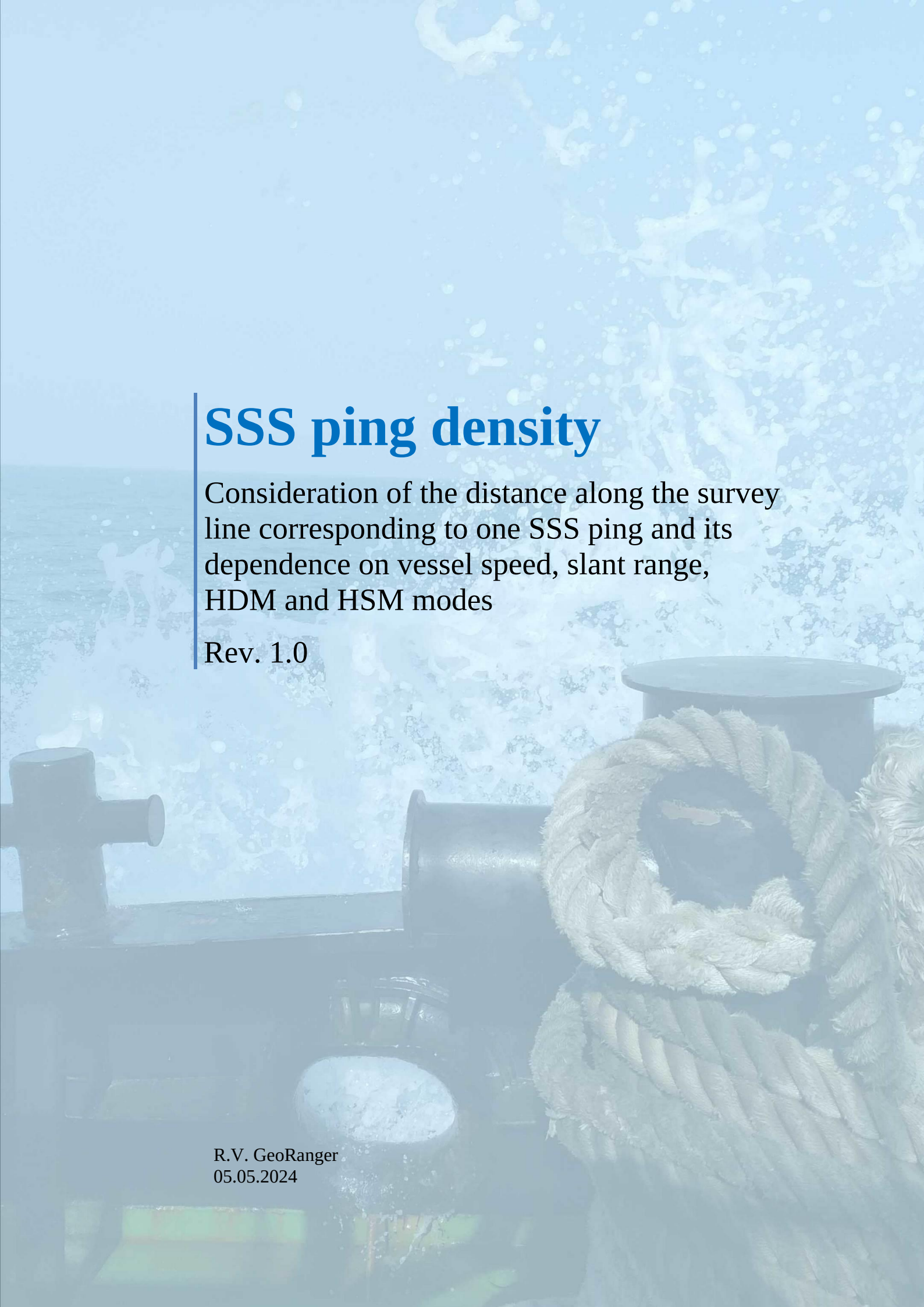

SSS ping density

Consideration of the distance along the survey line corresponding to one SSS ping and its dependence on vessel speed, slant range, HDM and HSM modes

Rev. 1.0

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Contents

History of changes

Version	Date	Description of changes
1.0	2024-05-05	First issue document // Ivan D.

