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History and Development of Radar

1.1 Radar - What is it?

The word **'RADAR'**, an acronym derived from the phrase 'Radio Detection and Ranging', was coined by the United States Navy during World War II but the principles of its operation can be traced back to mid 19th century. Radar is a means of gathering data about distant objects. By directing electromagnetic waves at a target and analysing the echo, information about that target which may otherwise be unobtainable or invisible to the unaided eye is revealed. Measuring the length of time taken for a reflection to return allows calculation of range and directional information is provided by antenna position. Developed in great secrecy and more or less simultaneously in Britain, France, Germany and the USA, its original purpose was to provide advance warning of approaching enemy aircraft. The names for radar frequency bands such as X band, K band, Ka band, L band, etc., are a legacy of this period when secrecy was of paramount importance.

Removal of military security restrictions in 1946 allowed attention to be focused on development of civilian applications such as weather radar, astronomy and civil aviation. In today's technologically advanced world radar is indispensable for many military and domestic applications.

1.2 History and Development of Radio Detection

Development of radar cannot be attributed to a single inventor or even to an identifiable group of inventors but its basic concepts have been understood as long as those of electromagnetic energy. In 1904 Christian HULSMEYER, a German engineer, was granted the first patent for a radar-like device in several countries including Britain, Germany and the USA. Technical limitations made his system ineffective at distances in excess of about 1600 metres.

The principles of Hulsmeyer's system were known much earlier through the experimental work of English physicist, Michael Faraday, and the experiments and mathematic investigations of Scottish physicist, James Clerk Maxwell. Maxwell predicted the existence of radio waves but it was left to German physicist, Heinrich Hertz to experimentally test Maxwell's theories. In 1886 Hertz succeeded in proving the existence of radio waves and that they could be reflected from solid objects.

Radio echo for detection purposes was mentioned in scientific papers after Hertz's demonstration of reflection but was not seriously considered until 1922 when Italian engineer, Guglielmo MARCONI presented a paper on radio detection. This caused the US Navy Research Laboratory to test his ideas experimentally. They produced a device with a continuous wave transmitter and a separate receiver capable of detecting a wooden ship passing between the two parts.

Pulse modulation was first developed in 1925 in the USA but for several years was applied only to weather and ionospheric investigations. During the 1930's America, using pulse modulation techniques, developed a radar system which, by the end of 1936 could achieve a range of 11 kilometres. During the same period France was developing domestic uses for radar whilst Germany worked on aircraft and ship detection as well as position data for effective anti-aircraft fire. Britain began research in the mid 1930's but by the end of 1935 ranges greater than 64 kilometres were achieved.

Imminent threat of war in Europe encouraged much research into radar systems during the 1930's but efforts were hampered for want of a device capable of producing the high frequencies required at a power level which produced sufficient range. In 1939 the USA developed the Klystron, a device capable of producing the frequencies required at a power level of 1 watt. This was still not sufficient power and in the same year Britain developed the Magnetron, a device which produced 20000 watts of power. Modern radar was born.

1.3 Doppler Radar

In 1842 Christian Johann DOPPLER, an Austrian physicist, theorised that since the pitch of sound from a moving source varies for a stationary observer, the colour of light from a star should alter according to the star's velocity relative to Earth. This 'Doppler Effect' is defined by Encyclopedia Britannica as -

> *the apparent difference between the frequency at which sound or light waves leave a source and that at which they reach the observer.*

1.3.1 Advantages

Continuous wave doppler radar accurately measures a wide range of relative velocities and is not affected by the presence of stationary targets. Circuitry is simple and compact with low power consumption and low transmitted power, is very fast, accurate and reliable.

1.3.2 Applications

Doppler radar is used extensively in aircraft navigation systems to determine speed, rate of ascent/decent and altitude determination in vertical take-off aircraft such as the Sea Harrier and the lunar landing module. The most commonly encountered application is in microwave speed indicators used by traffic law enforcement agencies worldwide.

1.4 The First Doppler Radar

Although the doppler principle was well known as a method of measuring relative velocity, it wasn't applied to radar until after WWII. Radar for police purposes was one of the first applications of the doppler shift principle to radar and the first primitive device became available in 1948. The radar could be purchased for $US3600 when a fully equipped police vehicle could be obtained for $US1800. It was necessary to climb underneath the host vehicle each time the device was installed or removed. In short, the first radar devices were crude, expensive and cumbersome. High cost coupled with unreliable operation and inconvenience, particularly with regard to periodic maintenance, soon caused the enthusiasm for police radar amongst law enforcement agencies to wane.

Despite initial difficulties and consumer resistance, steady progress in police radar development continued. Rapid technological advances, particularly in electronics and knowledge of microwave propagation, and efficiency in manufacturing techniques allowed more sophisticated, reliable, functional devices to be designed and produced. During the 1950's initial scepticism and resistance gave way to genuine interest and radar's potential as a law enforcement tool became more apparent. As demand for radar instruments gained momentum the devices became less cumbersome, more reliable, easier to use, cheaper to produce, purchase and maintain. Modern radars have solid state circuitry, are often microprocessor controlled and adaptable to an almost endless variety of purposes in addition to speed limit enforcement.

1.5 Police Radar in NSW

The first radar devices used by NSW Police Force were obtained during the early 1960's. Two 'pie' radar devices were purchased and used extensively throughout the State. However, replacements were soon sought because these sets were so large that a panel van or utility was necessary to transport and operate them. The transmitter frequency was about 2 gigahertz and the power requirements of the system made it necessary for the engine of the police vehicle to be left running to keep the battery charged.

The Pie radar was replaced during the late 1960's with a more sophisticated and much less cumbersome system, the Traff-o-matic 'S-5'. These devices were used until 1971 when, during a Court hearing, serious doubts were cast upon the reliability of acceptance tests carried out on each new S5 radar. These tests were carried out by a private company because the NSW Police Force had no microwave testing facility at that time. The S5 was withdrawn from service.

Before the introduction of a replacement system the NSW Police Force established its own microwave testing facility, then called the Radar and Breath Analysis Maintenance Unit and, in 1973, recommenced radar surveillance of the motoring public with the introduction of Digidar 1. Digidar was a stationary, direct doppler system with solid state circuitry, digital display and accuracy previously unattainable in such a compact device. Between 1973 and 1977 some 65 Digidars were purchased and most remained in service until finally withdrawn in December 1987. The Digidar 1 was manufactured in America by Smith and Wesson and operated on a frequency of 10.525GHz or X-band. Frequencies in X-band are now being utilised for satellite communication therefore licenses for radar and other devices operating in X band have not been issued since 1 January 1990.

New South Wales was the first Australian State to utilise a Police radar system capable of mobile operation when, in 1980, it introduced the Kustom KR11. A similar Kustom device, the KR10SP, was introduced in December 1986 to perform the same functions as the KR11 - i.e. stationary and moving radar operation. Whilst the KR11 is no longer in general use in NSW, both KR10 and KR11 are still being manufactured in the USA. In May 1996 the first Silver Eagle Radar was placed in Service and in 2007 the Silver Eagle II Radar was introduced.

KR10SP, Silver Eagle and Silver Eagle II radars are direct doppler devices - that is, the energy must be transmitted directly toward the target and relative motion between radar and target must exist for the device to work. The presence of more than one target in the effective beam can cause difficulty in target identification therefore, to cope with high volume 'city' traffic, the AWA 449 Vehicle Speed Radar ("slant") was introduced in December 1986. The device emits a continuous beam 'across' the roadway at an angle, thereby overcoming many multiple-target difficulties. Slant radar was developed in Australia and was manufactured at Holden Hill, South Australia by AWA Defence Industries Pty Ltd. The Slant Radar has since been replaced with lidar for use in high volume 'city' traffic situations.

The radar devices used by this NSW Police Force have a long history of proven reliability and accuracy. For many years they have been valuable assets in our traffic law enforcement programs.

1.6 Methods of Speed Measurement

1.6.1 Average Speed Method

Probably the oldest and simplest form of speed measurement is the Average Speed Method. A target is timed over a known distance and a simple calculation using the data obtained reveals the average speed of the target over the distance.

This method has two inherent faults. If the distance between the datum points is large, parallax error becomes a significant factor. If the distance between the datum points is reduced to overcome parallax error, the reaction time of the operator becomes significant and may introduce an unacceptably high error.

Both problems are overcome by using automatic sensors to start and stop the timer. Pneumatic tubes are one form of sensor but they are inconvenient to set up. Other systems are suitable for permanent installation only, or require components on both sides of the carriageway. The NSW Police Force Aerial Surveillance program took advantage of the average speed method by timing a target over 500 metres to minimise the effects of reaction time, and overhead observation of the target minimised the effects of parallax error.

1.6.2 Microwave Doppler Radar Method

All radars presently used in Australia (except Laser) are part of a group of devices which take advantage of the Doppler Effect to determine relative velocity. There are two basic types of doppler radar - those which must be aimed parallel to the roadway and directly at the target, and those which are aimed across the roadway at some angle. Virtually all types of direct radar are capable of stationary operation and some have the additional advantage of mobile operation. Slant radar systems are usually restricted to stationary operation but a few do have limited mobile capability. Both direct and slant doppler radars rely on the transmission of electromagnetic energy and analysis of the echo received from the target.

2.1 Theory of Doppler Radar Operation

Radar is a means of obtaining information about a target from a remote point. A very high frequency radio signal is directed at a target so that some of the energy bounces off and returns to the point of transmission. A radio receiver detects the returned signal and compares it with the transmitted signal. Analysis of the difference between the two signals provides data about the target.

Silver Eagle II radar transmits a continuous wave of electromagnetic energy down the roadway at a frequency of 34.9 GHz (34900 million Hertz) at the speed of light. When the wavefront strikes a moving object its frequency changes slightly in direct proportion to the relative velocity of the object (Doppler Shift). Some of the energy is reflected back to the source (radar antenna) where the slight change in frequency is utilised to determine the relative velocity of the target in kilometres per hour.

2.2 Alternating and Direct Current

What is meant by 'continuous wave', 'electromagnetic energy', 'frequency', 'doppler shift', etc. Since electromagnetic energy exhibits some of the properties of electricity our quest for understanding can begin with a brief study of some of the characteristics of electricity.

Electricity is simply a flow of electrons (current) through a conductor. The standard unit of current is the ampere (amp). The volt is a unit of electrical pressure and is a more widely used term when discussing electricity. For convenience sake we tend to use the term 'voltage' and in so doing we are really stating the pressure available to force a flow of electrons.

2.2.1 Direct Current (dc)

Direct current is very briefly defined as a continuous flow of electrons in one direction through a conductor; i.e. the voltage (or pressure) is permanently applied so that electrons always flow from the negative terminal through the conductor to the positive terminal.

Direct current is produced by batteries, fuel cells, rectifiers and generators with commutators. Probably the most common uses for dc are in the electrical systems of motor vehicles, in flashlights and other battery-powered devices.

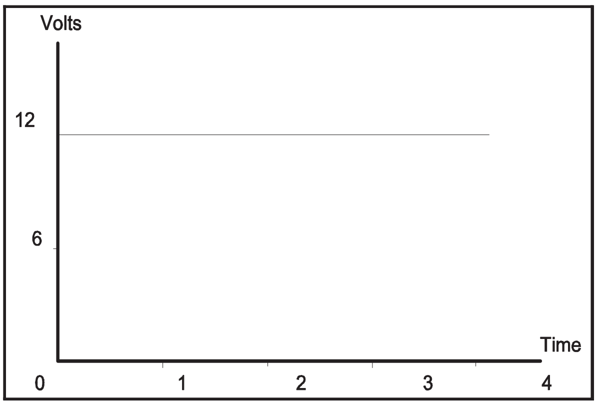


Figure 2.1.1 DC waveform

If we were to measure the voltage of a motor vehicle battery at regular intervals of time (say 1 millisecond) we would notice no change in reading as time progressed provided load conditions remained unchanged. A graphic representation of this result would be the same as figure 2.1.1.

2.2.2 Alternating Current (ac)

Alternating current, like dc, is a flow of electrons but unlike dc, it flows in one direction for a brief time, then reverses to flow in the opposite direction for a similar period of time. This is illustrated in figure 2.1.2 where the graph of an alternating voltage is plotted against time. Each half-cycle represents the flow of electrons in opposite directions and each complete cycle (one positive cycle plus one negative cycle) is one wave.

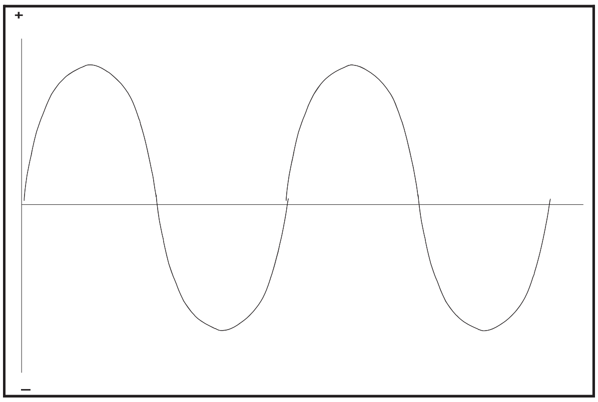


Figure 2.1.2 AC waveform

2.2.3 Frequency

Frequency is simply the rate at which a regular event occurs - e.g. the number of times a clock ticks in one hour, the number of revolutions of a wheel in one minute, the number of cycles per second of an alternating waveform. When applied to electronics, frequency refers to the number of complete waves per second. One wave (cycle) per second is called one Hertz. Since normal household electricity goes through 50 complete cycles every second, its frequency is given as 50 Hertz. The radars used by the NSW Police Force transmit energy at a frequency of 34.9 GHz, i.e. 34900 million cycles per second.

2.2.4 Wavelength

Electromagnetic energy travels at the speed of light - i.e. 300 million metres per second. If the radar transmitted one cycle per second (1 hertz), the leading end of the wave would be 300 million metres away at the instant the trailing end was leaving the transmitter - the wavelength would be 300 million metres. If the frequency was two hertz, the wavelength of each wave is 150 million metres. Police radar units transmit 34.9 GHz therefore the wavelength is 8.59 millimetres. In Figure 2.2 wavelength is indicated by the arrows.

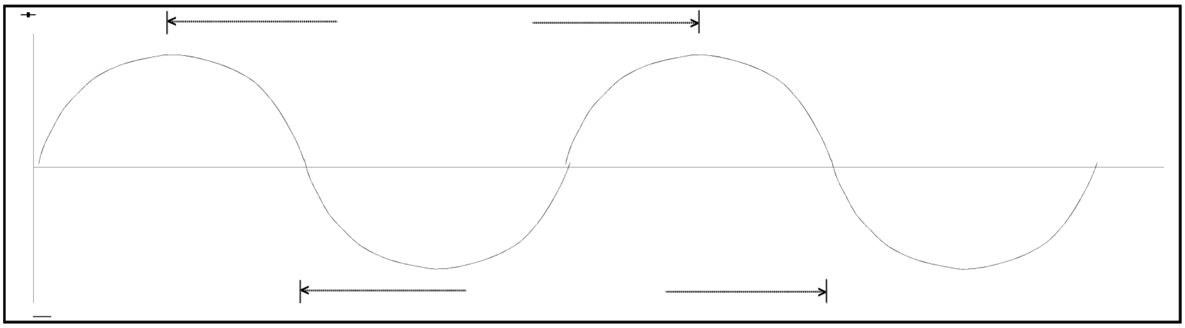


Figure 2.2

2.2.5 Electromagnetic Radiation

As the name implies, electromagnetic energy is composed of an electric field with a magnetic field perpendicular to it. Both fields are perpendicular to the direction of propagation. Electromagnetic radiation is the propagation of energy through space by means of electric and magnetic fields that vary in time. The study of the electromagnetic spectrum is, structure of E.M. waves and their propagation is outside the scope of this course, therefore Figure 2.3 is provided as a matter of interest only.

