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RADius, a New Contribution to Demanding Close-up DP Operations

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ABSTRACT

Kongsberg Seatex AS has developed a new relative positioning system, RADius, for short-range positioning applications, which currently is in use in the North Sea. The system is designed for "close by" DP operations where the need for robust and reliable performance is critical. Statistics shows an increasing number of contacts or collisions between vessels and installations offshore. As a consequence several operators requires DP class 2 vessels for operations within safety zones of their installations. Further IMO guidelines (ref [2]) require minimum three reference systems for class 2 and 3 DP vessels. RADius is developed to meet these requirements and is a contribution to increase the safety for these kinds of operations. RADius utilizes FM-CW (Frequency Modulated – Continuous Wave) technology to measure range and bearing to one or several transponders located on target vessel or installation. The system is fully solid state without any moving parts and operates in all weather conditions. Relevant operational scenarios for use of the system are also described.

INTRODUCTION

Close by DP operations where vessels are positioned near structures or other vessels, which can be non-stationary, are types of DP operations with special characteristics.

Figure **1**, Example of a close by DP operation

Obviously these operations contains elements of risk in their nature, and the eminent danger of collisions if loss of position control occurs can be a major stress factor for the DP operators.

This type of operations contain special challenges to position reference systems due to the fact that nearby vessel/structure can influence on the traditional position reference systems.

The number of collisions world wide is of great concern both to oil companies and ship-owners.

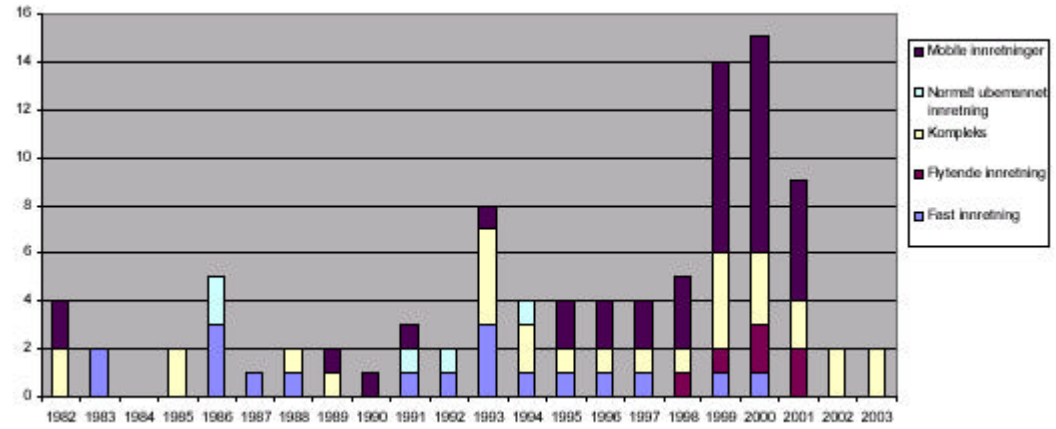


Figure **2**, Number of collisions in the North-Sea over the last 20 years (ref. [1]).

The Petroleum Safety Authority of Norway is also concerned with the growing tonnage involved in these contacts.

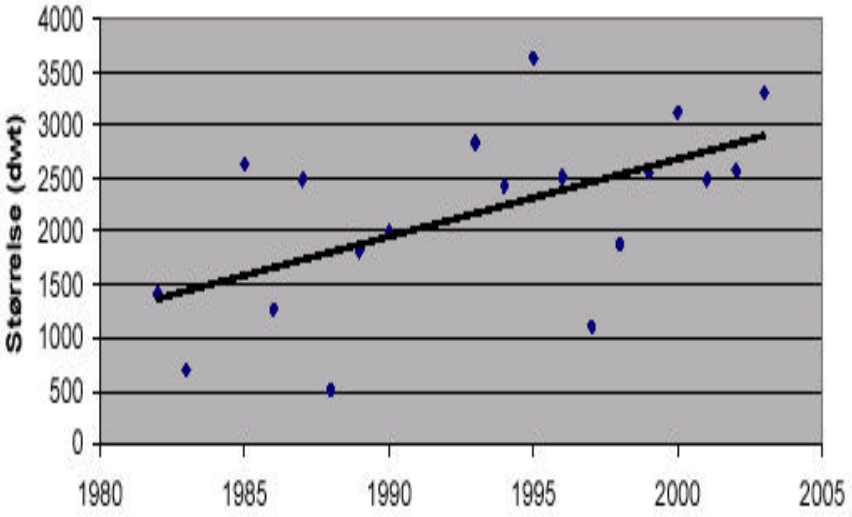


Figure **3**, Tonnage involved in collisions in the north sea over the last 20 years (ref. [1]).

As a consequence to the facts above, there is an increasing will among operators and vessel-owners to find reasons for, and thereby means to reduce, the number of contacts between vessels.

Operators identify that the professional market is driven by performance requirements since the ability to operate safely and efficiently will depend on the ability to accurately and safely monitor the position, velocity and heading of the vessels under all types of conditions. This means improved safety and thereby better long-term economy.

