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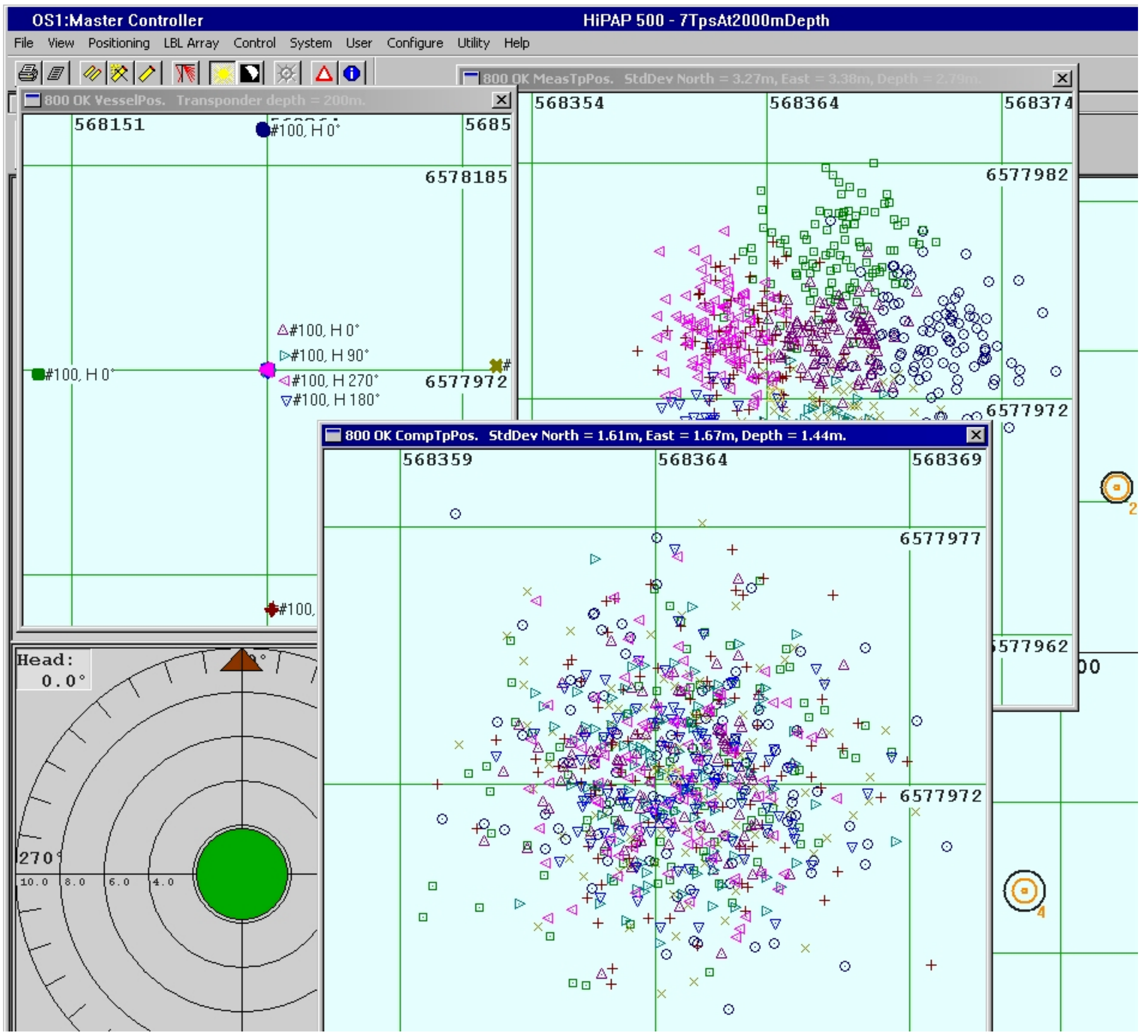
Patterns for Transducer alignment

This note analyses patterns for vessel positioning relative to the seabed transponder when logging dGPS and HiPAP/SSBL positions for transducer alignment. It is based on the Transducer Alignment function in the Kongsberg Simrad APOS.



Document revisions

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Document history

Rev.A	Initial version

1 INTRODUCTION

The purpose of the Transducer alignment function is to calculate the horizontal offset and / or the inclination values of the HiPAP / SSBL transducers. It can also calculate the misalignment between the VRU and Gyro forward axes.

The calculation is based on simultaneous measurements of the position of a transponder on the seabed relative to the vessel, and the geographical position of the vessel as measured by a dGPS system. The transponder position and the dGPS position are valid at the same time. They are named a position pair. The alignment function calculates the parameters of the transducer on which the acoustic measurements are done.

