6 EM 300 ALIGNMENT

6.1 Scope

This chapter describes the required alignment of a Kongsberg Simrad EM 300 system. The procedures include the alignment of the external sensors after installation.

6.2 Introduction

The EM 300 is a precision instrument for bathymetric swath sounding. Seabed charts produced by the EM 300 can be much more detailed than charts produced by conventional means because of the much higher density and accuracy of soundings given by the EM 300. The detailed maps will reveal the shape of the seabed terrain, but they will also reveal all misalignments and errors made during data collection and processing without mercy.

To be able to produce maps that are both detailed and correct, it is necessary to calibrate the survey vessel more accurately than what may have been standard practice earlier. The required calibration consists of:

- measurement of where sensors are located
- measurement of how sensors are oriented
- measurement of the water-line vertical location
- alignment of angular measurement sensors
- determination of any offsets in sensor data
- determination of any time delays in sensor data

The results, with all measurements taken in a common vessel coordinate system, are to be entered in the EM 300 Operator Station.

Calibration should be taken seriously and it is recommended that this task and the continued control of the map consistency is assigned to one interested and qualified person in the organization. To achieve the best results, the calibration should be planned carefully, and followed up throughout the installation and first sea trials, and by regular checks throughout the operation of the vessel.

6.3 Measurements

What to measure

The measurements which must be taken after installation, are the horizontal and vertical positions of the:

- EM 300 transducer arrays
- the motion sensor
- the positioning system (radio antenna)

In addition, the angular orientation of the transducers must be measured. The measurements on the transducers must be done with the vessel in dry dock, the others may be done with the vessel berthed.

The alignment of the motion sensor and the heading sensor must be adjusted so that they provide zero values for pitch, roll and heading with the vessel lying still with normal trim and a true North heading, or alternatively the offsets from zero must be determined. This is best done with the vessel berthed and according to the procedure described in the sensors' manuals.

Any time delays of the motion sensor and positioning data from their time of validity to the time when they are available at the interface ports of the EM 300 must be determined (they may be available from the sensor manufacturer). Finally the vertical position of the water line must be measured with the vessel in normal trim. This should preferably be done at normal survey speed (which may be difficult!), and must of course be repeated as the loading and hence the draft of the vessel changes.

During the first sea trials calibration surveys should be run as described in the EM 300 operator manual. From these surveys any inaccuracies in the determination of the above parameters may be determined and the values entered in the EM 300 Operator Station corrected accordingly.

It is advisable to perform a calibration survey at regular intervals or before large surveys to ensure against any changes in the determined offsets. Alternatively any changes should be looked for in the data from regular surveys as these make possible. At the very least calibration surveys should be performed if any sensor is replaced. Note also that older analog motion sensors such as the Hippy 120 may require regular calibration as their offsets change with time.

Vessel coordinate system

A Cartesian coordinate system must be defined for the vessel. The following definition must be adhered to: *X* forwards, *Y* to starboard, *Z* pointing downwards. There is no restriction on where the coordinate system's origin is located. The sea surface with the vessel in normal trim defines the horizontal (X-Y) plane. Thus the water line should be marked on the hull with the vessel in normal trim before any dry docking.

Reference points should be established on the vessel at selected positions as needed to be used during measurement of sensor positions. Visual markings at these positions should be prepared and noted on the vessel drawings with XYZ coordinates in the vessel coordinate system.

Sensor location

The EM 300 transducers should be located according to the guide-lines given elsewhere in the installation manual. With regard to the location of other sensors the following guide-lines should be followed, but otherwise should be chosen according to the manufacturer's documentation.

The transmit transducer array should be aligned along the vessel's keel, while the receive transducer array should be aligned 90° on the keel. Both transducers should be horizontal, but tilted 2° to 3° forward. There is no need for the arrays to have the same heading, roll and pitch.

The vessel motion sensor (giving heave, roll and pitch) should normally be mounted on the centre line of the vessel, either close to the EM 300 transducers or close to the vessel's heave-roll-pitch centre. The latter point is recommended if the sensor is used for other purposes than just with the EM 300, or if its accuracy is sensitive to horizontal accelerations. Note that if there is any point in the fore-and-aft direction which does not change height with respect to the water-line with changes in vessel speed, then this is the ideal location for the motion sensor (this will eliminate any errors from squat induced height changes which is not measured by today's motion sensors).

The accuracy of a heading sensor (usually but not necessarily a gyrocompass) may be sensitive to accelerations and should then be mounted close to the heave-roll-pitch centre. Note that it and the motion sensor must both be aligned with the vessel centre line.

Measurement accuracies

The required measurement accuracies given below have been determined from considerations on how they contribute to total system accuracy, i.e. that any errors in these measurements shall not significantly contribute to depth or position errors in the soundings. Note that the given accuracies are maximum values, and if easily achievable, better accuracies should be obtained.

