How Radar Works

Radar is something that is in use all around us, although it is normally invisible. Air traffic control uses radar to track planes both on the ground and in the air, and also to guide planes in for smooth landings. Police use radar to detect the speed of passing motorists. NASA uses radar to map the Earth and other planets, to track satellites and space debris and to help with things like docking and maneuvering. The military uses it to detect the enemy and to guide weapons.

Operation Specialist 2nd Class Gilbert Lundgren operates radar equipment in the combat information center of the USS Carney. Photo courtesy Department of US Defense

Meteorologists use radar to track storms, hurricanes and tornadoes. You even see a form of radar at many grocery stores when the doors open automatically! Obviously, radar is an extremely useful technology.

When people use radar, they are usually trying to accomplish one of three things:

- **Detect the presence of an object at a distance** - Usually the "something" is moving, like an airplane, but radar can also be used to detect stationary objects buried underground. In some cases, radar can identify an object as well; for example, it can identify the type of aircraft it has detected.
- **Detect the speed of an object** - This is the reason why police use radar.
- **Map something** - The space shuttle and orbiting satellites use something called **Synthetic Aperture Radar** to create detailed topographic maps of the surface of planets and moons.

All three of these activities can be accomplished using two things you may be familiar with from everyday life: **echo** and **Doppler shift.** These two concepts are easy to understand in the realm of sound because your ears hear echo and Doppler shift every day. Radar makes use of the same techniques using radio waves.

Understanding Radar

The echo of a sound can be used to determine how far away something is, and the Doppler shift of the echo can be used to determine how fast something is going. It is therefore possible to create a "sound radar," and that is exactly what **sonar** is. Submarines and boats use sonar all the time. You could use the same principles with sound in the air, but sound in the air has a couple of problems:

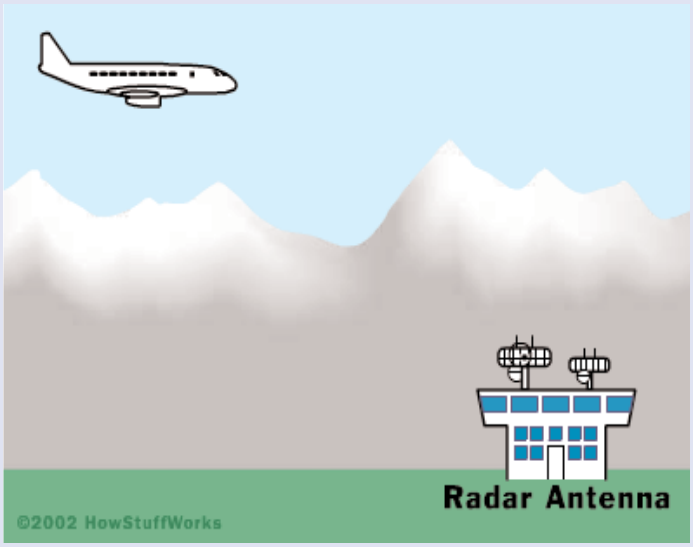
- Sound doesn't travel very far -- maybe a mile at the most.
- Almost everyone can hear sounds, so a "sound radar" would definitely disturb the neighbours (you can eliminate most of this problem by using ultrasound instead of audible sound).
- Because the echo of the sound would be very faint, it is likely that it would be hard to detect.

Radar therefore uses radio waves instead of sound. Radio waves travel far, are invisible to humans and are easy to detect even when they are faint.

Left: Antennas at Goldstone Deep Space Communications Complex (part of NASA's Deep Space Network) help provide radio communications for NASA's interplanetary spacecraft. Right: Surface search radar and air search radar are mounted on the foremast of a guided missile destroyer. Photo courtesy NASA (left), Department of Defense (right)

Let's take a typical radar set designed to detect airplanes in flight. The radar set turns on its transmitter and shoots out a short, high-intensity burst of high-frequency radio waves. The burst might last a microsecond. The radar set then turns off its transmitter, turns on its receiver and listens for an echo. The radar set measures the time it takes for the echo to arrive, as well as the Doppler shift of the echo. Radio waves travel at the speed of light, so if the radar set has a good high-speed clock, it can

measure the distance of the airplane very accurately. Using special signal processing equipment, the radar set can also measure the Doppler shift very accurately and determine the speed of the airplane.



The radar antenna sends out a short, high-power pulse of radio waves at a known frequency. When the waves hit an object, they echo off of it and the speed of the object Doppler-shifts the echo. The same antenna is used to receive the much-weaker signals that return.

In ground-based radar, there's a lot more potential interference than in air-based radar. When a police radar shoots out a pulse, it echoes off of all sorts of objects -- fences, bridges, mountains, buildings. The easiest way to remove all of this sort of clutter is to filter it out by recognizing that it is not Doppler-shifted. A police radar looks only for Doppler-shifted signals, and because the radar beam is tightly focused it hits only one car.
Police are now using a laser technique to measure the speed of cars. This technique is called **lidar**, and it uses light instead of radio waves.

Lidar

The last section, looked at the conventional radar guns police have been using since the 1950s. These days, more and more police departments are using laser speed guns rather than conventional radar. The basic element in a laser speed gun, also called a **lidar gun** (for **light detection and ranging**), is concentrated light.

Two different lidar gun designs.
Photo courtesy K40 Electronics

The lidar gun clocks the time it takes a burst of infrared light to reach a car, bounce off and return back to the starting point. By multiplying this time by the speed of light, the lidar system determines how far away the object is. Unlike traditional police radar, lidar does not measure change in wave frequency. Instead, it sends out many infrared laser bursts in a short period of time to collect multiple distances. By comparing these different distance samples, the system can calculate how fast the car is moving. These guns may take several hundred samples in less than half a second, so they are extremely accurate.

Smile for the Camera!

Police may use handheld lidar systems, just like conventional radar guns, but in many areas, the lidar system is completely automated. The gun shines the laser beam at an angle across the road and registers the speed of any car that passes by (the system makes a mathematical adjustment to account for the angle of view). When a speeding car is detected, the system triggers a small camera, which takes a picture of the car's license plate and the driver's face. Since the automated system has collected all of the evidence the police need, the central office simply issues a ticket and sends it to the speeder in the mail.

This article and more information is available at **http://science.howstuffworks.com/radar.htm**

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