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Fusion of Data Received from AIS and FMCW and Pulse Radar - Results of Performance Tests Conducted Using Hydrographical Vessels "Tukana" and "Zodiak"

A. Krol, T. Stupak & R. Wawruch
Gdynia MaritimeUniversity, Gdynia, Poland

M. Kwiatkowski, P. Paprocki & J. Popik
Telecommunication Research Institute Ltd., Gdansk Division, Poland

ABSTRACT: Paper presents results of performance tests of the Integrated Vessel Traffic Control System realizing fusion of data received from shore based station of the Automatic Identification System (AIS) and pulse and Frequency Modulated Continuous Wave (FMCW) radars and presenting information on Electronic Navigational Chart issued by the Polish National Hydrographical Service – Hydrographical Office of the Polish Navy. Tests were conducted in real sea conditions using hydrographical vessels "Tucana" and "Zodiak" owned by the Maritime Office in Gdynia.

1 INTRODUCTION

Integrated Vessel Traffic Control System realizing fusion of data received from shore based station of the Automatic Identification System (AIS) and pulse and Frequency Modulated Continuous Wave (FMCW) radars and presenting information on Electronic Navigational Chart issued by the Polish National Hydrographical Service – Hydrographical Office of the Polish Navy is described in other paper presented on this conference. Described system was designed, built and tested in the scope of research work financed by the Polish Ministry of Science and Higher Education as developmental project No OR00002606 from the means for science in 2008-2010 years.

This paper described results of the exploitation test of the constructed system conducted in real sea conditions using hydrographical vessels "Tukana" and "Zodiak" owned by the Maritime Office in Gdynia.

2 DESCRIPTION OF THE MEASUREMENTS

Measurements were conducted on 30th of September and 24th of November 2010 using:

- Installed on shore in the radar laboratory of the Gdynia Maritime University:
  - Pulse radar Raytheon NSC 34;
  - FM-CW radar built by the Przemysłowy Instytut Telekomunikacji S.A.; and
  - Class A ship borne AIS type R4 produced by SAAB.
- Hydrographical vessel "Zodiak" equipped with:
  - Receiver GPS RTK Trimble R7 L1L2 using during the tests GPS reference station ID 745 situated in Gdynia; and
  - Ship borne AIS R4 produced by SAAB.
- Hydrographical vessel "Tucana" equipped with:
  - Receiver GPS RTK R7 using during the tests the same GPS reference station; and
  - Ship borne AIS R4 produced by SAAB too.

Basic parameters of utilized ships and radars are described in Tables 1-3. Vessels are presented in Figures 1 & 2.

Table 1. Basic parameters of the hydrographical vessels "Zodiak" and "Tucana"

Ship's parameter	Value	
	Zodiak	Tukana
Displacement	751	71
Length	61.3 m	23.0 m
Breadth	10.8 m	5.8 m
Mean draught	3.3 m	2.2 m
Power	2 x 706 kW	2 x 280 kW
Maximum speed	14.0 knots	12.0 knots
Height of the radar scanner above sea level	16 m	6.5 m

During the measurements were good weather conditions without rainfalls. There were sea waves 0.5-1m high.

The main goal of the test was assessment of the accuracy of information about ship's position, course over ground (COG) and speed over ground (SOG) received from both shore based radars and AIS before and after their fusion in comparison with values of these parameters indicated by ship borne DGPS receiver. Due to that there were automatically registered positions, COG and SOG of the vessel indicated by:

