Experimental Evaluation of the Slow Moving Beacon Location Accuracy in the Medium Earth Orbit Segment of the COSPAS-SARSAT System

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Abstract. The COSPAS-SARSAT Demonstration and Evaluation phase is being performed. Its purpose is to determine the maintenance characteristics of the Medium Earth Orbit Search and Rescue System (MEOSAR) being developed at present. This article shows the experimental results of a slow moving EPIRB obtained at the Medium Earth Orbit Local User Terminal (MEOLUT) equipped with 4, 6, and 12 antennas. These results match the theoretical conclusions and mathematical simulations made earlier: the MEOLUT with four antennas cannot locate slow moving beacons with the specified quality (5 km in 95%). Meanwhile, the measurements from six satellites (a MEOLUT should have at least six antennas) are sufficient to meet the accuracy requirements for slow moving beacons.

Keywords: COSPAS-SARSAT, MEOSAR, MEOLUT, Demonstration and Evaluation, locating, experimental results, moving EPIRBs

Introduction

As it is shown in [1], when using the measurements of frequency for independent determination of the coordinates in the Medium Earth Orbit (MEO) segment of COSPAS-SARSAT, unlike the Low Earth Orbit (LEO) segment, the presence even of a small speed at a beacon (EPIRB) can lead to big and unpredictable mistakes if this speed is not considered. As a rule, an EPIRB has its own speed being on the surface of water under the influence of currents and wind, at the same time its speed does not exceed 5 m/s. Later, an EPIRB, which move with the speed no more than 5 m/s (18 km/h), will be considered as mobile.

As maritime EPIRBs make the most part of the park of all beacons [2], and, besides, introduction of a new type of the aviation beacons activated in a flight (ELT-DT) is expected, therefore, the problem of mobile EPIRBs gains a huge value for the Medium Earth Orbit Search and Rescue (MEOSAR) satellite system.

In [1], it is shown that independent determination of the coordinates of mobile EPIRBs according to the measurements of the frequencies of the received signals (FOA – frequency of arrival) is possible in the presence of the measurements not less than from six relay satellites received from the same message of an EPIRB. When solving a navigation task of the measurements of the time of signals' arrival (TOA – time of arrival), the measurements from the same message of the EPIRB received not less than via three relay satellites are required.

At the achievable accuracy of the measurements of TOA (standard deviation = 25 microsec) and FOA (standard deviation = 0.08–0.20 Hz) on a MEOLUT, the accuracy of determination of the coordinates on the measurements of TOA is much lower than when using the measurements of FOA [1]. As a mathematical simulation, which results are given in [3], has shown, the MEOLUT equipped with four antennas is not capable to determine the coordinates of mobile EPIRBs by the measurements of TOA with the required accuracy of 5 km in 95% of cases in any zone, while the MEOLUT equipped with 6 antennas is capable to determine the coordinates both motionless and mobile EPIRBs.

At the present moment, within the international Demonstration and Evaluation tests of MEOSAR, an experimental inspection of the ability of a MEOLUT to determine the coordinates of an EPIRB with the required accuracy has been carried out only for a motionless EPIRB on the ground. This article gives the results of an experiment on determination of the coordinates of a mobile EPIRB, which has to show an experimental confirmation or a denial of the results of theoretical researches.

Experiment description

A maritime EPIRB (number 2065E84560FFBFF) was placed onboard the vessel moving between four ports near Bodø, Norway. This EPIRB was activated from May 3 to May 6, 2016. The route of this EPIRB built according to AIS data is presented in Fig. 1. The measurements of TOA/FOA were received by several MEOLUTs including the Moscow MEOLUT and the MEOLUT of the European Union (the EU).

