

CHAPTER 2 BASIC PRINCIPLES OF RADAR SPEED MEASUREMENT

FUNDAMENTAL CONCEPT

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

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

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

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

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

THE WAVE CONCEPT

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

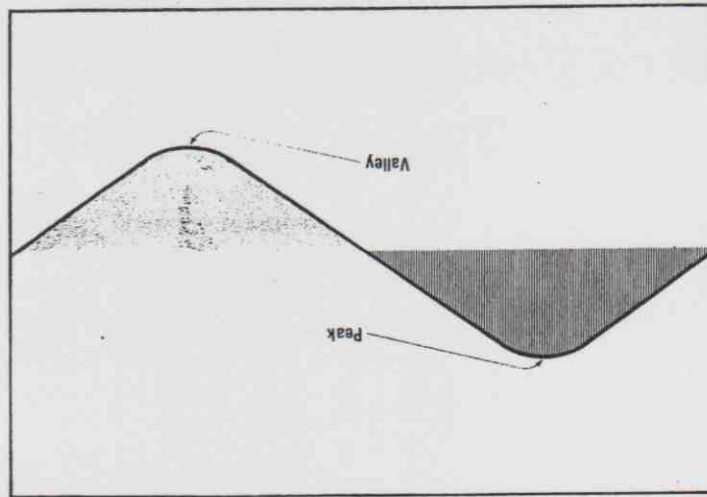


ILLUSTRATION #1

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

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

- The signal speed—constant. All RADAR signals travel at the speed of light. This is equivalent to 186,000 miles per second, or 30 billion centimeters per second. Both transmitted and received RADAR signals always travel at that speed.
- The wavelength—variable. The distance from the beginning of the peak to the end of the valley of a wave may vary.
- The frequency—variable. The number of waves transmitted in one second of time may vary.

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

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

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

Police Traffic RADAR Assigned Frequencies

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

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

- X-band was the initial frequency used. It has a frequency of approximately 10.525 billion waves per second, or 10,525,000,000 gigahertz (giga = billion). This frequency has a wavelength of approximately three centimeters, or about 1-1/5 inch.
- K-band RADAR operates at a frequency of 24,150,000,000 billions waves per second (24.150 gigahertz). Its frequency wavelength is approximately 1-1/4 centimeters, or about half an inch.
- Ka-band RADAR is the newest frequency to be used for police traffic RADAR. It operates in a frequency "range" of 33,400,000,000 to 36,000,000,000 billion waves per second (33.4 - 36.0 gigahertz). Its wavelength is approximately 8.75 millimeters, or about 3/8 inch.

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

THE DOPPLER PRINCIPLE

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

Principle: Doppler actually studied sound waves but it was later found that the principle applies to all wave energy, including light waves and radio waves.

Almost everyone has had the opportunity to hear how the Doppler Principle affects sound waves. An observer standing by the side of a railroad track will notice that an approaching train makes a highpitched sound. (Pitch is another word for frequency.) As the train passes the observer, an immediate drop in pitch occurs. The frequency of the wavelengths that carry the train's sound has changed. The same thing can be heard alongside a road listening to the sounds of passing cars and trucks.

The Doppler Principle can be expressed as follows:

- When there is relative motion between two objects, one of which is transmitting wave energy, the frequency of the signal as received by the other object changes due to that relative motion.

- If the relative motion brings the objects closer together, the frequency will be increased.

- If the relative motion takes the objects farther apart, the frequency will be decreased.

- How much the frequency is increased or decreased is determined by the exact speed of the relative motion.

What is most important about the Doppler Principle is that the frequency change happens only when there is relative motion between the objects. If both objects are standing still, there is no relative motion, and the received signal has the same frequency as the transmitted signal. There is also no relative motion between two objects if they are moving in the same direction at the same speed. Relative motion requires that the distance between the transmission source and the receiver of the wave energy must be changing in some way.

Relative motion will occur:

- If the object receiving the energy stands still and the transmission source moves.

- If the transmission source stands still and the object receiving the energy moves.

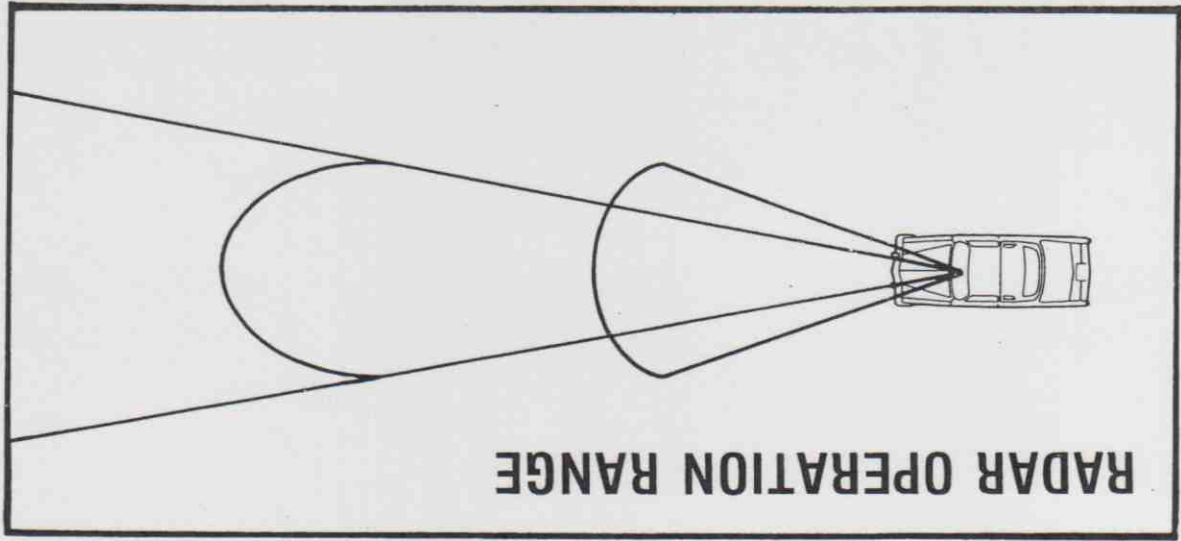
- Or, if both the transmission source and the object receiving the energy move, as long as they do so at different speeds or in different directions (so that the distance between them changes).

In each case, the Doppler Principle says that the transmitted signal, as perceived by the receiver, will have a different frequency. Police traffic RADAR merely measures this change in frequency and converts it to a speed reading. In order to operate police traffic RADAR, you don't need a complete understanding of how or why the Doppler Principle works. It is enough for you to be aware that there is a valid scientific basis for RADAR speed measurement.

The RADAR Beam

The radio wave energy transmitted by police traffic RADAR is concentrated into a cone-shaped "beam". Most of the energy transmitted remains in the central core of the beam. The concentration of energy drops off quickly as one gets farther away from or off to the side of the main beam.

ILLUSTRATION #3—The operational area or "range," of a RADAR beam normally exceeds one-half mile.



If a RADAR beam's operational range could be seen, it might take on the appearance of an elongated cigar. While this cigar shape is not the entire transmission of RADAR energy, it does represent that area of the beam from which useable reflections back to the antenna can normally be achieved. Most police traffic RADAR now in use is capable of receiving and displaying reflected signals from targets more than half a mile away. Under some conditions, this distance may extend to well over a mile.

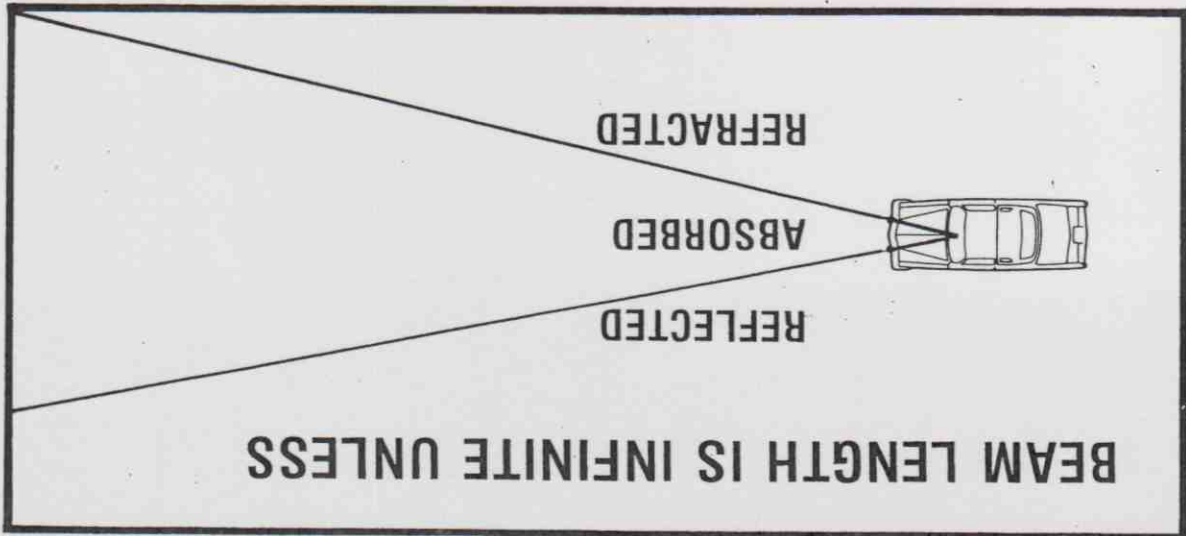
The range, or maximum distance, at which a reflected signal can be interpreted by the RADAR is dependent on the sensitivity of the antenna receiver. In other words, the RADAR antenna will not respond to every signal it receives. It can only respond to those signals that are strong enough to be recognized.

