Signals parametrization method of sailing vessels

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The expansion of maritime transport is directly connected with increased risk of the appearance of unidentified vessels in the approaches to ports, wind farms, and other sensitive places in the water-body.

Creating a parameters database of sailing objects, based on recorded dynamic variations of different physical fields with the specified aims of increasing security within the strategic offshore areas.

Keywords: hydroacoustic, pressure, magnetic, multi-influence module, database

1. Introduction

The article focuses on the parameterization of signals from hydroacoustic sensors, a magnetometer and a pressure sensor. Presentation of the above-mentioned signals in the form of a set of parameters increases the possibility of creating and managing the database of various objects moving on the body of water surface near the underwater measurement module. The many underwater sensors were part of an underwater multi-influence module [1]. Simultaneous recordings together with the Automatic Identification System (AIS) allows you to determine the trajectory of an object, and its basic parameters required to create new, and complement previous, records. The obtained dataset will be used to develop methods for classification and identification of vessels.

2. Vessel groups and their attributes

Objects sailing on the sea surface can be classified using a division method based on different features. Attributes can be determined from the perspective of functions compiled by the object or its destination. There can be mentioned types of commercial vessels as follows:

- Passenger ships,
- Container ships,
- General cargo ships,
- Bulk carriers,

- Tankers,
- Vehicle carriers,
- Liquefied gas carriers,
- Chemical tankers,
- Reefers,
- Ro-Ro,
- Tugs,
- Other specialized ships.

Attributes of vessel groups stem directly from belonging to that group. The parameters describing the selected vessel include:

- Total length / length on the waterline,
- Width,
- Draft,
- Displacement,
- Gross tonnage,
- Speed,
- Trim,
- The number of propellers,
- The diameter of the propellers,
- The number of blades,
- Engine power,
- Other parameters.

Creating a ship database, we use all available information in order to unmistakably determine the object, which creates a single database record. The worldwide unified Automatic Identification System (AIS) gives the user a clear, and understandable, picture of the situation in the observed area. The absence of information about a moving vessel from AIS is appropriate to get all the parameters from another observation system, based on the monitoring of subsea physical field disturbances.

A vessel moving on the surface is an object with specific static parameters (size, draft, etc.) and dynamic ones too(related to its movement). Moving such an object causes disturbances of local physical fields, which include:

- Acoustic field,
- Pressure field,
- Magnetic field,
- Electric field,
- Seismic field.

These variations can describe the source of their occurrence with some accuracy. For this purpose, there was used an underwater measurement system integrating a set of sensors with processing and recording units. This paper describes the disturbances of the acoustic field, pressure and magnetic fields, as a base to determine an individual vessel’s parameters.

3. Hydroacoustic field analysis

Hydroacoustic fields describe disturbances of the sound pressure connected with the movement of the ship, and the noises coming from the working machinery located inside it [2]. Due to the nature of these fields, sound propagation is vibration transmission from the source toward the sensor, which is a hydrophone. Recorded frequencies are bandwidth-limited by the transducer, with a signal processing circuit, and also the distance between the source and the receiver. Attenuation absorption prevents the transmission of high frequency sound over long distances [3].

Hydroacoustic fields from a moving object can be divided into a high-frequency part, and a low-frequency part. Presenting the first one can primarily rely on the frequency domain. We use narrowband frequency analysis to determine occurrences of the characteristic harmonic**s**. It is usually carried out using the Fast Fourier Transformation. The parameters of the output signal are determined by the frequency domain parameters.

A frequency resolution is primarily dependent on the analyzed signal duration. The resulting parameters obtained during this analysis are the amplitude and frequency of the dominant harmonic within a predetermined band.

