User’s Guide for:

SeaSonde® Radial Site

Operating Theory

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Please read the disclaimer on the last page of this publication.

This Guide explains the basics of how SeaSonde works. For the scientific reader, references are given (see footnotes) that give more technical details **of SeaSonde.**

For **block diagrams**, **schematics,** and explanations of SeaSonde **electronics circuit theory**, please refer to the *SeaSonde Hardware Guide*.

SeaSonde is a **compact**, **simplified radar system** that measures **currents** near the **surface** of the **ocean**.

SeaSonde was **developed** by **scientists and engineers** in California's Silicon Valley.

This Guide contains **seven** sections:

1. A brief explanation of **conventional radar**.
2. **Pulsing** in SeaSonde.
3. SeaSonde's **efficient** method of measuring **range**.
4. **Range cells**: measuring the ocean, one step at a time.
5. The SeaSonde **Receive Antenna**: **three antennas** combined to find **bearing**.
6. How SeaSonde measures **speed**.
7. Summary.

Section 1: A brief explanation of **conventional radar**.

Radar stands for *ra*dio *d*etecting *a*nd *r*anging.

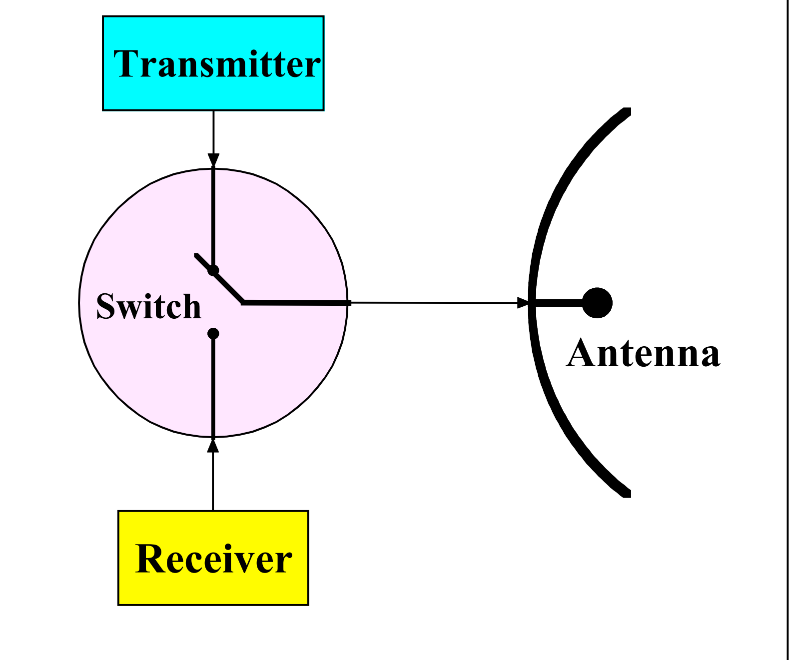
Radio waves are sent toward an object known as a "**target**." Reflections bounce back from the target. Reflections are analyzed to find the **distance** (called "**range**"), **direction** ("**bearing**") and **speed** of the target.

Once again, radar measures the **range**, **bearing**, and **speed** of a **target**.

American and British scientists invented Radar during World War II. The original targets were **ships** and **airplanes**.

SeaSonde's "targets" are **waves** on the surface of the **ocean**. By measuring ocean waves, the **direction** and **speed** of **currents** near the water's surface can be calculated, using proprietary **software**.

Here is a **block diagram** of conventional radar:



Conventional Radar Block Diagram

The **same antenna** is used for transmit and receive.