As a consequence, more and more of the contractors demand DP vessels for operation within safety zones of installations. The introduction of DP vessels has however not solved all the problems and the requirements have shown a tendency to increase to class 2 DP vessels.

Quote from the IMO guidelines, chapter 3.4.3 Position reference systems, ref [2]:

.2 *For equipment classes 2 and 3, at least three position reference systems should be installed and simultaneously available to the DP-control system during operation.*

.3 *When two or more position reference systems are required, they should not all be of the same type, but based on different principles and suitable for the operating conditions.*

Due to the way the IMO requirements above are formulated, there has been a discussion whether two can be of the same type while a third differ both in system and principle. Further whether all have to be different types and at least one based on different principle compared to the other two. The optimal solution is however if all three are different and based on different principles as long as all have sufficient performance. RADius is a mean to fulfill these optimal requirements.

THE RADius SYSTEM (patent pending)

RADius is developed to be a position reference system contributing to increase redundancy, robustness and thereby the availability and safety of "close by" DP operations.

RADius consists of an interrogator located on the DP vessel and one or several transponders with unique identity deployed on the target (vessel or installation). The RADius system measures distance and bearing from the interrogator to the transponders

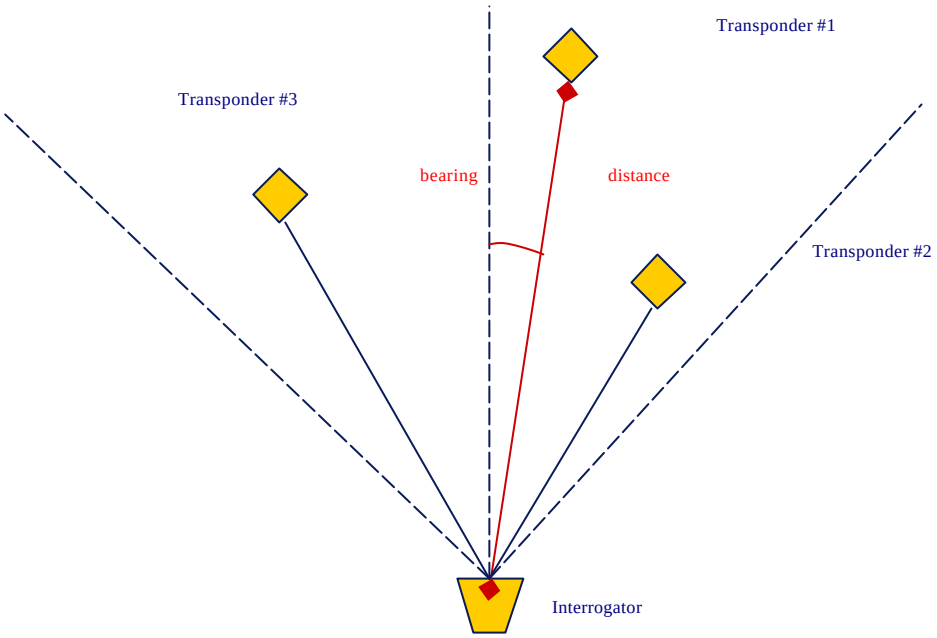


Figure **4**, RADius measurements

Operational, one transponder is sufficient for DP operations and the system can utilize up to five transponders simultaneously, increasing robustness and reliability. A transponder can serve several interrogators simultaneously providing multi user functionality in the system.

When operations are carried out relative to moving vessels, relative positioning systems are needed. Floating production units can both move and change heading during loading operations, and supply vessels will have to move with them during these operations.

Figure **5**, Operations relative to moving vessel.

It is usually assumed that availability of satellite signals is satisfactory at sea. This is not always true. As shown in Figure 6, offshore structures can be large and block the horizon for satellite signals, degrading the performance of GPS based positioning systems.

Figure **6**, Structure disturbing GPS signals.

These structures may not only make a challenging environment due to signal blocking, but also with regard to radio interference since many types of equipment actively uses radio frequencies for a variety of purposes, affecting radio based systems not optimized to suppress such interference.

The structures may contain numerous of surfaces creating optical reflections, which can influence on availability and continuity performance of optical reference systems.

The RADius system is designed to operate close by structures or other vessels. The use of identifiable transponders eliminates the risk of tracking false echoes or mix up transponders.

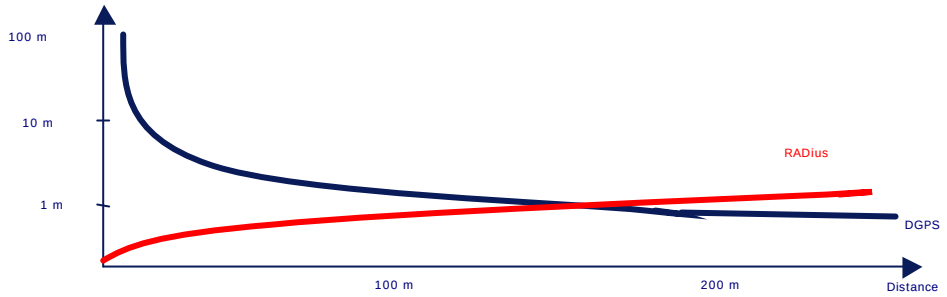


Figure **7**, Illustration of system accuracy as a function of distance from structures.

