Codar of Radar System

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Abstract - **Oceans cover almost three-fourth of the total land mass of the Earth. So practically it can tell many significant information of our history. The study of oceans have been a huge challenge because of its versatility. But, by taking various factors in account systems have been developed for the purpose of its study. The various light and sound spectrums can be used to get necessary data for study for example-radio waves, micro waves, gamma rays etc. One of the most efficient method is the Radar system which uses the electromagnetic spectrum (radio waves). Various components can be studied by this like the ocean currents, current velocity, orientation of waves, current directions, navigation in rough terrain etc. Now, particularly the coastline line plays a very important role as it may affect the habitat living around. A special radar system known as CODAR is the system is used here. It is specifically used in coastal regions to bring into notice factors like wave density, directions to know about weather conditions and many other things**

keywords - **Codar,bragg scattering,doppler effect,resonance .**

1 INTRODUCTION

Radar System -It is an electromagnetic system and it stands for radio detection technique. It serves the work of detecting objects, its distance and location from the point of setup of the radar system. It can also detect shape and size of the object. It can also work far than line of sight.Types of Radar systems

1. Bistatic Radar
2. Doppler Radar
3. Monopulse radar
4. Weather Radars

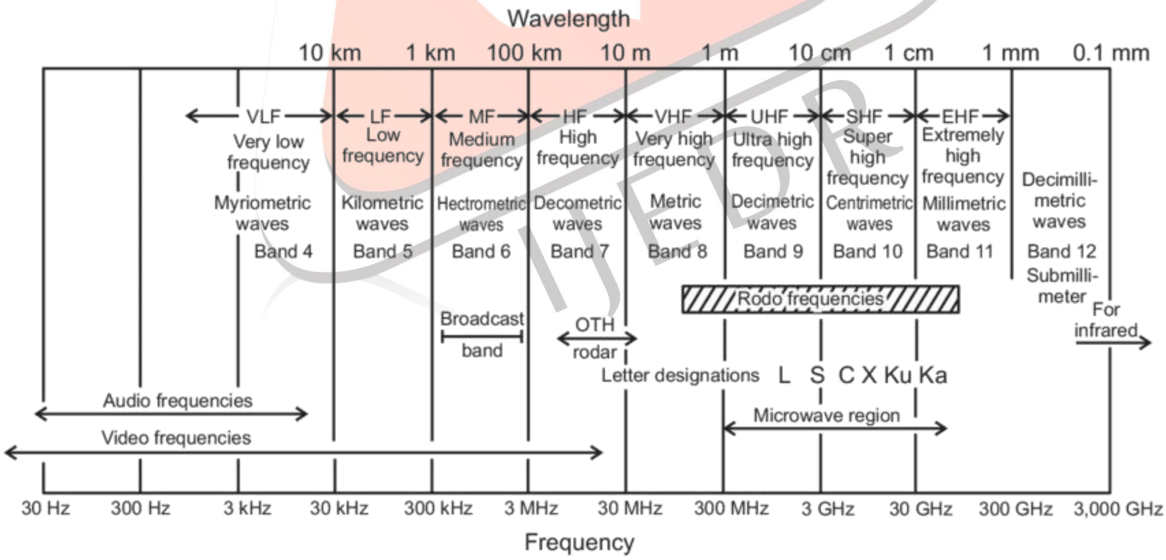

Fig 1 This figure shows the spectrum of electromagnetic waves

2 WORKING PRINCIPLE

This system radiates energy into the space, generally of microwave range which then monitors the reflected or echoed radiations from the object of concern. The time for the signal to travel and the speed of the signal if known the distance can be measured using a précised watch.

Working components: -

- **A Transmitter**: The device used to transmit energies into the space. Examples of such devices can be power amplifier(klystron), travelling wave tube etc.
- **Waveguides**: The transmission lines for transmission of the signals of the RADAR.
- **Antenna**: It works as a parabolic reflected in the whole process. It has shape bent so it mainly focuses the signals into an exact and narrow signal. They are placed close to the ocean surface to reduce signal attenuation.