List of Figures

Introduction

The document considers the distance along the survey line corresponding to one SSS ping; hereafter it is referred to as "ping length". ***Figure 0.1*** summarizes typical SoW requirements for SSS survey performance. The following characteristics should be emphasized:

-- 3 pings must "cover" an object of 0.3x0.3 meters, i.e., there must be 0.1 meters per ping;

-- the beam width in the horizontal plane should be less than 0.3 degrees.

1. Dual frequency system.
2. High frequency of 500 KHz or greater, compatible with n.4 .
3. Horizontal beam width less than 0.3 degrees.
4. Seabed objects of 0.3m x 0.3m x 0.1m or greater to be detectable over the entire range.
5. Survey speed and range should be optimised so that 3 pings land on the minimum required seabed object to be detected .
6. SSS altitude to be approximately 10% of the range scale used.
7. Overlap between adjacent lines required to record data at nadir.
8. System must be decoupled from vessel heave, pitch and roll.

Figure 0.1 Example of SSS survey requirements

1. Ping frequency at different SSS slant range

Figure 1.1 shows a table with the number of pings per second at the different slant range for SSS. The table is derived from experimental measurements for the SSS ET4200. Only one SSS frequency was involved, and measurements were performed in High Speed Mode (HSM) and High Definition Mode (HDM). For HSM mode the ping frequency is twice as high as for HDM mode.

4200HF (300/600)					
HighResolution 1F (HighF)			HighSpeed 1F (HighF)		
Range	Pings/sec	Freq	Range	Pings/sec	Freq
4.994	53.491	550.030	5.011	105.174	564.230
10.005	53.492	550.030	9.988	105.174	564.230
14.930	44.015	550.030	14.999	85.321	535.745
19.907	34.050	550.030	20.010	66.508	535.745
24.918	27.260	549.985	24.987	54.431	564.230
29.929	23.070	549.985	29.998	44.444	564.250
39.917	17.417	549.985	39.986	34.288	535.745
49.939	14.131	549.985	50.008	27.907	535.745
99.948	7.038	550.000	100.017	14.346	535.745
149.921	4.791	550.000	149.990	9.703	564.250
299.946	2.447	550.000	300.015	4.925	564.250

Figure 1.1 Number of pings per second at different SSS slant range (single frequency operation)

Figure 1.2 shows a table with the number of pings per second at different slant ranges for SSS obtained when two frequencies are recorded simultaneously. As can be seen from the comparison of *Figure 1.1* and *Figure 1.2*, there is a slight increase in the number of pings when only one frequency is recorded, but we can say that the number of pings per second is almost the same whether one or two frequencies are recorded. There is an anomalous decrease in the number of pings per second (highlighted in yellow) in HDM for LF at a slanted range of 5-10 meters; it is probably related to the design features of the ET4200 model for which the experimental measurements were performed.

4200HF (300/600)											
HighResolution 2F (HighF)			HighResolution 2F (LowF)			HighSpeed 2F (HighF)			HighSpeed 2F (LowF)		
Range	Pings/sec	Freq	Range	Pings/sec	Freq	Range	Pings/sec	Freq	Range	Pings/sec	Freq
4.994	53.495	550.030	5.011	26.752	231.475	5.011	105.169	535.745	4.977	84.216	238.980
9.919	52.672	550.030	9.884	26.336	231.475	9.988	105.181	564.230	10.022	84.224	238.980
14.930	38.966	550.030	14.930	38.966	231.475	14.999	85.326	564.230	14.999	82.310	238.980
19.941	30.944	550.030	19.907	30.944	231.475	20.010	66.503	535.745	19.976	64.591	223.975
24.918	25.652	549.985	24.883	25.652	231.475	24.987	54.431	564.230	25.021	53.144	223.975
29.929	21.900	549.985	29.929	21.896	231.475	29.998	44.438	535.745	29.998	43.693	238.495
39.917	16.955	549.985	39.882	16.954	231.475	39.986	34.279	535.745	40.020	33.839	224.505
49.939	13.826	549.985	49.905	13.826	231.475	50.008	27.908	564.250	49.974	27.598	238.495
99.948	7.038	550.000	99.948	7.040	231.500	100.017	14.345	535.745	100.017	14.180	224.505
149.921	4.657	550.000	149.921	4.657	231.490	149.990	9.704	564.250	149.990	9.435	237.995
299.946	2.411	550.000	299.912	2.411	231.490	300.015	4.925	535.745	299.981	4.855	237.995

Figure 1.2 Number of pings per second at different SSS slant range (dual frequency operation)

A summarized table for different speeds, in which the SSS slant range and the number of pings are converted to the “unit ping length”, is shown in *Figure 1.3*. As can be seen in *Figure 1.3*, a 10 cm ping length in HDM will correspond to:

-- a slant range of 25 meters at a vessel speed of 5 knots;

-- a slant range of 40 meters at a ship speed of 3 knots.

