Radar sensors implementation in River Information Services in Poland

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Abstract—**Implementation of River Information Services in Poland on area of Lower Odra river according to RIS Directive was done in 2014. Several kinds of sensors was used during system construction like AIS base station, CCTV cameras, FMCW radars, radar water level gauges, hydro meteorological station. In the article problems of radar sensors – surveillance radar and radar water level sensors implementation are described.**

Index Terms— ***River information Services, radar sensors, sensor network, sensor location planning, viewshed analysis***

I. INTRODUCTION

Radar sensors are very often used in the process of navigation in marine environment as well as in inland navigation. Navigation on inland waterways is much more difficult because of depth and vertical clearance limits, where draft and air draft should be compared with local water level conditions. Important problem in inland navigation is target detection and tracking in narrow and curved waterways with very close distance of approach [1,2,3,4,5,6].

The requirement for tracking in inland waterways stated both in European Community documents as well as in IALA regulations, points at AIS, as the most effective source of information about targets. However radar is still indicated as the main source of such information. Target tracking in inland shipping can be defined in three different ways [7]:

- estimation of target's approach and movement parameters, based on information received from sensors;
- monitoring movement of the vessel for the needs of transport planning and logistics – often referred to as tracing;
- focusing on the target and continuously showing it on the screen – this approach is known from computer vision and is applied to cameras.

Another problem is to analyze data from radar with other sensors like CCTV cameras or AIS [7,8,9,10,11,12].

Radars used in maritime VTS shall be supplemented with other systems, like CCTV or smaller radars along the river. Especially useful for inland navigation is to use FMCW radars according to their known advantages [19,20,21,22]. FMCW radars could be used also for inland ships self-positioning using comparative navigation methods. This approach is especially useful due to possibility of obtaining the autonomous ship position [23,24].

Navigational data also from radar sensors are usually processed [25,26,27,28] to be presented on the common view with Electronic Navigational Charts [29,30,31,32].

Very useful in the process of sensor planning are methods of Digital Surface Model construction similarly like for model of bottom creation [33,34,35,36,37].

In this article aspects of radar sensor implementation for River Information Services are described.

II. THE ROLE OF RADAR SENSORS IN RIS

Radar sensors are basic component of Vessel Tracking Systems (VTS). They should ensure proper safety level in navigation. In general it is realized by delivering actual information about the navigational situation on the fairway. This information is further used to make decisions and should effectively support process of navigation or vessels movement management.

At the beginning, surveillance radars were implemented for purposes of marine navigation as shore radar stations. Currently a lot of attention is also given to the safety of inland waterway transport. Some of these effects were creation of River Information Services (RIS). RIS determines various categories of information services and relation between them and systems. RIS also takes into account the use of radar sensors. Shore based radars are arranged to provide data for such services as traffic information, traffic management and calamity abatement support.

Important information for inland navigation is also water state, which decides on opening or closing navigational waterways. This data are determined by measurement of river water level. Currently water level can be measured by various methods. The simplest is visual data reading by using staff gauge. More complex and modern systems use sensor networks, where data can be obtained in near real-time. Among the various sensors of water level measurement are also radar sensors allowing for remote-sensed data acquisition. This way of data acquisition has obvious advantages for navigation process, where water state can be calculated very quickly.

III. DESIGN OF RADAR SENSORS NETWORK

Each sensor network should be properly designed. Final configuration decides on overall data quality, adequacy and their usefulness. Same of this data can be used further by other system and again reprocessed. E.g. radar image can be used for target tracking or as an element of navigational electronic chart. Data of water level can be further used for automatic depth calculation in electronic chart systems or can be used in flood monitoring systems.

A. Surveillance Radar Sensors

Till now surveillance radar sensors are still improved. The new technology radars are pulse compression, continuous wave and solid state radars. For Polish RIS were chosen continuous wave *Broadband 4G™ Radar*. The motivation of application of these kinds of sensors was mostly their low output power, small size, weight and width of the radar beam. The basic parameters of device were presented in Tab. 1.

TABLE I. BASIC PARAMETERS OF BROADBAND 4G™ RADAR

Radar Technology	Broadband FMCW
Radar Power Requirements	12v / 20 Watt
Output Power	165mW nominal
Transmitter Frequency	X-band - 9.3 to 9.4Ghz
Diameter [mm]	489 mm
Product Height	280 mm
Product Weight	7.4 kg
Beam Width	Adjustable between 2.6° and 5.2°

The first factor is very important due to the impact on the environment. More part of waterways required for radar surveillance was situated in urban or port areas, in many cases in the vicinity of public assembly facilities. This is the main reason of application of radar sensors with low output power. Also important are next sensor features, i.e. small size and weight. In urbanized area practically is not possible to build dedicated platforms like masts. This forces the use of existing facilities and light sensor mountings connected to them. An example is light steel mounting with radar and CCTV cameras installed to the bridge structure (Fig.1). These parameters from the technical side of the project often determine the choice of the sensor.

