Search and Rescue Radar Transponder under Dynamic Operating Conditions

Radar odgovarač traganja i spašavanja u dinamičkim uvjetima rada

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Summary

The Search and Rescue Radar Transponder (SART) operates in the frequency range from 9.2 GHz to 9.5 GHz. The SART is used on conventional and, partly, non-conventional vessels in search and rescue operations at sea. It is also used, to a certain extent, on inland waterways, rivers and lakes. As for their construction and design, SART transponders are self-contained, portable units. With regard to their technical characteristics and design requirements, they comply with the regulations of local registers of shipping when fitted to new-build vessels or in case of subsequent installation. This paper presents the influence of the real-life conditions to the SART radio horizon. When the device is operated on various survival crafts and life-rafts, the actual ranges achieved under dynamic conditions, depending on the changes in the SART antenna height, differ very much. However, it can be noted that the application of the SART in real-life conditions in practice does not achieve the results required by relevant recommendations. The paper also provides suggestions for potential improvements in SART operation and use.

KEY WORDS
SART
vessels
dynamic conditions
radio horizon

Sažetak

Radio horizont radar odgovarača traganja i spašavanja (SART) radi na frekvenciji od 9.2 GHz do 9.5 GHz. SART-om se koristi na konvencionalnim i djelomično na nekonvencionalnim plovilima u operacijama traganja i spašavanja na moru. Također se njim u određenoj mjeri koristi na kopnenim plovnim putovima, rijekama i jezerima. Što se tiče izrade i konstrukcije, SART odgovarači su samostalni prijenosni uređaji. Tehničke karakteristike i propisi izrade su u skladu s propisima lokalnih registara brodova kada se postavljaju na nova plovila ili kada se naknadno ugrađuju. U radu se prikazuje utjecaj realnih uvjeta na SART radio horizont. Kada uređaj radi na raznim plovilima za preživljavanje ili splavima za spašavanje, stvarni domet postignut u dinamičkim uvjetima znatno varira, ovisno o razlikama u visini antene SART-a. Ipak, može se primijetiti da primjena SART-a u realnim uvjetima u praksi ne postiže rezultate propisane u relevantnim preporukama. U radu se također predlažu moguća poboljšanja u radu i uporabi SART-a.

KLJUČNE RIJEČI
SART
plovila
dinamički uvjeti
radio horizont

1. MODEL FOR CALCULATING THE TRANSPONDER'S RADIO HORIZON / *Model za izračun radio horizonta odgovarača*

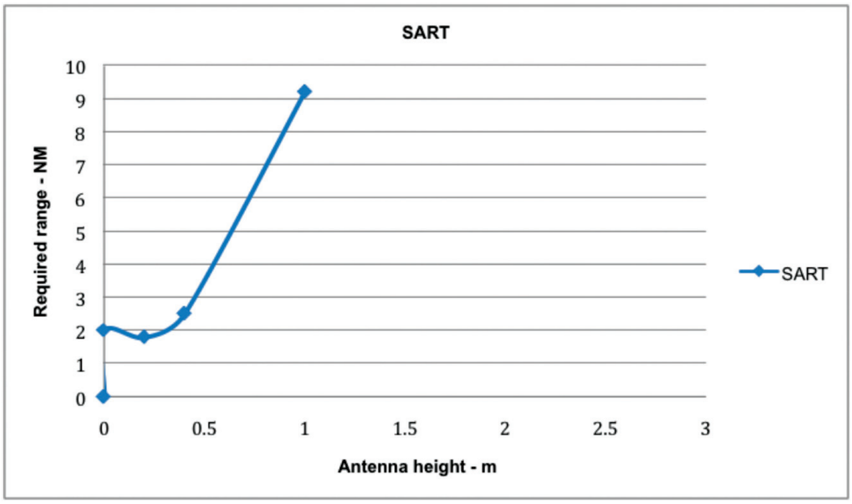
The radar horizon is typically calculated according to the radio horizon pattern derived from the calculation of the geometric horizon [8]. The geometric horizon (G_h) for the values:

r – radius of the Earth ≈ 6378 km or 3440 NM
h_a – height of aerial above sea level
G_h – geometric horizon

is calculated according to the pattern:

$$G^2{}_h = (r + h_a)^2 - r^2 \Rightarrow G_h = \sqrt{(r + h_a)^2 - r^2} \quad (1.1.)$$

Geometric horizon calculations result in relatively accurate values. They are relatively accurate because the Earth is a geoid and its flattening is generalised in the calculation pattern. Hence, in practical applications, it should be considered that the SART radio horizon [9] (R_{hSART}) is larger than the geometric horizon (G_h) by 15%. SART systems, including the associated antenna systems, are mounted on vessels in compliance