RADAR Range

The term refraction refers to the radio waves that may pass completely through some substances and continue to infinity. As they do, though, their direction or velocity may be changed slightly. Almost all forms of glass and many plastics will refract the RADAR beam. (An example of light waves being refracted can be seen when a straight object that's been put partway into water appears suddenly to be bent.)

Once transmitted, the length of the beam is infinite unless it is reflected, absorbed, or refracted by some object in its path. The typical objects from which the beam is reflected are made of metal, concrete, or stone. The beam is largely absorbed by grass, dirt, and leaves, with little energy being reflected back to the antenna.

ILLUSTRATION #2—The length of a RADAR beam is infinite unless reflected, absorbed, or refracted by an object in its path.

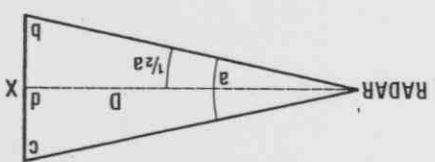


Located close to the antenna are much smaller cone-shaped beams. These beams, or side lobes, are a byproduct of the RADAR antenna and are so reduced in power that they normally don't affect RADAR operation.

RADAR Beam Width

The initial angle of the emitted RADAR beam will determine the relative beam width. This initial angle may vary from 11° to over 18° depending on the manufacturer. For example, a beam emitted at an 18° angle will be approximately 80 feet wide at a distance of 250 feet from the source; 160 feet wide at a distance of 500 feet; and 320 feet wide at a distance of 1,000 feet. Even with a device that emits a beam with a relatively narrow angle of 11°, the beam width would be approximately 50 feet at a distance of 250 feet; approximately 100 feet wide at a distance of 500 feet; and approximately 200 feet wide at a distance of 1,000 feet.

BEAM WIDTH FORMULA



X = Width of signal (unknown)
 D = Distance
 $\frac{a}{2}$ = Known angle
 $\frac{X}{D} = \tan \frac{a}{2}$
 $X = 2 \times D \times \tan \frac{a}{2}$
 $X = 2(\tan \frac{1}{2} a) \times D$

(CONSTANT)

for 12°, X = 2(tan 6°) or () × D
 for 16°, X = 2(tan 8°) or () × D
 for 18°, X = 2(tan 9°) or () × D
 for 24°, X = 2(tan 12°) or () × D

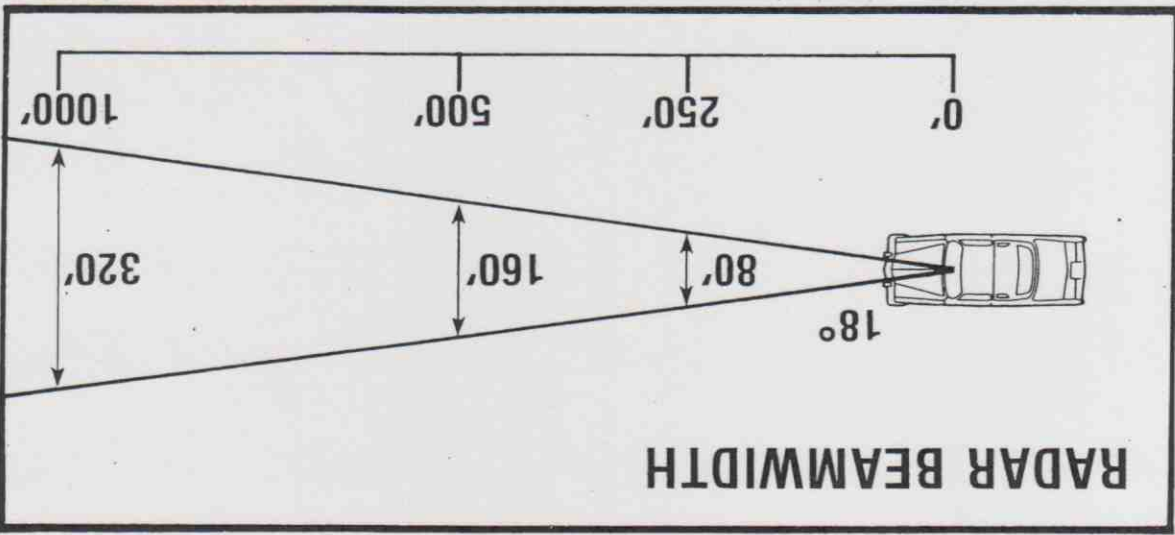


ILLUSTRATION #4—Standard RADAR beam widths vary from about 11° to about 18°. No police RADAR is lane selective.

As previously stated, X-band and K-band are the primary frequencies used today for police traffic RADAR. With

at the object's speed. If the object is moving toward the RADAR source, the reflected waves will be shortened in wavelength and therefore the frequency of the waves will be increased. If the object is moving away, the reflected RADAR waves will be lengthened and the frequency of the waves will decrease. It is this change in frequency—produced by the object's motion, or Doppler shift—that the RADAR measures against the original transmission frequency to arrive

back to the transmission source at the same frequency and wavelength as those transmitted. There is no relative motion by the object to produce a Doppler shift in frequency. If the object is in motion toward or away from the RADAR source, the Doppler Principle comes into effect.

To relate the Doppler Principle to police traffic RADAR, the theory must be modified to include a transmission source that is also a receiver (e.g., RADAR antenna) and an object that can reflect the transmitted radio waves back to the transmission source (e.g., a target vehicle), one or both of which are moving.

Stationary RADAR operation, like all police traffic RADAR, is based on the Doppler Principle. Remember, the Doppler Principle involves a transmission source (for example, a train) and a wave-energy receiver (for example, a human observer), one or both of which are moving.

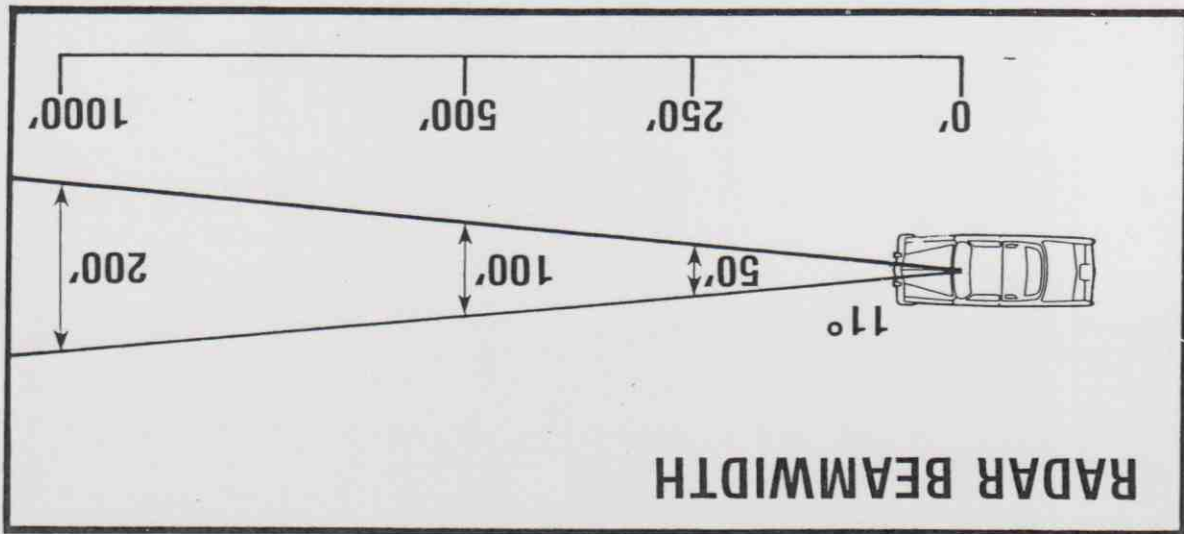
Principles of Stationary RADAR

All of the transmitted energy is not contained within a specific designed beam width. A small amount may be emitted at a much greater angle. The operator should not be alarmed when a vehicle's speed is displayed from an approach angle in excess of the prescribed beam width. This will occur most often when a single vehicle is approaching the RADAR. Because the beam's strength decreases dramatically outside its main area, vehicles within the main beam normally will be displayed by the RADAR over vehicles outside of it.

The operator, it is also vital to note, does not have to know the beam width of the RADAR wherever it is being aimed. The beam width at any significant distance is much wider than the roadway being focused on. In other words, the operator must acknowledge that lane selection is virtually non-existent with current RADAR devices.

This makes it impossible for RADAR to select or focus in one particular traffic vehicle at any significant distance. It is vital that the operator understand that simply pointing the antenna at a specific target vehicle will not necessarily result in a speed reading from only that vehicle when other vehicles are within the RADAR's operational range. Other criteria must be used to determine which vehicle's speed the RADAR is displaying. These criteria will be discussed in the target identification section of this Manual.

ILLUSTRATION #5—Standard RADAR beam widths vary from about 11° to about 18°. No police RADAR is lane selective.



the X-band frequency, an increase or decrease of 31.4 waves per second, or Hertz, is equal to 1 mph in speed for a target vehicle. Therefore, a shift of 314 hertz exists for each 10 mph and 3,140 hertz for each 100 mph. For the K-band frequency, an increase or decrease of about 72 waves per second, or hertz, is equal to a 1-mph change in speed.

| DOPPLER SHIFT | | |
|---------------|----------------|----------|
| K-BAND | 72 waves/sec | 1 mph |
| | 720 waves/sec | 10 mph |
| | 7200 waves/sec | 100 mph |
| X-BAND | 31.4 waves/sec | 10 mph |
| | 314 waves/sec | 100 mph |
| | 3140 waves/sec | 1000 mph |

ILLUSTRATION #6—The number of waves-per-second for each mile-per-hour change in speed is a constant.

