



# *Speed-Measuring Device Operator Training*

*Participant Manual*

**R. A. D. A. R.**



## **R.A.D.A.R. COURSE OVERVIEW**

This course is designed to prepare students to operate a R.A.D.A.R. speed-measuring device.

- Learning Objectives
  - Describe the origin of R.A.D.A.R. technology as related to speed measuring
  - Explain the Doppler Principle
  - Explain the scientific principles of R.A.D.A.R. technology as related to speed measuring
  - Discuss modes of R.A.D.A.R. operation
  - List the elements of tracking history for each mode of operation
  - Discuss R.A.D.A.R. effects
  - Identify the components and features of the specific R.A.D.A.R. device(s) used
  - Set up R.A.D.A.R.
  - Perform function tests
  - Discuss legal considerations pertaining to R.A.D.A.R.
  - Discuss the requirements needed for citation documentation and/or courtroom testimony
  - Operate a R.A.D.A.R. speed-measuring device
- Section Review
- Optional Written Pretest
- Written Posttest
- Practical/Proficiency Testing
- Course Evaluation

## **Materials**

- Presentation slides
- Flipchart
- Markers
- Tape
- Copy of agenda/schedule

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# INTRODUCTION/HISTORY

Estimated time for Chapter 1: 15 Minutes

**R. A. D. A. R.**

## » Objectives

By the end of this chapter, you will be able to:

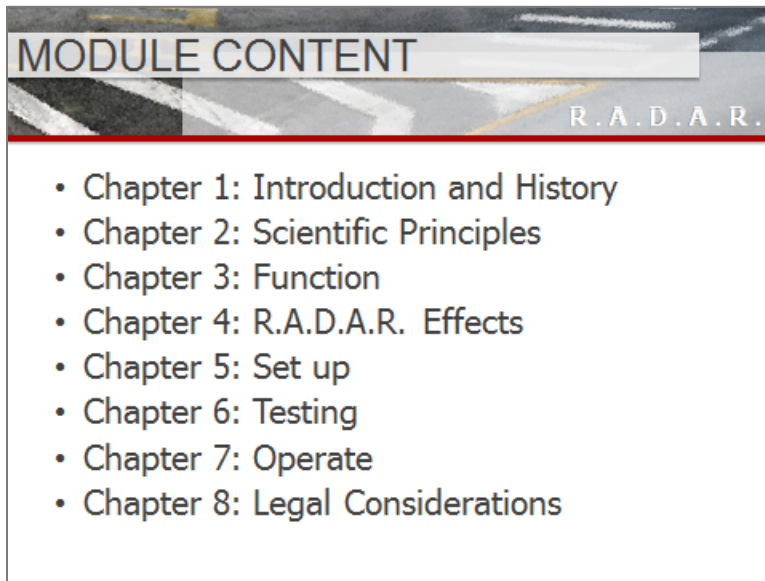
- Describe the origin of R.A.D.A.R. technology as related to speed measuring

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## MODULE OVERVIEW



Slide 2.

The Speed-Measuring Device Operator Training course is designed to improve speed enforcement programs and enable agencies to better allocate their resources. The R.A.D.A.R. module is specifically designed to provide operators the knowledge and skills necessary to properly operate R.A.D.A.R. speed-measuring devices.

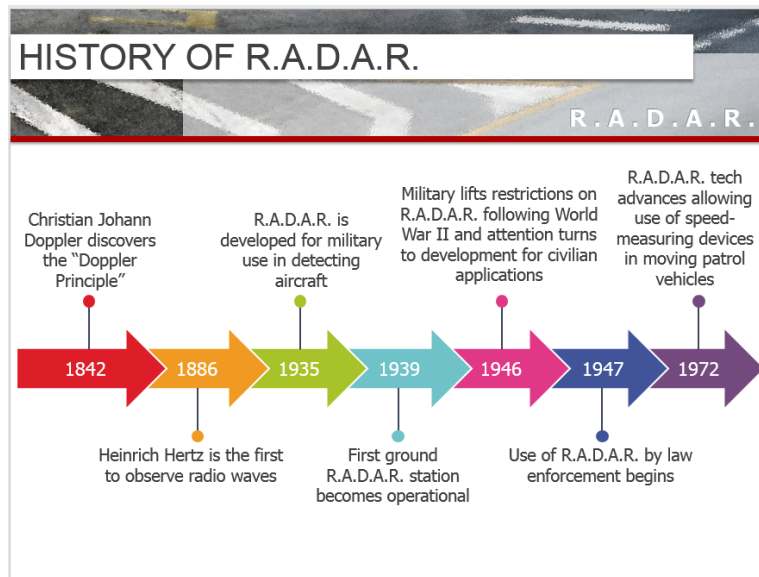
Students must understand how a R.A.D.A.R. device works and identify components, features, and functions before they can effectively operate the device.

R.A.D.A.R., like any other law enforcement tool, must be used in compliance with laws, court's decisions, and department policy. Students must know the elements of the speeding offense before enforcement action can be taken. The officer's responsibility does not end with issuing a speeding citation; the charge must stand up in court. Officers must be prepared to present evidence and testimony in court.





## HISTORY OF R.A.D.A.R.



Slide 4.

In 1842, Christian Johann Doppler, an Austrian physicist, discovered that relative motion causes a signal's observed frequency to change by studying soundwaves. It was later determined that this principle applies to all kinds of waves, including light and radio waves. We now refer to this scientific fact as the "Doppler Principle."

Physicist Heinrich Hertz first observed radio waves in 1886 while conducting experiments verifying theoretical predictions made 20 years earlier by James Clerk Maxwell.

R.A.D.A.R. was first used for measuring distance. In 1935, R.A.D.A.R. was developed for use by the military in detecting approaching aircraft and in determining its position. The first ground R.A.D.A.R. stations became operational in 1939. The military lifted security restrictions for R.A.D.A.R. following World War II. In 1946, military research in R.A.D.A.R. declined and attention turned to the development of civilian applications like radio astronomy and weather R.A.D.A.R.

In 1947, law enforcement began using R.A.D.A.R. for measuring the speed of vehicles. In 1972, R.A.D.A.R. technology was advanced which allowed for speed-measuring devices to be used in moving patrol vehicles.

# SCIENTIFIC PRINCIPLES

Estimated time for Chapter 2: 60 Minutes

**R. A. D. A. R.**

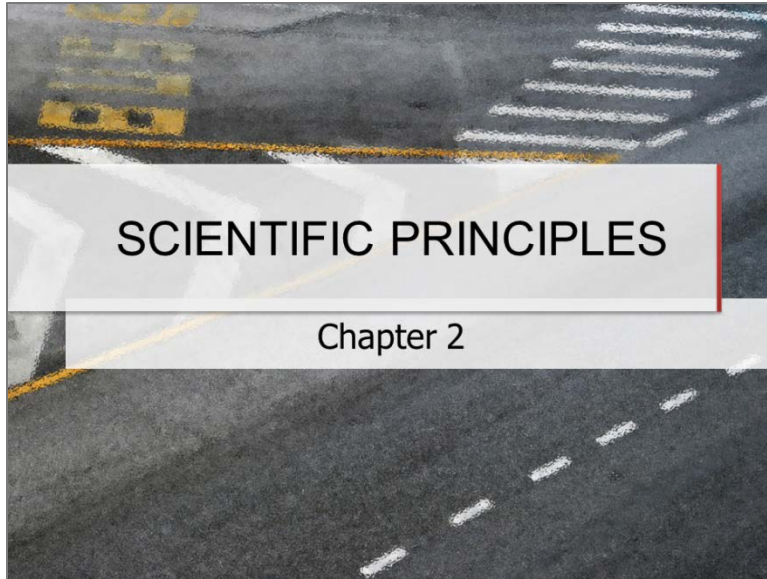
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»» Objectives

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By the end of this chapter,  
you will be able to:

- Explain the scientific principles of R.A.D.A.R. technology as related to speed measuring



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Slide 5.

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Even though there are many variations and features between types and models of R.A.D.A.R., the scientific principles remain the same: radio-frequency energy is generated by a transmitter, the antenna forms the energy into a beam, and the energy is propagated into space. When the energy 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 recognized or “detected.” This indicates that a target is present in the beam. The way in which the energy is reflected from the target is processed by the receiver, which determines what type of information will be available to the operator.

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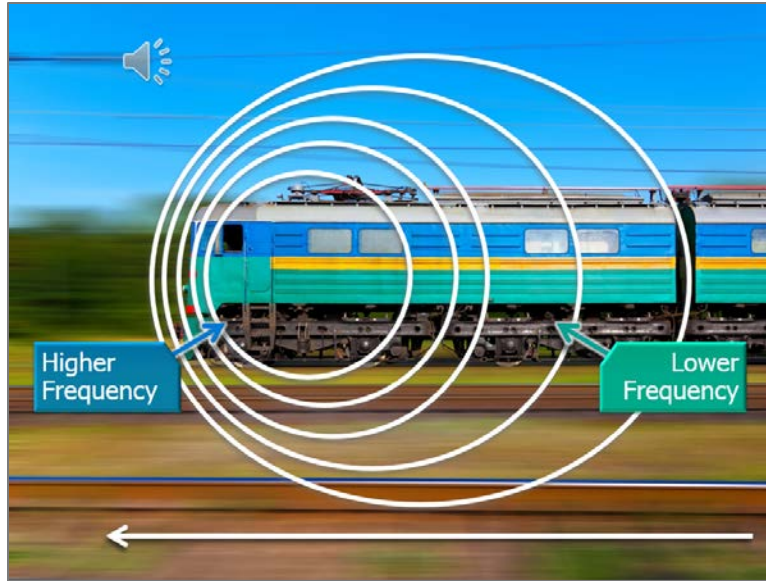
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Slide 7.

Most know how the Doppler Principle affects sound waves. By standing near a railroad track, the sound of an approaching train has a higher pitch than after the train has passed. The frequency of the train's sound is changed due to relative motion; as the train approached, you heard a higher frequency sound, as soon as the train started to move away, the sound changed to a lower frequency.

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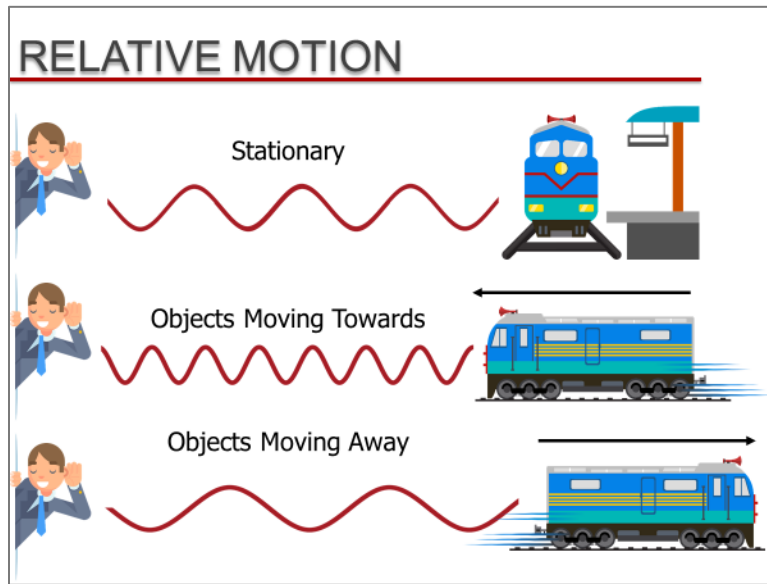
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## RELATIVE MOTION



Slide 8.

R.A.D.A.R. devices use specific characteristics of radio energy to measure speed.

When the Doppler principle is applied to R.A.D.A.R., if there is relative motion (toward or away) between a R.A.D.A.R. and an object, the frequency of the reflected signal will be different from the frequency of the transmitted signal. This change, or shift, in frequency is known as the "Doppler shift." The greater the relative speed, the greater the frequency shift.

If the relative motion is bringing the object and the R.A.D.A.R. together, the reflected signal will have a higher frequency than the transmitted signal.

If the relative motion is moving the object and the R.A.D.A.R. apart, the reflected signal will have a lower frequency than the transmitted signal.

By measuring the amount of the frequency shift, the R.A.D.A.R. can calculate and display the target speed in miles per hour.

The point to remember about the Doppler Principle is that the frequency change only occurs when there is relative motion between the R.A.D.A.R. and the object. Relative motion will occur only when the object and the R.A.D.A.R. are not moving in the same direction, at the same speed.

**RELATIVE MOTION**

R . A . D . A . R .

- R.A.D.A.R.s can determine
  - ✓ Target presence
  - ✓ Direction
  - ✓ Speed
  - ✓ Range

Police traffic R.A.D.A.R. devices compute speed from **RELATIVE MOTION ONLY**

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Slide 9.

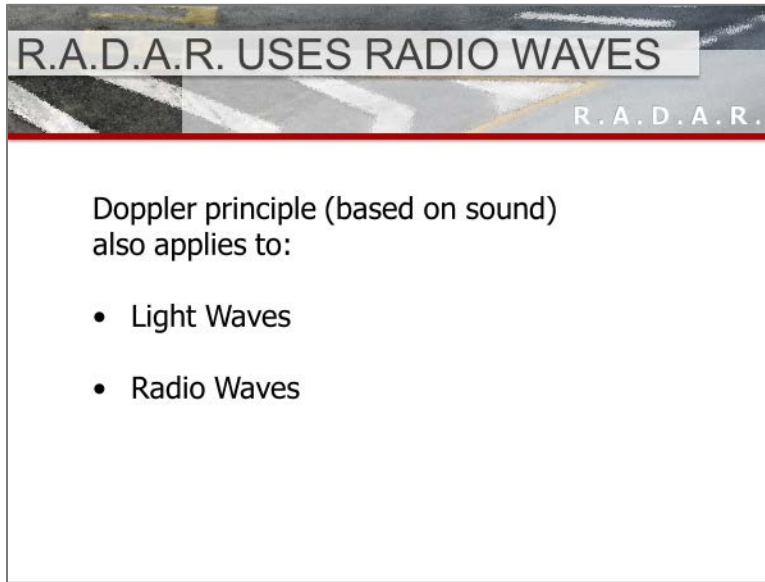
Three types of Relative Motion:

1. R.A.D.A.R. stands still and the object moves
2. R.A.D.A.R. moves and the object stands still
3. Both the R.A.D.A.R. and the object are moving, if they both move at different speeds, or in different directions, so that the distance between them is changing

When the Doppler Principle is applied, R.A.D.A.R. compares the transmitted and reflected frequencies to determine the speed of the relative motion. The R.A.D.A.R. cannot determine whether the object is moving, if the R.A.D.A.R. is moving, or if they are both moving. The R.A.D.A.R. determines how fast they are moving relative to each other.

It is not necessary to understand how or why the Doppler Principle works to become a competent R.A.D.A.R. operator. However, operators should be aware that there is valid scientific basis for R.A.D.A.R. speed measurement.

## RADIO WAVES



R.A.D.A.R. USES RADIO WAVES

R . A . D . A . R .

Doppler principle (based on sound)  
also applies to:

- Light Waves
- Radio Waves

Slide 10.

Radio waves are produced when rapid reversals of current in a conductor create coherent electromagnetic energy of a measurable wavelength and frequency.

Radio waves spread out from the transmitter in a predictable manner at the speed of light. Given the time and location of transmission, frequency, wavelength, and speed of propagation, we can easily obtain useful information by calculating the difference between the original transmission and its reflection.

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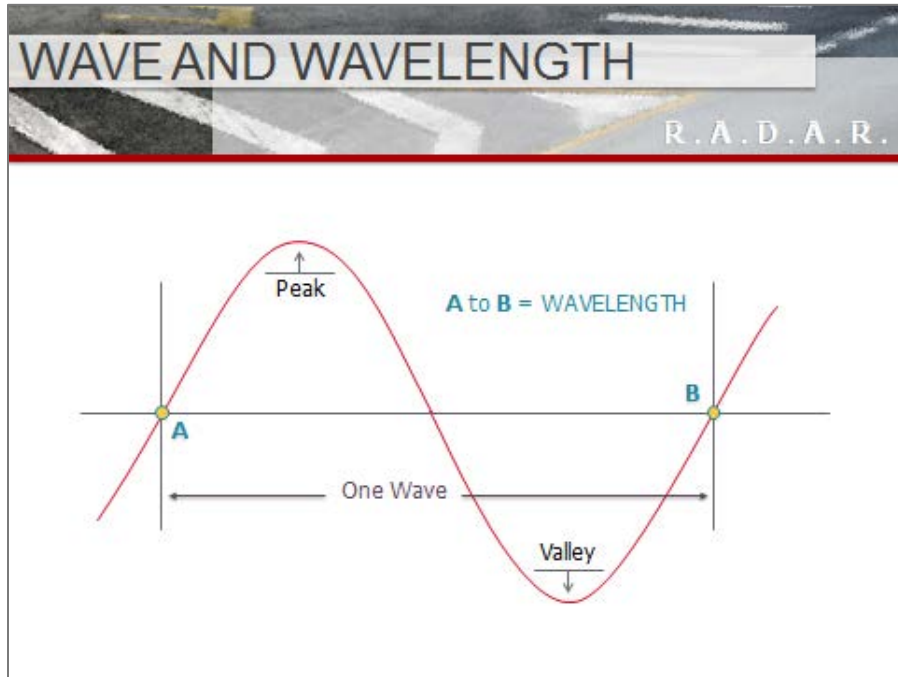
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# WAVELENGTH AND FREQUENCY



Slide 11.

## The Wave Concept of Radio Signals

To understand how R.A.D.A.R. measures speed we must understand how radio signals can be changed. Radio signals are made of waves. Even though we cannot see radio waves, we can see other kinds of waves, e.g., waves on water. Each wave is made of a series of peaks and valleys.

Every radio signal has its own characteristic wave. If the signal is changed, then the wave is changed.

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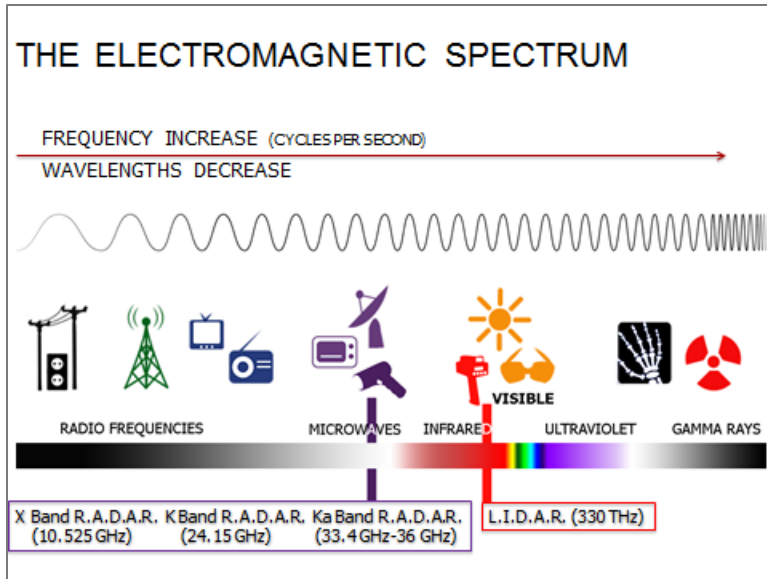
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Slide 13.



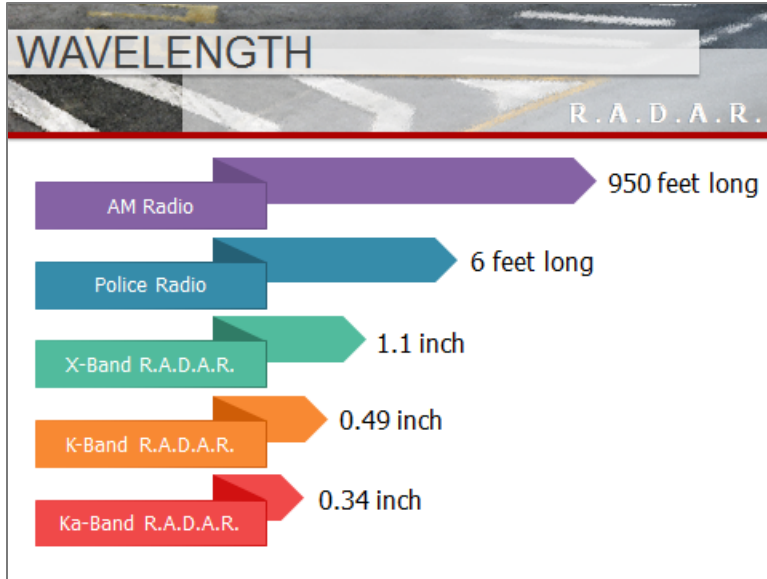
## SUPPLEMENT 1: Frequency Formula

### R.A.D.A.R. Speed-Measuring Devices Assigned Frequencies

R.A.D.A.R. speed-measuring devices transmit in the microwave frequency band, which means billions of waves per second (gigahertz). Compared to other types of radio transmissions, the wavelength of these signals is very short.

The Federal Communications Commission (FCC) has assigned the following R.A.D.A.R. frequency bands:

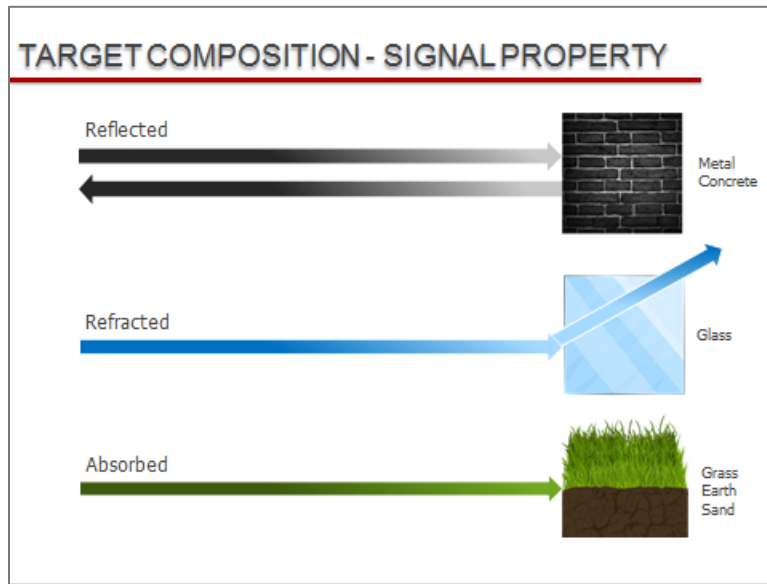
1. The **X-band R.A.D.A.R.** frequency is 10,525,000,000 waves per second (10.525 gigahertz).
2. The **K-band R.A.D.A.R.** frequency is 24,150,000,000 waves per second (24.15 gigahertz).
3. The **Ka-band R.A.D.A.R.** frequency ranges between 33.4 and 36 gigahertz.



Slide 14.

1. The **X-band R.A.D.A.R.** wavelength is about 1.1 inches (2.79 centimeters).
2. The **K-band R.A.D.A.R.** wavelength is about .49 inch (1.24 centimeters).
3. The **Ka-band R.A.D.A.R.** wavelength is between .35 inches and .33 inches (between .88 and .83 centimeters) respectively.

## THE R.A.D.A.R. BEAM



Slide 15.

### R.A.D.A.R. Beam Characteristics

The distance the transmitted beam travels is infinite unless it is reflected, absorbed, or refracted by an object. To various degrees, waves striking a surface are always reflected and refracted by the surface and absorbed by the medium beneath the surface.

#### ***Reflected***

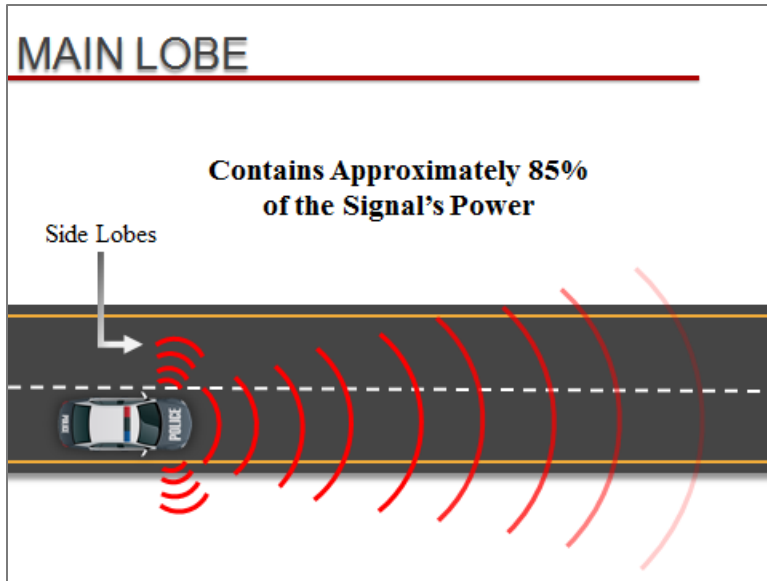
The beam is reflected from a solid, nontransparent material. Typical objects that reflect the beam are made of metal, concrete, or stone.

#### ***Refracted (glass, plastic)***

The beam is refracted because it passes through a material that is transparent to the R.A.D.A.R. beam. The term refraction refers to the change of direction of radio waves passing through some substances. Almost all forms of glass and plastic will refract the R.A.D.A.R. beam. (An example of refraction becomes evident when a straight object placed partway into water appears to be bent.)

#### ***Absorbed***

The beam is absorbed into the material. The beam is largely absorbed by grass, dirt, and leaves, with little energy being reflected to the antenna.



Slide 16.

The radio wave energy is transmitted by the antenna on the R.A.D.A.R. device and is concentrated into a cone-shaped "beam" that resembles a flashlight's beam. Most of the transmitted energy remains near the central core of the beam. The amount of energy decreases rapidly as the distance from the device increases. This energy is measured at points on a line at right angles to the main axis of the R.A.D.A.R. beam.

The portion of the R.A.D.A.R. energy close to the antenna is called the side lobes. The energy level in the side lobe is weak and normally does not affect R.A.D.A.R. operation.