The last parameters, radar beam width, plays important role in radar image quality of inland waterways. Greater beam width, more angular distortion of banks returns, which finally narrow the field of observation [16]. This kind of distortion increases proportionally to the distance from sensor position. Thus, especially for inland VTS, radars should have as much as possible narrow beam width.

Figure 1. Radar sensor mounted to the bridge structure on the West Oder (photo by J. Lubczonek)

A. Radar Level Sensors

Level measuring has currently very high applicability. This includes measuring the level of liquids in various open and closed tanks. Level measurement also applies to natural watercourses and reservoirs, such as rivers, dams, canals and lakes. Most of these cases refer to levels monitoring in order to assess the current hydro-meteorological situation. In inland shipping this measurements are important for the purpose of determining the state of the water. This applies to both low and high water levels. Finally, water levels data are necessary to establish the navigability of the sections of waterways.

For level measurement can be used various kind of sensors. Part of them is submerged, like pressure sensors, and the other group can perform remote-sensed measurements. In this field can be identified two sensor types, which use sonic or microwave waves. In industrial applications, the latter are widely used.

Radar level sensors are less complicated in implementation compared to surveillance radars. First of all they are non-imaging sensors. They are directed down to river surface and their main task is to measure distance. Further this value can be processed to calculate the actual value of bridge vertical clearance or information about water state. An example of radar level sensor and CCTV cameras mounted to the bridge structure is illustrated in Fig.2.

The main parameters, which should be taken into consideration, are distance to wall, clear view under sensor and maximum measurement range. The last parameter should be adjusted to the water level changes at measurement point. Some technical requirements can be different for various sensor types. Basic parameters of applied radar level sensors are in Tab. 2.

TABLE II. BASIC PARAMETERS OF VEGAPULS WL 61

Radar Technology	Puls radar
Transmitter Frequency	K-band, 26 GHz
Diameter [mm]	115 mm
Product Height	300 mm
Product Weight	0.7-3.4 kg (depending on process fitting)
Beam Width	10°
Max. measuring range	15 m

Figure 2. Radar level sensor mounted to the bridge pylon on Parnica River (photo by J. Lubczonek)

B. Sensors Location

Proper design of sensor network affects further quality of the whole system. In planning the location of surveillance radar sensors were used GIS techniques. GIS environment is proper choice for spatial planning, but not enough. Spatial planning of radar sensor location can be realized by performing viewshed analysis [14,17] on raster Digital Surface Model (DSM), but this method is not perfect for radar image prediction. Radar image has distortion caused by radar beam width and pulse length [13]. Similar effects is also observed for continues wave radar. Modified viewshed analysis for radar image modelling was presented in [16], where it was complemented by basic radar distortion. In [15] was also studied the influence of DSM on viewshed analyses accuracy. Apart from this for viewshed analysis can be applied 3D model of environment, especially during the first phase of sensor location planning [18]. All methods can be merged, to enforce the whole planning process. Above methods help to answer essential questions:

- What radar will see from analyzed location?
- Where and how big are the radar shadows?
- Is the existing platform proper for sensor location?
- What correction is required in sensor location?
- Where to locate the new platform?
- What height should have the new platform?

Example of modified viewshed analysis was illustrated in Fig. 3. In this case the radar sensor was situated on top of the bridge. Darker shade of gray denotes simulated radar image distortion, brighter shade – visible area from sensor position. Analysis was performed for two various radar beam widths. In Fig. 3 was simulated radar image with wider and narrower beam, which gives a view of the impact of radar distortions on the actual size of the observation area. Thus, such analysis not only allows estimating effective area of observation but also helps to determine the proper radar beam.