4200HF HighResilution/HF/2F meter_per_ping							
Range	Pings/sec	0,514m/s	1,028m/s	1,542m/s	2,056m/s	2,570m/s	3,084m/s
5.0	53.495	0.010	0.019	0.029	0.038	0.048	0.058
10.0	52.672	0.010	0.020	0.029	0.039	0.049	0.059
15.0	38.966	0.013	0.026	0.040	0.053	0.066	0.079
20.0	30.944	0.017	0.033	0.050	0.066	0.083	0.100
25.0	25.652	0.020	0.040	0.060	0.080	0.100	0.120
30.0	21.900	0.023	0.047	0.070	0.094	0.117	0.141
40.0	16.955	0.030	0.061	0.091	0.121	0.152	0.182
50.0	13.826	0.037	0.074	0.112	0.149	0.186	0.223
100.0	7.038	0.073	0.146	0.219	0.292	0.365	0.438
150.0	4.657	0.110	0.221	0.331	0.441	0.552	0.662
300.0	2.411	0.213	0.426	0.640	0.853	1.066	1.279
		1 knot	2 knots	3 knots	4 knots	5 knots	6 knots

Figure 1.3 Unit ping length as a function of speed and slant range of SSS in HDM (for HSM the ping length must be divided by two)

One thing to consider is that the indicated speed is the speed relative to the ground. The speed relative to the water may be higher or lower depending on the strength and direction of the current in the work area. The minimum speed recommended by EIVA when working with ScanFish is 4 knots relative to the water, at this speed the slant range of the SSS survey will be **30 meters**. Normal ScanFish survey is performed at a speed of 5-5.5 knots; reducing the speed to 4 knots will reduce the ping length from 12-15 cm to 10 cm, but will increase the survey time by 1.3-1.4 times.

2. HDM and HSM modes for ET4200

In order to increase the survey speed, it seems logical to use HSM mode instead of HDM mode. A comparison of these modes is shown in ***Figure 2.1***. The main difference is that in HDM the two antennas are “combined” into a single one that performs both transmitting and receiving of the SSS ping. This reduces the survey speed, but at the same time reduces the SSS beam width and increases the resolution capacity.

HDM High Definition Mode	HSM High Speed Mode
In HDM, the 4205 operates as a conventional 'single pulse' simultaneous dual frequency system.	In HSM, the 4205 uses EdgeTech's Multi-Pulse technology to operate as a 2 pulse 'multi-pulse' simultaneous dual frequency system.
Combines 2 sub-arrays into an extra long array.	Uses one sub-array for transmit and the other for receive.
• Longer Arrays give narrower beam widths, so better resolution.	• More pings on a target, or higher speed operations for the same number of pings on a target. • Motion Tolerance reduces weather dependency
Some customers prefer HDM.	Allows the system to be towed at speeds of up to 10 knots while meeting NOAA and IHO-44 requirements for minimum 3 pings on a 1 meter target.

Figure 2.1 Comparison of HDM and HSM characteristics

Figure 2.2 and ***Figure 2.3*** show two tables with the characteristics of ET4200 and ET4205. In ***Figure 2.2***, a beam width of 0.3 degrees corresponds to frequencies of 900kHz in HSM and 400kHz in HDM. That is, for a horizontal beam width requirement of 0.3 degrees (***Figure 0.1***) the ET4200 frequency when surveying in HSM can only be 900kHz.

