

# A Review of Wireless Tire Pressure Monitoring System for Vehicles

**Avinash Kale**  
Govt. College of Engineering, Amravati,  
Maharashtra, India  
avi7kale@gmail.com

**S. S. Thakare**  
Govt. College of Engineering, Amravati,  
Maharashtra, India  
thakare.shubhda@gcoea.ac.in

**Abstract** - The tire pressure monitoring system (TPMS) is used for safe drive on super highways to avoid fault in the tires. The system can automatically detect the tire pressure, temperature and send out warning sound in real-time before the accident actually happens, reminding drivers to take measures to prevent tire puncture. This paper reviews the influence of tire pressure and temperature, also describes the importance of TPMS on traffic safety and environmental protection, and discusses different designs for vehicle tire pressure monitoring system with and without sensors. It also suggests the use of Serial Peripheral Interface (SPI) to improve the functionality of TPMS.

**Keywords** - Serial Peripheral Interface, Tire Pressure Monitoring System, Wireless Communication.

## I. INTRODUCTION

Along with the rapid growth in number of automobiles, the traffic accidents are also increasing which causes damages to vehicles as well as human body. The most important reasons of serious traffic accidents are tire bursts. Tire failure is very difficult to prevent and hence it is one of the major concerns for the drivers. It is found that tire burst is mainly caused by abnormal tire pressure and higher tire temperature [4]. It is also observed that the death rate is nearly 100% when speed of the vehicle is 160 kmph or above has the tire blowout. Therefore the abnormal tire pressure affects the quality and the safety of automobile driving. The traffic accidents due to tire puncture can be prevented if the tire pressure is regularly monitored during driving [7]. Researches shows that the tire-break can be avoided by keeping the tire pressure near to its standard value and discover tire pressure release in time. Thus, many researchers and engineers are working on tire pressure monitoring system (TPMS). Currently, TPMS can be divided into two types: one is based on the wheel speed also called as indirect TPMS. In this system the difference between the speeds of the tires is compared through the Antilock Braking System (ABS) wheel speed sensor system of the vehicle to achieve the purpose of monitoring the tire pressure. The disadvantage of this system is that it can not work in the condition of two under-inflation tires and running car whose speed exceeds 100 kmph [8]. This system works only when the wheels speed is up to a certain margin. The other is based on the pressure sensor also called as direct-TPMS. This system makes use of pressure sensor which installed in each tire to measure the tire pressure directly and displays and monitors the pressure of each tire [1].

A TPMS consists of sensors inside a car's tires that measure pressure, and a central wireless antenna and one antenna in each wheel. The central control unit picks up

the signal, and a warning light on the dashboard of vehicle warns a driver when tire pressure drops below permissible limit. The central control unit calculates pressure changes as well as removes noise from sensors in neighboring cars, and compensates for changes in pressure due to temperature. According to the TREAD Act passed by US Congress in 2008, it is necessary for all automobile manufacturers to install this tire pressure monitoring system in their vehicles produced or sold in the United States [9].

## II. SYSTEM COMPOSITION

The tire pressure monitor system is mainly composed by two parts i.e. the transmitter module also called as pressure monitoring module and the receiver module. Pressure monitor module mainly consists of pressure sensor, temperature sensor, microcontroller unit and radio frequency transmission chip. The receiver module contains microcontroller unit, RF transceiver chip, LCD display and the buzzer circuit. The TPMS systems works at different frequencies like 2.48 GHz, 3.15 GHz or 4.33 GHz. In order to avoid interference due to noise frequency shift keying, Cyclic Redundancy Check (CRC) or Manchester Coding scheme can be used [1]. The system structure for generalized TPMS is as shown in Fig. 1

TPMS uses the pressure sensor to monitor the tire pressure in the automobile, and then launches the observed value through the transmitter module, with receiver module receives the pressure information. When the pressure value is higher than or lower than the permissible normal range, the system sends out warning signal to the driver. The wireless transceiver module which transmits or receives radio-frequency signal, is interfaced with microcontroller unit using different buses like Local Interconnect Network (LIN), Controller Area Network (CAN) or Serial Peripheral Interface (SPI).

