Glaser

Car Radars Could Be Standard in the 1980s

Researchers claim Detroit auto manufacturers could have a car radar on the road next year that audibly warns of imminent collisions. Impact mitigation radars should be standard in five years.

Frank J. Moncrief
Associate Editor

Research on car radars has come a long way since General Motors' first efforts in 1958. Norm Schubring, microwave group manager, and supervisor for present car radar research, recalls, "We mounted an X-band klystron and waveguides on the bumper of a 1958 Chevrolet stationwagon. The back of the wagon was filled with the high-voltage power supply and other equipment. Velocity was all we could determine; you had to guess at the range rate by the magnitude of the Doppler returns. Research was shelved until 1968, but we've had an on-going program since then."

Car radars have changed drastically since 1958. Prototypes recently developed at Bendix Research Labs, Southfield, Mich., have an 8-in.-dia antenna/radome/transceiver, which is mounted in the car grill. A Gunn diode provides the 36-GHz RF, and the 3 × 5 × 10-in. electronics package can be mounted under the hood.

"If Detroit so desired, they could have a car radar on the road next year that audibly warns the driver of an imminent collision," asserts Dr. Fred Sterzer of RCA Research Labs, Princeton, N.J. RCA has been investigating car radar since 1971 and is evaluating two radar-activated braking system prototypes.

The bulk of funding for car radar research is presently distributed by DoT's National Highway Traffic Safety Administration (NHTSA), which is evaluating all current developments. A minimum of $12 million has been allocated for auto safety research through 1980. Primary funding has been split between Minicars Inc., Goleta, Calif., which subcontracted to RCA, and Bendix Corp., Baltimore, Md. Minicars was awarded about $500,000 for its Research Safety Vehicle (RSV) (Fig. 1), of which roughly $300,000 went to RCA, according to Gerry Kossar, NHTSA contract coordinator for the Minicars program. Bendix received $400,000 for its latest research phase, which was completed in March.

Although RCA and Bendix have evolved as "heavyweights" in car radar research, recent work at Sperry Research Center, Sudbury, Mass., resulted in development of an inexpensive L-band radar that employs a novel signal-processing technique for reducing beam width. Also, researchers at General Motors Corp. have investigated differences in radar signatures for cars and roadside obstacles. Results of this study could play a significant role in solving

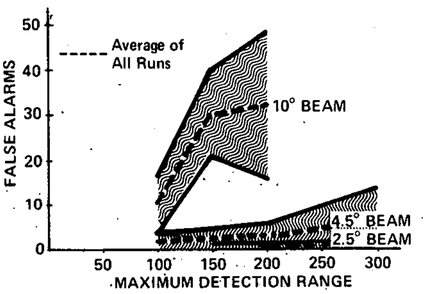
1. Minicars RSV prototype incorporates safety features in a stylish design. Estimated mass-production cost of the 2200-lb vehicle during the 1980s is $3470 with CB/AM-FM radio and air conditioning.

the false alarm enigma—if a microprocessor is developed that can perform FFTs on the order of milliseconds.

The Future Is Bright. Because funding for automobile radar research is being provided by the Federal Government, most researchers are confident that commercial availability is inevitable. A paper presented at EASCON-77, Arlington, Va. (Sept. 25-28) by Carl P. Tresselt of Bendix and Dr. Yung-Kuang Wu, contract technical advisor for the NHTSA, elicited considerable interest—primarily because it confirmed DoT's commitment to this program, in addition to unveiling some impressive Bendix research.

Parameters of the two latest Bendix prototypes include:

- Diplexed-CW format.
- 25-mW peak power at 36 GHz, with alternate pulses spaced by 820 kHz.
- An 8-in.-diam antenna/radome/receiver assembly.



2. Bendix 36-GHz prototype radar achieved a zero false alarm rate for a 2.5-deg beamwidth in the 30–45-m range. An audible warning could sound for targets between 45–75 m, with braking under 45 m.

Range information is obtained using phase comparison between two receiver channels. Relative velocity is determined by processing Doppler frequency in one channel. Phase lag between channels is used to specify changes in relative velocity. Antenna feeds are placed at 45 deg relative to the horizon. Hence, opposing systems will be cross-polarized, thereby preventing one radar from "blinding" another.