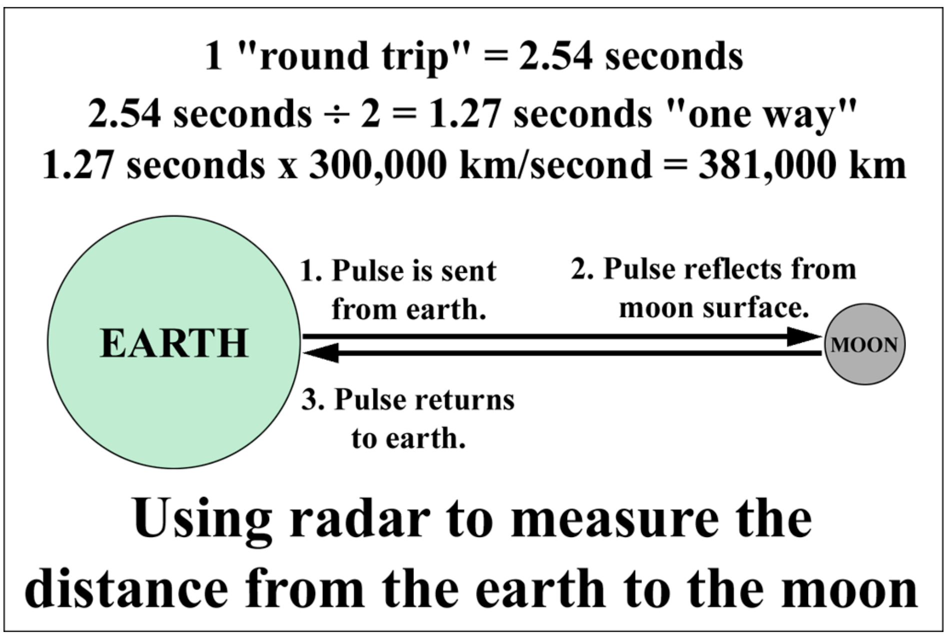
Among many other uses, radar can **measure** the **distance** from the **earth** to the **moon**. This is done by **sending radio waves toward** the Moon in **short bursts,** known as **pulses**.

The **time** it takes for a pulse to **return** to the Earth is measured, and divided by the speed of light.

Radio waves travel at the **speed** of **light**: about **300,000 kilometers/second**.

In **one microsecond** (.000001 seconds), radio waves travel about **300 meters**.

Each pulse has to make a "**round trip**." **Return time** is **divided** by **two** and **multiplied** by the speed of light, to calculate the distance to the moon:



There is a **serious problem** with this method of calculating the distance to the moon. The **pulse rate cannot** be **faster** than once every **2.54 seconds**. **Each pulse** has to have **enough time** to make a "round trip" before the **next pulse** is sent.

There is no way to tell **one pulse** from **another**, except to **send one**, and **wait** for it to **return**.

This radar system is **idle** most of the time, **waiting** for **reflections**.

Conventional radar is extremely **inefficient** because it is **idle** most of the time.

The technical term for the time a radar system is **actually sending signals** is "**duty factor.**"

A **higher** duty factor is good, because the system **sends signals more often**, and is **idle less**. Conventional radar typically has a duty factor of no more than **10%**. It is **idle 90%** of the time.

