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I. INTRODUCTION

Since 1955 most charges based on radar evidence alleging that a motorist was traveling in excess of the lawful speed limit have resulted in guilty pleas or convictions. Notwithstanding that many defendants are indeed guilty of speeding, a significant factor contributing to the high incidence of guilty pleas and convictions is the judicial notice accorded the reliability of traffic radar,[1] as if the speed-measuring device carried some Divine imprimatur. Many courts simply rubber-stamp radar evidence as proof beyond all doubt that a driver is guilty of speeding every time the device records a violation.[2] The authors acknowledge that in the great majority of cases radar is both accurate and reliable; however, even radar manufacturers admit that some errors occur.[3] The Texas De-

1. *See, e.g.*, Everight v. Little Rock, 326 S.W.2d 796, 797 (Ark. 1979); State v. Graham, 322 S.W.2d 188, 195 (Mo. Ct. App. 1959); Cromer v. State, 374 S.W.2d 884, 887 (Tex. Crim. App. 1964) (Morrison, J., dissenting).

2. Courts do so when the prosecution establishes that the radar unit was tested for accuracy and reliability by an operator with proper knowledge of the radar unit's operation. *See* Gano v. State, 466 S.W.2d 730, 732 (Tex. Crim. App. 1971); Wilson v. State, 168 Tex. Crim 439, 443, 328 S.W.2d 311, 313-14 (1959). Legal commentary upon the history, theory, and application of radar is fairly substantial. *See* Carosell & Coombs, *Radar Evidence in the Courts*, 32 DICTA 323, 357 (1955) (questioning the validity of police radar evidence); Kopper, *The Scientific Reliability of Radar Speedmeters*, 33 N.C. L. REV. 343, 381 (1955) (advocating admissibility of police radar evidence). *See generally* Forkosh, *Speeding and Due Process*, 28 FORDHAM L. REV. 115 (1959); Greenwald, *Scientific Evidence In Traffic Cases*, 59 J. CRIM. L.C. & P.S. 57 (1968); McCarter, *Legal Aspects of Police Radar*, 16 CLEV.-MAR. L. REV. 455 (1967); McCormick, *Scientific Evidence in Traffic Cases—Some Legal Problems*, 4 S. TEX. L.J. 193 (1959); Comment, *Radar and the Law*, 10 S. TEX. L.J. 269 (1968); 14 Sw. L.J. 394 (1960).

3. *See* Operator's Manual, Kustom's KR-11, at 22-27 (1978) (Kustom Signals, Inc., 1010 West Chestnut, Chanute, Kansas 66720); Interview with Ed Pfeiffer, Factory Sales Repre-

partment of Public Safety reports that its officers issued 830,186 speeding citations in 1978.[4] During that same period there were 130,845 speeding cases filed in municipal courts of Houston, Texas.[5] Approximately 85 percent of these tickets were issued on the basis of radar evidence.[6] The fines collected from these citations by the City of Houston alone represented approximately $3 million.[7] Radar is used for traffic control and as a revenue generating device in all states. With such nationwide use of police radar, the question that must be asked is, "How many tickets are being issued and fines collected wrongfully?"

In recent years criticism of police radar has increased.[8] The attacks have not been on the scientific principles which form the basis of radar, but have been confined to its current mode of use in police radar systems.[9] Accordingly, this article will examine traffic radar units presently used by law enforcement agencies and analyze whether radar evidence should be judicially noticed by courts. This analysis will discuss the history of radar, the underlying scientific principles, accuracy and reliability of police radar, and its operational use.

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sentative for M.P.H. Industries, Inc., Houston, Texas (Oct. 22, 1979).

4. *See* letter from Michael Anderson, Manager of Statistical Services of the Texas Department of Public Safety to Joseph Gary Trichter (Oct. 1, 1979) (speeding citations for 1979 through July totaled 408,675).

5. *See* letter from John E. Jonietz, Administrative Assistant to the Director and Presiding Judge of the Municipal Courts of the City of Houston to Joseph Gary Trichter (Sept. 27, 1979) (speeding citations for 1979 through June totaled 58,619).

6. The 85 percent figure represents an estimate based upon interviews conducted during the fall of 1979 with officers and officials of the Texas Department of Public Safety and the Houston Police Department.

7. The minimum penalty for excessive speed when a violator plead guilty and simply mailed in the fine was $27.50. The 85 percent figure, *supra* note 6, multiplied by 130,875 total speeding citations issued in Houston, results in an estimated 111,245 citations based on radar evidence. At the $27.50 minimum penalty, the estimated revenue attributable to radar in Houston was approximately $3 million during 1978.

8. *See generally* State v. Aquilera, No. 711-101S (Fla. Dade County Ct. May 7, 1979); Wisconsin v. Hanson, 270 N.W.2d 212, 215-16, 218 (Wis. 1978); Blackmore, *Radar: Caught In Its Own Trap*, POLICE MAGAZINE, Sept. 1979, at 23; Dornsife & Miller, *The Radar Ripoff*, HOT ROD MAGAZINE, Mar. 1979, at 44.

9. *See generally* State v. Aquilera, No. 711-101S (Fla. Dade County Ct. May 7, 1979); Wisconsin v. Hanson, 270 N.W.2d 212, 215-16, 218 (Wis. 1978); Blackmore, *Radar: Caught In Its Own Trap*, POLICE MAGAZINE, Sept. 1979, at 23; Dornsife & Miller, *The Radar Ripoff*, HOT ROD MAGAZINE, Mar. 1979, at 44.

II. What is Radar?

The word "radar" is derived from the phrase, "radio detection and ranging."[10] "It would [probably] 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."[11] Dr. John Kopper, a professor of electrical engineering, has described the radar principle in lay terms as:

> [A] method . . . that may be used to detect the presence of a target and determine the distance of that target from the radar set. Radar methods can also be used to obtain information on the bearing of a target, its altitude, and speed. In all the methods electromagnetic energy in the form of radio waves is radiated from antenna of the transmitter of the radar set so as to "illuminate" the target; when the target is thus illuminated, it reflects a certain portion of the energy back to the receiver of the radar set. Searching the sky for a target by means of a radar set is like scanning the sky at night with a searchlight. If a part of the light sent out by the searchlight [is reflected,] . . . we deduce from this fact that in the sky there is a cloud or airplane acting as a reflector. All this is a roundabout way of saying that we see a target. In a similar way a radar set is said to "see" a target.[12]

III. History

Radar had its genesis during the Second World War.[13] The world learned of the wonders of radar in military target tracking and navigation through the veil of secrecy surrounding all military secrets. Its "war-time reputation . . . created . . . [a lasting] impression, *through name alone,* of such perfection in design [and] . . . performance integrity, that psychologically everyone [was] im-

10. *See* Carosell & Coombs, *Radar Evidence in the Courts*, 32 Dicta 343, 345 (1955).
11. *Id.* at 345.
12. Kopper, *The Scientific Reliability of Radar Speedmeters*, 33 N.C. L. Rev. 343, 344-45 (1955).
13. The history of radar evidence in the courts exceeds the scope of this article. For discussion of early radar case law see Carosell & Coombs, *Radar Evidence in the Courts*, 32 Dicta 323 (1955); Forkosh, *Speeding and Due Process*, 28 Fordham L. Rev. 115 (1959); Greenwald, *Scientific Evidence in Radar Cases*, 59 J. Crim. L.C. & P.S. 57 (1968); Kopper, *The Scientific Reliability of Radar Speedmeters*, 33 N.C. L. Rev. 343 (1955); McCarter, *Legal Aspects of Police Radar*, 16 Clev.-Mar. L. Rev. 455 (1967); McCormick, *Scientific Evidence in Traffic Cases—Some Legal Problems*, 4 S. Tex. L.J. 193 (1959); Comment, *Radar and the Law*, 10 S. Tex. L.J. 269 (1968); 14 Sw. L.J. 394 (1960).

pressed."[14] The reader must recognize that police radar units are not the same sophisticated and expensive instruments used then and now by the military. The underlying scientific principles axiomatic to the design and operation of military radar are significantly more complex than the basic operative principles of police radar.

A. *Military Radar: How It Works*

Military, or "pulse type" radar, operates by sending out electromagnetic energy[15] in a beam at regular intervals which is reflected off of or bounced back from an object in its path.[16] These electromagnetic energy transmissions travel to and from the object detected in straight lines the same as light rays travel.[17] The transmitted energy travels at the speed of light, 186,282 miles per second.[18] Measurement of elapsed time between outgoing and incoming electromagnetic energy allows computation of the position and movement of the detected object relative to the position and movement of the transmitter. The method of computation is "by multiplying the speed of light by one-half the time elapsing between transmission of a pulse [radio microwave] and the reception of its echo . . . ."[19] Knowing the elevation and bearing of the radar beam, one can use military radar technology to determine the elevation of the reflecting object as well as its angle of elevation. It is important to note that pulse radar has these capabilities because hundreds of millions of dollars and many years of extensive research were invested to develop its accuracy.[20] Absent such investment it is doubtful that its technological capacity to compute time in millionths of seconds would have evolved to present standards of accuracy.

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14. Carosell & Coombs, *Radar Evidence in the Courts*, 32 DICTA 323, 324 (1955) (emphasis added).

