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OPERATIONS

RADASCAN APPLIED TO VESSEL UNDERWAY REPLENISHMENT AT SEA DP OPERATIONS

Dr. Dominic Pearce

Guidance Navigation Ltd (Leicester, UK)

Abstract

The accurate control of two vessels at sea whilst personnel and materials are transferred from one to the other is emerging as an important DP operation in both military and civilian circles. This paper firstly introduces the 'RadaScan' system, explaining how X-band FMCW radar technology has been combined with the use of transponders for the very accurate measurement of range and bearing to two or more locations. This includes details of the latest development to the RadaScan product, 'Mini RadaScan', a miniaturized version of the original RadaScan sensor which provides extended market access to microwave technology. By combining sensor measurements into a position and heading solution that is then supplied to the dynamic positioning system for vessel manoeuvring control, this unique radar sensor allows one vessel to track and follow the other vessel at close quarters and in heavy sea states whilst the transfer operations are conducted. A real life example is described, presenting data showing a successful track and follow replenishment at sea operation involving an OSV and a US Coastguard vessel for straight line and turning manoeuvres.

Introduction

Dynamic positioning (DP) systems for large industrial vessel control have been in use for many years, predominantly in the oil and gas industry where applications require vessels to station keep against fixed or moving installations, or 'track and follow' each other in functions like sea floor pipe or cable laying. Such operations require very accurate local reference measurements to be supplied to the DP system. Global reference systems such as GPS are not well suited for these types of demanding application. Until recently, the only available sensors were laser systems, or alternatively sea floor based acoustic or taut wire systems. For the track and follow application, the only real choice was a laser reference. The weather susceptibility of laser systems meant that these operations could only be carried out in fine sea conditions, leading to down time in the more severe working areas of the world. Recently however, a microwave based reference system has been developed which has the equivalent accuracy of the laser reference as well as the ability to work in all weather conditions and of the more unusual man made conditions for example in dust or steam filled atmospheres.

RadaScan System Description

A. Overview

The RadaScan system represents a next generation in local reference sensor technology. It has been specifically designed to overcome some of the shortcomings of traditional local position reference systems.

Figure 1a: RadaScan Antenna

Figure 1b Mini RadaScan Antenna

Being a microwave radar sensor, it is insensitive to the harsh environmental conditions often experienced in an offshore environment, being largely unaffected by heavy rain, fog, or other prevailing sea conditions. RadaScan is a compact ship mounted swept microwave radar system which can interrogate radar retro-reflective transponders [1].The sensor is capable of finding and predictively tracking [2] transponders out to 750m and beyond. The sensors in the RadaScan product family are shown in Figures 1a&b and are frequency modulated continuous wave (FMCW) [3] radars operating over a 100MHz bandwidth within the maritime radiolocation band centered at 9.25GHz. Two transponder options are available to be used with the system, either a miniature portable amplified transponder or an ATEX/UL approved totally passive version, requiring a battery to drive only the modulation electronics that impart a unique code on the reflected radar return, with no implicit amplification of the microwave signal. This second variant is approved for use in explosive atmospheres.

B. Principle of Operation

RadaScan is a 'Frequency Modulated Continuous Wave' (FMCW) radar. In this type of radar you have a continuous signal being transmitted. The signal is however continually ramping in frequency (hence frequency modulated, see Figure 2). In this way we can deduce the time (and hence range) between the signal that's being received and the signal that's being transmitted, by looking at the difference in frequency.

