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Present State and Main Characteristics of the Geostationary Relay Satellites of the COSPAS-SARSAT System Based on the Louch-5A and Louch-5V Spacecraft

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Abstract. The paper presents the results of the flight tests of the Russian geostationary segments of the COSPAS-SARSAT system built on the base of the relay satellites Louch-5A and Louch-5V of the Multifunctional relaying space system (MRSS) Louch and ground stations for reception of the data from EPIRBs. The tests have shown high performance characteristics of the relay satellites and the ground stations that are considerably greater than that of the geostationary segments of the countries-manufactures of similar equipment. The geostationary complex included into the Louch-5A spacecraft and into the ground stations in Khabarovsk is ready to operate in the COSPAS-SARSAT system. In 2017, it is planned to put into operation the ground stations for reception in Zheleznogorsk for future introduction into service of the complex based on the Louch-5V spacecraft.

Keywords: COSPAS-SARSAT, search and rescue operations, Russian segment, relay satellite, geostationary complex

Introduction

The geostationary segments (GEOSAR) of the COSPAS-SARSAT system were created by different countries of the world (the USA, the European Union, India, and Russia) in the 90th of the last century as an additional segment of the system for the LEOSAR system. The GEOSAR systems considerably increase the efficiency of detecting the messages of the emergency beacons (EPIRB) comparing to the present LEOSAR systems. Excluding the polar regions, the maximum time of receiving a reliable message in the GEOSAR systems does not exceed 10 minutes that it is significantly less than in the LEO segment where it reaches up to 1.5–2 hours.

Inclusion of the user navigation equipment (UNE) of the global navigation satellite systems (GLONASS, GPS) into the EPIRB makes it possible to detect the EPIRB's coordinates with the accuracy up to tens of meters. If an EPIRB has no UNE, so geostationary satellites of the COSPAS-SARSAT system allow one in due time to distress alerting while the coordinates of the EPIRB in distress are received by means of the LEOSAR system with delay.

The geostationary segment consists of spacecraft in the geostationary orbit with the repeater of EPIRB signals and ground receiving stations. An onboard repeater of EPIRB signals receives messages in the range of frequencies of 406.0–406.1 MHz and relays these signals in the range of frequencies of 1544.5 ± 0.05 MHz to the ground receiving stations, which detect the relayed EPIRB messages and allocate a reliable information from them.

The COSPAS-SARSAT repeaters of signals are established usually on the satellites of another mission as an additional payload. Nowadays the repeaters of EPIRB signals of the geostationary segments of the COSPAS-SARSAT system are placed on the Russian spacecraft Louch-5A (167°east longitude) and Louch-5V (95°*east longitude*) of the Multifunctional relaying space system (MRSS) Louch, the Electro-L spacecraft No. 2 (76° east longitude), and on the foreign spacecraft: the European Union — spacecraft of the MSG series (3.4° west longitude; 0°; 9.5° east longitude); the USA — spacecraft of the GOES series (75° west longitude; 105° west longitude; 135° west longitude), and India — the INSAT-3D spacecraft (82° east longitude).

The ground distress beacon data receiving stations (DBDRS) that successfully underwent tests with Electro-L are used as ground receiving stations for the geostationary ground segment based on Louch-5A and Louch-5V.

The article presents the results of the flying tests of the Russian geostationary segments of the COSPAS-SARSAT system created on the base of the Louch-5A and Louch-5V relay satellites (RS) and DBDRS as well as the results of the international tests of the geostationary satellite search and rescue system based on the Louch-5A spacecraft.

Dependence of the main functional parameter of the geostationary system (SC+ DBDRS) on the characteristics of the relay-satellite

The main functional parameter of the COSPAS-SARSAT geostationary segment is **the probability of receiving a reliable message** ($P_{reliable}$) from the EPIRB which is in the visibility area of the RS for the set time (not more than 5 minutes) [1].

When using RS, the radio line, over which an EPIRB signal is transmitted to DBDRS, is made of two lines: EPIRB–RS and RS–DBDRS.

A general view of the ground DBDRS, as well as of the Louch-5A and Louch-5V spacecraft, are given in Figs. 1, 2.

The probability of $P_{reliable}$ depends on the energy potential (H), i.e., the relation of the signal power P_s to the spectral density of the noise power N_{noise} on the input of the DBDRS receiver, as well as on the parameters of the message signal: the number and duration of the symbols ("bit") in the message, type and index of the modulation, and method and parameters of the applied code for detection and correction of mistakes. These parameters of a signal of the message in the COSPAS-SARSAT system were chosen in the 70th of the last century when designing a LEO segment of this system [2], i.e., long before the beginning of designing a geostationary segment. By the beginning of this design, a rather big fleet of EPIRBs consisting of several hundred thousand pieces had been created. Therefore, real methods to obtain the required high probability of the reliable message during the creation of the geostationary segments are:

1. Increase in energy potential of the radio lines of EPIRB – RS – DBDRS.

2. Optimization of processing of the signals received by DBDRS, including the opportunity to accumulate the energy of the signals of messages by means of their coherent summation.