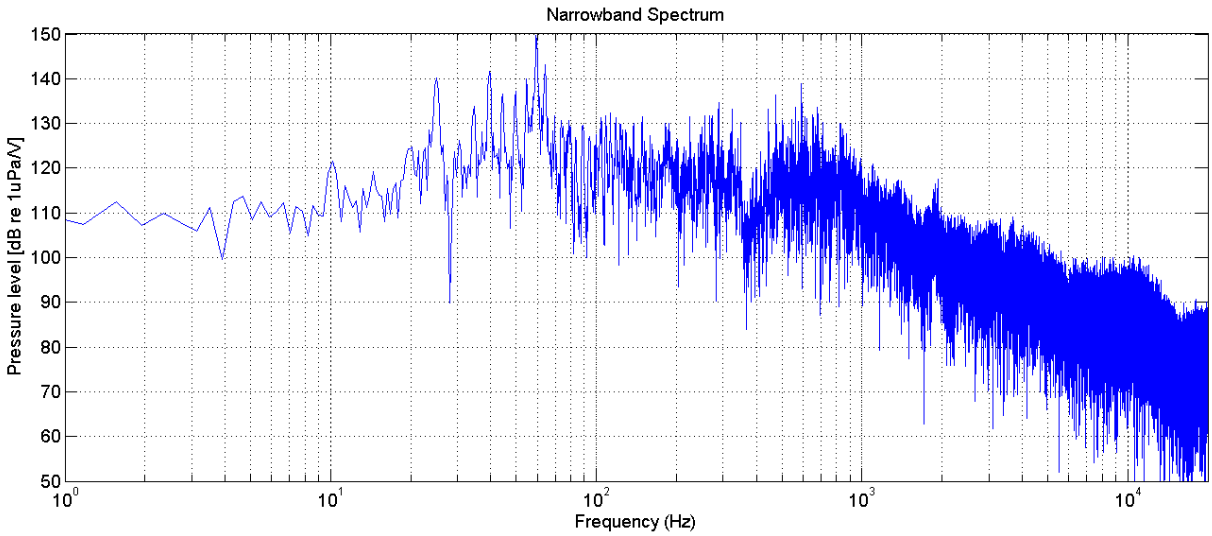

Fig. 1. Sample graph of the spectrum after narrowband analysis.

Fig. 1. presents the acoustic pressure level for each frequency obtained as a result of narrowband analysis. Shown bandwidth is dependent on sampling frequency, which equals 51.2 kHz.

Another method is based on the presentation of spectra in one-third-octave (OTO) bands [4]. Using OTO filters and frequency analysis, results obtained in the form of amplitudes gives information about the acoustic pressure level for each subsequent band. Both the narrowband analysis and OTO are represented in a logarithmic scale relating to 1 μPa, in order to combine the single graph data for small and large values.

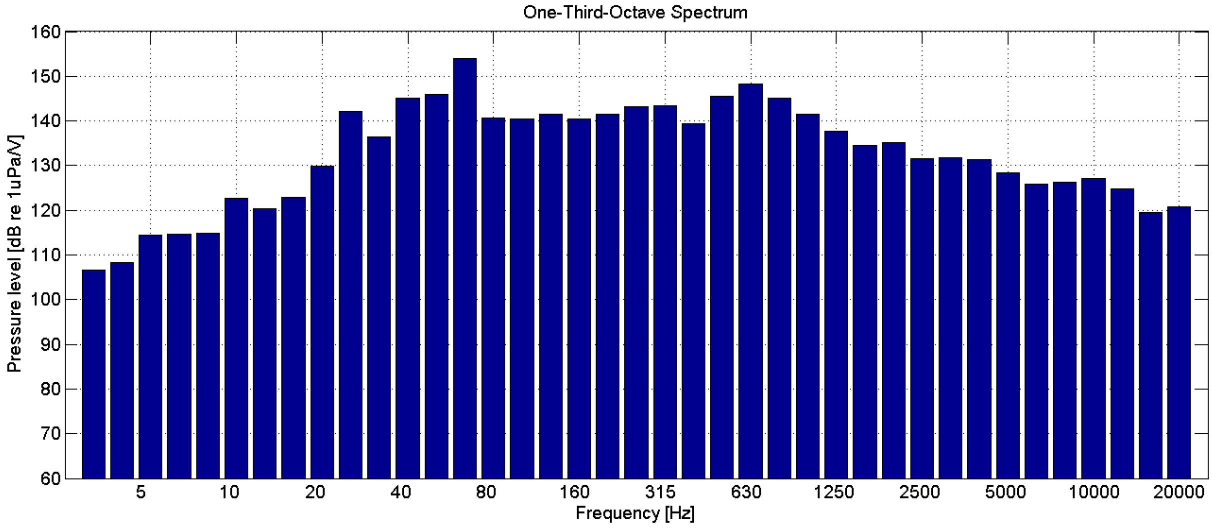

Fig. 2. Sample graph of the spectrum of a moving object after one-third-octave analysis.

