

# Sparse arrays and array health check tool

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**Abstract**—Removing one or several microphones from an array creates a so called sparse array compared to the original design. The array geometry is then an altered version of the intended design, with a different beampattern than the full array. The mainlobe width and side lobe levels of the beampattern are affected, and the resolution capabilities of the array is diminished. In the Nor848A software, an array health check tool is implemented to assure the correctness of the array being used.

**Index Terms**—Sparse arrays, beampattern, ghost image, side lobe level

## INTRODUCTION

WHEN one or more microphones in a microphone array is disabled, the array is no longer the same as compared to the specifications it was designed after. Since the geometry is now different, the beampattern will also be different, as the mainlobe width and side lobe levels are altered. Especially additional side lobes with a higher level may be introduced in the beampattern, which in turn degrades the optimal resolution capabilities of the original design. High side lobe levels can for instance result in the so called ghost spot effect, you measure and display a source that doesn't exist.

Although we in this context are talking about sparse arrays as arrays where one or more microphones have failed or been disabled, sparse array design is a big research field for a simple reason; economy. If a simpler design with less elements can achieve comparable performance of a full array, this design may be cheaper to produce. Remember that arrays don't only have to be acoustic microphone arrays, but could for instance be electromagnetic antenna arrays sending signals out in space. Each element of the overall array design consists then not of different small microphones, but big antennas that may be of substantial cost and located several kilometers from one another. Reducing the number of antennas in the array design may thus be of great economic importance.

## I. ANALYSING SPARSE ARRAYS

### A. Simulations on 1.0 m and 32 element ring array

Now let's try to simulate the effects of removing several microphones from an array configuration. In Fig. 1 is a 1.0 m ring array with 32 elements. To create a sparse version of that array, 50% of the elements have been randomly removed, to make a 16 element array with the same diameter.

Since the elements are randomly removed, removing different elements than what is shown in Fig. 1 would make

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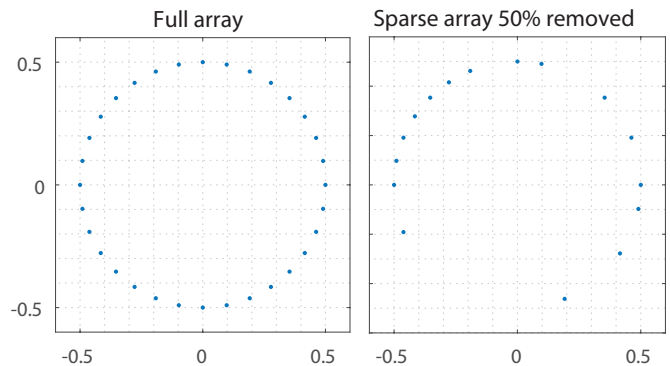


Fig. 1. Geometry of full ring array with diameter 1.0 m and 32 elements, and sparse ring array with 50% of elements removed.

a different sparse array, and also a different sparse beampattern. However the calculations offer some insight into a general principle of what happens with the beampattern and resolution of a sparse array compared to the full array, even though the results may vary for each different simulation.

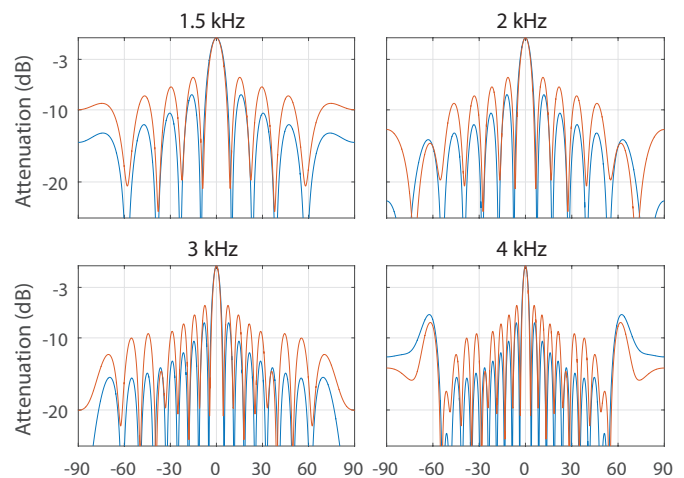


Fig. 2. Beampattern for various frequencies for 1.0 m and 32 element ring array. Response of full array shown in blue, and response of sparse array with 50% of elements removed shown in orange. The dynamic range of the plots are set at 25 dB.

