Scientific Journals
of the Maritime University of Szczecin

Zeszyty Naukowe
Akademii Morskiej w Szczecinie

2015, 44 (116), 196–203
ISSN 1733-8670 (Printed)
ISSN 2392-0378 (Online)
DOI: 10.17402/077

Received: 31.08.2015
Accepted: 06.11.2015
Published: 07.12.2015

New radar system along the Polish coast and inside Polish ports

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Key words: National Maritime Safety System, radar subsystem, types of installed radars, radar parameters, installation positions, detection range calculation, radar subsystem evaluation

Abstract

This paper presents the radar system installed by the Polish maritime administration within the scope of the "National System of Maritime Safety (KSBM)" project. One of the main objectives of introducing the system is to improve the safety of navigation on the fairways, routes and in traffic separation schemes and ports, as well as the environmental protection of the coastal waters of Polish maritime areas. Radars are intended mainly for the early detection and accurate tracking of ships for the purpose of preventing maritime accidents and pollution of the sea and coast line. They are connected to a digital exchange network that allows remote handling and data transfer in relation to radar station – control centre – radar station and between control centres.

The basic technical parameters of the purchased radars, installation position and the detection ranges, calculated by means of the CARPET program for objects and conditions defined in the IALA Recommendation V-128, are described.

Introduction

The paper "Implementation of the Polish National Maritime Safety System (KSBM) – stage I and II" was presented at the conference described by the project "National Maritime Safety System – KSBM" which is being currently implemented by the Polish maritime administration within the scope of the Operational Programme "Infrastructure and Environment" for 2007–2013. It is being realized with a time delay with the support of EU funds, financed in the Priority VII "Environmentally-friendly Transport" under Measure 7.2 "Development of Maritime Transport". One of the main tasks of this project is establishing a so-called Marine Traffic Surveillance and Monitoring System based on modern radars, VTS, AIS, system of video cameras and VHF communication, designated for monitoring and analysis of the situation, managing maritime traffic in sensitive areas, warning of dangers and providing information relating to maritime safety in order to prevent maritime accidents and pollution of the sea and coast line, and to conduct efficient action in the event of their occurrence. The system covers Polish coastal waters and seaports from Szczecin and Świnoujście to the border with the Kaliningrad Region. The works were and are based on contracts signed 28.02.2011 (stage I – KSBN-I) and 20.12.2012 (stage II – KSBN-II). The first stage involved is the purchase and installation of radar, computer and radio equipment and the construction of a radio communication network, the second is mainly the fibre optical communication network.

This paper describes the radar components of the above-mentioned system, designed mainly for the early detection and accurate tracking of ships for the purpose of preventing maritime accidents and the pollution of the sea and coast line. Radars are connected to a digital exchange network that allows remote handling and data transfer in relation to radar station – control centre – radar station and between particular control centres. Radar parameters have been defined by the purchaser, based on those issued by the International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) Recommendation V-128 on Operational and Technical Performance of VTS Systems, edition 3 from June 2007 (IALA, 2007c) and Guideline 1056 "Establishment of VTS Radar Services", edition 1 from 2007 (IALA, 2007a). During the preparation, specifications for radar equipment was not yet available as IALA Guideline 1111 on Preparation of Operational and Technical Performance Requirements for VTS Systems was published in 2015 (IALA, 2007b) and its recommendations were not included in the prepared technical and operational requirements for the ordered equipment and systems.

Basic parameters of installed radars

The investor distinguished, according to the IALA recommendation V-128, three types of coastal radars which were the subject of the purchase (IALA, 2007c):

- Basic – applicable to VTS performing information service and, where applicable, navigational assistance service;
- Standard – applicable to all types of VTS as identified by IMO conducting information service, navigational assistance service and traffic organisation service in areas with medium traffic density and/or without major navigational hazards;
- Advanced – applicable to VTS working in areas with high traffic density and/or specific major navigational hazards.