Table 2. Basic parameters of the radar Raytheon NSC 34

Parameter	Value
Output power	25 kW
Carrier frequency	9410±30 MHz
Range	0.25; 0.5; 0.75; 1.5; 3; 6; 12; 24; 48; 96 NM
Pulse length	0.06 µs, 0.25 µs, 0.5 µs, 1.0 µs,
Pulse repetition freq.	3600 Hz, 1800 Hz, 900 Hz
IF bandwidth	20 MHz, 6 MHz
Antenna length	2.1336 m
Beam width horizontal/vertical	1.0°/23° dB
Polarisation	Horizontal
Gain	29 dB
Rotation speed min/max.	22/26 rpm
Display size	28 inch
Resolution	1600 × 1200 pixels
Acquisition	automatic up to 40 targets
Tracking	automatic of all acquired target
Range accuracy	0.3% of selected range or 6.4 m (whichever is greater)
Angle resolution	0.3°
Bearing accuracy	1.0°

Table 3. Basic parameters of the FM-CW radar

Parameter	Value
Output power	1mW-2W (switched)
Carrier frequency	9.3 – 9.5 GHz
Frequency deviation switched according to the required scale range:	54 MHz at 6 NM 27 MHz at 12 NM 13.5 MHz at 24 NM
Range scales	0.25 NM – 48 NM
Modulation	DDS based linear FMCW
Sweep repetition period	1 ms
IF bandwidth	4 MHz
Frequency curve slope of IF amplifier	6 dB/oct; 12 dB/oct; 18 dB/oct
Antenna length	3.6 m
Beam width horizontal/vertical	0.70°/22° dB
Polarisation	Horizontal
Gain	32 dB
Rotation speed min/max	12/30 rpm
FFT signal processing	8192-points FFT
Sampling frequency	8 MHz
Display size	22 inch
Resolution	1280 × 1024 pixels
Acquisition	automatic up to 100 targets
Tracking	automatic of all acquired targets
Range accuracy	1% of selected range or 50 m (whichever is greater)
Angle resolution	0.1°
Bearing accuracy	0.7°

Figure 1. Hydrographical vessel "Zodiak"

Figure 2. Hydrographical vessel "Tucana"

– GPS RTK receivers onboard ships;
– AIS and radars Raytheon NSC 34 and FM-CW installed onshore in radar laboratory; and
– Display unit of the integrated system after fusion of data from above mentioned sensors.

Figure 3 presents complete track of the ship "Zodiak". Dots indicate positions in ten minutes time intervals.

Figure 3. Complete track of the ship "Zodiak" during the measurements showing its positions received from onboard DGPS MX 420 receiver.

In figure 11 is presented part of the "Zodiak" track utilised for analysis presented in further part of this paper.

Figure 4 shows track of the vessel "Tukana" during the measurements received from onboard GPS RTK receiver and from shore based radar Raytheon.

3 RESULTS OF THE MEASUREMENTS

3.1 *Accuracies of the data available on shore from AIS and radars*

Tested integrated system performs fusion of data received from two connected radars and AIS. Due to that one of the main goals of the described tests were measurements of the accuracies of data available from shore based AIS station and radars and computation of their errors by comparison with data registered in onboard GPS receiver for the same moments of time.