Shown in Fig. 2 is the beampattern of both the full 32 element array, and the 16 element sparse array for various frequencies. The response of the full array is shown in blue, and the response of the sparse array is shown in orange. As can be seen from the beampatterns, the mainlobe width doesn't vary that much, since this is mostly decided by the overall extent of the array. However there is a large difference of the side lobe levels. Now what does this mean in terms of resolution of an image?





Fig. 3. Simulated image of eight point sources at frequency 3.5 kHz with ring array with all elements. Image shown with dynamic range 3 dB.



Fig. 4. Simulated image of eight point sources at frequency 3.5 kHz with sparse ring array with 50% of elements removed. Image shown with dynamic range 3 dB.

Seen in Fig. 3 is a simulated acoustic image consisting of eight point sources all of the same strength and frequency, located at a distance of 3 m from the array. The dynamic range of the image is set at 3 dB. As can be seen from the image we have no problem in distinguishing the different sources. Now however let's try making the same image by using the sparse array with 50% of elements removed as seen in Fig. 4. Now due to the changes in the side lobe levels of the beampattern, all of a sudden the so called ghost spots, or ghost images, start appearing and degrades the resolution of the image. We are visualising sources at positions where there are none.

### B. Simulations on 1.0 m and 256 element Nor848A-10

Now we can do the same kind of simulations with the 1.0 m Norsonic Nor848A-10 256 element array. Again we are randomly removing 50% of the elements to create a sparse array consisting of 128 microphones as seen in Fig. 5. Although we are removing half of the elements of the array, since the number of microphones are that much greater than the 32 element ring array, we still have a lot more microphones covering the original extent of the array as seen from the figure.

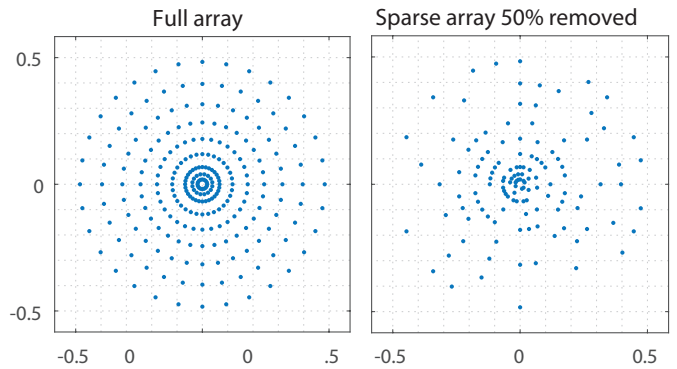


Fig. 5. Geometry of Norsonic Nor848A 1.0 m array with 256 elements, and sparse array with 50% of elements removed.

Shown in Fig. 6 is the beampattern for both the full 256 element array, and the 128 element sparse array for various frequencies. The beampattern for the full array is shown in blue, and the sparse beampattern is shown in orange. Again compared to Fig. 2 the mainlobe width stays more or less the same, and the side lobe levels are elevated. Note however how the plots in Fig. 6 are shown with 50 dB dynamic range, so the side lobe levels are still around 20 dB lower than the mainlobe even for the sparse array.

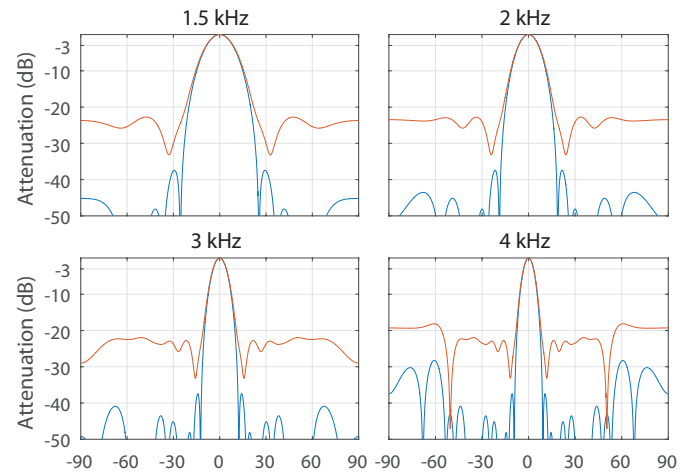


Fig. 6. Beampattern for various frequencies for the Norsonic 1.0 m and 256 element array Nor848A-10. Response of full array shown in blue, and response of sparse array with 50% of elements removed shown in orange. The dynamic range of the plots are set at 50 dB.