Figure 7 illustrates the complementary characteristics of a DGPS system and a RADius system. The DGPS system will suffer from a limited view of the sky when moving close to the structure. This can be crucial when the dynamic GPS constellation is at its minimum and the most important satellite disappears behind the structure. The RADius system increases its performance as the vessel moves closer to the transponders located on the structure.

MEASUREMENT PRINCIPLES

Range

RADius measures range based on the FM-CW (Frequency Modulated Continuous Wave) principle.

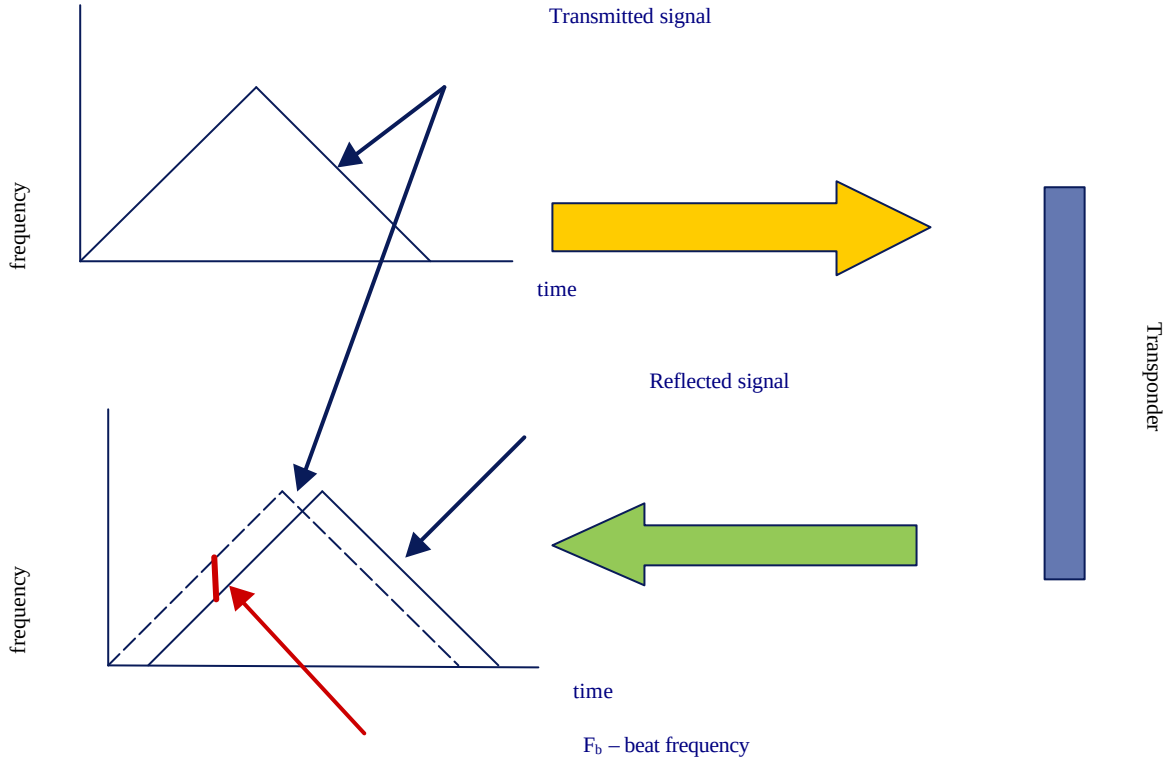


Figure **8**, RADius principles for range determination.

The transmitter sweeps the output frequency and the received signal is mixed with the transmitted signal. The transmitter signal has changed frequency during the time of flight compared to the signal received and the difference between these two frequencies is measured. This frequency difference is proportional to the distance to the transponder.

The distance is then solved with the equation:

$$\text{Distance} = \frac{1}{2} \bullet \frac{F_b}{F_s} \bullet T_S \bullet c$$

F_b – Beat Frequency

F_s – Sweep Deviation

T_s – Time of Sweep

c – Speed of Light

Bearing

RADius determines bearing to transponders by utilization of several receiver antenna elements integrated on a circuit board.