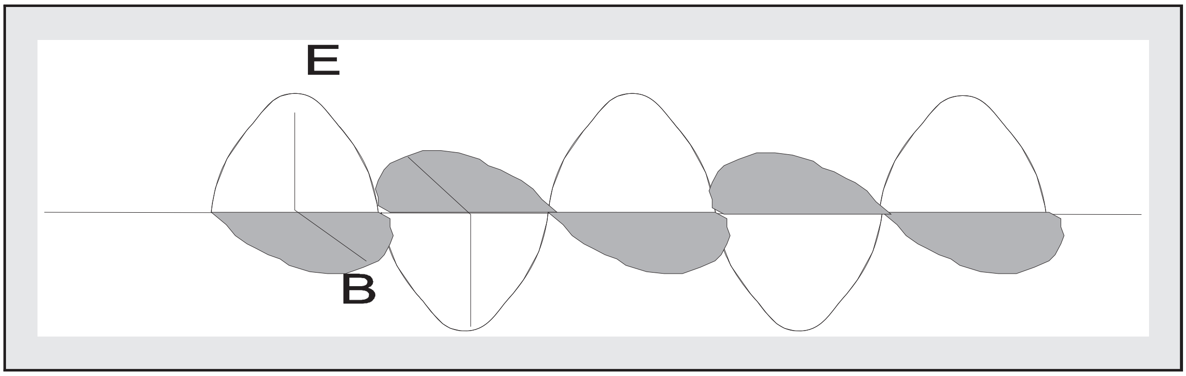


Figure 2.3 Radiation fields in which vectors E and B are perpendicular to each other and to the direction of propagation. (Encyc. Britannica)

2.3 The Doppler Effect

When the wavefront of the transmitted energy strikes a moving target, the wavelength of the returned energy is different to that which was transmitted. If the beam strikes a moving target which is approaching the transmitter, the wavefronts are compressed, that is, the wavelength is shortened (frequency increased). A receding target causes expansion of the wavefronts (longer wavelength - lower frequency). The degree of compression or expansion of the wavefronts is determined by the velocity of the target relative to the radar instrument. This principle can best be understood by studying its effects on sound waves. Consider a source of sound such as a whistle which emits one single note (pitch). When the source is stationary sound waves are emitted in all directions and they form concentric rings as illustrated in Figure 2.4. No matter where the observer stands with respect to the sound source the same pitch is heard. If the sound source is moving, the wavefronts are compressed in the direction of travel and expanded in the opposite direction as illustrated in Figure 2.5. The wavefronts still form rings but they no longer share a common centre. To an observer the sound is higher in pitch as the sound source approaches and lower in pitch as it departs.

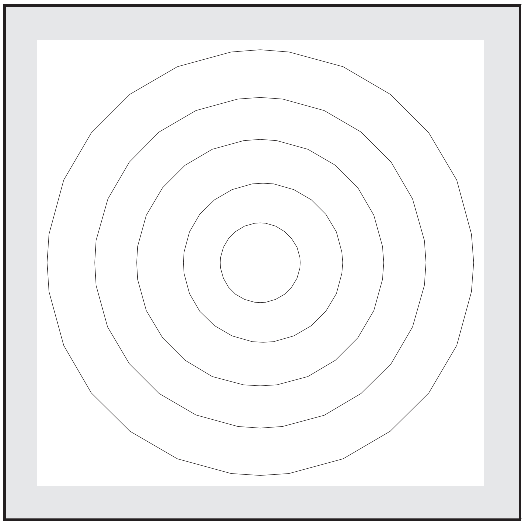


Figure 2.4 Stationary Sound Source

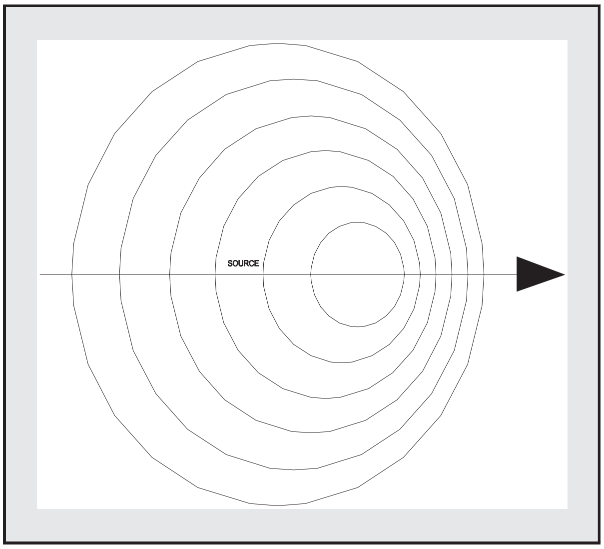


Figure 2.5 Moving sound source

2.3.2 Doppler Shift

The Doppler Shift is the actual frequency change which takes place as a result of movement between antenna and target. The doppler shift could be called the "difference" frequency because it is the difference between the transmitted and received frequencies.

The standard doppler formula is:

$$FR = \frac{(C + V) \times Ft}{(C - V)}$$

where Fr = Received frequency
Ft = Transmitted frequency
c = Speed of Light (in metres per second)
v = Speed of target (in metres per second)

Since we are interested in the difference between Fr and Ft, we can simplify the equation thus:

$$Fd = \frac{2VFt}{C}$$

where Fd = Doppler shift frequency (in hertz)

2.3.3 Doppler Formula Examples - Stationary Mode

Silver Eagle II radar transmits a frequency of 34.9 GHz. Radio waves travel at the speed of light, i.e. 300 million metres per second. Calculate the Doppler Shift Frequency (Fd) for a speed of 1 km/h.

$$Fd = \frac{2 \times V \times Ft}{C}$$

$$= \frac{2 \times 0.27778 \times 34{,}900{,}000{,}000}{300{,}000{,}000}$$

$$= \underline{64.6 \text{ Hz}}$$

A speed of 1 kilometre per hour causes a doppler shift frequency of 64.6 Hz. In other words, when a target is moving toward or away from a stationary radar unit the frequency reflected back to the antenna will be changed by 64.6 Hz for each kilometre-per-hour of target speed.

Let us now take an example of a vehicle travelling at a speed of 100 km/h and approaching a stationary radar unit:

$$= \frac{2 \times 27.7778 \times 34{,}900{,}000{,}000}{300{,}000{,}000}$$

$$= \underline{6462.9 \text{ Hz}}$$

This means that the reflected signal arriving at the radar antenna will now be Ft plus Fd:

$$Ft + Fd = 34{,}900{,}000{,}000 + 6462.9$$

$$= \underline{34,\ 900{,}006{,}462.9 \text{ Hz}}$$

Consider a vehicle moving away from a stationary radar instrument at a speed of 90 km/h.

$$= \frac{2 \times 25 \times 34{,}900{,}000{,}000}{300{,}000{,}000}$$

$$= \underline{5816.6\ \text{Hz}}$$

This means that the reflected signal arriving at the radar antenna will now be

$$Ft - Fd = 34{,}900{,}000{,}000 - 5816.6$$

$$= \underline{34{,}899{,}994{,}183\ \text{Hz}}$$

Note: *an approaching vehicle causes an INCREASE in frequency and a receding vehicle causes a DECREASE in the frequency of the returned energy. The radar unit is concerned only with the CHANGE which takes place, therefore it is unaware of the direction of travel of the target. What occurs when a stationary vehicle is being illuminated by energy from a stationary radar?*

$$Fd = \frac{2 \times 0 \times 34{,}900{,}000{,}000}{300{,}000{,}000}$$

$$= \underline{0\ \text{Hz}}$$

These examples show clearly that a doppler shift occurs only when a target is moving. When both the energy source and the target are stationary there is no doppler shift and the transmitted frequency is unaltered. This effectively means that a stationary vehicle will have no influence at all on any speed reading obtained by radar.

2.3.4 Doppler Formula Example - Moving Mode

So far we have dealt with stationary radar monitoring an approaching or receding target. We must now consider the doppler shift which occurs in moving mode. Remember that the radar measures the **RELATIVE VELOCITY** between the radar and the target.

When a police vehicle fitted with a radar instrument is patrolling a roadway, the instrument is moving in relation to the roadway and to other stationary objects in close proximity. This relative movement between the radar and its surroundings causes a doppler shift. At this point it is important to understand that it doesn't matter whether target or radar is moving as long as there is relative motion between the two. Patrol speed in moving mode is obtained from the doppler shift which occurs due to the forward motion of the radar.

Once patrol speed is established the device searches for a closing rate speed - i.e. Patrol speed plus Target speed. Closing rate speed (or combined speed) will always be greater than patrol speed alone therefore combined speed always causes a higher doppler shift frequency. The frequency will change by 64.6 Hz for each kilometres per hour (same as stationary mode).

Consider a radar-equipped vehicle travelling at 60 km/h and a target approaching at 100 km/h. Radar would first establish a patrol speed in a similar manner to that used to establish target speed in stationary mode because a doppler shift is caused by the forward movement of the vehicle. Once patrol speed is determined the device searches for a frequency which is higher than that generated by patrol speed. The device detects the combined patrol and target speeds (60 + 100 = 160). To apply the formula for determining the doppler shift we must convert kilometres per hour to metres per second (see mathematics section). 160 km/h is 44.44 m/s.

$$Fd = \frac{2 \times 44.44 \times 34{,}900{,}000{,}000}{300{,}000{,}000}$$

$$= \underline{10339.7 \text{ Hz}}$$

Once CRS is established, the radar subtracts the patrol speed and displays the balance as a target speed.

2.3.5 Doppler Tone

The doppler tone emitted by the radar system is the **DOPPLER SHIFT FREQUENCY** (Fd) divided down for listening comfort. In stationary mode, Fd is caused by the target only since the radar is not moving. In stationary mode Fd is divided by 6 therefore the frequency or pitch of the tone can be calculated using the formula

$$\boxed{Pitch = \frac{Fd}{6}}$$

In moving mode Fd is caused by combined target and patrol speeds and is divided by 12 to produce the doppler tone. The frequency of the tone can be calculated using the formula

$$Pitch = \frac{Fd}{12}$$

The pitch of the tone varies with changes in **CLOSING RATE SPEED** because the doppler shift frequency varies with changes in relative velocity. Higher speeds cause higher doppler shift frequencies which produce higher-pitched tones.

Pitch is of no consequence but the **CLARITY** of the emitted tone is important. Any interference to normal radar operation caused by multiple targets, strong electromagnetic fields, etc., is evident in a broken or distorted tone. The distortion usually sounds similar to static on a commercial radio receiver. A clear tone indicates that the radar is monitoring only one target and is not being subjected to any interference.

The presence of a clear tone is a necessary ingredient of any speeding offence detected by use of direct doppler radar therefore it must be given in evidence at any court hearing - e.g. "... I checked the speed of the vehicle for about 4 seconds and during that time the tone was clear...". It is not necessary that the pitch be constant for the whole period of the check but if it does alter, some evidence of a changing speed must be given - e.g. "...I checked the speed of the vehicle for about 4 seconds and during that time the displayed speed decreased from 100 to 90 km/h and the tone decreased in pitch but remained clear...".

Note: *tone is proportional to the closing rate doppler shift frequency therefore any change in PATROL speed can cause a change in pitch. When two targets are present in the checking area the device will attempt to emit BOTH simultaneously and the tone will be unclear. A minimum distance of 200 metres MUST separate target vehicles of similar size.*

The Operator may select the Patrol threshold on the Silver Eagle Radar II (16 Km/h or 32 Km/h). From this point on the figure 16 Km/h will be used in all examples as this is the lowest threshold that can be set. When **ANY TARGET SPEED** (16 km/h or greater) is present the Silver Eagle II doppler tone will be activated. By using the squelch control the operator may choose to have tone present or absent when no target speed is displayed.

Summary

1. Police microwave speed indicators transmit a continuous transverse electromagnetic wave at a frequency of 34.9 GHz and a wavelength of 8.59 mm at the speed of light.

2. An approaching target causes the wavefronts to compress - i.e. shorter wavelength, therefore higher frequency.

3. A receding target causes wavefronts to expand - i.e. longer wavelength, therefore lower frequency.

4. Doppler shift frequency is the difference between the transmitted and received frequencies.

5. Doppler tone is the Doppler Shift Frequency divided by 6 or 12 for listening comfort.

6. Audio tone **must** be clear and unbroken for the duration of the check.

7. Evidence of changing pitch **must** be accompanied by evidence of altering speed.

3.1 Behaviour of Radar Energy

The electromagnetic energy transmitted by radar devices behaves in much the same way as visible light. Radar energy and visible light are both part of the electromagnetic spectrum and differ only in their frequency (or wavelength). The energy transmitted by radar can be reflected, refracted, diffracted, absorbed or retransmitted in much the same way as visible light.

3.1.1 Visible Light and Radar Energy - Comparison

Light	Radar
Visible	Non-visible
Reflect by mirrors	Reflected by most opaque materials
Passes through clear glass	Passes through clear glass
Partly passes through translucent glass	Passes through translucent glass almost unimpeded
Does not pass through opaque objects/ surfaces	Passes through most plastics but reflected from most opaque surfaces.

3.1.2 Reflection

Reflection is an abrupt change in the direction of propagation of a wave which strikes the boundary between different mediums. When a ray of light is reflected at a polished surface the angle of reflection between ray and normal (the line perpendicular to the surface) is exactly equal to the angle of incidence.

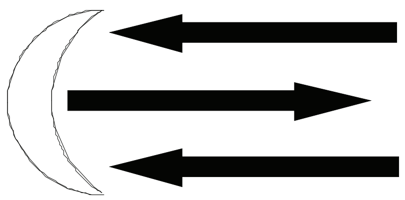


Figure 3.1 Ideal reflection

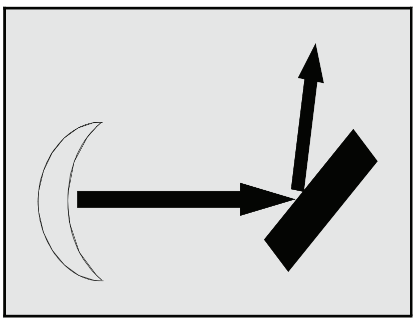


Figure 3.2 Energy lost

Radar relies upon energy being reflected from the target (echo) to operate therefore the radar beam should ideally strike the target perpendicular to its surface (Fig. 3.1) to have the best possible chance of returning to the source.

When the energy strikes the surface at an angle other than 90 degrees, much of it is reflected in directions away from the receiver and is lost (Fig 3.2). A motor vehicle is a good reflector but due to its irregular shape a large amount of energy is reflected in directions away from the source. However, some energy is always reflected in the direction of the receiver.

3.1.3 Refraction

When a ray of light meets the surface of separation between two transparent media, it is sharply bent or refracted. The ray is bent towards the normal as it enters a denser medium (figure 3.4.1) and away from the normal as it enters a less dense medium (figure 3.4.2).

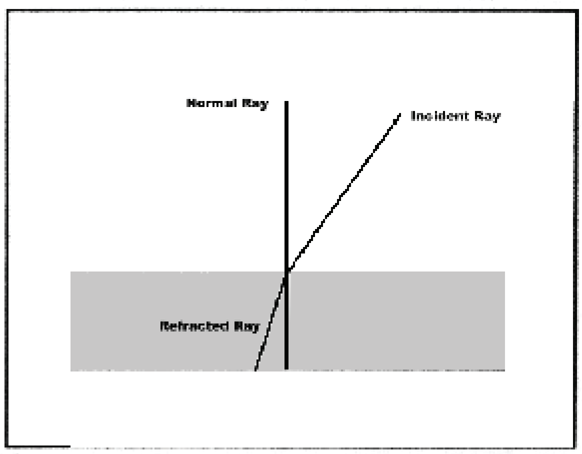


Figure 3.4.1 Into denser medium

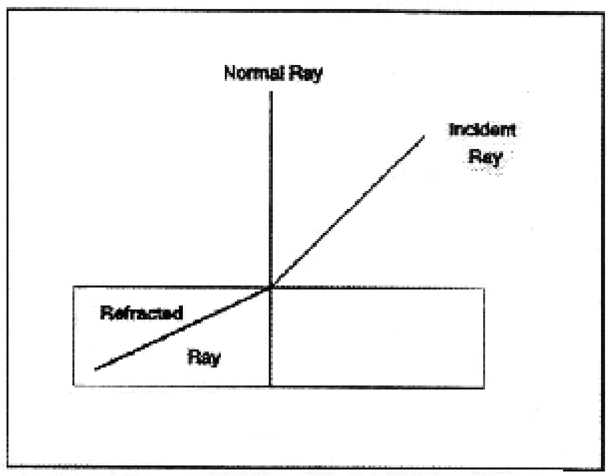


Figure 3.4.2 Into lighter medium

A partly submerged object appears to be bent at the surface due to refraction of the light rays. In a similar manner an object such as a coin in a cup may be hidden from view by the sides of the cup when empty but the coin becomes visible when the cup is filled with water.

As light rays enter a denser medium the speed at which the energy travels is reduced. Conversely, if light enters a less dense medium the speed is increased. The speed of light is normally quoted as 300 million metres per second, however, this is only true in a vacuum.

A more obvious example of refraction is a rainbow. The colours which appear as a rainbow are seven distinct frequencies or wavelengths ranging from that of red (longer wavelength) to that of violet (shorter wavelength). The spectral colours are produced when white light enters atmosphere of changed density. In the process the fundamental colours are separated.

In practical situations an operator would not normally be bothered by refraction. Perhaps some slight increase in range may be noticed on cool evenings. This comes under the heading of "super-refraction" which is outside the scope of the radar operator's course.

3.1.4 Diffraction

When electromagnetic waves are restricted by an aperture or by the edge of an obstacle, some of the energy spreads into the region not directly in line with the source. This bending of EM waves is called diffraction. As the aperture is decreased in size the effects of diffraction are increased as shown in figure 3.6.