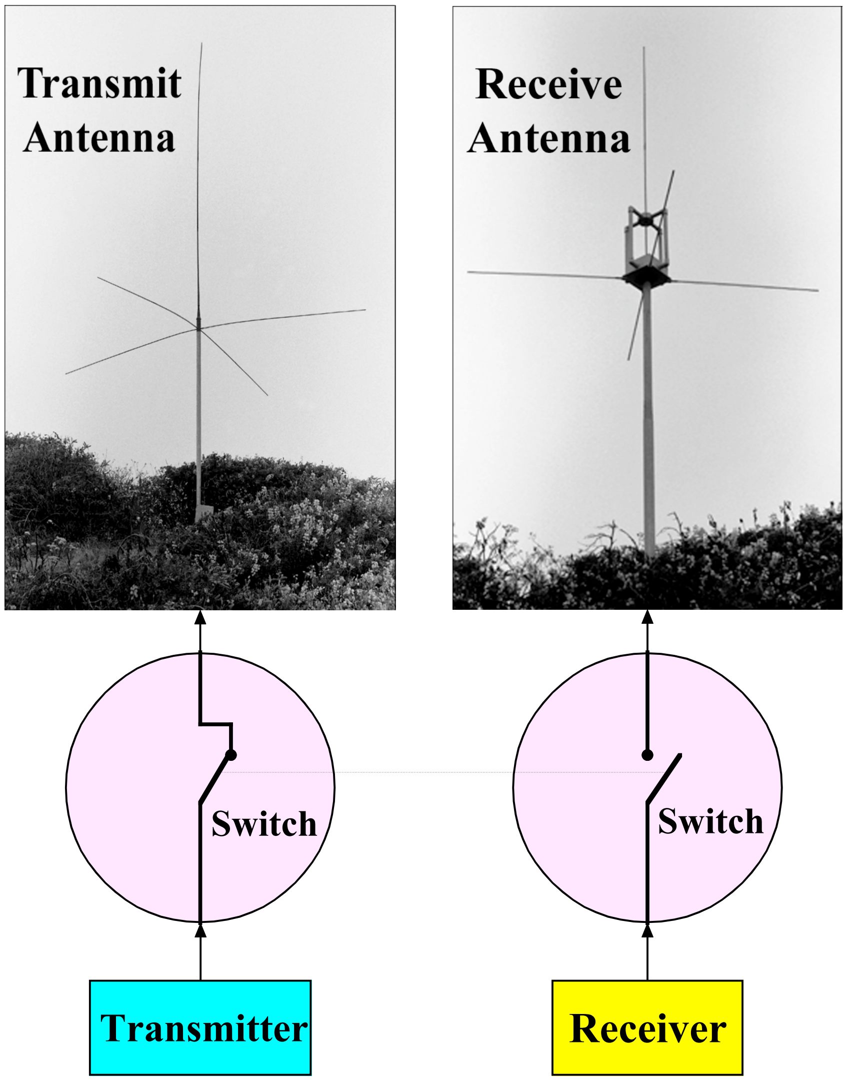
The inefficiency of conventional radar sometimes creates the need for **large antennas** (and **associated electronics)**:

SeaSonde **uses pulsing**, but for a totally **different purpose** than for measuring distance to target[1], as is done in conventional radar.

[1] D. E. Barrick, B. J. Lipa, P. M. Lilleboe, and J. Isaacson (1994) Gated FMCW DF radar and signal processing for range/Doppler/angle determination, U. S. Patent 5 361 072.

Section 2: **Pulsing** in SeaSonde.

SeaSonde electronics **switches between** the Transmit and Receive Antennas, to keep signals from the Transmit Antenna from **overloading** the Receive electronics. The two Antennas are mounted close together:



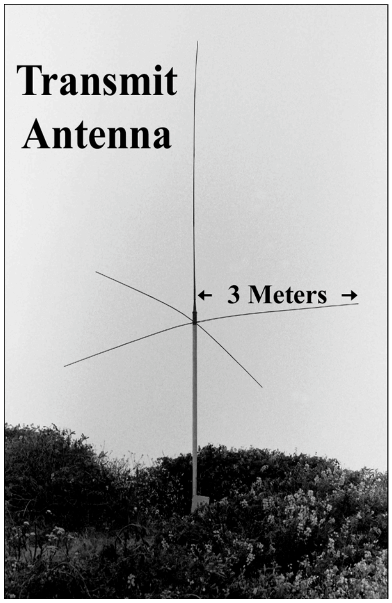
Switching Between Transmitter and Receiver

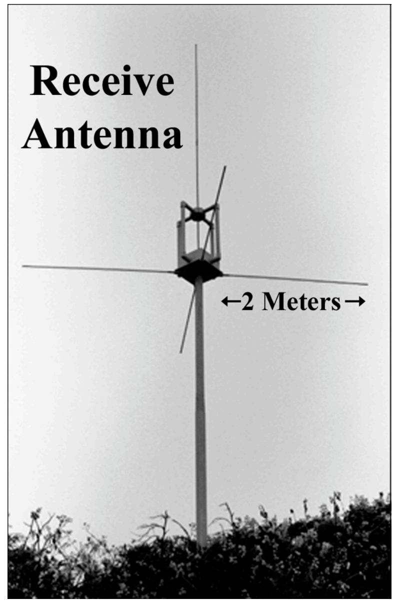
SeaSonde's **duty factor** is **50%**, a **five-fold improvement** over most radars. It **transmits half** the time, **receives** the other half, never at the same time.