These changes in frequency produced by moving vehicle are very small compared with the original transmitted frequencies, which consist of billions of waves per second. Nevertheless, RADAR is sensitive to these small changes and automatically computes them many times each second. In the case of stationary RADAR, the following examples characterize this process.

Example 1. A stationary RADAR beam is transmitted into empty space with no object in its path. It will continue on forever without being reflected back to the antenna. There will, of course, be no reading obtained.

Example 2. A stationary RADAR beam is transmitted down a roadway around which there are a number of large stationary objects—parked vehicles, trees, and the roadway itself. Because these objects are reflective, a small portion of the original transmission beam will be bounced back to the antenna. Since none of the objects are moving, the same frequency that was transmitted will be returned to the antenna. Since there is no change in frequency, there will be no reading displayed on the RADAR.

Example 3. A stationary RADAR beam is transmitted down the same roadway on which there is a moving vehicle. If the vehicle is approaching at a relative speed of 50 mph, the increase in frequency due to the Doppler shift would be received by the antenna and converted by the counting unit to exhibit the speed of 50 mph on the RADAR. The same would apply if the target is moving away from the stationary RADAR. In that case, though, the RADAR would receive a decrease in frequency equal to 50 mph.

These examples describe how stationary RADAR functions. When applying the Doppler Principle to police traffic RADAR, remember that the transmitted and reflected signals are compared to determine only the relative motion of the target vehicle to the antenna. Doppler RADAR cannot tell the operator whether the target, the RADAR unit, or both are moving. All that can be determined is how fast they are moving relative to one another. The RADAR instrument cannot tell whether the target is getting closer or farther away but only how fast the distance between them is changing.

A stationary RADAR in a moving patrol car will, therefore, display the relative speed of the patrol car to the stationary terrain, or in other words, the patrol car's own speed and if a target vehicle approaches, display the relative (or closing) speed of the two vehicles.

Stationary RADAR Angular (Cosine) Effect

If a target vehicle is moving directly toward or away from the RADAR, the relative motion as measured by the RADAR should be equal to the target vehicle's true speed. Very often, however, this is not the case. For safety reasons, a stationary RADAR is usually set up a short distance from the traveled portion of the road. Therefore, cars travelling along the roadway will not be heading directly toward or away from the stationary RADAR—in other words, some angle between the car's direction of travel and the RADAR's position is created.

**ANGLE BETWEEN RADAR ANTENNA AND
VEHICLE MUST BE AS SMALL AS POSSIBLE
TO AVOID ERROR READING.**

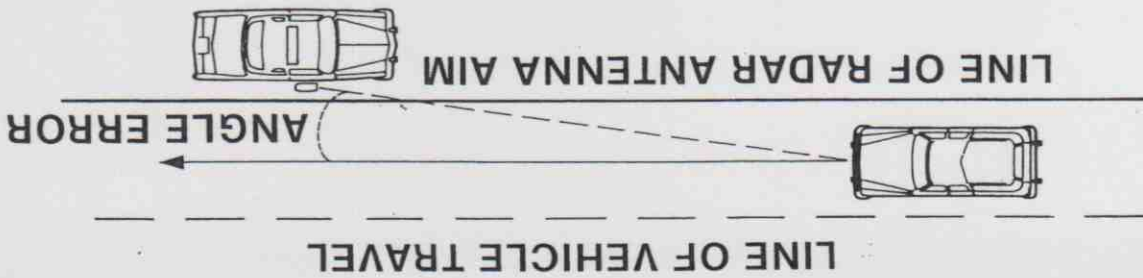


ILLUSTRATION #7

When a target vehicle's direction of travel creates a significant angle with the position of the stationary RADAR, the relative speed will be less than the true speed. Since the change in the signal's frequency is based on the relative speed, the RADAR speed measurement may be less than the car's true speed. This is known as the angular, or cosine, effect. (Cosine is a trigonometric function related to this principle.)

The difference between the measured and true speeds depends upon the angle between the object's motion and the RADAR's position: The larger the angle, the lower the measured speed. This effect always works to the motorist's advantage when the RADAR is stationary.

Loosely speaking, the angular effect is not significant as long as the angle itself remains small. Illustration #8 indicates how a stationary RADAR speed measurement can differ from true speed as a function of angle.

As can be seen in this table, the angular effect does not become a factor until the angle reaches about 10°. When a target vehicle passes by at a 90° angle, the RADAR is unable to perceive any of the vehicle's speed because at an angle of 90° the target is getting neither closer to nor farther away from the RADAR. This can best be understood by imagining a target vehicle being driven in a perfect circle around a RADAR unit. Because the vehicle is getting neither closer to or farther from the RADAR there is no relative motion and no possibility of a Doppler shift. Therefore, no speed can be displayed on the RADAR.

True Speed as Affected by Angular Effect

TRUE SPEED

| Angle | 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 |

Example: If an automobile traveling 70 mph moves in a direction that makes an angle of 15° with the RADAR antenna, the RADAR speed measurement could be 67.61 mph. (See bold entry in the above table.) Because current police traffic RADARs only display speeds in whole numbers, the speed actually displayed is rounded down to the nearest whole number (e.g. 67 mph).

The angular effect on stationary RADAR manifests itself in two ways.

The most common is the most recognizable to the operator. The antenna on a parked patrol car is pointed directly down an adjacent roadway. Well down the road, a target vehicle enters the RADAR's operational area. A speed reading is displayed on the unit. Because the target vehicle is so far away, the angle that exists between it and the RADAR unit is very small and thus the RADAR's perception of the target speed is identical to its true speed. As the target vehicle approaches the RADAR unit, though, the angle between them increases. As soon as this angle becomes large enough, the RADAR unit will perceive the target's speed as less than it really is. The operator may notice that the target vehicle's speed drops several mph on the RADAR unit before it passes by.

The second way is less recognizable. In this case, the RADAR antenna is pointed sharply across the adjacent roadway. This delays the RADAR unit's perception of an approaching target vehicle, so that speed reading will not be displayed by the unit until the target is relatively close. At that point the existing angle of the target in relation to the RADAR unit is already significant and the RADAR may display a target speed less than the true speed. Pointing the antenna across the roadway in this fashion gives away too much speed to the motorist and should be avoided.

To minimize the angular effect on stationary RADAR, the angle should be kept small by setting up the RADAR as close to the road as possible without creating safety risks. The antenna should be aligned straight down the adjacent roadway so that target vehicles can be perceived and displayed by the RADAR before they get close enough to create an angular effect.

It should be stressed again that with stationary RADAR, the angular or cosine effect is always in the motorist's favor. With moving RADAR, this is not always the case. The angular effect on moving RADAR will be discussed in detail next.

The moving RADAR's antenna is able to detect and process two reflected signals simultaneously—one from the stationary terrain, the other from an approaching target vehicle. The signal coming back from the target vehicle has undergone a frequency change known as a high Doppler shift—a change caused by the relatively fast closing speed between the patrol car and the target vehicle. The signal returning from the stationary terrain has undergone a so-called low Doppler shift—a lesser frequency change caused by the patrol car's lower relative speed in respect to the stationary terrain. The moving RADAR then computes the difference between the low and high

When the moving RADAR beam is transmitted, most of it simply goes on forever without striking anything. A portion of the beam strikes the moving target vehicles and is reflected back. Still another portion of the beam strikes the stationary terrain in front of the RADAR and is also reflected back.

- The speed of the target vehicle in relation to the patrol vehicle.
- The speed of the patrol vehicle in relation to the stationary terrain around it.

The most important thing to remember about a moving RADAR device is that it uses the same RADAR beam to acquire two different speeds.

So far, we have only focused on stationary RADAR. While stationary RADAR has its uses, in recent years police have more and more been using traffic RADAR that can be operated from a moving patrol car.

Principles of Moving RADAR

The closer a vehicle gets to the RADAR, the greater will be the angle created and the lesser amount of speed perceived. "Shooting" RADAR across a road delays its perception of an approaching vehicle until a significant angle exists.

