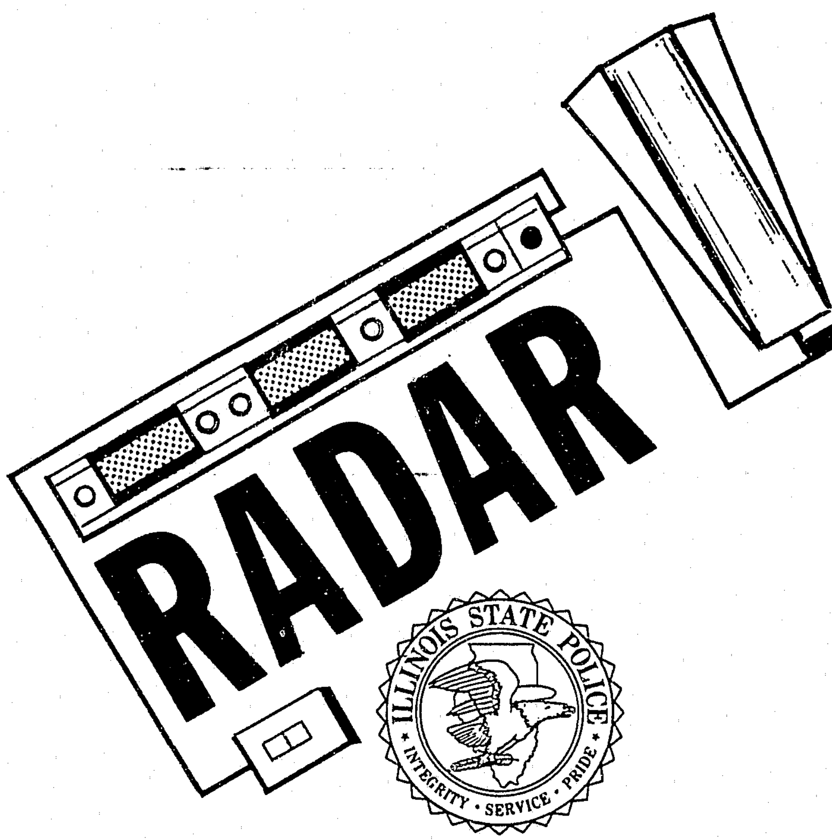
ILLINOIS DEPARTMENT OF STATE POLICE



STATE TROOPERS

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ILLINOIS DEPARTMENT OF STATE POLICE ACADEMY

BASIC TRAINING IN SPEED MEASUREMENT

INSTRUCTIONAL MANUAL

Prepared By

Bureau of Communications, Division of State Troopers

and the

Office of Training

ACKNOWLEDGEMENT

We wish to thank the many people and organizations that graciously gave us the use of their training manuals and assistance in the development of this training manual. We wish to express our thanks especially to the United States Department of Transportation National Highway Traffic Safety Administration who allowed us to utilize their Trainee Instructional Manual from which much information was taken, and the many State Police and Highway Patrols that allowed us to review their training materials.

Joseph T. Dakin
Superintendent
Office of Training

INTRODUCTION

This document is the principle study guide and reference source for the Basic Training Program in Radar Speed Measurement used by the Division of State Troopers. The manual lists the training objectives and content. The training objectives express what it is that you are expected to be able to do at the completion of the training program and the specific requirements needed to receive certification as a radar operator. This information will be expanded and supplemented by the instructor's presentation, classroom discussions, and hands-on practice sessions.

The Radar Instructional Manual is a basic reference document, but should not be considered to be a complete training course in itself. Much of the training must come from classroom and practical participation on the part of the student. By the end of the course, you should have a thorough knowledge of the subject through the use of lecture notes and reference citations, which together with the content of this manual, will constitute a complete body of information about Speed Measurement.

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COURSE OVERVIEW

Overall Course Objective

The basic goal of all police work is to protect the lives, property, safety, and well-being of the public. All law enforcement activities seek that goal. Traffic law enforcement is no exception. Traffic laws have arisen from safety related needs. Avoiding accidents requires well designed roads and vehicles, and well regulated driving behavior, and prevents injuries, preserves property, and saves lives. If there were no traffic laws, or no traffic law enforcement, there would be no regulation of driving behavior. People would do as they pleased: they would follow their own rules and take whatever risks they felt like taking. The result would be chaos, confusion, frequent accidents, and many deaths and injuries.

To avoid this situation, good traffic laws are necessary and these should be enforced as effectively as possible. There is, of course, no traffic law that is unimportant. But some laws are more important than others, and deserve special emphasis in enforcement. In general, the most important traffic laws are those that regulate the most dangerous driving behaviors.

Vehicle speed laws belong to this most important class. Research shows that excessive speed is a major contributing factor to motor vehicle accidents. Further, excessive speed increases the severity of accidents that do occur: a high-speed crash is much more likely to produce death or serious injury than is a low-speed crash. And research also shows that vehicle speeds can be reduced, and thousands of lives can be saved each year. But the research is equally clear that this can happen only as a result of vigorous, effective speed enforcement.

Where does RADAR fit into all of this? After all, RADAR is the focus of this course.

RADAR is of interest to law enforcement agencies because it is a practical method of measuring vehicle speed. An accurate, on-the-spot measurement of how fast a suspected speeder is traveling is indispensable for effective speed enforcement: in most cases, an officer cannot take enforcement action against a suspected speed violator, or hope to obtain a conviction, unless his speed can be established. RADAR is an important and potentially very effective means of establishing an accurate measurement of speed. It is not the only means available, and it may not be the best means in certain cases. But RADAR has numerous advantages, including high accuracy (if operated properly), that makes it the most widely used method. In recent decades, RADAR technology has advanced significantly, and its cost effectiveness has continued to improve. RADAR has made a major contribution to our speed enforcement capability; a traffic law enforcement officer who is well trained in RADAR operation has a very effective tool at his disposal.

The Illinois State Police believes that police traffic radar is an effective enforcement tool. The role of police radar in traffic safety enforcement continues to be of critical importance, especially in view of the safety and fuel conservation benefits of the 55 mile per hour speed limit and the requirement that all states meet the national 55 mile per hour compliance criteria enacted by the Congress. Police traffic radar provides a means of increasing enforcement effectiveness and permits police administrators to make better use of scarce personnel and increasingly costly fuel.

The basic purpose of this training program is expressed in the overall course objective: to improve the effectiveness of speed enforcement through the proper and efficient use of RADAR speed measurement instruments. It is our intention that every officer who completes this course will become a better enforcer of the traffic laws governing vehicle speed: that is, he will detect more speed violations, apprehend more violators, and secure more convictions. In becoming a better speed enforcer, he will receive training that will make him an expert operator of one or more RADAR instruments. But he also will receive other training, in other aspects of speed enforcement.

TYPES OF SPEED MEASURING DEVICES

STOPWATCH - Probably the first mechanical device to measure vehicular speed, this device was accepted by courts as early as 1906. In one form or another, this device is still utilized today.

PHOTO SPEED RECORDER - Developed prior to 1910, this device consisted of a camera synchronized with a stopwatch. By taking photographs at a measured time interval, vehicular speed could be calculated mathematically by comparing image sizes.

SPEEDOMETER - Used since about 1916, this device remained the "standard" for vehicular speed measurement for fifty years. Modern moving radar still relies upon the speedometer reading for patrol speed verification.

SPEEDWATCH - Basically an electronic timer, this device required two rubber tubes stretched across the road. As the vehicle crossed the first tube, the electronic timer started. When the vehicle crossed the second tube, the electronic timer stopped. From the final reading, vehicular speed was computed.

VASCAR - The Visual Average Speed Computer And Recorder is basically a time and distance computer. The unit is used to calculate the time required for a motorist to cross two fixed reference points and, from that information, convert the data into miles per hour.

RADAR - Based upon the Doppler Principle (Doppler shift), police traffic radar has become the most common device used to measure vehicular speed. Sophisticated police radar can "clock" vehicles while the patrol unit is stationary and while the patrol unit is moving in the direction opposite of the target vehicles.

Doppler Principle

The Doppler Principle was first described by an Austrian physicist named Christian Doppler in 1842.

The Doppler Principle is a principle of physics which states:
"When an energy, be it light, radio, or sound energy, is transmitted from a moving object and reflected from a stationary object or transmitted from a stationary object and reflected from a moving object, or both, it increases or decreases in frequency in direct proportion to the speed of the object." In the X-band radar frequencies, that Doppler shift occurs at the rate of 31.38 cycles per second. The Doppler shift for K-band is 72.02 cycles per second.

DESCRIPTION AND HISTORY OF RADAR

The acronym RADAR comes from RAdio Detection And Ranging. To operate, a beam of energy is transmitted from the set and is reflected from a target back to the receiver of the RADAR unit. The target is usually a motor vehicle, but the unit can also measure the speed of airplanes, baseballs, animals, etc.

RADAR was developed in World War II by the military of the United States, Great Britain, and Germany. It was not possible to be patented as a manufactured product because it was being developed by the military. Its primary function was to locate and estimate the time of arrival of enemy aircraft. Due to the military secrecy during World War II, the different frequencies were denoted by alphabetical letters, e.g., X-band, K-band, A-band, B-band, etc.

In 1948, the first police RADAR was introduced for use as an enforcement tool. It was big, bulky, and heavy. It took half an hour or more to set it up and an equal amount of time to dismantle the equipment. It operated with a paper graph recorder which utilized an ink pen and a cup to contain the ink reserve which would often spill upon the vehicle upholstery and the officer's clothing.

Radar in Illinois

The Illinois State Police first used RADAR in 1956. The equipment was very large and cumbersome and required a vehicle to be altered so that the equipment could be permanently mounted. The equipment consisted of a meter calibrated in miles per hour to allow the operator to receive a fast visual reading of the registered speed of a passing vehicle; a large recorder and graph which gave a permanent record on a roll of graph paper graduated in two mile per hour increments; and the transmitter-receiver which was approximately two feet by one foot in size, mounted upon a tripod.

The vehicle would be parked off the road and a cable, sometimes as much as 100 feet long, would connect the transmitter-receiver to the recording equipment in the RADAR car. Because of this arrangement, and the length of time required to place the equipment into operation, an additional vehicle was required to stop the suspect vehicle and issue a traffic ticket.

This created problems in many areas. First, there was no training in the use of RADAR equipment. The officer was supposed to "pick up" the method of using the equipment on his own. Second, the vehicle in which the RADAR was mounted had to be placed in such a manner as to allow the officer operating the RADAR to continually observe the suspect vehicle from the time it entered the RADAR beam until it was stopped by the officer in the assisting unit. Third, because of the difficulty and time required to place the unit into operation, the RADAR operator would have to work at the same location for extended periods of time. This caused the motorist to become aware of the RADAR and to simply slow down within this area and then speed up after he had traversed the area being checked.

In 1959, State Police General Order Number 105 was issued outlining "RADAR Operation and Procedure." The order briefly described the function of RADAR, where RADAR should be used, assigned responsibility for the use of the equipment, use of graphs, and the procedures to be followed to use RADAR. This set up a guideline to be followed and provided the first uniformity in the operation of RADAR by the State Police. But it still did not require or prescribe any type of training for the operator.

The first Illinois State Police RADAR training began in 1961 when a two-hour block of instruction was added to the Basic Recruit Curriculum. This block of instruction familiarized the officer with the "Doppler" Principle of RADAR. The instructor gave a lecture on how the RADAR wave operated and the theory or principle of speed detection.

This program continued for many years until the Trooper-Coach system of field training was developed. With the beginning of this first structured field training, the coach was required to show the probationary trooper the mechanics of operating the RADAR equipment. This was the first time any training was given to a new officer where he actually saw the equipment while being trained. Then in the 1970's, the lecture portion of the training was extended to four hours. The equipment had improved and was now reduced into a small hand-held "gun" that could be used while performing normal patrol duties. The probationary officer was given many hours of practical use of the equipment under the tutorage of an experienced field officer.

The system of operation by an officer who had simply learned to operate the equipment through practice continued until the Dade County, Florida case brought the question of expertise of the officer operating the equipment to national prominence. Then, the Illinois State Police started to evaluate the qualifications of the officer operating the RADAR and found that officers were lacking in both classroom training and supervised field experience. Also, about this time, a federal grant was obtained and a large number of moving RADAR units were purchased. With the purchase of this equipment, a training program by the manufacturer was started and all patrol officers within the State Police were trained in the use of the new equipment by classroom lecture and practical "hands-on" field training. This was good training as far as it went, but because the manufacturer was primarily interested in selling equipment, and not in preparing the officer to be a competent operator, it was felt that a program of training the new officer, administered by competent training officers, was needed. With this in mind, and by following recent court decisions, the following training and recertification program was developed.

BASIC RADAR OPERATION GOAL

The goal of this training is to certify all officers in the operation of the moving and hand-held radar units. It is intended that the pertinent knowledge and skills be developed to ensure proper radar speed measurement in order to effectively enforce the law.

Student Performance Objectives:

Upon completion of the course, the student will be able to demonstrate the following:

1. Describe the Doppler Principle.
2. Define the terminology utilized in radar operation.
3. Set up the procedure for normal operation of the radar equipment, including antenna placement, cable connections, and internal and tuning fork circuitry verification.
4. Switch operation for "moving" and "stationary" modes.
5. Operational limitations of moving radar.
6. Complete 20 practical performance tests.

BASIC PRINCIPLES OF RADAR SPEED MEASUREMENT

Even though there are different features and variations between types and families of RADARs, the underlying principle remains 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 (or signal, as it is commonly called) 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." Thus, the RADAR operator learns that a target is present in the beam. The way in which the energy reflected from the target is processed by the receiver determines what type of information will be available to the operator. If the RADAR is to compute range to the target, there will be timing circuits in the set that will time the round-trip travel period of the signal, starting at the time the signal is transmitted and ending when the reflected signal is detected by the receiver. The operation of these timing circuits is made possible by the fact that radio energy always travels at 186,000 miles per second, the speed of light. Both radio energy and light energy travel at that speed. The speed of radio energy is, therefore, a "constant" in all of the computations that are performed in any RADAR set. As will be seen later in this course, the speed of radio energy —186,000 miles per second — never changes even when the RADAR is used to determine the speed of moving targets.

Police RADARs use another characteristic of radio energy in order to measure speed. That is, the frequency (cycles per second) of a radio signal is changed when the signal is reflected from a target that is moving at a different speed than the RADAR set. This change or shift in frequency is known as the "Doppler" shift and will be explained in more detail later. However, that is the principle on which speed-timing RADAR works. To review: If there is relative motion between the RADAR and the target, there is a shift between the transmitted frequency and the frequency of the small signal received back from the target. The greater the relative velocity, the greater the frequency shift. By measuring the degree of frequency shift, the RADAR is able to display the target-vehicle speed in miles per hour.

The Wave Concept

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

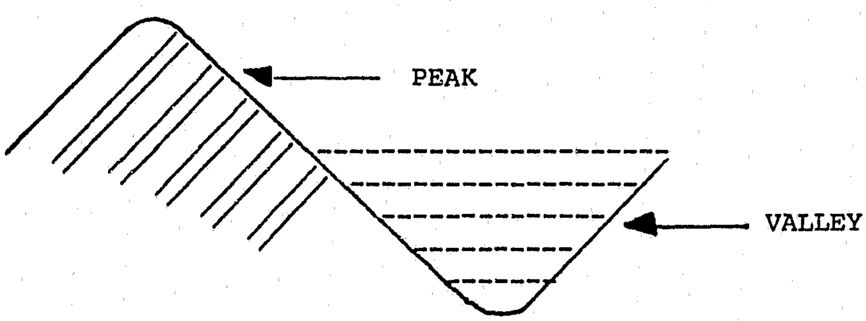


Figure 1

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 end is given a sharp upward "snap," one will observe a wave travel down the rope toward the pole: a distinct peak followed by a distinct valley. If one keeps "snapping" the rope steadily, a steady stream of waves will be generated — a continuing series of peaks and valleys.

This wave motion also exists in sound, light and radio; any sound or beam of light can be described in terms of a distinctive form of wave. Each RADAR device transmits a continuous series of waves. All radio waves have three distinguishable characteristics:

- The signal speed (speed of propagation) - constant
  - Every RADAR signal travels at the same speed, namely, the speed of light. This is equal to about 186,000 miles per second, or (equivalently) about 30 billion centimeters per second. Both the transmitted and received RADAR signals always travel at that constant speed.
- The wave length - variable
  - Literally, the physical distance, or length from the beginning of the peak to the end of the valley. Most RADAR signals have wave lengths of about 3 centimeters (about 1-1/5 inches).
- The frequency - variable
  - That is, the number of waves transmitted in one second of time. Police RADAR signals have frequencies of more than ten billion waves per second.

Note: Frequency usually is measured in cycles per second. One cycle is the same thing as one wave. Scientists and engineers use the term Hertz (abbreviated Hz.) instead of cycles per second. All of these terms have exactly the same meaning: one Hertz equals one cycle per second, which equals one wave per second. We will continue to use the expression "waves per second," since this helps to keep in mind the wave nature of RADAR signals. Thus, referring to a previous statement, a police RADAR operates at a frequency of over ten billion Hertz (10 gigahertz).

Figure 2 illustrates the physical characteristics of wave length and frequency.

With radio signals, wave length and frequency are closely related. Both radio and light travel at 186,000 miles per second. Therefore, any given radio wave length is associated with a specific frequency. For example, an X-band (10.525 gigahertz) RADAR signal has a wave length of approximately three centimeters and frequency of 10.525 billion waves per second. So, for an X-band signal,

> Frequency times wave length = 10.525 billion x 3 = 30 billion centimeters per second = 186,000 miles per second.

Similarly, a K-band (24.150 gigahertz) RADAR signal has a wave length of about 1 1/4 centimeters and a frequency of 24.150 billion waves per second; so in that case,

> Frequency times wave length = 24.150 billion x 1-1/4 = 30 billion centimeters per second = 186,000 miles per second.

ILLUSTRATION:

A signal with a frequency of 5 waves-per-second, and a wave length of 10 feet. If the signal transmitter is turned on for exactly one second, it will send out exactly 5 waves; each wave will be exactly 10 feet long (from beginning of peak to end of valley); the signal will travel exactly 50 feet during that second.

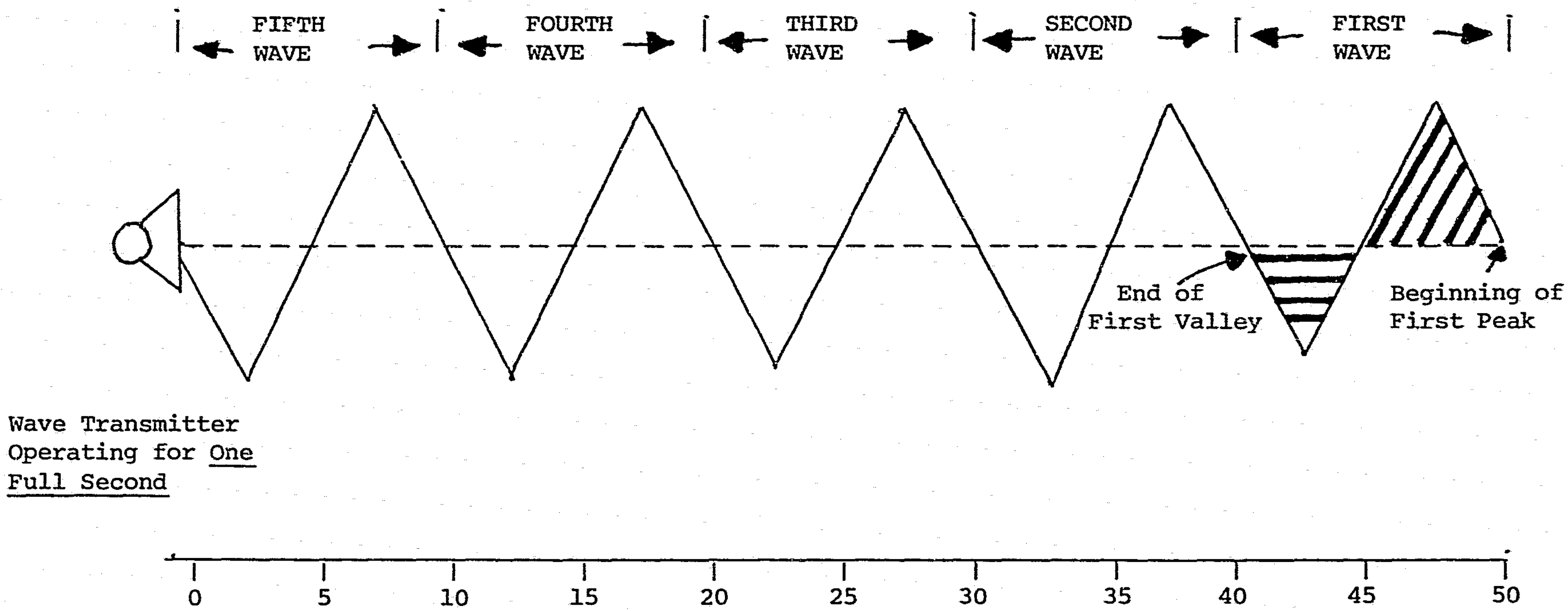


FIGURE 2 The Concepts of Wave Length and Frequency

In both cases, the frequency-times-the-wave length always equals about 30 billion centimeters per second, which is the speed of light (186,000 mps).

Since that fundamental relationship is true for every RADAR signal, we can now see what must happen whenever a RADAR signal is changed: when a change occurs, the signal's speed stays the same, but its wave length and frequency both change.

The Doppler Principle

Christian Johann Doppler, an Austrian physicist, is credited with having discovered the fact that relative motion causes a signal's frequency to change. He discovered this basic scientific principle by studying sound waves, but it was later found that the principle applies to all kinds of wave motions, including light waves, sound waves and radio waves. We honor this discovery by referring to this basic scientific fact as the Doppler Principle.

Practically everyone has had opportunities to observe how the Doppler Principle affects sound waves. If you have ever stood by the side of a railroad track as a train approaches, you probably noticed that the approaching train made a high-pitched sound. (With sound waves, "pitch" is another word for "frequency.") Then, as the train passed by your position, you noticed an immediate drop in pitch. What happened was that the frequency of the train's sound was changed due to the relative motion: as the train approached, you heard a high-frequency sound; as soon as the train started to move away, the sound changed to a lower frequency. Exactly the same observation can be made if you stand alongside a road and listen to the sounds of passing cars.

