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Jones was found guilty of violating Section 507.2 of the Traffic Code. The sole evidence against him was the result of a radar-meter speed check. This was obtained by the red line inscribed on graph paper by a stylus actuated by the return of microwave energy bouncing off the reflective surfaces of the target vehicle into the police radar receiver. In a fraction of a second, the stylus had delineated a line-trace to a peak speed reading of 38 m.p.h. in a 30 m.p.h. zone. At the time, Jones was driving a five months' old 1955 Oldsmobile, and his speedometer was seen to read about 28 m.p.h. Three other target vehicles were within the same 175 feet radio beam at the time the instrument record was made.

The above finding, repeated many times daily in some 42 states now using some variation of the radar-speed meter, is plainly very significant and presents a number of interesting and difficult questions.

I. WHAT IS RADAR AND ITS PRACTICAL APPLICATIONS AND LIMITATIONS?

The difficult questions of admissibility, entrapment, judicial notice, hearsay, prima facie evidence, and related problems, which are thus presented will be dealt with by touching upon them either directly or impliedly as we go along. We have placed our major effort in technical explanations, for obvious reasons. We deem it a compelling necessity, instead of reciting rules of evidence, presumably known by our readers, to devote most of this presentation to piercing the barrier of specialized information that seems to have resulted in a paralysis of thought afflicting the courts, lawyers, policemen, and laymen alike, when confronted with the name "Radar". The aura of mystery surrounding this harnessed cosmic force has produced confusion and helplessness because incomplete dissemination of information has left the public with the mistaken notion that an instrument of unerring and unchallengeable accuracy is involved.

Compare the radical departure from the orthodox trial, wherein demonstration of personal integrity of the motorist and open-minded reception to argument by the court gave the motorist at least the fighting chance to rely on the truth as he saw it for upholding his presumption of innocence; as against the "new" con-

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sternation the motorist experiences when a "Radar-Cop" speed-meter, advanced to roles of an instrumental Judge, Jury, and Prosecutor, is used to dominate him and subjugate anything he might say. Whereas, all the while, it is only the too-ready police *interpretation* of the instrumental record and a mistaken aura of radar infallibility that makes up the shell of positive assertion arguing *conclusively* for the radar patrol officer.

Radar was shrouded in secrecy during World War II, and like the atom bomb, captured the imagination of the American people. This was natural because the secrecy surrounding it allowed it to be known only in terms of wondrous tales of performance in applications of military target tracking, missile guidance, strategic bombardment of enemy targets, and as an aid to ship and airplane navigation. The war-time reputation of radar has created an impression, through name alone, of such perfection in design or performance integrity, that psychologically everyone is impressed. The Courts, among others, have ascribed to it miraculous powers that never would be tolerated or given unquestioned acceptance in instruments not associated with the magic name of "Radar". Unfortunately, the attributes of the great instruments of war-time repute are not reflected in all of the civilian applications which have hitched a free ride to a great reputation. Let us illustrate:

A.—*How the Public and Courts are Misled*

In the July, 1955, issue of *Car Life Magazine* under the title *"Radar—The Silent Patrolman"* we find these statements, explaining the *principle* of operation of the radar speed-meter:

> The radar set emits signals at regular intervals. For the sake of clarity, let's assume that it sends out waves each tenth of a second . . . the transmitter (Tx) sends a beam which is reflected from the oncoming automobile back to the receiver (Rx). The set electronically records the distance from the set to the car at 89.87 feet. One tenth of a second later, another beam hits the car and bounces back and the distance then is recorded at 80.31 feet . . . Using the formula to determine speed by time over a given distance, the radar stylus is activated and moves across the paper to show a speed of 65 m.p.h To avoid hitting other objects ahead of or behind you, the beam is adjusted to operate in a narrow zone . . . If it can be used to direct shells against enemy aircraft at 30,000 feet with startling accuracy, you'd best accept our word that it can nail you for speeding.

Actually, these excerpts quite satisfactorily explain the nature of range measurement in typical military *pulse* radar used in mapping or guidance applications. But, this explanation is completely invalid when applied to police doppler radar speed-meters. Analysis of the police instrument and testimony produced under both direct and cross-examination during the Denver trials proved beyond dispute, with final acceptance on both sides, that contrary to the above-cited principles of operation, the police set (1) Does *not* emit signals at regular intervals, but continuously (that is, it is not *"pulse"* radar but *continuous wave* "doppler" radar) ; (2) Does *not* electronically record the distance from the set to the car; (3) Is *incapable* of measuring either *time* or *distance,* and therefore; (4) Does *not* determine speed by formula or otherwise from *time* and *distance* relationships; and (5) Does *not* use a narrowly adjusted beam to avoid hitting other objects ahead or behind, but uses a beam 20° *wide,* which lumps into common reception *all objects* out to a nominal distance of at least 175 feet.

Is evidence to be considered fair when derived from an instrument that has been called "radar", when the whole hitherto unchallenged concept of its operation has been so erroneous as to receive nation-wide acceptance along the lines of the above delusion?

Instead of the above principle of characteristic radar action, the police instrument operates on the entirely different principle that when a target is moving, the reflection of a radio wave impinging on its surface shifts in *frequency* from the transmitted signal, due to motion of the vehicle, and this *frequency difference* is correlated to the proportionate velocity of the reflecting surface. This opens up a very different set of requirements to be observed in instrument design to make it initially capable, and to preserve this capability, of accurately representing velocity under the diverse conditions encountered on streets and highways.

When the very *concept* of operation is so completely erroneous or, similarly, when ex-military radar "experts" having only military operational experience instead of actual *design* acquaintance, use their operational experience to endorse anything that is called "radar", we see how dangerous it is for Courts and juries to accept "police radar" on faith and opinionated testimony of apparently reputable witness instead of verifiable facts dealing with the instrument itself.

B.—*Technical Description of Radar and Evidence Thereon*

What, exactly is RADAR? The official derivation of the coined word "Radar" is that it comes from the descriptive phrase, "Radio Detection And Ranging". The same definition source [1] states that it would be more descriptive to make the phrase "radio direction-finding and ranging," for the *direction* and the *range* of objects in its field of view are the two basic qualities radar has to offer.

The police "radar" set measures *neither direction nor range* of target vehicles within its field of view and therefore does not even fit this definition of radar. Rather, it belongs to a wide category

[1] Official U. S. Government Publication: *Report on Science at War*, published by Joint Board on Scientific Information Policy for Office of Scientific Research and Development, Army and Navy Departments.

of different function instruments that have been called "Radar" simply because they happen to use a principle of reflected radio waves. This principle of itself has nothing to do with *accuracy*. Just as with any other kind of echo or reflection, the measurement may be made accurately or inaccurately, depending on the *design integrity* of the instrument used to make the measurement. There are many kinds of "Radar," and the integrity belonging to one category of design and purpose cannot arbitrarily be ascribed to all "Radars". Moreover, the vast expenditures for research and development of military radar, which in practical application requires a complex organization of highly trained personnel for proper operation, does not allow us to infer a corresponding integrity of research and development for police radar sets, compromised in design and operated as they are by relatively untrained personnel.

We must further note that the military systems are dominantly *pulse* radar, whereas the police radar instrument uses a *continuous-wave* or *c-w* system. Thousands of times as much work has gone into *pulse* radar as into *any other kind*, and the overwhelming majority of this work has been concerned with microwave-pulse radar, not continuous-wave radar. Thus, the perfection of military systems, derived from great research and development expenditures, amounting to hundreds of millions of dollars,[2] cannot arbitrarily be ascribed to the police systems of different design and different functional use.

Referring particularly to *c-w doppler radar* (which is the kind used in police sets), Reference 3 warns that quantative information is lacking on various points, even on important ones: ". . . adequate information simply is not available. This situation and others like it are the result of the fact that very little research has been done on *c-w* systems in comparison with that devoted to *pulse* systems."[3] Yet, the police system is just such a *c-w* system.

Besides lack of research in continuous-wave radars, economic and practical factors also bear on the accuracy which can be built into an instrument. For war use, national security justified production of equipment to perform a needed service without primary regard for the number of operators required or the overall *cost* of the service. In peacetime application, however, cost and inconvenience factors of use must be considered and necessary compromises of design may not be readily found, or may leave the instrument with a lower standard of accuracy and reliability.[4]

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[2] *Radar System Engineering*, Radiation Laboratory Series, Vol. 1, Pages ix, 3, and 131. Edited by Louis N. Ridenour, Professor and Dean of the Graduate College, University of Illinois, under the Radiation Laboratory, Massachusetts Institute of Technology. The twenty-eight volumes of this series are rated the outstanding technical publication in this field. Therefore, frequent references will be made herein to this series, as well as other authorities of unquestioned integrity. NOTE: Hereafter Vol. 1 of the series, entitled Radar System Engineering will be referred to as R.S.E.

[3] R.S.E., Chapter 5, Page 131. See 2, above.

[4] *Encyclopedia Americana*, 1953 Ed., Vol. 23, Page 115.

Limitations of physical *size, cost, weight,* and *engineering expediency* are all capable of influencing the design of radar in ways that will leave it without accuracy or flexibility required for unquestioned reliance thereon.[5]

For the first time in any Court, as found from a study by the defense of the comparatively few reported cases on this subject,[6] the "Radar Trials" of Denver proved indisputable existence of specific compromises in governing physical principles of operation, as applied in the police instrument. This was shown first through cross-examination of the city's own expert in the *first* trial, this trial resulting in a mis-trial when the Judge ruled he was prejudiced by false newspaper reporting when the witness was quoted as stating the instrument indicated true velocity; whereas, the witness had actually agreed, among other points, that the police radar "compounded confusion" when more than one target enters the view of the radio beam.

When, in the *second* trial, the city avoided calling back their expert witness of the first trial, the defense summoned a second expert witness from the same Research Institute as the first, who cited specific design details and world-recognized authorities in support of proof that specific compromises in design existed in the instrument, and that principles of operation were themselves compromised by manner of use. This testimony was never challenged. When some 23 limiting factors were summarized as adversely affecting the accuracy of the police radar sets, the city attorney affirmed to the Judge that he *accepted* testimony as to the existence of these limiting factors, in principle.

