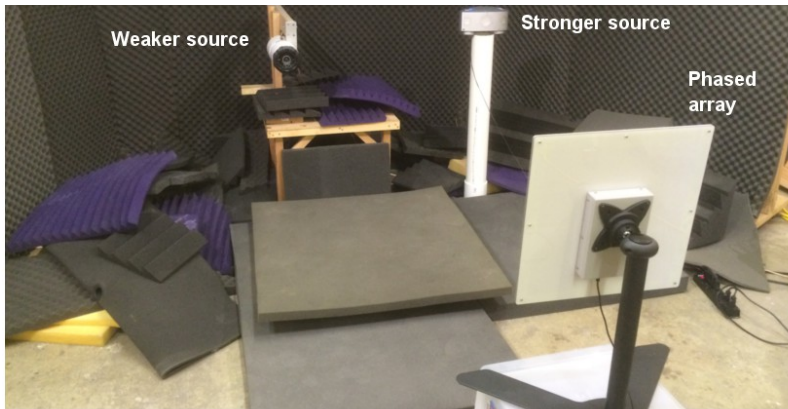


Figure 3. OptiNav and Conventional Beamforming of a strong source and the weak source, 8 kHz. OptiNav Beamforming shows the two sources correctly. Conventional beamforming has poorer resolution and shows a sidelobe of the strong source that is higher the true weak source.

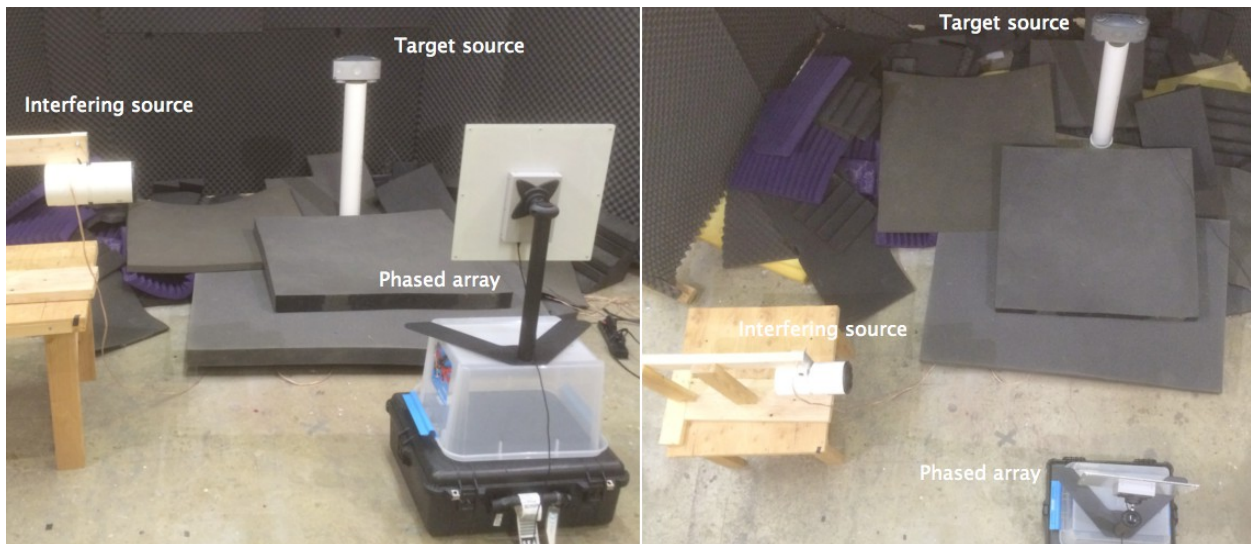


Figure 4. Setup for a test with a target source and a stronger interfering source that is located out outside the field of view of the camera. Left: horizontal view. Right: top view.