15. The energy is transmitted in the form of radio microwaves.

16. *See* McCarter, *Legal Aspects of Police Radar*, 16 CLEV.-MAR. L. REV. 455, 455 (1967).

17. *See id.* at 455.

18. *Id.* at 455.

19. Kopper, *The Scientific Reliability of Radar Speedmeters*, 33 N.C. L. REV. 343, 345 (1955).

20. *See* Carosell & Coombs, *Radar Evidence in the Courts*, 32 DICTA 323, 326 (1955).

B. *Police Radar: How It Works*

Police radar may be technically denominated "Doppler Effect" radar,[21] and does not operate on the same scientific bases as the "pulse" radar briefly described previously. The time and money invested in the development of military radar far exceeds that attributable to police radar development. Doppler radar emits a continuous beam of radio microwaves rather than a pulse.[22] Consequently, police radar will not measure time or distance with respect to the reflecting object in the same way as military radar.[23] Since police "radar" does not measure the direction or range of reflecting targets, its very denomination is inconsistent with the historical origins of the word radar.[24] The use of radio microwaves in the operation of Doppler "radar" account for the erroneous label.[25]

Doppler radar devices operate on a scientific principle known as the "Doppler Effect."[26] The principle was first recognized in 1842 by an Austrian physicist named Christian Johann Doppler.[27] To best understand Doppler's principle, note that police radar has both transmitting and receiving antennas, and that the transmitter continuously emits radio microwaves at a fixed frequency.[28] The

21. *See* McCarter, *Legal Aspects of Police Radar*, 16 CLEV.-MAR. L. REV. 455, 455 (1967). *See generally* Carosell & Coombs, *Radar Evidence in the Courts*, 32 DICTA 323, 324 (1955); Kopper, *The Scientific Reliability of Radar Speedmeters*, 33 N.C. L. REV. 343, 345 (1955).

22. *See* Carosell & Coombs, *Radar Evidence in the Courts*, 32 DICTA 323, 325 (1955).

23. *See* McCarter, *Legal Aspects of Police Radar*, 16 CLEV.-MAR. L. REV. 455, 455 (1967).

24. *See* Carosell & Coombs, *Radar Evidence in the Courts*, 32 DICTA 323, 325-26 (1955).

25. Actually police radar, because it transmits radio microwaves at a fixed frequency and receives radio microwaves at a fixed frequency, could have been characterized as something between a radio station and a radio.

26. *See* Kopper, *The Scientific Reliability of Radar Speedmeters*, 33 N.C. L. REV. 343, 346-47 (1955); McCarter, *Legal Aspects of Police Radar*, 16 CLEV.-MAR. L. REV. 455, 455 (1967).

27. *See* Kopper, *The Scientific Reliability of Radar Speedmeters*, 33 N.C. L. REV. 343, 346 (1955).

28. Police Doppler radar units operate on two bands called X and Y. The X-band frequency is 10.525 GHz and the Y-band frequency is 24.150 GHz. The frequencies are assigned by the Federal Communication Commission (FCC). The FCC requires the agency owning a radar device to be licensed but not the individual operator. The operator's license is derived from the general scope of the agency's license. Failure to be licensed carries a fine of $10,000 and/or one year in jail for the first offense, and $10,000 and/or two years in jail for the second offense. These are the only restrictions imposed by a government entity on police radar. There are no governmental regulations concerning minimum standards of police radar. If the arresting agency has no valid FCC license, assertion of the agency's illegal

number of radio microwaves leaving the transmitter is constant and the number radiated per second determines the frequency. The more radio microwaves transmitted, the higher the frequency and vice versa.

Theoretically, when the continuously transmitted microwave beam strikes an object in its path it is reflected back to the receiving antenna.[29] If the radar device and detected object are both stationary, the frequency transmitted will be the same frequency received. Conversely, when the target is moving, that portion of the fixed frequency beam striking the object is changed in direct mathematical ratio to the velocity of the target. This principle is the same regardless of whether the moving target is approaching or receding from the radar unit.[30] For example, assume the fixed frequency transmitted is X. When beam X reflects off a non-moving object it will return to the receiver X. However, when the target is

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operation of radar may constitute an innovative defense.

29. The word "theoretically" is used because the number of waves reflected back to the radar is affected by the aerodynamic design of the reflecting object. *See* Carosell & Coombs, *Radar Evidence in the Courts*, 32 DICTA 323, 340-41 (1955).

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

Id. at 340-41. Additionally, some objects are more reflective than others. *See* CAR & DRIVER MAGAZINE, Feb. 1979, at 79 (Porsche 911SC covered with microwave absorber was tested on police radar—reflectivity diminished by 20 percent).

30. *See* Kopper, *The Scientific Reliability of Radar Speedmeters*, 33 N.C. L. REV. 343, 344 (1955).

approaching the non-moving radar device at velocity *Y*, the signals returned to the receiver will be not only *X* but *Y* as well, or *X* plus *Y*. The difference between *X* and *Y* is called the beat frequency. This change in the frequency is known as the "Doppler Shift," and it is this shift that allows computation of the speed of the target.[31] The "Doppler Shift" or "Doppler Effect" is something we have all experienced as it "can be noticed for all kinds of motion of a wave-like nature, as for example, sound waves."[32]

Police agencies currently use two different types of Doppler radar. These modes are stationary and moving, and are distinguished as follows.

1. *Stationary Police Radar.* "Stationary police radar" describes exactly what the phrase depicts. The radar device is operated from a stationary position near a roadway. Operated in this manner, radar can determine the speed of a vehicle as it approaches and recedes the device's "zone of influence."[33]

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31. For a lengthy scientific explanation of the Doppler Formula see *id.* Following is a synopsis of the Doppler Formula:

$$\frac{v}{V} = (\tfrac{1}{2})\left(\frac{FD}{F}\right) \text{ or } v = (\tfrac{1}{2})\left(\frac{FD}{F}\right)(V)$$

v = velocity of the moving vehicle in miles per hour.

V = velocity of electromagnetic waves in space in miles per hour = 186,281 miles per second times 3,600, the number of seconds in an hour. This figure is constant.

FD = beat frequency, measured by the speedmeter.

F = frequency of oscillation of the radio waves from the meter 2,455,000,000 cycles per second. This is the frequency of the radio waves transmitted from the speedmeter. This frequency is hard to keep precisely constant. Dr. Kopper states that this frequency is maintained to within 0.1% of 2,455,000,000 cycles per second, and that this variation is the reason for the margin of error of the speedmeter being two miles per hour.

Greenwald, *Scientific Evidence in Traffic Cases,* 59 J. CRIM. L.C. & P.S. 57, 58 n.9; *see* Kopper, *The Scientific Reliability of Radar Speedmeters,* 33 N.C. L. REV. 343, 346-50 (1955).

32. Kopper, *The Scientific Reliability of Radar Speedmeters,* 33 N.C. L. REV. 343, 346 (1955); McCarter, *Legal Aspects of Police Radar,* 16 CLEV.-MAR. L. REV. 455, 455 (1967). The pitch of sound depends upon the relative motion of the source and listner. For example, when a jet airplane approaches a stationary listener its sound pitch ascends, and after it passes the pitch descends. *See* Kopper, *The Scientific Reliability of Radar Speedmeters,* 33 N.C. L. REV. 343, 346 (1955); McCarter, *Legal Aspects of Police Radar,* 16 CLEV.-MAR. L. REV. 455, 455 (1967).

33. McCarter, *Legal Aspects of Police Radar,* 16 CLEV.-MAR. L. REV. 455, 456 (1967). See 11 AM. JUR. PROOF OF FACTS, at 20 (Supp. 1979) for elaborate treatment of "zone of

2. *Moving Police Radar.* "Moving police radar" is operated while the patrol car is moving. All moving radar systems have the capability of operation in the stationary mode also.[34] Conversely, a radar system designed solely for stationary use cannot be operated accurately while the patrol car is in motion.[35] In addition, moving radar, operated in the moving mode, cannot record the velocity of vehicles receding from the device's zone of influence; it can only measure the speed of vehicles approaching.[36] Generally, moving and stationary radar operate on the same basic scientific principle;[37] however, the mechanical apparatus and circuitry are more complex in the moving radar unit than in the stationary unit. Prior to the introduction of moving radar in the early 1970's, readings could not be obtained while the patrol car was in motion.[38]

The manner in which moving radar computes the target vehicle's speed is easily comprehended once one understands the underlying theory. Moving radar transmits two beams of radio microwaves, one designated "low radar" and the other "high radar."[39] The low radar receiver monitors the speed of the patrol car by computing the Doppler Shift from stationary objects near the patrol car. High radar, on the other hand, monitors approaching traffic. The high radar beam is transmitted over and beyond the range of the low radar. When both low and high radar elements are functioning properly, the device's receiver will detect the corresponding reflections of the respective beams. The radar's internal computer will then subtract the patrol car's speed (low beam's beat frequency) from the target vehicle's reading (high beam's beat frequency) to compute the target's actual speed.[40] For example, if both vehicles are traveling at 55 m.p.h. then the closing speed will be 110 m.p.h. Subtracting the patrol car's speed of 55 m.p.h. from the total clos-

influence." Basically, the "zone of influence" is no more than the area covered by the radar's beam of radio microwaves when it is still possible for reflections to reach the radar receiving antenna.

