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Automatic Identification System of Vessels Using the Grid Method

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ABSTRACT

For many reasons, going from the environmental to the maritime safety, it is required a marine traffic control able to track in real time vessels approaching or moving away from the coasts.

The innovation of this Automatic Identification System of vessels - with regard to some others already existing – is that this one is not a satellite system and it is not limited to a certain coverage distance, as happens with the AIS. But it is not a system that excludes the latter either, since in some exceptional circumstances it is based on it.

This paper deals with the System technical approach for future implementation in certain sea routes with given traffic density.

1. Introduction

A maritime system for traffic control, able to track vessels approaching or moving away from the coasts, technically speaking is not a big deal; in fact there are very reliable systems for this task.

Since AIS is used, it has been revealed as an effective way to perform an efficient control. Its only weakness is the limitation of visual range (more/less 30 miles), characteristic of Very High Frequency (VHF).

This limitation is overcome through the use of frequencies present in the frequency band of High Frequency (HF), or by the use of some satellite-based techniques if the target is not to have coverage limitations. The first solution is ruled out despite of global coverage, due it depends on the different times on day, or even year seasons. It would not be possible to reach vessels located at a distance less than the estimated by the atmospheric rebound, besides there could appear some side effects like fading.

The second solution is quite good, technically speaking, but has the disadvantage that satellite connections are rather expensive and that space is saturated (Larrabe1 et al., 2010).

As previously said, the innovation of this Automatic Identification System of vessels (López, 2007; López, 2008) presented to identify vessels sailing on sea routes with certain traffic density, is that this one is not a satellite system (Inoue et al., 2005) and it is not limited to a certain coverage distance, as happens with the AIS. But it is not a system that excludes the latter either, since in some exceptional circumstances it is based on it.

So, this paper deals with an automatic identification system of vessels in Medium Wave MF.

It will be the result of the symbiosis of one transmitter, four receivers – two of which should include a Digital Selective-Calling system (DSC) – and a control computer capable of supporting a determined digital mapping that it should be implemented.

This mapping will coincide with the maritime area to be controlled, and it will be made up of a grid composed of cells. These could have any form and dimension depending on the frequency band used (MF) (Santi and Blough, 2003; Wen et al., 2007), the only condition is that the message radioed at the beginning of each cell will reach the end of the following one. All vessels situated on this elemental surface (cell) will adjust the System transmitters and receivers automatically in order to work

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in a series of channels already predetermined for a cell, corresponding to the MF tuning frequency assigned to the Maritime Mobile Service. This information will be provided to the computer integrated into the digital mapping of the controlled area.

The System will allow ships sailing in the area inside the squares to act as receivers – and therefore acknowledgement emitters– of a message launched from a Traffic Control Center (TCC). But they could also work as simple repeater stations for a message that is not targeted at them, making the message advance in the grid and arrive at the ship that has been called.

In order to avoid the conflict between possible repeaters when gaining access to the respective channel, the vessel working as a repeater would be, for example, the one located further to the south and further from the following cell. It could serve any criteria; the only important thing is establishing one. These waiting times are controlled by the computer from the positioning information given by the G.P.S. or any other positioning system.

To function correctly, the system should be introduced in maritime routes with a density of traffic of at least one ship in each cell.

The aim of this device is to identify a ship through a radio-packet launched by a Traffic Control Centre (TCC). This radio-packet is aimed at a certain ship using its call sign, the one corresponding to the digital selective calling (DSC). This radio-packet moves forward from cell to cell until a certain vessel detects it is for them, and therefore it will not work as a repeater of the message for the ships located in the following cell in the same line. Automatically, the ship in question will launch a message in the opposite direction. This acknowledgement will move back from cell to cell until it arrives at the receiving antenna in the Traffic Control Centre in which the first message started.

The message included in the acknowledgement will be made up of a dump from a real time data acquisition system – for example a black box–, indicative of the state of the vessel at that time.