Fig. 1. RSDBD placed on the operation station in the Khabarovsk region

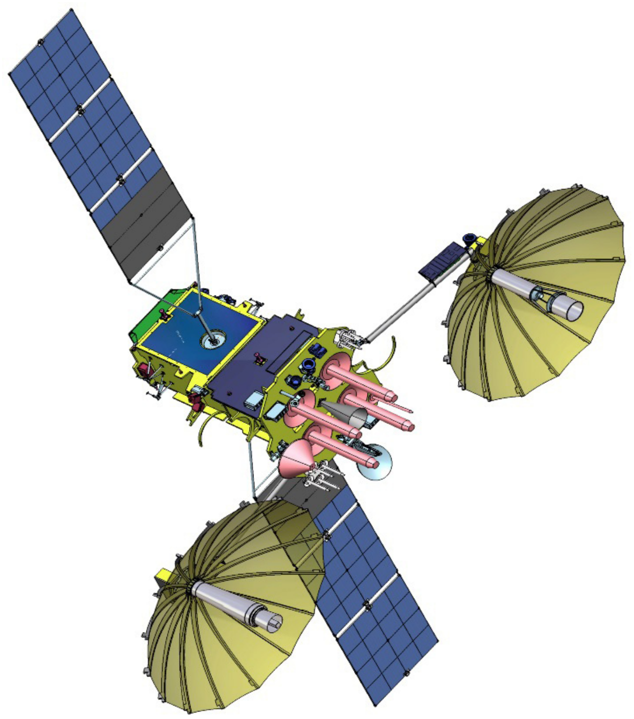

Fig. 22. A general view of the Louch-5A and Louch-5V spacecraft

The Bose-Chaudhuri-Hocquenghem (BCH) error-correcting code chosen in COSPAS-SARSAT contains 82 symbols, from which 61 are information and 21 are for testing, corrects up to three mistakes and detects the even number of errors equal or bigger than four [3].

This code cannot find and, especially, correct an odd number of errors bigger than three, and for any odd number of errors more than three will correct any three and consider this message reliable. To exclude such false messages, only those messages in which no more than two errors are corrected and more than two even errors are not detected are considered reliable in COSPAS-SARSAT. The message with the corrected three errors is considered doubtful.

At such decoding algorithm for the BCH code (82, 61), the probability of the reliable message equals *(allowing for the received message has already undergone checking for the presence of the right bit [15 bits] and frame synchronization):*

$$P_{reliable} = \sum_{k=0}^{k=2} C_{82}^{k} (1 - p_1)^{82-k} p_1^k \quad (1)$$

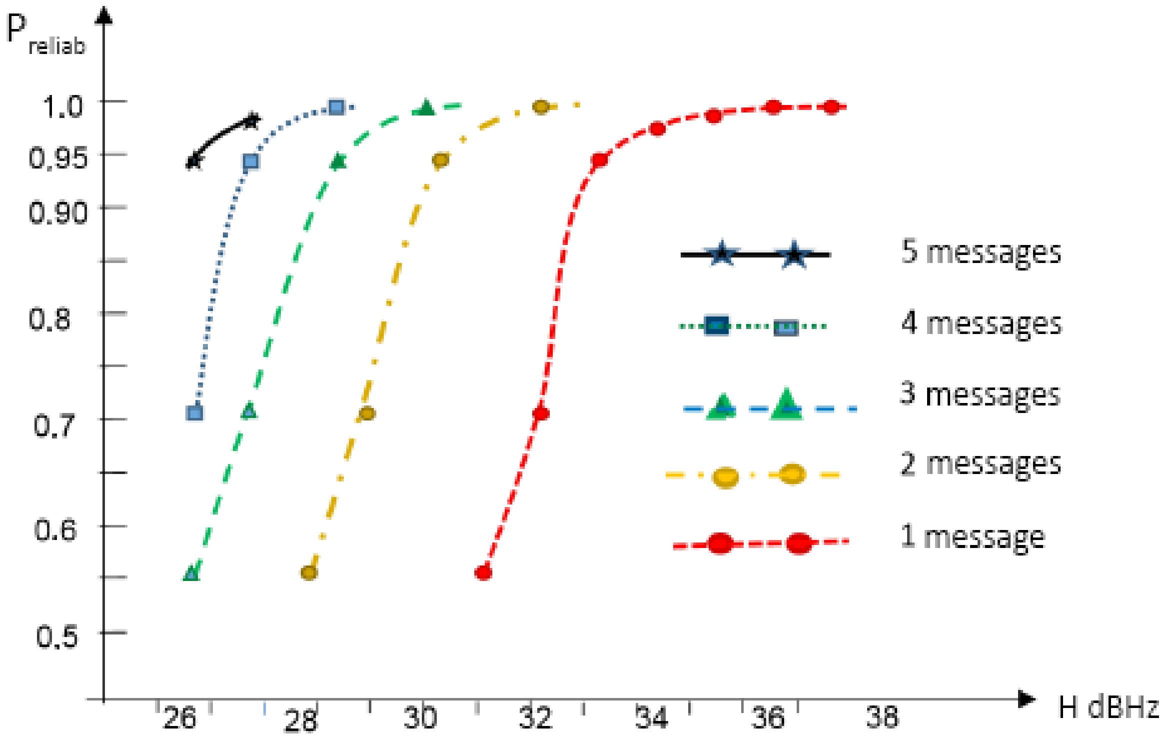

Fig. 33. Dependence of the probability of receiving a reliable distress beacon message on energy potential of the end-to-end radio line and the number of messages in accumulation

where C_{82}^{k} is the number of combinations from 82 on k;

p_1 is the probability of the error of one message bit.

