POLICE RADAR

A Guide To Basic Understanding

By

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PREFACE

RADAR, and the operators of radar, have come under much criticism and scrutiny during the past few years. The courts, the media, and individual citizens are not content today to blindly accept past practices. In some cases, improperly operated radar units and inadequately trained operators have contributed to the suspect reliability that currently surrounds the use of radar.

As a speed monitoring device, radar can and should be a viable complement to any traffic law enforcement program. It is, however, dependent on two crucial factors. First, the radar unit itself must be manufactured at a level of quality that will be accepted by the court systems throughout the United States. At the time of this writing, The National Bureau of Standards is testing various radar devices to see if they meet criteria set forth by the National Highway Traffic Safety Administration (NHTSA). The end result of this testing program will provide a "qualified product list" that is to be distributed to law enforcement agencies in all fifty states. Any agency purchasing radar equipment with federal funds will have to purchase only those approved by the NHTSA.

Secondly, the officers who operate radar units must be adequately and sufficiently trained. They do not need to be electronics experts, but they do need to be able to articulate to the courts an understanding of radar operation. Also, they need to know the susceptibility of radar to various forms of interference, and how to recognize radar anomalies or spurious readings.

There is no question in my mind that when a quality radar unit is used by a competent and adequately trained operator, it is a reliable speed monitoring device.

As with any written endeavor, it is necessary to acknowledge those individuals who have supported, guided, and encouraged me from beginning to end. I am extremely grateful to Lieutenant David L. Schumacher of the Wisconsin State Patrol for sharing his many years of experience, past training, and overall technical expertise. He has been very understanding in my learning process relating to radar and helpful in assisting me in any way that he could. For that, I am in his debt.

I must also thank the three most important persons in my life – my wife, Cathy, and my children, Christopher and Sarah. Their support and understanding throughout our lives together has been immeasurable. For them, I can only thank God and count my blessings.

R.E.N.

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POLICE RADAR

Chapter 1

HISTORY OF RADAR

"RADAR," the acronym for Radio Detecting and Ranging, first came into prominence during World War II. In its early application a pulse-type of radar was used to measure the distance and direction of enemy ships and aircraft. Pulse-type radar is identified as such because the radio waves are sent out intermittently. The distance between two objects is determined by how long it takes the waves to go out, reflect off a target, and return to the source. To calculate direction using the pulse-type radar, the angle at which the waves were transmitted is compared to the angle at which they are received on return.

Because of early military use, radar and its application was cloaked in a shroud of secrecy. It wasn't until the end of World War II that the security restrictions on radar were lifted, and its usefulness applied to fields outside the military parameters.

In 1948, radar was first introduced to traffic management, with its primary purpose to aid in the study of traffic patterns and to help set speed limits. The early radar units were quite heavy and cumbersome. Some of them weighed as much as seventy pounds and, were extremely time consuming to set up in order to begin initial operation. With the introduction of space-age technology in the 1950s and 1960s, radar became more streamlined and refined. Today, radar units are highly sophisticated and may be operational within a matter of minutes.

All modern radar units operate on the same principle — the "Doppler effect." In 1842, Christian Johann Doppler, an Austrian physicist, discovered that there was a change in the frequency of pitch of sound waves between a transmitter and receiver as the distance between the two increased or decreased. This scientific principle applies not only to sound waves but also to radio waves, light waves, or any others.

A Doppler radar unit will send out or transmit radio waves at a rate of more than ten billion per second. This beam characteristic differs from the earlier pulse type in that it is a constant beam and measures only speed or relative motion. When the transmitted beam strikes a stationary object such as a brick wall, the waves are returned to the radar unit at the same frequency. However, if the sound waves strike a moving object such as a vehicle in motion, the waves will be reflected back to the radar unit at a frequency quite different. This frequency will be higher if the object is traveling toward the radar unit and lower if the object is traveling away from it. The receiver in the antenna then picks up this reflected signal and sends it to a computer in the counting unit which translates the changes or shifts in frequency to miles per hour.