A tabular summary of the frequency parameters resulting from the above signal analysis.

Tab. 1. Proposed parameters obtained after narrowband analysis.

f [Hz]	4.7	10.2	20.3	25	...	39.4	59.4	64.4	...
p [dB]	113.7	121.6	124.7	140.1	...	141.7	149.6	143.2	...

Tab. 2. Proposed parameters obtained after one-third-octave analysis.

f [Hz]	3.15	4	5	6.3	...	630	800	1000	...
p [dB]	107	108	114	115	...	148	145	142	...

In Tab. 1. You have sound level in a very narrow frequency band (0.2 Hz bandwidth), in Tab. 2. there are averaged OTO band values.

Some parameters characterizing the low-frequency part of the hydroacoustic field, such as:

- Signal time duration (t);
- The maximum ship noise level (p_{max});
- Moment of p_{max} (t_{max}),
- The energy of the signal as a surface area below p(t) ?(p_{sa}). – will be explained later.

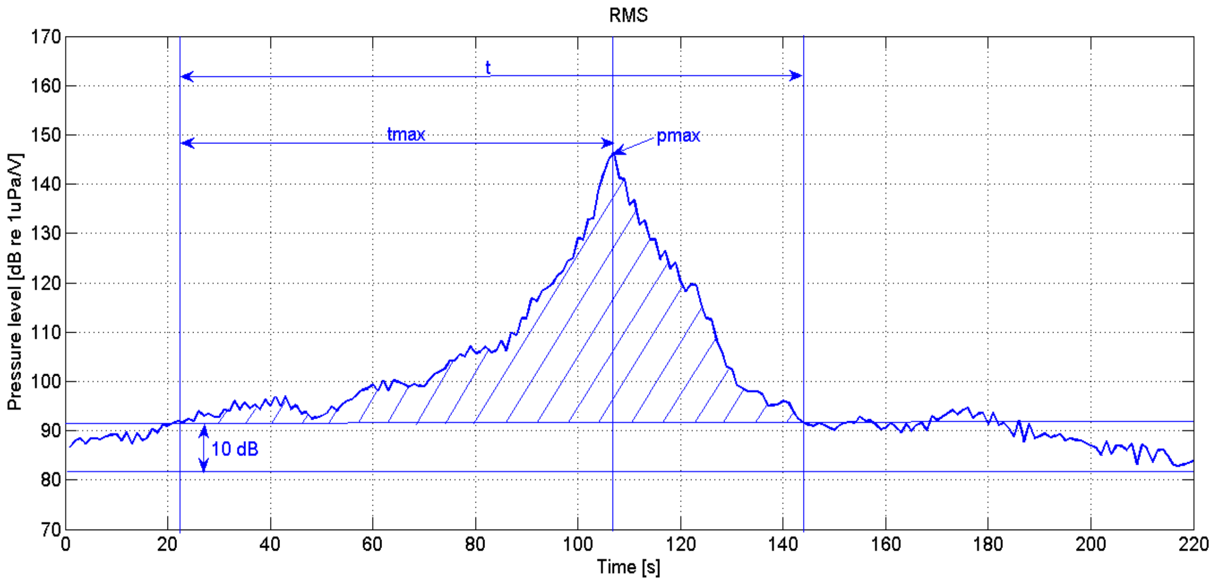

Fig. 3. Here is time series, or variations in time, of the RMS pressure level.

By designating the duration of the passing of the measuring point ship noise, the average level of ambient noise (p_{bgn}) in the 5 min before the measurement, is determined. Start time is determined when the acoustic signal from a ship exceeds ambient sea noise level by 10 dB, while the end is defined by the moment when the ship noise level is diminished at least to the values p_{bgn} + 10 dB. The time between these two points is defined as the signal duration.

The maximum signal level is the maximum level of the entire signal bandwidth. A product of time for which the pressure level is the highest is named moment of p_{max}.

The energy of the signal is defined as the surface area below the p(t) curve and the straight line passing through p_{bgn} + 10 dB value.

Tab. 3. The list of low-frequency parameters of the hydroacoustic field.