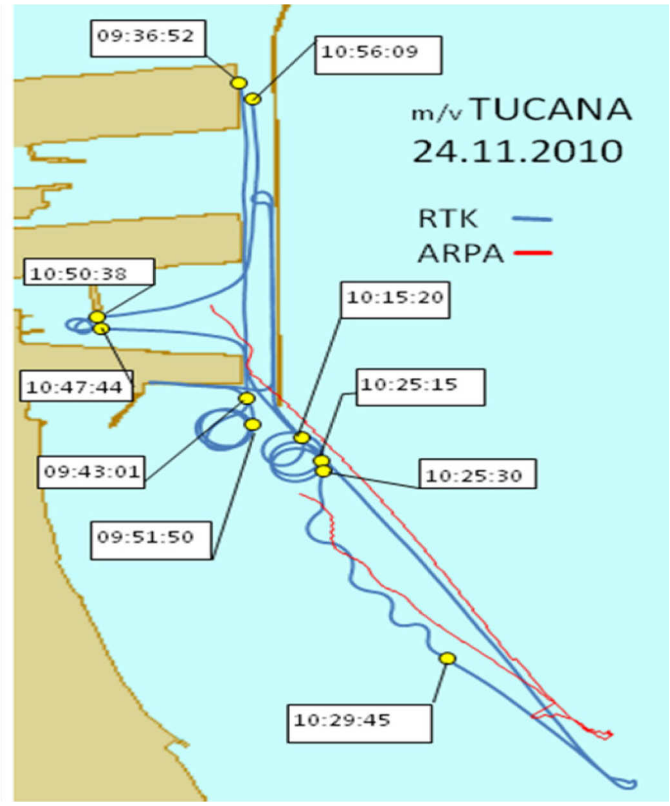

Figure 4. Track of the vessel "Tucana" during the measurements received from onboard GPS RTK receiver and from shore based radar Raytheon.

Figure 5 presents differences during the test between ship's positions, course over ground (COG) and speed over ground (SOG) available for the same moments of time onshore from AIS station and onboard "Zodiak" from DGPS receiver. They were accounted as differences between data: last received from onshore AIS and presented by onboard DGPS receiver. Errors arise due to the time differences between receiving by AIS data from ship's GPS receiver and its transmission according to the SOTDMA time schedule mainly. Additionally not all ship's transmissions were received by the shore AIS station. For ship's speed during the test (approximately 4.6 m/s) vessel's way between two consecutive AIS transmission was equal to 45 m (for passages with steady courses) or approximately 15 m (for course and/or speed alteration). Any fault in receiving AIS message causes errors directly proportional to this way.

Received results are compliant to conclusions done on the base of measurements of the AIS data accuracies conducted on the ship "Dar Młodzieży" and described in [1].

Radars begun to track echo of „Zodiak" after leaving by this ship port in Gdańsk and lost vessel at the entrance to the port in Gdynia when they connected its target with echo from coastline. Tracking was resumed after leaving the port and continued during ship's passage back to the Gdańsk.

Figure 6 presents differences between values of courses speeds and positions indicated onshore by ARPA Raytheon NSC 34 and by onboard DGPS receiver.

Figure 7 shows accuracies of ship's positions received from FM-CW radar during the test conducted with vessel "Zodiak" and calculated in relation to its AIS positions. Errors distribution of these positions indicated incompatibility of cartographical coordinate systems used for calculation of ship's positions transmitted by AIS and received on the base of radar measurements. It was eliminated by corrections introduced to the radar coordinates (0.0049' to the North and 0.0016' to the West). Corrected radar data was used for its fusion with information received through AIS system.

