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Analysis of the Concepts for Design of Complexes for Receiving, Processing and Retransmitting of Information from the International COSPAS-SARSAT System and the Prospects for Their Development

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Abstract. This paper describes the operation principles of various complexes of onboard systems of the search and rescue spacecraft deployed in the low, medium, highly elliptical and geostationary orbits.

An analysis of the basic technical characteristics of the existing airborne complexes of various segments has been carried out. It has been shown that it is possible to form generalized requirements for on-board equipment that meet the requirements of the international search and rescue system COSPAS-SARSAT, taking into account the performance features of the equipment.

A possible future design of a unified complex is presented, which, with a minimal reconfiguration, can be used in the spacecraft of all the segments of the international search and rescue system COSPAS-SARSAT.

Keywords: COSPAS-SARSAT, medium-orbit search and rescue system, geostationary search and rescue system, on-board unified SAR complex

Introduction

The international search and rescue system COSPAS-SARSAT has been successfully developing since the late 80s of the 20th century, when the basic agreement regulating mutual obligations of the parties (the USSR, the USA, France and Canada) was signed [1]. The system, according to [1], included a space segment consisting of a minimum of 4 low-Earth orbiting spacecraft that must receive and process signals from emergency beacons and transmit them to ground stations.

Subsequently, the search and rescue system was modernized. Initially, it was augmented by spacecraft in the geostationary orbit (1998), as an addition to the low-orbit segment relaying data packets from radio beacons to ground stations without signal processing on board. In 2000, consultations were started and a decision was made to start the development of a fundamentally new (medium-orbit) search and rescue system (MEOSAR), which in future should replace the low-orbit segment. At the end of 2016, it was decided to start the phase of early operational readiness of the MEOSAR system anticipating its final commissioning, which, according to the current development plans, is scheduled for 2020.

The MEOSAR in theory combines the advantages of the low-orbit (LEOSAR) system (the ability to independently determine the coordinates of a beacon – the geostationary system (GEOSAR) is deprived of this capability) while eliminating its shortcomings: the alert signal retransmission service becomes available to the consumer in almost real time, since there is no need to wait for a communication session with the spacecraft.

Successive modifications and expansion of the number of segments of the search and rescue system COSPAS-SARSAT, in fact, led to the actual creation of several different types of onboard equipment, which, with the exception of the LEOSAR, performs the same task: relaying of the signal from an emergency beacon located in the range of the spacecraft to a ground station.

At the present time, the signaling function of the search and rescue system is implemented on the low-Earth space vehicles such as Meteor-M (RK-SM-MKA equipment), geostationary spacecraft of the Electro-L type (channel 8 of the onboard radio unit) and Louch (COSPAS-SARSAT channel of the RDATS), prospective highly elliptical spacecraft of the Arktika-M type (COSPAS-SARSAT onboard radio unit channel) - (the complex is at the stage of ground testing), as well as medium-orbit GLONASS-K spacecraft of different generations (BRKS, BRKS-K2 and the prospective BRKS-2-M).

Within the scope of this article, technical characteristics of the search and rescue equipment are analyzed, and a way of development of these complexes is proposed: the unification of onboard equipment for all segments of the COSPAS-SARSAT system, taking into account the need for additional processing of signals onboard low-earth orbit spacecraft.

Description and principle of operation of COSPAS-SARSAT onboard equipment of various space segments

Below is a brief description of the space complexes used in the current configuration of the system.

The RK-SM-MKA complex

The RK-SM-MKA (modernized rescuing radio complex for small-sized spacecraft) is intended for installation on low-earth orbit spacecraft and in accordance with the latest decisions of the SC Roskosmos will be installed onboard Meteor-M No. 2-1 and No. 2-2 spacecraft.

Similar to the RK-SM complexes [2, 3, 4], a more modern RK-SM-MKA product is designed to receive COSPAS-SARSAT emergency beacon signals at a frequency of 406 MHz, measure the Doppler frequency shift of the package with simultaneous recording of the receiving start time, acquisition of the information part of the message, as well as the formation of a data frame with its subsequent transmission to a ground station.

The basic principles of operation of the complex are presented in Figure 1 [2].

From the antenna-feeder system (AFS), the beacon signal of COSPAS-SARSAT system in the frequency range 406.01 ... 406.09 MHz is fed into the linear section of the receiver, where the frequency is halved (IF1-46.05 MHz and IF2-35 kHz, where IF is an intermediate frequency). At the first intermediate frequency (IF1), the working band of the 90 kHz signal is formed. At the output of the linear section of the receiver, the signal at the second intermediate frequency (IF2) is digitized and enters the digital section of the receiver.