Moreover, no challenge was made against the defense expert's quoted authority (cited later in this paper) that it is not *possible* to determine whether an observed radar indication is in fact due to radar signal or noise, or even to determine the *probability* that it is signal and not noise, without duplicating the complete and innumerable circumstances attendant *to each condition of observation* in controlled tests.

This controlled scientific test would require re-constructing the entire roadway, reproducing all the conditions of radio-wave reflection from still and moving objects, re-establishing identical placement and movement of all vehicles in the traffic situation at the precise moment the recording was made, and comparing the recorded instrument velocity with the true velicity established by independent means, in completely controlled observations. Yet, this impracticable if not impossible condition is the burden of proof implicitly placed on the *motorist* when a Judge rules that an acquittal would require that the instrument be proven in ex-

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[5] *The Journal of Architecture, Engineering, and Industry,* Vol. 9 (1948), Page 12, by Frederick E. Brooks, Jr., Professor of Engineering, University of Texas.

[6] *Traffic Digest and Review,* Traffic Institute, Northwestern University, February, 1954.

cessive *error* at the particular *time, place,* and *circumstance* of each alleged violation.

Notwithstanding this burden of proof that would be placed on the motorist, when a defense expert witness appealed to the manufacturer for test information deemed by the latter to establish the claimed 2 m.p.h. accuracy of the police-radar instrument, his request was denied. Nor has anybody else disclosed any controlled laboratory measurements to support the claimed accuracy limits of the instrument.

On the other hand, similarly being in no position to re-construct the circumstances of past events in controlled tests, the city's expert in the Denver trials had only to testify from what was "told to him" by others, less trained in electronics than he, as to the "circumstances" under which the speed checks were made, "how" the sets were operated, "what" they "understood" happened, and his own "understanding" of operation as derived from a manual of operations provided by the manufacturer of the set.

This is a serious hearsay problem, particularly since, as we shall expand on later, it is the nature of radar that no expert can testify, even from personal knowledge, that field and laboratory tests of a police radar set made at one time and circumstance necessarily mean that at a different *time* and *circumstance* of alleged violation the instrument reliably checked the speed of a motorist. For an instrument of such caracteristics, it is clearly unscientific and inadmissible to permit the conclusion that because a police radar set—not necessarily the one used in checking the violation—was found reliable under ideal laboratory conditions and circumstances, it can be "assumed" to accurately reflect the actual situation at issue. Even less admissible is expert opinion which accepts unquestioningly the non-disinterested "word" of a manual of operations, written by the *manufacturer* of the equipment, and devoid of the necessary supporting scientific data for proper evaluation. Obviously, the asserter of a fact is not in the equivalent position of the person in actual possession of the fact asserted, because in the absence of the person with actual knowledge and personal experience thereof, he cannot be cross-examined as to the grounds for the fact asserted nor his qualifications to make it.[7]

C.—*Police Doppler Radar Set*

Perhaps the most vital fact that would have to be established in Court before it could properly be decided that a given police radar instrument is in fact accurate is that the short-time frequency stability of the instrument lies within proper limits. The reason for this is that the police type of instrument determines vehicular velocity by the frequency shift the motion of the vehicle causes in the transmitted wave, and anything that causes the transmitted beam *itself* to shift in frequency will result in a velocity indication

[7] Ingles v. People, 90 Colo. 51, 6 P. 2d 455; Carter v. People, 119 Colo. 342, 204 P. 2d 147.

just as surely as the doppler shift produced by a moving target vehicle. Likewise, any given vehicular velocity that is checked may be registered in excess of its true speed by an amount proportional to such frequency shift. No proper short-term frequency stability has been established in Court for the police instrument.

Moreover, substitute reliance upon a statement in the "Operating and Maintenance Manual" for the police radar set will mislead both the Courts and the police. This manual states:

> The transmitter oscillator has a high inherent frequency stability on the order of plus or minus 0.1%. If the frequency were to try to shift out of this range due to any changes in tube characteristics, etc., the cavity stability is such that it would render the oscillator inoperative. In practice, the oscillator is adjusted to within 1 megacycle of 2455 megacycles.

Indeed, in the Denver trials, the City cited laboratory test as confirmation of instrument compliance to these frequency limits, with implication that instrumental accuracy was confirmed thereby.

Since doppler radar speed indication accuracy is, indeed, dependent on frequency stability, the cited statement is readily seized upon by prosecution witnesses to impress the Court as a 0.1% accuracy specification; but in reality the statement connotes no such accuracy confirmation. What *does* this statement mean, insofar as any connection with instrumental accuracy of *velocity indication* is concerned? 0.1% of the 2.455 megacycles per second transmission frequency of the police instrument is 2,455 megacycles or 2.455.000 cycles. Now, when we recall that, in accordance with a verifiable figure cited elsewhere in the instruction book, each 7.31 cycles of doppler frequency shift corresponds to 1 m.p.h. velocity indication, we see that anything so gross as 0.1% stability is no error restriction at all, for a mere 731 cycles of short-term shift out of the total leeway of 2,455,000 cycles allowed by 0.1% frequency stability would alone correspond to *error* equal to the entire 100 m.p.h. velocity range of the instrument.

In reality, an accuracy as crude as plus or minus 1 m.p.h. would require a short-term frequency stability of 7.31/2,455,000,000 or 0.000,000, 3%, not 0.1%. Thus, we see that a frequency stability guarantee of the order of plus or minus 0.1% does not begin to approach the order of stability required to connote accuracy of *velocity* indication, missing such factor by the order of 300,000 times. The 0.1% figure in reality only connotes conformance to channel frequency assignment, which is an altogether different matter.

Independent authority is cited which affirms the importance of short term stability in doppler radar and sets an even higher frequency stability requirement for military use.[8] Attention is also directed to requirements for careful (design) attention to microphonics and power-supply filtering. We shall show later that police radar sets are *in fact* susceptible to microphonics. We also report, at this point, that a check-up with a major radio parts supply house revealed a demand in great quantities for the replacement of transmitter oscillator tubes for police radar sets because of the rapid rate at which such tubes deteriorate due to overheating. Variation in temperature is the most common cause of frequency instability in all electronics equipment and its consequences in a police radar set may be readily inferred from the above computations.

Upon examination of a police radar set one of the first things to catch trained eyes is the instrument's use of a single antenna for both transmission and reception of the radar waves. While this is common and proper practice in military *pulse* radar, where time multiplexing allows distinctive reception to take place *between* transmission *pulses*, the situation is entirely different in *continuous wave* radar of the police type. In the police instrument, transmission and reception of signal energy is not separated by pulse spaces, but takes place *simultaneously* through the same antenna. To use a single antenna under this condition is hazardous design practice because direct connection of the receiver detector with the transmitter power source tends to damage the crystal detector of the receiver, and makes it respond to extraneous modulation of the transmitter along with the difference frequency that corresponds to vehicular velocity. Exceptional design attention, not found in the police radar set, is required to render this modulation unobtrusive to the very weak reflected radar signal.[9]

In a police radar set, the simultaneous antenna function is accomplished by use of a bridge-like ring modulator of the type used, under different conditions, in telephone repeaters. However, this has been found to be hazardous design practice in a doppler system because it tends to introduce microphonic error. Use of two *separate* antennas, on the other hand, keeps the transmitter power modulation out of the receiver and avoids this trouble.[10]

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[8] R.S.E., Page 138. Under *Apparatus Considerations* for the simple doppler system, it is stated: "The most important consideration in doppler work is keeping the transmitter frequency modulation down . . . it should be noted here that short-time frequency stabilities of the order of a part in 10^{10} must be attained if the system is to work with full sensitivity in the presence of ground clutter. This requires careful attention to microphonics and to power-supply filtering." (Note that one part in 10^{10} is one part in ten billion or 0.000,000,01%.)

[9] R.S.E., Pages 132-3.

[10] *Id.*, Page 133. "It has often been suggested that a single antenna would be satisfactory if a bridge-like system were used similar to that used in two-way telephone repeaters. Ordinarily, however, the single antenna is not satisfactory. For one thing, the increased antenna gain resulting from greater available dish area is lost because of the power used in the 'artificial' antenna which balances the real one. More important, since very slight mechanical changes will spoil a 60-db balance between two equal voltages, such bridge systems tend to be highly microphonic."

Microphonic error susceptibility does, in fact, exist in the police radar set. This is easily demonstrated by striking a rod or surface in the proximity of the instrument. The mechanical vibrations alone will cause the instrument to respond with corresponding miles per hour indications just as surely as to a moving target vehicle within its radio range.

No further confirmation of this police radar design susceptibility to outside error sources is needed than the fact that the manufacturer has supplied musicians' type *tuning forks* for making quick checks on the meter calibration. Struck so as to produce only a barely perceptible hum or musical pitch, the tuning fork, when held a short distance in front of the instrument, will produce actual observable velocity indications on the meter corresponding to 50 m.p.h. or other calibration value, depending on the mechanical vibration *frequency* (not velocity as such), just as truly as though a traffic vehicle were approaching at high speed. Once this susceptibility (technically due to instrumental leakage modulation) is established, *the meter is known to be susceptible to erratic indication since it responds to other sources than car velocity.* The closing of the police car door, adjustment of the trunk lid, or the microphonism of the police radio, can send the meter shooting up to velocities exceeding the speed limit.

Moreover, while a doppler design might ordinarily be arranged to filter out very low and very high extraneous modulation frequencies, *any modulation at a frequency corresponding to the doppler frequency of the moving targets for which the system is designed cannot be filtered out without removing the desired target signal also.*[11]

Since the police instrument is required to cover a velocity range of zero to 100 m.p.h., it must remain responsive over the corresponding frequency range, so low frequency sources of disturbance from *at least* 0 to 731 cycles per second, as well as high frequency disturbances having any harmonic or modulation acceptance by the input circuit cannot be excluded from the system.

