Safety Device for Fishing Vessels

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Introduction to Problem

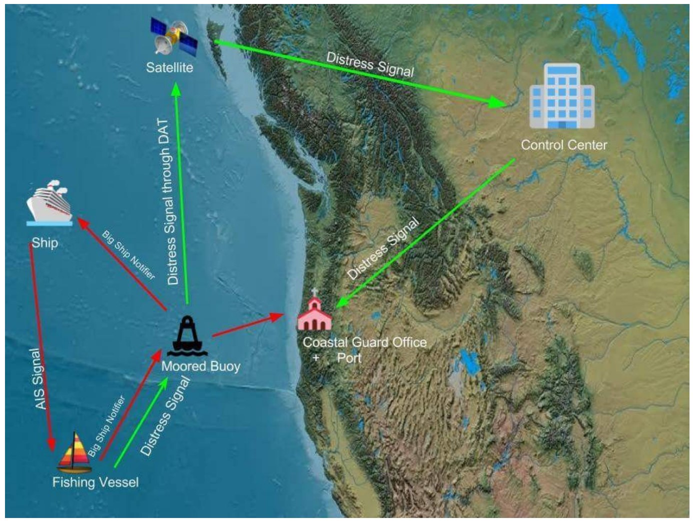
Currently, small marine vessels lack any safety mechanisms for anti-collision with other vessels. This often leads to collision of small vessels with huge ships especially during night time when the visibility is close to zero, which is caused due to many weather conditions like heavy rainfall or atmospheric fog. Very often, fishing vessels tend to turn off their power to conserve fuel when not needed rendering the conventional safety measures useless.
This calls for cheap, power-efficient and independent anti-collision system which can be easily installed on these fishing vessels. The currently available systems have a subsidized price around ₹35000.

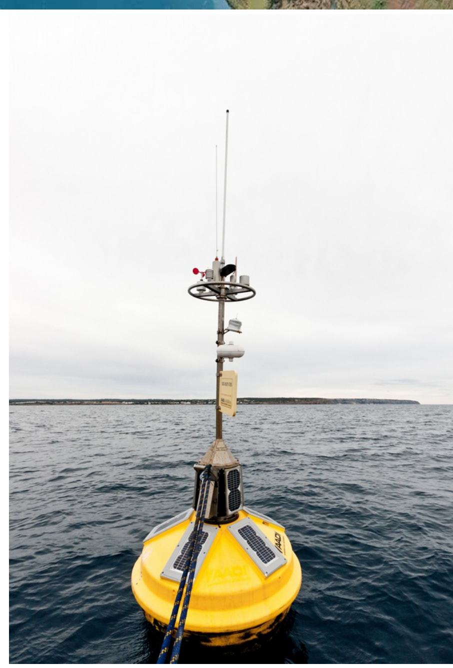
Overview of Proposed Solution

Hence, a robust and power efficient solution which is drastically cheaper than the currently prescribed solution is proposed in this document. The basic principle of working is the fact that signals attenuate with the inverse square of distance. AIS signals, which operate up to line-of-sight limit, just like any other electromagnetic wave, show the same attenuation characteristic. As the transmission power and frequency of AIS signals if fixed globally at 12.5W and 161.975MHz for Class-A or 2W and 162.025MHz for Class-B, the distance to the source can be easily calculated and compared against a threshold to see if a large vessel is at perilous proximity. The mathematical formulation and the circuit diagram are presented later in this report.
The next problem tackled is determining the relative direction of the large ship with respect to the fishing vessel. This is achieved by using a unidirectional antenna which is rotated *by 10° every 5 seconds.* Moving ships transmit a signal every 2 seconds and hence with this rate of rotation, missing signals from any direction shall be avoided. When a ship is in close proximity, the power threshold is crossed. As the antenna is unidirectional, the direction of closest approach can be predicted up to a precision of 45°. Based on this information, the fishing ships can safely navigate in a direction away from the ship. Thus, even in situations of poor visibility, the fisherman can plan a route for safe navigation.
The notification system is also triggered when the power threshold is crossed. The notification system shall consist of three components.

- A loud alarm for the benefit of the occupants of the fishing vessel.
- A marine navigational signal light is lit up when the system is triggered. These type of lights are used on buoys to aid navigation and are effective to draw attention towards the fishing vessels.

● An elaborate communication network that sends an alerting signal to the approaching big ship. This network shall use the buoys which are already present in the sea. The below picture shows an overview of the network. This same network is also used to send distress signal for alerting the coast guard.





Moored Buoys

The power consumption of the system is mainly attributed to the following three subsystems:

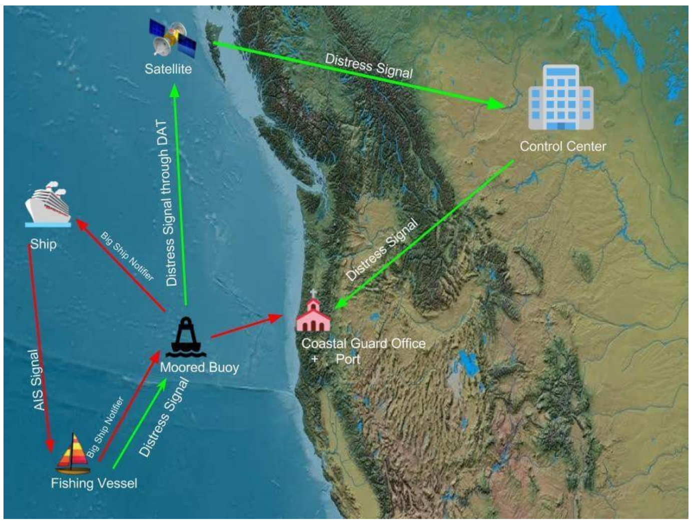
● **Subsystem-1:** Continuous running of the power detector and comparator circuit. Extremely low power is needed for its operation.