We can express the Doppler Principle in RADAR terms as follows:

a. Whenever there is relative motion between a RADAR and an object, the frequency of the transmitted signal will be different than the frequency of the reflected signal.

b. If the relative motion is bringing the object and the RADAR closer together, the reflected signal will have a higher frequency than the transmitted signal.

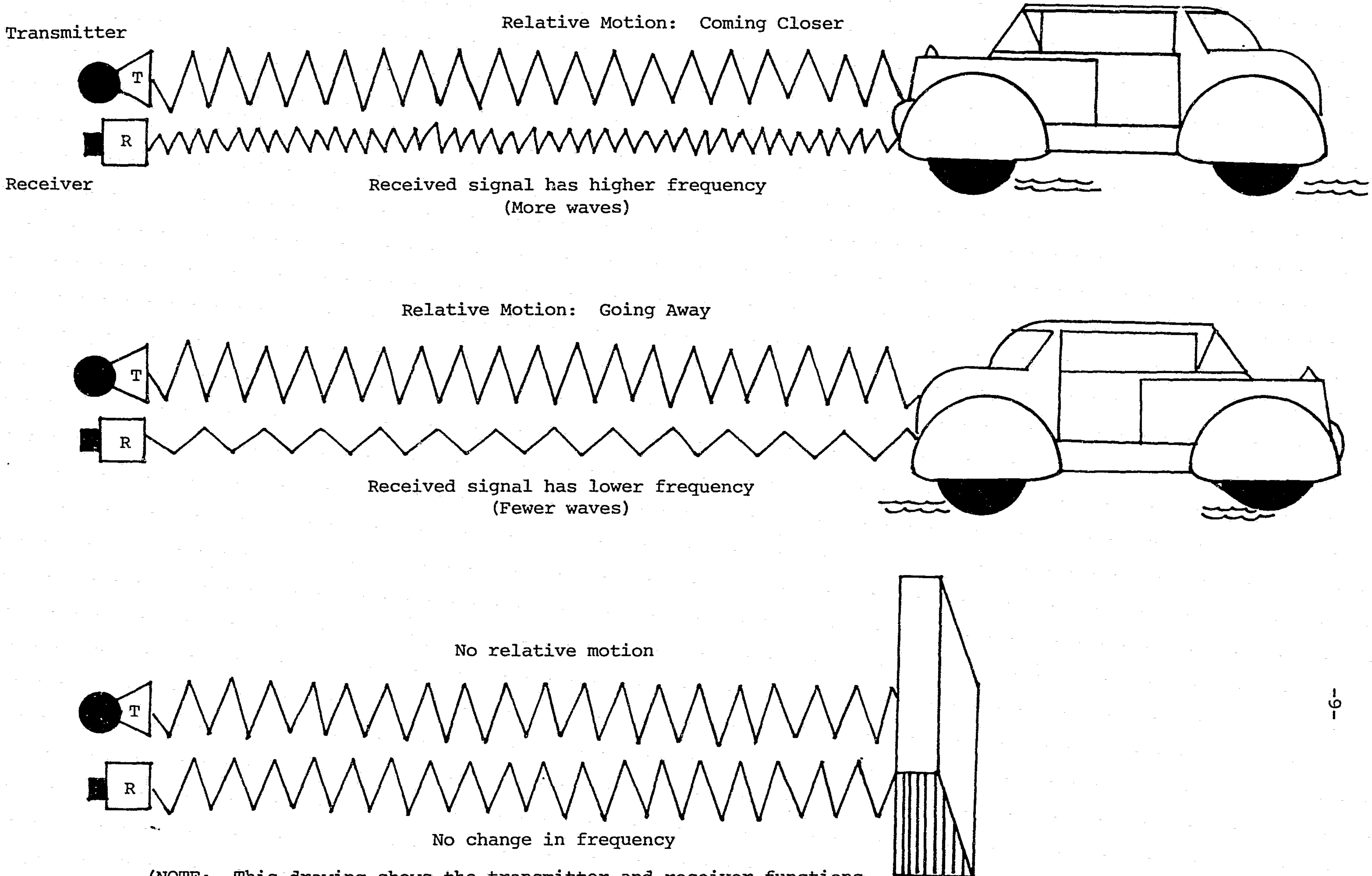
c. If the relative motion is taking the object and the RADAR farther apart, the reflected signal will have a lower frequency than the transmitted frequency.

d. The speed of the relative motion determines exactly how much higher or lower the reflected signal's frequency will be.

Figure 3 illustrates the basic facts of the Doppler Principle.

The key point to remember about the Doppler Principle is that the frequency change happens only when there is relative motion between the RADAR and the solid object. If the RADAR and the object are both stationary, then there is no relative motion and the received signal has the same frequency as the transmitted signal. (That is what is happening in the lowest picture in Figure 3, where a stationary RADAR is transmitting toward a solid wall.)

In summary, relative motion will occur only when the solid object and the RADAR are not moving in the same direction, at the same speed. It will occur if:



(NOTE: This drawing shows the transmitter and receiver functions separately only to simplify the illustration. The actual equipment consists of a single unit--a "transceiver.")

Figure 3 Basic Facts of the Doppler Principle

a. The RADAR is stationary and the object moves;

b. The object is stationary and the RADAR moves; or

c. If they both are moving, as long as they move 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 and the reflected signal will have different frequencies if there is relative motion between the RADAR and the object.

Finally, when the Doppler Principle is applied, the reflected frequency is compared with the transmitted frequency and the speed of the relative motion can be determined by this frequency difference. We cannot tell whether the object is moving, or the RADAR is moving, or both. All we can tell is how fast they are moving relative to one another. The RADAR instrument cannot even determine whether the object and the RADAR are getting closer together or farther apart. All it can tell is how fast the distance between them is changing. But, of course, that is very helpful and important information for speed enforcement purposes.

In order to become a competent RADAR operator, it is not absolutely necessary that one understands how or why the Doppler Principle works. It is sufficient to be aware that there is a valid scientific basis for RADAR speed measurement.

Angular Effect in RADAR Speed Measurement

If the RADAR is stationary, any relative motion must be caused by the object itself. Now, it might happen that the object is moving directly toward or directly away from the RADAR. If that is the case, then the speed of the relative motion will be exactly equal to the object's true speed. But usually we do not have that situation. For obvious safety reasons, we usually set up a stationary RADAR alongside a roadway, at least a short distance off the traveled portion of the road surface. Then, cars traveling along the road surface will not be heading directly toward us (we hope!), but rather will miss us by at least some small margin of safety when they pass by. Whenever we have that common situation, what we have done is to create an angle between the car's direction of motion and the RADAR's position. Figure 4 illustrates that situation.

It is an established scientific and mathematical fact that when a car's direction makes an angle with the position of a stationary RADAR, the relative speed will always be less than the true speed. And, since the change in the signal's frequency is based on the relative speed, the RADAR speed measurement will be lower than the car's true speed. This is known as the angular effect*, which we can state in stationary RADAR terms as follows:

> A stationary RADAR will measure the true speed of an object only when that object is moving directly toward or directly away from the RADAR. Under any other circumstance the angular effect will cause the stationary RADAR speed measurement to be lower than the object's true speed. The amount of difference between the measured speed and true speed depends upon the angle between the object's motion and the RADAR's position: the larger the angle, the lower will be the measured speed. This effect always works to the motorist's advantage when the RADAR is operated in the stationary mode.

*The angular effect is sometimes called the cosine effect, in recognition of the mathematical principle from which it derives.

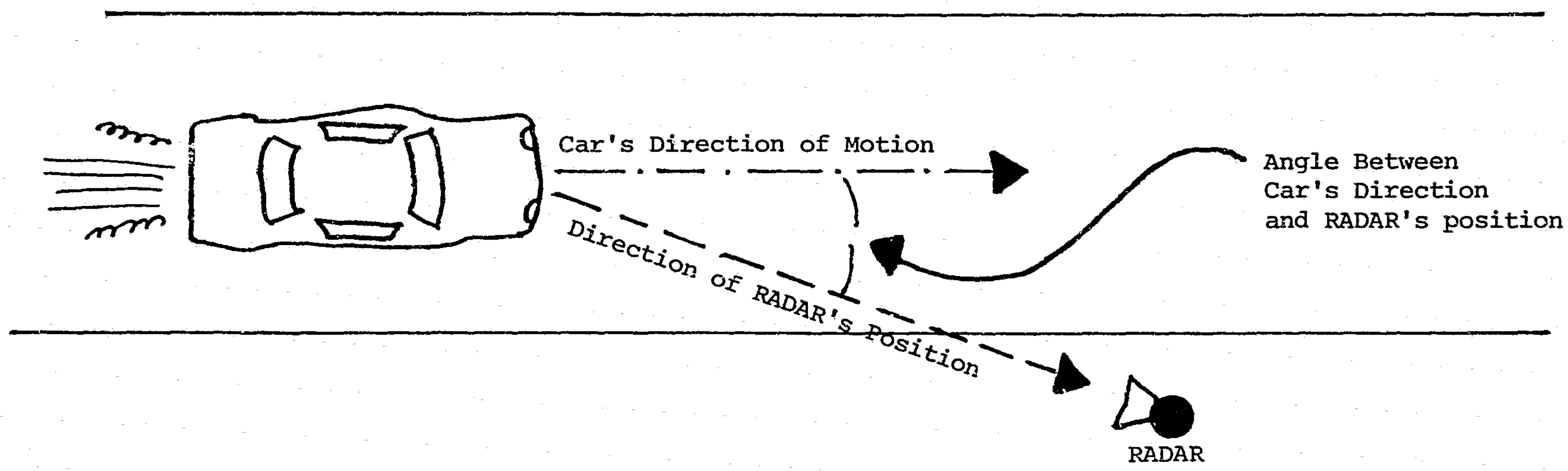


FIGURE 4 Stationary RADAR Set-Up: Angular Effect

The influence angular effect will have on the RADAR speed measurement will be determined by the size of the angle. Generally speaking, the angular effect remains small as long as the angle itself remains small (see Figure 5). Table 1 indicates how a stationary RADAR speed measurement will differ from true speed as a function of angle. (Entries in the table are stationary RADAR speed measurements in miles per hour.)

In order to minimize the stationary RADAR angular effect, the angle should be kept as small as possible. This means, usually, that we try to keep as close to the traveled road surface as practical without creating risks to officer safety or to the safety of other motorists or pedestrians. But even then the angle will depend on how far away the car is whose speed is to be measured: as the car gets closer, the angle will grow steadily larger. This is illustrated in Figure 6, which shows three successive positions of a vehicle traveling along a road at a steady speed.

Table 1

True Speed as Affected by Angle of RADAR

Angle (Degrees)	True Speed: 30 MPH	40 MPH	50 MPH	55 MPH	60 MPH	70 MPH
	Measured Speed					
0^{o}	30	40	50	55	60	70
1^{o}	29.99	39.99	49.99	54.99	59.99	69.99
3^{o}	29.96	39.94	49.93	54.92	59.92	69.90
5^{o}	29.89	39.85	49.81	54.79	59.77	69.73
10^{o}	29.54	39.39	49.24	54.16	59.09	68.94
15^{o}	28.98	38.64	48.30	53.12	57.95	67.61
20^{o}	28.19	37.59	46.99	51.68	56.38	65.78
30^{o}	25.98	34.64	43.30	47.63	51.96	60.62
45^{o}	21.21	28.28	35.36	38.89	42.43	49.50
60^{o}	15.00	20.00	25.00	27.50	30.00	35.00

EXAMPLE: If an automobile traveling 70 miles per hour moves in a direction that makes an angle of 15^{o} with the RADAR beam, the RADAR speed measurement will be 67.61 miles per hour.

At the first position in Figure 6, relatively far from the RADAR, the angle between the vehicle's direction and the RADAR's position is quite small. At the second position, the angle obviously has increased. At the third position, the angle has become noticeably large. Thus, the closer the vehicle is to the RADAR, the larger will be the angle, and the greater will be the angular effect. In other words, the measured speed appears to decrease as the vehicle approaches the RADAR.

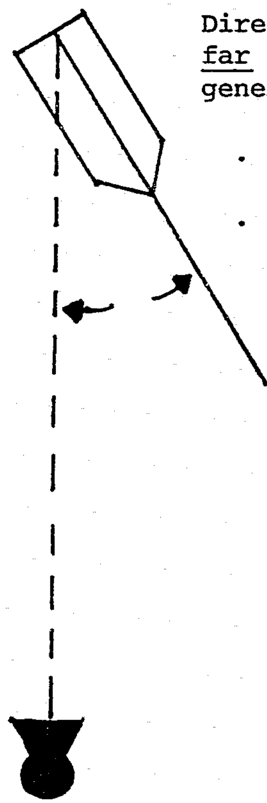
In summary:

The closer to the traveled portion of the road the RADAR is positioned, the better the control over angular effect.

Some police RADAR operators occasionally set up at an appreciable distance from the road surface, in order to conduct covert surveillance. Whatever the merits might be for that practice, be aware that it will magnify the angular effect. The result may be that some speed violators will escape apprehension because your RADAR speed measurements are lower than the true speeds.

Direction of motion close to direction of generator:

- small angle
- relative speed close to true speed



Direction of motion far from direction of generator:

- large angle
- relative speed appreciably less than true speed

FIGURE 5   Relationship between Angle and Relative Speed

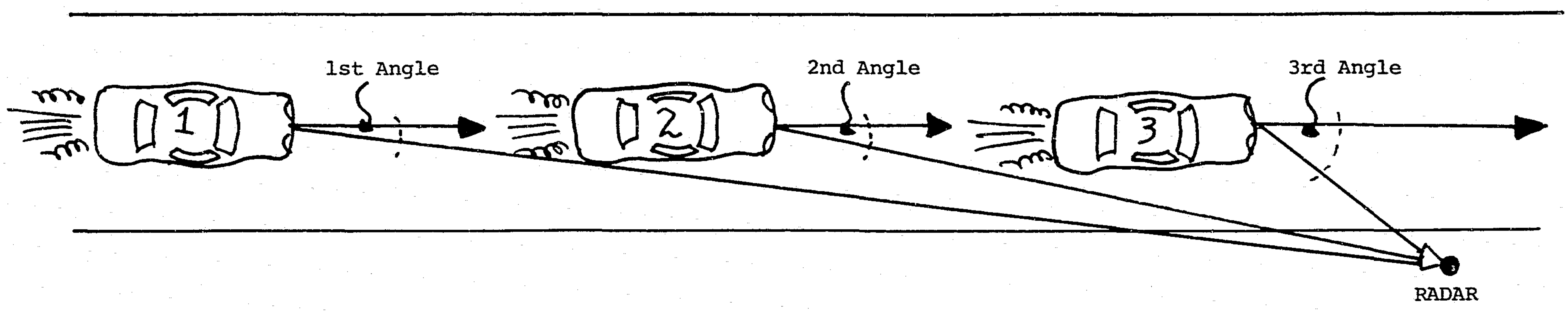


FIGURE 6 Effect of Vehicle's Position on Measurement Angle. As the target vehicle approaches and passes the RADAR unit it appears to slow down.

How we aim, or point, the RADAR device will have an impact on the magnitude of the angular effect.

In our example, it was assumed that the RADAR device would be pointed directly at the vehicle by the time the vehicle reached its minimum measurement distance. But if we are careless in setting up, we might position the RADAR in such a way that it does not "see" the on-coming vehicle until it gets much closer to its position. Figure 7 illustrates what can happen in that situation.

In the upper picture of Figure 7 (Situation "A"), the RADAR has been carelessly aimed: it is pointed across, rather than down, the road. As a result, a speed measurement will not be obtained until the car is quite close to our position and when the angular effect is fairly large.

In the Situation "B" picture, the RADAR is well aimed: it is pointing directly at the on-coming car when that car is at the desired measurement distance. This helps to make sure that the angular effect is kept within reasonable bounds.

Remember, with stationary RADAR the angular effect is always in the suspect's favor. The angular effect on moving RADAR is discussed in the following sections.

RADAR Target Selectivity and Sensitivity

In all of the discussions thus far, we have assumed that a RADAR device will always detect the reflected signal from any moving object toward which it is pointed. That is not quite true. Depending on the size, shape, speed, and exact location of the object, its reflected signal may not be "seen" by the RADAR unit. In other cases, when there are additional moving objects nearby, the RADAR unit might "see" the signal that is reflected from one of these additional objects instead of the wave reflected from the object with which we are most concerned. Therefore, RADAR devices are not always completely sensitive to all types of moving objects under all circumstances. And, they are not always selective in measuring the speed of a particular object as opposed to others that may be nearby. This lack of complete sensitivity and selectivity affects the way RADAR devices can and should be used.

To understand how problems with target sensitivity and selectivity can occur, we need to understand how the RADAR beam spreads, and how it is reflected by the objects it strikes. The RADAR transmitter does not send out energy in all directions. Instead, the transmitter's antenna focuses most of the energy into a cone-shaped beam. This RADAR beam is very similar to the beam of light that is sent out by a searchlight. A RADAR beam, if visible, would resemble a cone containing a cigar-shaped or elongated football-shaped core. Figure 8 gives a rough sketch of the shape of a RADAR beam. As indicated in Figure 8, most of the energy in the RADAR beam is concentrated in the cigar-shaped central core. A small portion of the energy escapes outside the main beam, in what is known as the side lobes. These side lobes are caused by minor imperfections in the RADAR antenna. They usually are insignificant in power. Within the central core of the beam the concentration of energy, or beam strength, decreases the farther we go from the transmitter. If an object is far from the transmitter, it will be struck by relatively little energy; therefore, it will reflect relatively little energy back toward the RADAR unit. If an object is close to the transmitter, and directly in the path of the maximum beam strength, it will receive and reflect more energy.