Amplitude modulation of the direct leakage signal from transmitter to receiver may be caused by power-supply hum, microphonics, fluctuation noise, intermittent contacts, etc. Barlow[12] computes that in a typical doppler system the modulation coefficient of the leakage carrier should be held to less than 4 parts in one million, and notes:

> This is an extremely difficult requirement to meet and necessitates extreme care in eliminating hum and microphonics. Voltage-regulated power supplies, shock-mounting, and acoustic shielding are needed. Care must be taken with the cooling of the transmitter output tube

[11] "Doppler Radar" by Edward J. Barlow, Sperry Gyroscope Company, *Proceedings of the Institute of Radio Engineers*, April, 1949, Page 352.

[12] *Proceedings of the Institute of Radio Engineers*, April, 1949.

to prevent an impinging air or water blast from introducing microphonics in the output.

The tube replacement problem in police radar sets, caused by overheating, has already been cited. Moreover, the police instrument exhibited in the Denver trials had no acoustic shielding and no anti-microphonism type of shock-mounting. While the instruction book indicated a tripod was initially available, which allowed the instrument to be set up outside the police car, such a tripod was not being used by the police, and mounting in the car made the instrument susceptible to vehicular vibrations. With respect to power supply, it is noted that the *Operating and Maintenance Instruction Manual* itself, under Paragraph 8, *Calibration and Test* states:

> Tube V208 in the output circuit relies on the balanced operation of its two sections for zero stability with respect to power input. The test for zero stability is made by varying the input line voltage between the limits of 105 and 125 volts. A tube should be selected which has less than 2 m.p.h. change of the zero reading over this range of input line voltage.

Thus, a leeway of 2 m.p.h. is accountable in this one tube alone with varying line supply voltage. The error leeway when operated from a continuously draining battery supply is not stated.

Another limiting factor of design in doppler radar instruments of the police type is receiver crystal noise, which noise operates to limit the signal sensitivity. This crystal noise increases with decreasing frequency and is enormous compared to thermal noise for *audio* frequencies, which includes the doppler frequency range from 0 to 731 cycles per second. To avoid this excess noise, normal good design practice is to introduce a local oscillator and amplify the signal at some normal intermediate frequency, 30 Mc/sec for example. At this higher frequency the excess noise is made negligible.[13]

The police instrument uses such a receiver crystal, but does *not* use a local oscillator to reduce the noise from the enormous proportion that occurs at low frequency. To obtain a quantitative indication of what this noise increase will be, we note that measurements made at the University of Pennsylvania, of the noise temperature in the video- and audio-frequency range, show that the noise temperature of a crystal converter increases as 1/f in the doppler range.[14] Taking the ratio of the cited 30 Mc (30 million cycles), where a local oscillator would be provided, to 219 cps (the latter being the doppler frequency corresponding to 30 miles per hour), by way of example, we obtain a ratio of possible in-

[13] R.S.E., Page 133.

[14] *Radiation Laboratory Series*, Vol. 16, "Microwave Mixers," Page 95.

crease in the crystal noise temperature of more than one hundred thousand times, as a result of the design omission of the local ascillator in the police instrument.

D.—*Propriety of Application*

Let us turn to the *propriety* of application of the doppler radar instrument in the police mode of use, both with regard to manufacturers' recommendations, and practices that have been adopted by the police.

First, let us note that, within certain limits of approved application, we raise no question about the accuracy that *can* be built into a doppler c-w radar system, any more than any other radar system, where there is no limit to effort and expense to overcome design deficiencies. Nevertheless, even then, it must be recognized that many of the precise measurements that may be cited for radar instruments, including doppler radar in military fields of use, depend not only on optimum *design* but *averaging processes* or highly complex mathematical computations applied after reading the radar indication, in order to obtain the high order of accuracy that may be credited to the instrument.

No such correction factors are applied to the police instrument because the instrument is not designed to register with such accuracy that mathematical correction would be practical or significant. The instrument, to begin with, does not even have a manufacturer's represented accuracy under plus or minus 2 m.p.h., notwithstanding the fact that police do not hesitate to read the instrument to a precise miles per hour without any expressed tolerance.

How does the police mode of application compare with authoritatively recognized limitations of radar? Radiation Laboratories sources state:

> Even the most advanced radar equipment can only show the gross outlines of a large object, such as a ship . . . Because of this grossness of radar vision, the objects that can usefully be seen by radar are not as numerous as the objects that can be distinguished by the eye. Radar is at its best in dealing with isolated targets in a relatively featureless background, such as aircraft in the air, ships on the open sea, island and coastlines, cities in a plain, and the like.[15]

The significance of this limitation of even the most advanced radar becomes pointed when compared with police use wherein radar patrol officers testify to using the recorded graph of the instrument to single out target vehicles traveling in common view with other cars in multi-lane traffic on the arterials and city streets —amid the most complicated and varying background of *clutter*

[15] R.S.E., Page 1.

one could imagine. Using equipment compromised in design to begin with, the police application is extended to areas not sanctioned in military equipment for the most advanced designs!

One commercial and military application of radar that has been cited in court in support of the police instrument, because of similar use of continuous wave (c-w) instead of pulse transmission, is the radar altimeter used in airplanes. But, this is completely invalid comparison because of the difference in conditions prevailing. In the case of the plane altimeter, there is but one target below the plane, namely the earth, and there is no other object in all the space between. This conforms to the proper conditions cited by Reference 15. Moreover, observations are made 100 times per second in typical radar altimeters, *to permit reduction of errors by averaging.*[16]

These are completely non-comparable circumstances to the street or highway speed radar where the target motor vehicle may typically lie in the same radar beam with utility poles, trees, sidewalk curbs, buildings, reflective pavements, and other vehicles, both stationary and moving. Moreover, the target *motor vehicle* not only has continually varying *distance* to the instrument but also continuous change in aspect *angle,* which produces a different velocity correspondence with each change of angle as the car passes to the side of the instrument. The reading therefore constantly *changes* instead of gaining emphasis through *coherence* or *averaging* of a relatively constant signal. This is so because the police *doppler* set responds to a *radial* velocity measured along lines between the target vehicle and the doppler instrument, off to one side; whereas, the velocity of *interest* is the true velocity of the car in its own direction down the street.

It is obvious from the above, and will be further established later in this paper, that besides being deficient in design, some of the fundamental areas in which police doppler radar cannot be given free sanction in *principle* and *physical* law include the very street situations in which they are being used. Accordingly, like the lie detector, such instruments must be deemed questionable as to admissibility as evidence. Since a trustworthy scientific basis is not adequately established for the police doppler speed-check, as presently constructed and operated, to otherwise justify the admission of results, such checks are not substantive evidence of anything.[17]

However, there are many *more* points that disprove propriety of application. Under cross-examination, a typical radar patrol

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[16] R.S.E., Page 132.

[17] CONTRA, People v. Kitz, 129 N.Y.S. 2d 8 (1954); People v. Sarver, 129 N.Y.S. 2d 9 (1954); People v. Buck, 130 N.Y.S. 2d 354 (1954); State v. Dantonio, 105 A. 2d 918 (1954). But none of these cases is a Supreme Court decision, and in none of them was the evidence presented as herein outlined. All of them hold that such evidence, although admissible (provided the proper foundational requirements are met) is not conclusive, and the jury must determine its weight.

officer, fortified by his meager knowledge of radar, testified unequivocally that it is common practice to use the police radar set in multi-car and multi-lane traffic, and that offending cars traveling in groups of three are *unerringly* picked out! This would require, through a species of mental process, almost instantaneous interpretations of recorded graphs to reach such deductions in time to warn the arresting officer, read and assign license numbers to different inflections on a common graph recording, and *to ascribe accurate identification of the particular offending car*—all predicated on the instrument's ability to even make such distinction. At 40 m.p.h., a car enters and leaves the effective radar beam in the space of about 2 seconds.

Obviously, to establish such distinction of cars without question, in a very short time, requires that such instrument perform not only with almost absolute integrity, but that the governing principles allow such capability in the manner of application. This is, of course, if the stimuli-response processes of the officer himself are also at the same time operating with unerring efficiency.

Not even the instruction manual for such instruments gives unequivocal support to the radar officer's claimed ability to interpret the instrument record. Under the heading *Operation,* it is stated:

> When there are a group of vehicles within the operating range, and speed meter reads the speed of only one vehicle at a time. Among the factors determining the *selection* of a particular vehicle are its *speed, target area,* and *nearness* to the transmitter-receiver. In single lane approaches, the speed meter will *ordinarily* read the *nearest* vehicle. However, on a multi-lane highway, where a vehicle on one lane is traveling appreciably faster and passing a vehicle in an adjacent lane, this *faster* vehicle will be read on the meter, and also can be easily identified by the observer. The *increased sensitivity* to higher speeds is due to the speed meter being designed with a larger zone of operation for higher speed vehicles than for lower speeds. The stated range of the unit actually corresponds to speed of *40 to 50 miles per hour.* The operating zone is made sufficient for the needle of the indicator to reach its full value. (Emphasis ours)

Even this partial instruction book sanction to the aforesaid practices states that in single lane approaches the speed meter will only *ordinarily* read the nearest vehicle; because the *selection* of the offending car also depends on speed, target area, zone of operation, and whether or not the speed is in the range of 40 to 50 miles per hour. Since the word *ordinarily* carries its own refutation as to constancy, it is an admission the speed meter does NOT always read the nearest vehicle. Actually, as will be shown later in this paper, the instruction book statement also does not adequately limit the true capabilities of the instrument.

Radar itself, even in its most efficient military application, is challengeable. The essentiality of complete integrity of instrument performance simply does not exist, such that any human can be unerringly certain of his deductions therefrom. Even if Courts should overlook the limitations of human capabilities in such situations, the principles of radar science show that outside influences (unless removed under rigidly controlled situations) dominate weaknesses in radar principles and cause erratic responses. Such weaknesses of radar are in fact exploited in the military science called *Radar Countermeasures,* whose primary *objective* is to cause enemy radar units to respond erratically.

E.—*The Achilles' Heel of Radar*

"The Achilles' Heel of Radar"[18] is a point of fundamental weakness in the radar principle. This weakness is manifest in the fact that the reflected "echo" energy coming back from a target is so small a fraction of the directly transmitted radar wave, that a host of extraneous *outside* sources of energy impinging *directly* (not as an echo) upon the radar receiver, may easily *exceed* the small radar "echo" energy corresponding to the intended target.

