APPLICATIONS OF A NOVEL MAGNETIC TRACKING METHOD TO MULTI-INFLUENCE RANGES AND SECURITY MONITORING SYSTEMS

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ABSTRACT

A vessel track determination method has been developed to enable signature modelling of sea-going vessels without the use of on-board tracking equipment. The vessel's magnetic signature is used to determine the vessel's track and requires no co-operation from the vessel. The magnetic tracking method has been developed for and is currently in service on magnetic signature harbour entrance ranges, but is also widely applicable in many surface and underwater ranging scenarios. Applications include signature modelling at check range facilities, covert signature determination or operation as part of an exclusive economic zone (EEZ) security monitoring system. The magnetic tracking method can also replace current tracking systems on acoustic ranges or allow multi-influence (e.g. alternating and static UEP and magnetic) signature modelling of deep ranged submarines.

INTRODUCTION

In previous papers (Davidson et al (1), (2)) we have discussed the reasons behind the development of the magnetic tracking method. A requirement existed to allow accurate vessel magnetic signatures to be gathered without the need for on-board tracking systems. The primary locations were at harbour entrance sensor arrays: the purpose of such ranges is to monitor the signature magnitudes of vessels entering and leaving the harbour. A problem had existed that, when comparing the signature measurements made on different occasions, that the signatures varied depending on the tide depth and array crossing point: an vessel could appear to have a signature maxima different by up to 25%. In order to achieve accurate results which take into account variations of the tide and array crossing point, signature modelling is required. To enable signature modelling, an accurate vessel track is required.

The magnetic tracking method, which was developed to solve the above problem, has wide application in all areas of ranging. These include check ranging (Davidson et al (2)), deep sea ranging, acoustic and multi-influence ranging, security monitoring systems and covert signature gathering.

THE BENEFITS OF SIGNATURE MODELLING

Signature modelling allows magnetic signatures to be determined more accurately than if a measurement range is utilised. To illustrate this, consider the schematic diagrams in Figures 1 and 2. Figure 1a shows a vessel crossing directly over one sensor of a measurement range. Figure 2a shows the signature that would be measured. Figure 1b shows a vessel crossing between two sensors; the corresponding measured signature is shown in Figure 2b. The measured signatures are found to be highly dependent on the array crossing point. Another important factor which can cause similar changes is the variation of water depth with tide.

Magnetic modelling uses the measured magnetic data to create a model of the vessel from which the signature can be predicted at any location. The most useful display format shows the signature of the vessel as though it traveled directly over the central array sensor at the required target depth for that vessel class. In other words, if the vessel crossed the array as shown in Figure 1b, the modelled signature would be appear as Figure 2a. We conclude that in order to achieve accurate results which take into account variations of the tide and array crossing point signature modelling is required. A full description of magnetic modelling and benefits thereof are given in Webb (3).

THE MAGNETIC TRACKING METHOD

In order to calculate the magnetic track two fundamental assumptions are made: firstly that the vessel travels in a straight line and secondly that it travels at a constant speed. Although these conditions are not fulfilled in every case, the vast majority of vessels in transit are travelling on a given bearing at a given speed. Often there is only one navigable channel into a port which determines the vessel course and these assumptions are therefore suprisingly effective. The magnetic tracking method can be applied to a variety of sensor systems; the minimum number of sensors required is two. A typical check range facility comprises between three and five tri-axial magnetic sensors positioned to ±7cm accuracy. The vessel should ideally pass between the two outer sensors of the array (Figure 3). A typical harbour entrance range can comprise many more sensors in order to cover effectively the mouth of a wide estuary. Figure 4 shows a schematic diagram of a five sensor range covering a narrow channel. Most important is that the sensors are spaced at less than water depth in order to ensure sufficient accuracy in the measured signature. Adequate signature to noise ratio is also necessary.

The performance of harbour entrances ranges and check ranges utilising magnetic tracking have been verified by comparisons of the calculated track and signatures with known results (Davidson et al (1), (2)). Vessel headings are typically determined to within less than 1 degree of the true heading, the sensor array crossing point to within less than 1.0m and the vessel speed to within less than $30cms^{-1}$. Accuracies in the modelled signature peaks are generally accurate to less than 3% and typically to less than 0.1% in calm sea states. Figure 5 show the track found using the magnetic tracking algorithm for a run travelling on a actual heading of 25 degrees at a speed of $5ms^{-1}$ with a closest point of approach to the array centre of 7.3m. In Figure 5 the crosses represent the range sensors and the line represents the track of the vessel. The actual signature and the signature predicted using a magnetically tracked signature is shown in Figure 6. The three dotted lines represent the three axis of the actual magnetic signature. The three solid lines represent the predicted signature in a similar fashion. The error in the maximum total field between the two signatures is 1.3%.