Graph 1. SART range under required operating conditions
Graf 1. Domet SARTa u propisanim uvjetima rada

with the international and national recommendations and requirements [2]. It should be noted that the end user, e.g. the master or officer of the watch, is not familiar, or he is only partly familiar, with the fact that the SART radio horizon is calculated under stable or ideal weather conditions. Furthermore, some authors [8] recommend the calculation of the radio horizon along the arc of curvature (G_{hl}):

$$G_{hl} = \frac{r \cdot \Pi \cdot \beta}{180^o} \quad (1.2.)$$

r – radius of the Earth ≈ 6378 km or 3440 NM
β – angle essential for calculating the horizon along the arc of curvature

According to [8], calculating the horizon along the curvature arc (G_{hl}) (1.2.) allows for the correction of the relatively small error contained in the generally accepted model for calculating the radio horizon, as defined by (1.1.) The above procedure can be also applied when calculating the SART horizon.

2. INTERNATIONAL REQUIREMENTS REGARDING THE SART / *Međunarodni zahtjevi za SART*

The operating area of the 9 GHz bandwidth, for radars engaged in locating survival craft or distressed vessels at sea, was defined by the regulations of the International Maritime Organization (IMO), Annex 3-6-6 of the IMO manual for Global Maritime Distress and Safety System (GMDSS Manual), as well as by the technical instructions for search and rescue radar transponders, described in the recommendations of the International Telecommunication Union (ITU) and regulations III/6.2.2 and IV/7.1.3 issued in 1988, and by the amendments to the Convention on Safety of Life at Sea (SOLAS) [10]. In line with the SOLAS, all passenger vessels, irrespective of their size, and all cargo vessels up to 500 GT must carry at least one device [7]. Ships over 500 GT must be equipped with two SARTs [1]. According to technical requirements defined by IMO, the SART should cover the range of 12 NM from the life-raft or survival craft to the receiving antenna of the rescue vessel, which is mounted at a height of at least 15 m. As for technical requirements of the Croatian Register of Shipping (CRS) [6], Section 14 / 9.1.7 states that the rescue radar transponder should have the range of at least 10 NM and at least 15 m high antenna when searching and locating the SART on a life-raft or survival craft. The following chapters of the paper discuss the SART range under required, ideal and dynamic operating conditions, providing possible solutions to the detected problems [4].

3. SART UNDER REQUIRED OPERATING CONDITIONS / *SART u propisanim uvjetima rada*

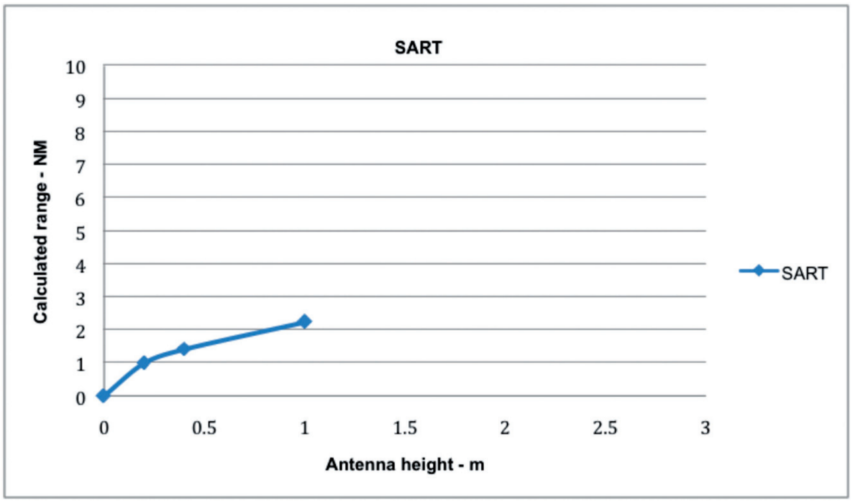
Nowadays the SART required operating conditions have been defined by IMO resolution A.697(17) specifying the required minimum range of 5 NM. Compared to the initial 1992 requirements, the range has been reduced considerably. IMO tested six SART devices produced by different manufacturers and the results obtained under real conditions gave the detection range of 9.2 NM with an antenna height of 1 metre above the water. The tests have also shown the importance of maintaining a SART antenna height. If the SART is placed lying on the floor of the life-raft / survival craft, the required range amounts to 1.8 NM, whereas the SART standing upright on the floor has a range of 2.5 NM. If the SART is floating in the water, its range is 2 NM [1]. However, the tests do not describe the weather conditions or geographic locations where the measurements were made. (Graph 1)

4. SART UNDER IDEAL OPERATING CONDITIONS / *SART u idealnim uvjetima rada*

The range of the marine VHF communication devices is calculated according to the radio horizon pattern that is derived from the calculation of the geometric horizon [8].

$$d_{rv} = 2{,}23\sqrt{V_h} \quad (1.3.)$$

Therefore the SART range can be calculated by following the same pattern:



Graph 2. SART range according to the formula (1.3.)
Graf 2. Domet SARTa prema formuli (1.3.)