- **Subsystem-2:** Continuous rotation of the unidirectional antenna. This subsystem requires considerably more power as shown is the following section. *
- **Subsystem-3:** Functioning of the notification system. Even though the power required by this subsystem is high, it draws power only when a large ship is detected nearby.

The entire system is powered using a solar panel interfaced to all individual elements using regulators. The system ratings required for the task are explained later.

***continuous power consumption of the entire system can be drastically reduced if a normal non-directional antenna is used instead of a unidirectional antenna but the system shall lose its ability to anticipate the direction of closest approach.**

Communication method and proposed system:



The above given image explains the communication protocol that we designed in order to have a long range communication warning network between small fishing trawlers and big ships. As a part of additional objective, we also developed a low cost distress communication system to aid the small ships with distress system as a part of our system to provide warning signals. Mentioned below is an overview of how is the communication protocol designed and in the later documentation, every single task is explained in detail.

Communication system for nearby big ship warnings to small ship and vice versa:
Big ships emit AIS signals (frequency 160.95 MHz and 161.25 MHz and transmission power= 12 watts) as a global protocol for their own safety and to avoid calamities of accidents with other ships. In other words, AIS is the sea's traffic control system. The small ship will know whether a big ship is near or not by knowing how much power of the signal it has received and setting the cut-off experimentally. More

details on this are explained later on. Now, as the small ships get a positive response from the system, it implies that some big ship is nearby and now it activates its low range transmitter to transmit a raw signal with very less modulation on channel c1 (frequency f1). This signal will reach the nearest moored buoy (under a range of k1 kilometers). Now, every single buoy will have its own transmitter and receiver. The role of buoys in warning big ships is to process the signal transmitted by a small ship in case big ship is nearby and to transmit a better modulated long range signal (frequency f1). The big ships will receive this warning signal from the moored buoy and will interpret that there are some small ships nearby and need to be careful. More details explained later.

Distress signal system:
A switch will be provided with the system which, if switched on will stop every other system and start transmitting mildly modulated distress signal of frequency f2. This signal will be received by nearest buoy. The existing system of global distress signal uses a device known as Distress Alert Transmitters (DAT). This is a onetime usable device which can be started by pressing a button and it transmits a signal to INSAT satellite which then transmits the data to the control center. Now, in our proposed system, the moored buoys will have these DAT instead of every single small fishing trawler. Just the only difference will be that instead of triggering DAT with pressing of button, it will get triggered by specific frequency of signal. After that, work remains same that of DAT. Details are explained later in this documentation.

Technical Details

(Including Plan for Mass Production)

This section contains the technical details in terms of mathematical formulation, accuracy, chances of error, durability etc. For mass production, an optimal procedure would be to manufacture each system in a modular fashion, i.e. manufacture each system separately and then integrate the individual modules during installation. This will ease the installation of the system onto the fishing vessel.

Ship Detection using Power Estimation Circuit

- Input Voltage: 5V
- Input Current: 7-8mA
- Total Power Requirement $\simeq$ 40mW

Mathematical Formulation

As the AIS signal is a GMSK modulated signal, which falls under the family of FM modulation scheme, the power of the signal is largely independent of the information coded within it. So just like any electromagnetic wave, the power of the

AIS signal decays quadratic ally with distance (confirmed in many research papers like this).

$$\lambda/4\pi d ¿^2$$
$$Pr=k\cdot Pt\cdot ¿$$

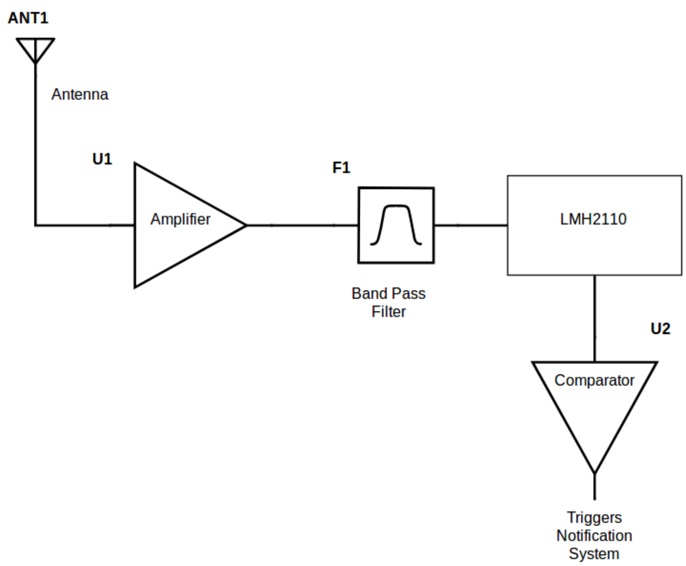
Where,

Pr is the received power,
Pt is the transmitted power,
k is the antenna gain factor (depends on the antenna receiver used)
λ is the wavelength of the received signal and
d is the distance from the source

To determine the power of the received wave, we can use the IC, LMH2110. 5V supply will be used to power it. Its power consumption is extremely low around 25mW. *The output range of the IC is -40dBm to 5dBm.* The output pin of the IC gives the value in Volts. This reading can be mapped to dBm values via a linear function of output power (Vout).

$$P(rms-dBm)=-40+9\cdot Vout(V)$$

The block diagram of the circuit is shown below:



The threshold of the comparator is determined by the antenna gain and hence has to be determined experimentally.
Mass production of this circuit is not a challenging task as all components are available very easily including LMH2110. A PCB of the above circuit can be manufactured at any circuit manufacturing agency in the country.