EEZ SECURITY MONITORING SYSTEMS AND COVERT SIGNATURE GATHERING

The magnetic tracking method is particularly suitable for monitoring vessel entering and leaving a harbour or port. The advantages of the method are that accurate models of vessel signatures can be determined without a requirement for on-board tracking equipment to be fitted to every vessel. This is a clearly an important factor when monitoring non-cooperative vessels. Likely vessel types can be determined purely on the basis of the measured magnetic signature. A range operated in conjunction with a video camera allows determination of identified vessel signatures.

A suitable sensor array configuration would consist of sufficient tri-axial sensors to cover the width of a channel and require the same range configuration as would be used on a harbour entrance range. It is important that the spacing between the sensors is not more than the water depth at the range site. (Figure 3). Harbour entrance and check range facilities currently in use consist of between three and sixteen sensors.

DEEP RANGING AND ACOUSTIC RANGING

Magnetic ranging of submarines is typically carried out with the vessel surfaced. Tracking in this situation is usually supplied using a GPS, infra-red (IR) or laser system (Davidson and Webb (4)). Increasingly however there is a demand for vessels to be ranged in deep water. There are several reasons for this. Firstly it is widely recognised that magnetic signatures can vary with depth due to pressure effects (Parker et al (5)). Secondly it is clearly beneficial to undertake ranging of vessels under all operating conditions. For example, acoustic rangings will be required with the vessel operating at high speeds when submerged. With regard to the electric field signature can vary depending on whether the hull is fully submerged, because its magnitude depends to some extent the degree of hull wetting (Beattie and Hubbard (6)).

Tracking systems currently utilised in surface rangings will not operate sub-surface. Acoustic systems are currently available to track pingers attached at several locations to the vessel. Magnetic tracking is a viable alternative to acoustic tracking and does not require any tracking system to be attached to the hull.

Sensor layouts for a range utilising magnetic tracking would be similar to either a check range or an harbour entrance range, the only practical difference being the width of channel to be covered. A typical range could comprise three to five tri-axial magnetic sensors spaced at 30m thereby covering a width of between 60m and 120m. Range accuracy is unaffected by the depth at which the range is situated given that a measurable magnetic signature is present at the sensors.

MULTI-INFLUENCE RANGING

In addition to being used in single influence ranging systems, the magnetically determined track can be utilised to model many other influences. These could include alternating magnetic fields, static electric and alternating electric fields (Webb et al (7)), and acoustic signatures. Given a minimum of three to five static magnetic field sensors, a track can be determined and used to model influence data from any number of co-located or distributed influence sensors given that their locations are known.

The corrosion related magnetic signature (CRM) is small when compared to the magnetic signature at typical distances from vessel to sensor (e.g. 20-30m). An accurate method of determining CRM is by modelling the electric field signature (Webb et al (8)) and predicting the CRM signature. This method avoids the complication of trying to separate the small CRM and larger magnetic field signatures.

CONCLUSIONS

The magnetic tracking method is a versatile method of tracking any vessel when no other tracking method is available if the vessel has a sufficiently large magnetic signature. One clear advantage of this method is that the signatures can be modelled without the vessel being aware of or co-operating in the signature determination process. The magnetic tracking method can also be of benefit given a cooperative vessel for check range methods. In addition, unlike GPS, IR or laser tracking methods a submarine can be ranged at depth without the need for a separate vessel tracking system.

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(8) G.J.Webb, S.J.Davidson and M.A.Houghton, ‘Enhancement of magnetic range performance by compensation of the corrosion related magnetic field’, 1997, UDT Conference Proceedings, pg 443-446.