Bendix research determined that a 2.5-deg beamwidth provides a zero false alarm rate for a 30–45-m detection range (Fig. 2). However, a maximum range of 45 m compromises system effectiveness. Consequently, an audible warning is issued for targets detected between 45-75 m.

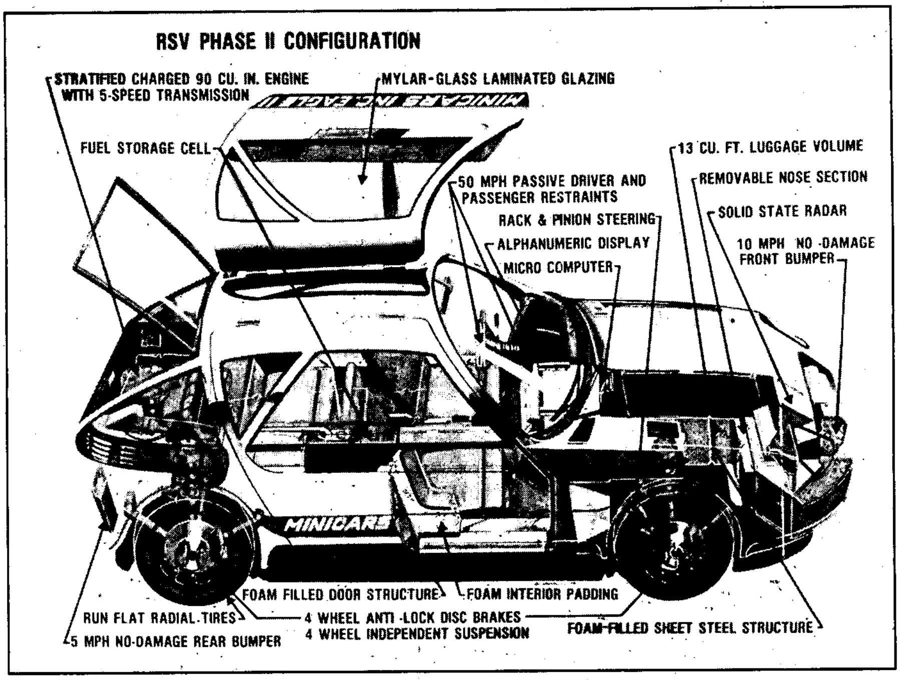
Brakes are activated for targets detected under 45 m if a collision is imminent. A driver can automatically disengage microprocessor control by turning the steering wheel or applying the brakes. "The purpose of this system is to mitigate impact rather than totally avoid collisions," remarks William Troll, project consultant for Bendix.

The Bendix prototypes were delivered to the NHTSA after routine tests were completed in March. A contract for further testing should be awarded this month. Dynamic Science, Phoenix, Ariz., which evaluated the internationally sponsored Electronic Safety Vehicle in 1973, was mentioned as a potential bidder. "The future is bright for this program," affirms Dr. Wu.

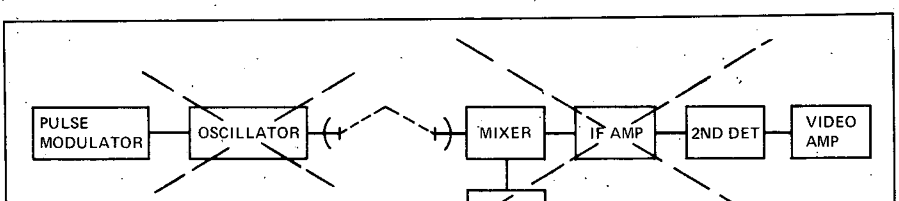
Optimism also prevails at RCA. The objective at RCA is also impact mitigation. However, its approach to the false alarm problem has been to incorporate a maximum range of 30 m. Two FM/CW radars are under evaluation with parameters of:

- 10.5 and 17.5 GHz.
- 27-mW output power.
- 1-kHz modulation rate.
- 6-W power consumption.
- 6–30-m range.
- 0–160-km/h range rate.
- 25-dB antenna gain.
- 5-deg azimuth and 10-deg elevation beamwidths.

