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Memorandum

U.S. Department
of Transportation

National Highway Traffic Safety Administration

Subject: **ACTION:** Ex Parte Briefing Docket Submission

Date: OCT 20 2004

From: Samuel Daniel Jr., Safety Standards Engineer
Office of Crash Avoidance Standards

Reply to Attn. Of: NVS-120

To: U.S. Dept. of Transportation Docket Management System
Docket No. 2004-19054 - 20

THRU: Jacqueline Glassman
Chief Counsel

On September 21, 2004, NHTSA representatives met with Mr. Alan Burns, of MLHO, Inc. located in California. MLHO is developing a direct, battery-less Tire Pressure Monitoring Systems (TPMS) that uses magnetically coupled sensors to determine tire pressure. The magnetic fields generated as the wheel rotates are sensed by a chassis-mounted receiver.

According to Mr. Burns, the pressure monitoring system is not sensitive to the distance between the pressure sender and the magnetic pickup sensor, so large variations can be tolerated. He also stated that the system will function as designed with tires that have steel belts, since the belts produce only minor disturbances in the magnetic field generated by the pressure sender. Additionally, Mr. Burns stated that the system is low cost compared to other direct TPMS.

A list of individuals who attended the NHTSA briefing and a copy of the slides provided by Mr. Burns at the briefing are attached.

2 Attachments

Attachment 1

List of Attendees

MLHO, Inc.

Mr. Alan Burns

NHTSA

Mr. Eric Stas

Mr. Samuel Daniel

Mr. Jonathon Mueller

Ms. Terry Lacuesta

Mr. John Finneran

Attachment 2

MLHO

PATENT PENDING

Direct Tire Pressure Measurement System

Magnetically Coupled TPMS

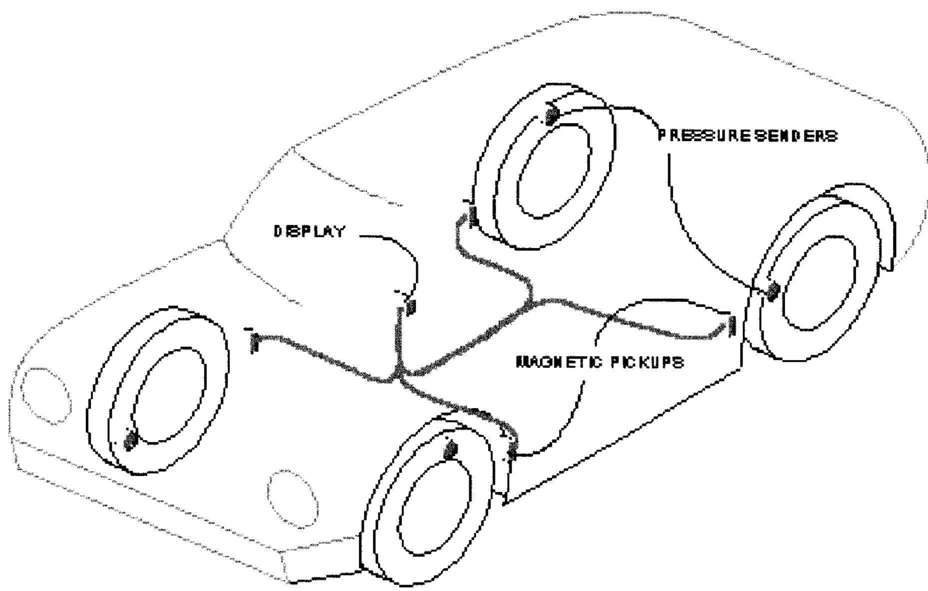
MLHO, Inc.
415-816-2553

9/17/04

MLHO

PATENT PENDING

Magnetically Coupled TPMS



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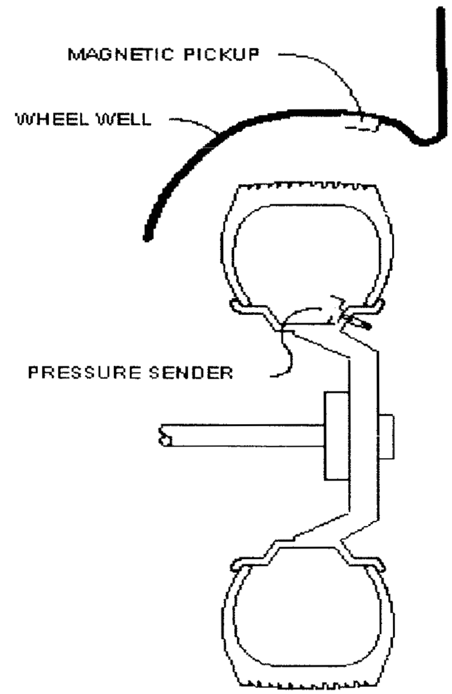
Basic Concept

