



# Novel Sensor Position on Vehicle Wheels

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**Abstract.** Nowadays, thieves aim for a vehicle's wheel rims because it has the least security among all parts of the vehicle. It can cost up to a thousand ringgit for sports rims especially. Products are available in the market with lug-nut structured key which may help to secure wheel rims. However, they are not that much helpful.

Our wireless electronic wheel security prototype can provide more flexibility and protection that can assist the vehicle owner in unexpected situations.

Another product related to our project would be the TPMS which is in the market now. This product has electronic sensors in the tire valve to detect tire pressure and tread integrity warning but they are difficult to replace or service. In future TPMS could be equipped with predicative road condition system that could assist autonomous vehicle and navigation service provider with warning system. This is not tested due to lack of space and power source of the TPMS system.

We have found a novel solution for the above problem. The novel new placement suggested on a rotation wheel mass of the vehicle will provide ample space, power source and plug and play capability. Our device can perform all four functions - rim security, tire pressure, tire tread and road condition warning system. The accuracy is sufficient for pre-warnings to drivers.

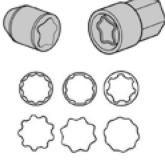



**Keywords:** Vehicle electronic lug nut · bolt wheel · rim security · anti-theft · TPMS · Tyre · Tire Tread Integrity Monitoring System · Autonomous driver predicative road condition

## 1 Introduction

A rotating part such as the wheel is the most difficult part to position electronic sensors. For many years now Mechanical Wheel Security (MWS) mode 1 in Table 1 is the preferred choice for car enthusiasts. This anti-theft lug nuts is capable of securing expensive wheel rim from thieves. Many attempts to design an Electronic Wheel Security (EWS) system [1] and [2] resulted in failure of implementation due to un-strategic sensors placement and limited power source availability.

One of the success story of sensor placement on vehicle wheels is the Tire Pressure Monitoring System (TPMS). TPMS is now fitted in the new vehicles produced or even can be installed as after sales kit [5]. But there is a big challenge to the TPMS. As newer applications associated to TPMS are emerging in the market now, example the EWS [2], tire tread integrity monitoring system [9] and autonomous driver predicative road

**Table 1.** Methodology showing how our novel EWMS performance compared to existing devices.

Method, Image	Title, Reference	Functionality	Advantages	Drawbacks
 <p>Mode 1</p>	MWS	Structural design of lug-nut key lock.	Takes more effort and time for theft of wheel with pre-planned tools needed for a success theft.	A simple modified tool with a hard knock to the lug-nut can open the lug-nut bolt.
 <p>Mode 2</p>	MWS and EWS monitor [1].	Structural design of lug-nut key lock. Placement of battery, wireless device, PIR distance sensor on the hub cap.	Electronic combination structural lock with high security features and early anti-theft alert system.	The electronic system expose to the outside of the wheel making them easy to be tempered. The sport rim design needs to confine with the wheel cap enclosure limiting the rim beauty.
 <p>Mode 3</p>	EWS monitor [2], TPMS monitor [3] [4] [5] [6], Tread monitor [7] [8], and Road condition monitor [9] [10].	Placement of battery, wireless device, air pressure sensor and accelerometer inside of the tire.	The sensor closes to the subject need to monitor making the accuracy good.	It is not PnP module difficult to do maintenance. The device size is small resulting the battery size is small. Not able to do all the function at once.
 <p>Mode 4</p>	EWS monitor [2], TPMS monitor [3] [4] [5] [6], Tread monitor [7] [8], Road condition monitor [9] [10], Disk lug nut protector [11] and our novel EWMS design.	Placement of battery, wireless device, force sensor, fly fish sensor and accelerometer between break hub and wheel rim.	PnP module and the system have large space for battery reduce maintenance. All the function can be done once in this location.	Placement of sensors a bit far from the subject needed to be monitored. But the accuracy good enough for early warnings.

condition [10] all of which incorporate the TPMS. As before TPMS only needs small energy source as most of the time it goes into sleep mode but with this new application it needs bigger energy source and space for components. The TPMS could not install all this due to limited space inside the tire. Any attempt to increase the size would result to tire performance failure.

