how it works

OEM production applications typically use valve-mounted sensors.

ENGINEERS TAKE DIFFERENT ROADS IN DEVELOPING SYSTEMS THAT MONITOR AND EVEN REPRESSURIZE TIRES ON MOVING VEHICLES.

Tires go high-tech

By Dan Joseph, Contributing Editor

THE AUTO INDUSTRY IS BRACING for a change that will whisk the century-old inflatable rubber tire into the computer age during the next four years. Automakers, semiconductor suppliers, federal regulators, and tire manufacturers are paving the way for the change, laying a technical foundation that could one day be adopted by car manufacturers worldwide.

"By 2006, we think there will be 30 million vehicles with tire-pressure-monitoring solutions ," notes Merv Carse, president of Cycloid, a manufacturer of the systems. If Carse and others are right, more than 100 million tires will soon have the ability to communicate with dashboards. They will monitor their own pressures, track their temperatures, "know" their loading conditions and, in some cases, quietly command onboard pumps to add air.

Automakers and tire manufacturers are squarely behind the idea, because it offers the potential to prevent blowouts, save lives, and dodge mammoth legal battles, such as those in the recent Ford-Firestone tire debacle. Enthusiasm for the concept has grown so dramatically in the past year that even White House officials have weighed in, with federal regulators examining government policies relating to the technology.

That's not to say that everyone is in lock-step agreement on how best to bring silicon sensors, RF transmitters, and other sensing techniques to tires. More than three dozen suppliers—including BERU AG, Bosch, Cycloid, Delphi, Goodyear, Infineon, Lear, Michelin, Motorola, Schrader Electronics, SensoNor, Siemens, SKF, SmarTire, STMicroelectronics, Texas Instruments, TRW, Visteon, and Wabco, as well as every major automaker—are now involved in the technology, leading to an almost mind-boggling breadth of options.

Still, suppliers say they share the same goals. The technology exists to warn the driver earlier, says Alain Charlois, director of product planning and occupant-safety-system products for TRW Automotive. No matter which technique manufacturers use, he notes, they are all trying to achieve the same objective.

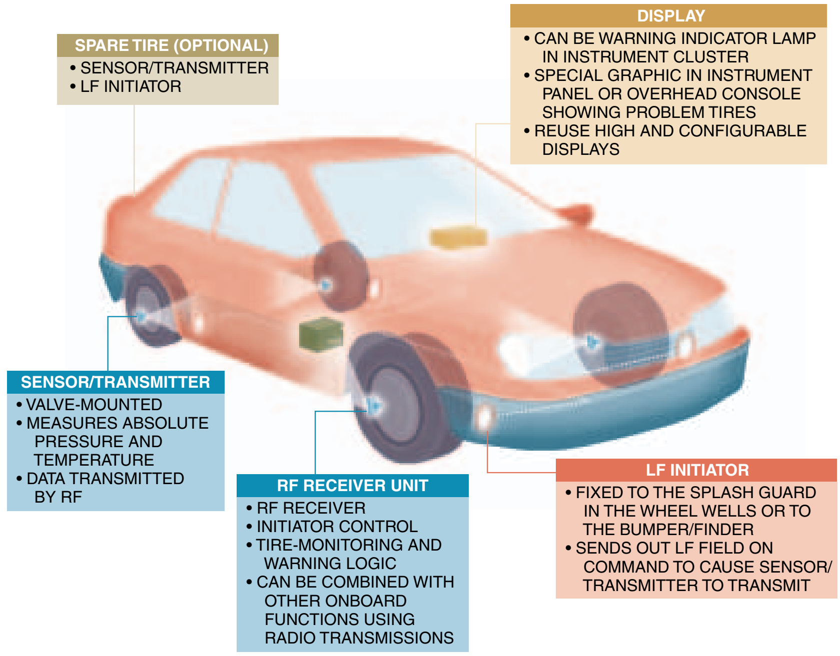
SmarTire's strap-mount sensor targets retrofit applications.

INDIRECT OR DIRECT?

Even with the recent publication of a tire-pressure-monitoring directive by the US NHTSA (National Highway Traffic Safety Administration), automakers, tire manufacturers, and suppliers are still struggling to agree on a mutually acceptable monitoring method. Many of their disagreements revolve around the use of so-called indirect or direct techniques to check tire pressures while vehicles roll down the highway.

Today's most common technique, the indirect method, has been in use since the mid-1990s and is already featured in more than 2 million General Motors vehicles, as well as in Ford cars. Many automakers favor the indirect technique because it's inexpensive and requires no additional hardware if a vehicle is ABS (antilock-braking-system)-equipped. Instead of adding new sensors, the system merely uses the wheel-speed sensors (usually switched reluctance or Hall Effect) in the ABS to count the revolutions of each wheel, then employs a software algorithm in the ABS controller to compare the revolutions at each wheel. As a result of that comparison, the software determines whether one wheel is spinning faster and, if so, whether that wheel is underinflated. The system bases its decision on the assumption that a smaller, underinflated wheel rotates faster than a fully pressurized one.