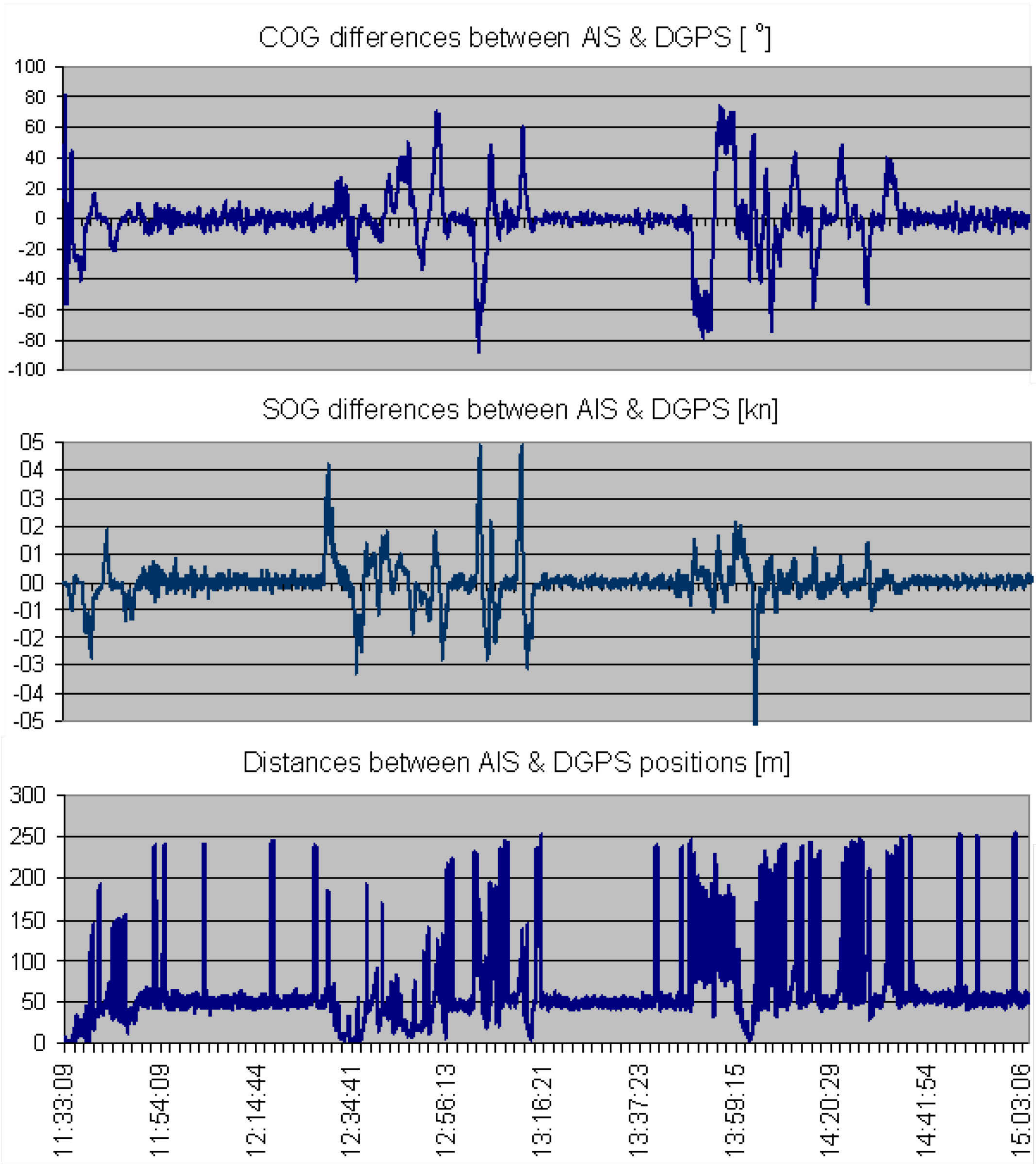

Figure 5. Differences between values of courses, speeds and positions available from onshore AIS and DGPS receiver onboard the ship