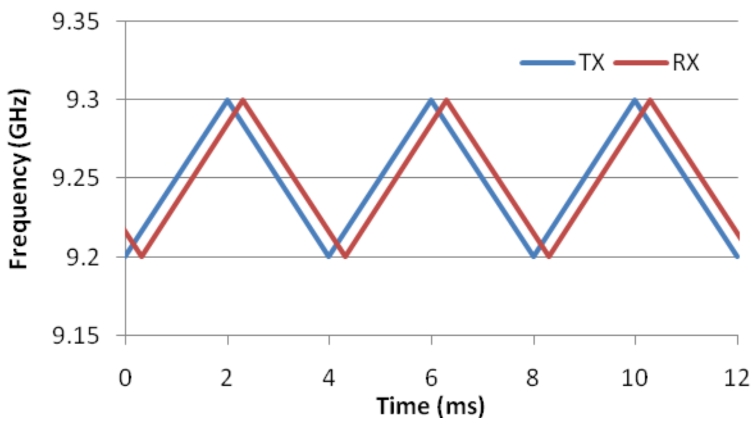

Figure 2: RadaScan FMCW Radar Output and Return Signals

We mix the outgoing and incoming signals together and the heterodyne/superposition effect produces a signal with a beat frequency which itself is equal to the difference between the two frequencies, and proportional to the range to the transponder.

C. Retro-Reflective Transponders

The transponder has been uniquely developed in conjunction with the radar sensor to ensure that the system as a whole is easy to use and setup. The transponders are true retro-reflectors based on the Van-Atta array principle [1], i.e., a signal received at the transponder is reflected back to its point of origin. At the same time, the transponder flips the polarization of the reflection by 90 degrees whilst imparting an identifying modulation code. Two different modulation schemes are in use at the moment. Both methods have advantages and disadvantages for different application settings. This id code is used by the radar processing system to not only identify the transponder, but to reject the background clutter normally encountered by any marine radar system, by coherent detection of the id. Such detection means the radar can effectively ignore the clutter from the sea surface, and the signature of the large installation or vessel where the transponder is placed, as well as clutter from other sources, such as other vessels. There are still significant challenges with multi-path, but as long as some basic principles are adhered to with regards to transponder location, these can usually be negated. The transponders have a very wide viewing or acceptance angle.

Figure 3: RadaScan Portable & Fixed Transponders

D. Measurement Accuracy

Dynamic positioning relies on high quality measurements and repeatability from its sensors. RadaScan is therefore faced with the challenge of supplying data which is comparable in accuracy with a measurement laser system. For station keeping duties, a typical DP system expects standard deviation of resolved and motion corrected positions measured by a sensor to be within 3 feet. A sensor is generally automatically discounted from consideration by the DP system if the standard deviation strays beyond 9 feet even in very rough sea conditions. It is quite a challenge to achieve these accuracies with an X-band radar system. The processing flow has been specifically designed to maximize this measurement accuracy. Figure 4 shows a position plot for static measurement of a transponder at 180m (~590 feet) from the sensor.

