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Radar Sensors Planning for the Purpose of Extension of River Information Services in Poland

Andrzej Stateczny*, Jacek Lubczonek, Tadeusz Kantak****

* Marine Technology Ltd.
Klonowica 37/5, 71-248 Szczecin, POLAND
Email: a.stateczny@marinetechnology.pl

**Institute of Geoinformatics, Maritime University of Szczecin
Waly Chrobrego 1-2, 70-500 Szczecin, POLAND
email: j. lubczonek@am.szczecin.pl, t.kantak@am.szczecin.pl

Abstract: *The first section of the River Information Services (RIS) system in Poland was implemented in 2013 in an area of 97.5 km of waterways on the river Oder from the city of Szczecin up to the town of Ognica. Three options of the RIS extension towards the south are under development. Each option incorporates the FMCW radars. This article presents an analysis of the FMCW radar site planning.*

1. Introduction

The River Information Services system was implemented on Poland's inland waterways in 2013. The system currently covers inland waterways in an area from the city of Szczecin, including Lake Dąbie, up to the town of Ognica. These waterway sections are essential in view of the development of local waterway transport, including without limitation the enhancement of navigation on the Berlin-Szczecin-Baltic Sea stretch. Apart from standard inland vessels, the area is seasonally used by small seagoing craft, what reveals its inland navigation potential. To improve safety of navigation, especially at night time, the use of shipborne radars has been made obligatory. The RIS system uses five radar sensors which enable surveillance of vessel traffic in the area. Twelve FMCW radars of low output power have been deployed in locations which, for various reasons, are difficult for navigation, such as bridges, sections in which the traffic scheme alters, or sites where the inland sea routes merge with the national inland waterways. At present, plans are being made for an extension of the RIS system up the river Oder, which include options of expansion of the network of sensors, including radar sensors. Certain aspects of planning the radar sensor sites and processing of navigational data are discussed in [2-23]. In the process of creating navigation systems, electronic navigational charts and methods of numerical terrain model development are applied [24-34].

The first option of the RIS extension covers a 30-km stretch of the Oder from the town of Ognica to the German town of Hohensaaten. It will create a navigable route from Szczecin to Berlin of uniform, high-quality parameters of providing river information. The second option of the RIS extension covers the lower reaches of the Oder from the town of Ognica to the town of Kostrzyn, where the Oder merges with its tributary the Warta. The river Warta connects Poland's two major rivers – the Vistula and the Oder. The third option, which enlarges the RIS system spread area to its maximum, covers a 150-km stretch of the Oder from the town of Ognica to the river Nysa Łużycka, i.e. from 542,4 km up the reaches of the Oder upwards. RIS extension options were illustrated in Fig. 1.

2. Future RIS Area Characteristics

On the stretch of 161.7 km in question, the river Oder features various hydrotechnical facilities of different amounts of wear and tear and technical parameters. Taking into consideration its characteristics, the border stretch of the Oder can be divided into three smaller operational sections [35]:

- the section from the mouth of the Nysa Łużycka (542.4 km) to the town of Kostrzyn upon Oder (the mouth of the river Warta – 617.6 km down the reaches),
- the section from the town of Kostrzyn upon Oder (the mouth of the river Warta – 617.6 km down the reaches) to the town of Hohensaaten (entry to the Oder-Havel Canal – 667.2 km down the reaches),
- the section from the town of Hohensaaten (entry to the Oder-Havel Canal – 667.2 km down the reaches) to the town of Widuchowa (where the Oder splits into the West Oder and the East Oder – 704.1 km down the reaches).

The first section of the river, 75.2 km in length, with groynes installed on both banks, has a relatively stable flow. At present, the river channel of the trained section from 542.4 km to 594.0 km down the reaches varies in width from 64 m to 68 m, and from 594 km down the reaches, where only mean water training is left, the channel has a width of 80 m. Throughout the section, the training facilities (groynes) negatively affect the morphology of the river channel, causing formation of fluvial deposit which reduces the transit depth. Other obstacles include four bends of a radius of R=600 m. The section features five bridges.
The second section of 49.4 km in length has mean water training (groynes). Its three bends have a small radius of R=650 m. The river channel has a geometric shape and a wide bed. All these features cause a variable flow of current and formation of fluvial deposits which differ in duration, length and degree to which they reduce the minimum depth. Additional obstacles to navigation are bars forming in the Oder channel at the mouth of the Warta. There are two bridges on this section of the river.
The third stretch has a length of 36,9 km. Its subsection of 16 km from 667.2 do 683.0 km down the reaches features groynes on both banks, and the river current flow is similar to that of the abovementioned section from 617.6 to 667.2 km down the reaches. The trained river section finishes at 683 km down the reaches, and further current flow is defined by a break of the longitudinal slope. Here, tidal backwater effects become observable. The altered hydraulic conditions of the current flow cause formation of river sediment, which is carried down the river. Accumulation of the sediment is observed e.g. at the mouth of the river Rurzyca, the branch of the Schwedt Canal, in the area where the Oder splits into two channels off Widuchowa and further down the reaches. There is one bridge on this section of the river. Table 1 presents basic navigational parameters of the bridges [35].

Table 1. Basic parameters of bridges, by RIS Extension Option (RIS EO)

Bridge name	RIS EO	Vertical clearance [m]	Horizontal clearance [m]
Road bridge Świecko	I	15.22	40
Rail bridge Świecko	I	6.74	35
Road bridge Słubice	I	5.15	30
Road bridge Kostrzyn	I	4.31	25
Rail bridge Kostrzyn	I	3.67	25
Rail bridge Siekierki	II	4.14	50
Road bridge Osinów Dolny	II	5.09	50
Road bridge Krajnik Dolny	III	5.55	50

Figure 1. Poland's RIS system extension options.