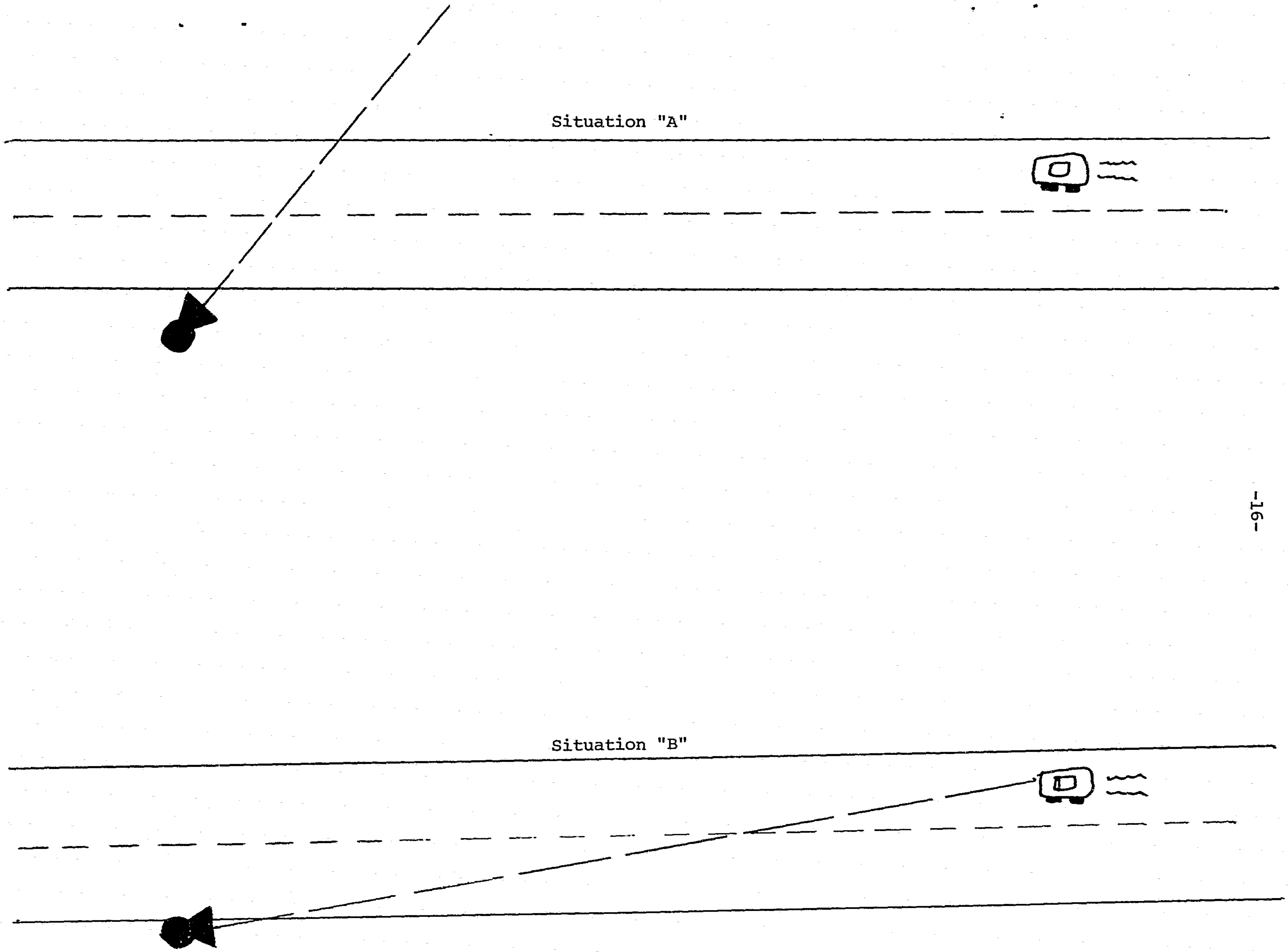


FIGURE 7 Impact of RADAR Aiming on Angular Effect

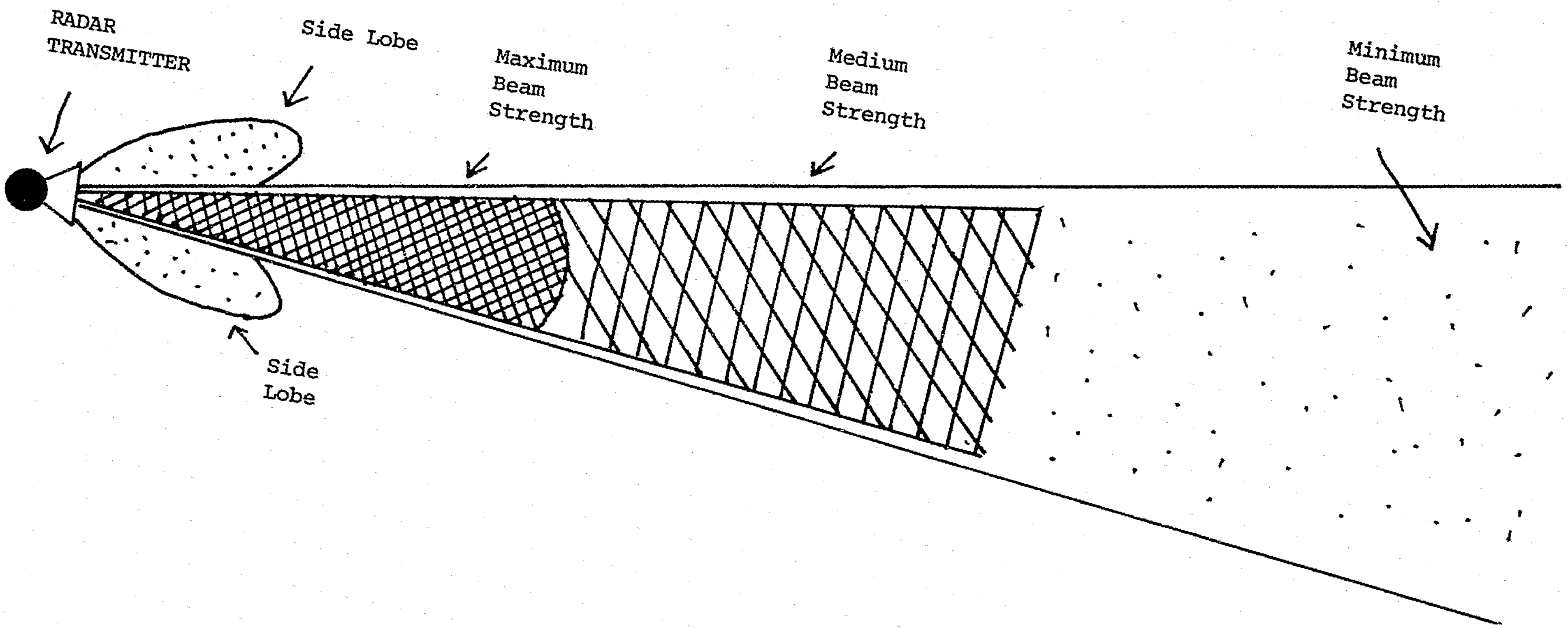


FIGURE 8 Illustration of a Typical RADAR Beam

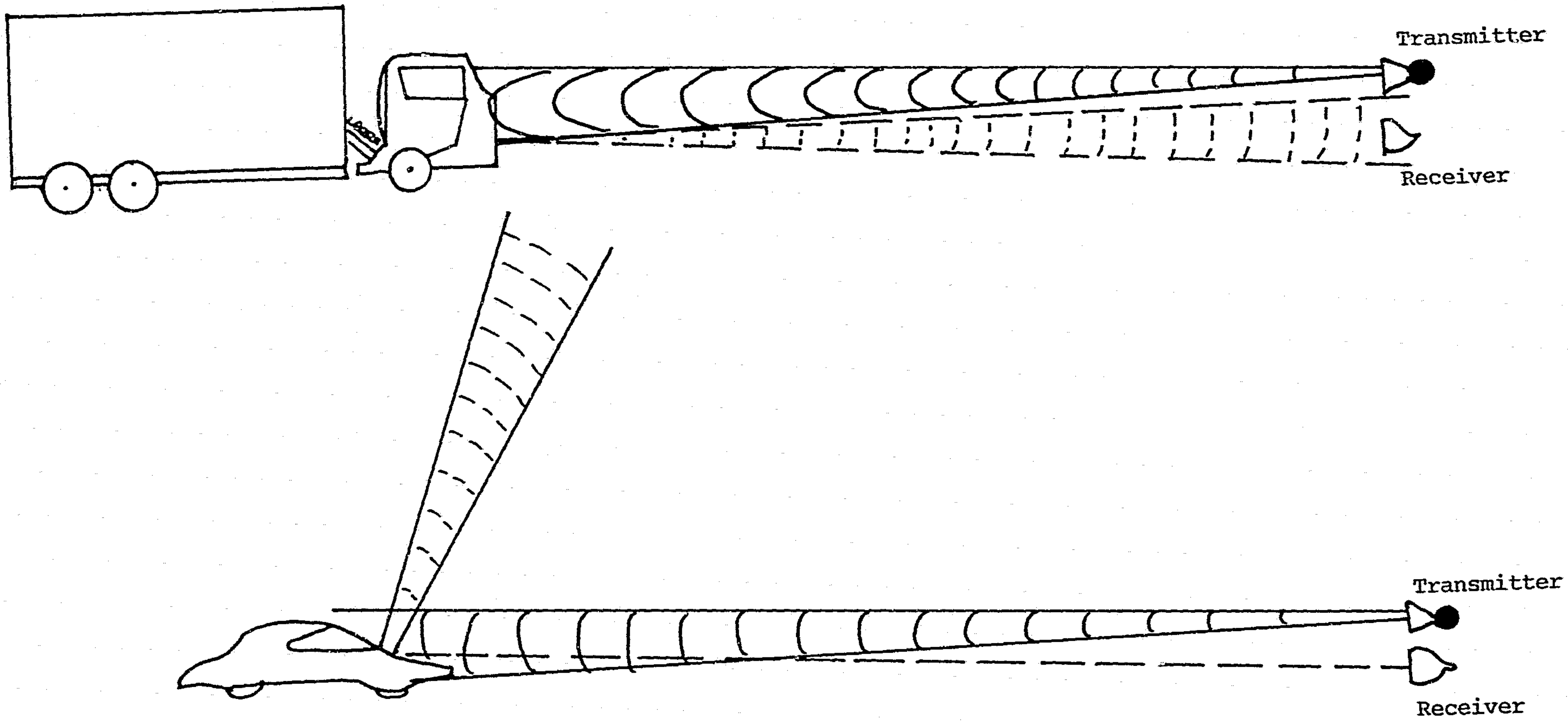
One factor that has very little affect on target selectivity is the RADAR aim. It might seem logical to think that, using careful aim, the RADAR beam could be pointed right to the particular vehicle in which we are interested and kept off any other vehicles that happen to be in the area. The problem is that a RADAR beam is fairly wide (as illustrated in Figure 8). Even the narrowest-beam RADAR currently available is about 11 degrees wide; some instruments have beams that are more than 20 degrees wide. A beam whose angle is 11 degrees will be more than 38 feet wide at a point 200 feet down the road. It will be more than 57 feet wide at a point 300 feet away. Obviously, by the time the beam extends even a few hundred feet, it is impossible to keep all of it within a single lane of traffic, and certainly not on a single vehicle.

It should be emphasized that it is very important to aim the RADAR as carefully as possible, in order to minimize the angular effect, as was discussed earlier. But RADAR aiming is not a very helpful solution to target selectivity problems, since most of the beam will almost always "spill over" onto other vehicles and objects. One thing that can be done, with certain RADAR instruments, is to carefully set the RADAR's beam range. The term "beam range" is sometimes confusing: it does not mean the length of the transmitted beam. A RADAR signal's length actually is infinite, i.e., it will travel forever unless it is stopped by some object that reflects or absorbs it. When "beam range" is used, however, it means how far away an object can be and still be "seen" by the speed-measuring RADAR.

Not all objects reflect RADAR energy equally well. Metal objects reflect RADAR beams quite well, as do objects made of concrete and stone. Glass and plastic objects allow most of the beam to pass through them without reflection, just like they permit beams of light to pass through. Other objects, such as leaves, tall grass, etc., absorb much of the RADAR energy that strikes them, thus reducing the amount of energy reflected. The net result is that the amount of energy reflected back from the object depends on its composition. It also depends on the size of the object: a large mass of metal, for example, will be struck by and will reflect more energy than will a smaller mass.

What this basically means is that a RADAR unit will be more sensitive to some objects than to others, depending upon location, composition, and size. If the RADAR is to "see" an object, it has to receive at least a minimum amount of energy from that object. If the object is too small, or too far away, or made of transparent material, the RADAR might not be sensitive to it. For example, a motorcycle is small, and contains little metal in comparison to other vehicles. Therefore, motorcycles reflect relatively little energy back toward the RADAR: very often, a RADAR simply will not measure a motorcycle's speed until it is quite close to the transmitter. On the other hand, a tractor-trailer contains a great deal of metal mass and reflects a relatively large amount of energy. Therefore, a RADAR might be able to measure a truck's speed even when the truck is far from the transmitter.

The shape of a vehicle or object will also affect how much energy it reflects back to the RADAR receiver. A RADAR beam will bounce off a surface at the same angle at which it strikes the surface. If the surface is perpendicular to the beam, most of the reflected energy will be reflected back to the RADAR. But if the surface is slanted, some of the reflected energy will be deflected into space and will not be picked up by the RADAR receiver. Figure 9 illustrates this phenomenon. There are two vehicles, a truck and a sports car, being struck by transmitted RADAR beams. The truck has a large, vertical surface that reflects energy back toward the RADAR. The sports car has a streamlined, slanted surface that allows much of the RADAR beam to ricochet off away from the receiver. Thus, a streamlined vehicle may not be "seen" by a RADAR as easily as a "box-shaped" vehicle. The problem we have been discussing deals with factors that affect the detection range of a given size target.



(Note: This drawing shows the transmitter and receiver functions separately only to simplify the illustration. The actual equipment consists of a single unit - a "transceiver.")

FIGURE 9 Effect of Vehicle Shape on Strength of Received Signal

Figure 10 illustrates this situation. In the figure, three different vehicles are traveling in adjacent lanes toward a patrol/RADAR unit. The closest vehicle, a motorcycle, is within range of the maximum beam strength. However, because the motorcycle is small, only a small amount of energy is striking it and being reflected back. The next vehicle, a standard passenger car, is in the medium beam strength range. Less energy per square inch is striking the car than is striking the motorcycle. But the car has many more square inches of metal surface to reflect the energy. Therefore, the car might actually send back a stronger signal than the motorcycle. The third vehicle, a truck, is even farther away, in the minimum beam strength range. But the truck also is much larger, and therefore more reflective, than the car or the motorcycle. Again, the signal reflected from the distant truck might be stronger than either the car's or the motorcycle's signal. In the situation shown in Figure 10, a good speed measurement might be obtained, but the operator could not be certain whether it was the truck's, car's, or motorcycle's speed being displayed. And, an instant later, after these vehicles had moved somewhat closer, the relative strength of their signals might change, and a different speed measurement might be obtained as the RADAR switches from the truck to the car or from the car to the motorcycle. Again, the RADAR would not be able to select a specific vehicle to measure; it would simply respond to the strongest reflected signal at any instant of time. Some RADAR units are designed so that they will not show any speed measurement if they receive two different signals having nearly the same strength; other units will always show the speed of the strongest received signal. In either case, the operator must know how the RADAR unit is designed to operate before the target can be correctly identified.

Range Control Adjustment

If the RADAR unit has a range control, adjusting that control changes the sensitivity of the RADAR receiver. As indicated earlier, a RADAR's sensitivity means the minimum amount of energy it must receive before it will respond to (or "see") a reflected signal. If the sensitivity is set low — so that the RADAR responds only to very strong signals — only nearby targets will usually be seen. If the sensitivity is set high — so that even relatively weak reflected signals can be "seen" — the speed of more distant vehicles can be measured.

The reduction of beam range can help improve target identification. If the operator sets a short range, the signals returning from other vehicles in the same traffic lane can be eliminated. Figure 11 illustrates the effect of range setting.

In this figure we see three vehicles: A, B and C. Vehicles A and B are approaching the RADAR unit. Vehicle C is in the adjoining (opposite direction) lane, heading away from the unit. All three vehicles are within the RADAR beam. Suppose we want to measure the speed of Vehicle A. If we adjust a RADAR unit's range to a low level, only Vehicle A is "in range." Vehicle B has not yet come into range, and Vehicle C already has passed out of range. In theory, only Vehicle A will produce a reflected signal that is strong enough to be "seen" by the RADAR; therefore, an accurate measurement of Vehicle A's speed will be obtained. If, instead, the range had been adjusted to its maximum level, all three vehicles presumably would reflect back signals strong enough to be "seen," and this might "confuse" the RADAR and prevent accurate speed measurement.

It might seem from this discussion that range setting provides the perfect solution to target selectivity problems. Why not just set the range as short as possible (say, only a few feet) to make sure that only one vehicle is ever "in range" at any given time? Then, there would never be any question about which target is the correct one, since there would be only one target at a time.

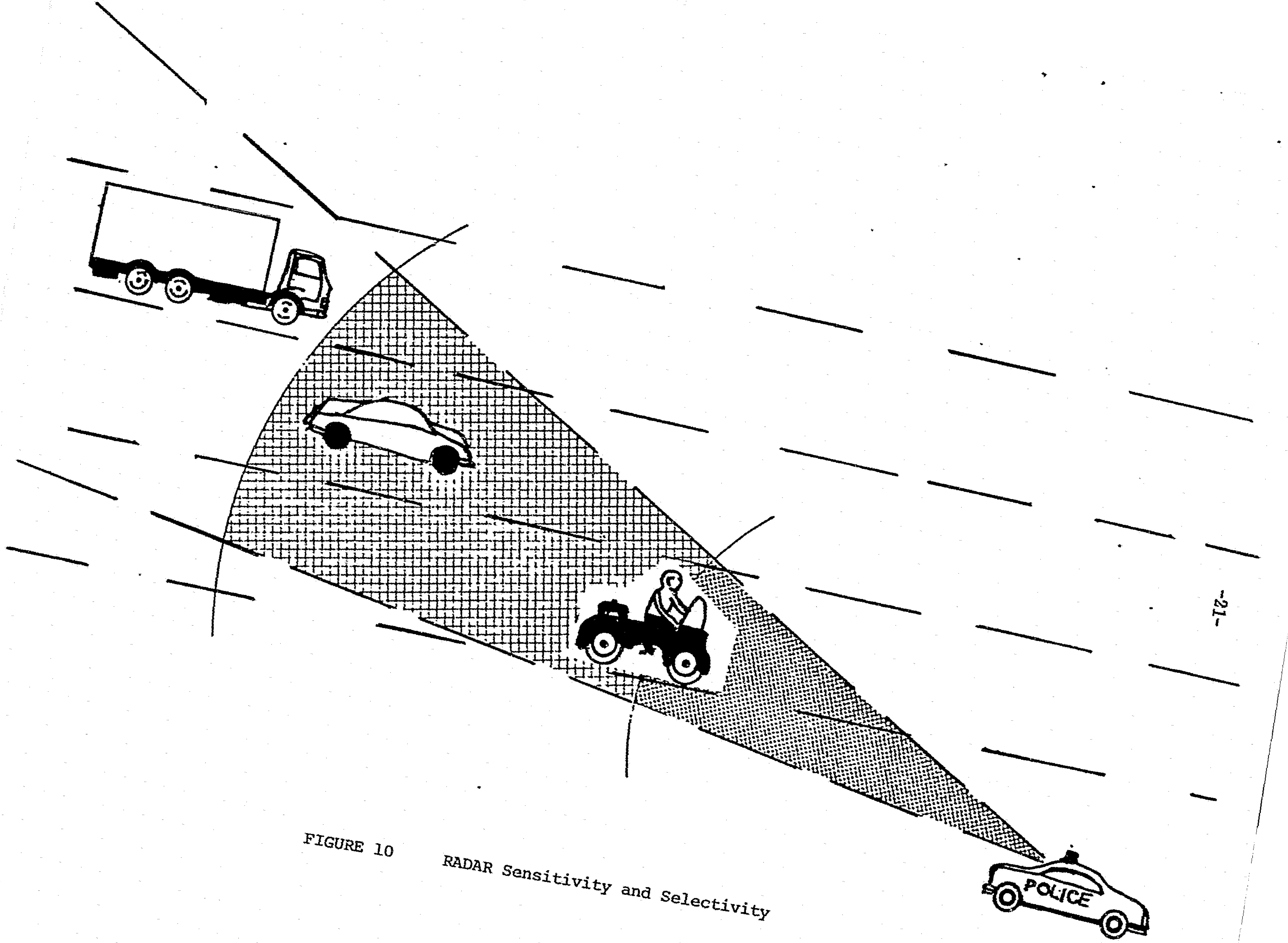


FIGURE 10 RADAR Sensitivity and Selectivity

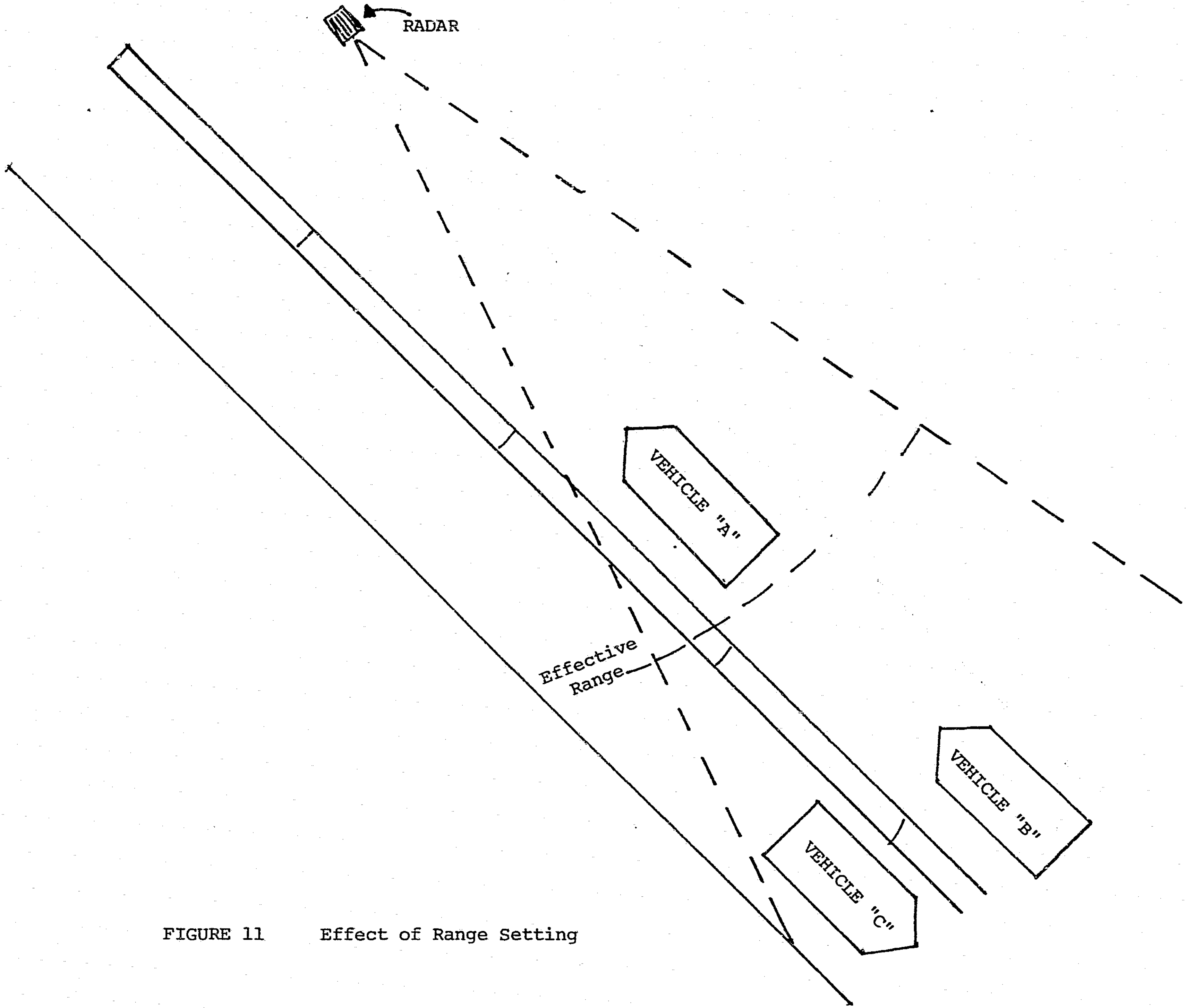


FIGURE 11 Effect of Range Setting

The problem with that idea is that it would not allow enough time to obtain the necessary information and evidence, and take the proper actions. If the range is set too short, vehicles will pass into and out of range in just a few seconds, or even fractions of a second. During that brief interval, it would be difficult for the RADAR to process the signal and display a speed reading. Also, at very short ranges, the angular effect would tend to make the measured speeds much lower than the true speeds.

On the other hand, it is not desirable to set the range too long: this would increase the sensitivity and make the RADAR unit more susceptible to interference (as will be discussed later). We need to strike a reasonable balance in range setting, so that a reasonable degree of target selectivity is achieved as well as an adequate lead time for apprehension. As a general rule, the appropriate beam range depends on the amount of vehicle bunching:

> If operating at locations where vehicles tend to travel clustered close to one another, relatively short range setting should be used to provide reasonable target selectivity. If, on the other hand, vehicles tend to be widely separated, a longer range setting should be used.

It should be noted that some RADAR devices do not have range setting controls. This method of dealing with selectivity problems obviously cannot be used with those devices; however, changing the vertical position angle of the antenna can affect range: down for short range, up for longer range.

It is important to understand that a RADAR unit's range setting is approximate, not precise. Remember that what the range setting actually does is to adjust the minimum signal strength to which the RADAR will respond. Most RADAR units are designed so that the average, standard shaped automobile will reflect a RADAR signal of that particular strength when it is at the approximate selected range from the transmitter. Some larger vehicles might send back a sufficiently strong signal even though they are at a greater range. Some smaller vehicles will not reflect a signal that is strong enough to be "seen" until they are much closer to the transmitter. So, when adjusting the RADAR's range setting, be aware that you will be able to measure some vehicles' speeds at longer ranges and that you will not be able to measure other vehicles' speeds until they are well within range. Again, the range setting is only approximate, for the average vehicle. Only experience will teach the proper use of the range setting (sensitivity control).

One final point should be mentioned in this context: the beam range setting has absolutely no affect on RADAR detectors, i.e., instruments used by some speed violators to obtain advance warning of RADAR speed measurement. Those detectors sense the RADAR beam. You cannot reduce the effectiveness of RADAR detectors simply by reducing the range, because the power in the beam remains constant regardless of the range control setting. The range control only determines the sensitivity of the receiver.