In the digital section of the receiver, algorithms for detecting the signals of emergency beacons, information

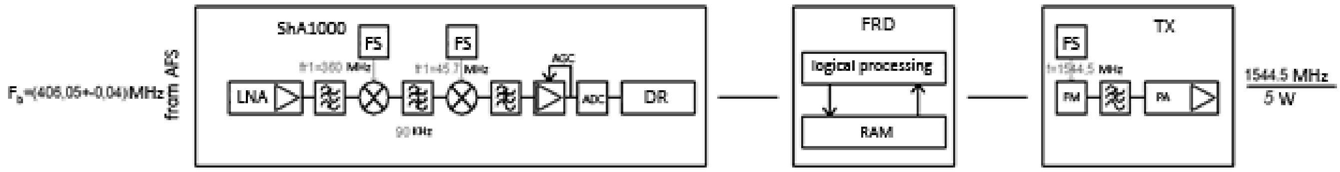

Fig. 1. Functional diagram of the complex RK-SM-MKA. where

FS - frequency synthesizer;
AFS - antenna-feeder system;
LNA - low noise amplifier;
AGC - automatic gain control;
DR - digital receiver;
ADC - analog-to-digital converter;
FRD - framing and recording device;
RAM - random access memory;
FM - phase modulator;
PA - power amplifier;
TX - transmitter.

extraction, as well as measuring the Doppler frequency and time shift of the sending are implemented. The received information is sent to the frame formation and recording unit (FRD), where an information packet is formed for data output to the complex transmitter (TX). In the TX, phase modulation is performed at the carrier frequency of 1544.5 MHz and the gain is 5 ± 1 W. The FRD also records up to 2000 beacon transmissions in the RAM.

The COSPAS-SARSAT channel from the onboard radio unit of the Elektro-L spacecraft

In Fig. 2 the simplified functional scheme of the channel 8 fulfilling the function of relaying the signals of the COSPAS-SARSAT system [5] is presented.

The channel C8 (COSPAS-SARSAT) is combined with the channels C6 and C7 at the input of the onboard radio unit of the Electro-L spacecraft [5, 6]. For all three channels (C6, C7, C8), the LNA is common. Channels C7 and C8 have a common converter CONV-0.4, which performs the first frequency conversion. The LNA has a wide reception bandwidth, since it provides reception of signals at 402 MHz (channel C7), 406.05 MHz (channel C8) and 465 MHz (channel C6). Structurally, the LNA is made as a separate device with external power supply (+15 V), but not removed to the AFS. In CONV-0,4 preliminary frequency selection and the initial frequency reduction are carried out. The signal of the C8 channel is transferred to the frequency of 26.05 MHz and without narrowband filtering fed to the RSC8 unit. The RSC8 unit performs frequency selection by external commands:

- Fnom - 26.05 MHz, 2ΔF - 120 kHz;
- Fnom - 26,025 MHz, 2ΔF - 30 kHz.

The spectrum of the signal thus formed is shifted to the low-frequency end (at a central frequency of 50 or 25 kHz) and as a modulating signal is fed to the LFM with a carrier frequency of 1544.5 MHz. Taking into account the modulation index, the signal efficiency in the spectrum does not exceed 20%. The generated signal is fed to the PA, where it is amplified up to 5 W and is fed to the AFS.

The COSPAS-SARSAT channel from the prospective onboard radio unit of the Arktika-M spacecraft

Radio unit servicing the relay channel for search and rescue information (BRTK-VE) of the Arktika-M spacecraft is a logical upgrade of the radio unit of the Electro-L spacecraft and is intended for installation on a high-elliptical orbit spacecraft. Figure 3 shows the enlarged structural diagram of the Arktika-M radio unit providing the COSPAS-SARSAT relay channel

The main difference between the BRTK-VE equipment and the radio relay installed on the Electro-L spacecraft is the absence of the C6 channel. In addition, the center frequency of reception, transmission and the intermediate frequency of the channel C7 (DATS) is shifted upwards by 500 kHz. However, these differences did not affect the functional circuit of the COSPAS-SARSAT BRTK-VE channel, which repeats the scheme of the C8 channel of the Electro-L spacecraft radio unit. All the devices included in the channel pipeline are kept intact and for unification purposes the broadband LNA remains unchanged, despite the redundancy of