Associated with this echo sensitivity weakness is the fact that such instruments cannot distinguish the nature of small targets. One small object, capable of returning an echo, looks to the radar just about the same as another. To a radar, an airplane or a ship is a small object. It has been found that a number of thin metallic strips, cut to a proportional length to the wave length used by a radar, can return a remarkedly strong echo to that equipment.[19]

To fully appreciate the significance of the outside influence factor in the police instrument, it should be realized that the maximum rated out-going *signal power* from a typical police instrument is only two-tenths of *one watt;* and that only a minute fraction of even this small signal, measured in microvolts (millionths of 1 volt) comes back as the echo reflection from which the velocity is derived.

This vulnerability to outside influences is inherent to basic radar principles and can be alleviated only to limited degree by express intricate design complication for each known source. In civilian, as well as military use, outside noise influences may well be capable of dominating the response under conditions when there is not deliberate man-contrived exploitation, but only innocent noise or interference sources arising from common everyday surroundings.

This basic vulnerability is acknowledged in the instruction

[18] *Electronics Warfare, Report on Radar Countermeasures,* Joint Board on Scientific Information Policy, Office of Scientific Research and Development, United States Government Publication.

[19] *Id.*

manual for the police radar instrument. This manual cites conditions causing erratic zero of the indicator, as follows:

> 1. Movement of objects such as tree limbs, etc., in the field of the transmitter may produce enough signal to prevent a clean zero. 2. Neon or fluorescent lights in the field of the transmitter appear as moving targets, and may produce an unsteady zero. 3. A worn or hashy vibrator (K301) in the power supply may generate noise in the equipment or cause shifts of 2 or 3 m.p.h in the instrument zero. 4. In some cases the output of the 2C40 tube (V-101) may increase after the unit has been used for a few months. This condition causes too close coupling of the transmitter cavity to the transmitter antenna and appears as excess noise which may indicate on the meter.

It might be inferred from these instructions that disturbance may occur *only* near zero indication. This would be an erroneous assumption, however. The zero point merely happens to be the only point where the indication may be *checked* directly.

Nor does checking at zero give any assurance that the instrument is not susceptible to error from the same causes at a higher velocity indication. For, a direct correspondence does not exist to assure corresponding correction at higher traffic velocities where the instrument is *more sensitive!* The manual states: "The increased sensitivity to higher speeds is due to the speed meter being designed with a larger zone of operation for higher speed vehicles than for lower speeds. The stated range of the unit actually corresponds to speeds of 40 to 50 miles per hour." Also, under *Theory of Operation* it is stated that the circuitry is designed to prevent operation until a reasonable signal level is reached. Therefore, the extraneous noise sources may never be manifest at zero, *but only at a higher velocity indication when the indicator is activated by a passing vehicle*, or when the noise corresponds to *higher* and more *sensitive* velocity registration.

Likewise, the possible *noise error* is not restricted to so little as 2 or 3 m.p.h. For, the responsivity of the instrument to velocity is not primarily due to *strength* of returned signal, but rather to the *frequency* of signal from whatever source that is sufficiently strong to actuate the instrument. Extraneous noise can just as easily have a frequency correspondence to 50 m.p.h. as to 2 m.p.h. —more so, in fact, because the instrument is more sensitive to frequencies corresponding to the higher traffic velocities. Indeed, under the instrument's own theory of operation, a velocity of 1 m.p.h. will be derived for each 7.31 cycles per second of doppler frequency. This means that 60 cycle disturbances would correspond to 8.2 m.p.h. Noises arising from various other sources may have frequency correspondence up to the full 100 m.p.h indication of the instrument and cause *velocity errors of 100% or* *more.* Yet, for a given tire inflation, a *speedometer* can be set and guaranteed to accuracy within 3% or better.

Who can know, except under controlled conditions for any given traffic situation, whether the speed indication was due solely to the returned signal from the target vehicle, or extraneous noises, or a combination of both? The factor of sensitivity to noise factors, particularly at higher velocity correspondence, makes it highly questionable whether *any* expert may properly testify in Court that, because his check of the instrument might have showed it to be reasonbaly accurate under certain test circumstances, it also accurately read the speed of the motorist at the time and circumstances in issue and NOT a velocity indication boosted by other causes.

Like the tuning fork, the simultaneous operation of the *police radio* during the speed check can cause an instrumental velocity indication without ever a car passing. Under cross-examination, radar patrol officers acknowledged this to be a fact. Independent tests established that this indication could be 45 m.p.h., or virtually any velocity, depending on the microphonic conditions of the radio.

In spite of this fact, standard operating procedure is for the operator of the radar car to transmit observed speed information *by radio* to another officer in an interceptor car up the street, who makes the arrest—and, note, not on what the arresting officer has himself observed, but on information radioed to him by the radar officer whose radio at the same moment of the transmission of such intelligence may have contributed to or caused the velocity indication of the "offending" target vehicle.

Besides the matter of instrumental error involved, this manner of operation not only again brings up the serious problem of hearsay, based on possible and probable misinterpretation of the true cause of velocity indication, but a *peak speed indication obtained in a fraction of a second, is not necessarily an indication of the sustained careless or willful speeding which the traffic ordinances contemplate.*

Even the shaking of a pocket ring of keys in relative proximate view of the instrument can cause recordings of, say 40 m.p.h. without ever the necessity of a reflected echo from a vehicle. The less the range from instrument to noise source, the less need be the power of the noise to over-ride or affect the very small signal echo from a vehicle, other conditions being equal. In this connection, let us bear in mind that the radar beam, shaped like a dew drop, is *not* confined within the specific area of a single target vehicle, but embraces an area extending from the instrument to sidewalks and other lanes of travel.

The police instrument is claimed to be effective within a cone of approximately 20° throughout a range of 175 feet. This range is based on the *expectancy* of an adequately strong reflected signal from the target vehicle's surfaces. But, *extraneous* noise sources —replete in city streets—may operate not only in the area of the beam, but from greater distances where, with the greater power radiated by commercial stations or amateur transmitters (for example) they may be capable of actuating the radar instrument.

In none of the previous cases reported, nor in the case tried in Denver, was any testimony presented to prove that in selecting the speed-trap location, as part of a check-up of instrument accuracy, the police made any attempt to exclude such extraneous influences.

By way of illustration of the mechanism or error introduction, the instrument may be in the process of recording the velocity of a target vehicle at a distance of 150 feet, while *noise* emanating from a slow-speed jalopy within 10 feet of the radar car, or noise from microphonism in the radar car itself, or interference from a transmitter not far from the radar trap, may, in fact, be partially or wholly responsible for the maximum velocity recorded. Requiring the composite additional reflected energy from the vehicle to trigger the instrument above normal zero indication, the recorded graph could rise from zero with the approach of the vehicle and have all the attributes of a normal curve while, in fact, influenced by the extraneous noise source.

F.—*The Radar Equation Factors*

It should be observed at this point that for an expert to *properly evaluate* the police instrument and understand the radar principle involved he should know, not only the mathematics, but, also, the significance of *The Radar Equation.* Otherwise, like the radar police officer, it would be like qualifying the *nurse* that took the x-rays to testify thereon in place of the *doctor.*

The reflected radar energy is not determined merely by physical area of the target, but by the *effective* area and many other factors.[20] Like light waves, very short radar waves are not reflected evenly from curved and irregular surfaces. Most of the energy is reflected at glancing angles in hemispherical directions, with only small portions of energy reflected squarely back into the little box-like instrument from which they were transmitted. Even among the rays that are reflected in the right direction, interference takes place because of different distances traveled. Further complication takes place because of the fact that some rays travel directly to the target, in this case the automobile, while other rays follow reflected paths from the pavement.

Under these conditions of extremely weak and varying echo signal, seemingly insignificant objects may become major sources of instrument response. In much the same way that a metal rod constituting a car radio aerial is a better receptor than the whole surface of a car, so also a resonant rod only about 2½ inches long corresponds to a half-wave length at the transmitter frequency of 2455 Mc for this radar instrument. There are many possible vibrat-

[20] R.S.E., Pages 18-22.

ing accessories which could be resonant or inordinately responsive in their influence on the meter. Radio antennas and tire chains are examples.

The example of a car wheel, say a spoked wheel, will illustrate the complexity of the situation. It is a principle of mechanics that the top of a rolling wheel travels at twice the velocity as the axle which corresponds to the forward vehicular speed. The bottom of a wheel momentarily has zero velocity, but lies in an insensitive part of the beam. The succession of flashing spokes at the top region of the wheel, enhanced by being at the approximate height of beam center and passing through angles of perfect reflection as the car approaches the radar set, can become excellent radar signal reflectors. Now, remembering the radar instrument manual's statement that the instrument has *greater sensitivity to higher velocities,* we see that under certain conditions of reflection the higher speed of the upper wheel surfaces can produce a velocity indication in excess of the automobile's true forward speed. Indeed, since the top of the wheel does, *in fact,* travel at twice the linear velocity of the car itself, one might properly question the radar's accuracy if it *failed* to read the higher velocity.

The fact that an automobile has many flat surfaces, some of which might be *assumed* surely to be square with the radar antenna, does not necessarily decide the issue. This is affirmed by Reference 21 which states under the heading *Properties of Radar Targets:*

> Strong specular reflection will result whenever a flat surface happens to be oriented normal to the line of sight; yet the mere presence of flat surfaces is not enough to guarantee a strong reflection. If these surfaces were oriented in random directions, the probability of finding one at just the right orientation would be so low that the average signal from such a group of flat surfaces would be no stronger than the average signal from a collection of isotropic scatterers filling about the same volume.[21]

While no analyses of actual reflection conditions off the complex contours of an automobile are known to have been made, in the thorough manner in which aircraft have been studied, authorities have shown the extreme *variation* of reflected energy with change of aspect angle of airplane surfaces, not unlike those of an automobile. Reflected energy was found to vary as much as 3000 times in power as the aspect angle was changed, with changes of as much as 15 db (about 31 times) for changes as little as ⅓ degree in aspect angle.[22]

A car is an equally complex target, with wheels, fenders, curved and sharp surfaces, aerials, and other accessories; and the

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[21] R.S.E., Chapter 3, Pages 100-101.