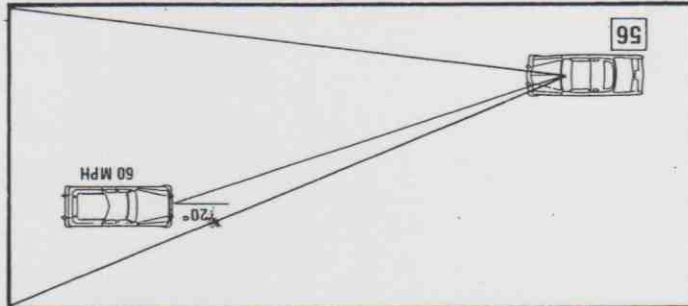


ILLUSTRATION #11

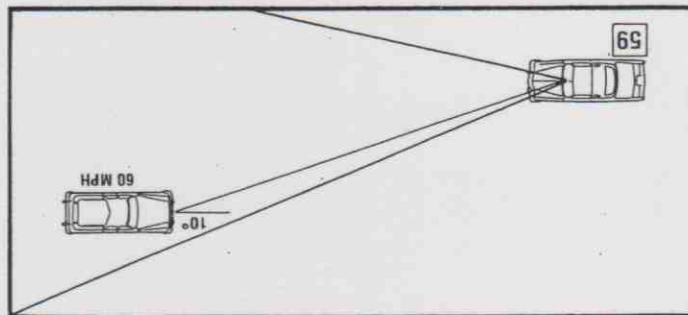


ILLUSTRATION #10

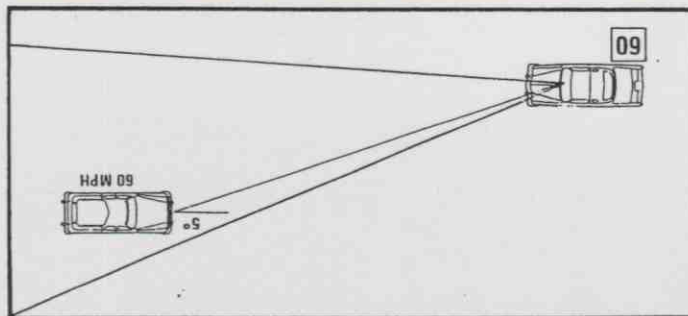


ILLUSTRATION #9

TS = 60 mph

TS = 105 - 45

TS = CS - PS

Certain unavoidable road conditions can result in the RADAR making it seem that the patrol car is traveling more slowly than it actually is. If a less-than-true patrol speed measurement is taken by the RADAR, the calculation of TS = CS - PS will produce an incorrectly high target speed. For example, suppose the target vehicle's true speed is 55 mph, and the patrol vehicle's true speed is 50 mph. The true closing speed between the two vehicles would be 105 mph. If an angular effect produces a low patrol speed measurement for example, an apparent patrol speed of only 45 mph—the following computation would be made:

An improperly high RADAR target display can result due to the angular effect through conditions that exist naturally or are created by the officer. It is critical that the officer know how to avoid these situations when possible and, when they are unavoidable, to recognize that the speed displayed is artificially high.

In examples of moving RADAR cosine or angular effect, RADAR readings in favor of the motorist can result only if the RADAR unit is correctly computing the patrol car speed.

A curve in the road can cause a similar situation. If a target vehicle is approaching a moving patrol unit from around a curve, it is unlikely to be moving straight at the antenna. Again, the RADAR may perceive the target's speed as less than it really is.

This occurs most frequently when an approaching target vehicle gets close enough to the antenna to create a significant angle. The RADAR may momentarily display a target speed that is less than true. This happens most often on expressways where the median is wide enough to create a large angle between the RADAR antenna and the target vehicle.

With moving RADAR, just as with stationary RADAR, angular effect can produce RADAR displayed speeds less than the target's actual speed. In order for this to occur the patrol speed must be accurate.

Moving RADAR Angular (Cosine) Effect

This double signal-gathering from a single transmitted RADAR beam and the computing of the target speed are performed continuously and automatically by the moving RADAR unit.

ILLUSTRATION #12—The target speed is computed continuously and automatically.

| |
|--|
| MOVING RADAR |
| $\frac{\text{Closing Speed} - \text{Patrol Speed}}{\text{Target Speed}}$ |

Target Speed = Closing Speed - Patrol Speed
TS = CS - PS

For example, a patrol car is traveling upon a roadway at 50 mph while a target vehicle is approaching it at 70 mph. The two vehicles then are closing in on each other at a relative speed of 120 mph. The moving RADAR receives a high Doppler frequency change equal to that relative speed of 120 mph and a low Doppler frequency change equal to the patrol car speed of 50 mph. The RADAR subtracts the relative patrol car speed from the closing speed, and the relative target speed of 70 mph appears on the RADAR display. This process can be summarized as:

Doppler shifts and translates that difference into a displayed target vehicle speed measurement.

The target speed displayed to the operator would be 5 mph higher than the target's true speed. Any enforcement action taken due to this displayed speed would, of course, be improper.

Conditions that create a low RADAR perception of the patrol car speed sometimes are beyond the operator's control. The patrol car speed signal is received primarily from the stationary terrain in front of the patrol car. A parked vehicle, a building, a large metal sign, or some other highly reflective stationary object alongside the road may sometimes send a stronger signal back to the RADAR than the roadway directly ahead. The reflected signal could actually then be coming from an object that is at a significant angle to the RADAR unit. Because of the angular effect, the relative motion between the patrol car and the roadside object would be less than the patrol car's true speed. Therefore, the patrol speed may be briefly perceived as less than the patrol car's true speed. A high target speed may then be briefly displayed.

Roadways that have large buildings or many reflective objects close to the roadside are most susceptible to this. Wet or icy roads are less reflective than dry ones and may enhance the RADAR's susceptibility to angular effect. This factor can become a severe problem if the moving RADAR antenna is not aimed properly. If the antenna is significantly out of alignment with the patrol car's direction of travel, the effect will be immediate and significant on the patrol car's low Doppler signal. The target closing speed high Doppler signal will normally be unaffected. Because the low Doppler reflected signal is being continuously received from stationary terrain not directly in front of the patrol car, the patrol speed may continuously be perceived as less than it really is. The resulting target vehicle speeds could then continuously be displayed as higher than actual. This condition is very recognizable to the operator when the displayed patrol speed is compared to the calibrated speedometer (to be discussed shortly). However, deliberately misaligning the antenna is unnecessary and extremely undesirable.

It is important that the operator point the moving RADAR's antenna as straight as possible into the patrol vehicle's direction of travel. The operator can obtain an alignment very close to 0° by merely "eyeballing" the antenna in relation to the patrol vehicle.

It is true that the mathematical potential for angular effect causing an improper target reading is not likely until there is about 10° angle present (see Table 5). However, the operator should not deliberately misalign the antenna of the moving RADAR because:

- Even a slight alignment of the antenna out of the patrol car's direction of travel may increase the susceptibility of the RADAR to receiving a low Doppler signal from objects on the side of the roadway. This problem probably will not be continuous, but may be more frequent than is necessary or desirable.
- It may harm the operator's credibility in court. Because few RADAR antennas are provided with mounting brackets with degree markings on them, it is difficult for the operator to testify that the antenna was aligned only 1°, 2°, or 9° off center. (Where RADAR units possess antenna brackets with such markings, testimony probably would have to be given showing that the brackets had been properly installed.) On the other hand, every-one is familiar with the term "straight ahead." The burden on the operator to disprove the existence of a low patrol speed angular effect is much less if it is concerned only with pointing the antenna straight ahead. Even a argument alleging the RADAR could be a few degrees off can be refuted because a few has no appreciable effect on the RADAR target reading.

It should be stressed that, with proper antenna alignment, the angular effect on moving RADAR does not often produce speed measurements that lead to high target speed readings. Most often the angular effect will produce low readings. The point is that the angular effect can work either way when moving RADAR is involved. The possibility that the angular effect may produce a low patrol speed measurement and give a higher-than-true target speed is of most concern.

Even properly operated, the RADAR can perceive a less-than-true patrol speed when certain unavoidable conditions exist. The operator must have some way of recognizing these conditions so that the resulting improper target speed reading can be disregarded. This is why all moving RADAR units now on the market have both a target speed display window and a patrol car speed display window.

Vitality important to the operation of moving RADAR is the close monitoring and comparison of the patrol car calibrated speedometer with the patrol speed displayed on the RADAR. This safeguard will be discussed shortly.

Same Direction Moving RADAR

Theory of Operation

Same direction moving RADAR uses the same fundamental Doppler Principle that all police traffic RADAR instruments employ. The manner in which it operates and is operated is different from traditional opposite direction moving RADAR.

Opposite direction moving RADAR computes target speeds using the formula:

$$\begin{aligned} \text{Target Speed} &= \text{Closing Speed} - \text{Patrol Speed} \\ \text{TS} &= 125 \text{ mph} - 55 \text{ mph} \\ \text{TS} &= 70 \text{ mph} \end{aligned}$$

If the target vehicle has already passed by the moving vehicle patrol vehicle and is receding, target speeds can still be computed, provided:

- A. that the antenna is turned and pointed to the rear, or
- B. a second rearward-facing antenna is used.

The formula changes to:

$$\begin{aligned} \text{Target Speed} &= \text{Separation Speed} - \text{Patrol Speed} \\ \text{TS} &= 125 \text{ mph} - 55 \text{ mph} \\ \text{TS} &= 70 \text{ mph} \end{aligned}$$

Opposite direction moving RADAR will always have a closing speed or separation speed greater than that of the patrol vehicle. Therefore, the patrol speed will always be subtracted to produce a target speed.

Same direction moving RADAR also measures the difference in relative motion between the target vehicle and the patrol vehicles.

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

All same direction moving RADAR instruments are unable to automatically discriminate between targets moving faster or slower than that of the patrol vehicle.

The operator is required to discern which case is present and manually switch the RADAR to the proper mode for correct computation of the target speed.

These examples serve to illustrate how same direction moving RADAR computes target speeds.

Example One: A 75 mph passenger car is traveling in the same direction and in front of a 55 mph patrol vehicle will be processed in the following manner when the operator has placed the RADAR in the "Target Faster" computation mode.

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

Example Two: A 70 mph target vehicle is being pursued by a patrol vehicle traveling 85 mph will be processed in the following manner when the operator has placed the RADAR in the "Target Slower" computation mode.

| | | | | |
|--------------|---|--------------|---|---------------|
| Target Speed | = | Patrol Speed | - | Closing Speed |
| TS | = | 85 mph | - | 15 mph |
| TS | = | 70 mph | - | |

Same direction moving RADAR's with the antenna pointed rearward or possessing a second rear antenna go through the same computations.