At the optimum processing of the received DBDRS signal, the probability of the error in one bit is [4]

$$p_1 = 1 - F\left(\sqrt{\frac{2E_1 n}{N_{noises}}}\right) = 1 - F\left(L_E\, H \tau\, n\right) \qquad (2)$$

where $E_1 = l_E\, P_c\, \tau$ is the energy of one bit of the received signal;

H is the energy potential on the input of the DBDRS receiver;

τ is one bit duration (τ = 1/s, where s is the speed of information transmission from the EPIRB equal 400 bit/s);

$L_E = m\, l_{realiz}$ is the coefficient of the energy losses of one signal, i.e., a share of the signal power for modulation of its useful information taking into account the losses for realization;

m is the share of the power for modulation of its useful information from the sum signal;

$l_{realization}$ is the losses for realization;

N_{noise} is the spectral density of the power noise in the input of the DBDRS receiver

$$F(z) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{z} e^{-\frac{x^2}{2}} dx \text{ - is the probability integral;} \qquad (3)$$

n is the number of EPIRB messages coherently summed to receive a rather few errors in the message to provide its validity checking when decoding of the BCH code.

Taking in the formulae (1), (2), (3) the values of the loss coefficients m = ‑ 1 dB that corresponds to the losses at the phase modulation with the index 1.1 rad received in the EPIRB [1];

$l_{realiz} = -2\, dB$,

the following is obtained:

$$\frac{E}{N_{noise}} = H - 10\ lg\ c + 10\ lg\ n = H - 26 + 10\ lg\ n. \qquad (4)$$

The calculation results by the formulae (1)–(4) are given in Fig. 3.

As this figure shows, P_{reliab} is defined by the H and n values.

The energy potential of the EPIRB→RS→ DBDRS end-to-end radio line can be calculated by the formula:

$$\frac{1}{H_\Sigma}=\frac{1}{H_1}\left(1+\frac{N_{\text{int}1}}{N_{noiseRS}}\right)+\frac{1}{H_2}\left(1+\frac{P_{\text{int}\Sigma}}{P_{S\,receiver\,RS}}\right)+\frac{\Delta f_{RS}}{H_1H_2} \quad (5)$$

where H_1 is the energy potential of the DBDRS-RS radio line;

H_2 is the energy potential of the RS-DBDRS radio line;

Δf_{RS} is the bandwidth of the repeater to RS;

$N_{\text{noise RS}}$ is the spectral density of the noises power in the input of the RS receiver;

$N_{\text{int}1}$ is the spectral density of the broadband interference power in the input of the RS receiver;

$P_{\text{int}\Sigma}$ is the sum power of the broadband interference and narrowband interferences operating in the receiving band of RS;

$P_{S\,receiver\,RS}$ is the signal power of the EPIRB message in the RS input.

The formula (5) is a kind of modification of the formula for calculating the energetics of the radio lines in the satellite communications radio systems [5]. When there are no external interferences, this formula is the following:

$$\frac{1}{H_\Sigma}=\frac{1}{H_1}+\frac{1}{H_2}+\frac{\Delta f_{RS}}{H_1H_2} \quad (5a)$$

The energy potentials of the EPIRB-RS-(H_1) and RS-DBDRS-(H_2) lines are calculated according to the formulae:

$$H_1=EIRP_{EPIRB}+(G/T)_{RS}+20\lg\left(\frac{\lambda_1}{4\pi D}\right)+L_{mp.}+L_{pol}-228.6\ dBHz/K \quad (6)$$

$$H_2=EIRP_{RS}+(G/T)_{DBDRS}+20\lg\left(\frac{\lambda_2}{4\pi D}\right)+L_{losses}-228.6\ dBHz/K \quad (7)$$

In these formulae,

EIRP is the equivalent isotropic radiated power of the EPIRB or RS respectively;

G/T is the quality parameter of the reception system of RS or DBDRS;

$\lambda_1 = 73.88\ cm$ is the wavelength in the EPIRB-RS radio line;

$\lambda_2 = 19.42\ cm$ is the wavelength in the RS-DBDRS radio line;

$L_{\text{mp.}}$= −2.0 dB is the losses due to the multipath effect in the EPIRB-RS radio line;

$L_{\text{pol.}}$ = −4.1 dB is the polarization losses in this line;

L_{losses} = −1 dB is the additional sum losses in the RS-DBDRS radio line.

The losses due to signal propagation in the atmosphere will be considered in additional sum losses in the RS- DBDRS radio line.

All values in the formula (5) are expressed in natural values and the values in (6) and (7) are expressed in decibels.

