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DYNAMIC POSITIONING CONFERENCE
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Sensors I

Field Applications and Environmental Challenges in the Use of Radascan

Dr. Dominic Pearce

Guidance Navigation Ltd. (Leicester, UK)

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Abstract

This paper considers the Guidance Navigation 'RadaScan' system, a microwave local position reference sensor. The paper will explore some of the dynamic positioning applications that the system has been employed in since its launch to market 2 years ago. For example, Platform Supply Vessel (PSV) operations in the North Sea (UK) against fixed oil producing platforms, and Floating Production Storage and Offloading vessels (FPSO); Operation of two PSV's equipped with RadaScan against a single installation; Long range operation by Dive Support Vessel's (DSV) at ranges greater than 700m; Operation of two vessels taking their position fix from the same transponder; Track and follow applications; The safe use of the system by a PSV along side an FPSO during shuttle tanker operations using the Artemis system and the adoption of the system by construction and de-construction vessels.

The paper will consider the extreme environments in which the system has been required to work. For example the high sea states experienced in the North Sea over the winter season and the challenges of tracking a fixed (or moving) transponder under conditions of heavy pitch roll and heave. The range of temperatures that the system has been proven to work over from high temperatures in the Persian Gulf through to low temperatures experienced in Northern Russia during winter. Finally, some of the unique working conditions that can be found next to an oil producing platform, such as steam dumps and thick fog, where a laser based system cannot cope.

Finally, the paper looks at the best working practices for achieving optimum performance with a microwave system in harsh sea environments. What are the effects of wave motion on sensor measurements? What are the technical challenges that need to be overcome to ensure that the sensor and DP system work together optimally in heavy sea conditions? What lessons have been learned in the North Sea for improving RadaScan transponder tracking, where other local and global position references are failing?

Introduction

RadaScan is an advanced position reference sensor based on microwave technology for use in DP and other vessel control applications. It is a local sensor system with high precision range from 20 to 1000m. It complements GPS/DGPS for close range work and overcomes the operational limitations of traditional laser and taut-wire systems. RadaScan is fully compatible with all types of modern DP system.

RadaScan comprises a sensor that is mounted on the operating vessel, a control/display PC which can be installed with the DP control system and one or more retro-reflective transponders which are placed on the target installation. The sensor accurately measures the range and bearing to the transponder(s) to allow calculation of vessel position and continuously relays this to the DP system via an industry standard telegram.

RadaScan gives the positional accuracy (range and bearing) normally associated with a laser sensor but with much greater target tracking stability and complete immunity to false reflections and bad weather. 360° scanning ensures target lock even during demanding vessel maneuvers; this is further enhanced by the wide viewing angle of the transponders making complex moves possible without hardware adjustment or operator input.

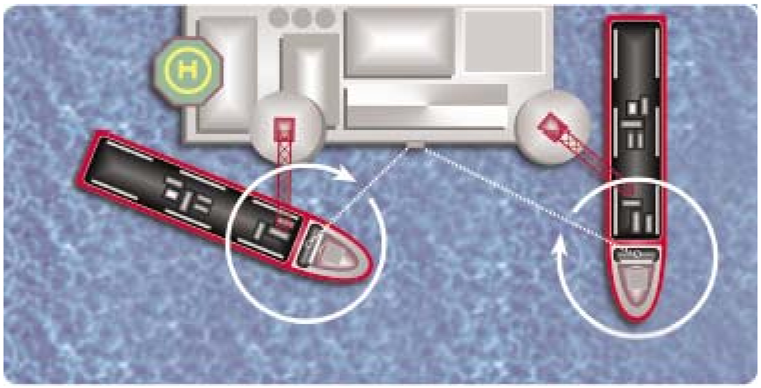
The system is now in use around the world and has proven its reliability under the most extreme of environmental conditions, from those of freezing winter down to -25°C found offshore Sakhalin Island, Russia made possible due to in dome heating, through to summer heat +55°C and 100% humidity offshore UAE in the Persian Gulf. RadaScan has demonstrated its ability to continue working in many weather conditions where laser systems fail to perform, such as thick fog, heavy rain, snow & ice, sand storms and heat haze. RadaScan has also been shown to work under some of the unique man made environments that occur at some offshore installations, for example during hot water / steam dumps, or in dusty conditions (e.g. cement dust). With the oil industry trend to install rigs in more and more hostile areas of the world, RadaScan has been tested to the limits of DP operations in sea states up to 4.5m. The challenges and solutions to operation in these types of conditions will be discussed in this paper.