Target Identification Considerations

Same direction moving RADAR is subject to all the same target identification variables, which impact on opposite direction moving or stationary RADAR.

These include the RADAR decision-making factors of:

- A. Reflective capability
- B. Position
- C. Speed

Same direction RADAR is also affected by three additional target identification factors specific only to its operation.

First, same direction moving RADAR is limited in the range of target vehicle speeds it can display.

Opposite direction moving RADAR can display speeds from a few mph all the way up to about 200 mph, regardless of the patrol vehicles own speed.

Same direction moving RADAR only permits 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 RADAR used but is most often at least half of the patrol vehicle speed.

Second, same direction moving RADAR's now in use are limited in their ability to display target speeds very close to the patrol vehicle speed.

These RADAR instruments will not process target speeds closer than 3-6 mph, up or down, from the patrol vehicles actual speed depending upon the manufacturer.

The RADAR operator can not establish patrol car speeds at or near the enforcement threshold point to be enforced.

A patrol vehicle's speed, matched to the flow of traffic about it, will be blind to the majority of those vehicles.

RADAR in the same direction-moving mode can ignore a number of 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 RADAR.

Third, is the ability of this RADAR to discriminate between faster and slower targets.

The operator is required not only to survey the operational area of the RADAR for faster vehicles being correctly displayed in "Target Faster" mode but also slower vehicles being incorrectly displayed in "Target Faster" mode by

The inability of current same direction moving RADAR's to discriminate between faster and slower targets, decidedly complicates the operation of this type of RADAR—but not insurmountably so.

The operator has a ready means available for determining if a target speed displayed is in the proper "Target Faster" or "Target Slower" mode.

If the RADAR has correctly computed the target speed, changes in the patrol vehicle's 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.

The following examples illustrate why.

• **Example One:** A target vehicle traveling at a steady 70 mph is pulling away from a patrol vehicle which is slowing accelerating from 50 to 55 mph. With the RADAR in "Target Faster" mode, the following computations will occur.

| | | | | | | |
|--------------|---|--------------|---|------------------|---|-----|
| 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 |

• **Example Two:** A RADAR has been incorrectly left in the "Target Faster" and is displaying a steady 30 mph vehicles as a 70 mph vehicle with the following computations occurring:

| | | | | | | |
|--------------|---|--------------|---|------------------|---|-----|
| 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 |

By gradually varying the patrol speed vehicles speed up or down a few mph, 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 RADAR may be calculating a target speed in the wrong mode.

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

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

It should be noted that allegations of Batching Effect can be refuted as long as the changes in patrol car speed are gradual.

Target Vehicle Identification

Up until now the discussion has dealt with obtaining a speed reading from a single target vehicle. When more than one vehicle is present, RADAR operations must include the accurate identification of a specific target vehicle. In such cases, the operator must:

- Understand how a RADAR unit "decides" which target vehicle's speed to display.
- Realize that the RADAR is only one piece of several pieces of supportive evidence required for the positive identification of a speeding motorist. Together this group of evidence is called a "tracking history."

The RADAR "Decision" Process

A considerable effort has been made to explain how police traffic RADAR works in relation to the Doppler Principle. When multiple targets are present in the RADAR beam, additional factors must be considered.

A RADAR beam may be only a few inches wide at the antenna but several hundred feet wide at its maximum operational range. The antenna may receive reflected signals from many vehicles. Most RADAR now in use in this country is designed to display the strongest of the multiple signals available.

The RADAR unit's operation is affected by three factors: the reflective capability of the various targets; their position in relation to each other and the RADAR; and, occasionally, their actual speed.

Reflective Capability

Most of the vehicles on a given road will be of different sizes. A large truck will obviously have a larger reflective area than a smaller passenger vehicle will. Thus, a truck can create a stronger reflected signal than a passenger vehicle. By the same token, a passenger car can have a stronger reflected signal than a motorcycle.

The shape and physical makeup of a target vehicle will also affect its reflective capability. Low-profile, streamlined vehicles have less surface area to reflect a RADAR signal than vehicles of the same relative size that aren't streamlined. Vehicles containing a large amount of plastic materials or those made of fiberglass are generally less reflective than those of metal. Streamlined vehicles, or those made of fiberglass, will reflect a RADAR signal. However, the distance at which the RADAR displays a reading for such vehicles will be reduced.

DECISION MAKING AFFECTED BY:

- Reflective capability
- Position
- Speed

ILLUSTRATION #13

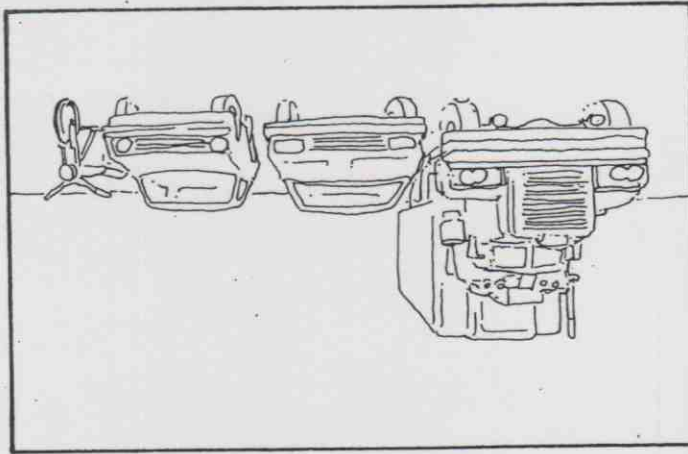


ILLUSTRATION #14—The reflectivity of a vehicle is affected by its size, shape, and composition.

Position

The position of a target vehicle relative to other vehicles and the RADAR antenna is important in regard to which vehicle's speed the RADAR unit will display. Normally, the closer a vehicle is to the antenna, the stronger the reflected signal. In other words, the closer a vehicle is to the antenna, the larger the portion of the cone-shaped beam it occupies. If vehicles of comparable size are in question, the target vehicle closest to the antenna will most often be the one displayed by the RADAR unit.

Speed

The speed of a target vehicle is the last factor affecting how a RADAR unit will operate. How much a target vehicle's actual speed will affect the RADAR unit's "decision" depends on the make and model of RADAR being used. Generally speaking, speed is usually the least dominant of the three primary factors. Some specific circumstances where speed may be a factor will be described later.

Understanding the RADAR "Decision" Making Process

When multiple targets of unequal size are present, either reflective capability or position will most often be the determining factor. It is vital that the operator understand that reflective capability and position are completely different. With this understanding, the operator will be better able to tell which factor is governing any particular multiple-target situation. To illustrate this, an explanation of what actually happens to the radio energy wave after leaving the antenna is in order.

If a slice of the cone-shaped RADAR beam could be observed 250 feet from the antenna, you would find that almost all of the energy originally transmitted is still there. However, instead of being contained in a circle a few inches in diameter, as originally transmitted, the energy would be dispersed over a circle approximately 70 feet in diameter.

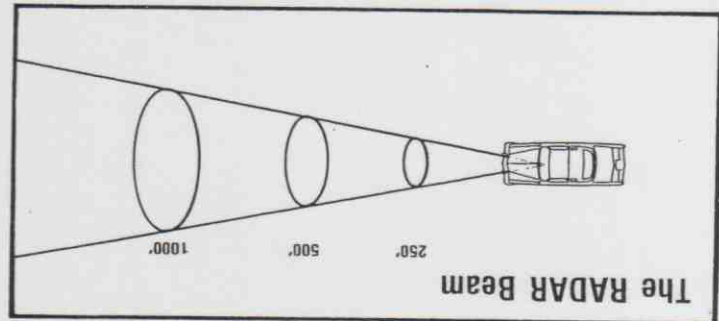


ILLUSTRATION #15

Due to the Inverse Square Rule, each time the distance from the antenna is doubled, the strength of the signal is reduced by a factor of four times.

If this distance is now doubled to 500 feet, the energy would be spread over an area four times as large as at 250 feet. If the distance is again doubled to 1,000 feet, the energy would be spread over an area four times as large as at 500 feet, but 16 times as large as at 250 feet.

It is apparent the farther a target vehicle is from the RADAR unit, the lesser the amount of energy available to be reflected back to the antenna. This relationship between energy and the distance from its source is called the inverse square rule.

The Inverse Square Rule and Target Identification

To understand the impact of reflective capability, imagine a full-sized passenger vehicle 500 feet away and approaching the RADAR unit. At the same instant, a truck is also approaching the RADAR unit, 1,000 feet from the antenna. Given these reflective positions, there is four times less RADAR energy per square foot to be reflected from the truck at 1000 feet. However, if the truck has five times the reflective surface of the car, its reflected signal will probably be stronger. In this case reflective capability would probably determine which vehicle's speed is displayed by the RADAR unit.

Visual estimation of target speed: This is the most critical element. Testimony must substantiate that the vehicle in question was observed to be speeding. An officer's ability to estimate speeds is established separately from the RADAR evidence. The officer should be able to testify

Several elements are involved in the valid identification of a target vehicle. Together these elements comprise what is referred to as a complete "tracking history" and are listed below:

The Role of Supportive Evidence—The Tracking History

The interpretive process that results in valid target identification is generally easy for the trained operator because a RADAR reading is only one part of the evidence the operator has to have to establish a speed violation.

