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Sonar with electronically steered transmitted beam

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ABSTRACT

The ahead looking sonar with 60° sector projected by multielement cylindrical array and analog beamforming technique used multielement linear array for selecting 4° x 15 beams is presented .The aim of this paper is to study the pattern directivity of the linear multielement receiving transducer of the sonar SHL-100M for application to electronically steered beam projector . This paper presents the result of the computer aided calculations of the beam patterns as the function of the weighting excitation parameters and damaged elements for steered linear array .

INTRODUCTION

Many vessels and underwater vehicles are equipped with an ahead - look sonars . The most common application is obstacle avoidance and searching school of fish. The ahead -look sonar also provides mine detection capabilities . Several types of ahead - look sonar are commercially available. They may be grouped into three general categories:

- the mechanically scanned ALS,
- projector insonified the entire horizontal field of view or coverage sector,
- the electronically steered projector insonifies almost simultaneously by a few beams the entire horizontal field of view.

The single beam sonar with step-by- step searchlight which consist of a single mechanically swept over the coverage sector , will not be discussed . The projector consisting of transducers array are subdivided into a large number of elements or staves and are almost always either a straight line array or a circular arc array . Some sonars use the circular arc array as projectors and receivers. The presented conventional sonar (SHL-100) is configured with two independent transducers . The circular arc array has been used as projector but the line array transducer as receiver .The sonar with the circular arc array projector and line array receiver transducer has many disadvantages:

- two different types of transducers,
- large number of elementary transducers,
- large number of staves and transmitters for circular arc projectors,
- high precision for circular arc projector is required [1].

The linear array transducer used as projector and receiver has many advantages:

- only one type of transducer,
- less number of elements,
- less number of staves,
- simple array construction,
- the smallest transducer dimension.

The main disadvantages of line array transducers are limited projected sector and difficult to apply electronically steered beam for larger sectors . The sonar SHL-100M made in Poland by R&D Marine Technology Centre[1] in Gdynia is equipped with two separated transducers. The projector of the sonar is the 6x32 staves array of the elementary rectangular transducers distributed on the cylindrical surface , characterised by its length L=541mm , height h=82mm , chord 2a=512mm and sector angle α=70.5°.For the sonar operating frequency 60kHz , we obtained λ=25mm , h/λ=3.28 and L/λ=21.6 . The paper [5] show the theoretic directivity patterns for cylindrical arrays in the case of harmonic uniform excitations. Far field directivity patterns for uniform harmonic excitation, are keep 3 dB level of the irregularities within the beam. The experience with that transducer is much worse. Only by special tuning procedure has been kept 8 dB level of the irregularities within the beam for higher power excitations . Also the source level of the beam was below expected level for highest power excitations.

The aim of this paper is to study the pattern directivity of the linear multielement receiving transducer of the sonar SHL-100M for application to electronically steered beam projector .The 189 individual 60 kHz elementary transducers are arranged in 21 staves. The studded transducer is the 9x21 staves linear array of elementary transducers characterised by its length L=334mm, length of elementary transducer a=14mm, equally spaced at the distance d=16mm. Since there are 189 individual transducers in the array , arranged in 21 staves , it is not practical to generate each of those independent beamforming signal with a separate circuit. The number of separate transmitters can be reduced do 21 staves. For the sonar operating frequency 60kHz and λ=25mm,we obtained d/λ=0.64 . The scanned sector which should be covered by steered beam is ±30°.

[1] in close cooperation with the Technical University of Gdańsk , Departament of Acoustic.

RESULTS

The examples presented in these paper are referred to the elementary transducers treated with their individual radiation pattern presented in the Figure 1.

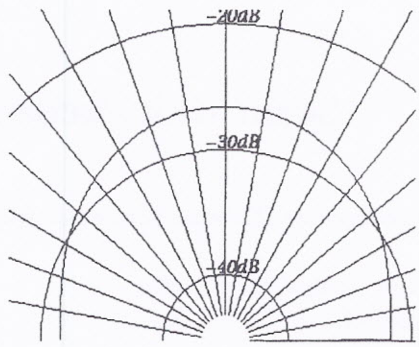

Fig 1. Far -field ,one way beam patterns of the elementary transducer for 60kHz and a=14mm.