Using a public tender procedure, depending on the functions envisaged for implementation (required range of work, accuracy of indications, etc.), the following numbers of particular types of pulse radars manufactured by the Danish company Terma were chosen (Terma, 2002; http://www.umgdy.gov.pl):

- 3 basic radars – single frequency Terma SCANTER 2001 fitted with 3.66 m (12-feet) long scanner;
- 18 standard radars (14 completely new radar stations and 4 replaced radars currently in operation) – single frequency Terma SCANTER 2001i with scanner 5.49m (18-feet) long;
- 6 advanced radars – Terma SCANTER 2001i FD with frequency diversity fitted with scanner 5.49 m (18-feet) long (radar in Ustka) and 6.405 m (21-foot) long (radars designated for other locations).

Prior to installation, the investor planned Frequency Modulated Continuous Wave (FM CW) radars in several places but decided against this investment, primarily because of the high prices of these devices.

Basic operating parameters of the above-mentioned Terma pulse radars are listed in Table 1.

The purchased radars used Slotted Wave Guide (SWG) scanners (antennas). They have several features available such as programmable Pulse Repetition Frequency (PRF), programmable Pulse Width (PW) and random stagger to enable task-specified setup of the transceiver. Auto-adaptive Sensitivity Control (ASC) to provide automatic two-dimensional Sensitivity Time Control (STC) eliminates the need for operator's settings of the radar during normal operation. Digital Fast Time Constant (FTC), sweep-to-sweep correlation (white noise suppression) and sweep-to-sweep integration are used to improve signal-to-noise ratio. Radar is designed for remote operation and has a Built-in Test Equipment (BITE) function providing continuous information on the transceiver condition. Independently of this function, each radar has a small display unit mounted together with a transceiver for service work, in addition to the operational display unit designated for installation in the traffic control centre (VTMS centre, VTS centre, harbour master duty officer's room, etc.). Remote Transceiver Control and Monitoring (RTCM) software and so-called Static Map Tool (SMT) provide remote radar control and transmission of radar video images using the network. For ease of radar control there is the ability to save 16 predefined profiles of control functions. Setting profiles are carried out in a block called Video Distribution and Tracking (VDT). This block creates a software package "SCANTER 2001 Control and Tracking Unit" running on a commercial PC. Particular profiles are defined during the installation and running of the VDT as sets of parameters corresponding to the different operating environments (weather conditions, tasks, radar, etc.). Correctly defined profiles should provide the proper values of radar transceiver parameters for radar working, according to the operator's requirements in current weather conditions. The network connection between VDT and the display unit containing the control function and monitoring allows the operator to work with specific echoes, setting zones with specific tracking characteristics and tuning some of the main parameters of the radar to optimize the profile (Terma, 2002).

Table 1. Basic operating parameters of the purchased Terma pulse radars (Terma, 2002)