[22] *Id.*, Pages 21 and 75-81.

aspect angle relative to the police instrument is necessarily constantly *changing* because motorists pass to the side from front to back or vice versa, not precisely toward or away from the radar instrument.

Bearing in mind the words of the Denver trials' judge who stated that if just one person were convicted unjustly by the evidence of the police instrument, that would be one too many, the question any fair appraiser of the equipment should like to have answered is: How great must noise be to dominate the velocity reading, and how can one know when an accurate reading is rendered?

Our best hope of answer to this question would come from a highly involved computation using all the factors of The Radar Equation. Unfortunately, as applied to the *c-w type* of radar used in the police instrument, *the necessary information to fully determine this question is not completely known to science.*[23]

The difficult nature of the signal versus noise indication is authoritatively discussed in References 24 and 25, and the below-noted quotations should be read for an appreciation of this problem. The reader of these statements could scarcely give credence to any "expert" witness who glibly testifies that an equipment is "accurate" without benefit of scientific data.

Under the circumstances of authoritatively stated limitations of known knowledge of c-w radar signal-to-noise relationships, there is, indeed, much greater justification for challenging any claimed accuracy for the instrument, whatever the figure, than to place the burden of proof that the instrument is in error on the motorist.

G.—*Identification of Multiple Targets*

Let us now look at some further limitations of the police instrument, which cannot be disregarded in application. Possessing only a single beam-width antenna, there is nothing in the radar

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[23] R.S.E., Page 131.

[24] R.S.E., Page 35, under the heading The Statistical Problem: "Let us summarize what we *do* know, once we are provided with the overall noise figure, and band width of the receiver, the transmitted power, *and the geometrical factors in the radar equation which concern the antenna and the target.* We know the ratio of the amplified signal power to the average value of the amplified noise power. We are *not* yet able to say how large this ratio must be before the signal can be identified with reasonable certainty. The root of the difficulty is that we have to do with a statistical problem, *a game of chance.* The answers must be given as probabilities, and will depend upon many features of the system by which the signal is presented to the observer, as well as upon the precise description of the 'reasonable certainty' mentioned above." (Emphasis ours.)

[25] *Id.*, Page 37. "One can *never* be *absolutely* sure that any observed peak is not due to a chance noise fluctuation, and one cannot even say how *probable* it is that the peak is not due to noise, unless one knows how probable it is, *a priori*, that the peak is due to something else—namely, signal plus noise. Knowledge of *a priori* probability of the presence of signal is possible in controlled experiments such as those described in Volume 24, Chapter 8." (See also page 131, paragraph 3.)

principles of the police instrument to distinguish one traffic lane from another, and there is nothing in the graphical record of the instrument recorder to identify either traffic lanes or separate cars within lanes. Any such indication on the tape record presented in Court is only as ascribed by the radar *operator*. When multiple cars are in a common field of view, the instrument record is a *composite* curve affected to some degree by all the cars, and it is malevolent for an officer to ascribe a velocity peak on this composite indication to any *one* of the cars involved. An officer may think he is justified in doing this when he sees in the "steps" of the curve a semblance to the order of entry of cars into the beam, but the *velocity measurement* is *invalid* under this composite condition.

Moreover, in simple doppler radar of this type, no other identifying information of the target is revealed by the instrument than *radial* velocity and even this cannot be resolved for multiple target vehicles when there is no discriminating antenna or separate indicator response channels in the instrument.

The characteristic indistinguishability of radar target information, alike for both c-w and pulse radar, is authoritatively discussed in Reference 26, as quoted below. As noted, when (as in the police instrument) the radar beam is *not* considerably smaller in cross section than the individual objects viewed, there can be no identification or distinction of targets by shape or otherwise.

Keeping in mind the complicated nature of *reflection* we have discussed herein, it is presumptuous, indeed, for a radar patrôl officer to interpret multiple inflections of radar graphs, and ascribe these inflections to particular cars, all in the 2 seconds of time that it takes cars to travel through the beam at 40 m.p.h., while at the same time he must identify the target vehicle and its license number—*and no instrument capability exists for resolving multiple targets.*

H.—*Operation of Police Radar Sets*

In operation, the police radar transmitter-receiver unit is set up near the edge of the street. The set is mounted either in the

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[26] R.S.E., Page 126. "The reader may well ask whether a phenomenon has been overlooked which could be used to distinguish some targets from others. There appears to be no possibility for such a phenomenon in the elementary process of reflection of electromagnetic waves from inhomogeneities in the medium through which they travel. A returning wave is characterized by *frequency* (including *phase*), intensity, and polarization. If two targets within the radar beam—for example, a telephone pole and a stationary man—produce echoes similar in the respects listed, they are utterly indistinguishable, as much as we might prefer to label one clutter and the other the true target. Such echoes may very well be identical in the respects listed since no significant difference exists at these frequencies between the electromagnetic properties of a man and those of a piece of wood. To put it another way, the dimension of 'color' is not available because the radar cross section of most objects varies in no systematic way with frequency. Distinction by shape, on the other hand, is possible only when the radar beam is considerably smaller in cross section than the object viewed."

trunk of the police car or on the left rear fender, directly facing traffic approaching from the rear. A radio wave is sent out over an area of almost the width of the street and for a distance of about 175 feet. As a target vehicle passes through that operating zone, an indicated speed is read directly on the meter and graph. The operator of the radar car observes the license number and make of car and radios this information to a second car parked several blocks or more ahead. The second car, often referred to as the interceptor car, stops the motorist and issues a warning or ticket.

Since the radar officer sits in his car with his back to oncoming traffic, he must perform the multiple function of operating and watching both the graph and meter in front of him on the dash board of his car and simultaneously observe oncoming cars *through the rear-view mirror.* The license numbers of over 50 feet are extremely difficult to read, and, moreover, *appear backwards from right to left in the mirror.* By actual test, it takes more than five seconds to read numbers in motion, for the ordinary individual not trained to read backwards; whereas, the approaching vehicle is typically in the beam only 2 seconds.

It is only *after* the motorist comes up from the rear into view ahead of the radar car, *after the instrument record has been made,* that the officer reverses his field of vision from mirror to direct view of the *now* rear end of the passing car, that the license numbers appear in true sequence—if time and traffic even then permits reading. If a second observer is used, sitting on the other side of the car, he has an even more restricted view of traffic.

To comprehend the difficulty of this observation, one may well test himself with reading from street side the license numbers of any 40 m.p.h. or faster car passing from the rear, or from the front for that matter, without having anything else to note than the license numbers.

Actually, doppler radar theory (the police instrument kind of radar) does not sanction such use of simple continuous wave doppler radar where multiple moving targets are involved.

> *The doppler system can handle only one target at a time, or roughly one target per beam-width for a scanning system. By contrast, a high-resolution pulse system has something like 1,000 separate range elements, and hence can handle many targets per beam-width.*[27] (Emphasis ours)

That is, the police instrument is not the right kind of radar to deal with conditions of multiple targets, such attributes belonging to high-resolution *pulse* systems. Further, in the simple doppler system, approaching and receding targets are indistinguishable, insofar as both produce the same doppler frequency.[27]

[27] *Doppler Radar*, Proceedings, Institute of Radio Engineer (1949), Page 345, by Edward J. Barlow.

The police instrument is not a scanning system, and the antenna has only one relatively broad beam-width, about 20° wide, utterly unable to discriminate between targets in an area out to the instrument range of 175 feet. All reflected radar energy from the entire conical area of this beam joins energy from noise and vibration sources, including that conveyed through microphonism in directions outside the beam, and enters the instrument in unresolved catch-all packs of energy. Since the instrument must remain responsive to all doppler frequencies corresponding to velocities from 0 to 100 m.p.h., in accordance with its stated capabilities, it cannot select with positive discrimination any separate velocities corresponding to different targets without having separate channels of registration.[28] Merely providing for different *sensitivity* of response amid all the other conflicting factors affecting the radar transmission is not enough.

Considering this lack of discrimination of targets in a view 20° wide and 175 feet long, let us ask what would be the reaction of the public to use of such an instrument to single out the winner of a horse race, for example, where comparable speeds are involved, and where a *light* beam of shorter wave length than *radar* waves, impinging on a photoelectric cell, has been found deficient to the extent that a photograph must be taken besides?

The police instrument is able to resolve no such identification or target distinction in the whole field of view, and this is not the type of radar which can separate targets by discrete measured differences in range and direction... Such properties of *resolution* do belong to some of the great military and airport systems we read about; but, remember, the police instrument is *not that kind of radar.*

I.—*Accuracy of Calibration*

There is another area in which direct testimony of police radar patrol officers reveals use of their instrument beyond the limits for which doppler radar laws give sanction. Officers testify in Court that the instrument indication is checked by having another patrol car drive by the radar car, and having the driver call out the miles-per-hour reading of his *speedometer* as he passes by. It is then asserted that if the radar reading checked the speedometer exactly, the radar instrument calibration is accepted as accurate and placed in use to check other cars.

In addition to the serious departure of this method of calibration from radar laws, a serious problem of hearsay is apparent. One Court held such testimony to be inadmissible hearsay, for each officer had no first-hand knowledge of what the other officer told him. The radar officer knew only what he had heard. Since, if radar evidence is to be admissible, the testimony of officers is re-

[28] R.S.E., Page 159.

quired as to the accuracy of the radar speed meter as part of the city's case, a grave problem of proof is raised.[29]

Unfortunately for the motorist, when the instrument calibration is established in the above-described manner, the instrument will read excessively high when applied, not to a car passing almost abreast of the instrument, like the police car, but to approaching cars at distances of 125-175 feet down the street—which is the range recommended by the instrument book as the nominal range at which more typical instrument triggering of oncoming traffic record occurs.