The principle of angle determination is based on measuring the carrier phase simultaneously on the different antenna elements. When the signal source is directly in front of the antenna elements, the carrier will be equal on all the elements showing that the angle to the transponder is 0. When the transponder is off center from the antenna elements, the radius beam will hit them asymmetric. The difference is then used to determine the angle to the transponder. The principle is shown below:

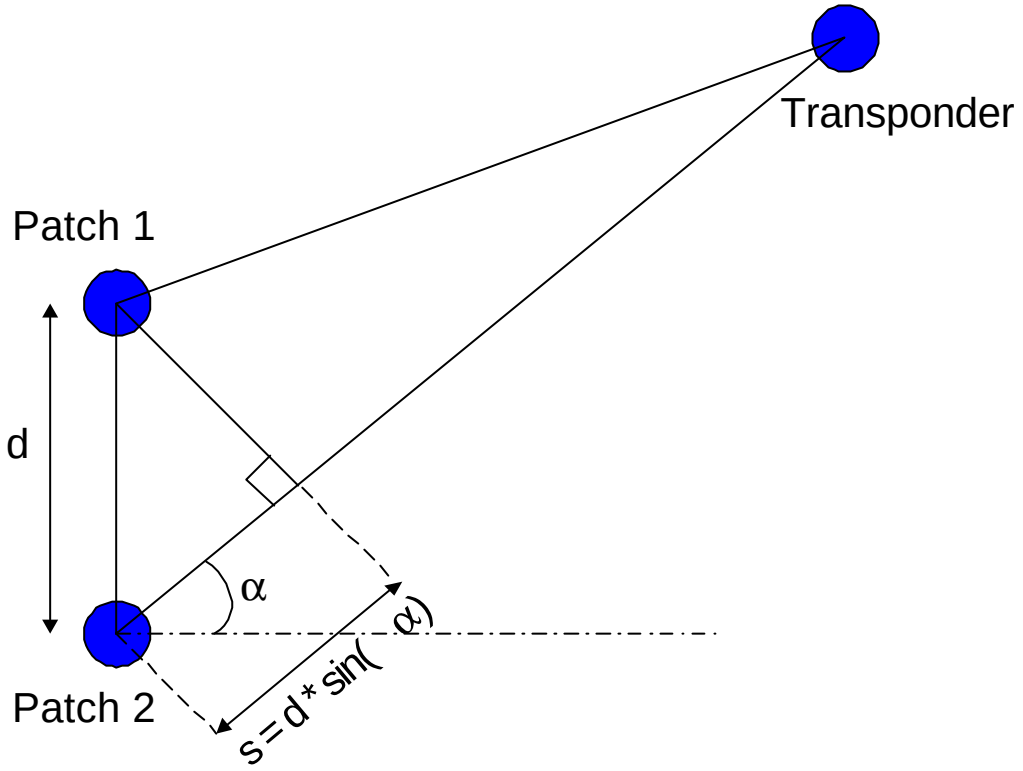


Figure **9**, Angle determination, combining two patches.

The angle, α, shown above can be extracted from the phase measurements with the equation:

$$f_d = s \bullet \frac{2p}{l}$$

s – Shown in figure above

$?$ – Wave length of carrier

f_d – Phase difference, patch 1 and 2

RADius MODULES

The RADius system modules consist of the RADius 1000 interrogator, the controller unit with video display unit and transponders.