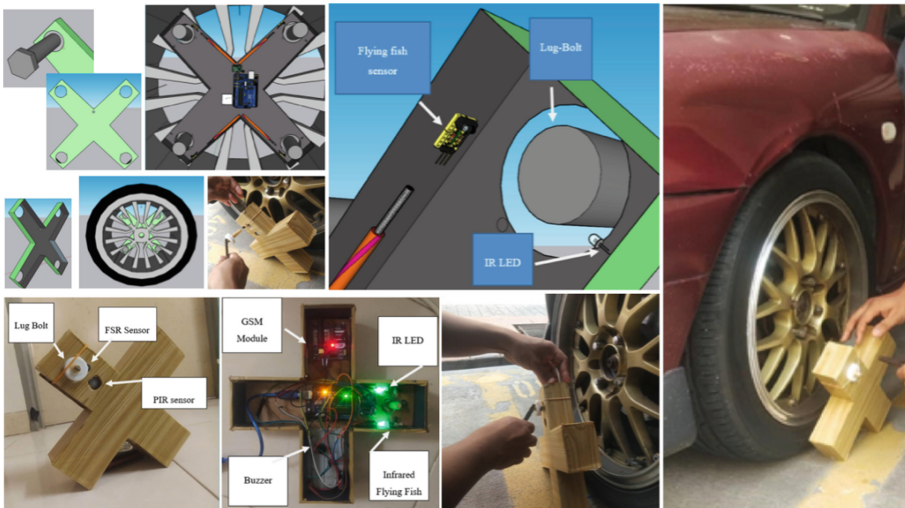
TPMS success story lead us to design our own novel sensor positioning system - the Electronic Wheel Monitor System (EWMS) that has the similar Plug and Play (PnP)

capability as the TPMS but with much large space for additional features, sensors and energy storage.

## 2 Research Method

Our first prototype shown in Fig. 1 which is the imitation of mode 2 features a combination. This prototype has flying fish sensor and PIR distance sensor with GSM module. The flying fish sensor could detect if the bolt is turning as bar code strip painted on the bolt. The PIR distant sensor could detect any person or object close to the vehicle tires. This is a 2 stage EWS alert system via wireless GSM to vehicle driver. The prototype developed in Fig. 1 enhanced with replacing the PIR sensor with axial accelerometer and with additional force sensor. Figure 2 show how this new 3 stage EWS wireless GSM alert system works when the car is parked. The accelerometer tested is very sensitive as it could even detect road the vibration of the road due to a heavy vehicle passing. The accelerometer is also used during car drive mode. During this mode it could detect tire pressure, tire tread and tire wobbling alert on dashboard LCD.

Our second design is the novel mode 4 prototype where, now we have transition from a hub cab design of mode 2 and 3 to a unique structural disk design as shown in Fig. 3. This design is more hidden inside, between break hub and wheel rim. Even though it is hidden, it is designed with PnP in mind. Battery maintenance is convenient as it could be done at a interval of 10,000 km mileage where at this time normally a wheel crossing is performed. Furthermore, this design gives ample space for electronic devices compared to a TPMS mode 3 design. TPMS mode 3 design could only perform tire pressure, where else tread monitor and road condition monitor are proposed only to be incorporated in the module. They are not in the market currently due to lack of space for battery. But in our project, we have incorporated them all as shown in Fig. 4. Our system could be fitted