34. *See* Blackmore, *Radar: Caught In Its Own Trap*, POLICE MAGAZINE, Sept. 1979, at 27.

35. *See id.* at 27, 30.

36. *See id.* at 27, 31.

37. *See id.* at 27.

38. *See id.* at 27.

39. *See id.* at 27. The computation is based upon echoes from the surrounding terrain, the road itself, and other *non-moving objects. See id.* at 30.

40. *See id.* at 27.

ing speed of 110 m.p.h. will show the target vehicle's speed as 55 m.p.h. Stated simply, the radar unit subtracts the Doppler Shift of the patrol car from the Doppler Shift of the target vehicle, the difference being the true velocity of the target.[41]

IV. Texas Law on Radar

To date there has been no statutory enactment specifically concerning radar by the Texas Legislature.[42] The Texas Court of Criminal Appeals, however, has not been silent on the topic.[43] *Wilson v. State*[44] was the first case the court heard involving police radar. After examining a trial record devoid of any in-depth or extensive scientific evidence to support or negate the accuracy and reliability of radar, the court impliedly took judicial notice of the reliability of radar evidence.[45] There was evidence in the trial court that the radar device used had been electronically tested twice by an electronics supervisor for the state.[46] These tests were performed approximately three months before issuance of the speeding ticket in question and again two months following the alleged violation.[47] Further, the arresting officer testified that he had tested the radar device on location;[48] however, the officer failed to offer evidence substantiating these test results.[49] Notwithstanding the electronic test evidence and the officer's testimony, the court reversed the speeding conviction holding that, before radar evidence will support conviction, the "accuracy of the radar unit *on*

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41. *See id.* at 27.

42. *See generally* Tisdale, *Proposal for a Uniform Radar Speed Detection Act*, 7 J. L. Ref. 440 (1974) (proposed uniform law to maximize effective radar utilization and minimize misuse of radar).

43. Only four Texas cases directly concerning police radar have been decided. *See generally* Gano v. State, 466 S.W.2d 730 (Tex. Crim. App. 1971); Cromer v. State, 374 S.W.2d 844 (Tex. Crim. App. 1964); Holley v. State, 366 S.W.2d 570 (Tex. Crim. App. 1963); Wilson v. State, 168 Tex. Crim. 439, 328 S.W.2d 311 (1959).

44. 168 Tex. Crim. 439, 328 S.W.2d 311 (1959).

45. The court ostensibly did so because of the widespread acceptance of radar throughout the nation. *See id.* at 441-45, 328 S.W.2d at 312-14. From the decision it appears as if the court judicially noticed not only the Doppler principle but also any electronic device named "radar." The court did not address the design integrity of the particular unit nor its application of the Doppler principle. *See id.* at 439-46, 328 S.W.2d at 311-15.

46. *See id.* at 440, 328 S.W.2d at 312.

47. *See id.* at 440, 328 S.W.2d at 312.

48. *See id.* at 444, 328 S.W.2d at 314.

49. *See id.* at 444, 328 S.W.2d at 314.

the location" must be proven.[50] The court established the requirement that a "witness using the apparatus as the source of his testimony *must be one qualified for its use by training and experience."*[51] Unfortunately, the court did not delineate more precise requirements in this regard, nor does the decision rely upon the lack of qualifications of the operator as a basis for reversal.[52]

Four years later the Texas Court of Criminal Appeals decided *Holley v. State.*[53] In *Holley* the record reflects that two different kinds of accuracy tests were performed on location before the issuance of the citation. Additionally, the officer testified "that he checked the unit after the arrest and at the end of the test period," but failed to record these results.[54] Thus, the only tests proven were those performed prior to the alleged violation.[55] Accordingly, the court acknowledged that the preliminary evidence of the radar's accuracy on location fell below the *Wilson* standard.[56] Regardless of this defect, the court upheld the conviction based upon independent opinion testimony by the officers that the defendant was traveling in excess of the legal speed limit.[57]

Less than one year after the *Holley* decision, the court decided its first case involving portable police radar in *Cromer v. State,*[58]

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50. *See id.* at 445, 328 S.W.2d at 314 (emphasis added).

51. *Id.* at 443, 328 S.W.2d at 314 (emphasis added). The court noted that the officer had 9½ years experience with traffic as a highway patrolman, but was silent concerning the extent of his experience with radar. Certainly, the court intended that the "training and experience" required be with the use of radar. *See id.* at 443, 328 S.W.2d at 314.

52. *See id.* at 439-46, 328 S.W.2d at 311-15.

53. 366 S.W.2d 570 (Tex. Crim. App. 1963).

54. *See id.* at 570-71. The officers checked the unit's calibration by means of a tuning fork test and by driving the patrol car through the radar beam at a predesignated speed, thus checking the radar unit reading against the patrol car speedometer. *See id.* at 570-71.

55. *See id.* at 571.

56. *See id.* at 571.

57. *See id.* at 571. Unlike the *Wilson* opinion, *Holley* makes no reference to any requisite "training and experience" of the ticketing officer. *Compare id.* at 570-71 *with* Wilson v. State, 168 Tex. Crim. 439, 443, 328 S.W.2d 311, 314 (1959). In fact, the *Holley* opinion does not discuss whether the officers had any training and experience with police radar. *See* Holley v. State, 366 S.W.2d 570, 570-71 (Tex. Crim. App. 1963).

58. 374 S.W.2d 884 (Tex. Crim. App. 1964). This case can be construed as Texas authority for judicial notice of the reliability of portable police radar devices. *See id.* at 887. Prior to development of portable units, radar was bulky and set up in a patrol car's trunk, or along the road side near the patrol car. *See generally* Greenwald, *Scientific Evidence in Traffic Cases,* 59 J. CRIM. L.C. & P.S. 57, 58 (1968); McCarter, *Legal Aspects of Police Radar,* 16 CLEV.-MAR. L. REV. 455, 455-56 (1967); Comment, *Radar and the Law,* 10 S. TEX. L.J. 269, 278 (1968).

sustaining a conviction based on evidence that the radar unit used had been checked for accuracy on location by two different tests performed both before and immediately after the defendant had been ticketed.[59] The court held that the testimony of officers, based on the readings of a radar unit that "they were trained to operate and to test for accuracy, and which they did operate and test and found accurate" is sufficient evidence, standing alone, to support conviction.[60] The court stated explicitly that such witnesses need not qualify as experts in the field of radar.[61] Thus the State is not required to provide witnesses "who understand the principles by which speed was measured and registered . . . and the repair of radar sets, and who were qualified to testify as to the manner and means whereby the accuracy of a radar set may be tested by . . . a tuning fork, as well as the accuracy of the tuning fork . . . ."[62]

The only other case involving radar decided by the Texas Court of Criminal Appeals was *Gano v. State*.[63] The court in *Gano* upheld yet another conviction based on the officer's testimony that he had checked the calibration of his radar unit immediately before recording the defendant and was thoroughly familiar with and experienced in the operation of police radar.[64] The opinion fails to specify the nature or number of calibration checks necessary to sustain conviction.

In summary, the reliability of police radar has been judicially

59. *See* Cromer v. State, 374 S.W.2d 884, 886-87 (Tex. Crim. App. 1964). The radar unit was tested with a tuning fork, and the digital readout was compared to the patrol car's speedometer. *See id.* at 887. The court noted "[w]e are not prepared to hold that the state was required to call qualified experts and prove the accuracy of the speedometer in the patrol car." *Id.* at 887. This holding is vulnerable to criticism since it allows the radar unit's accuracy to be verified in part by a speedometer reading when the accuracy of the speedometer has not been established. *See id.* at 887 (Morrison, J., dissenting). The authors do not contend that expert testimony should be required to establish accuracy of a tuning fork or a speedometer each time radar evidence is offered. Periodic test of speedometers and tuning forks conducted by an expert qualified to certify accuracy would provide a reasonable standard.

60. *Id.* at 887.

61. *See id.* at 887.

62. *Id.* at 887.

63. 466 S.W.2d 730 (Tex. Crim. App. 1971).

64. *See id.* at 732. It should be noted that the kind of accuracy test, or tests, conducted by the officer is not discussed in the opinion. As in *Wilson*, the radar evidence was supplemented by the officer's opinion testimony, based upon observation, that the defendant was exceeding the lawful speed limit. *See id.* at 731.

noticed in Texas;[65] however, radar evidence is inadmissible until the State establishes that: 1) accuracy of the radar instrument has been verified by sufficient testing on location, and 2) the witness is trained to operate the set and test its accuracy.[66] Clearly, proof of two different kinds of accuracy tests conducted on location constitutes adequate verification to warrant the admission of radar evidence.[67] The unit must be shown to have been "properly set up and recently tested for accuracy,"[68] and at least one case indicates that radar unit accuracy must be verified by tests conducted both before and after issuance of the citation unless the radar evidence is supplemented by independent evidence.[69] Precisely what degree of training and what kind of experience constitutes the *de minimus* legal requirement is not clear since no Texas decision establishes any qualitative or quantitative guidance.