Field Applications

This section of the paper is intended to give the reader an overview of the different DP applications that RadaScan has been employed in.

Platform Supply Vessels (PSV's) Against Fixed Installations

Currently this application accounts for the biggest users of the RadaScan system, with the adoption of RadaScan by Shell and BP in the North Sea on DP class 2 PSV's. Typically, a PSV uses its DP system to station keep next to an offshore installation whilst loading or offloading maneuvers are conducted by crane, or fluid transfer via hose.

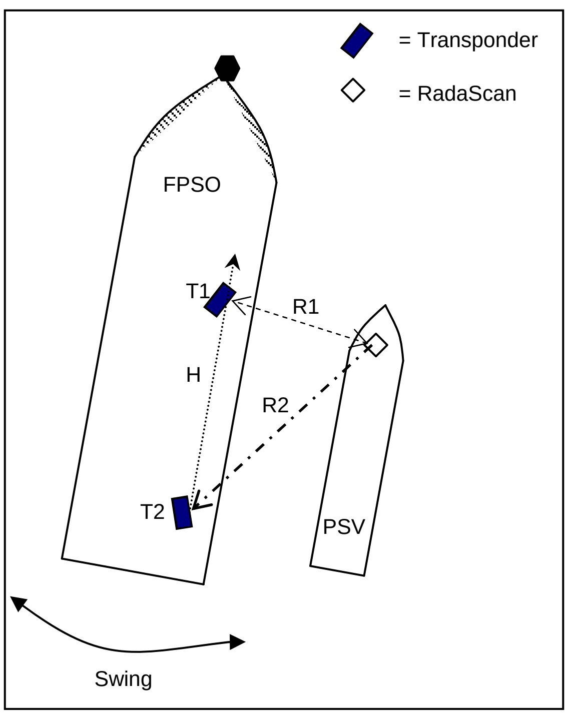


During these operations, RadaScan is used in conjunction with other positioning sensors such as DGPS and laser based systems. Transponders may already be pre-installed on the installation, or the boat can transfer their own mobile transponder over to the installation for use during DP operations. RadaScan provides range and bearing to one or more transponders which is updated once a second. The flexibility of RadaScan is clearly advantageous in this application. The ability of the scanner to view 360° means that the DP operator has the ability to carry out more complex maneuvers without losing the local reference provided by RadaScan. For example it is common for a vessel to turn 180 degrees so that loading / unloading can be approached from the starboard or port side of the vessel. The large acceptance angle of the transponders (up to 170° for close range less than 50m) increases the flexibility.

The use of DGPS along side large installations can sometimes be problematical, resulting in the GPS antenna being 'shadowed'. GPS is unable to provide an accurate reference when it can only receive communication from satellites across only half the sky. As well as weather dependence, a notorious problem with laser reference systems is the scenario when a position fix can jump from a true laser reflector on to a target presented by the reflective tape of a rig worker's boiler suit as that individual walks past the laser target. This results in the vessel trying to follow the moving target requiring quick intervention by the DP operator. RadaScan does not succumb to any of these problems, since it only sees the transponders, with their unique coding, and ignores all other distractions. This ability to overcome these traditional problems has meant that DP operators in the North Sea have come to rely on the RadaScan technology on a daily basis.

Experience gained in the North Sea has shown that it is critical to the performance of the RadaScan system that transponders are correctly positioned on installations. Since this is a microwave system users do need make sure that transponders are not placed inside corners, or beneath overhangs, due to multi-path reflections of the radar signals from RadaScan, or momentary obscuration of the transponder due to wave motion of the vessel. A more detailed discussion of transponder location can be found in a later section of this paper.