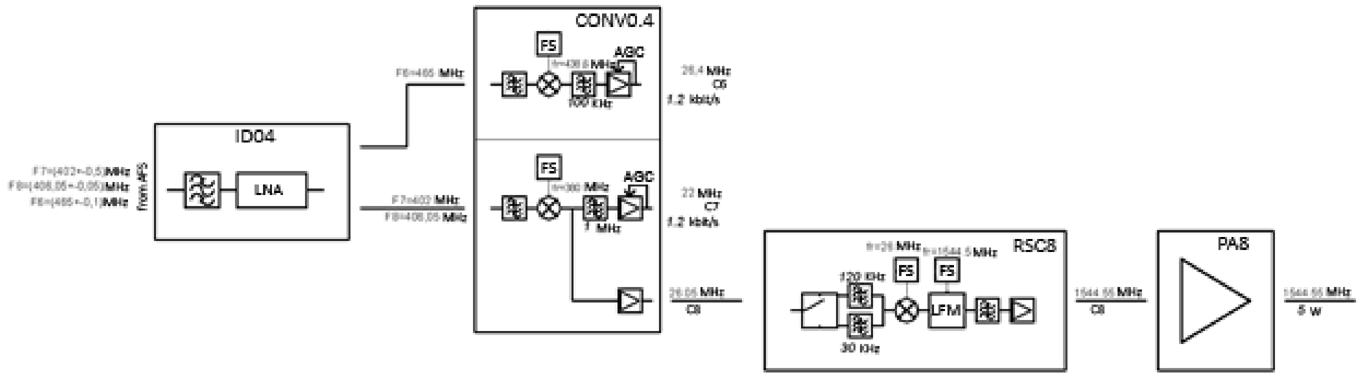

Fig. 2. Enlarged functional diagram of the COSPAS-SARSAT channel of the onboard radio unit of the Electro-L spacecraft, where

ID04 - an input device of the 0.4 GHz band;
CONV0.4 - down converter from the 0.4 GHz band to the 20 MHz band;
RSC8 - response signal conditioner of channel 8;
UM8 - power amplifier of channel 8;
LFM - linear phase modulator;
F6 - the input frequency of the channel C6 - 465.0 ± 0.05 MHz;
F7 - input frequency of the channel C7 - 402.0 ± 0.5 MHz;
F8 - the input frequency of the channel C8 - 406.05 ± 0.05 MHz;
C6 - channel 6 - channel for retransmission of data from data acquisition platforms (DAPs) obtained via low-orbit satellites;
C7 - channel 7 - channel for direct retransmission of data acquisition and transmission system (DATS);
C8 - channel 8 - the COSPAS-SARSAT channel.

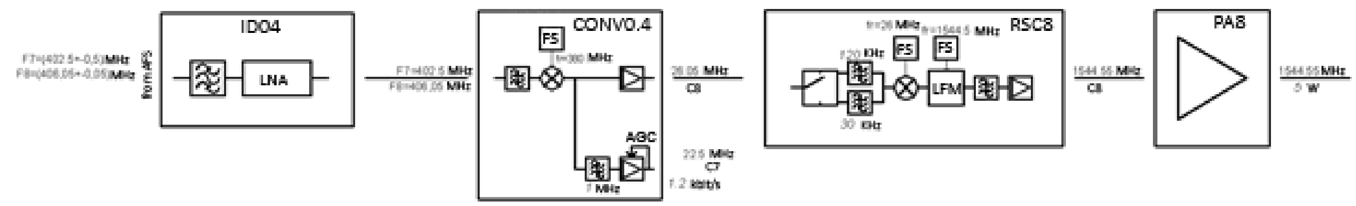

Fig. 3. Enlarged functional diagram of the COSPAS-SARSAT channel of the radio unit of the Arktika-M spacecraft

the bandwidth. Thus, the operation principle of the C8 channel, given in the previous section, is also similar for the COSPAS-SARSAT channel of the Arktika-M onboard radio unit.

The COSPAS-SARSAT channel from the SC of the multifunctional relay space system (MRSS) Luoch-5 series

Meteorological geostationary spacecraft of the Electro-L type are not the only ones equipped for relay of signals from the international search and rescue system COSPAS-SARSAT. Currently, the Louch-5A, Louch-5B and Louch-5V spacecraft, which are part of the Louch MRSS, operate successfully in the geostationary orbit. The Luch-5A and Luch-5V spacecraft have channels for relay of COSPAS-SARSAT signals [6].