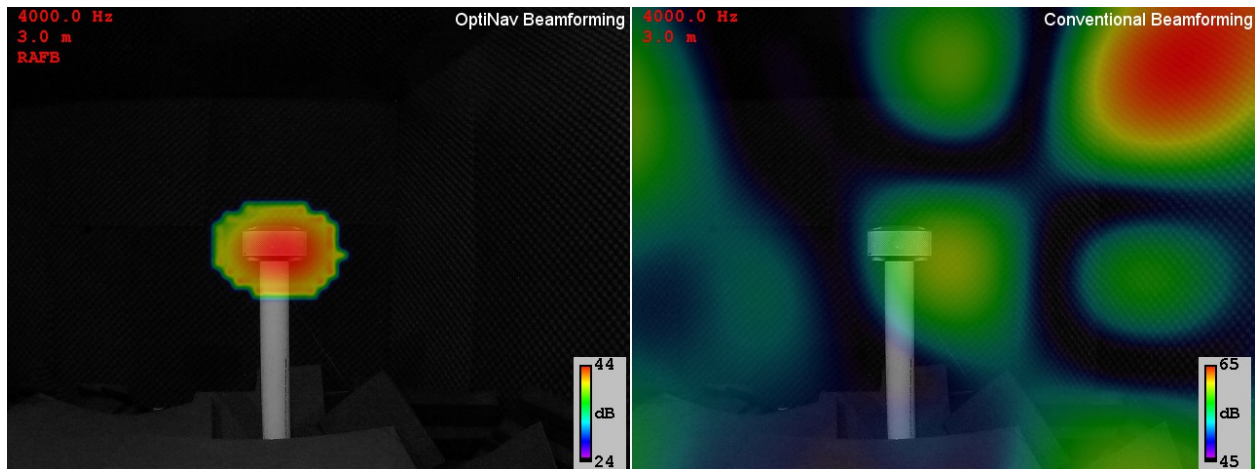


Figure 5. OptiNav and Conventional Beamforming of a weak target source, in the presence of a strong interfering source outside the field of view, 4 kHz. The interfering source is about 30 dB louder than the target source (with the in-view peak sidelobe 10 dB lower), and is located as shown in Fig. 4. OptiNav Beamforming finds the target source correctly. Conventional beamforming shows sidelobes from the interfering source and completely misses the true source. Deconvolution processing could probably not be used in cases like this.

### Is this a product or a prototype?

It is a product. It is shipping now with a 60 day lead time.

### How much does it cost?

It is much more affordable than other systems. Contact OptiNav, Inc. for a formal quote.

Email: [rpd@optinav.com](mailto:rpd@optinav.com)

Tel: (425) 891-4883

Web: [www.optinav.com](http://www.optinav.com)