- **Duplexer**: The antenna can be a gaseous device, when the transmitter is working it may generate a short circuit at the input to the receiver
- **Receiver**: It should consist of elements which can detect the signals and process it using a processor.
- **Threshold Decision**: The output which is detected is compared by default threshold values, if output is above this threshold values them a object is said to be detected, if the output is lower than threshold level then it is said that it is the noise in the channel which has created disturbances.

3 Radar equations

HIGHEST RADAR DETECTION RANGE(when object is at the middle of the antenna)

$$Rmax = 4\sqrt{\ } Pt$$
$$\lambda 2G2\sigma/(4\pi)3Pmin$$
$$= 4\sqrt{\ } Pt$$

…..(1)
Pt' = Transmit power
'Pmin' = Minimum detectable signal
'λ' = Transmit wavelength
'σ' = Cross-section of the target radar
'fo'= Frequency in Hz
'G' = Gain of an antenna
'C' = Light speed

Least detected signal when there is noise

$$Pmin = k\ T\ B$$
$$F\ (S/N)min$$

…(2)
Pmin' is the least detectable signal
'k' is the Boltzmann's constant like 1.38 x 10-23 (Watt*sec/°Kelvin)
'T' is a temperature (°Kelvin)
'B' is the bandwidth of a receiver (Hz)
'F' is the Noise Figure (dB), Noise Factor (ratio)
(S/N) min = Least S/N Ratio

Received Power

$$Prec = Pt$$
$$\lambda 2G2\sigma/(4\pi)3R4max = Pt$$
$$C2G2\sigma/(4\pi)3R4fo2$$

……(3)
'Prec' is the received power
'Pt' is the transmit power
'fo' is the transmit frequency
'λ' is the transmit wavelength
'G' is the gain of an antenna
'σ' is the cross-section of radar
'R' is the range
'c' is the speed of light

4 CODAR(Coastal Ocean Dynamics Application Radar)

This is a coastal radar which is used in huge coastal areas for various purposes.
CODAR are basically high frequency radars which are a very vital tool for mapping special distributions very remotely. One of its application is to measure surface current velocities on the coasts of seas and oceans. Its applications are less efficient on fresh water than salt water. So in this article we will be focusing mainly on saltwater applications of the codar. Using this a full current system can be generated every fifteen minutes over a range of approximately 70km.Codar uses Multiple Signal Classification algorithm for finding directions.
As we have discussed Data acquisition is a very important aspect ,hence this aspect can be resolved by dividing it measuring components into categories:-

i. Current Velocity of Target (Radial Component)
ii. Range to Target
iii. Angle of Target

i.Current Velocity Target
The phenomenon of backscattering of radio signals is used in this technology. The ocean waves are not flat, backscattering process of waves are done efficiently if it was not so no signals may not be received by the antenna. The radio signals are radiated to the ocean waves in all directions some of them are scattered, echoed or directly bounced back to the antenna for its directions. These signals which are received back by the antenna are by default having less power in them. So, to amplify their power we use the concept of resonant Bragg scattering.

…(4)

Bragg Scattering is the phenomenon which amplifies the power of these signals directly directed straight towards the antenna.
25 MHz transmission -> 12m EM wave -> 6m ocean wave
12 MHz transmission -> 25m EM wave -> 12.5m ocean wave
5 MHz transmission -> 60m EM wave -> 30m ocean wave

The following chart shows three typical HF operating frequencies and the corresponding ocean wavelengths that produce Bragg scattering.
We assume that the angle of incidence of the signals emitted from the CODAR are at 0 degree angle with the ocean surface.So, the above equation changes to:

$$\lambda_s = \frac{\lambda_t}{2}$$

$$\Delta f = \frac{2\, V_R}{\lambda_t}$$

Where :

Δf = Frequency Shift
V_R = Radial Component of Velocity

…(5)

All the signals returned are said to be in phase hence all the signals returned to the antenna are lined up and are thus amplified. The signal send out from the Codar is twice the wavelength of an ocean wave to fulfill the purpose of making the signal strong.Now all the equations mentioned above consider that the waves are not moving but practically we know that the waves are moving so here the concept of Doppler effect comes into picture.