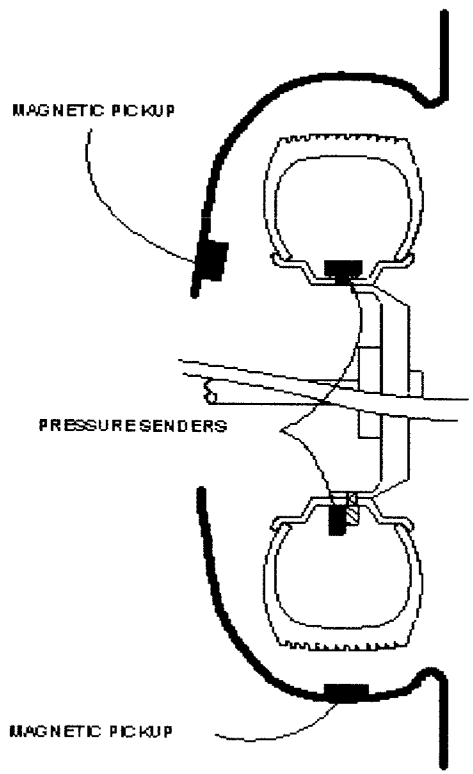
- Magnetically coupled pressure sensor
  - pressure rotates magnet wrt wheel (all running wheels)
  - magnetic field waveforms sensed as wheels rotate
  - processors calculate asymmetry (SKEW) of sensed waveforms
- Non-critical sensor location
  - large sender-sensor spacing
  - similar values of SKEW for different field components

- Typical installation as seen from above:

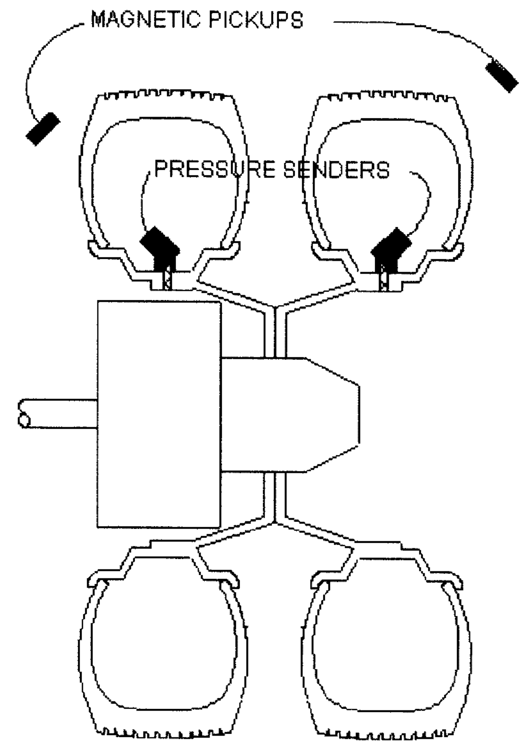


Alternative Installation Possibilities

- Sender mounted on wheel

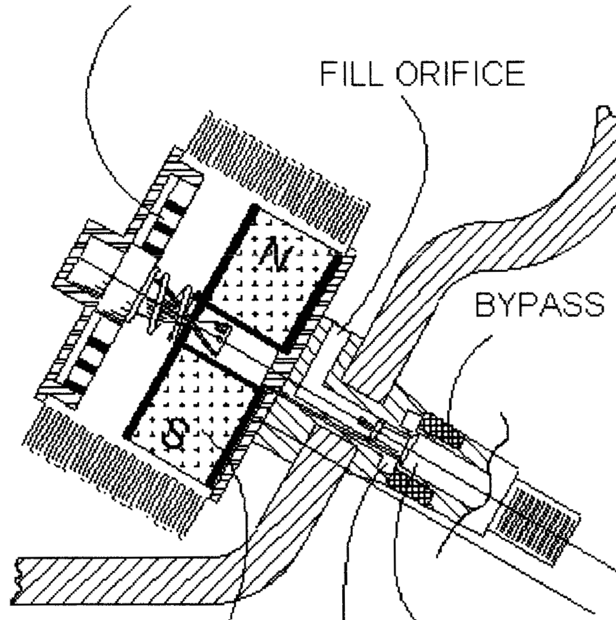


- Duals



Basic Magnetic Pressure Sender

- Bellows plus helical cam
  - robust, lightweight, and inexpensive (low-cost ceramic “refrigerator” or smaller rare earth magnet)
  - built-in temperature compensation (bi-metallic spiral spring)
- Vented to atmosphere
  - responds to gauge pressure
  - leak tolerant (no vacuum)
- Alternatively, may be mounted on wheel center