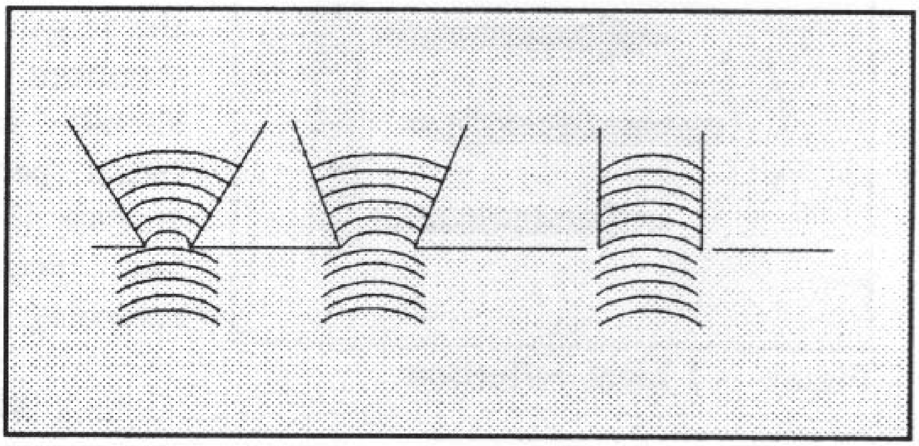


Figure 3.6 Diffraction

Figure 3.7.1 shows a situation which could occur if radar is operated outside present guidelines. If 'HOLD' is not used, a target speed may be registered by the radar before the operator has had the opportunity to identify the target and estimate its speed. Figure 3.7.2 shows the 'shadow' area which forms behind vehicles in the radar beam.

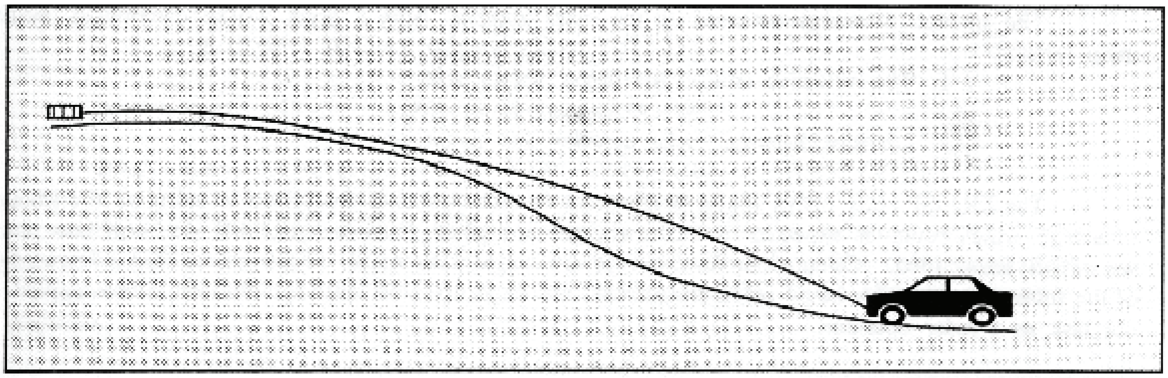


Figure 3..7.1 Diffraction over a crest.

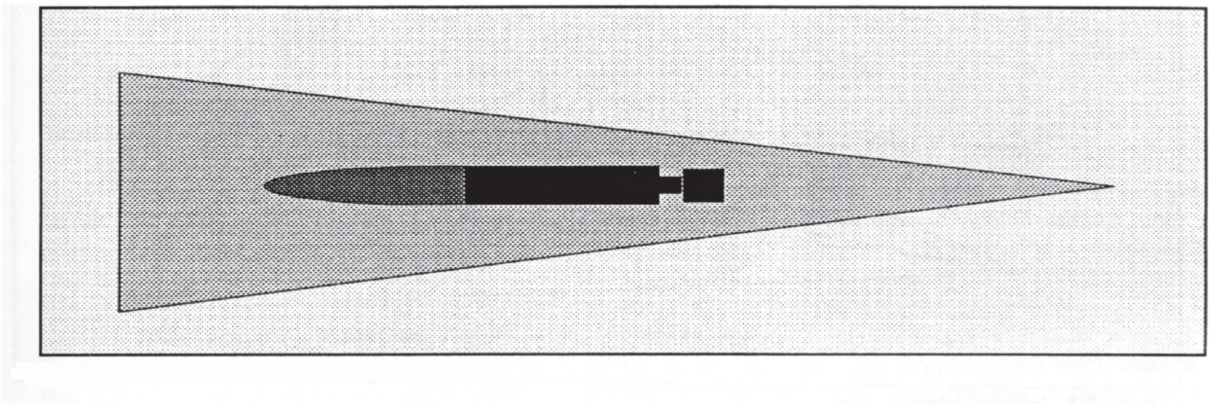


Figure 3.7.2 Shadow behind a vehicle.

3.1.5 Absorption

Electromagnetic energy at the frequency used by police radar will be absorbed by some compounds. There are several energy-absorbing materials available, usually a fibre or rubber/plastic based sponge, which has been specially constructed and treated to absorb a particular range of frequencies. However, these materials are somewhat impractical as a radar avoidance measure due to heat dissipation problems and to their very high cost.

The most common energy-absorbing compound for police radar is water. Since Police radar operates at 34.9 GHz a substantial amount of its transmitted energy is absorbed by any material with a high water content. Grass, leaves, shrubs and similar materials will in fact absorb the energy to varying degrees, occasionally resulting in substantial loss of range.

3.2 Inverse Square Law

The amount of energy returned to the radar antenna from a target will be determined by two main factors:

1. The reflective area of the target (target size).
2. Distance between radar antenna and target.

The Silver Eagle II radar obeys the inverse square law which makes it possible to calculate the amount of energy which could be expected to strike a target at a given distance, provided we know how much we initially transmitted. Calculations of this type are outside the scope of this course but a knowledge of the inverse square law helps us to understand the importance of size and distance when applied to our task as a radar operator.

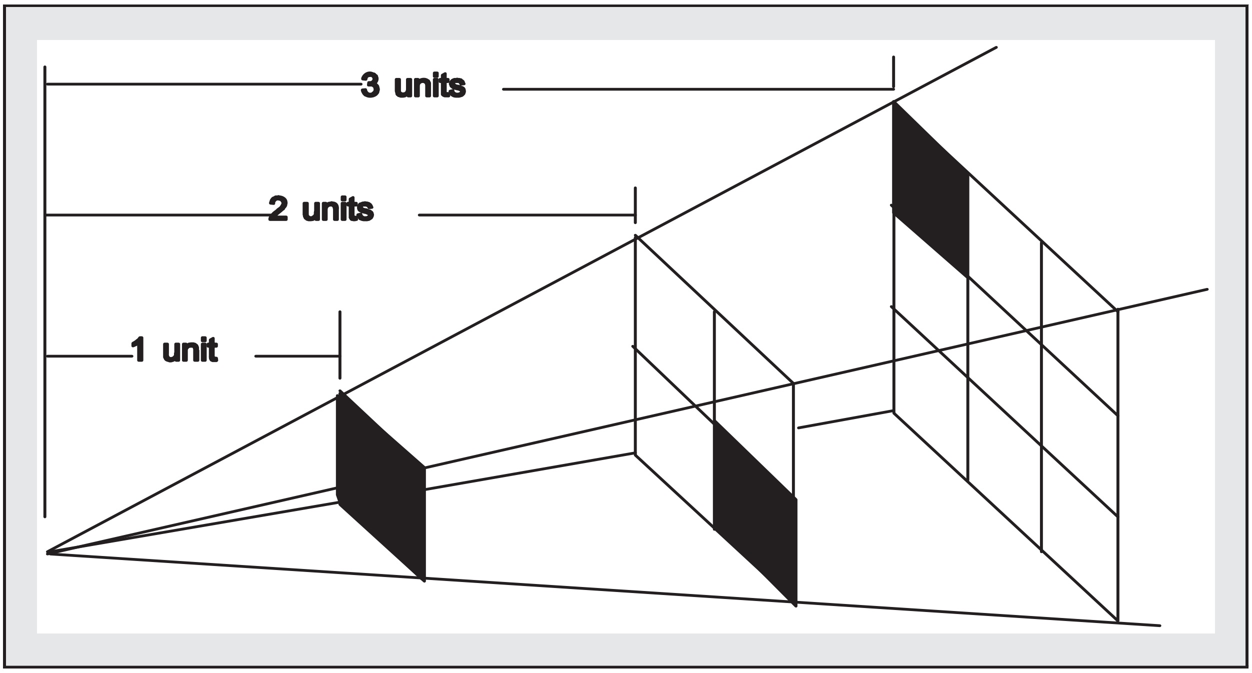


Figure 3.8 Inverse square law

Figure 3.8 is a diagrammatic representation of the inverse square law in operation. Screens at distances of one, two and three units have areas of one, four and nine square units respectively. This means that the energy at twice the distance from a given point will be only 25% of the intensity per unit area. The inverse square law could be easily demonstrated using the light source of a movie projector.

To assist in understanding the mechanics of the inverse square law, consider the following example concerning target size.

If a motor vehicle is illuminated then a certain amount of surface area will actually come into contact with the energy. As stated before the shape has a dramatic effect. If a large truck illuminated at the same distance as the above mentioned vehicle, then it stands to reason that a truck will catch more energy than the vehicle. (i.e, a car)

When considering the inverse square law, one can conclude that a truck having approximately four times the reflecting surface area in comparison to the motor vehicle that the truck will be able to reflect as much energy at twice the distance of the car. This is providing that the distance involved is within the effective range of the radar instrument. This is an important factor when operating the radar.

There is a minimum amount of energy required before the radar will register a speed. Whilst this quantity varies from one instrument to another, it still obeys the inverse square law. The variation between instruments is apparent in the differing range of two sets operated under identical conditions.

Summary

1. With some exceptions, EM energy behaves in much the same way as visible light.
2. EM energy may be reflected, refracted, diffracted, absorbed, re-transmitted.
3. EM energy obeys the inverse square law.

4.1 Interference

Interference may be broadly defined as any external event which adversely influences the normal operation of radar. The effects of interference are often the subject of questions at court and various media articles (often misleading, uninformed or biased) have highlighted various perceived shortcomings of police radar equipment. The radar operator must fully understand this subject so that action can be taken to avoid mistakes due to interference.

Interference always has a reason, however, the reasons are often impossible to explain because there are too many variables to be considered. In practice, as long as the patrol speed is verified with the checked speedometer, a clear tone is obtained, AND this data is compatible with the operator's own observations, utmost confidence in the speed reading will be maintained.

4.2 Effects of Interference

It must be emphasised at this point that interference does not add to or subtract from any target speed reading. Interference will cause a number to be displayed or prevent a target from registering. From the operator's viewpoint, interference has one of two effects:

1. Display of a speed in the absence of a target.

2. No displayed speed when a target is present.

If one of these conditions prevails, it is reasonable to assume that the radar instrument is being subjected to some form of interference. To overcome the problem, change location. If the problem persists return the device, together with a detailed description of the behaviour to the Radar Engineering Unit.

4.3 Types of Interference

There are two fundamental categories of interference - natural and man-made.

4.3.1 Natural Interference

Natural interference basically reflects and diffuses (scatters) the radar energy. Large trees, bushes and signs moved by the wind, heavy rain or snow, windblown dust, in fact any particulate matter in the air will tend to diffuse the radar's energy or mask low-level signals, resulting in a decrease in effective range.

4.3.2 Heavy Rain

It has been found from wide experience that heavy, driven rain falling non-perpendicular to the roadway can add to or subtract from correct patrol speed depending upon the relative direction of the radar. This problem is avoided by adherence to the operational guidelines. Fog, light rain or drizzle will cause some reduction in effective range but will not affect accuracy.

4.3.3 Birds

The subject of birds has often been raised in relation to natural interference. These creatures have been blamed for flying at 78 km/h for at least 3 seconds. Consider this:

A bird, say the size of a seagull, consists of tissue which is not very conducive to reflection of radar energy at any useful range. The bird is NOT an opaque object, nor does it have a good reflective shape. This means that an object with the basic shape and composition of a bird can activate the radar instrument at a range no greater than 1 metre (assuming that the bird flies at a constant velocity). At 78 km/h, a distance of 21.66 metres is travelled per second, therefore a total distance of 65 metres is covered in 3 seconds. The bird, as mentioned earlier, can only activate the radar at a maximum range of 1 metre. Instruments capable of detecting and displaying the location of birds do exist, e.g. maritime navigational radar equipment but Police radar systems cannot perform this function. Police radar, although a product of similar technology, must never be likened to navigational radar.

4.3.4 Random Movement

Natural interference may cause a speed reading on the radar instrument under some circumstances. Movement constant enough to produce a frequency change equal to or greater than the threshold could produce a speed reading. A movement having a constant repetition rate or frequency component must prevail to be meaningful to this type of radar instrument. Movements of a random nature cannot cause a speed to register but it will almost certainly cause a reduction in effective range which may or may not be evident to the operator.

4.4 Man-Made Interference

Man-made interference is by far the most troublesome and constitutes the largest category. Large advertising signs if rotating or swinging may reflect the beam. Large broad-bladed fans may also reflect sufficient energy to cause a speed reading. Electronic emissions from fluorescent lights, power transformers, x-ray and medical diathermy machines, high voltage transmission lines with leaky insulators, radio transmitters, mobile phones, automobile inverters, etc., may, in some circumstances, cause a speed reading or a reduction in effective range.

4.5 Shielded Cable

Interference from a vehicle's electrical system can enter the radar through the connecting cables. To overcome this, all Highway Patrol cars are fitted with shielded cable to ground any spurious emissions and thus negate the adverse effects of electrical interference. Other vehicles are not normally fitted with shielded cable therefore radar cannot be operated from those vehicles.

4.6 Radio Frequency Interference

Under normal operating conditions the presence of Radio Frequency Interference should not be a cause for concern by the operator. The Silver Eagle II radar has an RF detector which, when activated by excessive RFI, causes the displays to blank. This is an automatic feature of the system and is beyond the control of the operator. On the front panel, indication of RFI presence is given in the form of 'rfi' being displayed in the Target window of the Radar. There is no need for any action to be taken by the operator - the instrument will return to normal operation once it is no longer being interfered with.

4.7 Effect of Radar Detectors

After stopping a motorist with an early warning device (radar detector) fitted to their vehicle, operators may find that a speed reading appears in the absence of a target. For this to occur the detector must be within 3 metres of the antenna and directly facing it. Although it may be considered interference to radar operation, it is merely a display brought about by the modulation of the beam by the early warning device. The radar instrument cannot be affected by the detector during the speed check.

4.8 Multipath Interference

This phenomenon is likely to occur on long straight roads where Armco railing and similar barriers are used. As the name implies, it is the arrival of two energies at different time intervals at the receiver. Refer to figure 4.1. E2 arrives at the receiver earlier than E1 due to the shorter distance it needs to travel. On arrival at the receiver E1 and E2 oppose one another, often resulting in cancellation of both. This phenomenon causes short ‘blips’ in the audible tone and only occurs for very short periods (maximum duration about 1 second). Multipath does NOT affect the accuracy of any speed reading.

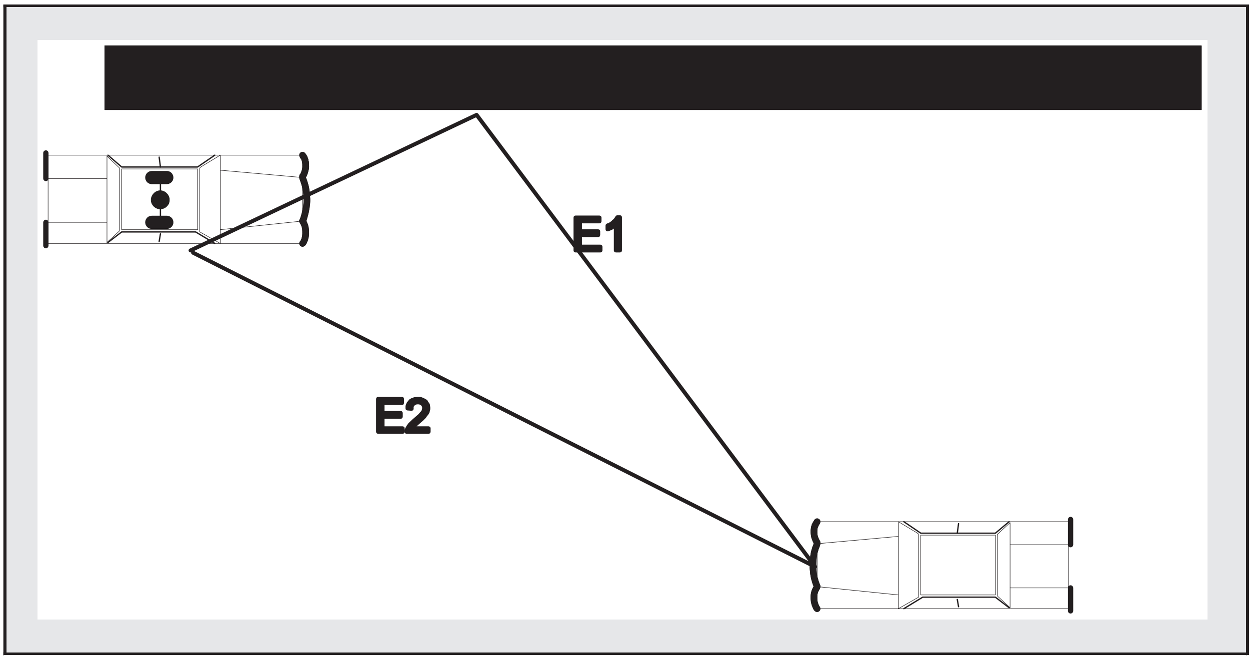


Figure 4.1 Multipath interference

Summary

1. Interference is any external event which influences the operation of radar.

2. Two fundamental types of interference - natural and man-made.

3. Natural interference may cause a reading on radar but not as a result of random movement. Usually reduces range.

4. Heavy rain can affect patrol speed.

5. Birds do not cause a reading on radar.

6. Man-made interference is primarily electrical in nature.

7. Electrical interference is effectively controlled by using shielded cables.

8. Radio frequency interference is detected by the radar and the displays are forced blank. 'rfi' will be displayed in the Target window of the Radar.