V. Early and Modern Radar Distinguished

The police radar that was judicially noticed throughout the nation in the late 1950's is not the same as the radar of the 1980's. All four radar cases decided by the Texas Court of Criminal Appeals dealt with stationary police radar; however, the majority of radar systems being purchased by law enforcement agencies today are of the combined moving-stationary mode.[70] Moreover, nonmodern police radar was "true Doppler" radar.[71] These non-mod-

65. *See, e.g.*, Gano v. State, 466 S.W.2d 730, 732 (Tex. Crim. App. 1971); Cromer v. State, 374 S.W.2d 884, 885, 887 (Tex. Crim. App. 1964); Holley v. State, 366 S.W.2d 570, 571 (Tex. Crim. App. 1963).

66. *See* Gano v. State, 466 S.W.2d 730, 732 (Tex. Crim. App. 1971).

67. Both *Holley* and *Cromer* indicate that verification of accuracy is sufficiently established by the combination of a speedometer comparison with the tuning fork test. These cases also suggest that the accuracy tests be conducted on location and within a reasonable time of the alleged violation. *See* Cromer v. State, 374 S.W.2d 884, 887 (Tex. Crim. App. 1964); Holley v. State, 366 S.W.2d 570, 571 (Tex. Crim. App. 1963).

68. Wilson v. State, 168 Tex. Crim. 439, 444, 328 S.W.2d 311, 314 (1959).

69. *See* Holley v. State, 366 S.W.2d 570, 571 (Tex. Crim. App. 1963). In *Holley* there was no proof of any post-citation accuracy test, but there was independent opinion evidence by police officers that the defendant was exceeding the speed limit. The court found "the evidence sufficient to sustain the conviction." *Id.* at 571. *See generally* Masquelette v. State, 579 S.W.2d 478, 482 (Tex. Crim. App. 1979) (dictum) (failure to object to state's failure to establish radar operator's training and experience constitutes waiver of error); Comment, *Radar and the Law*, 10 S. Tex. L.J. 269, 278-82 (1969).

70. Interview with Edward Pfeiffer, sales representative for M.P.H. Industries Inc., in Houston, Texas (Oct. 29, 1979) [hereinafter cited as Pfeiffer].

71. *See generally* Carosell & Combs, *Radar Evidence in the Courts*, 32 Dicta 323, 325-

ern units, stationary and early moving radar, required several seconds for the device to compute speed from the reflected radio microwaves.[72] "True Doppler" radar would not lock onto a target's reflection unless the target's speed remained constant for a second or more.[73]

By contrast, modern radar devices employ a system of microcircuitry called "phase lock loop."[74] This modern system is significantly less expensive to manufacture than "true Doppler" radar.[75] It has a longer range than the older systems — sometimes up to 7,500 feet.[76] Additionally, a "phase lock loop" system will lock onto the target vehicle's reflected signal much more quickly than "true Doppler" units. Experts contend that such a system can lock onto a signal in a few hundredths of a second.[77]

VI. Theoretical Methods of Testing the Accuracy of Police Radar

Absent malfunctions, design defects, operator error, and outside interference, the following methods are effective in checking the accuracy of police radar units.[78] Criticisms of each method will follow the description.

A. *External Tuning Fork*

Generally, one or two tuning forks for calibration checks are supplied by the radar manufacturer when a unit is purchased. These forks are designed to vibrate at a particular frequency when struck

26 (1955).

72. *Trial Summary Update No. 2* in Legal Information Index on Police Speed Radar, Summary of Materials Introduced as Evidence in State v. Aquilera, No. 711-101S (Fla. Dade County Ct. May 7, 1979) (compiled by Dade County Florida Public Defender's Office and Electrolert Inc.) (defense testimony of expert witness Andrew L. Soccio). (Electrolert Inc., 475 Park Avenue South, New York, New York 10016 is manufacturer of "Fuzzbuster" radar detection devices).

73. *Id.*

74. *Id.*

75. *Id.*

76. *Id.*

77. *Id.*

78. An operator of a speed measuring device does not actually "calibrate" by following any of the testing procedures. The radar unit is calibrated at the factory during manufacture: these testing procedures do no more than verify proper calibration.

against a non-metallic object.[79] Each tuning fork is engraved with a number corresponding to miles per hour that the unit should record when exposed to the frequency emitted by the vibrating fork. The test is performed by passing the vibrating tuning fork through the radar beam. Then a comparison of the radar's reading and the tuning fork's inscription is made. When the two are the same the radar unit is said to be accurate.[80]

Criticism: A tuning fork test only checks the accuracy of half the radar unit: the receiver and its circuitry.[81] If the transmitter is miscalibrated at a higher frequency than is normal, it will not be detected by a tuning fork test.[82] Additionally, a tuning fork test only checks the accuracy of the radar at the particular calibration of the fork used. For example, if the fork is designed to vibrate at a frequency corresponding to 60 m.p.h., the tuning fork check does not test the radar unit at 59 m.p.h., 61 m.p.h., or 90 m.p.h.[83] Abuse of tuning forks by officers is another concern.[84] A tuning fork vibrates at a designated frequency because of its structural design and tong spread.[85] These forks are often left on the patrol car seat where they can be sat upon, thrown carelessly in the glovebox, or carried in the officer's back pants pocket where they may be sat on.[86] Examination of tuning forks will often reveal they are nicked, dented, or even bent. When the fork is bent, it will vibrate at a frequency different from the designed and inscribed specifications.[87] Hence, when the radar unit is out of calibration and is being checked for accuracy with a bent tuning fork, the radar test could possibly in-

79. *See generally* Operator's Manual, Kustom's KR-11, at 14-15 (1978) (Kustom Signals, Inc., 1010 West Chesnut, Chanute, Kansas 66720). "Striking the tuning forks too hard will produce false overtones which may be read as speeds slightly above or below those specified." *Id.* at 15.

80. *Id.* at 14. The operator's manual specifies that in order to test radar in the "moving mode" by the tuning fork method, *two* tuning forks must be used, one to check the "low radar" range and another to check the "high radar" range.

81. Trial Record, State v. Aquilera, No. 711-101S (Fla. Dade County Ct. May 7, 1979).

82. *See id.*

83. *See generally* Comment, *Radar and the Law*, 10 S. TEX. L.J. 269, 280 n.56, 281 n.57 (1968).

84. *See id.* at 281 n.57.

85. *See generally id.* at 280 n.56, 281 n.57.

86. *See id.* at 281 n.57. As a former law enforcement officer the author, Joseph G. Trichter, had many occasions to witness abuse of tuning forks by radar operators.

87. Trial Record, State v. Aquilera, No. 711-101S (Fla. Dade County Ct. May 7, 1979).

dicate accuracy, when in fact the unit is out of calibration.[88] Finally, tuning forks are rarely, if ever, rechecked to assure continuing accuracy.[89]

B. *Internal Tone or Internal Tuning Fork*

Checking the calibration of radar by means of an internal tuning fork is a method by which an electronically activated tong is caused to vibrate within the unit itself.[90] The test is performed by the operator pushing a button on the control panel of the apparatus. When the operator tests the unit and it is working properly, the digital reading of the target vehicle speed display will show a predetermined number of miles per hour, per design of the manufacturer.[91] If the reading is different from the design specifications of the internal tuning fork, the radar is said to be operating improperly.[92]

Criticism: An internal tuning fork, like the external tuning fork, only checks the accuracy of the receiving part of the radar unit.[93] It in no way verifies the accuracy of the transmitter. Further, it only checks the unit at the fixed miles-per-hour level predesignated by the manufacturer.[94] Allowing the radar's own circuitry to attest its accuracy could be characterized as letting the unit bootstrap itself into accuracy.[95] A partially malfunctioning unit could be accepted as accurate based upon feedback from a single circuit of the multiple-circuit unit.[96] Lastly, internal tuning forks, like external tuning forks, are rarely, if ever, rechecked for

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88. *See id.* An indication of accuracy will occur only if the tuning fork and the radar unit have the identical calibration or are out of calibration to the same degree.

89. *See* Comment, *Radar and the Law*, 10 S. TEX. L.J. 269, 281 n.57 (1968).

90. Interview with Michael Lederberg, Public Defender in *Aquilera*, Dade County Public Defender's Office, Miami, Florida (Sept. 20, 1979) [hereinafter cited as Lederberg]; Interview with the Honorable Alfred Nesbitt, Chief Judge and Administrator for Dade County Traffic Courts, Miami, Florida (Sept. 19, 1979) [hereinafter cited as Nesbitt].

91. Trial Record, State v. Aquilera, No. 711-101S (Fla. Dade County Ct. May 7, 1979); Lederberg, *supra* note 90; Nesbitt, *supra* note 90.

92. Trial Record, State v. Aquilera, No. 711-101S (Fla. Dade County Ct. May 7, 1979); Lederberg, *supra* note 90; Nesbitt, *supra* note 90.

93. Trial Record, State v. Aquilera, No. 711-101S (Fla. Dade County Ct. May 7, 1979); Lederberg, *supra* note 90; Nesbitt, *supra* note 90.

94. Trial Record, State v. Aquilera, No. 711-101S (Fla. Dade County Ct. May 7, 1979); Lederberg, *supra* note 90; Nesbitt, *supra* note 90.

95. *See* State v. Gerdes, 191 N.W.2d 428, 431 (Minn. 1971).