The report analyses different approaches for positioning of the vessel relative to the seabed transponder when logging measurements.

The approaches below are analysed in this report:

1. Four cardinal points plus four headings on top of the transponder. The approach is explained in more detail in the APOS on-line help, with animation showing the vessel position and heading.
2. A circle around the transponder.
3. A triangle around the transponder.
4. Figure eight made of either two circles or two triangles.

The report is based on simulated measurements. 64 dGPS / SSBL positions are used in each calculation. Gaussian noise can be added to the correct positions. The standard deviation of the SSBL noise is 0.3 degrees in the direction measurements and 0.20 m in the range measurements. The standard deviation of the dGPS noise is 1 m in both the north and the east direction.

APOS assumes that the measurements are done with approximately the same gaussian noise as described above. It is the basis for the covariance matrixes for the measurements. These covariance matrixes, together with the number of measurements and the geometry between the vessel and the transponder, decide the covariance matrix of the results. The covariance matrix of the result is used to calculate the 1-sigma uncertainty of the results. The report uses these uncertainties as basis when comparing the approach in the logging.

We have checked several times that the accuracy of the result matches well with the calculated 1-sigma uncertainties. This check is not the scope of this report. Therefore, we did not put any gaussian noise on the measurements that is the basis for this report. The gaussian could have disturbed the comparison between the approaches.

All simulated positions are based on an error in the transducer roll, pitch and gear inclination, as shown below.

	Transducer roll	Pitch	Gear
Installed values	2.00 °	-1.10 °	2.3 °
Correct values	2.80 °	-1.80	3.2 °

There is no error in the transducer offset or in the GPS antenna offset. The transducer offsets below are used, except in the last chapter.

	Transducer Forward	Starboard	Down
Installed and correct values	- 2.10 m	1.20 m	9.80 m

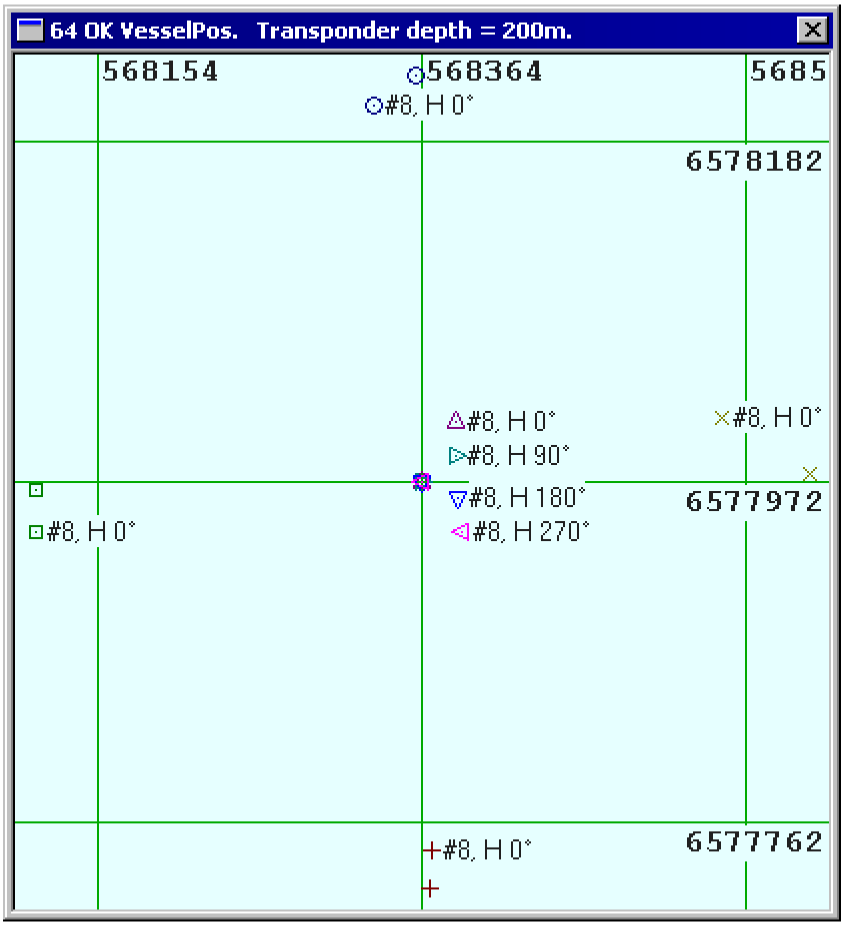
The roll and pitch of the vessel is zero.

In some of the approaches, the vessel has a circular movement when logging the measurements. Kongsberg Simrad has often experienced that change of heading causes the attitude values to be wrong. In some cases, we have seen that the values read from the attitude sensors needs a constant heading for 15 minutes before the values stabilise. The effect of unstable attitude sensors is not taken into account in the numerical values presented in the note.