After completing sending EPIRB messages, the EU presented the MEOLUT measurements along with high-precision AIS data on the location of the vessel to carry out an analysis of the opportunity to determine the coordinates of the mobile EPIRBs with the required accuracy.Fig. 2 taken from [2], depicts the results on the accuracy of the independent solutions depending on the own velocity of an EPIRB received in on the MEOLUT of the EU as well as by means of the LEO segment of COSPAS-SARSAT. The green line indicates the required accuracy of 5 km, the number under the dots is the quantity of solutions of the set velocity. When determining the EPIRB coordinates, it was considered that it was motionless. As it is shown, with the increase of the EPIRB velocity, the error of determination of the coordinates grows rapidly reaching hundreds and thousands of kilometers. Under such conditions, own value of an EPIRB influences greatly less on the accuracy of the solutions received with the help of a LEO segment.

To estimate a possibility of a MEOLUT with various numbers of antennas and to determine the coordinates of mobile EPIRBs on the basis of the measurements received on the MEOLUT with four antennas in Moscow and on the MEOLUT with twelve antennas of the EU, the following scenarios were reproduced:

• **Scenario 1.** A MEOLUT consisted of four antennas; to determine the coordinates, only the measurements of TOA were used. Input data of the Moscow MEOLUT were taken. Only the decisions received on the measurements from four spacecraft were included into the statistics.

• **Scenario 2.** The operation of the virtual MEOLUT consisting of six antennas was considered. Input data were