**Fig. 1.** Hardware construction of our first prototype.

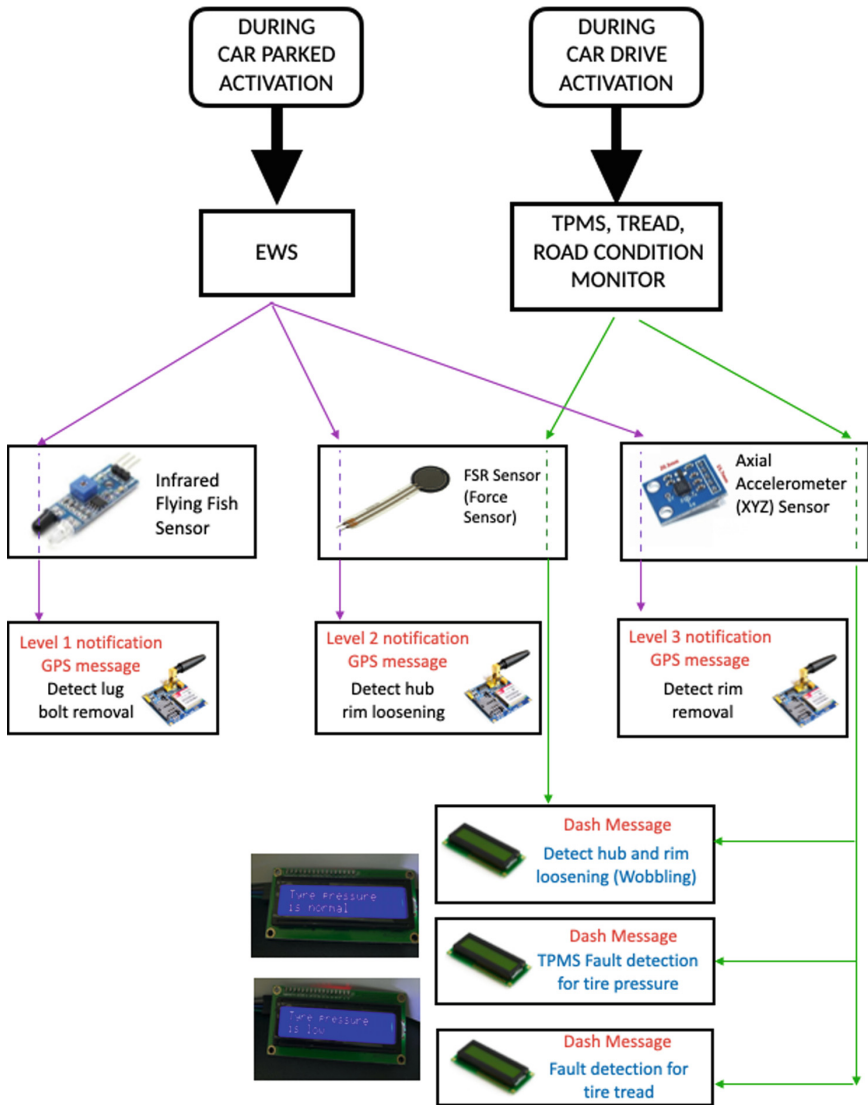
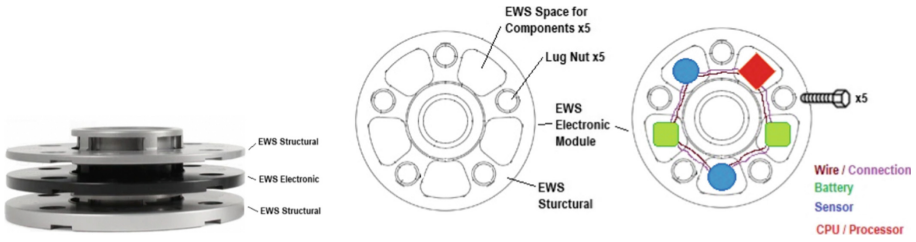


Fig. 2. Flow chart of our EWS system.