Parameter	Value	
Transmitter and scanner		
	High power magnetron	Low power magnetron
Pulse width	50–1000 ns	40–300 ns
Nominal magnetron peak power	25 kW	4 kW
Peak power over magnetron lifetime	20 kW +2/–1 dB	3.0 kW +2/–1 dB
Standard transmitter frequencies	9375 ± 30 MHz	9410 ± 30 MHz
Special transmitter frequencies	9410 ± 30 MHz; 9170 ± 30 MHz; 9438 ± 25 MHz; and 9490 ± 30 MHz	9375 ± 30 MHz
Frequency for transmitters with frequency diversity	9170 MHz and 9438 MHz	
Pulse width (PW): very short; Short; Medium; Long; Very long	40 ns (pulse repetition frequency (PRF) – 800–8000 Hz, intermediate frequency bandwidth (IF BW) – 50 MHz); 50–120 ns (PRF – 800–8000 Hz, IF BW – 20 MHz); 120–300 ns (PRF – 600–3300 Hz, IF BW – 8 MHz); 300–600 ns (PRF – 400–2200 Hz, IF BW – 3 MHz); 600–1000 ns (PRF – 400–1200 Hz, IF BW – 3 MHz)	
Pulse rise and fall times	< 20 ns and < 30 ns	
Pulse repetition frequency (pseudo random) stagger available in programmable mode	0% stagger – no staggering; 2%, 4% and 8% staggers – from +2 to –2% from nominal PRI in 7 steps	
Sector transmission[1]	Available 4 sectors 10° – 350° width	
Gain at the antenna input	≥38 dB for scanner 6.405 m long; ≥ 34 dB for other scanners	
Width of the characteristic in the azimuth	≤ 0.60° for scanner 3.66 m (12-feet) long; ≤ 0.42° for scanner 5.49 m (18-feet) long; ≤ 0.36° for scanner 6.405 m (21-foot) long	
Width of the characteristic in the vertical	≤ 0.16° for –3 dB and ≤ 0.55° for –20 dB for all scanners	
Azimuth coder	8192 pulses	
Scanner rotation rate	10 – 48 rpm for scanner 3.66 m (12-feet) long; 10 – 24 rpm for scanner 5.49 m (18-feet) long; 6 – 66 rpm for scanner 6.405 m (21-foot) long	
Receiver		
Noise level	Normal – 2.5 dB, overall in 0–30°C ambient temperature – 3.5 dB, overall within 30–55°C ambient temperature – 4.0 dB	
Intermediate frequency (IF) amplifier	Logarithmic, fast response	
Intermediate frequency	100 MHz	
Dynamic range	> 105 dB, combining active and saturation region	
Spurious signals suppression level	≥18 dB (typical value – 20 dB)	
Analogue-to-Digital (A/D) conversion	8-bit, 80 MHz	
Fast Time Constant (FTC)	Time constant selectable in the range 0.1 to 0.2 μs	
Static (blanking) map:		
• Range resolution	Number of cells – 1024; cell size at minimum and maximum ranges – 10 m and 168 m;	
• Azimuth resolution	512 cells, corresponding to 0.7°	
Dynamic map:		
• Range resolution	Number of cells – 256; cell size at minimum and maximum ranges – 41 m and 672 m;	
• Azimuth resolution	128 cells, corresponding to 2.8°	
Sea clutter discrimination	3 (single scan, 2 scans, 3 scans)	
Mean Time Between Failure (MTBF)	20000 hours	
Data communication		
Number of serial communication lines	4 including 1 reserved for communication between units	
Interface level	RS-422A / RS-232	
Protocols	Terma 262020 SI, NMEA 0183 (Subset)	

[1] – defined as either prohibit sector or transmit sector; the area outside a sector is denoted blanking area.

Proposed as advanced equipment, the pulse radar Terma SCANTER 2001i FD works with frequency diversity. This means that it has two transceivers, as shown in Figure 1. Its magnetrons transmit sequential pulses with the same width and power but on two different frequencies, 9170 MHz and 9438 MHz respectively. By proper synchronisation between the two transmitters, the two high-frequency pulses are transmitted by the antenna in different directions (giving a so-called squint effect), immediately after each other. The diplexer ensures guidance of these two frequency pulses to the scanner and guidance of the received echoes to the corresponding receivers. The squint effect makes sure that the sea's surface and objects are visible from different angles and gives an additional advantage by integrating pulses in the same direction, but with the difference of the squint angle apart, in effect providing both time and frequency diversity. The two radar video signals, corresponding to the same horizontal scanner directions, are combined using different logical operations (AND, ADD or range dependent combinations of the two). The radar video processor corrects for the difference in squint between the two frequencies used and aligns the sweeps angularly by correcting for the delay between the first and the second pulse in each pulse repetition interval (Terma, 2002).