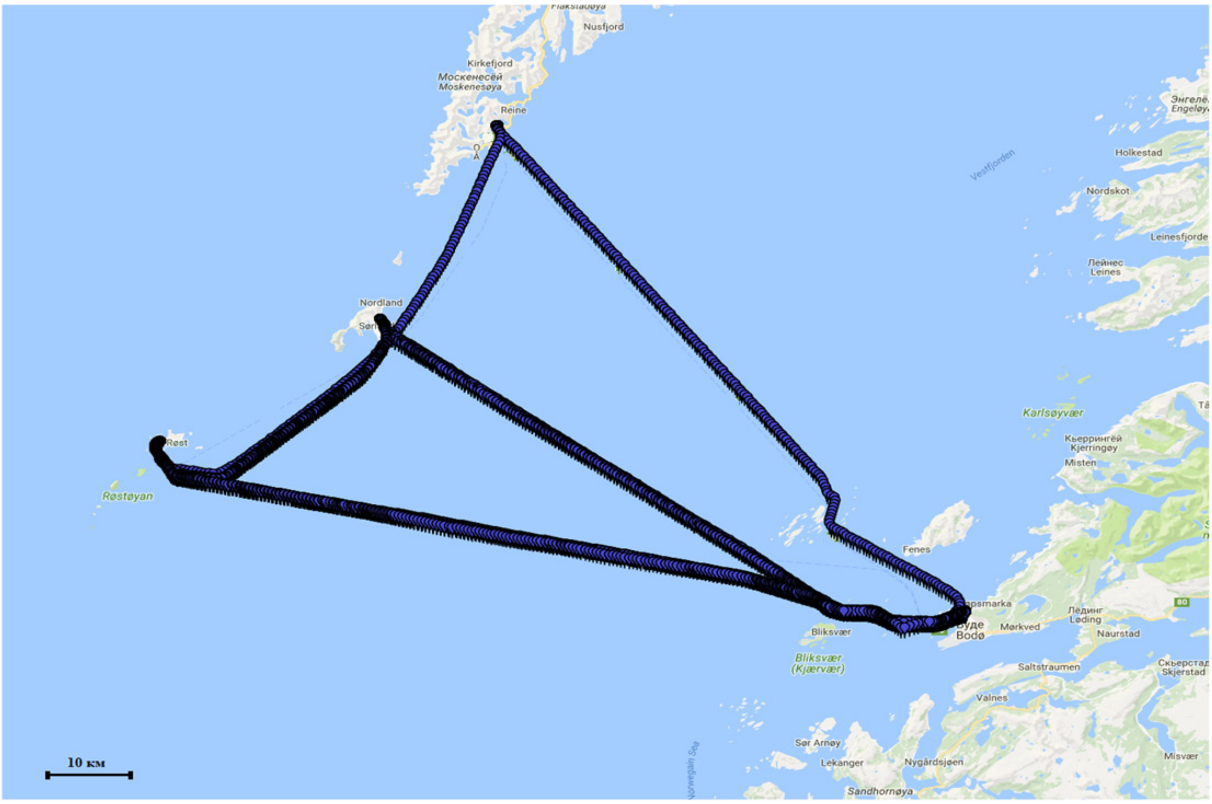

Fig. 1. Route of the EPIRB placed on the vessel

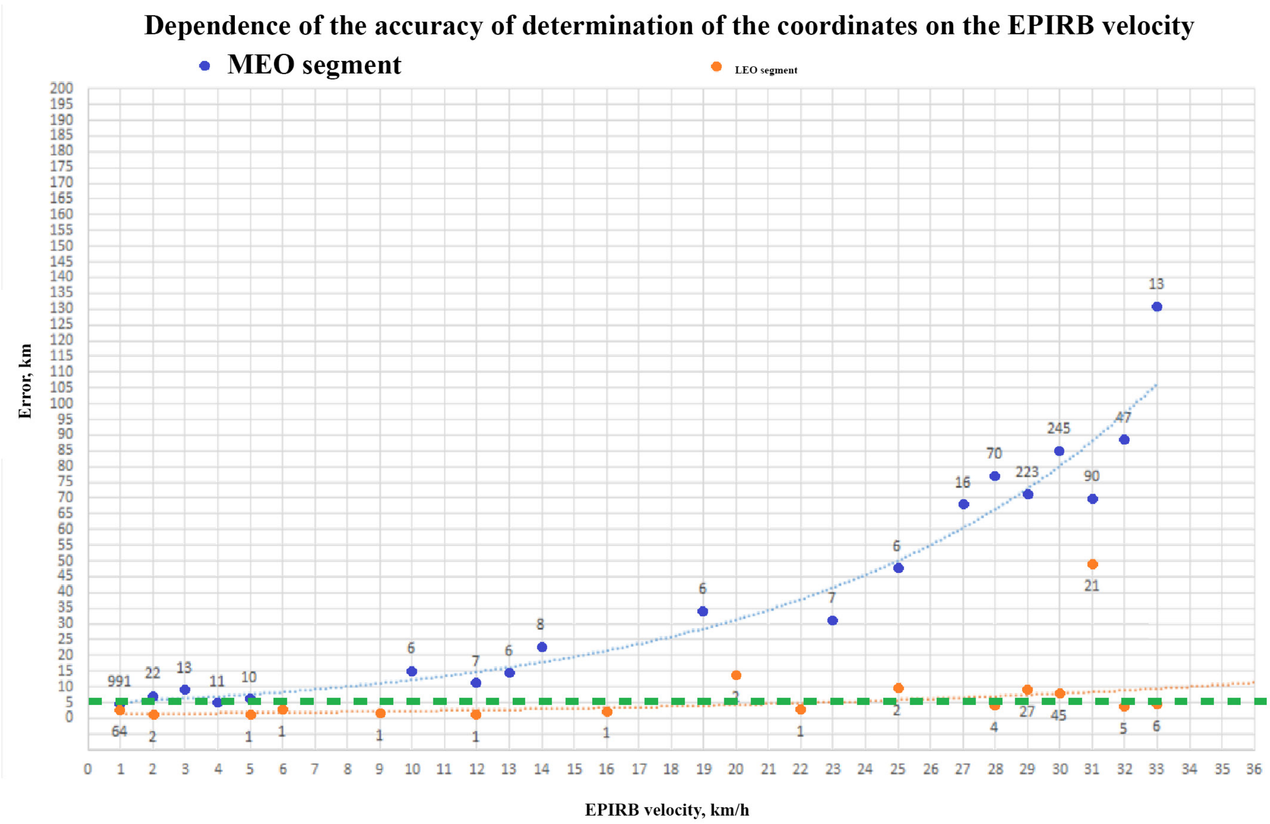

Fig. 2. Results of determination of the coordinates of a movable EPIRB by means of the MEOLUT of the EU (blue dots) and by means of a LEO segment of COSPAS-SARSAT (red dots)

