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ESTIMATION OF THE POSSIBILITIES OF SHIP'S DETECTION BASING ON THE MEASURED PHYSICAL FIELDS.

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Passive detection and localization of objects in the water environment is a desirable undertaking not only from the point of view of underwater defense technology but it is also associated with the military aspect of security, especially in respect to the protection of narrow passages, waterlines and ports. Observation of a specific region of the sea area, besides the technical means (hardware) that allow the data acquisition, requires also the application of a specific algorithm for the determination of ship's localization (software). This article presents the possibilities of ship's detection basing on the analysis of acoustic, magnetic, electric and pressure fields.

1. THE CONDITIONS FOR DETECTION OF PHYSICAL FIELDS

A ship is a source of many physical fields, which provide information about her as a technical object. Such information after proper processing and analysis, can be used in many ways – in underwater warfare: for actuation of non-contact mines, for torpedo homing systems and for the detection, localization and identification of the source of a physical field by other systems located underwater. When we limit the sphere of interest to the water space, we can analyze the following physical fields generated by a ship: acoustic field; magnetic field; electric filed (UEP); hydrodynamic field. All above fields carry different types of information and have their specific ranges of propagation.

2. THE ACOUSTIC FIELD OF A SHIP:

From all the physical fields of a ship mentioned above the acoustic one covers the greatest area of water environment because the acoustic energy generated by a ship propagates in the sea with the lowest losses.
The passive detection of hydrocoustic noise of a ship in a given sea area may be at big distances from the source by an array of hydrophones set up at the sea bottom.
From the point of view of detection, this field should be subjected to analysis in different frequency ranges from 5-20 Hz to 150-200 kHz.

Propagation of acoustic waves in the water depends on many factors, but the biggest influence on it has the suppression factor (β) which is a function of frequency, water viscosity, salinity, temperature, thermal conductivity and pressure.
If we know a hydrological condition, we can estimate changes of pressure level on a fixed depth as a function of distance from the ship to sensor.(Fig.1.)

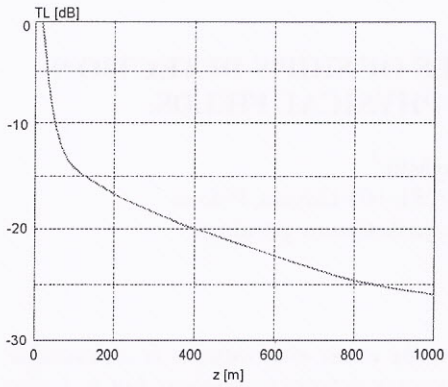

Fig.1.

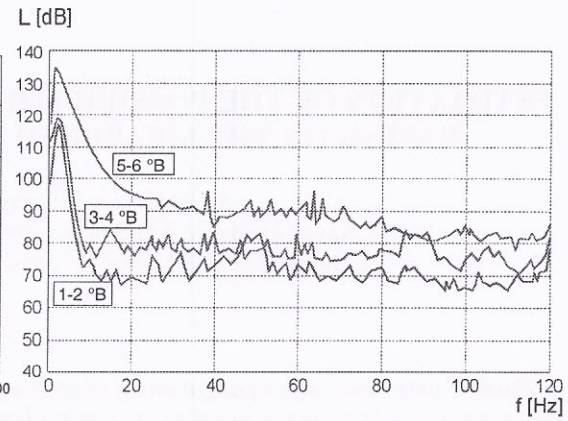

Fig.2.

Acoustic surveys are always conducted in the presence of ambient noise, especially in the coastal zone where the man-made interference is serious.(Fig.2.)[2]
Ship signatures, obtained during these surveys are difficult to interpret, so detection and localization of source are seriously limited.
Basing on research of different types of ships moving at different speed during different sea states conducted in the area of Puck and Gdańsk Bay, the detection range of a ship by acoustical means were estimated.
Depending on the frequency characteristic of a ships noise (/250-600 Hz/ or higher amount of energy on lower frequencies /10-300Hz/), and also depending on the sea state, so the estimated detection range is approximately equal to:

characteristic frequency	sea state 2-3 °	sea state 7-8 °
250 – 600 Hz	3500 m	1200 m
10 – 300 Hz	5000 m	1700 m

It is easy to notice, that the range of detection of a ship depends directly on the frequency characteristic of the ships noise and on meteorological condition at the moment of survey.