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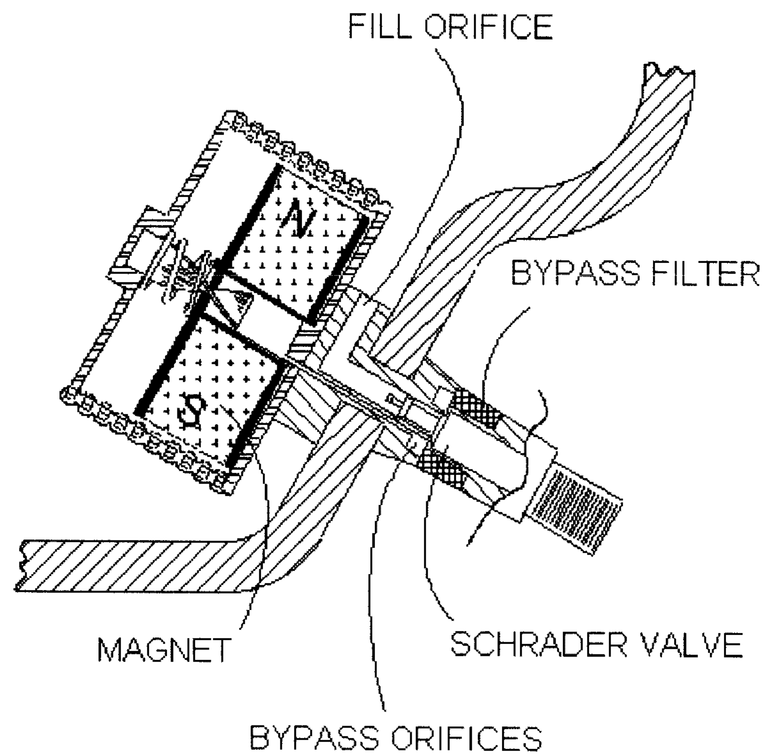
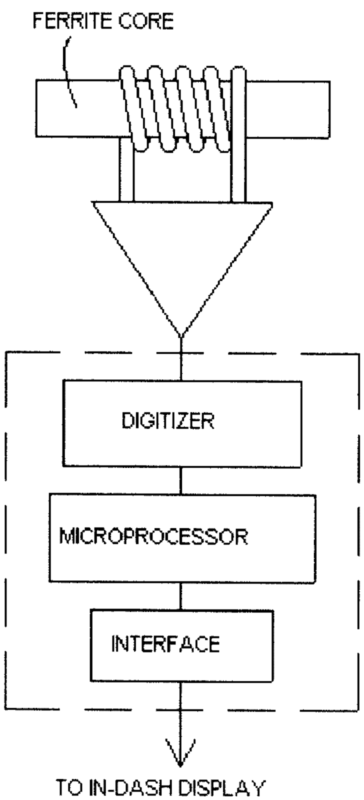
Pressure Sender Alternatives

- Elastomeric bladder supported by helical spring
  - embedded spring provides lateral support
  - a bi-metal spring provides temp compensation (entire bladder twists)
- Magnetic coupling to helical translating element
  - pole pieces on magnet
  - no mechanical wear
- Rare-earth magnets
  - lighter, higher cost



Magnetic Pickup Sensor

- Induction coil is preferred
  - low-cost ferrite rod 'antenna'
  - voltage induced as sensor 'orbits' wheel axle
  - 5-100 MPH nominal range
  - radial or tangential orientation wrt. axle
- Signal processor
  - amplifier + digitizer
  - microcontroller (local)
  - continuous operation (no timing requirements)



