International Journal of Engineering & Technology, 7 (4) (2018) 4191-4194

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET
doi: 10.14419/ijet. v7i4.21104
Research paper

Surveillance radars onboard stratospheric platform systems (SPS) for ship tracking

Dimov Stojce Ilcev *

Durban University of Technology (DUT), Durban, South Africa
**Corresponding author E-mail: ilcev@dut.ac.za*

Abstract

In this article is proposed and described new solution for ship tracking via surveillance radars onboard of Stratospheric Platform Sys-tems (SPS) or as known as High Altitude Platforms (HAP). Such tracking system has significant competitive edge in contrast to the surveillance radar at shore or onboard ships, aircraft and spacecraft. The idea and proposal of employing Tracking Surveillance Radars (TSR) onboard SPS is novel and very cost effective as well. Such a system is suitable to be implemented for control of maritime traffic and tracking of ships at sea, approaching to the anchorage, in passages and in coastal waters where must be provided higher security and safety conditions. The TSR system works very similar as radar installed onshore and used for observation and controlling certain part of sea areas for seagoing ships or air space for aircraft. The new proposal of possible placing of TSR onboard three SPS stations between Grate Britain and Ireland islands is presented as well.

Keywords: *SPS; HAP; TSR; Airship; Aircraft; UAV.*

1. Introduction

The surveillance radars are appointed to detect location mostly of movable targets in the area of radar's coverage. It is used for military and civilian purposes to provide control of ships movements, aircraft motion and so on. In fact, these radars can be stationary mounted at shore or some moving objects like spacecraft and any space platforms or onboard of vehicles dependently on applications. Today, surveillance radars are in use for many applications, however in this paper will be introduced their implementation onboard stratospheric platforms. The radar system is based on the simple idea of radiation and receiving of backscattered signal with counting of time delay of traveling of radio signal radiated by radar, reflected from target and returned back at the radar receiver and display.

The basic principal of surveillance radar operations allows identifying tree main parameters of target such as distance between target and radar, azimuth angle of target, speed of movable target, etc. Thus, the ordinary onshore or onboard ship radars are dealing with the following disadvantages:

1) The system has limited observation area or visibility by azimuth angles, which is only up to line of horizon or the visibility is reduced by Line-Of-Sigh (LOS);
2) This system shows ambiguity during signal detection of grouped targets positions in case if one target is behind of another. In this case of limited detection, on the radar screen can be seen only one target instead of two, because that the second target object is shadowed by the first one, and so on for the following targets; and
3) In the bigger distance radar is receiving lower detecting resolution and then all worse nearby standing targets can be detected.

To eliminate mentioned problems and improve surveillance radar detection is delineated idea for new tracking application of surveillance radar mounted onboard of SPS. Accordingly, in this article will be proposed and elaborated an application of the surveillance radar specifically for maritime tracking application, such as controlling of ship traffic in strategically important areas, approaching to seaports, coastal navigation, busy channels and surveillance of pirated ships. Proposing the ships tracking by surveillance radar system can contain two or four target detecting beams and special beams system to provide tracking of certain targets, this operational principal in details will be further described. Design and construction of the TSR system onboard SPS can provide surveillance of all targets either tracking of separate target in the circle of observation area by elevation angles.

The TSR detecting structure of ships is comprised by the observation-sectored beams and tracking beams. At this point, the observation-sectored beam provides detection of ship or group of ships in certain sector in the observation area and the tracking beam provides detecting of certain positions of the ship in detected certain sector with the observation beam. In addition, such TSR installed onboard of SPS gives four main advantages in comparison to the ordinary surveillance onshore or offshore radar:

1) The TSR infrastructure onboard SPS airships or aircraft stations is significantly expanding radar observation area and because of presence of elevation angles radar is not limited by the horizon line or LOS;
2) This system improves ambiguity detecting of moving targets due to observation from the top, so observed ships cannot shadow each other;

2. Structure of SPS for operation and data transfer

The proposed maritime Tracking Surveillance Radar (TSR) onboard of SPS can comprise several sectored observations beams (a, b, c and d), which permanently turn around can use the left or right side turning, and can provide scanning of water surface as shown in Figure 1.
Such tracking system is capable to provide observation of strictly round area with certain diameter and detecting of the targets (vessels) in determined sector (sectored detecting of target is delineated in the third subsection) of this round area. This system can be exploited with different quantity and combination of observation beams as follows:

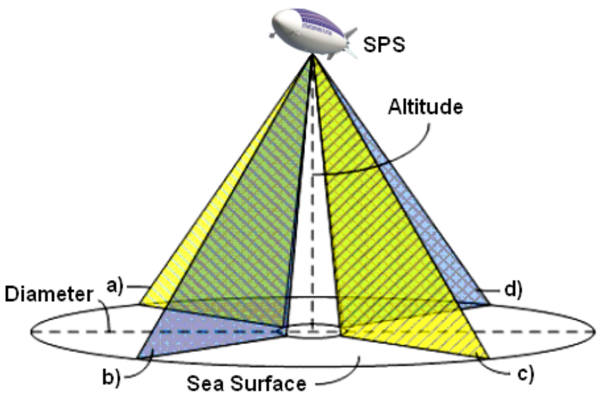

Fig. 1: Sea Surface Look by SPS Amplifier with Positive Feedback [1].

1) With one observation TSR beam projected from SPS "a" as depicted in Figure 1;
2) With two observation beams "a" and "b" as is illustrated in Figure 1; and
3) With all four observation beams together "a", "b" "c" and "d" as shown in Figure 1.

The quantity of observation beams can be automatically switched on or off by the system. The quantity of switched on observations beams can depend on number of vessels, speed of their motion and necessary frequency of refreshing of the targets on the radar screen. Such automatic switching of the observations beams allow safely consume energy from SPS onboard power systems, dependently on situation in the radar visibility.
In fact, all data about position of ships collected in observation area are saved and preliminary processed by onboard computer. For data transmitting to the ground traffic control centre, the SPS is equipped by radio transmission (Tx) and Rx) equipment to provide automatic and permanent radio connection with ground tracking control centre through stable radio channel [1], [4], [5].

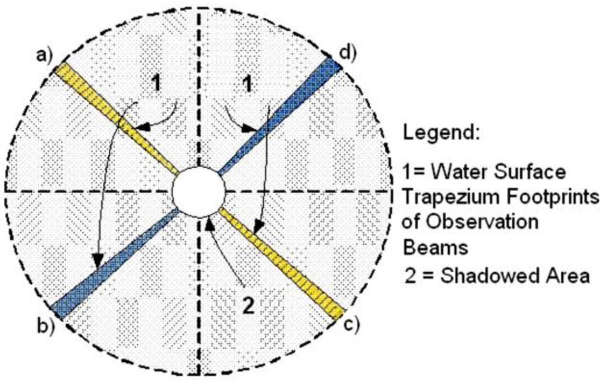

Fig. 2: Footprint Shapes of Observations Beams [1].

3. Detecting and tracking of vessels via SPS

Firstly should be considered the fact that under TSR units onboard SPS, equipped with space surveillance radars, there is directly shadowed area, which is out of radar visibility, as illustrated in Figure 2. The shadowed area is occurred as result of sophisticated shape of footprint of the observations beams and in the shadowed area detecting of targets are impossible. Ideally the shape of footprint for such purpose must be as a sector of circle, it means must have shape of three-angle. However, the real shape of radiation pattern for such system that can really be implemented is close to the rectangular or trapezium shapes, which is illustrated in Figure 2. At this point, such shape as trapezium is self-overlapped during its rotation, and hence as result of rotation this area becomes ambiguous for determination of target.
Therefore, length of space radar observation beams must be technically limited at the centre as much as possible to prevent self-overlapping of the observation beams. The square of the shadowed area is relatively small comparing to the square of entire observation area. Thus, it can be selected optionally by designer depends on the size of width of the observation beam and diameter of observation area. This radar system provides detecting and tracking of targets that occurred in two stages:

1) First stage is to detect ships or some moving targets without certain coordinates that occurred with help of the four main observation beams "a", "b", "c" and "d" as illustrated in Figure 2. As was written above the number of observations beams can be automatically selected by the system. If any ship or ships come into the area of space radar visibility their positions can be detected as angle position of the observation beams where have been received reflected signal from the some targets. It should be taken into account the fact that received radar signal indicates on the screen image that has been detected some ship or ships. The surveillance system cannot identify exact quantity of detected targets, because the space radar fixes reflected signal from entire observation beam footprint rather than from certain position. The possible square of area where can be ship or ships is equal to the square of footprint of the observation beam. Thus, when certain angle of positions of ship or ships are detected and known all sectors, the first stage of targets detecting is finished;
2) Second stage is to figure out information of quantity of ships in the detected certain sector, with help of the space radar observation beam, and their certain positions. In such a way, the system is able to detect one or more than one ship in one sector. Surely, certain determining of targets is occurred with help of frequent scanning of the ships positions of special tracking beam, which comprises seven separated auxiliary beams [4], [5], [6].