In most of the approaches the vessel is moving, either on a straight line or in a circle, when logging the measurements. This requires APOS to be accurately synchronised with the clock in the GPS receiver. Otherwise it is not possible to timetag the HiPAP/SSBL position to the same clock as the GPS position, and it introduces an error. The effect of this deskew error is not taken into account in the numerical values presented in the note.

2 FOUR CARDINAL POINTS PLUS FOUR HEADINGS

The figure below shows the position of the vessel. The heading is 0 when being in the four cardinal points. The heading is 0, 90, 180 and 270 degrees when being on top of the transponder. The transponder is in the centre of the figure.



The same type of figure is shown for each of the approaches analysed in this report.

The vessel position is shown with different symbol and colour combination for each log series. For each log series, a legend is displayed with the symbol in front. The legend also includes the number of measurements (#) and the average heading (Hxxx°). In the figure above, the 8 symbols in each log sequence are in exactly the same position, and it looks as one symbol. That is the position of the vessel. The legend is displayed adjacent to the position.

The boxed-in position of the seabed transponder is in the centre of the figure.

In APOS, the same symbols are used when displaying the positions of the transponder. It allows us to see the connection between the vessel position and the transponder position

2.1 Shallow water

The waterdepth is 200m. The four cardinal points are 250 m away from the transponder in the horizontal direction, i.e. approximately 1 times the water depth.

8 SSBL / dGPS position pairs are logged in each of the 8 positions.

The 1-sigma uncertainties of the calculation are:

Transducer inclinations			**Transducer offsets**	
Roll	**Pitch**	**Gear**	**Fwd**	**Stb**
0.06 °	0.06 °	0.08 °		
0.08 °	0.08 °	0.08 °	0.28 m	0.28 m

2.2 Deep water

The waterdepth is 2000m.

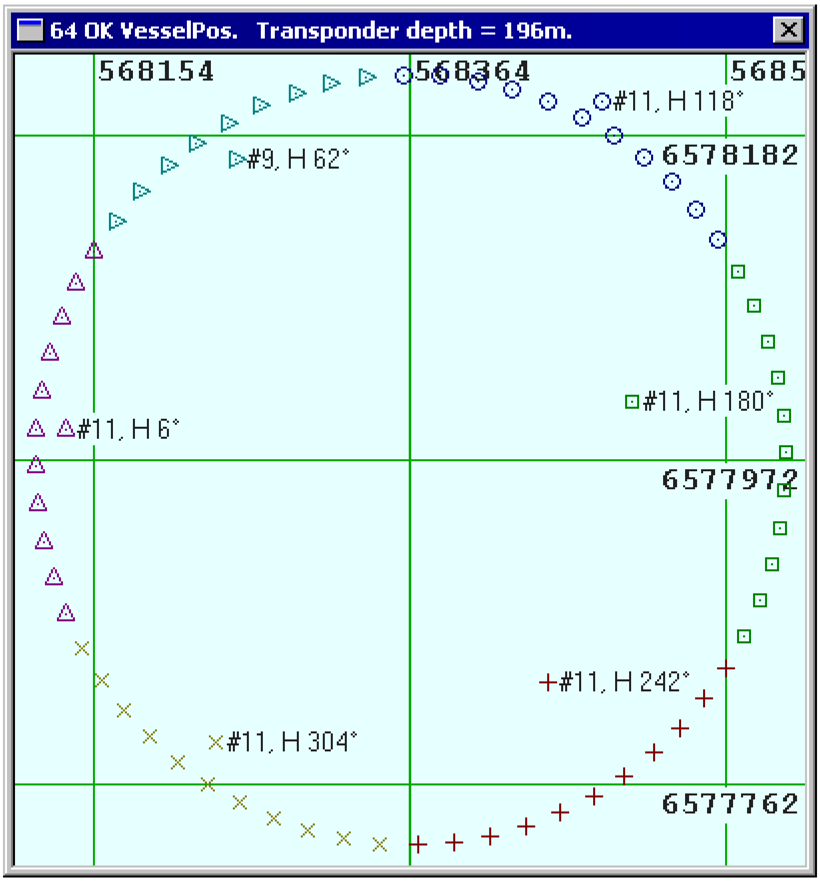
The four cardinal points are 500 m away from the transponder in the horizontal direction, i.e. the vessel is close to the +- 15 degree beam limit of a narrow beam transponder.

