A Study on the Development of Shipborne Collision Avoidance System

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1.Introduction

From the beginning of navigation at sea, the human being has been managing to solve two fundamental problems: ship's positioning and collision avoidance. Along with the technical development, the human has made considerable progress in solving these problems. The problem of ship's positioning has been overcome since the emergence of GPS (Global Positioning System). However, the equipment used for collision avoidance has some problems with practice. The method of operating ship for collision avoidance is not changed as compared with that in last century. The method is still turning the ship's heading at a large angle (usually at 10 degrees) to show own attempt for avoidance of collision or whistling to inquire other ship's attempt when ships approach to a certain distance. The potential risks exist in this method, especially in constrained waters, bad weathers and areas with high density of ship. Why is the method continuous to be used today? The reason is that the aid provided by Radar and GMDSS has some problems with practice for collision avoidance. The purpose of my research is to solve this problem. A completely new navigational aid system will be proposed, named as Shipborne Collision Avoidance System (SCAS), which can provide functions of surveillance, identification, situation awareness and communication. This system will satisfy the requirement of operating ship for collision avoidance.

2. Basic concept

The basic concept of the SCAS (shown in Fig.1) is that navigators on the bridge are able to conveniently and quickly obtain all information for preventing collision, to easily communicate each other and to finally reach an agreement on collision avoidance before taking action actually. The information includes that of own ship, other ships and even shore. The idea of the SCAS is the automatic ship report. Its technology is the dynamic interlinkage among computers on the bridge of ships. In general, the distance is limited in

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terms of collision avoidance. For example 12 nautical miles, namely, "cell". When both ships approach to this distance, the computers on the bridges are able to automatically interconnect each other and then exchange their data.

The ship's dynamic information such as ship's position, speed and course, together with the ship's identity, call sign, name and navigational status, broadcasts on the network. The other ships within the same cell would receive the information and display it in text and image. This realizes the ship's identification, surveillance and situation awareness.

Navigators are able to communicate each other by means of the SCAS. The SCAS provides two manners of the communication, which are text transfers and talk. Navigator easily communicates with others because he has known the identities of other ships. Communication calling is automatically done through the computer network. The navigator only need to click one button and then is able to talk each other, just like using a hot line. It saves the time for navigator. Since the SCAS covers ships out of the control of SOLAS, it is possible that speaking English is difficult for some navigators. Therefore, the SCAS provides text transfer to overcome that language barrier. Navigator is able to communicate for collision avoidance using his native language and finally reach an agreement.