Error analysis

The error in measurement of the power is due to inaccuracy in the IC LMH2110. As can be seen in its documentation (attached above), it has a precision of 0.5dBm. By using a good antenna, accuracy of measurement of the distance can be within 5% at a distance of 200m.

Robustness

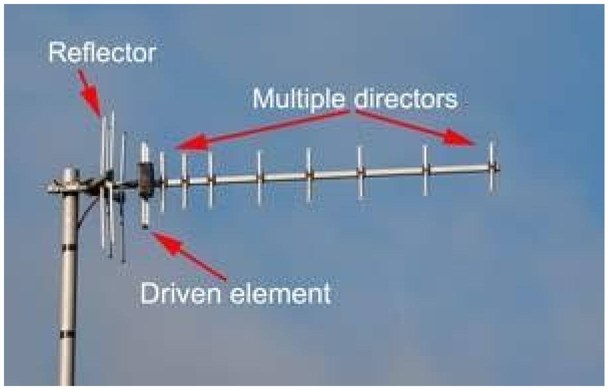
The attenuation of electromagnetic waves often depends on the environmental conditions like fog or rain. However, for the frequency range in which the AIS signals are deployed i.e. <500Mhz, the attenuation is negligible. This can be confirmed in the research papers by C.Sim [2003] and C.C.Chen[1995]. As mentioned in the above papers, the attenuation is less than the order of 10^{-4} times even in the cases of very poor weather conditions.

This method of estimating distances using power estimation is not widely used as the usually on land, signals suffer from reflections and diffractions, especially in urban environments. However, these phenomena will not play any detrimental role at sea and hence this method can be safely used.

Antenna Design

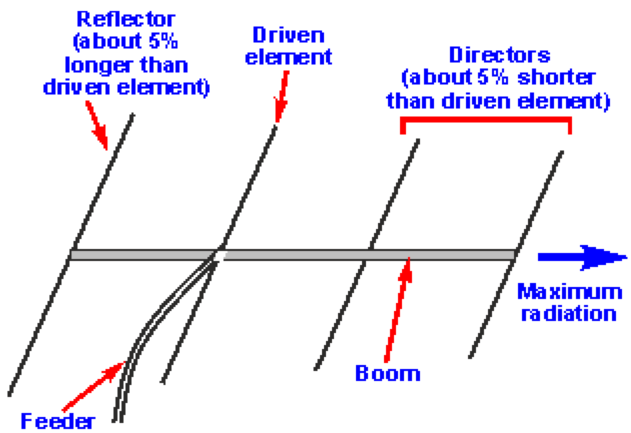
As described above, we are planning to use a directional antenna with high gain in this system for receiving AIS signals. Directional antenna will help the small ships to retreat in the direction other than that of the incoming big ship, which will help the ship navigate in the ocean even with low visibility away from the danger of striking with big ships. High power gain of antenna will help to set the power cut-off more accurately and precisely, which in turn make the system more precise in predicting nearby big ships. These features can be designed in Yagi-Uda antennas.

The Yagi antenna or Yagi-Uda antenna aerial is one of the most successful RF antenna designs for directional antenna applications. This antenna is used in a wide variety of applications where an RF antenna design with gain and directivity is required. Not only is the gain of the Yagi antenna important as it enables better levels of signal to noise ratio to be achieved, but also the directivity can be used to reduce interference levels by focusing the transmitted power on areas where it is needed, or receiving signals best from where the emanate.



Yagi Uda antenna showing element types

The Yagi antenna design has a dipole as the main radiating or driven element. Further 'parasitic' elements are added which are not directly connected to the driven element. These parasitic elements within the Yagi antenna pick up power from the dipole and re-radiate it. The phase is in such a manner that it affects the properties of the RF antenna as a whole, causing power to be focused in one particular direction and removed from others.



basic concept of Yagi Uda antenna

There are three types of element within a Yagi antenna:

- ***Driven element:*** The driven element is the Yagi antenna element to which power is applied. It is normally a half wave dipole or often a folded dipole.
- ***Reflector:*** The Yagi antenna will generally only have one reflector. This is behind the main driven element, i.e. the side away from the direction of maximum sensitivity. Typically, a reflector will add around 4 or 5 dB of gain in the forward direction.
- ***Director:*** There may be none, one or more reflectors in the Yagi antenna. The director or directors are placed in front of the driven element, i.e. in the direction of maximum sensitivity. Typically, each director will add around 1 dB

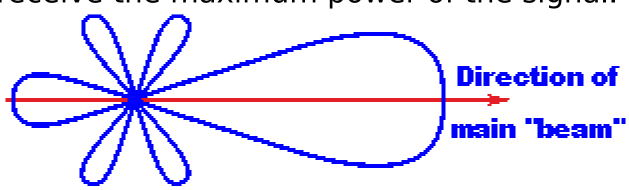
of gain in the forward direction, although this level reduces as the number of directors increases.