Figure 4 shows the enlarged functional scheme of the COSPAS-SARSAT channel from the composition of the Louch-5 spacecraft from the MRSS Luch

According to [6], the relay of the data acquisition and transmission system (RDATS) provides simultaneous retransmission of the signals of the two systems: COSPAS-SARSAT with receive frequency of 406.05 MHz and DATS with receive frequency of 402 MHz. Receipt from AFS is carried out by the RX unit. The RX unit is a low-noise input amplifier that provides the minimum effective noise temperature of the product and a down-converter that shifts the signal spectra from the input frequency range to the IF range (41.375 ± 0.5) MHz for the

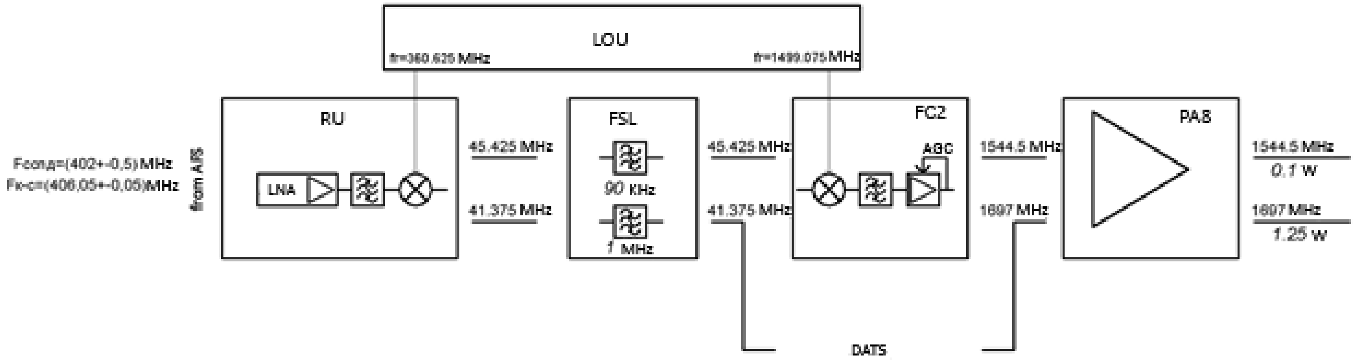

Fig. 4. Enlarged functional scheme of the COSPAS-SARSAT channel from the RDATS of the Louch-5A spacecraft, where
LOU - local oscillator unit;
RU – receiver unit;
FSL - frequency-selective limiter;
FC2 - frequency converter;

DATS channel and (45.425 ± 0.04) MHz for the COSPAS-SARSAT channel. Signals at intermediate frequencies are fed to the FSL unit, which provides narrow-band frequency selection and separation of signals. From the FSL, the COSPAS-SARSAT signal at the center frequency of 45.425 with a 90 kHz band is fed to the FC2 unit, where it is converted to the center frequency of 1544.5 MHz and is fed to the PA. The PA provides simultaneous amplification and transmission of two signals: the DATS signal at a transmission frequency of 1697 MHz and the COSPAS-SARSAT signal at a frequency of 1544.5 MHz. In this case, the output level of the COSPAS-SARSAT signal should be up to 100 mW. Frequencies of the local oscillators, in contrast to the previously considered systems, are formed in a separate LOU.

The BRKS-K1 system from the GLONASS-K1 spacecraft

The BRKS-K1 system installed on board the GLONASS-K 11L and 12L spacecraft [7, 8] is equipped with an integrated LNA providing reception of signals with the minimum standing wave ratio (SWR) and noise factor (NF) at a frequency of 406.05 MHz (Fig. 5). The relay system is autonomous and has no connections with the broadcast signals of other systems. The relay [8] is built on a circuit with a double frequency conversion. The intermediate frequency is 44.9 MHz. At the intermediate frequency, frequency selection is performed by selecting a filter:

- F_{nom} - 44.9 MHz, 2ΔF - 120 kHz;
- F_{nom} - 44.893 MHz, 2ΔF - 90 kHz.

The generated signal is transferred to a frequency of 1544.9 MHz and is fed to the power amplifier.

The BRKS-K2 system from the GLONASS-K2 spacecraft

The BRKS-K2 system, planned for installation onboard the future spacecraft GLONASS-K2 13L and 14L, is currently at the stage of ground tests. Thus, before the completion of the ground tests, it should be considered only as a prospective one.

One of the differences between BRKS-K2 and BRKS-K1 is the removed LNA, which is part of the AFS of the spacecraft. In addition, in BRKS-K2 equipment there are no switchable filters at the intermediate frequency. The signal is selected by a single filter with the Fnom of 44.9 MHz, 2ΔF - 90 kHz. Otherwise, the data relay circuit is similar to the one used in the BRKS-K1 system.