SONAR SPECIFICATIONS	STANDARD	WITH OPTIONAL MP TECHNOLOGY	
Frequency	Choice of either 100/400, 300/600 or 300/900 kHz dual simultaneous		
Operating Range (meters/side)	100 kHz: 500m, 300 kHz: 230m, 400 kHz: 150m, 600 kHz: 120m, 900 kHz: 75m		
Horizontal Beam Width:	100 kHz: 1.5°, 300 kHz: 0.5°, 400 kHz: 0.4°, 600 kHz: 0.26°, 900 kHz: 0.2°	In High Speed Mode: 100 kHz: 1.26°, 300 kHz: 0.54°, 400 kHz: 0.4°, 600 kHz: 0.34°, 900 kHz: 0.3° In High Definition Mode: 100 kHz: 0.64°, 300 kHz: 0.28°, 400 kHz: 0.3°, 600 kHz: 0.26°, 900 kHz: 0.2°	
Resolution Along Track	100 kHz: 5 m @ 200 m 300 kHz: 1.3 m @ 150 m 400 kHz: 0.6 m @ 100 m 600 kHz: 0.45 m @ 100 m 900 kHz: 18 cm @ 50 m	High Definition Mode: 100 kHz: 2.5m @ 200m 300 kHz: 1.0m @ 200m 400 kHz: 0.5m @ 100m 600 kHz: 0.45m @ 100m 900 kHz: 18 cm @ 50m	HIgh Speed Mode: 100 kHz: 4.4m @ 200m 300 kHz: 1.9m @ 200m 400 kHz: 0.7m @ 100m 600 kHz: 0.6m @ 100m 900 kHz: 26 cm @ 50m
Resolution Across Track	100 kHz: 8 cm, 300 kHz: 3 cm, 400 kHz: 2 cm, 600 kHz: 1.5 cm, 900 kHz: 1 cm		
Vertical Beam Width	50°		
Depression Angle	Tilted down 20°		

Figure 2.2 Characteristics of ET4200 (4200-Brochure-Low-Res072414)

The horizontal beam width values shown in *Figure 2.3* for the ET4205 are close to those for the ET4200 - for HDM the frequency should be at least 410kHz, for HSM (MP/MT) at least 850kHz.

SONAR SPECIFICATIONS	4205 TRI-FREQUENCY	4205 MULTI-PULSE/MOTION TOLERANT (MP/MT) AND HIGH DEFINITION MODE	
Frequency	120/410/850 kHz 230/540/850 kHz	120/410 kHz, 230/540 kHz 230/850 kHz	
Operating Range (meters/side)	120 kHz: 600m, 230 kHz: 350m, 410 kHz: 200m, 540 kHz: 150m, 850 kHz: 90m		
	TRI-FREQUENCY	**MP/MT**	**HDM**
Horizontal Beam Width (2-way)	120 kHz: 0.7° 230 kHz: 0.4° 410 kHz: 0.28° 540 kHz: 0.26° 850 kHz: 0.23°	120kHz: 0.95° 230kHz: 0.63° 410kHz: 0.38° 540kHz: 0.35° 850kHz: 0.30°	0.7° 0.44° 0.28° 0.26° 0.23°
Resolution Along Track	120 kHz: 2.4m @ 200m 230 kHz: 1.2m @ 150m 410 kHz: 0.5m @ 100m 540 kHz: 0.45m @ 100m 850 kHz: 0.20m @ 50m	120kHz: 3.3m @ 200m 230kHz: 1.7m @ 150m 410kHz: 0.7m @ 100m 540kHz: 0.6m @ 100m 850kHz: 0.26m @ 50m	2.4m @ 200m 1.2m @ 150m 0.5m @ 100m 0.45m @ 100m 0.20m @ 50m
Resolution Across Track	120kHz 8cm; 230KHz 3cm; 410kHz 2 cm; 540kHz 1.5cm; 850kHz 1cm		

Figure 2.3 Characteristics of ET4205 (4205 Side Scan System User Hardware Manual, 0021769_REV_G 02/26/2024)

Let us compare the sonograms obtained by ET4205 in HDM and HSM modes at the frequencies of 850kHz. *Figure 2.4* shows the SSS ping distance plots calculated by SonarWiz. As can be seen from the plots, the ping spacing is 0.15 m for HDM and 0.07 m for HSM. The plots are shown for the survey lines, the mosaics for which are shown in *Figure 2.5*, *Figure 2.6*, *Figure 2.7*.

