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Analysis of Beam Sharpening Effectiveness in Broadband Radar on Inland Waters

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Abstract: *The paper presents results of the research on beam sharpening effect in inland waters. The idea of the research was to verify influence of beam sharpening on range and bearing discrimination in real environment. Research scenario assumes analysing the screen correlated with distance between targets, which allows examining real efficiency of beam sharpening process. The research set consist of SIMRAD 4G radar connected to processing computer. The area for the research covers inland waters near Szczecin. The new built RIS system includes also broadband antennas, thus the research has not only scientific, but also utilitarian background. The results presented in the paper will allow determining usefulness of broadband radar with beam sharpening effect for navigation, monitoring and tracking purposes.*

1. Introduction

The Broadband radars, known also as FMCW radars (Frequency Modulated Continuous Wave) are more and more popular alternative for the pulse radars at sea [1]. The technology is usually used on small boats and yachts (small antennas) or in VTS systems (large antennas). In case of boat, the antennas are part of multifunctional navigation systems and in case of VTS they are a part of radar monitoring system chain integrated in VTS centre [2]. In both situations tracking of targets is enabled for the user and is provided by software manufacturer for enhanced traffic safety and surveillance. Tracking methods were discussed in [3-10]. Particularly interesting in inland waters are the systems provided for boats, which has very small scanners (ab. 0,6 m), which means theoretical horizontal beam width of 5,2°. This can be however reduced to 2,6° with advanced digital signal processing, called beam sharpening techniques. Such radars can be used not only on boats but also in River Information Services (RIS) systems for traffic monitoring. Aspects of sensors planning for RIS purpose were presented in [11-15]. In both situations screen resolution, understood as range and bearing discrimination, is crucial for target separation on screen and for target acquisition for target tracking.

2. Beam sharpening effectiveness in broadband radar

The main purpose of this paper is to present effects of FMCW radar beam sharpening. Beam width influences also directly on bearing measurement error. Thus, importance of beam sharpening possibilities has to be emphasized. The quality of radar information is also important, as such sensor could be fused with another navigational data sources to provide comprehensive navigational information. Very interesting is aspect of radar, AIS and other sensors fusion [16-21]. Very often for navigational data processing, Artificial Neural

Networks (ANN) are used [22-28]. Some aspects of other methods of navigational data processing were presented in [29 -35].

In scope of future sensor fusion, but also for radar navigation, there are many aspects of radar information affected directly by screen discrimination and indirectly by beam sharpening technique. Key elements on inland waters are:

- target separation
- target identification
- radar positioning (range and bearing measurements)
- target tracking.

The impact of beam sharpening on target separation derives from the angular size of echoes. If echoes are smaller, the distances between them are bigger and it is much easier to separate them visually. In such situation it is also much easier to identify targets by comparing radar picture with chart. This is of vital meaning while trying to establish radar position. The better discrimination is, the more accurate are the measurements. This influence mostly range measurements, during which size of echo is an important issue. The accuracy of measurements has a direct impact on target tracking, for which relative positions of targets are input values. It is assumed that in every situation listed above beam sharpening should have a positive impact.

3. Research concept

The research described in this paper aimed at checking analytical assumptions stated above with empirical research. For this purpose SIMRAD 4G broadband radar has been employed. It was mounted on a training boat of Maritime University of Szczecin – HYDROGRAF XXI. She is in fact floating laboratory for hydrographical and navigational purposes. She is a motor boat with the length of approx. 10 m and deadweight of about 2,5 GT. She is used mostly for hydrographic surveys and therefore is equipped with high quality hydrographic devices. It is however possible to use her for other purposes, therefore she is also equipped with navigational systems like AIS, ECDIS, etc. On-board radar is an important supplement of existing navigational equipment.

Research took place at the Odra River and radar was set to present both – screen with and without beam sharpening function. Continuous monitoring of radar screen was performed and some situations were recorded as screenshots. Research focused mostly on observation of river banks and occasionally on other targets, as this are crucial information from user's and RIS point of view.

4. Research results

Research results are presented in the selected radar screens with (4G) and without (3G) beam sharpening effect. In fig. 1 the influence of beam sharpening on river banks observation is presented. The river itself seems to be wider in the left side, as the echoes themselves are smaller. The further from radar antenna, the more influence of beam sharpening effect can be observed. Finally at the distance of about 500 meters river banks are not separated anymore and their echoes are connected.

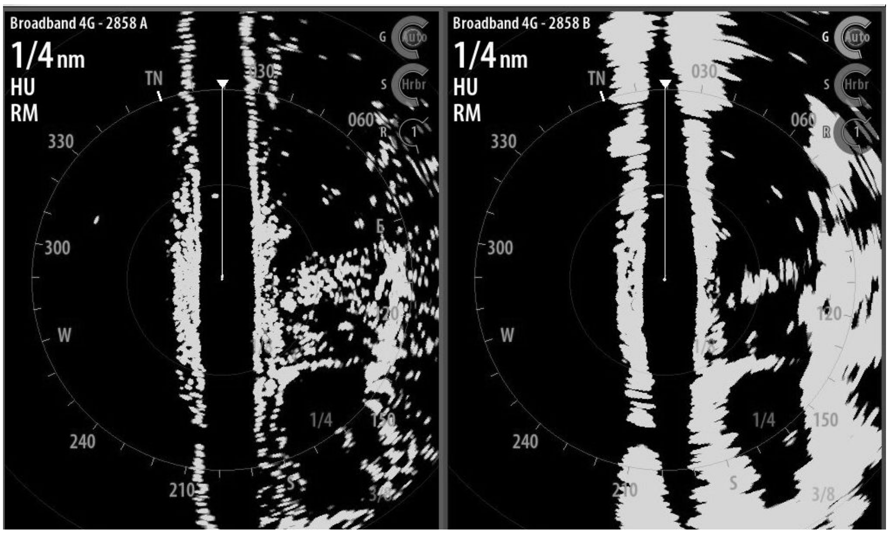

Figure 1. An example of river bank view with beam sharpening (left side) and without beam sharpening (right side)

In fig. 2 another example of target separation enhancement is given. Additionally a part of official electronic nautical chart is given in fig. 3 to compare radar screens with it. The chart is however oriented north-up, while radar screen is oriented head-up on course 170°.

