

SMART Digital Selective Calling User Interface on the Base of Integration Maritime Navigation and Radiocommunication Equipment

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ABSTRACT: High level solution S4 of the IMO E-navigation Strategy Implementation Plan provides integration and presentation of available information in graphical displays received via communication equipment. At the same time, the problem of the correct application of digital selective calling (DSC) operational procedures in navigation practice has existed since the introduction of the GMDSS and requires a solution. This problem may be resolved on the base of integration maritime navigation and radiocommunication equipment. The article proposes approach for practical realization of this integration by implementing a SMART (specific, measurable, assignable, realistic, and timely) DSC interface within S4. Using this approach the practical realisation integration of AIS – DSC – Information display was implemented. It makes possible implementation of user-friendly human-machine interface (HMI) for navigator. An experimental prototype of communication graphical interface is designed, which allows effective decision-making on radio communication control/monitoring. The use IEC 61162-1/2 (Maritime navigation and radiocommunication equipment – Digital interfaces) data transfer provides standard inter-module connections and eliminates the negative impact of the equipment diversity from different manufacturers by means uniform HMI implementation.

1 INTRODUCTION

Terrestrial maritime radio communication system using digital selective calling (DSC) during the practical operation as the core part of the GMDSS revealed obvious imperfections for the user - the officer of the watch (OOW) of a marine vessel. Evident shortcomings of DSC were noted from the first years of the GMDSS operation to the present [7, 8, 11]. The complexity of DSC operational procedures, the choice of frequencies and the variety of transceiver control panels evidently do not contribute to the correct implementation of radio communication procedures by the OOW, and often leads to neglecting the DSC at all. Attempts to correct the situation within the framework of improving only the DSC equipment

(enlarged screen, soft keys, scroll handles) did not give much result.

The idea of radically improvements DSC interface on the base of integration communication and navigation equipment was suggested first in [8]. This suggestion is fully compatible with the E-navigation strategic direction which (that) envisages further development of means of radiocommunication and navigation on the base of their integration (on the platform of Integrated Navigation System (INS)) and the implementation of modern digital information technologies in navigation.

In fact in document “First draft of revision of resolution A.806 (19)” [11] the improvements of MF/HF DSC were suggested to be provided in the frame of E-navigation concept.

Particularly Germany [11] proposes to implement a simple process to connect station based on the DSC protocol, namely:

“4.2 The equipment should provide a standard interface to enable the selections of frequencies and setting of MMSI to be called from remote control unit (e.g. INS) by using standardized interfaces.

4.3 A function to establish a connection between stations of the mobile maritime service by simple means using DSC should be implemented.”

It was recalled that the Strategy for the Development and Implementation of E-navigation approved by MSC 85 provided for specific High-level needs for robust communication and data and system integrity. It was anticipated that these requirements would be applied for VHF, MF, HF and satellite technologies, as well as onboard networks capable of effectively integrating onboard E-navigation systems.

From the E-navigation concept’s perspective the relevant devices within the ship environment with sensors and applications should be connected to the INS.

This paper presents analyse of documents and existing standards concerning INS and Integrated Communication Systems (ICS) and some practical results on AIS – DSC – Information display integration and joint processing of AIS and DSC data using standardized data exchange interface of IEC 61162 series.

2 INTEGRATED NAVIGATION AND COMMUNICATION SYSTEMS

Integrating of data received via communication equipment into the integrated navigation system makes it possible to optimize control of a vessel and to avoid possible misses and incorrect decisions by the navigator.

Implementation of IMO’s E-navigation strategy leads to a larger variety higher volume of information and increased information exchange. Consequently there is a need to handle information more efficiently in standardized way on the base a common data structure.

At MSC 95, it was approved that a planned output on “Additional modules to the revised performance standards for INS (Resolution MSC 252(83)) related to the Harmonization of Bridge design and display of information; “the development of draft Guidelines for the harmonized display of navigation information received via communication equipment” and “Guidelines on standardized modes of operation” be included in the High-level action plan as items consequently 5.2.6.1, 5.2.6.2.

