Acoustic Imaging

Download acoustic imaging theory in Pdf format

In the following pages you will find a brief introduction to the beam forming theory that is behind acoustic imaging and directions for the minimum hardware requirements to produce good results.

As for example, we demonstrate that it is not necessary to use high class and costly microphones to create the array. Simple and good electret microphone are far enough.

Thanks to the antenna simulation software that we have developed, we also compare various microphone distributions showing that there is no unisersal antenna to address all the noise problems and it is possible to find the best distribution for a particular problem.

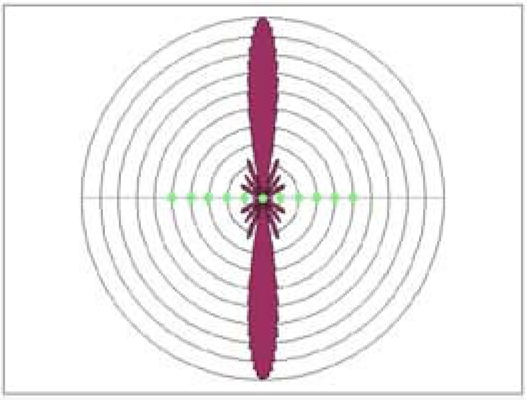
In order to be the most flexible, we have invented SpyFrame and IPM. SpyFrame is a standard grid with 5 cm spacing and IPM is a systems that automatically finds the X,Y grid coordinates of the microphones and fills them in into the software for the appropriate calculations. SpyFrame and IPM will allow you to create almost any type of microphone distribution other the grid without the burden of measuring the microphone coordinates.

If you would like to have a better insight into the theory and the technique, we can set up for you a comprehensive training that will be adapted to your needs.

Do not hesitate to contact us for further explanations !

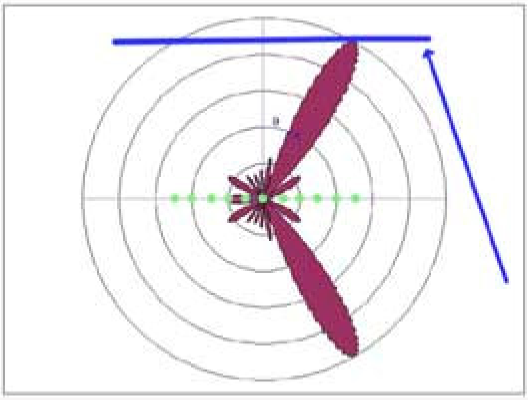
Antenna Directivity

Acoustic Imaging - Antenna Directivity



In the beam forming technique a distribution of microphones over a grid possesses a directivity that is linked to the microphone repartition.

That is illustrated in the side picture for 11 aligned micophones.



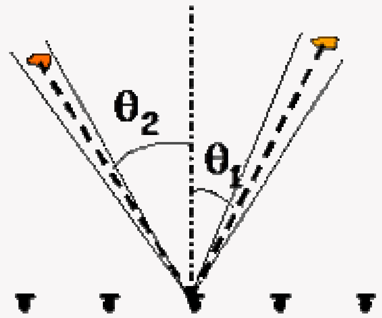
When one applies phase delays that are calculated according to spherical and/or plane wave propagation in air it is thus possible to modifiy the directivity towards an area of interest.

When one proceeds in that way over a dicretized area it then becomes possible to construct a point by point acoustic image (like a true image with pixels). This is equivalent as to having placed the same number of virtual microphones at each discretized points on the area.

Imaging Home - Plane & Spherical Waves 1/2

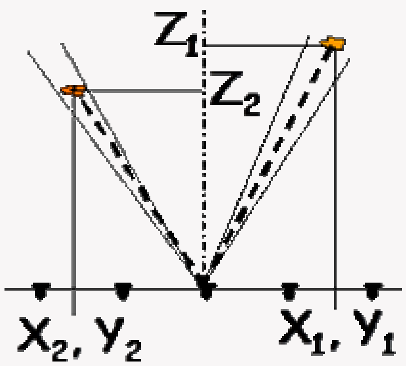
Acoustic Imaging - Plane & Spherical Waves 1/2

Classical Beam Forming Plane Wave Angular Description of sources



In the Classical beam forming theory which uses plane wave theory one localises the sources within an angular sector without a clear notion of the distance.