The outward message sent by the TCC to the ships will be broadcast using a data communication system called B-mode/SITOR-B (FEC). The Traffic Control Centre broadcasts an open group message, containing the name of the ship that they want to locate. An indicative of each ship acting as a repeater in each cell is added to the original message, until that ship is found in some cell of a line.

The return message sent by the ship to the Traffic Control Centre will use the A– mode/SITOR-A (ARQ), a point-to-point transmission system. The return could be made in ARQ-mode since on the outward journey some indicatives of the stations acting as repeaters had been added, so the way back is already established.

Both outward and return messages will be emitted or received in each antenna located at the beginning of each line of cells.

The number of necessary channels will be twice the number of existing cells.

The modulation to be used will be F1B or J2B and the speed of transmission proposed would be 100 bauds to comply with the Global Maritime Distress and Safety System (GMDSS).

In MF it is necessary to use wide band to provide working channels below 1800 KHz, within the section assigned to the Maritime Mobile Service, so that they are not affected by undesirable forces such as "fading".

2. Detailed exposition of the system

In figure number 1 we can see the diagram of the system on board (assuming that the ship is located in cell A-1 in fig. Nº 2). In terms of radiocommunications, it will consist of four receivers and one transmitter, each one having its own respective antenna. Two of those four receivers – A and D – will have a DSC device, so that in case they receive a message they can send it one way or another depending on whether it is targeted to them or not. They can never go both ways at the same time. The other two receivers – B and C– are just listening receivers, and they will give us information to establish whether a determined channel is free or engaged. The checking will be made by a computer connected up with all the receivers, the transmitter, the GPS (or any other positioning system) and the black box (or any other data acquisition system).

Within the constructive possibilities to bring the above to fruition, we must consider:

- Implement some or all of the necessary radio-frequency devices to satisfy the described functions to the current GMDSS, apart from the control unit and the digital mapping of the area.
- Concentrate all the functioning logistics in specially adapted equipment and independent from GMDSS.

On-board devices must be provided with an infrastructure capable of supporting four different possibilities (Akyildiz et al., 2005; Ge et al., 2007; Hekmat and Van Mieghem, 2006), in order to guarantee the correct functioning of the system:

A. Necessary infrastructure to pass on outward traffic.
   1. Outward traffic for a repeater station.
   2. Outward traffic for us.

B. Necessary infrastructure to pass on return traffic.
   3. Return traffic for us.
   4. Acknowledgement

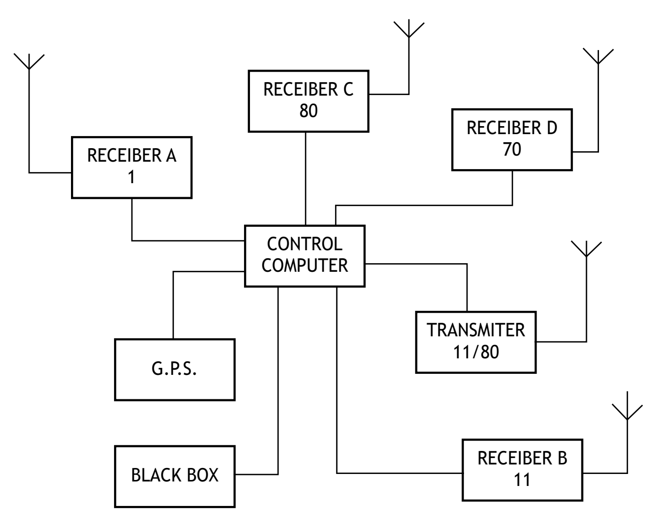

Fig. Nº1: Diagram of the system on board. The own ship is assumed to be located in cell A-1 in Fig. nº 2.

A. NECESSARY INFRASTRUCTURE TO PASS ON OUTWARD TRAFFIC.

It works in B-mode/SITOR-B (FEC).