3. THE MAGNETIC FIELD OF A SHIP:

The basic method of research of a magnetic field is a measurement of the intensities ($\vec{H}$) or the magnetic induction ($\vec{B}$). Variability range of fields, being in practice an object of measurements of ship signatures on a background of geomagnetic ambient noise, we can approximately estimate on $10^{-9} \div 10^{-4}$ [T]; (0, 001μT ÷ 100 μT).

For the ships having different dimensions and steel or plastic hull, we can estimate maximal value of magnetic induction on: 0 ÷ 100 μT and 0 ÷ 1 μT – respectively.

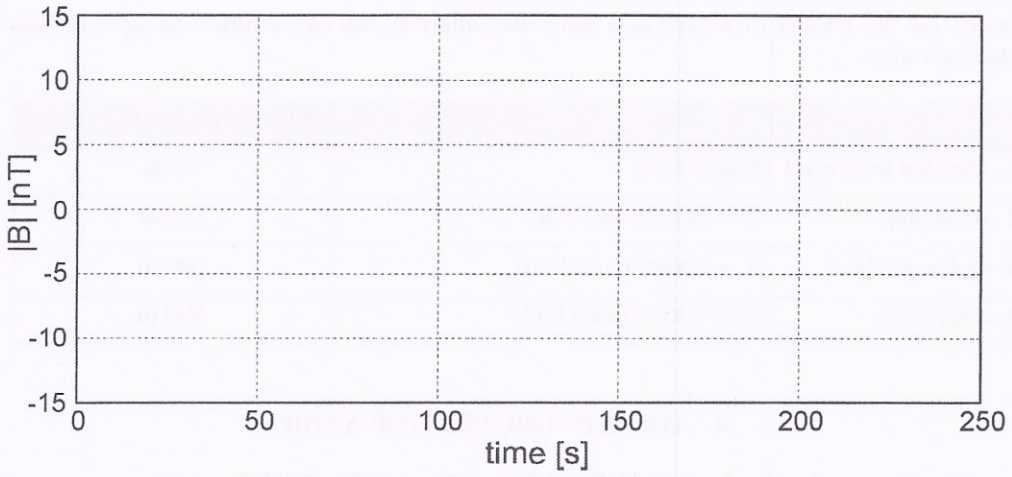

Fig.3. Interference of magnetic field in the coastal zone.

In the most cases, during survey and analysis of magnetic field signatures is usually limit to vertical composition (H_z) of field intensity vector, for the reason that he has decisive quantitative character in total vector of magnetic field. Magnetic surveys conducted in the coastal zone are influenced by Earth magnetic field (about 49 ÷ 50 μT) and man-made interference, which usually has alternating character and frequency equal to power network and higher.(Fig.3.). There are a few methods for compensating this interference during the survey.