Many engineers say that the indirect technique is less effective than the direct method. Shortcomings of the indirect technique include an inability to accurately measure tire pressure on ice or in off-road conditions, mainly due to wheel slip. What's more, its threshold—the level of underinflation required before it detects the problem—is not as good as the direct method's. Most suppliers agree that the indirect technique recognizes underinflation after the tire has lost about 25% of its pressure—probably the high end of what an indirect technique can achieve, according to Charlois of TRW, a company that makes both the direct and indirect technologies.



EnTire Solution from TRW directly measures pressure with tire-mounted silicon sensors and then sends data via an RF signal to the vehicle's head unit.

"Because an indirect system detects differences in pressure, it is difficult to detect two or more underinflated tires," says Fanie Duvenhage, RFIC product manager at Microchip Technology, a manufacturer of microcontrollers and RF components for direct pressure monitoring. He says that case is one concern of system suppliers he has talked with, including providers of ABS brakes and indirect tire-pressure-monitoring systems. Similarly, recalibration of an indirect system would be necessary, Duvenhage notes, if an owner installed a different diameter wheel/tire combination. An indirect system would not have any recalibration provisions in the electronics on the wheel, he says.

Many automotive engineers believe that the capabilities of the indirect technique are sufficient for warning drivers of an imminent problem, however. The fact that such systems don't warn drivers until a tire is more than 25% underinflated is not a problem when tires are hot and internal pressure is higher than the cold pressure rating, they say. "It's a lot better than it sounds," notes Al Walenty, technical lead for tire-pressure monitoring at General Motors's Advanced Chassis Control System Group. "The indirect technique can provide fair warning if there's a problem."

TRW's valve-mounted sensor package measures a little over an inch in length.

Suppliers claim that domestic automakers lobbied hard for indirect methods with legislators last year, ultimately causing White House officials to step in and allow such techniques to be used in parallel with direct measuring methods during an evaluation period that ends in November 2006. During that period, most observers expect indirect techniques to maintain automakers' continued support. The indirect technique, they say, uses proven hardware, requires no batteries, and provides a low-cost option for entry-level vehicles.

SILICON SENSING

Still, a growing number of semiconductor makers, automotive-electronics suppliers, and tire manufacturers are eyeing the market for direct tire sensing and predicting a big potential market. TRW, Delphi, Siemens, Cycloid, SmarTire, and others are already hard at work on components for such systems.

The direct technique, which measures pressure, instead of inferring it through speed sensors, offers the capability of providing an absolute pressure readout. "If it says the pressure is 32 psi, then it's exactly 32 psi," says Charlois of TRW, maker of a direct system known as the EnTire Solution.

Most direct units employ a pc board measuring about an inch long. The pc board typically contains a silicon-based pressure sensor, an RF transmitter, a lithium battery, and an inexpensive processor with a small amount of ROM and a clock speed of less than 4 MHz. You can place the sensors on the valve stem or on a strap that fits around the wheel. SmarTire Systems, which makes both types of sensor systems, typically sells the strap-mounted unit for retrofit applications on virtually any vehicle. The company also sells a swivel-mounted sensor, which you can turn in a way that prevents it from being damaged. The swivel-mounted sensors are typically sold to OEMs for production applications.

SmarTire engineers are also working

with automakers on fixed-mount sensors that can be custom-designed as a means of reducing manufacturing costs. If your vehicle platform has 2 million vehicles, it's more economical to design the sensor system in conjunction with the rim, says Erwin Bartz, director of technical operations for SmarTire.

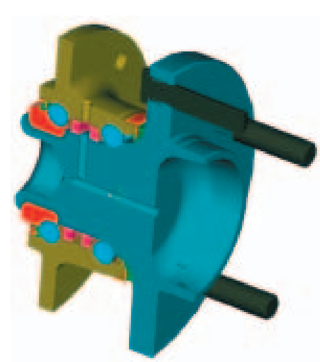
Whichever type of sensor the system uses, most of the direct systems work by measuring the pressure and temperature in the tire, then sending the information via radio frequency, usually in the megahertz range, to a "head unit" in the dash. The dashboard-based controllers can be designed in a way to enable the display of almost any amount of data. They can provide a simple warning that tire pressure is low, or show the pressure level of each tire.

You can mount the Wabco air compressor, which is the size of a shoebox, in the trunk to repressurize tires during driving.