Number	1	2	3	4
Parameter	T	p_{max}	t_{max}	p_{sa}

As opposed to the hydroacoustic field, the pressure one is described only for low-frequency parameters because of the character of this field. The source of this field's disturbance is the moving hull of the ship thrust into the surrounding water (En.). This value depends on the hull shape, the current draft, and the vessel's speed. Detection range of the dynamic pressure disturbances is much smaller in comparison to the hydroacoustic field. With increasing distance from the source, the value of underpressure / overpressure detected by the pressure detector decreases significantly.

The parameters characterizing the low-frequency pressure field:

- Duration of the first overpressure (t_{O1}),
- The maximum value of the first overpressure (p_{O1})/ first overpressure energy (p_{O1sa}),
- Duration of the underpressure (t_U),
- The maximum underpressure (p_U), / underpressure energy (p_{Usa}),,
- Duration of the second overpressure (t_{O2}),

- The maximum value of the second overpressure (p_{O2}), / second overpressure energy (p_{O2sa}).

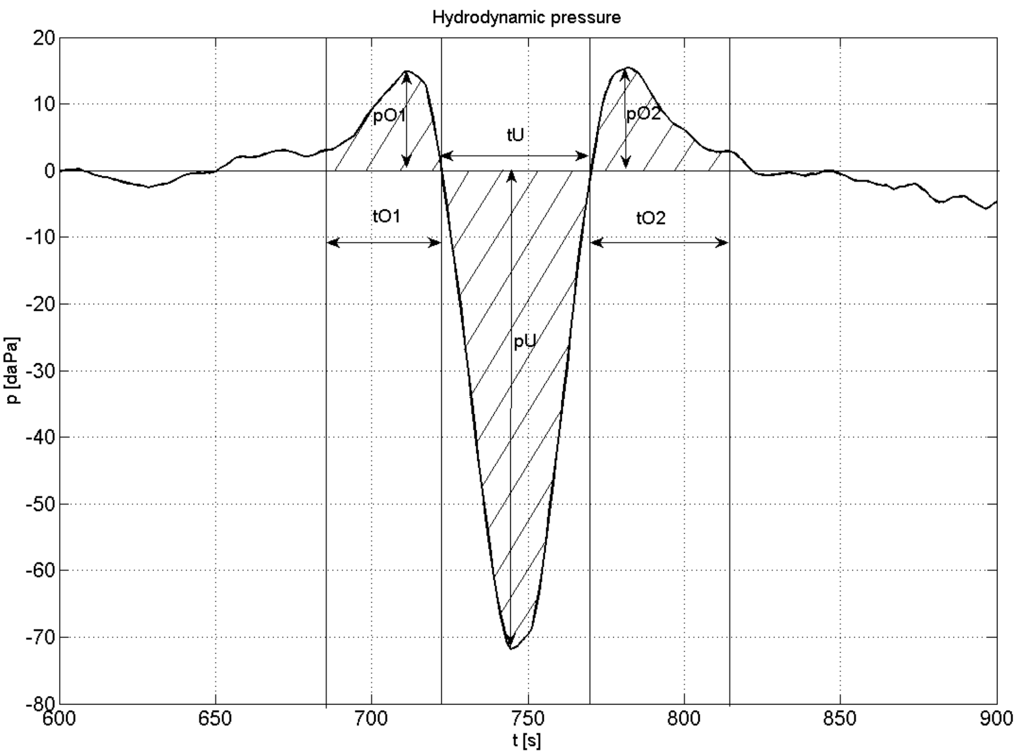

Fig. 4. Analyzing signal obtained from pressure sensor.

Duration calculation of both overpressure and underpressure been taken into account with the average pressure level for 1 min prior to measurement of the hydrostatic pressure (P_{st}). The hydrostatic pressure has been subtracted from the measured value, so overpressure has positive values, underpressure has negative values. Overpressure duration is the time from the moment when exceeding the analyzed value of 1 daPa. The duration of underpressure is determined between zero crossings. The maximum value of overpressure and underpressures are measured for the proper time periods. Energy is defined by the surface area between the pressure curve and the straight line indicating 0 daPa (P_{st}).

Tab. 4. Proposed parameters of low-frequency pressure field.