The possible combinations of these factors—reflective capability, position, and speed—are infinite. You are not expected to have to compute the relative sizes or positions of target vehicles mathematically. It is enough for you to have a general understanding of the impact these factors have on how the RADAR unit selects which target vehicle's speed to display.

Under certain circumstances, RADAR devices can select which vehicle to display on the basis of speed. The most common instance involves multiple target vehicles of comparable size on an expressway. If a vehicle approaching the RADAR unit is being overtaken by a similar-sized vehicle at a significantly greater speed, the faster vehicle's speed may be displayed. This normally will not occur, however, until the faster vehicle is reasonably near the lead vehicle. The RADAR unit is less likely to be speed-selective on two-lane roadways because the front vehicle is likely to block the radio waves from striking the following vehicles. Operators should be aware that with most RADAR units currently in use, the individual speeds of approaching target vehicles do not normally determine which vehicle will be displayed.

It should be noted that with each of the examples cited, the reflective capability of the vehicles' size, shape, and composition remained the same. The position of the vehicles relative to the RADAR antenna was the factor changed.

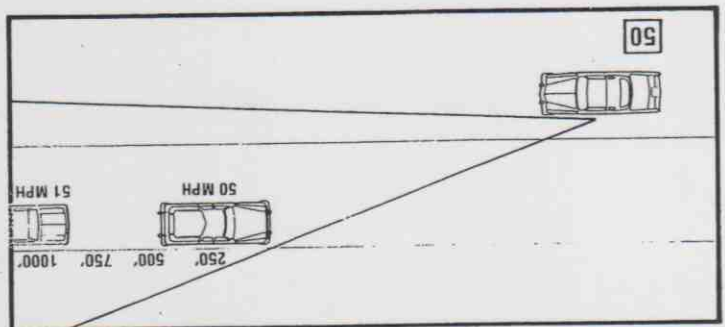


ILLUSTRATION #17

By moving both the car and the truck 250 feet closer, the cars speed would probably be displayed due to position.

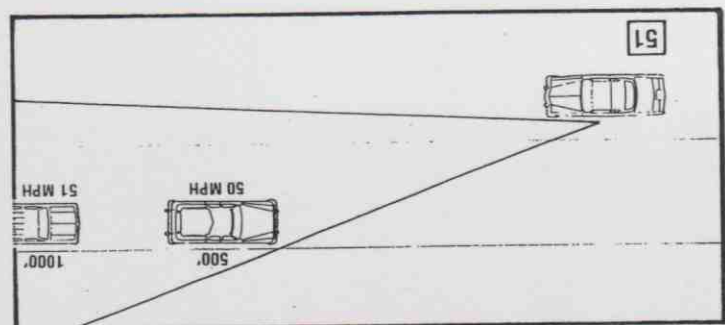


ILLUSTRATION #16

Though twice as far away, if the truck has five times as much reflectivity, its speed would probably be displayed.

To illustrate the impact of position, it is necessary to advance the positions of these imaginary vehicles to where passenger vehicle is 250 feet from the antenna and the truck 750 feet. At 250 feet the passenger car now has four times as much RADAR energy being reflected from each square foot of surface area as it did at 500 feet. The truck also has more reflected RADAR energy per square foot at 750 feet than it did at 1,000 feet, but proportionally hasn't increased nearly as much as the car. In this case, position would probably determine which vehicle's speed the RADAR unit would display.

that a target vehicle was traveling faster than the speed limit even if no RADAR or similar device was used.

Audio tracking: The audio feature common on many police traffic RADARs allows the operator to hear the incoming Doppler signal. A stable target signal will result in a single pure, clear audio tone. The higher the pitch of the signal, the faster the speed of the target producing the signal. With experience, an operator can correlate this pitch with actual speeds.

Interference that could affect the RADAR is heard as static or buzzing and is not consistent with the pure, clear Doppler return from valid target vehicles.

Target Speed Display: The target speed displayed by the RADAR must correspond reasonably with the visual and audio estimations. Each of the three must reinforce the other. If any of them is incompatible, the reading must be disregarded.

With stationary RADAR, these three elements would be enough to constitute a valid tracking history.

ILLUSTRATION #18

TRACKING HISTORY CHECKLIST STATIONARY MODE

1. VISUAL OBSERVATION.

a. Identify target.

b. Estimate speed.

c. Confirm target is in range.

d. Check environment.

2. AUDIO CONFIRMATION.

a. Pitch - Indicates speed.

b. Amplitude - Indicates motion.

3. RADAR SPEED VERIFICATION.

a. Stable readout for three-five seconds.

b. Readout must agree with visual and audio.

c. Manual lock. (optional)

One additional element is required for moving RADAR. Patrol Speed Verification (Moving RADAR Only): Current moving RADARs, as previously noted, possess not only a target-vehicle, speed-display window but also a patrol-car, speed-display window. The patrol speed indicated on the RADAR must correspond with the reading on the patrol vehicle's speedometer, which must be certified as well. This verification ensures that the RADAR computation of the target speed is based on a valid patrol car speed. This additional element has been mandated by case law for moving RADAR and is to be considered essential for a valid moving RADAR case.

TRACKING HISTORY CHECKLIST MOBILE MODE

1. VISUAL OBSERVATION.

- Identify target.
- Estimate speed.
- Confirm target is in range.
- Check environment.

2. AUDIO CONFIRMATION.

- Pitch - Indicates speed.
- Amplitude - Indicates motion.

3. RADAR SPEED VERIFICATION.

- Stable readout for three-five seconds.
- Verify patrol speed.
- Readout must agree with visual and audio.
- Manual lock. (optional)

A tracking history must be obtained for each RADAR-based enforcement action. Whenever RADAR speed measurements are conducted, two points must be kept in mind:

- The RADAR-displayed speed measurement is only one part of the evidence and cannot be the sole basis for any enforcement action.

- In order to be valid and admissible, the RADAR speed measurement must be obtained in strict compliance with all applicable case law.

These two points have significant implications for the manner in which RADAR operations are conducted. Related to the first is the officer's need for the good judgment and experience in making visual estimates of a vehicle's speed. Almost everyone can estimate speeds visually: it would be impossible to drive a motor vehicle or walk across a busy street without some understanding of how fast traffic is moving. Because observing traffic is a major part of their job, traffic law enforcement officers in particular can and do become very good at estimating speeds.

Never base a decision on instant RADAR measurement. Instead, watch speed measurement and listen to the audio output for at least a few seconds to make sure that the signal received is from a real, identifiable vehicle.

The biggest impediment to obtaining a valid tracking history is the locking feature that most current RADAR instruments have. This feature allows the operator to press a button or pull a trigger and cause whatever speed measurement is appearing at that instant to freeze on the display. Many RADARs have an automatic locking feature that causes this freeze to occur as soon as some specified speed is exceeded.

The idea behind the locking feature is to preserve the evidence. Whatever the idea's merits might be, locking the speed measurement can prevent the operator from correlating changes seen or heard in the target vehicle's speed with the speed on the RADAR display. If a good, complete tracking history has been obtained, the RADAR speed reading may be manually locked. Neither statutory or case law in Texas requires or forbids use of the manual lock. DPS policy does not forbid its use but cautions that the operator should not sacrifice quality tracking history just to lock in the target speed. **THE AUTOMATIC LOCKING FEATURE SHOULD NEVER BE USED FOR ENFORCEMENT PURPOSES.**

When multiple targets are present, it is often preferable to continue observing the target speed measurement, paying close attention to what happens when the suspect vehicle passes out of the beam. The display might suddenly either blank out or abruptly change to another speed. If that happens, the implication is that the speed measurement obtained was from the suspect vehicle.

On the other hand, the display might hold steady after the suspect vehicle passes out of the beam. The implication in that case would be that the RADAR was displaying some other vehicle's speed. The Doppler audio feature present on many units is also very useful in this respect. If there is no change in the Doppler sound, you can infer that the suspect vehicle was not being displayed.

The burden of proof is obviously less if the operator can show that there were no other vehicles between the RADAR and the target vehicle. Remember, however, that other vehicles farther away can produce a stronger reflected signal. Again, good visual and auditory observations validate the speed reading and complete the tracking history.

Some of the later model RADAR units have a third read-out window which allows the operator to manually lock in the target speed while retaining tracking history. This feature also permits multiple tracking by locking one target then tracking the second. While this may have a ring of efficiency, the practice is discouraged by our Department as a matter of routine operation. While special circumstances may dictate the stopping of multiple vehicles in one operation, it is generally best to deal with one traffic violator at a time. Never sacrifice case quality for quantity of arrests.

RADAR operations should be conducted only at the appropriate times and places. If traffic flow builds up to the point where target identification becomes problematic, stop using the RADAR. RADAR is not the only speed measurement method available, nor are speed violations so uncommon that they can only be found in one place. RADAR is a very effective tool. Like any tool it has to be used properly and only for the job that is has been designed.

Finally, and perhaps most important, if any doubt exists, take no enforcement action.

Effect of Terrain on Target Identification

Road terrain may affect the RADAR unit's ability to process and display target vehicle readings. The best areas for RADAR operation are straight, level roadways. When traffic RADAR is operated on hilly or curved roadways, you must take their effect on the RADAR into account. Police traffic RADAR units are designed to function on a "line of sight" basis and will seldom display a vehicle behind a hill or around a curve.