In 1972, a new dimension to vehicle speed measurement was introduced: moving radar. Previously, radar units had to be in a stationary position in order to measure vehicle speed readings. With the advent of moving radar, operators could now monitor traffic in a moving patrol cruiser and greatly increase their area of speed detection.

A year later in 1973, America was faced with an oil embargo, which was to have far-reaching effects on traffic law enforcement. This nation was expending nearly 40 percent of its total energy consumption on transportation. The majority of the use was attributed to the automobile, and something had to be done.

In 1974, the federal government established a mandatory 55 miles per hour speed limit to aid in the conservation of energy, especially oil. Coupled with a lower speed limit was a stronger emphasis placed on strict traffic law enforcement. The states were now faced with increased compliance of the speed limit or the potential loss of federal aid. The choices were few.

Because of the pressures for compliance with the lower speed limit, the federal government made available millions of dollars to the states for the purchase of speed detection equipment, most of which was radar.

In a 1979 Florida court case, *State v. Aquilera,* radar received its most severe setback to date. In this much-publicized decision, eighty radar cases were dismissed because of certain anomalies associated with radar and the lack of proper operator training.

Today, the National Bureau of Standards (NBS) is in the process of evaluating the radar units presently in use to enable the National Highway Traffic Safety Administration (NHTSA) to establish a "qualified product list." Such a list will hopefully force some radar manufacturers to improve their finished product and provide law enforcement agencies with better quality speed measurement devices.

The NHTSA is also expected to establish a program for radar operator training, including manuals and audiovisual aids to be distributed in 1981.

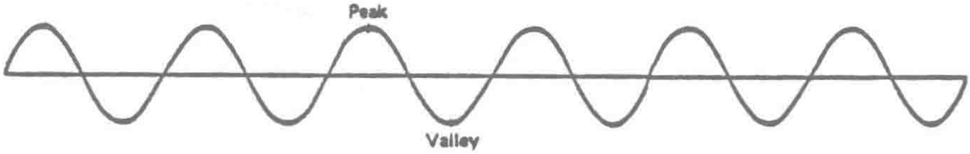
Chapter 2

BASIC PRINCIPLES OF RADAR

IN this chapter the basic operating principles associated with vehicle speed measurement devices will be presented. Comprehensive training in the fundamental concepts is necessary for the radar operator to be competent and effective.

Wavelength, Frequency, and Speed

In order to understand the radar unit, it is important to know that radio waves are transmitted in a constant beam of continuous peaks and valleys.



Radar waves have three properties in common: length, frequency, and speed. The wavelength of most radar signals is one-third inch to approximately one inch. The waves are measured from the peak of one wave to the peak of the wave immediately preceding or following it.

Frequency may be defined as the number of waves leaving a transmitter in one second. Common radar frequencies are measured in Gigahertz (GHz), or one billion waves per second; a frequency region called microwave. An X-band radar unit will transmit a signal of 10.525 GHz (10,525,000,000 waves per second), while a K-band radar unit will transmit a signal of 24.150 GHz (24,150,000,000 waves per second). It should be mentioned that most radar units in use today operate on the X-band or K-band frequency.

As shown, the length and frequency are variable in that as the wavelengths get shorter the frequency increases and as the wavelengths get longer the frequency decreases.

Meanwhile, the speed of radio waves is equal to the wavelength times the frequency and is always constant at 186,000 miles per second, or the speed of light.

Microwave Energy

Radar waves as microwave energy travel in a straight line or line of sight and behave much like a beam of light. Radar speed measurement devices have the capability to send or convey this energy from one place or thing to another. As this energy force is transmitted out it may be:

- *Reflected,* or cast back from a solid surface. A radar signal may be reflected from solid objects made of metal, concrete, or wood.
- *Absorbed,* or taken in without refraction. Grass, leaves, and other certain fibrous materials are capable of absorbing microwave signals.
- *Refracted,* or bent in passing through an object. Refraction can result when a radar beam is transmitted through a transparent material such as glass or plastic.

Doppler Effect

Modern vehicle speed measurement devices operate on the scientific principle called the *Doppler effect.* Transmitted wave motions that strike a moving object will undergo a change in frequency. If the object moves toward the signal, the returned frequency of the waves will be increased. If the object moves away from the signal, the returned frequency of the waves will be decreased.