### What is the frequency range?

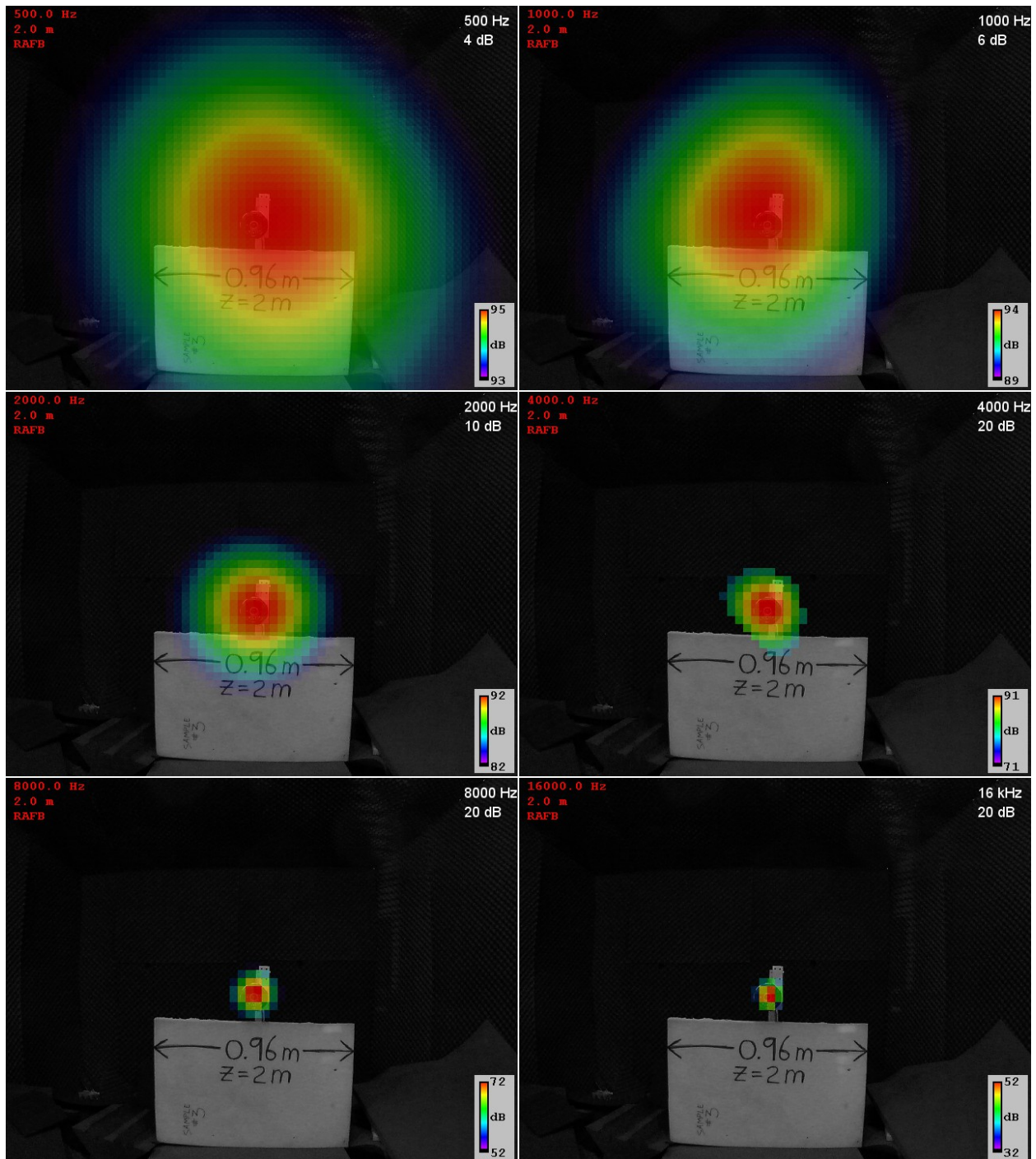
The upper frequency limit is 25 kHz, set by the microphones. If there is a strong tone in the range of 25-28 kHz, then the effective upper limit is reduced to 23 kHz by the anti-alias characteristics of the microphones.

The lower frequency limit for imaging is set by the size of the array and the beamforming algorithm. This is not a hard limit. The array works very well at 4 kHz and above. As the frequency is reduced below 4 kHz, the spot size tends to increase. In order to keep the spots from becoming too large, the dynamic range of the color scale is gradually decreased as the frequency is reduced. Fig. 6 illustrates this. A speaker source, 2 m from the array, is shown using OptiNav beamforming on the High Dynamic Range scale. The analysis frequencies and the plot dynamic ranges are shown on in the upper right. The spot size can be evaluated by comparing the speaker spot with the width of the foam rubber sheet, approximately 1 m. The non-circular shape of the spots at the lowest frequencies is caused by interaction between the sound and structures near the speaker: the table and the floor. The foam rubber is not very effective at these frequencies. Based on these results, it may be reasonable to take the lowest



frequency for the current array as 500 Hz. SIG is working on a larger array that should push the lower frequency limit downward.

If conventional beamforming is used instead of OptiNav beamforming, then the lower frequency limit is increased. Referring to Fig. 7, the lower limit for conventional beamforming could be taken as about 2 kHz. In this sense, OptiNav Beamforming effectively increases the size of the array by a factor of 4. Figure 7 also shows the odd spot shape and sidelobes of the array at high frequency that are avoided with OptiNav beamforming.



