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Possibility and Effectiveness of Including the Geostationary Segment into the Medium Earth Orbit Segment of the COSPAS-SARSAT System

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Abstract. This article describes necessity of having frequency measurements obtained through at least six satellites to locate slow moving beacons (velocity < 5 m/s) with the required accuracy in the Medium Earth Orbit segment of COSPAS-SARSAT. The possibility of adding two geostationary channels to the Medium Earth Orbit Location User Terminal (MEOLUT) with four antennas to achieve the required accuracy for slow moving beacons is shown. The necessary revision of hardware and software is described; the results of the mathematical simulation of the service area of the resulting LUT with six antennas are provided.

Keywords: MEOSAR, MEOLUT, DBDRS, service area, slow moving beacons, navigation task

Introduction

The coordinates of the emergency beacons (EPIRBs) in the Medium Earth Orbit (MEO) segment of COSPAS-SARSAT are determined by the measurements of times of arrival of an EPIRB signal to relay satellites (the time has the designation TOA) and their frequencies (FOA). EPIRB signals are relayed to MEOLUTs, where there is a measurement of the TOA and FOA values, and then the coordinates of the EPIRB that radiated a signal are determined.

Theoretical and experimental studies [1, 2] have shown that a high precision of determination of the EPIRB coordinates can be reached solving a navigation task of the FOA measurements of high precision (standard deviation is 0.04–0.08 Hz). At the same time the errors of such definition will be less than 1–2 km with probability ≥ 95% that it is better than the required accuracy (5 km with probability of 95% [3]) by 2.5–5 times.

To obtain such an accuracy of the solution of navigation tasks, it is necessary to use not less than three relay satellites when determining the coordinates of a motionless EPIRB, and, generally, not less than six relay satellites located not less than in three different orbital planes for determination of the coordinates of the EPIRBs moving under the influence of currents, winds, and sea rolling [1].

During the design of the Russian MEOLUTs, on the grounds of economy of expenses, it was decided to create a four-channel station capable to receive signals only from four relay satellites. To ensure the reception of EPIRB signals at least from six spacecraft, it was supposed to use the exchange of measurements with others (Russian and foreign) MEOLUTs.

Today the first Russian MEOLUT located in Moscow showed high precise characteristics when determining the coordinates of the motionless EPIRBs according to the results of international Demonstration and Evaluation tests of MEOSAR at the II stage [2]. This MEOLUT showed its results after the production in 2013 at the development test. The reached precision characteristics were better than the requirements by 2.5–5 times, and considerably (more than by 5 times) better than the accuracy received by all other foreign MEOLUTs.

When determining the coordinates of maritime movable EPIRBs, in view of the lack of a necessary number of measurements from different spacecraft, only the measurements of TOA were used that led to a considerable deterioration in accuracy. The errors of the determination reached 10–15 km and even more.

A low accuracy of determination of the coordinates of maritime EPIRBs, as it follows from the above, is explained by the insufficient number of relay satellites, signals from which this MEOLUT can accept (only four instead of necessary six) simultaneously.

The exchange of measurements with foreign MEOLUTs to obtain the necessary number of measurements and precise measurement of the coordinates of movable EPIRBs is much less effective in view of a low accuracy of the FOA measurement on them. In addition, the exchange of the measurements with foreign MEOLUTs is not a reliable source of data, as, according to the COSPAS-SARSAT specifications, it is an optional function and is not obligatory to be fulfilled [3].

Solving a navigation task by means of the measurements received from MEO and GEO segments

In this article a new way of the solution of a problem of determination of the coordinates of movable EPIRBs with the required accuracy is offered. The essence of this way is that when solving a navigation task, the measurements of the EPIRB relayed by the geostationary artificial satellites equipped with COSPAS-SARSAT retransmitters and received by distress beacon data receiving stations (DBDRS) are used in addition to the measurements received from four channels of this MEOLUT. Though the measurements of FOA from geostationary spacecraft cannot directly help to determine the EPIRB coordinates (since a geostationary spacecraft is almost not movable relative to the Earth and the movement of the spacecraft does not cause a considerable Doppler shift of frequency), they help to determine the EPIRB velocity, since the EPIRB speed in this case causes a Doppler shift of frequency. Thus, when solving a navigation task of the FOA measurements, to determine six unknown parameters (longitude, latitude, three components of velocity, and an unknown frequency of radiation), at least three measurements from MEO spacecraft and at least three more measurements from MEO or GEO spacecraft are required.