IMO E-navigation Strategy Implementation Plan (SIP) [13] provides particularly solution S4 which is focused on “Integration and presentation of available information on graphical displays INS, received via communication equipment” and sub-solution S 4.1.2 “Standardized interfaces for data exchange should be developed to support transfer of information from

communications equipment to navigational systems (INS)”.

IMO has summarized the practical shipboard user needs, which are expressed in a desire for greater standardization of functionality for navigation displays (human-machine interface) [13].

In documents NCSR 3/6/1 (Submitted by China) and NCSR 3/6/2 (Submitted by Norway) were provided proposals to the new modules to the Performance standards for INS.

The last revision of the Performance standard for INS made the performance standards modular. That gets the possibility for any new facility to be added to the performance standards by adding appropriate module for that facility. The modular concept of INS Performance standards provides provisions for individual configurations and extensions by adding new modules with new demands and standards as the industry and technology develop new systems. It is important both for integration of the navigation safety related information received via communication equipment into INS and for the information exchange between ships (ships–shore, shore–ships) on the base of integration navigation and communication equipment and both of which are directly connected with implementation of High level solution S4 of the SIP.

A new module on display of information will ensure that the INS can display the information received via communications equipment. This module will outline the standardized interfaces for data exchange to support transfer of information from communication equipment to an INS interface so that information received via such equipment can be processed, filtered, routed and displayed on the navigational system. This module should take in to account the new guidelines being drafted for the harmonized display of navigation information received by communications equipment. The added new modules for the purposes of information exchange must contain a dedicated gateway supported two way connections between navigation equipment and communication equipment (NCSR3/6/1). Information display (Conning display) should to bring all the relevant and important information for conning the ship to one place – Information display (NCSR 3/6/2).

Report of the Correspondence Group on the Development of additional modules to Performance Standards for Integrated Navigation System (INS) was presented in document NCSR 4/7. First draft of the Guidelines for the harmonized display of navigation information received via communication equipment was given in document NCSR 4/8 [9]. These Guidelines identify human factors principles relevant to the display of information to ensure effective situational awareness and assessment. In documents NCSR 4/7 (annex 2) and NCSR 4/8 [9] (annex) also there were pointed out communication equipment/systems, which may be interfaced with an INS including VHF/MF/HF DSC in the frame of E-navigation concept. More over as it is pointed in document NCSR 4/7 “the data exchange and interface requirement in module F should support two-way communication between INS and communication

equipment/systems". Additional symbols for possible addition to SN.1/Circ.243/Rev.1, including symbols for the purposes of two-way DSC linking were represented in document NCSR 4/8 [15], annex (appendix), and see also [5]. In document NCSR 4/7/1 a proposal of providing two-way connection of communication equipment, including VHF DSC controller, with INS through the Information display was considered.

E-navigation concept is supposed to simplify the exchange of information between ships, as well between ships and shore by means effective, user-friendly tools with human factor principles consideration (MSC 95/19/8). This solution must be based on agreed guidelines.

In document NCSR 5/6/1 [10] the drafting of Guidelines for integration and presentation of available navigation-related information exchange provided via communication equipment by means of interfacing VHF/MF/HF DSC with an Information display (Conning display) was proposed. This display, in turn, is integrated within an INS (including AIS, ECDIS, and satellite AIS). All actions on information exchange by means of DSC are performed using software of the Information display on the base of standardization of DSC interface using the common communication protocol for VHF DSC controller as well as MF/HF DSC controller.

It is very convenient to use system which contain all three DSC controllers together for practical realisation those standardized DSC interface. As reported in document NCSR 2/22/4 International Electrotechnical Commission (IEC) informed that a new standard was being developed – IEC 62940: Integrated communication system (ICS) [6]. This standard would specify HMI to allow operation of the communication equipment designed so that it can be made available on a bridge workstation dedicated to communications with multi-function display which combined interfaces of different kind of communications by itself for remote control purposes. ICS [6] would be used for supplying the information to Information Display (Conning display) INS for the purposes of two-way information exchange between DSC controllers, including in ICS, and Information Display of INS. But this ICS by itself can't be integrated with INS because standard [6] isn't destined for the interaction with electronic chart contained in Information display of INS. For this purpose special interfacing module should be added to ICS [6], including hardware and software parts.

