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# MULTI-BEAM SIDE-SCAN SONAR

Andrzej Elminowicz
R&D Marine Technology Centre, ul. Dickmana 62, 81-109 Gdynia
e-mail: andrzeje@ctm.gdynia.pl

*Conventional single beam side-scan sonars with beams at about 1° are not well suited for the detection and identification of very small objects TS < -25 dB – e.g. minelike objects. Sonars of very high angular resolution at 0.1° - 0.2° operate in the nearfield and the speed of the sonar's transducer towing has to be reduced significantly. The paper presents a design approach to a multi-beam side-scan sonar where the above mentioned drawbacks have been removed. The sonar has several narrow parallel (not conical) beams simultaneously formed using the method of beam shaping in the nearfield. Two methods of beam shaping in the nearfield are presented. Thanks to them sonars of various quality and cost can be designed. Selected beam patterns for the two methods of beam forming in the nearfield are presented and compared.*

## INTRODUCTION

Conventional side-scan sonars use a single beam on each side to get a picture of the sea bottom. The principle of operation of this type of sonar suggests that as the distance increases the resolution deteriorates and the speed of towing must be less than 5 knots to penetrate the entire surface of the bottom. Conventional single beam sonars can also be used to scan objects such as wrecks at high speeds and then accurately present the detected object using low towing speed.

There are two methods through which increased angular resolution of side-scan sonars can be achieved. One is to build sonars with synthetic apertures and the other is to build multi-beam sonar with a high aperture transducer to ensure high angular resolution.

This paper covers certain aspects of how a multi-beam side-scan sonar should be designed to ensure a high angular resolution similar to that of sonars such as the 5000 multi-beam side-scan sonar made by Klein or 8012 sonar made by Reson. As there are no publications on the principle of operation and design of these sonars, no comparison to the principle of operation and design of the sonars presented in this paper could be made.

## THE APPLICATION AND PARAMETERS OF THE MULTI-BEAM SIDE-SCAN SONAR

The objective of this paper is to analyse the design of a side-scan sonar used for the detection of small objects whose target strength is less than – 25 dB and size at about 30 cm, from distance of 100 m. When the shadow method of detection is used, these parameters require a beam that is 0.18° wide, and when the sounding repetition is 3/s the transducer has to be towed at 0.9 m/s (about 2 knots). To increase the speed of towing up to 4.5 m/s, the sonar must have 5 parallel beams, 30 cm wide within a range of 5 m to 100 m.

The basic parameters of the sonar are the following:

- operating frequency 440 kHz
- five beams, 30 cm wide each
- width of zone scanned at one time 1.5 m
- three transmissions per second
- speed of towing 4.5 m/s (9 knots)
- number of transducer receiving elements 128
- transducer length 1024 mm
- elements spacing d = 8 mm.

For a 1024 mm long transducer with operating frequency at 440 kHz, the nearfield ends at about 300 m. Consequently, the sonar operates in the nearfield. Wavelength $\lambda$ is 3.3 mm and $d/\lambda$ is about 2.4, which causes the occurrence of two grating lobes, which should be beyond the observation sector. The widest observation sector is about 18 ° and occurs for the smallest distance equal to 5 m. Five beams are formed simultaneously. The idea is to steer the beams to ensure that they remain in the five parallel zones and not go beyond them.

## 2. FORMING THE BEAM PATTERNS OF THE MULTI-ELEMENT LINEAR TRANSDUCER IN THE NEARFIELD

For a transducer whose parameters are described above a simulation of beam patterns in the nearfield was made. The main lobe is presented in Fig. 1.

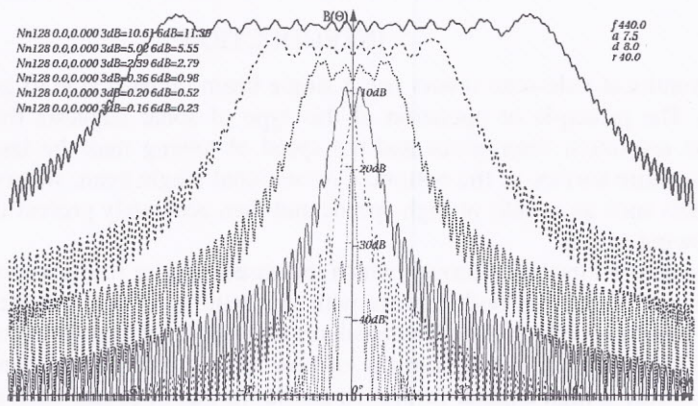


Fig. 1. Beam patterns of a 128 element linear transducer, 1024 mm long, operating frequency f=440 kHz at distances: ——— 5m; – – – · 10 m; ·········· 20m, ——— 50 m and – – – – 100 m.

The width of the main lobe at 6 dB is 11.3° for 5 m and gradually decreases down to 0.18° for the far field for 300m. These wide beam patterns are not used when the sonar uses the shadow method, even for small targets at small distances visible at wide angle.

The paper analyses two methods of narrowing the beam in the nearfield. The beam patterns in the nearfield can be narrowed by shortening the transducer (by limiting the number of active elements) and deep weighing. As a result, the range of the nearfield is shortened and the beam is narrowed. Fig. 2 shows the narrowing of the beam for several distances.