A 50% duty factor **maximizes** the time the Transmitter and Receiver operate, without interfering with each other.

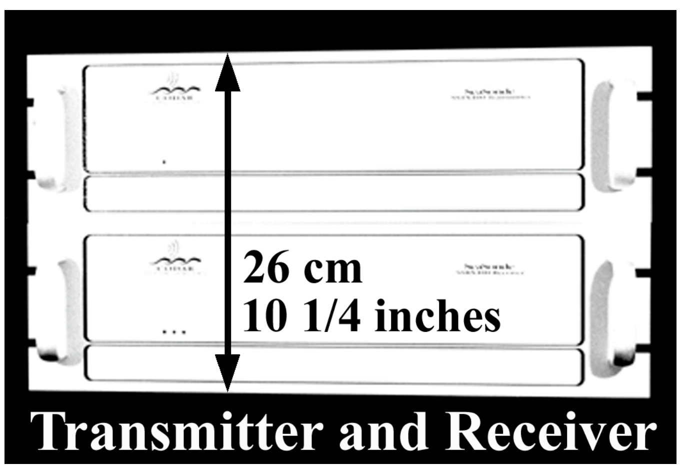
Section 3: SeaSonde's **efficient** method of measuring **range**.

SeaSonde Antennas are **small** compared to most radar systems:





SeaSonde **electronics** are also compact. The Transmitter and Receiver chassis **together weigh less** than **30 kilograms**, and occupy a small amount of standard rack space:



SeaSonde's compactness is possible because of **high efficiency**.

Compared to conventional radar, a completely **different method** of **measuring range** (**distance** to **target**) is used.

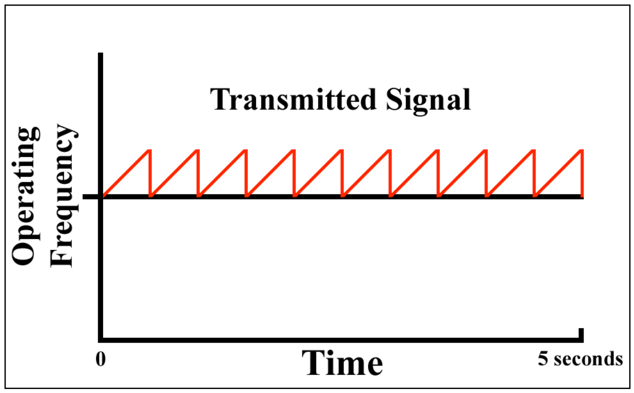
This reduces the **size**, **weight**, **electric consumption** and **heat dissipation** of SeaSonde compared to most radar systems.

SeaSonde uses an efficient **swept frequency** method to find range to target.

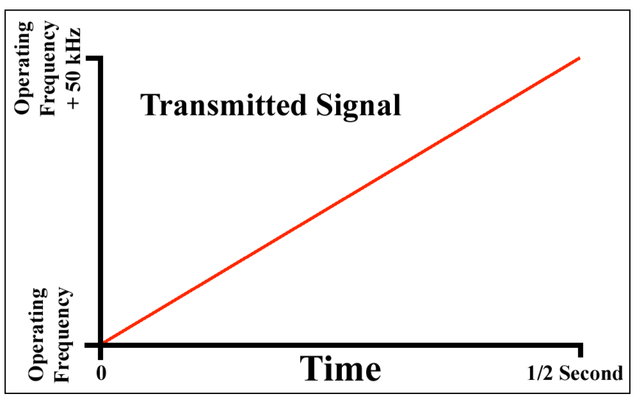
SeaSonde's Transmitter sends a signal that makes **periodic**, **linear sweeps** in **frequency**.

The **frequency change** during each sweep is typically **50 kHz** (50,000 Hertz). This is **small**, compared to the **operating frequency** of SeaSonde, which is **between 4 MHz** (4,000,000 Hertz) and **50 MHz**, depending on the system.