RadaScan can be used with one or more transponders. North Sea installations where transponders are permanently installed have adopted two per working face. RadaScan has also been used by two separate vessels at the same installation.



Platform Supply Vessels (PSV's) Against Moving Installations

Distinct from a static installation, a PSV (or other vessel on DP) can no longer rely on a global positioning system for station keeping next to a moving target. Here any station keeping operation must be conducted using a local reference sensor. RadaScan is now routinely used for station keeping next to FPSO's during loading and unloading operations. Typically an FPSO may hold its own position by use of its own DP system, or by being moored to a tether, allowing the vessel to freely swing to face approaching weather conditions. Using RadaScan in multi-target mode allows the DP operator to station keep at a suitable position relative to the FPSO, whilst simultaneously matching the heading of the FPSO, measured and supplied by the RadaScan system. In the figure (left), RadaScan measures the ranges R1 & R2 to transponders T1 & T2 respectively. RadaScan then calculates the FPSO heading H, and supplies this along with position information to the DP system. As the FPSO swings, the DP system automatically adjusts the heading of the host vessel to that supplied by RadaScan, whilst maintaining relative

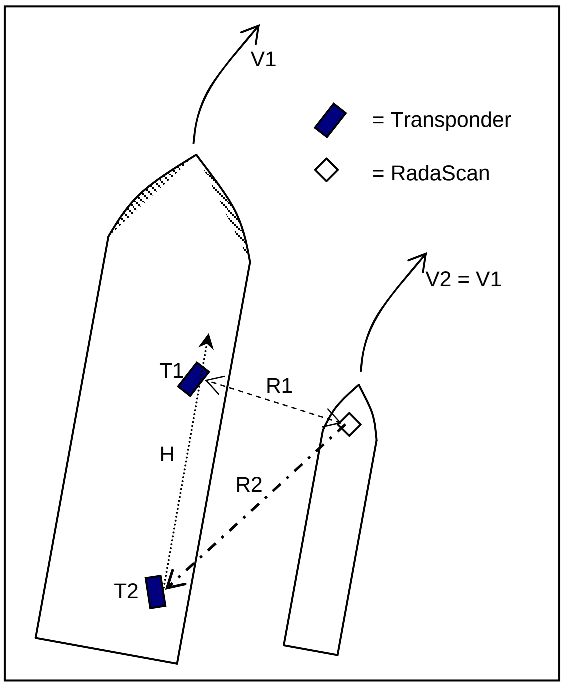
position. For added flexibility, the RadaScan system allows the heading it supplies to be aligned to any reference that the host DP system desires, such as the ships compass or other vessel frame.
Often during FPSO operations there may already by an accompanying shuttle tanker present. These vessels typically use the Artemis system to maintain their position aft of the FPSO. An important point to make is that whilst RadaScan and Artemis both operate in the same frequency band, there is no interference effects between the two systems.

Dive Support Vessels (DSV's) and Construction Vessels

Activities conducted by DSV's and construction vessels frequently need accurate position keeping by DP systems. When working close to other offshore installations, these activities need local references for accuracy and sensor redundancy. These vessels are normally DP class 2 or 3. RadaScan is growing in acceptance for these vessel types. The advantages are the easy setup and operation, whilst 360 degree scanning capability gives the best flexibility for setup. There are numerous examples where RadaScan has been employed out to ranges of 800m on these types of vessels.

Shuttle Tankers

Having already mentioned the Artemis system in a previous section, operators of shuttle tankers are now looking towards RadaScan to provide the same positioning reference duties. RadaScan has the advantage that it does not require a manned or supervised mobile station (typically on the FPSO) as is required with Artemis. This is replaced by an easily maintained transponder. The transponder can be picked up at long range and can be used as a position reference on the approach to the FPSO, as well as for station keeping during offloading.