Theory Behind Yagi Antenna:

The key element to the Yagi theory is the phases of the currents flowing in the additional elements of the antenna. The parasitic elements of the Yagi antenna operate by re-radiating their signals in a slightly different phase to that of the driven element. In this way the signal is reinforced in some directions and cancelled out in others. In view of the fact that the power in these additional elements is not directly driven, the amplitude and phase of the induced current cannot be completely controlled. It is dependent upon their length and the spacing between them and the dipole or driven element. As a result, it is not possible to obtain complete cancellation in one direction. But, we can achieve very high gain in a particular direction.

Directional properties of Yagi Antenna:

The antenna exhibits a directional pattern consisting of a main forward lobe and a number of spurious side lobes. The forward lobe indicates the direction from which it will receive the maximum power of the signal.

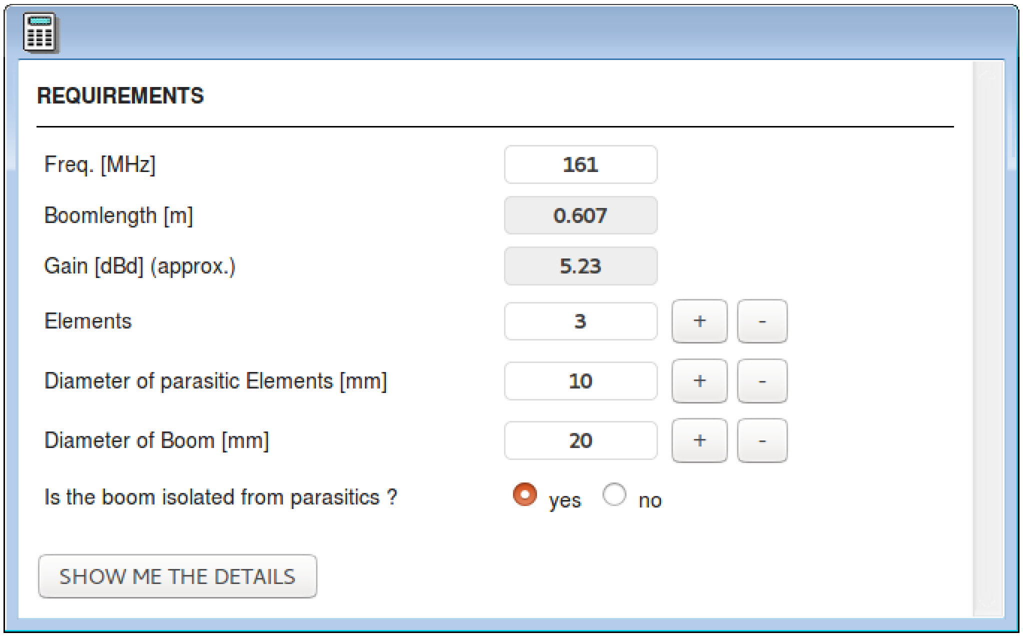


Yagi antenna radiation pattern

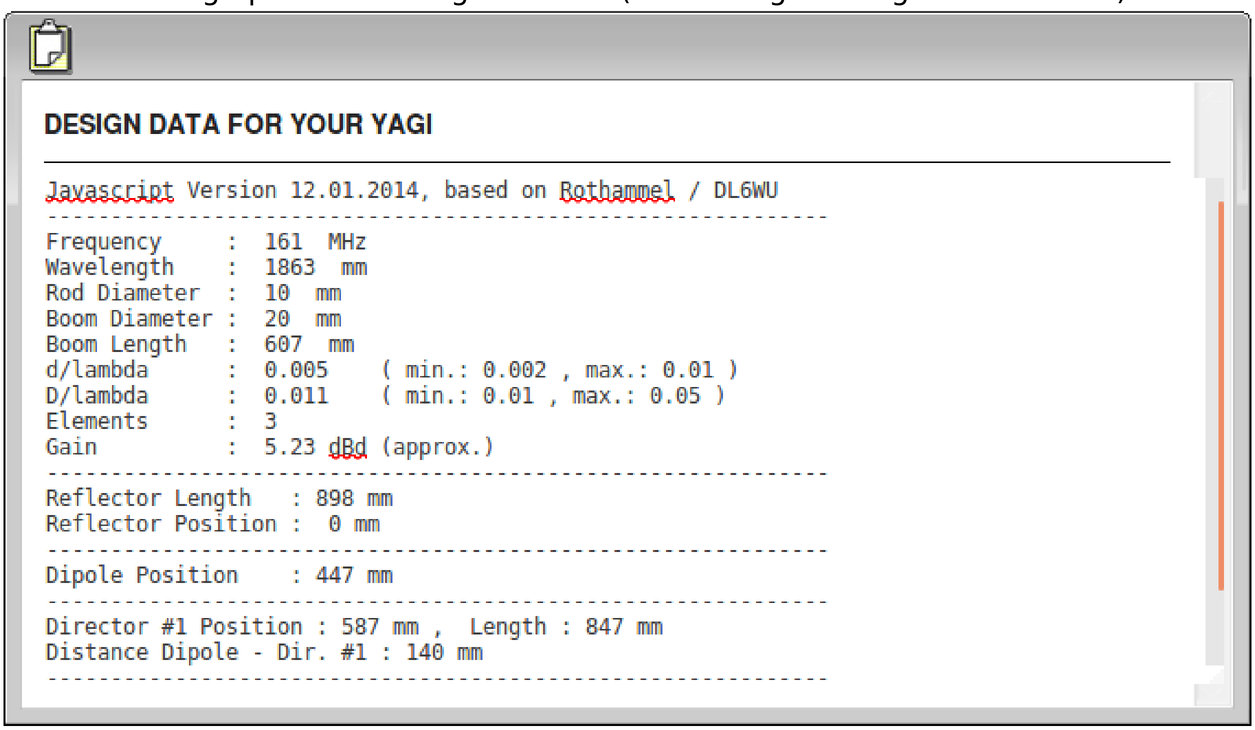
161 MHz Yagi antenna for detecting AIS signals:

Yagi antenna's elements must be carefully made of specific lengths as their lengths determine the properties of the antenna. For e.g., how many director elements to add, length of boom, length of reflector, diameter of boom, etc. These features of antenna decide what power gain it will achieve and how much directivity it can gain. We used some softwares made specifically for this purpose. e.g.: Yagi antenna calculator and YagiCAD for designing the antenna.

Firstly, we made a 3 element antenna for 433 MHz for testing, the results were impressive and after that we started developing our 161 MHz Yagi antenna. The wavelength is quite large and so will be the Yagi antenna. Below represented is the values for 161 MHz Yagi antenna. (We made an experimental antenna of 3 elements for 161 MHz).



Filling up details in Yagi-Antenna (boom length and gain is auto set)



Complete Details of Yagi-antenna for 161 MHz

We used aluminum strips as our parasitic elements and half-dipole driver element. First, we tested antenna model made for 443 MHz and then worked on the design of 161 Mhz. This antenna would be rotating with the help of a rotating motor, so that we won't miss any of the signals from big ships from any direction.

Rotating system of antenna and other details:

This antenna will be connected on a rotating servo motor which will be programmed to rotate a certain amount of angle in a specific time interval. This will ensure 360 degree check on the AIS signals, which indicates the big ships. When the antenna reads the signals from that particular direction (as the antenna is directional), and if the power of signal received is higher than the cutoff power, it will start the warning notification process, which will notify the people in the boat that the big ship is nearby and heading from a particular direction. This would help them plan their escape route even in less-visibility conditions.

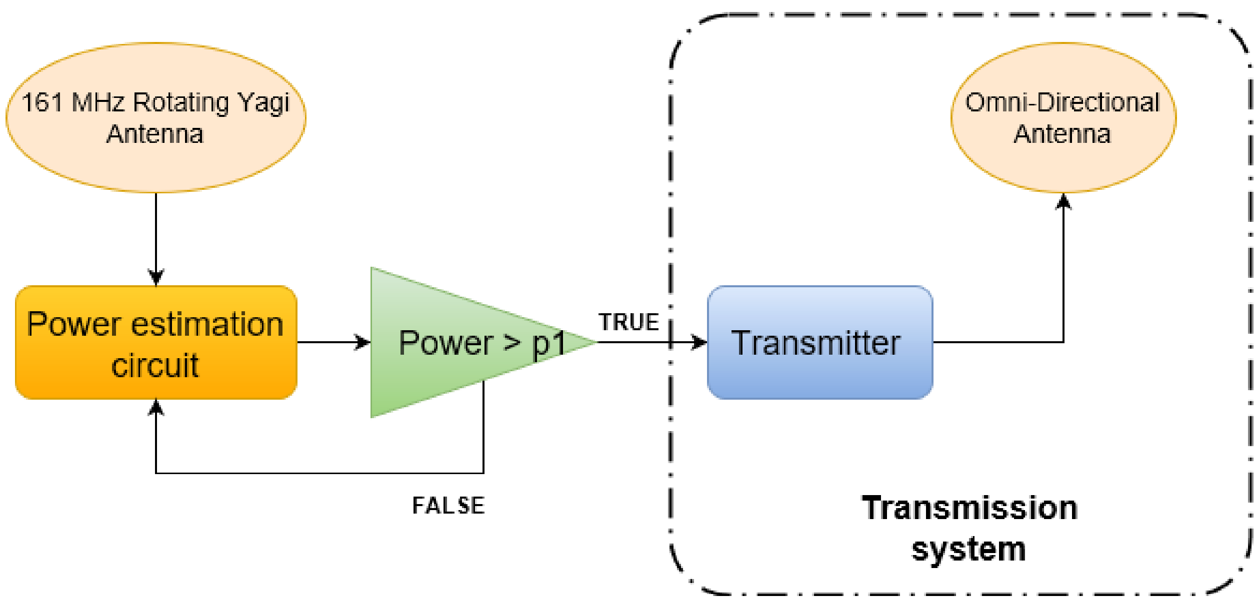
Notification System

For the small fishing trawlers:

To notify the fisherman, a simple school bell type electromagnetic alarm bell is to be used. Whenever the system detects a Big ship nearby, this alarm would turn on which will wake up the fishermen on board of small ship. In addition to this, our device is capable of interpreting the direction of incoming Big ship. So, a LED grid is used to notify the fishermen about the direction of approach so they can safely maneuver away. This system can be built cheaply and it power consumption is 50mW.