The essential difference between the systems is the presence of a return channel with processing of the acknowledgment signal (AS) onboard for transmission as part of the navigation signal L1OC. From a separate LNA output, the noise-like signal of the AS at the central frequency of 405.928 MHz is fed to the receiver-processor (RX-PRC), which processes, extracts and stores the target information, then the packet is sent to the on-board control complex via the multiplexed exchange channel (MEC) for insertion in the appropriate line of the navigation frame. In addition, the signal from the LNA output goes to another adjacent special purpose system with a similar functional and operating principle.

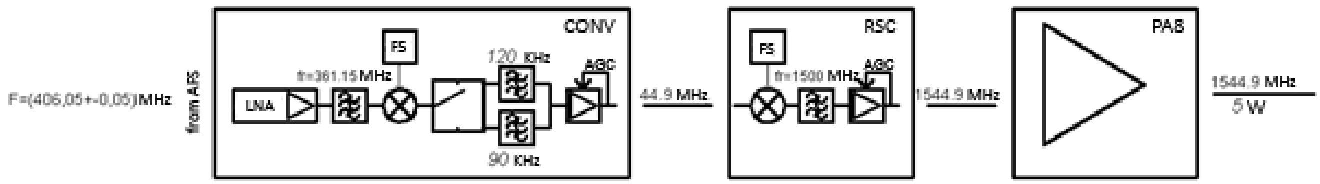

Fig. 5. The enlarged functional diagram of the BRKS SC GLONASS-K1 where CONV - converter; RSC - response signal conditioner.

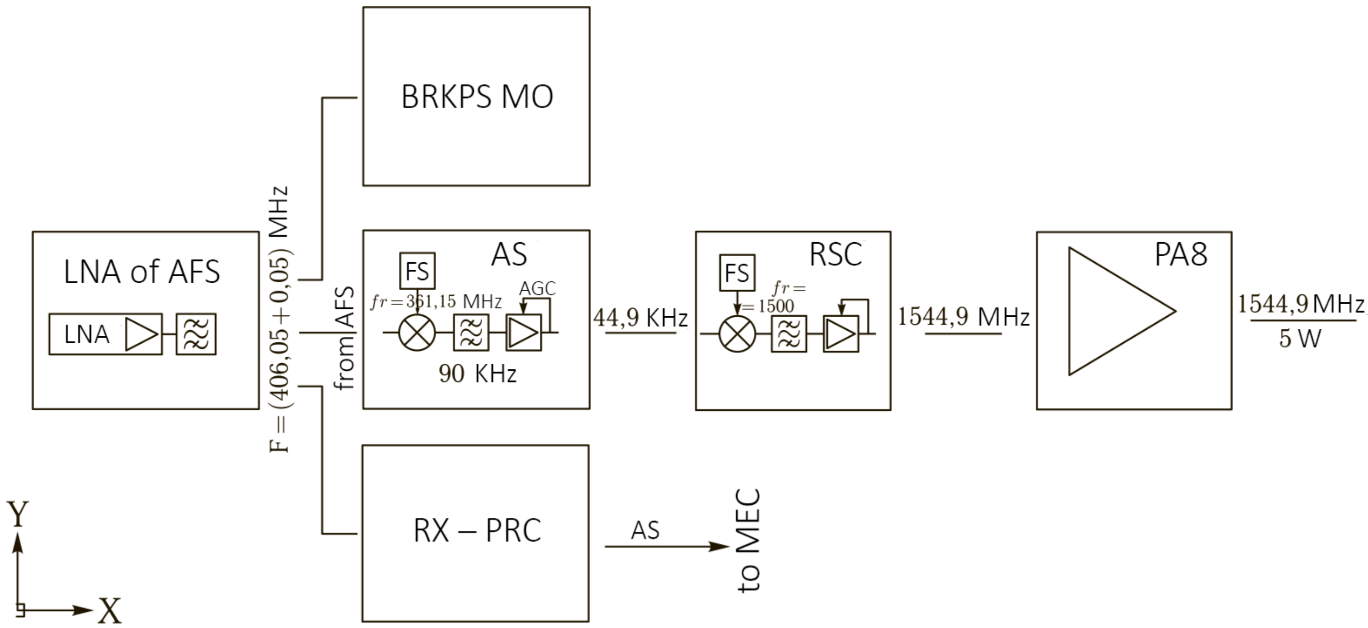

Fig. 6. The enlarged functional scheme of the prospective BRKS-K2 of the GLONASS-K2 SC

Figure 6 shows the enlarged functional diagram of the prospective BRKS-K2 system for the GLONASS-K2 spacecraft.