This disparity of calibration comes about through another compromise in the police instrument; this time not a point in design, but in the theory of operation itself. Doppler radar, unlike the mapping type radars which show relationships between many points at once, as derived from different indicated *ranges* and *directions,* is only able to show velocity of a target *along a line toward itself.* Since the car passes not directly toward but at an angle to the instrument, *the measured and true velocity only become one and the same when the instrument lies in the path of the moving vehicle, which, on straight streets, would be the direction of a head-on crash, and, therefore, not realizable.*

The police instrument *Operating and Maintenance Manual* recognizes this point, but deprecates its significance somewhat arbitrarily, justifiable only under restricted circumstances of use. Having cited the doppler frequency formula, the Manual, under the heading, *Theory of Operation,* states:

> The above formula is specifically true only when the direction of movement of the target is in the same direction as the shortest distance between the Transmitter-Receiver and target. An angle between the two directions requires a cosine factor for the more general solution. The cosine of the angle, less than 10 degrees, however, yields an accuracy within 2%; this factor can, therefore, be dropped.

The arbitrary selection of a figure of 10 degrees here presumes use of the instrument at a minimum distance of approximately *57 feet,* when the instrument is placed at the 10 feet distance from the edge of the road allowed by the Operating and Maintenance Manual (i.e., tangent of 10/57 = 10°).

Yet, under *Operational and Electrical Characteristics*, the manual clearly states: "Operating Zone: Vehicle detection is effective within a cone of approximately 20° *throughout a range of 175 feet.*" (Emphasis ours).

Both direct and cross-examination testimony of the police radar patrol officers substantiated the fact that the instrument is activated at ranges of 25 to 175 feet. Use down to at least 25

[29] People v. Offerman, 204 Misc. 769, 125 N.Y.S. 2d 179.

feet was also observed by an engineer witness, and testimony has already been cited wherein radar patrol officers stated they checked speedometer indications against the instrument as another police car *passed by*.

At such lesser distance of 25 feet down the street, the disparity in angle when the instrument is placed 10 feet off the traffic lane is *not* 10°, corresponding to a 2% error, but is the tangent of 10/25, or approximately 22°, *the cosine error of which is 7.3%.*

Actually, the degree of error is greater than that computed because, as the Instruction Manual notes, the instrument is required to be set up no more than 10 feet "from the edge of the road." It is well known that speeding vehicles, particularly in multi-lane traffic, do not travel at the very *edge* of the road. The difference angle and consequent velocity error could, therefore, be very much greater than that computed from an assumption of only 10 feet to the vehicular line of travel. *For a line-of-traffic separation distance equal to down-the-street vehicular distance, the indicated radial velocity of the instrument would differ from the true velocity of the vehicle by the cosine of 45°, or an error correspondence of 29.3%.* This, along with all the many other separate error sources cited, confutes the "popularly" held notion, as expressed by a Justice of the Peace, sitting in the trial of an offending motorist, that the instrument is *only* 2 miles per hour "off".

In another phase of testimony, in the Denver trials, a police radar patrol officer testified that he "proved" the instrument's ability to distinguish multiple targets by parking his radar car along Santa Fe Road, about 50 feet from the railroad tracks, and checked the speed of both a police car and the train, as viewed simultaneously through vehicular traffic on the road. This officer claimed exact correspondence between instrument reading and the speed held by the engineer of the train.

Under this condition of 50 feet separation from the railroad (which, incidentally, violates the Instruction Manual's admonishment under Section II that "The Transmitter-Receiver should be located as close to the moving traffic as safety and convenience will allow, in no case more than 10 feet from the edge of the road".), a 10-degree difference angle to hold to 2% error would require that the train be observed at a parallel road distance of 274 feet (i.e., tangent 50/274 = 10°), or, an actual diagonal distance of 288 feet to the train (i.e. sine 50/288 = 10°).

Since the *Operating and Maintenance Manual* recommends adjustment of the instrument to intercept traffic at a nominal maximum distance of 175 feet, the officer's "proof" by identical velocity indications can mean only two things: (1) *The calibration of the radar instrument would have to be excessively high in order that the cosine velocity component alone (to which the instrument responds) would equal the true velocity of the train, (at an angle greater than the 10° limit ascribed by the Instrument Manual for*

2% error), and/or (2) *The instrument must be sensitive to relative effective area of the target to a degree which, in typical traffic, could cause varying velocity response of the instrument according to the different angular distances at which different size vehicles would actuate the instrument.*

Agreement of speed readings when the instrument was so much as 50 feet abreast from the train was therefore in reality a confirmation of error in the instrument calibration, instead of the "proof" of accuracy represented to the Court. For, the velocity calibration would have to be *more than 100% of true* if the instrument's sensitivity to only the *cosine component* (which must always be a fraction smaller than 1 at an angular displacement) was itself equal to 100% of the train's reported true velocity.

This, in fact, complete reversal of the alleged "proof" points out nakedly how utterly incompetent such testimony as the above is, and the abuse of the rules of evidence when operations officers are allowed to testify on technical matters.

Whether the disparity between the radar instrument's reading of *radial* velocity as compared with *true* velocity will under other circumstances favor or weigh against the motorist, will depend entirely on the police calibration procedure. While nominally the radial velocity must be less than the true velocity, arbitrary procedure of establishing instrument calibration in a short distance or wide angle test, and then using this reading to check motorists at the lesser angle of maximum approach distance will assuredly result in an increase *over* 100% of true velocity being ascribed to the motorist, by an amount proportional to the difference in cosines of the two different angles of *test* and *application.*

For the same reason, a very large bus or van, to which the instrument is sensitive at greater distances, will be "seen" at greater distances (corresponding to more nearly parallel angles) and will tend to show *higher* velocities than police vehicles checked at closer range; whereas, smaller sport cars (perhaps most likely to be speeding), presenting lesser reflective surfaces, will tend not to "trigger" the instrument until shorter distances are reached where the sharper angles to the side result in a lower cosine component of velocity being indicated by the instrument.

We see, therefore, that the instrument readings are subject to still further sources of error by reason of arbitrary calibration procedure.

J.—*Reliability of the Claim by Radar Car Officers that they can Correlate Visual Observations to Complex Instrument Records.*

We have already cited authoritative theory explaining why the police type instrument is not capable of separating multi-car signal information, having as it does only a single fixed radar beam and a single indicator channel. Likewise, claims of separation by reason of varying sensitivity are not valid in an instrument which must *remain sensitive* over a 0 to 100 m.p.h. range, and affected by multitudinous other sensitivity factors such as nearness, effective area, zone of operation, and wave cancellation by reflections and interference.

So, *also invalid* is the claim by the operating officers that they may directly correlate their visual observations with the instrument record, to establish further interpretation of instrument record than that contemplated in instrument theory and design. The fallacy of this notion is supported by the *Operating and Maintenance Manual* itself. Under the heading *Theory of Operation,* it is explained that the meter actuating circuit depends on a tube which is *prevented from operating* until a "reasonable" signal reaches its grid. Then, *as the signal increases* in magnitude the preceding stages operate as *limiters.* It is further stated that in order to *suppress* some signals and to take care of *decreases* in signal amplitude which might cause the meter to *lose its reading* for an instant, an automatic *expander* is incorporated in the circuit. *Clamping* action is also involved, working off the output tube.

Such design was obviously intended to produce clean, readable graphs, instead of showing all the effects of signal variation. But, can even a layman read through the cited use of *signal prevention* circuits, *limiters, suppressed* signals, *expander* action, and *clamping* action without failing to appreciate that the *output* signal to the meter is *not linear* with the *input* signal to which the instrument responds? Without a direct or one-to-one correspondence between input and output, it is impossible to correlate the external physical occurrence with the instrument output record except as an intricate scientific problem in which one would be required to know, among other things, the precise signal levels at which all the various clamping, limiter, and expander circuits were designed to "trigger" and operate.

As a point of fact, the arbitrary use of limiters and volume expander, to *over-ride* the true doppler signal tendency of the velocity meter to follow a cosine-law of response as the radial component of velocity changes, creates a *delusion* in the operator of thinking he is seeing a *true* velocity record instead of the *radial* velocity to which doppler radar really responds. The testimony of officers in the Denver trials showed they were so deluded. If the instrument output truly corresponded to the input signal obtained from a vehicle traveling at constant speed in a straight-line course past the instrument, the recorded velocity should *not* be similarly constant because the *actuating velocity* is only the cosine component of the true velocity; this component velocity decreases as the angle to the vehicle becomes greater until, when the car passes at right angles or 90°, the actuating velocity is, in fact, *zero.* Hence, the delusion when circuitry is devised to *artificially* sustain and *record* a velocity indication at a level not corresponding to the velocity being derived by the radar beam at that time.

Even a skilled radar engineer could not fully interpret the graphical record to correlate all possible traffic movements from one moment to the next, beyond the limits (1) cited in doppler radar theory, and (2) as established by intricate laboratory controlled tests of the precise signal levels at which the suppression, expansion, clamp, and other circuits are triggered or activated in an instrument of particular design.

When a Court expert witness sought, by direct request to the instrument manufacturer, radar test data of a type which would permit instrument evaluation, including the various circuit signal thresholds and the basis used for establishing the instruction book stated accuracy figure of plus or minus 2 m.p.h., his request was denied. How, then, can the presumptuous interpretations of a radar car *officer,* interpreting the manifold graph inflections of multiple-car situations "seen" by a single catch-all radar beam, possibly be regarded as admissible evidence in Court?

We conclude this part of this presentation by asking these fundamental questions: Who *does* affirm that any and all of the multifarious factors capable of influencing radar accuracy to indeterminate degrees may be *arbitrarily neglected* in establishing the plus or minus 2 m.p.h. accuracy claimed for the police instrument?

Who affirms what the characteristic response of the instrument will be under the different conditions of sensitivity and expander circuit adjustments made *accessible* to non-scientific personnel in the instrument?

Who ventures to affix even the *probability* of receiving signal unaffected by noise under *all* the conditions of traffic use and uncontrollable surroundings, in the face of all the cited authority that says this is not possible except in fully controlled circumstances of laboratory test?

By letters under dates of January 6, 1955, and June 7, 1955, respectively, both the *United States Bureau of Standards* and the *Federal Communications Commission,* state that neither agency has been requested to conduct detailed study of the so-called "radar" speed meters. Thus, as of this writing, there seems to be no government agency or recognized technological institution that has determined the *standards of performance and operation* that shall be observed in such instruments. It goes without saying that in the absence thereof, legislative sanction for checks on speed by use of "radar" devices, and making such checks prima facie evidence of speed, is not only improper but certainly subversive of established and long-tested rules of evidence.

