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MICROWAVE REFERENCE SYSTEMS

Paper discussed unique microwave systems used in offshore industry for position referencing. First purpose built system entered market in 1972 and was partly associated with Dutch Delta Works. This system after several modifications is still in use as Artemis Mk6.Currently, two other, more advanced microwave reference systems are in use. Their introduction eliminated some disadvantages of earlier equipment. Today, reliable microwave reference systems are extensively used in offshore industry for high risk operations in difficult meteorological conditions.

INTRODUCTION

Position reference systems have begun their development in early 1960's to answer demand from fast growing offshore industry. Exploration of subsea oil and gas reservoirs required reliable position reference systems capable of work without any land based infrastructure. Satellite navigational systems were not available at that time. Additionally, multiple positioning systems were needed for position reliability. First dynamically positioned drillship which used microwave position reference systems was CUSS 1, pictured below:

Fig. 1. *Drillship CUSS 1. Source [9]*

Vessel successfully conducted several deep water drillings in spite of modest position referencing equipment. As microwave position reference system was used standard marine radar, measuring distance to four anchored buoys. Readings from radar display allowed operator to manually adjust four thrusters to maintain position. Despite of obvious success of such basic equipment, better microwave system was badly needed by offshore industry.

Demand for such system was also echoed by project Dutch Delta Works which started in 1954 and lasted 43 years until 1997 [8]. The first purpose built microwave position reference system had been built in Netherland. Technological advance in microwave electronic resulted in even more sophisticated systems which play important role in safety of offshore operations. It is necessary to discuss their principles of work and as well problems associated with their use.

1. POSITION REFERENCE SYSTEM ARTEMIS

Challenge of building of such equipment had been taken up by Dutch manufacturer CHRISTIAAN HUYGENSLABORATORIUM B.V.and system called Artemis was introduced into market in 1972. System was based on microwave technology commonly used for marine radars of this time. Carrier frequency was chosen as 9.2-9.3 GHz, just below frequency band of navigational radar 9.3-9.5 GHz. To avoid interferences from navigational radars, Artemis works with vertical polarization. Stations are transmitting continuous wave with code pulse modulation for identification and voice link in earlier version of equipment. Pulse modulation allows for range measurement using pulse time delay. Complete set of Artemis reference system consists of two identical stations: Fixed and Mobile, as shown below:

Fig. 2. *Artemis station. Source [10]*

Fixed station is positioned on board offshore installation, while Mobile station is installed on board of offshore vessel. Both stations are maintaining microwave radio link at power level approximately 100 mW. Fixed station requires calibration by optical aiming of scanner to object with known true bearing and entering this value into system. Each pair of stations works on one of the four frequencies within allocated band and station identification is provided by two digit code. Frequency of Fixed and mobile stations are always apart by 30 MHz to avoid interferences. After activation of auto search mode scanners of both stations are locked on each other and tracking to maintain 'lock'. Manual searching is also provided. Antennae begins search with movement in small sectors, gradually increasing them even to 360°. Configuration of Artemis system in tracking mode is shown below:

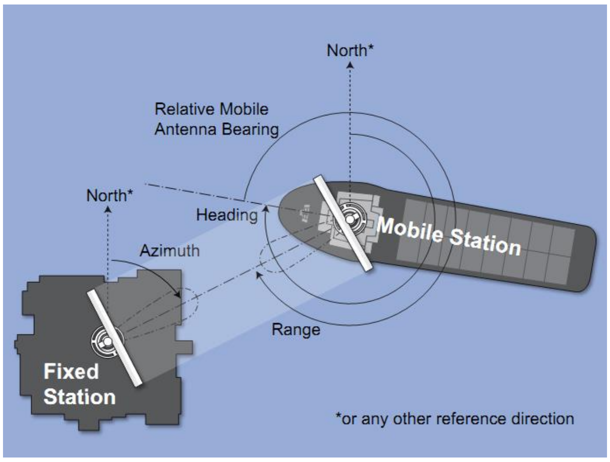

Fig. 3. *Artemis position reference configuration. Source [1]*

Despite of relatively small physical dimensions of scanner system is capable of determining of bearing with very high accuracy 0.033°. System uses maximum signal method for auto search purposes and minimum signal for precise angle measurement. Artemis scanner consists of two separate slotted array waveguides joined together. Left and right halves of antenna are connected to four ports: the Sum and Difference ports. The Sum ports are used for transmitting and receiving. The Difference ports are used for receiving only. Resulting Sum and Difference antenna pattern are graphically explained below:

