A STUDY OF THE FAR FIELD DIRECTIVITY PATTERN OF A HEMI-CYLINDRICAL ARRAY

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Abstract: Bats use echolocation to navigate their environment, to localize and identify prey. Researchers have proposed ultrasonic biomimetic systems that make use of the way bats echolocate. EMFi is a new material, which has good properties for air. We used this material to construct an ultrasound emitter capable to work in a similar way as bat's emitter. We did measurements in order to study the far field directivity pattern for an EMFi hemi-cylindrical array with four strips. Experimental studies of the directivity emission in far field for this type of transducer highlighted the capabilities of this emitter.

Keywords: array, bat, far field

1. INTRODUCTION

Bats produce a call and listen to the echoes to gather information from the surroundings. In the last years, there has been a challenge to build biomimetic systems that are constructed after a biological model, such as bat model. There are different systems that use two or three receivers [1 - 4] with the stated purpose to design and manufacture the best performing self-governed robots. Bats have high power ultrasonic emission systems combined with very sensitive reception. As their calls are emitted from a directional structure, i.e. the nostrils or the mouth, depending on species [5 - 6], it is necessary to study the shape of the emitter and the directional emission pattern. There are studies regarding the shape of emitters and the way this shape can influence the emission pattern [7 - 12].

The current hypothesis is that bats use spectral cues (i.e. the filtering of the received echo) for target localization (i.e. azimuth and elevation of the echo) [13]. These spectral cues are introduced by both the emission pattern of the bat and the reception (HRTF - Head Related Transfer Function). In order to accurately model the bat's system, one needs to have both components. The reception of the echoes has been accomplished [14]. But there are still problems regarding the emission pattern.

Building ultrasonic sonar systems, it is required to ultrasonic transducer with good properties, especially for air. PZT (Lead zirconate titanate) or PVDF (Polyvinylidene Flouride) transducers are commonly used, but for this type of work we propose Electro Mechanical Film (EMFi).

We investigated the far field directivity of a half-cylindrical emitter array with for 4 elements, made from EMFi, which can be applied for bats' research.

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2. EXPERIMENTAL SETUP AND RESULTS

As we mentioned before, we used in our measurements the azimuth and elevation angles. Azimuth angle θ is the angle with vertical mid-plane along the Oz direction, the positive plane is for the left direction of the bat, and elevation angle φ represents the angle with the bat's horizon, positive for directions above horizon Oz. In order to create an emitter that can act as a bat's emitter we propose an EMFi hemi-cylindrical array with four strips to study directivity emission in far field.

For measurements we used and EMFi emitter of four rectangular elements displayed on a half of a cylinder (Figure 1) with dimensions: height of an element h = 0.0035 m, distances between two elements d = 0.0025 m, and the radius of the cylinder r = 0.0125 m.

We calculated the directivity pattern in front of the emitter at the distance R = 0.030 m (on the Oz axis) in the frontal hemisphere, with azimuth and elevation (–90^o; +90^o). Because bats emit most of the echolocation call's energy in the frequency range between 90 kHz and 25 kHz, in our measurements the frequency swept between 20 kHz and 80 kHz, in 1 kHz steps. Acoustic measurements were accomplished by locating at the distances of 30 cm far a microphone (Knowles FG2232 – PO7) on a R17 robot arm.

In Figure 2 are plotted the directivity pattern in far field for the emitter considered, simulations and measurements. In the figure below are plots of the directivity pattern from 25 kHz and 75 kHz, in steps of 10 kHz. We introduced a time delay between the elements of the array, in order to introduce more spectral cues. Furthermore, the time delay was 0.028 ms.

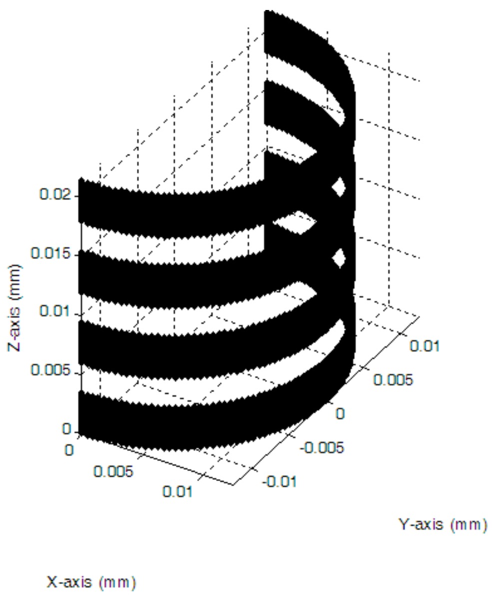

Fig. 1. Emitter with 4 elements displayed on a half cylinder.

The directivity pattern of an array is defined as the normalized pressure amplitude at any arbitrary directions, in our case azimuth and elevation angles. Studying the directivity emission of an array, we can extract very useful information about the main lobe width, grating lobes, side lobes, etc. The characteristics of the directivity are influenced by: the number of elements of the array studied, inter-element spacing, dimensions of the array and frequency. If these parameters are not chosen properly, damaging grating lobes with high amplitude and side lobes will exist in the beam field. To avoid this effect it is required to optimise the array parameters.