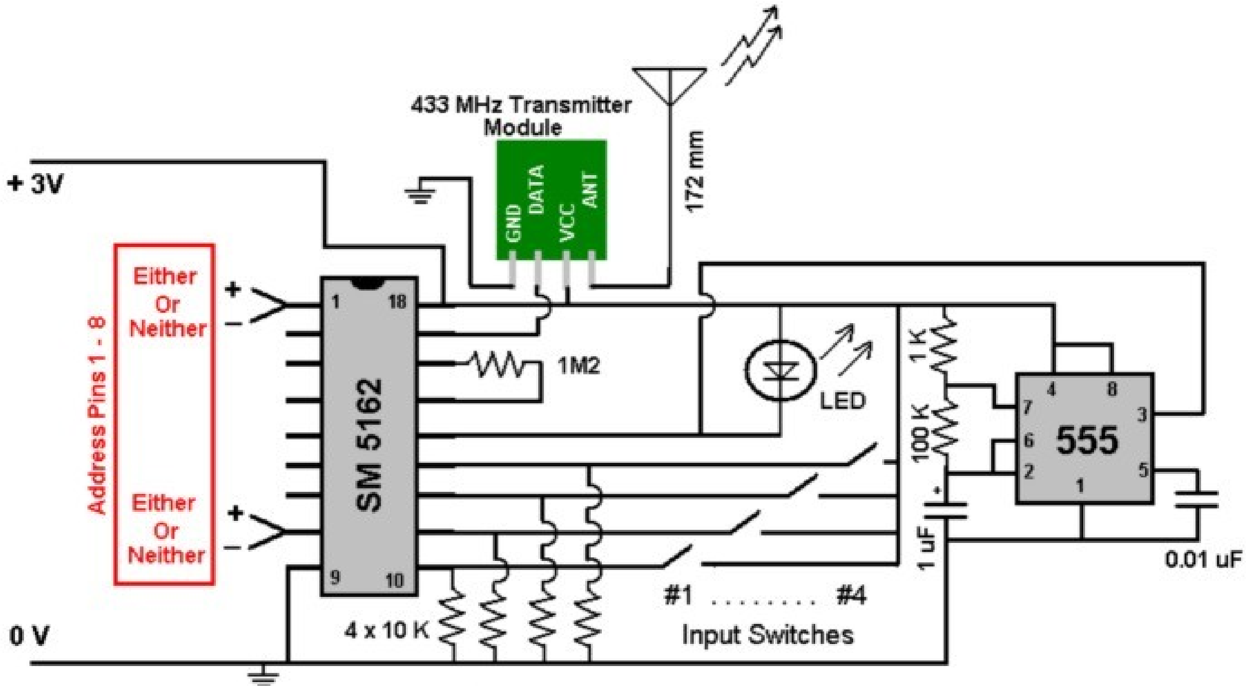
For the big shipping vessels:

1) Using transmitter onboard small ship (As a direct measure of caution)



Circuitry included in the device on the small boat

As explained above, the device power estimation circuit will calculate the power of signal received. The cutoff value of power p1 will be set up experimentally. If the power received is greater than p1 dBm, then the transmitter gets activated and start transmitting signals with some specific data which can be represented with the minimum amount of modulation in the signal. In our case, we used nRF24L01 transmitter at 2.4 GHz for demonstrating this transmission circuitry, but in real we can use any transmitter with frequency that is not already assigned for some communication purpose. This transmitted signal will be received by the nearest moored buoys, which will then transmit the signal to big ships.
Given below is a circuit diagram of 433 MHz transmission circuit. We can design such circuits for any frequency and number of channels can be adjusted accordingly.



4 Channel 433 MHz
Transmitter
Schematic Diagram

This transmitter uses an omni-directional antenna for transmission of the signal in all directions. Simple monopole antenna is an example of omni-directional antenna. One of the best designed omnidirectional antenna is VHF-UHF biconical antenna 170–1100 MHz with omnidirectional H-plane pattern. We used a rubber ducky antenna which is also a omni-directional antenna for demonstrating this transmission system.

H-wave omni directional antenna

Rubber ducky antenna

2) Marine navigational signal light: (As a visual measure of caution)

- Total Power requirement = 500mW (approx.).

As briefed earlier, a high power laser light matrix is used to notify the incoming ships. As the **direction of the incoming ship** is known, the light can be directed towards the ship. A 500mW light has a range up to two kilometers in clear condition. In foggy/rainy conditions, the range is reduced to around five hundred meters. This light has to ability penetrate thick fog and rainfall and is hence used already used widely in maritime activities all over the world.

Here, a visual notification system is used instead of audio notification (like using a foghorn as they might not be audible over the loud sound of the ship's engine and also in case of heavy rainfall. However, a foghorn and a marine flare gun (that would launch flares into the sky) can be added as extra or alternative precautionary measures.

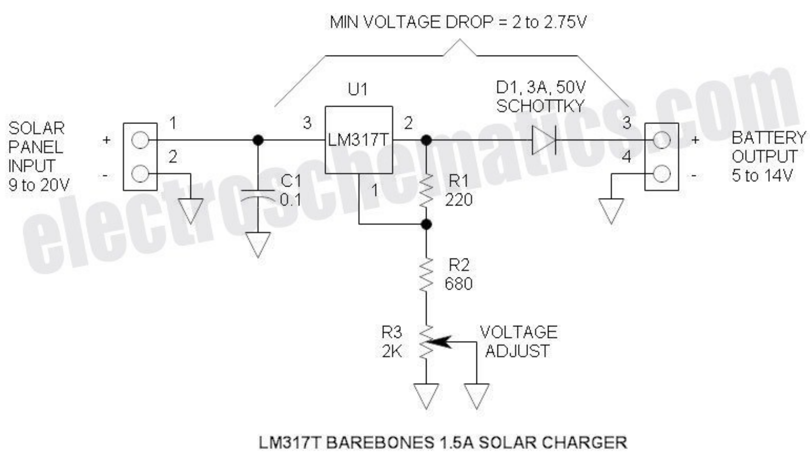
Powering the Entire System

We’ll use a 10W solar panel to charge a 5V battery and control the voltage through a regulator.