Number	1	2	3	4	5	6	7	8	9
Parameter	t_{O1}	p_{O1}	p_{O1sa}	t_U	p_U	p_{Usa}	t_{O2}	p_{O2}	p_{O2sa}

The magnetic field was analyzed for low-frequency characteristics. The magnetic field disturbances are related to the local magnetic field, and the field induced by a metal hull. The instantaneous values of the field are given by the three components x, y and z, or the total vector of magnetic induction. Any object moving close to the detector causes a disturbance in the local magnetic field recorded by the magnetometers. The rate of these changes enables us to use a small sampling frequency in comparison with the pressure field sampling analysis. A disadvantage of the detection of variations in the magnetic field is that it quickly diminishes with increasing distance from the source. The determined parameters defining the magnetic field disturbance are:

- Duration of the total vector (t),
- Total vector of magnetic induction (B),
- The moment of the maximum of the total magnetic induction vector (t_{max}),
- Energy as a surface area (B_{sa}),
- Duration of each component disturbances (t_{x1}, t_{x2}, t_{y1}, t_{y2}, t_{z1}, t_{z2}, t_{z3}),
- The maximum value of each component (B_{x1}, B_{x2}, B_{y1}, B_{y2}, B_{z1}, B_{z2}, B_{z3}),
- Energy as a surface area for each component (B_{x1sa}, B_{x2sa}, B_{y1sa}, B_{y2sa}, B_{z1sa}, B_{z2sa}, B_{z3sa}).

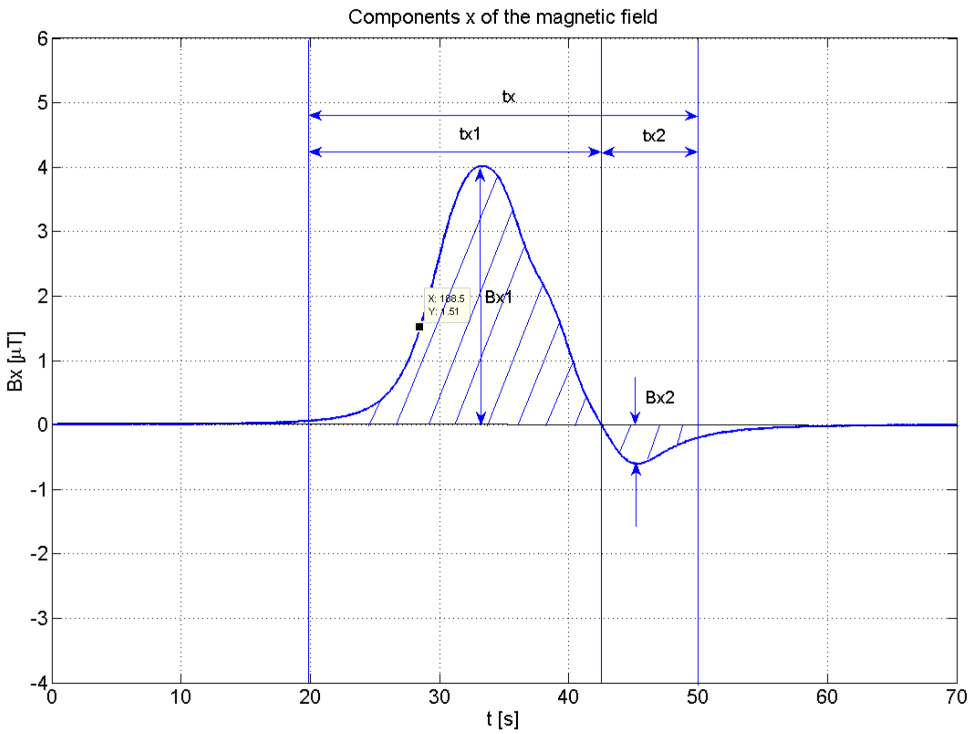

Fig. 5. X component of magnetic field analysis.