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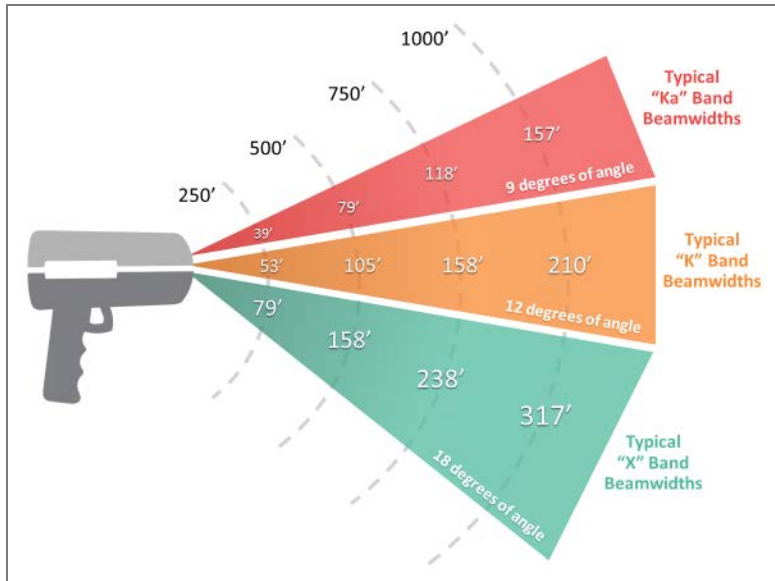
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Slide 17.

## R.A.D.A.R. BEAM WIDTH



### SUPPLEMENT 2: Beam Width Worksheet (15 Minutes)

Beam width will vary with each device model. The angle of the emitted R.A.D.A.R. beam will determine the relative beam width. This angle may vary from 9 degrees to 18 degrees depending on the manufacturer.

For example, a beam emitted at an 18-degree angle will be approximately 80 feet wide at 250 feet from the source; 160 feet wide at 500 feet from the source; and 320 feet wide at 1,000 feet from the source.

Even with a device that emits a beam with a relatively narrow angle of 9 degrees, the beam width would be approximately 40 feet at 250 feet from the source; approximately 80 feet wide at 500 feet from the source; and around 160 feet wide at 1,000 feet from the source.





# FUNCTION

Estimated time for Chapter 3: 60 Minutes

## R. A. D. A. R.

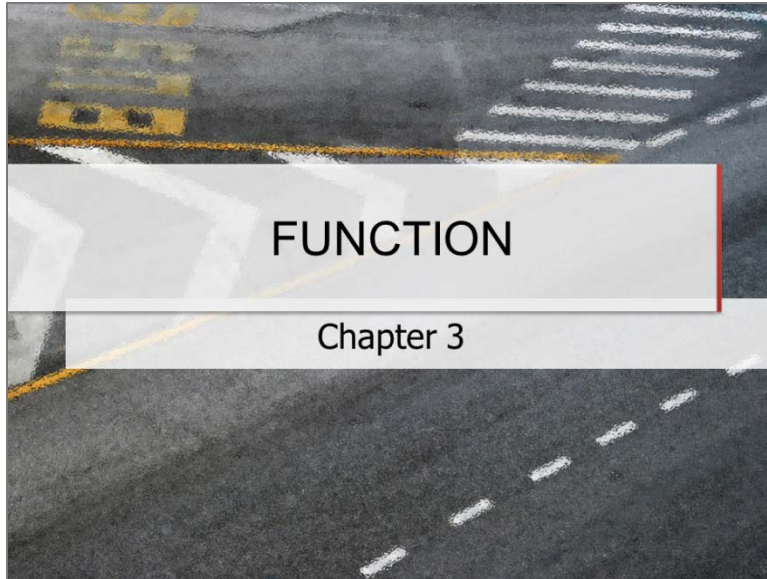
### Objectives

By the end of this chapter, you will be able to:

- Identify the components and features of the specific R.A.D.A.R. device(s) used
- Discuss methods of R.A.D.A.R. speed measurement
- List the elements of tracking history

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Slide 18.

### **Method of R.A.D.A.R. Speed Measurement**

R.A.D.A.R. devices transmit radio signals. When radio signals strike an object, some of the signal is reflected toward the R.A.D.A.R.

If there is relative motion between the R.A.D.A.R. and the reflecting object, the reflected signal will be different from the transmitted signal:

- The motion changes the frequency of the reflected signal
- The faster this motion, the more the frequency changes
- The R.A.D.A.R. device measures how much the frequency of the reflected signal has changed
- The amount of change indicates the speed of the relative motion

# DEVICES AND MODES OF OPERATION

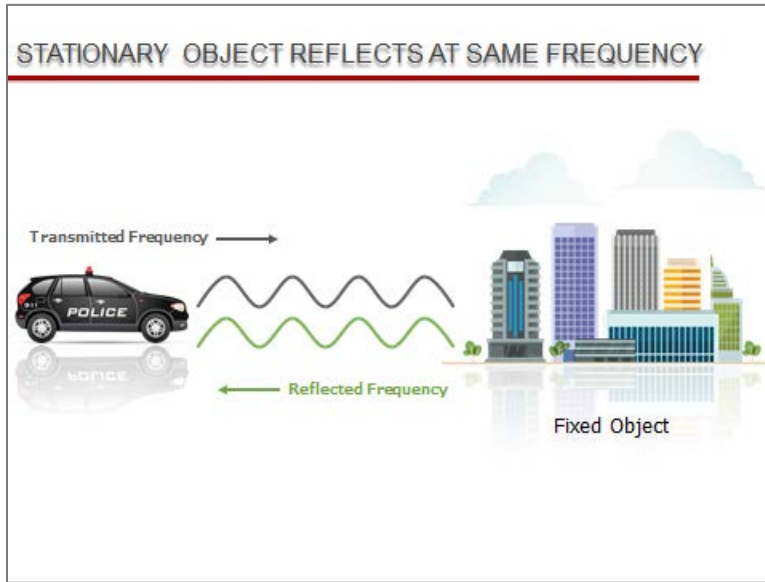
DEVICES & MODES OF OPERATION

R.A.D.A.R.

- Stationary
- Moving Opposite
- Moving Same

Slide 19.

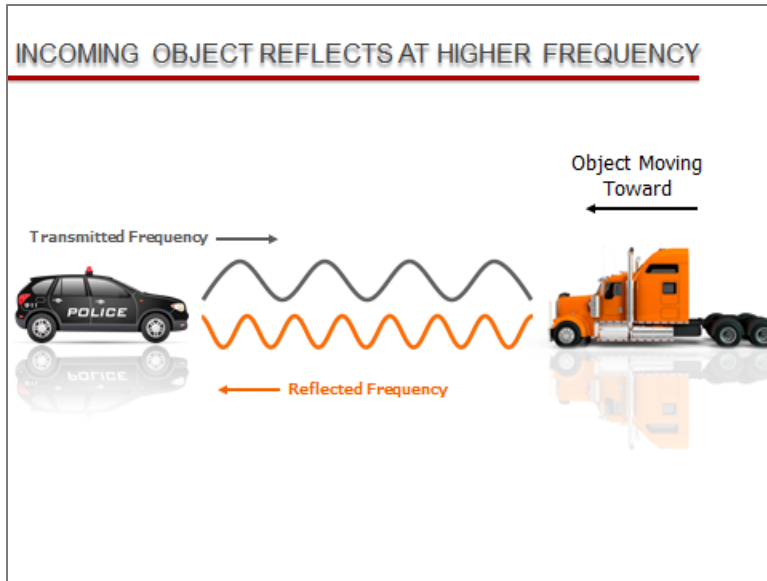
## STATIONARY R.A.D.A.R.



Slide 20.

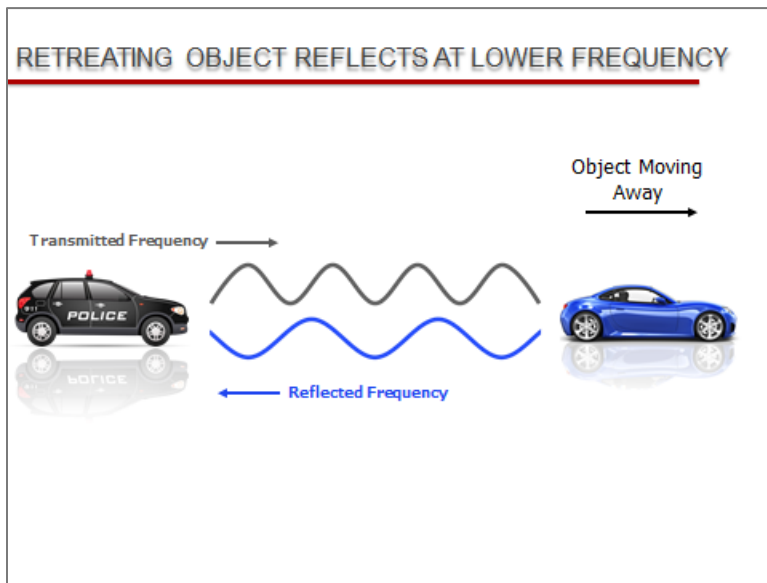
We illustrated the Doppler Principle in Chapter 2 with a moving train (transmission source) and a stationary detector (human listener). Stationary R.A.D.A.R. involves transmitting a signal from a fixed position. Some of the transmitted signal is reflected from a moving object and returned to the R.A.D.A.R.

- A R.A.D.A.R. beam transmitted into empty space will go on forever and obtain no reading
- A R.A.D.A.R. beam transmitted down a roadway on which no objects are moving will also obtain no reading



Slide 21.

If the target is moving toward the R.A.D.A.R. device, the frequency is increased.



Slide 22.

If the target is moving away from the R.A.D.A.R. device, the frequency is decreased.

Vehicle Speed M.P.H.	Frequency Shift (waves per second)		
	"X" Band	"K" Band	"Ka" Band
1	31.4	72	99.6-107.3
5	157	360	498-536.5
10	314	720	996-1073
15	471	1080	1494-1609.5
25	785	1800	2490-2682.5
40	1256	2880	3984-4292
55	1727	3960	5478-5901.5
70	2198	5040	6972-7511
80	2512	5760	7968-8584
100	3140	7200	9960-10730

Slide 23.



### **SUPPLEMENT 3: Doppler Shift Worksheet (15 Minutes)**

The stationary R.A.D.A.R. utilizes the difference between the transmitted and received frequencies multiplied by a constant to calculate target speed.

In the case of X-band, the constant for 1 mile per hour is 31.4 cycles per second.

In the case of K-band, the constant for 1 mile per hour is 72 cycles per second.

In the case of Ka-band, the constant for 1 mile per hour ranges from 99.6 to 107.3 cycles per second.

These frequency changes are measurable by the R.A.D.A.R. device.

Doppler R.A.D.A.R. can only measure the motion of the target vehicle relative to that of the R.A.D.A.R.

- Doppler R.A.D.A.R. cannot indicate which is moving: the target, the R.A.D.A.R. device, or both
- All that is determined is how fast the target and R.A.D.A.R. device are moving relative to each other

A stationary R.A.D.A.R. signal striking a motionless target will return a reflected signal at the same frequency that is being transmitted.

## R.A.D.A.R. "DECISION MAKING"



Slide 24.

The R.A.D.A.R. beam can be several hundred feet wide in its operational range. The R.A.D.A.R. may receive signals from all vehicles within the beam. The speed displayed on the R.A.D.A.R. is normally the strongest signal received.

R.A.D.A.R. "decision making" is affected by three factors:

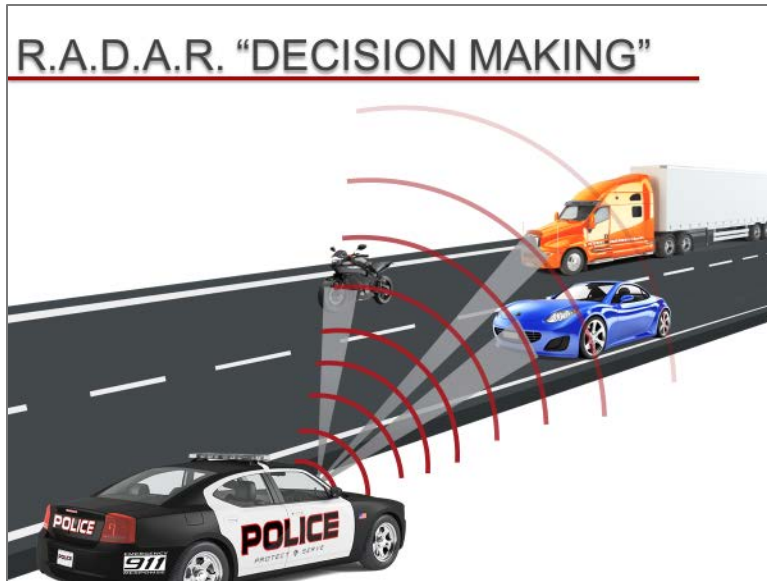
1. Reflective capability

- Depends on the vehicle's size and shape
  - A large truck will reflect a stronger signal than a passenger vehicle when both are the same distance from the R.A.D.A.R. device
  - The shape and composition of the target vehicle will also affect the signal reflected (e.g., fiberglass does not reflect as well as metal)

2. Position

3. Speed





Slide 25.

Position of the target vehicles relative to each other and the R.A.D.A.R. device affects the reflected signal strength. Normally, the target vehicle that is closest to the R.A.D.A.R. antenna will have the stronger reflected signal. This vehicle is normally the one displayed on the R.A.D.A.R. device. This is because the closer the target, the strongest the reflected signal appears to the R.A.D.A.R. device relative to the other vehicles on the road. The actual speed of the target vehicle is usually the least dominant of the three factors.

Most R.A.D.A.R.s are designed to display the strongest signal received.

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## The Inverse Square Rule

Reflective capability and position are the primary factors determining which vehicle's speed will be displayed by the R.A.D.A.R. Multiple targets of unequal size may create a problem in target identification. To understand this, it is necessary to understand what happens to the R.A.D.A.R. energy after it leaves the antenna.

1. When first transmitted by the antenna, almost all the radio wave energy is concentrated in a circle a few inches in diameter.
2. At 250 feet from the antenna, most of the energy is spread over an area 70 feet in diameter.
3. At 500 feet, the diameter of the circle is twice as large as at 250 feet and it contains about the same amount of energy, spread over four times the area.
4. At 1,000 feet, the same amount of energy is spread over a circle twice as large as the circle at 500 feet and four times as large as the circle at 250 feet. The energy is now spread over an area 16 times as large as it was at 250 feet and the signal is now correspondingly 16 times weaker.

This relationship between signal strength (energy) and distance from its source is called the inverse square rule. Speed does not follow the inverse square rule.

- Depending on the R.A.D.A.R. device used, speed becomes a factor when comparably-sized vehicles are approaching close to one another
- Speed is usually the least important of the three factors

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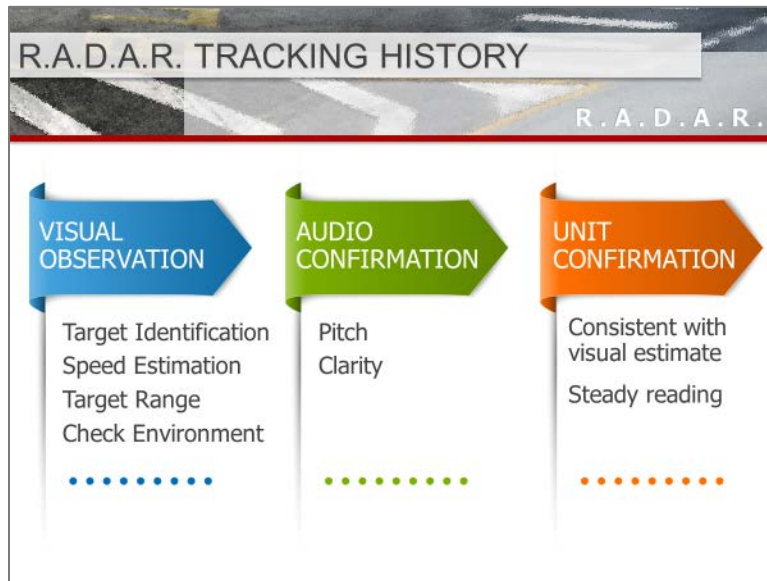
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## TRACKING HISTORY FOR STATIONARY OPERATIONS



Slide 26.

### ***VISUAL OBSERVATION***

- Target Identification
- Speed Estimation
- Target Range
- Check Environment

The visual element is the first part of any speed enforcement action. The officer's attention is drawn to the passing, weaving, etc. of the vehicle. Target identification has now been made.

Now that the vehicle in question has been identified the officer makes an estimation of that vehicle's speed. Additional observations of the vehicle's movement, compared to other vehicles, allow the officer to estimate the target vehicle's speed. The time between target identification and speed estimation will decrease and, with experience, estimation will be close to the target vehicle's true speed.

As the speed estimation is being determined, the officer should note the distance the target vehicle is from his/her location.

The officer should also note the environment in which the target vehicle is traveling. Weather, pedestrian traffic, business or school districts, and construction areas may later be essential in proving a violation of a specific speed law.

**AUDIO CONFIRMATION**

- Pitch
- Clarity

Audio confirmation of a target vehicle is also a part of developing a valid Tracking History.

A strong, clear tone indicates a good, clear, received signal. A broken or scratchy audio tone indicates a weak received signal, which could indicate that the device is picking up interference.

**UNIT CONFIRMATION**

- Displayed target speed is consistent with estimated speed and audio
- Steady reading

The final stage of developing a Tracking History is the confirmation of a speed-measuring device.

A steady read-out with a speed-measuring device is preferred. The key is to be able to articulate the device reading came from the target vehicle.

Once the steady read-out is obtained, it must match, within reason, the operator's visual estimation of the target vehicle's speed.

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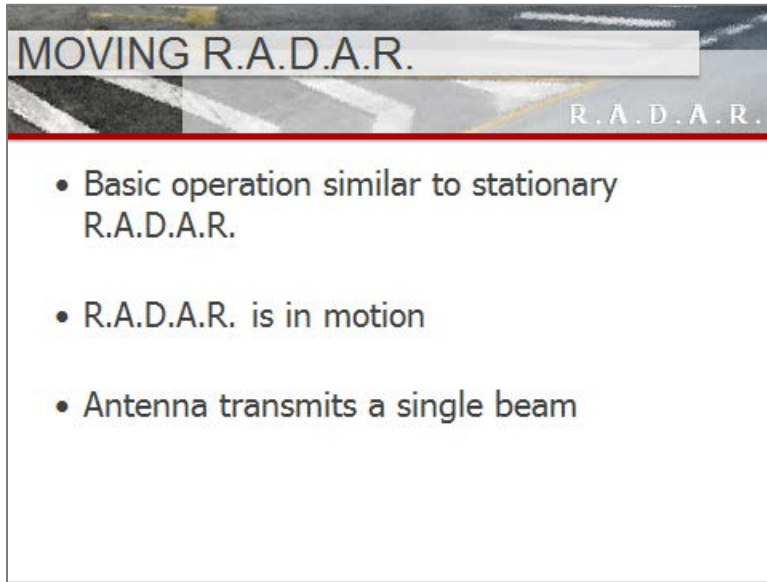
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## MOVING R.A.D.A.R.



**MOVING R.A.D.A.R.**

- Basic operation similar to stationary R.A.D.A.R.
- R.A.D.A.R. is in motion
- Antenna transmits a single beam

Slide 27.

### Principles of Moving R.A.D.A.R.

Moving R.A.D.A.R. is a R.A.D.A.R. device being operated from a moving patrol vehicle. Just like stationary R.A.D.A.R., it works based on the Doppler Principle.

Moving R.A.D.A.R. devices measure two speeds.

- The speed of the patrol vehicle relative to the roadway
- The speed of a target vehicle relative to the moving patrol vehicle

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**PATROL SPEED**

R.A.D.A.R.

- Doppler frequency determined by the R.A.D.A.R. beam reflected from roadway
- Normally, directly in front of the R.A.D.A.R. device

Slide 28.

**PATROL SPEED**

Moving R.A.D.A.R. uses these two speeds to determine the target vehicle's speed. It measures the patrol vehicle's speed relative to stationary terrain within the environment. The beam strikes the ground or objects beside the roadway and reflects to the R.A.D.A.R. This reflected signal undergoes a "low Doppler" shift.

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**LOW DOPPLER**  
R.A.D.A.R.

- The term given to the frequency shift reflected from the roadway or environment
- Must be established by the R.A.D.A.R. device prior to determine the target vehicle's speed

Slide 29.

**LOW DOPPLER**

The amount of Doppler shift indicates the speed of the moving R.A.D.A.R. relative to the stationary ground. The greater off angle ground reflections, the greater the patrol and target speed error. This will be discussed further in Chapter 4: Effects.

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**HIGH DOPPLER**

R.A.D.A.R.

- The term given to the higher Doppler frequency reflected from the oncoming vehicle
- Target vehicle speed can be calculated only if a low Doppler has been established

Slide 30.

## HIGH DOPPLER

The speed at which the target vehicle is approaching the patrol vehicle is also determined through the Doppler principle.

A R.A.D.A.R. beam transmitted from the moving patrol vehicle strikes the approaching target vehicle. The R.A.D.A.R. beam is reflected from the moving target to the moving patrol vehicle. The signal returned to the R.A.D.A.R. receiver has undergone a "high Doppler" shift.

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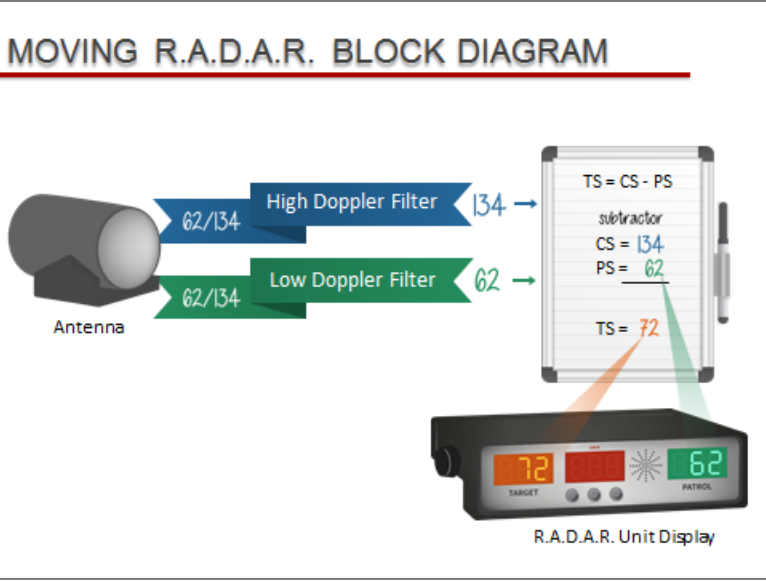
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Slide 31.

TS=Target Speed

CS=Closing Speed

PS=Patrol Speed

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**CLOSING SPEED**

R.A.D.A.R.

- The speed of the relative motion between the target vehicle and the patrol vehicle as the vehicles approach each other

Slide 32.

**CLOSING SPEED**

The R.A.D.A.R. device translates the Doppler shift into a speed measurement. This speed measurement represents the relative speed of the two vehicles. The amount of this Doppler shift depends on the relative speeds of the two vehicles.

What we want to know is the target vehicle's speed.

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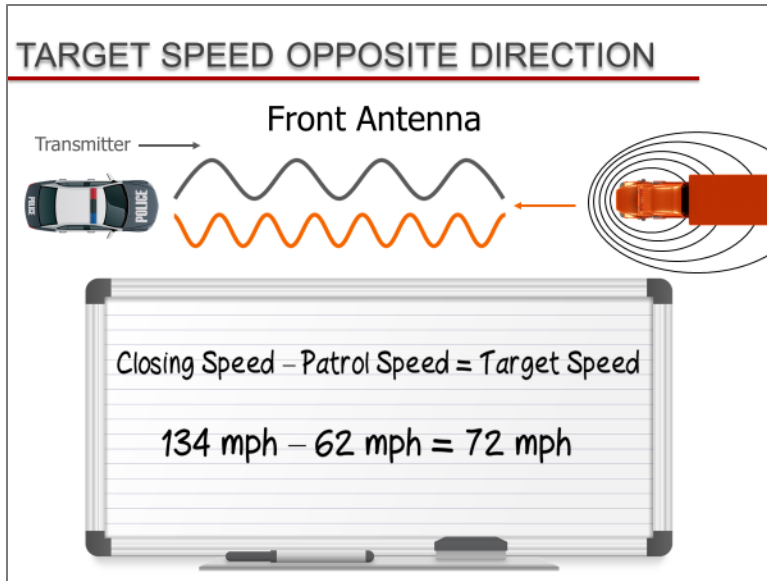
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Slide 33.

### TARGET SPEED OPPOSITE DIRECTION

With opposite direction, front antenna, the target vehicles speed is computed:

$$\text{target speed (TS)} = \text{closing speed (CS)} - \text{patrol speed (PS)}$$

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**SEPARATION SPEED**

R.A.D.A.R.

- The speed of the relative motion between the target vehicle and the patrol vehicle as the vehicles move away from each other in an opposite direction

Slide 34.

**SEPARATION SPEED**

With opposite direction, rear antenna - If the target vehicle has already passed by the moving patrol vehicle and is receding, target speeds can still be computed provided a rearward facing antenna is used.

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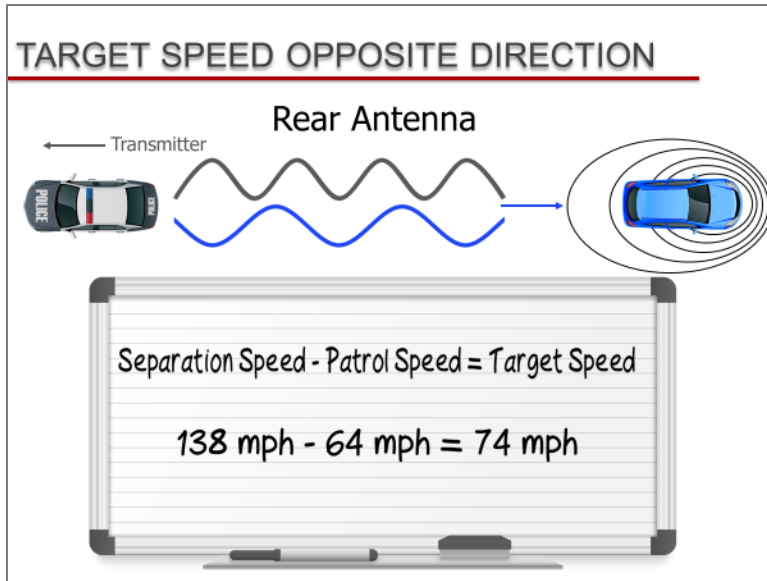
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Slide 35.