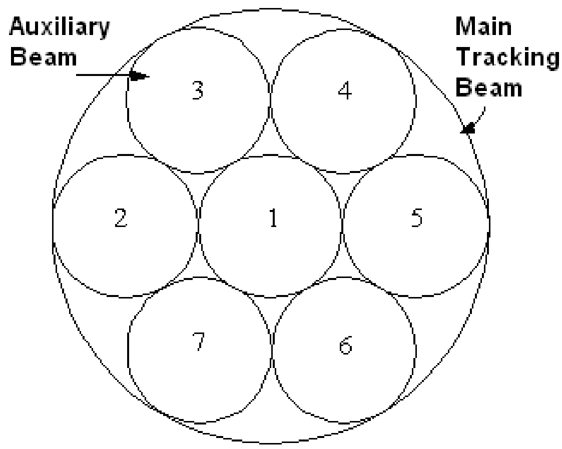

Fig. 3: Structure of Tracking Beam [5].

The structure of tracking beam of surveillance radar installed onboard SPS is illustrated in Figure 3. Such structure of the tracking beam allows providing detection of certain coordinates of ships and also permanent tracking of their positions.
In such a way, the space radar-tracking beam radiated form SPS coming works simply as seven separated beams of certain diameters. The diameters of auxiliary beams of the main tracking beam determine maximum resolution of detection. The seven separated beams of tracking sector work as seven separated radars in each direction of beam separately, which are transmitting signal toward sea surface and received reflected signal from the target in one of seven beams shows where ship, if is target under one of them determined. Thus, how works the tracking beam and being provided tracking of ships? The system tries to keep the ship in the auxiliary beam with number "1" exposed sector, keeping some ship in the auxiliary beam with number "1" means that certain ship is captured as shown in Figure 4a.
At this point, if the ship structure permanently moves in any direction the observed ship periodically comes to any another auxiliary beam which is placed around of the central auxiliary beam with number "1" of the main tracking beam.
Accordingly, then dependently in which number of auxiliary beam the ship is detected, system shifts position of tracking beam in such a way to keep the ship in the centre of tracking beam in the auxiliary beam with number "1" or radar system provide detecting of ship again. Described process of radar tracking and detecting of the ship is illustrated in Figure 4b.

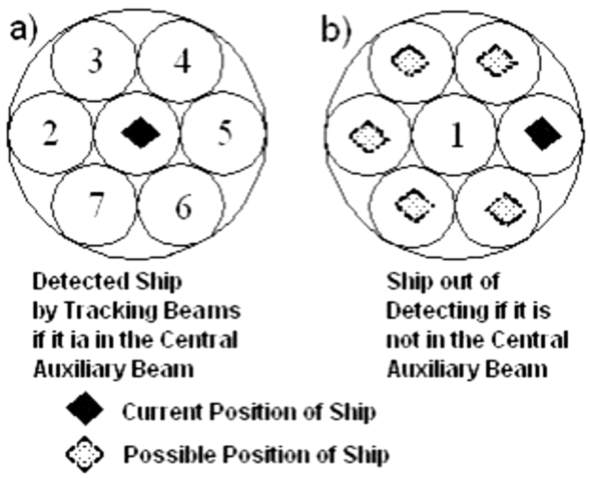

Fig. 4: Ships Detecting by Radar Tracking Beam [5].

Such operation of the radar system provides permanent detection and surveillance of current position of tracking beam and every position points of the targets are memorised by the processor system. If certain observation beam shows that there are some targets around, the radar system provides searching of target again with help of the main tracking beam and provides refreshing of positions of the ships.
In such a way, all received new coordinates over the time are integrated with previous detected by the system and as result of integration of individual position dots, it gives own tracks after every targets. All these processes are repeated automatically over again and second stage of detecting of certain coordinates and tracking of ships is finished.
The observation sea surface area via surveillance radars installed onboard SPS optionally is divided in four quarters as illustrated in Figure 5. Every quarter can be served by own radar tracking beam to provide more fast and reliable tracking of targets. Such division can be implemented dependently on preliminary analyzing of ship traffic in certain sailing area before the radar system is going to be installed [2], [5 - 7].