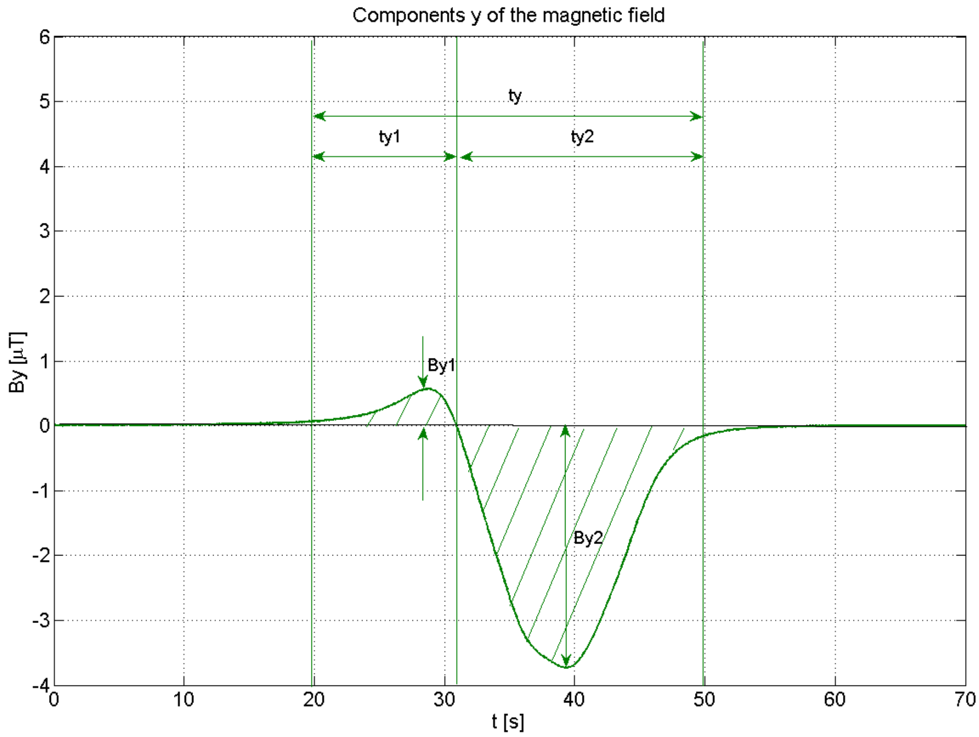

Fig. 6. Y component of magnetic field analysis.

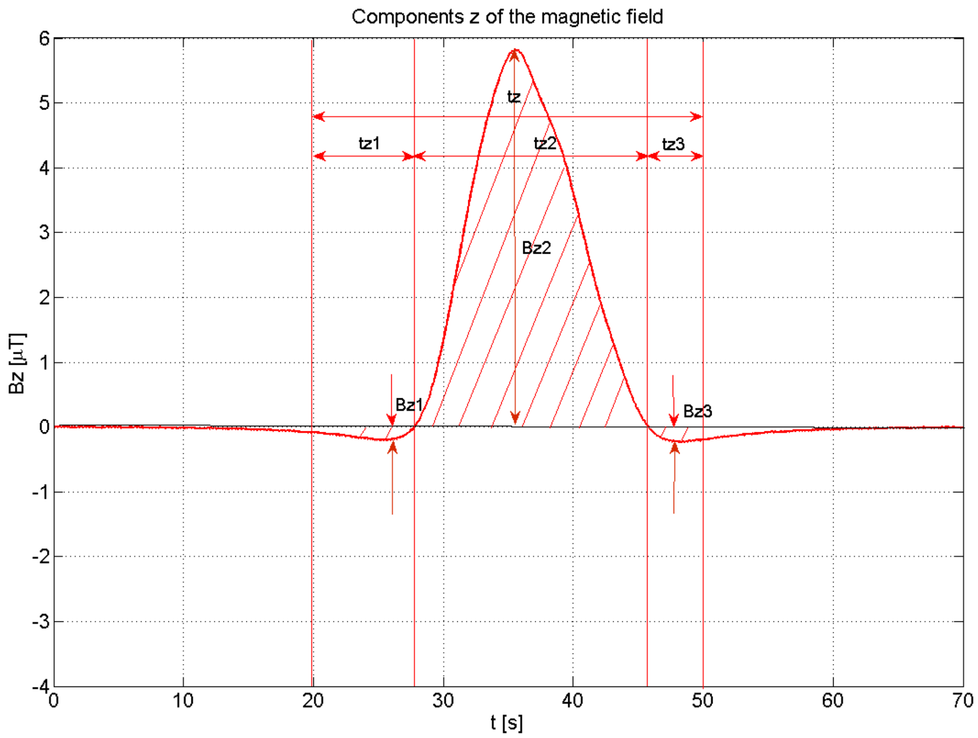

Fig. 7. Z component of magnetic field analysis.