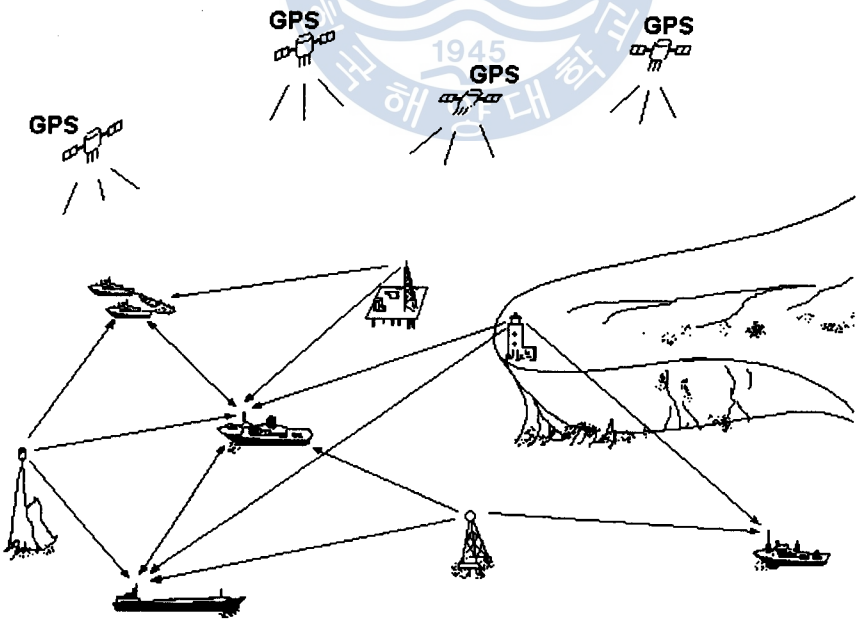


Figure 1 General concept of the SCAS

According to the received ship reports, the SCAS is able to automatically calculate parameters of preventing collision and to monitor the risk of collision. If the extent of risk reaches its critical level, the SCAS would alarm the navigator to take action.

It is important that the data link has high capacity since the SCAS includes all ships at sea. Moreover, since the SCAS is suitable for all phases of navigation at sea, specially at high sea, the communication must be self-organizing. That means no master station and no slave station. According to the requirement above, a new radio data link in marine VHF band, named as Marine VHF Data Link (MVDL), is defined, which is the development of the STDMA (Self-organized Time Division Multiple Access) technology.

When navigating at sea, navigators concern not only ships in the vicinity but also lighted beacons. Hence, the SCAS also includes them. The transponder of the SCAS is installed on a beacon light, which only transmits the beacon information. The coverage of the SCAS can be changed by adjusting the output power of the transmitter. The information emitted by the transponder fixed on a beacon light includes the identity, position and attribute of the beacon, which satisfies the requirement of guidance.

3. System configuration

The configurations of the SCAS are shown in Fig. 2. The part above real line is the standard configuration that is suitable for the ships controlled by the SOLAS. The top line is the static configuration that is suitable for the installation on beacon. The details of each component are described as following.

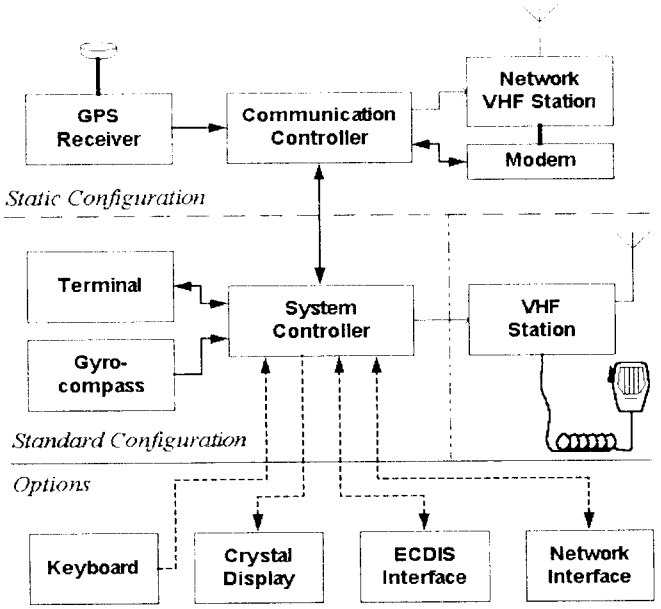


Figure 2 Configurations of the SCAS

- GPS Receiver: It receives the signal of the GPS[1] satellites and provides the ship's position, speed, course and the UTC time.
- Network VHF Station and Modem: they are the hardware of digital communication. By means of them, computers on the bridge of ships can interconnect and the ship reports can be broadcast.
- Communication Controller: It is a computer system. It controls the computer network.
- VHF Station: It is used for voice communication of navigators between ships. After navigators determine the communication channel through the network, the system automatically tunes this VHF station at that channel. And the navigators can speak each other just like using a hot line.
- Gyrocompass: It provides the ship's heading, which is one of the most important parameters for collision avoidance.
- PC Terminal: The terminal of the SCAS is a personal computer, which provides the man-machine interface. Through it, navigator can monitor the situation of the vicinal area, obtain the information and control the system.
- System Controller: It is a microcomputer system. It provides the information transfer and system control.