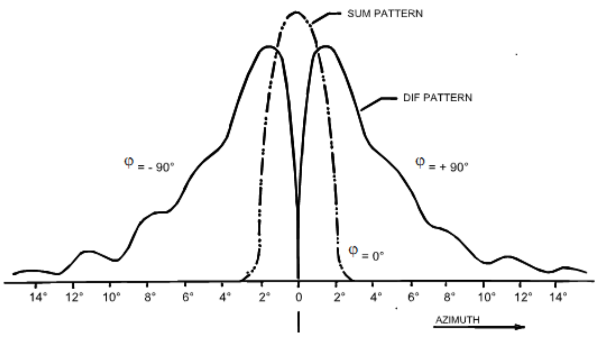

Fig. 4. *Artemis antenna Sum and Difference patterns. Source [3]*

Left part of Differential pattern has phase shift - 90° with respect to phase of Sum pattern. Right lobe of Differential pattern is shifted +90°. For signal received from direction perpendicular to scanner output from Sum ports is at its maximum and from Differential ports at the minimum.

Any deviation from this direction slowly reduces signal from Sum ports and sharply increases signal level from Differential ports. This solution allowed for high accuracy of bearing measurement, far greater than accuracy of marine radars with single slotted array antenna. Artemis is long range system, capable to work at distance 30 kilometers in some versions but dynamic positioning is generally limited to 10 kilometers. Accuracy of range measurements is greater for short distances due to averaging of more measurements within the same time. Mobile station is equipped with operator interface based on PC. Operator can adjust setting and monitor functioning of the system. Interface is subjected to continuous changes but example below fairly reflects system philosophy:

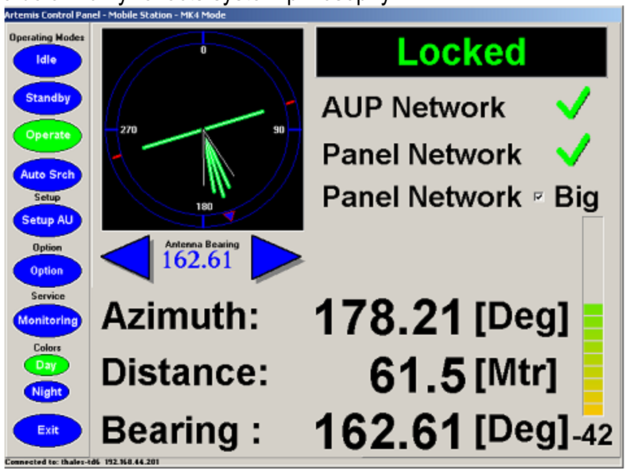

Fig. 5. *Artemis operator interface [2]*

Overall position accuracy of Artemis is considered as 1 meter at probability level 68%.and is sufficient for most offshore operations. System became standard outfit for numerous offshore terminals, owing to ability to work as microwave omni-directional beacon with Mobile station installed on board of shuttle tanker as shown below:

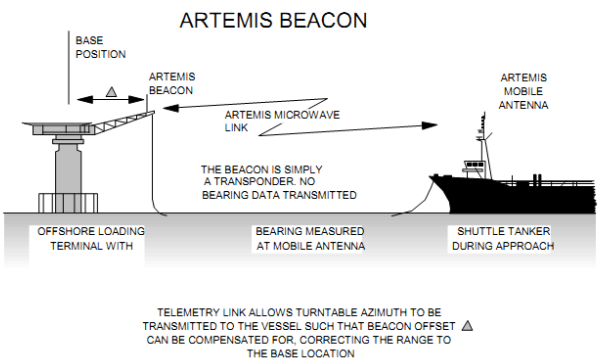

Fig. 6. *Artemis configuration for offshore loading terminal. Source [3]*

Artemis designed as long reference system suffers problems with dip zones when microwaves reflected from water surface are interfering with direct wave. This phenomenon occurs at certain distance from scanner and affect mostly long range operations. Second group of problems is associated with neighborhood of very strong transmissions from ship's navigational radars, interfering with Artemis signals. System is experiencing dropouts when vessel moves outside limits of Fixed station auto search or line of sight is being obstructed. Despite of these problems and obsolete principle of work system is being continuously upgraded in use in offshore industry. There is no other long range position reference system beside satellite based with ability to work in adverse meteorological conditions and well suited for offshore terminals. Early version of Artemis used serial transmission standards RS 232C and RS 423A for communication with dynamic positioning controller. Obsolete analog equipment could be hooked up to the system using 4-20 mA current loop. Last versions of position reference systems are using lightweight Ethernet communication to comply with recent trend among navigational and dynamic positioning equipment.