9. Multipath interference can cause cancellation of readings or poor tone but does not affect accuracy.

10. Interference does not affect the accuracy of speed readings but can reduce effective range.

5.1 Beam Characteristics

The radar beam leaves the antenna and spreads out at an angle of 12 degrees (plus or minus 1 degree). This angle is measured at the -3dB - the points where the power is half that of the source. This means that the width of the beam increases about 21 units for each 100 units away from the antenna. At a range of 200 metres the beam is approximately 42 metres wide between the half-power (-3dB) points. The energy continues to spread at this rate indefinitely. Whilst the length of the beam is **INFINITE**, the length of the effective beam (that part used by the radar) has a finite length and a different shape. The effective beam has a nominal length of 600 metres, however, this range varies considerably between instruments and is heavily influenced by operating conditions.

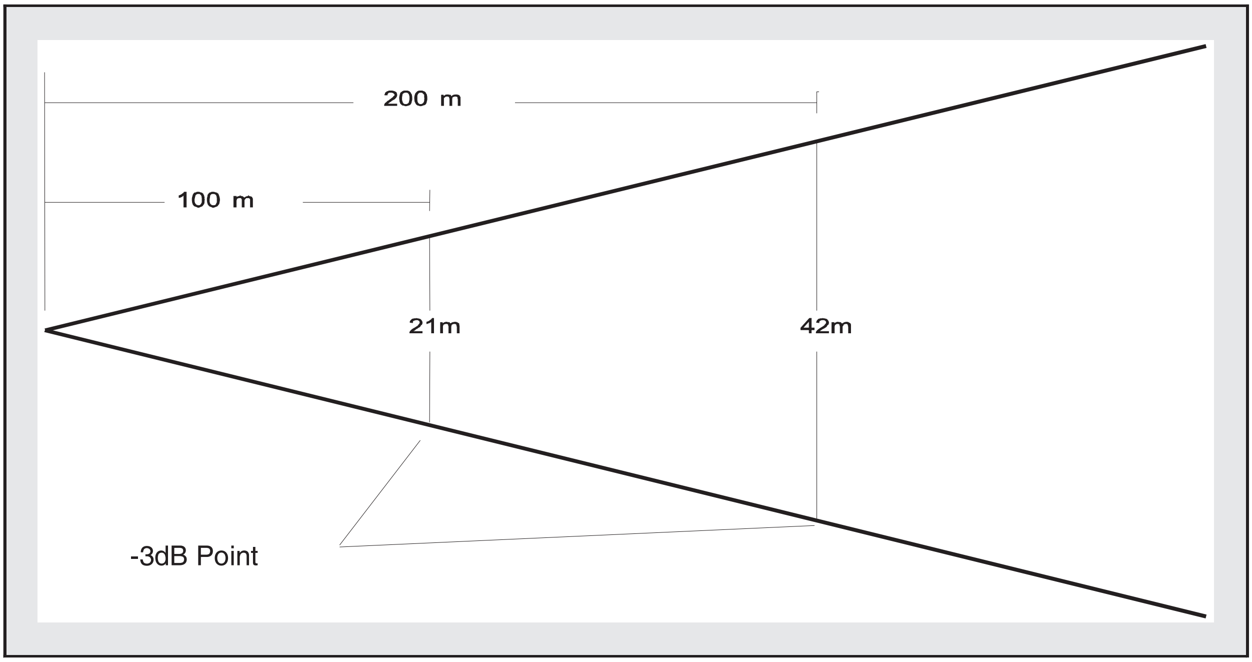


Figure 5.1 The Radar beam at -3dB points

5.1.1 The Effective Beam

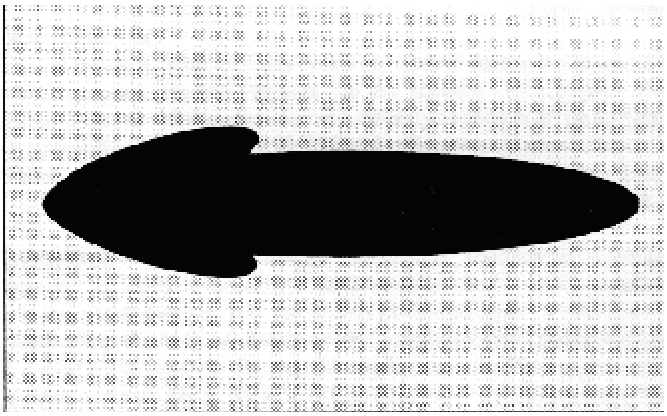


Figure 5.2 Effective beam

The shape of the effective or 'useable' beam is shown in figure 5.2. The main beam forms a long cigar shape, nominally 600 metres in length. The diagram also shows smaller lobes near its origin. These are referred to as 'side lobes' and are much smaller than the main beam. Side lobes are highly undesirable but under practical operating conditions their effect is negligible.

Note: *the beam width of a transmitted wave is complex and is referred to as the angular separation between the two 3dB down points. Operators should refrain from answering questions on the measurement of beam width as it refers to power ratios which effect vehicles differently according to reflective capacity.*

5.2 Antenna Aim

Beam shape cannot be altered by the operator as it is a function of antenna design but the importance of aiming the antenna from the police vehicle cannot be over-emphasised as it directly effects selectivity. The antenna should be aimed directly forward in moving mode or directly into the centre of the lane being monitored whilst in stationary mode.

5.2.1 Specifics of Antenna Aim

Antenna aim is composed of two elements - direction and tilt. Direction simply means pointing the antenna at a specific mark. Tilt is moving the antenna up or down relative to the mark and should not be confused with changing the height of the antenna above the roadway. For correct aim the operator may need to tilt the antenna up or down. Tilt upwards increases range whilst tilting downwards decreases range. Too much down-tilt may cause the beam to reflect off the roadway resulting in shorter range.

In moving mode it is important to reach a compromise between range and downward tilt. Downward tilt will ensure quick and easy acquisition of patrol speed but may result in loss of range. Range may be increased by upward tilt but too much will make patrol speed acquisition difficult.

5.2.2 Antenna Placement

The Australian Standards Association, the NSW Police Force and the Manufacturers each have certain rules, instructions and guidelines for the effective and correct operation of radar instruments. For best performance, and to comply with the requirements of ALL groups the following rules regarding antenna placement must be observed:-

1. The antenna should be mounted externally on the vehicle.

2. The antenna must be mounted not more than two metres and not less than one metre from the ground.

3. The antenna must face directly to the front and parallel with the roadway in moving mode.

4. The antenna must face front or rear and parallel with the roadway in stationary mode.

Note: *the NSW Police Force has granted permission for Radar instruments to be mounted internally if the vehicle is fitted with the approved mounting bracket*

Failure to electrically isolate the antenna effectively nullifies the advantages gained by using shielded cables, will cause a reduction in range and may result in spurious readings due to electrical interference.

Summary

1. Beam width between the half power points increases approximately 21 metres for each 100 metres of range.

2. The length of the beam is infinite but the effective length is nominally 600 metres.

3. Antenna should be mounted externally.

4. Antenna should be mounted between one and two metres from the ground and parallel with roadway.

5. Antenna should be aimed directly forward in moving mode.

6. Antenna should be aimed at the centre of the lane in stationary mode.

7. Ensure antenna body is electrically isolated.

6.1 Moving Mode Theory

When studying the Doppler effect we concentrated on stationary mode of operation and only briefly mentioned how radar operates in moving mode. The Silver Eagle II radar is able to determine the velocity of an approaching target vehicle and continuously update that information whilst the host vehicle is moving.

In moving mode the radar must perform three functions:

1. Determine and display patrol speed;
2. Determine combined speed of radar and target; and
3. Determine and display target speed.

When operating in moving mode the instrument must obtain **TWO** doppler shift frequencies - patrol speed (low) doppler and combined speed (high) doppler. It must be stressed at this point that the device does **NOT** transmit two separate beams. The one beam is used alternately to obtain all data but switching between low and high doppler acquisition is so frequent that it appears to occur simultaneously.

6.1.1 Patrol Speed

Patrol speed is obtained from energy reflected off the roadway and surrounding stationary objects. Since relative motion exists between radar and target (roadway) a compression of the wavefronts occurs and the change in frequency is converted to a speed in kilometres per hour. This function is identical to that which occurs in stationary mode with the exception that the instrument is moving instead of the target.

In our study of Doppler Effect we learned to calculate the doppler shift frequency (Fd). We can therefore calculate the change in frequency due to patrol speed in Figure 6.1. Remember, velocity must be in metres per second for the formula to work.

$$\text{Patrol speed Fd} = \frac{2 \times 16.67 \times 34900000000}{300000000} = 3878.5 \text{ hz}$$

Figure 6.1

Low doppler is passed to the computer section of the instrument (sometimes called the counting unit) where the signal is processed and the speed in kilometres per hour is indicated in the display labelled '**PATROL**'.

6.1.2 Combined Speed

Once patrol speed is established, the radar searches for a frequency which is much higher than low doppler. This higher frequency is caused by the closing rate speed or the combined patrol and target speeds. In figure 6.1 the forward movement of the radar causes a doppler shift equivalent to 60 km/h to occur (approx 3878 Hz). When the wavefront strikes the approaching target it is compressed further - an additional 90 km/h. Total compression of the wavefront is equivalent to 150 km/h, i.e. the combined speed of the two vehicles. Combined speed doppler shift or 'High Doppler' is

$$\textit{Combined Speed FD} = \frac{2 \times 41.67 \times 34900000000}{300000000} = 9695.2 \text{ hz}$$

Compare low doppler and high doppler in the above example. High doppler is a much higher frequency than low doppler and this will ALWAYS occur. Patrol speed is only one component of combined speed therefore it must always result in a lower doppler shift than combined speed. The device will always process the lower frequency as patrol speed.

6.1.3 Target Speed

Target speed is, in fact, a **CALCULATED** value. Patrol and target speeds are determined by analysing the respective doppler shift frequencies but target speed is determined by subtracting patrol speed from combined speed. In our example:

Target Speed = Combined speed - Patrol speed

= 150 - 60

= 90 km/h

Target speed is the **DIFFERENCE** between combined speed and patrol speed.

7.1 Correlation

The ability of the radar to display speeds accurately is entirely dependent on where the transmitted energy has been reflected. As we have already discussed electromagnetic energy transmitted by radar devices can be reflected, refracted, diffracted, absorbed or retransmitted.

Patrol speed is obtained from energy reflected off the roadway. Ideally this should be at a minimum distance of seven metres to the front of the patrol vehicle.

If a radar obtains an incorrect patrol speed due the transmitted energy being reflected from a stationary object at the side of the roadway it would result in a gross error displayed in the patrol and target displays of the radar. Gross error could be defined as an error greater than 10 km/h.

The importance of correlation between the patrol speed of the “Silver Eagle II” radar instrument and the checked digital speedometer cannot be over emphasised. An operator will be able to negate the possibility of an incorrect speed (patrol and/or target) being displayed as a result of an ‘effect’ simply by way of correlation. It is important to remember that when the radar is under influence of an ‘effect’ a **GROSS** error between the Patrol window and the Digital speedometer will be evident. Due to the variation in acquisition times between the two devices a very small fluctuation between the radar patrol speed and the digital speedometer may be evident when patrolling. The other reasons are usually environmental or when the cruise control of the vehicle is activated, therefore it is recommended that correlation should **not** be conducted when the cruise control is in use.

Correlation is an essential ingredient when determining whether a speed check is valid or otherwise. An operator must be fully aware and conversant with operational guidelines and requirements when performing speed enforcement duties of any kind.

7.1.1 Digital Speedometers

The digital speedometer fitted to all Highway Patrol vehicles must not be removed or tampered with in any way. If any damage to the speedometer or the wiring harness is evident speed enforcement of any kind shall cease immediately and it is to be brought to the attention of your supervisor. The Radar Engineering Unit should also be contacted.

Prior to performing any speed enforcement, operators **must** perform the following checks at the commencement and completion of their shift. If the operator changes to a different vehicle during a shift he will again perform the following checks:

1. Visual check of the speedometer and wiring for any damage.

2. Ensure that the two tamper proof seals are intact and not damaged in any way.

3. Turn on digital speedometer and observe all segments on the 7 segment displays. All segments must illuminate. If a failure occurs contact Radar Engineering Unit for advice immediately. The vehicle must not be used for any further speed enforcement of any kind.

4. At the commencement of your patrol a correlation check of the digital speedometer and the patrol speed of the radar must be performed. This should be done on a relatively straight, flat portion of the roadway with the speed of the vehicle being held constant and allowed to stabilise. Verify that the accuracy of the digital speedometer is within ± 2 km/h of the patrol speed displayed on the radar instrument.

5. If there is a speed difference greater than ± 2 km/h or any of the tamper proof tags have been violated, all speed enforcement shall cease and it be brought to the attention of your Supervisor and the Radar Engineering Unit for immediate attention. Full procedures for Digital speedometer use and calibration can be found on the Police Intranet site.

8.1 Effects

Police radar is a very complex device and this is particularly true when operating in moving mode. Certain situations require the operator to have more detailed understanding and to exercise greater care to avoid making mistakes. When these situations are encountered it is important to realise that the instrument is not malfunctioning - it is correctly processing the available data. The OPERATOR must be sure that the data provided to the device is reliable and accurate by following Police Force guidelines. Remember - the error is not caused by radar malfunction but by the situation in which it is operated.

There are five main effects which an operator could encounter:

1. cosine effect;
2. split speed;
3. differential effect;
4. double bounce; and
5. add-on speed.

8.1.1 Cosine Effect - Stationary Mode

Cosine effect is probably the most common situation encountered by a radar operator. Ideally, a target vehicle should travel directly toward the radar and in the centre of the effective beam, however, ideal conditions for the radar create a dangerous situation for the operator. To overcome the danger the radar is operated from a point which is not directly in front of the target, thus creating an angle between the direction in which the beam is transmitted and the direction of travel of the target. The angle referred to is shown in figure 7.1.

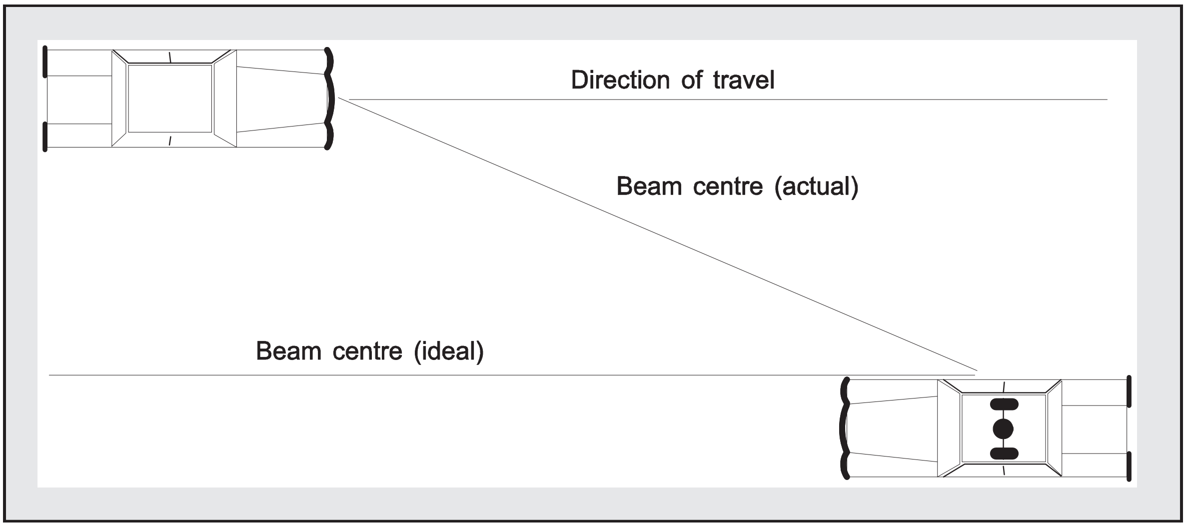


Figure 7.1 Cosine effect - stationary mode

The radar measures only that component of target speed which is directly toward the radar, that is, relative velocity. When the target approaches (or recedes) at an angle, the velocity relative to the radar is slower than the actual forward speed of the vehicle.