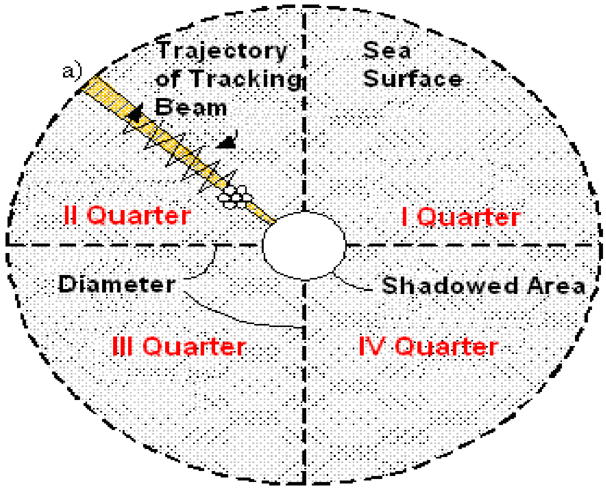

Fig. 5: Searching Target by Observation Beam [5].

4. Coverage of TSR onboard SPS

The practical applications of the surveillance radar onboard of SPS are most usefully in sea areas where there are groups of islands, sea passages, channels and complicated landscape of coastal line or simply where the existing application of usual onshore surveillance radar is not efficient. In practical sense, some islands like Great Britain and Ireland convenient as sample of application for surveillance radar onboard of SPS as is shown in Figure 6.
As shown in the Figure 6 three cost effective surveillance radars onboard SPSP for tracking of ships at sea can be placed in intersection between two islands. In addition, as can be seen three surveillance radars are enough to cover intersections completely and can provide reliable and quality tracking control of all ships passing in the channel.

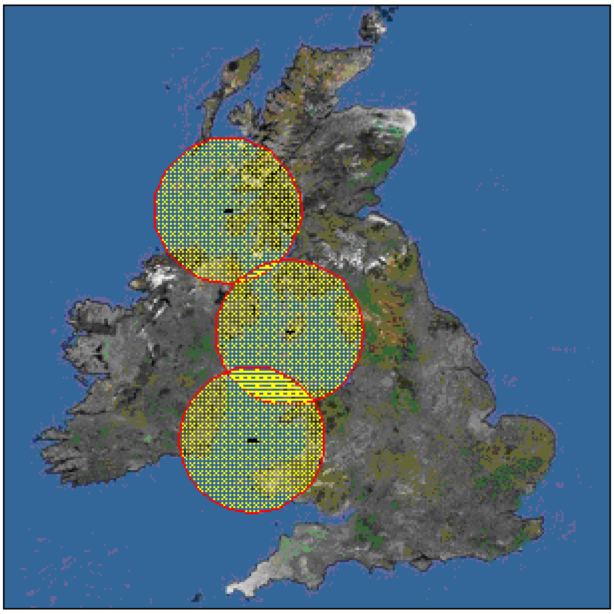

Fig. 6: Coverage between UK and Ireland [5].

Therefore, the total coverage area of a surveillance radar onboard stratospheric platform can be minimum of 300 Nm in radius, what will be enough that 3 stratospheric platforms with radars cover area between Ireland and UK coasts and provide surveillance and tracking service for all kind of vessels, including large oceangoing ships and fishing boats.
Finally, must be noted the important advantage of the space TSR system installed onboard of SPS in comparison with ordinary onshore surveillance radars provide large scale of sea areas and coastal landscape, while the offshore radars are able to provide detection and observation only in the several tenths of kilometers from shore.

In such a way, surveillance radars onboard of SPS can be placed in stratosphere of any desirable or strategically important sea areas, where must be provided very precise observation and control of sea-going ships coastal traffic and especially in areas of vessels piracy [4], [5]. [7], [8].

5. Transmission systems of TSR data

The TSR system is the same technology and technique as Satellite Surveillance Aperture Radar (SSAR), just with difference that radar surveillance equipment with antennas are deployed onboard SPS, such as airships and aircraft known as High Altitude Platforms (HAP) or onboard Unmanned Aerial Vehicles (UAV). The SPS station could potentially support monitoring activities related to safeguards at sea e.g. by imagery of ships movements and activities in local areas of interests, such as Search and Rescue (SAR), anti hijacking or pirate and smuggling, pollution and fishery control and so on, which sample of pirate boat, hijacked ship and SAR forces is illustrated in Figure 7. Thus, all data produced by the TSR equipment onboard SPS may be send to ground Gateway station.