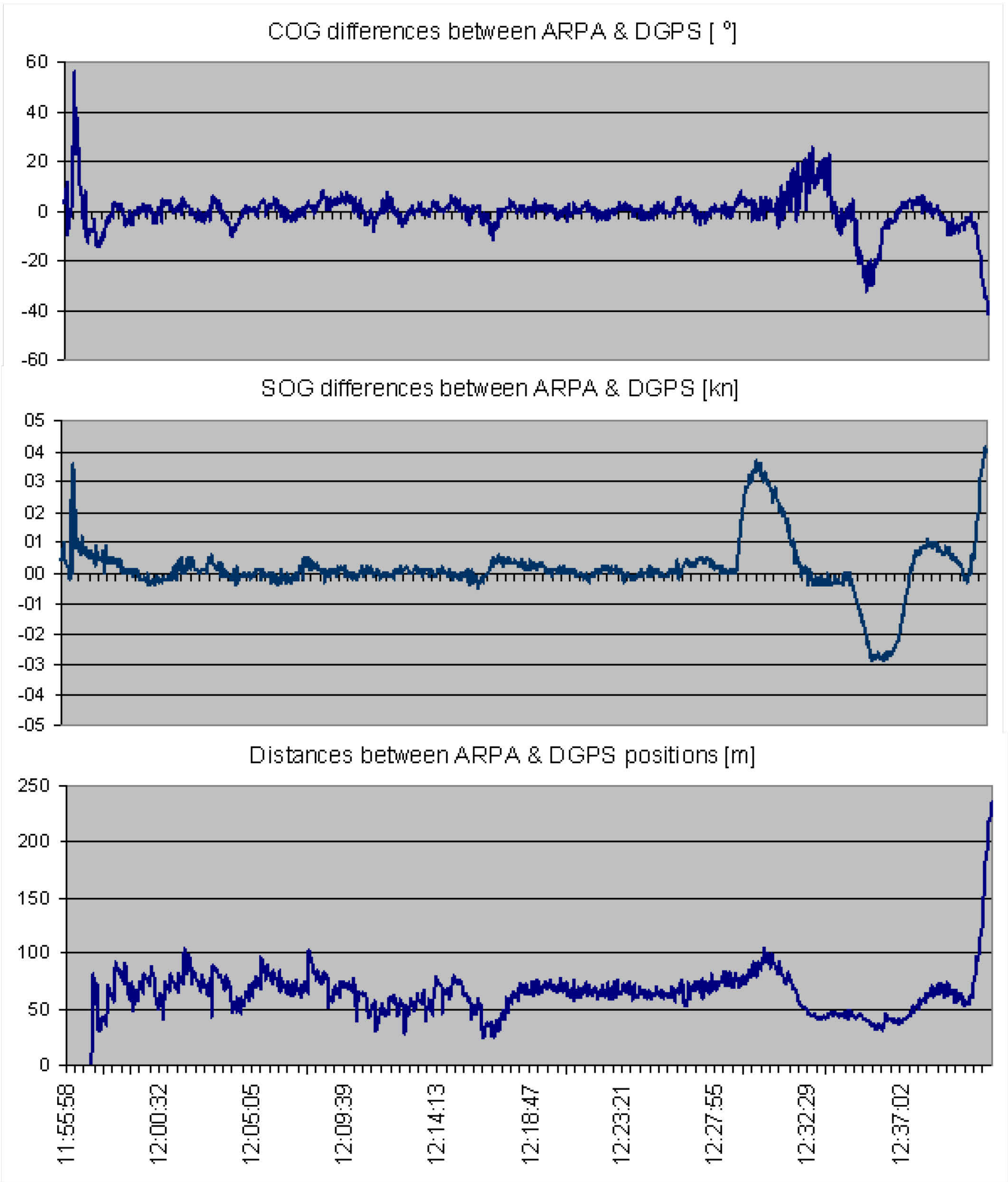

Figure 6. Differences between values of courses speeds and positions available from onshore radar Raytheon and DGPS receiver onboard the ship