1 The vertical location of the transducer centres must be measured to an accuracy of ±5 cm. Their horizontal location must be measured to an accuracy of ±10 cm.

- These measurements are to be done from the centre of the transducer faces.

2 The vertical location of the motion sensor must be measured to an accuracy of ±10 cm. Its horizontal location must be measured to an accuracy of ±5 cm.

3 The vertical location of the positioning system antenna must be measured to an accuracy of ±5 cm, but it is only required if the positioning system measures position in the vertical axis.

- This will be usually only be the case for real-time kinematic GPS and some optical positioning systems. The antenna's horizontal location must be measured to an accuracy of ±10 cm or 20% of the positioning system's accuracy.

4 The vertical distance to the water-line should be measured with an accuracy of ±5 cm.

- Note that with the vessel in normal trim, i.e. with an indicated pitch angle of zero from the motion sensor, the distance to the water-line may be measured anywhere on the vessel, but otherwise it must be measured at the fore-and-aft physical location of the motion sensor. The measurement should be taken on both sides of the vessel and averaged to remove any roll effects (simultaneous measurements are required if the vessel is moving).

5 The heading of the receive transducer must be measured to an accuracy of ±0.5°, the pitch to an accuracy of ±2° and the roll to an accuracy of ±0.05°.

6 The heading of the transmit transducer must be measured to an accuracy of ±0.25° and the roll to an accuracy of ±1°. The required accuracy with regard to pitch will depend on the alongtrack distance between the transducer centre and motion sensor. If this distance is less than 2 m, the required accuracy in pitch is ±0.5°, while if it is more than 20 m the required accuracy is ±0.05° (do a linear interpolation for in-between distances).

- Note that if the motion sensor does lever arm corrections on its heave measurements, i.e. outputs data valid at a location that is different from its actual physical location, it is the distance from this location to the transmit transducer center which should be used to determine required accuracy in the transmit transducer pitch measurement.

7 The heading sensor must be aligned with the X-axis of the vessel's coordinate system to an accuracy of ±0.25°. If this is not possible, the resulting offset must be known to the same accuracy.

8 The forward axis on the motion sensor must be aligned with the X-axis of the vessel's coordinate system to an accuracy of ±0.5°.

- The sensor should be aligned such that the indicated roll and pitch angles from the motion sensor when the vessel has a normal trim, i.e. the coordinate system's horizontal plane is horizontal, should be less than ±0.05° for the roll and ±0.05° to 0.5° for the pitch (the latter depending upon fore-and-aft separation between motion sensor and transmit transducer centre as discussed for the transmit transducer pitch orientation accuracy). If this is not possible, the resulting offsets must be known to the same accuracies.

6.4 Measurement of the transducer orientation

The heading of the transducers is measured as the average heading of the two fore-and-aft oriented sides of each transducer in the horizontal plane of the vessel coordinate system. Thus, the heading of the transmit transducer is the heading of the long sides, while the heading of the receiver array is the heading of the short sides. As the latter may be difficult to measure accurately, it may be better to measure the heading of the long sides, and then subtract 90° to achieve the correct value.

Roll and pitch measurements are made according to standard conventions with positive pitch angle if the transmitter array's forward end is above the aft end (tilts up), and positive roll if the starboard side of the receiver array is lower than the port side.

The actual measurement of the installation angles may be done by two different methods.

- The most accurate method is to use land surveying techniques, establish a horizontal plane and do distance measurements to and in this plane
- The second method is to use an inclinometer to measure roll and pitch angles combined with the distance measurements in the horizontal plane for heading. This method is simpler, but will require a sufficiently accurate inclinometer.

6.5 Mounting frames and structures

No actual measurements of the orientation or location of the transducer mounting structures are required. However, the mounting structures must not deviate from a flat surface by more than 0.5 mm This can be checked by placing a ruler along the long side of the transducer array, and check the opening between the side and the ruler. This opening must not be larger than 1 mm. In addition, you must use an inclinometer to check the tilt on the short side of the array. For the receive transducer the maximum tilt difference is 1°, and for the transmitter transducer it is 0.5°.

6.6 Heading sensor calibration

It is usually not possible to calibrate the heading sensor through sea trials, but the calibration is normally done with the vessel berthed.

On the quay the geographical coordinates of two points must be known or measured so that the heading of a line on the quay can be established to an accuracy of ±0.1°. The distance from two points on the centre line of the vessel (fore and aft) are then measured so that the vessel's heading can be calculated. The heading sensor is then aligned to this heading or its measured offset determined.

The vessel must be turned 180° as many times as necessary and the alignment or offset checked and repeated until the mean error is within the specifications of the heading sensor.