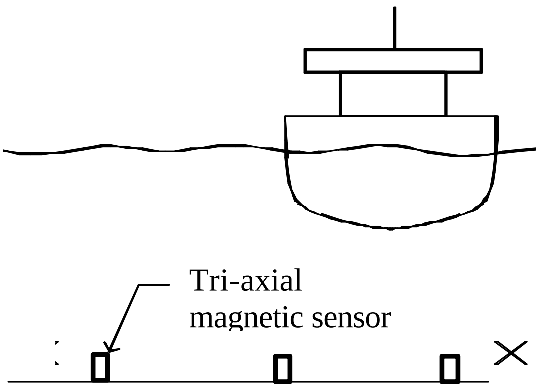


Figure 1a

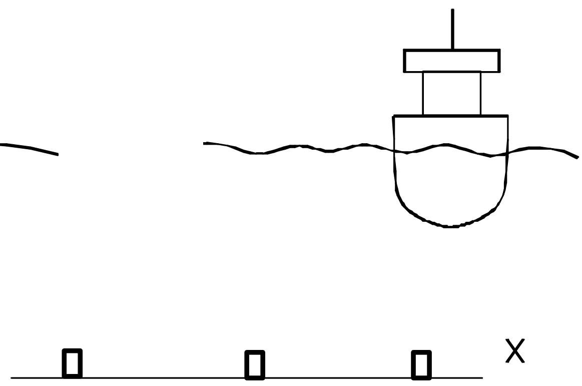


Figure 1b

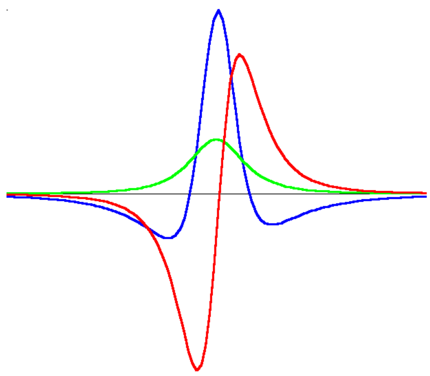


Figure 2a

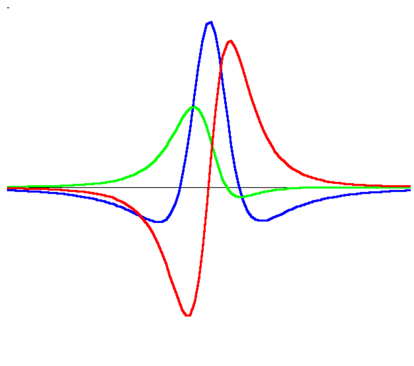


Figure 2b

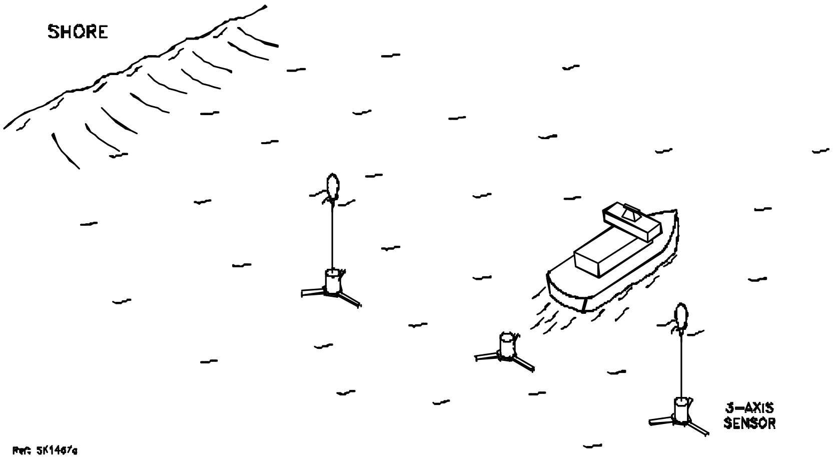