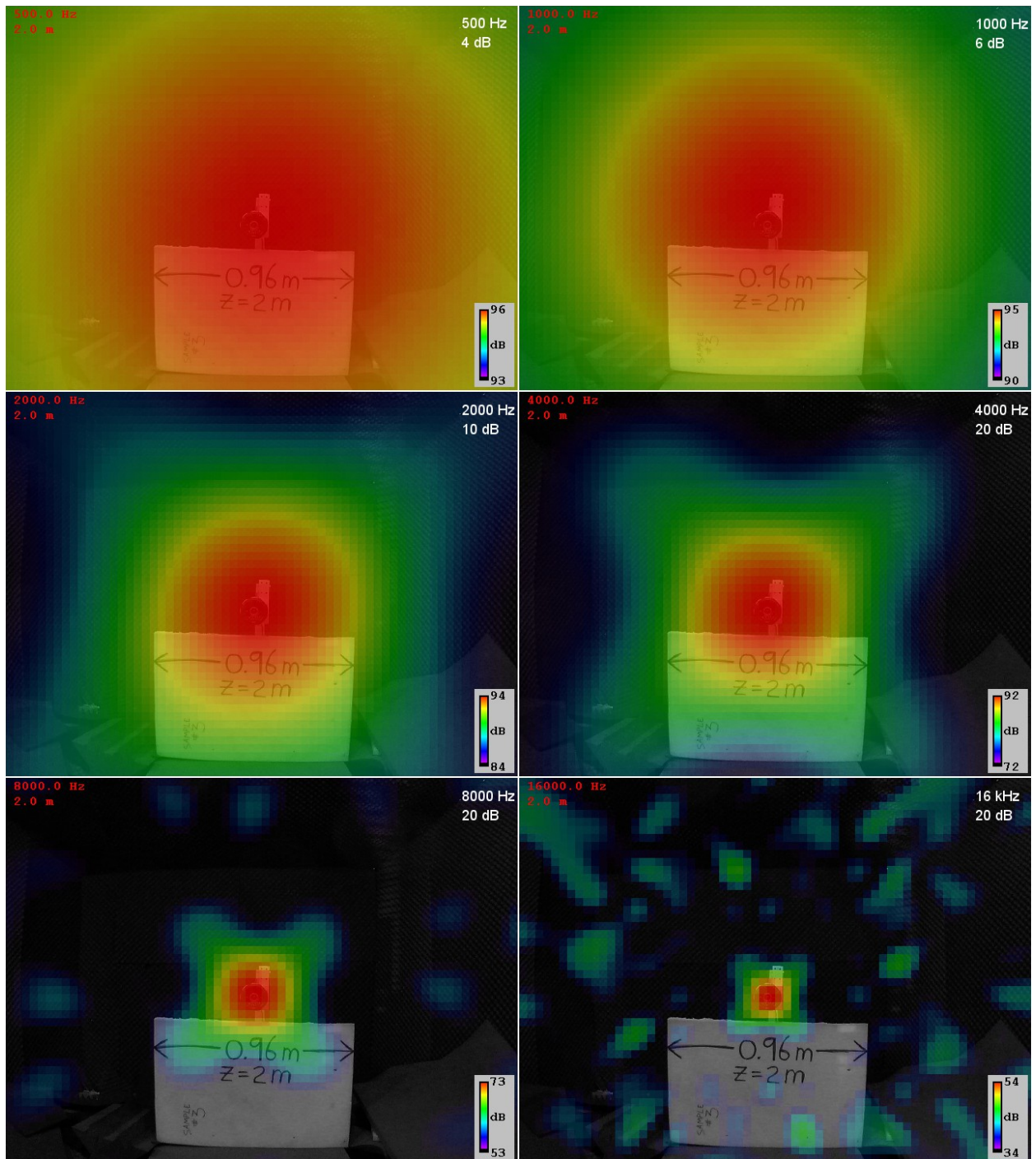


Figure 7. Spot size vs. frequency for ACAM 100 using conventional beamforming.