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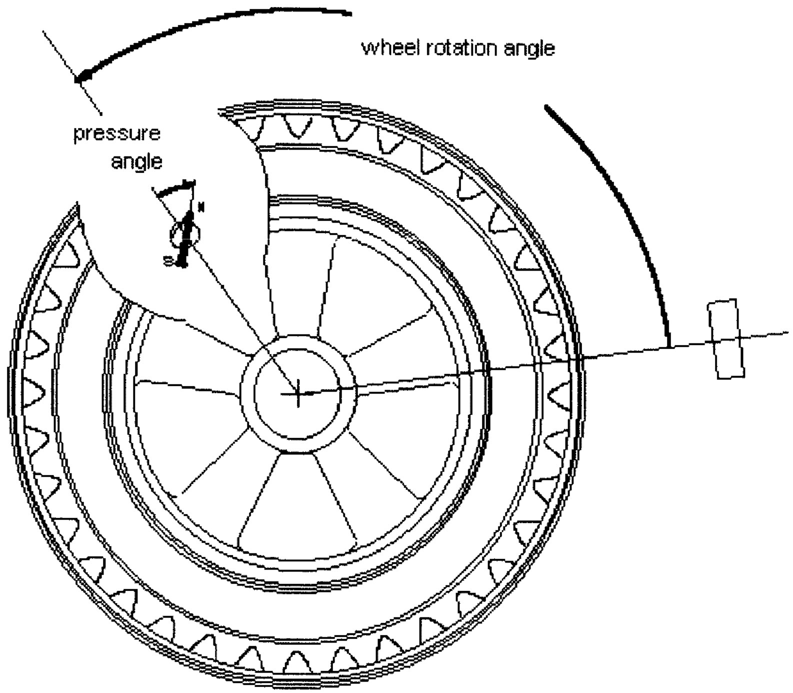
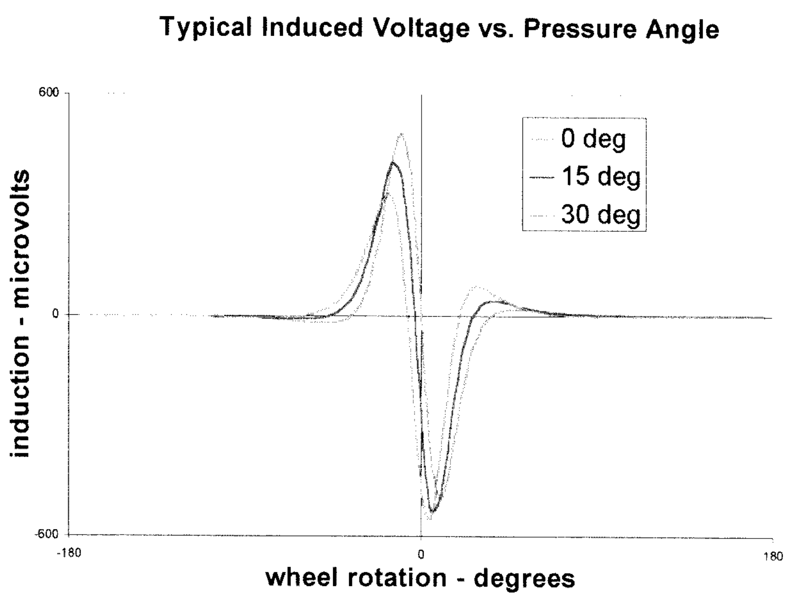
Geometry

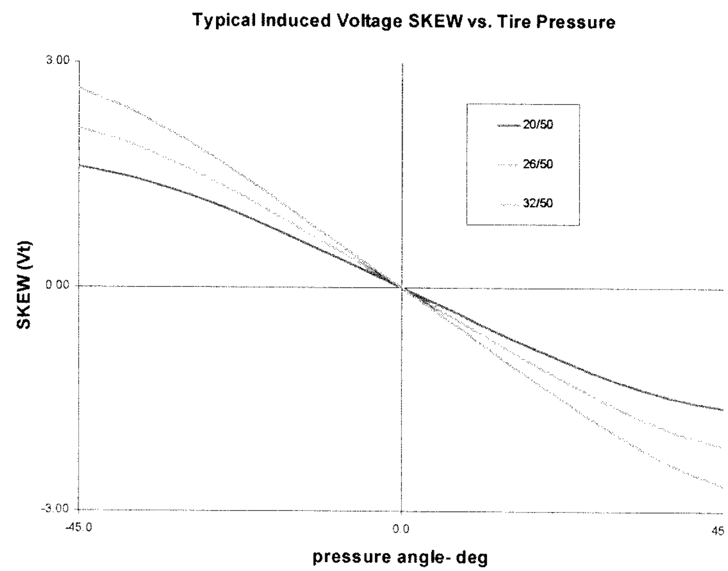
- Magnetic pickup responds to rotating magnetic field
- Primary factors affecting SKEW and pressure sensing are:
  - distance (radius) of valve stem sensor from axle
  - distance of magnetic pickup sensor from axle
  - inclination of valve stem sensor magnet to 'orbital' plane
  - offset between sensor 'orbital' plane and pickup
- SKEW is *independent* of magnet strength



Induced Voltage and SKEW

- Tire pressure changes produce significant asymmetric variations of magnetic field and voltage waveforms
  - asymmetry quantified by normalized third moment (SKEW)
  - SKEW is independent of wheel rotation rate