The analysis of the formula (5) shows that the maximum possible value H_Σ is always less than H_1. If the following is fulfilled:

$$H_2 >> H_1 \text{ and } H_2 >> \Delta fRS \quad (8)$$

with interferences being rather small:

$$N_{\text{int}} << N_{nRS} \text{ and } P_{\text{int}\,\Sigma} << P_{s\,receiver\ RS}\cdot\frac{H_2}{H_1} \quad (9)$$

and the following is met: $H2 > 10H1$, $\Delta f_{RS} < 0.1H_2$, so

$H_\Sigma = H_1 - 1.1$ dBHz.

If the conditions $H_2 > 3H_1$, $\Delta f_{RS} << 0.1H_2$ are met, so

$H_\Sigma \cong H_1 - 3$ dBHz.

Excluding the interference coinciding in the spectrum with the message signal, which cannot be decreased by any increase in H_1 or H_2, other inequalities in (8) and (9) are amplified with the grow of H_2. Hence, to increase the probability of receiving a reliable message, it is necessary to increase H_1 and H_2.

As it can be seen from the formulae (6) and (7), the key parameters that define H_1 and H_2 in the geostationary segment of the COSPAS-SARSAT system and can be changed when creating its separate parts (RS and DBDRS) are $(G/T)_{\text{RS}}$, $EIRP_{RS,}$ and $(G/T)_{\text{DBDRS}}$.

Results of the flight tests of the geostationary segments of the COSPAS-SARSAT system based on the Louch-5A and Louch-5V relay satellites

The *G/T* measurements and definition of the EIRP repeater, as well as the calculation of the probability of reception of the reliable message were carried out based on the Programme and Methodology of COSPAS-SARSAT C/S T.013 [1].

Prior to these tests, the parameter of quality (*G/T*) of the Moscow DBDRS equal 9.8 dB/K was determined. As a result of the taken measurements, the following results were received:

- The equivalent isotropic radiated RS power: EIRP = 26.9 dBmW.
- The parameter of quality of RS: G/T = – 9.2 dB/K.
- The transmission bandwidth of the repeater according to the level of 3 dB: Δf_p = 80 kHz.

The probabilities of receiving reliable messages depending on the EIRP of a test radio beacon ($EIRP_{TEPIRB}$) are given in Table 1.

Table 1. Probabilities of receiving a reliable EPIRB message when accumulating the energy of the messages within 5 minutes ($P_{5message}$) and one message ($P_{1message}$)

$EIRP_{TEPIRB,}$ dBmW	H_{mean}, dBHz	MSD, H_{mean}, dBHz	$P_{5message}$	$P_{1message}$
32.4	42.2	1.5	1.0	0.97
29.0	37.2	1,3	1.0	0.98
28.0	36.3	1.4	1.0	0.94
26.0	34.9	0.7	1.0	0.90

H_{mean} is the value of the mean energy potential on all radiated message measured on DBDRS, and MSD H_{mean} is its mean quadratic value (σ).

The probability of receiving a reliable message according to the C/S T.009 standard within 5 minutes is 0.99 that is carried out for all values of the radiated power of the test EPIRB. The requirements to receiving a reliable message on the first radiated one in the COSPAS-SARSAT documents are not raised, however the values given in Table 1: P_{1mess} = 0.98 for $EIRP_{TEPIRB}$ = 29 dBmW, and $P_{1message}$ = 0.9 for $EIRP_{TEPIRB}$ = 26 dBmW are very good.

The energy store of the COSPAS-SARSAT geostationary complex based on the Louch-5A spacecraft is:

The store of the system is 11 dB (37 dBmW–26 dBmW), where 37 dBmW is the nominal value of $EIRP_{TEPIRB}$ (C/S T/.001 [2]), and 26 dBmW is the smallest value of the $EIRP_{TEPIRB}$, at which the set probability of P ≥ 0.99 to obtain a reliable message established at the tests is provided.

According to the data of Table 1, the actual store of the system is even more. The requirements to the energy store are not made by the COSPAS-SARSAT documents; however, they contain the recommendation to have this store as large as possible, since it will allow one to receive emergency messages at unsuccessful locations of EPIRBs:

- At the location of the beacon's axis close to the direction on RS.
- Presence of the EPIRB in the woods or other powerful vegetation.
- Presence of overshadowing or reflecting objects of the EPIRB radiation close to the EPIRB.

The results of the tests show a very high level of the main characteristics of the geostationary segment on the basis of the Louch-5A spacecraft. To prove this statement, Table 2 will be considered, which includes the main characteristics of the operating geostationary segments of the developments of the USA, the EU, and Russia together with the characteristics of the segment based on Louch-5A.

Table 2. Comparing characteristics of the main parameters of the geostationary segments of the COSPAS-SARSAT system

System / Parameter	GOES, the USA	MSG, the EU	Electro-L, Russia	Louch-5A, Louch-5V, Russia
G/T, dB/K	–18.5	–21.3	–16.5	–9.2
$EIRP_{mean}$, dBmW	45.0	–20.0	50.1	26.9
Δf_p – broadcast bandwidth, kHz	100	180	138	80

This Table shows that the key parameter (G/T) defining the probability of a validated reception of the emergency message at the bad energetics of the of EPIRB–RS radio line, **RS of Louch-5A is much better** than that of all other spacecraft used in other geostationary segments. According to other parameters, Louch-5A corresponds to the requirements and to the level of other RS. The exception makes only a small value of $EIRP_{RS}$. For RS MSG, this value is even less, but the last one uses ground reception antennas with the diameter of 9 m and only 5 m on DBDRS. The influence of a small EIRP on the quality of a geostationary segment will be considered in the following section.