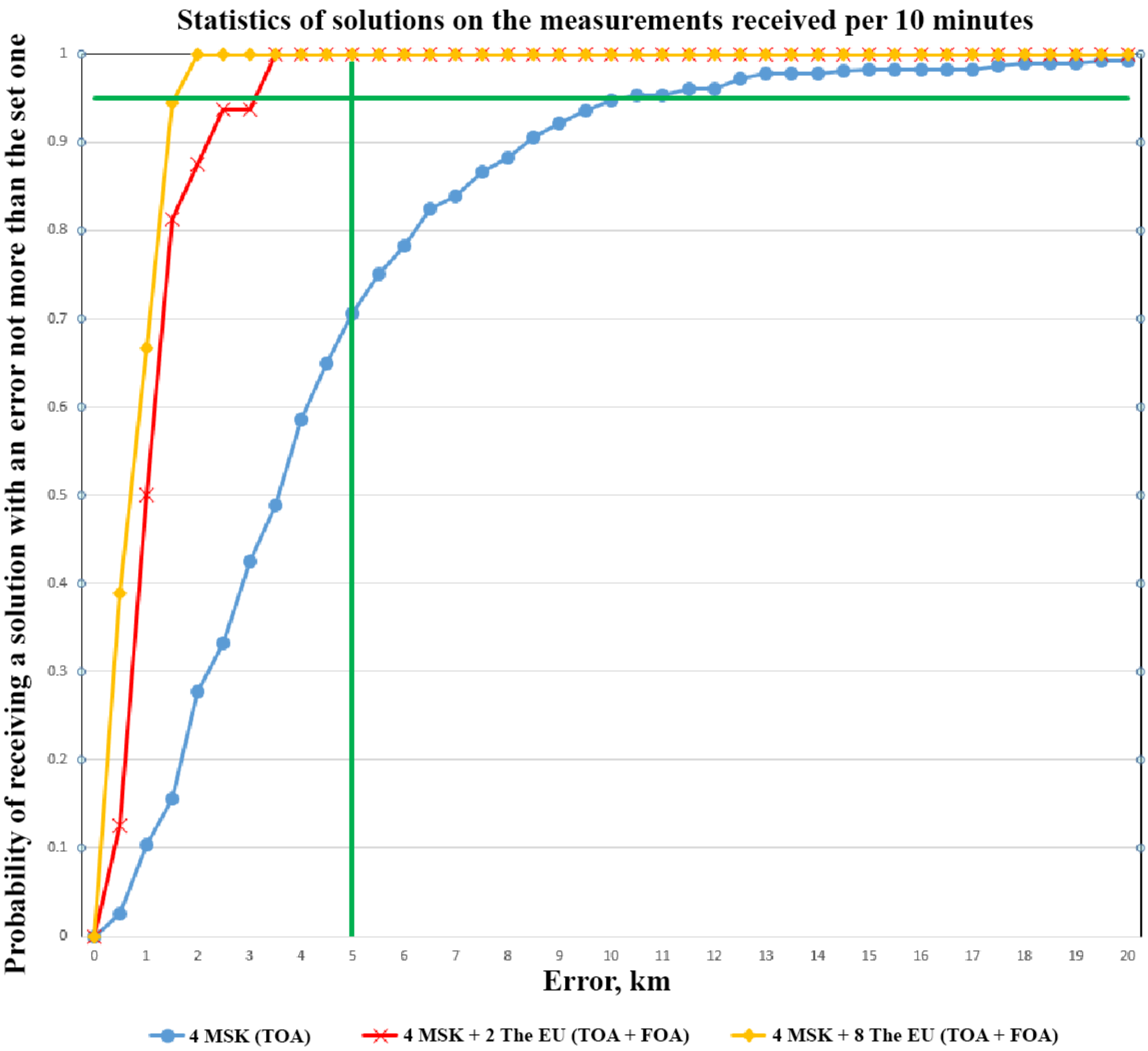

Fig. 3. Diagram of the probability of receiving a solution with an error not more than the set one