It can be noticed on the pictures that only main fairway can be seen on picture without beam sharpening. The other canal (marked 1 in the right screenshot) is not discriminated on the screen and it can be treated as part of land or a small bay. This might be very confusing in practical navigation. The width of the canal is 62 meters and the banks are not separated at the distance of about 400 meters. This observation makes beam sharpening technique almost a necessary tool for navigating in inland waters with broadband radar.

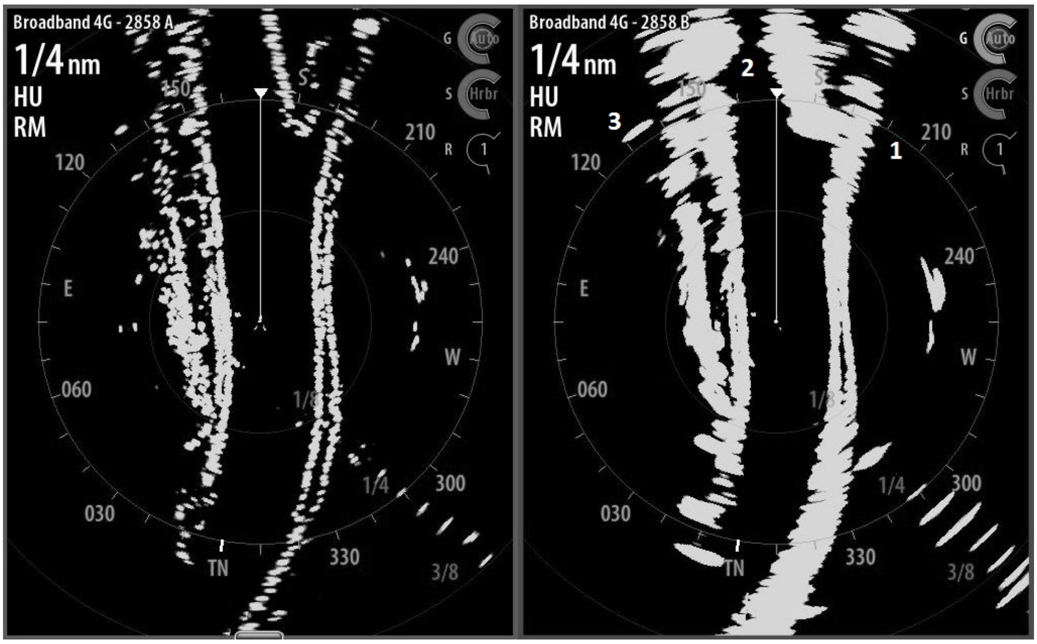

Figure 2. An example of target separation with beam sharpening (left side) and without beam sharpening (right side)

Apart of the canal also the main fairway is much narrower on 3G radar screen. Main fairway (marked 2 in the right screenshot) has a width of 150 meters and in 3G screen it is much closer (almost closed). This confirms earlier observations.

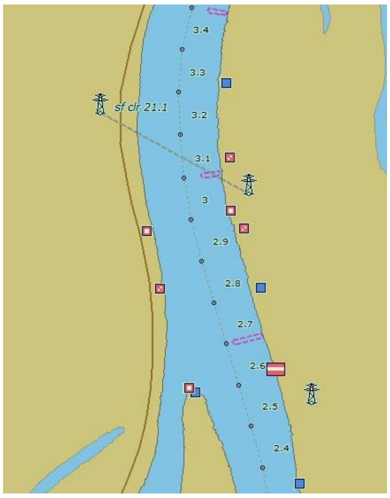

Figure 2. A part of InlandENC P17OD704 (source: www.ris-odra.pl)

It can be however noticed that additional beam sharpening has not always positive impact on target recognition. For example a tower located on the land can easily be seen in the 3G screen (marked 3 on right screenshot) and is much smaller in 4D screen. In the first sight it might be treated as one of many disturbances.

5. Conclusions

The paper discussed issues about beam sharpening in broadband radars with small antennas. This kind of solution is being more and more popular among recreational users. It also used in RIS system on the Odra River. The problem of beam sharpening is of particular importance on small boats which have to use small antennas on board. Usually angular resolution and discrimination derives directly from the size of antenna. In general the smaller antenna, the worse resolution and discrimination is. Beam sharpening might be a useful technique for improving detection and separation possibilities. It has been proved in the paper, based on research examples that beam sharpening gives very good results in most cases. In case of inland waters the main effect is preventing of artificial expanding of shores and as a result visual closing of some waterways on the radar screen. Some canals can be hard to find in distances of a few hundred meters. On the other hand however enlargement of echoes in radar picture without beam sharpening may be useful for detection of targets. Smaller targets can be easier noticed in the screen especially in longer distances. To sum up it can be said that beam sharpening technique may be very useful in inland waters in in many cases seems to be necessary. However users of broadband radars has to be familiar with the technique itself and they should remember that use of it performs some additional signal processing and radar screen itself is not raw representation of reflected radar waves.

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