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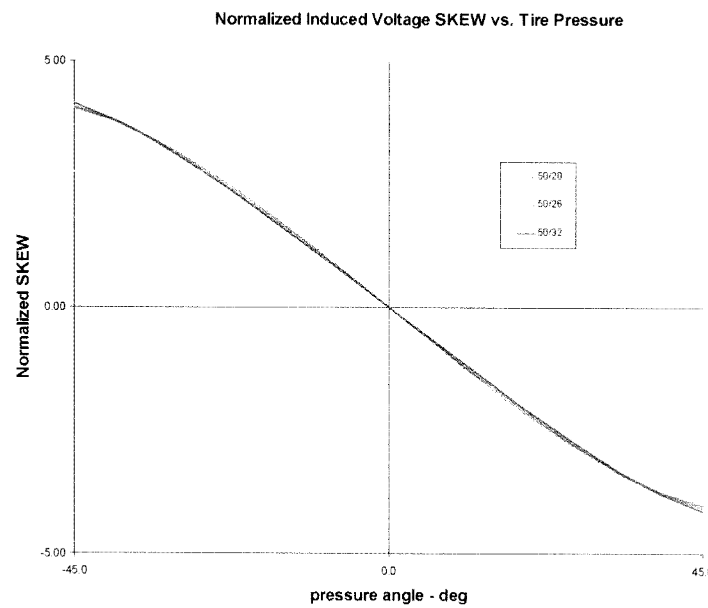
Normalized SKEW

- SKEW normalized by ratio of axle-sensor distance to axle-sender distance is effectively independent of installation geometry
  - ‘universal’ sender - permits easy tire/wheel replacement or interchange
  - waveform variance plus tire rotation rate (both already calculated) provides the normalization factor
  - sensor can self-adjust for tire/wheel changes



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Signal Processing

- Calculate in-tire magnet angle from waveform asymmetry
  - continuous data averaging over many wheel revolutions
  - process occurs when vehicle speed exceeds threshold
    - 5-10 MPH
    - motion sensed by the magnetic pickup itself
- Apply calibration factor to obtain pressure
- Communicate pressure to in-dash display
  - via automotive data bus
  - to stand-alone display
- Microcontroller based, on each wheel
  - low data rate implies a low-cost controller
  - custom ASIC

Issues Raised and Addressed - I

- AC 50/60 Hz pickup
  - desired magnetic pressure signals are in 10-200 Hz range
  - by symmetry, $SKEW_{AC}$ = 0, so no direct effect
  - indirectly---affects SKEW normalization---must insure strong pressure signal sufficient to overwhelm extraneous pickup (easy)
- Sensor (valve stem) must be properly marked and oriented to wheel for pressure reference point
  - 2-3° per psi (i.e., not critical)
  - use jig during installation
- Aftermarket wheels may change calibration
  - system is self-calibrating (via variance measurement)

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Issues Raised and Addressed - II

- Steel-belted tires
  - belts produce minor magnetic field offset
  - do not significantly affect SKEW
- Steel rims and other such parts nearby sender or sensor have similarly small effects on SKEW
- Atmospheric reference vent filter plugging (ice)
  - traps atmospheric-pressure air inside bellows/bladder
  - no effect unless atmospheric pressure or vehicle altitude changes significantly
  - ±5% (~±1.5 psi) worst case expectation

Benefits

- Low cost
- Lightweight (example used 1 ounce magnet)
- Senses pressure for all running wheels
- High accuracy
- Passive
  - no batteries
  - unlimited lifetime
- No RF devices or interference
- Could do double-duty as ABS wheel rotation rate sensor

Issued and Pending Patents (MLHO/Burns)

- Magnetically coupled remote pressure sensing and display
  - U.S. Patents No. 6,520,006, 6,647,771, and 6,761,072
- Patents pending (magnetic coupled display/pressure sensing)
  - App. Ser. No. 10/673,599 (filed 09/29/03)
  - App. Ser. No. 10/764,711 (filed 01/26/04)
- Other recent inventions/co-inventions
  - U.S. Patents 5,564,698/5,912,700 (FoxTrax™ Hockey Puck)
  - U.S. Patent 6,003,376 (Underground Pipeline Location)
  - U.S. Patent 6,493,631 (Geophysical Navigation System)
  - U.S. Patents 6,546,797 and 6,672,156 (Level Sensing)
- Other pending patents
  - App. Ser. No. 60/56,313 (C-MANPADS Airliner Defense)

Conclusion

- Novel magnetically coupled direct TPMS system offers a low-cost alternative to existing designs
  - battery-less
  - no radio frequency signaling
  - simple and robust
- Patents issued and pending
- Available for licensing