

Tire Pressure Monitoring Systems

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6. Summary

1. Background

- 1) TPMS of conventional tires recently came into use on vehicles mainly as a convenience device for drivers.
- 2) On the other hand, a FMVSS 138 rule on TPMS was published on June 5, 2002 and offers manufacturers 2 options:
 - Option 1: TPMS to warn within 10 minutes after the inflation pressure in one or more (up to four) of the vehicle's tires, becomes equal to or less than 25% below the recommended pressure.
 - Option 2: TPMS to warn within 10 minutes after the inflation pressure in one of the vehicle tires falls to equal or be less than 30% below the vehicle manufacturer's recommended pressure.
- 3) By March 1, 2005 reconsideration will be given to establishing the performance requirement for the period beginning November 1, 2006.
- 4) There is a discussion concerning TPMS also in Europe.



We believe it is helpful to present an understanding of the TPMS technologies of both direct type and indirect types.

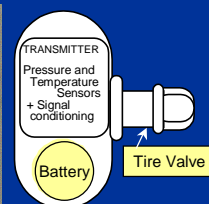
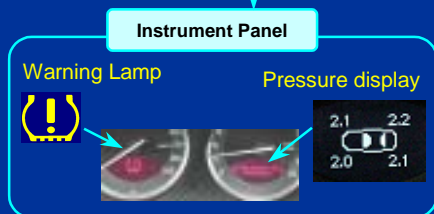
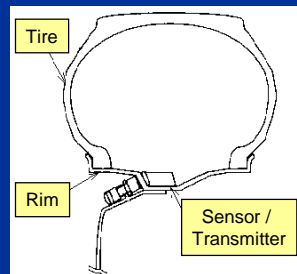
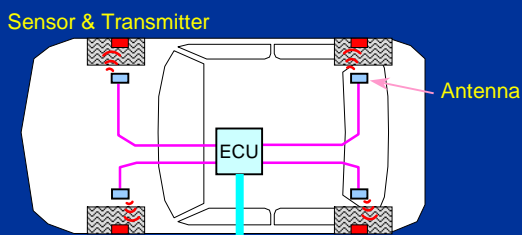
2. System Classification

	Direct TPMS	Indirect TPMS
Detection	- Absolute pressure measurement	- Relative tire pressure - Absolute pressure (estimated)
Accuracy	- More accurate method.	- Depends on tire characteristics.
Reliability		- High reliability because there is no additional hardware.
Cost	- High cost - Sensor batteries have to be changed periodically.	- Using ABS sensors means only a small on-cost.
Convenience	▲ Tire pressure on each wheel can be displayed. ▼ Additional sensors needed with snow tires (user's on-cost) ▼ Wheel type is restricted by integrated sensor/valve	▼ In some cases, it may be difficult to guarantee the TPMS performance on all replacement tires

3. Direct TPMS

3-1. Typical Example of the Direct Type

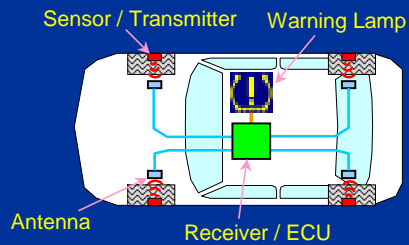
Direct type: a system using the actual measurement of tire pressure.



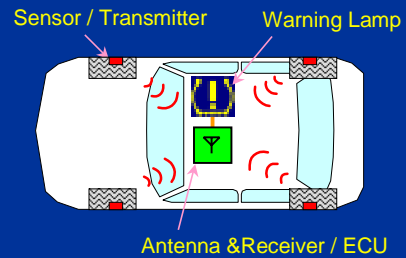
3-2. New Development of Direct TPMS

For cost reduction, the number of the antenna is reduced from 4 to 1.