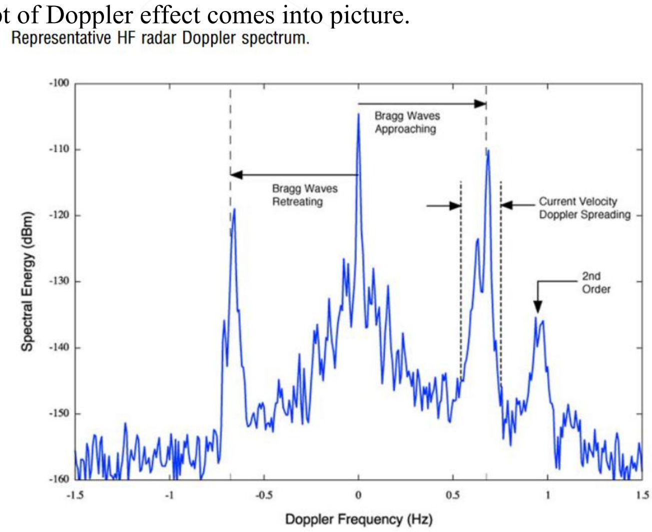

Fig 2[Shows the Doppler frequency range]

$$\lambda_s = \frac{\lambda_t}{2\cos(\Theta)}$$

Where :

λ_s = Wavelength of Surface Waves
λ_t = Wavelength of Transmitted Signal
Θ = Incident ∠ of the Signal

The amount of shift in the frequency of the signals will be scattered by the wave depending on the nature of the signal's movements. If the signal is transmitted from the antenna towards the ocean and the wave is moving away then the frequency shift is negative and in vice versa case the frequency shift is positive Now the magnitude of the shift can be calculated:-

…(6)

In the equation we assume that no surface current changes the motion of the waves. The current can be measured from the doppler shift from the original frequency range
Now using the Linear Wave Theory, the velocity of surface current can be calculated but the velocity calculated is only one component of the velocity. The Codar must use at least one more component of the radial velocity to calculate the total current vector with min error. The pecks in the graph of result measured by Bragg scattering and doppler effect can tell about the way the waves move.

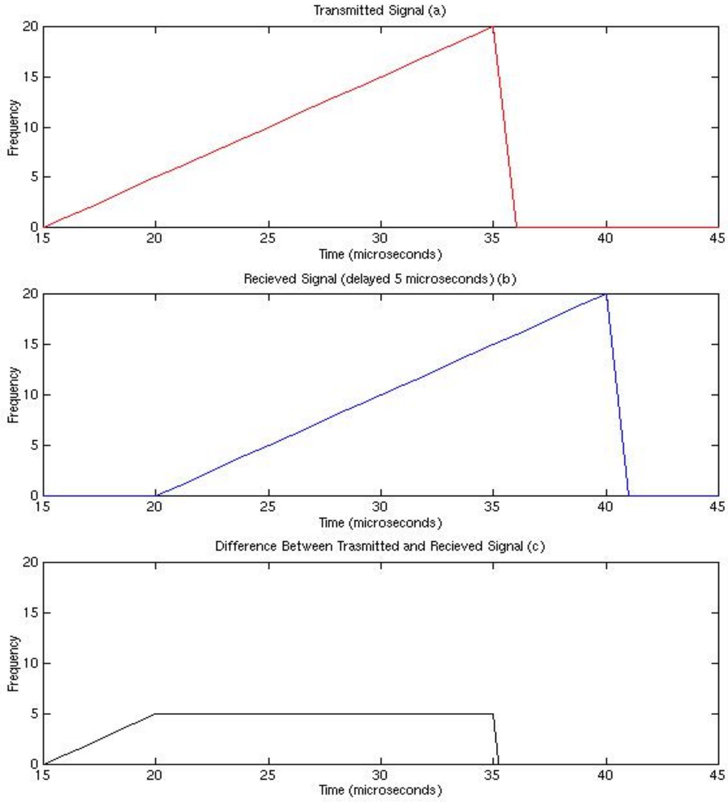

Fig 3[The graph shows the effect of bragg frequency and doppler effect.]