Two microprocessors are used, one for radar control and one for the display console, which monitors myriad convenience and safety-related functions. In addition to initiating braking, the microprocessor works in conjunction with a



3. RSV radar fits in a radome in the hood, while microprocessor and display are near the dash. Foam-filled structure absorbs energy from impacts. Microprocessor-controlled anti-skid brakes are being considered.



4. Elements of a high performance radar are represented by upper block diagram, while lower diagram represents components of Sperry prototype car radar.

cruise control to maintain a predetermined distance between cars.

The Last Hurdle. "Our efforts are now geared toward developing algorithms for minimizing false alarms. A microprocessor-controlled radar that activates the brakes with an acceptable false alarm rate could be on the road in five years," predicts Dr. Erwin Belohoubek, project manager for RCA. Target discrimination involves so many variables, such as overpasses, traffic signs, heavy rain, wind-blown debris, or signals from other car radars, that development of a system that would be accepted by consumers will be a long time in coming, Belohoubek theorizes.

Estimated cost of the RCA system includes $50 for the radar, $90 for the microcomputer, and $30 for the display. "If mass production of this system occurs in the '80s, cost could be reduced to about $100 per system," predicts Dr. Sterzer of RCA.

Estimated cost for mass production of the Minicars RSV, including air conditioning and CB/AM-FM radio, is $3470 per car (Fig. 3). Minicars President Donald Friedman and several colleagues from General Motors Corp. formed Minicars in 1968 to do R&D on cars that auto makers have little incentive to build. Two RSVs are undergoing tests at Minicars, while construction of up to 17 RSVs is scheduled for this spring. Delivery of prototypes to the NHTSA for evaluation should begin within a few months.

A Possible Alternative. Dr. Gerald Ross of Sperry designed an inexpensive radar under NHTSA funding that has an effective beamwidth of 2.5 deg using a 6 × 6-in. aperture at 1.75 GHz. The emitted beam for this configuration is typically ±40 deg. However, Dr. Ross narrowed the beam that the system responds to by using a novel signal-processing technique involving an interferometer and a delay-line comparison network.

Because of low power requirements, much of the equipment needed for high-performance radars was omitted in this design (Fig. 4). A baseband pulse drives a step-recovery diode located at the mouth of a dipole antenna and situated in front of a corner reflector. One transmitter is used with two receivers, which are separated by 0.76 m. Received signals activate two identical pulse generators, which feed pulses into the delay-line comparison network (Fig. 5). Both pulses are generated simultaneously when the target is directly ahead of the transmitter; consequently, they coalesce at the delay line's center. If the

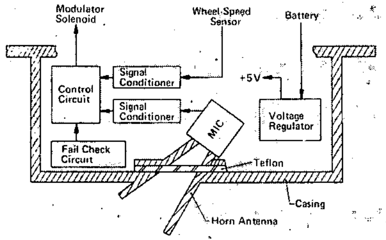
Japanese Use Car Radar For Skid Control

While U.S. researchers are assailing the problems of collision mitigation radars, Japanese engineers are marketing a skid control radar system. Jointly developed last year by Hitachi Ltd. and Nissan Motor Co., the system uses a microcomputer-controlled radar system that prevents brakes from locking during emergency stops.

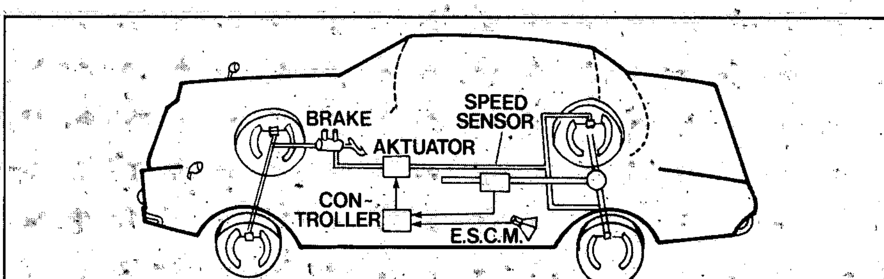
A 24-GHz Doppler radar using a Gunn oscillator is mounted at a 45-deg angle beneath the car (Fig. 2). The electronic skid control module detects wheel-slip, and modifies brake pressure in rapid on-off cycles to prevent the wheels from locking. The slip detector is a simple logic circuit incorporating one counter. It determines wheel-slip from the ratio of wheel speed to vehicle speed. When this ratio reaches a predetermined value, the minicomputer commands the hydraulically activated braking system to release pressure.