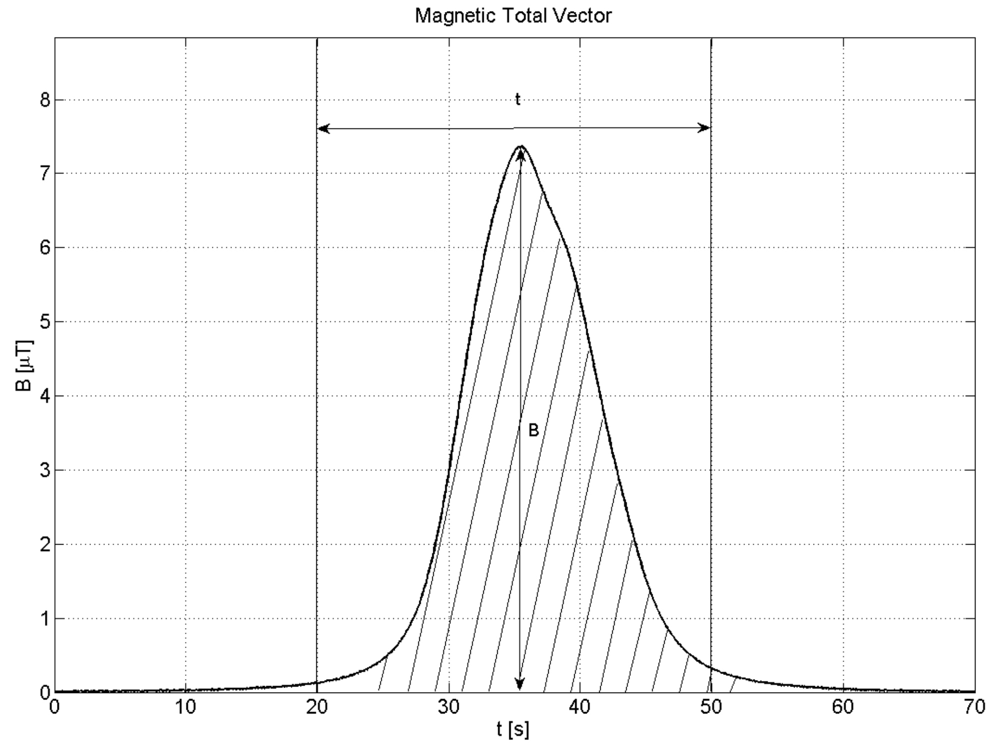

Fig. 8. Magnetic field total vector analysis.

Duration of the total magnetic induction vector is measured from the time when the local magnetic field value (B_{bgn}) exceeded a preset value till the moment of decreasing values below B_{bgn} + preset value. B_{bgn} is subtracted from the total value for analyzing only deviations. Its maximum value is the second parameter.

The moment of the total vector maximum value is calculated from the beginning of disorder duration.

The energy is determined by the surface area between the disturbance curve and the straight line indicating a value of 0 μT. In analogy to the total vector there were parameters determined for each component.

Tab. 5. Low-frequency parameters of magnetic field disturbance.

Number	1	2	3	4	5	6	7	8	9
Parameter	t	B	t_{max}	B_{sa}	t_{x1}	t_{x2}	t_{y1}	t_{y2}	t_{z1}
Number	10	11	12	13	14	15	16	17	18
Parameter	t_{z2}	t_{z3}	B_{x1}	B_{x2}	B_{y1}	B_{y2}	B_{z1}	B_{z2}	B_{z3}
Number	19	20	21	22	23	24	25		
Parameter	B_{x1sa}	B_{x2sa}	B_{y1sa}	B_{y2sa}	B_{z1sa}	B_{z2sa}	B_{z3sa}		

4. Conclusions

The proposed method of signals parameterization simplifies description of tested ship signatures. The database, based on a set of parameters measured of physical fields, enables the classification of sailing objects. To complement the database, parameters coming from the electric and seismic fields could significantly improve the result of the method recommended here.

References

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