96. *See id.* at 431.

accuracy.[97]

C. *Automobile Speedometer*

This method is used in checking the accuracy of both stationary and moving radar.[98] Stationary radar may be checked by a pace car speedometer in two ways.[99] First, while the radar unit is stationary, a vehicle is driven through the radar's zone of influence, and the apparatus' recording is compared with the speed shown on the moving vehicle's speedometer.[100] The second method is to aim the stationary radar forward in the patrol car while the automobile is moving.[101] A comparison is then done of the radar's reading of stationary objects with the patrol car's speedometer.[102] When the radar's digital display recording is the same as the speedometer reading, the unit is said to be accurate.[103]

There is a major distinction between stationary and moving radar when the speedometer of the patrol car is used to check the accuracy of the unit. In testing a moving radar unit the patrol car's speedometer is measured against the digital display of the "low radar."[104] When this low radar reading and the patrol vehicle's speedometer are the same, the radar is said to be operating

97. *Cf.* Comment, *Radar and the Law,* 10 S. TEX. L.J. 269, 281 n.57 (1968) (external tuning forks are rarely rechecked for accuracy).

98. Trial Record, State v. Aquilera, No. 711-101S (Fla. Dade County Ct. May 7, 1979); Lederberg, *supra* note 90; Nesbitt, *supra* note 90.

99. Trial Record, State v. Aquilera, No. 711-101S (Fla. Dade County Ct. May 7, 1979); Lederberg, *supra* note 90; Nesbitt, *supra* note 90.

100. This type of testing presents a hearsay problem for the prosecution. As a result of this hearsay obstacle, the prosecution should be required to have the radar operator testify about the radar reading, and the test car officer testify about the vehicle speedometer reading. Without testimony of both officers, the hearsay rule can preclude the trial court from accepting the radar evidence as accurate.

101. Trial Record, State v. Aquilera, No. 711-101S (Fla. Dade County Ct. May 7, 1979); Lederberg, *supra* note 90; Nesbitt, *supra* note 90.

102. Trial Record, State v. Aquilera, No. 711-101S (Fla. Dade County Ct. May 7, 1979); Lederberg, *supra* note 90; Nesbitt, *supra* note 90.

103. *But cf.* Comment, *Radar and the Law,* 10 S. TEX. L.J. 269, 281 n.57 (1968) (American made autos may have inaccurate speedometers). At least one radar and speedometer technician has stated that American automobile speedometers register 1.5 to 2 miles per hour faster than a true speed of 20 miles per hour. This error compounds with each additional 20 mile per hour increment of increased speed. *Id.* at 281 n.57.

104. Trial Record, State v. Aquilera, No. 711-101S (Fla. Dade County Ct. May 7, 1979); Lederberg, *supra* note 90; Nesbitt, *supra* note 90.

accurately.[105]

Criticism: Automobile speedometers are not inherently error free. Authorities estimate the margin of error at about seven percent.[106] When a vehicle's tires have been changed to either a smaller or a larger size the speedometer must be recalibrated, otherwise the vehicle speedometer fails to measure the true speed of the vehicle.[107] When the speedometer of the pace vehicle is malfunctioning or there has been a tire size change without subsequent recalibration, an error in the radar unit may go undetected if the radar's error is identical to the speedometer error.[108] Again, like the external and internal tuning forks, patrol car speedometers are seldom rechecked for accuracy.[109]

D. *Factory*

Following assembly the radar unit is factory tested and certified as accurate by trained experts of the manufacturer using special electronic equipment.[110]

Criticism: This method fails to verify accuracy of the radar device on location.[111] The most thorough factory test cannot insure accuracy of the unit after it leaves the manufacturer even when the unit is returned periodically for recalibration. Some errors will occur solely because of the geographical, electrical, and weather conditions existing at the time of a particular recording.[112]

105. Trial Record, State v. Aquilera, No. 711-101S (Fla. Dade County Ct. May 7, 1979); Lederberg, *supra* note 90; Nesbitt, *supra* note 90.

106. *See* Comment, *Radar and the Law,* 10 S. TEX. L.J. 269, 281 n.57 (1968). The seven percent figure represents the minimum projected speedometer error for an American made automobile traveling at 50 miles per hour pursuant to the formula in note 103, *supra. See id.* at 281 n.57.

107. Trial Record, State v. Aquilera, No. 711-101S (Fla. Dade County Ct. May 7, 1979); Lederberg, *supra* note 90; Nesbitt, *supra* note 90.

108. Trial Record, State v. Aquilera, No. 711-101S (Fla. Dade County Ct. May 7, 1979); Lederberg, *supra* note 90; Nesbitt, *supra* note 90.

109. Trial Record, State v. Aquilera, No. 711-101S (Fla. Dade County Ct. May 7, 1979); Lederberg, *supra* note 90; Nesbitt, *supra* note 90.

110. Pfeiffer, *supra* note 70.

111. Trial Record, State v. Aquilera, No. 711-101S (Fla. Dade County Ct. May 7, 1979); Lederberg, *supra* note 90; Nesbitt, *supra* note 90.

112. Trial Record, State v. Aquilera, No. 711-101S (Fla. Dade County Ct. May 7, 1979); Lederberg, *supra* note 90; Nesbitt, *supra* note 90.

E. *Radar v. Radar*

Here, one radar unit's reading is compared to the reading of another unit. When the two units have identical readings, the tested unit is said to be accurate.[113] This type of testing can be done with the units operating one at a time or simultaneously.[114]

Criticism: When the control unit is inaccurate, comparison with a "suspect" unit will fail to detect any inaccuracy if the suspect unit manifests the same inaccuracies present in the control unit.[115] Where both units are operating simultaneously, and the radio microwaves transmitted by the control unit are picked up and locked onto by the untested unit, the result will be the reception of a transmission reflection from the wrong radar unit.[116] Additionally, when the radar units are tested one at a time, a malfunctioning unit could be affected by electrical interference present only while it was being tested.[117] This interference could cause the miscalibrated unit to produce a reading identical to the functional unit's reading. Under such circumstances the radar v. radar method of testing would indicate a malfunctioning unit was working properly.[118]

VII. Types of Error Affecting Police Radar

A. *Numeric Display*

All radar devices display radar readings by means of a lighted digital display.[119] The lighted numbers are illuminated in exactly the same way as the numbers of a digital watch or clock. The po-

113. Trial Record, State v. Aquilera, No. 711-101S (Fla. Dade County Ct. May 7, 1979); Lederberg, *supra* note 90; Nesbitt, *supra* note 90.

114. Trial Record, State v. Aquilera, No. 711-101S (Fla. Dade County Ct. May 7, 1979); Lederberg, *supra* note 90; Nesbitt, *supra* note 90.

115. Trial Record, State v. Aquilera, No. 711-101S (Fla. Dade County Ct. May 7, 1979); Lederberg, *supra* note 90; Nesbitt, *supra* note 90.

116. Trial Record, State v. Aquilera, No. 711-101S (Fla. Dade County Ct. May 7, 1979); Lederberg, *supra* note 90; Nesbitt, *supra* note 90.

117. Trial Record, State v. Aquilera, No. 711-101S (Fla. Dade County Ct. May 7, 1979); Lederberg, *supra* note 90; Nesbitt, *supra* note 90.

118. Nesbitt, *supra* note 90. Judge Nesbitt noted with suspicion that the prosecution in *Aquilera* had been requested to submit evidence on the "radar v. radar" test and had refused to do so.

119. Trial Record, State v. Aquilera, No. 711-101S (Fla. Dade County Ct. May 7, 1979); Lederberg, *supra* note 90; Nesbitt, *supra* note 90.

tential for error exists when the radar loses one or more segments in the numeric display.[120] Accordingly, when a segment of the numeric display element burns out, a six might be read as a five, or a seven as a one. This type of error usually results in a lower number and, consequently, indicates a speed lower than actual target speed.[121] Nevertheless, a malfunctioning digital display can indicate a speed faster than the target's true speed.[122] For example, an eight might be read as a nine. The strength of this potential error as a defense is limited, however, as judges dislike an 80 m.p.h. violation as much as they dislike a 90 m.p.h. violation.[123]

B. *Batching*

Batching is a common error associated with moving radar resulting from the device's failure to respond instantly to changes in the patrol car's ground speed.[124] For example, when the patrol car takes off in pursuit of an alleged violator and accelerates suddenly, the radar may read the increase in closing speed between the patrol car and the target vehicle, and add patrol car acceleration to the speed of the target.[125]

C. *Panning*

This error occurs almost exclusively in hand-held stationary radar units.[126] Panning can result when an operator moves the unit while taking a reading. The motion of the transmitter gun is added to the target vehicle's speed producing an erroneous reading.[127]

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120. Trial Record, State v. Aquilera, No. 711-101S (Fla. Dade County Ct. May 7, 1979); Lederberg, *supra* note 90; Nesbitt, *supra* note 90.

121. Trial Record, State v. Aquilera, No. 711-101S (Fla. Dade County Ct. May 7, 1979); Lederberg, *supra* note 90; Nesbitt, *supra* note 90.

122. Trial Record, State v. Aquilera, No. 711-101S (Fla. Dade County Ct. May 7, 1979); Lederberg, *supra* note 90; Nesbitt, *supra* note 90.