One method of dealing with the selectivity problem is simply to continue to observe the speed measurement and watch what happens when the first vehicle passes out of the beam. Look at Figure 12. Both vehicles are within the beam, but in a few seconds Vehicle A will pass out of the beam and start to pass by the RADAR. When that happens, Vehicle A no longer will receive RADAR energy, and so it will stop sending back a reflected signal. At that instant, one of three things will happen:

- The speed measurement might suddenly change noticeably. If that happens, the implication is that the speed measurement was from Vehicle A, but abruptly switched to Vehicle B when A passed out of the beam. Thus, we would conclude that the speed measurement seen just before the switch occurred was from Vehicle A.

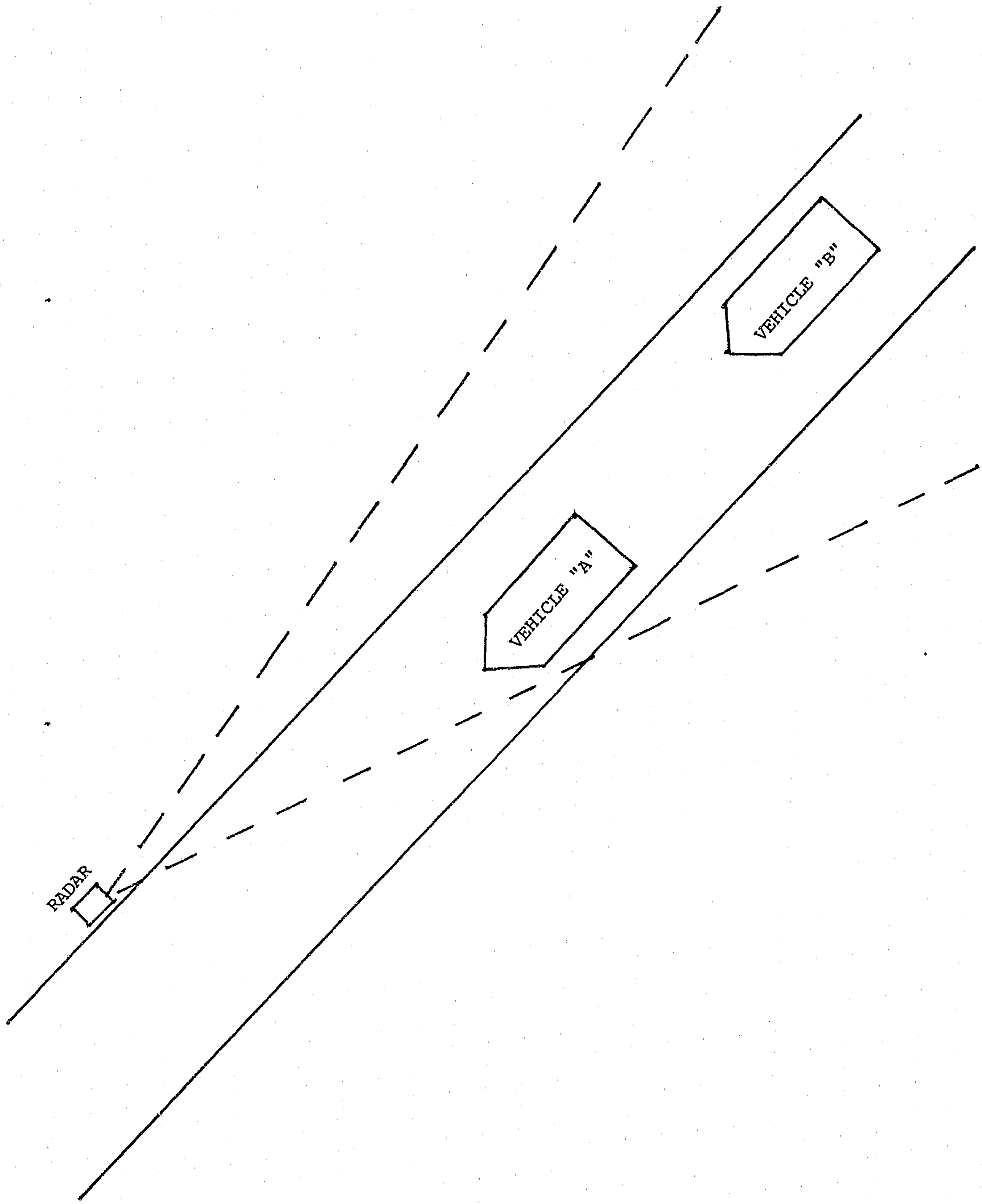


FIGURE 12 Vehicle Location and Selectivity

- The speed measurement might hold essentially steady until Vehicle B finally passes out of the beam. In other words, no change occurred when Vehicle A passed by. The implication would be that we were measuring B's speed all along.

- The speed measurement might hold essentially steady until both Vehicle A and Vehicle B pass out of the beam. The implication, supported by your visual speed estimation, would be that both Vehicle A and Vehicle B were traveling at the same speed.

The important thing to remember is:

> If there is any doubt in your mind as to which target vehicle is being tracked, TAKE NO ENFORCEMENT ACTION.

The biggest impediment to this method is the "locking" feature that virtually every RADAR instrument has. This feature allows the operator to press a button or pull a trigger and cause the current speed measurement to "freeze" on the display. It may also stop the RADAR from transmitting. Many RADARs have an automatic locking feature which causes this "lock" to occur as soon as the speed measurement reaches a predetermined level.

The purpose of the locking feature is to "preserve the evidence" so that the operator does not have to look at the RADAR's display window or try to remember the reading. Whatever the merits of this feature, "locking" the speed measurement prevents observation of the switching that might occur when the first vehicle passes out of the beam. Therefore, manual locking should not be used when facing a possible selectivity problem. The automatic locking feature should never be used for enforcement purposes.

Perhaps the most basic way to minimize target selectivity problems is to rely on your own ability to estimate vehicle speeds. Experimental studies have shown that people can learn to judge the speeds of vehicles quite accurately on the basis of their own visual and auditory observation. Traffic law enforcement officers in particular can, and do, become very proficient at estimating speeds because observing traffic is such a major part of their job. If you are not already proficient in visual speed estimation, you should practice by observing vehicles being driven at controlled speeds or by pacing to establish a vehicle's speed. After becoming proficient, an officer can visually estimate the speed of every vehicle that he suspects might be exceeding the limit. He can then compare the visual estimate with the speed measurement that was obtained from the RADAR instrument. If his estimate and the RADAR measurement agree reasonably well, he can be more confident that he obtained the measurement from the appropriate vehicle. But if the RADAR measurement is significantly higher or lower than his own estimate, he can conclude that there is a good possibility that the measurement is inappropriate, due to a selectivity problem or some other factor. If that is the case, he should disregard the RADAR speed measurement. Then, of course, he should try to ascertain the cause of the inappropriate measurement and overcome it by moving to another location or by following correct procedures for the situation.

Some RADAR instruments have a feature that will allow the operator to use his sense of hearing to supplement his visual observations, and help to eliminate selectivity problems. That feature is known as audio tracking. Instruments that have it produce a sound as well as a visual indication of the speed measurement. The sound essentially is a translation, into sound waves, of the Doppler frequency shift experienced by the RADAR beam. A high pitched sound means a fast moving target; a low pitched sound means a slower target. Also, if there are two or more vehicles in the beam, returning signals of nearly equal strength, the audio tone may produce "fluctuations," a characteristic sound indicating that selectivity problems may be present.

Audio tracking, if it is available with the RADAR instrument you are using, is a potentially helpful tool for avoiding selectivity problems. If it is available, be sure to take advantage of it: it is not good practice to turn the audio tracking volume off, or to keep it too low to be useful.

One final point needs to be made before leaving the subject of selectivity: proper antenna aiming, proper selection of beam range, and constant observation of speed measurement can help to reduce selectivity difficulties; they cannot prevent those difficulties altogether. If traffic is relatively congested, there is no way to guarantee that the speed of the correct target vehicle is being measured. When that is the case, RADAR should not be used. Some other method, such as pacing or stopwatch should be used instead.

Interference, Jamming, and Detection of RADAR Transmitters

A lack of target sensitivity or selectivity can hamper RADAR speed measurement; however, other factors also can reduce RADAR effectiveness. Some of these factors occur naturally or accidentally; others occur because of purposeful attempts by speed violators to "beat" RADAR. All such factors need to be understood in order to deal with the problem.

Interference (Non-Optimum Conditions of Operation)

"Interference" encompasses a wide range of natural and man-made phenomena that affect either transmitted or reflected RADAR beams. For purposes of this manual, when the term "interference" is used, it is referring to something that accidentally affects the RADAR. Purposeful attempts to subvert or otherwise affect RADAR will be discussed later.

One type of natural interference is known as "multi-path beam cancellation." In essence, this produces RADAR blind spots. For example, you might observe a target vehicle heading toward you, monitor its speed, then observe that the speed measurement simply disappears for a few seconds, and then suddenly reappears. All of this happens while the vehicle remains constantly in sight. "Multi-path beam cancellation" results when a phase inversion occurs in the signal and cancels the energy reflected from the target vehicle. During this brief period no signal is received and the RADAR display blanks.

Interference occurs more commonly because of man-made objects. Moving objects, such as rotating signs, alongside the road will reflect the RADAR beam and — because they are moving — cause Doppler shifts that are interpreted by the RADAR receiver as target vehicles. The rotating blades of fans (such as those found on building roofs and air conditioning units) also can act as "false targets." Indeed, the patrol vehicle's own defroster fan sometimes can create interference when the RADAR beam is transmitted through the front windshield. Also, many man-made objects give off RADAR frequency waves that can be "seen" by the RADAR as apparent vehicles. Fluorescent lamps, neon signs, and similar devices are examples of objects that can create these false signals.

Interference was the cause of some of the more bizarre and highly publicized "inaccuracies" that surfaced in Dade County 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 was pointed at a banyan tree (which obviously was not moving) and a reading of approximately 85 mph appeared on the display window. Not so widely reported was the fact that a CB radio transmitter located in the same vehicle as the RADAR was keyed at that instant. Some of the radio signal sent out from the CB was picked up by the RADAR, and that was what caused the 85 MPH reading. It did not matter that the RADAR happened to be pointed toward the tree at that time; it could have been pointed at the ground, a house, the sky, or any place else. The actual source of the interfering signal was the CB, not the tree.

One might wonder why a CB radio can interfere with a RADAR, and whether this is likely to be a common problem since so many cars are equipped with CBs. CB radios and RADAR operate on different frequencies. The operating frequency of any of the CB channels is about 27 million waves per second (27 million Hertz). The X-band RADAR operates at approximately ten billion waves per second (10 billion Hertz).

Under ordinary circumstances, the RADAR will not pick up the CB signal. But when the CB and the RADAR are extremely close together (like in the same car) interference can result. The problem is that the RADAR receiver is a broad band device. If enough energy is present, even at far removed frequencies, the RADAR receiver might "hear" the interfering signal if the CB is very close, and if there are no other stronger signals being received.

Another well reported incident from the Dade County situation was the case of the so-called 28 mph house. Here again, interference was the culprit. The RADAR was aimed at the house through the car's front windshield. Some of the energy was deflected down from the windshield toward the window defroster unit, which was on at the time. What the RADAR actually measured was the speed of the defroster fan's blades.

Other types of interference received considerable attention in Dade County and elsewhere. Two of these types are known as the scanning effect and the panning effect, respectively.

The scanning effect occurs when the RADAR unit itself is moved (when operating in stationary mode) while a speed measurement is made. For example, a hand-held RADAR might be swung swiftly past the side of a parked car, a brick wall, or some other stationary object, and a speed measurement may be produced. What happens, of course, is that swinging the instrument creates relative motion between the RADAR and the stationary object, and the relative motion induces a change in frequency between the transmitted and received signals. The scanning effect can be avoided by refraining from moving the stationary mode RADAR while a speed measurement is being made.

The panning effect happens only to two-piece RADAR units, i.e., instruments whose antennas and counting units are physically separated from one another and connected by a cable. If the antenna is pointed at its own counting unit, an erroneous speed measurement might appear on the display. This is caused by electronic feedback between the two components.

As indicated earlier, interference becomes a more difficult problem when the RADAR unit is operated on a long-range setting. So it is sometimes possible to reduce interference by reducing range. But there will be locations where it is not possible to eliminate interference, or reduce it to a tolerable degree. When that happens, you will have to abandon RADAR operations at that location, and move on to another site so that there will be no possible question about the accuracy of your speed measurements. Interference causes "false" signals that are usually fairly weak. The RADAR will ignore those false signals if a sufficiently strong signal is received from a moving vehicle.

Jamming

Purposeful attempts to create false or distorted RADAR signals are what we mean by the term "jamming." This is not a widespread problem, especially since jamming devices tend to be expensive and somewhat complicated. Still, the officer may occasionally encounter this phenomenon.

The most common jamming device is a RADAR frequency transmitter. It sends out a relatively strong signal with a frequency close to that of the speed measuring RADAR. The RADAR receiver "sees" that signal rather than (or in addition to) the signal reflected from the speeding vehicle. The result is that the RADAR indicates either a false speed or no speed at all. These transmitters must be licensed by the Federal Communications Commission, just like any other RADAR transmitter must be licensed. The FCC will not issue a license for a device whose purpose is to jam police RADARs. Even if a transmitter happened to be licensed, for whatever reason, it would still be in violation of Federal regulations if it were used purposefully to jam police RADARs. If you happen to encounter a jammer, the nearest FCC field office should be notified immediately.

One occasionally will encounter, or hear of, other "techniques" for jamming police RADARs. Among the more common "jammers" based on pseudo-scientific superstitions, one will find:

- Aluminum paint stripes or metal foil strips placed on the outer surface 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 attached to the underside of a vehicle. (This might help to keep static electricity from building up on the vehicle, but it will not distort or reduce the RADAR energy the vehicle reflects.)

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

- Furious honking of the horn. (The vibrating diaphragm of the horn could modulate a RADAR signal; however, since the horn is under the hood, those vibrations are not detected.)

In short, none of these cheap "home remedies" has any effect on the speed measuring RADAR.

Detection

Obtaining advanced warning of the presence of a police RADAR is probably the oldest method used by speed violators to avoid apprehension. The most common means of detecting the RADAR involves a cooperation among the violators. Within a short time after RADAR was first introduced for speed enforcement, violators acquired the habit of flashing their headlights to warn other drivers of the RADAR's presence. This practice continues today, and undoubtedly does reduce the number of enforcement actions that are taken. However, the flashing headlight method probably enhances the deterrent effect of speed enforcement, and thereby has a positive influence on highway safety.

The "headlight flashers" tend to send out their warnings for several miles in advance of the RADAR site, and cannot inform the oncoming traffic of the exact location of the transmitter; the result is that traffic typically slows down to the legal speed limit for several miles in both directions. Of course, it is precisely this kind of compliance with the speed limit that is expected to be achieved through enforcement efforts! It should also be noted that the flashing headlight warnings are totally ineffective against moving RADAR operations, since the opposite direction traffic is itself under surveillance in that case.

The same view can be taken about the other major method of obtaining advanced warning about RADAR operations: namely, the RADAR detector. Those instruments are RADAR receivers, designed to give an audible (and/or visible) signal when exposed to a sufficiently strong RADAR beam. Detectors have been on the market since 1962. 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 the RADAR had already "seen" the vehicle. However, there have been some recent improvements in this type of device, and late models are able to detect RADAR transmitters while still out of range of speed measurement. Together with these improvements, there has been some increase in the number and proportion of drivers who use these detectors. The newer model RADAR units are designed so that they can be turned on and off at will and, thus, avoid early detection.

The experience of recent years proves that it is possible to do a very effective job in speeding enforcement despite attempts by some segments of the driving public to thwart police efforts. We have seen that violators can be apprehended, that speed can be reduced, and that lives can be saved. Neither the modern nor the old fashioned methods of communication among violators have been very effective.

Principles of Moving RADAR

In all of the discussions and illustrations so far, we have focused primarily on RADAR devices that remain stationary at all times. Recently, there has been increased use of more advanced speed-measuring RADAR, capable of operation from a moving patrol car.

The most important thing to remember about a moving RADAR is that its beam measures two different speeds:

- The speed of the target vehicle relative to the patrol vehicle.
- The speed of the patrol vehicle relative to the ground.

The phrase "speed relative to the patrol vehicle" needs to be understood clearly. A simple example may help. Suppose the patrol car is traveling in the northbound lane of a roadway at 50 mph, while another car (the target vehicle) is traveling southbound at 70 mph. The two vehicles are closing on each other at their combined speed, which is 50 + 70 = 120 mph. Thus, the speed of the target vehicle relative to the patrol vehicle is 120 mph.

The importance of this "relative" speed is this: the frequency of a RADAR beam sent from the moving patrol car to the moving target vehicle and reflected back again will undergo a Doppler shift, and the amount of Doppler shift will depend upon the relative speed. In the example just described, if a standard (stationary) RADAR were used on board the moving patrol car to measure the speed of the southbound target, it would show a speed of 120 mph; it would not show the 70 mph target speed. The speed of the total relative motion between the patrol car and the target vehicle is 120 mph.

Then how do we get an accurate measurement of the target's speed with a moving RADAR? That type of RADAR must also determine the speed of the patrol car at that same instant. Thus, moving RADAR produces two measurements: the patrol car's own speed, and the combined speed (or closing speed) of the two vehicles. This combined speed is the sum of the patrol car's speed and the target's speed. So, if we subtract the patrol car's speed, we are left with the target's speed. In simple arithmetic:

TARGET'S SPEED = COMBINED SPEED - PATROL'S SPEED

or

TS = CS - PS

We know how the RADAR measures the combined speed; it applies the Doppler Principle that we described earlier. How does it measure the patrol car's speed? One thing it does not do is use the patrol car's speedometer, although many people mistakenly think this is how moving RADAR works. The speedometer has nothing to do with this equipment, and will not affect the RADAR measurement. Instead, the RADAR also uses the Doppler Principle to measure the patrol car's speed, by determing the frequency shift in the beam reflected from the ground or from other non-moving objects.

When the RADAR beam is sent out, part of it strikes the target vehicle and is reflected back. Another portion of the beam (usually, most of it) simply goes on forever without striking anything. Still another portion of the beam strikes stationary objects (e.g., the ground) and also is reflected back.

The moving RADAR's receiver is able to detect and process simultaneously two reflected signals: one from the ground, the other from the target vehicle. The signal coming back from the target vehicle has undergone a frequency change known as a "high Doppler shift," i.e., a rather large change caused by the fast relative motion between the patrol car and the target. The signal coming back from the ground has undergone a "low Doppler shift," i.e., a lesser frequency change caused by the patrol car's own speed. The moving RADAR then computes the difference between the low and high Doppler shifts, and translates that difference into a target vehicle speed measurement. Figure 13 is a simplified illustration of the moving RADAR principle.

Because moving RADAR is based on radio signals and the Doppler Principle, it is subject to basically the same factors that affect stationary RADAR. It can be affected by natural and man-made interference. It can be detected and jammed. And, it is susceptible to the angular effect. However, the angular effect might cause a moving RADAR to produce a target speed measurement that is higher than the target's true speed.

Moving Angular Effect

This problem can arise because the angular effect can cause the moving RADAR to produce a patrol speed measurement that is lower than the patrol car's true speed. Suppose, for example, that there is a parked vehicle, or a building, or a large metal sign, or some other highly reflective stationary object alongside the road. A large part of the beam might strike the roadside object instead of striking the ground ahead of the patrol car. Then, the reflected signal that the RADAR "thinks" is coming from the ground ahead actually would be coming from an object that is at an angle from the patrol car. Because of the angular effect, the relative motion between the patrol car and the roadside object would not be quite as fast as the patrol car's true speed. Therefore, the patrol speed measurement would be low.

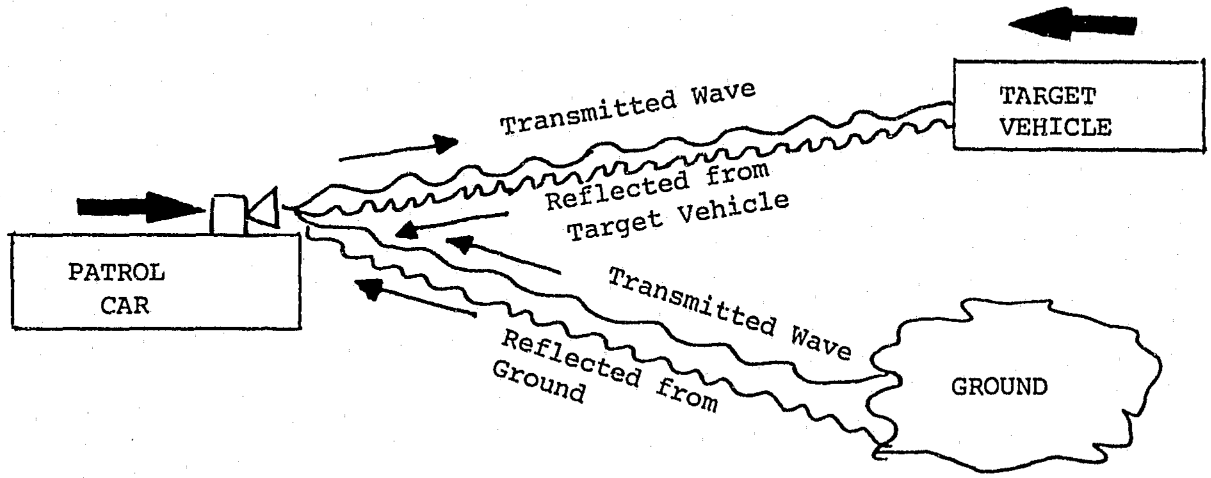


FIGURE 13 Principles of Moving RADAR Speed Measurement

This problem can also arise if the moving RADAR is not aimed properly. The antenna should be aimed approximately 5 degrees left, which virtually eliminates this type of angular effect. If the moving RADAR is not aimed properly, the angular effect could produce a low patrol speed measurement.

If we have a low patrol speed measurement, the calculation of TS = CS - PS will produce an erroneously 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. Then, the true closing speed between the two vehicles would be 105 mph. But now, suppose the angular effect produces a low patrol speed measurement: instead of 50 mph, the angular effect gives an apparent patrol speed of only 45 mph. Then, the computation would go as follows:

$$TS = CS - PS$$
$$TS = 105 - 45$$
$$TS = 60 \text{ mph}$$

The target speed result would be 5 mph higher than the target's true speed. Under some circumstances, enforcement action might be taken when there actually had been no violation.