In a hardware, such a solution demands costs only for retrofitting of DBDRS with the equipment of measurement of frequency and time of arrival of signals from geostationary spacecraft.

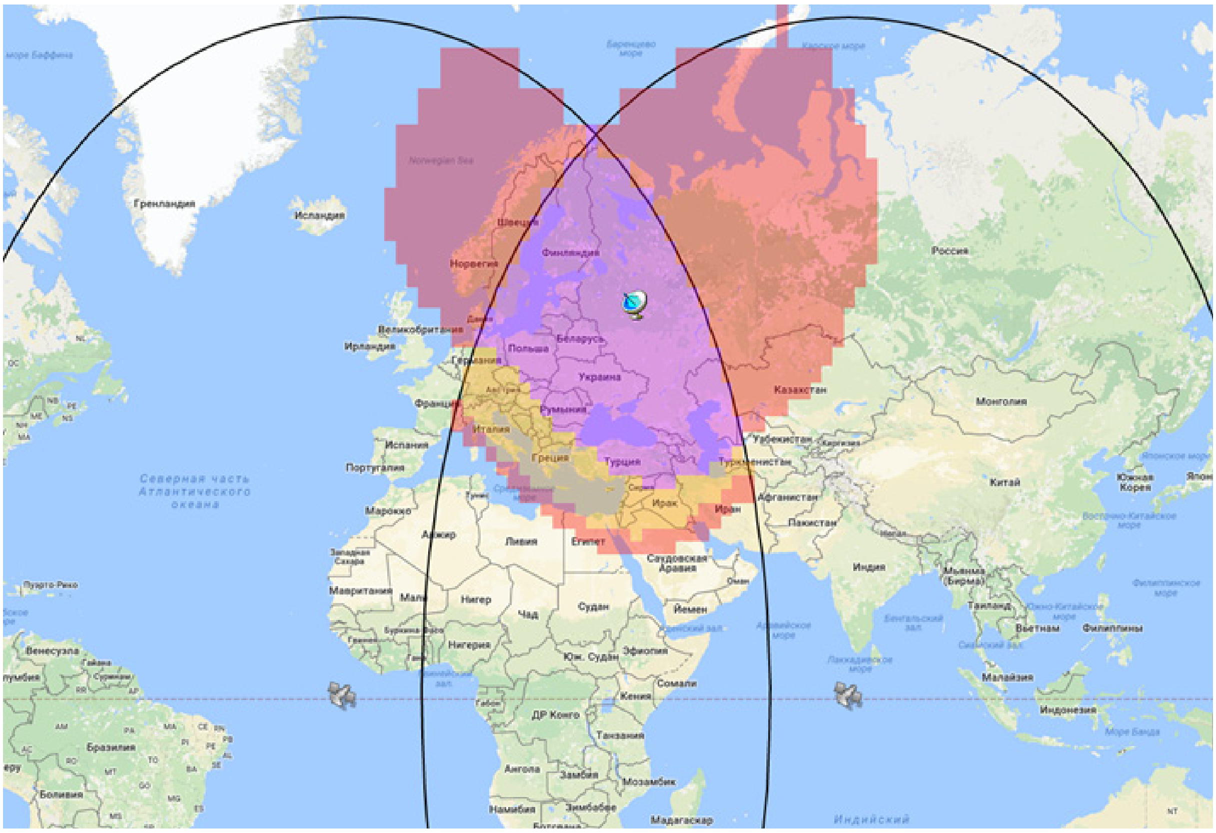

Fig. 1. Service area of the MEOLUT with four antennas with two geostationary channels when working with slow moving EPIRBs

To check the expediency of using the measurements from geostationary relay satellites, a computer simulation in which the Moscow MEOLUT with four antennas used the measurements from two DBDRS stations, which received data from the geostationary spacecraft Electro-L No. 1 (14.5 west longitude) and Electro-L No. 2 (76.0 east longitude) was carried out. The results of this simulation are shown in Fig. 1.