123. Error attributable to a burned out segment can be detected by testing in modern radar units. The check is accomplished with a "light" test that illuminates all segments simultaneously for operator examination. When this test is performed before and after each citation, the digital display should be operating properly.

124. HOT ROD MAGAZINE, Mar. 1979, at 45.

125. *Id.* at 45.

126. Trial Record, State v. Aquilera, No. 711-101S (Fla. Dade County Ct. May 7, 1979); Lederberg, *supra* note 90; Nesbitt, *supra* note 90.

127. Trial Record, State v. Aquilera, No. 711-101S (Fla. Dade County Ct. May 7, 1979); Lederberg, *supra* note 90; Nesbitt, *supra* note 90.

The same phenomenon occurs in photography when a photograper moves the camera while the shutter is open. Just as the camera's motion affects the developed photograph, the motion of the radar is sensed by its receiving antenna and manifested in the digital readout produced.[128]

D. *Automatic Lock*

This is one of the chief criticisms of police radar. The radar's "lock" capacity is an electronic stopping of the digital display at a single reading.[129] Locking can be done manually by the operator[130] or automatically by the unit. Once the unit automatically locks onto the target's speed, it will record only increases in speed, and not decreases.[131] For instance, when the signal received indicates the target's speed as 65 m.p.h. and the target subsequently accelerates to 70 m.p.h., the faster reading will be recorded and locked into the digital display. When the initial signal received is 65 m.p.h., subsequent deceleration will not be shown on the locked digital display.[132]

The true detrimental potential, inherent in the automatic lock capability, occurs when the radar unit picks up a momentary ghost or false signal and locks onto it.[133] The erroneous reading is thus locked in and attributed to the target vehicle.[134] Because the automatic lock will not show decreases in the numeric display, the operator will not be apprised of the momentary character of the readout, nor able to monitor the target vehicle's continuous radio

128. Interview with Dr. William Wilson, Professor of Electrical Engineering, Rice University, Houston, Texas (Oct. 9, 1979). Dr. Wilson suggested that panning occurs when there is a reflecting object in the panning field, and the potential for error is compounded directly as the distance from the radar unit to the object decreases.

129. Theoretically, the target vehicle's speed is thus locked into the radar unit digital display.

130. This is done with a manual locking control on the radar unit. Once a reading is manually locked in, the digital display will not change until manually released by the operator.

131. Trial Record, State v. Aquilera, No. 711-101S (Fla. Dade County Ct. May 7, 1979); Lederberg, *supra* note 90; Nesbitt, *supra* note 90.

132. Trial Record, State v. Aquilera, No. 711-101S (Fla. Dade County Ct. May 7, 1979); Lederberg, *supra* note 90; Nesbitt, *supra* note 90.

133. Trial Record, State v. Aquilera, No. 711-101S (Fla. Dade County Ct. May 7, 1979); Lederberg, *supra* note 90; Nesbitt, *supra* note 90.

134. Trial Record, State v. Aquilera, No. 711-101S (Fla. Dade County Ct. May 7, 1979); Lederberg, *supra* note 90; Nesbitt, *supra* note 90.

microwave reflections.[135] These false signals can be caused by electrical storms, power transformers and transmission lines, CB radio signals, police radio signals, aircraft radio transmissions, commercial air conditioners, neon lights, or even microwave ovens.[136]

E. *Catch-Up*

Catch-up error happens in stationary radar and is similar to the batching error because it occurs when the patrol car accelerates from a dead stop.[137] If the officer has not manually locked on the radar, and the device's automatic lock is on, the acceleration speed of the patrol car will be added onto the target vehicle's speed.[138]

F. *Cosine or Angle Error*

To obtain a precisely accurate reading through radio microwave reflections, the radar unit must be either directly in front of, or directly behind the target.[139] Such optimum positioning rarely, if ever, occurs because the juxtaposition of the radar-equipped vehicle to the target vehicle seldom results in emission of microwave signals parallel to the path of the target vehicle.[140] There is almost invariably an angular disparity between the linear axis of the sig-

135. Some modern radar units have three digital displays: one for monitoring the patrol car speed and two for monitoring the target vehicle's speed. Only one target display has automatic locking capacity. This represents a major step forward by the radar industry; however, these technological advances do not ensure error free performance. During a factory representative's demonstration of a new three display unit in Houston, October 29, 1979, the author, Joseph G. Trichter, observed many instances when the control display and the automatic lock display varied as much as 8 m.p.h. In addition, there were times when the patrol vehicle display varied with the patrol vehicle speedometer as much as 60 miles per hour.

136. *See generally* Blackmore, *Radar: Caught In Its Own Trap*, POLICE MAGAZINE, Sept. 1979, at 31-32; Nesbitt, *supra* note 90; Pfeiffer, *supra* note 70. At least one police radar manufacturer advises against the use of the automatic locking device. Telephone interview with Ken McCoy, President, M.P.H. Industries, Inc. (Oct. 1979). M.P.H. units retain the automatic lock capacity in order to meet specifications required by some law enforcement agencies. *Id.*

137. Trial Record, State v. Aquilera, No. 711-101S (Fla. Dade County Ct. May 7, 1979); Lederberg, *supra* note 90; Nesbitt, *supra* note 90.

138. Trial Record, State v. Aquilera, No. 711-101S (Fla. Dade County Ct. May 7, 1979); Lederberg, *supra* note 90; Nesbitt, *supra* note 90.

139. Trial Record, State v. Aquilera, No. 711-101S (Fla. Dade County Ct. May 7, 1979); Lederberg, *supra* note 90; Nesbitt, *supra* note 90.

140. Trial Record, State v. Aquilera, No. 711-101S (Fla. Dade County Ct. May 7, 1979); Lederberg, *supra* note 90; Nesbitt, *supra* note 90.

nal emitted and the linear axis of the target vehicle's path.[141] If the radar beam hits the target at a precise 90 degree angle, no cosine distortion will be recorded.[142] However, when the angle of intersection is greater than or less than 90 degrees, the radar beam will lose some of the target's reflection, and the unit's digital display reading will be less than the actual speed of the detected target.[143]

In stationary radar, any angle error will favor the motorist.[144] Conversely, when moving radar is used and the low angle component of the system suffers angular distortion, the radar could erroneously underestimate the velocity of the patrol car.[145] When subtracted from the total "closing speed" this phenomenon would produce a corresponding overestimation of the target vehicle speed. For example, a patrol car traveling at 40 m.p.h. with a low radar angle error of 10 m.p.h. will result in a target vehicle traveling 50 m.p.h. to be recorded at 60 m.p.h.[146]

G. *Shadowing*

This error is similar to the batching and cosine error because it occurs with moving radar. Shadowing occurs when the low radar fixes on slow-moving objects rather than stationary ones.[147] The radar's reception of the low angle reflections is distorted producing an underestimation of the speed of the patrol car, and a corresponding upward distortion of the target vehicle's speed.[148] Moving radar has two digital displays, one indicating the patrol car's speed and one for the target vehicle's speed. The manufacturers claim that a radar operator can detect shadowing error simply by com-

141. Trial Record, State v. Aquilera, No. 711-101S (Fla. Dade County Ct. May 7, 1979); Lederberg, *supra* note 90; Nesbitt, *supra* note 90.

142. Trial Record, State v. Aquilera, No. 711-101S (Fla. Dade County Ct. May 7, 1979); Lederberg, *supra* note 90; Nesbitt, *supra* note 90.

143. Trial Record, State v. Aquilera, No. 711-101S (Fla. Dade County Ct. May 7, 1979); Lederberg, *supra* note 90; Nesbitt, *supra* note 90.

144. Trial Record, State v. Aquilera, No. 711-101S (Fla. Dade County Ct. May 7, 1979); Lederberg, *supra* note 90; Nesbitt, *supra* note 90.

145. Trial Record, State v. Aquilera, No. 711-101S (Fla. Dade County Ct. May 7, 1979); Lederberg, *supra* note 90; Nesbitt, *supra* note 90.

146. *See generally Blackmore, Radar: Caught In Its Own Trap,* POLICE MAGAZINE, Sept. 1979, at 30; Nesbitt, *supra* note 90; Pfeiffer, *supra* note 70.

147. Trial Record, State v. Aquilera, No. 711-101S (Fla. Dade County Ct. May 7, 1979); Lederberg, *supra* note 90; Nesbitt, *supra* note 90.

148. Trial Record, State v. Aquilera, No. 711-101S (Fla. Dade County Ct. May 7, 1979); Lederberg, *supra* note 90; Nesbitt, *supra* note 90.

paring the radar reading to the patrol car's speedometer.[149] However, Dr. Lee Nichols, a professor of electrical engineering and a radar defense expert, asserts that the manufacturers' claim is oversimplified:

> We've got to get officers to realize how difficult a job it is and how error-prone moving radar can be, . . . there are essentially four things an operator has to do when he is in the moving mode. He has to drive the car, he has to read the radar to determine that a violation is taking place, he has to make visible verification that an offense is taking place, and, if he is doing his job, he has to check to verify [the read-out of the patrol car's speed] against his calibrated speedometer. To do all these things at once is tough, demanding work—not something an officer can maintain all day long without making errors.[150]

The possibility of shadowing error is intensified when the officer is operating the radar with the automatic lock. The automatic lock system locks onto the highest signal within the zone of influence and thereafter displays no decreases.[151] This locking occurs in as little as a hundredth of a second,[152] and affords the officer very little time to perform each of the verification checks suggested by Dr. Nichols.