Track & Follow

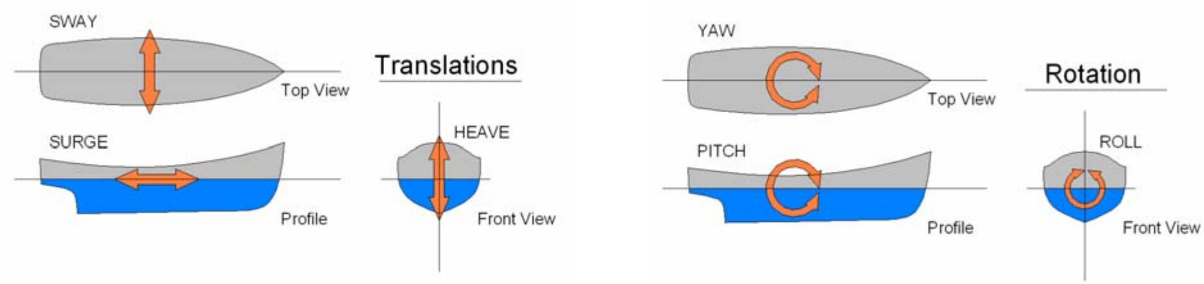
In track and follow, the host DP system tracks and matches speed and heading of another vessel. This can only be done by using a local reference sensor. RadaScan has been used for this application using a multi-target approach shown in the figure (left). As with the FPSO application RadaScan provides the DP system with the position to a 'primary' target, as well as the heading of the other vessel calculated from the baseline between the multiple targets. The DP operator has the flexibility of aligning this heading to any reference desired (such as the ships compass). Once tracking mode is activated, the DP system is now able to track speed (V1) and heading (H) of the other vessel, and maintain its position relative to it. This typically finds application in cable laying or pipe laying, as well as some other unique applications.

Environmental Challenges

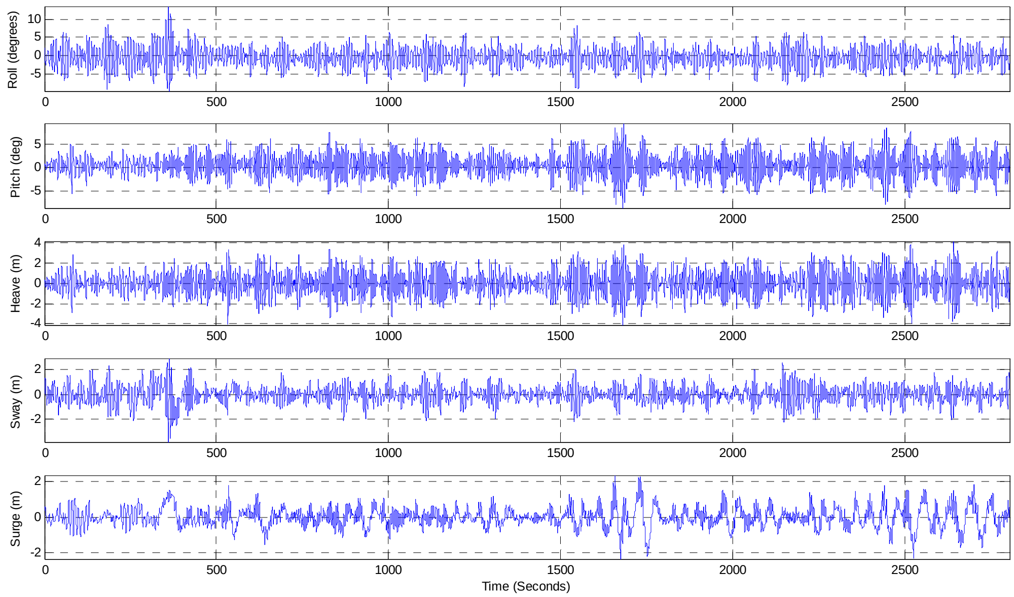
This section will consider the challenges for microwave sensor technology working in conjunction with a host DP system in sea conditions that are considered to be on the limits of safe operation. As oil exploitation moves in to more hostile parts of the world, these kinds of conditions are more frequently experienced. Here we will consider the experiences gleaned from the operation of the RadaScan system in the North Sea over the winter season 2007/8.