The BRKS-K2-M system from the GLONASS-K2 spacecraft

At the moment, the modernized BRKS-K2-M system is being developed at the stage of preliminary design, the main difference from BRKS-K2 system is the substitution of imported components with the promising Russian components. The technical characteristics of the system, the operating principle and the functional scheme of the upgraded system are assumed to be unchanged compared to the BRKS-K2 system. Completion of the design and development work is planned for 2020.

Analysis of the characteristics of the onboard equipment of the COSPAS-SARSAT system of various space segments (LEOSAR, MEOSAR and GEOSAR)

As already mentioned above, at present all the complexes for receiving and relaying of the signals of the search and rescue system are created to comply with various requirement specifications, moreover, the products (since they are placed on various spacecrafts) are created at the request of various head enterprises. Therefore, the requirements specification for this equipment, as a rule, do not coincide.

As an example, we can cite the requirements for switching the bus of the onboard network of spacecraft manufactured at various industrial enterprises. Lavochkin

Table 1 The main technical characteristics of COSPAS-SARSAT relays for different satellites

	Channel 8 of Electro-L RU	Channel 8 of Arctic-M RU	BRKS-K1 of GLONASS-K1 SC	BRKS-K2 of GLONASS-K2 SC	COSPAS-SARSAT channel of the Louch-5A RDATS	RK-SM-MKA of Meteor-M No. 2-1 and No. 2-2 SC
Transmission frequency, MHz	1544.55	1544.55	1544.9	1544.9	1544.5	1544.5
Radiation power, W	>4	>4	3-5	3-5.5	0.01-0.1[1]	4-6
Direct retransmission	LFM modulation	LFM modulation	yes	yes	yes	LFM modulation
Processing on board	no	no	no	optional processing of the acknowledgment signal	no	data acquisition, measurement of Doppler frequency offset and the reception time of the packet, data framing
Reverse channel	no	no	no	yes	no	no
Receive bandwidth, kHz	120/30	120/30	120/90	90	90	90
Intermediate frequency, MHz	26.05/26.025	26.05/26.025	44.9/44.893	44.9	45.425	46.05
NF, K^0	160	160	190	150	140	requirements are not imposed
Receiving sensitivity, dBW	-173-173	-173-173	-160	-160	-155	-161
Autonomy	Reception multiplexing with the DATS channel in the range of 402 MHz and MLS in the range of 465 MHz	Reception multiplexing with a DATS channel in the range of 402 MHz	Autonomous system	AS in the L1OC signal, is integrated by reception (LNA) with adjacent special-purpose system	Integration by reception (402 MHz) and transmission (1697 MHz) with the DSP channel	Autonomous system
LNA form factor	Dedicated device with external power supply (+15 V)	Dedicated device with external power supply (+15 V)	Integrated	Autonomous device as a part of AFS	Integrated into RX	Integrated
Service life, years	10	7	10	10	10	5
Operating conditions (orbit)	GSO	HEO of the Molniya type	medium-high circular (h = 19,100 km, i = 64.8)	medium-high circular (h = 19,100 km, i = 64.8)	GSO	Low close to circular (h = 900 km, i = 81.2)

Table 2. Proposals on the unification of COSPAS-SARSAT equipment requirements for various platforms.

Parameter	Value
Transmission frequency, MHz	1544.5 (for the on-board data frame for the LEOSAR and for direct relay for the GEOSAR and HEOSAR) 1544.9 (for direct re-broadcast of the MEOSAR)
Radiation power, W	4-6
Relay type	Direct
Processing on board	1. Data acquisition, measurement of Doppler frequency offset and the reception time of the packet, data framing 2. Acknowledgment signal processing, data framing
Reverse channel	yes
Receive bandwidth, kHz	90
Intermediate frequency, MHz	44.9
NF, K^0	140
Receiving sensitivity, dBW	-173
Autonomy	Reception multiplexing with the DATS channel in the 402 MHz band, with the special-purpose system and a channel for retransmission of DAP data acquired by the LO satellites in the 465 MHz band
LNA form factor	A dedicated stand-alone device with separate power supply, not integrated in the AFS

(the head company for the creation of the Electro-L and Arktika-M) adheres to the principle of switching the negative bus, while the Reshetnev (the head enterprise for the creation of spacecraft of the GLONASS and Luch series) switches the positive bus.