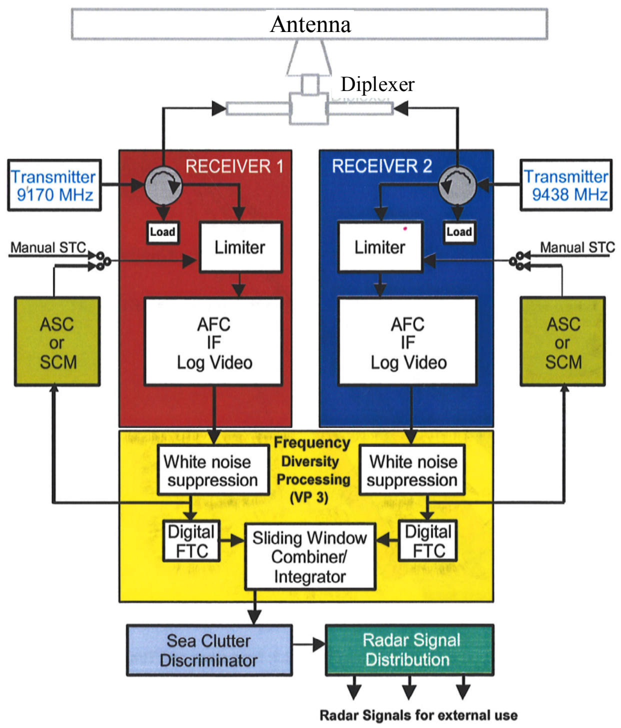

Figure 1. Scheme of the radar Terma SCANTER 2001i FD (with frequency diversity) (Terma, 2002)

The advantages of frequency diversity are (Terma, 2002):

– The total transmitted power is the total combined power of the two pulses integrated non-coherently;
– Target fluctuations are reduced after integration of signals from independent pulses;
– Targets and clutter are hit by the two beams separated by the difference in squint angle; it means that radar echoes from clutter having the usual rapid RCS variation will average rather than add up, whereas echoes from surface objects like vessels, buoys, etc. will add rather than average.

The combined effect of frequency diversity processing is reduced fluctuation of desirable targets and enhancement of targets received from real objects relative to the clutter. The mentioned benefit of the additional power on target and the reduction in target fluctuations is highly dependent on the target characteristics. Full benefit of the frequency diversity can only be obtained when dynamic characteristics are adapted to actual weather condition with complex clutter situations typical in most coastal areas. Due to that, Auto-adaptive Sensitivity Control (ASC) is standard for such applications (Terma, 2002).

The STC (Sensitivity Time Control) is utilized for the discrimination of sea clutter and close range echoes. Its characteristics are programmable and remotely controllable. Additionally, the attenuation can be controlled by feedback signals from the ASC (Auto-adaptive Sensitivity Control), providing suppression of clutter signals automatically adapted to actual weather conditions.

The signal processing module consists of (Terma, 2002):

- The video processor performing an 8-bit analogue to digital conversion of the radar video signal, its digital processing and output signals;
- The ASC optimising detection of real objects by automatic adaptation of the voltage threshold in range and azimuth to the clutter and noise level (the clutter level is calculated in a number of small range-azimuth cells for a radar scan, based on the actual clutter level in a number of surrounding reference cells after the exclusion of stationary targets);
- The Static Clutter Map (SCM) creating a grid for masking of the static clutter sources in close range applications like ports;
- The Sea Clutter Discriminator (SCD) performing discrimination between echoes from objects on the water's surface and sea clutter by scan-to-scan processing of the radar video signal realised in 3 parallel channels:

- The first channel performing sliding window correlation with very low threshold over 3 consecutive scans designated to distinguish clutter and very small objects with slow speed, normally up to 4.1 m/s (8 knots);
- The second channel performing sliding window correlation with low threshold over 2 consecutive scans designated to distinguish clutter and small objects with medium speed, normally up to 8.2 m/s (16 knots);
- The third channel without scan-to-scan correlation with normal detection threshold to detect bigger vessels sailing faster than 8.2 m/s (16 knots).

The white noise cancellation is done using 3 out of 4 sweep-to-sweep correlations.

Installation positions and detection ranges of purchased pulse radars

The investor defined the position and height of the particular radar scanner installations taking into account the currently available technical infrastructure and the required maximum and minimum values of detection distances.