taken as the measurements of the Moscow MEOLUT (four antennas) and the data of the MEOLUT of the EU (two antennas). The coordinates of an EPIRB were determined by the measurements of TOA/FOA. Only the decisions received on the measurements from six spacecraft were included into the statistics.

• **Scenario 3.** The operation of the virtual MEOLUT consisting of twelve antennas was considered. The data of TOA/FOA from four antennas of the Moscow MEOLUT and eight antennas of the MEOLUT of the EU were taken as the input data. As a result, 6 – 11 measurements were received on one radiated message of EPIRB.

σTOA = 25 microsec, σFOA = 0.08 Hz (Moscow), 0.20 Hz (the EU) were taken as the accuracy of the measurements.

When solving a navigation task according to the TOA data, the entire period of radiation of messages was considered (from 2016.05.03 11:00 to 2016.05.06 12:50 UTC). When solving according to the TOA/FOA measurements, a shorter interval was used (from 2016.05.06 03:00 to 2016.05.06 06:00 UTC). The choice of such intervals is connected with the existence of a large number of the abnormal FOA measurements in the EU data. On the chosen three-hour interval, there were no abnormal values.

The EPIRB coordinates were determined by the measurements received for a 10-minute interval, at the same time, the decisions were taken to the middle of a 10-minute interval (it was made to minimize an error because of the change of the EPIRB position).