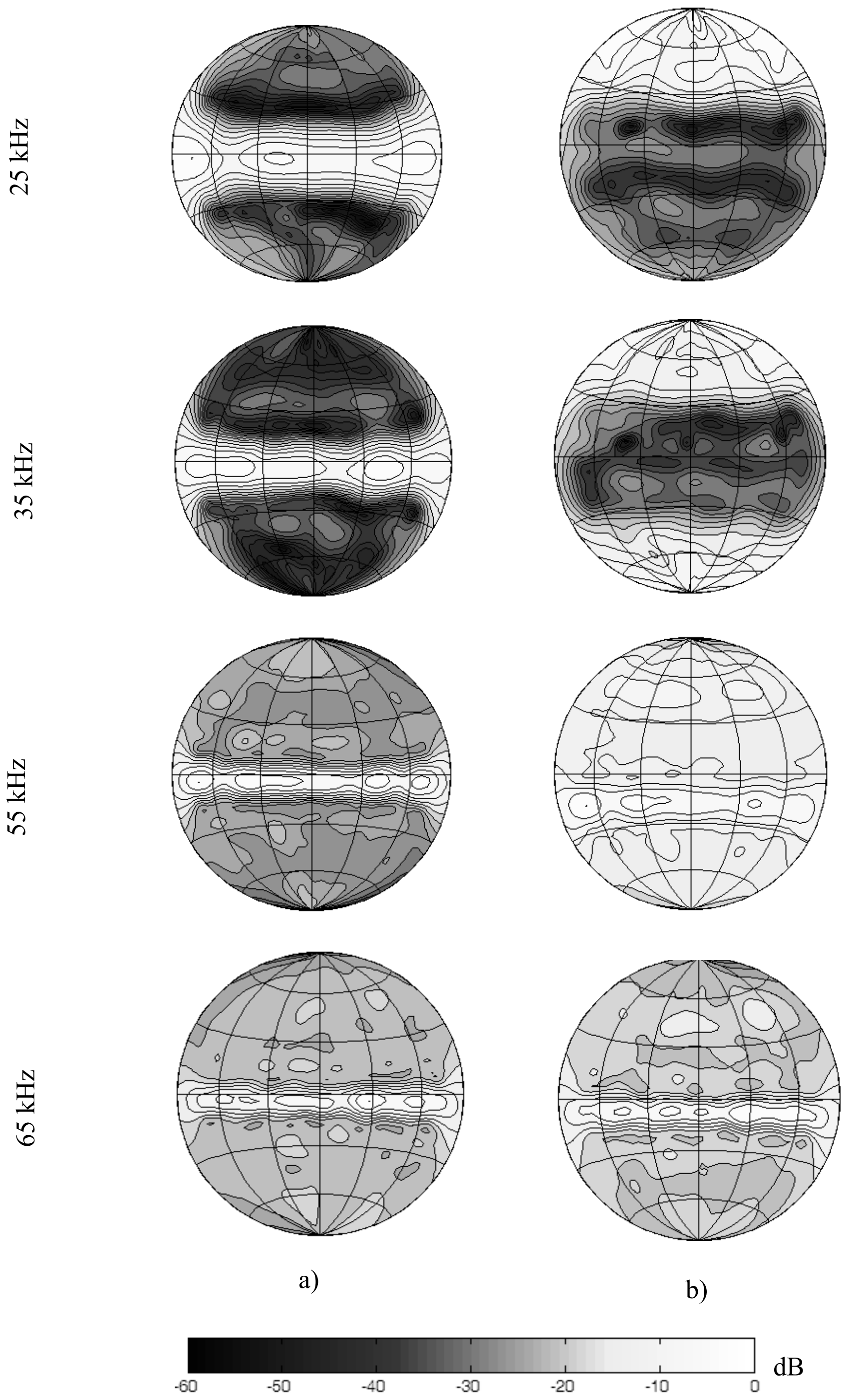

Fig. 2. Directivity pattern in far field for an array with 4 elements displayed on a half cylinder:
a - no time delay; b - with time delay.

Studying the plots from Figure 2, we can see that for small values of frequency, when there is no time delay, the directivity emission has a main lobe in the azimuthal plane. As the frequency increases there are side lobes and grating lobes, that affects the directivity. For example, in the plot with 35 kHz, it is clear that we have a main lobe and a grating lobe (has almost the same amplitude as the main lobe and usually brings errors in the plots). As the frequency increases, the main lobe and the side lobes move along the azimuthal plane.

In the plots where there is a time delay between elements, we can observe that this type of array steers in elevation. For the highest frequency the main lobe appears pointed towards negative elevation, and tends to get better with increasing frequency. The maximum pressure value, in this case, does not always occur on the axis. It makes sense because the radiating surface is curved.

4. CONCLUSIONS

In this paper, we studied the far field directivity pattern of an EMFi emitter array with for strips displayed on a half of a cylinder. From our measurements we can conclude that we have a better directivity pattern for the case when there is no time delay.

As further research, it can be interesting to study the same array but, with different dimensions of the rectangular elements, or the number of the elements. But, we have to keep in mind, that the emitter should have dimensions very close to a bat's emitter.

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