The angular effect does not always produce speed measurements that lead to high results. Sometimes the angular effect will produce low closing speed measurements that in turn could lead to low target speed calculations. The point is, the angular effect can work either way when moving RADAR is involved. Obviously, our greatest concern must be the possibility that angular effect will produce low patrol speed measurements, and give higher-than-true target speeds. To guard against that, make certain your moving RADAR is always aimed in the patrol car's direction of motion with a position of not over five degrees left of center. This will help to ensure that reflected signals are from the ground ahead and not from roadside objects that are off at an angle. In addition, closely monitor the patrol speed and obtain a "tracking history" on the target vehicle before manually locking the target speed and/or taking enforcement action.

Patrol Speed Shadowing

The operator should also be aware that moving RADAR may be susceptible to some special problems that do not affect stationary RADAR. One of these problems is known as the shadowing effect. Like the angular effect, it can produce a lower-than-actual patrol speed measurement and result in a high-than-true target speed calculation.

Figure 14 illustrates the shadowing effect. This figure shows the same situation that we saw in Figure 13 with one important difference: now there is a large moving truck ahead of the patrol vehicle. The RADAR beam that is intended to strike the ground is striking the truck, and the truck reflects a stronger signal than the ground. (Remember, the truck is large, metallic and close to the patrol vehicle and is thus an efficient reflector.) So, the RADAR uses the signal reflected from the truck and indicates a lower-than-actual patrol speed. This occurs because the truck and patrol car are moving in the same direction, and the relative speed — of the patrol car to the truck — is less than the patrol car's actual over-the-road speed. For example, if the patrol car is moving at 50 mph and the truck at 40 mph, the speed of the patrol car relative to the truck is only 10 mph. And the moving RADAR would mistakenly measure the patrol car's speed at 10 miles per hour. In effect, the RADAR would "think" that the truck is the ground, and this "ground" happens to be moving at 40 miles per hour.

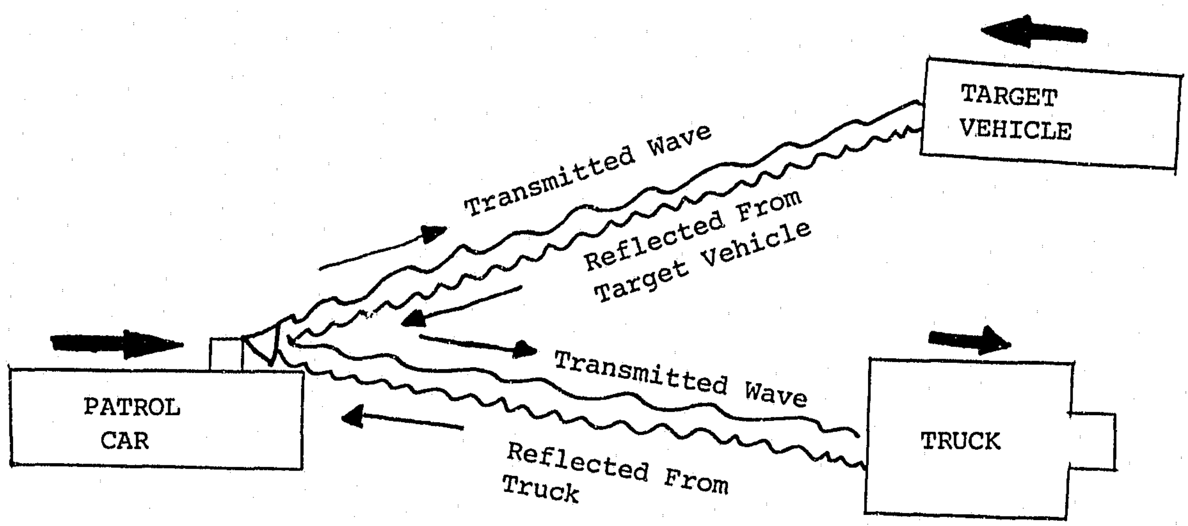


FIGURE 14 SHADOWING EFFECT
IN MOVING RADAR USE

Meanwhile, the "other" RADAR beam that is striking the target vehicle is continuing to undergo a Doppler shift caused by the combined speeds of the target and patrol car, and so the RADAR measures this combined speed (120 mph, as indicated in the earlier example). Now the computer goes into action:

$$TS = CS - PS$$

But unfortunately the computer believes that PS (patrol speed) is only 10 mph. So, as far as it is concerned, the target is traveling at 110 mph (120 - 10). Obviously this is a very large deviation from the target's actual speed of 70 mph. Even worse from a legal standpoint, the deviation is not in the suspect's favor. Fortunately, this type of problem rarely occurs because the signal reflected back from the ground is usually stronger than that reflected back from roadside objects or from other vehicles in the patrol car's lane. This situation will occur; however, it can easily be detected by monitoring your patrol speed and comparing it with your speedometer. This problem can be avoided by obtaining a tracking history before manually locking the target speed and/or taking enforcement action.

Batching

Another special problem that applies only 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, the batching effect can lead to either low or high target speed results, depending upon the circumstances.

The batching effect might happen if the patrol car is substantially changing its speed (i.e., rapidly accelerating or decelerating) while the RADAR speed measurements are being made. In simple terms, the computer may not be able to keep up with these drastic speed changes. Instead of using the patrol speed at the instant that the closing speed is measured, the computer may use the speed that the patrol car was traveling a few fractions of a second earlier. Suppose the patrol car is rapidly accelerating (speeding up); 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. Suppose the patrol car is rapidly decelerating (slowing down); then its speed a fraction of a second ago was higher than its present speed, and the target speed calculation may be lower than true. The batching effect can be avoided by maintaining a relatively steady speed when taking speed measurements and by monitoring your patrol speed.

In summary, the moving RADAR angular effect, shadowing effect, and batching effect are particularly significant because they might lead the officer to think that a suspect is traveling faster than he really is. The experienced officer will avoid situations where these conditions can occur. The patrol car's speed should be kept reasonably steady to eliminate the batching problem; it is particularly important to avoid any sudden accelerations and/or decelerations. Aim the moving RADAR approximately five degrees left of the center line. Keep a large distance between the patrol car and any other vehicles that could produce the shadowing effect. In general, be aware that it usually is not advisable to conduct moving RADAR operations in congested traffic where selectivity problems and shadowing are likely to occur, or at places where there are many reflective objects alongside the road that might contribute to the angular effect. But in all cases when using moving RADAR, verify that the correct patrol speed has gone into the target speed calculation. Many of the latest model moving RADARs have two display windows so that the target speed and patrol speed measurements can be seen simultaneously. Finally, verify that the RADAR and speedometer agree on the patrol speed, before accepting the target speed result as valid.

One additional point concerning moving RADAR needs to be made clear: the arithmetic relationship, TS = CS - PS, works only when the patrol vehicle and target vehicle are moving in opposite directions. It is only in that case that the vehicles' closing speed (CS) is equal to the sum of their individual speeds. If the target vehicle were traveling in the same direction as the patrol vehicle, we could still point the moving RADAR at it and obtain a Doppler shift. But in this case, the Doppler shift would be caused by the difference between the patrol vehicle's speed and the target vehicle's speed. That is, when moving in the same direction,

CLOSING SPEED = TARGET'S SPEED - PATROL SPEED

So, in this case, to obtain an accurate measurement of the target's speed, a different arithmetic relationship must be used, namely:

TS = CS + PS

Always keep in mind that the "computer" portion of the moving RADAR operation has to perform a different calculation when the target is moving opposite to the patrol car as opposed to when it is moving in the same direction as the patrol car. The first moving RADARs that were developed were capable of performing only one calculation (namely, TS = CS - PS) and so could be used only for targets moving opposite to the patrol car. Recently, some instruments have become available that are capable of operation for targets moving in the same direction. Always be aware of the capabilities of the instrument you use to ensure accurate, valid speed measurement.

Reflections from Fixed Objects

When operating in the moving mode and no valid target vehicles are approaching, spurious readings can appear. Such readings are caused by reflections from large stationary objects alongside the road (e.g., large billboard). Such objects can reflect the transmitted signal toward another vehicle either behind or ahead of the patrol vehicle. That reflected signal could, in turn, then reflect from the vehicle back to the billboard and then to the patrol vehicle. That twice-reflected signal, having undergone a Doppler shift, would generate a display in the "target" window. However, it is unlikely that a vehicle would be speeding in such close proximity to a patrol vehicle. Also, the conditions for such readings would persist for only a short time. Therefore, those spurious readings should not create a problem. However, be aware that such readings can appear under the conditions described here and are not to be used in any enforcement action.

Reading the Air Conditioner, Heater or Defroster

With the antenna inside the car, RADAR will have a tendency to read the pulse of the fan motor. This problem can occur regardless of the speed of the fan and is not an electrical problem. If the fan speed is displayed in a target window from time to time, the reading will disappear when the target comes in range, and the RADAR will read the target correctly. RADAR cannot add fan speed to the target's speed, but the fan can distort or "chop up" the normal return from the street and shorten the range from some targets. Sometimes a steady fan speed will override a patrol car speed reflected from the roadway.

With windshield wipers, the RADAR signal is sometimes momentarily interrupted by wipers moving in front of the antenna. The wipers will reflect a signal. This can cause distortion of patrol speed signal return. When this happens, the reading on patrol car speed may be lost.

Rapid Braking Situation

A rapid deceleration by the violator may cause a moving RADAR to go blank. With a RADAR detector, the violator could be warned enough in advance to escape detection with hard braking. RADAR cannot update itself quick enough to produce a target reading. In this situation, the target window will not register anything. It goes blank.

Patrol Speed Limitation (Batching or Target Speed Bumping)

When using RADAR while moving, a constant patrol speed is desirable. Rapid fluctuations in speed can cause delays in RADAR verifying the speed of the patrol vehicle.

CIRCUITRY VERIFICATION

There are two forms of calibration:

1. Internal circuitry verification of read-out unit.

2. External verification using tuning fork.

To withstand scrutiny of the courts, an external verification is required at the start and end of each shift. An external verification check is required after each speed arrest.

Definition of Circuitry Verification

1. The internal verification circuit electronically verifies the accuracy of the counting mechanism in the read-out device but does not check the function of the antenna. This test is performed in both the moving and stationary modes. In the stationary mode, the verification speed will appear in the target window. In the moving mode, the verification speed will appear in both the target and patrol windows. Consult the operator's manual for the make and model RADAR used for the proper verification numbers that should appear in the target and patrol windows if the machine is in proper working order.

2. The tuning fork does check the function of the antenna. Cut to vibrate at a known frequency, the tuning fork is accepted by the courts as an acceptable method to check the operating condition of a police traffic RADAR. The frequency at which they vibrate represents the equivalent speed as per the Doppler shift.

   Each fork will be serially numbered, stamped with a miles-per-hour reading, and, if designed to check the operating condition of K-band units, will be identified as a K-band fork. It is important to note that X and K-band forks, although stamped with the same miles-per-hour reading, are not interchangeable. X-band forks must be used with X-band devices. K-band forks must be used with K-band devices.

   When two forks of different frequencies are used to check moving RADAR, the lower of the two will read as the patrol speed. Once this speed appears on the read-out unit, striking the second fork will result in the difference between the mph stamped on the two forks to be displayed in the target window.

3. Meter Verification - the verifying procedure typically begins with an internal circuitry test. These circuitry tests vary with the make and model of RADAR. Consult the operating manual for your particular device.

   The next procedure involves an operation check of the indicating meter using a tuning fork. This tuning fork should not be confused with those used for "tuning" musical instruments. The RADAR tuning fork is specially calibrated for use with a RADAR device. Each RADAR unit comes equipped with its own tuning fork. NEVER use a tuning fork from a K-band RADAR unit to make an equipment check on an X-band unit or vice versa. Tuning forks are not interchangeable among RADAR units operating on different frequency bands.

4. Tuning Fork - Figure 15 represents a diagram of a typical tuning fork. To use the fork simply grasp the fork by the handle and strike one of the tynes against a surface. NEVER strike the fork against a surface harder than its own surface, such as another metal object or concrete. The heel of your shoe, or a padded steering wheel present acceptable surfaces for striking. Also, never strike the fork when it is wet or excessively cold as these conditions will affect the vibrating frequency of the fork.

5. Circuitry Verification Procedures - Strike a tyne of the tuning fork and hold it horizontally so that only one tyne of the fork faces the center of the RADAR head (see Figure 16) about 1/4" from the antenna face. DO NOT turn the tuning fork so that both tynes face the antenna (see Figure 17) or hold the fork pointing downward (see Figure 18).

   When a reading is displayed on the RADAR meter, make sure that it is the proper speed which should be produced by the fork. If a fork is designed to produce a 65 mph reading, ensure that 65 mph registers on the RADAR meter. An error allowance of plus or minus 1 mph is acceptable. That is, if a 65 mph fork registers 66 or 64 mph on the RADAR meter, the circuitry verification check is acceptable. If a different reading occurs, attempt the check once more. If a reading discrepancy greater than plus or minus 1 still registers on the RADAR meter, REMOVE the RADAR unit from use. Return the unit to your headquarters for further checks. DO NOT attempt to use the RADAR unit in the field.

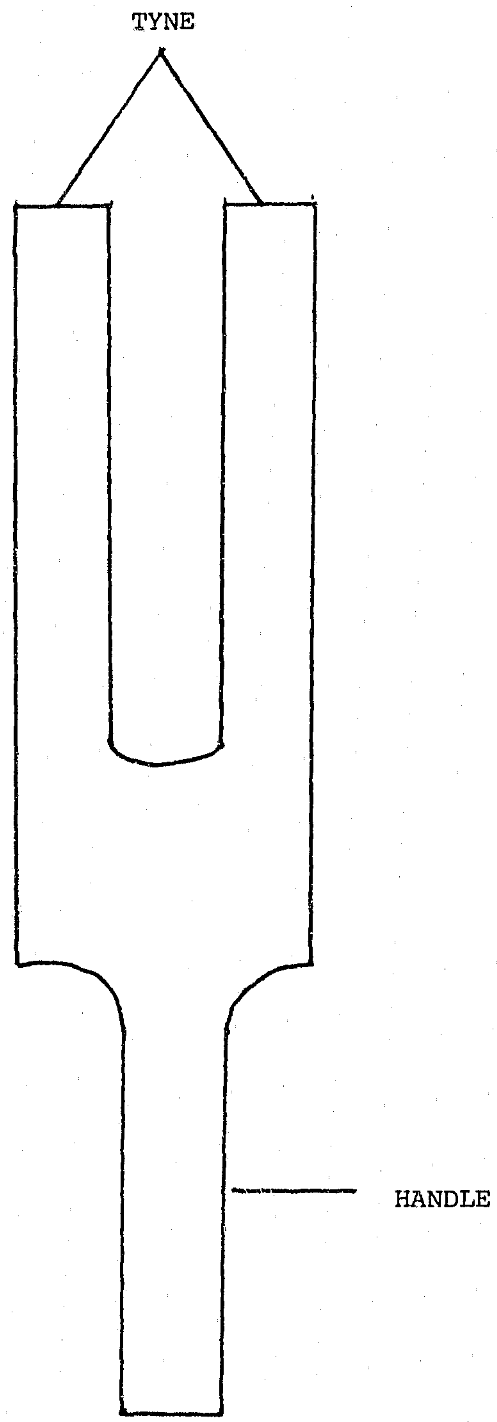
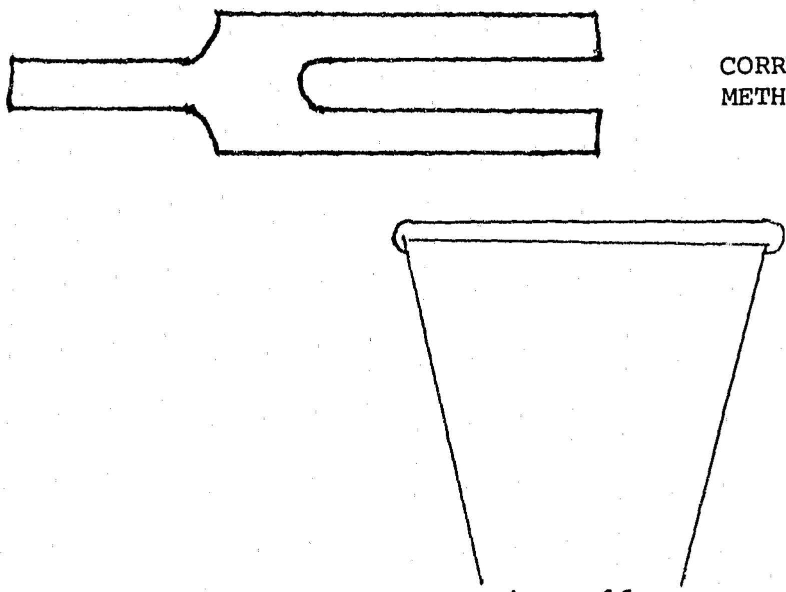


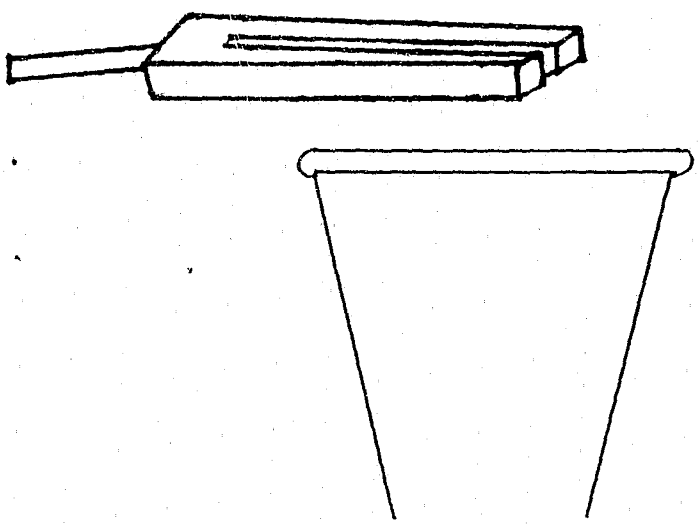
FIGURE 15



CORRECT
METHOD

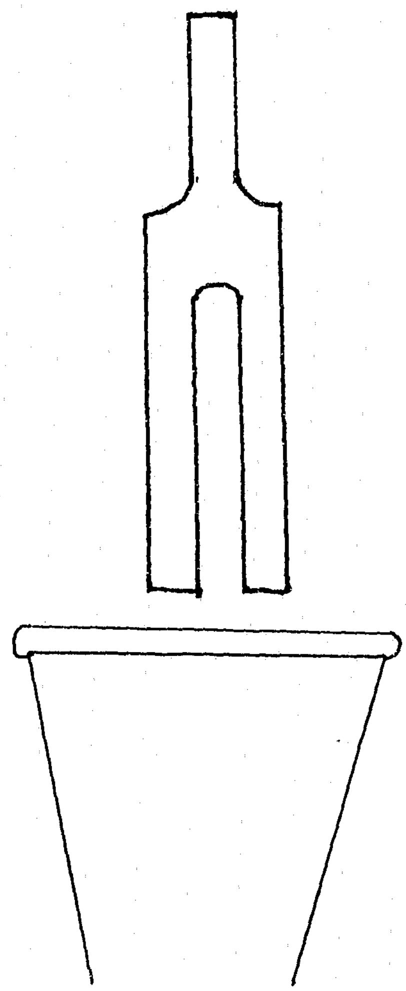
Figure 16

Figure 17



INCORRECT
METHODS

Figure 18



A Summary of Errors Which May be Encountered in Moving RADAR

1. Shadowing or Vehicle Interference - The tendency of a moving RADAR to substitute the signal reflected from a slow moving vehicle as the "patrol speed" signal.

   Symptoms: Displayed patrol speed does not agree with speedometer (the displayed patrol speed will be too low). The Doppler tone "warbling" with no apparent change in target or target speed.

   Effect: A decreased patrol speed reading will cause a proportional increase in the target speed reading.

   Remedy: Operators should be aware of the shadowing effect and recognize its symptoms, should know its cause and that its effect can best be detected by comparing the RADAR patrol car speed with the patrol car speedometer.

2. Batching (Target Speed Bumping) - Target speed varies when the patrol speed varies.

   Symptoms: Erratic target speed display when patrol vehicle accelerates or slows. Doppler tone warbling.

   Remedy: Operators should know what it is and how it occurs and that its effect can be avoided by maintaining constant speed when making RADAR speed measurements.

3. Panning Error - Moving the RADAR antenna while it is aimed at the RADAR display unit. (Note: It would be difficult for operators to "pan" the K-55 since it is not a hand-held unit.)

   Symptoms: A reading is displayed although no target is in sight.

   Remedy: The RADAR should not be mounted with the display unit in the antenna beam.

4. Scanning Errors - When the RADAR operator moves his antenna too quickly, or when the antenna is pointed at the dash with the heater/air conditioner fans running.

   Symptoms: Displayed speed with no target or Doppler warbling with a single target in view.

   Remedy: The RADAR antenna should be mounted so that it is not pointing toward air conditioner or heater fans.

5. Cosine Angle Effect - The error that occurs when the patrol unit and target are not headed directly toward each other.

   Note: In our opinion, cosine angle effect is a phenomenon of the Doppler effect and does not vary according to RADAR manufacturer or type. The error is normally very small in the "moving" mode and almost always favors the violator. This problem has been discussed in detail earlier in this manual.

6. Heat Buildup - Speed errors due to solid state component instability caused by excessive heat.

   Symptoms: Erratic readings.

7. Power Surge - False readings caused when unit is switched on or when unit is switched from squelched to operate condition.

8. External Electrical Interference - High tension power lines generating electrical noise which is "read" by the RADAR.

   Symptoms: Erratic readings when no target is present.

9. Patrol Vehicle Ignition Noise Errors - Erratic readings caused by ignition noise either picked up by the antenna or through the 12 VDC voltage source.

   Symptoms: Erratic readings with motor running which vanish when the engine is turned off.

10. CB and Police Radio Transmitter Interference - Erratic readings when either the CB or police radio transmitter is activated.

    Remedy: Do not transmit on CB or police radios while measuring speed in either the stationary or moving mode. Be aware that nearby units can also cause interference.

11. Double Bounce - Occurs rarely.

    Remedy: Be aware of the problem especially in areas with a high volume of truck traffic. If the patrol speed is maintained at 55 mph, the target display resulting from double bounce will be easily recognizable (i.e., a very high number).