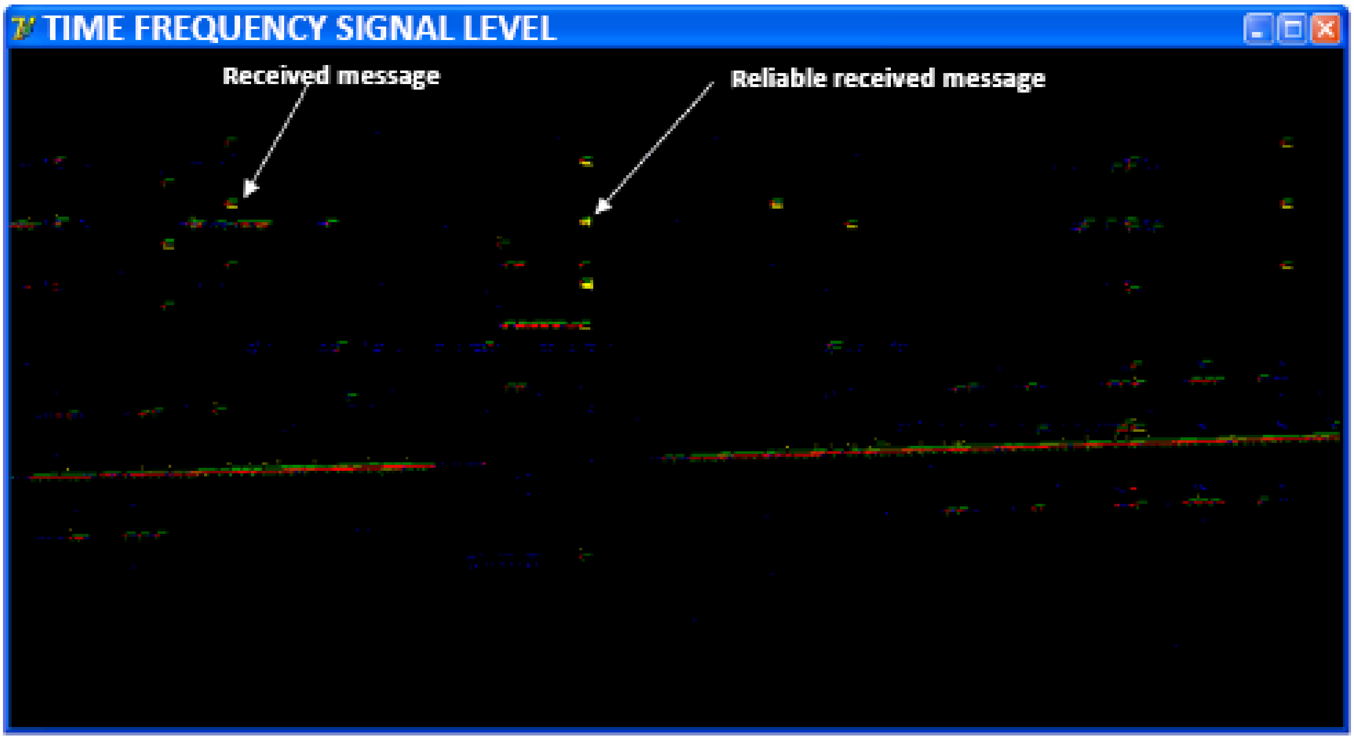

Fig. 4. Frequency and time panorama of the signals spectrum in the input of the DBDRS processor. 26.09.2012, 2 p.m. MSK