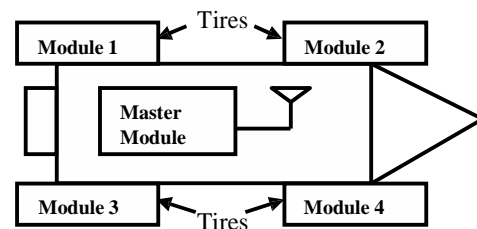


Figure 1. System structure

### III. TIRE PRESSURE MONITORING SYSTEMS

#### A. TPMS using LIN bus

This system is designed by using Local Interconnect Network (LIN) bus. It consists of two main parts: the central receiving module and the tire pressure monitoring i.e. NPX module which is installed in the vehicle's tire. The NPX module which is powered by 3V lithium battery receives low-frequency signal, send out high-frequency signal, and measure the pressure as well as temperature. The central receiving module is fixed in front of the driver in the automobile. The MCU is interfaced with peripherals to get sound and light alarm, LCD display functions. Local Interconnect Network (LIN) bus is used to connect master MCU with low frequency module. The receiver receives the high-frequency signals of tire pressure monitoring module, and shows the information through LCD display which helps the driver to identify the various tire pressure and temperature situations. When the tire pressure and temperature values are abnormal, the system will alert the driver with sound and light which remind the driver to reduce speed, or do the proper maintenance and checking, which helps to improve driving safety. In this system T5754 is used as a radio frequency chip which operates with a frequency of 434 MHz [4].

Further, the system function can be extended to achieve an automatic emergency braking function by sending a warning signal to the ABS control unit. Brakes are applied with the help of a control signal sent by the ABS control unit. Also this system can be connected with GPS. As a result, the system can effectively prevent the occurrence of traffic accidents due to tire puncture, and thus has broad application prospects. The Figure 2 above shows TPMS where the dark arrow represents LIN bus [4].

#### B. TPMS using Wireless SAW Sensors

In this system three SAW resonators are used to measure pressure and temperature of the air inside car tires. Three SAW resonators are C in the middle, B parallel to C and A which is inclined. These SAW devices have three different resonant frequencies  $f_c$ ,  $f_b$  and  $f_a$  respectively. The resonant frequencies of the SAW sensors

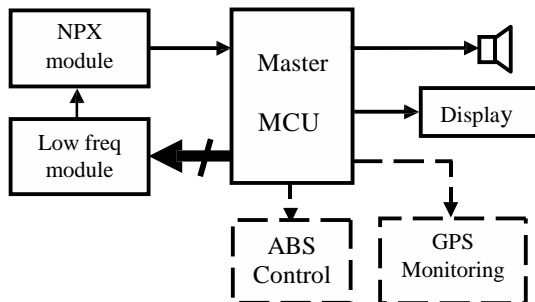


Figure 2. TPMS using LIN bus

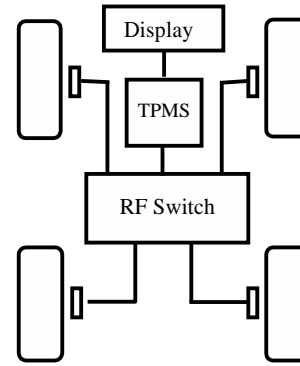


Figure 3. TPMS using Wireless SAW sensors

are in the industrial, scientific and medical (ISM) band and separated at least 200 kHz apart from each another.

The system is assembled in such a way that a tension will be generated on sensor A with fluctuations in tire pressure. Due to this the resonant frequency of sensor C ( $f_c$ ) increases while the frequency  $f_b$  of the reference sensor B, will remains unchanged. The change in the difference between these two frequencies ( $f_c - f_b$ ) is directly proportional to the difference in pressure between the tire and reference. By measuring the difference ( $f_b - f_a$ ) between the resonant frequencies of sensor B and sensor A, the temperature can be determined. Both sensor A and sensor B are relatively not sensitive to pressure. This system offers pressure resolution better than 0.4psi, and 0.5°C. This system also offers excellent system accuracy as well as sensor stability [13].

#### C. TPMS using Controller Area Network (CAN) bus

This system consists of pressure sensor, temperature sensor, and accelerometer. It also has an analog to digital converter, sample and hold, SPI rim, and the digit signal processing unit. This paper chooses IC T5750 and T5760 of the ATMEL Corporation as RF transmitter and receiver chip. Here SP12 is used as the pressure sensor. The SP12 is interfaced with microcontroller which deals with the measured signal. The RF transmitter transmits the measured signal under the control of the microcontroller by using frequency shift keying (FSK). Then this signal is modulated to RF by using the carrier of 433MHz and sends it to the receiving output module by using RF communication. The receiver module receives the RF signal sent from the transmitting module, converts them to the digital signal, then send the digital signal to the microcontroller. The microcontroller examines the received signal and conveys them to the output display. In this system interfacing is done by using CAN bus and RS232 bus. CAN bus is the international standardized bus used for automobile electronic control system [3].