### What is the SPL range?

The microphones clip at 120 dB. Since the hard array plate doubles the pressure, array clipping would occur at 114 dB. Beamforming can still function in the presence of some clipping, provided it is not too severe. Figures 8 and 9 show examples from circular saw and an electric jackhammer, respectively.

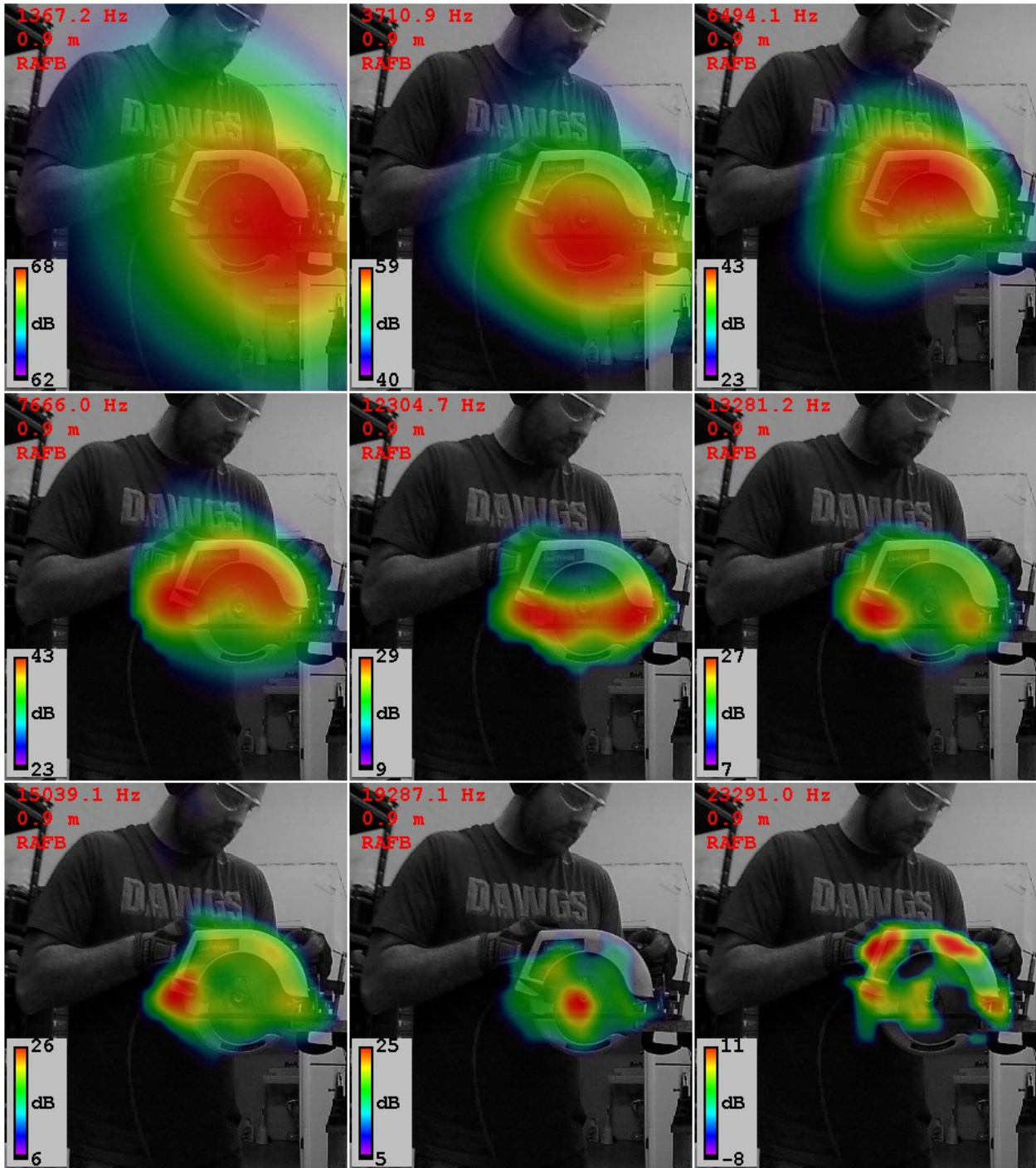


Figure 8. Circular saw beamforming. 101 dBA.