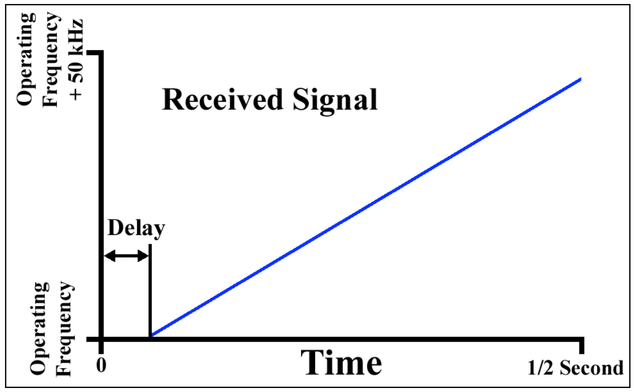
Each sweep, starts at the **operating frequency** of the SeaSonde, **moves upward**, then **falls back** to the operating frequency:



To understand how frequency sweeping can be used to measure distance, consider a **single sweep**, which takes a **half-second**:

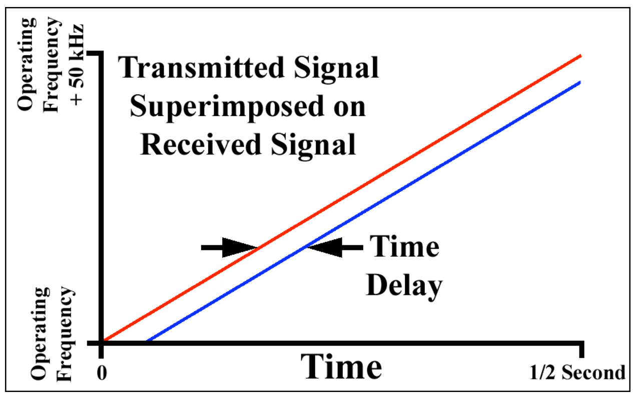


SeaSonde's **Receiver** picks up the signal **reflected** from the **target**. The reflected signal also **sweeps upward** in **frequency**, but is **delayed**, by the time it takes for the signal to **reach** the **target** and **return**:



Notice the Transmitted and Received signals are **identical** except for **time delay**. The transmitted signal **starts** at “**0**” on the time scale, the Received signal a little **after** “0.”

Placing one graph **over** the other shows they are the **same**, **except** for **time delay**:



What happens if **one graph** is **subtracted** from the **other**? The two graphs are **straight lines**, and are **parallel**. The difference between them is a **straight**, **horizontal line**. The **height** of the line is **proportional** to **range** to **target**:

Subtracting one signal from another is done with a device called a "**mixer**." Mixers, among other devices, are employed in SeaSonde electronics. The electronics of SeaSonde are explained in *SeaSonde Hardware Specifications.*

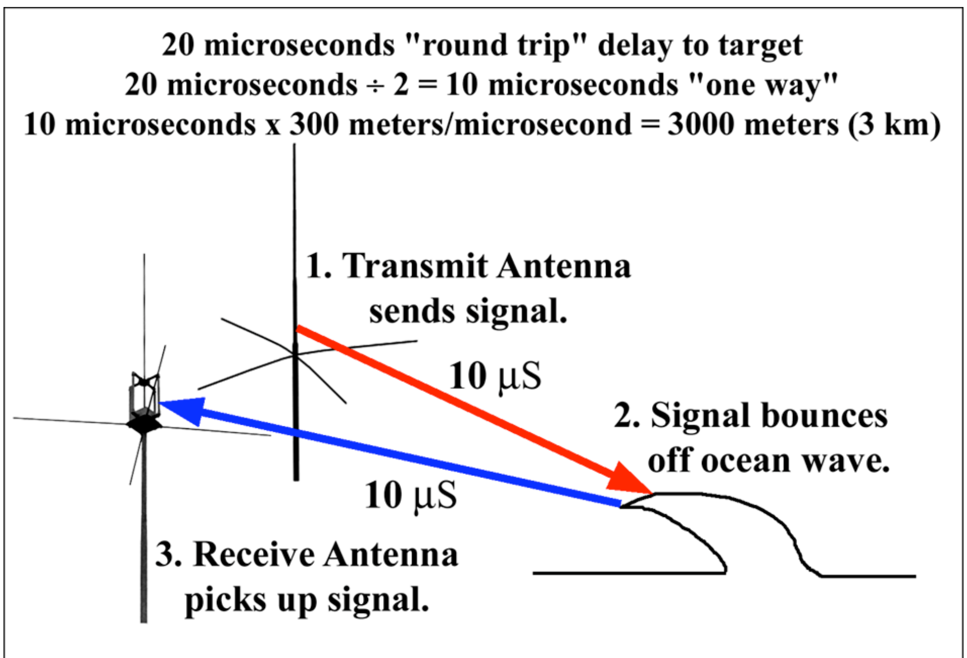
Notice the **vertical scale** has changed from "**Frequency**" to "**Distance to Target**."