**TARGET SPEED OPPOSITE DIRECTION**

For opposite direction, the formula changes to:

$$\text{target speed (TS)} = \text{separation speed(SS)} - \text{patrol speed(PS)}$$

The target speed is computed automatically by the R.A.D.A.R. device. All moving R.A.D.A.R. devices must display the target speed and patrol speed.

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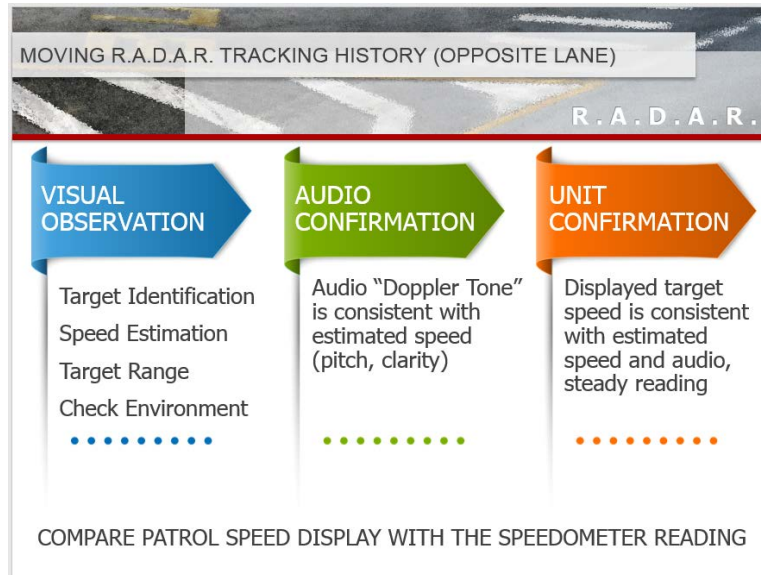
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## MOVING R.A.D.A.R. TRACKING HISTORY (OPPOSITE LANE)



Slide 36.

### *Visual Observation*

- Identify Target
- Estimate Speed
- Estimate Range
- Check Environment

### *Audio Confirmation*

- Pitch
- Clarity

### *Unit Confirmation*

- Steady Readout
- Consistent with Visual Estimate
- Verify Patrol Speed

***Track through Lock***

This term refers to the ability of R.A.D.A.R. devices to continue tracking a target after the target speed has been locked. This enables the operator to continue to develop the tracking history.

Automatic locks and/or alarms are not approved features of current R.A.D.A.R. devices and should never be used. A qualified technician should disable these features, if present. Use of the automatic lock or alarm does not allow proper tracking history.

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## SAME DIRECTION MOVING R.A.D.A.R.

SAME DIRECTION MOVING R.A.D.A.R.

R.A.D.A.R.

$$\begin{aligned} \text{Target Speed} &= \text{Patrol Speed} + \text{Separation Speed} \\ \text{TS} &= 55 \text{ mph} + 20 \text{ mph} \\ \text{TS} &= 75 \text{ mph} \end{aligned}$$
$$\begin{aligned} \text{Target Speed} &= \text{Patrol Speed} - \text{Closing Speed} \\ \text{TS} &= 85 \text{ mph} - 15 \text{ mph} \\ \text{TS} &= 70 \text{ mph} \end{aligned}$$

Slide 37.

Same direction moving R.A.D.A.R. uses the same Doppler Principle that all R.A.D.A.R. devices employ.

Same direction moving R.A.D.A.R. also measures the difference in relative motion between the target vehicle and the patrol vehicle.

The relative motion measured between the vehicles may be added or subtracted from the patrol vehicle speed depending upon whether the target vehicle is traveling faster or slower than the patrol vehicle.

Normally, same-direction moving R.A.D.A.R. devices are unable to automatically differentiate between the target moving faster or slower than that of the patrol vehicle.

The operator must determine which case is present and manually switch the R.A.D.A.R. to the correct mode for computation of the target speed.

The following examples serve to illustrate how same direction moving R.A.D.A.R. computes target speeds.



**Example One:**

A 75-mph passenger vehicle traveling in the same direction and in front of a 55-mph patrol vehicle is calculated in the following manner when the operator has placed the R.A.D.A.R. in the "Target Faster" computation mode.

$$\text{target speed} = \text{patrol speed} + \text{separation speed}$$

$$TS = 55\text{mph} + 20\text{mph} = 75\text{mph}$$

In this example, if the R.A.D.A.R. is incorrectly placed in "Target Slower" mode, the 20-mph would be subtracted from the patrol speed and an erroneous 35-mph target speed displayed.

**Example Two:**

A 70-mph target vehicle being pursued by a patrol vehicle traveling 85-mph is calculated in the following manner when the operator has placed the R.A.D.A.R. in the "Target Slower" computation mode.

$$\text{target speed} = \text{patrol speed} - \text{closing speed}$$

$$TS = 85\text{mph} - 15\text{mph} = 70\text{mph}$$

In this example, if the R.A.D.A.R. is incorrectly placed in "Target Faster" mode, the 15-mph would be added to the patrol vehicle speed resulting in an erroneous 100-mph target speed display.

Same direction moving R.A.D.A.R.s with the antenna pointed rearward or one that has a second rear antenna go through the same computations.

**Target Identification Considerations**

Same direction moving R.A.D.A.R. is subject to all the same target identification variables that affect opposite direction moving or stationary R.A.D.A.R.

These include the R.A.D.A.R. decision-making factors:

- Reflective capability
- Position
- Speed

Same direction R.A.D.A.R. is also affected by three additional target identification factors specific only to its operation. Same direction moving R.A.D.A.R. devices:

1. Only permit targets to be processed and displayed that are within a fixed range, up or down, from the speed the patrol vehicle is traveling at that moment. This "window" of speeds is relatively wide and will not pose any real operational problem. The width of this window is dependent upon the specific model of R.A.D.A.R. used, but is most often at least half of the patrol vehicle speed.
2. Are limited in their ability to display target speeds very close to the patrol vehicle speed. These R.A.D.A.R. devices will not process target speeds closer than three to six miles per hour, up or down, from the patrol vehicle's actual speed depending upon the manufacturer. The R.A.D.A.R. operator cannot establish patrol vehicle speeds at or near the enforcement threshold point to be enforced. A patrol vehicle's speed, matched to the flow of traffic around it, will be blind to most those vehicles. R.A.D.A.R. in same direction moving mode can ignore many large close-by trucks and display the speed of a distant motorcycle. Outside of this narrow range, reflective capability and position again become significant factors. Testing indicates that the greater the Doppler shift the greater the sensitivity of same direction moving R.A.D.A.R.
3. Some R.A.D.A.R.s discriminate between faster and slower targets. The operator is required not only to survey the operational area of the R.A.D.A.R. for faster vehicles being correctly displayed in "Target Faster" mode but also slower vehicles being incorrectly displayed in "Target Faster" mode by the R.A.D.A.R. device. This inability of same direction moving R.A.D.A.R.s to discriminate between faster and slower targets decidedly complicates the operation of this type of R.A.D.A.R. The operator has a ready means available for determining if a target speed is displayed in the proper "Target Faster" or "Target Slower" mode. If the R.A.D.A.R. has correctly computed the target speed, changes in the patrol vehicles speed will not affect the target speed reading. If the incorrect mode is being used, the target speed will go up and down respectively with the acceleration and deceleration of the patrol vehicle.

CORRECT MODE SETTING				
R.A.D.A.R.				
Target Speed = Patrol Speed + Separation Speed = mph				
TS	=	50 mph	+	20 mph = 70
TS	=	51 mph	+	19 mph = 70
TS	=	52 mph	+	18 mph = 70
TS	=	53 mph	+	17 mph = 70
TS	=	54 mph	+	16 mph = 70
TS	=	55 mph	+	15 mph = 70

Slide 38.

**Correct Mode Setting**

***Example One:***

A target vehicle traveling a steady 70-mph is pulling away from a patrol vehicle which is slowly accelerating from 50- to 55-mph. With the R.A.D.A.R. in “Target Faster” mode, the computations on the slide above will occur.

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INCORRECT MODE SETTING				
R.A.D.A.R.				
Target Speed = Patrol Speed + Separation Speed = mph				
TS	=	50 mph	+	20 mph = 70
TS	=	51 mph	+	21 mph = 72
TS	=	52 mph	+	22 mph = 74
TS	=	53 mph	+	23 mph = 76
TS	=	54 mph	+	24 mph = 78
TS	=	55 mph	+	25 mph = 80

Slide 39.

## Incorrect Mode Setting

### *Example Two:*

A R.A.D.A.R. has been incorrectly left in the “Target Faster” mode and is displaying a steady 30-mph target vehicle as a 70-mph vehicle with the following computations occurring:

By gradually varying the patrol vehicle’s speed up or down a few miles per hour, the target speed display should remain constant if the correct calculation mode is being used. If the target speed display does fluctuate up with the patrol speed changes, the R.A.D.A.R. may be calculating a target speed in the wrong mode.

Rapidly changing target speed window fluctuations can also be the result of the R.A.D.A.R. displaying several different vehicles intermittently.

In the correct mode, the separation speed will decrease as the patrol speed increases thus keeping the target speed a constant and accurate 70-mph.

When a same direction moving R.A.D.A.R. is in an incorrect mode for the proper calculation of target speed, the target speed display will change by two miles per hour for each one mile per hour change in patrol vehicle speed.

Regardless of the cause, rapid target window fluctuations are not acceptable and any readings obtained should be disregarded for enforcement purposes.

***Target Speed Discrimination Test***

To ensure that the target speed displayed is being correctly interpreted by the same direction moving R.A.D.A.R. in respect to the "Target Faster" or "Target Slower" modes, the operator must gradually vary the patrol vehicles speed by a few miles per hour up or down.

If the target speed display remains constant, the R.A.D.A.R. is verified as calculating in the correct speed discrimination mode. If the target speed display fluctuates with the patrol speed changes, then the operator must disregard the target speed for enforcement purposes.

This test becomes an integral part of tracking history for same direction moving R.A.D.A.R.

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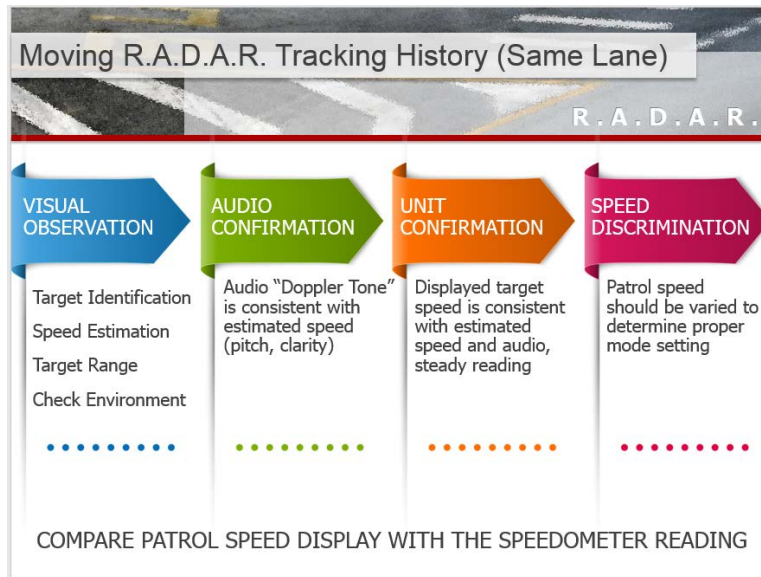
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## MOVING R.A.D.A.R. TRACKING HISTORY (SAME LANE)



Slide 40.

### *Visual Observation*

- Identify Target
- Estimate Speed
- Estimate Range
- Check Environment

### *Audio Confirmation*

- Pitch
- Clarity

### *Unit Confirmation*

- Steady Readout
- Consistent with Visual Estimate
- Speed Discrimination Test
- Verify Patrol Speed

**AS WITH ALL R.A.D.A.R. ACTION WHEN IN DOUBT, DO NOT ISSUE A CITATION.**

# R.A.D.A.R. EFFECTS

Estimated time for Chapter 4: 45 Minutes

## R. A. D. A. R.

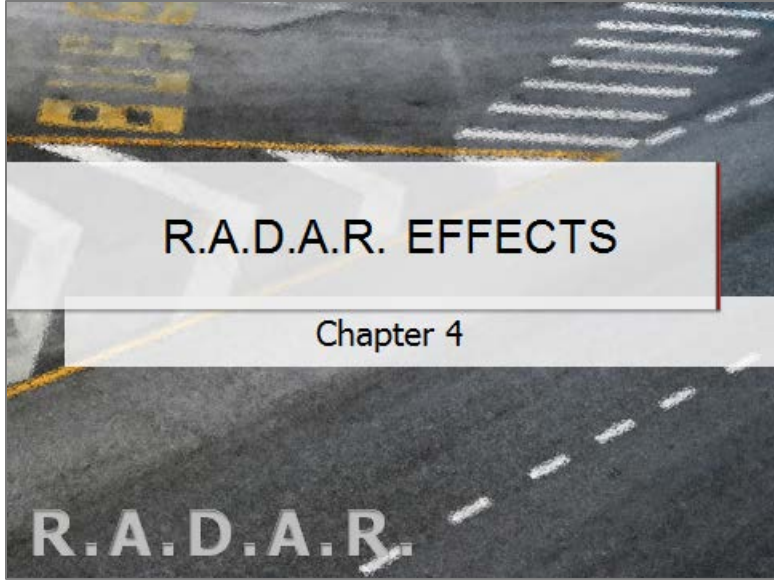
### Objectives

By the end of this chapter, you will be able to:

- Discuss R.A.D.A.R. effects

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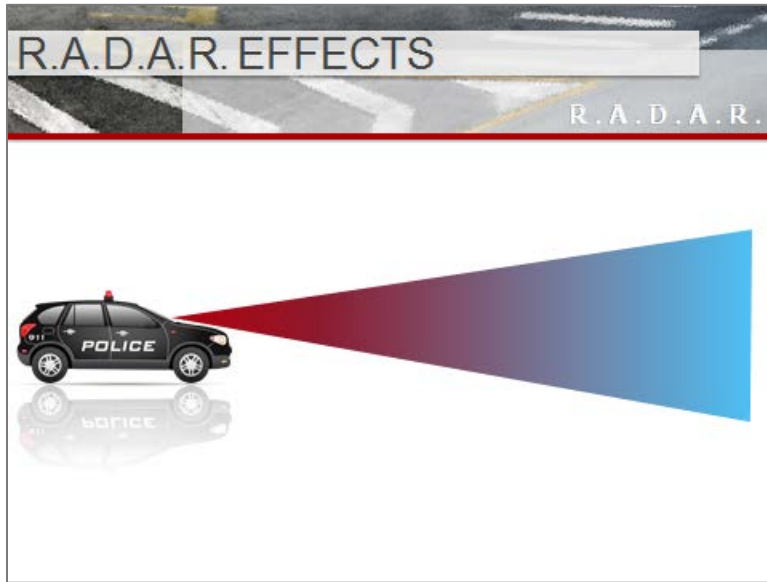
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Slide 41.



## FACTORS AFFECTING ALL R.A.D.A.R. OPERATION



Slide 42.

Charges have been made that false readings can be displayed on a R.A.D.A.R. device. This is true, but most of these instances are avoidable with proper understanding of the R.A.D.A.R. device. Some are a result of natural causes, and most are recognizable to the trained operator. It is important to understand that interference can make it appear that a R.A.D.A.R. device is not working properly. A well-publicized court filing in Dade County, Florida v. Aguilar, in the spring of 1979 cast considerable doubt on R.A.D.A.R.'s accuracy. The case cited examples where R.A.D.A.R. devices clocked a tree moving at over 80-mph and a house moving at 28-mph. The cause of the strange readings was interference combined with improper operating procedures. Knowing how to avoid interference can reduce problems of this type.

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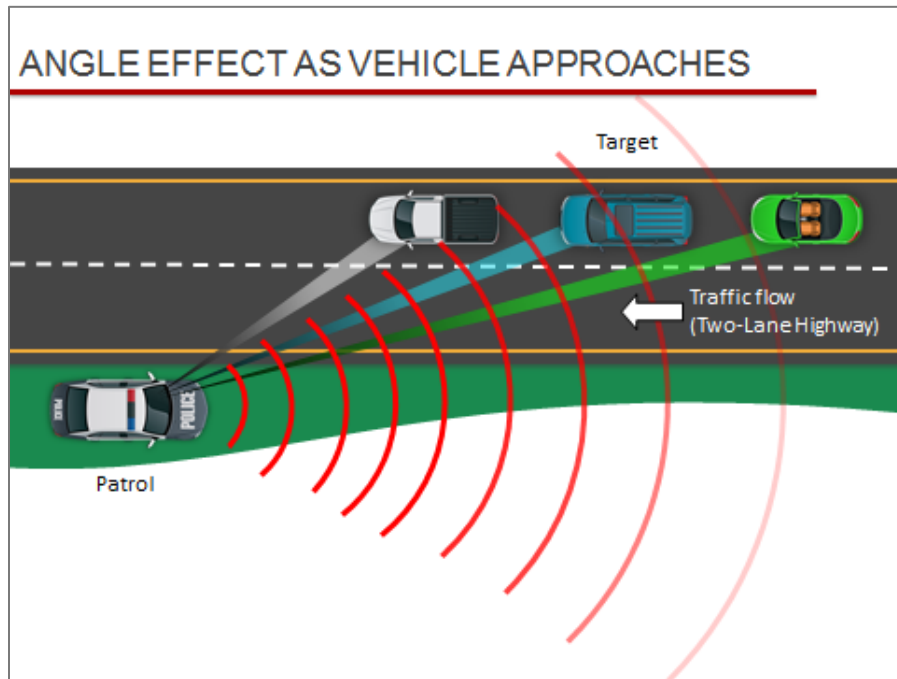
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## STATIONARY COSINE EFFECT



Slide 44.

R.A.D.A.R. will only measure the exact speed of a target vehicle when it is traveling directly at or straight from the R.A.D.A.R. device. If an angle exists, the cosine effect occurs.

The cosine effect only results in a stationary R.A.D.A.R. device displaying a speed less than the target vehicle's true speed. **This will always be to the motorist's advantage.**

### TRUE SPEEDS AS AFFECTED BY THE COSINE EFFECT

Angle Degrees	30 mph	40 mph	50 mph	55 mph	60 mph	70 mph
0	30	40	50	55	60	70
1	29.99	39.99	49.99	54.99	59.99	69.99
3	29.96	39.94	49.93	54.92	59.92	69.90
5	29.89	39.85	49.81	54.79	59.77	69.73
10	29.54	39.39	49.24	54.16	59.09	68.94
15	28.98	38.64	48.30	53.12	57.94	67.61
20	28.19	37.59	46.99	51.68	56.38	65.78
30	25.98	34.64	43.30	47.63	51.96	60.62
45	21.21	28.28	35.36	38.89	42.43	49.50
60	15.00	20.00	25.00	27.50	30.00	35.00
90	00.00	00.00	00.00	00.00	00.00	00.00

Slide 45.



#### **SUPPLEMENT 4: Stationary Cosine Effect Worksheet (15 Minutes)**

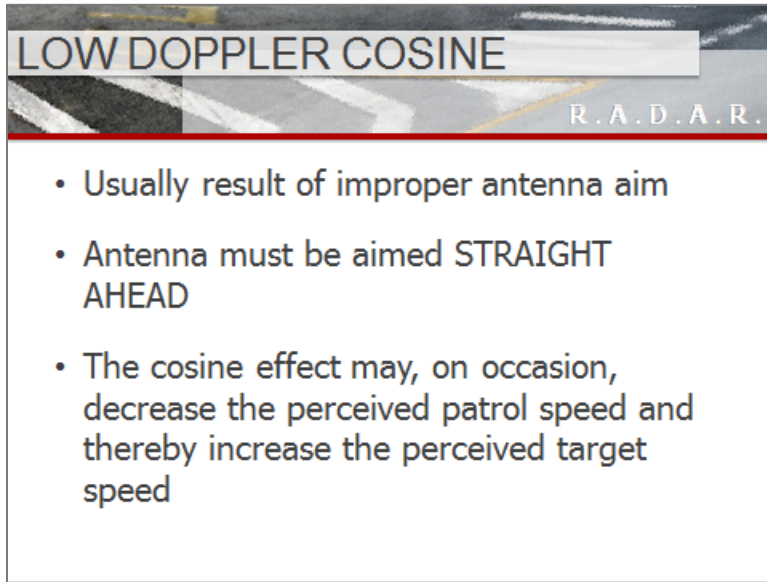
The cosine effect is not significant if the angle remains small. It starts becoming a factor at about 10 degrees. At a 90-degree angle, the R.A.D.A.R. device will not see a target vehicle speed because the motion of the target is moving neither towards nor away from the R.A.D.A.R. device.

The speed of a vehicle driving in circles around a R.A.D.A.R. device would not be displayed because the cosine effect would make it effectively invisible. The R.A.D.A.R. device would see no relative motion.

With the R.A.D.A.R. antenna pointed at an approaching vehicle, as the vehicles get close enough to produce a significant angle, the result is a reduced display of the target vehicle's speed.

The R.A.D.A.R. operator should set up the R.A.D.A.R. device as close to the roadway as possible. A rule of thumb is 10 feet from the edge of the roadway for every 100 feet the target vehicle is down the roadway. Align the antenna as straight down the road as possible. Based on the unit's decreasing speed reading, it may give the appearance that the vehicle is slowing down as it passes. Although this may be partially true, this is due to the cosine effect.

## MOVING R.A.D.A.R. COSINE EFFECT



LOW DOPPLER COSINE

R.A.D.A.R.

- Usually result of improper antenna aim
- Antenna must be aimed STRAIGHT AHEAD
- The cosine effect may, on occasion, decrease the perceived patrol speed and thereby increase the perceived target speed

Slide 46.



### SUPPLEMENT 5: Moving R.A.D.A.R. Cosine Worksheet (15 Minutes)

The cosine effect with moving R.A.D.A.R. may result in a high target vehicle speed display, but most often, the cosine effect with moving R.A.D.A.R. will result in a low target vehicle's speed, just as in stationary operations.

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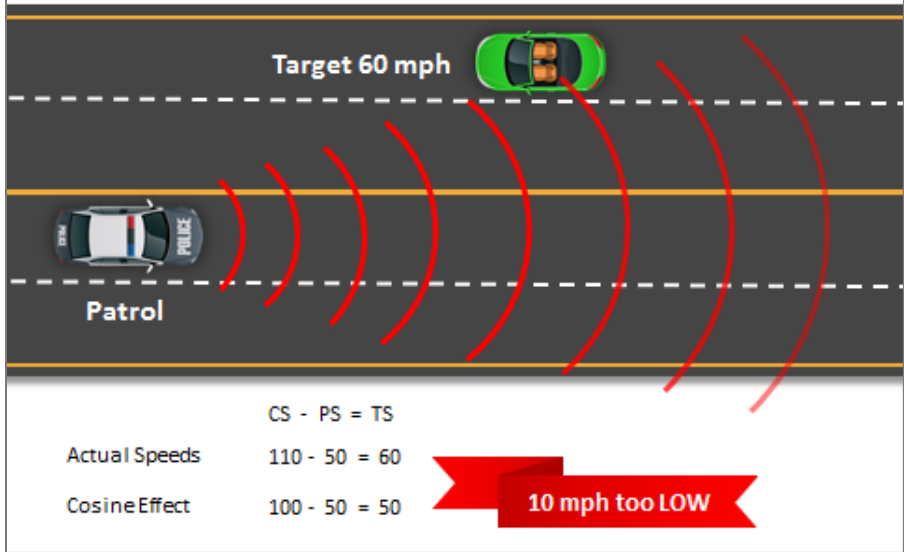
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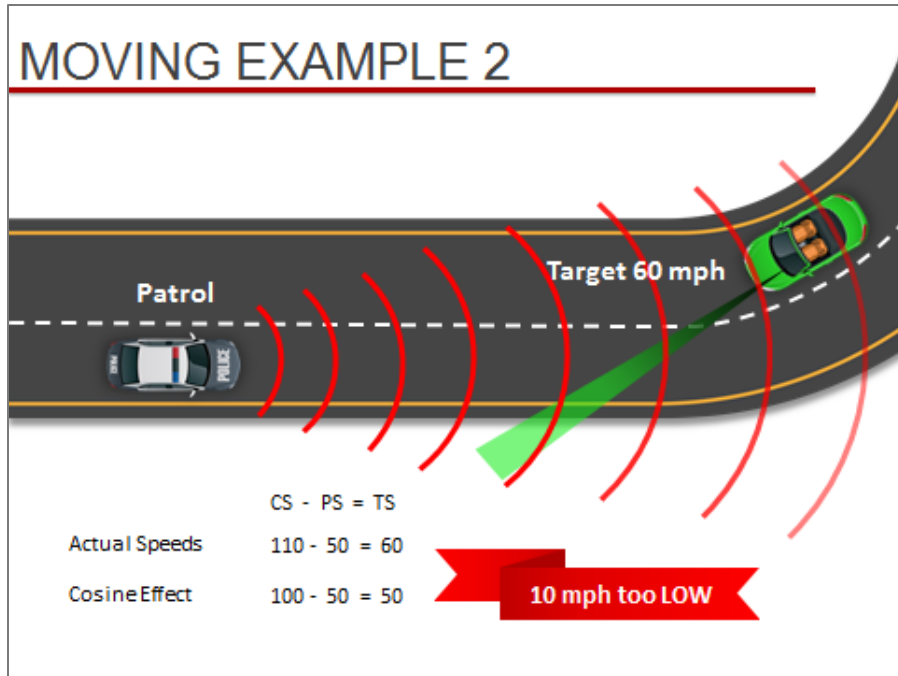
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# MOVING EXAMPLE 1



Slide 47.

When an approaching vehicle gets close enough to the R.A.D.A.R. to create a significant angle, the result is a LOW target vehicle speed.