Hilly terrain creates the worst problems in target identification. For example, if the patrol vehicle is positioned on the crest of a hill, with the RADAR antenna focused straight ahead rather than down, the RADAR beam may "overshoot" the approaching lead vehicle and display a vehicle behind it. A dip in the roadway may also affect the RADAR's ability to display the lead vehicle. In this case, the roadway itself may shield most of the reflective surface of the lead vehicle and again cause the RADAR to pick up a following vehicle. When roadway terrain problems exist, you must exercise discretion in using RADAR, tracking the target vehicle long enough to be certain of target identification.

Operational Range Control

Some RADAR instruments have a control that permits the adjustment of operational range. The range control allows an adjustment to the RADAR instrument's sensitivity to reflected signals, and can be used to reduce target identification problems. It must be stressed that the RADAR transmission remains steady and unaffected by this range control. This control only affects the RADAR's ability to receive and process a signal.

Thus, a low sensitivity setting means that the RADAR will only perceive fairly strong signals—the RADAR won't "see" a vehicle until it is fairly close. A high sensitivity setting means that the instrument will perceive even fairly weak signals from vehicles that are quite far away. Atmosphere and other environmental conditions can affect the RADAR's sensitivity to target vehicle signals. Try experimenting with the range control to find the most appropriate setting each time you use the RADAR unit.

When using stationary RADAR, the recommended procedure is to first turn the range control to its minimum setting (i.e., its lowest sensitivity) and then slowly increase the RADAR's sensitivity.

By observing when and where approaching target vehicles begin being displayed on the RADAR, you can establish an effective operational range. This range must be long enough to allow a target vehicle to be displayed for

car.

Moving objects—The second source of interference results because Doppler RADAR is designed to measure the relative motion of moving objects. This can mean any moving object, not just motor vehicles. The most common moving objects that may interfere with RADAR are vibrating or rotating signs near the roadway and fan blades moving either inside or outside the patrol

Harmonics—The first source of interference, harmonics, refers to RADAR's tendency to occasionally process the wrong radio frequency. Harmonics may include radio energy released by airport RADAR, mercury vapor and neon lights, high-tension powerlines, high-output microwave transmission towers, and police radios.

Generally, interference can be attributed to two primary sources:

"Interference" encompasses a wide range of natural and artificial phenomena. For this manual, the term "interference" will refer to RADAR effects that happen unintentionally. Purposeful attempts to subvert or otherwise affect RADAR will be discussed later.

Interference

The following discussion is broken down between factors that affect police traffic RADAR as a whole and those that apply only to moving RADAR operation. Often a false reading is directly attributable to an operator's inaction or inappropriate action. Where avoidable factors can arise to give false readings, the discussion will describe them and note how to avoid them. Where a cause is unavoidable, the discussion will show how to recognize it. Only those factors affecting RADAR that possess some credence or those that have received a lot of publicity will be addressed.

It is sometimes alleged that police traffic RADARs often display "false" target readings. In fact, certain factors can affect RADAR devices. Many of these can be avoided, provided you operate the RADAR unit properly. Some are unavoidable, the result of natural causes. All of them should be recognizable to be trained, experienced operator. Police traffic RADAR, like any measurement instrument, has inherent and logical limitations. When a false reading is displayed, the RADAR unit is not making an error—it has simply been subjected to conditions beyond its capabilities. As a rule, though, it is more likely that the operator, rather than the RADAR, will make an error. This can happen if the operator forces the device to operate beyond its limitations or fails to recognize when its limitations have been passed.

Factors Affecting RADAR Operation

One final point should be mentioned: Adjusting the beam's range control will have absolutely no effect on RADAR detectors (i.e., devices used to give speeders advance warning of a RADAR's presence). You can't outwit a RADAR detector by turning down your range setting, because the power in the beam remains constant regardless of the range control setting.

In the past, operators often attempted to control RADAR sensitivity by tilting the antenna up or down. This tilting is not recommended, since it may cause or worsen interference. If your RADAR unit has no range control, keep the antenna pointed straight ahead and stay alert—don't tamper with the antenna.

For moving RADAR, the sensitivity setting must be significantly higher, because both vehicles are moving, and the distance between the patrol car and the target vehicle changes very rapidly. This means that moving RADAR must be more sensitive to target at longer ranges than stationary RADAR to achieve a proper tracking history. It is important for you to understand that a RADAR unit's range setting is approximate, not precise. Most range control units are designed so that the average automobile will be displayed when it is in the selected range. Small vehicles may not reflect a signal strong enough to be displayed until they are close to the transmitter. Larger vehicles, of course, may be displayed even though the vehicles are farther away.

The time necessary to complete a proper tracking history, but not so long as to create unnecessary identification problems.

A RADAR antenna's sensitivity or capability to receive and process a signal depends on the number and relative strengths of the reflected signals it is receiving. Strong signals received from bona fide target vehicles will almost always override weaker interference.

Interference caused some of the more bizarre and highly publicized "inaccuracies" that surfaced in Dade County, Florida and other places where RADAR has been challenged. The infamous "85-mph tree" is a case in point.

The news has been well circulated that a RADAR antenna was pointed at a banyan tree (which obviously was not moving) and that a reading of approximately 85 mph appeared on the display. Not so widely reported was the fact that a CB radio transmitter located in the same vehicle as the RADAR had been turned on and that at the instant the reading was made a reporter whistled into the microphone. Feedback from the CB was picked up by the RADAR, and that caused the 85-mph reading. It did not matter that the RADAR was pointed toward a tree; it could have been pointed at the ground, a house, the sky, anything. The actual source of the 85-mph reading was the CB's interference, not the tree. Ordinarily, RADAR will not pick up a CB signal. But when the CB and the RADAR are extremely close together (as in the same vehicle), interference can result.

Another well-reported incident from Dade County was the "28-mph house." Here again, interference was the culprit. The RADAR antenna was aimed at the house through the car's front windshield. Meanwhile, within the antenna's range the window defroster had been turned on and its fan blades were spinning. What the RADAR actually measured was the speed of the defroster fan's blades.

Most interference will come from inside the patrol vehicle. Radio transmissions from within the patrol car and, occasionally, faulty ignition wires may cause harmonic disturbances; air conditioning and heater fans may cause moving interference.

Outside the patrol vehicle it is less likely that moving objects will cause interference with RADAR. However, proximity to such harmonic sources as airport RADAR, high-tension powerlines, and high output microwave transmission towers may create readings.

Having a Doppler audio feature on the RADAR unit will help a lot in recognizing interference—instead of clear, pure tone, the audio will emit fluttering or buzzing sounds.

The trained operator will ignore interference-induced readings, since:

- There is generally no vehicle within the operational range of the RADAR and, therefore, no visual clue on which to make a speed determination.
- Interference is usually weak, and when a bona fide target vehicle enters the RADAR's operational range it will almost always override the interference reading.
- The Doppler audio effect caused by interference will be scratchy and inconsistent, unlike the good, clear tones of a true Doppler target signal.
- Usually interference is momentary, not lasting for the several seconds necessary for a valid tracking history.

The operator must be careful to avoid known interference sources and not to make radio transmissions while actively tracking a vehicle on RADAR. If the RADAR antenna is inside the patrol vehicle, dashmounting the antenna and aligning it away from fan vents will minimize movement-related interference.

Incident weather (e.g., rain or snow) does not affect RADAR's accuracy as often as is alleged. Inclement weather may, however, decrease the unit's operational range sensitivity. Moisture-laden air tends to scatter the RADAR beam slightly, thus reducing its effective range.

Multi-Path Beam Cancellation Effect

Multi-path beam cancellation refers to the RADAR blind spots produced by occasional oddities in roadway terrain. The RADAR operator may be monitoring the speed of an approaching vehicle when suddenly the speed displayed will disappear for a few seconds and then, just as suddenly, reappear. All this happens while the vehicle remains

constantly in sight.

Technically, multi-path beam cancellation results when a 180-degree phase inversion occurs between the direct path signal from the target vehicle and the signal from the reflected path. The signals, in effect, cancel each other out as far as the RADAR is concerned. During this brief period the RADAR display goes blank. However, the operator must be alert to the possibility that a vehicle behind the lead target may briefly display a speed on the RADAR when the lead vehicle's signal has momentarily been cancelled. Obtaining a good complete tracking history will minimize the problem of multi-path beam cancellation.

Scanning Effect

A hand-held RADAR antenna that is swung swiftly or "scanned" past the side of a parked car, a brick wall, or some other stationary object is alleged to produce a speed measurement. The idea behind this charge is if the antenna moves, the relative motion will be registered by the RADAR.

This effect is extremely difficult to produce. However, by not moving the RADAR antenna while making a speed measurement, you will eliminate any (faint) possibility of its contributing to a false reading. In any case, swinging an antenna around does not help obtain a valid tracking history.

Panning Effect

The panning effect can occur only with two-piece RADAR units—instruments whose antenna and counting units are physically separate. If the antenna is pointed at its own counting unit, a speed reading may appear on the display because of electronic feedback between the two components. When this is done, the Doppler audio becomes a very inconsistent squeal. To avoid the panning effect, don't point the antenna at the counting unit.

Turn-On Power Surge Effect

Suddenly turning on the RADAR unit's power may result in a speed reading displayed because of the sudden surge of voltage to the unit. Operators are said to do this with the idea of outwitting illegal RADAR detectors.

Many newer-model RADAR units have a "transmission-hold" switch that keeps the power turned on in the computer module but prevents the transmission of the RADAR signal until the target vehicle is within range. These "anti-fuzz-buster" switches are considerably more effective than flipping the unit off and on and they don't constitute misoperation.