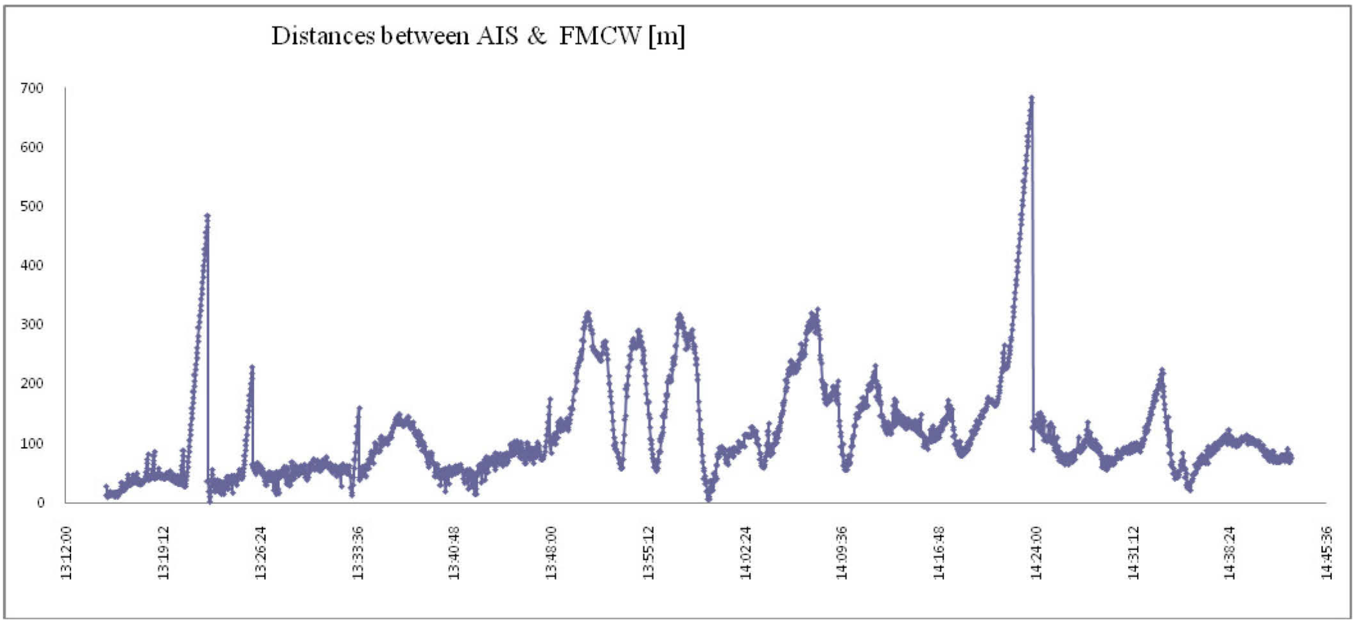

Figure 7. Accuracy of positions of vessel “Zodiak” received from FMCW radar

3.2 *Data fusion*

Data after its fusion is presented in Figures 8-11.

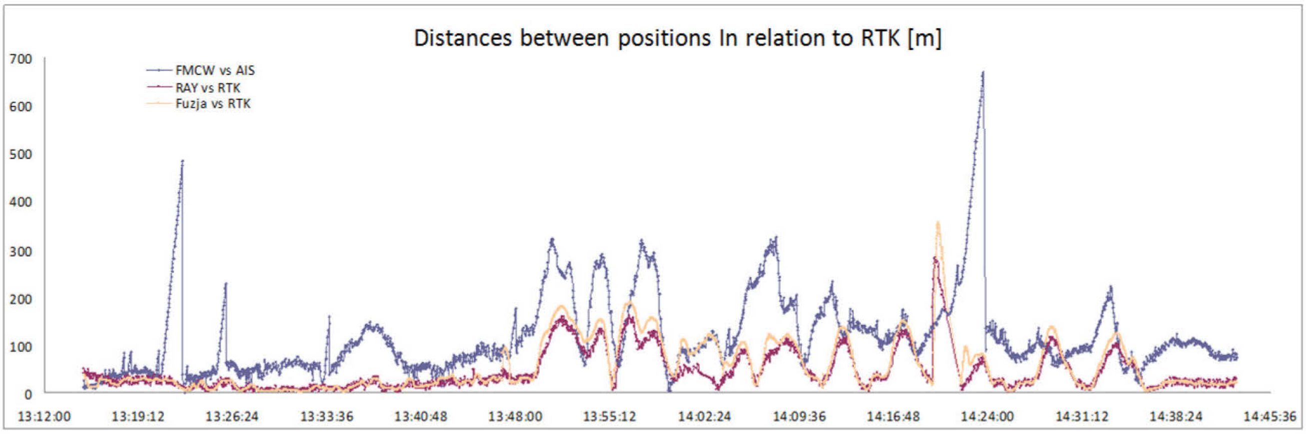

Figure 8. Distances between ship’s positions indicated by particular radars and display unit of the integrated system (after data fusion) and AIS or GPS receiver