Solar battery charger specifications

- Solar panel rating: 10W (6V)
- Output voltage range: 5 to 14V (adjustable) (may be reduced further by shorting R2)
- Typical dropout voltage: 2 to 2.75V (depending upon load current)
- Maximum current: 1.5A (internally limits at about 2.2A)
- Voltage regulation: ±100mV (due to regulation of series rectifier)
- Battery discharge: 0mA (this control will not discharge the battery when the sun doesn’t shine)

Solar battery charger schematic



5V Application:

- Output Voltage: Set for 6V
- Input voltage:
  - Battery discharged (5): 8.75V Min @ 1.5A
  - Battery charged (6V): 9V Min @ 10mA

System on Buoys

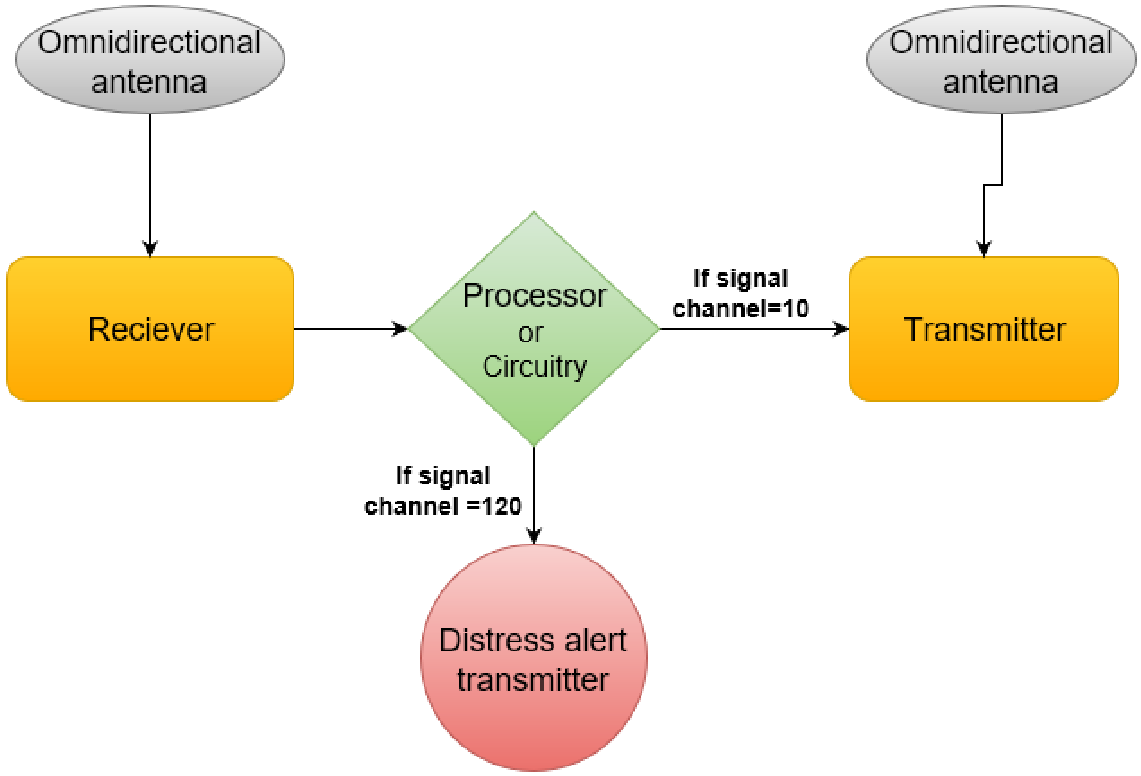
A Buoy

Buoys are weather sentinels of the sea. They are in general, an integral part of ocean research, port traffic management, fishing, etc. Buoys are designed in different ways to serve different purposes. But, the common thing among almost all of moored buoys is that they are supplied power from solar panels and battery on the moored buoys. Moored buoys are self-powered.

We propose a low power transceiver system to be deployed on the moored buoys that will not only help communicate the warning message covering a large area, but it will also help managing a large number of signals from many small fishing trawlers and decrease power usage on the small boats using our proposed device. Also, other benefits of using moored buoys as a local center of network includes a low cost distress warning system, ** international boundaries warning**, safety hinge for small boats during bad weather conditions, etc.

Transceiver system

The transceiver system consists of a transmitter and a receiver with a processor or circuitry that can modulate or demodulate the signal and can check for some conditions. In our case, we used nRF24l01 transmitter and receiver working at 2.4 GHz with two channel access (Channel 10 for [small boat -> big ship] signal and Channel 120 for distress signal). In our system, the transmitter is just a slave of receiver. The flowchart of the system is as follows:



System proposed on the moored buoy

The transmitter and receiver are set default at channel 10, which is the frequency used by transmission warning signal from the small boat regarding big ships in the vicinity. When the receiver receives a signal from the small boat, it interprets this signal and orders the transmitter to send the same warning signal with some more data modulation. This increases the coverage range of the signal as well as it can ease the complications of the proposed device on the small boats.