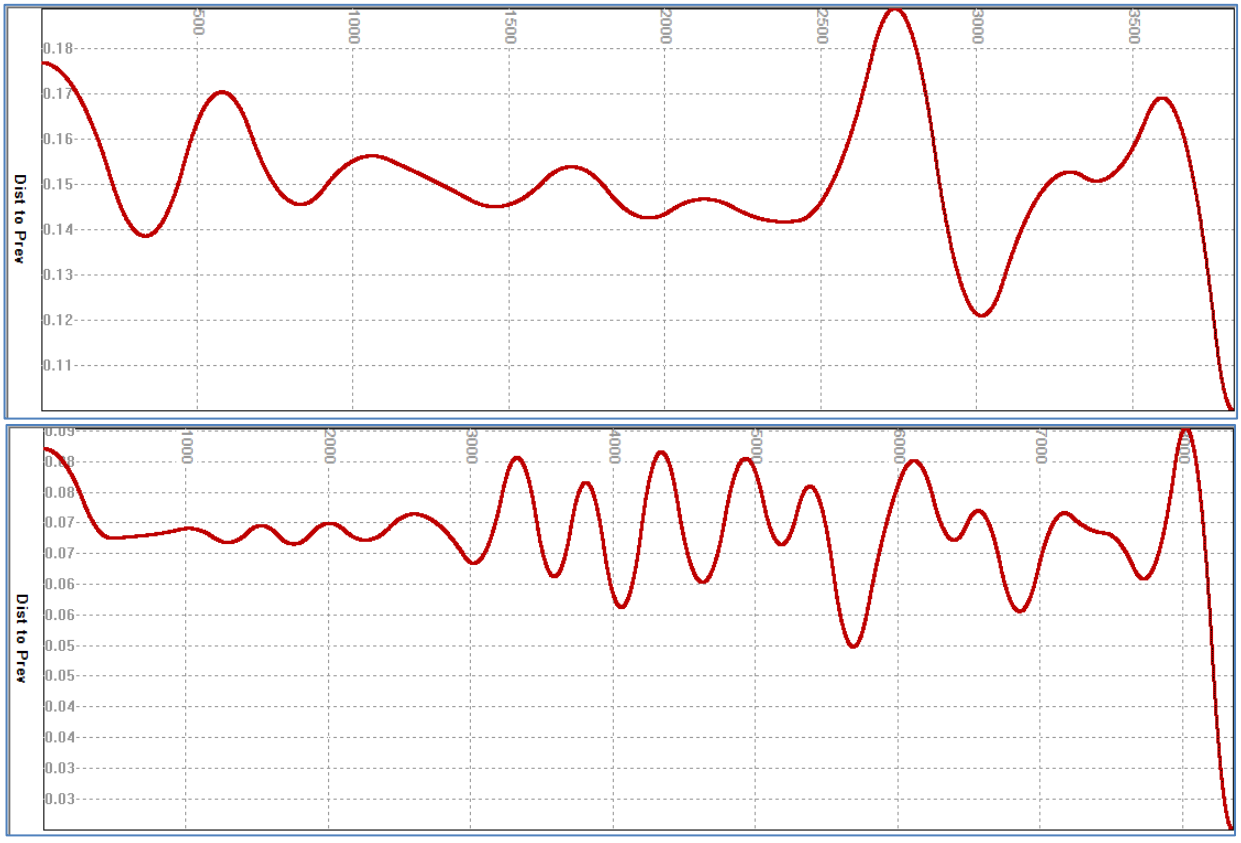

Figure 2.4 Comparison of ping distance for HDM and HSM

Figure 2.5 shows the comparison of mosaics by lines surveyed in HDM and HSM at a frequency of 850kHz, when processing with EGN. As can be seen from the figure, when using EGN, the background shade of the mosaic lines is different. Therefore, in order to compare them or use them to build a single mosaic, it is necessary to use different processing settings.