In addition, there are four options of the SCAS. Crystal Display and Simple Keyboard form a simple terminal that provides the basic function of the display and system control. It is designed for the small ships, such as fishing boat. The ECDIS Interface is used to connect the SCAS with the ECDIS. And the interface of the Onboard Network makes the SCAS connecting to the onboard network.

4. Operating principle

The SCAS operates based on the mode of broadcast transponder, as shown in Fig.3. It needs two VHF channels. One is used for establishing the digital communication of the computer network, which is a worldwide exclusive marine VHF channel required to be defined by ITU. The other is used for the voice communication by navigators on the bridges, which is any available channel in the marine VHF band.

Each SCAS has its operating area. That is the range of coverage of the VHF radio data link, named as "cell". The range of the cell is determined as 12 nautical miles according to the requirement of collision avoidance. We can adjust the output power of the transmitter to fulfil it.

The SCAS always listens in the network channel and constantly broadcasts its information in it. This information includes four types as following:

- Identity: Marine Mobile Service Identity (MMSI)
- Basic information: Name and Call sign, Length and Beam, Gross ton, Type of ship, Draught
- Dynamic information: Ship's position, Course, Speed, Heading, Navigational status, UTC time
- Waypoint: It is within 12 miles.

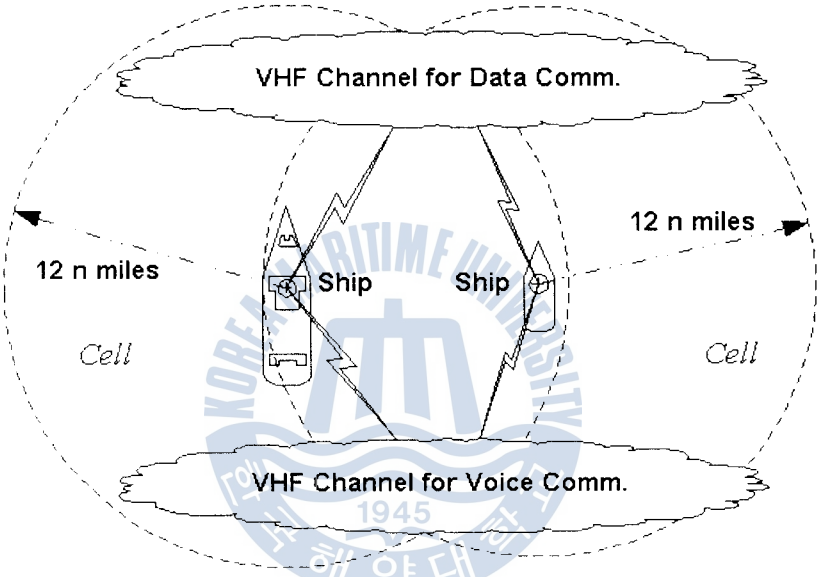


Figure 3 Operating principle of the SCAS

The dynamic information is primarily from GPS receiver. The above information sufficiently satisfies the requirement of identification, surveillance and communication for collision avoidance[2]. This information has tow update rates: High update rate and Low update rate. The ship's identity and dynamic information have high update rate that is between 2 seconds and 3 minutes dependent on the ship's speed and course alteration. The others have low update rate that is about 6 minutes.