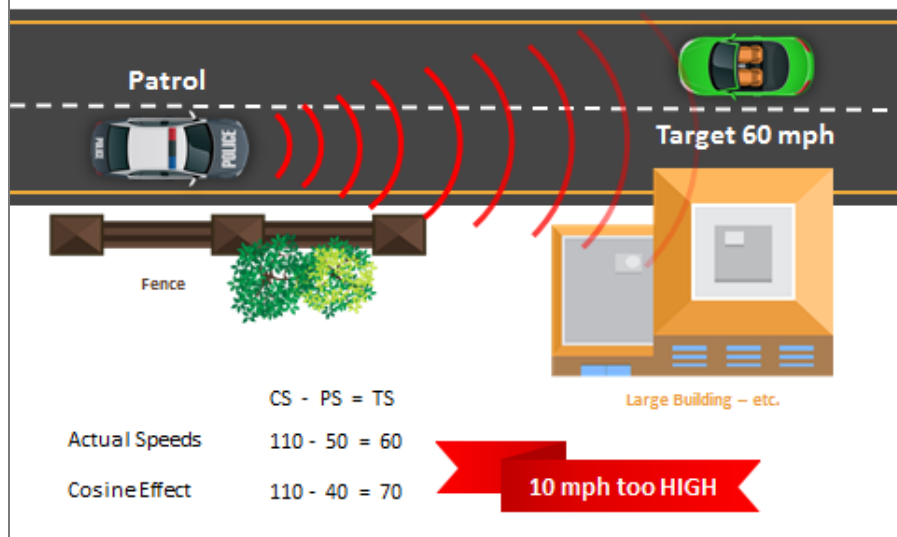


Slide 48.

A curve in the road could cause the target vehicle to approach the R.A.D.A.R. at a significant angle resulting in a LOW target vehicle speed.

A low target speed reading can result only if the patrol vehicle speed is being computed correctly. Conditions can exist that will lead to a high target vehicle speed being displayed by the R.A.D.A.R. device. The computation of a higher target speed could result if a less-than-true patrol speed is used by the R.A.D.A.R. device.

## MOVING EXAMPLE 3

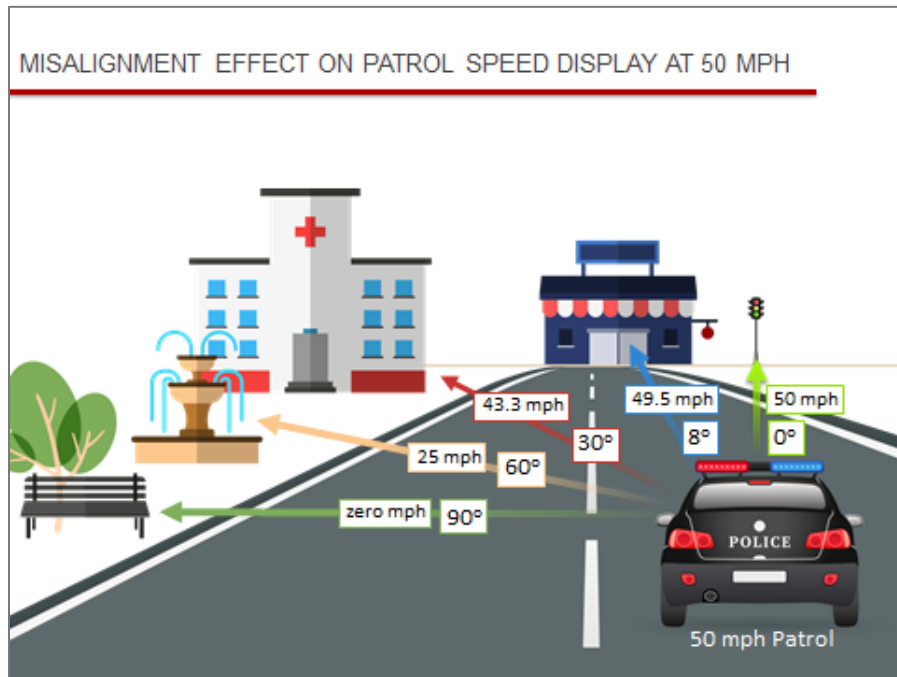


Slide 49.

An improper target speed can result if the patrol speed signal is received from some roadside object at an angle to the patrol vehicle's path of travel not from the stationary terrain ahead of it, e.g., a fence by the side of the road. The target speed will be high because the R.A.D.A.R.'s reading of the patrol vehicle's speed is low. This condition normally occurs only for a short period and is easily detected by the operator comparing the displayed patrol speed with the patrol vehicle's speedometer.



## MISALIGNMENT EFFECT ON PATROL SPEED DISPLAY AT 50-MPH



Slide 50.

A patrol vehicle signal less than actual speed will result in a higher-than-actual target speed reading.

Straight-ahead antenna alignment is necessary. Misalignment of the antenna, no matter how slight, may increase the possibility of a high target speed reading.

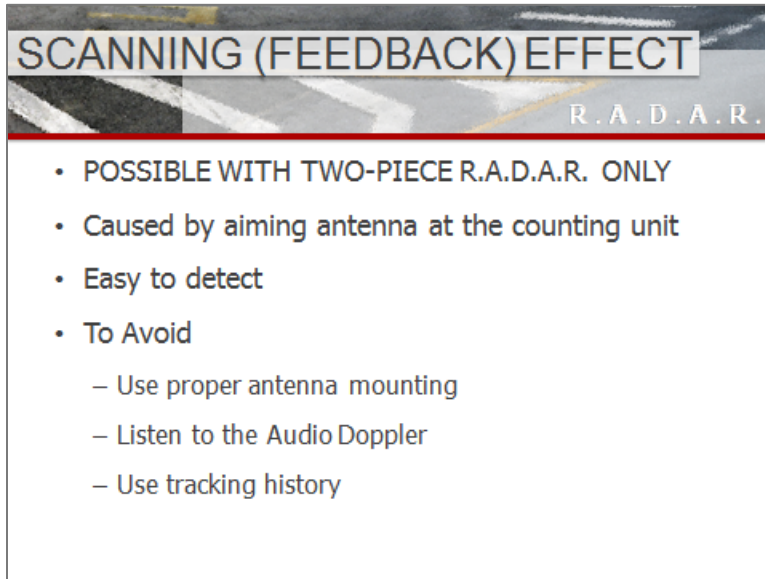
Unavoidable conditions may also create improperly high target speeds.

All moving R.A.D.A.R. devices must have both a target speed display and a patrol speed display.

Comparing the patrol speed display with the certified patrol vehicle speedometer allows the R.A.D.A.R. operator to ensure that the R.A.D.A.R. device is measuring the patrol vehicle's speed accurately.

This test is an integral part of tracking history for moving R.A.D.A.R.

## SCANNING (FEEDBACK) EFFECT



**SCANNING (FEEDBACK) EFFECT**

R.A.D.A.R.

- POSSIBLE WITH TWO-PIECE R.A.D.A.R. ONLY
- Caused by aiming antenna at the counting unit
- Easy to detect
- To Avoid
  - Use proper antenna mounting
  - Listen to the Audio Doppler
  - Use tracking history

Slide 51.

This effect, possible only with a two-piece R.A.D.A.R. device, occurs when the antenna is aimed across the counting unit. The result is an erroneous display accompanied by a high squealing audio Doppler. This is avoided by the proper set up and/or use of the device.

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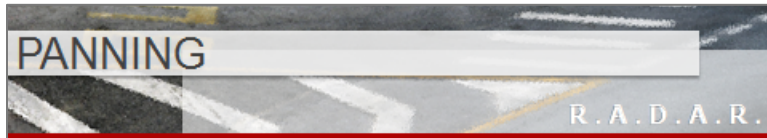
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# PANNING EFFECT



PANNING

R.A.D.A.R.

- R.A.D.A.R. detects motion
- Panning causes R.A.D.A.R. to interpret its own motion as speed
- Possible with two-piece R.A.D.A.R. if antenna is hand-held
- To Avoid
  - Use mounting devices provided
  - Disregard readings while antenna is in motion
  - Use tracking history

Slide 52.

This is caused by the rapid movement of the R.A.D.A.R. antenna. Remember that R.A.D.A.R. detects motion and cannot differentiate between antenna movement and target movement.

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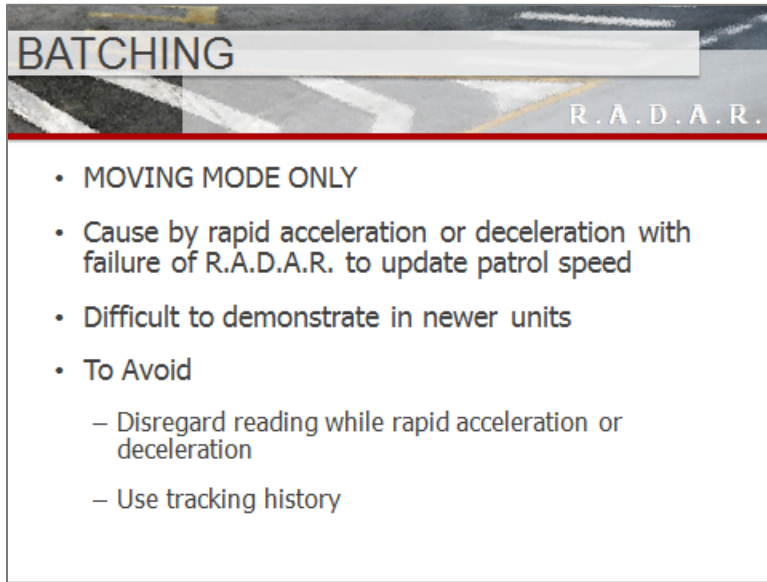
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## BATCHING EFFECT (MOVING MODE ONLY)



**BATCHING**

R.A.D.A.R.

- MOVING MODE ONLY
- Cause by rapid acceleration or deceleration with failure of R.A.D.A.R. to update patrol speed
- Difficult to demonstrate in newer units
- To Avoid
  - Disregard reading while rapid acceleration or deceleration
  - Use tracking history

Slide 53.

This is caused by the R.A.D.A.R. device's failure to update the patrol speed during rapid acceleration or deceleration. Current devices are not subject to this effect, but older devices may display false readings. It is caused by the R.A.D.A.R. updating the low Doppler and high Doppler signals at different intervals. Proper tracking history will help alert the operator.

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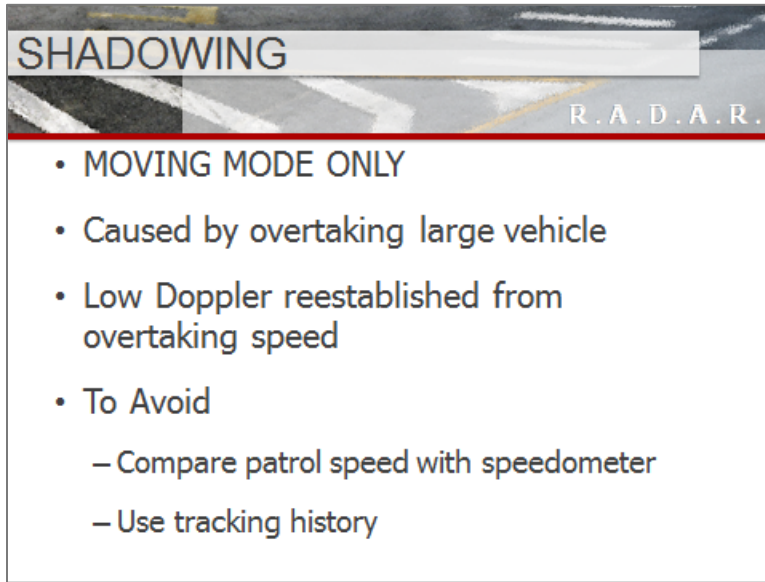
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## SHADOWING (MOVING MODE ONLY)



SHADOWING

R.A.D.A.R.

- MOVING MODE ONLY
- Caused by overtaking large vehicle
- Low Doppler reestablished from overtaking speed
- To Avoid
  - Compare patrol speed with speedometer
  - Use tracking history

Slide 54.

This effect occurs when the closing or receding speed between the patrol vehicle and a slow-moving vehicle ahead is interpreted as the patrol speed (low Doppler). The “hot spot” has shifted from the roadway to the rear of the slow-moving vehicle. The result is a higher target speed display. Verification of patrol speed during the tracking history will identify this affect.

# SHADOWING EXAMPLE

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	CS - PS = TS	
Actual Speeds	110 - 50 = 60	
Shadowing Effect	110 - 15 = 95	<div style="background-color: red; color: white; padding: 2px 10px; border: 1px solid red; font-weight: bold;">35 mph too HIGH</div>

Slide 55.



## SUPPLEMENT 6: Shadowing Worksheet (10 Minutes)

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## CLOSING SPEED CAPTURE (MOVING MODE ONLY)

The patrol speed is no longer displaying the ground speed but is now displaying the closing speed. A closing speed may be displayed in the patrol speed window if the ground speed (low Doppler) is lost.

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## OWN SPEED CAPTURE

**OWN SPEED CAPTURE**  
R.A.D.A.R.

- MOVING MODE ONLY
- Same speed reading in both patrol and target displays
- Result of "triple Doppler shift"
- To Avoid
  - Decelerate patrol vehicle & check display for reading
  - Use tracking history

Slide 56.

This effect results from the patrol speed appearing simultaneously in both the patrol and target windows. It is caused by the R.A.D.A.R. beam bouncing from the "hot spot" back to the front of the patrol vehicle, then back to the roadway, and back to the R.A.D.A.R. antenna. A "triple shift" has occurred which results in a false target speed reading.

Some R.A.D.A.R. devices have the capability to blank the display when identical readings occur.

To avoid, simply decelerate the patrol vehicle by taking your foot off the accelerator. If the patrol speed displayed changes from an identical reading to a lower speed than the target window, the target speed reading is correct.



## EXTERNAL MECHANICAL INTERFERENCE

EXTERNAL MECHANICAL INTERFERENCE

R.A.D.A.R.

- Remember that R.A.D.A.R. detects MOTION, not DIRECTION
- Any large moving object in R.A.D.A.R. beam may cause a reading
- To Avoid
  - Check operating environment
  - Develop a valid tracking history

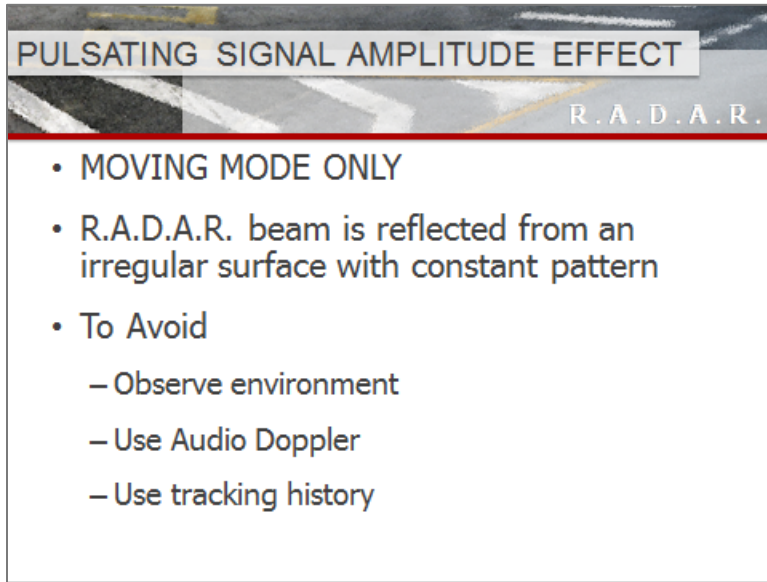
Slide 57.

Remember that R.A.D.A.R. detects motion and not direction. In addition to moving vehicles, many other objects in our enforcement environment are in motion. These moving objects can cause a reading on the R.A.D.A.R.

Large signs in motion, roof air conditioning fans, and other mechanical devices are examples of moving objects that may cause external mechanical interference.

When a valid target vehicle produces sufficient signal strength to overcome the weak signal of the moving object, the target vehicle will produce the display. Use of the tracking history will allow the operator to identify mechanical effects and disregard them.

## PULSATING SIGNAL AMPLITUDE EFFECT



The slide features a header with the title "PULSATING SIGNAL AMPLITUDE EFFECT" and the acronym "R.A.D.A.R." on the right. Below the header is a list of bullet points:

- MOVING MODE ONLY
- R.A.D.A.R. beam is reflected from an irregular surface with constant pattern
- To Avoid
  - Observe environment
  - Use Audio Doppler
  - Use tracking history

Slide 58.

If the R.A.D.A.R. beam is reflected from an irregular surface with a consistent pattern, such as a chain link fence, the returned signal may be interpreted as a multiple Doppler shift. A false target speed display may occur. The audio Doppler sound will be consistent with the pattern that is returning the R.A.D.A.R. signal.

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## R.F.I. FROM OTHER ELECTRICAL SOURCES

RADIO FREQUENCY INTERFERENCE (R.F.I.)

R.A.D.A.R.

**ELECTRICAL SOURCES**

- Possible source of interference
- Usually accompanied by loud audio noise
- The higher the voltage the greater possibility of interference
- To Avoid
  - Choose location carefully
  - Check location with Audio Doppler
  - Use tracking history

Slide 59.

Electrical sources of Radio Frequency Interference (R.F.I.) include overhead high-voltage power lines, transformers, and certain other electrical devices such as arc welders and medical equipment. This interference is usually identified by very noisy buzzing or humming of the audio Doppler.

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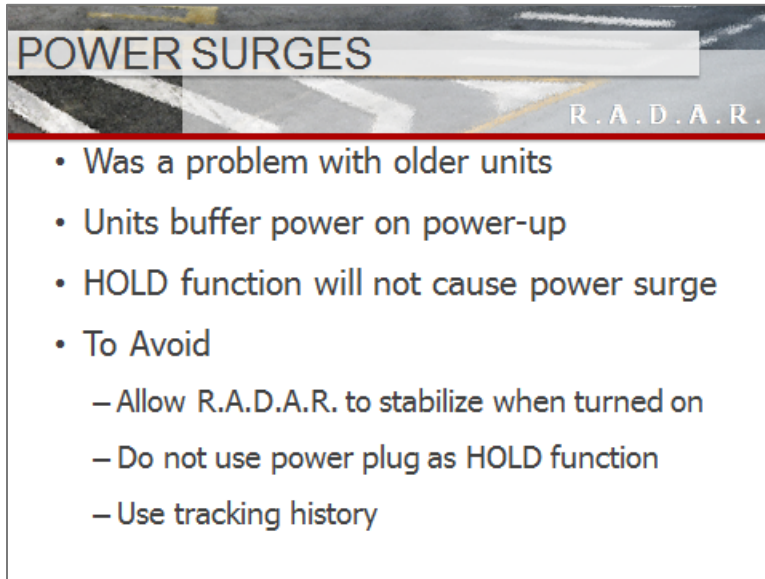
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## IRREGULAR POWER SUPPLY CONDITIONS



**POWER SURGES**

R.A.D.A.R.

- Was a problem with older units
- Units buffer power on power-up
- HOLD function will not cause power surge
- To Avoid
  - Allow R.A.D.A.R. to stabilize when turned on
  - Do not use power plug as HOLD function
  - Use tracking history

Slide 60.

Either abnormally high or low power to the R.A.D.A.R. device may cause problems. High voltage (power surge) although infrequent may cause device damage or the fuse to blow. Low voltage usually results in the device automatically shutting off.

Police motorcycles tend to be highly susceptible to this condition. General results will be the blanking of any locked speed and possible complete shutdown.

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# R.F.I. THROUGH POWER AND ANTENNA LEADS

R.F.I. THROUGH POWER, ANTENNA LEADS  
R.A.D.A.R.

- Power lead capable of causing interference
- To Avoid
  - Use well shielded power and antenna leads
  - Do not intertwine power and antenna leads
  - Use tracking history

Slide 61.

The vehicles' electrical system is a prime source for R.F.I. through the lack of proper or adequate shielding of the various wires. Shielding refers to the wrapping of copper braid or tin foil strips around the primary current carrying part of a wire. The shielding prevents the radio frequency energy from "escaping" the protected lead. To avoid this effect, make sure the antenna and power leads are well shielded and kept separate.

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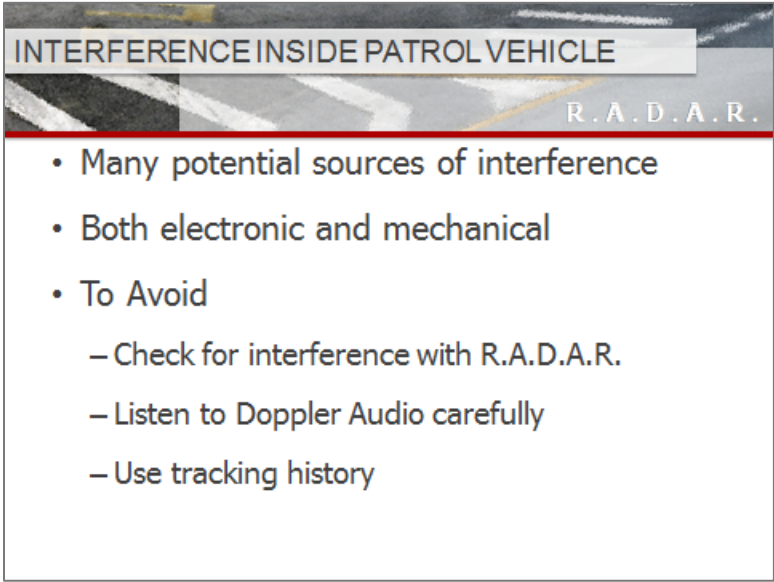
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# INTERFERENCE INSIDE THE PATROL VEHICLE



The slide features a header with the title 'INTERFERENCE INSIDE PATROL VEHICLE' and the R.A.D.A.R. logo. The main content is a bulleted list:

- Many potential sources of interference
- Both electronic and mechanical
- To Avoid
  - Check for interference with R.A.D.A.R.
  - Listen to Doppler Audio carefully
  - Use tracking history

Slide 62.

Within every patrol vehicle, there are a surprising number of interference sources. Sources range from mechanical devices such as heater/defroster fans and transmission components to electronic devices such as the various radios (AM/FM radio, CB radio, police radio), electronic clock, or computerized engine ignition parts. Audio Doppler is most important in this situation.

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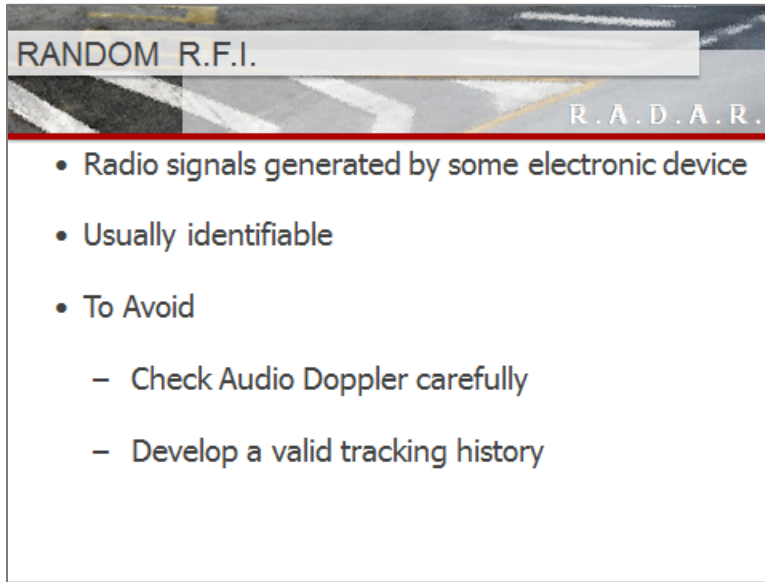
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## RANDOM R.F.I.

The slide features a header with the text "RANDOM R.F.I." on the left and "R.A.D.A.R." on the right, set against a background of a road with white dashed lines. Below the header, there is a bulleted list of points.

RANDOM R.F.I.

R.A.D.A.R.

- Radio signals generated by some electronic device
- Usually identifiable
- To Avoid
  - Check Audio Doppler carefully
  - Develop a valid tracking history

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Slide 63.

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There are ever increasing numbers of electronic devices capable of generating R.F.I. signals. These signals are potential sources of interference due to the sensitivity of R.A.D.A.R. devices. However, these interference signals are quite weak and using tracking history will allow accurate R.A.D.A.R. use.

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## R.F.I. FROM RADIO TRANSMISSIONS

R.F.I. FROM POLICE AND BUSINESS RADIOS

R.A.D.A.R.

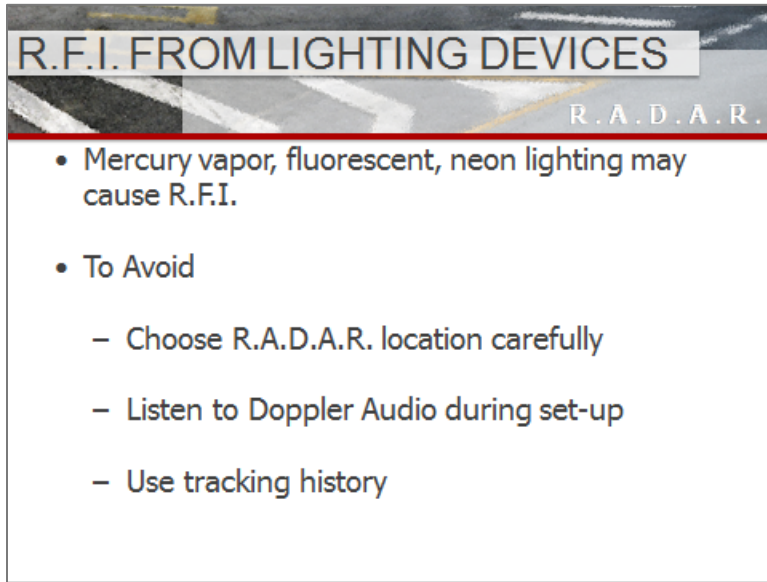
- May cause interference
- To Avoid
  - Don't transmit while using R.A.D.A.R.
  - Disregard if other transmitter is nearby
  - Use tracking history

Slide 64.

R.A.D.A.R. devices may be affected by R.F.I. from radios both inside and close to the patrol vehicle. This is a result of both transmitter power and inadequate shielding. These include police band, CB, cellular phone, and business band radios. Tests have proven that external radio transmitters must be very close to a patrol vehicle to cause R.F.I. However, prudent operation should include checking the environment for their presence. Use of the tracking history will help identify these sources of R.F.I.



## R.F.I. FROM ELECTRICAL LIGHTING



R.F.I. FROM LIGHTING DEVICES

R.A.D.A.R.

- Mercury vapor, fluorescent, neon lighting may cause R.F.I.
- To Avoid
  - Choose R.A.D.A.R. location carefully
  - Listen to Doppler Audio during set-up
  - Use tracking history

Slide 65.