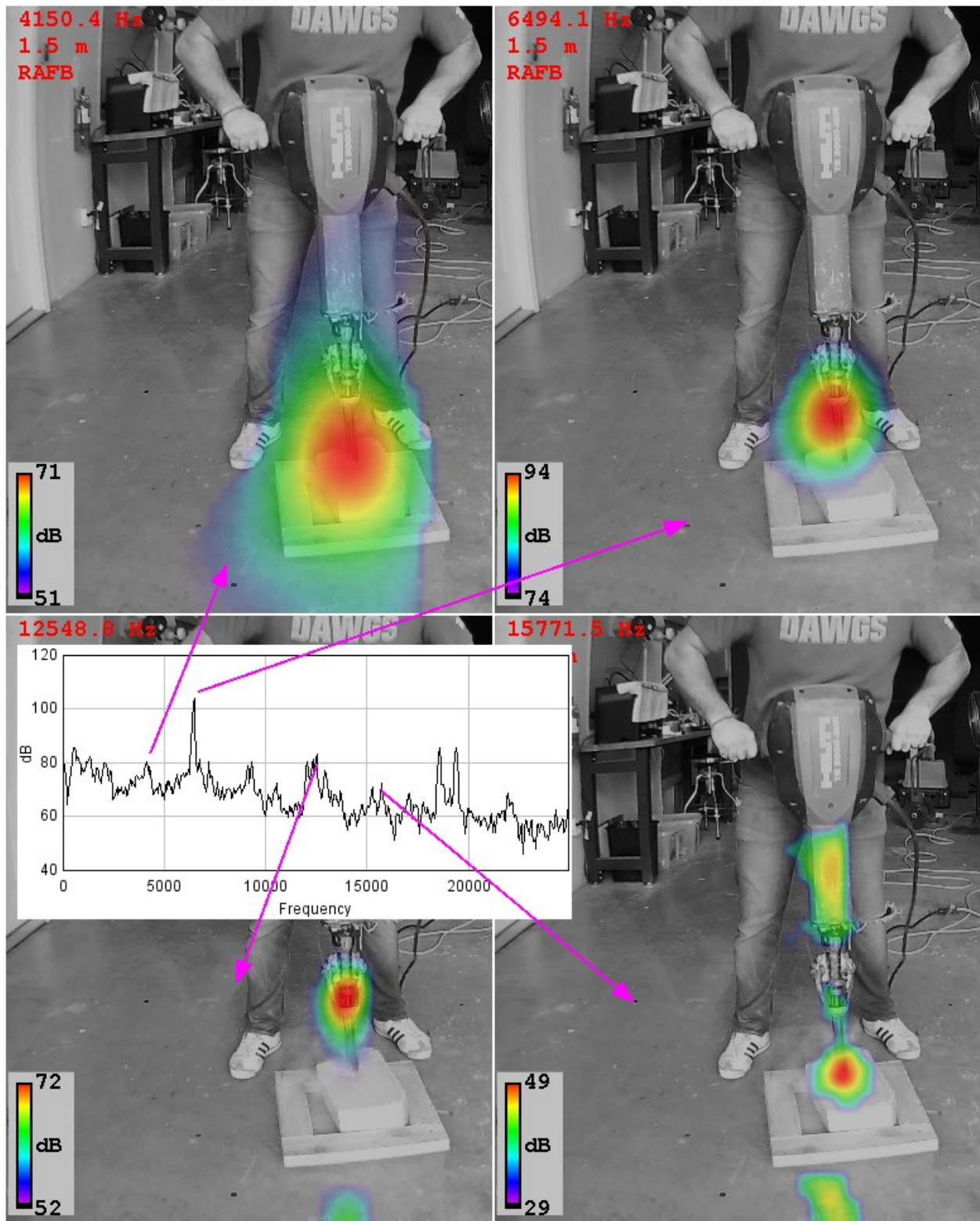


Figure 9. Electric jackhammer noise.