H. *Antidetection Switch*

With the advent of radar detection devices,[153] radar manufacturers developed the antidetection switch. Activation of the switch

149. Trial Record, State v. Aquilera, No. 711-101S (Fla. Dade County Ct. May 7, 1979); Lederberg, *supra* note 90; Nesbitt, *supra* note 90.

150. Blackmore, *Radar: Caught In Its Own Trap*, POLICE MAGAZINE, Sept. 1979, at 30.

151. Trial Record, State v. Aquilera, No. 711-101S (Fla. Dade County Ct. May 7, 1979); Lederberg, *supra* note 90; Nesbitt, *supra* note 90.

152. Trial Record, State v. Aquilera, No. 711-101S (Fla. Dade County Ct. May 7, 1979); Lederberg, *supra* note 90; Nesbitt, *supra* note 90.

153. A radar detection device is actually a radar receiver designed to sound an alarm when its receiving antenna detects radio microwaves. These devices alert a driver that radar is being used in the area; they have no radar jamming capacity. *See* Bedard, *Smoking Out Old Smokey*, CAR & DRIVER MAGAZINE, Feb. 1979, at 69. A pamphlet published by M.P.H. Industries suggests that the radar detection device industry has actively supported an anti-radar campaign in order to discourage state laws prohibiting radar detection devices. *See* M.P.H. Bulletin: Of Fools and Knaves (Sept. 14, 1979) (published by M.P.H. Industries, Inc., 15 South Highland, Chanute, Kansas 66720). Three states and the District of Columbia have enacted legislation prohibiting radar detection devices, and the Department of Transportation agressively supports their prohibition. *See id.*

cuts power to the transmitter while allowing the remainder of the radar unit to function normally.[154] The switch allows the radar unit to be on and warmed-up without transmitting radio microwaves.[155] When an operator of a radar unit observes a vehicle he believes to be speeding within range of the radar unit, he simply flips off the antidetection switch, allowing the transmitter to radiate.[156] Hence, he can receive the reflection of the target's speed and record it before the suspect can reduce speed. The source of error associated with this procedure is known as a power surge.[157] When re-activated the transmitter can receive too much electricity too quickly and produce a higher than normal beam frequency.[158] This initial surge of higher frequency radio microwaves is reflected off the target vehicle exaggerating its recorded speed.[159]

VIII. *Florida v. Aquilera*: The Miami Radar Trial of 1979

In May 1979, Judge Alfred Nesbitt, Chief Judge of Dade County Traffic Courts, heard over 2,000 pages of testimony and examined 33 exhibits presented by highly trained and experienced experts in a trial on the accuracy and reliability of radar.[160] Testimony was presented by experts in mathematics, electrical engineering, and the design, construction, and testing of radar devices. The controversy in Miami dealt only with radar currently used by police as a speed-measuring device.[161] There was no controversy as to the reliability of the "Doppler Effect" concept, but only as to its use in current traffic radar units.[162]

After hearing evidence on all potential errors previously dis-

154. Trial Record, State v. Aquilera, No. 711-101S (Fla. Dade County Ct. May 7, 1979); Lederberg, *supra* note 90; Nesbitt, *supra* note 90.

155. Trial Record, State v. Aquilera, No. 711-101S (Fla. Dade County Ct. May 7, 1979); Lederberg, *supra* note 90; Nesbitt, *supra* note 90.

156. Trial Record, State v. Aquilera, No. 711-101S (Fla. Dade County Ct. May 7, 1979); Lederberg, *supra* note 90; Nesbitt, *supra* note 90.

157. Trial Record, State v. Aquilera, No. 711-101S (Fla. Dade County Ct. May 7, 1979); Lederberg, *supra* note 90; Nesbitt, *supra* note 90.

158. Trial Record, State v. Aquilera, No. 711-101S (Fla. Dade County Ct. May 7, 1979); Lederberg, *supra* note 90; Nesbitt, *supra* note 90.

159. Trial Record, State v. Aquilera, No. 711-101S (Fla. Dade County Ct. May 7, 1979); Lederberg, *supra* note 90; Nesbitt, *supra* note 90.

160. Trial Record, State v. Aquilera, No. 711-101S (Fla. Dade County Ct. May 7, 1979).

161. Trial Record, State v. Aquilera, No. 711-101S (Fla. Dade County Ct. May 7, 1979).

162. *See* State v. Acquilera, No. 711-101S (Fla. Dade County Ct. May 7, 1979).

cussed in this article and on most radar units now manufactured, the court ruled that "the reliability of the radar speed measuring devices as used in their present modes . . . has not been established beyond and to the exclusion of every reasonable doubt . . . ."[163] Accordingly, the radar evidence was excluded from the trial.[164] In his opinion Judge Nesbitt stated:

> I recognize that many millions of dollars in revenue are involved in "speeding" fines but let it be understood once and for all, the function of the traffic court is to convict the guilty, acquit the innocent, and improve traffic safety, . . . not to be merely an arm of any revenue collection office. At the same time, if the errors alleged by the opponents of radar do exist, then one must wonder—What percentage of these millions of dollars has been collected from erroneously convicted defendants?—How many of these defendants have suffered the additional penalties of extremely higher insurance rates, and the unnecessary compiling of points with the consequent loss of driver's licenses and perhaps jobs?[165]

Since the *Aquilera* decision, all but one of the eighteen Dade County Courts have refused admission of radar evidence.[166] Several Northern Florida County Traffic Courts have also followed the decision;[167] *Aquilera,* however, has had negligible impact, if any, on other jurisdictions throughout the nation.[168] The reluctance of other jurisdictions to follow the *Aquilera* decision may be attributable to a variety of factors. The fact that the case was never reviewed by an appellate court limits its precedential value. Other courts may be aware of the *Aquilera* decision but not the evidence underlying the decision. The cost of presenting evidence comparable to that presented in *Aquilera* would no doubt discourage most defendants charged with a mere traffic violation.[169]

In addition to the potential errors in radar evidence previously discussed in this article, the Florida court recognized two other

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163. State v. Aquilera, No. 711-101S (Fla. Dade County Ct. May 7, 1979). *But see* State v. Wojtkowiak, No. B1-78 (N.J. Super. Ct. Aug. 2, 1979).

164. The State of Florida did not appeal the decision. Nesbitt, *supra* note 90.

165. State v. Aquilera, No. 711-101S (Fla. Dade County Ct. May 7, 1979).

166. Nesbitt, *supra* note 90.

167. Nesbitt, *supra* note 90.

168. Corpus Christi Caller, Oct. 1, 1979, at 4A, col. 1 (spot check by Associated Press indicated *Aquilera* had little impact beyond Dade County).

169. The cost of the defense in *Aquilera* exceeded $40,000. Lederberg, *supra* note 90.

substantial reasons for holding radar unreliable and inaccurate. First, it was determined that the current range and beam width design of radar made it inherently susceptible to error. Second, the court found that there was a substantial lack of training in error recognition by radar operators.[170]

A. *Range and Beam Width*

With respect to the first finding, the court recognized that manufacturers had purposely increased their respective unit's range and not narrowed the beam width, as a means of making their units more attractive to unsuspecting buyers.[171] The error enhancement became clear when both defense and state experts testified that the maximum range of radar was approximately 7,500 feet and its average beam width was 19 degrees. The court found that when the radar's range was long, the unit would be receiving and locking in on signals long before the operator could visually identify the vehicle. Beam width was recognized to be an equally significant defect because of the wide degree of coverage. At a range of 100 feet, the beam width was 34 feet; at 500 feet, it was 172 feet; at 1,000 feet, it was 344 feet; at 5,000 feet, it was 1,720 feet; and at 7,500 feet, it was 2,580 feet.[172] At half a unit's range, therefore, its zone of influence would easily include over ten lanes of traffic. With such a wide area for the operator to observe, the court concluded that the chance of misidentification was simply too great to permit operator testimony based on radar.[173]

B. *Operator Training*

The critics of radar will agree there is an almost total lack of proper training by law enforcement agencies in the use and operation of speed-measuring devices. Even the radar industry acknowledges that the training programs of traffic enforcement agencies are inadequate.[174] After evaluating evidence presented, the

170. *See* State v. Aquilera, No. 711-101S (Fla. Dade County Ct. May 7, 1979).
171. Nesbitt, *supra* note 90.
172. Lederberg, *supra* note 90.
173. Trial Record, State v. Aquilera, No. 711-101S (Fla. Dade County Ct. May 7, 1979).
174. Pfeiffer, *supra* note 70. Mr. Pfeiffer believes the *Aquilera* decision may provide long overdue impetus for law enforcement agencies to improve training of radar operators. Pfeiffer, *supra* note 70.

Aquilera court found as a fact that police radar operators lacked sufficient training. While most operators possess the basic knowledge necessary to operate their department's radar equipment, at least some acknowledge unawareness of the fundamentals of error recognition.[175] Considering these potential errors, any reading obtained by an operator who lacks proper training and sensitivity to error recognition can be characterized as "unreliable."