12. Look Past - The RADAR "looks past" a small vehicle in front of a large vehicle, and records the latter.

    Remedy: Be aware of the problem. It is more liable to occur when the antenna is tilted upward slightly, thereby giving extremely long range, and on highways with a slight rise in elevation, where the larger vehicle would be on higher ground than the smaller vehicle.

THE K-55 MOVING RADAR INSTRUMENT

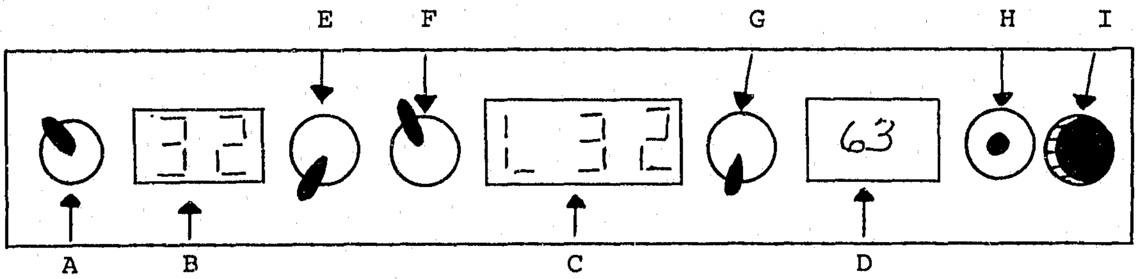


Figure 19

A. ON/OFF Toggle switch supplies power to unit in the "ON" position.

B. PATROL window displays patrol vehicle speed via lighted seven segment tubes.

C. TARGET window displays target vehicle speeds from 0 - 199 mph.

D. VIOLATION thumbwheel allows operator to set any speeds from 00 to 99 as a threshhold over which the unit will activate manual or automatic alarm/lock functions.

E. CAL/LT allows operator to test the internal circuitry of the unit.

F. MOV/STA toggle switch allows officer to select moving or stationary mode of operation.

G. AUTO/MAN allows selection of automatic or manual modes of operation:

- N.T.H.S.A. Standards prohibit use of the Automatic Mode.
- In the manual mode an audible alarm will sound alerting officer when target speed exceeds setting on VIOLATION control. Speed display must be manually locked in.

H. LOCK/RELEASE button allows officer to lock in display readings when unit is in manual and will clear or release readings in both automatic and manual modes.

I. VOL - the volume control allows officer to adjust the audio level of Doppler signals received.

The K-55 manufactured by MPH Industries, Inc. of Chanute, Kansas is an X-band (10.525 GHz frequency) RADAR unit with moving, stationary, hand-held or pacing RADAR capabilities. The unit consists of two pieces: (1) the antenna and (2) read-out unit. Figure 19 represents a pictorial reproduction of the read-out unit with a listing of the controls and their functions. When the operator has familiarized himself with these controls, he is ready to place the unit into operation using the steps below.

(1) Connect Unit

- Follow A-B-C instructions.
- Mount read-out unit on dashboard.
- Turn unit on (flip toggle switch to "ON" setting).

(2) Perform Light Test

- Set toggle switch to "MOV" setting (moving mode).
- Set toggle switch to "L/T" setting (Light Test).
- Unit will automatically display 88 in PATROL window and 188 in TARGET window.
- All segments of read-out tubes have been tested.

(3) Perform Internal Circuitry Test

- Set toggle switch to "MOV" setting.
- Set toggle switch to "CAL" setting.
- A reading of 32 should be displayed in both TARGET and PATROL windows.
- Set toggle switch to "STA" (stationary mode).
- A reading of 32 should be displayed only in TARGET window.
- If any number other than 32 appears . . . REMOVE UNIT FROM SERVICE.

(4) Tuning Fork Circuitry Verification Check

- Set toggle switch to "STA" setting, select tuning fork (MPH supplies 35, 50, 80 mph forks), strike and hold fork in front of antenna, and check speed stamped on fork with speed displayed in TARGET window.
- Set toggle switch to "MOV" setting.
  - Select two tuning forks (be sure they are X-band forks).
  - If the forks are stamped 35 mph and 80 mph, strike the forks (low fork first) and hold them simultaneously in front of the antenna, and the PATROL window should display "35" while the TARGET window should display "45" (remember, a discrepancy of plus or minus 1 mph is acceptable).

(5) Mount and aim antenna

(6) Speedometer/Unit Comparison

- Set toggle switch to "MOV" setting.
- Drive patrol vehicle and compare speed displayed on unit with patrol vehicle speedometer. If discrepancies exist, REMOVE VEHICLE AND RADAR UNIT FROM SERVICE AND TEST.

(7) Set VIOLATION control to prevailing speed limit, or as desired.

(8) Adjust AUDIO volume (gives the Doppler sound)

- Turn "AUDIO" switch clockwise until desired volume of Doppler sound is reached.

Patrol Use

As indicated earlier the MPH Model K-55 allows the operator to monitor traffic in the following modes: Moving, Stationary, Hand-held, or Pacing. Each of these uses are described below.

Moving RADAR

In the moving mode the unit monitors the speed of vehicles approaching the patrol vehicle from the front. The unit displays the speed of each approaching vehicle in the TARGET speed window. The unit also monitors the patrol vehicle speed which is displayed on the PATROL window. The unit will register patrol vehicle speeds from 27 - 79 mph only.

As the patrol vehicle speed is displayed, the operator must check the speed displayed against the patrol vehicle's speedometer reading. If discrepancies exist, remove the RADAR UNIT from service and test.

Stationary RADAR

The stationary mode allows the officer to monitor vehicles moving in either direction while the patrol vehicle is stopped. In the Stationary mode the unit displays only the target vehicle speed in the TARGET window. The unit will display speeds from 1 - 199 mph.

Hand-held Mode

The K-55 RADAR unit has a specially designed antenna mount which allows the antenna to be swung in any direction. It can therefore utilize the same working concepts of hand-held RADAR units without actually having to hold the antenna, simply by turning the antenna in its bracket.

Pacing RADAR

The K-55 RADAR also offers a pacing mode. By placing the unit in the Stationary mode and driving the patrol car, the unit will display the patrol vehicle speed in the TARGET window. The officer then follows the basic pacing method. In this mode of operation, it is possible that the RADAR will detect and process a signal from other traffic and read out a closing speed. The officer can verify that he is reading patrol car speed by comparing the readout to his speedometer. There should be close agreement between the two devices. If there is not, he is reading the closing speed between his vehicle and other traffic.

Illinois Department of State Police
RADAR OPERATION PROFICIENCY TEST

1.

RANK LAST FIRST MIDDLE ID# DIST.

RADAR UNIT: 2. 3.

MFR. SERIAL #

UNIT SET-UP PROCEDURES

1. Mounting Location (Meter and Antenna) 4.
2. Cable Connections 5.
3. Power Supply 6.
4. Light Test 7.
5. Audio Check 8.

TESTING

1. Internal Circuit 9.
2. Single Tuning Fork 10.
3. Double Tuning Fork 11.
   (Moving Radar Only)
4. Speedometer/Unit Comparison 12.

PATROL OPERATION 13.

1. Stationary Mode 2. Moving Mode 3. Pacing Mode

TYPE OF RADAR USED 14.

HHR ______ MOVING ______ STATIONARY ______

15. **PROFICIENCY TEST**

INDICATE ERRORS	SPEED ZONE	MODE	Visual Test: Over Limit	Visual Test: Under Limit	Actual Speed: Radar	Actual Speed: Speedometer*	TRAFFIC DENSITY	TYPE OF ROAD	WEATHER
1. 16	17	13	18	18	19	20	21	22	23
2.									
3.									
4.									
5.									
6.									
7.									
8.									
9.									
10.									
11.									
12.									
13.									
14.									
15.									
16.									
17.									
18.									
19.									
20.									

TOTAL ERRORS 24.

Tested by: 25.
Name Date

Approved by: 26.
Name Date

RECOMMEND CERTIFICATION ☐

27.

RECOMMEND FURTHER TRAINING ☐

*To be used when utilizing DSP vehicle as target vehicle.

ILLINOIS DEPARTMENT OF STATE POLICE
RADAR OPERATION PROFICIENCY TEST
COMPLETION INSTRUCTIONS

1. Identify the person tested (rank, name, ID.#, district). Please print legibly.

2. Print the name of the manufacturer of the traffic radar device used during the test along with the model identifier. For example: MPH-K-55 or Decatur Ra-Gun.

3. Enter the serial number of the device used during the test. For two-piece devices, use the number on the rear of the readout (meter) unit. DO NOT use the State of Illinois inventory number.

4. For moving radar, check (✓) after observing that the device is properly mounted in the patrol vehicle. The antenna should be aimed properly (not more than five degrees off the center line of the target vehicle). See Manufacturer's Instructional Manual.

5. Check (✓) after observing properly made cable connections. See Manufacturer's Manual.

6. Check (✓) after the device is turned on "ON" and continuously working. See Page 42 (A) Radar Manual.

7. Check (✓) after observing readouts lamps continuity test. See Page 43 (2) Radar Manual.

8. Check (✓) after observing the operator tune the Doppler audio volume to proper level (when the device is so equipped). This test may be made during the Patrol Operation phase of the proficiency test. See Page 44 (8) Radar Manual.

9. Check (✓) after observing the operator's use of the internal circuitry test feature (if the device is so equipped). See Page 43 (3) Radar Manual.

10. Check(✓) after operator performs a singe tuning fork test (moving-mode and hand-held devices). See Page 43 (4) Radar Manual.

11. Check (✓) after operator performs double tuning fork test (moving-mode device only). See Page 43 (4) Radar Manual.

12. Check (✓) after operator has made such a comparison (moving-mode and hand-held devices). This test may be made during Patrol Operation phase of the proficiency test. See Page 43 (6) Radar Manual.

13. List different types of modes to be used with proficiency test. When testing with moving radar, at least ten tests must be made in the moving mode. Hand-held radar devices should be demonstrated in the stationary and pacing modes. The test mode is to be listed in the proficiency test by number.

14. Check (✓) type of equipment used.

15. The proficiency test will be conducted in the following manner: The first five tests will require a Division of State Trooper vehicle. This vehicle will be the "target" vehicle, and its speedometer will be checked for accuracy by the radar device in the testee's vehicle. The testee will then make an initial determination of the target vehicle's speed. The target vehicle driver will then advise the testing officer of the speedometer reading. Both the estimated speed by radar and the speedometer reading will be recorded in the "actual speed" column, lines 1 through 5.

    Example 54/55 - the reading should be plus or minus 1 mph in 5 out of 5 instances.

16. The testor is to indicate in this column the speed zone in which the test was administered if other than the 55 mph zone.

17. This area is used to record a visual estimate of the speed of the target vehicle. The testee will advise whether he/she believes the target vehicle is traveling over the speed limit or under the speed limit. The testor will then check ( ) the appropriate box on the form. The estimation will then be compared to the registered speed on the radar. The testee must be able to estimate 18 <u>out of a possible 20</u> correctly.

18. Record the speed of the target vehicle as registered by the radar.

19. Record the speed as advised by the driver of the target vehicle. (To be used <u>only</u> when utilizing a Division of State Troopers vehicle as target vehicle.)

20. Record traffic density at the time and location of each clock. Example: light, moderate, heavy. Ditto marks (") may be used to indicate road type similar to that at the previous clocking situation.

21. Record type of road at the clocking location. Example: two-lane, four-lane, four-lane divided. Ditto marks (") may be used to indicate road type similar to that at the previous clocking situation.

22. Record weather at the time of the proficiency test. Example: clear, dry, drizzle, rain. Unless the weather conditions change, only one entry at the top of the weather column is necessary.

23. The testor is to sign the form and transmit it to the District Commander or his authorized agent.

24. The form should be approved and signed by the District Commander or his authorized agent and forwarded to the Radar Program Coordinator at the Department of State Police Academy.

25. Check (✓) if the operator has demonstrated an acceptable level of competence in each phase of the proficiency test.
    a. Operators who have demonstrated their proficiency with moving-mode radar may be certified to use both moving-mode and hand-held radar.

    b. Operators who have demonstrated their proficiency with hand-held radar will <u>NOT</u> be certified to use moving-mode radar.

    Check (✓) when the operator has not demonstrated an acceptable level of competence in each phase of the proficiency test. NOTE: Provide a brief explanation and any further recommendations on the reverse side.

DISTRICT COURT OF KENTUCKY

GALLATIN COUNTY

Case No. 80-T-014

COMMONWEALTH OF KENTUCKY PLAINTIFF

vs. ORDER AND JUDGEMENT

DAVID WILSON ROSE DEFENDANT

* * * * * *

The above styled and numbered action arises out of a traffic citation issued on January 1, 1980 by Trooper Robert C. Noble, an officer of the Kentucky State Police assigned to LaGrange Post No. 5, to the defendant charging him with speeding 70 miles per hour in a 55 mile-per-hour zone on I-71 in Gallatin County. The Commonwealth was represented by the County Attorney, John G. Wright of Warsaw. The defendant was present and represented by David B. Sloan of Covington.

The defendant filed a motion to suppress the evidence obtained by Trooper Noble's use of a moving radar speed-measuring device. At a hearing on February 19, 1980 the court announced that it would take judicial notice of the fact that a properly constructed and operated radar device is capable of accurately measuring the speed of a motor vehicle. The parties agreed with a suggestion by the court that it withhold ruling on the motion to suppress until the completion of all the evidence. The matter was then continued until April 17, 1980. On that day the court heard the testimony of Trooper Noble and the defendant and the arguments of counsel. The court has read the very complete briefs which were most helpful.

Trooper Noble testified that he graduated from the Kentucky State Police Academy in November 1974. During his formal training at the academy he received several hours instruction on the use of radar speed-measuring devices. These devices were capable of operating only in a stationary mode. Shortly after graduating from the Kentucky State Police Academy Trooper Noble was assigned to the LaGrange Post. He was given an opportunity to share the use of a radar speed-measuring device with another trooper assigned to the LaGrange Post who patrols principally in adjoining Carroll County. Trooper Noble spent several days riding with this other trooper and becoming familiar with the operation of the radar speed-measuring device which is known as an MR-7. Later Trooper Noble used the MR-7 in his car two days out of each week. In 1976 Gallatin County purchased a radar speed-measuring device known as a Speedgun. It is similar to the MR-7 in that it is capable of operating in the moving mode. In the moving mode the device is capable of measuring the speed of on-coming or target vehicles while the patrol car is moving. Trooper Noble received no formal instruction on the use of the Speedgun and taught himself to use it by reading the operator's manual and experimenting with the device in his patrol car. He employed the Speedgun daily until April 1979 when the Kentucky State Police provided him with the MPH K-55 device. On the day that he was issued the MPH K-55 device he received eight hours of training. Half of the training was in the classroom under the direction of a state radio technician. The other half was "hands-on" training in the use of the device on I-64 near Frankfort. At the time of receiving this training Trooper Noble had accumulated more than four years experience with the two devices previously mentioned and had written in excess of four thousand traffic citations for speeding employing one or the other of the radar speed-measuring devices. Since being issued the MPH K-55 device Trooper Noble has used it exclusively in his daily patrol activities. The device has not required any service, repair, or adjustment.

The trooper further testified that on January 1, 1980 he followed his usual routine commencing his patrol at 4:00 p.m. after testing the MPH K-55 device by the use of two tuning forks. The MPH K-55 device provides a digital display of Trooper Noble's patrol speed which can be visually compared with the readings on his calibrated speedometer as frequently as may be desired. Trooper Noble testified that on that day as on all other days the patrol speed visually displayed on the MPH K-55 device agreed with the speed indicated by his calibrated speedometer.

At approximately 5:50 p.m. Trooper Noble was about four miles South of Glencoe and proceeding North on I-71 with the MPH K-55 device installed and operating in his vehicle. This device is equipped with a remote anti-detector switch. This switch allows all of the device's electrical circuits to operate except the transmitter. The transmitter is activated by this switch which also has the ability to lock the display. Trooper Noble observed the defendant approaching Southbound on I-71. He said the traffic was light, that the defendant was about a quarter of a mile away when first observed, that there was another vehicle approximately two hundred feet behind the defendant but that the defendant's vehicle was out front by itself and nearest to the radar. He visually determined that the defendant's vehicle was traveling at an excessive rate of speed. Using the remote switch he activated the transmitter of the MPH K-55 device and read the speed of the defendant's vehicle at 70 miles per hour. At the time of the radar reading he compared the patrol speed as indicated on the visual display of the radar device with the speed indicated on his calibrated speedometer and found them to be the same. Again using the remote switch described above he locked the display on the radar device and crossed the median in pursuit of the defendant's vehicle. He stated that the defendant's vehicle was out of his sight for only a second or two. He overtook the vehicle and caused it to stop. He then issued the citation to the defendant.

Mr. Sloan's cross-examination of Trooper Noble reviewed Trooper Noble's training and experience in the use of radar speed-measuring devices. Further, Mr. Sloan inquired again into the circumstances and events leading up to the issuance of the citation to the defendant and with respect to these matters no new information was discovered. The remainder of the cross-examination was devoted to the operational characteristics of the MPH K-55 device. Particular emphasis was placed on those operational characteristics which produce inaccurate readings.

One operational characteristic of moving radar which can produce an inaccurate reading is the so-called shadowing error. The device must correctly measure the patrol speed to compute the speed of the on-coming target vehicle. When the patrol car is in near proximity of a larger vehicle traveling the same direction but at a slower speed the radar may unlock from the true patrol speed of the patrol car and lock onto the differential speed between the patrol car and the larger vehicle traveling in the same direction. Trooper Noble was familiar with this particular operational characteristic and testified that the conditions necessary to produce an inaccurate reading were not present at the time he measured the defendant's speed.

Another operational characteristic which can produce an incorrect reading is known as low-speed combining. In this case both the patrol car and the target vehicle are traveling at slow speeds which are then combined and displayed as patrol speed. Because of this operational characteristic the MPH K-55 device is not reliable in the moving mode when the patrol speed is less than 16 miles per hour. Again, Trooper Noble was familiar with this operational characteristic and testified that the conditions necessary to produce an incorrect reading were not present at the time the defendant's speed was measured.

A third operational characteristic which is capable of producing an incorrect reading in some radar speed-measuring devices is known as batching. This is based on the possibility that if the radar speed-measuring device is being operated in the moving mode and the patrol car rapidly accelerates or decelerates the computation element of the device could store readings which are processed in a later time frame. This could result in a subtraction error and cause the unit to display a target speed in excess of the true speed. The technical material appended to the Commonwealth's brief indicates that the computational element of the MPH K-55 device subtracts in "real time" and simultaneously. Accordingly, the court is convinced that the device is incapable of a batching error and hence there was not any such error in this case. The term batching was used by counsel during the hearing in another context. In the hearing the term batching was used to describe the situation where the radar speed-measuring device is presented with a number of target vehicles in close proximity to each other with all of them approximately the same distance from the device. These circumstances are meant to infer that the device then receives a "batch" of reflected signals and somehow becomes confused in processing these signals, possibly combining them in some way to produce an erroneous reading. This is in reality an identification problem. The nature of electromagnetic wave propagation is such that the device will read the first target to the detriment of others no matter what their size if reasonable distance obtains between them. There is an inverse fourth order relationship to distance so that if the second target is twice the distance it would have to be sixteen times larger to reflect the same signal strength. Correct operating procedures are a necessity. The target vehicle that is identified must be out in front and closest to the radar speed-measuring device. Trooper Noble testified that at the time the reading was taken the defendant's vehicle was out in front and closest to the radar speed-measuring device. Therefore, the conditions necessary to produce a false reading were not present when the defendant's vehicle speed was measured.

A fourth operational characteristic which is capable of producing an incorrect reading is that the device is subject to both internal and external electrical interference. Interference by other radio transmitters near enough the fundamental frequency of the radar or a harmonic frequency may result in an incorrect reading. Additionally, defroster, heater, or air conditioner fans, ignition, alternator, and alternating current interference may cause the device to display numbers which would be inaccurate if applied to the speed of traffic. Such interference may also result in a loss of range rather than a false reading. Trooper Noble testified that he was familiar with the effects of electrical interference on the MPH K-55 device and that no such interference was present at the time the defendant's speed was measured.

A fifth operational characteristic which can result in an incorrect reading is known as the cosine error. When the angle between the path of the patrol car with the radar device and the target vehicle increases there is a reduction in the combined speed of closing which is proportional to the angle and predictable. The error will be in favor of the target vehicle because the radar speed-measuring device will display a target speed less than the actual target speed. Accordingly, the alignment of the antenna to intersect on-coming traffic is an important consideration in the proper operation of a radar speed-measuring device. The trooper initially testified that the antenna of his MPH K-55 device was deflected thirty degrees but on re-direct examination reconsidered his answer and testified that the angle of deflection was less than he originally stated. The court is more impressed with the officer's actual experience than his knowledge of geometry and chooses to believe that the angle of deflection was substantially less, but the matter is of little consequence. If the angle of deflection was greater, then the target vehicle speed would be read at less than actual speed. Stated more simply, the error, if any, is in the defendant's favor.

A sixth operational characteristic which may result in an incorrect reading results from a multiple reflected signal or what is more commonly called ghosting. In the absence of a strong primary signal, a radar speed-measuring device may receive a signal that has been reflected from a stationary object to a moving target and back again. As soon as a strong primary signal is received the weaker signals will be displaced. This characteristic was discussed in relation to the location of two roadway overpasses in the general vicinity of the place on I-71 where the violation is alleged to have occurred. Trooper Noble testified that the reading taken on the speed of the defendant's vehicle occurred at a point when defendant's vehicle was clear of either roadway overpass. Trooper Noble testified that he was familiar with this operational characteristic, and the conditions necessary to produce a false reading were not present when the defendant's vehicle speed was measured.

The defendant's testimony was unremarkable. He admitted a total lack of knowledge concerning the operational characteristics of radar speed-measuring devices. The defendant merely stated his belief that he was driving within the speed limit and to the presence of another vehicle which had overtaken him at a high rate of speed. The defendant expressed a belief that Trooper Noble may have measured the speed of this other vehicle rather than the speed of the defendant's vehicle. Trooper Noble testified to the presence of other traffic but had no recollection of another high-speed vehicle in close proximity to the defendant's vehicle other than the vehicle previously mentioned approximately two hundred feet behind the defendant's vehicle. The court is persuaded beyond any reasonable doubt that Trooper Noble's identification of the defendant's vehicle was accurate because at the time the reading was taken the defendant's vehicle was out in front and closest to the radar speed-measuring device. The court does recall that the testimony was at odds concerning the color of the defendant's car. However, given the number of citations written by the trooper and the passage of time the court does not believe this variance has much significance. The trooper did readily identify the defendant in open court.