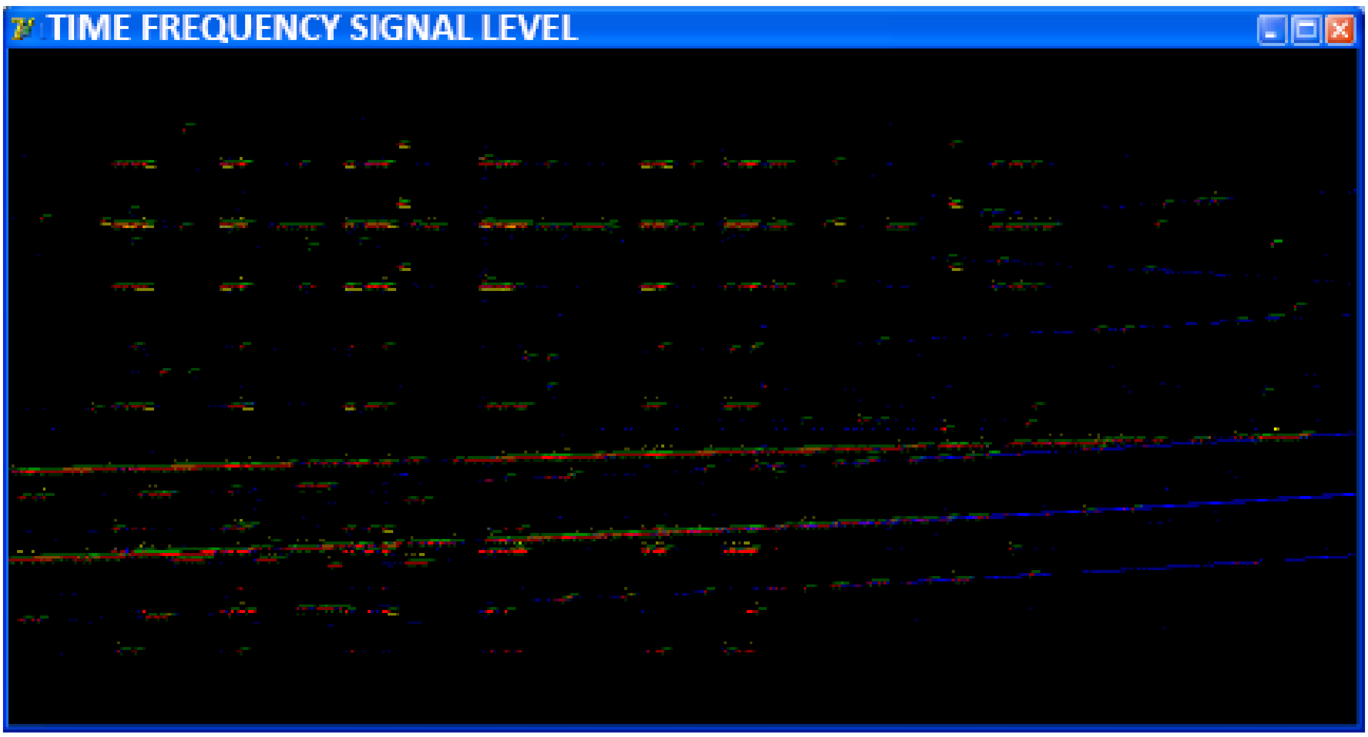

Fig. 5. Frequency and time panorama of the signals spectrum in the input of the DBDRS processor. 26.09.2012, 7 p.m. MSK

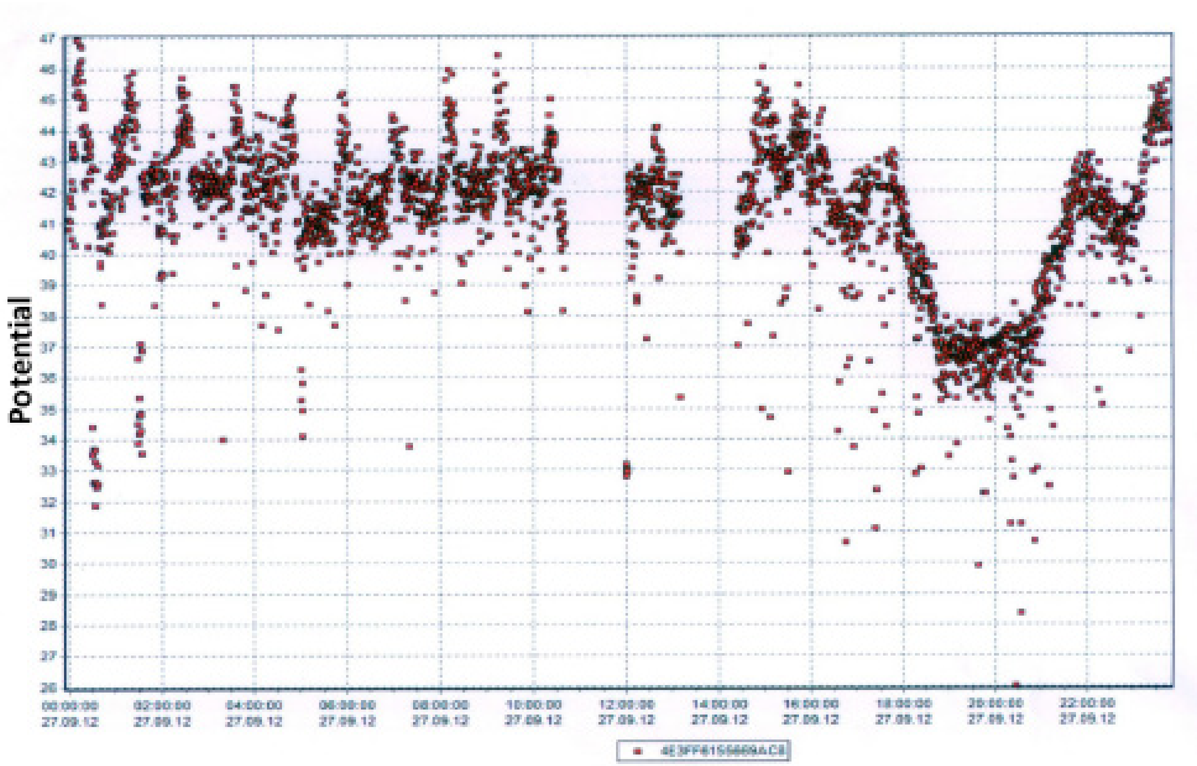

Fig. 6. Energy potential of the ORB of the Kerguelen Islands retranslated by Louch-5A on 27.09.2012