II.—ADMISSIBILITY OF RADAR SPEED CHECKS

It will be recalled that Jones was convicted of speeding on the *sole evidence* as shown by the indicator graph. It was objected to on the ground that no trustworthy scientific basis had been established for the particular speed check made under the unique and uncontrolled conditions existing at the time to justify the admission of such check as substantive evidence of anything. This was overruled.

In *State v. Moffitt*,[30] over a similar objection, the Court allowed the question to go to the jury with this instruction:

> In the present case, however, before you can return a verdict of guilty under this contention—that is, a finding by reason only of the speed meter—you must be satisfied beyond a reasonable doubt that the speed meter used in the present case was functioning properly, was properly operated at the time, and was in fact, an accurate recorder of speed; further, that its accuracy had been properly tested within a reasonable time from the date of its use, January 6, 1953.
>
> If these essentials are found by you to exist, you may determine that the Speed Meter recorded the accurate speed of the defendant's vehicle at the time of the test on January 6, 1953, and such finding standing alone, if made by you, would furnish sufficient evidence for the conviction of the defendant in the present case.

While we do not disagree with the instruction, we challenge the sufficiency of the radar facts presented in this case in view of what we outlined above respecting the variables, imponderables, uncertainties, and questionable design of the radar instrument. Without those facts, how can a jury of laymen possibly arrive at a fair verdict?

This problem of sufficiency, related to admissibility, was, however, recognized in *People v. Offerman*,[31] wherein the defendant had been convicted in the City Court of speeding, based on evidence shown only by the radar speed meter. The judgment of conviction was reversed upon appeal on the ground that the *accuracy* and *reliability* of the device had not been shown by *proper* and *competent* evidence. In remanding the case for re-trial, the Appellate Court said:

> Law enforcement should keep in stride with the advances of science, and Courts should receive scientific proof when presented in accordance with the established rules of evidence. These rules have safeguarded our lives, our freedoms, and our property since the establishment of the common law, and should not be lightly set aside in the name of convenience. It may be that these electronic devices will become a great and much-needed weapon in the armory of law enforcement . . . In the not too distant future this science may bring civilization the horrors of a push-button war, but it must not bring push-button justice unless and except such justice is surrounded by the long-established rule of evidence.

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[30] 100 A. 2d 778 (1953).

[31] 125 N.Y.S. 2d 179.

This latter decision recognizes also the problem of scientific dependability, which we have outlined above, about radar speed meters. The fact that the defendant in the *Offerman* case, upon retrial, was again convicted, and that the same result was obtained in *People v. Torpey*,[32] follow from the practically total lack of evidence on the limitations of radar, as prevailed in the *Moffitt* case, supra, allowing the prosecution in all three cases a field day.

In all three of the aforementioned cases, the city relied on an expert's opinion. In none of these cases did the defense have experts evaluate not *only* the manufacturer's claims for radar speed meters, but a scientific analyses of the whole situation. It is obvious that where only the "bright" side of the picture is presented and the "dark" side is not presented, considering the complexity of radar principles and application, ordinary jurymen are bound to be persuaded by the still-existing mystery surrounding the name "radar". It should be clear, too, that an expert's opinion on what actually occurs at the time the speed checks are made must be based necessarily on the assumption that *all* variables and idiosyncracies of radar were under control at the time and place of the speed check, and the instrument was influenced *only* by the return echo from the target vehicle. Indeed, such assumption and such speed check, as we pointed out above, should have no efficacy whatever unless the factors of radar limitations are properly explained for each and every traffic violation tried on the basis of *only radar* evidence.

On this point of admissibility, the few representative cases cited herein, seem to stand for the proposition that the results of radar speed tests are admissible if the proper foundational requirements are met, and these seem to be limited to a radar expert's opinion; and this, without any showing of compliance with competently pre-determined standards of performance and operation that shall be observed in the design and operation of radar speed meters at the *time* of the alleged violation.

III.—THE PROBLEM OF ENTRAPMENT

Most popular references, mainly newspapers, refer to the radar speed check as "Radar Trap." No human likes to be trapped, however laudable the purpose. Entrapment under special circumstances may be a defense to criminal prosecution. With such an attitude by the public against speed traps, a serious problem of "relations" between the police and public is raised. If the police are to be regarded as the true guardians of the law and the servants of the people whom they shall protect, this problem of entrapment should receive serious attention. To assert "that radar traps are aids to law enforcement and assist in curbing senseless slaughter of human beings on our highways and streets," as justification for the *means* employed, is to misapprehend the damage those means can do. Who can doubt the wisdom that actively patrolling the

[32] 128 N.Y.S. 2d 564.

streets is the tested and best way of *preventing* unlawful speeding, and that *prevention of crime* is far better than apprehension after the *preventable* crime has taken place![33]

California, Oregon, and Washington have adopted statutes prohibiting the use of speed traps, in response to public demand.[34] On the other hand, the states of Virginia and Maryland have adopted statutes governing the use of radar for traffic control.[35]

If radar speed traps must be used, to prevent the development of bitterness and anti-social feelings, legislative sanction first should be obtained and such legislation should lay down the *standards of performance and operation* for radar speed checks. Moreover, the fact that the police in the exercise of discretion will not arrest speedsters whose radar indications do not exceed the speed limitations by 7 to 12 miles, to allow for error, is, in fact, a specie of "Discriminatory Legislation" giving rise to the question of *who* in our coordinate branches of government, should decide that a 30 m.p.h. speed ordinance really means 37 m.p.h.? This raises the serious question of *due process of law* under which an ordinance must be sufficiently explicit in its description of the offending acts and related to an *ascertainable standard of guilt.*

Such legislation, suggested to overcome these criticisms, presumes the will of the people reflects itself therein, and, when enacted, it is the people themselves who sanction the use of speed traps and hence, because such legislation may be repealed, should not be heard to complain. Surely this is the better policy under our system of government, than for an executive agency, like the Police Department, exercising authority under the police power, to usurp legislative authority and even invade the province of the Courts, no matter how well intentioned, by the arbitrary adoption of said radar instrument in the absence of definite legislatively sanctioned standards of design and operation, including a statute making proof of certain facts prima facie evidence without affecting the ultimate burden of proof.

IV.—THE PROBLEM OF JUDICIAL NOTICE

Obviously in the present state of radar speed devices judicial

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[33] Fleming v. Superior Court, 196 Cal. 344, 238 Pac. 88.

[34] Cal. Vehicle Code, Sec. 751 (1948); Cal. Vehicle Code, Sec. 752 (Supp. 1953); Ore. Rev. Stat., Sec. 483.112 (1953); Wash. Traffic Code, R.C.W. 46.48.120 (1937). In respect to the Wash. Statute, the Attorney General of that state is of the opinion that the statute is designed to apply to a situation where there is a measured course, a lapsed time clocked by an officer, and a computation of speed. The Attorney General felt that the Legislature had *considered* the elimination of human error in such situations by taking notice of the fact for example, that a car traveling at 50 m.p.h., over a course 600 feet in length will cover that distance in 8 seconds; and that a lag of 1 second in human perception will result in an error of 6 m.p.h., therefore the wording of the statute does not prohibit the use of radar traps because with a "radar" device there is *no possibility* of human error, and consequently radar evidence is admissible.

[35] Md. Ann. Code, Gen. Laws, Art. 35, Sec. 99 (Supp. 1954); Va. Code, Sec. 46-215.2 (Supp. 1954).

notice of their accuracy cannot be expected. Proper foundational requirements must be met first as a condition precedent to the admission of such evidence. Moreover, if admissible at all, the weight of such proof is a question for the jury to determine, the same as any other evidence. All of the reported cases seem to hold this view.

In the case of *People v. Torpey*[36] the Court stated:

> No expert testimony was offered on the part of the people to establish the fact that the so-called radar equipment is a mechanism that correctly and accurately records the speed of passing automobiles. The use of radar is comparatively new as a means of bringing about the arrest of violators of ordinances pertaining to the speed of automobiles, and until such time as the Courts recognize radar equipment as a method of accurately measuring the speed of automobiles, in those cases in which the people rely solely upon the speed indicator and the radar equipment, it will be necessary to establish, by expert testimony, the accuracy of radar for the purpose of measuring speed.[37]

In another case, *People v. Beck*,[38] the Court refused to admit that the accuracy of radar was so generally known that a court of justice should take judicial notice thereof and reversed the conviction of the defendant against whom the evidence consisted partly of a radar speed meter results and partly of eye-witness testimony as to speed. The Court held that the eye-witness testimony was admissible, but that the radar testimony was not admissible unless supported by expert testimony. And because it did not appear from the record that the defendant was convicted solely on the basis of admissible evidence, the case was reversed and remanded.

In the only other case, aside from the Denver trials, wherein the defendant attempted to prove the inaccuracy of the radar speed meter, *State v. Dantonio*,[39] the New Jersey Court heard the testimony of both radar and tachograph experts. The radar expert testified that *all* defects in the radar equipment resolve in favor of the motorist! This was unchallenged. The radar officers testified they operated as a team of two—one in the radar car, and the other in the interceptor car. The manner of testing and setting up the equipment was the same as outlined previously in this article and the instrument was the same. But unlike *State v. Moffitt*,

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[36] 128 N.Y.S. 2d 864 (1953).

[37] 5 MERCER L. REV. 322 (1954); wherein this view receives unqualified support by the observation "the modern mind has a tendency to pay homage to the advancements of science by accepting, without question, hypothesis (sic) coming even from the very frontier of research."

[38] 130 N.Y.S. 2d 354 (1954).

[39] 105 A. 2d 918 (1954).

supra, and *People v. Offerman*, supra, the police, in this case, produced and introduced in evidence, *as part of* the speeding proof, *the written record of the speed of the bus as made at the time of the violation over a distance of 46¼ miles.* The defense countered by introducing expert evidence on the accuracy of the tachograph with which the bus was equipped. The evidence of this instrument showed that the bus slightly exceeded the speed limit of 60 m.p.h. But, in no part of the evidence in this case, and for that matter, we repeat, in no other case reported, was the radar instrument and the manner of its operation properly evaluated to disclose its limitations in practical application.