Allegations that using the transmission-hold switch may also cause a power surge affecting the speed display is spurious. Extensive testing by the National Bureau of Standards on various makes of RADAR indicates no support for this charge.

Mirror Switching Effect

Some hand-held type RADARs can have the numerals of the readout displayed backwards when a switch is thrown. This lets the operator point the RADAR rearwards and read the numbers correctly through the rearview mirror. The claim here is that the operator may forget to switch the display back again when the unit is pointed forward and mistake the reversed reading for a proper reading. For example, a reversed speed reading of 18 mph may be observed as 81 mph by the operator. If the operator stays normally alert the mirror switching effect should not be a problem.

Factors Affecting Moving RADAR Operation

The operator should be aware that moving RADAR is susceptible to some special problems that do not affect stationary RADAR. Like the moving RADAR angular effect, these can produce a lower-than-actual patrol speed measurement and thus a higher-than-actual target speed calculation.

Patrol Speed Shadow Effect

Remember that moving RADAR depends on two speed readings, that of the target vehicle and that of the patrol

RADAR's proper operation requires supportive evidence: a significant period of visual and audio tracking of the target vehicle, the verification of the patrol car speed against the calibrated patrol car speedometer (if moving), and a RADAR reading that is consistent with the visual and audio estimation. If all of these elements of the tracking history exist, the likelihood of any of these factors affecting RADAR causing an improper traffic citation to be issued

- ALL OF THEM WILL LACK THE NECESSARY SUPPORTIVE EVIDENCE FOR A VALID TARGET READING.
- Many of them arise only through blatant misoperation of the RADAR instrument.
- Some have no basis in fact.
- Many will almost never occur when the RADAR is being operated properly.
- Most will only affect the RADAR unit momentarily.

Looking at all of the factors alleged to affect RADAR operation, several conclusions can be reached:

Conclusions on Factors Affecting RADAR

Most RADAR units are fast enough to keep up with the significant speed changes, thus avoiding the batching effect, and/or blank out when such changes occur. You can avoid even the possibility of an improper speed reading due to the batching effect by maintaining a relatively steady speed when taking speed measurements.

The batching effect may occur if the patrol car is rapidly changing its speed while the RADAR speed measurements are being made. Some RADAR counting units may not be able to keep up with drastic changes in speed. Instead of using the true speed of the patrol car to measure closing speed, the counting unit may use the speed that the patrol car was traveling a few fractions of a second earlier. If the patrol car is rapidly accelerating, then its earlier speed was lower than its present true speed, and the target speed calculation may be higher than the target's true speed. If the patrol car is rapidly decelerating, then its speed a fraction of a second before was higher than its present speed, and the target speed calculation may be lower than its true speed.

Another problem unique to moving RADAR is known as the batching effect. This is caused by slight time lags in the moving RADAR's sensing/computing cycle. Like the angular effect on moving RADAR, the batching effect can lead to the display of erroneously low or high target speeds.

Batching Effect

There will be two glaring inconsistencies. One, the target speed displayed will be in excess of the visual estimation of the target as perceived by the operator. Two, when the operator checks the patrol car displayed speed after the false target reading is obtained, it will in no way correspond to the calibrated patrol car speedometer speed. For example, if a patrol car is actually driving 55 mph and has locked onto a truck doing 40, the RADAR may display a target vehicle supposedly doing 100 mph while the patrol car is supposedly doing 15. The reading obtained should then be ignored as it lacks the necessary supportive evidence for complete tracking history.

Most RADAR units can be made to shadow, under the right conditions. During normal moving—RADAR operations, this effect is largely unavoidable; but luckily it is reasonably rare; and most importantly, is extremely noticeable to the operator.

If this occurs, the patrol car's speed will be displayed as the difference in speeds between the patrol car and truck rather than the patrol car and the stationary terrain. If a target vehicle is approaching at this time, the remainder of the patrol car's speed could be added to the target's speed by the RADAR. (Closing Speed - Patrol Speed) It should be noted that there must be a significant difference in speed between the truck and the patrol car to produce this effect.

A shadow effect may be caused if the beam that is supposed to determine the patrol car speed by tracking the stationary terrain locks instead onto a large moving vehicle in front of the patrol car. This large vehicle usually a truck must be close enough to the RADAR unit to effectively reflect a major portion of the normal beam.

will be negligible.

Provided you understand its capabilities and limitations, RADAR will remain a valid tool in the police arsenal for speed enforcement, resulting in both accident reduction and energy conservation.

Jamming and Detection of Police Traffic RADAR

In recent years, a small percentage of the motoring public has used increasingly sophisticated means to try to sidestep police traffic RADAR, offering rationales like, "RADAR is unfair!" and "Maybe some people can't, but I can drive safely and fuel-efficiently at higher-than-allowable speeds." Whatever reasons they offered, they all sound foolish when compared to the documented evidence that speed wastes energy—and speed kills.

Jamming Devices

Purposeful attempts to create false or distorted RADAR signals are called "jamming." This is not yet a widespread problem (jamming devices are illegal, and tend to be expensive and complicated), but various agencies are encountering it more and more.

The most effective jamming device is a radio transmitter that sends out a relatively strong signal with a frequency close to that of police traffic RADAR. The RADAR receiver "sees" that signal rather than (or in addition to) the signal reflected from the speeding vehicle, with the result that the RADAR displays either a false speed or no speed at all. The Federal Communications Commission (FCC) will not license a device whose purpose is to jam police RADARs. Even using an already-licensed radio transmitter would violate Federal regulations if the use were to purposely jam police RADARs.

It is easy to tell when a RADAR jammer is being used, because most of the jamming devices now in use are crude. When a jammer is being used close by, your Doppler audio should be inconsistent and uneven in tone. The speeds displayed on a RADAR being jammed tend to fluctuate, even though you can see no obvious change in the speeds of approaching vehicles. The best tipoff that a jammer is around occurs with the RADAR units that have transmission-hold switches. Some RADAR devices are capable, when on transmission-hold, of receiving and processing incoming signals. If the RADAR is displaying a speed and the audio is emitting a tone even when the RADAR is not transmitting a RADAR signal, a jammer is almost certainly being used nearby.

If you encounter a jamming device, you can contact the nearest FCC regional office for assistance. In addition, some States and local governments have language in their statutes outlawing the use of jamming devices similar to that in Federal law. In any event, be sure of what laws apply before actually confiscating the device or arresting its owner.

One will occasionally encounter or hear of other "techniques" for jamming police RADARs. These usually range from the laughable to the ridiculous. Among the more common "jammers" based on pseudoscientific superstitions, one will find:

- Aluminum paint stripes or metal foil strips on the outer side of a violator's vehicle. (If anything, this only increases the vehicle's ability to reflect the RADAR beam and makes it easier to measure its speed.)
- Hanging chains under a vehicle. (This might help keep static electricity from building up on the vehicle, but it certainly will not distort or reduce the radiowaves the vehicle reflects.)

- Hiding small metal objects or strips of metal foil inside a vehicle's hubcaps. (The only thing this can do is create unpleasant rattling sounds; the RADAR beam will not penetrate the hubcap.)

- Furious honking of the horn in short beeps, long bursts, or whatever. (The vibrating diaphragm of the horn could modulate a RADAR signal—but since the horn is under the hood, these vibrations are not detected.)

In short, none of these "techniques" has any effect at all on police traffic RADAR.

Getting advance warning of the presence of a police RADAR is probably the oldest method used by speed violators to avoid getting caught. The most common means of getting advance warning involves cooperation among violators. Soon after RADAR was first introduced for speed enforcement, violators acquired the habit of flashing their headlights to warn one another when it was around. People still do this, and undoubtedly it does reduce the number of enforcement actions taken. However, the flashing-headlight method probably has a positive influence on highway safety. The headlight-flashers tend to send out their warnings for several miles around the RADAR site, since they cannot inform the oncoming traffic of the exact location of the transmitter. The result is that traffic typically slows down to legal speeds for several miles each way.

In recent years the proliferation in the number of citizens' band (CB) radios in use has resulted in some motorists' using them to warn others that "Smoke" is "taking pictures." Unlike the headlight-flashers, CB users can tell their listeners exactly where the RADAR patrols are located, thus helping some motorists escape the law. However, CB's positive applications in terms of assistance to law enforcement agencies, and to motorists themselves when emergency situations exist, far outweigh this negative aspect.

A third major method of obtaining advance warning of RADAR operation is the RADAR detector. These instruments are nothing more than RADAR frequency receivers, designed to give off an audible and/or visual signal when exposed to a transmitted RADAR signal.

RADAR detectors have been on the market for many years. Early models were generally ineffective and suffered frequently from false alarms (buzzing when there actually was no RADAR in operation). Typically, they did not detect the RADAR until it was too late. However, recent improvements have resulted in models that can detect RADAR transmitters while still out of range of speed measurement, so there has been some increase in the number of drivers who use RADAR detectors.

A few States have legislation that bars the possession or use of such devices. A number of other States have introduced similar legislation. It is because of RADAR detectors that many recent police traffic RADARs have been equipped with "anti-fuzzbusters," switches that delay the RADAR transmission until the target vehicle is well in range. Using this feature, along with completing a proper traffic history, is an effective way to defeat RADAR detectors.

The experience of recent years proves that it is possible for police to do a very effective job of speed enforcement, despite some drivers' attempts to avoid getting caught. Violators can be apprehended, speed can be reduced, and lives can be saved. Neither the modern nor the old-fashioned methods of RADAR detection have significantly reduced the impact of a much-needed and effective speed control tool: police traffic RADAR.