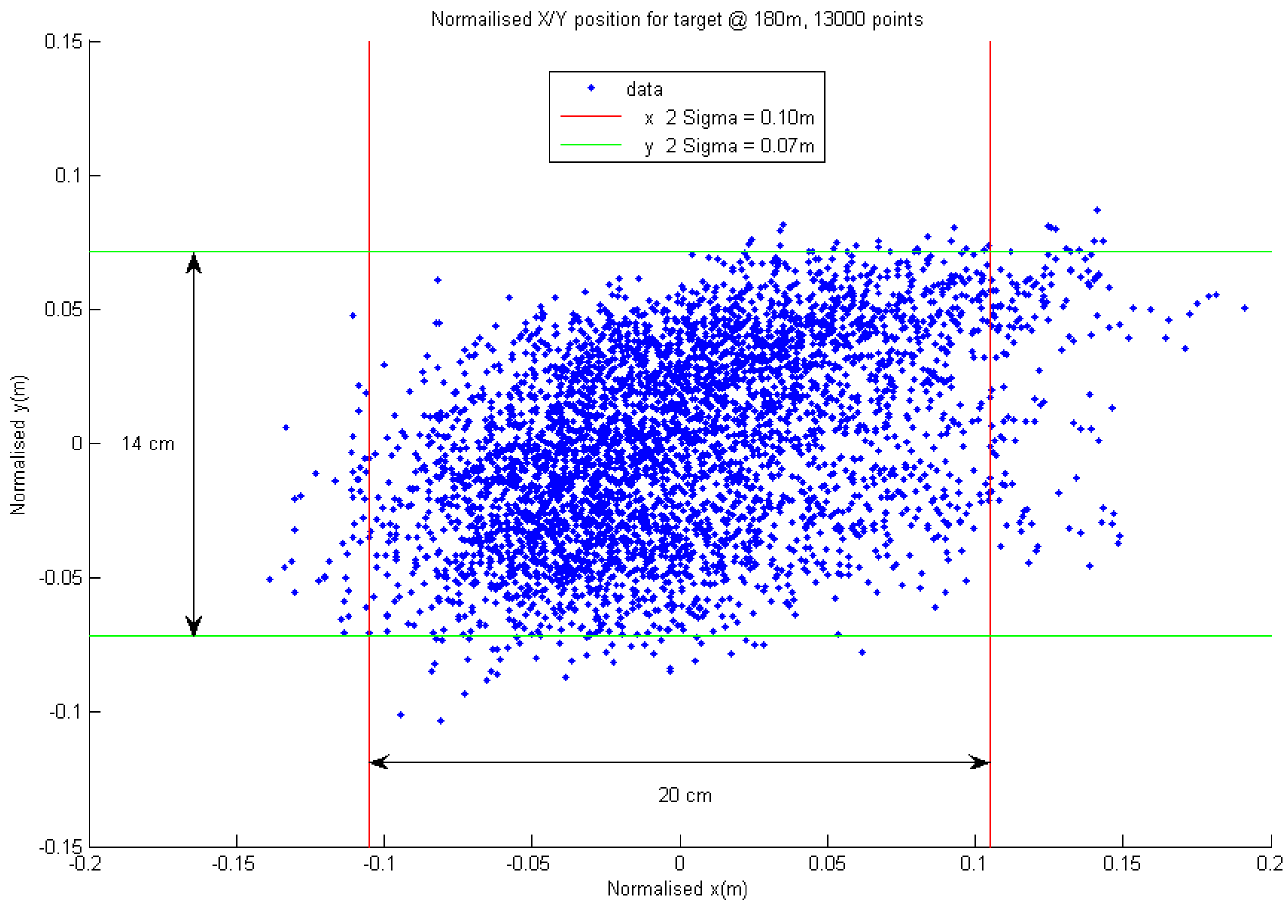

Figure 4: RadaScan transponder position plot at 180m (590feet)

For static measurements the system can resolve position from combined range and bearing measurements with standard deviation of a few inches.

Replenishment At Sea (RAS)

The process of replenishing one vessel from another at sea is generally carried out whilst both vessels are in transit alongside each other. This is achieved by one vessel maintaining a course whilst the other vessel tracks its position velocity and heading under computer control. It is however also possible to maintain this mode whilst maneuvering through turns. A crane or other loading equipment is then used to offload from one vessel to the other. This mode of operation can only be done by using a local position reference sensor. RadaScan has been used for this application using a multi-transponder approach shown in the Figure 5. RadaScan provides the DP system with the position to a 'primary' transponder T2, as well as the heading of the other vessel calculated from the baseline defined between multiple transponders (T1 & T2). 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 velocity (V1) and heading (H) of the other vessel, and maintain its absolute position relative to it, by controlling the vessels engines and/or thrusters automatically. The accuracy with which the heading and position of the other vessel can be estimated is very much dependant on the inherent measurement accuracy of the RadaScan system. The accuracy of the vessel track that can be maintained relative to the other vessel is influenced by the prevailing sea conditions and the DP system.