As mentioned earlier the court will take judicial notice of the fact that a properly constructed and operated radar device is capable of accurately measuring the speed of a motor vehicle. The court is persuaded beyond any reasonable doubt that the MPH K-55 device used by Trooper Noble in measuring the speed of the defendant's vehicle at the time and place mentioned in the citation was an accurate and reliable device. The court further believes beyond a reasonable doubt that Trooper Noble has the training and experience to properly operate the MPH K-55 device assigned to him which has been in daily use by him since April 1979 and did properly operate the device at the time and place mentioned in the citation. Further, the court has determined that the testing requirements of Honeycutt v. Commonwealth, 408 S. W. 2d 421 (1966) are not only met but exceeded. In that case the appellate court required the radar speed-measuring device to be tested within a few hours of its specific use and that it be found to be accurate by the use of a calibrated tuning fork and by comparison with a speedometer of another vehicle driven through the radar field. When the MPH K-55 device is operated in the moving mode the patrol car in which the device is installed is equipped with a calibrated speedometer and is constantly being driven through the radar field generated by the device. A reading of the patrol car speed as measured by the device is continuously displayed. The comparison required by the appellate court can be made not just once within a few hours of a specific use but simultaneously with its use.

IT IS ORDERED AND ADJUDGED that the defendant be and he is hereby found guilty of speeding 70 miles per hour in a 55 mile-per-hour zone and is sentenced to pay the statutory fine of $30.00 and costs. Defendant is granted leave to pay the fine within ten days from this date. Bond on appeal is set at $50.00 cash.

Done at Warsaw this 2nd day of May, 1980.

Robert F. Greene
Judge

SUPERIOR COURT OF NEW JERSEY
LAW DIVISION (CRIMINAL)
BURLINGTON COUNTY
DOCKET NO. APP. 81-78

STATE OF NEW JERSEY, Plaintiff-Respondent,	)	
v.		Criminal Action OPINION
DOUGLAS WOJTKOWIAK, Defendant-Appellant.	)	

Decided August 2, 1979

On appeal from Burlington Township Municipal Court

Mr. George Ciszak argued the cause for respondent (Mr. John J. Degnan, Attorney General of New Jersey, attorney).

Mr. Allen Etish argued the cause for appellant (Messrs. Greenberg, Shmerelson, Greenberg & Weinroth, attorneys).

WELLS, III, J.S.C.

This is an appeal from defendant's municipal court conviction for speeding 68 m.p.h. in a 55 m.p.h. zone. At the request of the defendant, and with the State's consent, the Court opened the record below for the sole purpose of determining the scientific reliability of the K55 Radar Speed Detection Device. Defendant's conviction rests on a speed reading displayed by the K55 in State Trooper Albert J. Dempster's troop car as he and the defendant approached one another, Trooper Dempster in a northbound lane and defendant in a southbound lane, on Route 295.

Because defendant, unrepresented below, did not raise it, and because both defendant and the State, on this appeal, advised the Court that questions about the reliability of the K55 were affecting the administration of justice in the municipal courts, the Court believed limited re-opening of the record was warranted. Rule 3:23-8(a) authorizes the Appellate Court to hold a "plenary trial *de novo* without a jury" where "the rights of the defendant were prejudiced below." Because prejudice to the defendant could only have arisen from the municipal judge's unchallenged assumption of reliability of the K55, the trial *de novo* is limited to that issue. All other matters will be decided on the record below.

Further authority, by analogy, is found in two recent instances in which the Appellate Division, itself, returned cases to the trial court for plenary hearings on the scientific reliability of devices used in law enforcement. *State v. Hibbs* 123 *N.J. Super.* 108 (App. Div. 1972) on remand 123 *N.J. Super.* 152 (Cty. Ct. 1972) aff'd 123 *N.J. Super.* 124 (App. Div. 1973); *State v. Boyington,* 153 *N.J. Super.* 252 (App. Div. 1977).

The legal criteria to be applied in admitting scientific evidence are well established. Before the results of any scientific test may be admitted in evidence it must be shown that the equipment or the methodology used has a high degree of scientific reliability; and that the test is performed by qualified persons. *State v. Chatman,* 156 *N.J. Super.* 36, 38 (App. Div. 1978).

Speed-measuring radar in various forms has been accepted since *State v. Dantonio,* 18 *N.J.* 570 (1955). See *State v. Overton,* 135 *N.J. Super.* 443 (Cty. Ct. 1975), (Mark VIA); and *State v. Boyington,* 159 *N.J. Super.* 426 (L. Div. 1978), (Decatur Ra-gun); *State v. Musgrave,* ... ... *N.J. Super.* (L. Div. 1979), App. No. 87-78 an opinion approved for publication July 1, 1979 in which Judge Wichman held the K55 Speed Detection Device reliable. This last decision is, of course, entitled to, and has received, great respect as that of a court of coordinate jurisdiction; but it does not appear that Judge Wichman heard conflicting expert testimony and, accordingly, this court offers its opinion on the same issue to analyze the reliability of the K55 in light of expert criticism.

Four experts, two called by each side, testified. In addition, the State called Trooper Dempster. The State's witnesses were principals of MPH Industries, manufacturer and distributor of the K55. The first witness, Mr. Robert E. Patterson, who built a crystal radio at age 10, is "entirely responsible for the total technical design and construction and manufacture of the K55 radar" (T 12-21). He is a high school graduate with two years of college and graduated from the Army's Signal School at Fort Monmouth and ended his military career as head of maintenance of school equipment at the Missile Guidance School at Redstone Arsenal. This military career gave Patterson extensive theoretical and practical knowledge of radar of all types. Mr. Patterson, after his military discharge, held successive jobs as Chief Electrical Engineer at several companies in the electronics and radar industry in each of which degreed engineers reported to him. He holds five patents in various types of electronic circuitry design and built the first solid state cardiac monitors; he has also designed or contributed to the design of music amplification equipment, police radar (before the K55) and cardiac telemetry equipment. These devices depend on a common thread of theory and practical technology applicable to radar-informed speed measuring equipment; and, in several instances, Mr. Patterson was in the forefront of the developing technology which finally emerged in various speed measuring radar devices.

The second State's witness was Edward Walker Sergeant. His qualifications are detailed in *State v. Musgrave, supra.* In this case Mr. Sergeant testified solely about the training programs offered by MPH, and, in particular, about the one he gave to a class of New Jersey State Troopers among whom was Trooper Dempster.

The defense's experts were Mr. Andrew L. Soccio and Dr. Leo Nichols. Mr. Soccio's qualifications are outlined later in this opinion. Dr. Nichols possesses a B.S. in Electrical Engineering from Virginia Military Institute, a Master of Science in Electrical Engineering from Ohio State and a PhD in the same subject from Virginia Polytechnic Institute. Although Dr. Nichols holds a license as a Professional Engineer in Virginia, his primary profession is that of teacher, having risen from an instructor to his present position as head of the Department of Electrical Engineering at Virginia Military Institute, a job he has held for 11 years. He has taught basic electric circuits, thermodynamics and microwave theory and techniques. He has testified as an expert many times in several states on the theory and operation of traffic radar.

It is from the testimony of these witnesses, and Trooper Dempster, that the court makes its findings on all aspects of the theory and operational characteristics of the K55 and, finally evaluates its reliability.

PRINCIPLES OF DOPPLER RADAR

It is necessary to review certain basic ideas in order to understand the K55 and to describe its limitations.

Engineers generally depict radiant energy as moving in an undulating wave form pattern called "cycles". The number of cycles passing a given point in a given period of time is called "frequency". In music, the frequency at which sound reaches the ear determines the pitch people hear. Middle C on the piano, for example, when played, produces a sound wave at a frequency of X cycles per second; and the C one octave above middle C will generate a sound wave at 2X cycles per second. The higher the frequency, the higher the pitch will be. Note at the outset that this relationship between frequency and pitch is direct and not affected by other factors. For instance, it makes no difference how loudly or how softly you play middle C, or if you play it loudly and the octave C softly, the two sound waves produced will still reach the ear at the same frequency, X and 2X cycles per second. Nor does distance from the source of the sound make a difference. If a pianist in a concert hall plays middle C, that note is heard as middle C whether a listener is in the front row or in the last balcony row.

So far, we have considered a stationary source of sound waves. Let us now take a moving source. Assume a passenger at a station awaiting a train. Down track, the train approaches at 50 m.p.h. The engineer blows his whistle which sounds a single high pitched note. The awaiting passenger will hear that single note slide up the scale; or, as we have just learned, its frequency increases. This natural phenomenon, imparting the vaguely romantic wailing sound of approaching or receding train whistles, is the Doppler effect (or "shift") at an audible frequency. Note once again the strength of the source (i.e. whether the whistle blows loudly or softly) or its distance from the listener has no bearing on the effect—the pitch will slide up the scale, regardless of these factors as the train approaches. Furthermore, by definition, the Doppler effect cannot be heard from a stationary source. The frequency changes only with movement of the source.

All radar, including the K55, transmit or broadcast high frequency microwave energy which emanates from the transmitter in the cycle pattern and "echoes" back to the source. Sound, of course, does this too, but the reflector must be quite large whereas, with microwaves, small objects can and do reflect them.

If either the source of the microwave transmission is moving or a reflecting object is moving, the Doppler shift occurs. Thus if a person sitting in the moving source could "hear" microwaves, he would note a change in frequency of the returning cycles: increased frequency if the reflector is moving toward him (as in the case of the road or an approaching car) and decreased frequency if the reflector is moving away. Physicists have measured the frequency change and expressed the measurements in one of those simple, elegant formulae to which all nature appears ultimately reducible:

$$f_{dop} = \frac{2vf}{c}$$

where f_{dop} is the frequency of the returning microwaves, v is the velocity (speed) of the reflector, f is the transmitted frequency from the microwave source and c is the speed of light. Since c is always constant and the transmitter sends out microwaves of a known f, the only variable in this formula is v. Note, once again, that distance between source and reflector is absent from the formula as is any factor for the strength of either the transmitted or echoed energy.

DESCRIPTION OF THE K55 — ITS IMPLEMENTATION OF DOPPLER PRINCIPLES

The K55 unit is a small rectangular instrument which resembles a digital clock radio with switches, buttons and two windows on its face, one for patrol car speed and one for target vehicle speed. These readings appear as lighted, red digital numbers on a black background much as a digital clock or modern calculator. When no readings are being displayed only the black background can be seen. The set is secured to the dashboard of the patrol car directly behind the steering wheel and can be readily seen either over or through the wheel. It is so small that it cannot obstruct the driver's vision through the windshield. The set can be plugged into the vehicle's power source in several ways, one of which is through the cigarette lighter and it comes with an antenna and transmitter-receiver which is secured to the center of the dashboard.

The transmitter-receiver and antenna are constructed of standard components based on well known and accepted technology for the transmission and reception of high-frequency energy. The K55 does not use any experimental, new or patentable component or process in the antenna or transmitter-receiver. Every transmitter is factory tested with instruments which derive their accuracy from the National Bureau of Standards in Washington, D.C. The transmitter-receiver has also been tested by an independent concern to verify that it transmits at the frequency assigned to enforcement radar by the F.C.C.

When the set is turned on and calibrated[1] it may be operated in two modes: stationary and moving[2] Each mode may be controlled in either manual or automatic position[3] With the antenna pointed straight out the windshield over the imaginary centerline of the patrol car and the power on, the transmitter will emanate a large lobe of high frequency microwave energy down the road. The set may be adjusted to give audible warning of a motorist approaching in excess of a predetermined speed; but the warning signal is not a prerequisite to reliable operation. The machine displays readings continuously for speeds between 20 m.p.h. and 99 m.p.h.

As the patrol car moves over the road, the microwaves reflected from the road will arrive back at the receiver at a frequency, predicted by the Doppler formula, varying with the speed of the patrol car. Let us call that frequency, frequency "X". Now assume a target vehicle approaches the patrol car. Microwaves reflected from the target vehicle will arrive back at the receiver at a frequency predicted by the Doppler formula varying with the sum of the speeds of both cars. Let us call that frequency, frequency "Y". Virtually by definition, frequency X will always be less than frequency Y. In the stationary mode only the high frequency "Y" is received and computed into a readable speed.

Thus in the case of vehicles approaching one another ("closing") there are two returning frequencies, X & Y, both higher than the frequency originally transmitted, but Y always being greater than X. Because the transmitted frequency is constant, it can be dropped from further consideration and attention focused on the difference between X & Y and they can now be called the low frequency (X) and high frequency (Y) returns.

We are now finished with the Doppler effect. All the rest of the K55 is devoted to processing the low and high frequency return signals into a readable speed in miles per hour of the patrol car and target vehicle. But review what has been accomplished: Because of a single variable, speed, in one case relative to the road and, in another case, relative to a closing vehicle, two completely distinct frequencies have been generated, which can be computed into the speeds that generated them.

DESCRIPTION OF THE K55-SIGNAL PROCESSING & DIGITAL UNITS

The high and low frequency returns from the receiver flow into the signal processing and digital unit of the K55. A precise technical description of the components and circuitry of the signal processor would take hundreds of pages; but the Court finds that all of its individual components are standard and used in the K55 within their respective design limitations. The components are manufactured by reputable concerns such as RCA and Texas Instruments and are available generally on the wholesale or retail market for a wide variety of uses in electronic circuits from radios and pace-makers to satellite telemetry. They all have known and accepted parameters of performance and durability in the industry.

Although the exact combination of components comprising the circuitry of the signal processing unit may be unique to the K55 (in one case a patent is pending with respect thereto) the overall circuitry design is also within industry-known, and accepted, electronic theory and practice. Neither the function nor the efficiency of any component is frustrated by its particular use or placement within the design of the signal processing unit.

The signal processing unit has 10 functions all of which it performs more or less simultaneously and in milliseconds: (1) it amplifies the high and low frequency returns from the receiver; (2) it filters out frequencies resulting in patrol car speed of less than 20 mph; (3) it separates the signal into low and high frequency channels of parallel design; and as to each channel; (4) it filters random frequencies (commonly referred to as "noise") from the Doppler frequency being returned; (5) it tracks and locks on the Doppler frequencies and verifies them as the frequencies to be computed into vehicle speeds and; in the case of the high frequency channel; (6) it passes the now clear and verified signal into a subtractor; and in the case of the low frequency channel; (7) it passes one part of the signal directly to a digital computer unit which computes and displays patrol car speed in miles per hour; meanwhile (8) it passes the other part of the low frequency signal into the subtractor; where, (9) it subtracts the high and low frequency signals; and (10) it computes and displays the target speed in miles per hour.

The processing unit sweeps through these functions so quickly that a newly computed reading arrives at the viewing window about 15 times per second. In the manual mode the re-verification and computing process is continuous throughout the time and distance the vehicles are closing and thus permits the officer to lock in a reading manually when, in his judgment, the target has been properly identified and the reading stabilizes. In contrast, in the automatic mode, the K55 itself, automatically, locks in the first reading computed from a discerned signal. MPH does not recommend the use of this position and present State Police policy forbids it.

One of the most important overall operations of the machine that emerges from the ten step process described above causes it to focus on or to tune to, precisely and automatically, the strongest frequencies being passed to it by the receiver. To use a mundane simile, also from the law enforcement field, the K55 acts like a well-trained bloodhound, who once given an example of the target scent wants to, and can, filter out or discriminate between all the other distracting scents its nose senses and track the target scent. This simile, however, should not be misunderstood. The "strongest" signal to a radar may not mean the fastest car. Thus, as we shall see, signal strength depends on proximity to the transmitter and thus a slower target may well dominate the radar to the exclusion of a faster, but more distant, target.

THE TECHNICAL CHALLENGE

After extensive direct and *voir dire* examination, Mr. Andrew L. Soccio was permitted to testify for the defense as a highly experienced technician in the field of electronic circuits. Mr. Soccio is not a physicist, scientist or engineer; he has not designed a radar-informed speed measuring device from scratch. But he is entirely familiar with electronic circuitry, the various components that comprise modern circuitry and the various methods common in testing such circuitry. Mr. Soccio can build a complex electronic circuit from a schematic diagram; he can analyze its function; test performance of that function and evaluate its performance. In certain cases the Court believes Mr. Soccio has the experience to design or redesign electronic circuitry to improve its intended function or increase its efficiency. After a wide variety of experience in various jobs in the electronics industry, Mr. Soccio opened his own business which is devoted to troubleshooting and repair of traffic radars in South Jersey. He has not, under contract or otherwise, serviced the K55.

Mr. Soccio's qualifications did not include extensive or intimate knowledge of the K55. He disassembled one in Florida this winter, and examined certain parts of its signal processing unit for about an hour; he observed K55s in operation on police cars for about 6 hours; and he obtained and copied a partial schematic diagram of the signal processing unit issued by MPH to police departments for making repairs. Using this schematic, Mr. Soccio built, in his home laboratory, out of standard components, two elements of the circuitry in the signal processing unit and tested them. These elements were the "phase lock loops" and related components used in the high and low frequency channels. (See step 5, page 3, *infra).* Based on these tests, it was Mr. Soccio's opinion that the phase lock loops in both the high and low frequency channels possessed too wide a latitude in which to monitor and lock on an incoming frequency. Depending on minute transient errors in voltage the phase lock loops operating in such a latitude could lock on a wrong frequency and pass it through to be computed.

Mr. Patterson, called in rebuttal, challenged both the design of Mr. Soccio's home-made circuits because the schematic was incomplete and his tests were inadequate. It was his view that the overall design of components aligned after the phase lock loops in the circuit functioned together to nullify both the underlying assumptions of the Soccio tests and the test methods and equipment used.

Thus was framed the most important and difficult single issue in this case: to believe the architect of the K55 or the technically astute opposing witness. After due consideration the Court is satisfied that the Soccio tests do not raise a reasonable doubt as to the technical capability of the signal processing unit of the K55 to turn the high and low Doppler frequencies into accurate readings of patrol car and target speeds. The Court is not satisfied that there was sufficient similarity in all necessary respect between the Soccio prototypes and the actual, complete circuitry of the K55. Furthermore, the Court does not believe the test methods used by Soccio were sufficiently accurate to ground the broad opinion he gave on the K55's potential for displaying undetected, erroneous readings to a reasonably skilled operator.

THE OPERATIONAL CHALLENGE

The operational challenge to the K55 was grounded in the testimony of Dr. Nichols. He highway-tested the K55 in both Ohio and Florida for about 20 hours altogether. On these occasions, accompanied by others, he operated the K55 himself and observed others doing so. All the participants were civilians with engineering training and experience. No K55-trained policeman assisted, nor had anyone performing the tests received training from MPH. In at least one instance, the test was financed by Fuzzbuster, a manufacturer of traffic radar countermeasures.

In Florida, six makes of radar were operated in a single vehicle, calibrated and tested for interference with internal noises such as generators, fans and the like. Then the vehicle, with the radars switched on in pairs, was driven on randomly selected highways in Miami and its environs. No written record of the tests were made, nor were any targets of known speed run through the radars. The radars were operated in both stationary and moving modes and in manual and automatic positions. Based on this experience and his own academic background, Dr. Nichols' thoughts fell into four general problem areas: (1) problems of target identification where there were several possible targets approaching; (2) problems of co-sine error resulting in computation of lower-than-actual patrol car speed; (3) problems of internal and external mechanical, radio or microwave frequency interference; and (4) problems of a subjective nature. In all of these areas, the K55 seemed to be most prone to potential error where it was switched to the automatic position.

Dr. Nichols identified two sources of difficulty relating to target identification. Both problems arise from the necessity to decide which of several possible targets is actually generating the speed readout.

As indicated on page 3, one of the design characteristics of the K55 is to track, hold and verify the strongest frequency being echoed to it. In practice, the strongest return frequency is usually that which is closest to the receiver. Thus, MPH in its Operator's Manual (D6 in Evid.) directs:

> "Care should be taken by the operator that he recognize the violator is traveling at a higher rate of speed than the norm, *that the vehicle is out in front, by itself, nearest the radar.*" (Emphasis Added)

But Nichols testified that a large target, rather than one closer to the patrol car, may actually be reflecting the strongest signal. Thus if a truck is following a Volkswagen—the K55 may compute the truck's speed rather than the Volkswagen's, contrary to the above-quoted identification rule. He also pointed out that some materials and shapes are better reflectors than others and could result in a more distant target, producing the reading, if made of such materials or in such shapes.

The Court is satisfied that this problem could and probably does occur in a very close-following situation, and policemen should be alerted to the possibility of an incorrect identification. But Dr. Nichols gave no guidance whatsoever as to what was "close following". He apparently could not and did not say whether at 50 feet, 25 feet or at what distance between the approaching truck or VW, the rearward truck would begin to produce the stronger signal. Thus, the Court finds the above quoted rule a reasonably reliable guide on which to base identifications in the situation described.

Dr. Nichols also sought to describe target-identification problems where a possible violator was closer to the centerline of the transmitted microwaves than a target nearer in distance to the transmitter. He (as well as other witnesses) described the imaginary extended centerline of the patrol car (with the antenna so aligned) as the line of maximum transmitted power, and suggested that a return signal along that line would also be strongest. He pointed out that signal strength falls off far less as one moves away from that centerline than it does as one moves away from the transmitter. It has been found that one-half of the energy transmitted lies within an angle of 8° on either side of the centerline and, Dr. Nichols estimated, if the sides of that angle are carried out as much as 1500 feet from the patrol car 85% of all the transmitted energy would lie within it. According to Nichols, therefore, a target physically closer to the centerline, but more distant from the patrol car than the target nearest the patrol car, *might* produce a reading. An unwary policeman *might* attribute that reading to the vehicle closest to the patrol car, thus resulting in an unjust arrest.

But Dr. Nichols' views in this respect were unsupported by any precise measurements or detailed tests. None of his highway tests were performed under controlled conditions. No experimental results or theoretical models were adduced to demonstrate Nichols' theories, to any degree of scientific probability, that a nearer target would produce a signal less strong than a more distant one, notwithstanding such distant target's proximity to the centerline of the micro-move-energy lobe. In fact, in most situations presented him, Dr. Nichols appeared to believe the nearest vehicle to the patrol car would generate the reading. Because it is true that signal strength (not frequency & hence not accuracy of a reading) falls off by the square of the distance from the transmitter, the Court finds it more probable that that distance is, in fact, the key one, and therefore, once again, finds the quoted rule of identification reasonably reliable.