For linear array of 21 transducers equally spaced at the distance d=16mm one from the other , and uniformly excited , the radiation beam pattern from a computer simulation is shown in the Fig.2.

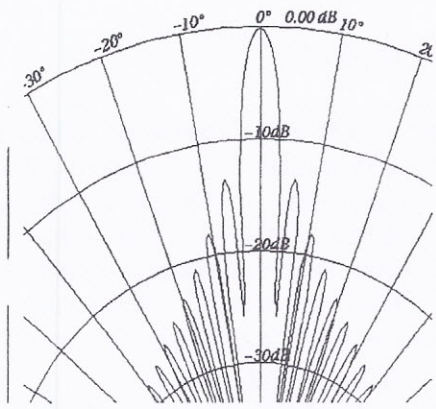

Fig 2 . Far -field radiation beam pattern for uniformly excited linear array .

An improved angular response of the transducers may be achieved only by using an array of transducers. A highly directional acoustic beam with suppressed side lobes can be obtained by a non uniform excitation of the transducer elements . The directivity pattern depends on the number , the spacing and the geometric configuration of the transducer elements. Following types of a non-uniform excited function were tested:

0.54+0.46cos x
0.84+0.46cos x and
sin x /x

The comparison of the selected projector radiation beam patterns with those of the uniformly excited is presented in the Fig 3 and 4

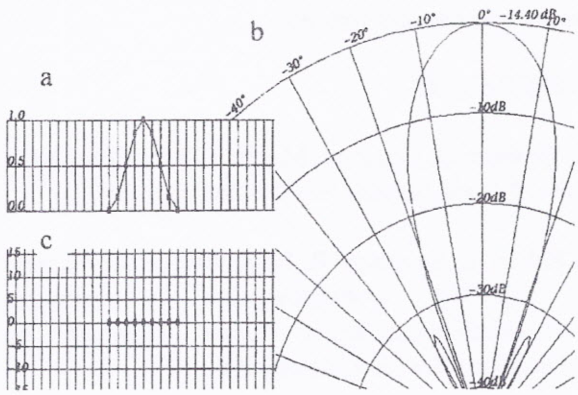

Fig 3. Far-field , one way beam pattern for excitation function 0.54+0.46 cos(2πl/a)
(a) The excitation function
(b)Fare-field , one way beam pattern
(c) Time of delay.

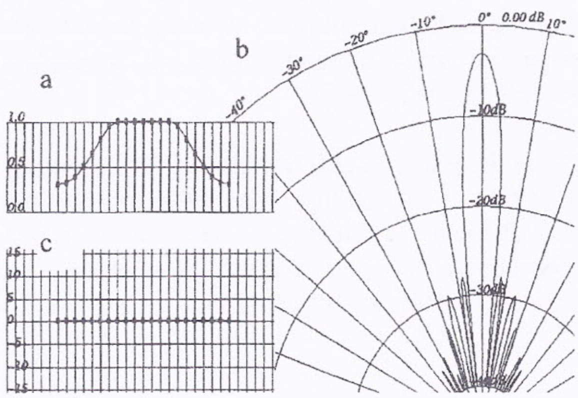

Fig 4. Fare-field , one way beam pattern for excitation function 0.86+0.46cos(2πl/a).
(a) The excitation function
(b)Fare-field , one way beam pattern
(c) Time of delay.

The array for our sonar has 21 transmitter staves each is composed of nine transmitting sources. Transmitting signals are delivered by 21 power supply amplifiers , which perform amplitude weighting and source level selection , according to the sonar mode of operation. The projector radiation beam can also be formed by sin x/x excitation function . That function secure proper source level and beam width with all excited staves.