According to the IALA Recommendation V-128, edition 3 from June 2007, detection distances (ranges) of the purchased radars were calculated for the intended position and height of their scanners' installation (presented in the Project KSBM documentation (Maritime Office, 2014)) and described in the IALA recommendation objects reflecting radar pulses and propagation conditions, using Computer Aided Radar Performance Tool (CARPET) prepared by Toegepast Natuurkundig Onderzoek (TNO) Physics and Electronics Laboratory in the Netherlands. It should be emphasized that the program CARPET can only simulate the point object of a specific radar cross section (RCS) located at a predetermined height above sea level (ASL), while the real reflecting objects are continuous over their entire height ASL. In addition, this program does not allow for consideration of the digitalization process carried out in the radar and allow a further improvement in detection probability, particularly in the area of clutter generated by the sea's surface. This means that the real values of detection distances should be greater than those calculated in this manner.

Installation positions and detection ranges of basic radars

As required by the IALA Recommendation V-128, edition 3 from June 2007, basic radar shall detect an object with RCS = 3 m^2 and a height of 2 m ASL when the sea state is degree 3 in the Douglas scale, in the absence of rainfall and during rainfall with an intensity of 2 mm/h from a distance of 7.408 km (4 nautical miles (NM)) (IALA, 2007c).

Calculations carried out using the program CARPET allowed detection ranges to be achieved for these radars and installation positions presented in Table 2.

Table 2. Basic radar detection ranges for the sea state degree 3: in the absence of rainfall (condition 1) and during rainfall with an intensity of 2 mm/h (condition 2)

Height and position of radar scanner installation, remarks	Detection range	
	Condition 1	Condition 2
At a height of 12.12 m ASL on the new radar tower built in the northern part of the Kosa Peninsula in Świnoujście (location Kosa-N)	12.22 km 6.6 NM	9.07 km 4.9 NM
At a height of 16.30 m ASL on the new radar tower built in the western part of the Uznam Island near the Piastowski Canal (location Paprotno)	14.08 km 7.6 NM	10.74 km 5.8 NM
At a height of 17.5 m ASL on the radar tower in Inoujście	14.45 km 7.8 NM	11.11 km 6.0 NM
Detection range recommended by IALA Recommendation V-128	7.408 km 4 NM	7.408 km 4 NM

The results presented in Table 2 indicate that all three basic radars fulfil IALA recommendations regarding detection distances. They have these distances for object and conditions defined by IALA, significantly exceeding the distance of detection set out in this recommendation. This may result in a significant increase in the minimum detection range, which could be disadvantageous in particular for radar locations in the VTMS Szczecin–Świnoujście.

Installation positions and detection ranges of standard radars

According to the IALA Recommendation V-128 edition 3, standard radar shall detect an object with RCS = 10 m^2 and a height of 3 m ASL when the sea state is degree 3 in the Douglas scale, in the absence of rainfall from a distance of 12.96 km (7 NM) and during rainfall with an intensity of 4 mm/h from a distance of 7.408 km (4 NM) IALA, 2007c).

Calculations carried out using the program CARPET allowed detection ranges to be achieved for these radars and installation positions presented in Table 3.

Table 3 presents the results of calculations conducted according to the IALA Recommendation V-128, edition 3, which indicate that all standard

Table 3. Standard radar detection ranges for the sea state degree 3: in the absence of rainfall (condition 1) and during rainfall with an intensity of 4 mm/h (condition 2)