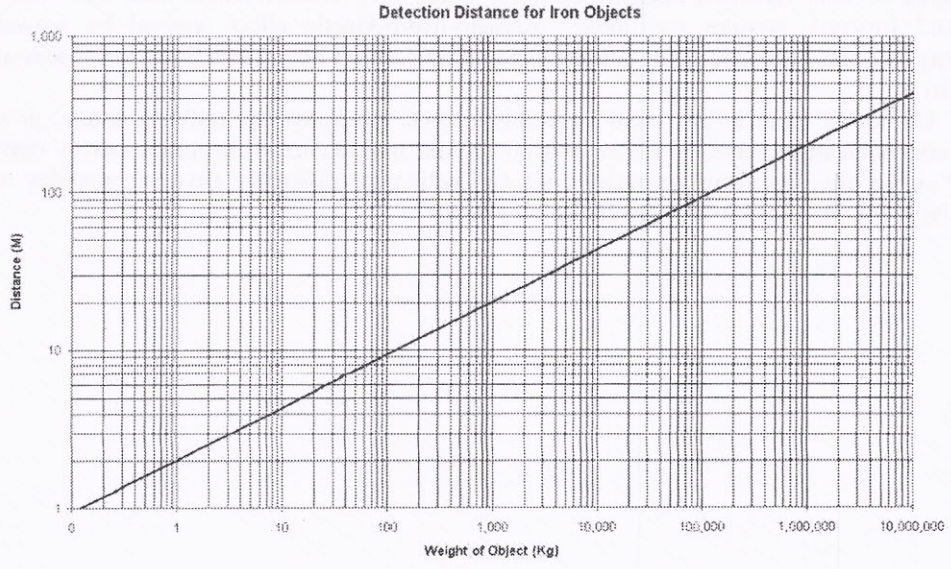

Fig.4. Estimated range of detection for iron objects.

Range of ship detection directly depend on the her geometrical dimensions, so that are proportional to quantity of ferro-magnetic mass.(Fig.4.)
Finally, on the ground of survey and signatures analysis, we can estimate an approximate detection range.

Ship		Approx. detection distance
1. minimal field level	(plastic hull)	60 m
2 small ships	(L ≈ 50m) (steel hull)	120 m
3. medium ships	(L ≈ 100m) (steel hull)	200 m
4. large ships	(L > 100m) (steel hull)	500 m

4. THE ELECTRIC FIELD OF A SHIP:

Underwater electric potential (UEP) of the ship, is determined during the survey and can be fixed with accuracy to constant number, named zero or the reference potential.
In most analytical tasks, we assume that this potential is in infinity, but during the survey at sea reference sensor is placed in the area where the UEP should disappear.
This permits to accept the assumption, universally used in related physical problems, that besides this area, UEP of the ship resets oneself.
In practice, measured UEP field of the ships embraces space several times exceeding its linear dimension. Main disturbance of UEP field comes from natural electric field of the Earth, which has a complex structure, and its value in significant degree depends on place of survey.

Essential components of electric field of the Earth are telluric currents, induced under influence of solar radiation intensity changes, which vary in wide range: from $0{,}01*10^{-3}$ to $10*10^{-3}$ [mV/m]. Besides the above, magneto-hydro-kinetic effect (caused by seawater moving in Earth magnetic field) and diffusive effect (caused by ion concentration – seawater salinity).

Obviously there is also man-made interference, generated by: railway system, power and communication network. In the coastal region, interference from these sources during UEP survey are significant, especially we can notice the difference between weekday and holiday (Fig.5), and between daytime and nighttime.

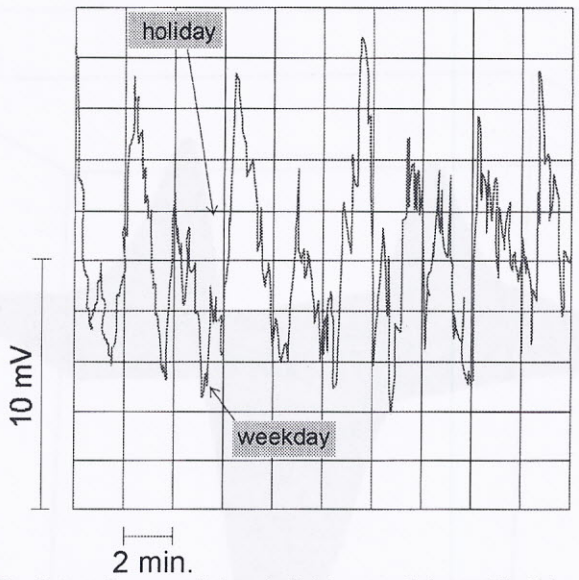

Fig.5. Interference of electric field on weekday and holiday.

Spatial distribution of UEP field directly depends on electrochemical potential of the ship's hull. Using different measurement systems and different sensors (silver-chloride, zinc or carbon-fibre electrodes), we can estimate the range of ship detection on the ground of its UEP survey.