5. Functionality

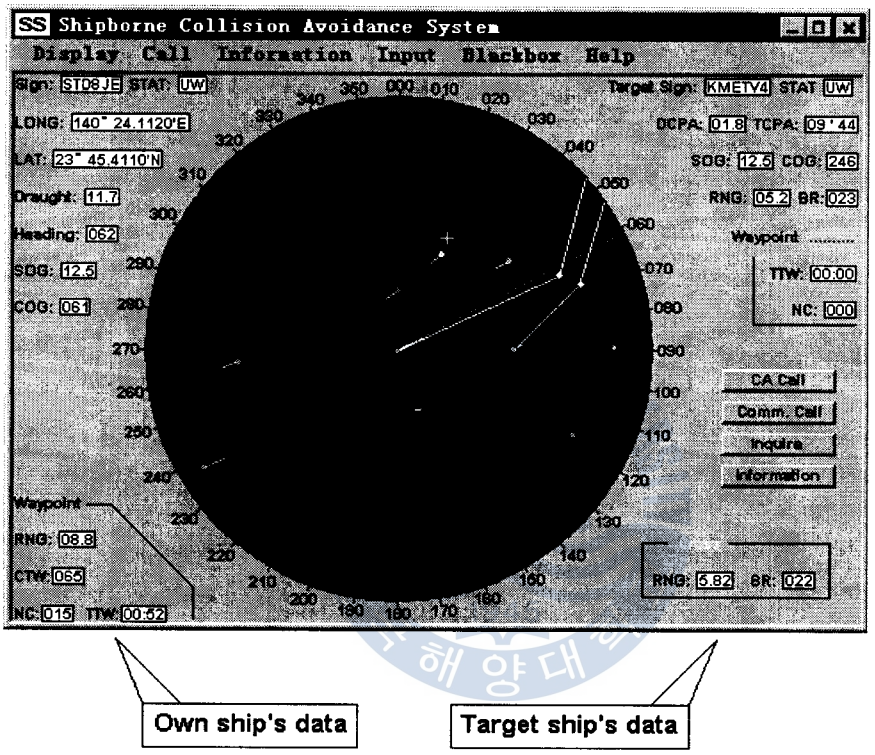
The functions of the SCAS are identification, surveillance, situation awareness and communication for collision avoidance. The man-machine interface is shown in Fig. 4. The detailed content is described as the following.

(1) Broadcasting ship reports autonomously: The SCAS autonomously and automatically broadcast the ship reports through the network. This information is used for ship's identification and surveillance.

(2) Replying the interrogation from other ships automatically: If the SCAS receives

and recognizes the interrogation for itself, it will replies it with the latest data. This can be done automatically, don't need the control of navigators.

(3) Plotting the positions and speed vectors of all ships in the cell: Based on the ship reports, the SCAS plots the vicinal ships' positions, speeds and courses on the terminal screen.



Note:

STAT: Navigational Status	CTW: Course to Waypoint
LONG: Longitude	TTW: Time to Waypoint
LAT: Latitude	RNG: Range
SOG: Speed over Ground	BR: Bearing
COG: Course over Ground	NC: New Course

Figure 4 Display of the SCAS

(4) Displaying the information of all ships in the cell: The SCAS display the information of all ships in the cell using text. This information includes ship's reports and calculated parameters on collision avoidance such as DCPA and TCPA.

(5) Realizing calling and tuning the VHF station for speech: Navigator is able to call any ship on the screen. After determining the communication channel, the SCAS automatically tunes the VHF station for speaking at that channel. The navigator can speak to the others just like using a hot line.

(6) Manual interrogation: The navigator can use this function to get the latest data of other ships.

(7) Reaching an agreement for collision avoidance: It is one of the most important functions. The SCAS provides voice and text communications for navigator to confer with others on the measure of collision avoidance. The text communication, like e-mail in Internet, has English and native language interfaces. That means navigator can use his native language to exchange the attempt of collision avoidance.

(8) Calculating the parameters for collision avoidance automatically: Based on the ship reports, the SCAS automatically calculates parameters of collision avoidance such as DCPA and TCPA, and shows them to navigator.

(9) Alarm: The SCAS can alarm navigator through light and voice signals. These alarms include system failure, collision risk and calling from another ship.

(10) Black box: The SCAS stores the latest four hours' data of the ship's position image and the text of communication on collision avoidance. This storage is controlled by the system. Navigator can not interfere. So, this information can be as the evidence for investigating the ship's collision.