In document NCSR 3/6 (Submitted by the IEC) IEC proposes a new edition of IEC 61162-1 (Maritime navigation and radiocommunication equipment and systems-Digital interfaces - Part 1: Single talker and multiple listeners) for the purpose to display information received via communication equipment, using standardized interfaces.

Existence of such standards created all pre-conditions for development and design appropriate module for two way transfer information between ICS [6] and INS and creation integrated communication and navigation system with predetermined good user properties. And it isn't ICS system, but new system which we call "SMART" system. This term at first was

used for the MF/HF DSC with good properties in document COMSAR 15/INF.3 (Submitted by Nautical Institute). Besides ICS would be used for supplying the information MSI to Information Display (Conning display) INS from Satellite Communication System (Enhanced group call service in the case of the Inmarsat system, and SafetyCast service in the case of Iridium system), from NAVTEX receiver, from MF/HF MSI service.

It is essential that the method of forming/viewing calls on the base ICS will be preserved as a supplementary means to the automatic method of forming/viewing calls in the integrated navigation and communication equipment system on the base of platform INS, when is something wrong with soft of INS. Distress calls will be sent both by means integrated into INS with the its modernized module C for the requirements of the Alert management, and by means of ICS [6]. It is important to be noted, that all systems, sources and sensors, incorporated sensors connected to the INS should be part of the alert management (MSC.252 (83), paragraph 26.1.1).

With consideration the fact that not every ship may be equipped by the ICS it was worked out another variant integrated system without ICS for investigation purpose. It includes VHF RT/DSC, interfacing module for integration with INS (including AIS and Information Display). Both variants are investigated in this article.

The importance of the further development of standardized interfaces for data exchange used on board (IEC 61162 series) to support transfer of information from communication equipment to navigation systems, including appropriate firewalls for information security (IEC 61162-450 and IEC 61162-460), is also highlighted. Obviously, the same desires are applicable to radio communication systems.

The core of proposal [8] to improve the DSC communication interface lies in the joint AIS and DSC data processing by means using a graphical display for AIS targets mapping and implementing DSC control/monitoring directly from the graphical interface. Initially, it was planned to use the Electronic Chart Display and Information System (ECDIS) display for that mapping [12], however, the ECDIS is quite loaded with navigation tasks and the additional function can degrade the performance of these tasks. Therefore, it was proposed to use additional information (conning) display for graphical interface in order to control the DSC communication [10]. It is supposed that the information display for control/monitoring DSC communication shall be included in the INS according draft [11].

Industrial standard [6] defines ICS as "a system in which individual radiocommunication equipment and installations are used as subsystems, i.e. without the need for their own control units, providing outputs to and accepting inputs from a communications human machine interface (COM-HMI)". The COM-HMI is designed so that it can be made available on a bridge workstation either dedicated to communications or as part of a multi-function display. ICS is based on using Lightweight Ethernet (LWE) official standard [5], which supports high speed data transfers between

shipboard navigation and radiocommunication equipment (ECDIS, Radar, VDR) as well as existing interface standards IEC 61162-1/2. The example of LWE network designing for INS with connected IEC 61162-1/2 devices is given in Figure 1.

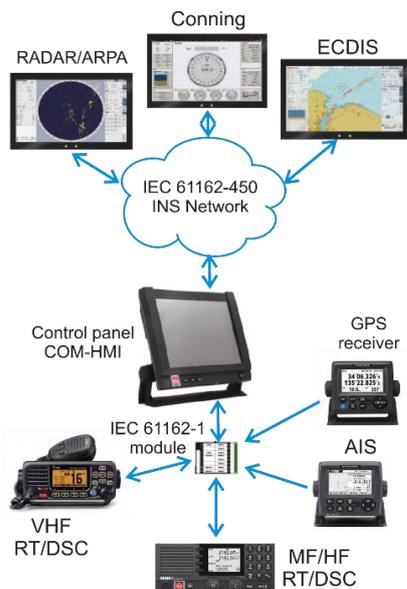


Figure 1. Integrated communication system. Logical connections

Connected devices play role of sensors or transducers, sensor when the radio module operates in the receiving mode and transducer in the transmitting mode. It is important that radio modules are controlled/monitored remotely from information display without mechanical knob operations and visualization using front panel but by means graphical user interface (GUI) and standard IEC 61162-1/2 sentences for control/monitor.