The color areas in Fig. 1 depict the service area, different colors correspond to different accuracy of determination of the coordinates, the presented satellites are Electro-L No. 1 and Electro-L No. 2, black lines mark an area of radio visibility of these spacecraft, and the antenna marks the MEOLUT and two DBDRS stations located in Moscow.

Improvement of DBDRS and MEOLUT necessary to realize and master the offered method

The efficiency of adding the measurements of EPIRB signals relayed by at least two geostationary spacecraft to the measurements received by the Moscow MEOLUT with four antennas is shown in the previous section. For implementation of this decision, at the moment there are almost all sophisticated and expensive means:

– The Electro-L geostationary spacecraft:

• No. 1 – will be transferred to the position of 14.5° west longitude;

• No. 2 – being in the position of 76° east longitude;

• No. 3 – will be put to orbit to the position of 165° east longitude;

– The Louch-5 geostationary spacecraft:

• Louch-5A – being in an orbit in the position of 167° east longitude;

• Louch-5V – being in an orbit in the position of 95° east longitude.

All these spacecraft have EPIRB signal repeaters of COSPAS-SARSAT;

– The Moscow DBDRS was put into operation as a part of the Russian geostationary segment of the COSPAS-SARSAT System in 2013 and now is successfully performing the functions together with Electro-L No. 1;

– Four more DBDRSs are placed in the cities: Moscow,

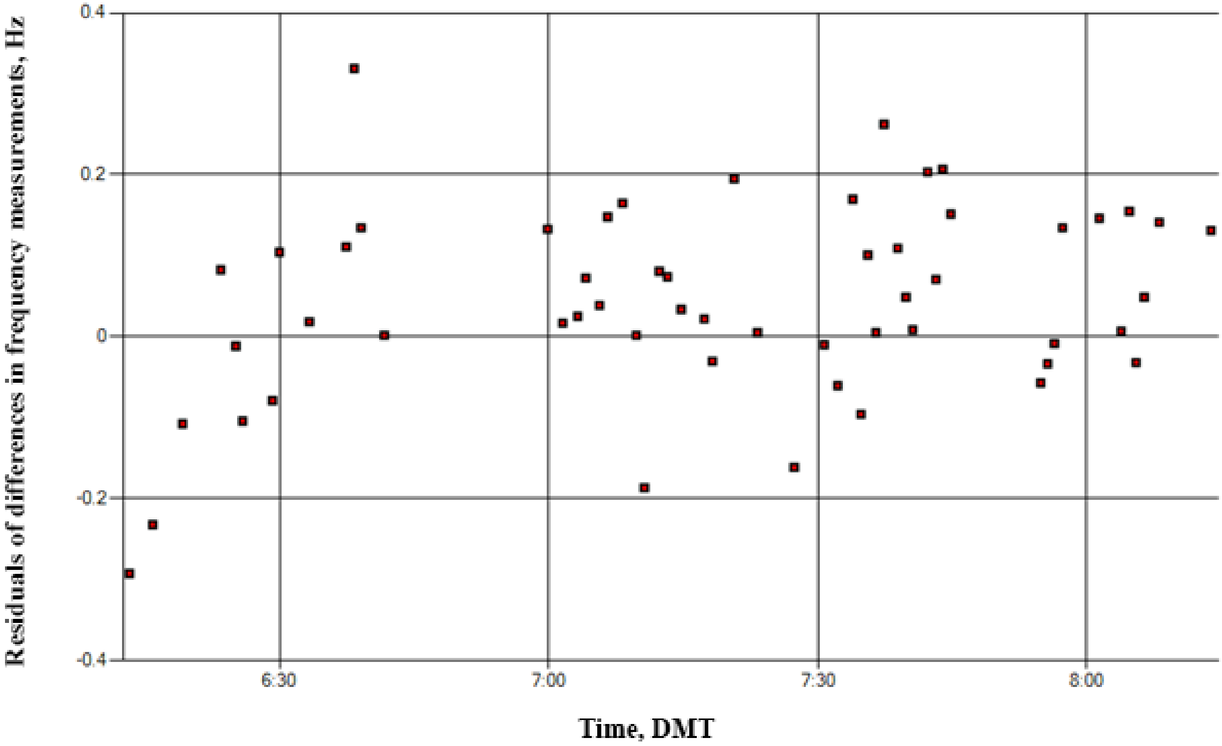

Fig. 2. Residuals of differences in the FOA measurements from Electro-L No. 1 and GPS No. 12, 22.10.2015.