Control module circuitry is housed beneath the car (Fig. 1). The radar is built around the microwave circuit assembled in the 24-GHz waveguide. The integrated circuit is placed on a 3 × 5 × 3 mm TiO_2 substrate. A stripline resonator stabilizes the Gunn oscillator, which radiates RF energy directly from the horn antenna.

Tests were conducted using a 1.5-ton car on surfaces including various types of concrete and asphalt, gravel, snow, and water. As compared with a car without this system, stopping distances increased by less than 5 percent for dry conditions. Under wet conditions, stopping distances were shorter than those for standard braking systems. The vehicle speed-sensor maintains a 0-10 percent error range under good conditions. During heavy rain or travel over water-covered roads, speed error reaches 50 percent. Use of this system in the United States would require FCC licensing. ■



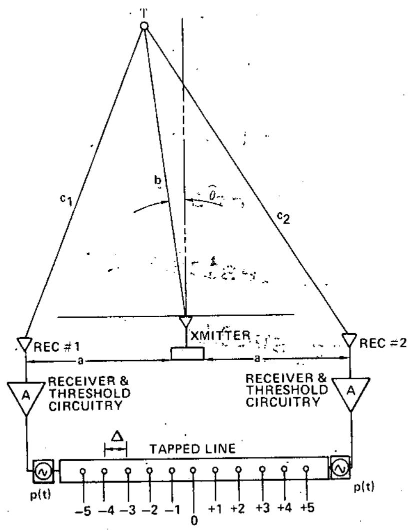
1. Control module circuitry contains an MIC, an analog IC, 6 digital MOS ICs, 4 small-signal transistors, and 2 power transistors. Part of the casing forms the horn antenna. Module (top) is mounted beneath the car.



2. Electronic skid control module uses a 24-GHz radar focused on the road at 45 degrees. Ratio between vehicle speed and angular speed of the wheels is used to trigger on-off control of brakes to prevent lockage.

target is not dead-ahead, excitement of one pulse generator is delayed by Δt, and coalescence occurs in a correspondingly off-center register. When pulses coalesce, their voltages are added, and threshold detection circuits placed at discrete points along the line insure that only one tap circuit detector will be activated for a given delay. Hence, only signals returned from a 2.5-deg beamwidth, which spans a traffic lane at 45 m, are routed to the rest of the processing circuitry (Fig. 6).

"This design offers several advantages over X- and K_u-band systems," notes Dr. Ross. "Sidelobes are not a problem with this configuration. Also, operation near 1.75 GHz is better suited for bad weather than at X- or K_u-band frequencies." Low cost is another benefit of this design. Off-the-shelf tunnel diodes cost about \$8, while step-recovery diodes cost



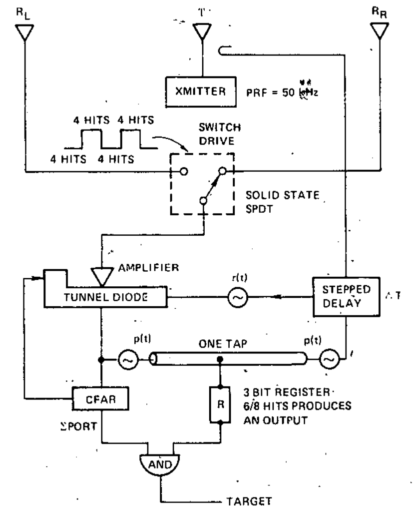
5. Delay line of Sperry radar. As the target (T) moves outside a 2.5-deg beamwidth, the differential time delay is acknowledged in a correspondingly off-center register. Only returns from 2.5 deg are routed to the rest of the circuitry for a possible braking command.