In this case, we can consider two possibilities:

1. that the on-board station works as a repeater station of a message that they receive but that is not targeted to them.
2. that the station works as a receiver station of a message, and it sets in motion the machinery capable of creating a return message that contains the current information in the black box on board. This message will be an acknowledgement to the TCC transmitter, and a signal to the rest of the ships in its grid not to work as repeater stations because the receiver has been found, this way the message will not continue moving forward in the line.

A1. OUTWARD TRAFFIC. STATION WORKING AS A REPEATER.

The given control software will control the hardware as follows:

— Each ship will have a different waiting time programmed depending on their position inside the cell. For example, for ships situated in cell A-1 in Figure nº 2, the closer the ship will be to cell B-1, the greater the waiting time will be. In the same position from B-1, the more to the North it will be, the greater the waiting time will be.

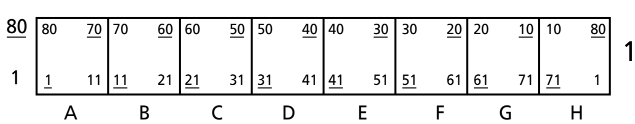

Fig. 2: Area object of a study, covered by a grid made up of just one line (1) and eight columns (A-H). The underlined channels are the ones working as receivers.

With these conditions the aim is:

- To avoid the conflict when possible repeaters try to gain access to channel 11. The ship further South and further from B-1 will work as a repeater. Any other criteria will work, the most important thing is taking one. These waiting times will be determined by the control computer.
- To increase the probability that the ship that has worked as a repeater of the outward message will still be in cell A-1 when it receives the return message, so that it will not be necessary to put any exceptional measure into practice.

— At a functional level:

We will situate the ship in cell A-1 in figure nº 2 in order to make a functioning analysis as realistic as possible. When it receives a message that is not aimed at it on channel 1, it will listen to channel 80 (receiver C) – before re-transmitting it on channel 11 – to find out if the destination is a ship in the same cell it is in. Once we have listened to the channel and made sure that this is not the case, we have to listen to see if channel 11 (receiver B) is free. If it is, we have already complied with the necessary premises to make our ship work as a repeater of an outward message.

This way, the system is ready to re-transmit the message on a different channel, working as a repeater.

A2. OUTWARD TRAFFIC FOR US

In this case, the control system will work this way:

We will still consider the ship in cell A-1. All the ships located in this cell hear the message on channel nº 1, tuned in receiver A. All ships but one detect that the message is not targeted at them. Before one of them carries out its task of repeating it on channel 11, the ship to which the message is aimed will start the return message process. The purpose is replying to the request from the TCC, and those ships in the same cell as it – and that listen to channel 80 through receiver C – detect that the acknowledgement has already been sent, and therefore they do not have to work as repeaters.

Obviously, the said ship will be faster answering than the others, since its imposed delay time will be the least.

Before continuing note that if channel 80 is engaged in the situation just mentioned it is because an acknowledgement of a previous message is being passed on. In order to get the ship that is being called on channel 1 as fast as possible, that acknowledgement will be stopped momentarily in the memory given to the receiver D of the ship that is working as a link in the chain previously established for the return message at that moment, leaving channel 80 free. After this eventuality, the traffic of the acknowledgement stopped will be re-established.

B. NECESSARY INFRASTRUCTURE TO PASS ON RETURN TRAFFIC.

It works in A-mode/SITOR-A (ARQ). The calls will not be open as in outward messages, since there is a list in which appear all the stations that have worked to take a message from the TCC to a ship. Therefore, the return message will just follow that list in reverse order.

The equipment in this new system could pass on the return traffic towards the TCC since the control software will take into account two different working situations:

B3. RETURN TRAFFIC TARGETED TO US.

The ship located, for example, in cell C-1 in figure nº 2 and that had previously been included in a list – in which all the stations appear that have helped to take a message from the Traffic Control Centre to a determined ship – will help again to end this traffic. On this occasion they will take the return message from the previously involved ship, located in cell D-1, and they will send it to the next link in the return chain – in cell B-1.