Sea States.

Throughout the period March – April 2008, Guidance Navigation installed motion reference sensors on several RadaScan equipped vessels to monitor vessel motion whilst RadaScan was being used during DP operations. When ever the RadaScan system is selected by a DP operator for 'navigation', the sensor automatically logs all the system variables of operation. We can use these logs to analyse the performance of the sensor, and compare this performance with sea motion conditions measured by an independent reference. An Octans MRU was used to log all vessel motion information:



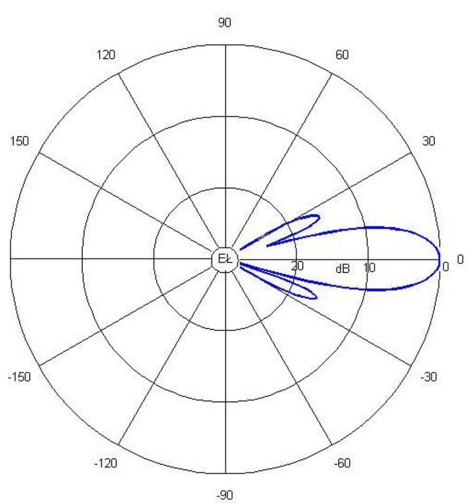
A typical dataset is shown below:



Heave peaks at just over 4m, pitch ±10 degrees, roll ±12 degrees, and surge / sway ±2m.
These are challenging sea conditions for station keeping, and we must be sure that the RadaScan sensor and the DP system are working together optimally to ensure good DP performance.

Motion Effects.

RadaScan is constantly supplying a range and bearing to one or more transponders to the host DP system. The effect of vessel motion means that the range and bearing measured by RadaScan is constantly changing. The DP system must correct the RadaScan measurements for the effects of wave motion by using a motion reference unit. Accurate correction relies on two things; firstly that the offset of the centre of the RadaScan antenna with respect the vessel's centre of motion (COM) is accurately known. Secondly, any time delay between the time RadaScan actually measured range and bearing, and the time that it is actually delivered to the DP system is known. No sensor can measure and deliver information with no time delay. We will call this 'data lag'. If this data lag is not accounted for, then any MRU corrections at the DP system will be out of phase with when the measurement was actually conducted at the DP system. This in turn leads to a position error. In practice, the further the sensor is from the COM, the greater the error in wave compensation, particularly in terms of increased height above COM.



Coping with Wave Motion.

RadaScan has been specifically designed to cope with the kind of wave motion experienced for the limits of DP operation. The system is able to keep track of transponders by the use of a wide beam in elevation (left).

A 3dB beam width of ±16 degrees and side-lobes at more extreme angles means that we do not loose the transponder even during large wave events.

RadaScan also employs predictive target tracking algorithms that tell the system where to look for the transponders on the next revolution of the scanner. For these to work effectively we must have good knowledge of the likely rates of change in bearing and range to our transponder, so that the trackers can cope with the most severe of wave motion that the system is likely to encounter. To determine these a mathematical model was developed. The model accepts real MRU data as an input, and models what RadaScan should measure in terms of range and bearing to one or more transponders. By comparing the output of this model with real data measured by RadaScan under the same wave conditions, it is possible to assess the performance of the system, and tune our tracking filters optimally. Since the input to the model is data from an MRU, totally independent of RadaScan, this is a great way to verify that RadaScan is performing correctly.

Motion Model & Doppler.

The model was written using MATLAB Simulink. As well predicting the changes in measurement due to wave motion, it also considers another important error source that must be taken in to account, that of Doppler shift due to the microwave source moving towards and away from the target, since RadaScan is a Frequency Modulated Continuous Wave (FMCW) system. In our case the velocity of transmission of the wave is far greater than the relative speed between the source and the observer; hence the change in frequency due to the Doppler Effect can be approximated by:

$$\delta f = \frac{fv}{c} = \frac{v}{\lambda}$$

Where: f = transmitted frequency, v = velocity of the transmitter relative to the receiver in m/s (+ve towards / -ve away), c = speed of light, λ = wavelength of the transmitted wave.