Certain types of lighting equipment such as mercury vapor, neon, and fluorescent lights can cause erroneous readings. This is due to their emission of a signal that is equal to multiple R.A.D.A.R. operating frequencies. The audio Doppler will be especially helpful in detecting this interference source.

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# HARMONIC SIGNAL INTERFERENCE

The slide features a background image of a road with white lane markings. At the top, the text 'HARMONIC SIGNAL INTERFERENCE' is displayed in a white box, and the 'R.A.D.A.R.' logo is visible in the upper right corner. The main content consists of a bulleted list:

- Harmonic is a multiple of a base frequency
- Some electrical devices may produce interference
- To Avoid
  - Use the Doppler Audio to identify harmonics
  - Use tracking history

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Slide 66.

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A harmonic is a multiple of a base frequency. There are many electrical devices that may emit a harmonic signal capable of interfering with the R.A.D.A.R. This interference will also produce noisy audio Doppler.

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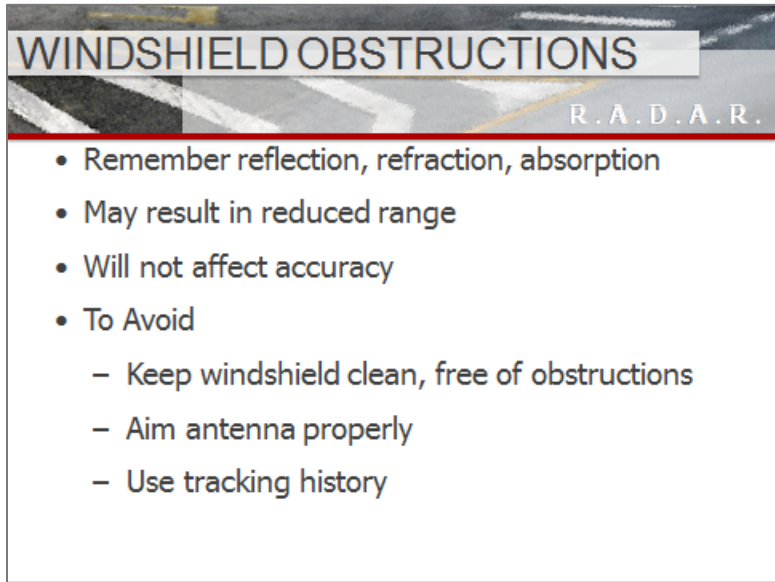
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# WINDSHIELD OBSTRUCTIONS



**WINDSHIELD OBSTRUCTIONS**

R.A.D.A.R.

- Remember reflection, refraction, absorption
- May result in reduced range
- Will not affect accuracy
- To Avoid
  - Keep windshield clean, free of obstructions
  - Aim antenna properly
  - Use tracking history

Slide 67.

Windshield obstructions can cause reduced range. The windshield should be kept clean and clear of obstructions.

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## DENTED ANTENNA HORN

The slide features a header with the title "DENTED ANTENNA HORN" and the acronym "R.A.D.A.R." in the top right corner. A red horizontal line separates the header from the main content area, which contains a bulleted list of effects and mitigation strategies.

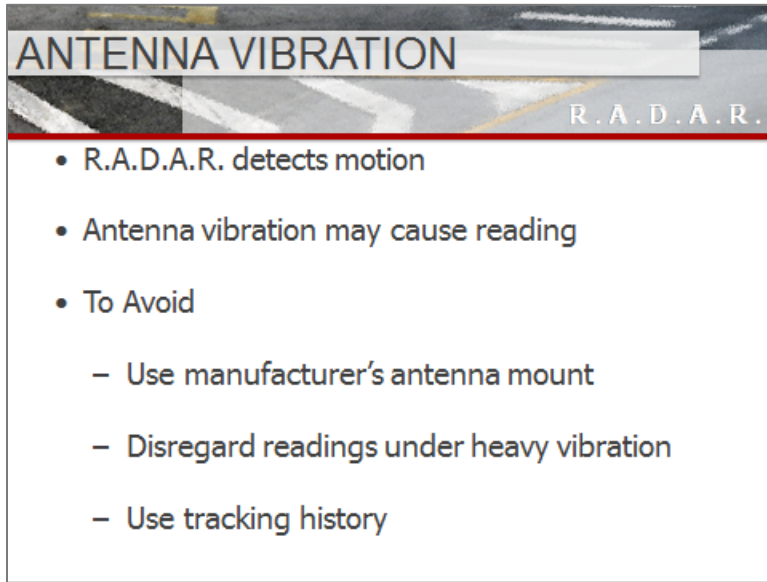
- WILL NOT affect accuracy of R.A.D.A.R.
- WILL affect range, beam shape
- To Avoid
  - Prevent abuse of unit
  - Use tracking history

Slide 68.

Some R.A.D.A.R. antennas are subject to damage. A dented antenna horn may cause distortion of the shape of the R.A.D.A.R. beam as it leaves the antenna. This may result in the beam striking and/or R.A.D.A.R. receiving signals from an unanticipated target.

Devices with damaged antenna horns should be repaired.

# ANTENNA VIBRATION



**ANTENNA VIBRATION**  
R.A.D.A.R.

- R.A.D.A.R. detects motion
- Antenna vibration may cause reading
- To Avoid
  - Use manufacturer’s antenna mount
  - Disregard readings under heavy vibration
  - Use tracking history

Slide 69.

Again, the vibration of the R.A.D.A.R. antenna may cause a false reading. The antenna should be mounted per the manufacturer’s recommendations in a manner that will reduce vibration. Readings obtained while traveling over very rough or uneven roadways should be carefully checked for tracking history.

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## AUDIO EFFECT

**AUDIO EFFECT** R.A.D.A.R.

- R.A.D.A.R. detects motion; loud noises may cause antenna vibration
- Requires a harmonic of R.A.D.A.R. frequency
- To Avoid
  - Do not allow loud noises around antenna
  - Use tracking history

Slide 70.

The audio effect is the result of very loud sounds vibrating the R.A.D.A.R. antenna or objects in the R.A.D.A.R. beam which results in the interpretation of the vibration as motion. Avoid the operation of R.A.D.A.R. in the presence of loud noises.

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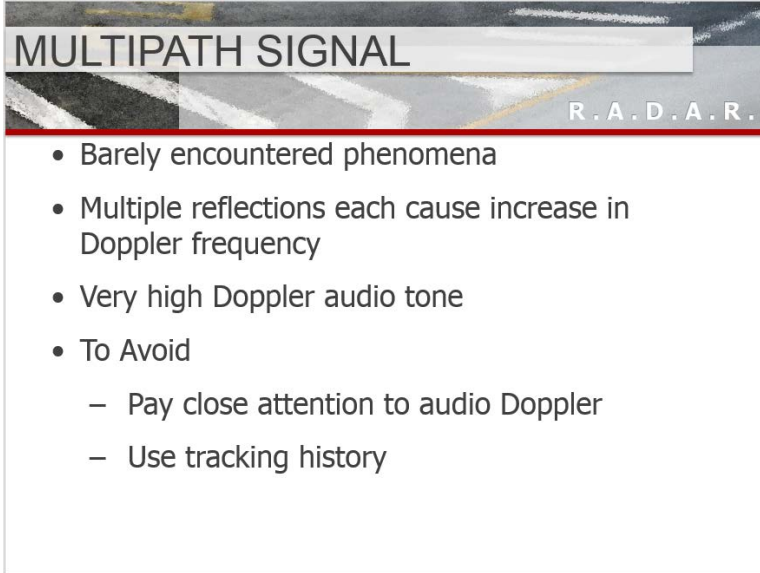
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## MULTIPATH SIGNALS



- Barely encountered phenomena
- Multiple reflections each cause increase in Doppler frequency
- Very high Doppler audio tone
- To Avoid
  - Pay close attention to audio Doppler
  - Use tracking history

Slide 71.

These are caused by multiple reflections of the R.A.D.A.R. signal, which increase in frequency with each reflection. The results are an unusually high target speed and audio Doppler. The tracking history will disclose this effect.

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## MULTIPATH BEAM CANCELLATION

A 180 degree "phase inversion" of the R.A.D.A.R. signal causes the reflected signals to interfere with each other. This results in R.A.D.A.R. blind spots - locations where vehicles simply cannot be "seen" by the R.A.D.A.R. even though visible with the naked eye.

Blind spots are created at places where the R.A.D.A.R. beam is reflected off many surfaces, such as roadway, fence posts, buildings, or trees. The reflected beams, in effect, cancel each other out. The operator must be alert to the possibility of the R.A.D.A.R. displaying a vehicle well behind the target vehicle in the blind spot. There is no remedy to multipath beam cancellation besides avoiding such areas and obtaining a complete tracking history.

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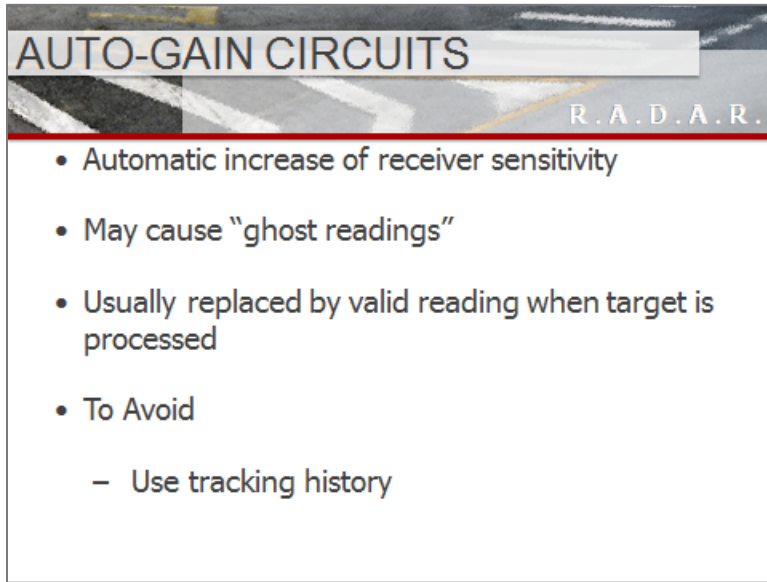
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## AUTOMATIC RECEIVER GAIN



**AUTO-GAIN CIRCUITS**  
R.A.D.A.R.

- Automatic increase of receiver sensitivity
- May cause "ghost readings"
- Usually replaced by valid reading when target is processed
- To Avoid
  - Use tracking history

Slide 72.

In the absence of a valid target, some R.A.D.A.R. devices will attempt to seek a signal. In doing so, the R.A.D.A.R. receiver is "wide open" allowing spurious (ghosts) readings to occur. An example frequently given is the infamous 88-mph tree. Lack of a valid target and no tracking history will alert the operator to this condition.

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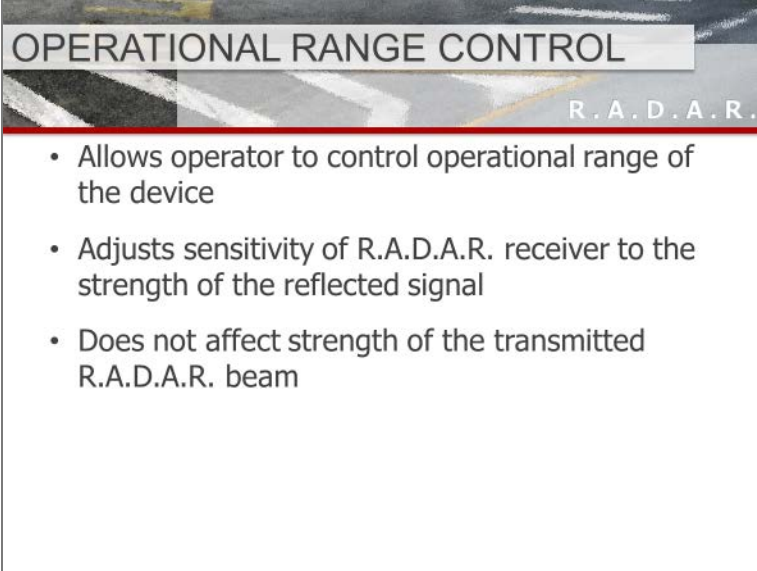
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## THE EFFECT OF TERRAIN ON TARGET IDENTIFICATION

The optimum terrain for R.A.D.A.R. enforcement is a straight, level roadway. R.A.D.A.R. works on a line-of-sight basis and will not normally display vehicles around a curve or over a hill. Hills can cause the greatest problem in target identification.

- R.A.D.A.R. can overshoot lead vehicles and strike vehicles far behind
- Operator discretion in the selection of a working area is necessary

## OPERATIONAL RANGE CONTROL



OPERATIONAL RANGE CONTROL

R.A.D.A.R.

- Allows operator to control operational range of the device
- Adjusts sensitivity of R.A.D.A.R. receiver to the strength of the reflected signal
- Does not affect strength of the transmitted R.A.D.A.R. beam

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Slide 73.

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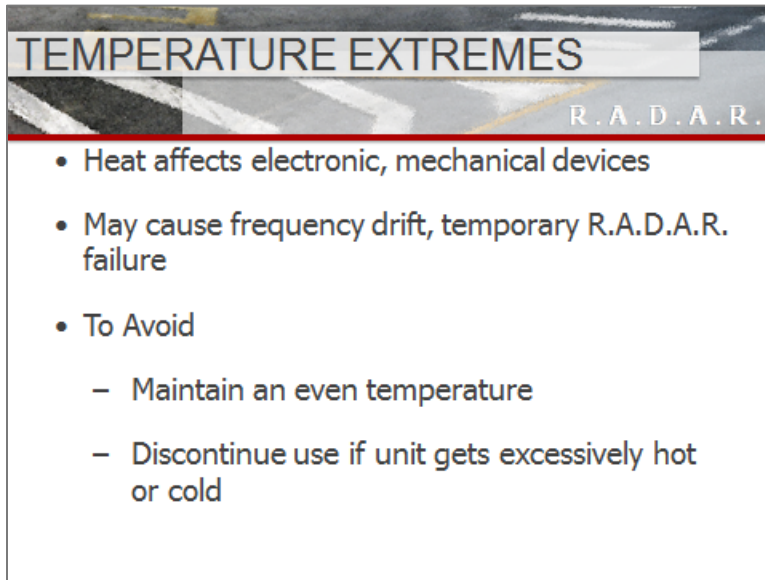
Some R.A.D.A.R. devices allow the operator to control the operational range of the device. This feature adjusts the sensitivity of the R.A.D.A.R. receiver to the strength of the reflected signal. It does not affect the strength of the transmitted R.A.D.A.R. beam - this remains steady.

Operational range control can be used to reduce target identification problems. A low setting will cause the R.A.D.A.R. to be sensitive to only very strong signals, thereby reducing its effective range. A high setting will cause the R.A.D.A.R. to be sensitive to very weak signals, thereby increasing its effective range. Experimentation at each enforcement location is necessary to obtain the optimum range. The range setting must be high enough to allow a significant tracking history to be obtained.

1. Set the sensitivity level at a low setting
2. Increase the sensitivity while watching vehicles until the optimum range is found for the location

For moving R.A.D.A.R., the sensitivity setting must be higher. The operational range control is only approximate. The control is usually designed to account for the "average" vehicle. Rain or snow will decrease the R.A.D.A.R.'s range slightly. Adjusting the R.A.D.A.R.'s range control, which affects only the sensitivity of the R.A.D.A.R. receiver, will not fool R.A.D.A.R. detectors, which monitor the unaffected transmission.

## TEMPERATURE EXTREMES



TEMPERATURE EXTREMES

R.A.D.A.R.

- Heat affects electronic, mechanical devices
- May cause frequency drift, temporary R.A.D.A.R. failure
- To Avoid
  - Maintain an even temperature
  - Discontinue use if unit gets excessively hot or cold

Slide 74.

R.A.D.A.R. devices may be sensitive to extremes of heat and cold. They may cause total failure or improper readings. Your set-up accuracy tests will tell you whether the devices are operating correctly.

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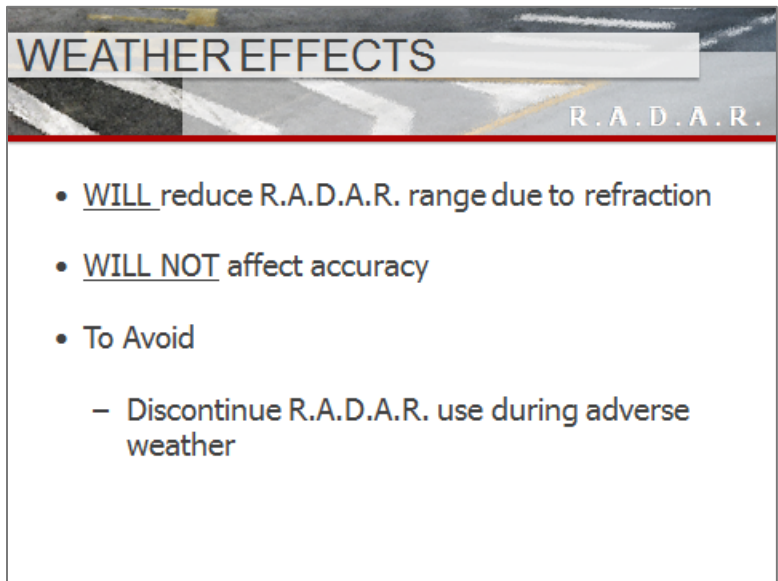
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## WEATHER EFFECTS



WEATHER EFFECTS

R.A.D.A.R.

- WILL reduce R.A.D.A.R. range due to refraction
- WILL NOT affect accuracy
- To Avoid
  - Discontinue R.A.D.A.R. use during adverse weather

Slide 75.

Rain, snow, and fog will cause R.A.D.A.R. beam scattering and refraction. The usual result is reduced range. Wet roadways may also cause the loss of the low Doppler signal thereby losing patrol speed, resulting in no reading. Adverse weather conditions also inhibit the acquisition of good tracking history.

## AUTOMATIC LOCK, AUTOMATIC ALARM

AUTOMATIC LOCK, AUTOMATIC ALARM
R.A.D.A.R.

- NOT ALLOWED IN NEW R.A.D.A.R. UNITS
- Should be deactivated in older units
- To avoid
  - DO NOT USE AUTOMATIC LOCK OR ALARM

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Slide 76.

DO NOT USE!

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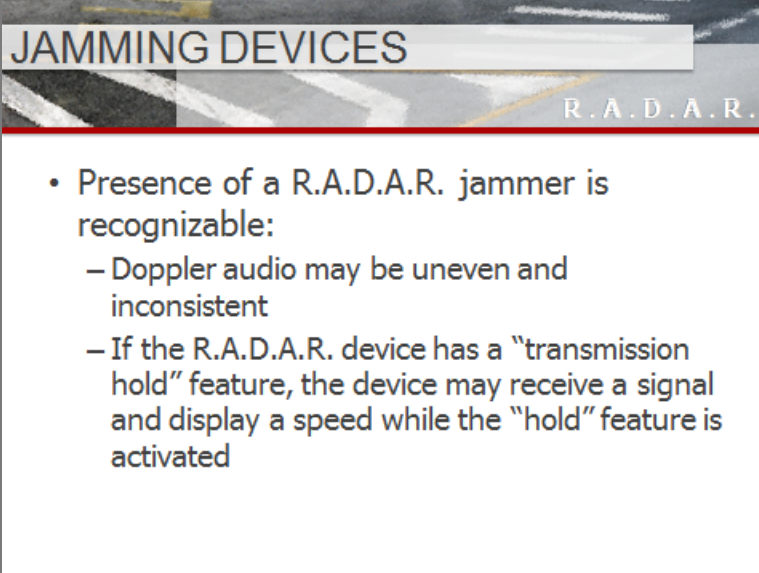
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## JAMMING DEVICES



**JAMMING DEVICES**

R.A.D.A.R.

- Presence of a R.A.D.A.R. jammer is recognizable:
  - Doppler audio may be uneven and inconsistent
  - If the R.A.D.A.R. device has a “transmission hold” feature, the device may receive a signal and display a speed while the “hold” feature is activated

Slide 77.

Attempting to create false or distorted signals is known as jamming. Jamming is rarely encountered. The primary types of jamming devices are L.I.D.A.R. and R.A.D.A.R. transmitters. A frequency transmitter sends out a strong signal with a frequency close to that of the police speed-measuring device.

- The device “sees” this signal instead of the signal reflected from the vehicle  
The speed-measuring device records either no speed measurement or an obviously inaccurate measurement
- The R.A.D.A.R. frequency transmitter, when used as a jamming device, violates FCC regulations
- Make sure of your legal ground before taking any enforcement action

The presence of a R.A.D.A.R. jammer is recognizable:

- If the Doppler audio is uneven or inconsistent
- If the R.A.D.A.R. device has a “transmission hold” feature, the device may receive a signal and display a speed while the “hold” feature is activated

Public misconceptions believed to be able to jam R.A.D.A.R.:

- Strips of metal foil on vehicle
- Hanging chains
- Metal objects in hubcaps
- Horn-honking

Estimated time for Chapter 5: 20 Minutes

## R. A. D. A. R.

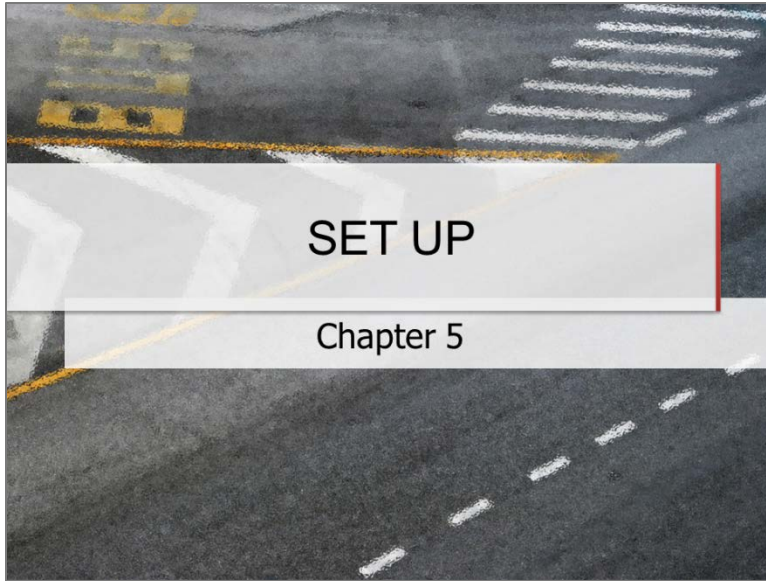
### » Objectives

By the end of this chapter, you will be able to:

- Set up R.A.D.A.R.

### » Contents

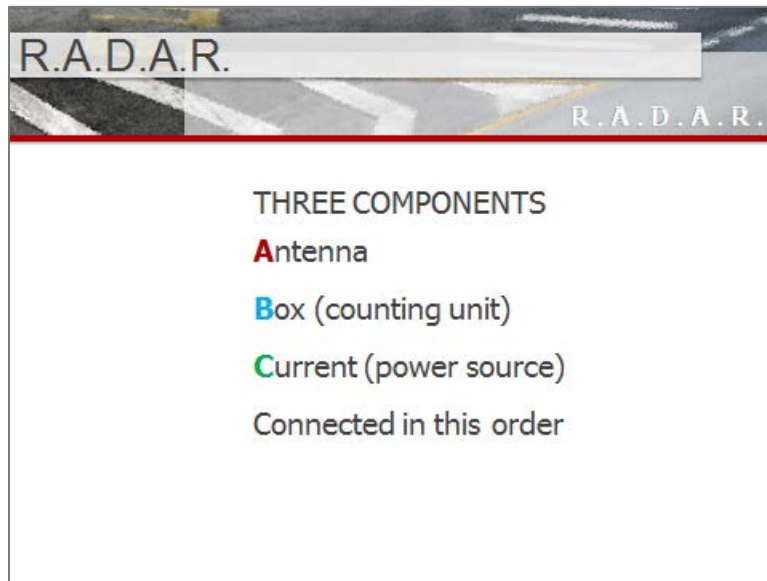
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Slide 78.



## R.A.D.A.R. INSTALLATION CONSIDERATIONS



Slide 79.

### Instrument Component Assembly

R.A.D.A.R. devices fall into two categories: one-piece and two-piece. A one-piece device has the R.A.D.A.R. antenna and the counting unit housed in a single component. Two-piece devices have separate components for antenna and counting unit.

The R.A.D.A.R. device's structure (one-piece, two-piece) and the manufacturer's recommendations will determine how and where it will be installed in the patrol vehicle.

(The safety of the patrol vehicle driver and passengers should be the paramount consideration). A poorly secured R.A.D.A.R. device can become a dangerous projectile in the event of any sudden change of patrol vehicle speed or direction. Since a two-piece R.A.D.A.R. device creates the most problems in installation, proper mounting of the counting unit and antenna must be discussed.

### General Operational Considerations

Most R.A.D.A.R. devices currently on the market require similar setup procedures. First you assemble and install the device components, then perform the required tests for accuracy. Chapter 5 will detail the exact procedures for the specific R.A.D.A.R.(s) you will use (there are differences among the various manufacturers devices and the exact procedures involved). However, certain procedures are common for all R.A.D.A.R. devices; this section will deal with those procedures.

# HANDHELD



Slide 80.

A one-piece device requires no component assembly. The device is merely plugged into a power source (typically a cigarette lighter) to be ready for use. However, always be sure that the device's power is turned off before plugging in the device. Leaving the switch on during plug-in can result in a blown fuse or damage to the device.

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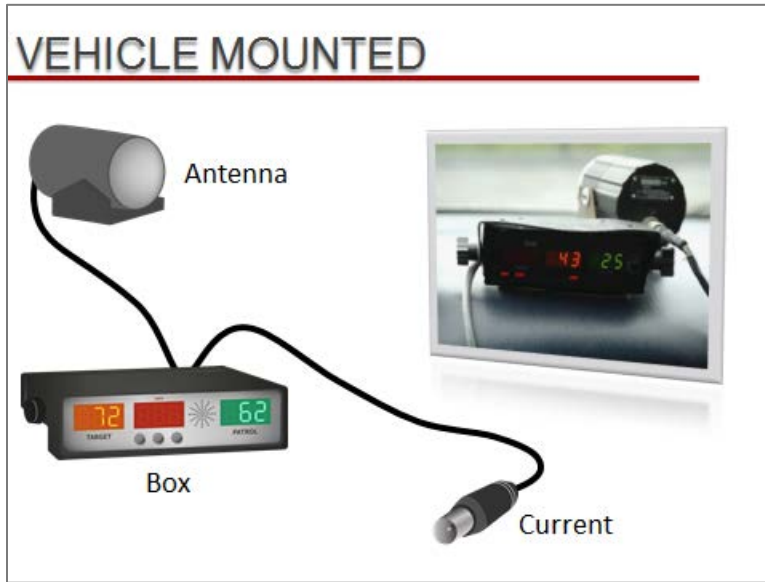
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## VEHICLE MOUNTED



Slide 81.