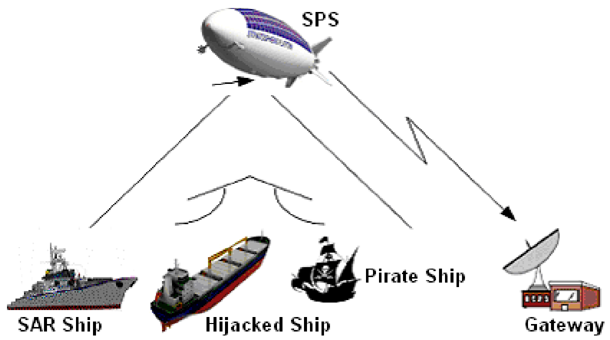

Fig. 7: Surveillance Radars onboard SAR for Detecting of Pirate Ships [5].

Stratospheric airship and aircraft SPS are intended to be flown in an altitude band between 16 and 30 Km, while SPS at 16-20 km are usually selected to take advantage of lower wind speeds for facilitating station keeping. The SPS stations of airship can be divided into Lighter Than Air (LTA) systems that receive their entire buoyancy from a gas cell that contains a gas, which is lighter than air, e.g. Helium or Hydrogen, or hybrid systems which substitute a small fraction of the lighter than air lift with an aerodynamic lift component that is generated by small wings and the platform propulsion system. The airship platform can carry the same synthetic aperture radars for all applications including ships tracking and detecting, illustrated in Figure 8.

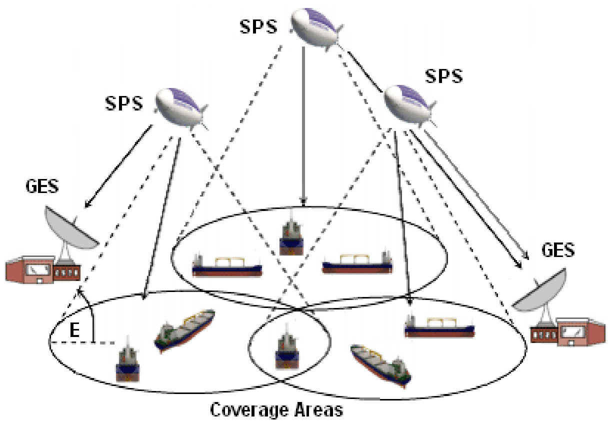

Fig. 8: Surveillance Radars onboard SPS for Area Ships Detecting [5].

For instance, 3 SPS airships equipped with onboard TSR (surveillance radars) can cover large area of sea surface and each can provide in real time sophisticated radar surveillance of oceangoing ships in own coverage area with Elevation angles (E) similar as spacecraft. The SPS airship can send TSR images via transmission system to fixed Ground Earth Station (GES) or Gateway for processing and resending to SAR centre. In addition, the TSR onboard SPS may include as well as mobile onboard ship receiving and processing stations [5], [7],]9].

6. Conclusion

The SPS system with transponder is designed similar to a satellite payload as a relay station to receive signals from ground stations using feeder links and to retransmit them to subscribers using service links. In the similar way, TRS onboard stratospheric platform like a satellite is carrying a payload with corresponding transponders and antenna system.

The launch of SCP into position is much simpler and more cost effective than putting a satellite into any orbit. The satellite cannot be returned on the ground for any reason. The SPS station can be launched to the station-keeping position in stratosphere. After minimum 6 months of exploitation the recovery phase goes in the opposite direction, namely the SPS airship station is shifted from the station-keeping position in stratosphere on the ground for maintenance and preparation for new space mission. The SPS station also experiences less propagation delay with regards to satellite communication systems and compared with satellite systems, the propagation distance is shorter by about 1/1800.

The TSR can be also applied in some parts of sea areas where are happening captures of ships by pirates, whereby in particular can be increased safety and security at sea. Therefore, the proposed TSR system can be ideally used as anti-pirate solution in the sea areas where pirates operate, because such system for searching of captured ships by pirates does not need special SAR merchant and military ships to be equipped with any extra and sophisticated radar surveillance equipment onboard.

The SCP with TSR onboard will be also able to carry some extra payload for other purposes beside of radars, such as very sophisticated high-resolution video cameras equipment for video surveillance any application including pirate ships. With special high resolution optical camera taken pictures can be zoomed as required for sufficient visibility of ships in certain ocean areas. To increase flexibility of the optical equipment should be used other different types of camera such as infrared camera s well.

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