CHAPTER 2
BASIC PRINCIPLES OF RADAR SPEED MEASUREMENT

FUNDAMENTAL CONCEPT

The word "RADAR" is an abbreviation of the phrase RAdio Detection And Ranging. This acronym implies that all RADARs are capable of finding a target (detection) and calculating its distance (range). The acronym, as defined, does not exactly fit the description of police traffic RADARs. Police traffic RADARs can provide a speed reading on a detected target, but they cannot measure the range to the target.

Actually, the inventors of RADAR did not make a mistake in their acronym. The concept of "ranging" is correct for about 90 percent of the RADARs in use today. It is police traffic RADAR that is in the 10 percent of RADARs that provides no range information.

It is important to recognize that many types of RADARs exist. Some are complex, while others, like the police unit, are simpler. Even though there are many variations and different features among types and families of RADARs, the underlying principle remains the same: Radio-frequency energy is generated by a transmitter; an antenna forms the energy into a beam; and the beam is transmitted into space. When the energy, or signal, strikes an object, a small amount is reflected back to the antenna. From the antenna, it is sent to the receiver, where, if the signal is strong enough, it is detected. This is how the RADAR operator learns that a target is present in the beam.

The way that the energy reflected from the target is processed by the receiver determines what information will be available to the operator. If the RADAR is to compute range to the target, timing circuits in the set will time the round-trip travel period of the signal—starting at the time the signal is transmitted and ending when the receiver detects the reflected signal. Timing circuits are made possible by the fact that radio energy always travels at 186,000 miles per second—the speed of light. The speed of radio energy is therefore, a constant in all computations performed in any RADAR set.

Police traffic RADARs use another characteristic of radio energy to measure speed. A radio signal's frequency waves per second is changed when the signal is reflected from a target that is moving at a speed different from that of the RADAR set. This change or shift in frequency is known as the Doppler shift and will be explained in more detail later.

THE WAVE CONCEPT

To examine how reflected radio signals are changed by relative motion requires an understanding of their wave nature. Everyone is familiar with waves occurring in water: Each water wave consists of a peak and a valley, as shown in the illustration below:

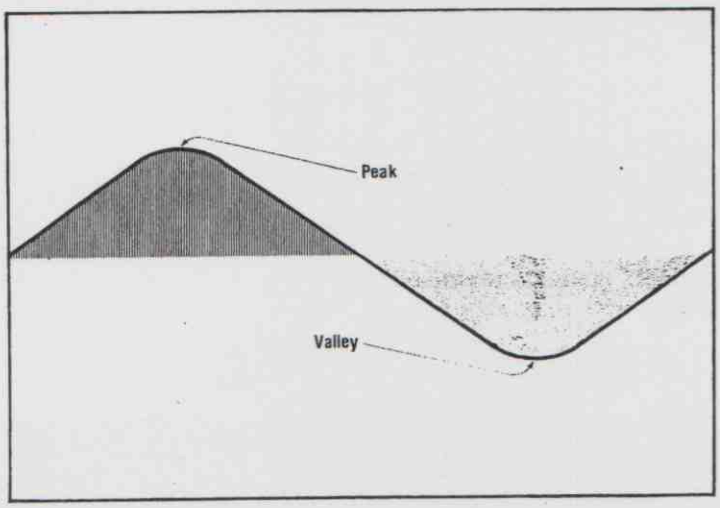

ILLUSTRATION #1

Waves can also be observed on a tightly held string or rope. If one end of the rope is tied to a pole and the other is given a sharp upward snap, a wave will soon travel down the rope toward the pole: a distinct peak followed by a distinct valley. If the rope is snapped steadily, a regular stream of waves—a continuing series of peaks and valleys—will be generated.

Sound, light, and radio energy can each be described as a distinctive form of wave. Each police traffic RADAR device transmits a continuous series of radio waves, which have three characteristics:

- The signal speed—constant. All RADAR signals travel at the speed of light. This is equivalent to 186,000 miles per second, or 30 billion centimeters per second. Both transmitted and received RADAR signals always travel at that speed.

- The wavelength—variable. The distance from the beginning of the peak to the end of the valley of a wave may vary.

- The frequency—variable. The number of waves transmitted in one second of time may vary.

Frequency is usually measured in cycles per second. A cycle is the same as a wave. Scientists and engineers often use the term hertz (abbreviated Hz) instead of cycles per second. All these terms have the same meaning: One hertz equals one cycle per second, which is the same as one wave per second. "Waves per second" will be the terms most often used, since this will help you keep in mind the wave nature of RADAR signals.

Because the speed of radio waves is constant at 186,000 miles per second, wavelength and frequency have an inverse relationship. As the number of radio waves transmitted each second (frequency) increases, the length of the waves (wavelength) must decrease. The reverse is also true. If frequency decreases, wavelength must increase.

Theoretically, if a radio were to transmit only one wave per second, the length of that wave would have to be 186,000 miles. Conversely, a radio transmitting 186,000 waves per second would produce a wavelength of one mile. If is obvious then that any given radio frequency must be associated with a specific wavelength.

Police Traffic RADAR Assigned Frequencies

Police traffic RADAR devices operate in the microwave frequency band; they transmit billions of waves per second. The wavelength involved is therefore very short (hence microwave). Almost all police traffic RADARs operate on one of three Federal Communications Commission (FCC) assigned frequencies.

Police traffic RADAR operates within three assigned microwave frequencies: X, K, and Ka:

- X-band was the initial frequency used. It has a frequency of approximately 10.525 billion waves per second, or 10,525,000,000 gigahertz (giga = billion). This frequency has a wavelength of approximately three centimeters, or about 1-1/5 inch.

- K-band RADAR operates at a frequency of 24,150,000,000 billions waves per second (24.150 gigahertz). Its frequency wavelength is approximately 1-1/4 centimeters, or about half an inch.

- Ka-band RADAR is the newest frequency to be used for police traffic RADAR. It operates in a frequency "range" of 33,400,000,000 to 36,000,000,000 billion waves per second (33.4 - 36.0 gigahertz). Its wavelength is approximately 8.75 millimeters, or about 3/8 inch.

In either case, the frequency times the wavelength always equals the speed of light (186,000 miles per second). This relationship exists for all radio signals and is fundamental to understanding how the Doppler Principle is used to obtain a valid speed measurement.

THE DOPPLER PRINCIPLE

Christian Johann Doppler, an Austrian physicist, is credited with having discovered that relative motion causes a signal's frequency to change. We now honor his memory by referring to this basic scientific fact as the Doppler