If the signal received is of channel 120, it indicates that the small boat has activated the distress switch, thus in need of help. This “channel 120” signal triggers the DAT (Distress Alert Transmitter) which then can help the people in need during such disastrous times. Distress system will be explained later on in the documentation.

Cost Estimation

Small boat device

Component	Cost
Power-Detector circuit	₹ 130
Yagi antenna	₹ 300
nRF24L01 and its antenna	₹ 300
Arduino	₹ 350
Power System (Battery + Alternator + Regulator)	₹ 2000
Marine navigational signal light	₹ 1000
Servo, switches, wires etc.	₹ 700
Total	**₹ 4780**

Big ship

Component	Cost
nRF24L01 and its antenna	₹ 300
Total	**₹ 300**

Moored Buoy

Items	Cost
nRF24L01 (x2)	₹ 600
Mega-Arduino	₹ 650
Total	**₹1250**

Buoys are always placed around the coast and ports, but in case moored buoys are not already installed in the sea/ocean, the total cost of installing a moored buoy is ₹60,000-7,50,000.

Total Cost of the Device: ₹ 4780 (To be installed on the ship)

Optional Objectives

Here, a mechanism to deal with each of the optional objectives is proposed.

Weather Alert

Indian coastline is hit by a number of cyclones during ‘North Indian Ocean Cyclone Season’ between April and December. In 2017, these cyclones caused a total damage of approximately $8.88 billion (2017 USD) with 761 fatalities.

Small vessels usually don’t have any access to satellite weather data leaving them vulnerable to adverse weather conditions (primarily Cyclone).

Within 36 hours of the center passage, the pressure begins to fall. According to Indian Meteorological Department a Deep Depression (next only to cyclone strength) occurs if the sea level pressure lies between 999-990 hPa. Further according to a Newsletter of IUSSTF by IIT-BBS(link), Pressure drop related to different categories of cyclone is as follows:

Sl. No.	Category of System	Pressure Drop (hPa)	Maximum Wind Speed knot (kmph)
1.	Low (L)	< 1.43	< 17 (< 32)
2.	Depression (D)	1.43 – 3.61	17 - 27 (32-50)
3.	Deep Depression (DD)	3.91 – 5.40	28 - 33 (51-61)
4.	Cyclonic Storm (CS)	5.73 – 10.95	34 – 47 (62-88)
5.	Severe Cyclonic Storm (SCS)	11.43 – 19.68	48 – 63 (89 – 117)
6.	Very Severe Cyclonic Storm (VSCS)	20 – 49	64 – 119 (118-220)
7.	Super Cyclonic Storm (SUCS)	≥ 50	≥ 120 (≥ 221)

Our system aims at providing warning of approaching cyclone by observing the change in pressure.

Our system measures barometric pressure using BMP180(digital pressure sensor). It takes 5 reading in interval of 10 minutes and average them. If the pressure turns out to be less than 1000 hPa, an alarmed is rang. Further the arrangement stores the average pressure read of last hour and if the current pressure is less than 1000 hPa than check out the change in pressure in the last hour.

- If the pressure difference is less than 0.12 hPa then it glows level 1 indicator.
- If the change is between 0.12hPa and 0.24 hPa it shows level 2 indicator,
- If the change is more than 0.24 hPa, level 3 signal is triggered indicating approaching Severe Cyclone Storm.

Alerting the Coast Guard

We are going to implement the system using a transmitter on the boat and installing Distress Alert Transmitters (DAT) on the moored buoys in the sea/ocean.

DAT operates via INSAT-3A with full coverage of the Indian subcontinent. It works on Indian Disaster Management dedicated frequency and each equipment has a unique identification number.

The system works like this: immediately on receipt of distress signal from the boat in sea, the Coast Guard through DAT will be able to identify the boat and its precise location. The equipment has in-built GPS to give precise position and time of information. The signal from the DAT first goes to INSAT 3A satellite and from there to the Chennai-based Maritime Rescue Coordination Centre (MRCC), which is a hub linked to coordination centers in each coastal State. MRCC immediately coordinates the rescue operation from air and sea.

In case of an emergency, the user can press a switch which will prompt the transmitter placed on the small boat to send a signal at a frequency generally used for distress signals. The transceiver placed on the moored buoys shall act as a switch for the DAT. It will receive the distress signal from the boat, and then enable the DAT to send a signal to the coast guard. The signal coming from the boat shall have an approximate location of the boat which will be passed on to the coast guard. For testing, we shall be using nRF24L01 as the transmitter on the small boat.

Cost of the System

In India, about 60 lakh fishermen, belonging to 3,930 villages, fish in the exclusive economic zone comprising 2.04 million square kilometers. There are about 2,00,000 traditional craft, 55,000 beach landing craft with outboard motors and 51,000 mechanized fishing vessels.

The cost of a DAT system is ₹ 9999. Now, installing a DAT on every boat costs a lot of money which is why the current system is not feasible to implement everywhere. However, by installing DAT on only the nearby moored buoys which are way less in number compared to the number of boats we can cut down on the total cost of the system by a huge margin.

National Boundary Alert

To alert the fishing vessel when it crosses the territorial boundary, we once again use our grid of buoys in the sea. The transmitters on the buoys will always send a signal carrying no information. If the fishing vessel is in the proximity of the port, it shall keep on receiving the signal. The received signal does not need to be demodulated, it just needs to be received. If the receiver fails to gather the signal, it implies that the fishing vessel has travelled too far away from the port and hence trigger an alert.