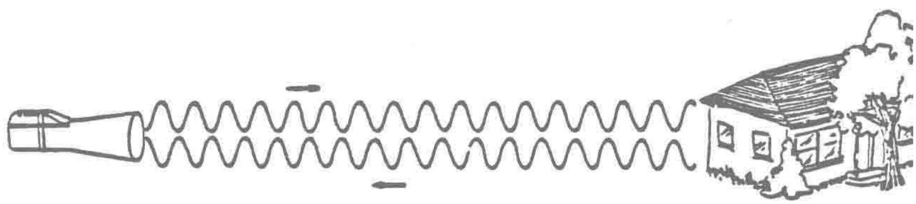
Doppler Shift

The change that occurs when a signal of known frequency strikes a moving object is called the *Doppler shift*. Such a shift happens either when an object moves toward or away from the transmitter.

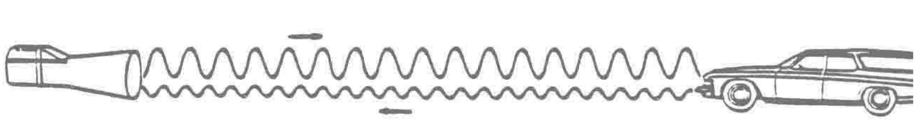
"Up" Doppler shift occurs when a signal strikes an object moving toward the transmitter. The signal becomes compressed and is reflected back to the radar antenna at a higher frequency.

On the other hand, "down" Doppler shift results when a signal strikes an object moving away from the transmitter. The reflected portion of the signal is expanded and returns to the radar antenna at a lower frequency.

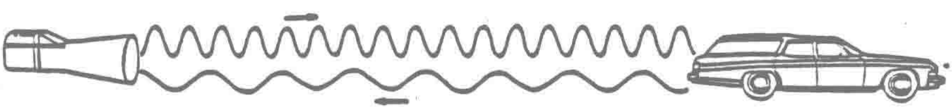
1. Here, the transmitted signal is sent out and returned at the same frequency since there is no relative motion present.



2. "Up" Doppler — The transmitted signal is compressed and returned at a higher frequency.



3. "Down" Doppler — The transmitted signal is expanded and returned at a lower frequency.

