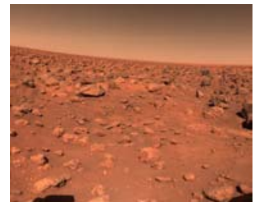


The Doppler Shift

Introduction

We have all experienced how the sound of a police or ambulance siren gets louder as it approaches us and diminishes as it goes away. We also notice that the pitch of the sirens changes as the vehicle passes us. The change in the pitch of the siren is referred to as the Doppler shift and we are familiar with the Doppler shift for sound waves because our ears hear this shift almost daily.

The Doppler shift is observable for light as well as sound and is responsible for the so-called red shift of the spectral lines from objects in space moving away from the solar system. This is the same principle as the Doppler shift for sound waves.

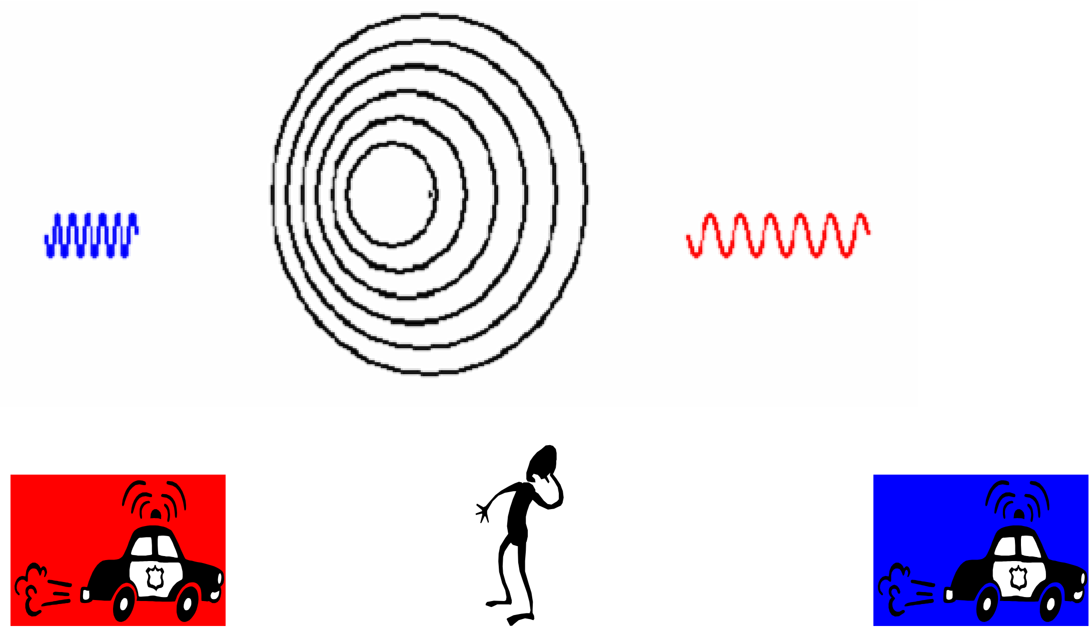
When radar is used, generally three things are being accomplished: the distance of an object can be detected, the speed of an object can be detected, or something can be mapped. Radar can do all three things by using radio waves and taking advantage of the Doppler shift. Radio waves travel far and are easy to detect even though they are faint.

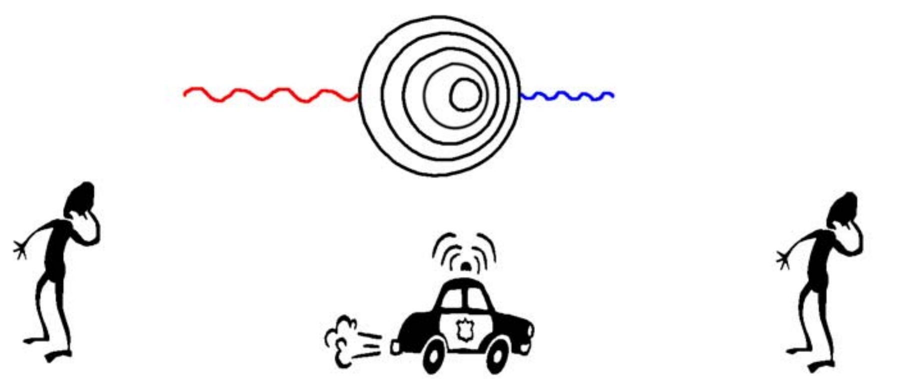
When a moving target is involved in radar, the signal undergoes the Doppler shift. The target becomes the source of the reflected wave. The speed or velocity of the target is measured by applying the Doppler shift. If the target is moving toward the radar unit, the frequency of the returned signal is greater than the frequency of the transmitted signal. If the target is moving away from the radar unit, the returned frequency is less.

Objective: To observe the Doppler shift with sound waves and apply the principle of Doppler shift to light waves.

Procedure

1. Examine the following illustration of a sound wave.





Red shifted **Blue** shifted

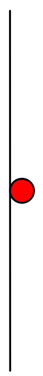
As the police car approaches, the sound waves from its siren are compressed toward the observer. The intervals between the waves become less, which means that the frequency or pitch increases. As the police car passes an observer, the sound waves stretch causing the frequency of the sound wave to decrease.

By analogy, the electromagnetic radiation given off by a moving object will exhibit the Doppler shift. When the radiation given off by an object moving toward an observer is compressed, its frequency appears to increase and shifts toward the blue end of the electromagnetic spectrum. We indicate the object is blueshifted. If the frequency of the object decreases, it shifts to the red end of the spectrum and is redshifted.

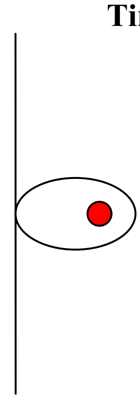
2. The above illustration relates to the Doppler shift for sound. The following explanation is an attempt to help explain the Doppler shift for light.

If a radar transmitter sends a pulse or signal to a target, it returns a target distance and the time is recorded for this return signal. At a different time, a pulse is sent to the same target and returns a target distance. In the interval between the pulses the target has moved, so a new target distance will be recorded. The target's velocity will shift the frequency of the echo signal depending on whether the target is moving toward the radar antenna or away from it. If the target was always moving at the same velocity relative to the radar, it will have a constant Doppler shift, which indicates its speed in the range direction. This last remark is important: the Doppler shift only applies along the line of sight, i.e., motion across the field of view does not cause a Doppler shift.

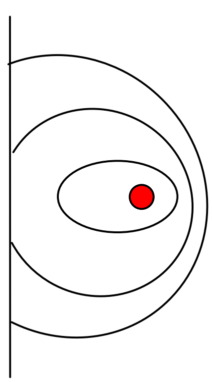
Time 0 Doppler



Time 2 Doppler



Time 4 Doppler



Time 6 Doppler