Height and position of radar scanner installation, remarks	Detection range	
	Condition 1	Condition 2
At a height of 39.4 m ASL on the roof of the observation post in Świnoujście. Radar fitted with SCD (Sea Clutter Discriminator) module, designated for observation of ships on the fairway to the port	18.52 km 10.0 NM	14.45 km 7.8 NM
At a height of 34.5 m ASL on existing radar tower in the Base of Aids to Navigation (BON) in Świnoujście	15.93 km 8.6 NM	11.48 km 6.2 NM
At a height of 23.7 m ASL on the top of existing tower in the ferry terminal in Karsibór	14.63 km 7.9 NM	11.11 km 6.0 NM
At a height of 28.5 m ASL on existing tower of the first fairway gate Szczecin – Świnoujście. Radar fitted with SCD module	15.19 km 8.2 NM	12.04 km 6.5 NM
At a height of 64.5 m ASL on the rear beacon of the leading light "Police"	23.34 km 12.6 NM	18.71 km 10.1 NM
At a height of 35.0 m ASL on the roof of elevator "Snop" in Szczecin	17.78 km 9.6 NM	13.71 km 7.4 NM
At a height of 66.5 m ASL on the mast on roof of elevator "Ewa" in Szczecin	24.08 km 13.0 NM	18.89 km 10.2 NM
At a height of 32.4 m ASL on the new radar tower built on the Dąbrowiecki wharf in Szczecin	16.11 km 8.7 NM	12.41 km 6.7 NM
At a height of 28.25 m ASL on the tower near the entrance to the port of Kołobrzeg.	15.56 km 8.4 NM	12.04 km 6.5 NM
At a height of 30.5 m ASL on the new radar tower built in the port of Darłowo	15.74 km 8.5 NM	10.56 km 5.7 NM
At a height of 29.0 m ASL on the mast on roof of the Harbour Master building in Gdańsk – New Port. Radar designated for observation of ships on the fairway and roadstead of this port and in the western part of the Gulf of Gdańsk (near Sopot)	16.11 km 8.7 NM	12.41 km 6.7 NM
At a height of 19.9 m ASL on the new radar tower built on Wendy wharf near the building of Maritime Office in Gdynia (location Gdynia-S). Radar fitted with SCD module, designated for observation of the south entrance to the port of Gdynia and anchorages of this port	12.96 km 7.0 NM	10.00 km 5.4 NM
At a height of 19.2 m ASL on the radar tower built on the southern breakwater in the port of Hel (location Hel-SW). Radar designated for observation of vessels approaching and leaving this port.	12.96 km 7.0 NM	10.00 km 5.4 NM
At a height of 42.05 m ASL on the lighthouse "Hel" in the place of antenna being used previously (location Hel-LM). Radar fitted with SCD module, designated for observation of ships approaching and leaving TSS "Zatoka Gdańska"	19.08 m 10.3 NM	15.19 km 8.2 NM
At a height of 55.0 m ASL on the lighthouse "Krynica Morska" in the place of antenna being used previously. Radar fitted with SCD module designated for observation of ships in the eastern part of the Gulf of Gdańsk	22.04 km 11.9 NM	17.41 km 9.4 NM
At a height of 18.0 m ASL on the existing radar tower in Górki Zachodnie in place of antenna being used previously. Radar fitted with SCD module designated for observation of ships on the fairway to the Gdańsk Port Północny	12.41 km 6.7 NM	9.45 km 5.1 NM
At a height of 75.0 m ASL on the roof of Harbour Master building in Gdańsk Port Północny in the place of antenna being used previously. Radar fitted with SCD module designated for observation of ships on the fairway to this port and on its anchorages	24.63 km 13.3 NM	19.45 km 10.5 NM
At a height of 34.0 m ASL on the roof of Harbour Master building in Gdynia in the place of antenna being used previously. Radar fitted with SCD module designated for observation of ships on the fairway to this port and on its anchorages	17.78 km 9.6 NM	13.52 km 7.3 NM
Detection range recommended by IALA Recommendation V-128	12.96 km 7 NM	7.41 km 4 NM

radars, with the exception of the two planned for installation in locations Gdynia-S and Hel-SW, have detection distances of an object defined by IALA which exceed, sometimes significantly, the distance of detection set out in this recommendation. This may result in a significant increase in the minimum detection range which can be disadvantageous in some radar locations, mainly in the VTMS Szczecin–Świnoujście. Radar planned for installation in the location Hel-SW fulfils the IALA recommendation but does not enable observation of vessels entering and leaving the port in Hel due to the value of the minimum detection distance being too high (Figure 2).