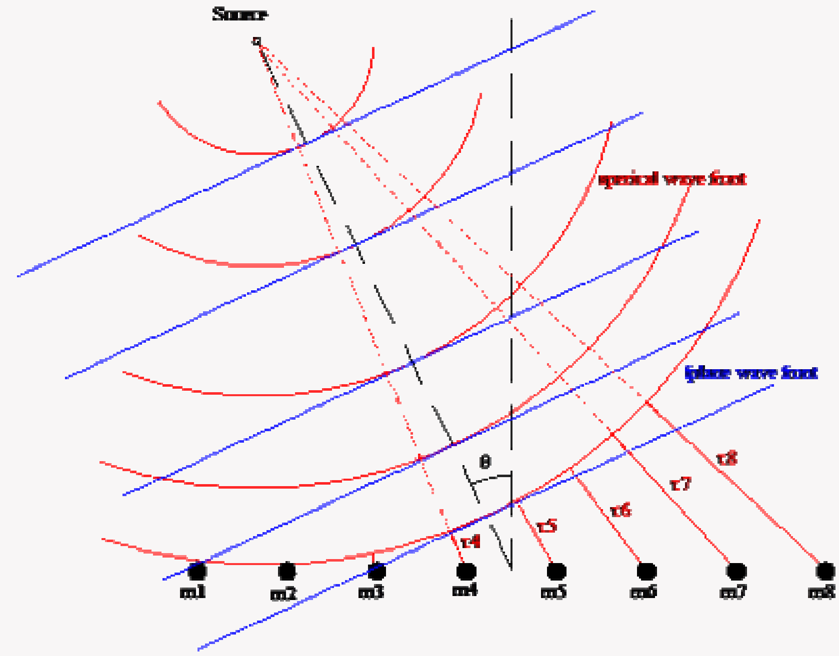
Advanced Beam Forming Spherical Wave Spatial Description of sources



In the advanced beam forming theory the notion of distance between source and microphone array is introuduced thanks to the spherical propagation of waves (monopole sources). It introduces a notion of depth of field which gives the ability to focus on the "exact" source location.

Antenna Directivity - **Plane & Spherical Waves 2/2**

Acoustic Imaging - Plane & Spherical Waves 2/2



The above drawing shows that:

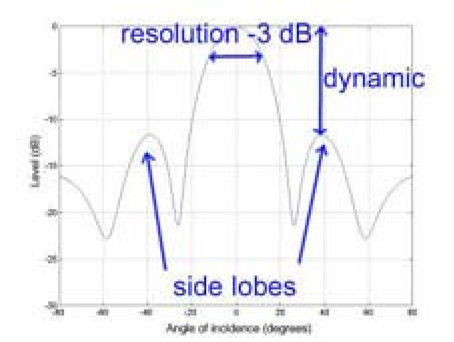
- The phase delay calculations using the plane wave theory can only give an indication of the direction in which the source is.
- The phase delay calculations using the spherical wave theory allows to focus on the "exact" source position (rays concentrate towards the source).

Plane & Spherical Waves - Resolution, lobes

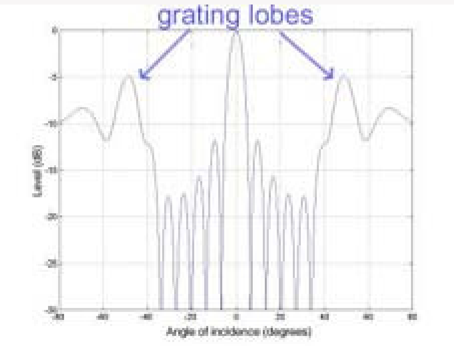
Acoustic Imaging Resolution, lobes

There are 3 major elements which characterise beam forming acoustic imaging:

- Resolution (at -3 dB)
- Secondary or Side lobes
- Grating lobes



The side lobes give an indication on the measurement dynamics of the array (dB level difference between major lobe and side lobes).