Estimation of the level and influence of interferences on the geostationary segment of COSPAS-SARSAT based on the Louch-5A spacecraft

The research of interferences in the range of the working frequencies of COSPAS-SARSAT 406.01–406.09 MHz and their influence on the operation of the geostationary segment was conducted by two ways:

- A visual observation and the analysis of the time-and-frequency panorama of the accepted DBDRS signal;
- A measurement on rather extended intervals of time the level of the signals received by DBDRSs from the orthographic radio beacon (ORB) placed on the Kerguelen Islands (70° east longitude, 50° south latitude) and constantly, with the period of 30 s, radiating rather powerful (with EIRP ~ 38–40 dBm) signals. When there are no interferences, the energy potential of the received signals of the ORB has to be 48–50 dBHz. Reducing the actually received energy potential of the ORB arises because of the action of interferences. By the value of reduction of the actually received energy potential of the ORB relative to the energy potential of the ORB when there are no interferences, it is possible to estimate the sum power of the last ones.

Figs. 4 and 5 present the examples of time and frequency panoramas received by DBDRS from Louch-5A. The frequency is on the vertical axis and the time (MSK) is in on the horizontal one. The level of interferences is colored: blue is weak, yellow-green is average, and red is big. This level is measured in the band of the elementary filter of fast Fourier transform ≈ 10 Hz. (Figs. 4, 5). The yellow short lines depict the received beacon messages, the yellow horizontal line with the same vertical one after the horizontal one presents the received validated messages.

Fig. 4 is a frequency and time panorama in daytime (2 p.m. MSK 26.09.2012) and Fig. 5 is in evening (7 p.m. MSK 26.09.2012). The analysis of these figures shows that a number and intensity of interferences in daytime are significantly bigger and many messages cannot be reliably allocated.

Fig. 6 shows the dependence of the measured energy potential in the radio line ORB–RS Louch-5A–DBDRS from 12 a.m. to 11 p.m. on 27.09.2012. As this figure shows, in evening (from 6.30 p.m. to 9 p.m. MSK), the potential of the messages was considerably lower (by 5–6 dB) than in another time. This decrease can be explained by the presence in the frequency band of rather strong interferences not coinciding on the spectrum with the messages of the ORB of the Kerguelen Islands.

Fig. 66. Energy potential of the ORB of the Kerguelen Islands retranslated by Louch-5A on 27.09.2012

The sum power of these interferences is about –48 dBW, i.e., by 6 times more than the power of own interferences of a repeater. The same decreases in the potential were observed in other days in almost the same hours. Such decrease of the potential for the ORB placed the Kerguelen Islands due to a big EIRP in no way influenced the probability of a correct reception of its messages. However, for the emergency beacons, which because of the unsuccessful location can have a small EIRP (29 dBmW and less), the decrease in the potential due to such interferences will not allow one to receive the validated messages of these EPIRBs.

Since the increase in the share of the power of the repeater of the transmitter taken for retranslation of the COSPAS-SARSAT signals in the manufactured and placed into orbit Louch-5A is not possible, then it was decided to increase the G/T antenna of DBDRS. This increase could have been done by means of the change of the antenna exciter, LNA, and input filter. The corresponding improvement tests of the DBDRS were made in 2013, and in 2014 two DBDRSs were produced to be placed in the regions of Khabarovsk and Zhelezlogorsk according to the improved documentation.

After installation and putting into operation of DBDRS in Khabarovsk in November 2015, the tests of the geostationary segment consisting of this DBDRS and Louch-5A in the orbital position of 167° east longitude, as well as the tests of this DBDRS and Louch-5V in the orbital position 95° east longitude, were conducted.

The conducted tests completely validated high technical specifications of the RS Louch-5A and Louch-5V obtained during the tests in 2012. A significant (by 5 dB and more) decrease in the potential of the received messages due to the interferences that was detected in 2012 during the tests of the RS Louch-5A with the Moscow DBDRS on the improved DBDRS was not detected. All characteristics of the geostationary segment of Louch-5A and DBDRS in Khabarovsk completely meet the COSPAS-SARSAT requirements T.013 [1], and this segment can be given to the COSPAS-SARSAT Council to put into normal operation.

To put into normal operation in the COSPAS-SARSAT system of the Louch-5V geostationary segment and a DBDRS in Zheleznogorsk, it is planned in 2018 to put into operation this DBDRS and repeat the tests of this segment against correspondence of the C/S T.013 recommendations.

International tests of the geostationary satellite search and rescue system based on the Louch-5A spacecraft

In 2012, the decision of the 57th session of the COSPAS-SARSAT Council approved the intentions of national administrations of the Russian Federation, New Zealand, and the USA to carry out the tests to evaluate the characteristics of the geostationary satellite search and rescue system based the Louch-5A spacecraft to introduce an onboard repeater of this SC to the COSPAS-SARSAT system.

In 2017, after numerous specifications of the terms these tests were launched. The test objectives are:

1) The evaluation of the characteristics of the Louch-5A–DBDRS radio line.