In this paper, the above questions will not be considered. Also, the requirements for complexes for the resistance to the effects of external factors, including mechanical vibration, temperature regime and the impact of space factors, are not considered. Obviously, these characteristics are determined by the type of target orbit and means of launching the spacecraft. When creating the equipment of the COSPAS-SARSAT system, in relation to the specified types of effects, it is necessary to take into account the most stringent requirements currently imposed for each of their types.

The aim of this work is to analyze the technical requirements for the COSPAS-SARSAT equipment intended for installation on various space vehicles of various segments of the international system in order to determine the possibility of their harmonization in the development of the maximally unified solution. The basic requirements for the space complexes of all segments of the COSPAS-SARSAT system are determined by the system documents of the Program [4, 5, 7].

Let us consider the main technical characteristics of the COSPAS-SARSAT signal relay complexes. Table 1 summarizes all the main hardware requirements for different segments: receive and transmit frequencies, sensitivity, modulation type of the output signal, and conditionally (in the form of orbit types) gives the operating conditions.

Analysis of the table shows that the basic hardware requirements for all segments of the international search and rescue system are similar: the complexes must receive signals from beacons in the 406.0-406.1 MHz range, emit a signal in the 1544.0-1545.0 MHz range, the radiated power should be of the order of 5 W.

Nevertheless, there are differences. For example, the level of the output signal of the Louch-5A and Louch-5V SC is significantly lower than 5 W and is 0.1 W at maximum. However, even in this case, the repeater signal is received by the LUT with the signal-to-noise ratio necessary for decoding the information, since the

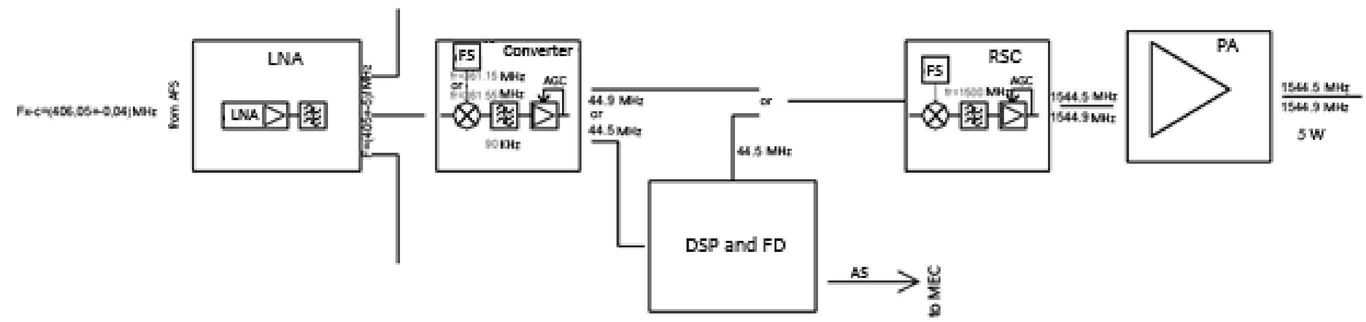

Fig. 7. Enlarged functional diagram of the unified on-board complex of the COSPAS-SARSAT system, where
LNA - low noise amplifier;
AFS - antenna-feeder system;
RSC - response signal conditioner;
PA - power amplifier;
DSP - digital signal processing;
FD - framing device;
FS - frequency synthesizer;
MEC - multiplex exchange channel;
AS - acknowledgment signal;
AGC - automatic gain control.

antenna parameters of the receiving stations were chosen with a significant margin in the design.

In addition, there are differences in the requirements for sensitivity of the equipment. Such a difference can be determined by the altitudes of the orbits on which the corresponding repeaters are supposed to be used. However, the difference, for example, in the types of modulation of the relayed signal is not easy to explain.

It should be noted that design solutions differ, which is clearly demonstrated by the example of LNA implementation. In the case of Electro-L or Arktika-M spacecraft, as well as BRKS-K2 on GLONASS-K2, this is an external device with a dedicated power supply. In the case of the RDATS on the Louch-5A or Louch-5V and BRKS-K1 on the GLONASS-K1, the LNA is integrated directly into the radio units. There is a lack of a systematic approach and a unified scientific and technical policy in the design of onboard equipment for search and rescue systems.

In order to further develop the system to reduce the cost of developing and manufacturing of equipment for different platforms, it is advisable to develop a single and maximally uniform set of requirements taking into account the selection of the most stringent requirements for equipment operating in different orbits.