Dr. Nichols described co-sine error as that error in target speed, which results from the fact that the Doppler frequency reflects along the line between the target to the patrol car, whereas the target is actually moving, not straight at the patrol car, but at an angle to it. Because of the trigonomic function of the co-sine, which is always less than 1, the error always favors the target, i.e. displayed target speed is less than the actual target speed. But Dr. Nichols also theorized co-sine error could reduce the display of patrol car speed. This is, potentially, a serious matter since reduced patrol car speed would result in, false, higher target speed readings. Thus, if a huge sign or a long building with a long reflective surface on the side of the road reflected a signal stronger than that of the road and thereby generated the low frequency return for computing the patrol car's speed, the angle of such an object relative to the motion of the car might theoretically reduce the patrol car's speed reading by the co-sine error.

However, the Court determines such situation would be necessarily rare, and the reading generated, transitory. Moreover, an alert officer, checking his patrol car readout against his speedometer, should note dropping speed and reject any target speeds obtained in that situation. Accordingly, the Court determines, that while co-sine error as it affects patrol car readout may be a theoretical problem, its significance in routine traffic situations is not such as to raise a reasonable doubt as to the reliability of the K55 when operated by a trained and experienced officer.

Dr. Nichols also testified to internal and external sources of interference with the K55 which can produce spurious speed readings. The K55 possesses circuitry designed to filter out most internal and some external interference. Like all radar devices, the K55 can, and does, receive signals other than that which it originally transmitted. A wide variety of devices in relatively common use transmit electromagnetic energy at frequencies at or close to those assigned by the F.C.C. to police radar. Depending on the strength of these signals, which again depends on how close the source is to the K55, a speed reading can appear.

The signal processing unit may itself reject the signal and cause the reading to go blank; or the reading will be erratic; or, so high or low as to tip the operator off at once that electronic interference may be present. Nonetheless, troopers are trained not to use their own radios when patrolling for speeders and to be mindful of the use of CB radios in the vicinity of the patrol area. Airports and even low strung high tension wires may also be common trouble spots. State and local police may well be advised to begin to catalog, within their respective jurisdictions, the existing sources, strength, frequency, range and direction of radiated energy which might intersect with or flow over the roads and highways. Armed with such information, tests could be run to determine the effect, if any, on the K55.

By so suggesting, however, the Court does not wish to leave the impression that external radio or microwave interference seriously detracts from the reliability of the K55. The Court is satisfied that the chance of an undetected interference increasing a speed reading, to the detriment of a motorist is so remote as not to raise a reasonable doubt under the "high degree" of reliability standard here at issue. Absolute perfection, of course, is not required.

As a result of his Florida tests, Dr. Nichols expressed certain subjective reservations about the K55. He expressed concern over the practical difficulties of target identification in the multiple lane, heavy traffic situation and surprise at the variety of response times in the various radars and the differences between them in the speed with which they repeated their readings. He stated the K55 did not give him "the personal satisfaction that it was as stable and as reliable in the quickness with which it reached a reading that seemed to satisfy the physical situation as the others". (TR111-17). He also stated "it seemed to be more erratic to me. It went up too far or down too far. The swings were more violent. Ultimately it would stabilize and come back and give an adequate and satisfactory reading". (TR 123-2).

Considering the qualifications of Dr. Nichols, these observations are entitled to respect. In fact, to the extent he notes that the K55 did come to an "acceptable" reading as compared with other radars, he points to the sensitivity of the K55 in the manual position in rejecting spurious readings or other transitory phenomenon. Since Dr. Nichols was as critical of the automatic position, with its ability to lock in a transitory reading, as Mr. Patterson, the Court finds it difficult to understand his subjective feeling about the K55. In any event, such feelings do not raise a reasonable doubt in the Court's mind as to the reliability of the K55 when operated in the manual position.

GHOSTS & SHADOWS

Every law enforcement tool, whether it be a radar set or a bloodhound, must be understood and used within its inherent limitations. The K55, as all radar, has such limitations. Transmitted signals echo randomly from anything the microwaves reach; and sometimes, that signal echoed from a tree, fence or billboard will a second time be reflected from a moving object out of the trooper's visual range and be received and processed as a speed reading. These are "Ghost" readings: spurious speed readings of unseen vehicles or stationary objects. He who seriously reports tracking speeding trees with the K55 is either a fool or a knave, since such a report presents an inherent conflict with the underlying Doppler principle.

Such ghosts will be either so transitory or display such erratic readings that any experienced operator will at once recognize them.

Moreover, ghosts will always be banished by a stronger signal because the K55 functions to find and lock on the strongest signal returning to it. Ghost readings cannot add to or detract from the speed of a real target. None of the experts challenged its reliability in that respect.

"Shadowing" occurs when the patrol car closely follows or is overtaken by a truck or large car with the K55 on in the moving mode. The signal usually returning from the road surface may now be temporarily supplanted by the stronger signal returning from the vehicle in front. Since that vehicle is traveling slower relative to the patrol car than the road was, the viewer will notice an apparent decrease in the speed reading of the patrol car. Any reading taken on a target vehicle under such conditions would be inaccurate[4]. But the evidence is clear that State Troopers are trained to check continually, while in the moving mode, the K55 display of patrol car speed with the speedometer. Any difference between the K55's reading and the speedometer is a trouble sign, which will suggest caution on the part of the trooper in relying on a target speed reading.

TRAINING

The Court finds that the operational reliability of the K55 is largely dependent upon the training and experience of the policemen who use it. In *State v. Dantonio*, 18 *N.J.* 570 at 573-574 (1955) the Court quotes a law review article stating that "the average person engaged in traffic control work can learn to use the radar speedometer after about one and one-half hours of instruction". Judged by that standard, the State Police get ample instruction in theory and practice on the K55. Trooper Dempster, for instance, received a full day of classroom and "hands on" practical instruction from MPH, Inc. representatiaves and then "practiced" with the machine in his own patrol car 80 hours before he arrested violators. Such a level of instruction and experience acquaints the officers with the technical capability of radar as well as practical use in everyday traffic situations. For instance, like our bloodhound who cannot, having found the source of the scent, identify it as a vicious criminal or a lost child; so also cannot the K55 identify the speeding vehicle: the officer using it must do that. Troopers are taught a three step procedure when the K55 displays a target speed: (1) identify the probable target producing the reading; (2) lock in the speed; and (3) compare visually the speed displayed with the officer's own estimate of the target's speed. This must be a complex procedure requiring well coordinated eye and hand movement as well as the exercise of quick judgment. The officer must, also, be monitoring his own speedometer with that of the K55's readout on patrol car speed and driving his car with safety. With some traffic patterns, such as heavy approaching traffic in multiple lanes where no one car is clearly in front, it will always be difficult if not impossible to identify a target. But experience should quickly expose such situations.

In view of the above, however, and the high degree of skill and judgment required to operate the K55 reliably, it is the Court's view that periodic follow-up training be instituted in order to verify continuing qualification as a K55 operator. Moreover, the skill and judgment of troopers who themselves instruct in its use should be most carefully evaluated.

Finally, it is clear from the testimony of all the witnesses, that the K55 should not be operated in the "automatic" position in either the moving or stationary mode. That is present State Police Policy and should remain so. By "automatic" in the sense used here, it is meant that position on the K55 which "automatically" locks on the first echo it receives and processes that echo to a readout and will not then process further echoes. Thus may be instantaneously captured an interfering signal or a ghost which would not be reflected from the visible target.

CONCLUSION

For all the reasons stated above the Court determines that a properly calibrated K55 Speed Detection Device installed in a car with a calibrated speedometer, has a high degree of scientific and operational reliability when used in either stationary or moving mode, in the manual position by a person having at least three hours of classroom training and two to three hours of practical instruction together with some minimum experience prior to use in actual law enforcement. The Court, on the record before it, cannot specify what the minimum experience should be but holds that 80 hours is, beyond doubt, sufficient.

When operated in the automatic position, the operational reliability of the K55 is subject to greater question and acceptance of readings while in that position must hinge to a far greater extent on detailed examination of the surrounding circumstances as well as the experience and training of the operator.

In view of the holding above, the Court will shortly schedule argument on any and all other issues defendant may choose to raise on the record below relevant to his conviction.

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[1]Calibration is accomplished with the use of two tuning forks, the accuracy of which must be the subject of documentary proof. Use of the K55 does not eliminate the need for such proof. *Cf. State v. Overton*, 135 *N.J. Super.* 443 (Cty. Ct. 1975)

[2]The "mode" of operation refers to what the patrol car does. In the stationary mode, the car is parked roughly parallel to the road directed at oncoming traffic. In the moving mode the patrol car operates in traffic and tracks vehicles approaching it in the opposite lane. All findings herein apply *equally* to both modes of operation.

[3]The difference is important and is explained in the text at page 5.

[4]See also the discussion, infra page 4 regarding reduced patrol car speed as the result of co-sine error.

STATE OF MICHIGAN
IN THE DISTRICT COURT FOR THE SECOND JUDICIAL DISTRICT

STATE OF MICHIGAN PLAINTIFF

V. File No. 79-3781

CARL WAYNE LEAMER DEFENDANT

The above listed case listed ten technical errors identified at the hearing to which radar is susceptible. However, each has a solution.

1. COSINE ERROR: This error results from the relationship of the target to the antenna of the radar. If the path of the target is exactly perpendicular to the face of the antenna, there is no error. Any departure from the perpendicular, however, does create an error. For each degree of departure from the perpendicular, the greater the error.

   SOLUTION: Since stationary police radar is designed to have this error always work in the defendant's favor (i.e., any error tends to reduce the speed shown by the radar for the target vehicle) there is no overriding need for solution. However, officers are trained to point the antenna of the stationary radar directly toward the approaching vehicle.

2. MOVING COSINE ERROR: This error occurs only in the moving mode, i.e., where the police vehicle is in motion. It results from the antenna not being aimed straight ahead. If the antenna is aimed to the right of centerline, it can give an erroneous reading which can inflate the target vehicle's speed. In the moving mode the radar is checking both the speed of the police vehicle and the "closing speed," i.e., the rate at which the police car and the target vehicle are approaching each other. A computer in the system automatically subtracts the police speed from the closing speed, resulting in the speed of the target vehicle. If the antenna is not properly aimed, the radar may show the police speed as too slow, thereby erroneously inflating the target's speed.

   SOLUTION: The operator should make sure that the antenna is kept horizontal and at zero degrees in reference to the target vehicle's approach (approximately five degrees left of centerline in the patrol car.)

3. SHADOWING ERROR: This error occurs only in the moving mode and results from the police vehicle following (i.e., "shadowing") a large vehicle with the target approaching from the opposite direction. Since the radar is supposed to compute the police speed by using stationary objects along the side of the road (i.e., signs, trees, etc.) the problem arises where the radar picks up reflected signals from the vehicle in front of the police car, which is also moving. This can result in a major discrepancy in the radar's display for the target vehicle.

   SOLUTION: It is relatively simple to avoid this problem. Radar models used in the moving mode should always have separate readouts for the police vehicle and the target vehicle (as do the models used by the Illinois State Police). By comparing the radar's computation of the police speed with the vehicle's own speedometer, it will be obvious when a shadowing error exists.

4. BATCHING ERRORS: This error also occurs only in the moving mode. It is found only at those times when readings are made while the police vehicle is rapidly accelerating or rapidly decelerating. In either case the computer in the radar cannot keep up with the sudden change of speed of the police vehicle. It results in an incorrect reading for the police vehicle and, therefore, also an incorrect reading for the target. During rapid acceleration the speed of the target is erroneously inflated; during a sudden stop of the police car, the target's speed registers erroneously low.

   SOLUTION: As in shadowing errors, the operator can avoid the problem by verifying the radar's calculation of the police car's speed with the speedometer. The error can be completely avoided by not taking speed readings during sudden starts or stops.

5. SCANNING ERRORS: This is generally associated with hand held radar models, but can be observed in other models. It results from the operator rapidly swinging the radar antenna from one direction to another. The sweep of the radar beam across the terrain gives an impression of speed and can result in a reading, even though there is no target vehicle present.

   SOLUTION: The operator should never take an enforcement reading while swinging the antenna.

6. PANNING ERRORS: This error results when the radar antenna is used to "pan" through its own display.

   SOLUTION: The operator should never take a reading while aiming the antenna at the readout unit.

7. ELECTRICAL INTERFERENCE ERRORS: This results from electrical impulses being read by the radar, rather than a target vehicle. The electrical impulses can originate in the patrol vehicle itself or outside, e.g., neon lights, x-ray equipment, airports, hedge trimmers, lawn mowers, CBs, etc. This effect usually occurs when there is no target vehicle in the radar's beam. If a car enters the radar's "field of vision," the radar will normally register the target vehicle's speed instead of the electronic interference.

   SOLUTION: Make sure the equipment is properly set up. Listen to the audio output of the radar set. The audio output of electronic interference is quite different from that produced by the radar waves returned from a target vehicle.

8. AUTOMATIC LOCKING ERRORS: This error is related to radar's method of determining speed. The frequency of the returning radar wave changes depending on the speed of the object being checked. If the radar returns at 314 cycles per second, it indicates 10 miles per hour, while a wave of 3,140 cycles per second indicates 100 miles per hour. The computer in some radar "checks" the cycles per second starting at zero and proceeding up to infinity. In other models it starts at infinity and works down to zero. This "checking" is done very quickly, of course. The problem is whether the "checking" process is so fast that it is actually at a different speed, (i.e., cycle per second) for the target vehicle by the time the automatic lock activates compared to the speed that actually caused the lock. It is something like the runner overshooting the mark before he can stop. If the radar model used checks from zero up to infinity, this overshooting results in an inflated speed from the target vehicle. However, for models that check from infinite cycles per second down to zero per second, any overshooting results in a low reading.

   SOLUTION: Automatic locks are not to be used. Illinois State Police radars providing automatic locking have had this feature disconnected.

9. <u>GHOSTING ERRORS</u>: This occurs where the radar reflects off a large stationary object, like a billboard, and actually monitors the speed of the police car itself rather than a target vehicle. It can also occur from other sources such as: internal car air conditioning and CB radio.

   <u>SOLUTION</u>: The officer should monitor the audio signal of the radar. Ghosting errors produce a squealing audio effect which is markedly different than the audio produced by a target vehicle. Also the spurious readings on the speed display, when no target vehicle is present, makes ghost errors easily recognized.

10. <u>TRACKING ERRORS</u>: Again this occurs in the moving mode. It results from the radar determining the speed of the patrol car by using other than a stationary object which is substantially at zero degrees from the path of the patrol car. It is similar to shadowing and certain ghosting errors.

    <u>SOLUTION</u>: The officer should always verify the radar patrol speed by comparing it with the vehicle's speedometer.

This list is not intended to be a complete detailed list of such situations. Rather, it is an attempt to briefly outline some of the general types of problems.

GUIDE TO RADAR COURT TESTIMONY

1. And what type of a radar unit is the ________________(MR-7, K-55, etc.)?

   Answer: Portable type that has the capability of monitoring the speed of a vehicle from a moving patrol car.

2. In the particular section where you were patrolling, how many lanes wide is highway US _________?

   Answer: It is a _________ lane highway.

3. Could you give us a particular reference on US Highway _________ at approximately where you were (at date and time of arrest)?

   Answer: ___________________________

4. In what direction was the traffic moving that you were monitoring?

   Answer: I was monitoring traffic moving in a _________ direction on Highway US _________.

5. Would you explain the component parts of your radar equipment and where each is set up?

   Answer: The unit consists of an antenna and an amplifier/counter as the basic unit. The digital readout is incorporated into the amplifier/counter unit. The antenna mounting is so designed that it may be mounted either inside or outside of the patrol car. The amplifier and readout are combined along with all other parts and can be held in the operator's hand or placed in the seat beside the operator or it can be suspended on the dash.

6. What direction were you traveling?

   Answer: ___________________________

7. Trooper _________, prior to the (date of arrest), had you received any instruction in the operation of a radar speed measuring device?

   Answer: Yes, sir. I have received several hours of instruction.

8. Who was your instructor?

   Answer: (Officer or Trooper who checked you out on the operation.)

9. Is Trooper _________ qualified to instruct on the operation of the radar?

   Answer: Yes, sir. He has operated radar units for _________.

10. Will you tell the Court approximately how many hours of operation you have had with this set?

    Answer: I have had about _________ hours of experience in operating this set.

11. Before you started using your radar equipment on (date of arrest) did you perform any type of tests to see that your equipment was functioning properly?

    Answer: Yes, sir.

12. Would you tell the Court what these tests were?

    Answer: The unit was calibrated by the tuning fork test, internal calibration and a comparison of speed indication by the radar and my speedometer by depressing the verify mode button.

13. Please explain to the Court how the internal test is conducted.

    Answer: With the stationary mode button depressed, turn the function switch to the calibrate position. The unit should read ________ mph (varies with different makes).

14. What speed was indicated?

    Answer: ________ mph.

15. Please explain the tuning fork test.

    Answer: Two tuning forks are provided with the system: one 35 mph and one 65 mph. The test is conducted by depressing the moving mode button causing a horizontal dash indicating a ground speed is not present. Then strike the two tuning forks and hold the 35 mph tuning fork (which represents the ground speed of the patrol car) about one inch in front of the antenna face. Upon obtaining the proper lock, as indicated by the disappearance of the horizontal dash indication and while still holding the first tuning fork in place, bring the second higher mph tuning fork 65 mph (which represents the closing rate of both vehicles) to within one inch of the antenna. The readout should now correspond to the mph difference (30) between the mph figures stamped on the two forks.

16. What speed did you observe while making the tuning fork test?

    Answer: 30 mph.

17. Please explain to the Court how the circuit calibration mode is used to check the accuracy of the system.

    Answer: The verification is done once the patrol car is in motion. The radar should indicate the same mph as that displayed by the patrol car's accurate certified speedometer.

18. What were the results of this test?

    Answer: The radar indicated an mph identical to that of the calibrated speedometer.

19. Did you perform any other tests on the day of (date of arrest)?

    Answer: Yes, sir. The circuit calibration test was conducted after every violation. The internal test was made periodically throughout the day. The tuning fork test was conducted at the end of my tour.

20. Who held the tuning forks on these tests?

    Answer: I did.

21. Please explain to the Court how the radar operates.

    Answer: One signal is transmitted from the antenna. A portion of this signal is reflected back to the antenna from the highway surface and surrounding terrain. This represents the speed of the patrol car. This information is stored in the computer. The other portion of the beam is reflected back to the antenna from the approaching vehicle which would be the closing rate in mph of both vehicles. This signal also goes into the computer where the patrol car's speed is subtracted from the closing rate of both vehicles — thus it reads out the speed of the oncoming vehicle.

22. Where are these miles per hour read?

    Answer: On the digital readout.

23. When did you first observe the defendant on (date of arrest)?

    Answer: I observed him approaching my vehicle from (direction) on Highway US __________. At the time I first saw him, I would estimate that he was about __________ of my location.

24. What sort of vehicle was he operating?

    Answer: He was operating a __________ etc. (whatever kind of car it might be).

25. What was the registration on the vehicle?

    Answer: The registration plate was __________.

26. What did you observe and do as the defendant's car approached you?

    Answer: I checked to make sure the antenna was aligned so that the approaching car would move into the radar beam. Then I observed the digital readout as the defendant's car approached. I looked back and forth from the readout to the approaching car several times. The readout locked onto __________ mph.

27. Trooper __________, how long before this __________ vehicle appeared in your radar beam was the prior car that preceded the (name of vehicle) in another direction on Highway __________?

    Answer: About __________ (time last car went through lane).

28. How long after the (name of the vehicle) car passed your radar beam did the next car come through the radar zone?

    Answer: About __________ later (time next car came through).

29. Were there any other vehicles in your vision that came through at the same time as the defendant's vehicle came through your zone?

    Answer: No, sir.

30. As a driver and otherwise, have you had occasion to observe the speed of moving vehicles on the highway?

    Answer: Yes, sir.

31. Have you had occasion to test your estimate of speed of moving vehicles against tested speedometers and other speed measuring devices?

    Answer: Yes, sir.

GLOSSARY OF RADAR TERMS

BATCHING or TARGET SPEED BUMPING	Target speed varies when the patrol speed varies.
BEAM DROPOUT	The Radar beam being directed skyward as the patrol vehicle proceeds up a steep hill.
BEAM WIDTH	The width (in degrees) of the beam of a power transmitted by the Radar antenna.
CIRCUITRY VERIFICATION	A procedure to determine that the Radar unit is operating properly and measuring speed correctly.
COSINE ANGLE EFFECT	The error that occurs when the patrol unit and target are not headed directly toward each other.
DISPLAY, PATROL SPEED	The digital display window on the Radar unit showing the speed of the patrol (Radar) vehicle.
DISPLAY, TARGET SPEED	The digital display window on the Radar unit showing the speed of the target vehicle.
DOPPLER PRINCIPLE	A principle stating: "When an energy is transmitted from a moving object and reflected from a stationary object, or transmitted from a stationary object and reflected from a moving object, or both, it increases or decreases in frequency in direct proportion to the speed of the object."
DOUBLE BOUNCE	This phenomenon is so remote it does not justify an explanation.
EXTERNAL ELECTRICAL INTERFERENCE	High tension power lines generating electrical noise which is "read" by the Radar.
LOOK PAST	The Radar "looks past" a vehicle and "reads" the speed of a more distant (and usually larger) vehicle.
MOVING MODE	The mode of operation whereby the patrol vehicle is also in motion while checking the speed of approaching vehicles.
RADAR DETECTOR	A Radar receiver designed to detect the presence of Radar signals.
RADAR JAMMER	A radio transmitting device designed to jam the signals of the Radar unit.
RADIO TRANSMITTER INTERFERENCE	Erratic readings when the CB or police radio transmitter is activated.
RANGE	The distance in which the Radar is able to "see" a target vehicle.

Glossary of Radar Terms (continued)

REFLECTED SIGNAL	A signal that has struck an object and is reflected.
REFRACTED SIGNAL	A signal that has struck a refractive material and has been deflected (bent) rather than reflected.
SHADOWING OR VEHICLE INTERFERENCE	The tendency of a moving Radar to substitute the signal reflected from a slow-moving vehicle as the "patrol" speed signal.
SQUELCH CONTROL	A switch on the Radar unit which turns off the Radar beam.
STATIONARY MODE	The mode of operation whereby the Radar unit is stationary. The vehicle in which it is mounted is not in motion.