Zheleznogorsk, and Khabarovsk (two complexes) to work with Electro-L No. 2, Electro-L No. 3, Louch-5A, and Louch-5V.

To realize the offered method, these DBDRSs have to be mastered in order to perform the measurements of FOA and TOA. It is possible to realize such improvement without difficult mastering the equipment and the DBDRS programs, however retrofitting will be required by the receivers used in a MEOLUT (analogue-to-digital receivers of a signal from MEO spacecraft) and low-directed antennas for reception of signals from navigation satellites by the special navigation (second) channel of these receivers and also carrying out necessary improvement of the software.

Apart from the listed improvements for realization of the offered method to increase the accuracy of determination of the coordinates of moving EPIRBs, it is necessary to solve two more technical problems:

- Operative measurement and record when processing the instant values of the frequencies of heterodynes (reference generators) of EPIRB signal retransmitters on geostationary spacecraft;
- A rather precise understanding the parameters of the orbits of geostationary spacecraft in real time.

To check a possibility of these tasks solving, the experiment was carried out. The EPIRB messages received from the Moscow DBDRS tracking the geostationary Electro-L No. 1 spacecraft were calibrated according to the French orbitografical beacon (No. 9C634E2AB509240) that possess a high frequency stability of the radiated signal and time of radiation. After calibration, the FOA measurements of a beacon No. BBBF0DEE6437320 located in Hong Kong were analyzed. As it is described in [1], it is expedient to make an analysis on the differences of the measurements from two spacecraft. Fig. 2 shows an example of the errors of differences of the frequency measurements (with the considered Doppler shift of frequency caused by the spacecraft movement) from the relay satellites Electro-L No. 1 and GPS No. 12 (the average value was 0.043 Hz; standard deviation is 0.118 Hz).

Thus, the conducted experiment shows a basic possibility of using the measurements from geostationary relay satellites to solve a navigation task for slowly moving EPIRBs in the MEO segment of COSPAS-SARSAT.

Conclusions

One of the methods to increase the accuracy of determination of the coordinates of mobile EPIRBs in the MEO segment of COSPAS-SARSAT is to use additional measurements of the frequency (FOA) of an emergency beacon received by DBDRS stations from the Electro-L No. 2, Electro-L No. 3, Louch-5A, and Louch-5V geostationary satellites. Such a method allows one to use, without large expenses, financially technical ground of the Russian geostationary stations to increase the accuracy of determination of the coordinates and expansion of a service area of emergency beacons of the Russian MEO segment of the COSPAS-SARSAT System.

References

1. Antonov D.V, Arkhangel'skiy V.A., Beloglazova N.Yu. Tochnost' opredeleniya koordinat avariynykh radiobuev po izmereniyam chastot i vremen prikhoda signalov etikh buev na kosmicheskie apparaty sredneorbital'nogo segmenta sistemy KOSPAS-SARSAT [The accuracy of independent location of a distress radiobeacon derived from the measurements of time and frequency of arrival at the COSPAS-SARSAT medium earth orbiting satellites]. *T-Comm: Telekommunikatsii i transport* [T-Comm – Telecommunications and Transport]. 2016, Vol. 10, No. 1, pp. 62–67. (in Russian)

2. Antonov D.V., Fedoseev A.V. Eksperimental'nye issledovaniya tochnosti opredeleniya koordinat avariynykh radiobuev v sredneorbital'nom segmente KOSPAS-SARSAT [The accuracy of independent location of a distress radiobeacon derived from the measurements of time and frequency of arrival at the COSPAS-SARSAT medium earth orbiting satellites]. *T-Comm: Telekommunikatsii i transport* [T-Comm – Telecommunications and Transport]. 2016, Vol. 10, No. 11, pp. 22–27. (in Russian)

3. *COSPAS-SARSAT MEOLUT performance specification and design guidelines*. C/S T.019, Issue 1, December 2015.