The first known example of integrated radio communication system (IRCS) IZUMI-900A allowed control/monitor radio communication blocks VHF DSC (JHS-32), MF/HF DSC (JSS-800), ship Earth stations Inmarsat-C (JUE-75) and Inmarsat-A (JUE-45), and Navtex receiver (NCR-300A) from the general display (Figure 2). The external radio blocks were connected to the workstation through proprietary not standardized inter-modular communication interfaces. IRCS in such embodiment presented a single complex, not meeting the principles of modular design, with easily replaceable modules that use standardized inter-modules. The rigid structure of the complex did not provide any replacement/addition of radio modules and updating the software.

Standard [6] defines ICS as “a system in which individual radiocommunication equipment and installations are used as subsystems, i.e. without the need for their own control units, providing outputs to and accepting inputs from a communications human machine interface (COM-HMI)”. Standard directly specifies the use of a new Lightweight Ethernet (LWE) and Internet Protocol (IP) as an official standard for high speed communication between shipboard navigation and radiocommunication equipment [4]. This choice reflects a general trend with a convergence to Ethernet-like technologies everywhere [1]. IP is also closely related to Ethernet, and the combination of

Ethernet and IP is a de facto standard for ubiquitous emerging networked systems, for domestic as well as industrial use. The LWE standard provides compatibility with widely used NMEA-0183 (IEC 61162-1/2) and is equally suitable for transferring large files at high speeds.

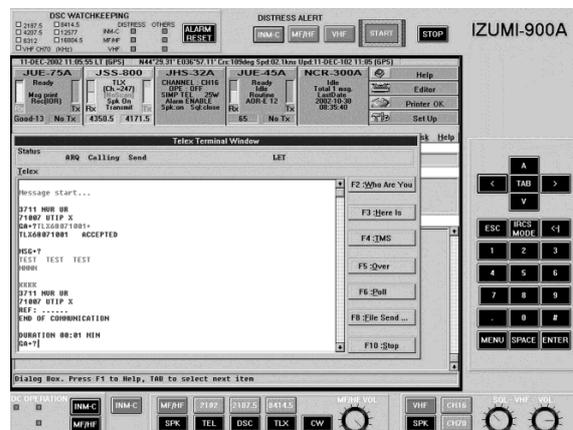


Figure 2. ICRS IZUMI-900A. Control display

Example of ICS on the base of LWE is given in Figure 3. The ISC network is designed primarily to work with devices directly supporting bidirectional LWE connection. Radio modules No.1 and No.3 are shown with IEC 61162-450 interface to the ICS network by solid blue lines.

Radio modules No. N and No. 2 are shown with options by dashed lines for using either an IEC 61162-450 or an IEC 61162-1 connection to the ICS. If an IEC 61162-1 connection is used, it is transformed to IEC 61162-450 by the appropriate converter.

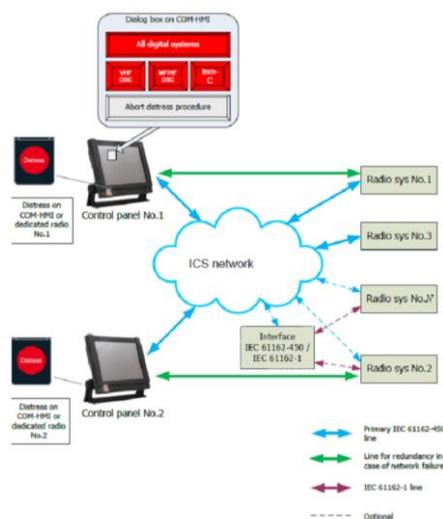


Figure 3. Integrated communication system [6]

Remote monitoring/control is carried out from two displays (control panel) main and backup. Redundant communication links between control panel and radio modules are provided in case of network failure.