The change in frequency represents an error in our range measurement, and it is in our interest to try and keep this as small as possible, or devise an algorithm to correct for this.

Example Model Output.

The MRU data was run through the model for a time period where a particular vessel was station keeping against a rig using RadaScan as its primary local reference sensor. RadaScan was scanning a transponder at about 84m.

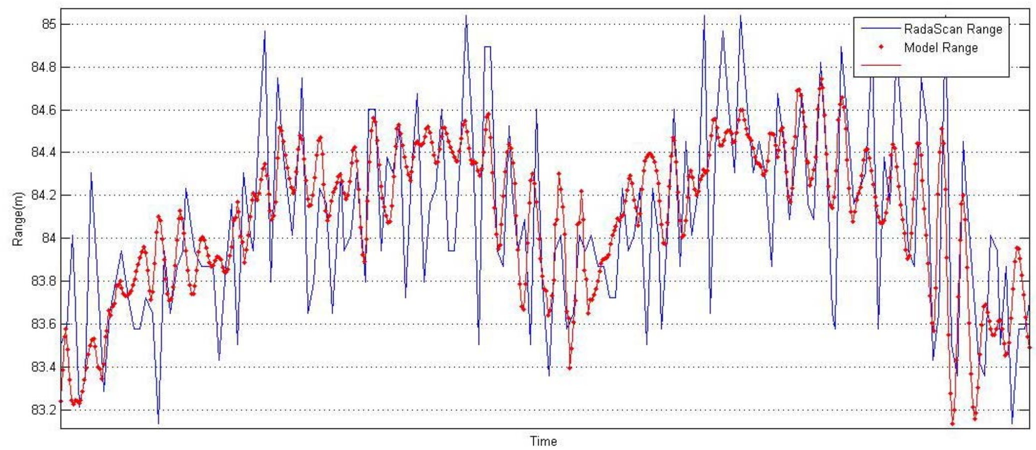


Fig (a)

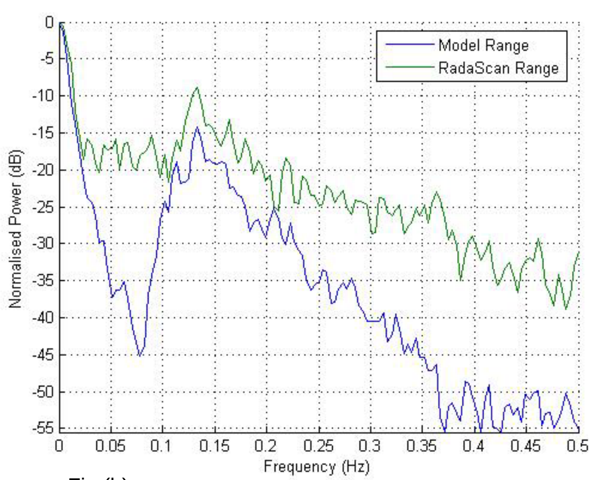


Fig (b)

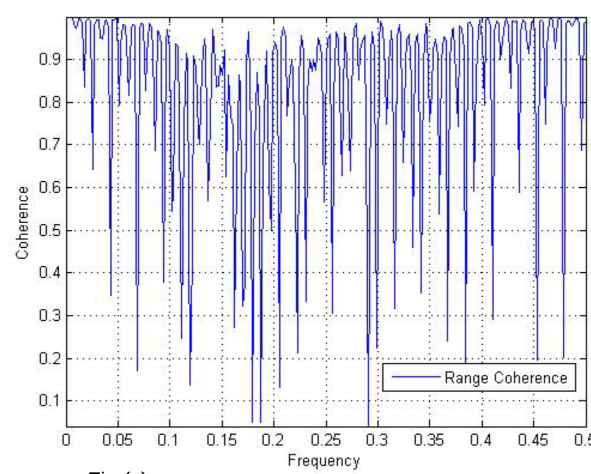


Fig (c)

Fig (a) above shows the model prediction for the transponder based on the MRU data for this time period (Model Range) plotted with the data that was actually measured for the same time period (RadaScan Range). It can be seen that there is a close match between the two datasets, calculated from independent sources.