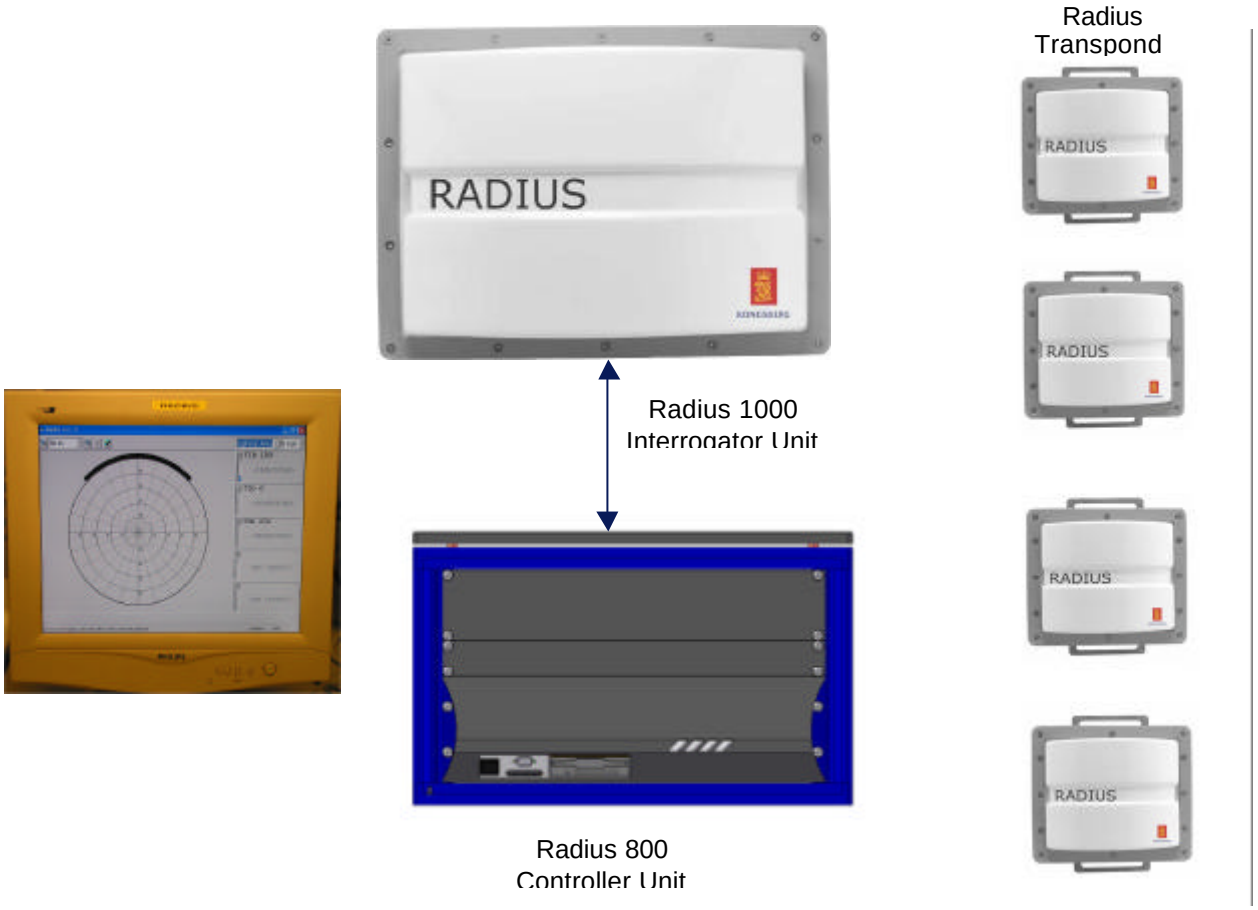


Figure **10**, RADius modules

The RADius 1000 interrogator unit is mounted outside on the vessel with free view to the horizon. It contains antenna elements, a receiver, a transmitter and a signal processing front end.

The RADius controller unit is a 6U 19" rack which contains the RADius processing unit that runs the final signal processing software, a graphical user interface and it provides serial interface lines to the DP and other possible users. The controller unit also contains keyboard and video display unit together with a power/connection module that provides network communication and power to the interrogator.

The RADius system also provides both low power (battery operated) and high gain transponders. These transponders can as well be supplied in Ex-certified versions.

RADius OPERATIONAL ADVANTAGES

The RADius system is a "solid state" system. There are no motors, stabilized platforms or other moving parts within the system.

It operates in all weather conditions and has wide opening angles both horizontally and vertically and will therefore be unaffected by high sea states.

The system allows for multi user operability, which means that several vessels can utilize the same transponders simultaneously.

It operates in a radio band that is allocated to marine radio navigation and is license free.

The system efficiently mitigates radio interference. This is due to the wide frequency range over which the transmitter is sweeping. The receiver has a very narrow bandwidth since it operates on the mixed transmitted/received signal. This means that radio noise in the band typically occur in narrow bands that are swept past and is effectively "clipped" out of the data in the signal processing.

The system evaluates its performance and outputs accuracy estimates of distance and angle measurements to the DP.

RADius OPERATING RANGE

RADius accuracy characteristics are a consequence from the measuring principles. As stated earlier, the accuracy is at its highest at close range where it is most required. The measurement characteristic as a function of range is then described in Figure 11.

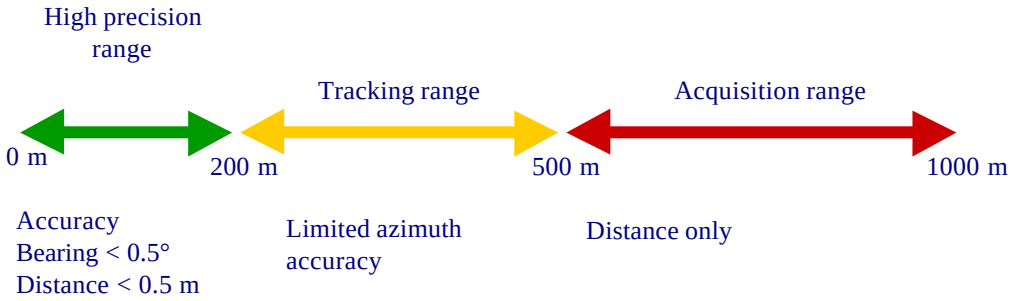


Figure **11**, RADius operating range

The system is able to identify transponders and measure range seamless out to 1000 meter. Closer than 500 meters of distance from the targets, the angle measurements become available. High accuracy and availability are assured closer than 200 meters from the transponders.

GRAPHICAL USER INTERFACE (GUI)

RADius is delivered with an easy-to-use graphical user interface.