#### D. TPMS based on resonance frequency method

This system works on the fact that the resonance frequencies of the wheel velocity signals are entirely different under different tire pressures conditions. It

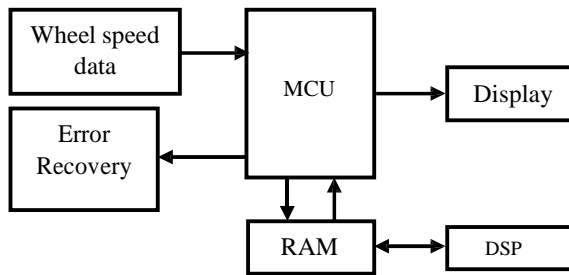


Figure 4. TPMS using based on resonance frequency method

becomes smaller as the tire pressure decreases, and increases as the tire pressure increases. This system comes under Wheel Speed Based (WSB) TPMS which is indirect type of TPMS as no physical sensors are used. The architecture of this system is shown in Fig. 4 Microprocessor central unit (MCU) receives the data related to wheel speed and rectifies the errors. Then the RAM passes the wheel speed data to digital signals processing chip (DSP). DSP deals with wheel speed data by using two algorithms i.e. adaptive weights preconditioned conjugate gradient (AWPCG) and the other based on non-uniform sampling wavelet transform (NUSWT). Then the resonance frequency of the tire is calculated and transmitted back to MCU by the RAM. The experiential values of the tire pressure and the resonance frequency are then compared with standard values. MCU determines the conditions of tires by comparing the results whether the tires are under-inflated or not. If the values are beyond limit, warning signals is displayed on LCD display [12].

#### E. TPMS using Touch Mode Capacitive Pressure Sensor

This system uses Touch-mode type silicon capacitive pressure sensor for measurement of pressure. It can detect low pressure or flat tires. In this system Radio Frequency Identification (RFID) technique is used to communicate between transponders in tires and display system with an antenna which is fixed inside vehicle. The transponder consists of a pressure sensor which is implanted in each tire, an ASIC with a temperature sensor and an antenna coil. Current is induced in the antenna coil in the transponder when it receives RF signal sent from the body antenna. This induced current drives the ASIC. The ASIC sends data of tire pressure, temperature and ID number of each tire, back to the body antenna by radio frequency signal.

Figure shows the cross sectional view of the Touch Mode Capacitive Pressure sensor. It basically consists of two parts: glass substrate with metal electrode and silicon substrate with a diaphragm. The diaphragm is made of Boron doped P<sup>+</sup> layer and acts as an upper movable electrode. The metal electrode is insulated with a thin film.

The diaphragm and the insulation layer are separated by a gap of few micrometers. The diaphragm deforms due to differential pressure and finally touches the insulation film. This touching area determines the

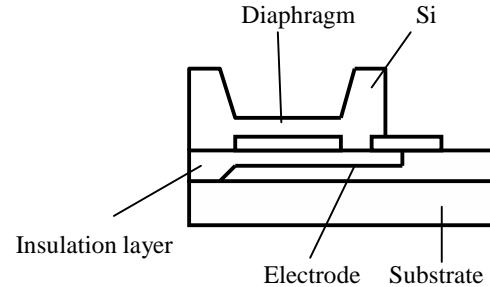


Figure 5. A cross-sectional view of Touch Mode Capacitive Pressure Sensor.

capacitance. The applied pressure is directly proportional to the capacitance since pressure at the closed gap is constant [14].

#### IV. SERIAL PERIPHERAL INTERFACE

SPI is a serial communication protocol that can be used in the tire pressure monitoring system. It is a synchronous protocol that allows a master device to initiate communication with a slave device. Hence in order to communicate between the microcontroller unit and radio frequency transceiver module Serial Peripheral Interface or SPI bus can be used. Data is exchanged between these devices. This protocol is mainly used because it allows serial communication between two or more devices at a high speed up to 10 Mbps and is reasonably easy to implement. Also the complexity is less as it is only 4 wired bus [1] [5].