The lower SPL limit is determined by the beamforming algorithm in combination with the single microphone noise floor. Figure 10 shows an OptiNav beamforming plot in which the noise source is an iPhone with the white noise output of Signal Scope Pro set to a very low amplitude. The level identified is approximately 0 dB re. 20  $\mu$ Pa over a 48.8 Hz band centered at 12 kHz. This value represents the projected average level from the source over the array determined by the beamforming, integrated over the band. The individual microphone level for this band was -3 dB. The origin of this single-microphone noise was a combination of background noise in the room (an office in a suburban industrial park at midnight with all nearby machinery turned off) and electronic noise from the microphone and the array.

Conventional beamforming is not sufficient to detect the weak source, as shown in Fig. 11. The array noise floor using conventional beamforming is  $-2 - 10 \log_{10} 40 = -18$  dB, but this is 11 dB too high for detecting the weak source.

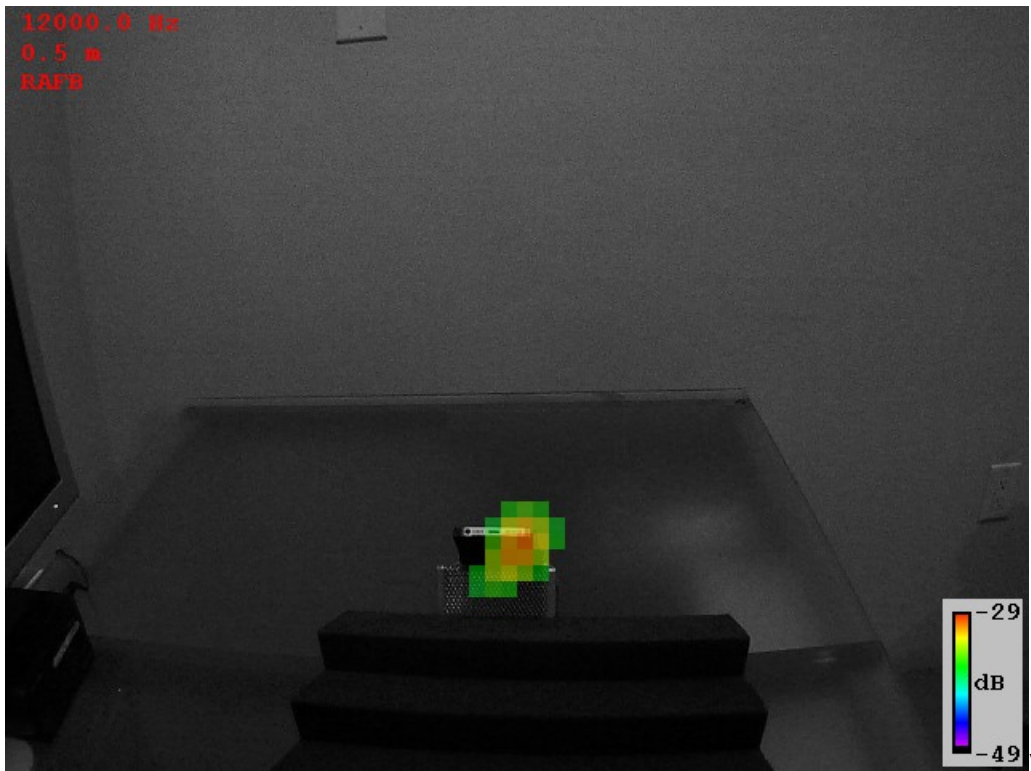


Figure 10. Beamforming a low SPL source. The broadband level is normalized to an integral of a 48.8 Hz band. The corresponding 1/3 octave band level is -11 dB. The iPhone speaker is at side of the bottom of the telephone, as indicted by the spot.