8 SSBL / dGPS position pairs are logged in each of the 8 positions.

The 1-sigma uncertainties of the calculation are:

Transducer inclinations			**Transducer offsets**	
Roll	**Pitch**	**Gear**	**Fwd**	**Stb**
0.04 °	0.04 °	0.19 °		
0.04 °	0.04 °	0.21 °	0.92 m	0.77 m

3 CIRCLE AROUND THE TRANSPONDER



The vessel moves clockwise around the transponder.

3.1 Shallow water one way

The waterdepth is 200m. The radius of the circle is 250 m, i.e. approximately 1 times the water depth.

64 SSBL / dGPS position pairs are logged when going clockwise around the circle.

The 1-sigma uncertainties of the calculation are:

Transducer inclinations			**Transducer offsets**	
Roll	**Pitch**	**Gear**	**Fwd**	**Stb**
0.77 °	11.84 °	9.05 °		
1.18 °	11.85 °	9.06 °	3.00 m	2.96 m

There is almost no information in the measurements to separate the pitch and the gear inclinations.

We have done simulations with an error in both the transducer offset and in the transducer inclinations. Then the calibration function calculates wrong values, but the transponder positions converge nicely close to the boxed-in position. Going in a perfect circle with the vessel around the transponder can tell if there is something wrong with the parameters. However, it can not tell that the parameters are correct!

When we simulate with vessel roll and pitch, the 1-sigma uncertainty is reduced because the transducer no longer has the transponder in the same position in its own co-ordinate system. However, we do not consider the circle one way pattern as good as the alternatives, and it is not covered any more in the note.

3.2 Shallow water two ways

The waterdepth is 200m. The radius of the circle is 250 m, i.e. approximately 1 times the water depth.

32 SSBL / dGPS position pairs are logged when going clockwise around the transponder, and 32 positions are logged when going counterclockwise.

The 1-sigma uncertainties of the calculation are:

Transducer inclinations			Transducer offsets	
Roll	**Pitch**	**Gear**	**Fwd**	**Stb**
0.06 °	0.07 °	0.06 °		
0.08 °	0.90 °	0.06 °	2.99 m	0.13 m

When not calculating the transducer offsets, the calculated values are OK. However, there is almost no information in the measurements to distinguish a pitch error from an offset error in the forward direction.

3.3 Deep water two ways

The waterdepth is 2000m. The radius of the circle is 500 m, i.e. the vessel is close to the +- 15 degree beam limit of a narrow beam transponder.

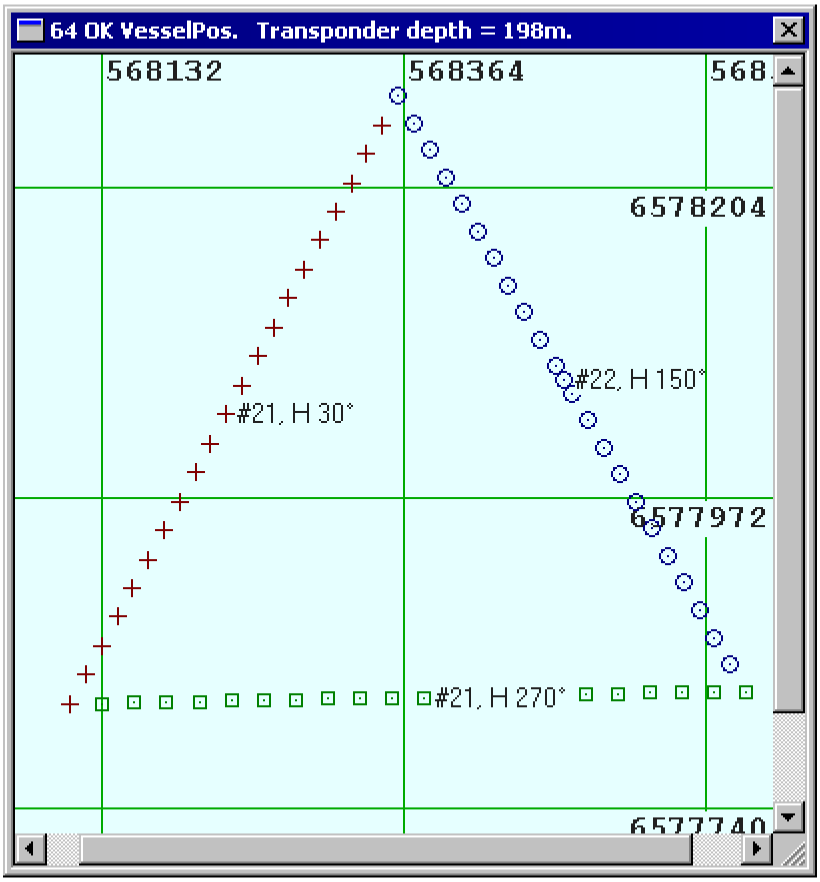
32 SSBL / dGPS position pairs are logged when going clockwise around the transponder, and 32 positions are logged when going counterclockwise.