Two-piece devices require some component assembly. First, the antenna must be attached to the counting unit. This in turn is connected to the power source. The R.A.D.A.R. device may then be turned on. As with one-piece devices, failure to follow this sequence can result in a blown fuse or possible device damage.

### Mounting the Box (Counting Unit)

The size and shape of the counting unit component is likely to dictate where in the patrol vehicle it may be mounted. Usually, it is mounted on the dash or console. In any case, the safety of the mount, the visibility of the R.A.D.A.R. speed display(s), and whether the counting unit is obstructing the operator's vision are all factors to consider in mounting.

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## SETUP OF COMPONENTS

VEHICLE MOUNTED

R.A.D.A.R.

### Setup of Components

- Do not twist antenna and power cables together
- Follow A-B-C, making sure that power is turned on LAST
- Mount component securely

Slide 82.

A good method to recall this procedure is to think of it as the “A-B-C” of R.A.D.A.R. assembly:

- A-antenna
- B-box (counting unit)
- C-current

Make sure to use a power source in accordance with manufacturer requirements.

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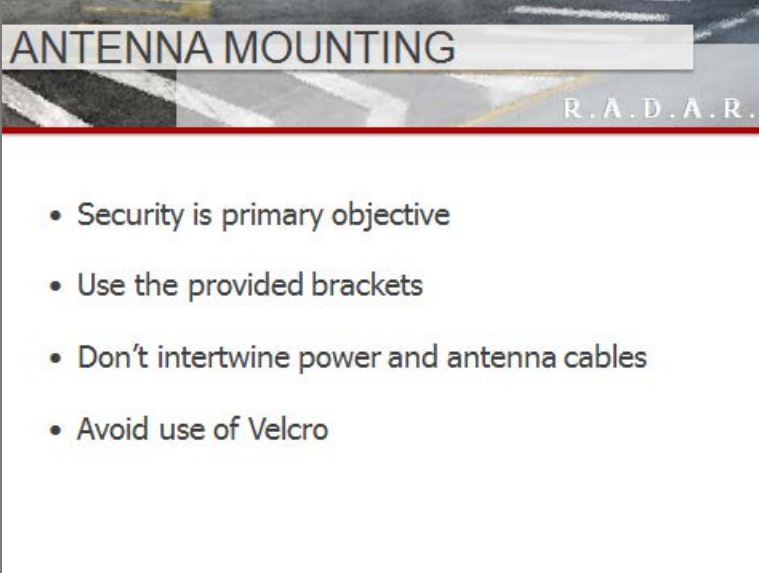
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## ANTENNA MOUNTING



ANTENNA MOUNTING

R.A.D.A.R.

- Security is primary objective
- Use the provided brackets
- Don't intertwine power and antenna cables
- Avoid use of Velcro

Slide 83.

The antenna may be provided with mounting brackets allowing inside dash mounting, outside window mounting, or sometimes both. The operator should be aware of the advantages and disadvantages of each type of antenna mounting. Again, the size and shape of the antenna will affect its mounting.

The primary advantage of mounting the antenna outside is that it is away from the potential areas of interference that may be generated inside the patrol vehicle. Its primary disadvantage is that the antenna may be exposed to inclement weather, which can cause increased maintenance problems. Few, if any, current antennas can be classified as weatherproof, although many are reasonably weather-resistant. It is strongly recommended that the antenna not be left outside in wet weather. Changes in temperature do not significantly affect the antenna. The possibility of the antenna being either accidentally or deliberately damaged when mounted outside must also be considered.

The antenna should be placed inside if the patrol vehicle will be unattended for any significant length of time.

The primary advantage of inside mounting is that you need not worry about inclement weather. The chances of vandalism and accidental damage are also minimized. The disadvantage of mounting the antenna inside is that there is more potential for interference within the patrol vehicle.

Dash-mounting the R.A.D.A.R. as close to the windshield as possible and maintaining the proper straight-ahead antenna alignment will significantly reduce the potential for interference.

The type of R.A.D.A.R. device (hand-held or two-piece), the mounting brackets available, the manufacturer's recommendations, and your agency's policies, will generally govern how you mount the antenna.

Basic guidelines include:

- Avoid mounting the antenna so that it is pointing at the operator or passenger
- Do not mount the antenna so that the counting unit is in the R.A.D.A.R. beam

### **Antenna Alignment**

With stationary R.A.D.A.R., the antenna can be aimed toward vehicles either approaching or going away from the R.A.D.A.R. When the antenna is aimed toward approaching traffic, the idea is to complete the speed measurement before the target vehicle reaches you.

When the antenna is directed toward receding traffic, the suspected speeding vehicle can pass the R.A.D.A.R.'s position and the idea is to make a speed measurement before it gets out of range.

Both antenna directions have their merits and there will be times and places where either one will be advantageous. It is important to understand that the stationary R.A.D.A.R. device will work equally well either way. Whether a target is approaching or receding has no effect on its speed relative to the R.A.D.A.R.

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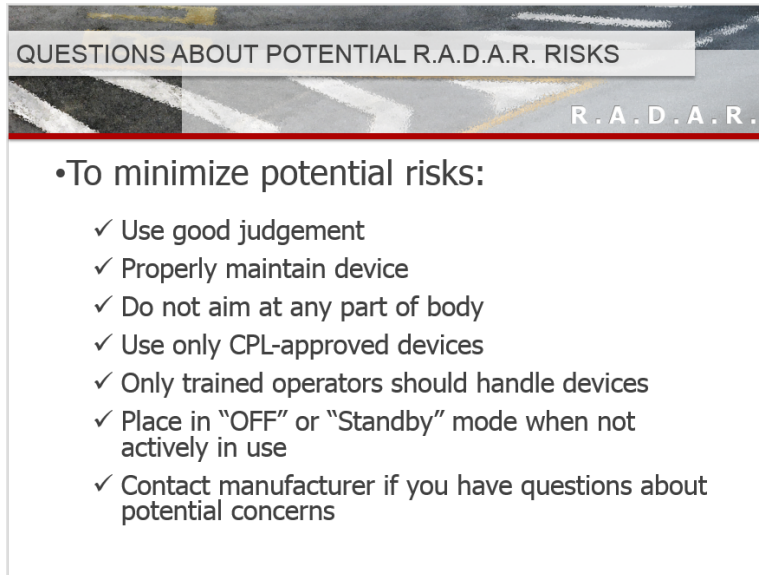
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## QUESTIONS ABOUT POTENTIAL R.A.D.A.R. RISKS



QUESTIONS ABOUT POTENTIAL R.A.D.A.R. RISKS

R . A . D . A . R .

- To minimize potential risks:
  - ✓ Use good judgement
  - ✓ Properly maintain device
  - ✓ Do not aim at any part of body
  - ✓ Use only CPL-approved devices
  - ✓ Only trained operators should handle devices
  - ✓ Place in "OFF" or "Standby" mode when not actively in use
  - ✓ Contact manufacturer if you have questions about potential concerns

Slide 84.

The potential risks of developing types of cancer from exposure to R.A.D.A.R. devices have periodically been studied for several years. Law enforcement officers face potential cancer risk through exposure not only to radiation, but to chemical compounds, sunlight, cell phones, tobacco use, and a host of other factors.

For many years, there have been concerns about cancer in general, and testicular cancer resulting from prolonged exposure to radiation from R.A.D.A.R. units laid on the lap of officers during periods of non-use.

Research into cancer risk and exposure for law enforcement officers has been, "sparse and subject to limitations in exposure assessment and other methods. Results from three studies suggested possible increased mortality risks for all cancers, and cancers of the colon, kidney, digestive system, esophagus, male breast, and testis, as well as Hodgkin's disease. Few incidence studies have been performed, and results have been mixed, although some associations with police work have been observed for thyroid, skin, and male breast cancer." <sup>1</sup>

Per the World Health Organization, "People who live or routinely work around R.A.D.A.R.s have expressed concerns about long-term adverse effects of these systems on health, including cancer, reproductive malfunction, cataracts and changes in

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<sup>1</sup> Wirth, M., Vena, J. E., Smith, E. K., Bauer, S. E., Violanti, J., & Burch, J. (2013). The Epidemiology of Cancer Among Police Officers. *American Journal of Industrial Medicine*, 56(4), 439–453. <http://doi.org/10.1002/ajim.22145>

behavior or development of children. A recent example has been the alleged increase in testicular cancer in police using speed control hand-held R.A.D.A.R. "guns." With respect to R.A.D.A.R. devices used by law enforcement, the World Health Organization indicates "**Speed control R.A.D.A.R.s** are handheld by police in many countries. The average output power is very low, a few milliwatts, and so the units are not considered hazardous to health, even when used in very close proximity to the body."<sup>2</sup>

Good judgement should be used in the handling and operation of any device that emits radiation. This includes traffic R.A.D.A.R. devices. Law enforcement officers should always operate the R.A.D.A.R. unit in accordance with the manual provided by the manufacturer and/or training provided in the use of the specific instrument. Some general guidelines for the handling and operation of R.A.D.A.R. include:

- Ensure devices are properly maintained
- Do not aim devices at any part of the body
- Use only CPL-approved devices
- Only trained operators should handle devices
- When not actively being used, place in "OFF" or "Standby" mode
- Contact the device manufacturer if there are questions about potential concerns

If there are questions about the safety associated with a R.A.D.A.R. device, use should be discontinued and the device taken out of service for maintenance and/or possible repairs by a qualified technician.

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<sup>2</sup> <http://www.who.int/peh-emf/publications/facts/fs226/en/>



# TESTING

Estimated time for Chapter 6: 10 Minutes

**R. A. D. A. R.**



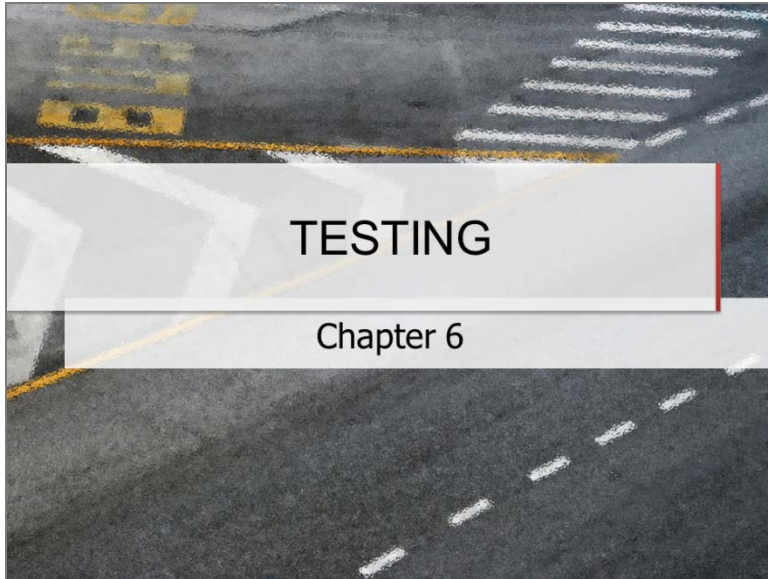
## » Objectives

By the end of this chapter, you will be able to:

- Perform function tests

## » Contents

Light Test .....	106
Internal Circuit Test .....	107
External Tuning Fork Test .....	108



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Slide 85.

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Over the years, procedures have evolved to test the accuracy of R.A.D.A.R. devices. Each device should be tested per the manufacturer’s specifications. Ideally, every device should be accompanied by a manufacturer’s operator manual.

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# LIGHT TEST

The slide features a header with the text 'LIGHT TEST' on the left and 'R.A.D.A.R.' on the right, set against a background of a road with white dashed lines. Below the header, there are three bullet points: 'All display indicators, lamps, etc. are tested', 'Usually display "8" (causes all seven segments to operate)', and 'All must function correctly'. At the bottom of the slide, a bold warning reads 'IF NOT, REMOVE FROM SERVICE UNTIL REPAIRED.'

Slide 86.

R.A.D.A.R.s must have a feature that allows the operator to test all the light segments on the R.A.D.A.R. display(s). A burned-out light segment could cause the operator to make a mistaken speed reading. If a burned-out segment is discovered, the R.A.D.A.R. device should be taken out of service and repaired. In some devices, this test and the internal circuit test are combined.

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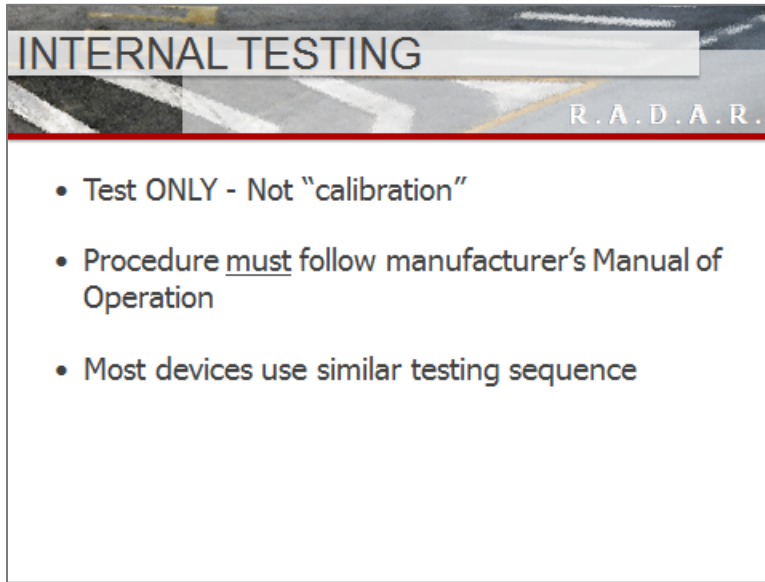
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## INTERNAL CIRCUIT TEST



INTERNAL TESTING

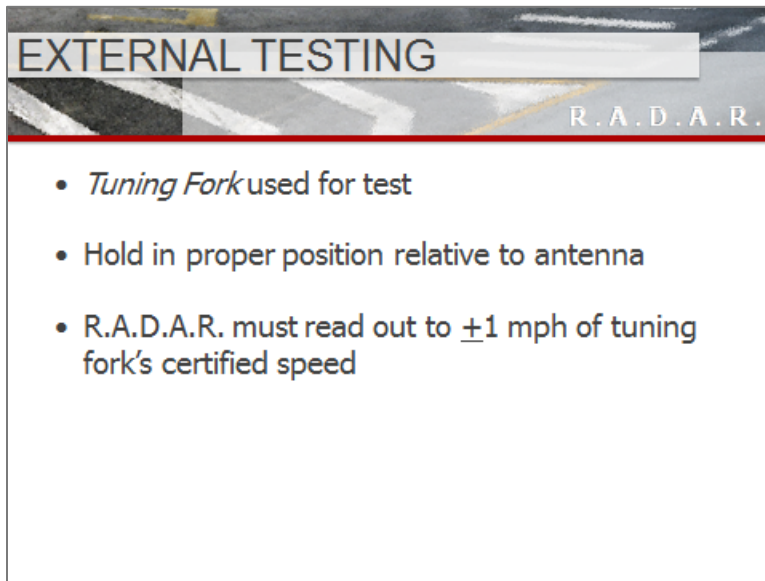
R.A.D.A.R.

- Test ONLY - Not "calibration"
- Procedure must follow manufacturer's Manual of Operation
- Most devices use similar testing sequence

Slide 87.

The internal circuit test (ICT) checks the circuits inside the counting unit. It should be noted that the internal circuit test checks only the counting unit, not the antenna. On most R.A.D.A.R. devices, the internal circuit test is performed by pressing a button and checking the displays to verify that a specific value appears. (Check operator's manual for the expected internal circuit test results). In all cases, the internal test is passed only if the proper number appears. If any other number is displayed, remove from service until repaired.

## EXTERNAL TUNING FORK TEST



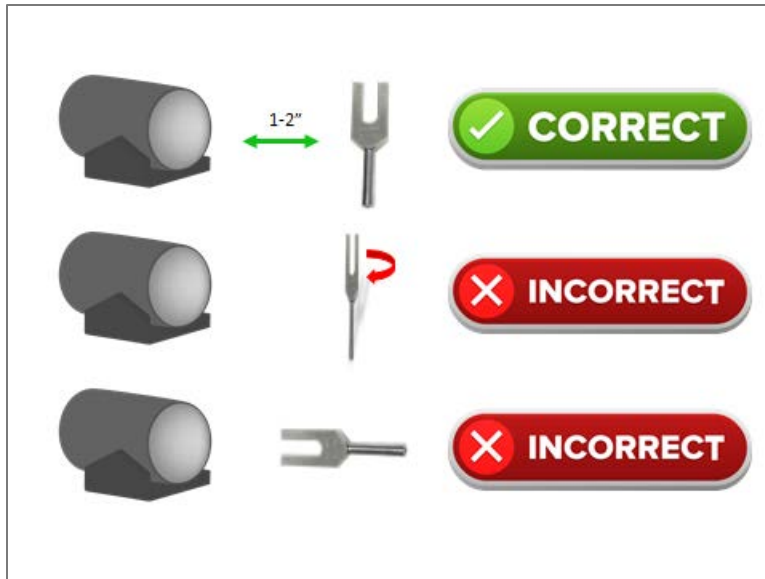
Slide 88.

The external tuning fork test checks both antenna and counting unit's ability to correctly process and display a simulated target speed.

To use the fork, grasp its handle and strike one of the tines against a firm surface. It is better to strike the fork against a surface that is reasonably firm but not as hard as the fork itself, such as the heel of your shoe or a padded steering wheel.

Striking the fork against a very hard surface, such as concrete or metal, may chip or break the fork. However, tests by the National Institute of Standards and Technology have shown that even a badly chipped fork will normally continue to vibrate properly and give accurate results.

Also, avoid striking the fork when the fork is extremely hot or cold. Extreme variations in temperature may cause an improper reading to be displayed. Holding the tuning fork comfortably in your bare hand will not affect the reading the R.A.D.A.R. displays. The allegation that a tuning fork being wet can affect the speed it displays on a R.A.D.A.R. device is without scientific basis.



Slide 89.

In preparing to perform the tuning fork test, point the R.A.D.A.R. antenna away from possible interference. If the antenna is pointed horizontally (i.e., toward any traffic) there may be interference with this test.

The actual distance the tuning fork is held from the antenna face is not critical, but one to two inches is accepted as optimum. The suggested procedure is to hold the fork so that the two tines line up one behind the other and only the side of one tine faces the antenna.

When you perform the tuning fork test, a speed measurement will appear on the R.A.D.A.R. device's display window. The speed measurement cannot differ from the fork's certified value by more than +1 miles per hour. For example, if you use a 65-mph fork to test the device's calibration, the test will be passed if the display does not read lower than 64 or higher than 66.

If the speed measurement should differ from the certified value by more than +1 miles per hour, the test should be repeated. If the deviation persists, remove the R.A.D.A.R. device from service until repaired.

Case law over the years has affirmed that using tuning forks is a valid check of a R.A.D.A.R. device's accuracy. Traditionally, only one tuning fork is needed to check a stationary R.A.D.A.R. device although local law or departmental policy may dictate using two or more forks.

For moving R.A.D.A.R., two forks are necessary. One tuning fork simulates a low-speed, usually 30- to 50-mph. The second tuning fork simulates a high-speed, usually between 60- and 90-mph.

Moving R.A.D.A.R. is checked by first striking the low-speed tuning fork and holding it in front of the antenna. This simulates the patrol speed in the patrol speed display window. A second, high-speed fork is then struck and held before the antenna. This simulates a closing speed. The second fork, presented in conjunction with the first fork, will simulate a target speed. The target speed should display the difference between the high and low-speed forks.

This process checks the R.A.D.A.R. device's ability to subtract the patrol vehicle speed from the closing speed (remember,  $TS=CS-PS$ ).

R.A.D.A.R. tuning forks must not be mixed between X-band, K-band, and Ka-band R.A.D.A.R.s. An X-band fork used to test a K-band R.A.D.A.R. (and vice versa) will not yield accurate results.

### **Patrol Speed Verification Test**

The R.A.D.A.R. tests for accuracy discussed so far (internal circuit test, light segment test, and external tuning fork test) apply to all traffic R.A.D.A.R. devices, moving and stationary. The final test, verification of the R.A.D.A.R. patrol speed readout against the patrol vehicle's certified speedometer, is required only for moving R.A.D.A.R. devices.

This check is to establish that the moving R.A.D.A.R. device is properly displaying the actual patrol vehicle's speed. The operator accelerates to a steady speed and compares the R.A.D.A.R.'s patrol speed readout with the patrol vehicle's certified speedometer. The speeds must correspond closely; if there is any noticeable deviation, the R.A.D.A.R. device should not be used.

It should be stressed that the R.A.D.A.R. device's failure to respond properly to any one of these tests calls for its immediate removal from service.

### **Subsequent Accuracy Tests**

It can be assumed that the R.A.D.A.R. device was working properly when a speed measurement was made if it can be shown that the R.A.D.A.R. device was working properly both before and after the measurement was made.

Law enforcement agencies must determine the minimum requirements for testing the R.A.D.A.R. devices as part of their standard practices and in response to case law applicable to its jurisdiction. Some general guidelines and suggestions can be offered here.

Agencies may require these tests be performed at least twice, at the beginning and end of the duty shift in which the R.A.D.A.R. is operated; they may occur more frequently.

# LEGAL CONSIDERATIONS

Estimated time for Chapter 7: 30 Minutes

**R. A. D. A. R.**

»» Contents

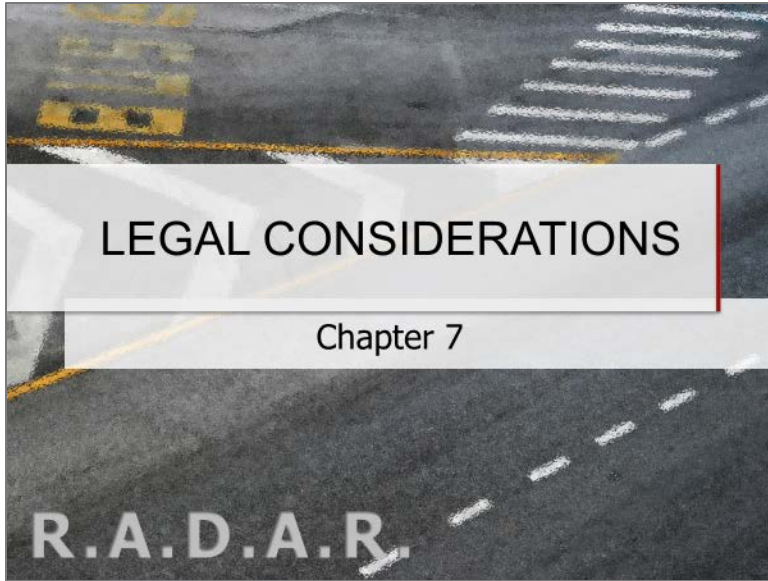
»» Objectives

By the end of this chapter, you will be able to:

- Discuss legal considerations pertaining to R.A.D.A.R.
- Discuss the requirements needed for citation documentation and/or courtroom testimony

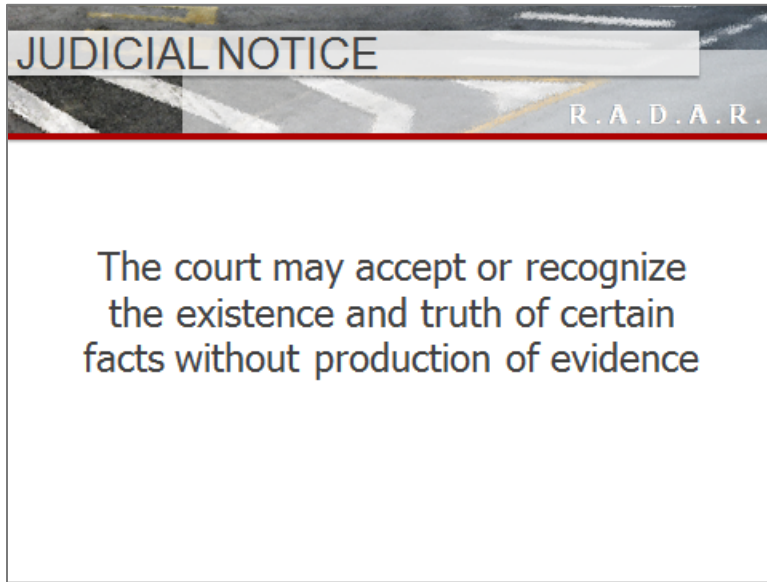
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## JUDICIAL NOTICE

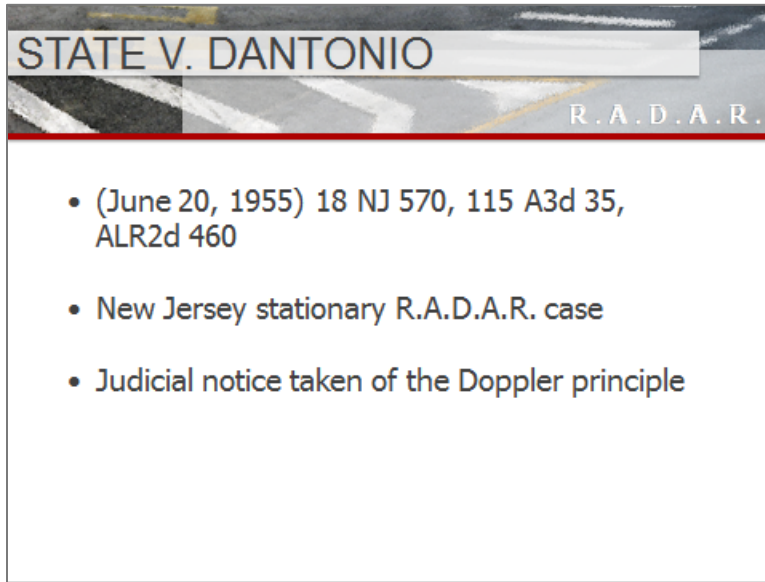


Slide 91.