Figure 3

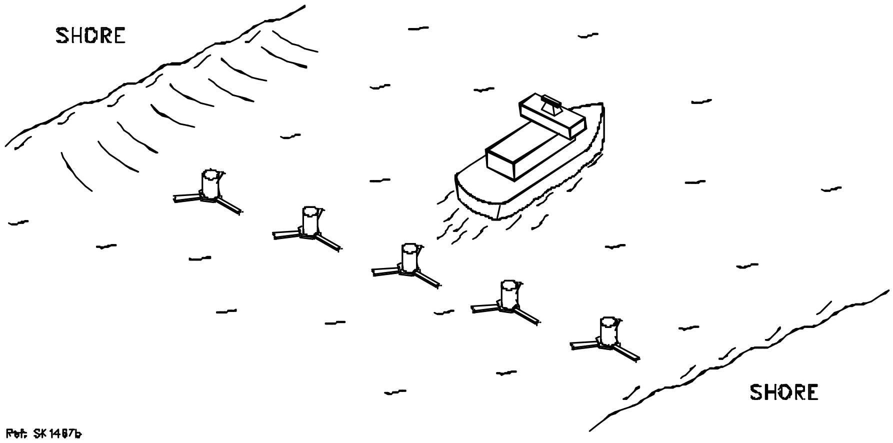


Figure 4

Heading 24.6 degrees CPA 8.2m

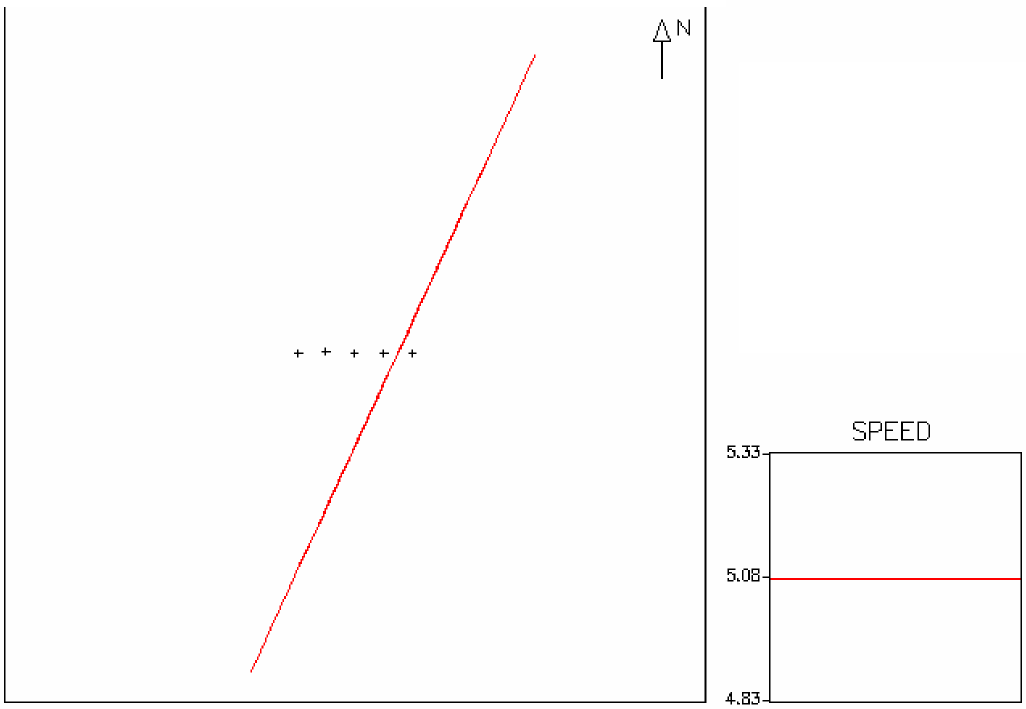
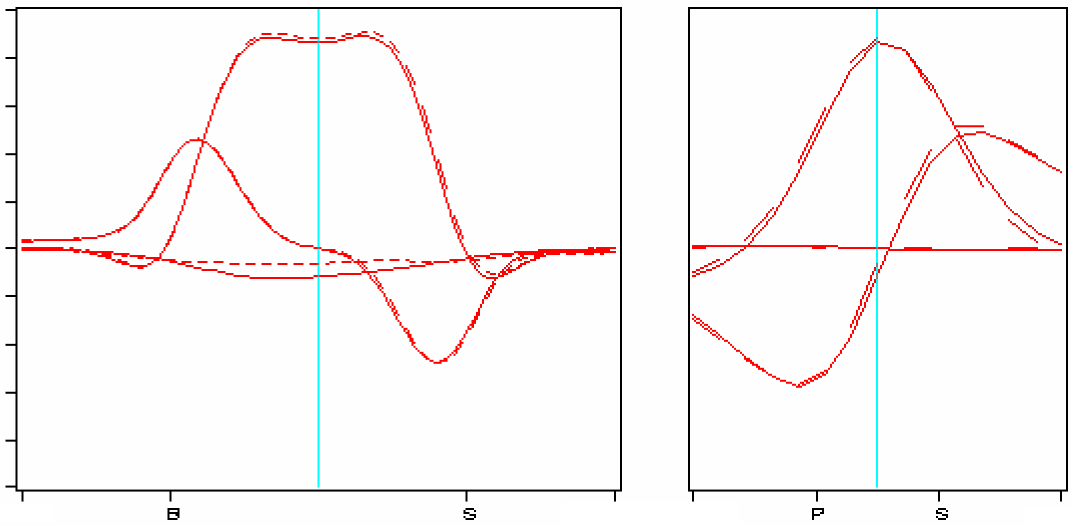


Figure 5

Magnetic Field



Distance from midships

Distance from keel

Figure 6