4 Antenna System



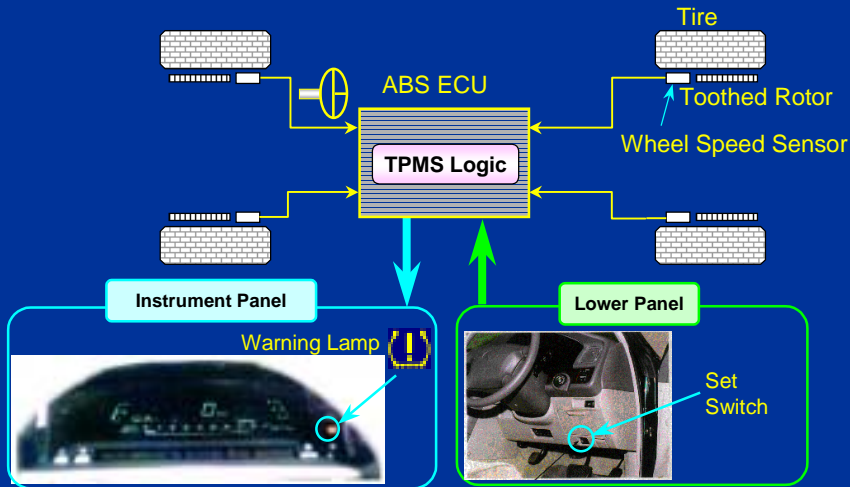
1 Antenna System



4. Indirect TPMS

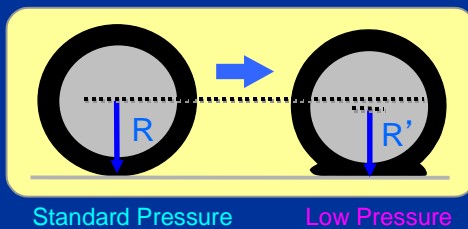
4-1. Typical Example of the Indirect Type

Indirect type: a system using the wheel speed signals from the ABS.



4-2. Detection Methods of Indirect TPMS

Rolling Radius Method (Conventional)



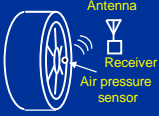


$$\alpha = \frac{VFR}{VRL} - \frac{VFL}{VRR}$$



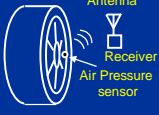
The diagram also shows a schematic of a four-wheel vehicle with labels VFR (top front), VRR (top rear), VFL (bottom front), and VRL (bottom rear). Arrows indicate the direction of travel.

Relative detection \Rightarrow Only one wheel deflation can be detected.

4-3. Variety of Indirect TPMS

System	Indirect Detect		Direct Detect
	A	B	
Characteristic	<p>Rolling radius</p> 	<p>Rolling radius + Resonance freq</p> 	
Input signal	Wheel speeds	Wheel speeds	Tire pressure
Wheels detection	In combination	Independent	Independent
Detection speed range	1 wheel deflation: 15 to 120km/h	1 wheel deflation: 15 to 120km/h Up to 4 wheels deflation: 15 to 100km/h	Up to 4 wheels deflation: 0 to 250km/h
Deviation of accuracy (approx.)	± 10% at best	± 10% at best	± 5%
Detection Time	2 to 10min	2 to 10min	15sec to 1min

4-3. Variety of Indirect TPMS continued

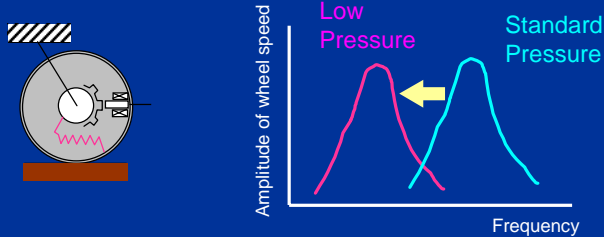
System	Indirect Detect		Direct Detect
	C	D	
Characteristic	<p>Rolling radius</p> 	<p>Rolling radius + Resonance freq</p> 	
Input signal	Wheel speeds + Stability Control System signals	Wheel speeds + Stability Control System signals	Tire pressure
Wheels detection	In combination	Independent	Independent
Detection speed range	Up to 3 wheels: 15 to 250km/h	Up to 3 wheels deflation: 15 to 250km/h Up to 4 wheels deflation: 15 to 100km/h	Up to 4 wheels deflation: 0 to 250km/h
Deviation of accuracy (approx.)	± 10% at worst	± 10% at worst	± 5%
Detection Time	2 to 5min	2 to 5min	15sec to 1min.

4-4. New Development of Indirect TPMS using resonance frequency

Up to 4 tires with pressure deficiencies can be detected by the resonance frequency method.

1) Resonance Frequency Method

Torsion spring constant is reduced with deflation of tire and consequently the resonance frequency drops



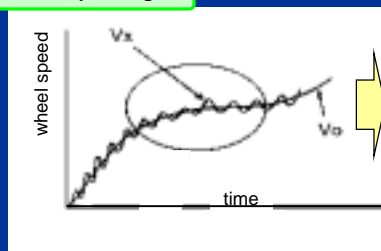
Independent and absolute detection

➔ Even natural leak deflation of any tire(s) can be detected

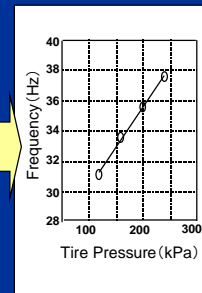
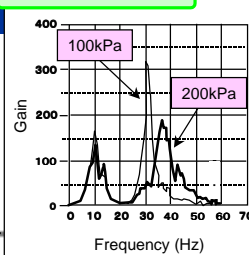
4-4. New Development of Indirect TPMS using resonance frequency

2) Actual vehicle data

Wheel speed signal



Frequency analysis



3) Concerns

Tire resonance phenomenon might be not measurable in the situations below.