Ship	Approx. detection distance
1. minimal field level (plastic hull)	10 m
2 small ships, steel hull (L < 50m)	50 m
3. medium ships, steel hull (50 < L < 100m)	100 m
4. large ships, steel hull (L > 100m)	200 m

5. THE PRESSURE FIELD OF A SHIP:

Ship moving in the seawater generates field of stream, which are accompanied with changes of water pressure. These disturbances are transmitted consecutively from a particle to a particle. Since this energy decreases its value very fast the range of ship pressure field is the smallest from all previously mentioned.

In seawater, exists only natural hydrodynamic field coming from wave motion of the seawater. This means that a superposition of the natural and target's field occurs in the area around the ship.

In spite of the small range of propagation, this field is very regularly and homogeneously characterized. Signatures are distinguished by existence of two areas: over-pressure (positive - located on bow and stern) and under-pressure (negative - located on midship)(Fig.6.).

This property associated with the low range of propagation is used in underwater warfare (mines) for actuation of non-contact fuses.

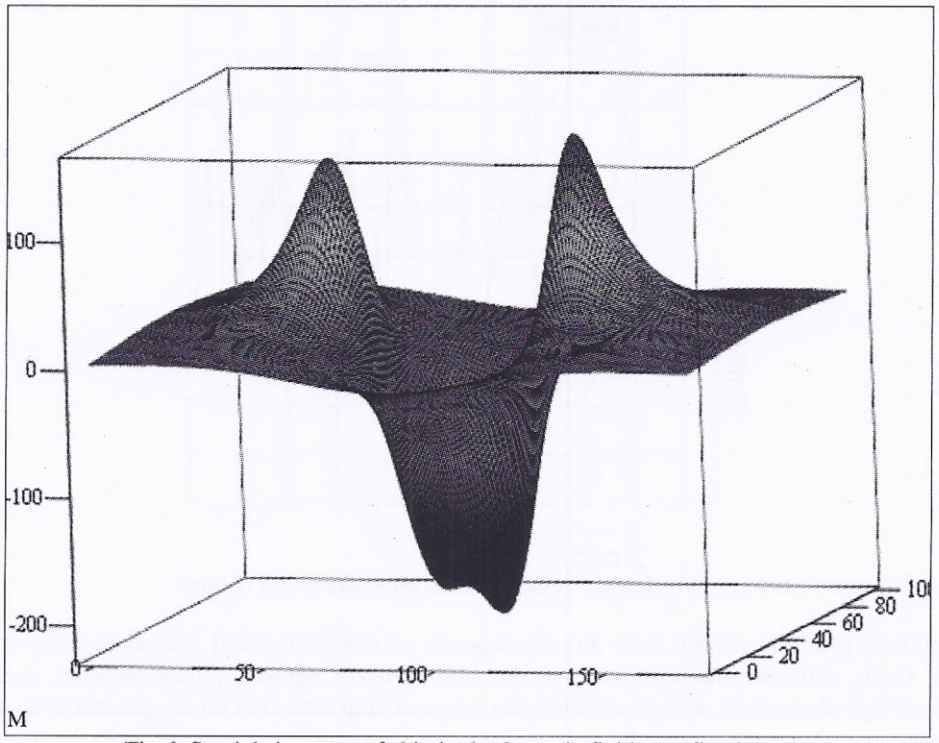

Fig.6. Spatial signature of ship hydrodynamic field on a fixed depth.

Signature of this field directly depends on shape of underwater part of the hull and the ship velocity. But independently from above, range of detection of this file doesn't exceed distance of about 100m long.

6. SUMMARY:

Analyzing the ship signatures, especially acoustic, magnetic, electric and pressure field we can estimate the detection range of this source, by the means located underwater. Consequently, using the specific methods and algorithms we can determine ship's localization basing on above fields, and realize an identification of swimming objects.

REFERENCES:

1. Kozaczka E., Grelowska G., Gloza I. – „Determination of the ship detection area in the coastal region." – Proceedings of EAA Symposium, Jurata 1997r.
2. Kiciński W. – „Underwater noise characteristics in the coastal zone." XII Symposium on Hydroacoustic, Gdynia – Jurata 1995r.
3. E.Kozaczka, I.Gloza, G.Grelowska – „General characteristics of ship noise in shallow water" – UDT 1998r.