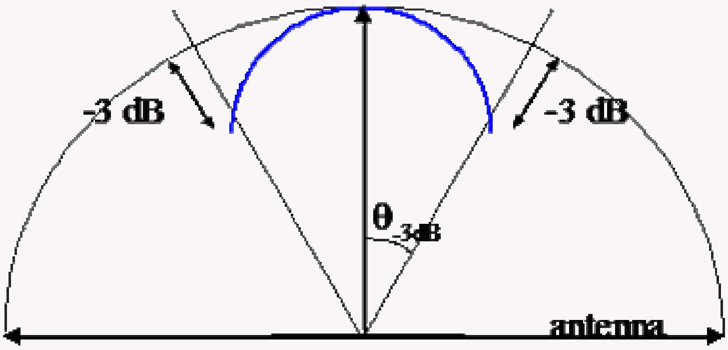
Resolution (at -3 dB) gives an indication on the size of smallest detectable source by the array. Side and grating lobes give ghost sources which makes it more difficult when interpreting the images.

We have embedded into our software an interpretation help module that helps customers to make the difference between real sources and ghost ones.. Grating lobes appear on regularly distributed microphone arrays when the spacing between microphones is bigger than half a wave length (on such a distribution they are also easy to detect and remove...).

Plane & Spherical Waves 2/2 - Resolution

Acoustic Imaging - Resolution

An approximated r the resolution at -3 dB derived for an in line microphone array with constant spacing is given below. It helps to better understand the interaction between the main parameters:



Angular resolution is given by:

$$2\theta_{-3\,dB} \approx 50^{\circ} \frac{\lambda}{Nd}$$

Where:

- d = microphone spacing
- N = number of microphones
- l = wavelength

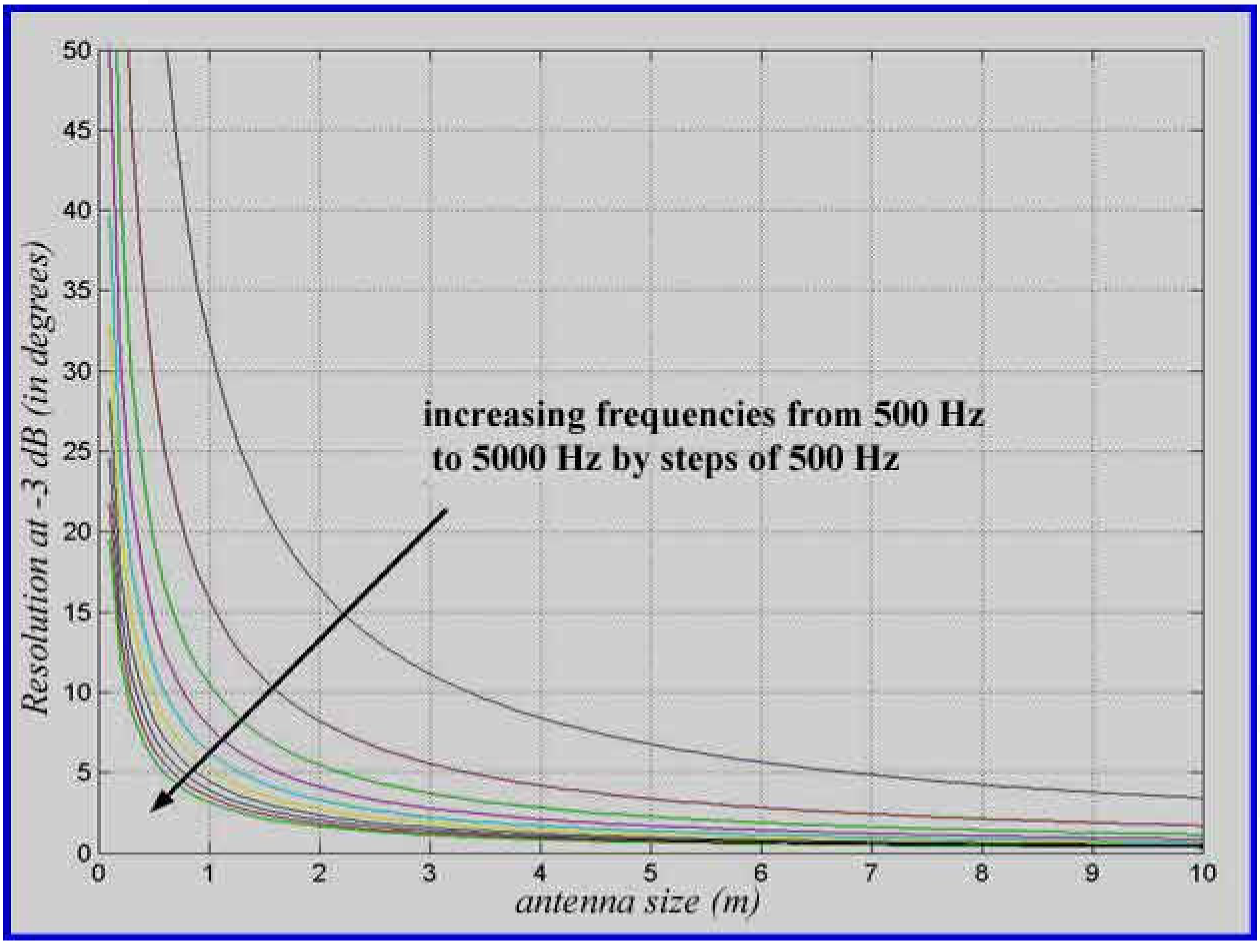
Consequently :