Based on the analysis of the performance characteristics of the equipment for various platforms, the criteria for maximum suitability and the worst case were used to formulate the general requirements with a view to its unification for future projects. These proposals are presented in Table 2.

The produced requirements take into account the need for signal emission at different frequencies, which is determined by the system requirements of COSPAS-SARSAT for the equipment of LEOSAR, GEOSAR and MEOSAR. In addition, the characteristics of the power of the output signal, the input band, the sensitivity of the intermediate frequency of conversion, and the basic performance requirements are suggested.

Fig. 7 presents the enlarged functional diagram of the proposed unified onboard complex of the COSPAS-SARSAT system.

In accordance with Fig. 7, on the LNA, which provides a noise temperature of not more than 140 K °, the signal is received in the frequency range 400-410 MHz. The LNA should have a sufficient number of outputs to support the operation of the COSPAS-SARSAT system, as well as the DATS system and the adjacent special purpose system.

Currently, the option of creating a unified common converter for the COSPAS-SARSAT and DATS channels is under consideration.

In the converter, the COSPAS-SARSAT signal is converted to the central frequency of 44.9 MHz or 44.5 MHz (depending on the version) and its filtering at the intermediate frequency is performed. Thus, the converter designs differ in the frequency of the local oscillator formed by the frequency synthesizer (FS), and in the filter with a band of 90 kHz at intermediate frequencies.

Therefore, for relays for geostationary spacecraft, such as the Electro-L and Louch series or spacecraft in a highly elliptical orbit, such as Arktika-M, a converter modification with a local oscillator frequency of 361.55 MHz and an intermediate frequency of 44.5 MHz with the appropriate filter setting is required. For a relay for medium-orbiting spacecraft of the GLONASS series, a converter with a local oscillator frequency of 361.15 MHz and an intermediate frequency of 44.9 MHz is required. It is assumed that such a configuration can be implemented through software modifications.

From the output of the converter, the signal is fed to the DSP, where it is digitally processed and information is extracted. DSP will also require different execution of software for different projects due to different input frequencies of the devices. In FRD, a data frame is formed and modulated at 44.5 MHz.

Internal switching of the devices can also be implemented in different ways. So, for the LEOSAR SC of the Meteor series, the signal to the RSC comes from the FRD. That is, relaying is carried out by signal processing followed by modulation. Therefore, direct HF communication between CONV and RSC is not required. In other cases, the signal to the RSC comes directly from the CONV, since only such a link provides direct relaying without processing. In general, DSPs and FDs are not used on relays for the GEOSAR. On-board systems of these spacecraft (the Electro-L, Arktika-M, Louch series) do not provide signal processing on board. DSP and FR are used on GLONASS SC, because they require a reverse channel with on-board processing of the acknowledgment signal (AS) for transmission as part of the L1OC signal. The generated sequence, however, is fed into the onboard control complex through the MEC for insertion into the corresponding row of the navigation frame.

In the RSC, the signal (44.5 MHz or 44.9 MHz) is transferred to the 1544 MHz band (the local oscillator frequency is 1500 MHz), then it is fed to the power amplifier (PA), where it is amplified up to 5 W and is fed to the AFS.

Taking into account the above, it can be concluded that the proposed variant of design of a prospective relay provides all the necessary options for signal transmission under a single unified scheme with the performance characteristics proposed in Table 2 with minimal modifications.

Conclusion

In the article technical characteristics of the existing and future complexes of the search and rescue system COSPAS-SARSAT intended for installation on various space vehicles are considered.

As a result of the analysis, unified requirements for prospective on-board equipment are formed, which, if developed and implemented as a part of the advanced DDWs within the framework of the Russian Federal Space Program 2016-2025 or the GLONASS Federal Target Program, can be installed on low-orbit, medium-orbit, geostationary and highly elliptical spacecraft of the system.

Taking into account the design of COSPAS-SARSAT advanced equipment in the form of a complex of basic elements with severely limited functionality, and also taking into account the need to implement the signal processing function for emergency beacons onboard low-earth orbiting spacecraft, it becomes possible to create a maximally unified search and rescue complex that with minimal reconfiguration can be used onboard any segment of the search and rescue system.

The development of the most unified complex will not only increase its reliability and reduce the costs of development and production, but also fundamentally reduce the time for adaptation to various spacecraft, reduce the required range of electronic products, expanding the list of used Russian-made components, and demonstrate the advantages of using a unified control and verification equipment.

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