SPI is also called as 4 wired protocol. The MOSI & MISO lines transfer the data to and fro between the microcontroller unit and radio frequency transceiver module. SPI is a Synchronous protocol because data transfer depends on clock. This clock signal is provided by the master to provide synchronization with the help of SCLK line. The clock signal controls when data will change and when it is valid for reading. Since SPI is synchronous, it has a clock pulse along with the data. RS-232 and other asynchronous protocols do not use a clock pulse; hence the data must be timed very accurately. The last line CS is used for selecting the slave device [5].

#### CONCLUSION

In recent years, TPMS is emerging as major part in the research of vehicle safety system. This paper reviews different designs of TPMS i.e. the Indirect TPMS as well as Direct TPMS which based on the wireless sensors technology, and also gives an idea about the selection of SPI protocol to improvise TPMS.

Further, research can be carried to reduce the power consumption of sensors used in the present systems so that the system can effectively monitor the tire pressure. With the improvement in the technology, the importance of safe

driving is increasing. Hence the monitoring of the real-time pressure and temperature of tires and alarm system will become one of the necessary functions in the safety of the vehicles. The tire pressure monitoring systems based on wireless sensor technology discussed here can also be used in the wide range of applications.

## REFERENCES

- [1] Y. Shiming, T. Jianbin, Hong Q., C. Chengrong, "Wireless Communication Based Tire Pressure Monitoring System," 1-4244-1312-5/07.
- [2] I. H. Ho, J. M. Chung, H. C. Chen, H. W. Chiu, "A Battery-less Tire Pressure Monitoring System," 978-1-4244-2517-4/09.
- [3] H. Wang, S. Yu, Y. Haung, Y. Pu, "Wireless Communication of Tire Pressure Intelligent Monitoring System Based on Sensor Networks Technology," International Conference on Intelligent Control and Automation 2006.
- [4] L. Yueming, H. Binghua, S. Jianchun, Y. Yuan, "Design and Implementation of TPMS Based on Wireless Sensor Network," International Conference on Intelligent System Design and Engineering Application, 2010.
- [5] F. Leens, "An introduction to I2C and SPI Protocol," IEEE Instrumentation & Measurement Magazine, 2009.
- [6] L. Liu, X. Zhou, "Design of Intelligent Tire Safety Pre-alarm System Based on ARM9" International Conference on Informatics, 2010.
- [7] M. Shao, W. Guo, "Tire Pressure Monitoring System," 978-1-4244-9439-2/11.
- [8] J. Zhang, Q. Liu, Y. Zhong, "A Tire Pressure Monitoring System Based on Wireless Sensor Networks Technology," International Conference on Multi media and Information Technology, 2008.
- [9] B. Fleming, "Tire Pressure-Monitoring Systems Rollout," IEEE Vehicular Technology Magazine, 2009.
- [10] M. Kowaleski, "Monitoring and Managing Tire Pressure," IEEE Potentials, 0278-6648/04.
- [11] Z. X. Wang, Y. Xu, G. J. Wang, "Design and Implementation of Tire Monitoring System Based on Zigbee", 978-1-4244-09.
- [12] Q. Zhang, B. Liu, "Design of Tire Pressure Monitoring System Based on Resonance Frequency Method," IEEE/ASME International Conference on Advanced Intelligent Mechatronics, 2009.
- [13] Dixon B., V. Kalinin, J. Beckley, R. Lohr, "A Second Generation In-Car Tire Pressure Monitoring System Based on Wireless Passive SAW Sensors," 1-4244-0074-0/06.
- [14] S. Yamamoto, O. Nakao, H. Nishimura, "Touch Mode Capacitive Pressure Sensor for Passive Tire Monitoring System". 0-7803-7454-1/02.

## ABOUT AUTHOR'S



### A. D. Kale

received the bachelor's degree in Electronics and Telecommunication engineering from SSGM College of Engineering, Shegaon, Maharashtra, India and currently pursuing M. Tech in Electronic System and Communication from Govt. College of Engineering, Amravati, Maharashtra, India.



### Shubhada Thakare

received the bachelor's and master's degree from Amravati University. Currently she is an Assistant Professor at Government College of Engineering, Amravati, Maharashtra, India with over 13 years of experience in teaching field. Her current areas of research are VLSI and Embedded Systems