This is how SeaSonde measures distance to target, **without** the **inefficiency** of **waiting idle** for reflections to return from the target.

The green line is **flat**. This target is **stationary**. Distance to target is constant with time.

When **measuring ocean waves**, the distance to target **changes constantly**, and the green line would be **sloped**.

How does **time delay** translate into **distance**? Radio waves travel **300 meters** in **one microsecond**. Radio waves have to **travel from** the **Transmit Antenna** to the target, and **return to** the **Receive Antenna**. A delay of **20 microseconds** means the target is **3 kilometers away**:

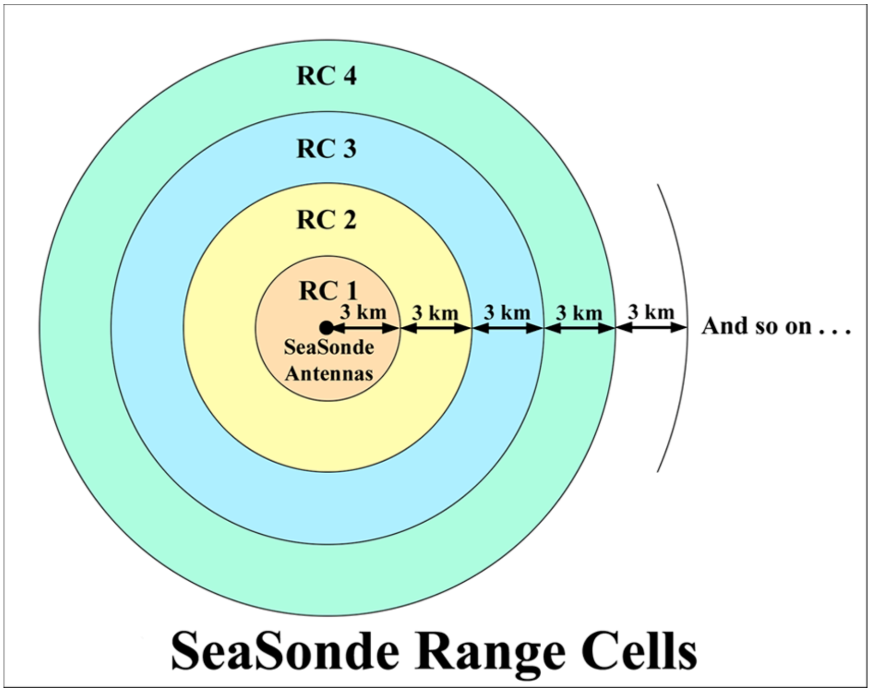


Converting Time Delay to Distance with SeaSonde

Section 4: **Range cells**: measuring the ocean, one step at a time.

In the last section, a SeaSonde with a sweep frequency of 50 kHz is described.

A SeaSonde with a **sweep frequency** of **50 kHz measures distance** in **steps** of **3 km**. Each step is called a "**range cell**:"



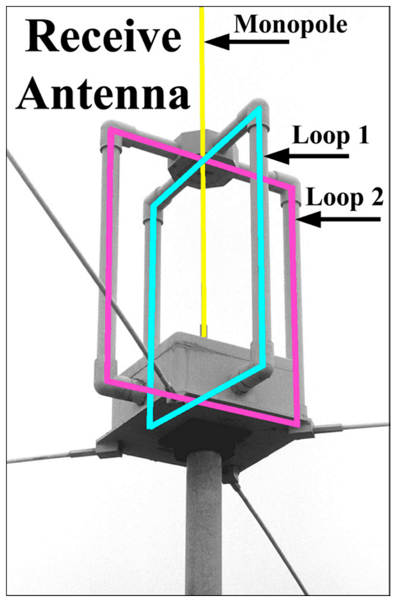
There is usually some **variation** in ocean currents within each range cell. SeaSonde's proprietary software uses a **precise mathematical equation** to calculate an average of **many readings** within each range cell.