- Resolution improves with increasing antenna size
- Resolution is better at higher frequencies.

[Resolution, lobes, etc.] - [Resolution, antenna size, frequency]

Acoustic Imaging - Resolution, antenna size, frequency

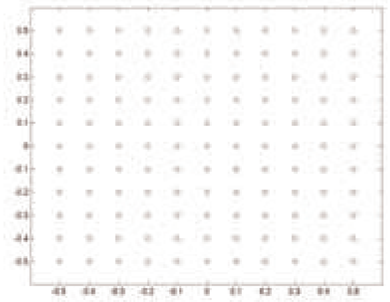
Influence of antenna size and frequency on the resolution level for a line array with constant microphone spacing:



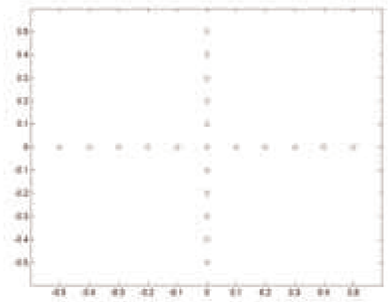
Acoustic Imaging - Antenna Comparison 1/5

Antenna performance varies with the microphone distribution. We give some examples of various distributions. All the antennas have the same size : 1m

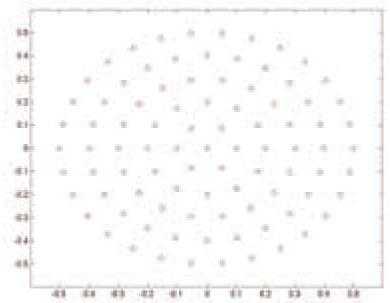