The 1-sigma uncertainties of the calculation are:

Transducer inclinations			**Transducer offsets**	
Roll	**Pitch**	**Gear**	**Fwd**	**Stb**
0.04 °	0.04 °	0.12 °		
0.04 °	0.09 °	0.15 °	3.00 m	0.25 m

When not calculating the transducer offsets, the calculated values are OK. However, there is little information in the measurements to distinguish a pitch error from an offset error in the forward direction.

4 TRIANGLE AROUND THE TRANSPONDER



The vessel moves clockwise around the transponder.

4.1 Shallow water one way

The waterdepth is 200m. The horizontal distance from the transponder to the corners of the triangle is 300m, i.e. approximately 1 times the water depth.

64 SSBL / dGPS position pairs are logged around the triangle.

The 1-sigma uncertainties of the calculation are:

Transducer inclinations			**Transducer offsets**	
Roll	**Pitch**	**Gear**	**Fwd**	**Stb**
0.07 °	0.09 °	0.09 °		
0.90 °	0.10 °	0.09 °	0.20 m	2.98 m

When not calculating the transducer offsets, the calculated values are OK. However, there is little information in the measurements to distinguish a roll error from an offset error in the stb / port direction

4.2 Deep waters one way

The waterdepth is 2000m. The horizontal distance from the transponder to the corners of the triangle is 600m, i.e. the vessel is close to the +- 15 degree beam limit of a narrow beam transponder.

64 SSBL / dGPS position pairs are logged when going clockwise around the triangle.

The 1-sigma uncertainties of the calculation are:

Transducer inclinations			**Transducer offsets**	
Roll	**Pitch**	**Gear**	**Fwd**	**Stb**
0.04 °	0.05 °	0.15 °		
0.10 °	0.07 °	0.27 °	0.54 m	3.00 m

The uncertainty of the calculated roll angle is strongly reduced compared to shallow waters.

4.3 Shallow water two ways

The waterdepth is 200m. The horizontal distance from the transponder to the corners of the triangle is 300m, i.e. approximately 1 times the water depth.

32 SSBL / dGPS position pairs are logged when going clockwise around the triangle, and 32 when going counterclockwise.

The 1-sigma uncertainties of the calculation are:

Transducer inclinations			Transducer offsets	
Roll	**Pitch**	**Gear**	**Fwd**	**Stb**
0.06 °	0.06 °	0.06 °		
0.06 °	0.07 °	0.06 °	0.19 m	0.16 m

4.4 Deep waters two ways

The waterdepth is 2000m. The horizontal distance from the transponder to the corners of the triangle is 600m, i.e. the vessel is close to the +- 15 degree beam limit of a narrow beam transponder.

32 SSBL / dGPS position pairs are logged when going clockwise around the triangle, and 32 when going counterclockwise.

The 1-sigma uncertainties of the calculation are:

Transducer inclinations			Transducer offsets	
Roll	**Pitch**	**Gear**	**Fwd**	**Stb**
0.04 °	0.04 °	0.11 °		
0.04 °	0.04 °	0.18 °	0.42 m	0.33 m

4.5 Shallow water, constant heading, one way

The waterdepth is 200m. The horizontal distance from the transponder to the corners of the triangle is 300m, i.e. approximately 1 times the water depth.