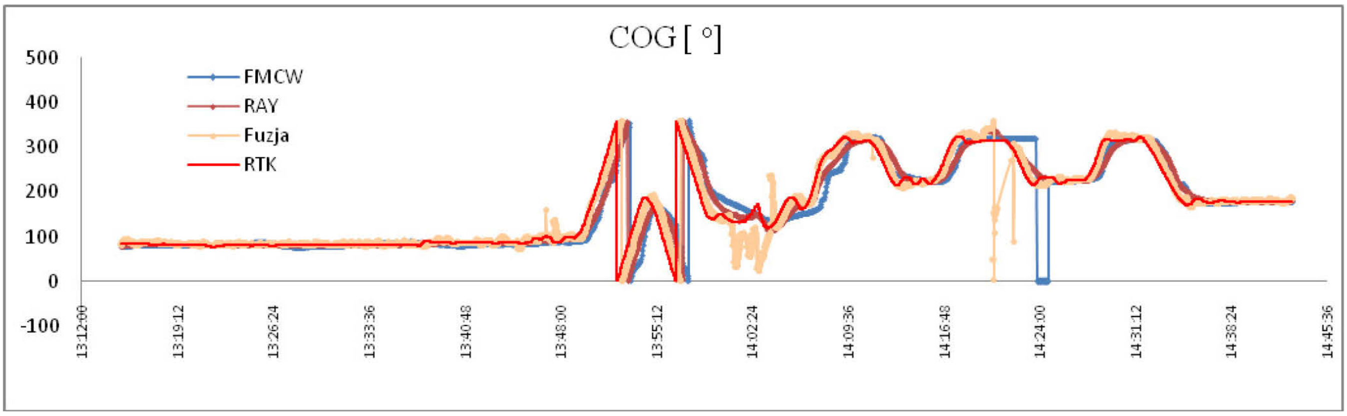

Figure 9. Information about ship’s course over ground (COG) indicated by onboard DGPS receiver (RTK) shore based FMCW (FMCW) and pulse (RAY) radars and integrated system (after data fusion - Fuzja)

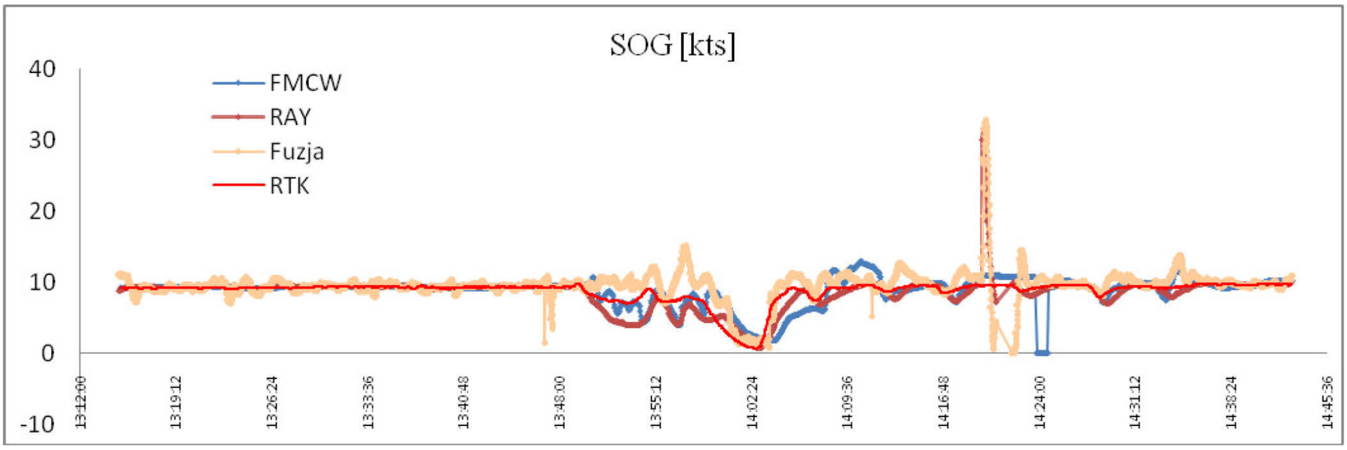

Figure 10. Information about ship's speed over ground (SOG) indicated by onboard DGPS receiver (RTK) shore based FMCW (FMCW) and pulse (RAY) radars and integrated system (after data fusion – Fuzja)