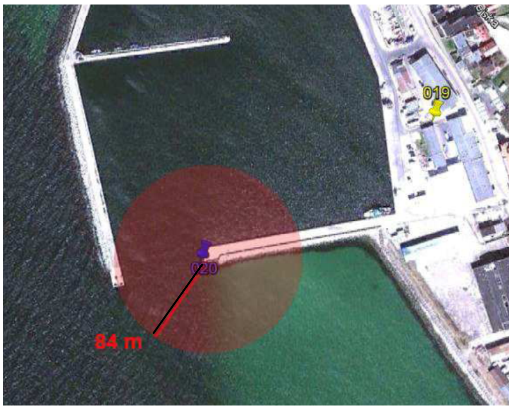

Figure 2. Minimum detection distance of radar planned for installation in the location Hel-SW

Table 4. Advanced radars detection ranges for the sea state degree 8: in the absence of rainfall (condition 1) and during rainfall with an intensity of 10 mm/h (condition 2)

Height and position of radar scanner installation, remarks	Detection range	
	Condition 1	Condition 2
At a height of 42.80 m ASL at the observation post in Świnoujście in the place of one of the old radar scanner. Radar designated for observation of ships on the fairway to the port and in the Pomorska Bay	39.26 km 21.2 NM	34.08 km 18.4 NM
At a height of 35.3 m ASL on the new radar tower in the southern part of the Chełminek Island	34.08 km 18.4 NM	31.48 km 17.0 NM
At a height of 37.0 m ASL on the new radar tower on SW side of the building in Modlinek (Ustka). Radar designated for observation of ships in the traffic separation Schema (TSS) "Ławica Słupska"	36.11 km 19.5 NM	31.85 km 17.2 NM
At a height of 32.4 m ASL on top of the reinforced concrete tower in Łeba on Kosciuszko Street No. 1. Radar designated for observation of ships in the approaching area to the TSS "Ławica Słupska"	32.78 km 17.7 NM	30.37 km 16.4 NM
At a height of 24.0 m ASL on the new tower built on the head of the eastern breakwater in Władysławowo. Radar for ships' observation in the area north of Rozewie and at the approach to this port	30.00 km 16.2 NM	27.41 km 14.8 NM
At a height of 45.95 m ASL in the eastern part of the platform Baltic-Beta (55°28,877'N, 018°10.966'E). Radar designated for ships' observation in the area around positions of the Lotos Petrobaltic platforms	38.34 km 20.7 NM	34.45 km 18.6 NM
Detection range recommended by IALA Recommendation V-128	37.04 km 20 NM	33.34 km 18 NM

Installation positions and detection ranges of advanced radars

According to the IALA Recommendation V-128 edition 3, advanced radar shall detect an object with RCS = 1000 m^2 and a height of 12 m ASL when the sea state is degree 8 in the Douglas scale, in the absence of rainfall from a distance of 37.04 km (20 NM) and during rainfall with an intensity of 10 mm/h from a distance of 33.336 km (18 NM) (IALA, 2007c). All radars shall be fitted with SCD modules.

Calculations carried out using the program CARPET allowed detection ranges to be achieved for these radars and installation positions presented in Table 4.

Conducted calculations showed that the IALA Recommendation on detection possibility will only be met by the radars installed in Świnoujście and on the platform Baltic-Beta.

Conclusions

The investor defined in the document "Description of the order" the number of ordered radars, their basic operating parameters and the required positions and height of their antennae installation. Additionally the investor decided that they should have a detection capability as outlined in the IALA Recommendation V-128 on Operational and Technical Performance of VTS Systems, edition 3 from June 2007 (Maritime Office, 2014).