**Fig. 3.** Shows our second prototype of EWMS disk design.

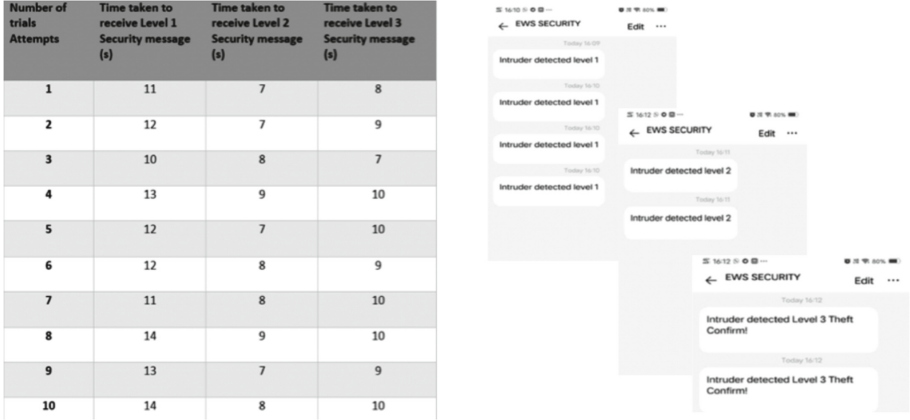


**Fig. 4.** Shows hardware our second prototype of EWMS.

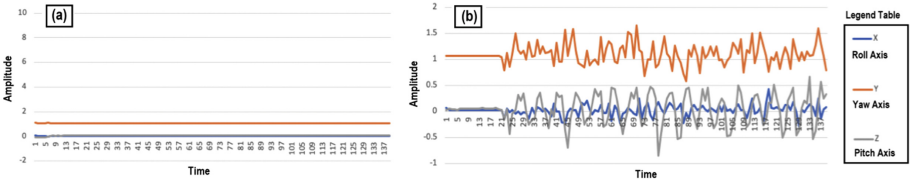
in all types of vehicles. The structural disk aluminium alloy cut by the Computerised Numerical Control (CNC) machine, can withstand ambient temperatures of 150 degrees that is produced from the brake disks for a short burst. Our EWMS package comes with wireless dash display, EWS disk and a longer anti-theft lug nuts (mode 1). This anti-theft lug nuts gives double security with MWS and EWS incorporated.

### 3 Results and Analysis

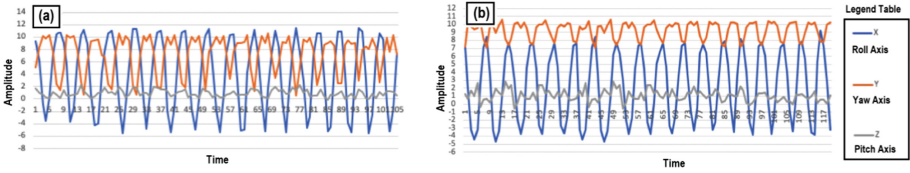
This section shows the results of our novel EWMS. Figure 5 show the average time is taken for a low priority level 1 message is 12 s, medium priority level 2 message is 8 s and highest priority level 3 message is 9 s wireless GSM response. The accelerometer is placed in 45 degrees angle for better data security. Figure 6 shows the accelerometer data when the car is parked still and when wheel rim theft is in progress. Figure 7 show difference between car tire pressure data of the accelerometer.



**Fig. 5.** Analysis on respond time to receive a text message.



**Fig. 6.** (a) With movement of rim during parked (b) without movement of rim during theft.



**Fig. 7.** (a) Normal tire pressure (b) low tire pressure

## 4 Conclusion

This project is a success as it is able to overcome all hindrances previously experienced by the automotive industry which primarily involves working in a mechanical rotating device (wheel/rim). Our project has the best of both worlds of MWS and EWS incorporated together. There are many applications other than EWS on this rotation area for example TPMS, tire tread integrity monitoring system and autonomous driver predicative road condition. For this project, TPMS is implemented and other ideas could not be fully implemented because the TPMS power system is too small. We have solved all of these hindrances with a simple PnP system that would be the next generation EWMS. Our system is sensitive enough to give early warnings to drivers. Future work suggestion would be to implement the design for heavy vehicles for example trucks and buses.



**Acknowledgements.** This project was made possible due to the Spin-Off Grant by Multimedia University Cyberjaya Malaysia to the main author. We would like to thank Society of Automotive Engineers Malaysia International Innovation Exhibition 2021 (SAEM-IIE) for the gold award for this project to the main author.

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