ii.Range to Target

A frequency modulated signal is sent, its frequency increases linearly with time. The time delay can be measured by subtracting the return signal from the transmitted signal. The range to the target is determined by the resultant time delay.

iii.Angular Direction of the Target

There are mainly their antennas in Codar

1. Monopole antenna-The signals received are independent of its directions. Also called omnidirectional antenna. These are used to normalize the resultant signal information.
2. Two loop antennas-They are dependent on the direction of the incoming signals. Both of them are at degree inclination to each other so that the signals received by each of them can be combined together with each to get some combined data.

At the end these signals from the loop antennas are mixed with the monopole antenna and at last the signals is normalized and A specific data is achieved which mainly consists of directions using arctangent function. This process is referred to as Direction Finding.At the central Data Combining center, the signals achieved at the antenna are studied theoretically by users at user-selected-time-intervals. Hence on prolonged studies complete vector map is achieved.

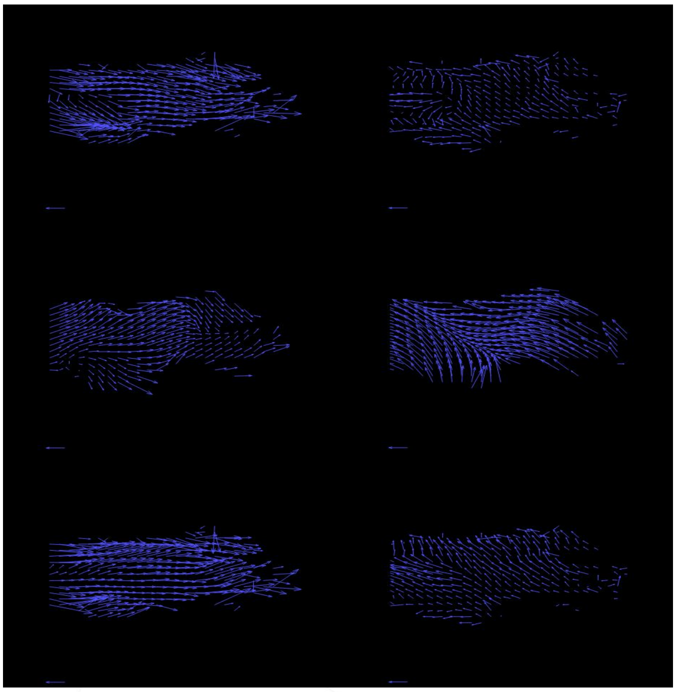

Fig 4[The picture shows the latitudnal and longitudinal currents measured by Codar]

5 ADVANTAGES

a) Resolution is high,so long distanced data can be studied properly.
b) Useful in bad weather conditions.
c) Accuracy level of results are high.
d) Huge areas can be taken as input at once.
e) Time required to get outputs are also less.
f) Computation of data is easy.

6 DISADVANTAGES

a) It does not measure current and waves in a range less than 2km.
b) Resolution is more than 5km.So,anuthing less than this area are not measured with accuracy.
c) Two codar system near to each other can afeect one another's results.

7 DISCUSSIONS

So the surface current are measured on knowing the following factors

a) In the radial directions, the velocity of the incoming waves.
b) The angle at which the waves are travelling with respect to Codar system.
c) Distance between the Codar and the area to be evaluated.

8 CONCLUSION

It is a noninvasive tool for measurements. Measurements can be in range of 1 km and as long as 150 km from the shore at a resolution of -0.3-3 km along a radial beam. It has directional resolution up to 1 degree. It can calculate surface current less than error of 4cm/s The difference in transmit frequencies used in this study may result in a roughly 10-cm difference in the effective depth of the radar measurement (1 m at 12.2 MHz,;0.9 m at 13.6 MHz)

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