The underlying operational principles must be shown to be scientifically reliable. Fortunately, these devices are receiving almost universal acceptance in court: some jurisdictions take judicial notice of their general suitability, but their scientific validity may need to be demonstrated in others. All courts may take judicial notice of the existence of certain conditions. To expedite the presentation of evidence, courts may recognize – or take “note” of – those facts or principles that are so widely known as to be familiar to reasonably well-informed people.

In the speed-measurement device context, for example, courts have commonly taken judicial notice of the existence of the Doppler effect – the principle underlying police R.A.D.A.R. – and of the underlying principles of devices, such as tuning forks, used to determine the accuracy and reliability of a speed-measurement device. Once the court takes judicial notice, no further proof of the issue is required.

## STATE V. DANTONIO, 1955



STATE V. DANTONIO

R.A.D.A.R.

- (June 20, 1955) 18 NJ 570, 115 A3d 35, ALR2d 460
- New Jersey stationary R.A.D.A.R. case
- Judicial notice taken of the Doppler principle

Slide 92.

Courts first took judicial notice of scientific principles underlying traffic R.A.D.A.R. in 1955. In *State v. Dantonio*, the New Jersey State Supreme Court first recognized the Doppler principle in the context of speed enforcement:

“The law does not hesitate to adopt scientific aids to the discovery of truth which has achieved such recognition... Since World War II members of the public have become generally aware of the wide-spread use of R.A.D.A.R. methods in detecting the presence of objects and their distance and speed...”

However, judicial notice does not relieve the prosecution of the burden of proving that at the time the defendant's speed was measured, the measurement device was working properly and the operator was using it properly.

## **Validity of underlying scientific principles: Frye-Standard**

If the jurisdiction has not yet taken judicial notice of the speed-measuring device's general validity, the prosecution must demonstrate the scientific validity of the device type before the operator can testify concerning readings obtained from the device.

Courts generally apply the Frye Standard – a test established in *Frye v. United States*, 293F. 1013 (D.C. Cir. 1923) – or variations of it. Proof must be offered, via expert testimony, that:

- The scientific principle that the device employs to measure speed is widely accepted in the scientific community  
For example, with R.A.D.A.R. devices, the prosecution must show that the Doppler Principle is an accepted scientific principle within the scientific community for measuring the speed of an object
  - With speed-measuring devices, it must be shown that the device used to measure a vehicle's speed employs an accepted scientific principle properly; and,
  - It must be shown that the speed-measuring device operator has been trained and followed the recommended operating procedures

## **Device condition**

It is not enough to offer in evidence the reading obtained from a speed-measuring device. It must be shown that the device was operating as designed when the reading was obtained.

This is universally recognized by the courts; in *Everight v. City of Little Rock*, the Arkansas Supreme Court took judicial notice of the principle underlying traffic R.A.D.A.R. but warned prosecutors and operators that case-specific proof would be required:

“We are of the opinion that the usefulness of R.A.D.A.R. device for testing [the] speed of vehicles has now become so well established that the testimony of an expert to prove the reliability of R.A.D.A.R. in this respect is not necessary. The courts will take judicial notice of such fact.

Of course, it will always be necessary to prove the accuracy of the particular device used in testing the speed involved in the case being tried.”

Defense attorneys often challenge the device's operation at the time the reading was obtained. Courts cannot take judicial notice that the device was working as designed – the prosecution must be prepared to demonstrate that the device was operating as designed immediately prior to, and immediately following, the time the reading was obtained. If the prosecution is successful, the trier-of-fact may infer that the device was working as designed when it detected the target vehicle's speed.

Courts may, however, take judicial notice of techniques and equipment used to determine that a device works as designed. Commonly called calibration devices, such equipment verifies that the device is, when tested, operating in the manner the manufacturer intended.

### **Operator Qualifications**

Defense attorneys often attack the operator's qualifications. Training and certification records must be kept ready for production in court.

#### *Training*

Defense attorneys typically challenge the adequacy of the complaining operator's training. The prosecution must be ready to demonstrate that training occurred and was adequate. Most courts follow the reasoning of the Kentucky Court of Appeals, in *Honeycutt v. Commonwealth*, and require only evidence that the operator knew basic operational procedures:

"It is sufficient to qualify the operator that [he/she] have such knowledge and training as enables him to properly set up, test, and read the device; it is not required that [he/ she] understand the scientific principles of R.A.D.A.R. or be able to explain its internal workings; a few hours' instruction normally should be enough to qualify an operator."

So, proof that the operator knew how to activate, read, and test the speed-measuring device, and followed its standard operating procedures, is usually sufficient.

*Certification*

Some jurisdictions have established certification requirements and required periodic recertification for operators of speed-measuring devices.

Successful prosecutions are impossible absent a certified or properly qualified operator. Evidence of adherence to all certification requirements and protocols will be required in Court.

Proof of a speeding violation follows a common scenario. First the operator must form a visual estimate of the driver's speed based upon experience and training in speed estimation. A violation must be under either a basic or statutory speed law. The operator's visual estimation can be corroborated by a variety of speed-measuring devices that include the speedometer, R.A.D.A.R., L.I.D.A.R., time-distance Systems (VASCAR), and/or automated speed-measuring devices.

Operator presentation of sufficient documentation of conditions, device reliability, driver statements, and proof of operator qualifications will often be sufficient for a conviction.

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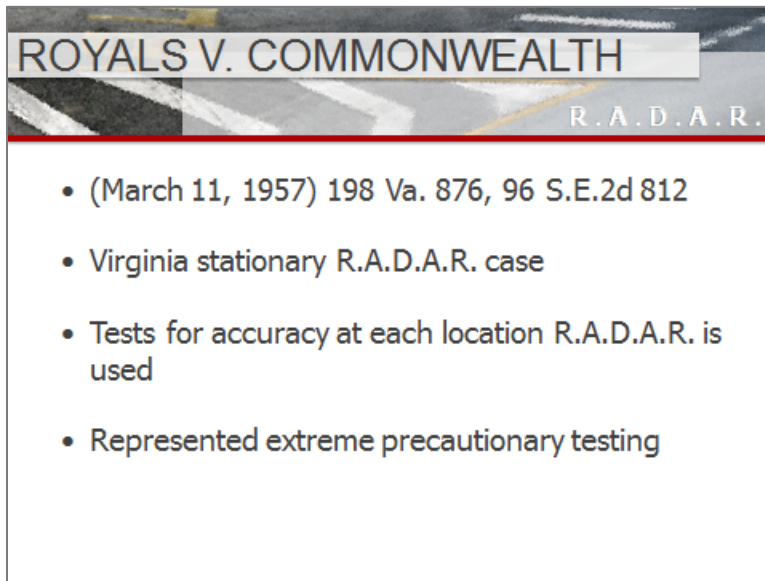
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## ROYALS V. COMMONWEALTH, 1957



ROYALS V. COMMONWEALTH

R.A.D.A.R.

- (March 11, 1957) 198 Va. 876, 96 S.E.2d 812
- Virginia stationary R.A.D.A.R. case
- Tests for accuracy at each location R.A.D.A.R. is used
- Represented extreme precautionary testing

Slide 93.

The accuracy of a R.A.D.A.R. device, as distinguished from the accuracy of the R.A.D.A.R. principle, is not a proper subject for judicial notice. No court can accept every R.A.D.A.R. device as always being completely accurate. The prosecution must prove that a device functioned properly at the time in question.

What the court may do is take judicial notice of certain methods or techniques for determining accuracy. It can reasonably be assumed that if a device was checked for accuracy at various established intervals and through accepted methods, that device's readings would be accepted as accurate.

In *Royals v. Commonwealth of Virginia*, the court quoted, with approval, Dr. John M. Kopper, a recognized authority on electronics:

"It is important to check the meter for accuracy each time it is set up for use; if the meter is to be used at two sites in one morning then it should be checked at each site to avoid the contention that the meter was thrown out of adjustment during transit. The meter should be checked before the beginning of the period of observation of highway and at the end of the period. In scientific work, it is usual to assume that if a given device reads correctly at the beginning and end of a set of measurements, its readings during the interval were also correct. The check can be made by having a vehicle with a certified speedometer run through the zone of the meter twice, once at

the speed limit for the zone and once at a speed 10 or 15 miles per hour greater. As the test vehicle goes by the meter the driver can notify the operator of the meter what [the] speed is. If the difference between the speedometer reading and the R.A.D.A.R. meter reading is more than 2 miles per hour, steps should be taken to see why this is the case and to remedy the matter. Such a test naturally requires a periodic checking of the speedometer of the test vehicle. If such a procedure is carried out each time the R.A.D.A.R. meter is set up, the check measurements made with the automobile speedometer become supporting evidence.”

These steps, however, represented the extreme in precautionary testing.

Although few operators test speed-measuring devices in such fashion today, the testing theory remains valid. Frequent accuracy checks improve cases. Devices should be checked at the beginning and the end of the operational period. Some courts and agencies require that devices be checked following each enforcement action. A Tuning fork, which cause R.A.D.A.R. devices to display a specific result, is an acceptable accuracy-checking device. Courts may require proof that the device was working properly.

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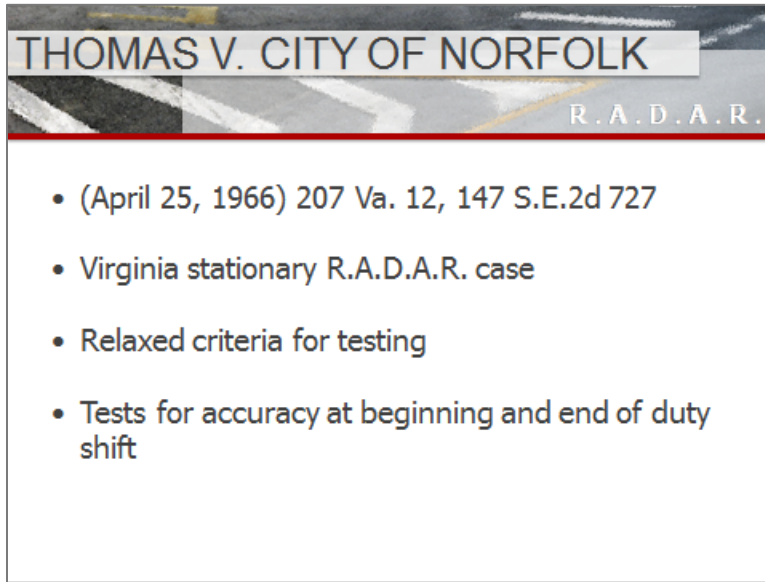
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## THOMAS V. CITY OF NORFOLK, 1966



THOMAS V. CITY OF NORFOLK  
R.A.D.A.R.

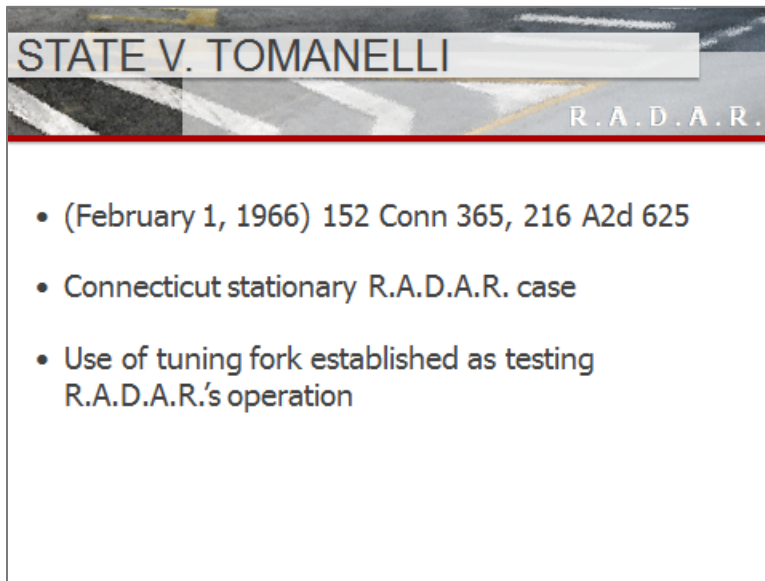
- (April 25, 1966) 207 Va. 12, 147 S.E.2d 727
- Virginia stationary R.A.D.A.R. case
- Relaxed criteria for testing
- Tests for accuracy at beginning and end of duty shift

Slide 94.

In **Thomas v. City of Norfolk**, the court indicated that it would be sufficient to test the R.A.D.A.R. device at the beginning and end of each duty shift. If the device tested properly at these times, it could be presumed to have functioned properly between times.

Many agencies instruct their R.A.D.A.R. operators to conduct the tests as part of both the setup and tear down at each place they make R.A.D.A.R. measurements. This ensures that the before and after tests are made within a reasonable time of any speed measurement and enforcement action. It also eliminates any possibility that the R.A.D.A.R. might malfunction in transit between locations.

## STATE V. TOMANELLI, 1966



STATE V. TOMANELLI

R.A.D.A.R.

- (February 1, 1966) 152 Conn 365, 216 A2d 625
- Connecticut stationary R.A.D.A.R. case
- Use of tuning fork established as testing R.A.D.A.R.'s operation

Slide 95.

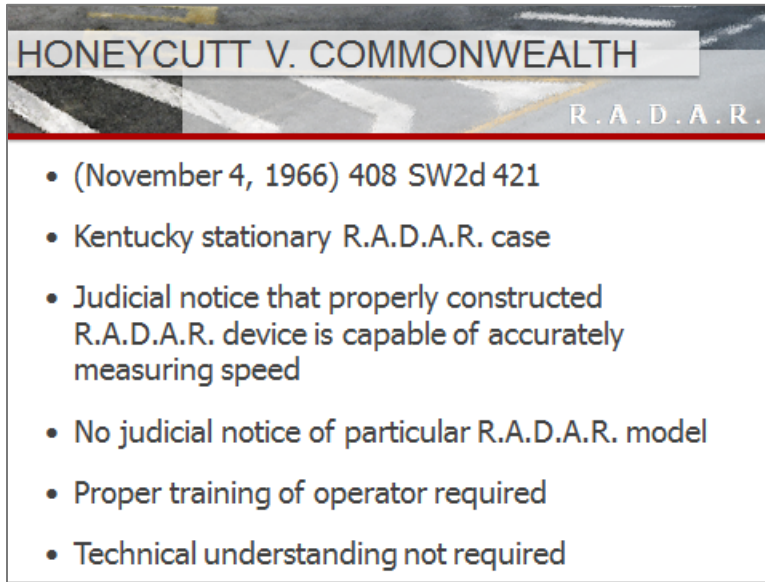
The use of a tuning fork is an efficient, convenient, and popular method of testing a R.A.D.A.R. device's accuracy. The use of the tuning fork as a reliable test of accuracy was established by the Supreme Court of Connecticut in *State v. Tomanelli*. However, the court pointed out that the tuning fork's own accuracy may be questioned:

"The operator relied, for his assurance on the accuracy of the device he was using, on tuning fork tests made before and after the defendant's speed was recorded. These tests, in brief, were made by activating what were described as 40-, 60-, and 80-mph tuning forks and by observing, in each test, that the speedometer and graphic recorder of the R.A.D.A.R. device indicated corresponding readings of 40-, 60-, and 80-mph.

The theory of the test is that each tuning fork is set to emit a wave frequency corresponding to a mile-per-hour speed equivalent. It is obvious that the tuning forks themselves must be shown to be accurate if they are to be accepted as a valid test of the accuracy of the R.A.D.A.R. device. No attempt appears to have been made to establish the accuracy of the tuning forks. On the other hand, no effort was made by the defendant to attack the accuracy of the tuning forks.... Under these circumstances the accuracy of the R.A.D.A.R. device was unimpeached."

In effect, the courts have recognized the tuning fork as an accurate testing device. If no challenge is offered, the tuning fork's accuracy may be assumed and therefore the accuracy of any R.A.D.A.R. device properly tested by that tuning fork.

## HONEYCUTT V. COMMONWEALTH, 1966



HONEYCUTT V. COMMONWEALTH  
R.A.D.A.R.

- (November 4, 1966) 408 SW2d 421
- Kentucky stationary R.A.D.A.R. case
- Judicial notice that properly constructed R.A.D.A.R. device is capable of accurately measuring speed
- No judicial notice of particular R.A.D.A.R. model
- Proper training of operator required
- Technical understanding not required

Slide 96.

The courts seemed to have had little difficulty in outlining the R.A.D.A.R. operator's qualifications. In *Honeycutt v. Commonwealth*, the Kentucky Court of Appeals defined them clearly:

"It is sufficient to qualify the operator that he [sic] have such knowledge and training as enables him to properly set up, test, and read the device; it is not required that he understand the scientific principles of R.A.D.A.R. or can explain its internal workings; a few hours' instruction normally should be enough to qualify an operator.... In the instant case the policeman had received 13 weeks training as a R.A.D.A.R. repairman and had operated R.A.D.A.R. device for almost 2 years. We think this was sufficient qualification to make his testimony competent. A reading of his testimony indicates that he understood how to operate the device."

The courts thus established that a R.A.D.A.R. operator need be neither technician nor physicist.

It is not important whether the operator fully understand everything about a R.A.D.A.R. device's internal workings.

The courts also established that the targeted vehicle be out front, closest, and well separated from the other vehicles on the roadway at the time of the speed measurement. Honeycutt also established that the R.A.D.A.R. operator will have made a visual estimate of the target vehicle speed.

### ***Sufficient Time of Observation***

The vehicle must have been observed for enough time to identify it specifically and to identify it as the speeding vehicle. Testimony must persuade the trier-of-fact that the observation period was long enough to allow the operator to identify the vehicle as the "right" one.

### ***Sufficient Circumstances***

The operator must have observed the vehicle under circumstances that render sufficient identification possible. The operator's testimony may need to include details permitting the trier-of-fact to find that the identification was reasonable: for example, operators must be ready to explain how they identified a speeding vehicle at night.

### ***Traffic density***

The defense may challenge the operator's identification of the target vehicle by claiming that traffic was too dense to permit proper target recognition.

### ***Attorneys may ask:***

1. How dense was surrounding traffic?
2. Was the speeding vehicle surrounded by vehicles? If so, were they smaller, the same size, or much larger?
3. How many vehicles were near the vehicle?
4. If other vehicles were near, how could the defendant's vehicle be singled out and identified as speeding?

***When vehicle identification is challenged, many courts require proof that:***

Visual observation suggested that the vehicle was speeding. The operator must testify that when he/she first saw the vehicle, it appeared to be speeding. This may require testimony indicating the operator had experience “visually estimating” speed violations, such as training in that technique and subsequent field experience.

Device-based measurement confirmed the initial suspicion. The operator must testify that he/she verified the suspicion by obtaining a timely device-based (i.e., R.A.D.A.R., VASCAR, L.I.D.A.R., TDS, stopwatch) reading on the target vehicle.

He/She should be ready to demonstrate that standard operating procedures and applicable regulatory protocols were followed (if any exist in the charging jurisdiction) and that there were minimal interfering conditions.

Sufficient tracking history - The operator should be able to show a good tracking history. In essence, that he/she obtained an initial visual estimation and a subsequent device-based verification and then “tracked” the vehicle visually and by device to affirm his/her initial findings. For example, the Audio Doppler feature available on some R.A.D.A.R. units can strengthen tracking history evidence.

***Vehicle characteristics***

Operators must be able to identify the target vehicle by its external characteristics.

Operators may typically be asked:

1. What characteristics or factors facilitated the identification?
2. Was the vehicle damaged?
3. Could distinctive noises be heard?
4. Was exhaust present?
5. What color was the vehicle?
6. Did it “stand out in the crowd?”
7. What was its make and model? How did you know?

### *Lighting conditions*

Operators may be asked:

1. Lighting conditions may affect operators' ability to identify the target vehicle.
2. Was it light or dark?
3. If it was dark, how was the vehicle readily identified?
4. Was the sun in the operator's eyes? If so, how could he/she identify the target vehicle?
5. Was the sun in the driver's eyes? If so, was the speed reasonable?

### *"Turn-around" and "catch-up" time*

Some delay is inherent in speed enforcement. Operators using stationary devices must start from a stopped position and catch up to the target. Operators using "moving" devices, such as moving R.A.D.A.R., must slow, turn around, and then catch up to the target.

Defense attorneys frequently ask these questions when challenging identification:

1. How long did it take to turn the police car around to pursue the speeding vehicle?
2. How long did it take to catch up?
3. If a turn-around was necessary, did the operator lose sight of the target vehicle?
4. If the operator lost sight of the target, how long was visual contact lost?
5. Did the operator identify characteristics of the target before the turn-around?

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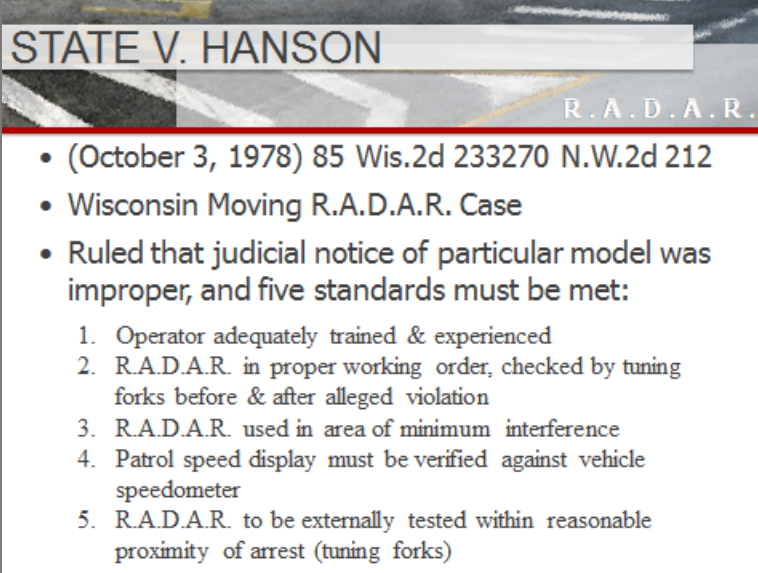
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## STATE V. HANSON, 1978



**STATE V. HANSON**  
R.A.D.A.R.

- (October 3, 1978) 85 Wis.2d 233270 N.W.2d 212
- Wisconsin Moving R.A.D.A.R. Case
- Ruled that judicial notice of particular model was improper, and five standards must be met:
  1. Operator adequately trained & experienced
  2. R.A.D.A.R. in proper working order, checked by tuning forks before & after alleged violation
  3. R.A.D.A.R. used in area of minimum interference
  4. Patrol speed display must be verified against vehicle speedometer
  5. R.A.D.A.R. to be externally tested within reasonable proximity of arrest (tuning forks)

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Moving R.A.D.A.R. presents special problems in vehicle identification because the speed of the patrol vehicle itself enters the picture. In effect, when moving R.A.D.A.R. is used, the courts demand that the officer verify both the defendant's vehicle speed and that of the patrol vehicle at the time of the violation.

In 1978, in the landmark case of State v. Hanson, the Wisconsin Court addressed several issues on the use of moving R.A.D.A.R. As with earlier case law, Hanson affirmed that:

- The operator must have sufficient training and experience in the operation of moving R.A.D.A.R.
- The moving R.A.D.A.R. device must have been in proper working condition when the violation took place

Of major interest was the court's ruling that the officer must establish that:

- The moving R.A.D.A.R. device was used where road conditions would distort readings as little as possible
- The patrol vehicle's speed was verified
- The device's accuracy was tested within a reasonable time before and after the arrest

## PROVING THE SPEED LAW VIOLATION IN COURT

PROVING THE SPEED LAW VIOLATION IN COURT

R.A.D.A.R.

- Each and every specific element of the charged offense must be established
- Core Elements of Proof
  - Driver
  - Vehicle
  - Time
  - Venue

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Obtaining a conviction for a traffic violation is like obtaining one for a criminal violation. Each specific element of the charged offense must be established. In cases charging speed law violations, this is true regardless of whether the Basic or Statutory Rules is charged and regardless of the type of device used to measure the speed.

### **Core Elements of Proof: Driver, Vehicle, Time, Venue**

The prosecution must prove through the testimony of the complaining operator that a specific driver drove a specific vehicle at a specific time and place. These elements are customarily proven from traffic citations upon which the complaining operator has detailed the critical information. The operator uses the information to refresh his/her recollection of the events. Accordingly, it is critical to review the citation before testifying.

#### ***Driver - Defendant***

(1) The driver charged with a speed law violation is the defendant. Prove his/her identity and that the operator stopped the vehicle and identified the driver as the defendant and that he/she was driving at the time the operator observed the violation. When the case comes to trial, the operator must identify the defendant as the same person he/she identified as the driver during the stop.



(2) Operators should note the driver’s remarkable characteristics: i.e., facial hair, unique hairstyles, scars, marks and tattoos, to aid in court identification. Because drivers sometimes switch places with passengers to avoid enforcement action, noting such characteristics as soon as a violation is observed, but prior to turnaround, should aid initial identification.

**Vehicle**

(1) Prove that a vehicle, as defined by the traffic code used in the charging jurisdiction, was used to commit the offense.

**Time and Venue**

(1) Prove that the driver drove the vehicle at a time and place. In most jurisdictions, speed laws apply only on roadways (as defined in the relevant traffic code); however, some jurisdictions also limit speeds in other areas, such as private property.

**Sufficient Observation**

The operator must be prepared to demonstrate that he/she observed the vehicle for enough time, and under sufficient circumstances, to form an opinion concerning its speed.

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## STAFFORD V. KARMANN, 1978

STAFFORD V. KARMANN

R.A.D.A.R.

- (April 28, 1978) 2 Kan.App.2d 248, 577 P.2d 836
- Kansas law
- An operator's testimony is admissible as "lay opinion" even if he/she cannot be considered an expert in the field, upon a proper showing of foundation

Slide 99.

### Opinion Concerning Speed

The operator must present an opinion regarding the alleged speed. However, opinion evidence, in the form of the operator's testimony, is inadmissible without a proper showing of foundation. In other words, the operator must demonstrate that he/she has some experience or training upon which to base the opinion. Courts generally find that opinion testimony may be based on foundation consisting of experience driving a vehicle, training, basis of knowledge, and sufficient observation.

An operator's testimony is admissible as "lay opinion" even if he/she cannot be considered an expert in the field, upon a proper showing of foundation. Some jurisdictions require lay testimony be rationally based upon the witnesses' observation and helpful to a clearer understanding of his/her testimony.

These factors may bear upon the admissibility of an operator's opinion:

#### *Observation Time*

How long did the operator observe the vehicle?