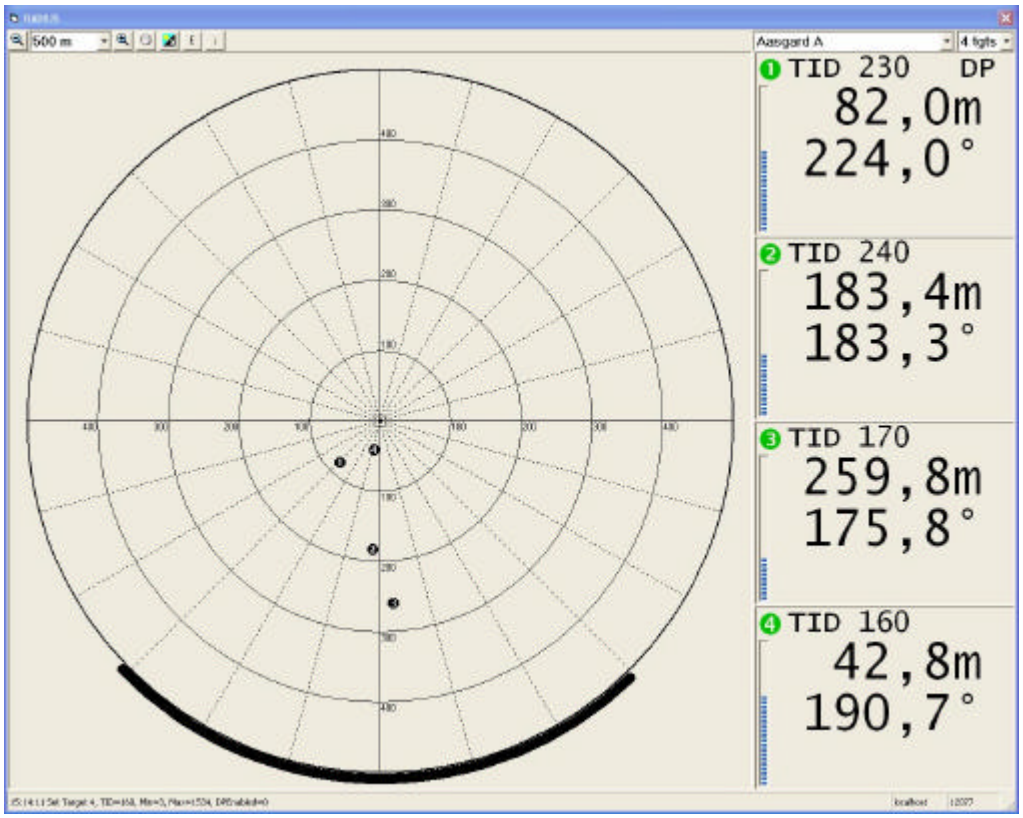


Figure **12**, Graphical User Interface

Figure 12 shows a scenario from a loading operation on board Skandi Sotra next to the FPSO Aasgard A in the North Sea. Figure 13 shows the same picture but with the two vessels illustrated.

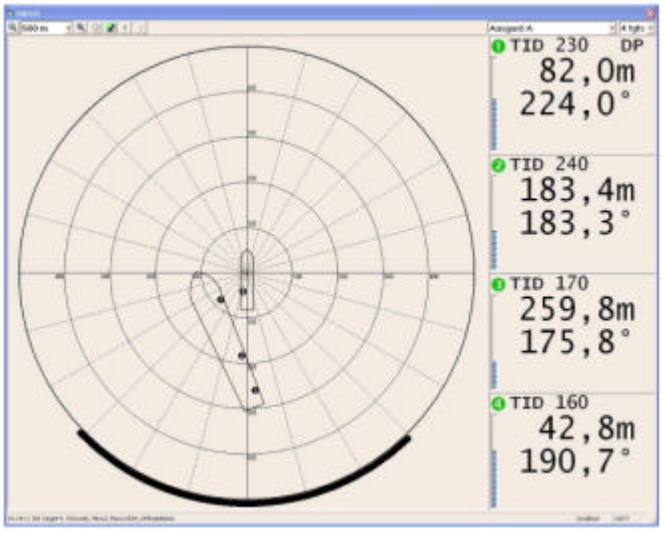


Figure 13, GUI with vessels illustrated

The display is easy to relate to and the status of the different transponders is shown on the right hand side together with tracking status (green/yellow or gray), the signal-to-noise bar indicator, the transponder ID number which identifies the transponders frequencies together with range and bearing to the different transponders.

OPERATING SCENARIOS

The RADius system's 90° opening angle of the interrogator in combination with several transponders allow for a wide range of operations for a supply vessel. It should also be noted that the system measures over a 120° opening angle at close range. This is illustrated in the next figures.

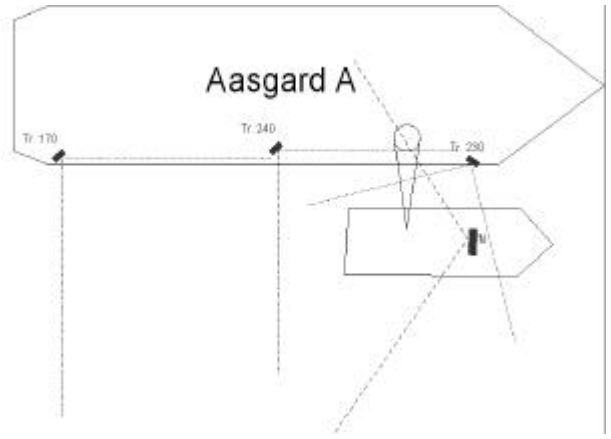


Figure 14, Typical operational scenario, 1

Here the interrogator sees two transponders simultaneously.