As has been said, return messages will be broadcast in ARQ-mode, since the calling will be made to just one determined ship. The others do not participate.

The control software will work as follows:

Let us take another example. Let us assume a ship in cell A-1 in figure nº 2. Its receiver D, in channel 70, receives a return message obviously aimed to itself, because otherwise it would not receive it.

First of all it is necessary to listen to channel 80 (receiver C) to realize that there is not any other ship passing on a return message at that moment. Immediately afterwards the retransmission of that traffic is continued using the respective channel – in this case channel 80.

As we said before, this retransmission process would just be interrupted if receiver A receives any other message, targeted either to itself or not, at that moment. This means a temporary interruption of the return traffic, not an abort of the return message. This message would stay in the memory of receiver D until the protocol for the unexpected outward message has been completed. After that, the return traffic will be resumed.

B4. ACKNOWLEDGEMENT

The given control software will also act as follows:

Continuing with the previous example, the ship located in cell A-1 working as a repeater station must send some acknowledgements to the transmitter station, located in cell B-1. In this particular case, these acknowledgements will be broadcast through channel 11, and that will be an indication that the message is being well or badly received.

The acknowledgements will be made if the following premises are carried out:

- Channel number 11 – listened to by receiver B – is not busy. The acknowledgements to the ship located in B-1 will be sent through this channel.
- Receiver A is not passing on any traffic, neither for it nor for a ship located in the following cell.

3. Other situations considered by the given control software

3.1 Change of cell of some of the ships involved in an outward message before it receives the corresponding return message

There would be no problem if some of the ships involved in an outward traffic would change cell at that moment. One of the things that the ship sending the acknowledgement has to know is the direction in which the ship they are going to communicate with is sailing. Let us see figure number 3, and let us assume that a ship located in C is the one that has to receive the return message coming from D. If that ship would be in D before receiving it, and both ships would move away from the Traffic Control Centre, the procedure would be as follows:

- The ship located in D transmits the return message thinking that the receiver of that message is in C, that is through channel 19.
- As it does not receive any answer, it assumes that the ship is already in D, so it repeats the task but through channel 12 now.
- The receiving ship transmits the acknowledgement through channel 22.

If to the contrary the emitter vessel would be the one changing cells at that moment – from D to E – the procedure would be as follows:

- First, the emitter would transmit the message to D through channel 12, thinking that the receiver could have also changed its position in the cell.
- If there was no answer, the emitter would try again through channel 19.
- The receiver vessel – situated in C – would send an acknowledgement to the emitter in E through channel 3.

If however, both ships navigate in the opposite direction than the one described before, that is, both towards the antennas of the TCC, the procedure would be exactly the same, but in reverse.

If the ships sail in different directions, then the procedure should consider the possibility of a distancing of two cells between them.

It is not necessary to indicate explicitly the channels in which the ships that receive the return message have to broadcast the acknowledgements to the emitter. That is because all the messages must have specified the last cell from which they have been transmitted, both on the outwards and on the return. This way, receiving vessels will just have to look at the channels in their memory in which the transmitters would listen to them, depending on their position as indicated in the message.

All the considerations we have just made do not mean breaking the laws of the grid functioning for the correct functioning of the system. This exception lasts just some seconds, and it is very unlikely to happen because there is an established premise in the station programming. The priority when choosing the outward traffic repeater is choosing the most southern repeater and the one at the beginning of the cell, so the said situation is purely just an anecdote.

A	B	C	D	E
14 7	7 26	26 19	19 12	12
1 8	8 15	15 22	22 3	3

Fig. 3: Grid designed for a determined area to be controlled. It is made up of just one line (1) and five columns (A-E). The underlined channels are the ones working as receivers.

3.2. Control of the new ships gaining access to a grid.

The procedure, that the system would execute automatically, is going to be described for the area shown in figure nº4.