The international standard IEC 61097-3 [3] includes significant innovations in relation to remote control of radio communications, in particular, new sentences (Annex N) have been added to support DSC remote control in connection with the introduction of automatic procedures for controlling radio communications. In particularly, it is noted that “It

(remote control) allows for the integration between radio and navigation equipment in the way that multiple automated procedures including subsequent communication can be handled on, for example, an ECDIS using compliant DSC radios".

The European standard [2] provides an interface for external control of DSC equipment. It is obviously that the interface for remote control of DSC equipment will be detailed in the announced in this standard series Part 8: Enabling Remote Control of DSC Radio Equipment, which is currently in its final stages.

It is expected that the maritime radio communications equipment market will respond on the existing de facto standards for remote control by the release of shipborn communication modules supporting IEC 61162 family interfaces.

ICS standard [6] foresees connection of automatic identification system (AIS) but only for optional mode. If interconnection with AIS is provided, the ICS shall be capable display safety-related notices, send and receive broadcast and addressed AIS safety-related messages and correlate distress information received by DSC with available information received via AIS channels. So AIS connection to ICS information is not used here to improve DSC monitoring/control and AIS connection doesn't use the abilities of "true" AIS – DSC integration that gives an additional quality not inherent the separated systems.

3 AIS – DSC INTEGRATION AND DATA FUSION

Experimental complex of the integrated DSC - AIS system and DSC remote control/monitoring using SMART (from specific, measurable, assignable, realistic, and time-related [18]) graphical user interface is carried out on the basis of the free software OpenCPN [14]. It includes maritime devices: GPS receiver AIS transponder, VHF DSC transceiver ICOM M330, notebook with OS Windows10.

The project did not have the goal of creating an ICS with all the mandatory functions, but was aimed only at implementing VHF the DSC control/monitoring functions using a graphical display and information exchange in the IEC 61162-1 standard [4].

The ICOM M330 radio of class D was used as a VHF DSC transceiver. Class D equipment is intended to provide minimum facilities for VHF DSC distress, urgency and safety as well as routing calling and reception, not necessarily in full accordance with IMO GMDSS carriage requirements for VHF installations. This radio supports DSC remote control to the extent specified for Class D equipment.

The operation of the GUI is described in the following scenario: Motor vessel A is calling motor vessel B using DSC on channel 70 VHF with parameters individual, routine, acknowledge requested (Figure 4). This type of DSC seems to be the most commonly used in maritime practice. Navigational safety largely depends on its correct and prompt execution, especially in urgent situations and difficult weather conditions.

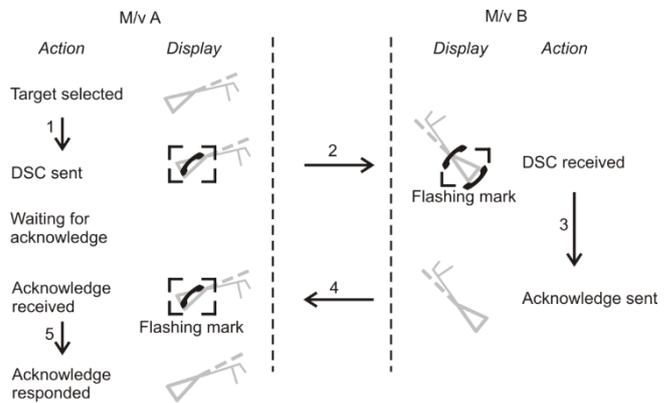


Figure 4. Additional marks in the DSC graphical interface. M/v A – the calling ship; m/v B – the ship to be called

To make a call ship A selects an AIS target (step 1) and broadcasts DSC on the air. In this case, the working channel is pre-set, for example, Ch77. A mark 1 appears in the form of corners and a tube (hereinafter mark 1) over the selected AIS target in accordance with the draft of Norway and IHO [9].