2. POSTION REFERENCE SYSTEM RADIUS

Development in microwave and solid state resulted in introduction into offshore industry short range position reference system RADius. Built by Konsberg Seatex AS at the beginning of 21st century, new system has no moving parts at all and offers several improvements in regard to previous one. System consists of vessel mounted interrogator, workstation and transponders as targets. RADius components can be viewed below:

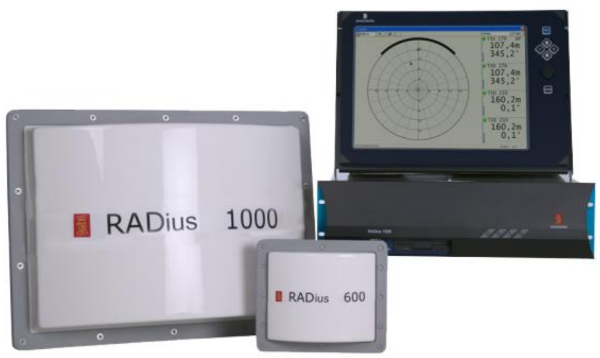

Fig. 7. RADius components. Source [4]

System works in frequency band 5.51-5.61 GHz to alleviated problems with interferences from marine radars. Interrogator works on continuous wave with frequency modulation. Transponder reflects back received signal with added identification number. Signal received by interrogator has frequency shift proportional to distance between interrogator and transponder and allows for precise range determination as can be seen on graphic below:

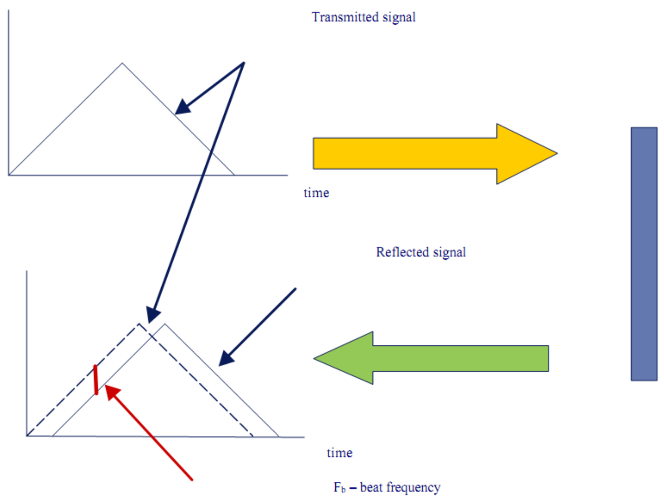

Fig. 9. RADius range measurement principle. Source [7]

Bearing is determined by measurement carrier wave phase shift between different elements of antenna as explained below:

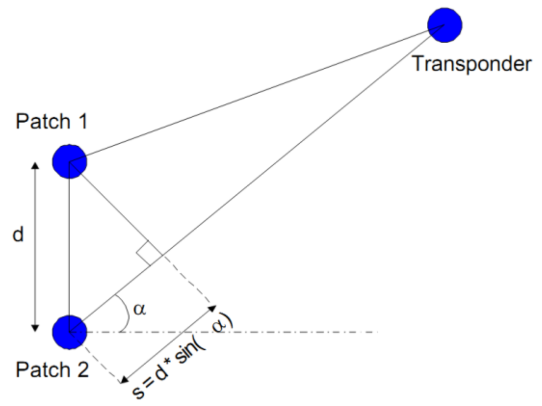

Fig. 8. RADius bearing measurement principle. Source [7]

Another improvement of reference system is capability to work with multiple transponders/targets (up to 5) for increased reliability due to elimination of position dropouts. RADius has been designed as complimentary to differential GPS (DGPS). Vessel approaching offshore installation has part of sky obscured and GPS poor configuration can render position less accurate. At distance 200 m from targets RADius accuracy is equal to that of DGPS. Sorter distances make accuracy even greater. 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. Each interrogator and transponders have opening angle 90° in horizontal and vertical planes to avoid signal loss when vessel works at rough sea. Working angle can be extended to almost 180° by adding second interrogator. Typical accuracy for angle measurement is 0.25° (1σ0) and 0.25 m (1σ). System communicates with associated equipment by five RS232C/RS422 interfaces and Ethernet port. System has proved its usability in harsh environment of the North Sea.