64 SSBL / dGPS position pairs are logged around the triangle. The heading is constant at 12 degrees.

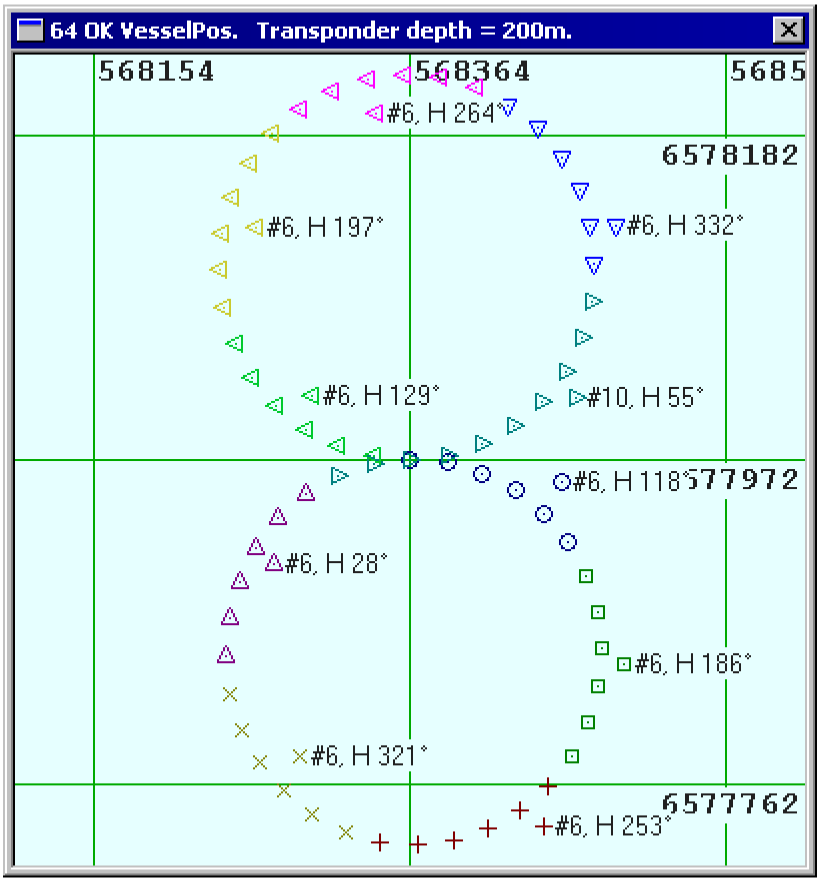
The 1-sigma uncertainties of the calculation are:

Transducer inclinations			Transducer offsets	
Roll	**Pitch**	**Gear**	**Fwd**	**Stb**
0.07 °	0.07 °	0.06 °		
0.07 °	0.07 °	0.06 °	2.96 m	2.96 m

When not calculating the transducer offsets, the calculated values are OK. However, there is little information in the measurements to detect an offset error.

We do not consider the triangle with constant heading as good as the alternatives, and it is not covered any more in the note.

5 FIGURE EIGHT ABOVE THE TRANSPONDER



The figure eight consists of two circles. The transponder is in the crossing between the two circles, i.e. in the centre of the figure. The vessel moves clockwise in the lower circle, and counterclockwise in the upper one. The logging can be done in one operation without stopping the vessel.

(We have also analysed figure eight based on two triangles and on two squares instead of based on the two circles . Figure eight based on two triangles is covered in the next chapter. Figure eight based on two squares does not give quite as good results as when it is based on two triangles, and it is more complicated for the steersman. Therefore, the figure eight based on two squares is not covered in this note.)

5.1 Shallow water

The waterdepth is 200m. The horizontal distance from the transponder to the outer part of the figure eight is 250 m, i.e. approximately 1 times the water depth.

64 SSBL / dGPS position pairs are logged around the figure eight.

The 1-sigma uncertainties of the calculation are:

Transducer inclinations			Transducer offsets	
Roll	**Pitch**	**Gear**	**Fwd**	**Stb**
0.06 °	0.06 °	0.07 °		
0.08 °	0.08 °	0.07 °	0.24 m	0.21 m

5.2 Deep waters

The waterdepth is 2000m. The horizontal distance from the transponder to the outer part of the figure eight is 500m, i.e. the vessel is close to and within the +- 15 degree beam limit of a narrow beam transponder.

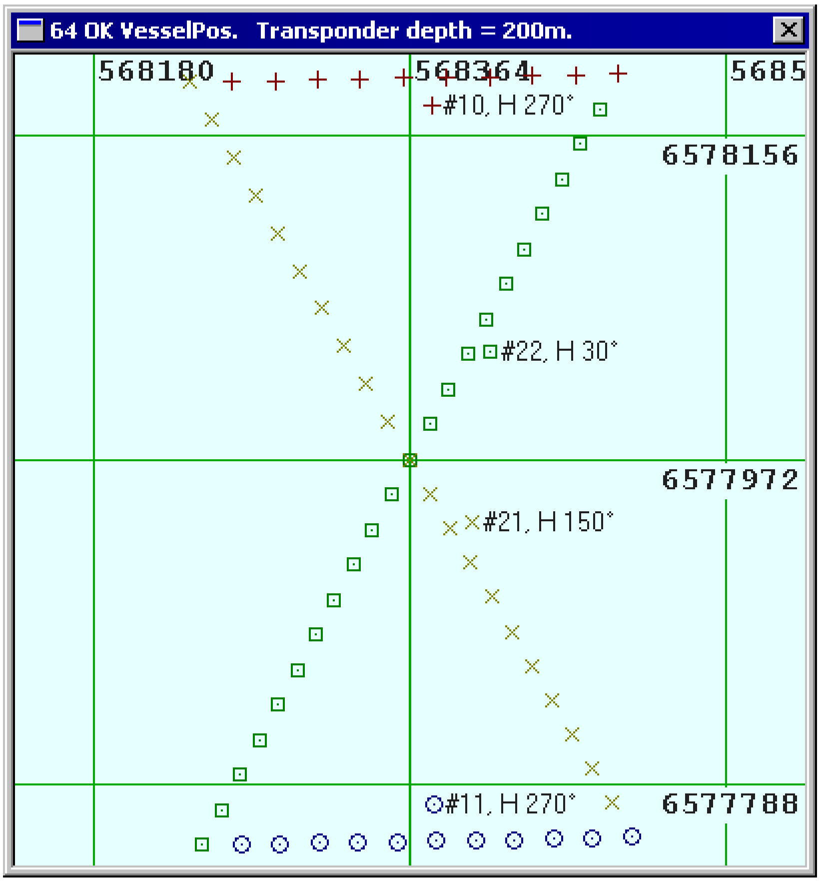
64 SSBL / dGPS position pairs are logged around the figure eight.