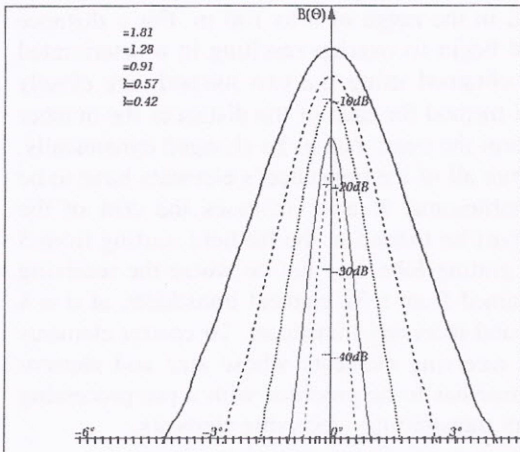


Fig. 2. Forming the receiving beam in the nearfield by changing the number of transducer elements and cos weighting function for various distances: ——— 5m; – – – – 10 m; ··········· 20m ——— 50 m and - · 100 m.

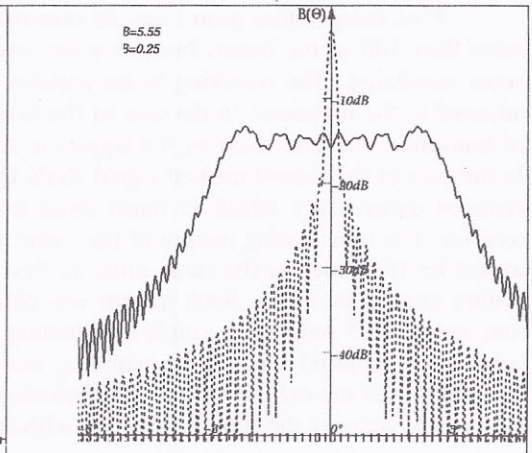


Fig. 3. Forming the receiving beam in the nearfield by shifting signals from the particular transducer elements: ——— unformed beam, – – – – formed beam.

The beam pattern in the nearfield can also be formed (narrowed) in the case of a multi-element linear transducer by shifting the signals from the particular elements of the transducer to match the focusing of the receiving beam, similar to how focusing happens in the transmitting mode [1 and 2].

By shifting signals from the multi-element receiving transducer (focusing), we can obtain a significantly narrowed beam of the linear transducer in the nearfield as shown in Fig.3.

The beam can be steered according to the rules of steering applied to multi-element linear transducers. The beam patterns of the beamformer at a distance of e.g. 10 m are given in Fig. 4.

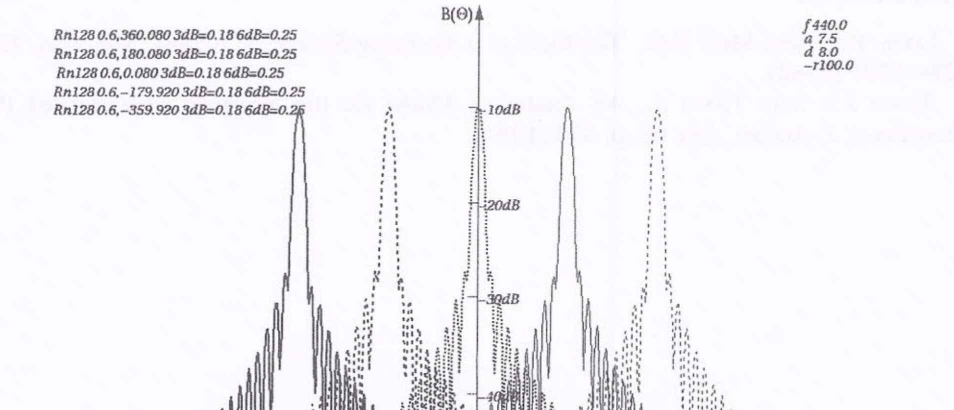


Fig. 4. Beam patterns of transducer-beamformer blocks for a distance of 10 m, formed using signals shift from the particular transducer elements.

Five independent beams can be obtained in the range of 5 to 100 m. For a distance more than 100 m the beams become wider and begin to overlap resulting in a deteriorated sonar resolution. The receiving beam patterns obtained using the two methods are closely adjusted to the distances. In the case of the first method for each of the distances the number of transducer elements used by the signals to form the beam has to be changed dynamically. In the case of the second method signal shifts from all of the transducer's elements have to be changed dynamically which is much more troublesome. It also increases the cost of the receiver. The transmitting pattern of the sonar must be formed in the far field starting from 5 m and be 18° wide. At the same time, its first grating lobe may not be where the receiving beam's grating lobe was. Such pattern was obtained from a 32 element transducer, at $d = 4$ mm and $a = 3.5$ mm. For a single transmitting and receiving transducer, 16 central elements have to be replaced with 32 transmitting and receiving elements whose size and element spacing is half the regular values. The beamformer has to be preceded with a pre-processing system that sums up the signals from two adjacent transmitting - receiving elements.

## 3. SUMMARY

High resolution of side-scan sonars, whose beam is less than 1° wide have to have the beam formed to be able to work in the nearfield.

The paper presents two ways of forming the receiving beam in the nearfield. One way to form the beam in the nearfield is to dynamically change the number of transducer elements combined with weighing using the cos function.

A narrower beam is obtained by shifting in time the signals from the particular transducer elements. This ensures that in the nearfield the beam's width and shape will be identical to that in the far field (with an adequately frequent and dynamic change of signal shift in time). Thanks to this two types of multi-beam side-scan sonars can be built ensuring a high angular resolution.

The sonar which forms the beam in the nearfield using the first method is easier to make (cheaper), the beams, however, are not sufficiently well formed.

## REFERENCES

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2. Tjotta J.N. and Tjotta S., An Analytical Model for the Nearfield of a Baffled Piston Transducer, J. Acoust. Am. 68, p. 334 (1980).