Refer to figure 7.2.
Assume a target's true speed is 80 km/h. A target approaching from one of the points marked A to G would cause the displays shown in the following table:

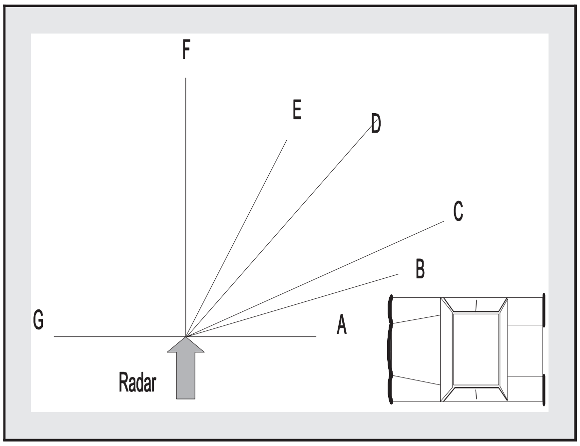


Figure 7.2 Angle of approach to radar

Point	Angle	Display
A or G	0	80
B	10	78
C	15	77
D	30	69
E	45	56
F	90	0

True vehicle speed can be calculated by using the cosine of the angle as a correction factor:

The following table shows the correction factor for some angles up to 90 degrees:

$$\text{Vehicle True Speed} = \frac{\text{Displayed Speed}}{\text{Cosine}}$$

Angle	Correction Factor
2	0.9993
4	0.9975
6	0.9945
8	0.9902
10	0.9845
15	0.9659
20	0.9396
45	0.7071
70	0.3420
90	0.0000

Operators should **NOT** attempt calculations of this nature under operational conditions because the magnitude of the angle cannot be determined with sufficient accuracy.

By application of the above formula it will be seen that relative velocity decreases as the angle increases. In short, the larger the angle the greater the error. It must be realised at this stage that the error is always to the advantage of the motorist when the radar is operated in stationary mode.

Consider the following examples:

A target causing a display of 99 has an angle of 20 degrees between the beam's central axis and the target's path of travel. Using the correction factor for that angle (0.9396) calculate the true speed of the target.

$$\text{True vehicle speed} = \frac{\text{Radar readout}}{\text{Correction factor}}$$

$$= \frac{99}{0.9396}$$

$$= 105 \text{ km/h}$$

The vehicle was actually travelling 6 km/h faster than the speed indicated by the radar. Using the same example with an angle of 10 degrees we find:

$$\text{True vehicle speed} = \frac{99}{0.9848}$$

$$= 100 \text{ km/h}$$

By reducing the angle from 20 to 10 degrees we have reduced the error from 6 km/h to 1 km/h. Obviously the angle should be as small as possible for greatest accuracy. The operator should therefore place the radar antenna as close as possible to the lane being checked to obtain the smallest possible angle.

8.1.2 Cosine Effect - Moving Mode

Cosine effect in moving mode occurs in the same way as it does in stationary mode. When the angle created by the direction of transmission of the beam and the direction of travel of the target becomes too great, an error will occur. Consider figure 7.3 and the following example.

Ratio	Angle	60 km/h	80 km/h	100 km/h
8:1	7.1	59	79	99
7:1	8.1	59	79	99
6:1	9.5	59	78	98
5:1	11.3	58	78	98
4:1	14.0	58	77	97
3:1	18.4	56	75	94
2:1	26.6	53	71	89
1:1	45.0	42	56	70

Figure 7.3

The police vehicle is travelling at 50 km/h and has obtained correct patrol speed. A target vehicle approaching the radar is travelling at 90 km/h. However, the closing rate speed between the two vehicles has a 20 degree angle involved. This means that the detected closing rate speed will be less than the true closing rate speed.

$$\text{Closing rate speed} = 140 \times \cos 20 \text{ degrees}$$

$$= 140 \times 0.9396$$

$$= 131 \text{ km/h}$$

Cosine effect occurring in this manner would, once again, favour the motorist. In practice it would be unusual to find such a large discrepancy for any prolonged period because it is a function of the radar to check for cosine effect by comparing the rate of change of relative velocity. A high rate of change is treated as an error. As large angle errors are theoretically possible, it is important that a radar operator be aware of the consequences should such an error prevail.

Under normal circumstances the ground speed of the police vehicle will be displayed within plus or minus 1 km/h. of true speed. Perhaps more correctly it can be said that the ground speed displayed on the radar instrument will usually be 1 km/h less than true ground speed. Cosine effect can cause a much greater error in patrol speed to occur. Since patrol speed is subtracted from combined speed to determine target speed, any reduction in patrol speed causes target speed to be greater.

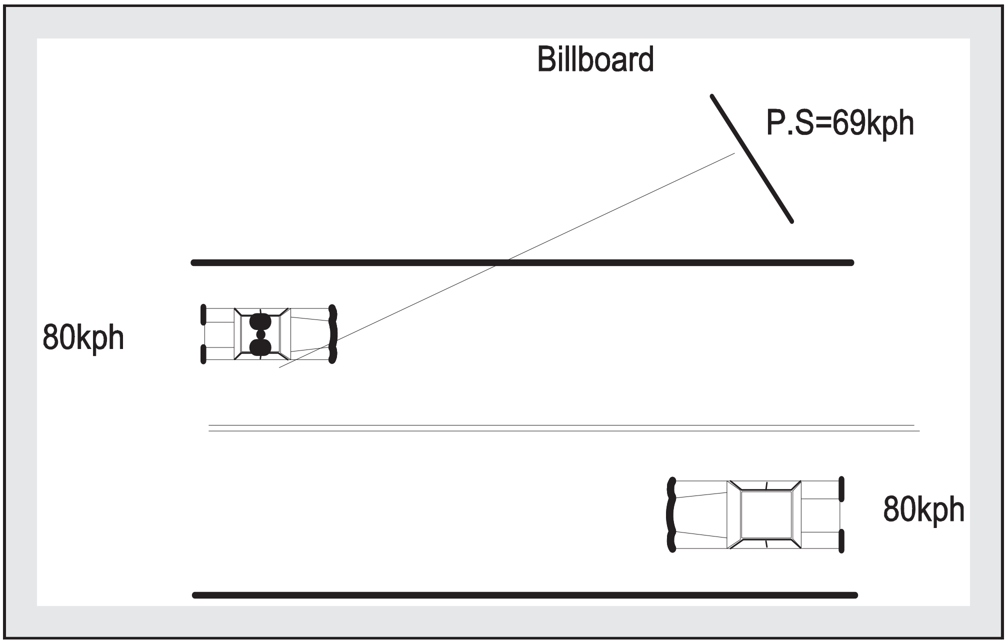


Figure 7.4

Consider figure 7.4 and the following example.

If, when establishing patrol speed, the radar received a stronger reflection from the roadside sign at an angle of 30 degrees, patrol speed would be reduced. Using the correction factor for 30 degrees (0.8660) it is possible to calculate the probable patrol display -

Displayed speed = True speed x cos 30 degrees

= 80 x 0.8660 = 69 km/h

The combined speed of the police vehicle and the target is 160 km/h (80 + 80), therefore displayed target speed is calculated as follows:

True target speed = Combined speed - DISPLAYED target speed

= 160 - 69

= 91 km/h

11 km/h has been added to true target speed.

An operator will not make any mistake due to cosine effect in patrol speed because

1. the patrol speed of the vehicle is always checked with the checked speedometer of that vehicle during every radar speed check; and

2. the computer section can detect such an error in patrol speed unless it is initially obtained with an error (in which case it will be detected when patrol speed is checked against the speedometer).

Cosine effect has raised many questions, particularly in American courts. Operators must therefore become familiar with its existence and with the reasons why it cannot present a problem if correct operational procedures are followed.

8.1.3 Multi-Lanes and Median Strips

When patrolling multi-lane roads and divided carriageways with median strips, attention should be paid to the distance between the path of the police vehicle and that of the target vehicle. The ability of radar to display speeds within plus or minus 2 km/h in stationary mode and plus 2 minus 3 km/h in moving mode is impaired once an angle of about eight degrees is exceeded.

8.1.4 The 7:1 Ratio

Estimation of the angle to the degree of accuracy necessary is difficult therefore a ratio of lane width to range has been calculated to allow the operator to estimate distances instead. The distance between the radar and the path of the target is multiplied by seven to determine the range at which any radar speed check must CEASE. Refer to figure 7.5. The distance between radar and target path is 10 metres, therefore the minimum three second speed check must cease at a range of 70 metres.

This 7:1 ratio can be applied in stationary or moving mode and will ensure that the angle is kept within acceptable limits (about eight degrees or less).

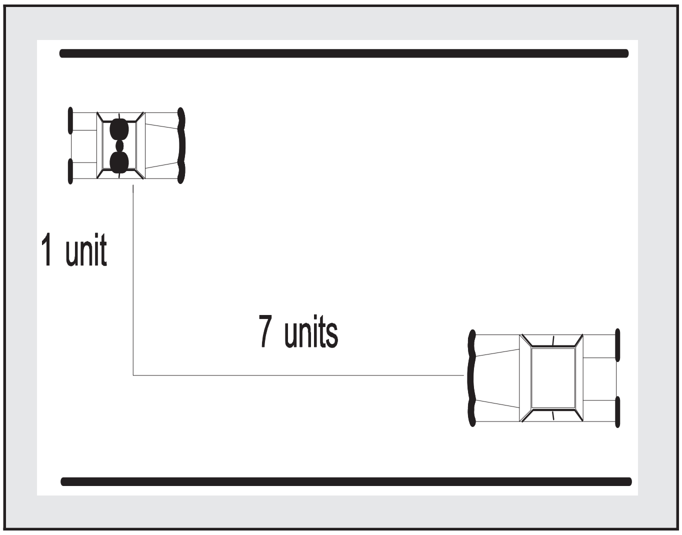


Figure 7.5 The 7:1 ratio

Table 7.3 clearly shows the effect which the ratio of lane width to range has on the angle and the relative velocity (displayed speed) for each ratio. True vehicle speeds of 60, 80 and 100 km/h have been chosen for convenience but the 7:1 ratio applies to all speeds capable of being measured by this device.

Cosine effect will not cause undue concern to a radar operator provided the 7:1 ratio is applied. In moving mode the 7:1 ratio must be kept in mind when operating across wide median strips or multi-lane roads but in most operational situations the police vehicle and the target meet more or less ‘head-on’. Correlation of patrol speed with the checked speedometer will overcome any possible error in patrol speed. In short, to avoid errors due to cosine effect:

1. Apply the 7:1 ratio

2. Correlate patrol speed with checked speedometer

8.2 Differential Effect

Differential effect may occur in moving mode when a target is checked whilst a large reflective vehicle (such as a truck or caravan) is immediately in front of the police vehicle. Whilst acquiring patrol speed a stronger reflection may be obtained from the vehicle in front resulting in the difference in speed between the two vehicles being displayed as patrol speed.

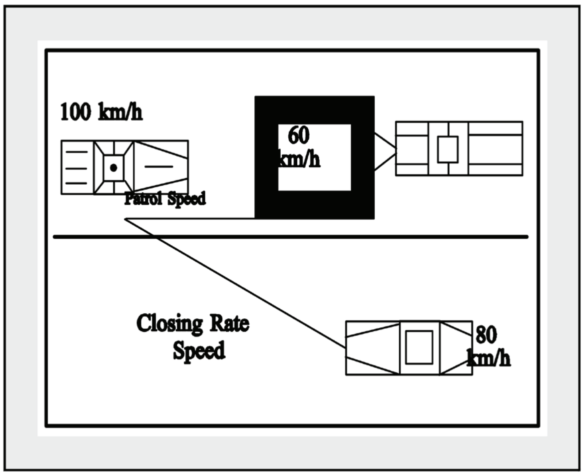


Figure 7.6 Differential effect

Consider figure 7.6. The police vehicle is travelling at a speed of 100 km/h and approaching the rear of a caravan travelling at 60 km/h. The relative speed between the police vehicle and the caravan is 40 km/h (difference between the speeds of the two vehicles). If differential effect occurred, the radar would treat the 'van as if it were stationary and display an erroneous patrol speed of 40 km/h. Once patrol speed is established the instrument searches for the higher velocity generated by combined target and patrol speeds - in this example 80 + 100 = 180 km/h. The following calculation then takes place.

Target speed = Combined speed - Patrol speed

= 180 - 40

= 140 km/h

Since patrol speed was in error by 60 km/h the displayed target speed has been increased by 60 km/h.

Operators will not make any mistakes as a result of differential effect provided two simple precautions are taken:

1. do not check the speed of a target whilst the police vehicle is close to the rear of a large moving object; and

2. verify that the displayed patrol speed is in fact the true patrol speed by correlation with the checked speedometer.

8.3 Double Bounce

In moving mode stationary objects such as overhead bridges, billboards and road signs, armco rails, etc. can assist in establishment of patrol speed because they are part of the stationary surroundings. If the radar is allowed to transmit a beam when no target is present it is possible to obtain target speed from these same objects. These objects are not responsible for the compression of the wavefronts but can cause the beam to be retransmitted toward a moving target which would not normally be detected by the radar.

The amount of energy arriving at the antenna as a result of double bounce is extremely small therefore it cannot interfere with any signal arriving from a legitimate target. Double bounce will only occur in the absence of a legitimate target due to this large difference in signal strength.

Double bounce can be more easily described and understood through the use of examples. *Figure 7.7* assumes that patrol speed has been correctly established in the normal manner. It shows how 'combined' speed only can be established in the absence of a target using the energy being reflected from an overhead bridge. This allows the police vehicle to become the target as well as the host vehicle. (A large road sign, advertising billboard, parked truck, in fact any large reflective surface, could be substituted for the bridge.) Each stage or 'leg' of the energy's journey is numbered from one to four in order of their occurrence. We will now consider each individual stage in the same order.

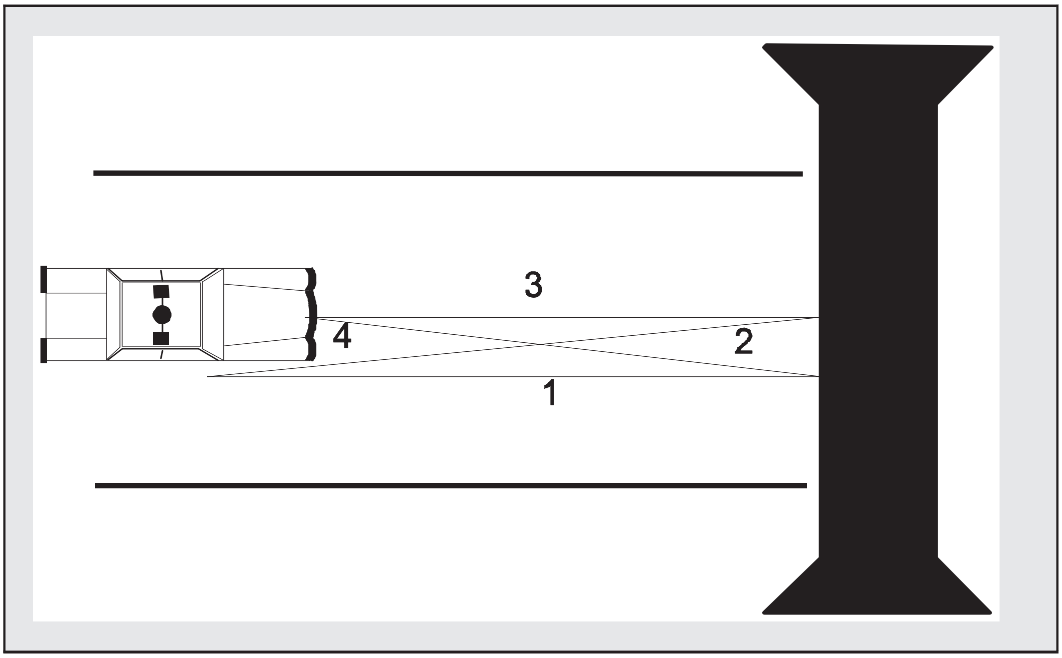


Figure 7.7 Double bounce - Police vehicle as host and target.