\$60 when ordered individually. At \$350, the preamplifier costs twice as much as the rest of the system. "Present work on receiver sensitivity indicates that we may be able to omit the preamp," asserts Ross. Although this system underwent preliminary testing, funding was not provided for extensive evaluation, and possible integration into one of the other NHTSA-funded systems is as yet undecided.

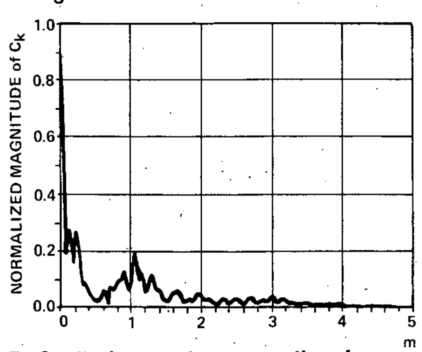
Another Piece of the Puzzle. Progress on target discrimination has been made by Dr. James Funke of GM Research Labs. Dr. Funke analyzed radar signatures from cars and common roadside reflection sources.

Transmitting and receiving antennas for the test radar were separated by 0.27 m, and frequency was swept across the X-band range. As expected, several scattering centers are apparent for an automobile signature (Fig 7). Frequency responses for a stop sign, yield sign, and an oil drum were also measured. A dominant peak occurred for each object (Fig. 8). It is evident that car signatures are recognizably different from the simple target signatures.

"My results are just another piece of the puzzle," states Funke. "The key to applying these data to a car radar system is the availability of a microprocessor that can take FFTs fast enough." A microprocessor would have to perform Fast Fourier Transforms on the order of



6. Sperry system uses a range-gated tunnel diode, which maintains maximum range sensitivity using post-detection integration and feedback techniques. Added signals from the constant false-alarm receiver port and the 3-bit register signify a target.

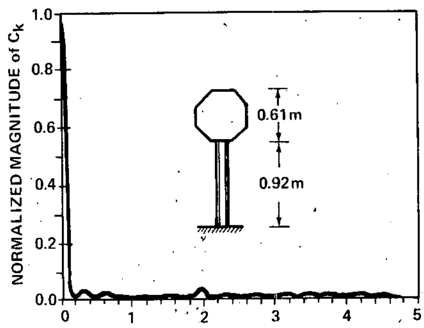


7. Scattering center separation for rear view of a 1975 Vega using a swept frequency X-band radar. A dominant peak occurred at the center and additional scattering centers appear out to about 3 m.

milliseconds to be useful in a collision mitigation car radar.

Will New μPs Expedite Car Radar? Les Zoltan, marketing manager for Intel Corp., a leading manufacturer of microprocessors, explains that the technology for microprocessors that can perform FFTs in milliseconds is just evolving. "It just so happens that Intel will be introducing a 16-bit microprocessor this year that can handle FFTs on the order of milliseconds," Zoltan notes.

Fairchild Semiconductor, Mountain View, Calif., introduced a 16-bit microprocessor in February that could prove to be the eventual predecessor of a car radar model. "Without knowing the operational parameters for a car radar it's difficult to say whether a single 16-bit microprocessor can handle the FFTs fast enough," notes Michael Scott, aerospace and development research manager.



8. Stop sign exhibits a single scattering center. If a microprocessor can be designed that acknowledges the difference between simple and complex targets on the order of milliseconds, the occurrence of false alarms may be reduced considerably.

"I'm pretty sure microprocessors could handle the FFTs in milliseconds, but it might require a 3- or 4-chip array. With 3–5 years of research we could certainly tailor a chip for car radars." Microprocessor-based radars have been built at Fairchild for the US Air Force that operate at range rate speeds of thousands of mph. However, they are very expensive and complex systems. "If mass-production demand were to develop in 4–5 years, we could offer microprocessors at under \$50 apiece," claims Scott.

All things considered, it appears to be only a matter of time before car radars become standard. GM's Norm Schubring summed up the future with "Car radars will undoubtedly be required or offered as an option during the mid-'80s." ■