IX. SHODDILY DESIGNED RADAR

Evidence was adduced at the *Aquilera* trial that, when top-of-the-line radar units were purchased in a large quantity, a $2,500 unit was sold for under $400. This means courts have been taking uncritical judicial notice of devices that transmit and receive radio microwaves, measure the speed of radio microwaves traveling at the speed of light in hundredths of seconds, compute differences in the waves, digitally display readings in miles per hour, yet sell for $400.[176] Even the radar industry admits there are units in use that can only be characterized as "garbage radar."[177] Currently, there exist no industry standards that manufacturers are required to follow in the production of radar systems.[178] The only government regulations applicable to police radar are frequency and licensing restrictions imposed by the Federal Communications Commission.[179]

175. Telephone interview with Sergeant C. V. Thompson, Houston Police Department (Oct. 9, 1979) (Houston police receive no in-class radar training—only field training); interview with Captain C. N. Wedemeyer, Harris County Sheriff's Office (Oct. 8, 1979) (Harris County Sheriff's deputies receive no in-class radar training—only field training). Field training by a non-expert officer is clearly not sufficient. *See* State v. Aquilera, No. 711-101S (Fla. Dade County Ct. May 7, 1979).

176. Nesbitt, *supra* note 90.

177. Pfeiffer, *supra* note 70. One large law enforcement agency was so dissatisfied with the performance of radar equipment manufactured by a competitor of M.P.H. Industries that it returned approximately 200 units following a year of use. Pfeiffer, *supra* note 70.

178. Trial Record, State v. Aquilera, No. 711-101S (Fla. Dade County Ct. May 7, 1979).

179. The Federal Communications Commission (FCC) has classified "police radar" as a "radio location device" under Part 90 of the Commission's Rules. Letter to Joseph Gary Trichter from Joan Frazier, Application Examiner of the Equipment Authorization Branch, Federal Communications Commission (Nov. 20, 1979). The characteristics of output signals subject to FCC regulation were described as: "radio frequency output power; spurious emission; occupied bandwidth; frequency tolerance; type of emission; and frequency of operation." *Id.* Additionally, police radar units "operating in the 24 GHz band are subject to certain requirements concerning gain and polarization of the antenna. *All of these requirements have been imposed by the Commission only for the purpose of limiting the capabil-*

The lack of industry or government standards permits new radar manufacturers to produce and sell their units with no design requirements other than specifications of purchasing agencies. Consequently, inferior speed-measuring devices have been characterized as reliable merely because they are designated "radar." In short, throughout the country, there is no guarantee of the design integrity of current radar units other than the promise made by individual manufacturers concerning their own units.[180]

X. Summary and Proposals

The Doppler radar systems judicially noticed in the 1950's are not the same devices used by traffic enforcement agencies today. Still, the modern radar systems continue to be clothed in a veil of court approval, ostensibly because they are called "radar." Supporters and opponents of radar alike acknowledge the validity of the scientific principles of police radar. Nevertheless, there is conflict concerning the best technological application of Doppler's principle of reflection to produce reliable scientific evidence. The

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ity of the device to cause interference to radiocommunication." Id. (emphasis added). The specific requirements can be obtained by writing the FCC and requesting *Criteria to be Met by Doppler Radars Operating in the 24.05-24.25 GHz Frequency Band,* FCC Bulletin OCE 37 (April 1979) and FCC Public Notice 16883 (April 27, 1979). Public Notice 16883 contains a listing, by model and manufacturer of all police radar units approved by the FCC.

180. Additionally, the radiation emitted by police radar devices may constitute a potential health hazard. *See* State v. Aquilera, No. 711-101S (Fla. Dade County Ct. May 7, 1979) (Professor Nichols testified concerning current research to ascertain effect of microwave exposure upon radar operator). Reportedly, two radar manufacturers have vastly exceeded FCC output requirements to increase the range of their radar units. Pfeiffer, *supra* note 70. This higher output amplifies the operator's radiation exposure. A study conducted by the C.P.I. Corporation to determine the possible effect of police radar on medical pacemakers yielded the following results: (1) a radar operator with a pacemaker would not be affected while operating the Doppler device so long as it was aimed out the automobile window, because the microwaves pass out of the vehicle; (2) a motorist with a pacemaker would not be affected while driving his vehicle through a radar beam because the exposure period is very limited and most of the microwaves would be reflected off his vehicle rather than penetrate it; (3) a radar operator and/or motorist with a pacemaker *will be likely to be affected* if they remain in a radar beam, near the device and unshielded, even though the pacemaker is shielded. Telephone interview with Ken Carnes, Sales Representative for C.P.I., Inc., 1935 West Country Road, St. Paul, Minnesota 55113, a manufacturer of medical pacemakers (C.P.I. conducted the study for the Minnesota Highway Patrol). It is very commonplace for a police officer and motorist to stand in the radar beam while the officer issues a citation. If either the officer or motorist has a pacemaker, this practice could be dangerous. *Id. But see* Dornsifer, The Ticket Book, at 103 (1978) (no record of police radar interference with pacemaker).

industry, federal and state governments, and courts have collectively failed to impose protective safeguards to insure design integrity of police radar systems. Moreover, there appears to be a clear failure by our law enforcement agencies to adequately educate radar operators in basic principles of radar, its operation, and error recognition.[181]

A. *Design Proposal*

Inasmuch as the potential for error is greatly enhanced while radar is in the moving mode rather than the stationary mode, it is suggested that moving radar not be accorded judicial notice by courts. Errors resulting from electrical interference, batching, shadowing, automatic lock devices, and cosine or angle error subject the accuracy and reliability of moving radar to reasonable doubt. Additionally, the inherent problems of misidentification associated with beam width and range are compounded when radar is utilized in its moving mode.

Stationary radar is also subject to outside and inside electrical interference, automatic lock error, and the same problems of error identification associated with range and beam width. For these reasons, it is suggested that stationary police radar not be accorded judicial notice. Subject to the design integrity of a particular system, however, the authors would support judicial acceptance of the stationary device if its range and beam width were corrected technologically to permit proper identification and the automatic lock device and antidetection radar switch removed. It is recommended that the state legislature institute a study of police radar systems to establish design guidelines for units to be used in Texas. Additionally, the legislature should mandate a course of training for radar operators and establish criteria for operator certification.

B. *Operator Training Proposal*

If any absolute truth may be uttered about radar, it is that the magic black box is only as good as the operator. The evidence sug-

181. This failure may be attributable to the fact that police administrators are seldom trained in the scientific principles of police radar. Normally, the only radar information available to police agencies is provided by radar manufacturers. *See* B. BOGNER & J. BODNAR, HOW TO DEFEND YOURSELF AGAINST RADAR IN TRAFFIC COURT WITHOUT AN ATTORNEY, at 6-12 (1979).

gests that most operators are not properly educated in the operation and use of radar and are not trained in error recognition. Defense experts, and at least one radar manufacturer, have suggested the following as formal prerequisites to radar operation:[182]

1. Testing on location by the operator.
2. Testing immediately before and immediately after citation.[183]
3. Testing by means of three separate tests, including:
   (a) Internal tone;
   (b) Two tuning forks at varying frequencies;
   (c) Driving an automobile through the unit's zone of influence and comparing the radar unit's reading to the certified calibrated speedometer.
4. A log should be made recording the results of each test.[184]
5. An annual certification of the unit's accuracy by the manufacturer.

The implementation of such a training program and operational procedures would not unduly burden traffic enforcement agencies. Considering the potential for inaccuracy of police radar, the millions of dollars in revenue produced by these devices, the penalty points assessed against operator licenses based upon radar evidence, the effect of a conviction upon insurance premiums, the potential loss of employment, and most importantly, our concepts of fairness and justice, these proposals are long overdue.

XI. Conclusion

The courts need to scrutinize the black box to see if it has, in its present form and manner of use, truly lost its magic. Indeed, the authors believe it has.[185] Changes in society's traffic patterns, road conditions, and electronic technology mandate that we analyze radar more closely. The judiciary, legislature, and traffic enforcement

182. Blackmore, *Radar: Caught In Its Own Trap*, Police Magazine, Sept. 1979, at 32.

183. This test is advocated by the leading pro-radar authority, Dr. John Kopper. *See* Kopper, *The Scientific Reliability of Radar Speedmeters*, 33 N.C. L. Rev. 323, 353 (1955).

184. Radar operators seldom log results of tests, even though many instruction manuals generally advise it. *See* Operator's Manual, Kustoms KR-11, at 31 (1978) (Kustom Signals, Inc., 1010 West Chestnut, Chanute, Kansas 66720).

185. So goes the story about the traffic court judge who asked an expert operator and scientist where he could locate a book in the library on the accuracy and reliability of radar—the candid answer: "try fiction."

agencies need to re-examine radar devices, traffic enforcement needs, realities of the 1980's, and their consciences, then make their findings known to the radar industry. Today this industry has literally unbridled discretion in the design of radar devices. If police radar manufacturers are reticent in correcting errors now inherent in radar systems, their products may be rendered obsolete by judicial decisions or legislative action. Time waits for nothing, not even the once magic black box.