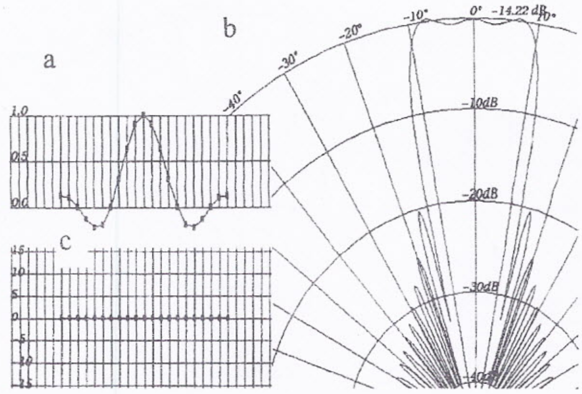

Fig 5.
(a)The excitation function of an array of 21 transducers spaced at d/λ=0.64
(b) Fare-field , one way beam pattern for excitation sin x/ x limited to 5π
(c) Time of delay.

The acoustic beam can also be electronically steered to the required direction by the line delayed excitation of the transducer elements . Scanned sector 60° can be covered by three beams of 20° .

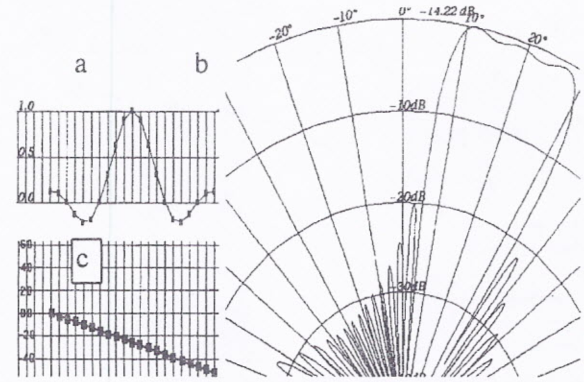

Fig 6.
(a) The excitation function of an array of 21 transducers spaced at d/λ=0.64,
(b) the corresponding fare-field radiation pattern
(c) delayed excitation of the transducer elements

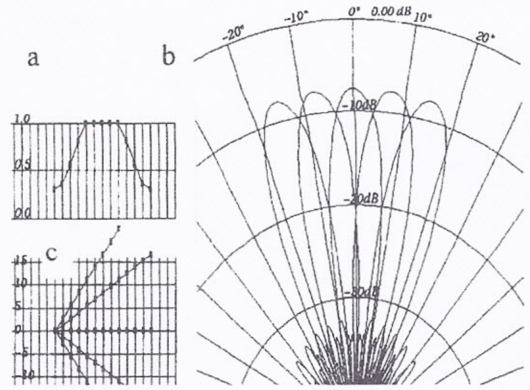

Fig 7 .
(a) The excitation function of an array of 13 transducer spaced at d/λ=0.64,
(b) the acoustic beam electronically steered for 5 directions ,
(c) 5 function of excitation delayed for 5 directions .

The computer - aided time domain method can also be used for study the fare-field radiation with damaged linear array transducer.

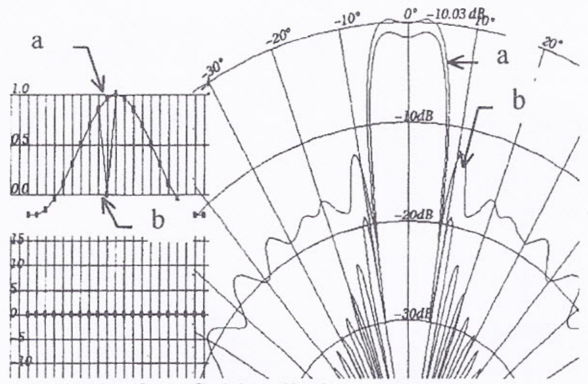

Fig 8.The fare-field radiation pattern
(a) for array of 21 transducer elements
(b) for damaged on element of the transducer .

CONCLUSION

1. The paper demonstrate the application of the computer aided time domain method for study and analysis the acoustic radiation patterns of linear array transducers. The transducer elements are treated as the individual radiation pattern [Fig1] of each element considered as a small array of point sources excited uniformly. The computer-aided time domain method presented in paper may be used for design of the linear array transducers .

2. The following excitation functions were selected during experimental research for 21 staves and d/λ=0.64 of the linear array transducer: 0.54+0.46cox , 0.84+0.46cosx and sin x / x . The optimum angular response for linear array transducer has been achieved for sinx / x excitation function.

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