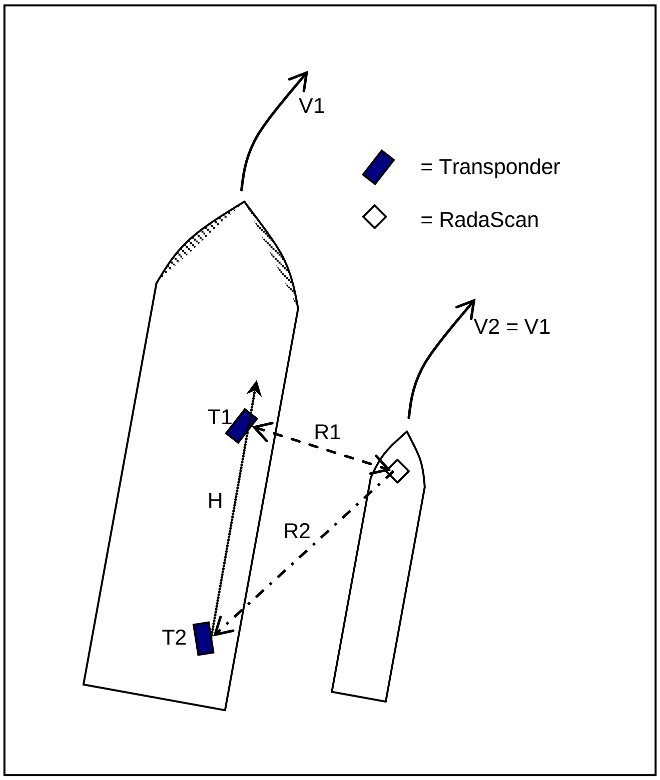

Figure 5: RAS vessel configuration

Trials with the U.S. Coastguard

In February 2009 a trial of the RAS application was conducted with the following partners; Guidance Navigation, U.S. Coastguard, Hornbeck Offshore and L3. The purpose of the trial was a demonstration of the combined technologies and expertise of all parties to implement the RAS between two vessels; the HOS Gemstone, a 300’ offshore supply vessel (OSV) and the USCGC Mellon, a 378’ high endurance cutter (HEC). The RadaScan system and L3 DP system were both located on the HOS Gemstone, whilst two RadaScan transponders were fixed to the handrails of the Mellon fore and aft, so that two units formed a baseline aligned with the Mellon’s primary axis. During the trial, the Gemstone was under computer control based solely on the position and heading information supplied by the RadaScan system. An example timeline is shown in figures 6a) through c) where with the Mellon navigating a straight course at 8 knots, the Gemstone under computer control is moved from a separation of 250’ to 60’ from the Mellon. This separation is maintained for a few minutes while a crane operation is conducted, and the Gemstone retires. In Figure 6(a), the data shows the gradual lateral approach of the two vessels as measured by RadaScan. The final approach occurs at around 500 seconds, and DP ‘lock’ is obtained where the vessel separation of 60’ is achieved between 700 & 800 seconds. During close in maneuvers with both vessels aligned and in DP lock, RadaScan data in Figure 6(b) demonstrates that fore and aft relative movements of the two vessels is no more than 2’, prior to this, the fore and aft motion slowly varies as the control system adjusts both lateral and fore / aft movement. Heading control inferred from the transponder bearing measurements shown in Figure 6(c) is to within a degree during DP lock, and shows a similar pattern on the approach path.