Receiving DSC by vessel B results in the formation of a flashing call mark 2 with two handsets (hereinafter mark 2), also in accordance with the document [9]. Upon receipt of DSC, the VHF transceiver of vessel B outputs a DSC command containing the MMSI of the calling vessel. The current list of AIS targets contains the MMSI of active targets based on received position reports from vessels within the AIS range [17]. The ship's MMSI is necessarily included in the position report and is coded with 30 bits, just like in the DSC system. The MMSI received on the DSC channel is correlated with the MMSI of the AIS target list. If it coincides, the DSC and AIS data are combined and a flashing mark 2 is formed on the information display screen at step 2 over the AIS target of the calling vessel at the point with the AIS vessel coordinates.

Vessel B makes DSC acknowledgment (step 3), after which mark 2 disappears.

Receiving acknowledgment by the vessel A in step 4 changes mark 1 into flashing mode. In this case, the call is processed according to the same algorithm as on ship B when receiving the initial call.

Vessel A looks through the acknowledgment call and opens the radio exchange on the working channel. The flashing mark 1 disappears (step 5).

The above radio handshake protocol is fully compliant with Recommendations [15, 16] for individual calls with routine priority.

The screen shots of the information display are shown in Figures 5, 6. The San Francisco Belle ship calls the Golden Gate ship. Available information received through the AIS channels on the called vessel is displayed on the right (Figure 5).

The screen shot of the display on the Golden Gate vessel upon receiving a call looks as shown in Figure 6. AIS calling target (San Francisco Belle) is surrounded by a flashing double tube marker. The available AIS information on the vessel is also displayed.



Figure 5. Screen shot of the AIS/DSC GUI window in AIS mode. M/v Golden Gate is the vessel to be called



Figure 6. Screen shot of the AIS/DSC GUI window in AIS mode. M/v San Francisco Belle calling me

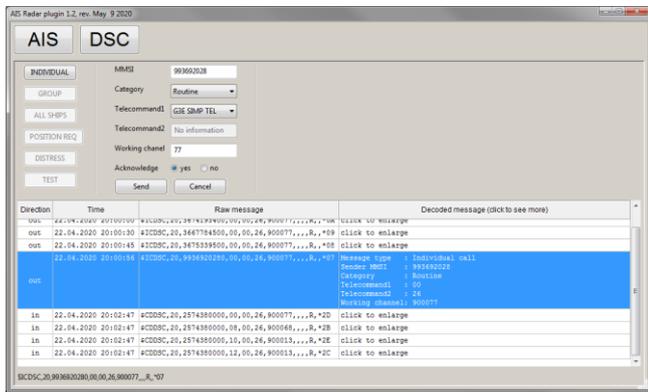


Figure 7. Screen shot of the AIS/DSC GUI window in AIS mode. Additional information to be entered if needed and log of the transmitted/received calls

An individual, routine ship-to-ship call can be implemented through the GUI without any additional manual data entry operations, such as MMSI inputting. All actions are intuitively understandable and are performed promptly against the background of the general navigation situation and the availability of the data necessary for decisions making without handling other means of navigation. SMART interface realizes the quick establishment of address radiotelephony exchange in urgent situations with full compliance with all procedures using DSC.

The menu for selecting/setting parameters of the DSC technical format is used for making other types of calls, for example, "all ships", distress relay, etc. (Figure 7). At the bottom of the screen shot, the current log of all processed calls is optionally shown.

This menu can be optimized to a standardized form without being tied to the instrument control of equipment from different manufacturers, and recommendations for using simple terminology when composing DSC messages [15].

4 CONCLUSION

The implementation of E-navigation opens up perspectives for improving navigation and radio communication systems. The existing problem of DSC operation is determined by its impracticality in ship conditions and can be solved by joint processing of AIS and DSC data and implementation of a graphical interface for radio communication control and monitoring.

Existing standards and guidelines technically allow remote control of radio modules in the IEC 61162 family standard, avoiding the problem of inconvenience and diversity of transceiver keyboards from different manufacturers.

The designed experimental example of the integrated system AIS - DSC - Information display demonstrated the advantages and technical feasibility of implementation within the framework of existing standards, and also identified problematic issues related to the implementation of automated procedures for simplified operation in shipborne equipment.

The creation of a friendly graphical SMART control interface based on AIS - DSC integration also contributes to the harmonization of maritime radiocommunication handling. The issues of the maritime COM-HMI can be solved by introducing appropriate additional modules within Integrated Navigation System.

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