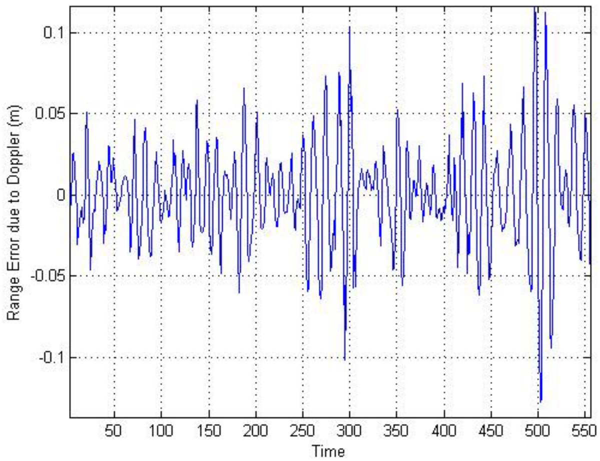
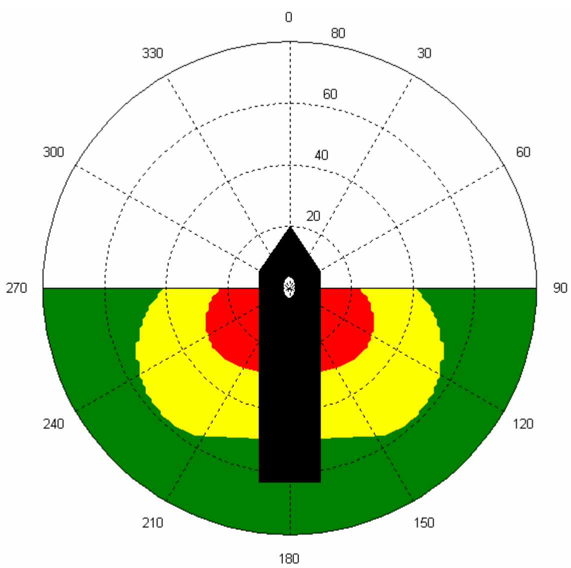


Fig (b) shows the frequency domain comparison for the two traces. Again there is good agreement between the model and the actual RadaScan measurement. Both exhibit a dominant peak at around 0.125Hz, which equates to the wave motion movement of the vessel along the line of sight to the transponder. The lower frequency component is the drift of the vessel (surge / sway) as the DP system tries to maintain position. Fig (c) is a coherence plot where a value close to one show's that the model and RadaScan measurements match closely. This is measured at each frequency. For this model run, the error due to Doppler shift is shown left. The error is generally less than 5 cm, which is acceptable.

Tracking Filters & Transponder Locations.