The 1-sigma uncertainties of the calculation are:

The 1-sigma uncertainties of the calculation are:

Transducer inclinations			Transducer offsets	
Roll	**Pitch**	**Gear**	**Fwd**	**Stb**
0.04 °	0.04 °	0.20 °		
0.05 °	0.05 °	0.21 °	0.82 m	0.73 m

6 FIGURE EIGHT TRIANGLES ABOVE THE TRANSPONDER



The figure eight consists of two triangles. The transponder is in the crossing between them, i.e. in the centre of the figure. The vessel moves clockwise in the lower triangle, and counterclockwise in the upper one.

The logging is done when moving the vessel in four straight lines, so the pattern is simple for the steersman.

6.1 Shallow water

The waterdepth is 200m. The horizontal distance from the transponder to the outer part of the figure eight is 250 m, i.e. approximately 1 times the water depth.

64 SSBL / dGPS position pairs are logged around the figure eight.

The 1-sigma uncertainties of the calculation are:

Transducer inclinations			Transducer offsets	
Roll	**Pitch**	**Gear**	**Fwd**	**Stb**
0.06 °	0.06 °	0.07 °		
0.08 °	0.06 °	0.07 °	0.17 m	0.24 m

6.2 Deep waters

The waterdepth is 2000m. The horizontal distance from the transponder to the outer part of the figure eight is 500m, i.e. the vessel is close to and within the +- 15 degree beam limit of a narrow beam transponder..

64 SSBL / dGPS position pairs are logged around the figure eight.

The 1-sigma uncertainties of the calculation are:

The 1-sigma uncertainties of the calculation are:

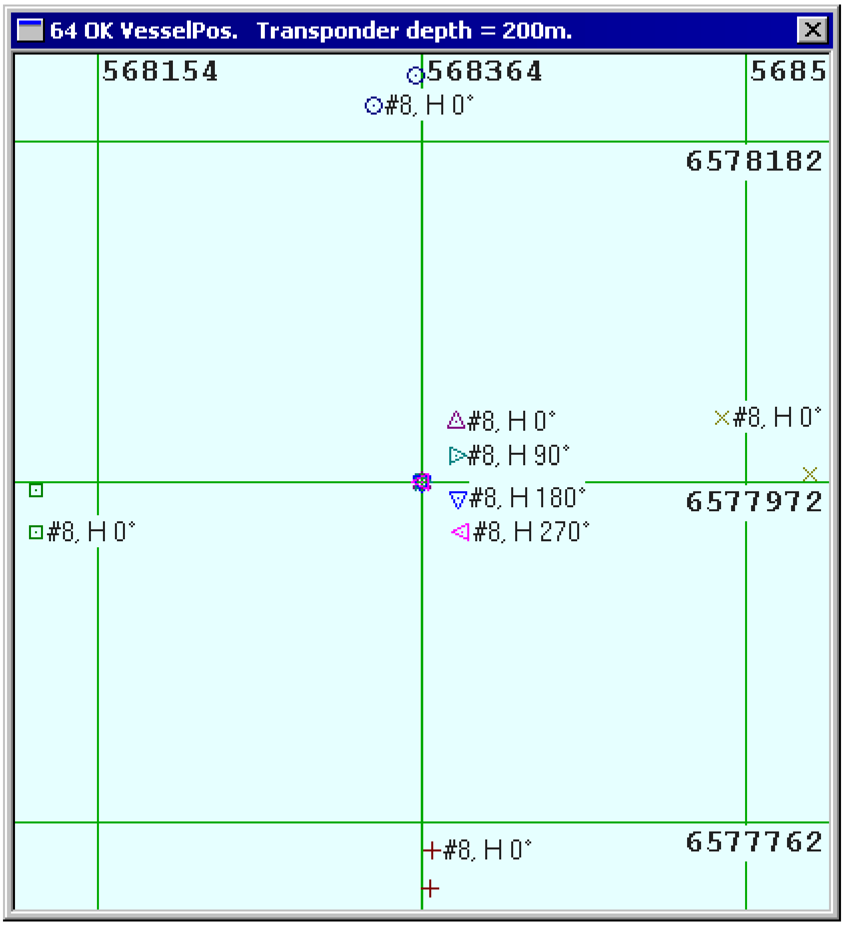
Transducer inclinations			Transducer offsets	
Roll	**Pitch**	**Gear**	**Fwd**	**Stb**
0.04 °	0.04 °	0.14 °		
0.04 °	0.04 °	0.21 °	0.49 m	0.50 m