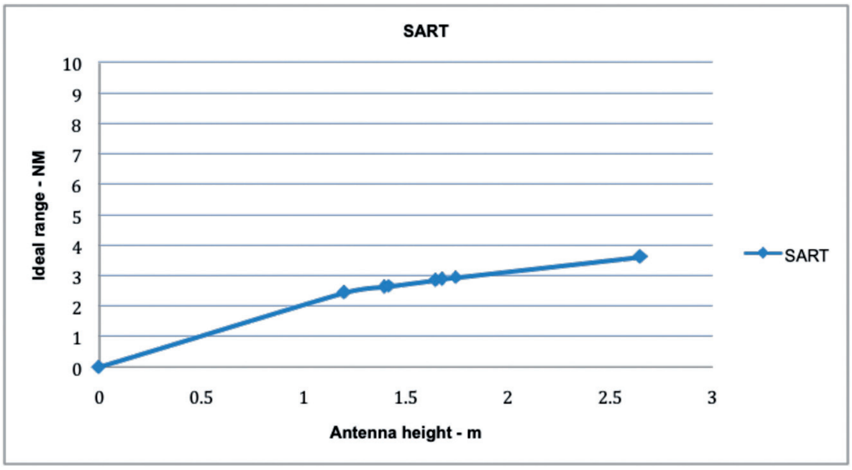
Typical heights of SOLAS life-rafts depend on the number of persons carried, ranging from 1.2 m for a six-man life-raft to 2.65 m for a fifty-man SOLAS life-raft [5]. These heights are expected to be used for mounting and/or holding the SART in the event of distress. (Graph 3)

It can be noted that there are considerable differences in SART range under required and ideal operating conditions. It is assumed that the differences in SART range under dynamic conditions might be even greater.

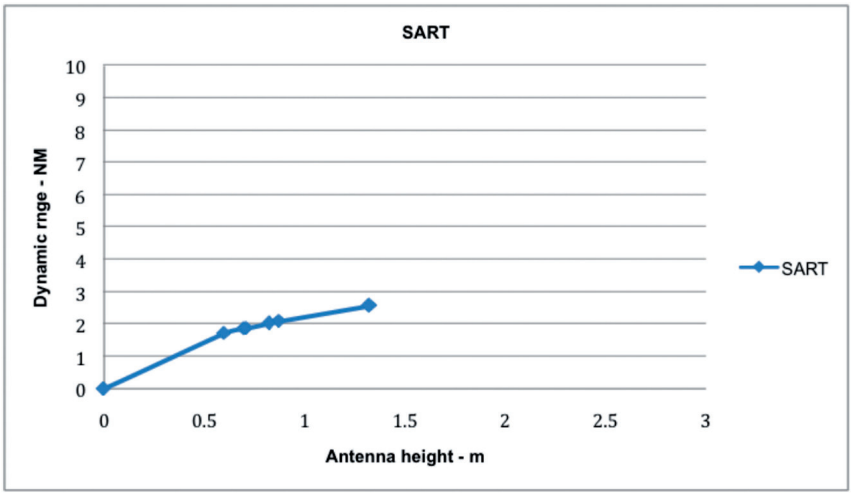
5. SART UNDER DYNAMIC OPERATING CONDITIONS / *SART u dinamičkim uvjetima rada*

Dynamic conditions of SART operation directly depend on various motions of the vessel. According to [3], the vessel motions are affected by the state of the sea and other weather conditions. Under dynamic conditions, vessel motions may be classified as translation and rotation motions. Translations include *sway* (linear side-to-side motion), *heave* (linear up/down motion) and *surge* (linear front/back motion). Rotations include *pitch* (rotation of a vessel about its transverse i.e. side-to-side axis), *yaw* (rotation of a vessel about its vertical axis) and *roll* rotation of a vessel about its longitudinal i.e. front/back axis). The SART is used for locating persons who have abandoned ship/boat due to emergency. It is assumed that the persons and their survival craft / life-raft is subjected to the impact of waves and sea conditions. When the SART is operated, it is assumed that the chances of capsizing are reduced, if any. However, under dynamic conditions, the life-raft or survival craft at sea moves according to the impacts of waves and winds. Therefore the SART horizon is to a great extent adversely affected by the motion of the life-raft / survival craft up and down the waves. It is likely that the life-raft occasionally happens to be out the radio horizon in relation to searching radar of rescue ship. This results in serious changes in the SART antenna's height relative to the sea level, with values ranging from 0 m to maximum designed height that is defined by the height of the life-raft or the survival craft (1.2 m – 2.65 m). This directly degrades the respective radio horizons and ranges. (Graph 4)