1. The forward movement of the radar causes wavefront compression equivalent to the speed of the host vehicle - 120 km/h. The energy continues to travel forward, collides with the bridge but received no further compression on this leg.

2. Energy is reflected from the bridge to the moving police vehicle where the wavefronts are further compressed upon collision with the vehicle. Total compression is now equivalent to 240 km/h.

3. Collision with the vehicle causes reflection back to the bridge. Again no further compression occurs upon collision with the bridge but the beam retains its total increase in frequency equivalent to 240 km/h.

4. Collision with the bridge causes reflection back to the radar.

Upon arrival at the radar the 120 km/h patrol speed is subtracted from the closing rate speed of 240 km/h and the difference, 120 km/h, is displayed as a target speed. Target speed will be the same as true patrol speed, plus or minus two km/h in these circumstances.

8.4 Split Speed

Split speed can occur when the police vehicle is travelling in excess of 120 km/h. The instrument is unable to obtain patrol speed from the roadway in front of the vehicle and obtains its speed at some angle to the side. As a result of the cosine effect the displayed speed is lower than the true patrol speed. The radar obtains true ground speed but, because it already has a patrol speed, treats it as a closing rate speed. The **DISPLAYED** patrol speed is subtracted from the closing rate speed and the difference is displayed as a target speed. When target and patrol displays are added together the total will equal the true patrol speed plus or minus two km/h.

8.5 Add-On Speed

Add-on speed usually occurs at low speeds when the police vehicle is moving at speeds below the radar's threshold (16 km/h) and the instrument must still establish patrol speed. Any oncoming vehicle within about 50 metres of the radar will return a better signal than the roadway and the instrument treats it as a stationary object. As a result the radar will display the closing rate speed between the radar and the oncoming vehicle. The two speeds are added together and displayed as a patrol speed.

8.6 Instrument Error

Kustom Signals Inc., the manufacturer of Eagle Traffic Radar System states that the accuracy of the device is:

Stationary mode - plus or minus 2 km/h; and

Moving mode - plus 2 or minus 3 km/h.

It must be appreciated that the radar can only display whole kilometres per hour. In fact, a speed of say 81.89 km/h would be displayed as 81 km/h only.

8.7 Receding Targets in Moving Mode

The operator of Silver Eagle II radar in moving mode does not need to be concerned about traffic travelling in the same direction as the radar vehicle. For those vehicles to cause any reading they must travel at twice the speed of the police vehicle plus the threshold speed of the radar (16 km/h). Even then the display would be the threshold speed.

The radar must first acquire a patrol speed then a closing rate speed which is higher than the patrol speed. In the case of Silver Eagle II radar a speed below 16 km/h will not register. The radar subtracts the patrol speed from the closing rate speed to determine the target speed.

Consider a radar vehicle travelling at 60 km/h with a vehicle in front travelling at 60 km/h. The closing rate speed is zero. Without a closing rate speed no target speed can be calculated. If the vehicle in front were to double its speed to 120 km/h -

$$\begin{aligned} TS &= CRS - PS \\ &= (120 - 60) - 60 \\ &= 0 \text{ km/h} \end{aligned}$$

If the target further increases speed to 136 km/h:

$$\begin{aligned} TS &= CRS - PS \\ &= (136 - 60) - 60 \\ &= 16 \text{ km/h} \end{aligned}$$

From the above examples it can be seen that Silver Eagle II radar cannot determine the speed of a vehicle travelling in the same direction in moving mode. The operator need not be concerned about such vehicles because that vehicle must travel extremely fast to register only slightly in excess of the speed limit.

9.1 Tuning Forks

Tuning forks are used to verify the accuracy of police radar instruments by simulating the frequency increase caused by a moving target. The tines, which oscillate at a known frequency, causes compression of the wavefronts thus generating a known speed. The Tuning fork tests establish two important points:

1. that the transmitter/receiver is functioning; and

2. the accuracy of the Logic Control unit.

Although a crystal test facility is provided, the Silver Eagle II radar system must rely on the tuning forks to verify the accuracy of the LCU. Two forks are provided by the manufacturer - one which causes a speed reading of 45 km/h and one which causes a speed reading of 80 km/h. These forks are used separately and together to check accuracy.

9.1.1 Stationary Mode

To correctly carry out tuning fork tests in stationary mode the following procedure must be adopted:

1. select STATIONARY mode;

2. cause the ‘45’ tuning fork to vibrate and hold it about 15 centimetres in front of the antenna - observe the numerals ‘45’ in the target display; and

3. cause the ‘80’ tuning fork to vibrate and hold it about 15 centimetres in front of the antenna - observe the numerals ‘80’ in the target display.

9.1.2 Moving Mode

After a tuning fork test in stationary mode, perform the following moving mode test procedure:

1. select MOVING mode;

2. cause the ‘45’ tuning fork to vibrate and hold it about 15 centimetres in front of the antenna - observe the numerals ‘45’ in the PATROL display; and

3. with the vibrating ‘45’ fork still held in front of the antenna, cause the ‘80 tuning fork to vibrate and hold it about 15 centimetres in front of the antenna - observe the numerals ‘45’ in the Patrol display and ‘35’ in the TARGET display.

In moving mode the 45 fork represents the patrol speed and the 80 fork represents combined speed therefore:

$$80 - 45 = 35$$

9.1.3 Care of Tuning Forks

Tuning forks are made of an aluminium alloy and are quite soft. They are imported from the U.S.A. therefore they are expensive and difficult to obtain. In order to avoid damage and unnecessary expense, and to ensure continued accuracy, the following rules must be adhered to:

1. tuning forks must **NEVER** be struck against any material which is harder than the fork itself (rubber boot heel is recommended);

2. when not in use the tuning forks should be carried in the police vehicle; and

3. when sent to the Radar Engineering Unit for periodic testing or for repair the allocated tuning forks **MUST** accompany the instrument.

Note: tuning forks have a serial number and are issued for use with a particular instrument. The tuning forks must be tested as part of the periodic calibration test therefore a certificate under *section 137 of the Road Transport Act 2013 No 18* cannot lawfully be issued when the tuning forks are not submitted with the instrument for testing. Instruments submitted without tuning forks will **NOT BE ACCEPTED** at the Radar Engineering Unit and will be returned until the forks are provided.

In order to comply with the manufacturer's instructions, requirements of the Australian Standards Association and Police guidelines for testing of radar instruments, tuning fork tests **MUST** be carried out.

Silver Eagle II

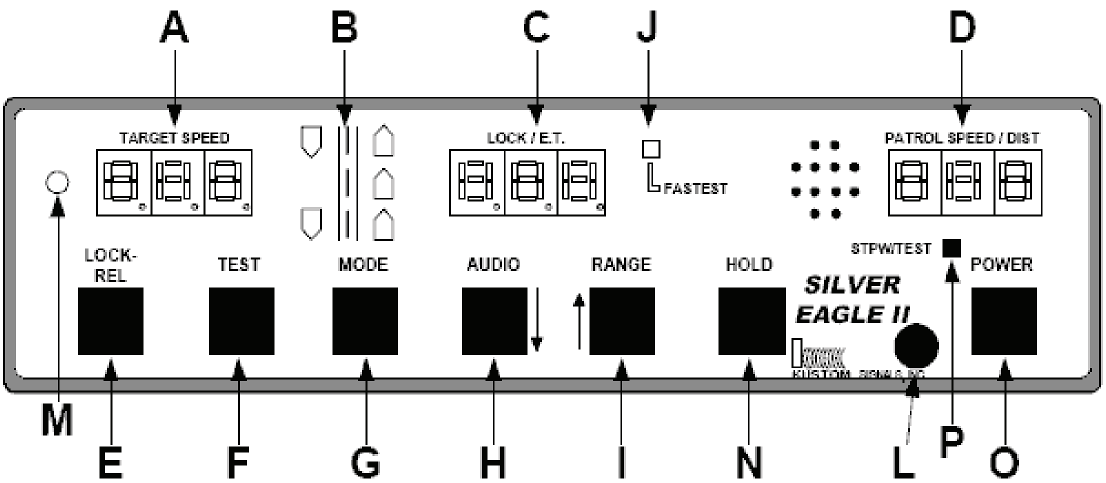
Traffic Safety Radar

The Silver Eagle II Traffic Safety Radar is manufactured in the U.S.A. by Kustom Signals Inc., Kansas. The Silver Eagle is a direct doppler Ka-Band Radar, all functions of the Silver Eagle II are controlled by a micro-processor at the command of the operator. The design includes computer intergrated circuits therefore additional functions may be added at a later date as required.

Notable features of the Silver Eagle II are:

1. the physical size of the Silver Eagle II;
2. the Silver Eagle II performs an automatic test;
3. the Silver Eagle II has a Stop Watch Mode;
4. the Silver Eagle II will continue tracking a target vehicle even though that speed has been locked on ensuring full traffic history; and
5. the rear port of the Silver Eagle II will drive a Kustom Signals, Giant Display or can be connected to an Eyewitness, in-car video system, an external printer or personal IBM compatible computer.

Figure 1: Silver Eagle II Remote Display Counting Unit (Front)



(A) Target Display - Registers

1. Target closing/opening rate speed in stationary mode.
2. Approaching vehicles speed in moving mode.
3. Displays calculated target speed in stopwatch mode.
4. Displays Aud when audio switch is selected.
5. Displays rng when range switch is selected.

(B) Road Graphic

1. Roadway indicates mode of operation whether stationary or mobile.
2. Which antenna is selected.

(C) Lock/et Display

1. Displays locked target speed.
2. In stopwatch mode, displays the elapsed time in seconds and tenths of seconds.
3. In the fastest mode, displays fastest speed **(Disabled).**

(D) Patrol Speed

1. Displays the speed of the patrol vehicle.
2. In the stopwatch mode, displays the distance to be used for speed calculations.
3. Displays a number with regard to audio level selected.
4. Displays a number with regard to range level selected.

(E) Lock/Release

1. Switch used to lock and unlock target and patrol vehicle speeds.
2. In the stopwatch mode, used to start, stop and clear the timing function.

(F) Test

1. Switch used to test the internal accuracy and ensure all segments and LEDS are lighted.

(G) Mode

1. Switch used to select operating mode: moving, stationary, or stopwatch mode.
2. Secondary function is to set fan interference on or off.

(H) Audio

1. This switch is used to display the level of audio currently selected.
2. Secondary function is the decrement down control.

(I) Range

1. Switch used to place the EAGLE in the range set mode.
2. Secondary function is the increment (up) control.

(J) Fastest Indicator (Disabled)

(L) Infra-red remote control sensor (option)

(M) Ambient Light Detector

1. Detects ambient light conditions and adjusts the brightness of the displays automatically.

(N) Hold

1. This switch is used to turn the microwave transmitter on and off.

(O) Power

1. Push button for on/off power control.

(P) Stopwatch Indicator Led

1. Lights in stopwatch mode.

Figure 2: Silver Eagle II Remote Display (Rear)

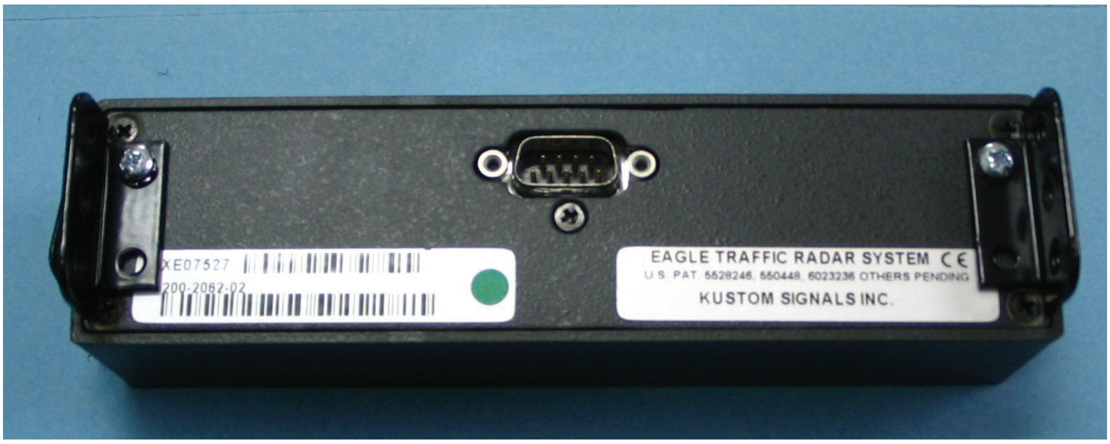
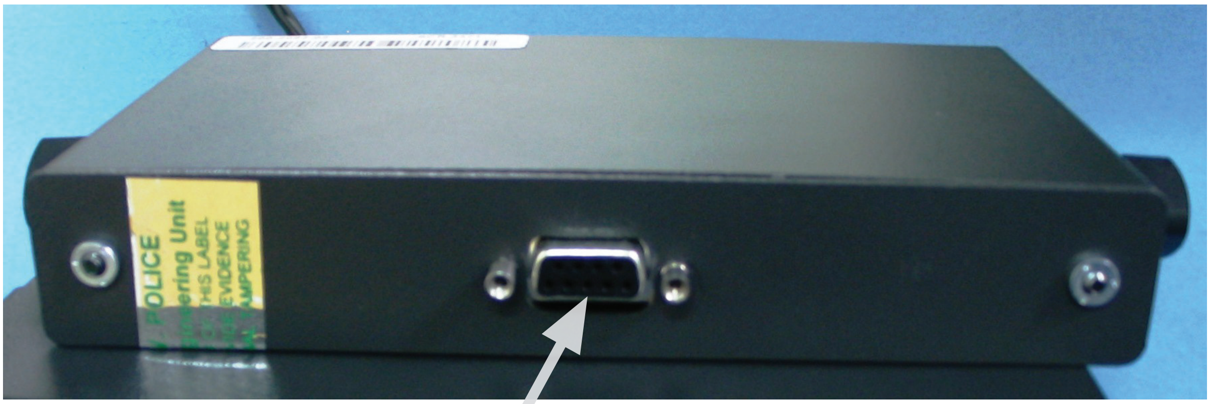
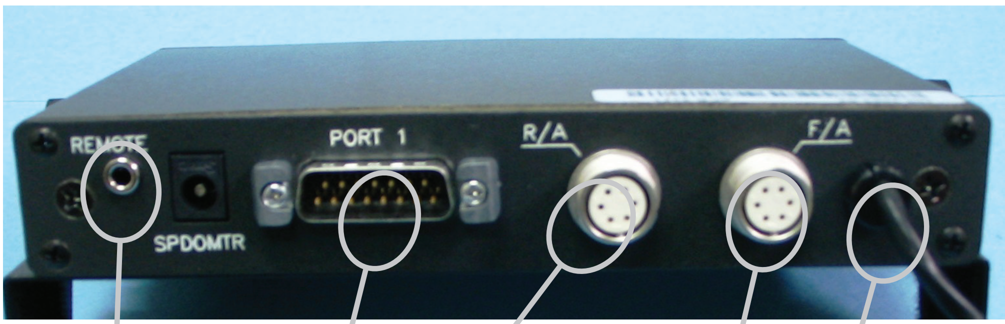


Figure 3: Computer Section Silver Eagle II (Front)



(A) Interface Connector With Remote Display

Figure 4: Computer Section Silver Eagle II (Rear)



(A) Remote control connector.

(B) Rear Port service I/O connector (communications) with external printer, personal IBM compatible computer, a Kustom Signals giant display, or eyewitness in car video system.

(C) Connector for rear antenna (not used).

(D) Connector for front antenna (accepts a 7 pin quick release connector).

(E) Power cord.

Figure 5: Silver Eagle II Ka-Band Antenna (Side)

Antenna cable receptacle.

Figure 6: Silver Eagle II Ka-Band Antenna (Rear)

Accepts 7 pin quick release connector which terminates the antenna cable.

Figure 7: Remote Control Assembly

(A) ***Lock/Release -*** performs identical functions as lock release on the remote display counting unit.

(C) ***Fastest vehicle –*** **(Disabled)**

(E) ***Patrol Select -*** pressing the switch displays the current minimum patrol speed setting.

(B) ***Front Hold -*** hold button for front antenna port.

(D) ***Rear Hold -*** hold button for rear antenna port.

Silver Eagle II Installation

The Silver Eagle II Radar System may be operated from any vehicle which is equipped with a shielded power supply and a speedometer which has been checked for accuracy. Reliability of any speed reading cannot be assured if **either** of these components is absent.

When placing the counter unit/remote display computer section and/or antenna in the vehicle it must be properly secured to prevent damage to the instrument and, more importantly, possible injury to vehicle occupants in the event of an accident. The *Work Health and Safety Act 2011 No 10,* places onus upon employee as well as employer for workplace safety. *Section 28* of the *Act* states:

While at work, a worker must:

(a) take reasonable care for his or her own health and safety, and

(b) take reasonable care that his or her acts or omissions do not adversely affect the health and safety of other persons, and

(c) comply, so far as the worker is reasonably able, with any reasonable instruction that is given by the person conducting the business or undertaking to allow the person to comply with this Act, and

(d) co-operate with any reasonable policy or procedure of the person conducting the business or undertaking relating to health or safety at the workplace that has been notified to workers.