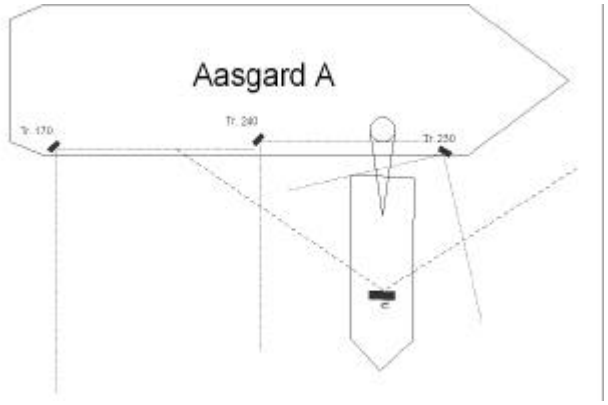


Figure 15, Typical operational scenario, 2

Here there are still two transponders visible to the interrogator.

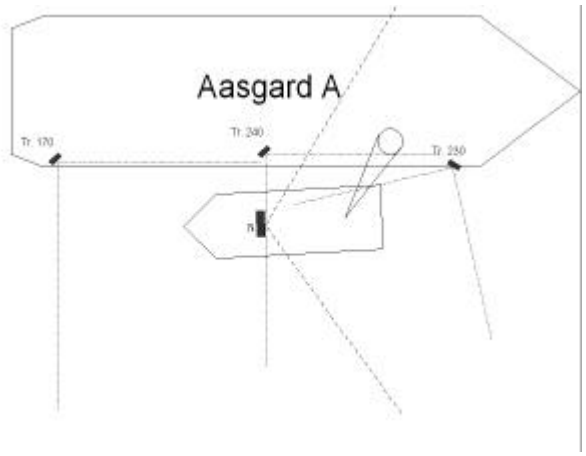


Figure 16, Typical operational scenario, 3

Here only one transponder is visible to the interrogator. However, only one is needed for DP operation. It is also not normal that the vessels have opposite directions since the FPSO is located with the bow against the weather.

RADius MODULAR EXTENTIONS

If the user requires extended sectors, utilizing an extra interrogator can solve this.

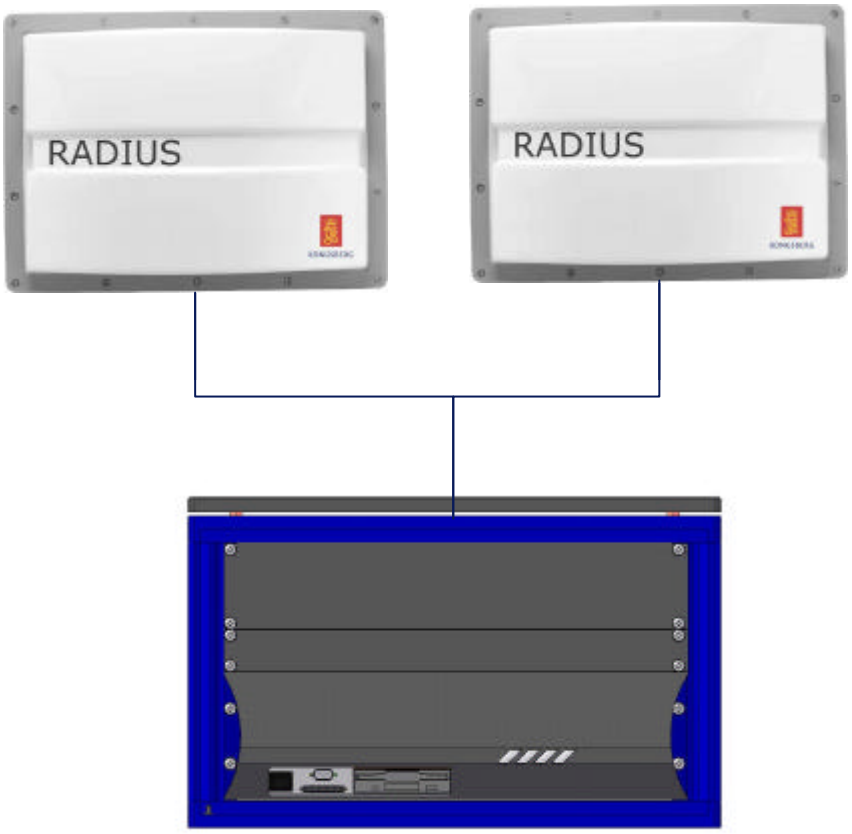
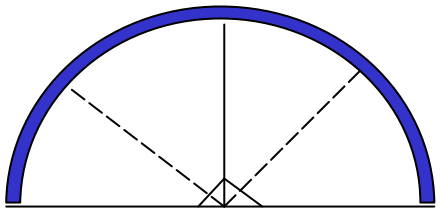


Figure 17, RADius with multiple interrogators

This type of configuration will provide an extended sector, as shown in Figure 18.



Extended sector

Figure 18, Extended sector from two interrogators.