So, in this battle of *Radar v. Tachograph* the issue was decided upon *rebuttal* testimony produced by the state. And this is significant. The rebuttal evidence was given by a traffic engineer, who testified "that the mileage from the toll booth at interchange No. 4 to mile post 80½, the point where the radar equipment was set, is 46¼ miles." He proved mathematically that for the bus to have travelled 46¼ miles—the bus must have been clocked and its time checked both at the toll booth and when it passed the radar instrument—in approximately 40 minutes, it must have travelled at an average speed of 66 m.p.h. Two facts should be noted here, (1) it was the distance and time factors between the toll booth and radar instrument, and (2) the indisputable mathematical computation which *decided the issue*—not either of the said instruments.

We observe that no judicial notice was taken of the accuracy of either instrument. Also, this case stands for the proposition that there is no adequate substitute, notwithstanding the miraculous claims made for radar and its *short-circuiting affects* in Court, for the long-established practice of producing *independent corroborative testimony.* Since we have shown that the radar speed instruments possess frailities not unlike in variety to those possessed by human witnesses, *why should Courts and juries accord its results unquestioned credibility,* not accorded to uncorroborated human witnesses?

We conclude this discussion on Judicial Notice with the pertinent observation and approval made by the New Jersey Court of the Court's statement in *People v. Offerman:*[40]

> The legislature in its wisdom might see fit to declare that the reading of an electrical timing device similar to the one here may be admitted in evidence as prima facie evidence of the speed of the automobile of an accused, after such device has been certified as accurate by the authority designated by the legislature. By such legislation, the People will be relieved of the burden of proving the accuracy of the electrical timing device upon each trial and by expert testimony. The traveling public will be protected against convictions based upon the reading

[40] 125 N.Y.S. 2d 179; 204 Misc. 769.

of an unproven and possibly inaccurate device, and of equal importance, the rules of evidence will not be violated.

Since, therefore, judicial notice of the accuracy of radar speed meters, if taken, would be cognizant of a fact deemed to be measured by general knowledge of the same fact,[41] it would pervert the truth, because such fact is not accepted without qualification or contention.

V.—THE HEARSAY PROBLEM

Keeping in mind how the radar instruments are tested before use, and the gap between the time and place of the radar check and the "information" given to the radar expert (whose tests of the instrument do not prove the conditions of the instrument), likewise, the *actual* manner of operation at the time, nor less definitely, the extraneous conditions prevailing at the time and place of the radar check, we are confronted with a serious problem of hearsay. In the case of *People v. Offerman,* supra, the only Court to discuss part of this problem, the Court held that the testimony of the radar police officers regarding their so-called checks for accuracy of the instrument was inadmissible hearsay. The radar officer, even if the radar principles involved were not a serious factor, had no precipient knowledge of what the other officer told him. He knew actually only what one had heard.

The position of the expert is even more delicate. He has to assume that the conditions prevailing when he tests the instrument were the identical conditions, *as told to him,* that prevailed at the time and place of the actual radar speed check. He must necessarily be confined to the evidence of facts in the case. And remember those facts are testified to by precipient witnesses, radar officers, who are not competent to accurately report the *radar factors* that actually prevailed at the time and place of the speed check. The expert's opinion based on such a foundation has no better status. If the expert bases his opinion upon his personal knowledge he must give the *facts* upon which it is based before stating it.[42] Since he is never on the spot at the time, this would be impossible unless the hearsay rule is violated.

VI.— PROBLEM OF THE PRIMA FACIE CASE

In the states of Maryland and Virginia where they have statutes [43] under which to make out a prima facie case, the prosecution has a relatively simpler problem. Since such statutes as, for example, the Virginia Code, provide that "The results of such checks shall be accepted as prima facie evidence of the speed of such motor vehicle in any court or legal proceedings where the

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[41] 20 Am. Jur., Evidence, Sections 17-18.

[42] 20 Am. Jur., Evidence, Sec. 794.

[43] MD. ANN. CODE, Gen. Laws, Art. 35, Sec. 99 (Supp. 1954); VA. CODE. Sec. 46-215.2 (Supp. 1954).

speed of the motor vehicle is at issue," all that need be proven thereunder is that the arresting officer was in uniform at the time; that speed signs were properly posted; that the radar mechanism was properly functioning; that the defendant was the driver of the car which was shown by the radar speed meter to have exceeded the speed limits; that the information regarding the offending car was immediately radioed to the interceptor officer who made the arrest. While the ultimate burden of proof is not affected by such statutes, they, nevertheless, make prima facie evidence of speed the *results* of a mechanism which we have pointed out is extremely vulnerable to many factors. The principal weakness here is that no *standards of design and operation* are laid down by the legislature. This opens up a whole field of dispute. May the legislature enact a law affecting the rights of citizens in Court, which law embraces intricate and complex scientific mechanisms, without specifying minimum essentials of compliance of said instrument to scientifically determined safeguards? Apparently it can, but is it right?

It seems to us that such statutes as mentioned take the place of judicial notice of the accuracy and reliability of such instrument. And we have seen that no appellate court has given such judicial notice because the accuracy and reliability of such instrument must be proven like any other evidence sought to be introduced. Until such standards of design and operation are specifically embodied in the law, we believe the Courts are right in refusing to admit such evidence until the *proper foundation* has been laid in each case. It is plainly obvious that radar facts and principles are *not* of such generalized knowledge and so universally known that they cannot reasonably be the subject of dispute. That being so not only is such *legislative notice,* as referred to, improper, but also otherwise a prima facie case is difficult to make, if not impossible, in view of the present status of radar speed meters.

When the *fact* of radar speed check accuracy is explained and contradicted, the foundations for a prima facie case in behalf of the proponent of that fact are destroyed, and, if not, the issue thus made must go to the jury for determination. Whether, therefore, the proponent of unquestioned accuracy of such instruments produces prima facie evidence showing the existence of the fact of accuracy and reliability as against the opposition's contradiction thereof, and thereby makes out (notwithstanding the contradictory facts) a prima facie case, depends on understanding of the scientific *facts* involved herein. And because a prima facie case is made out only by proper and sufficient testimony [41] in view of the scientific explanation herein given, we find that "radar" evidence alone, without supporting admissible corroborative testimony, is insufficient to establish a prima facie case.

[41] 32 C.J.S., Evidence, Sec. 1016.

VII.—CONCLUSION

When we stop to consider (1) that "radar" has to do with energy which travels at the speed of light, or *186,000 miles per second,* (2) that the activation of the instrument is in terms of *fractions* of seconds, and (3) that *human* operators possess limitations in the speed with which they may accurately respond, giving rise to all of the aforementioned imponderables, we cannot escape from the thought of whether or not Police Departments and Justices of the Peace have grasped at this speed device, not so much for laudable purposes, but for the more certain and greater number of "apprehensions" as a revenue measure!

This question cannot escape the thoughtful citizen when in the course of 3 months' use in Denver 1,600 motorists were nipped $20.00 each, or about $32,000.00! If, therefore, such devices are used in all the arterial highways of a city, and if the speed ordinances must be interpreted to mean that a violation for only a fraction of a second is sufficient for conviction, have we not through a "scientific gadget" found a way to "tax" our citizens without proper "representation" and, much worse, subvert the *true* purposes of our Courts?

It may very well be that the "experimenters" in the frontiers of research will eventually produce a radar speed device that cannot be questioned, and no suggestion is herein made that the law should drag behind the progress of science; but since the rights of citizens are involved, the better policy to pursue is for the Courts to resist the peddlers of electronics miracles and not allow "it [the science of electronics] to bring push-button justice unless and except such justice is surrounded by the long-established rules of evidence . . ." and, even then, not until "after such device has been *certified as accurate by authority designated by the legislature.*"[45] (Emphasis ours)

[45] People v. Offerman, 204 Misc. 769, 125 N.Y.S. 2d 179.

RECENT OPINIONS OF THE ATTORNEY GENERAL OF COLORADO

CITIES AND TOWNS

55-2777—February 7, 1955

REQUESTED BY: William Atha Mason, Attorney at Law Rifle, Colorado

FACTS: Members of the board of trustees or city council frequently sell supplies to or perform labor or services for the town while on the city council and charge the city for the same.

QUESTION: Is it permissible for a member of the board of trustees or city council to sell supplies to or to perform labor or

services for the city and charge the municipality for the same?
CONCLUSION: It is not permissible.

COLO. A & M COLLEGE—CITIES AND TOWNS—TAXATION

55-2767—January 6, 1955

REQUESTED BY: W. E. Morgan, President Colorado Agricultural and Mechanical College

FACTS: The City of Fort Collins desires to annex property owned by the State of Colorado and used as the Colorado Agricultural and Mechanical College. The state-owned property is contiguous to the Municipality.

QUESTIONS: 1. May the city annex state-owned land occupied by a state institution?

2. If this property is annexed, would the state lose its sovereign rights and power or subject the college to municipal taxation?

3. Does the State Board of Agriculture have the power to consent to the annexation, or will special legislation be required authorizing the board to consent to the annexation?

4. After annexation, would the college be subject to municipality building codes and zoning regulations?

5. Does the State Board of Agriculture possess the power to contract with the City for special rates on public utilities?

CONCLUSIONS: 1. A municipality may annex state-owned land used for purposes of a state institution.

2. After annexation, the City could not encroach upon the sovereign rights or powers of the state, and the college property would be free from taxation.

3. The State Board of Agriculture has the authority to consent to the annexation, providing the fee simple title to the state property is held by the Board. However, if the title is in the name of the State, then only the State, by special legislation, may consent to the annexation.

4. The City may not impose building and zoning regulations on the college property. The State has vested the power and duty to construct buildings and their type in the Board. However, should the college propose building in a zoned area, the city zoning laws would control.

5. The State Board of Agriculture may contract with the City for special rates on public utilities.

LEGISLATURE—CITIES AND TOWNS

55-2785—March 1, 1955

REQUESTED BY: William Bodan, Jr., City Attorney, Englewood, Colorado

QUESTION: Can a city councilman also hold office as a state representative?

CONCLUSION: There is no prohibition against a state representative holding office as city councilman inasmuch as he was elected to the latter office. See *Carpenter v. People*, 8 Colo. 116, 5 Pac. 828.