Assembly

1. Mount the antenna in accordance with the instructions for antenna placement and aim.

2. With the power off, insert the multi pin (7) pin plug terminating the antenna cable into the corresponding receptacle on the rear panel of the counting unit.

3. Connect counting unit to remote display with interface cable

4. Insert the remote control phone jack into the remote control receptacle on the rear panel of the counting unit.

5. Insert the power cable plug into the two-pin receptacle of the vehicle's shielded power supply.

6. Place the remote display for convenient viewing by the operator (remember the safety factor).

Testing Procedure

1. Visually check correct antenna placement and alignment.

2. Press power switch on. Check that the direction antenna - mode indicators are illuminated. The radar will process through a test to ensure all segments and indicators illuminate, an internal test (crystal check), and current audio and range settings are displayed sequentially.

3. Press and hold the ***test*** switch. All indicators and segments will illuminate. Release the test switch and "PAS" will appear in patrol and target displays (whilst in moving mode). In stationary mode "PAS" appears only in the target display.

4. Press the audio button and a number between zero and nine indicating the current audio level is shown in the patrol display. Pressing the ***range*** (up) or ***audio*** (down) adjusts volume.

5. Press the ***range*** switch and a number between one and six indicating the present range setting is shown in the patrol display. ***Range*** is adjusted by pressing the ***range*** button (increase) or ***audio*** switch (decrease).

6. Select ***stationary mode*** by pressing the ***mode*** switch and carry out tuning fork tests using both "45" and "80" km/h tuning forks.

7. Select ***moving mode*** by pressing the ***mode*** switch carry out moving mode tuning fork test using both forks simultaneously. Observe "45" in patrol display and "35" in the target display.

8. Commence patrol - correlate patrol speed with checked speedometer to ensure correct antenna alignment.

9. Select hold and continue patrol.

10. Perform internal calibration test (as described in point three above) at hourly intervals.

11. At the completion of duty repeat steps 3 to 7.

Technical Specifications

Frequency:	34.9 GHz plus or minus 0.1GHz.
Output Power:	12mW typical, 40mW maximum.
Source:	Gunn-effect diode.
Antenna type:	Conical horn.
Polarisation:	Left-hand, circular
3dB Beamwidth:	12 degrees plus or minus 1 degree.
Antenna Gain:	Approximately 23dB.
Power Density:	Less than 5mW/cm2.
Receiver type:	Low noise Schottky barrier diode.
Operating voltage:	10.8 to 16.5 volts dc.
Operating temperature:	-30 to +60 degrees celsius.
Rel. humidity:	90% at 37 degrees celsius, non-condensing.
Target speed:	Typically 16 to 320 km/h
Patrol speed:	Typically 16 to 239 km/h

Note: *combined patrol and target speeds will not exceed 320 km/h.*

System Operation

The *Silver Eagle II Radar System* has the capacity to be used in moving or stationary mode at the discretion of the operator. Moving mode is used when the host vehicle is moving and monitoring the speed of approaching targets. Stationary mode is used when the host vehicle is at a fixed position and monitoring approaching or receding targets.

Auto-matic Self Test

The *Silver Eagle II* performs an internal accuracy test whenever the unit's mode of operation is changed, such as changing from moving to stationary, or upon the lapse of a maximum time period of five minutes, as long as the unit is powered up. In addition, this self-test will be initiated at the end of each timing cycle in the stopwatch mode.

This test is automatic and will not interfere with any radar speed readings being taken. The test does not appear in the displays, but if an error is detected during this test, **the target display will indicate 'ErX' and further speed readings will be inhibited**.

Manual Test

The operator can depress the ***test*** switch at any time during normal radar operation to perform the indicator/segment and internal tests. If the *Silver Eagle II* is in the stopwatch mode and a timing cycle is in process, the test switch is inoperative until the timing cycle has ended.

Accuracy Testing

Depress the ***mode*** switch, if necessary, to place the *Silver Eagle II* in the stationary mode of operation. As per mode antenna indicator.

Momentarily depress the ***test*** switch. Holding the ***test*** switch depressed will light all displays. Upon releasing this switch, the *Silver Eagle II* will complete the internal test. If these tests pass, the *target window* will display "PAS" in the Target window. If the ***test*** switch is held depressed for greater than 10 seconds, the internal test will proceed as a default condition.

Note: no audio or range indications will be shown.

Depress the ***mode*** switch to place the unit in the moving mode. The opposite direction antenna/ mode indicator will be lit.

Momentarily depress the ***test*** switch. If the system is working properly, the unit will proceed through the lamp and internal tests as described above.

Internal test tolerance: +0.

Tuning Fork Testing

Supplied with the *Silver Eagle II* are two tuning forks, (45km/h and 80km/h). These tuning forks will simulate moving vehicles in the stationary or moving modes.

The tuning fork tests should be conducted in an area with no traffic. If this is not possible, point the antenna upward to avoid reflections from moving vehicles.

Tuning fork test tolerance: + or - 1Km/h.

Stationary and Moving Modes

Pressing the ***mode*** switch places the *Silver Eagle II* in either stationary or moving mode as indicated by ***mode/antenna*** indicator.

Adjusting Doppler Audio Squelch/Unsquelch

Adjust the Doppler audio for the desired listening level. Depress the ***audio*** switch. The target window will display "Aud" and the ***patrol window*** will display the current audio level.

With "Aud" still being displayed, depress either the ***audio*** (down) or ***range*** (up) switches to decrement or increment the audio level. The displays will return to their normal mode two seconds from the last switch entry or momentarily depress the ***hold*** switch to return to normal operation immediately.

To unsquelch the audio, depress the ***audio*** switch. The target window will display "Aud". Depress the ***mode*** switch. The ***Lock/Et*** window will display "Un".

To return to squelched audio, with "Aud" and "Un" being displayed, again depress the ***mode*** switch. The ***Lock/Et*** window will be blank and the audio will be squelched. Two seconds after the last switch entry, the displays will return to their normal functions or momentarily depress the ***hold*** switch to return to normal operation immediately.

Setting Range Level

Set the range control to the desired level. Depress the ***range*** switch and the ***target window*** will display "rnG" and the ***patrol window*** will display the current level (0-6). Range level six is maximum range, range level one reduces the *Silver Eagle's* range to its minimum distance, typically 100 metres.

Depressing the ***down*** (***audio***) or ***up*** (***range***) switches will decrement or increment the range level. The displays will return to their normal mode after approximately two seconds from the last switch entry or momentarily depress the ***hold*** switch to return to normal operation immediately.

Fan Interference Filter

Check the status of the fan interference filter by momentarily depressing the ***range*** switch. While "rnG" is being displayed, depress the ***mode*** switch to display "Fan" in the Target window and either "On" or "Off" in the lock window. Press ***mode*** again to change the status of the filter. The operator may activate or deactivate this filter depending on the amount of fan interference being experienced in a particular patrol vehicle. If the fan is interfering with radar operation, activating the filter will reduce the amount of fan interference.

The displays will return to their normal mode approximately two seconds from the last switch entry or momentarily depress the ***hold*** switch to return to normal operation immediately.

Note: *some degradation of system range may be noted with the filter activated. For maximum performance, if the patrol vehicle has little or no fan interference, it is suggested that the fan interference filter be turned off.*

Radio Frequency Interference

Figure 8: Radio Frequency Interference

Radio Frequency Interference (RFI) exists when there are strong RF transmitting stations in the immediate area of the radar unit, such as the patrol vehicle's transmitting radio, high power radio or television stations. These sources of interference will be detected by the *Silver Eagle II* and the Target window will display "rFi" until the source of interference is eliminated.

Low Voltage

Figure 9: Low Voltage

If the power supply voltage drops below the minimum operating voltage, the *Silver Eagle II* will not display any new speed readings until the low voltage condition no longer exists. "Lo" will be displayed in the target window.

Harmonic Detection

Strong reflections from roadside objects, such as large signs, parked cars and buildings can cause double bounce reflections which are the same as the patrol speed. These "harmonics" are detected by the *Silver Eagle II* which inhibits their display. The Target window will display "--" until this condition no longer exists.

Stopwatch Mode

Depress and hold the ***mode*** switch for more than one second. The ***mode/antenna*** indicators will turn off and the stopwatch LED indicator will be lit.

The ***Lock/Et*** (Lock/Elapsed Time) window will display "0.0" and the ***patrol/distance*** window will display a distance in one (1) metre increments, from 100 to 999 metres.

To activate the alert tone (beep at start and stop of timing), press the ***hold*** switch once after the stopwatch indicator lights. (This procedure cannot be done during a timing cycle.) To deactivate, press ***hold*** again.

Measure the distance between two marks. To change the distance displayed in the ***patrol window***, depress either the ***audio*** (down) or ***range*** (up) switches. Holding the switch depressed will cause the numbers to increment or decrement at a faster rate.

When the target vehicle is at the first timing mark, depress the ***Lock/Rel*** switch. The timer is started and a short alert tone will be heard (if the alert tine feature has been enabled). When the target vehicle crosses the second timing mark, again depress the ***Lock/Rel*** switch which stops the timer and another short alert tone will be heard.

The alert tones are used to verify the acceptance of the start and stop commands. The operator can set the volume level or turn the tone off by use of the audio level.

Locking and Releasing Targets

In moving and stationary mode the procedure for locking and releasing displays is the same. Patrol speed display will remain blank when in stationary mode.

The hand-held remote control ***Lock-Rel*** button or the counting unit ***Lock-Rel*** button is used by the operator to manually lock or release a target speed. To lock a speed on the operator must press and hold the ***Lock/Rel*** button until the locked in speeds flashes ***Lock/Et*** and the has beeped once.

Note: *if the auto-unlock feature is enabled, the locked speed will be automatically unlocked after 14 minutes.*

System Accuracy

Stationary --+/-2 km/h.
Moving --+2/-3 km/h.

System Operation

11.1 General Facts

11.1.1 Power Source

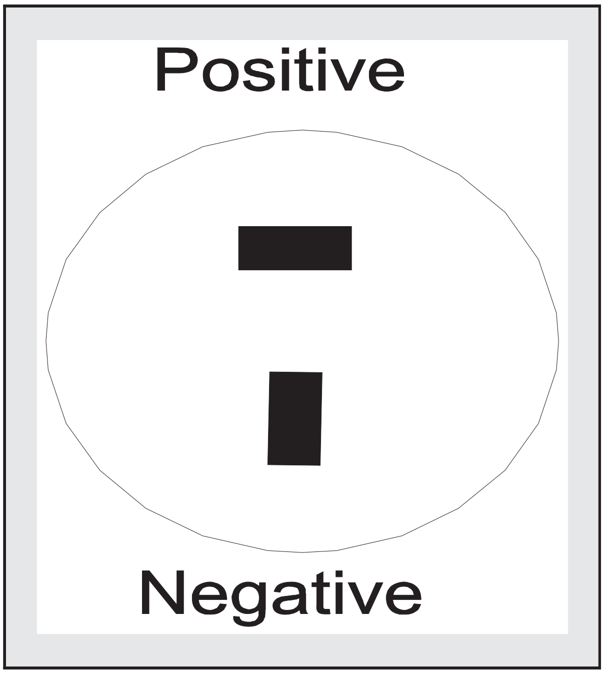


Figure 11.1 Polarised socket

Cigarette lighter receptacles are the traditional power source for traffic radar. However, poor grounding, electronic ignition bleedover, alternator noise, etc., can combine to create an unacceptably high level of ambient electronic interference. To combat this, police vehicles used for operating radar are fitted with a two-conductor shielded cable between the battery and a 'T' type polarised socket. An additional conductor connected at the battery end only ensures that any spurious emissions from the vehicle are grounded. Polarity of the polarised socket is shown in Figure 11.1.

11.2 Radiation Hazard

Microwave emissions need not be a concern to the radar operator or to members of the public being 'illuminated' by the transmitted energy. Extensive research overseas, particularly America, indicate that the amount of energy being emitted is well below defined safety levels for continuous exposure. Independent tests of radiation levels of police radar devices were carried out by the Australian Radiation Laboratories

The American National Standards Institute has set a safety level of 10 milliwatts per square centimetre. The level of intensity beyond three metres in front of the antenna is less than 1 microwatt per square centimetre.

The radiation levels present do not present a health hazard, however, operators and members of the public are advised **not** to look directly into the antenna close up for prolonged periods.

Independent tests have been performed by the Health Commission of New South Wales and the Australian Radiations Laboratories and each have certified that no radiation hazard to the operator or to the public is associated with the devices used by the NSW Police Force.

12.0 Operational Guidelines and Responsibilities

Forward

The primary function of the Highway Patrol is the protection of road users in New South Wales and to this end, members should concentrate their efforts on the detection of those road users who breach the Road Transport laws or who drive in a dangerous or irresponsible manner. In an earnest endeavour to improve driver behaviour within this State, police should be ever-ready to counsel those road users who commit minor or technical traffic offences.

12.1 Operational Guidelines

1. Radar/Lidar is to be set up and tested as per instructions.
2. Mobile radars in moving mode are to be used only in rural areas or in areas where traffic is sparse. This will ensure ease of target identification.
3. The minimum detection time is three seconds for a valid radar speed check.
4. At all times the instrument is to be in hold mode until a target is visually observed.
5. Whilst patrolling, police vehicles must maintain a reasonable, constant speed.
6. Never check an oncoming vehicle in moving mode when travelling close to the rear of a truck, caravan or other large vehicle.

7. In moving mode always compare the checked speedometer of the police vehicle with the patrol speed to ensure correlation during the period of the check.

8. Ensure a clear audio tone is heard throughout the period of the check.

9. Radar/Lidar instruments are to be used on relatively straight portions of roadway.

10. The radar antenna is to be aimed straight ahead or directly to the rear of the police vehicle

11. Accuracy of the Silver Eagle II radar is plus or minus 2 km/h in stationary mode and plus 2 km/h, minus 3 km/h in moving mode. A general tolerance of three km/h should be borne in mind when completing traffic infringement notices.

12. Never attempt any repairs or allow any other person to perform any repairs to the Radar/Lidar instruments. In the case of faulty equipment, or if the seals are broken, cease operation and forward the device to the Leader, Radar Engineering Unit.

13. All instruments must be sent to the Radar Engineering Unit for periodic calibration testing at intervals not exceeding twelve (12) months

14. The Radar/Lidar operator at the time of the offence shall be responsible for notifying the Radar Engineering Unit when a radar expert is required at Court.

15. When a radar equipped vehicle is to be left unattended the antenna head is to be detached from the mounting bracket and placed inside the vehicle. Replace antenna prior to resuming patrol.

16. Radar/Lidar must not be used in inclement weather. Protective covers are not to be used under any circumstances

17. Avoid subjecting the radar display unit to direct sunlight for extended periods.

12.2 Responsibilities

It is the responsibility of the all Traffic Enforcement Commanders, Highway Patrol Supervisors and indeed all radar /lidar operators to ensure that radar equipment is utilised in the most effective manner. Particular attention should be paid to the deployment of these instruments at complaint areas or locations which have a high accident potential.

So that there will be no misunderstanding as to the responsibilities of police engaged in the operation of radar/lidar instruments, the following requirements concerning the location and operation of such units should be borne in mind. They are **not** to be used:

1. within 50 metres of a speed restriction or de-restriction sign creating a change to the speed zone being enforced unless;*

   — speed is excessive (e.g. at least in excess of 20 km/h of the zoned speed limit); **or**
   — subject of complaint; **or**
   — where there is a high accident history;

   * this does not apply to school zones.

2. at any location or deploy a vehicle that would engender legitimate criticism or give rise to the complaint that they are a means of raising Government revenue.

When operating speed measuring instruments police should be aware of Australian Design Rules pertaining to motor vehicle speedometers.

12.3 Requirements for a Valid Speed Check

1. Visual observation and estimation of the target's speed.

2. Observe the numerals in the patrol and target displays.

3. Clear, constant (if appropriate) tone.

4. Correlation between patrol speed and checked speedometer.

5. Duration of the check (steps two, three and four) must not be less than three seconds.

6. Minimum of 200 metres between targets of similar size.

Estimation

Estimation of a target speed whilst conducting radar/lidar speed enforcement must be done by direct visual observation only. Estimation of target speeds using rear vision mirrors are not to be used under any cicumstances for radar/lidar speed enforcement.

Target Identification

A valid speed measurement shall only be taken when the target is clearly identifiable by direct observation

Visual Observation

The operator of a direct radar / lidar device shall visually monitor the object under investigation for sufficient time to identify it as a target. If the operator has any doubt that the speed measured by the radar / lidar device is not that of the object under investigation that speed shall be considered invalid

Audio Tracking

The operator shall monitor the audio doppler signal of a radar and audio tone of a lidar for sufficient time to identify the target prior to taking a valid speed measurement. The audio doppler over this period shall be a clear single tone and its pitch shall only vary in proportion to the visually observed changes in speed of the object under investigation.