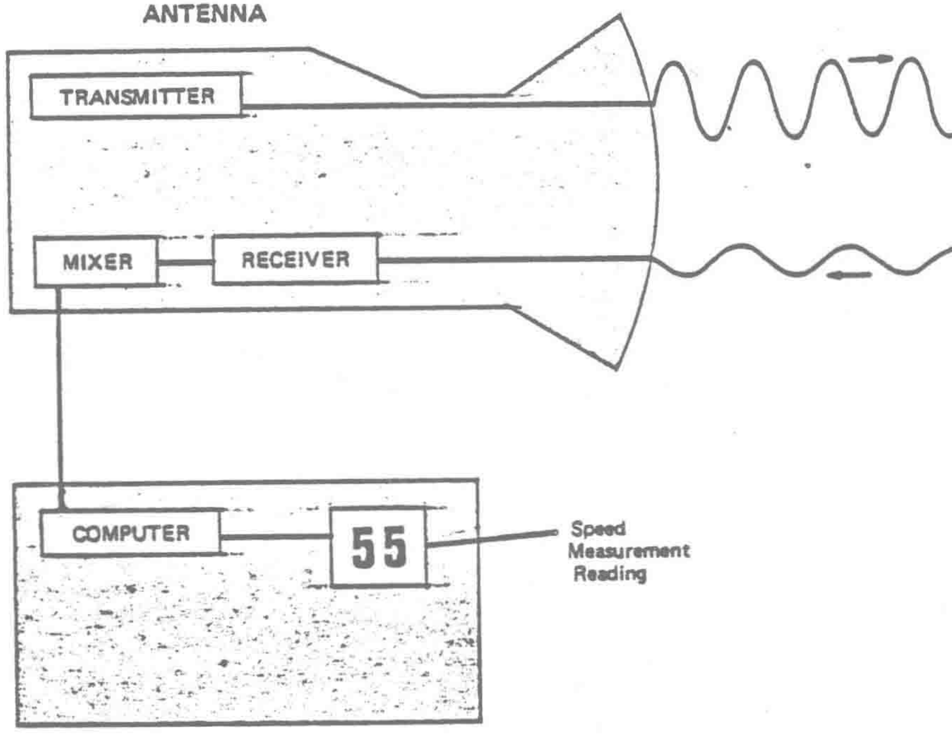


The amount of shift required for the radar unit to display a vehicle speed measurement varies between the X-band and K-band frequencies. As shown in the following chart, in order for the radar to respond to a 1 MPH speed measurement for X-band, a 31.4 difference in waves per second is necessary; whereas a 72.0 waves per second difference is required for K-band.

Vehicle Speed Measurement	*X-band Doppler shift (waves per second)*	*K-band Doppler shift (waves per second)*
1 MPH	31.4	72
5 MPH	157.0	360
10 MPH	314.0	720
20 MPH	628.0	1440
30 MPH	942.0	2160
40 MPH	1256.0	2880
50 MPH	1570.0	3600
55 MPH	1727.0	3960

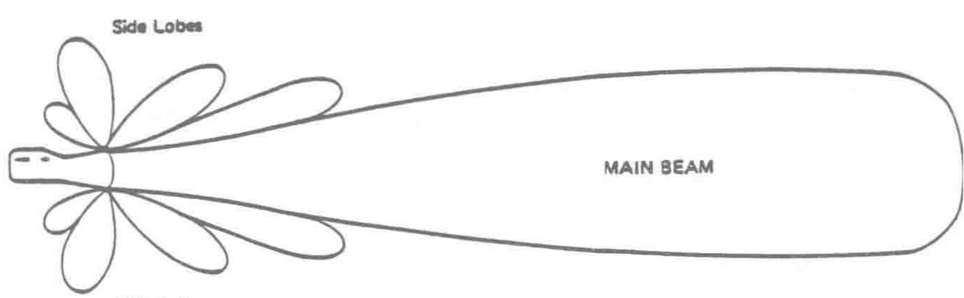
A radar unit will only register a speed measurement when there is a change or shift in the frequency between the transmitted and reflected signal due to the relative motion of an object. Typical two-piece radar units operate in the following manner.

A signal is emitted from the transmitter located in the antenna and leaves at a known frequency. When part of this signal is reflected back to the antenna, it collects in the receiver and in turn is channeled to the mixer. At this point a comparison of the transmitted and returned signal frequencies is made. Any difference caused by relative motion represents Doppler shift and is computed by the counting unit into a speed measurement reading.



Radar Beam

The course or path followed by energy emanated from a radar antenna is known as the *beam*. The radar beam concentrates most of its energy in an elongated or somewhat cigar-shaped central core. Although 80-85 percent of the unit's power is found in the central core, there is an inconsequential portion of the energy that escapes and forms side lobes. For the most part, these small areas are insignificant in power and are attributed to the design of the radar antenna. A radar beam may vary from 11 degrees to over 20 degrees in width and approx-



imately 2500—4000 feet in length depending on the particular radar unit.

Strength

Speed measurement devices such as radar will respond to and display the strongest reflected signal. The strength of the returned signal is determined not only by the size and shape of the moving target but also by the target's distance from the radar antenna. For example, a large truck will reflect a strong signal even though it might be considerable distance from the radar unit. Meanwhile, an object such as a motorcycle might be closer to the antenna and in the main beam, yet reflect a weak signal because of its smaller surface and amount of metal.

In order for radar operators to be able to make positive target vehicle identification they must be aware of the circular polarized fashion of the beam and the width of the transmitted signal. To show what happens to a signal at varying distances from the transmitter, let's use a common 12 degree beam width.

The *signal face width* of a 12 degree beam at 100 feet, 500 feet, 1000 feet, and 1500 feet would be computed using the following formula: $x = 2D (\tan < ½)$. Using this formula,