Calculations of detection possibilities of the purchased Terma pulse radars were made, using the IALA recommended CARPET prepared by TNO Physics and Electronics Laboratory in the Netherlands, for planned height of radar scanner installations and objects defined in the mentioned IALA Recommendation V-128. These allowed the following conclusions to be drawn:

1. Four advanced radars designated for installations in Chełminek, Modlinek (Ustka), Łeba and Władysławowo have maximum detection ranges smaller than that mentioned in the IALA publication. This is alarming, particularly in the case of radars for the observation of vessels in the TSS "Ławica Słupska" and at the approach to it from the east. Calculations showed that radars in Łeba, Władysławowo, and on the platform Baltic-Beta do not ensure the continuity of observation of traffic in the whole sensitive area north of Rozewie, where the courses of ships sailing to and from TSS "Ławica Słupska" intersect, as well as to and from the routes between the Ławica Słupska and Bornholm and north of the Bornholm in relation to: ports in the Gulf of Gdańsk and the eastern part of the Baltic Sea – the Danish Straits, the Kiel Canal and ports of the western Baltic Sea (Figure 3).
2. All standard radars, with the exception of the two planned for installation in the locations Gdynia-S and Hel-SW, are characterized by detection ranges significantly exceeding the distance of detection set out in the IALA document. The main reason for this is a large scanner installation height resulting in a correspondingly large value of the minimum detection distance, which may prevent observation of ships in sensitive areas, for example in the entrance to the port. It should also be emphasized that the fulfillment by radar of IALA recommendations does not always mean the fulfillment of users' expectations. For example, radar planned for installation in the location Hel-SW and designated

for observation of vessels approaching and leaving this port fulfils IALA recommendations, but due to the value of the minimum detection distance being too high, observation of these vessels is impossible (Figure 2).

3. All three basic radars have detection distances calculated for objects as defined by IALA which significantly exceed the distance of detection set out in Recommendation V-128. The effect of this may be similar to that described in the previous conclusion.

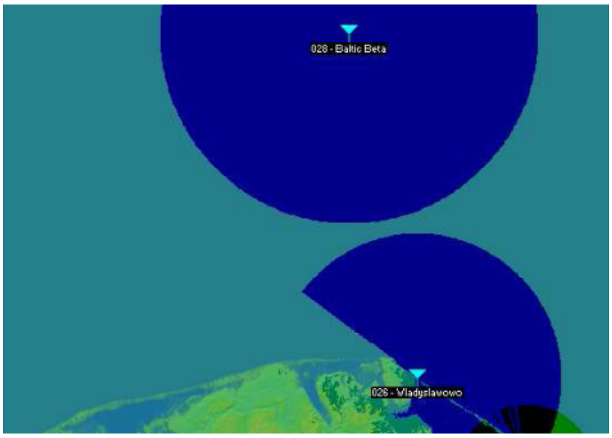

Figure 3. Detection ranges of radars installed in Władysławowo and on the platform Baltic Beta, calculated according to the IALA Recommendation V-128

A separate issue is the reference to the radar detection possibilities described in the IALA Recommendation V-128, edition 3. This publication recommends the calculation of the radar detection range for sea state expressed in Douglas scale: degree 3 for basic and standard radars and degree 8 for advanced radars, regardless of their installation position. According to the IALA Guideline 1111 "Preparation of Operational and Technical Performance Requirements for VTS Systems", Edition 1 from May 2015 (IALA, 2007b), the CARPET models adopted for this guideline derive the mean sea clutter reflectivity from the clutter model developed by the Georgia Institute of Technology (GIT). The average wave height in this model is derived from the hydrographic sea state so that fully developed sea conditions are assumed. The sea state 8 means wave heights: average 5.1 m and significant 8.5 m, sea state 3, respectively, 0.7 m and 1.2 m. These values of the height of sea waves are different to those in meteorological publications, pursuant to which degree 8 is characterized by waves with a height of 9–14 m and degree 3 by waves with a height of 0.5–1.25 m. These differences in the height of waves at degree of 8 in the Douglas scale, should be explained first. Besides, detection capabilities of radars, regardless of their type, intended for installation in different places but along the same coastline should be determined for the same hydro-meteorological conditions. It is difficult to understand why the detection distances of radars designated for sea surface observation and installed along the Polish coast in Kołobrzeg, Darłowo, Ustka, Łeba and Władysławowo should be calculated for different sea states.

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