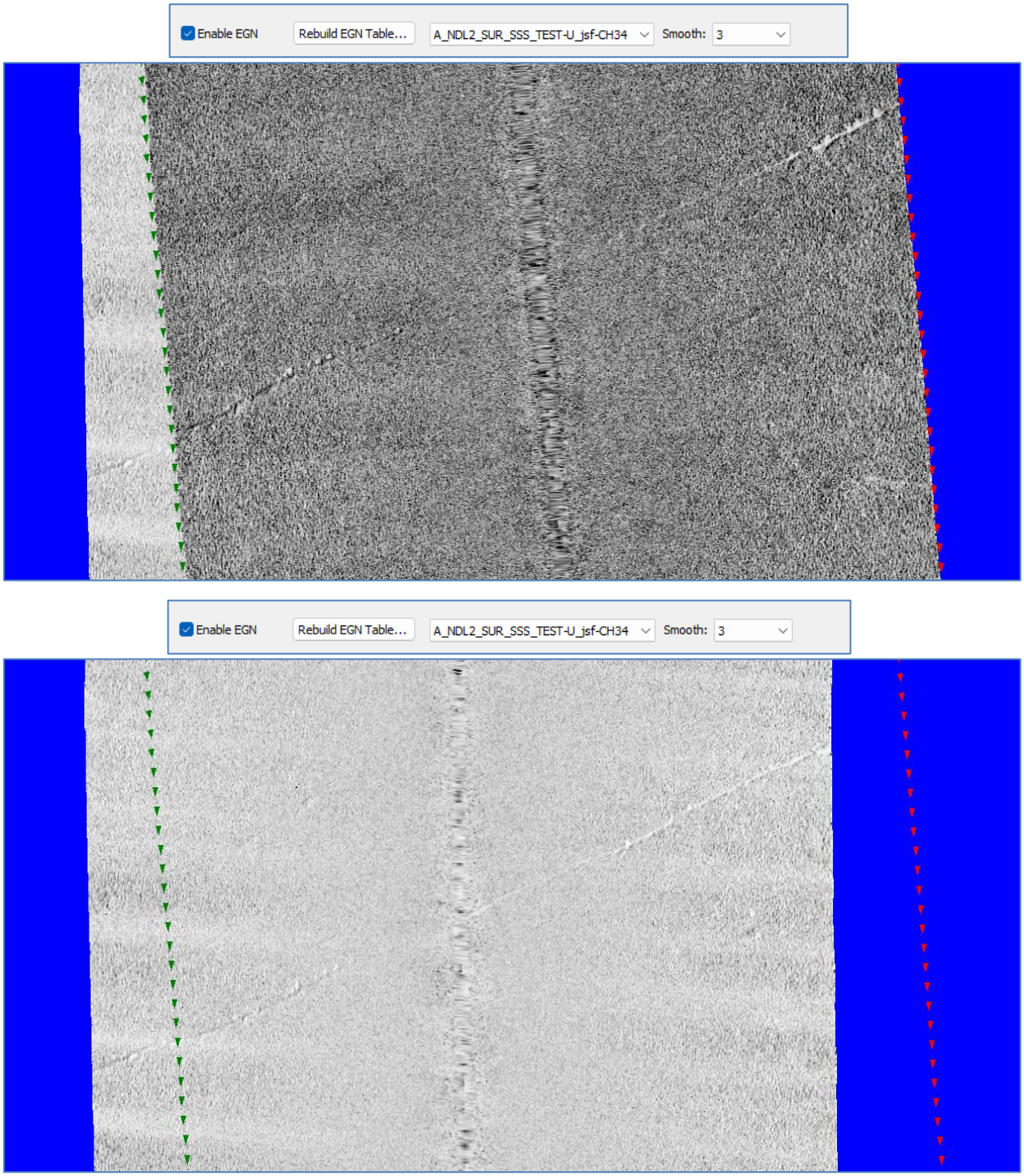

Figure 2.5 Comparison of mosaics in HDM (bottom) and HSM (top) at 850kHz with “Enable EGN”

Figure 2.6 shows the same mosaic fragments with Auto TVG. The quality of the captured fragments looks almost the same. When zoomed in, it is possible to see that the "pixel" size for HSM is smaller and, at the same time, the random noise level (the number of transitions from dark to light pixels) is higher. The increased noise level is probably caused by the fact that the SSS antenna length in HSM mode is half "less" than in HDM (probably the antenna length affects not only the beam width, but also the signal-to-noise ratio).