- high speed
- low aspect ratio tires

4-4. New Developments of Indirect TPMS using additional signals

By using Stability Control System's signals, up to 3 deflated tires can be detected.

1) Two 'low tires' on the same axle (Front or Rear)

<Concern>

It is difficult to judge whether a difference of wheel speed results from low pressure or from slipping under acceleration.

Development

Engine torque information distinguishes low tire pressure from wheel slip caused by acceleration.

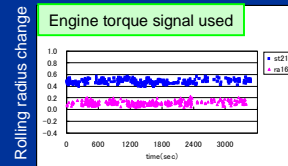
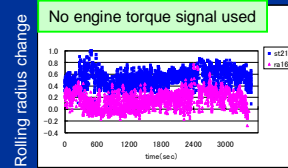
2) Two 'low tires' on the same side (Right or Left)

<Concern>

It is difficult to judge, whether a difference of wheel speed results from low pressure or is being caused by cornering.

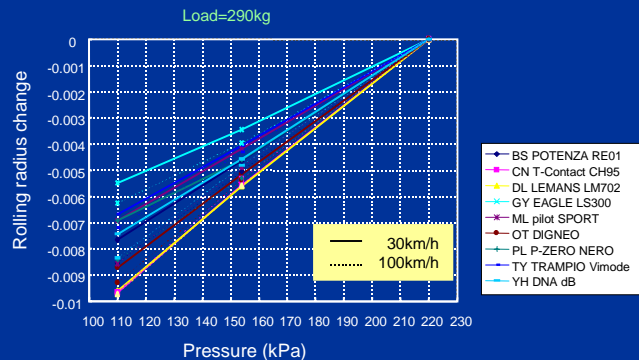
Development

Cornering information used in Stability Control Systems distinguishes low tire pressure from cornering.



4-5. Future Development of Indirect TPMS

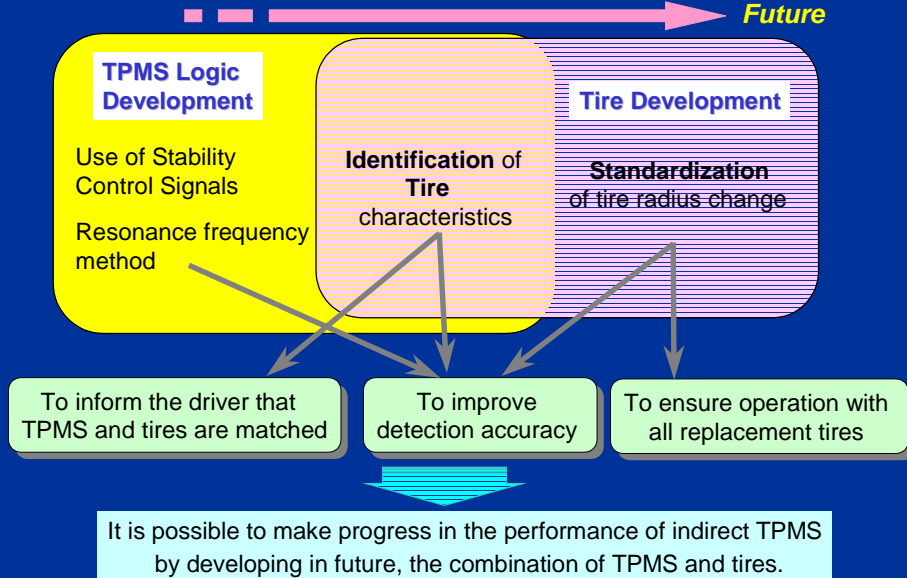
1) Tire characteristic for indirect TPMS



The effective rolling radius is altered as the tire pressure changes.
The value of the change depends on vehicle speed, load and tire variation.

4-5. Future Development of Indirect TPMS continued

2) To improve the performance of indirect TPMS



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6. Summary

1)

Both direct and indirect systems are able to contribute to the real world safety with regard to tire deflation

- Independent wheel detection
- Tire pressure detection level

2)

For direct TPMS the cost will become lower in future.

For indirect TPMS it is possible to make progress with the performance in future, by developing TPMS and tires in combination.