RELATIVE DP OPERATIONS, RELATIVE REFERENCE SYSTEMS

Figure 19, Offloading tanker connected to Norne

An important characteristic of a lot of relative DP operations is that the object to be positioned against is not stationary.

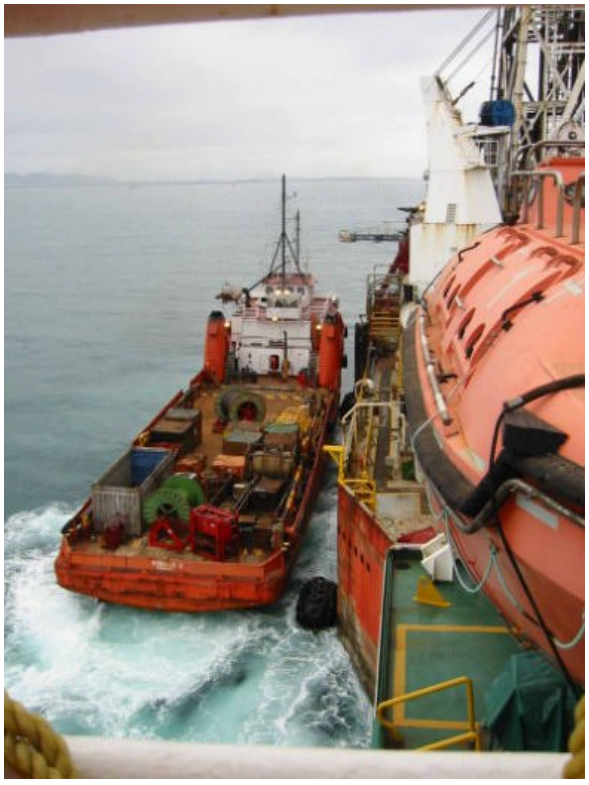


Figure 20, Relative DP operation between two moving vessels.

Such operations call for relative reference systems. Here an absolute DGPS system should be supplemented with a relative GPS system, such as DARPS in collaboration with RADius, supplying redundant relative position information to the DP system.

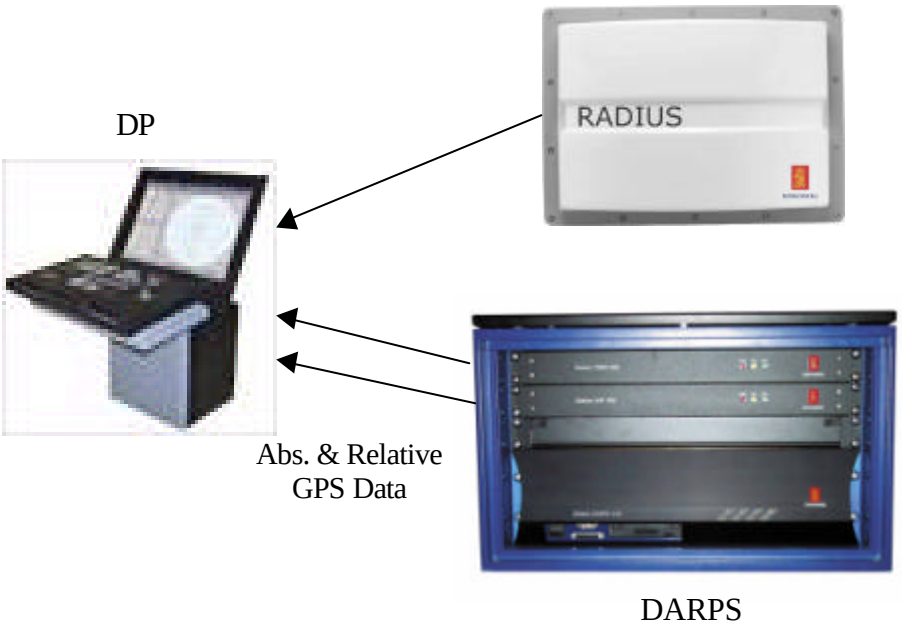


Figure 21, Redundant relative reference systems.

CONCLUSION

Size and complexity of vessels operating in offshore waters are increasing due to focus on efficiency and cost-effective use of assets.

Hence, statistics show an increase in unwanted episodes where vessels comes in contact with other vessels and installations, also with high cost consequences, and in some cases crew injury. Operators are determined to take action in this matter to decrease injuries and costs.

Traditional satellite based systems have their weaknesses, therefore DP Class 2 vessels need to be equipped with different positioning reference operating on different kinds of technology.

The RADius system is deployed and in operation as relative positioning system in the North Sea. The experience shows that RADius operates adequate, and gives robust positioning input to DP systems.

RADius, with its solid state technology and usability in all weather conditions, is a new relative position reference system contributing to fulfil IMO requirements related to the availability of reference systems based on different principles.

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[1] Petroleumstilsynet, *Utvikling i risikonivå på norsk sokkel. Fase 4 – 2003*
[2] International Maritime Organization, *GUIDELINES FOR VESSELS WITH DYNAMIC POSITIONING SYSTEMS*, MSC/Circ.645, International Maritime Organization, 1994.