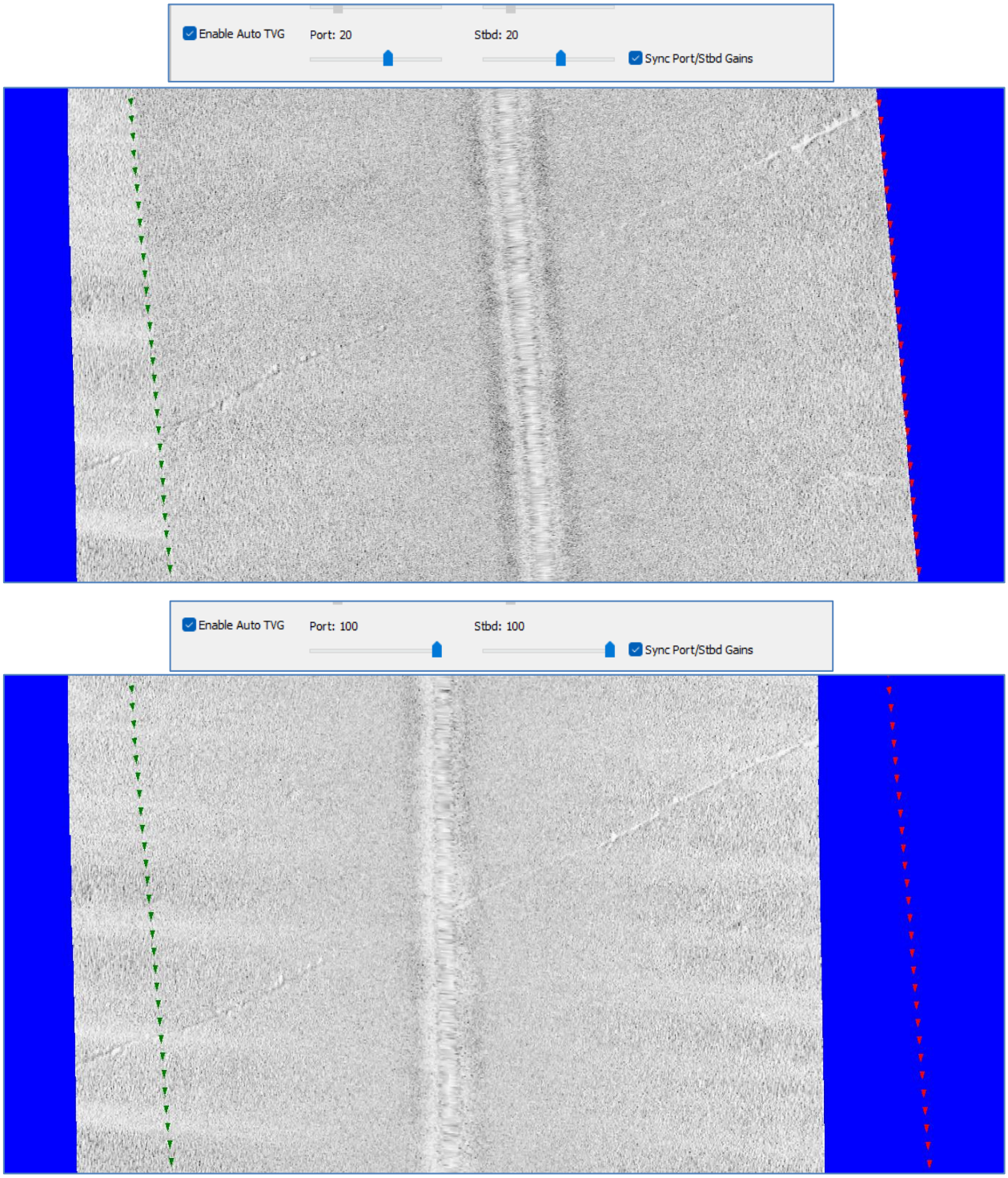

Figure 2.6 Comparison of mosaics in HDM (bottom) and HSM (top) at frequencies of 850kHz at "Auto TVG"

Figure 2.7 shows the trawl-mark on HDM and HSM mosaics. As can be seen from the mosaic fragments, despite the higher number of pings, the higher noise level does not allow to highlight the trawl-mark in HSM. That is, the goal of increasing the SSS resolution by the increased ping density is not achieved. “Object loss in HSM” is mainly applicable specifically to “grayscale”, where the object is “masked” by the high-level random noise. Features characterized by clear shadows (sharp difference between black and white) should be “rendered” better in HSM due to the higher ping density.