121 mics d =10 cm



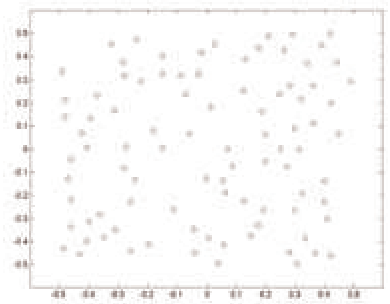
21 mics d =10 cm



91 mics d =10 cm



91 mics aléatoires

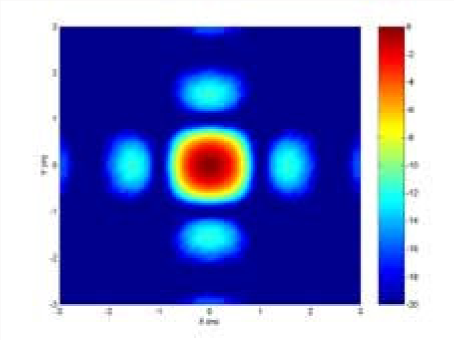


Acoustic Imaging - Antenna Comparison 2/5

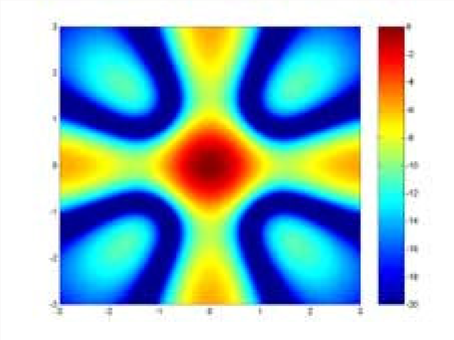
Source at antenna center at 3 m from antenna and at 1 kHz

image size 3m by 3m.

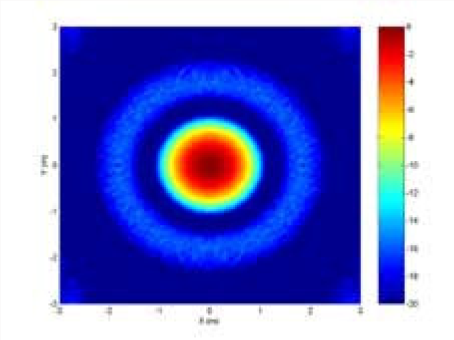
Regular



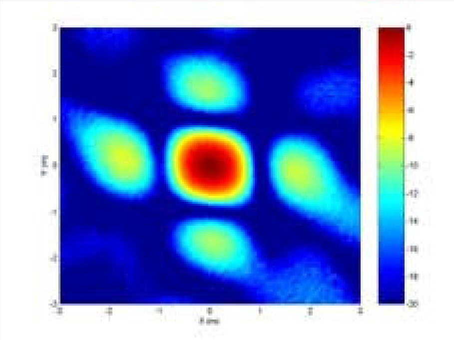
Cross



Circular



Random

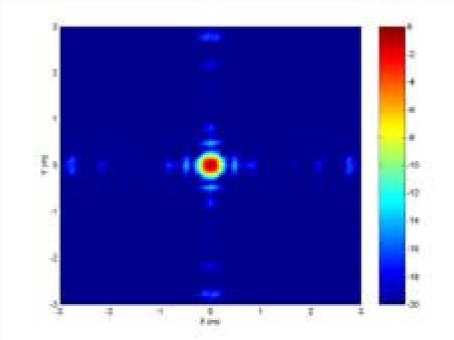


Acoustic Imaging - Antenna Comparison 3/5

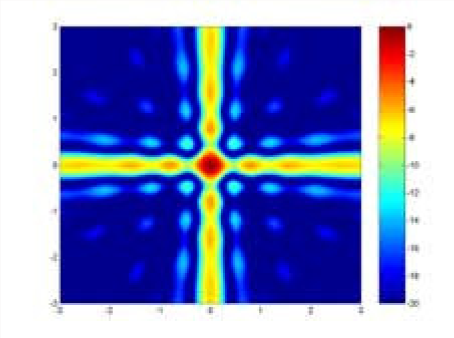
Source at antenna center at 3 m from antenna and at 3 kHz

image size 3m by 3m.