3. Radar Sensors Planning

Radar sensors in the RIS system should be deployed in locations where inland navigation is constrained. In the area in question, bridges constitute major obstacles to navigation. The first option of the RIS extension covers the river section with the greatest number of bridges. This section is of crucial importance as part of the Oder – Oder Havel Canal – Berlin route. Two bridges with the smallest clearance are in Kostrzyn. This is a frequently navigated route. The second option of the RIS extension covers a section with two bridges, the third one – with one bridge only. Bridges are best suited platforms for mounting radar sensors. Notwithstanding their clearances, they constitute obstacles to navigation on the route, offer unlimited possibilities of mounting radar sensors directly in selected locations, and enable connecting the sensors to the power grid. Easy maintenance of the system and direct access to the sensors mounted on a bridge are also of great importance. Alternatively, sensors may be mounted on masts in non-urbanized areas or on buildings in urbanized ones. The number of radar sensors to be deployed may depend on the priority to ensure navigability at night time, and also on the costs of implementation and further operation and maintenance of the system.

Before radar sensors are mounted on the bridges, an analysis of their locations must be performed. Two alternative solutions may be considered, with a different number of radar sensors and a different tracking coverage: (1) one sensor, located at a considerable height over the bridge, for surveillance of the area on both sides of the bridge, or (2) two sensors mounted on the opposite ends of the bridge, for one-sided monitoring.

The first solution is relatively easy and inexpensive to implement. However, an additional lightweight mast may be required for mounting the radar antenna. The downsides may include vibrations of the platform, caused by wind or vibrations of the spans. Another disadvantage of the solution lies in the fact that a sensor mounted at a considerable height has a larger blind sector caused by the vertical beam angle, thus a smaller tracking coverage of the area adjacent to the bridge. The relation between the size of the blind sector, the height at which the radar antenna is mounted and the vertical beam angle is presented in Table 2. A small vertical beam angle and a high location of the radar antenna may, in theory, produce a blind sector of several hundred meters.

Table 2. Blind sector range, depending on the height of sensor location and vertical angle beam.

Sensor height [m]	5	10	15	20	25	30	35
Vertical beam angle of 10°	57.2	114.3	171.5	228.6	285.8	342.9	400.1
Vertical beam angle of 20°	28.4	56.7	85.1	113.4	141.8	170.1	198.5
Vertical beam angle of 30°	18.7	37.3	56.0	74.6	93.3	112.0	130.6

The latter solution offers a better possibility for adjustment of the sensor location to cover a larger area. Moreover, sensors may be mounted at a lower height. These factors are extremely important where the tracking range must be maximised to cover river bends. Hence, implementation of the former solution may be considered where a bridge is on a straight section of the river, whereas the latter is better suited for bridges located in the proximity of river bends. The two-sensor solution eliminates the need of a dedicated mast. Instead, smaller platforms may be installed for mounting the sensors on the structure of the bridge. What is more, a sensor mounted on a bridge pillar is less susceptible to vibrations. Examples of a radar sensor mounted on one side of the bridge in the village of Osinów are presented in Figure 2.

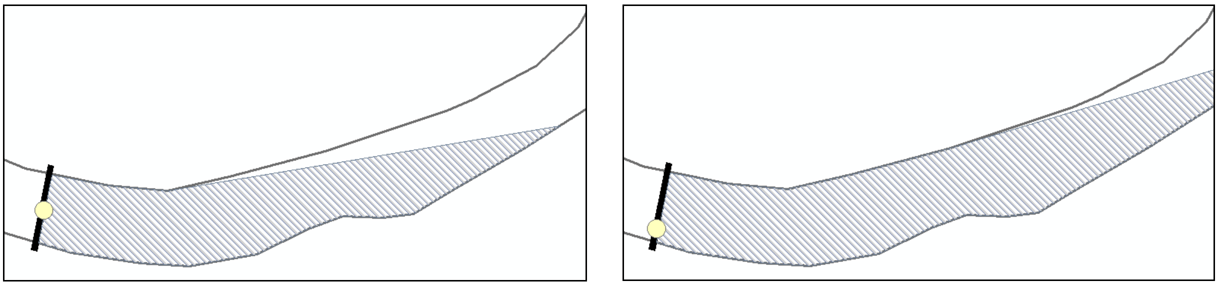

Figure 2. Maximisation of tracking coverage through changing the location of a radar antenna on a bridge.

If the antenna is situated in the middle section of the bridge, the river bend may restrict the radar coverage. Moving the radar antenna towards the centre line of the fairway in front of the bend maximises the coverage (Fig. 2). This position of the antenna is desirable, taking into consideration the high-rise forest in the right-hand section of the area, which casts prominent radar shadows. Visibility analyses, discussed in [4-6], constitute effective methods of determining the most beneficial radar sensor locations. These methods are also researched in connection with solving the problems related to the location of objects [1].

4. Conclusions

The paper presents selected aspects of planning radar sensor sites in the areas of extension of Poland's RIS system. The conducted analyses have led to the conclusion that bridges are best suited for mounting radar sensors, considering their proximity to the monitored waterways and the possibility of convenient mounting of sensors and their further operation and maintenance. The transit character of the waterways and their geometry facilitate the planning of locations of radar sensors, unlike a waterway network of complex geometry and water surface, such as the Szczecin harbour and the adjacent inland waterways [5]. The paper also discusses advantages and disadvantages of the possible options of radar sensor location. Each option should be considered individually, taking into account how the waterway sections under surveillance rank and how important they will be for future traffic.

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