#### *Experience*

How much experience does the operator have in speed estimation/measurement? Was this the operator's first speed enforcement experience or has he/she been involved in speed enforcement for some time?

***Training***

How much speed enforcement training, if any, has the operator received? Was formal training successfully completed?

***Certification***

Some jurisdictions require operators to hold current certification on speed-measuring devices. In these jurisdictions, the prosecution must prove that the complaining operator held current certification at the time the operator detected the charged violation.

***Perception***

Was the operator able to accurately perceive the vehicle? What is the operator's visual acuity?

**Speed Exceeded Lawful Speed**

The prosecution must prove that the defendant's speed violated the basic speed rule or a statutory speed law.

**Measurement Device and Operator Considerations**

Attacking the device used to measure the defendant's speed, and the operating operator's use of that device, are favorite methods for defense attorneys. Operators must be prepared to demonstrate that the device was suitable for the speed measurement, that the device was in proper working order when the defendant's speed was measured, and that the operator was qualified to use the device.

***Device Suitability***

R.A.D.A.R., L.I.D.A.R., time-distance (VASCAR, etc.) devices, and even stopwatches share a characteristic critical to successful speed violation prosecutions. Each must be shown to be suitable for the task of measuring vehicle speed.

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## MOOT COURT DISCUSSION (20 Minutes)

This practicum provides practical experience in prosecuting a R.A.D.A.R. speeding citation.

The preparation and presentation of the R.A.D.A.R. case for prosecution is the final step in the enforcement process. Each element must be present to be successful in court. This practicum will address elements necessary for the preparation of a R.A.D.A.R. speeding case.

The preparation of a R.A.D.A.R. case is no different from any other case. There are certain requirements that must be met or else the case will either be dismissed or will otherwise fail.

The preparation of the case follows a natural sequence so that the presentation phase is complete, concise, and correct. This exercise provides detail of the required elements in a typical case. Each jurisdiction should make sure that these elements meet the requirements of the local courts and make amendments or additions, as necessary.

Generally, the preparation of the case must ensure:

1. That all elements of the offense were present
2. That the speed-measuring device was utilized in compliance with appropriate law

Establishing the elements of the offense requires that the officer can show that certain requirements are met with regards to the location, officer, R.A.D.A.R. device, speeding vehicle and violator.

- The officer was working in a location which was within his/her jurisdiction of authority and that the alleged violator was also in that jurisdiction
- The alleged violation occurred where the public has a right of vehicular access
- The roadway in use by the alleged violator was marked or signed as required by State and/or local law
- The officer's location provided a clear and unobstructed view of the enforcement area, observed the violation, and made a visual estimate of the violator's speed based on that observation

- The officer, based on his/her training and experience, believed that the violator's speed exceeded the marked or signed statutory limit (or, basic speed under the conditions)
  - The officer has had the required formal R.A.D.A.R. training (qualification or certification)
  - The officer has sufficient experience and expertise in the use of R.A.D.A.R. and specifically in the particular device used
  - The R.A.D.A.R. device and its tuning fork(s) hold a current and valid certification of accuracy from an appropriately licensed R.A.D.A.R. technician
  - The R.A.D.A.R. device was set up and tested prior to its enforcement use using the manufacturer's recommended procedures (operator's manual) and that the device "passed" the operational tests therefore demonstrating that the device was operating properly
  - The R.A.D.A.R. device was tested at the end of its use and that the device was operating properly

**Note:** The recommended minimum testing interval is at the beginning and the end of the officer's duty shift. Agency or officer policy will determine the actual testing frequency, which may be more often, such as before and after each violator contact.

- The vehicle stopped was the same vehicle that the officer first observed and estimated its speed and subsequently measured its speed with the R.A.D.A.R. device
- The operator of the speeding vehicle was properly identified through accepted identification documents, i.e., driver's license, I.D., other
- The vehicle operator so identified was issued a citation, ticket, notice of infraction, etc.

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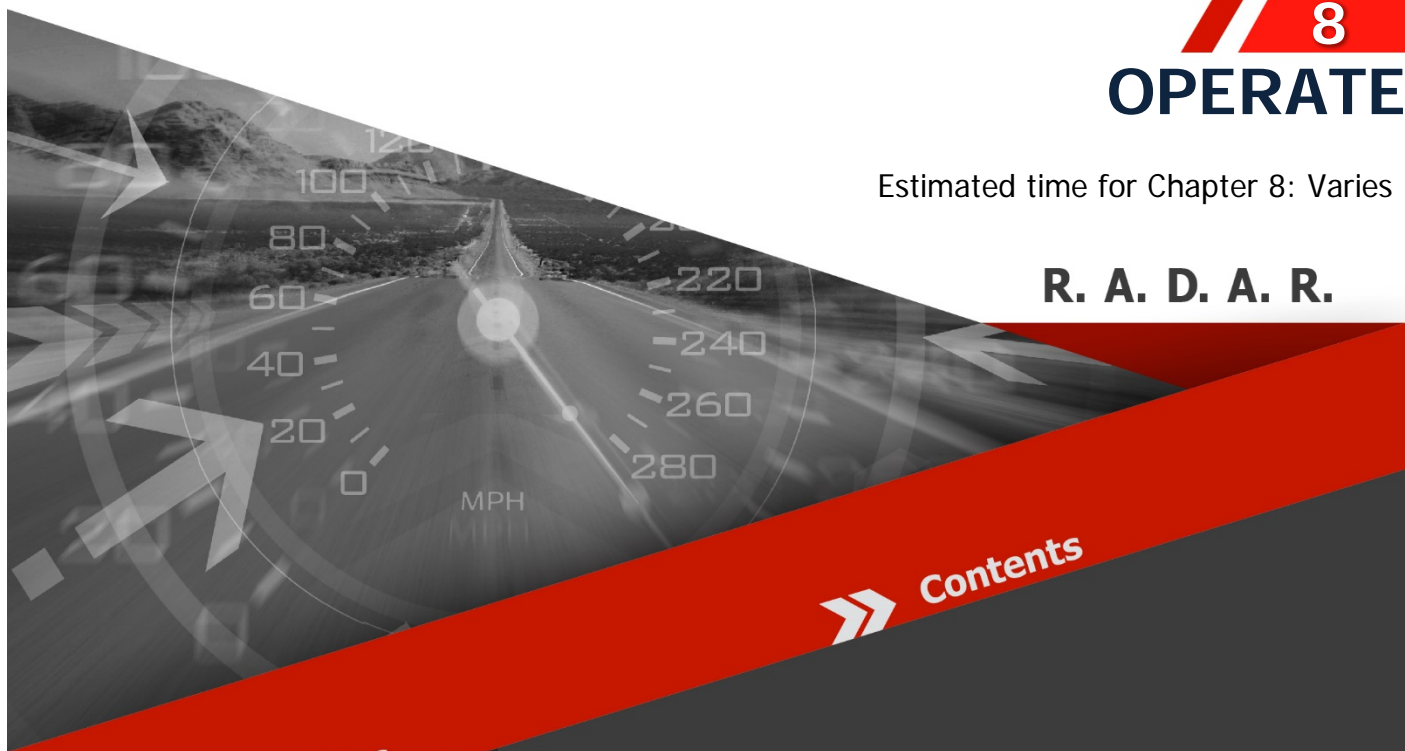
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Estimated time for Chapter 8: Varies

**R. A. D. A. R.**



**Objectives**

**Contents**

By the end of this chapter, you will be able to:

- Operate a R.A.D.A.R. speed-measuring device

Operator Practicum ..... 134

## OPERATOR PRACTICUM

**Note:** This is a perishable skill and individuals should practice occasionally. The operator should be acclimated to location prior to enforcement.

This purpose of this practicum is to give you the opportunity for hands-on practice with similar R.A.D.A.R. device(s) you will be using in your department.

Remember the most important criterion in this practicum is your safety, the safety of other students and of the motoring public.

Each student will take turns as the student driver/operator.

Begin by setting up the unit and running through its various testing procedures. You must follow all approved operating procedures that would be taken in actual patrol situations.

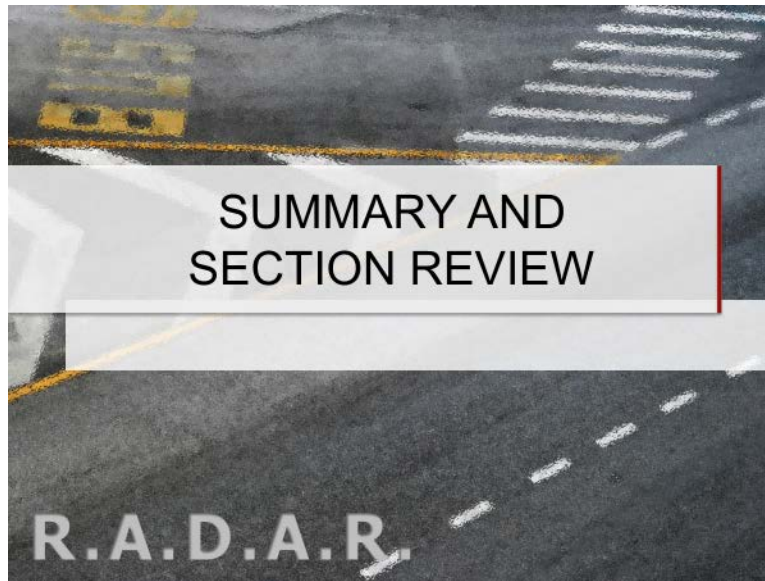
After setting up and testing the R.A.D.A.R. device, you will be allowed time for at least 20 practice target readings for each applicable mode.

You should feel free to ask questions during your hands-on training (e.g., about false or "ghost" readings, interference, the panning effect).

Keep in mind and point out various elements of supportive evidence to the instructor as they arise. The various elements of supportive evidence include visual estimate, audio Doppler, R.A.D.A.R. reading, and speedometer verification needed to develop a tracking history for each target vehicle.

You should evaluate other group members for any actions you consider inappropriate or inaccurate. You should disassemble and dismount the unit per your agency guidelines at the end of your turn. The groups will return to the classroom after everyone has had turns as driver/operator.

## SUMMARY AND SECTION REVIEW



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Slide 100.

## POSTTEST



## FREQUENCY FORMULA

Frequency x Wave Length = The Speed of Light

The speed of light as measured by National Institute of Standards and Technology, (NIST), is 186,282.396 miles per second.

There are 63,360 inches in a mile.

Most wavelengths can more easily be visualized in fractions of an inch than in fractions of a mile. Therefore, you must convert miles per second to inches per second. This is done by multiplying by 63,360 or dividing by 63,360 depending on which conversion you are attempting to make.

### Examples:

K-band:

$$\text{frequency} * \frac{\text{wavelength}}{\# \text{ of inches in a mile}} = \text{speed of light}$$

$$24,150,000,000 * \frac{.488729918 \text{ in}}{63,360 \text{ in}} = 186,281.999 \text{ miles per sec}$$

$$\frac{\text{speed of light} * 63,360}{\text{frequency}} = \text{wavelength}$$

$$\frac{186,282 * 63,360}{24,150,000,000} = .488729918 \text{ in}$$

## BEAM WIDTH COMPUTATIONS

$$BW = 2D \left( \tan \frac{1}{2} \angle \right)$$

	( $\angle$ ) TRANSMISSION ANGLE	( $D$ ) DISTANCE	( $BW$ ) BEAM WIDTH
1.	12°	105	FT.
2.	12°	286	FT.
3.	16°	116	FT.
4.	16°	306	FT.
5.	18°	96	FT.
6.	18°	319	FT.
7.	24°	84	FT.
8.	24°	510	FT.
9.	9°	686	FT.
10.	9°	544	FT.
11.	12°	1467	FT.
12.	24°	1270	FT.
13.	9°	1619	FT.
14.	18°	1598	FT.
15.	16°	1321	FT.

## DOPPLER SHIFT COMPUTATIONS

Compute the correct speeds in miles per hour given the following Doppler shift.

K- Band Transmitted Signal: 24,150,000,000 CPS

*Difference = Transmitted – Returned*

To calculate Doppler shift to speed:  $72\text{CPS} = 1\text{mph}$

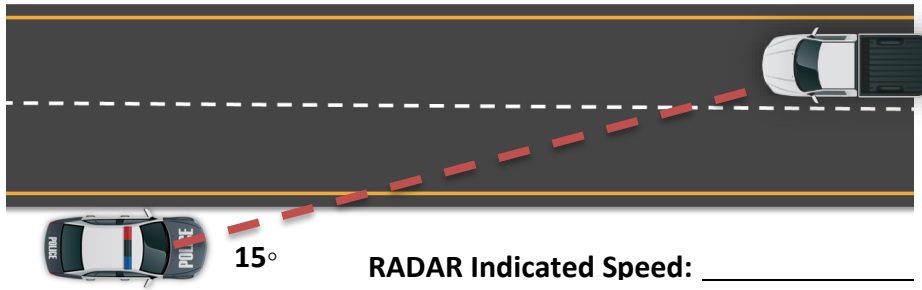
Example:  $3000 \div 72 = 41\text{mph}$

	<b>Returned Signal</b>	<b>Difference</b>	<b>Miles Per Hour</b>	<b>Toward or Away</b>
1.	24,150,002,880	2880 CPS		
2.	24,149,998,488	1512 CPS		
3.	24,150,005,616	5616 CPS		
4.	24,150,003,960	3960 CPS		
5.	24,149,994,816	5184 CPS		
6.	24,149,992,362			
7.	24,150,008,280			
8.	24,149,996,760			
9.	24,149,990,280			
10.	24,150,010,800			

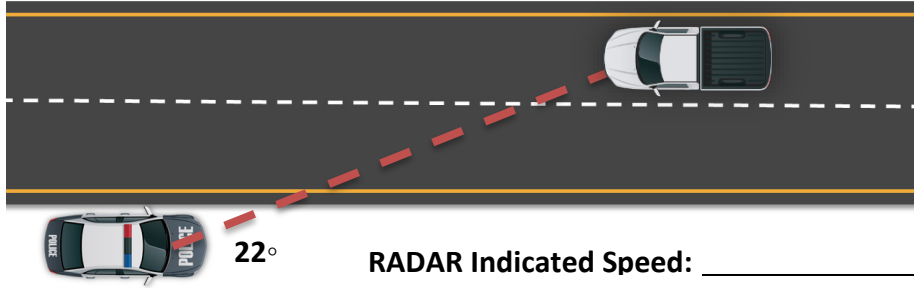
Look at the returned signal for each problem and determine whether the target is moving toward the source or away from the source.

# STATIONARY COSINE EFFECT WORKSHEET

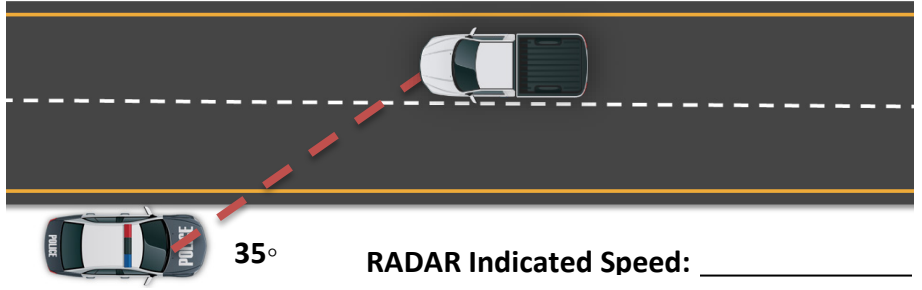
True Speed 60 mph



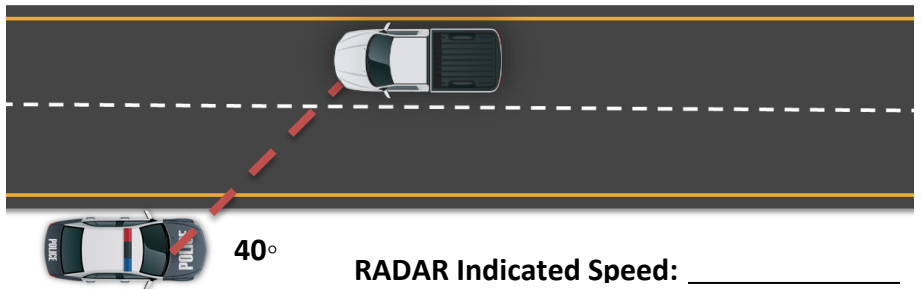
True Speed 60 mph



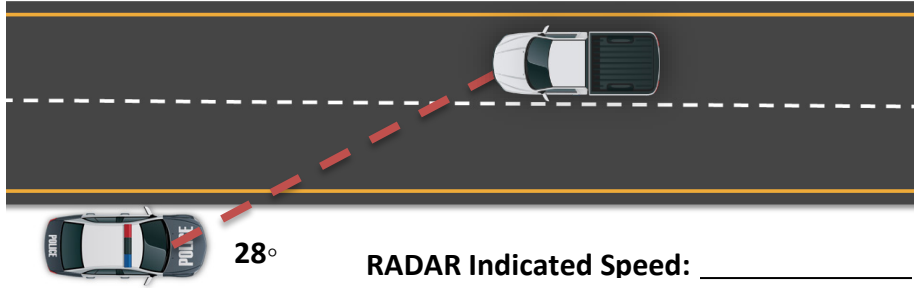
True Speed 60 mph



True Speed 45 mph

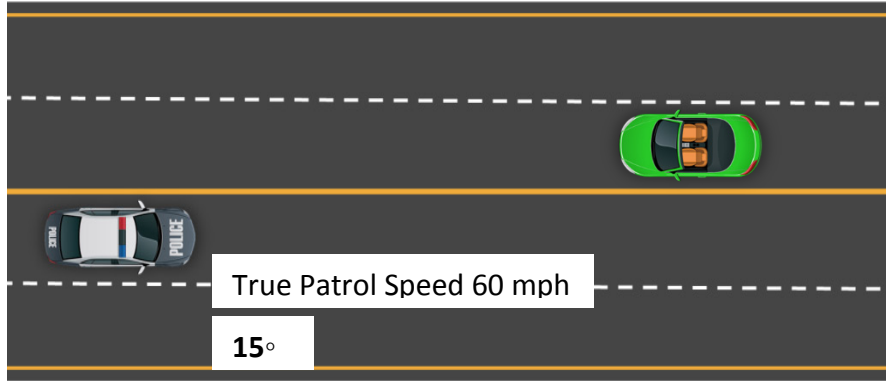


True Speed 57 mph



# MOVING COSINE EFFECT WORKSHEET

True Speed 60 mph

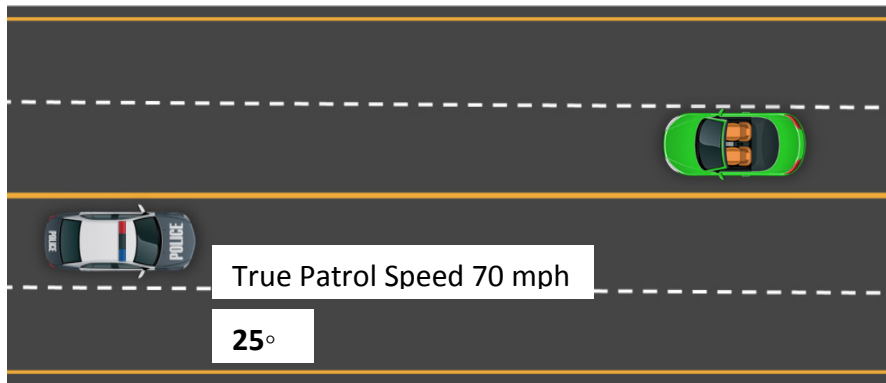


Closing Rate: \_\_\_\_\_

Patrol Indicated Speed: \_\_\_\_\_

Target Indicated Speed: \_\_\_\_\_

True Speed 65 mph

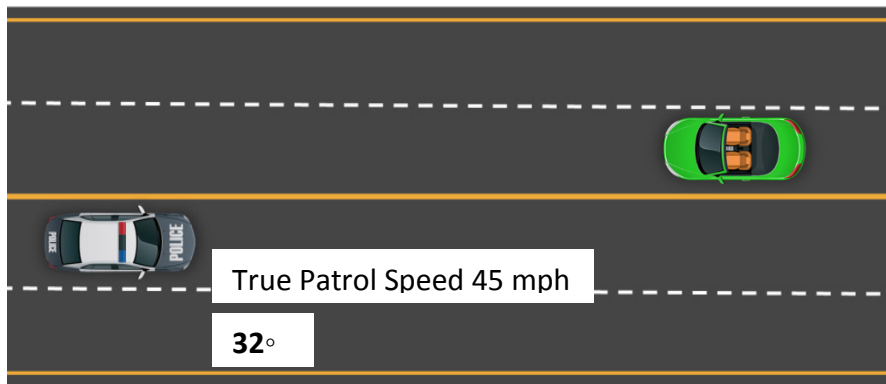


Closing Rate: \_\_\_\_\_

Patrol Indicated Speed: \_\_\_\_\_

Target Indicated Speed: \_\_\_\_\_

True Speed 50 mph



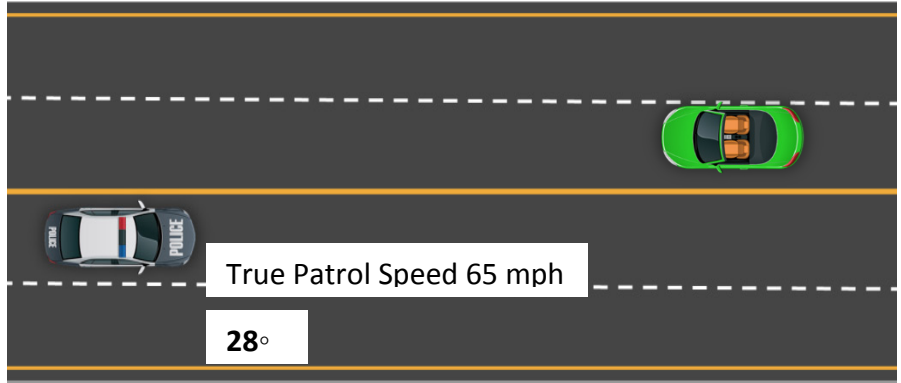
Closing Rate: \_\_\_\_\_

Patrol Indicated Speed: \_\_\_\_\_

Target Indicated Speed: \_\_\_\_\_

MOVING COSINE EFFECT WORKSHEET

True Speed 70 mph

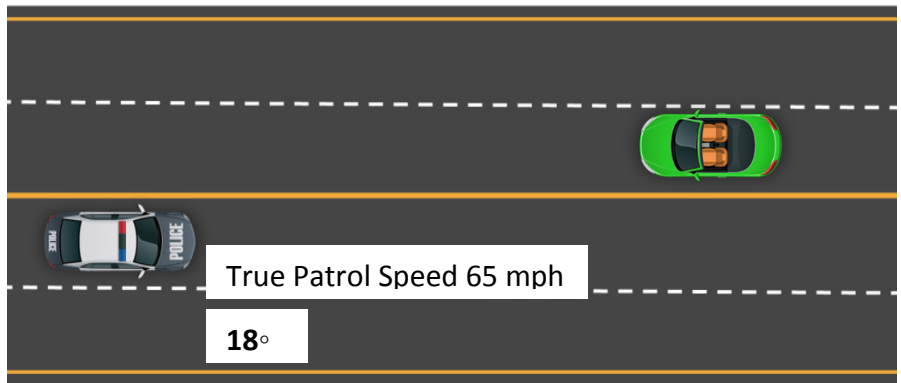


Closing Rate: \_\_\_\_\_

Patrol Indicated Speed: \_\_\_\_\_

Target Indicated Speed: \_\_\_\_\_

True Speed 65 mph

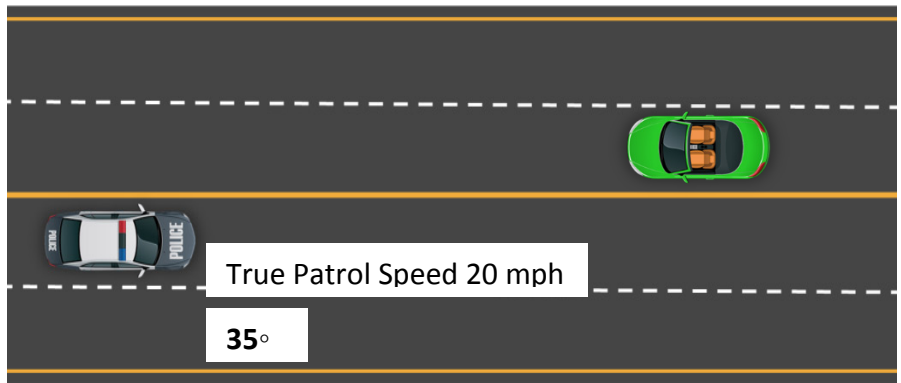


Closing Rate: \_\_\_\_\_

Patrol Indicated Speed: \_\_\_\_\_

Target Indicated Speed: \_\_\_\_\_

True Speed 23 mph

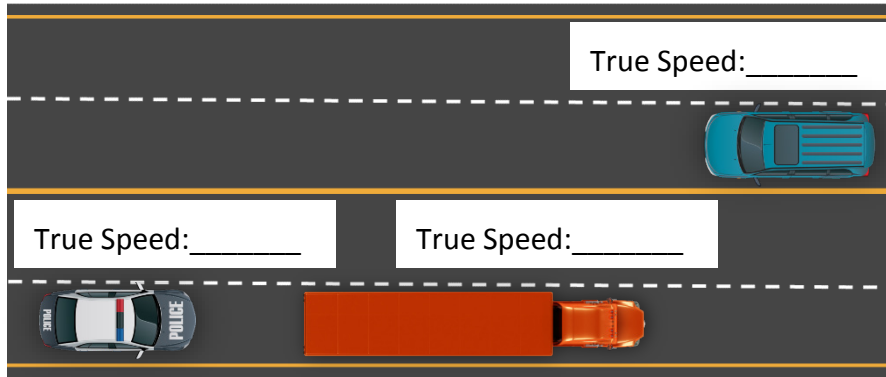


Closing Rate: \_\_\_\_\_

Patrol Indicated Speed: \_\_\_\_\_

Target Indicated Speed: \_\_\_\_\_

# SHADOWING EFFECT WORKSHEET



**Closing rate of speed computed by RADAR: \_\_\_\_\_**  
**Patrol vehicle speed displayed by RADAR: \_\_\_\_\_**  
**Target vehicle speed displayed by RADAR: \_\_\_\_\_**