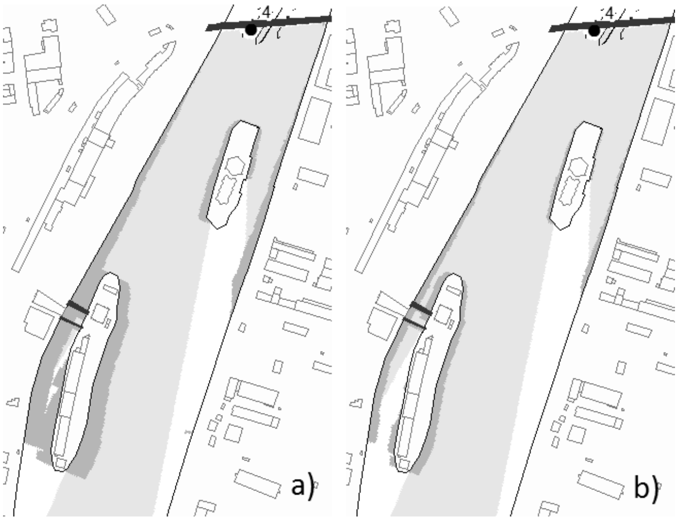

Figure 3. Exemplary viewshed analyses for radar beam of (a) 5.2° and (b) 2.6°

Location of radar level sensors required analysis of minimum distance from bridge elements. It was based on diameter of beam footprint on water surface to avoid any obstacles in the field of microwaves propagation. For some bridges are mounted two sensors on their opposite sides in order to increase the reliability of the system.

IV. SENSOR IMPLEMENTATION

In RIS were implemented 12 surveillance radar sensors and 14 radar level sensors. Surveillance radars were situated in areas, where inland navigation is difficult. In most cases it covered areas adjacent to the bridges, because they are the main obstacles and limitations on inland waterways.

Radar sensors are able to deliver information about movement of any boats and vessels in practical all weather conditions, especially during fog. Picture below (Fig.4) shows an example of difficult navigational situation, where on inland waters (West Odra River) adjacent to the bridge navigate two barges and two small boats with anglers in fog condition (all barges and boats were denoted by circles). Such situation without the doubt requires radar surveillance.

Figure 4. Example of difficult navigational situation, which requires radar surveilance (photo by J. Lubczonek)

In RIS nine radar sensors were planned on bridges, two locations were planned on masts, and one on building. Spatial distribution of surveillance radar sensors is illustrated in Fig. 5a.

Number of radar level sensors was 14 and all were installed on moutings connected to bridges. Distribution of radar level sensors is illustrated in Fig. 5b.

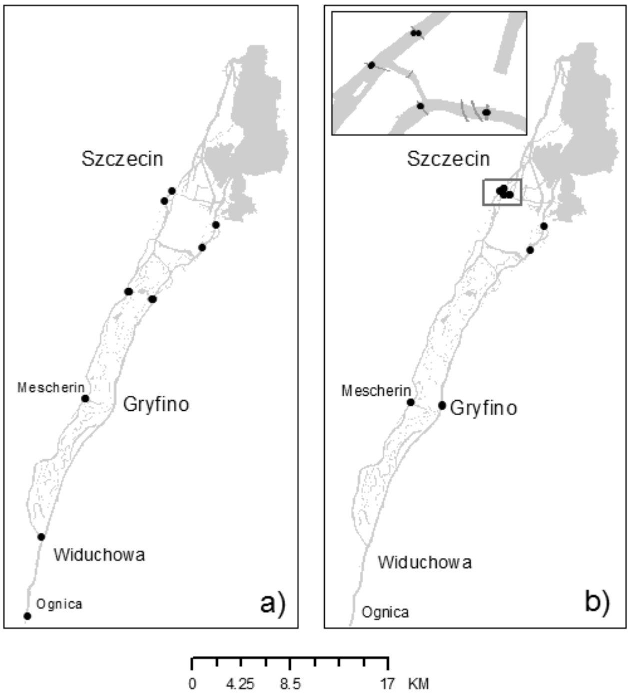

Figure 5. Distribution of (a) radar surveillance sensors and (b) radar level sensor in RIS area

In radar sensor implementation a big role plays also mountings. In many cases one mounting was designed for two or three devices: surveillance radar, CCTV camera and radar level sensor. Such way of installation simplifies devices connection to a power source and their later service. Apart of this, in this solution all sensor data have the same spatial reference, which should facilitate spatial analysis of navigational situation. Example of installed three sensors on one mounting, which was fixed to the bridge is illustrated in Fig. 6.

Figure 6. Common mounting for three sensors: surveillance radar, CCTV camera and radar level sensor (photo by J. Lubczonek)

V. CONCLUSIONS

The paper presents the results of radar sensors implementation on the RIS Lower Odra area. That area covered waterways in urbanized, port and non-urbanized areas. Aspects of surveillance radars and water level sensors planning and installation was described. The article presents some methods, which support implementation of radar sensors. The most effective for surveillance radars are based on GIS viewshed analysis, especially for aquatory or river with complex geometry. There is the first prototype installation in Poland. This installation could be field for research works for extension of Lower Odra RIS and also for system for Wisla River.

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