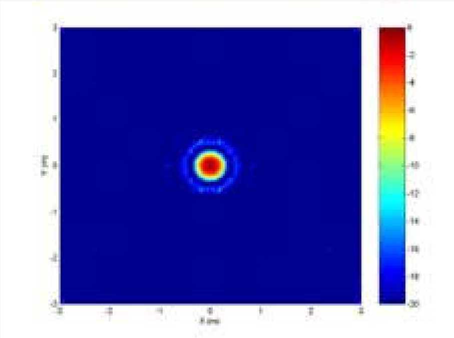
Regular



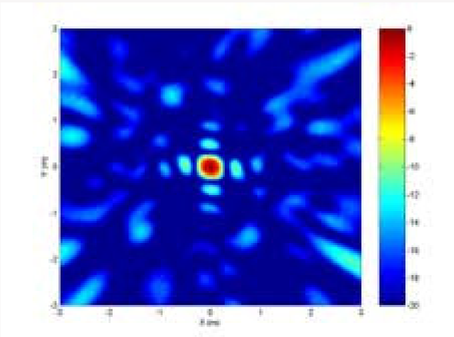
Cross



Circular



Random

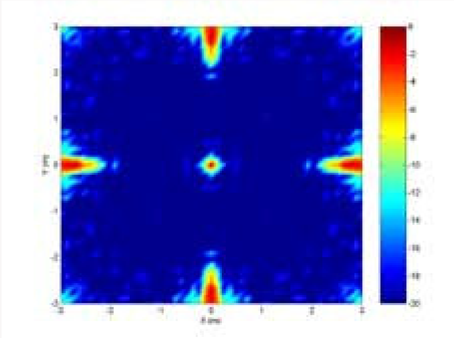


Acoustic Imaging - Antenna comparison 4/5

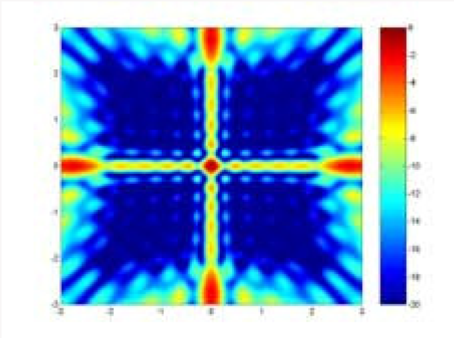
Source at antenna center at 3 m from antenna and at 5 kHz

image size 3m by 3m.

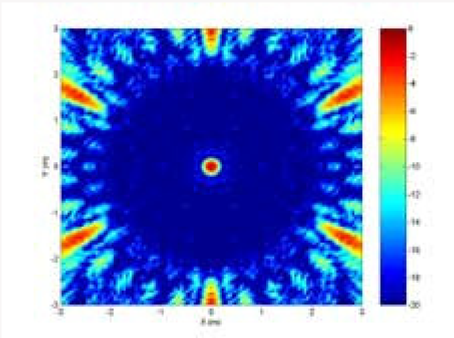
Regular



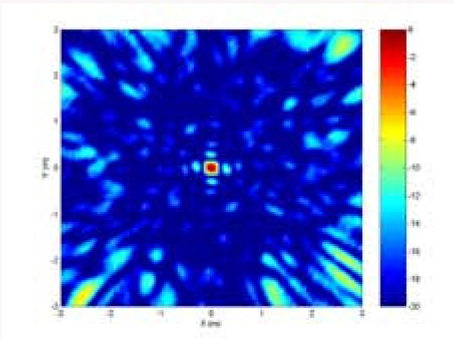
Cross



Circular



Random



Acoustic Imaging - Antenna Comparison 5/5

The previous images show all the antenna distributions have strenghts and draw back and that they are not all equivalent.
The cross antenna is from far the worst of all we have shown.
The random distribution has good results in high frequency, close to the resoltuion of the regular distribution but it exhibits random sides lobes which are harder to detect.
The regular distribution has the best resolution of all four shown and the side lobes are more easily detectable.
The circular geometry is also a good compromise close to the regular one but it has many more side lobes.

Thanks to our SpyFrame grids and our IPM system you will be able to create any type of antenna microphone distribution to best fit the noise problem you want to investigate !

Antenna Comparison 4/5 - **Back to home Theory**