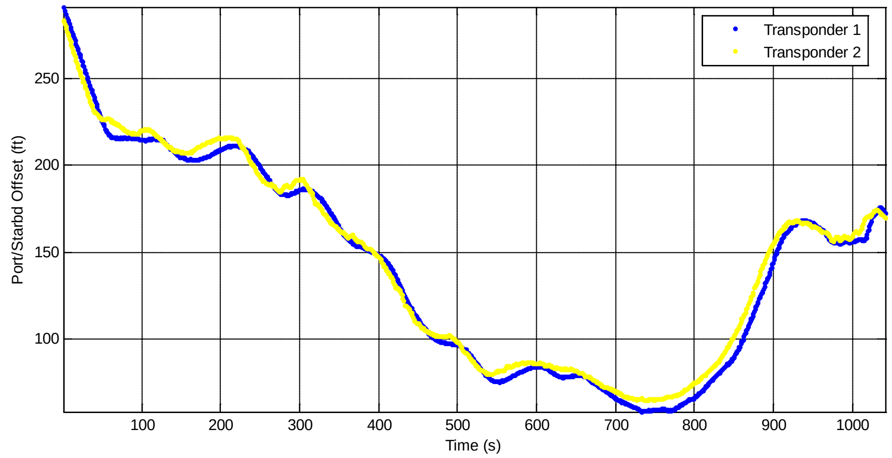

Figure 6(a): RadaScan transponder port / starboard offset during a RAS maneuver

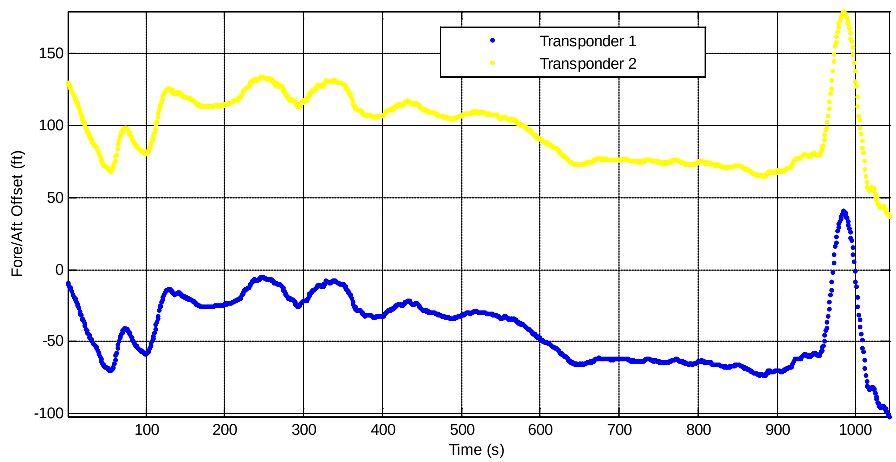

Figure 6(b): RadaScan transponder fore/aft data during a RAS maneuver

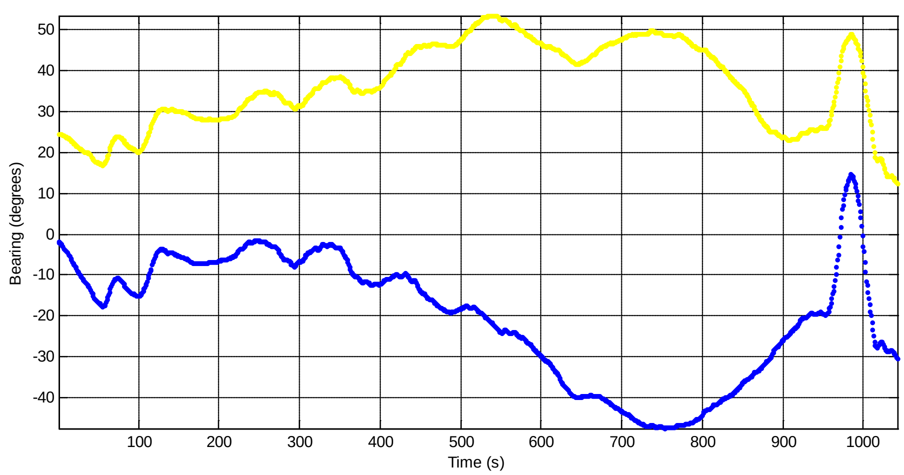

Figure 6(c): RadaScan transponder bearing data during a RAS maneuver

The hump at the end of Figures 6(b) & (c) are as the boats pull apart at the end of the RAS maneuver, and then start back in again for a further approach.

Figure 7: HOS Gemstone and USCGC Mellon on approach

Figure 8: HOS Gemstone and USCGC Mellon wake trails during turn

Figure 7 shows the two vessels as they approach each other preparing for crane operations, taken from a fast rescue craft following the two vessels. In a second test, whilst at 150’ station keeping separation at 8 knots, the Mellon pulled several turns, 30 degrees and 155 degrees. The Gemstone was able to successfully track these turns given the position and heading data supplied by the RadaScan system. Figure 8 shows the wake trails left by both vessels during one of these turns. It can clearly be seen that the separation is accurately maintained throughout the maneuver.

CONCLUSION

The RAS application is undoubtedly one of the most demanding modern DP applications and the RadaScan sensor has proven itself to be able to meet the challenges of using microwave technology to measure changing range and bearing to known locations with laser equivalent accuracy. The sensor resolves those range and bearings to positions and headings within the measurement accuracy required by the DP system.

Acknowledgment

Guidance Navigation thanks Hornbeck Offshore and the US Coastguard for granting permission to use the images presented in this paper.

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