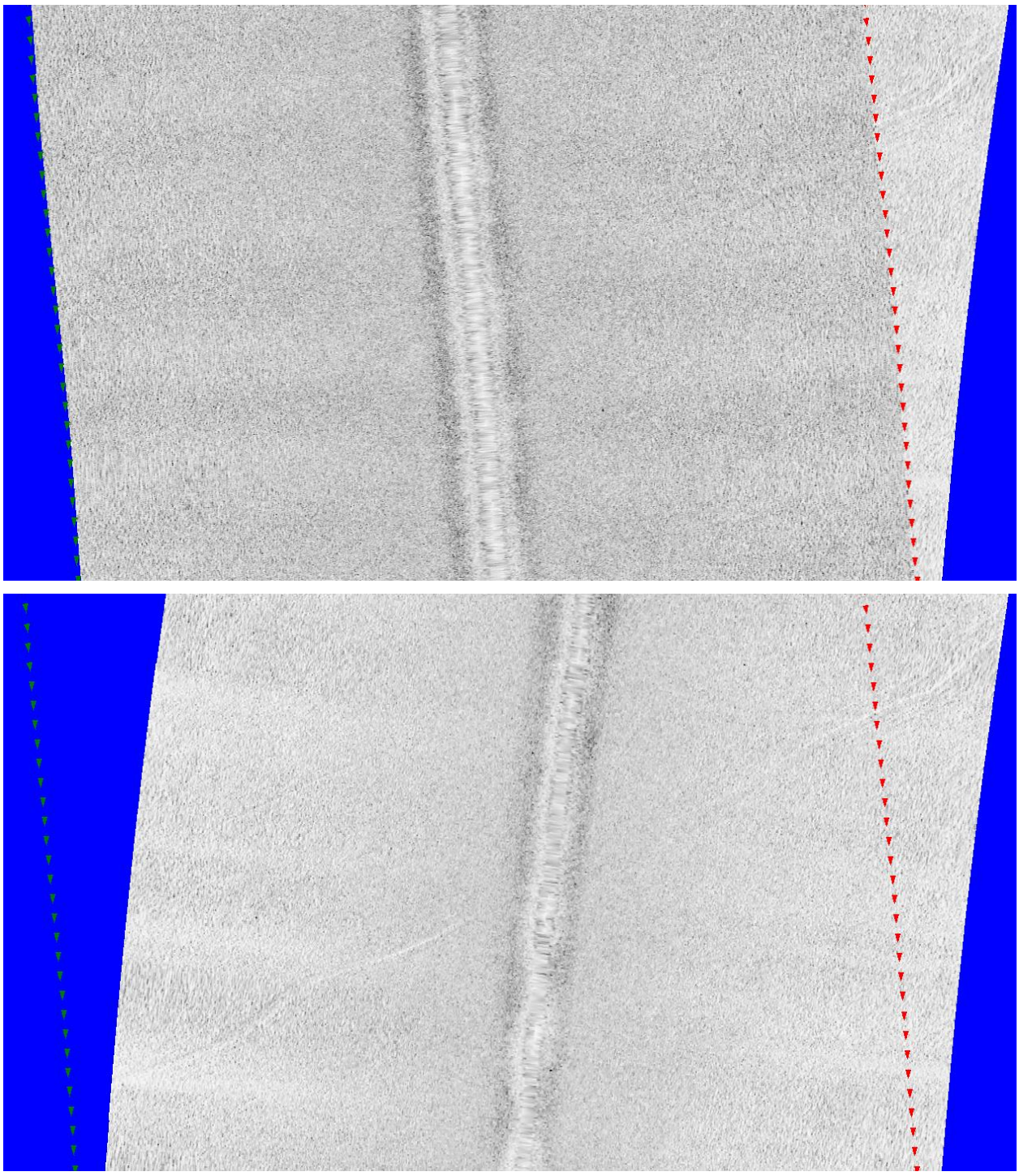

Figure 2.7 Comparison of trawl-mark visibility in HDM (bottom) and HSM (top); 850kHz, “Auto TVG”

3. SSS survey parameters

It is possible to achieve a “ping length” of 0.1 meter in the following ways:

-- Reducing the slant range of the SSS in HDM and reducing the surveying speed. In this case, a ping length of 0.1 meter will correspond to the following speed-slant range combinations:

-- 3 knots – 40 meters,

-- 4 knots – 30 meters,

-- 5 knots – 25 meters,

-- 6 knots – 20 meters.

The speed is given relative to the ground, without taking into account the effect of current velocity. Decreasing the slant range leads to an increase in the survey kilometers (tack density). Reducing survey speed results in longer survey time.

-- When using HSM, sonograms are characterized by increased noise levels along with the increased ping density. This may “mask” features on the sonar mosaic that are reflected in smooth color transitions.