Reflective Capability

The operator of a direct radar device shall take into account the effects of the relative size and shape of the target and its distance from the radar device when identifying the target.

13.1 Legislation

The statutes do not create a specific radar-related speeding offence. At court the radar operator and/or the reporting constable must be able to establish proofs of the offence such as driver, motor vehicle, road/related, excessive speed, etc. radar, like a checked speedometer, is merely an instrument used to measure the speed of the vehicle involved.

13.1.1 Government Gazette

NSW Government Gazette No 167 9/11/2007 p 8387

Road Transport (Safety and Traffic Management) Act 1999

ORDER

I, Professor Marie Bashir, AC, Governor of the State of New South Wales, with the advice of the Executive Council, and in pursuance of the Road Transport (Safety and Traffic Management) Act 1999 do, by this my Order, approve of the following type of speed measuring device described hereunder as being designed to measure the speed at which a vehicle is travelling.

Type of device:

The speed measuring device, Silver Eagle II

Signed and sealed at Sydney, this 1st day of November, 2007

By Her Excellency's Command,

Eric Roozendaal, M.L.C.,
Minister for Roads

NSW Government Gazette No 53 16/05/2008 p 3929

Road Transport (Safety and Traffic Management) Act 1999

ORDER

II, Professor Marie Bashir, AC, Governor of the State of New South Wales, with the advice of the Executive Council, and in pursuance of the *Road Transport (Safety and Traffic Management) Act 1999* do, by this my Order, approve of the following type of speed measuring device described hereunder as being designed to measure the speed at which a vehicle is travelling.

Type of device:

The speed measuring device, Ballinger Technology SDS Digital Speedometer

Signed and sealed at Sydney, this 7th day of May, 2008.

By Her Excellency's Command,

Eric Roozendaal, M.L.C.,
Minister for Roads

13.1.2 Road Transport Act 2013 No18

Division 4 Approval of traffic enforcement devices

Section 134

Approval of devices by Governor

(cf STM Act, ss 44, 45, 47A, 56, 57A and 57C)

(1) The Governor may, by order published in the Gazette, approve types of devices (or combinations of types of devices) as being designed for any one or more of the following uses:

(a) measuring the speed at which a vehicle is travelling (whether or not the vehicle concerned is also photographed),

Note. *The Governor may amend, rescind, revoke or repeal an order made under this section. See section 43 of the Interpretation Act 1987 and the definition of* ***repeal*** *in section 21 of that Act.*

(3) The Minister may not recommend the making of an order by the Governor under this section approving the use of a device for measuring the speed at which a vehicle is travelling (other than an average speed) without the concurrence of the Attorney General.

Division 5 Use of evidence obtained from approved traffic enforcement devices

Section 135

Definitions

(cf STM Act, ss 47 (7), 47B (4), 57 (1) and 57B (1); VR Act, s 22C (1))

(1) In this Division:

appropriate inspection officer *means:*

(a) in relation to an approved traffic enforcement device that measures the speed at which a vehicle is travelling but is not used in conjunction with, or as part of, a digital camera device:
(i) a police officer, or
(ii) a person authorised by the Commissioner of Police to test a device of that kind, or

(b) in relation to any other kind of approved traffic enforcement device—a person (or a person belonging to a class of persons) authorised by the Authority to install and inspect devices of the kind concerned.

(2) For the purposes of this Act:

(c) an approved traffic enforcement device is ***approved for speed measurement*** *if it is approved under section 134 for the use referred to in section 134 (1) (a)*

Section 137

Certificates concerning reliability of speed measurement devices

(cf STM Act, s 46 (1))

In proceedings for a speeding offence in which evidence is given of a measurement of speed obtained from an approved traffic enforcement device that is approved for speed measurement, a certificate purporting to be signed by an appropriate inspection officer for the device certifying the following matters is admissible and is prima facie evidence of those matters:

(a) that the device is an approved traffic enforcement device that is approved for speed measurement,

(b) that on a day specified in the certificate (being within the period prescribed by the statutory rules before the alleged time of the offence) the device was tested in accordance with the statutory rules and sealed by an appropriate inspection officer for the device,

(c) that on that day the device was accurate and operating properly.

Section 140

Evidence of accuracy and reliability not required if certificate tendered

(cf STM Act, ss 46 (2), 47 (6), 47B (3), 57 (4) and 57B (5))

If a certificate under this Division is tendered in proceedings for a detectable traffic offence, evidence:

(a) of the accuracy or reliability of the approved traffic enforcement device concerned, or

(b) as to whether or not the device operated correctly or operates correctly (generally or at a particular time or date or during a particular period), is not required in those proceedings unless evidence sufficient to raise doubt that, at the time of the alleged offence, the device was accurate, reliable and operating correctly is adduced.

Section 141

Rebuttal of evidence concerning operation of approved traffic enforcement devices

(cf STM Act, s 73A)

(1) This section applies to the determination of whether evidence is sufficient to rebut prima facie evidence or a presumption, or to raise doubt about a matter, as referred to in section 137, 138, 140 or 164 and for the purposes of proceedings to which those sections apply.

(2) An assertion that contradicts or challenges:

(a) the accuracy or reliability, or the correct or proper operation, of an approved traffic enforcement device, or

(b) *the accuracy or reliability of information (including a photograph) derived from such a device,*

is capable of being sufficient, in proceedings to which this section applies, to rebut such evidence or such a presumption, or to raise such doubt, only if it is evidence adduced from a person who has relevant specialised knowledge (based wholly or substantially on the person's training, study or experience).

Division 2 Speed measuring evasion articles

Section 119

Sale, purchase or use of prohibited speed measuring evasion articles

(cf STM Act, s 48)

(1) *A person must not sell or offer for sale, or purchase, a prohibited speed measuring evasion article.*

Maximum penalty: 20 penalty units.

(2) *A person must not drive a motor vehicle, or cause a motor vehicle or trailer to stand, on a road if a prohibited speed measuring evasion article is fitted or applied to, or carried in, the vehicle or trailer.*

Maximum penalty: 20 penalty units.

(3) *The responsible person for a motor vehicle or trailer that is driven or stands on a road in contravention of subsection (2) is guilty of an offence.*

Maximum penalty: 20 penalty units.

(4) *It is a defence to a prosecution for an offence against this section if the defendant proves to the court's satisfaction that the article concerned was not designed as a prohibited speed measuring evasion article but was designed for another purpose.*

(5) *It is a defence to a prosecution for an offence against subsection (2) or (3) if the defendant proves to the court's satisfaction that, at the time of the alleged offence:*

(a) *the vehicle was in the course of a journey to a place appointed by a police officer, an officer of the Authority or a court, in order to surrender the article, or*

(b) *the vehicle was the subject of a notice, issued in accordance with the statutory rules, requiring the responsible person for the vehicle to remove the article from the vehicle within a specified time and that time had not expired, or*

(c) *the defendant did not know, and in the circumstances could not reasonably be expected to have known, that the article concerned was fitted or applied to, or was being carried in, the vehicle or trailer.*

Section 120

Surrender and forfeiture of prohibited speed measuring evasion articles

(cf STM Act, s 49)

(1) A police officer who reasonably believes that:

(a) a prohibited speed measuring evasion article is being sold or offered for sale in contravention of section 119 (1), or

(b) a motor vehicle or trailer is standing or being driven in contravention of section 119 (2) because of an article fitted or applied to, or carried in, the motor vehicle or trailer,

may require a person in possession of the article to surrender it immediately to the police officer or, in the case of an article fitted or applied to a motor vehicle or trailer and not immediately removable, may by notice in writing served on the responsible person for the vehicle or trailer require the responsible person to surrender the article within a specified time and in a specified manner to the Commissioner of Police.

(2) An officer of the Authority who is authorised in writing by the Authority for the purposes of this section and who finds a prohibited speed measuring evasion article fitted or applied to, or carried in, a motor vehicle or trailer may, by notice in writing served on the responsible person for the motor vehicle or trailer, require the person to do either or both of the following:

(a) remove the article (if it is fitted to the motor vehicle or trailer),

(b) surrender the article within a specified time and in a specified manner to the Commissioner of Police.

(3) A person must comply with a requirement under subsection (1) or (2), whether or not the person is the owner of the article concerned.

Maximum penalty: 20 penalty units.

(4) A court that finds any person guilty of an offence against section 119 or under subsection (3) may order that the article concerned, if not already surrendered in compliance with a requirement under this section, be delivered to the Commissioner of Police within a time and in a manner specified by the court.

(5) An article surrendered as required under this section is forfeited to the Crown and may be destroyed or otherwise disposed of at the direction of the Commissioner of Police.

(6) No liability attaches to any person on account of the surrender by the person, in compliance with a requirement under this section, of a prohibited speed measuring evasion article of which that person is not the absolute owner.

13.1.3 Road Transport (General) Regulation

Clause 35

Testing and security indicators for approved traffic enforcement devices

(cf STM Reg, cll 156, 156A, 156B and 156D)

(1) For the purposes of section 137 (b) of the Act:

(a) an approved traffic enforcement device that is approved for speed measurement and is a radar based device of a kind to which the Australian Standard entitled AS 2898.1—2003, Radar speed detection—Functional requirements and definitions applies must be tested for accuracy and functional requirements in accordance with that Standard, and

(b) any other approved traffic enforcement devices that are approved for speed measurement must be tested for accuracy and functional requirements in accordance with the manufacturer's recommended calibration method as approved by the Commissioner of Police or (in the case only of a device that is used in conjunction with, or forms part of, a digital camera device) by the Authority, and

(c) the prescribed period is 12 months.

Note: **Any** certificate issued within the 12 month period preceding the date of the offence and which complies with the other requirements of *Section 137* may be tendered as prima facie evidence of accuracy and reliability. The most recent certificate should be produce wherever possible.

DUPLICATE CERTIFICATES CANNOT BE ISSUED BY THE RADAR ENGINEERING UNIT THEREFORE A COPY MUST BE PROVIDED FOR COURT RECORDS. THE ORIGINAL MUST BE RETURNED TO THE MEMBER OF THE SERVICE RESPONSIBLE FOR ITS SAFEKEEPING AT THE COMPLETION OF THE COURT HEARING.

13.1.4 Attendance of Radar Expert at Court

Attendance of a radar expert is not required in all defended radar matters. The *'Section 137'* certificate eliminates this need unless 'evidence that the device was not accurate or not reliable has been adduced'. This effectively means that the magistrate hearing the matter will, after the defence has produced the required evidence, direct that an expert attend.

Situations may arise where it would be prudent for a radar expert to be in attendance at court even though the certificate has not been tendered. In such cases a report setting out the circumstances of the matter should be submitted to the Commander, Traffic Services Branch, through the regional Legal Services Branch.

Definitions

Approved traffic enforcement device means a device of a type (or a combination of types of devices) approved under section 134.

Prohibited speed measuring evasion article means any device or substance that is designed, or apparently designed, to be fitted or applied, or to be carried in, a motor vehicle or trailer for the purpose of detecting, interfering with, or reducing the effectiveness of, an approved traffic enforcement device that is approved for speed measurement, and includes a radar detecting device and a radar jamming device.

Radar detecting device means a device designed or apparently designed to be fitted to or carried in a motor vehicle or trailer for the purpose of detecting electromagnetic radiations from an approved traffic enforcement device that is approved for speed measurement.

Radar jamming device means a device designed or apparently designed to be fitted to or carried in a motor vehicle or trailer for the purpose of interfering with the receiving by an approved traffic enforcement device that is approved for speed measurement of reflected electromagnetic **radiations**.

Mathematics

Basic Formula

$$\text{SPEED} = \frac{\text{DISTANCE}}{\text{TIME}}$$

Transposition of this basic formula yields formulas for time or distance calculations -

$$\text{DISTANCE} = \text{SPEED} \times \text{TIME}$$

$$\text{TIME} = \frac{\text{DISTANCE}}{\text{SPEED}}$$

In everyday use - Time is in hours
Distance is in Kilometres
Speed is in Kilometres per hour

When you consider that the average radar speed check is about 4 seconds duration, calculations involving kilometres and hours become somewhat cumbersome and meaningless. Calculations using seconds, metres and metres per second are more convenient and in fact give a much clearer indication of the quantities involved, therefore:

Time is always in seconds
Distance is always in metres
Speed is always in metres per second

unless answers are requested in other units.

Conversion from Kilometres per Hour to Metres per Second

Most motor vehicle speeds are given in kilometres per hour. It therefore becomes necessary to convert kilometres per hour to metres per second.

This really involves two operations:

Conversion of kilometres to metres
Conversion of hours to seconds

therefore, to convert 1 km/h to metres/second:

$$1 \text{ km/h} = \frac{1 \times 1000}{3600} \qquad (3600 = \text{seconds in one hour})$$

$$= \frac{D}{S} \quad \frac{10}{36} \quad \text{or} \quad \frac{1}{3.6} \quad \text{m/sec}$$

Any speed in kilometres per hour can be divided by 3.6 to give the same speed in metres per second. In our previous example the answer may be taken one step further and converted to decimal form.

A speed of 60 km/h can be converted to metres per second:

$$60 \text{ km/h} = \frac{60 \times 1000}{3600} = 16.67 \text{ metres per second}$$

or

$$\frac{60\text{km/h}}{3.6} = 16.67 \text{ metres per second}$$

To convert a speed in metres per second to kilometres per hour simply multiply by 3.6.

Application of Formulas:

Example 1

A vehicle travels for 9 seconds and covers a distance of 500 metres.

What is the vehicle's speed?

$$\text{Speed} = \frac{\text{Distance}}{\text{Time}} = \frac{500}{9} = 55.56 \text{ m/s}$$

ANSWER = 55.56 metres per second

If answer was requested in kilometres per hour:

$$55.56 \times 3.6 = 200 \text{ km/h}$$

Example 2

A vehicle travels at 120 km/h for 4 seconds. What distance is travelled by the vehicle in that time?

$$\text{Distance} = \text{Speed} \times \text{time}$$

$$= \frac{120}{3.6} \times 4 \text{ seconds}$$

ANSWER = 133.33 metres

Note: Speed must be converted to metres per second.

Example 3

A vehicle travels at 100 km/h. How long does it take to travel 350 metres?

$$\text{Time} = \frac{\text{Distance}}{\text{Speed}} \qquad \text{Speed} = \frac{100}{3.6} = 27.78\text{m/s}$$

$$= \frac{350}{27.78}$$

ANSWER = 12.6 seconds

In moving mode it is necessary to take into account the speed of the police vehicle as well as the target i.e. the Closing Rate Speed (CRS). Consider the following example:-

Example 4

A police vehicle travels at 49 km/h and an approaching target travels at 83 km/h. The vehicles are initially 700 metres apart.

Calculate:
- a) Time taken for vehicles to meet
- b) Distance covered by the target in 4 seconds
- c) Distance apart after 10 seconds (from start)

49 km/h ------------- CRS = 132 km/h ---------------- 83 km/h
D = 700 metres.

a) $$\text{Time} = \frac{D}{S}$$

distance is given as 700 metres, speed is the CRS (converted to m/s) therefore

$$\text{Time} = \frac{700}{36.67} \qquad \text{CRS} = \frac{132}{3.6} \text{ m/s} = 36.67$$

ANSWER = 19.09 seconds

b) Distance = S x T

$$= \frac{83}{3.6} \times 4 \text{ seconds}$$

ANSWER = 92.2 metres

Part (c) requires you to calculate ***distance apart***, not the distance travelled in the 10 second period. It is therefore necessary to calculate the distance travelled by ***both vehicles*** in 10 seconds and deduct the answer from the original 700 metres distance as follows:

c) Distance apart after 10 seconds

$$= 700 - \left(\frac{132}{3.6} \times 10\right)$$

ANSWER = 333.33 metres

Speed, Time, Distance Chart

Time in Seconds										
	1	2	3	4	5	6	7	8	9	10
70	19	39	58	78	97	117	136	155	175	195
75	21	42	62	83	104	125	146	167	187	208
80	22	44	67	89	111	133	155	177	200	222
85	24	47	71	94	118	141	165	188	212	236
90	25	50	75	100	125	150	175	200	225	250
95	26	51	79	105	131	158	184	211	237	263
100	27	55	83	111	138	166	194	222	250	277
105	29	58	87	116	145	175	204	233	262	291
110	31	61	91	122	152	183	213	244	275	305
120	33	66	100	133	166	200	233	266	300	333
130	36	72	108	144	180	216	252	288	325	361
140	39	77	116	155	194	233	272	311	350	388
150	42	83	125	166	208	250	291	333	375	416
160	44	88	133	177	222	266	311	355	400	444
170	47	94	142	189	236	283	331	378	425	472
180	50	100	150	200	250	300	350	400	450	500