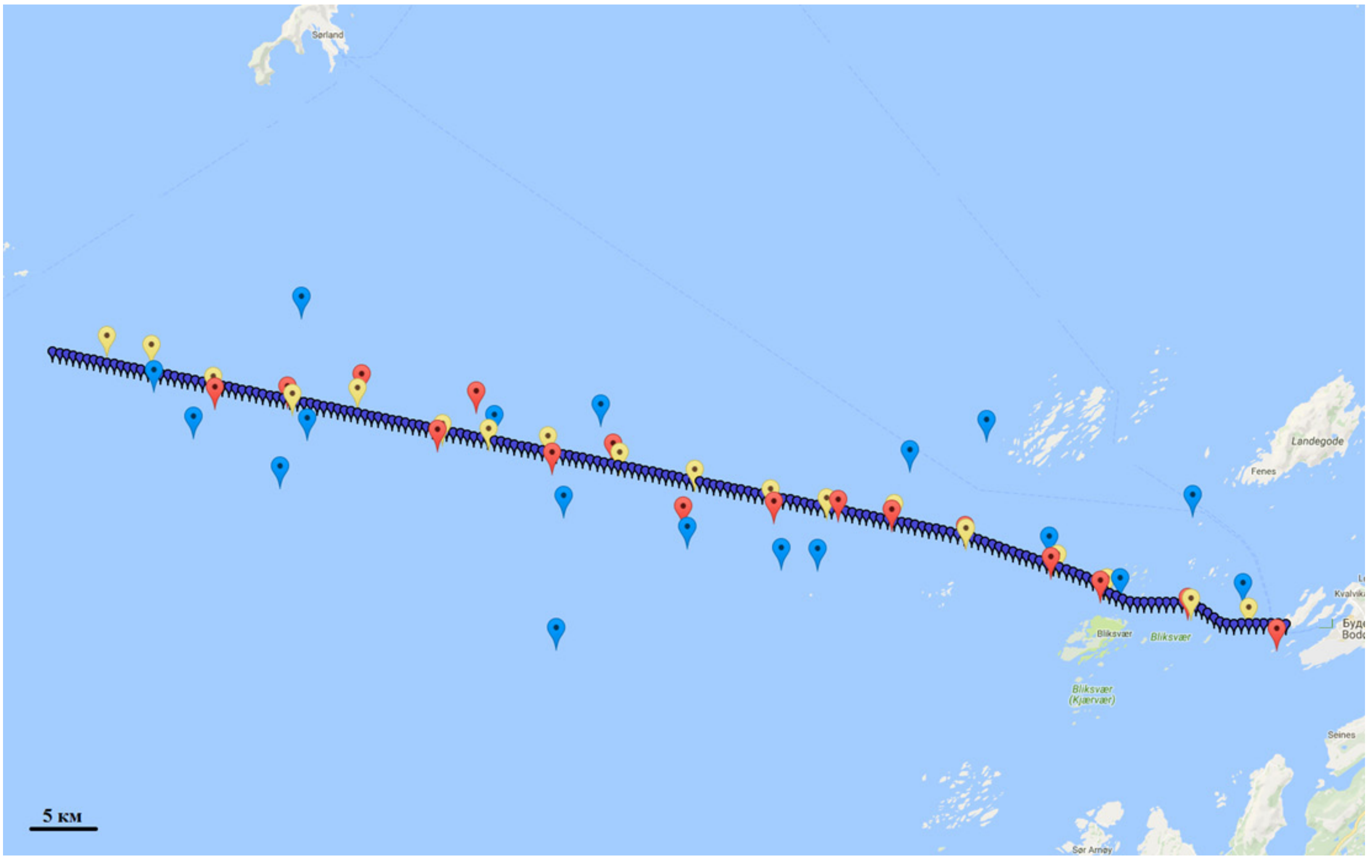

Fig. 4. Solutions received in different scenarios in the map. Blue makers are the 1st scenario (four antennas), red makers are the 2nd scenario (six antennas), yellow makers are the 3d scenario (twelve antennas). Small blue makers are the route of the vessel according to the analyzed period of time

Table 1. Statistics of determination of the coordinates of a slow moving EPIRB

				Solutions on messages received per 10 minutes			
No. of scenario	Number of antennas	Used data	Number of spacecraft in the solution	Number of solutions	Average theoretical accuracy indicator (95%), km	Scattering of the accuracy indicator (95%)	Final error in 95% cases
1	4	Moscow (4)	4	360	11.33	5.80–28.96	10.13
2	6	Moscow (4) + the EU (2) (TOA+FOA)	6	16	3.37	2.47–6.85	3.00
3	12	Moscow (4) + the EU (8) (TOA+FOA)	6–11	18	1.28	0.90–2.12	1.78

Experiment results

The results of the determination of the coordinates of the movable EPIRB depending on the scenario are given in Figs. 3–4 and in Table 1.

As expected, an error of determination of the coordinates of the movable EPIRB according to the TOA measurements of the MEOLUT with four antennas was worse than the required 5 km and was about 10 km.

The MEOLUTs with six and twelve antennas fulfilled the requirements for the accuracy of independent determination of the coordinates. The MEOLUT with twelve antennas, at the same time, showed a considerable stock on accuracy (approximately by 3 times). It should be noted that if the accuracy of the FOA measurement of all measurements would be 0.08 Hz (as on the Moscow MEOLUT), so the accuracy of determination of the coordinates would be even better.

Results

According to the results of the conducted experiment, the possibility of a MEOLUT to determine the coordinates of slowly moving EPIRBs with the required accuracy for the first time was shown, at the same time there were enough TOA/FOA measurements from six relay satellites. The accuracy of determination of the coordinates received on the MEOLUT with four antennas was worse than the required one by 2 times.

The conducted experiment on determination of the coordinates of a slowly moving EPIRB has shown the compliance with the theoretical calculations and mathematical simulations made earlier.

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