The **size** of **range cells** is **proportional** to **sweep frequency**. A sweep frequency of **50 kHz** means a range cell of **3 km** size. A sweep frequency of **150 kHz** means a **1 km** range cell.

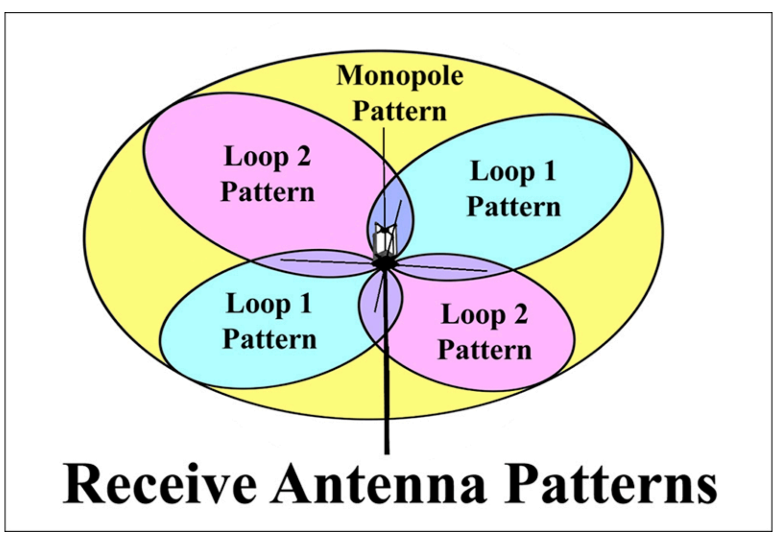
Higher sweep frequency translates into higher **range resolution**.

Section 5: The SeaSonde **Receive Antenna**: **three antennas** combined to find **bearing**.

The Receive Antenna contains **three** antennas in a simple, compact, rugged package:



Each **Loop Antenna** has a pattern consisting of **two ellipses** opposite each other, and the **Monopole** has a **circular** pattern:



SeaSonde calculates target bearing by **comparing signals** from the three Antennas, using techniques developed exclusively by Codar Ocean Sensors[2].

Section 6: How SeaSonde measures **speed**.

How does SeaSonde measure the **speed** of moving targets, such as **ocean waves**?

When a train passes, and **sounds** its horn or whistle, the **pitch** of the whistle seems to **change**, from the **perspective** of someone **standing nearby**:

Someone **riding** on the **train** does not notice this effect. A rider moves at the **same speed** as the train.

This **frequency change** from moving sources, observed from a **fixed perspective**, is known as the "**Doppler"** effect. Change in frequency is **proportional** to the speed of the moving object.

Among other uses, the Doppler effect is used in **astronomy**. By observing the **color shift** in **light emitted** from a distant **star**, its **speed** (relative to earth) can be calculated.

Radar targets move, like the train does. **Reflections** from radar targets contain measurable changes in frequency.

By measuring changes in frequency of reflections over time, SeaSonde calculates the speed of targets.

Section 7: Summary.

[2] B. J. Lipa and D. E. Barrick (1983), *Least-squares methods for the extraction of surface currents from Codar crossed-loop data: Application at ARSLOE*, *IEEE Journal Oceanographic Engineering*, vol. OE-8, pp. 226-253.

Radar sends radio waves to a target, receives reflections from the target, and analyzes the reflections to determine three variables: **distance**, **bearing** and **speed**.

SeaSonde measures **ocean currents** by analyzing **ocean waves**.

SeaSonde's innovative design allows it to be **compact**, **lightweight**, **efficient** and **rugged**, and to **consume little power**, compared to conventional radar.