3. POSITION REFERENCE SYSTEM RADASCAN

Parallel to development of RADius system, UK based manufacturer Guidance marine Ltd. came with another concept of microwave reference system called RadaScan. This system features rotating scanner for 360° operation but safely hidden inside radome. Due to advance filtering and signal processing, system can work at frequency band 9.25 GHz without risk of interferences from navigational radars. System designed as long range, can track up to five targets at distance from 1000-10 m. Targets are made as very specific transponders. They are retro-reflecting reflectors and they don't amplify any signal. Received signal is reflected back and the same time transponder flips polarisation of reflection 90º while imparting target identification code. This coding method eliminates most of the background clutter typical for marine radar. Battery power is needed only for electronics imparting target code which allows battery replacement once in two years only. This specific mode of operation is often termed as passive transponders. In manufacturers terminology they are called responders to emphasize their unique mode of operations.

All electronic needed for signal processing is accommodated inside radome as pictured below:

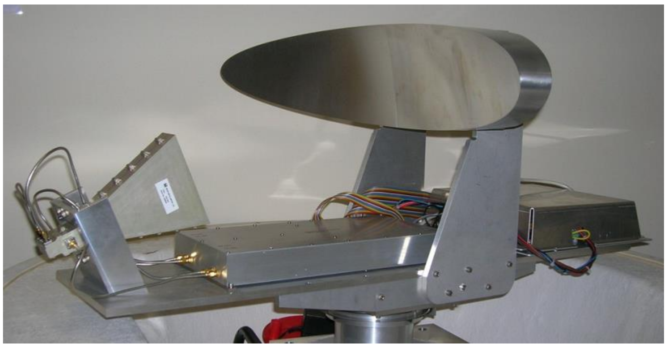

Fig. 10. RadaScan above deck equipment. Source [6]

Sensor is designed as monopulse radar with frequency modulated continuous wave (FMCW). Frequency modulation allows very precise range measurement and low power transmission. Monopulse radar requires twin transmitting and receiving circuits for angle measurement. Simplified schematic is given below:

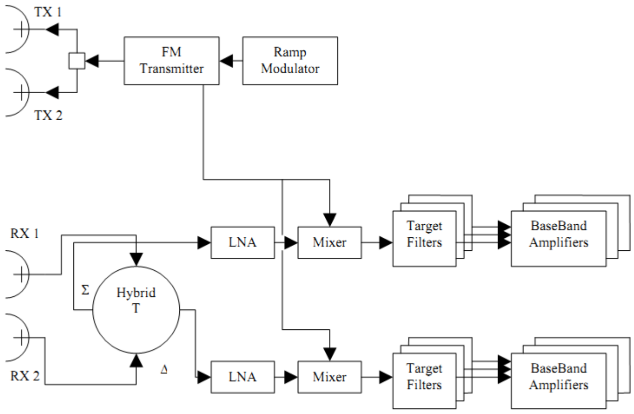

Fig. 11. Radar schematic. Source [6]

Below deck is installed operator's interface which is very simple and intuitive. Radom and interface are shown below:

Fig. 12. Radom and operator interface. Source [5]

It displays basic information like signal strength, target ID, range and bearing. Typical system accuracy is stated as 0.05% of range and 0.06° at 500 m. during field test at medium range position scattertest results were usually within 15 cm in both axes. Important feature of the system is capability to serve multiple sensors with the same set of responders without interferences. It allows several vessels to operate at offshore installation without need to install additional responders. Sensor is provided with heating system for operation in extremely low temperatures. Ethernet port and Internet protocols are used for communication with dynamic positioning system. Up to date this system is being considered as most advanced in its class.

CONCLUSION

Offshore industry is using extensively precise positioning systems for high risk operations. Safety of personnel and environment depends on reliability of such systems. Microwave systems are playing special role as they are capable to work in most adverse conditions. In many instances they are irreplaceable as complementary to differential GPS as primary position reference system. Years of continuous development resulted in implementation of unique microwave technologies and sophisticated signal processing.

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Mikrofalowe systemy referencyjne

Artykuł analizuje unikalne systemy mikrofalowe, używane w przemyśle offshorowym w charakterze systemów odniesienia pozycji. Pierwszy, zbudowany specjalnie w tym celu system, pojawił się na rynku w 1972 roku i był częściowo związany z Planem Delta. System ten, po wielu modyfikacjach, wciąż pozostaje w użytku jako Artemis Mk6.Obecnie, dwa inne, bardziej zaawansowane technicznie systemy są w eksploatacji. Wprowadzenie ich pozwoliło na eliminację pewnych niedostatków poprzedniego urządzenia. Obecnie, niezawodne mikrofalowe systemy odniesienia pozycji są powszechnie używane przez przemysł offshorowy w operacjach obarczonych wysokim ryzykiem i w trudnych warunkach meteorologicznych.

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