(11) Inputting own ship's data: The ship's data, such as navigational status, can be input by navigator.

6. Marine VHF data link

The key technology of the SCAS is the VHF data link. When ships approach into a same cell, the interlinkage is established automatically and will be hold. When a ship moves out the cell, the interlinkage with it is automatically cut. Because it is random that one ship enters another ship's cell, this data link must be self-organizing. Hence, a new radio data link in marine VHF band, named as Marine VHF Data Link (MVDL), is defined. It is a new application of digital radio communication. The MVDL is the name of a VHF radio data link. It is a self-organizing TDMA scenario, as shown in Fig. 5. There are no master stations or slave stations. The MVDL uses the concept of "frame". One frame equals one minute, which is divided into 2250 slots. The start of frame coincides with the UTC minute. Each SCAS establishes and stores through monitoring the TDMA channel a frame map that reflects TDMA channel activity. Then it chooses slots for its use according to the self-organizing rule. At current transmission, it reserves a slot in next frame for the future use. This method prevents the message collision. Hence, the capacity of the data link is very high. The MVDL supports both broadcast service and point-to-point communication service.

The SCAS has not only the function of surveillance described above but also the function of communication between users. On the one hand, the SCAS provides the

digital communication through network, by which the short text can be transferred such as manual interrogation, calling and the agreement on collision avoidance. On the other hand, the SCAS is able to tune the VHF station at the channel that is determined by navigators through the network in order to make their talks possible. By the two means of communication, navigators are able to communicate each other conveniently.

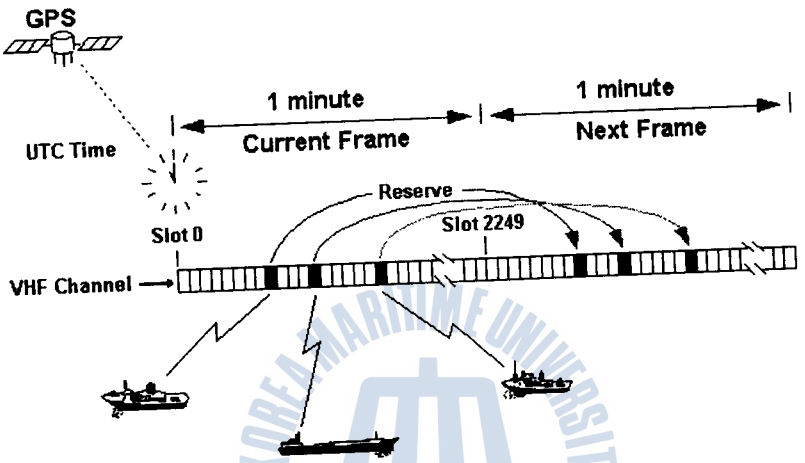


Figure 5 Marine VHF Data Link

7. Conclusion

The test results show that the SCAS can satisfy the requirement of surveillance and communication for ship's collision avoidance. The SCAS has been proved that it has better performance of surveillance than the Radar. The SCAS can provide more ship's information. The display of the SCAS is clearer because there is no echo noise that exists in the Radar system. In addition, the transmission of the SCAS has ability to propagate round small obstacles. Hence, the ship behind a hill can be found in the SCAS.

The point-to-point communication function provided by the SCAS allows navigator to send text messages between ships. It has been proved that this communication method is available and convenient for navigators to exchange their opinions of operating ship for collision avoidance. Since the SCAS is able to provide the English and native language man-machine interfaces, the text transfers can help some navigators to overcome their language obstacle in communication. This is a very important feature of the SCAS. It is the basis that the SCAS can cover all ships at sea.

The SCAS can realize that one system is suitable for all ships even beacons and one system is suitable for all phases of navigation of one ship. In the future, the implementation of the SCAS could completely improve the current situation of operating ship for collision avoidance and greatly improve the safety at sea.