2) The detailing of the COSPAS-SARSAT specifications and standards regarding the requirements to LUT ground stations, which are to carry out reception of signals from the SC of the Louch series.

Carrying out of the tests is made according to the programme and a technique given in the COSPAS-SARSAT document: C/S R.020. According to this programme, Russia is a coordinator of the tests and responsible for functioning of the onboard repeater during the tests and also provides ground reception facilities. New Zealand provides reception through its ground station, and the USA ensures functioning of the simulator of beacon's signals located on the Hawaiian Islands.

Up to the beginning of June 2017, the following tests out of the planned ones had been fulfilled:

1) Test No. 1 “Threshold characteristics of reception, system stock, and efficiency of processing of EPIRB messages”.

2) Test No. 2 “Time necessary to form reliable and validated messages”.

3) Test No. 4 “Capacity of the channel Louch-5A DBDRS”.

Based on the preliminary estimation of the results of the tests No. 1 and No. 2, it is possible to make the following conclusions:

1) The system stock in the geostationary satellite search and rescue system (GEOSAR) according to the

Russian and New Zealand DBDRS makes not less than 11 dB (the difference between the EIRP of a standard beacon in 37 dBmW and the EIRP of the EPIRB at the threshold of reception of messages by the DBDRS) that by 3–6 dB better than a stock in other GEOSAR (MSG, Electro-L, and GOES).

2) The average time of obtaining a reliable message in 95% of cases did not exceed 2 minutes for all EIRP levels of a beacon (from 24 to 37 dBmW).

It should be noted that the obtained preliminary results testify an obvious advantage of the radio line under estimation over the available ones in COSPAS-SARSAT (particularly over the SC of MSG, Electro-l, and GOES series). An indisputable fact also is that the contribution to the improved characteristics of the geostationary segment of COSPAS-SARSAT based on Louch-5A is provided by the COSPAS-SARSAT repeater on the Louch-5A SC.

In the nearest future after completion of the tests, the report on the tests and the recommendation of introducing the repeater into the COSPAS-SARSAT system will be sent for consideration to the COSPAS-SARSAT Joint committee.

Conclusion

The results of the flight tests of the Russian geostationary segments of the COSPAS-SARSAT system created on the basis of the Louch-5A and Louch-5V RS of the MRSS Louch and DBDRSs carried out in 2012–2013 showed a high level of the main characteristics of a geostationary segment based on Louch-5A.

Thus, based on one of the key parameters – G/T defining the probability of the reliable reception of the distress message, Louch-5A is considerably better (up to 10 dB) than the SC used in other geostationary segments of the COSPAS-SARSAT system (SC of MSG, GOES, and Elektro-L series). An energy stock of the radio line (a system stock), i.e., a difference between the EIRP of the nominal emergency radio beacon satisfying the COSPAS-SARSAT [2] specifications and the EIRP values when DBDRS still can fulfill the COSPAS-SARSAT requirements on the probability of allocation of the reliable message made not less than 11 dB that is by 3–6 dB more than for other RS of the COSPAS-SARSAT system.

In 2017, the international tests on the estimation of GEOSAR based on Louch-5A were carried out with the participation of the USA and New Zealand. The preliminary results testified an obvious advantage of Louch-5A over available ones in COSPAS-SARSAT. An indisputable fact is that the significant contribution to the improvement of the quality of characteristics of the COSPAS-SARSAT geostationary segment based on Louch-5A is provided through the relaying equipment available on board the Louch-5A SC. In the nearest future, the report on the tests and the recommendation of introduction of the SC into the COSPAS-SARSAT system will be sent for consideration to the COSPAS-SARSAT Joint committee.

Thus, high tactical and technical characteristics of Louch-5A and Louch-5V RS and ground stations confirmed by the results of national and international tests allow one to make a conclusion that the geostationary segments as a part of these RS and their ground stations are ready to be included into the COSPAS-SARSAT system.

The geostationary segment as a part of the Louch-5A spacecraft and the DBDRS placed in Khabarovsk from the technical point of view are ready to be put into operation in the COSPAS-SARSAT system in 2017. Commissioning of the complex based on Louch-5V will be carried out after putting into service of a DBDRS in Zheleznogorsk.

References

1. *COSPAS-SARSAT GEOSAR Space Segment Commissioning Standard.* C/S T.013, Issue 1, Revision 2, October 2013.

2. *Specification for COSPAS-SARSAT 406 MHz distress beacons.* C/S T.001 Issue 3, Revision 15, October 2014.

3. Clark Jr., George C., Cain, J. Bibb. *Kodirovanie s ispravleniem oshibok v sistemakh tsifrovoy svyazi* [Error-correction coding for digital communications]. Ed. Tsybako B.S. Moscow, Radio i svyaz', 1987. (translated from English)

4. V.I. Tikhonov. *Statisticheskaya radiotekhnika* [Statistical radio engineering]. Moscow, Sov. Radio, 1986. (in Russian)

5. James J. Spilker. *Tsifrovaya sputnikovaya svyaz'* [Digital Communications by Satellite]. Ed. Markov V.V. Moscow, Svyaz', 1978. (translated from English)