Figure 11. Conventional beamforming a low SPL source. The source strength, integrated over the 48.8 Hz band is about -29 dB, as shown by OptiNav beamforming in Fig. 10. The single microphone level for the band is about -2 dB. The SNR improvement of conventional beamforming with the 40 element array,  $10 \log_{10} 40 = 16$  dB gives an array noise floor of  $-2 - 16 = -18$  dB.

### How far away can the source be?

There is no limit. The perpendicular distance from the array,  $z$ , can be any value between, say, 0.1 m and infinity. If the perpendicular distance to the source is less than about 0.5 m, then the value entered in the user interface has to be reasonably accurate to avoid a defocusing effect. The example in Fig. 12 shows a car horn at a distance of 500 m.

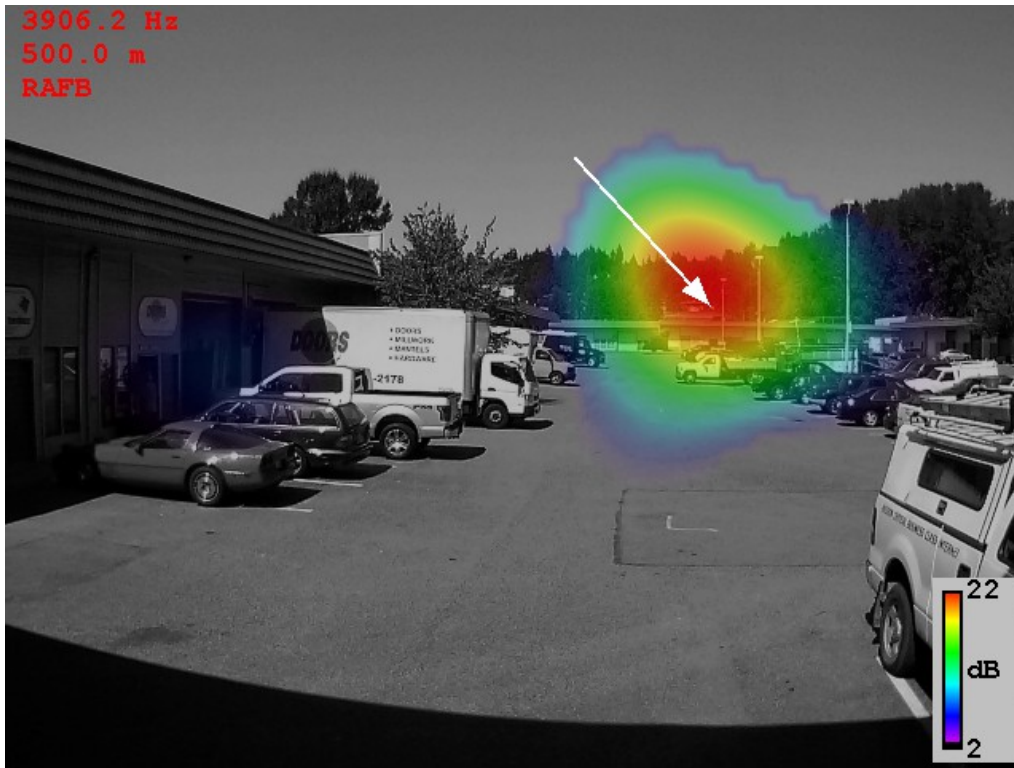


Figure 12. Car horn at 500 m. The car is on the hill several blocks beyond the industrial park in the foreground.

### Can you save an image?

There are four ways to save images:

1. Screen shot. Use the Windows Alt-PrtSc to capture a window with the control buttons included.
2. Ctrl-C to copy just the contents of a window (Spectrum, Spectrogram, or Display).
3. Record an .avi of the processed results and export the .avi for use in presentations, etc.
4. Save the raw data as a binary file and read it back into BeamformX for postprocessing. The binary file format is open for use in other analysis software if desired.