A	B	C	D	E
14 7	7 26	26 19	19 12	12
1 8	8 15	15 22	22 3	3

Fig. 4: Area object of a study, covered by a grid made up of just one line (1) and five columns (A-E). The underlined channels are the ones working as receivers.

- When the vessels located in D-1 are called by the TCC, located to the left of A-1, they receive the message through channel 22. They send an order through channel 3 for all the ships in E-1 to send them back identification through channel 12, before answering through channel 19.

- The ships located in cell E-1 will answer the message according to their position in the cell. The more northerly and the closer the ship is to cell D-1, the smaller the imposed delay times will be. That is an example of a premise, but it could be any one. What is obligatory is to take one.
- If a vessel located in D-1 is called by the Traffic Control Centre, and because it is in the aforementioned cell it was what is previously described but has not received any answer, when it passes to C-1 it will be contacted again by the TCC asking for the same information via channel 3 from the ships located in E-1 and waiting for a reply on channel 19. After that, it goes back to asking the same for D-1 on channel 22.
- If a ship could not report any ship following them during their movement through a cell, it could ask the last two cells it has passed through each time the Traffic Control Centre calls them. A message must cover the area of two cells.
- Let us assume there is no traffic at all in a cell. When a vessel is located in A-1 and identified by the TCC through the AIS, it will call some possibly non-detected ships again, supposedly in B-1, on channel 8, waiting for an answer on channel 7. If it does not get any answer, it will perform the same operation – this time on channel 15 – , and will wait for an answer on channel 7, trying to identify some ships located in C-1.
- Once a vessel has informed about any other following him, it will not be necessary to make this automatically.

3.3 Actions that the system will adopt if there are more ships than expected in the grid of the given digital cartography.

Once the grid for the controlled area has been established, it is necessary to make a study of the system capacity, in which we will pay attention to some elements:

- Evolution speed of outward and return messages
- Average speed of the vessels in the area.

To make the study, we will use an area that could be covered by a grid like the one shown in figure nº 5.

CCT	**A-1**	**B-1**	**C-1**	**D-1**	**E-1**

Fig. 5: Area o bject of a study covered by a grid.

The Traffic Control Centre wants to identify all the vessels located in an area covered by five cells.

The Traffic Control Centre could send a radio-packet each "*x*" seconds in order to locate a ship. This way, each time that they send a radio-packet, the previous one will be travelling from *B-1* to *C-1*, what prevents overlapping in the outward messages. Therefore, it is proposed to have an intermediate free cell, not just to prevent the overlapping, but to give time to return traffic. However, in these return messages this problem does not exist because if there is an excess of traffic at a determined moment, these messages will be stored in the memory of some of the intermediate stations until the normal flow of traffic is re-established.

Assuming, for example, an average speed of navigation of 22 knots, and a time to go from cell to cell of 15 seconds in an outward message, the Traffic Control Centre will send a radio-packet every 30 seconds.

In order to identify a ship at least once in each cell – assuming that each cell is, for example, a square of 44 x 44 nautical miles, because the adopted band of working frequencies is the medium wave – the system should call the ship at least every two hours.

It can be deduced that the maximum capacity for calling different vessels would be of one vessel every 30 seconds during two hours before staring to repeat. That results in a total of 240 ships.

In case that this number of ships would be exceeded, the new ships would be given the order to adopt the second grid for that area they would have in their memory, with different channels for each cell. Previously, some of the vessels located in every cell would be given the order of working in the second grid, in order to create a new line of communication. The vessel added to this grid in this situation, just has to make a scan of the channels and check which are the channels used by ships located in D-1 to call the ships that have just been added. This will lead them to adopt the second grid.

4. Conclusions

For many different reasons, a more effective control of real-time priority shipping routes is required.

A new Automatic System of Vessel Identification has been developed. It is not a satellite system. It is not limited by the coverage of working frequency like AIS (Hoye et al., 2008) nor it is exclusive of any of the currently introduced systems. It just uses them.

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