Seen in 7 is the same simulated condition as displayed in Fig. 3, with eight point sources at the same strength and frequency. The dynamic range in the image is set at 3 dB and the full array is used. Again we have no problem in pin pointing the location of the different sources. If we now use the sparse array with 50% of elements removed to make the same image, we get the results shown in Fig. 8. This time no image artifacts in terms of ghost images are introduced in the image, and we are still able to locate the correct source positions. Comparing Fig. 7 and Fig. 8 we see that the resolution of the sparse array has dropped some, although not substantially. Although these results are for a specific simulation, the general principle is that more microphones give an advantage.



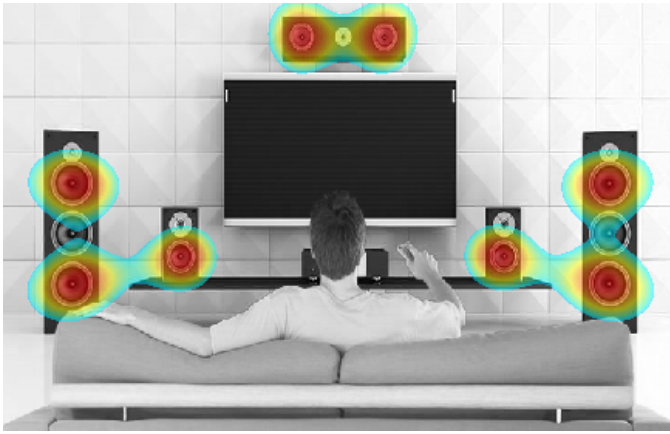


Fig. 7. Simulated image of eight point sources at frequency 3.5 kHz with Nor848A-10 with all elements. Image shown with dynamic range 3 dB.



Fig. 8. Simulated image of eight point sources at frequency 3.5 kHz with Nor848A-10 with 50% of elements removed. Image shown with dynamic range 3 dB.

## II. NORSONIC HEALTH CHECK TOOL

In the Nor848A acoustic camera software an improved microphone monitor is running that is checking microphones continuously. The monitor looks for microphones that deviates from the majority of microphones, by finding high- and low-level microphones, dead microphones, and noisy (high frequency noise or bad correlation) microphones. When calculating the output of the array to create an acoustic image, only the microphones marked as functioning according to specifications are used for the processing. As seen in Fig. 5, even though the array is sparse compared to the original design, it still have its original aperture size in almost all xy-directions. It's not optimal, but the array actually performs quite well as seen from Fig. 8

In addition to the microphone monitor that continuously checks all microphones, an array health check tool is also implemented in order to evaluate the effect of losing one or several microphones. The tool starts by retrieving the list of deviating microphones if there are any. Based on this list we evaluate the performance of the array with all microphones enabled, and compare that to an array where deviating microphones are removed, thus creating a sparse array. The

performance is evaluated by measuring the mainlobe width and the sidelobe level of a steered response. By doing this we retrieve information about the array performance both for different steering angles and multiple frequencies at once. If the sparse array has an increase in mainlobe width above a certain threshold, or the sidelobe level has gone up with a certain amount, the array is marked as being "not healthy".

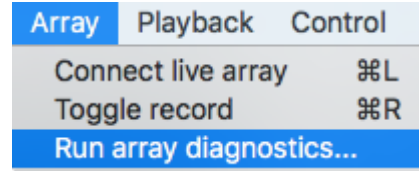


Fig. 9. Nor848A acoustic camera software toolbar

The array health check tool is enabled by pressing "Run array diagnostics" from the Array menu in the toolbar in the software as seen in Fig. 9. This will open up the diagnostics tool, where by running a diagnosis, the performance evaluation is starting as seen in Fig. 10. The diagnosis ends with a performance evaluation indicating if the array is healthy or not healthy.

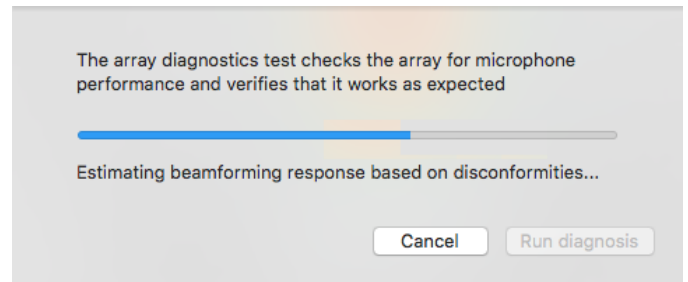


Fig. 10. Nor848A acoustic camera software array health check tool

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