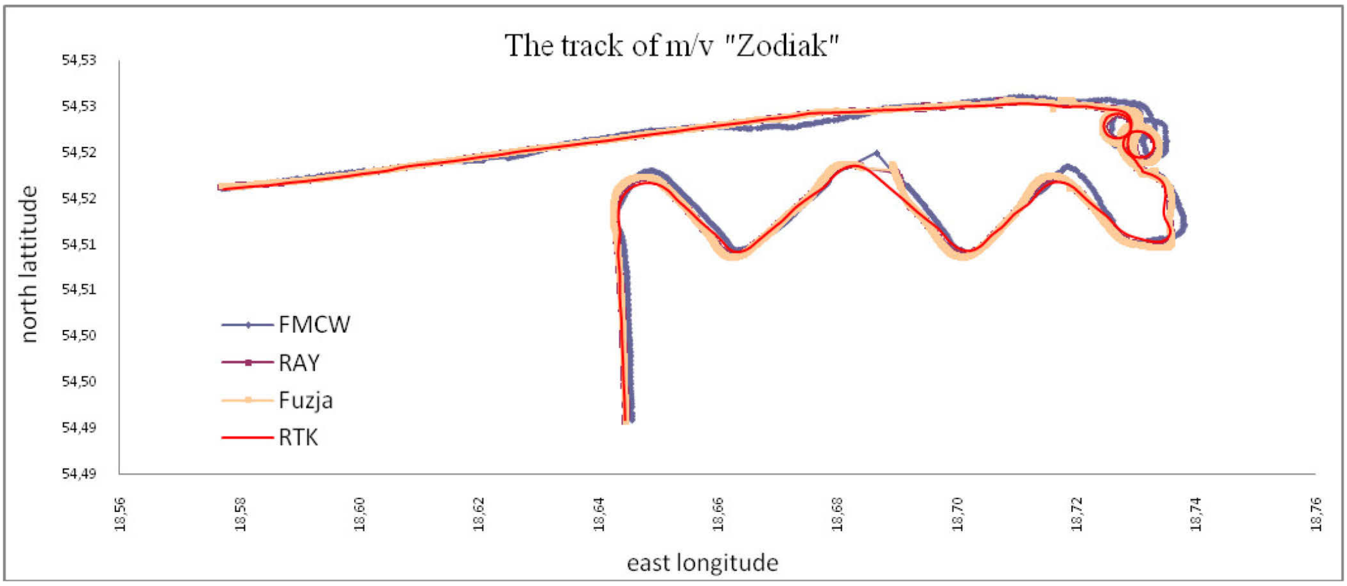

Figure 11.Track of the vessel "Zodiak" during tests plotted on the base of data available from onboard DGPS receiver (RTK) and shore based FMCW (FMCW) and pulse (RAY) radars and display unit of the integrated system after data fusion (Fuzja)

4 CONCLUSIONS

According to recommendation of the International Maritime Organisation (IMO) integrated navigational system (INS) shall, after checking that information received from AIS and radar tracking facilities concerns the same object, present for this object AIS data only. Conducted tests proved that AIS data may present inexact information about present vector of object's movement. Main reasons of this fault are problems with receiving AIS messages without time delay. Fusion of AIS and radar data as presented in this paper may be helpful in solving indicated problem. Additionally fusion of radar data increase reliability of radar data and its accuracy.

REFERENCES

[1] Król A., Stupak T: Dokładność rejestracji danych pozycyjnych statków w systemie nawigacji zintegrowanej. XIV International Conference Transcomp 2010, Logistyka 6/2010 str. 1675 – 1681.