Marine VHF communication devices have a wide application in navigation on board convention and non-convention vessels. As for their construction and design, marine VHF equipment may be classified as portable and stationary. By applying the automated system of real-time warning about the dynamic characteristics of the radio horizon under real conditions of



Graph 3. SART range under ideal operating conditions
Graf 3. Domet SARTa u idealnim uvjetima rada



Graph 4. SART range under dynamic operating conditions
Graf 4. Domet SARTa u dinamičkim uvjetima rada

the ship exploitation, the deck officers are provided with the Maritime Safety Information (MSI) on the actual radio horizon and the range of their marine VHF communication equipment. In case of emergency, this ensures additional possibility to achieve the desired radio horizon of the marine communication equipment by, for example, altering the course and/or speed [8]. Because of the movement of SART antenna in dynamic conditions comes to the low quality reception at the radar so that the signal reception is not good enough, which reduces the range of devices and receiving radar on vessel for search and rescue. When aircraft and/or helicopters are engaged in search operations, better results are achieved due to the increased radar horizon. It should also be remembered that the radar horizon of the searching craft and the radio horizon of the vessel transmitting a SART signal are in firm correlation. Consequently, the range of the initial SART transmission is increased and so are the chances of detecting the life-raft / survival craft in distress. Therefore, the range of the expected detection of the SART fluctuates considerably. It can be concluded that the range within the SART signal is expected to be received directly depends on correlation of radar horizons the SART and the searching radar. This probability is highly uncertain and it is further researched by the authors of this paper. In situations when the vessels are engaged in search operations at sea and heading towards the life-rafts or survival craft using SART technology, it is necessary to underline the difficulties related to degraded SART ranges and to suggest ways of solving the detected problem by means of defining relevant guidelines.

6. PROPOSAL FOR SOLUTION / *Prijedlog rješenja*

The following guidelines may be suggested with the aim of solving the detected problems in SART operation:

- Estimation of the indispensability or abandoning SART technology,
- Changes in the names of devices and the user's familiarisation with their real features,
- Exploring the efficiency of GMDSS systems performing the same tasks, and
- Development of new devices.

When estimating the indispensability of the SART, the results presented in this research may serve as the starting point. The goal is to make a sound assessment whether it is essential to keep or it is more reasonable to abandon this type of technology. One should at least be aware of the fact that the SART does not enable the expected range and that it is primarily a *homing* device and not a *search* device, as suggested by its original name.

Minimum changes should refer to the name of the device. Instead of "SART", it would be more appropriate to call the device *Homing Radar Transponder* (HRT). In addition, it is recommended to familiarise the SART users with its actual abilities, i.e. each SART device should carry the typical approved graphic mark indicating the characteristics of the radio horizon in the event of operation under dynamic conditions.

When studying the existent but unused abilities of GMDSS systems in performing search and detection tasks, it is necessary to explore the possibilities of the new technical and technological solutions by using, for example, the existent or recently developed potentials of the Space System for the Search of Vessels in Distress / Search And Rescue Satellite-Aided Tracking (COSPAS/SARSAT) and the International Maritime Satellite Organization (INMARSAT). Likewise, assuming the availability of legal regulations, the possibility of using homing and search services of other unofficial operators of the satellite communication systems should be evaluated.

If further research reveals that the SART is functionally indispensable in marine application but fails to comply with the required characteristics, then there is no doubt that a new device meeting all operational and other requirements, particularly under dynamic conditions, should be developed.

7. CONCLUSION / *Zaključak*

In practical maritime shipping and the associated activities including the navigation and other processes, it is considered essential to know the accuracy of a used device, i.e. to be familiar with any faults or deficiencies. For this reason, one should be aware that the SART ranges under required, ideal and real, i.e. dynamic operating conditions, differ considerably. In certain emergency situations at sea this may greatly affect the efficiency in locating and saving casualties.

Therefore, in order to contribute to the ability of officers to make correct decisions in distress situations, and especially when it is necessary to use the SART and other electronic navigation and communication equipment, the users should be warned about the real abilities of SART devices. In order to find quality solutions to the detected problem, it is necessary to carry out further research using the suggested guidelines, and to provide IMO with a concept of proposals aimed at the enhanced use of the SART.

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