7 ASYMETRY DUE TO BIG TRANSDUCER OFFSETS IN SHALLOW WATER

In chapter 2.1, we examined the expected accuracy with four cardinal points plus four headings on top of transponder. The transducer offset was small. Drill rigs usually have big transducer offsets. When the rig centre is on top of the transponder, the transducer is not. We therefore repeat the simulations in chapter 2.1 with big transducer offsets. Forward is – 125 m, Starboard is 100 m and Down is 30 m. The rig centre is in the four cardinal points and on top of the transponder.

The waterdepth is 200m. The four cardinal points are 250 m away from the transponder in the horizontal direction.

8 SSBL / dGPS position pairs are logged in each of the 8 positions.



The 1-sigma uncertainties of the calculation are:

Transducer inclinations			Transducer offsets	
Roll	**Pitch**	**Gear**	**Fwd**	**Stb**
0.08 °	0.07 °	0.07 °		
0.10 °	0.08 °	0.08 °	0.23 m	0.28 m

The results are approximately the same as when the transducer was close to the reference point. It shows that it is not mandatory for the transducer to be exactly in the expected positions. The APOS knows where the transducer is based on the offsets and the measurements, and takes it fully into account when doing the calculation.

8 CONCLUSION

The table below is a summary of the shallow water results. It is the 1-sigma uncertainties of the alignment values when the three inclinations and the horizontal offset are calculated. It is based on 64 measurements in 200 m waterdepth. The vessel is mostly less than 1 times the waterdepth away from the transponder.

Shallow waters	Transducer inclinations			Transducer offsets	
	Roll	Pitch	Gear	Fwd	Stb
Cardinal points	0.08 °	0.08 °	0.08 °	0.28 m	0.28 m
Circle two ways	0.08 °	0.90 °	0.06 °	2.99 m	0.13 m
Triangle	0.90 °	0.10 °	0.09 °	0.20 m	2.98 m
Triangle two ways	0.06 °	0.07 °	0.06 °	0.19 m	0.16 m
Figure eight	0.08 °	0.08 °	0.07 °	0.24 m	0.21 m
Figure eight triangles	0.08 °	0.06 °	0.07 °	0.17 m	0.24 m

The table below shows the same results in 2000 m deep waters. The vessel is within the +- 15° narrow beam of the transponder

Deep waters	Transducer inclinations			Transducer offsets	
	Roll	Pitch	Gear	Fwd	Stb
Cardinal points	0.04 °	0.04 °	0.21 °	0.92 m	0.77 m
Circle two ways	0.04 °	0.09 °	0.15 °	3.00 m	0.25 m
Triangle	0.10 °	0.07 °	0.27 °	0.54 m	3.00 m
Triangle two ways	0.04 °	0.04 °	0.18 °	0.42 m	0.33 m
Figure eight	0.05 °	0.05 °	0.21 °	0.82 m	0.73 m
Figure eight triangles	0.04 °	0.04 °	0.21 °	0.49 m	0.50 m

The approach with four cardinal points plus four headings on top of the transponder is the only one without change of heading and/or movement when doing the measurements. It also gives good results. These considerations are the main reasons for Kongsberg Simrad to recommend this approach. It is not mandatory for the transducer to be exactly in the cardinal points and just above the transponder, as shown in the previous chapter. When the vessel does not have DP, it may be drifting when doing the measurements. It is often better than using the thrusters heavily.

Figure eight based on two triangles is the best alternative to the four cardinal points. It gives better accuracy of the horizontal offset, and the same accuracy of the inclinations. It consists of four straight lines, i.e. it is simple with respect to vessel manoeuvring. It does require an accurate time synchronisation of the APOS, meaning that the APOS must be interfaced to the 1 PPS from the GPS receiver.

When you have a narrow beam transponder on the seabed, the transducer must be in the transponder beam to achieve the best measurements. As a rule of thumb, it is far more important to have good signals than to have a good geometry between the transponder and the transducer.