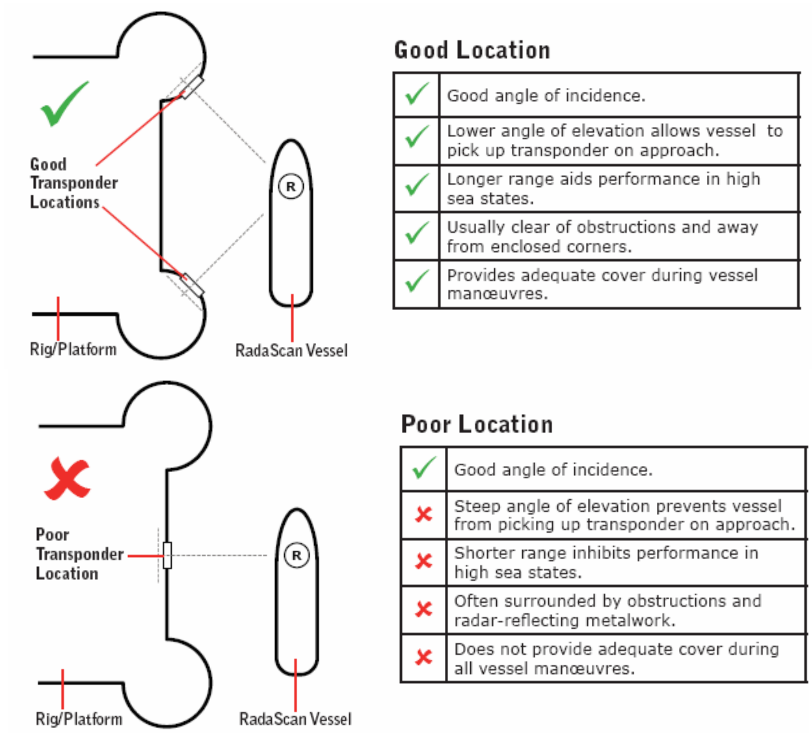
The sea motion model allows us to observe the locations of the most rapid rates of change in range and bearing for a typical DP setup measured by RadaScan, as well as considering where Doppler range errors will be largest. This output can be used to optimize the performance of the transponder tracking filters used in RadaScan, but more importantly it allows us to make some predictions about the best places to site transponders in heavy sea conditions.



RadaScan target tracking algorithms are designed to cope with the typical rates of change of motion under DP system control. Large vessel motion due to waves expands these rates of change. The model was run for a PSV station keeping scenario for all possible transponder locations out to 80m. By feeding in real MRU data, the model output shows the extremes of rate of change of bearing & range for each possible transponder location for the limit of DP operations. The model output was then converted to the 'risk' map left. This map shows the vessel with the location of RadaScan marked. The circles represent range from the RadaScan sensor, whilst the bearing is marked in degrees around the circle. The coloured zones indicate the frequency of dropouts (one dropout = target lost for one second by RadaScan) that may be experienced in heavy seas if the transponder is placed in this zone. The red zone should be avoided, as bearing movement will be large, as well as Doppler range error effects, whilst the transponders placed in yellow or green zones will perform well.

- Dropouts > 5% (Not recommended)
- Dropouts < 5% & > 1%
- Dropouts < 1%

This map then allows us to make some recommendations about where to place transponders for best system performance in heavy sea conditions at the limit of the DP system performance. These are summarized in the figures below. Transponders should be mounted no lower than 2 metres below the RadaScan sensor, and 5 metres above it. Make sure that transponders are mounted on the outside corners of rigs or platforms. Transponders should never be placed inside corners, below overhangs, or on lower service decks, below a main deck overhang.



Good Location

✓	Good angle of incidence.
✓	Lower angle of elevation allows vessel to pick up transponder on approach.
✓	Longer range aids performance in high sea states.
✓	Usually clear of obstructions and away from enclosed corners.
✓	Provides adequate cover during vessel manœuvres.

Poor Location

✓	Good angle of incidence.
✗	Steep angle of elevation prevents vessel from picking up transponder on approach.
✗	Shorter range inhibits performance in high sea states.
✗	Often surrounded by obstructions and radar-reflecting metalwork.
✗	Does not provide adequate cover during all vessel manœuvres.

To help with easier setup of transponders, and optimal angling, all transponders are shipped with a swivel bracket.

Ongoing Work.

All RadaScan systems now leaving Guidance are fitted with a Vertical Reference Unit (VRU). Data from this is logged when the RadaScan sensor is in use. Guidance has also invested in a wave table capable of 'replaying' the VRU data to simulate the conditions experienced offshore by the RadaScan. This approach allows continual improvement and monitoring of the performance of the system in heavy sea states.

Conclusion

Since its launch to market, RadaScan has proved its worth as a local reference position sensor in numerous DP system applications, some of which are described in this paper. Used worldwide, it has been operated in the most extreme of environmental conditions. RadaScan has been shown to overcome some of the traditional problems suffered by laser reference systems. This paper examined recent experiences of the use of the RadaScan system in the North Sea over the winter season 2007/8, and makes recommendations to improve performance of in rough sea conditions.