NHTSA engineers and vendors predict that such stand-alone units will typically add about $66 to the price of a vehicle. Most suppliers, however, say they want to reduce costs more by integrating the tire- pressure-monitoring system with remote-keyless-entry units, which also use RF control. "As much as possible, it would be beneficial to have one part number for both systems," says Charlois. "The idea is to take advantage of the existing hardware and to get a significant cost benefit by adding one more feature to the overall system."

PUMPING UP

Ultimately, many engineers believe that tire-pressure systems will be incomplete, however, until they are autonomous, releasing drivers from the onerous task of looking for service stations that offer pressurized air. Ideally, such systems could easily pump up the tires while a vehicle races down a freeway. "A lot of gas stations don't have air anymore, and if they do, then they often don't have a pressure gage," notes Carse. "But if you have pumps on board, you don't have to worry about that."



With SKF's patented bearing design, air passes through the bearing and into the tire while the vehicle is moving.

To solve the problem, Cycloid has developed the AutoPump, which employs a hockey-puck-sized, inertia-powered air pump on each wheel. The system, which works in conjunction with a direct tire-pressure-monitoring unit, uses the rotation of the wheel to activate the integral air compressor in each pump.

Similarly, a joint development effort involving Michelin Group and Wabco Vehicle Control Systems, along with the participation of TRW Automotive Group, and SKF Automotive Division also promises to repressurize tires, albeit with a different technique. The system, known as TIPM (Tire Intelligent Pressure Management), differs from the Cycloid technique in that it employs a single, powerful air compressor, rather than four small pumps. Built atop run-flat tire technology, TIPM comprises an RF sensor/transmitter at each wheel, a dashboard-mounted control and display system, and an air-generation and -distribution system. During operation, the tires' valve-mounted sensor/transmitters send information to the controller in the dashboard. If the controller discovers that one tire is low, it signals the repressurization unit.

Wabco, a specialist in air brakes and air-suspension systems for trucks, supplies the air compressor, tubing, and valves for the repressurization unit. The 380W air compressor, usually mounted in the vehicle's trunk or engine bay, can quickly repressurize a tire by cranking out 25 liters of air per minute. During operation, it sends air to a solenoid valve, which, based on information from the controller, directs air to the appropriate wheel. A valve block distributes air at each wheel and a bidirectional pneumatic valve allows air in and out, or holds it in when repressurization isn't taking place. "We're using the same kind of logic as the tire-pressure-management system, but we're using it to bring air back out to the wheel," says Steve Hampson, director of sales and marketing for Wabco Automotive North America.

Michelin engineers say that its TIPM offers advantages over competing systems that mount a pump at each wheel. The primary advantage, they say, is that the air compressor has the pumping capacity to quickly repressurize a leaky tire. This feature allows the system to "deliver air at a flow rate that enables us to react, correct, and prevent problems," says Pascal Mahier, project manager of intelligent-pressure-management systems for Michelin.

Engineers also say that the TIPM system differs from competitors in another critical way—delivering air through pneumatic tubing and, ultimately, through the wheel bearing. To accomplish that task, SKF's Automotive Division developed a so-called "air bearing" that provides a channel for the air to pass through the stationary and rotating parts of the bearing. Using a patented design, it moves air through a drilled hole in the stationary portion's outer ring. The air then passes through a specialized hub, into the rotating part of the bearing, and finally goes through one of the spokes in the wheel rim before reaching the tire. "We're essentially using the bearing as the transmitter for the pressurized air," says Andreas Ruetter, project manager of the SKF bearing team.

Engineers feel confident that the system's high power and flow rate will open the door to new capabilities in the future. "This system won't just compensate for pressure losses due to natural leaks and punctures," says Mahier. "We want to go further with it, and use it to adapt to load and speed conditions. And for that to happen, we need a significant air-flow rate coming from the compressor."

Even as automakers test the new technology and the NHTSA evaluates it, suppliers say they will continue to push for more breakthroughs in the technology. SmarTire, for example, has developed a 20g sensor that you can bond onto the rim of a tire using a proprietary bonding agent. The device, known as the LadyBug, not only offers low weight, but gives OEMs the capability of robotically installing the sensors in the drop center well of the wheel, the company says.

Although engineers aren't sure how long lithium batteries will last in tire-mounted applications, they believe that the development of a "batteryless" sensor would eliminate the need to install new sensors at least once during the life of a tire. Several suppliers are also said to be working on these sensors. One such sensor, under evaluation with SmarTire and developed by Transense Technologies, employs a SAW technique to send a pressure-related signal to a controller, thus eliminating the battery.

Ultimately, engineers believe that such technology will break into the automotive mainstream as sensor-equipped tires become the norm during the coming decade. And regardless of the conclusions government regulators reach during the next three to four years, most observers believe that tire-pressure-monitoring technology will prevail in some form. "Today, nothing tells us this is not possible," concludes Mahier.□

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Author's biography
Dan Joseph is an engineer and writer who has followed automotive developments for 20 years.