TPMS Receive Antenna Design for Large Vehicles

Anıl Özdemirli [1], M. Murat Bilgic [1], Korkut Yegin [1]

(1) Yeditepe University, EE Eng. Dept., Kayisdagi Cad. Ataşehir, 34755 Istanbul Turkey
anilozdemirli@gmail.com, kyegin@yeditepe.edu.tr

Abstract

TPMS (Tire Pressure Monitoring System) is becoming an industry standard for driving safety and fuel efficiency. The receiving antenna for TPMS resides in the near field of the sensor antenna and this makes it very difficult to establish a reliable RF link for large vehicles. In the design of receiving antenna, it is paramount to consider the electric field distribution around the vehicle due to transmitter sensor. Through extensive large vehicle simulations, we show optimum locations for the receive antenna and we designed two candidate antennas for best reception.

1. Introduction

Although the use of TPMS has increased drastically, there are very few studies made on the received signal strength calculations and receiver designs. For large vehicles such as van, SUV, midibus, the transmission of sensor information can be very difficult depending on the receiver antenna position. To improve the received signal strength, first step is to accurately calculate the electric field distribution around the vehicle due to transmitter sensor. Simulation results on electric field distributions due to a small loop antenna on a midibus model have been reported partly in [1].

Usually small loop antennas are used as transmitter antennas in TPMS systems due to their low cost, ease of matching to transmitter ICs, and minimal sensitivity to external environment. Based on the earlier studies which compared electric and magnetic dipole as transmitter, a small loop antenna is used for transmitter sensor. This work presents a detailed tire and large vehicle model. We also show complete tire model and minibus model. Comparison of two types of receiving antennas, which are placed on the side windows of midibus are presented.

2. Tire and Minibus Model

Detailed tire model used in the simulations is illustrated in Figure 1. Tires are modelled based on 215/65R-16 tire dimensions. Four different positions are specified for the transmitter in tire to model the rotation, as shown in Figure 1. The metal net placed inside the tire is also modelled as a metallic surface at the operation frequency. The tire dielectric constants and loss tangent values are taken from [2].

Figure 3 shows the complete vehicle model with the dimensions taken from Isuzu Turquise midibus. The vehicle was modelled using planar metal sheets of 1mm thickness over an infinite perfect electric conducting ground. The windows are not completely modelled to speed the simulation time. Since we base our analysis on comparative performance of two antennas, refined model of the windows is not needed.

3. Simulation Model

The field simulations and S-parameter analysis are made with a commercial 3D electromagnetic solver using Method of Moments. The operation frequency is selected as 433 MHz. The triangular segmentations of the wheels are meshed with $\lambda/17$ edge length due to the high dielectric constant of the tires. The midibus model, metal hood and windows, are meshed with $\lambda/5$ edge length triangular segmentation.

Earlier studies have revealed that, side windows are considered to be the best locations for receiver antenna placement as shown in Figures 3 and 4. For S-parameter analysis, 12 different positions are specified on the window for possible

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receive antenna locations as illustrated in Figure 5. Normally TPMS sensors use small loop antennas for transmitting information. Figure 6 shows a typical TPMS sensor with loop antenna. Small loop antennas are easy to implement on PCB and due to there inductive impedance they can be easily be matched to the capacitive output of transmitter IC's. A loop antenna, having an impedance of 100+j0 is used for receiving antenna, as displayed in Figure 7a. This loop is placed at 12 different positions and S-parameters are obtained for the 1st position of the transmitter in the tire. Whole analysis is carried out for 4 different positions of tire. The position, which has the maximum value of S_{21} for 4 different positions of the transmitter in the tire is recorded. Then, similar analysis is followed to design another receiving antenna which has higher S_{21} average than the loop antenna. The antenna configuration is shown in Figure 7b.

4. Results and Conclusion

We presented electromagnetic modelling of minibus and tire when a transmitting sensor loop antenna is placed inside the tire. On the receiving part, a loop antenna is used at optimal receive antenna locations on the window. Loop antenna is compared with another antenna by using S-parameters and the results are shown Table 1. We observe that second antenna model has better performance compared to the loop antenna.

The transmit sensor antenna inside the tire is in strong interaction of the vehicle and the receive antenna resides in the near field, reactive zone of the transmitting loop antenna. Unlike far-field antenna designs for vehicular communications, TPMS system works in a relatively complex and electromagnetically challenging environment. At first glance, one may be tempted to use a loop antenna at the receiver, however, we showed that this might not be the optimal solution. As an alternative, we developed an H-shaped receive antenna model and demonstrated its advantage over loop antenna for various tire positions. In addition to antenna selection, the location of the receive antenna can also impact the received signal. This effect can be observed for large vehicles easily.

References

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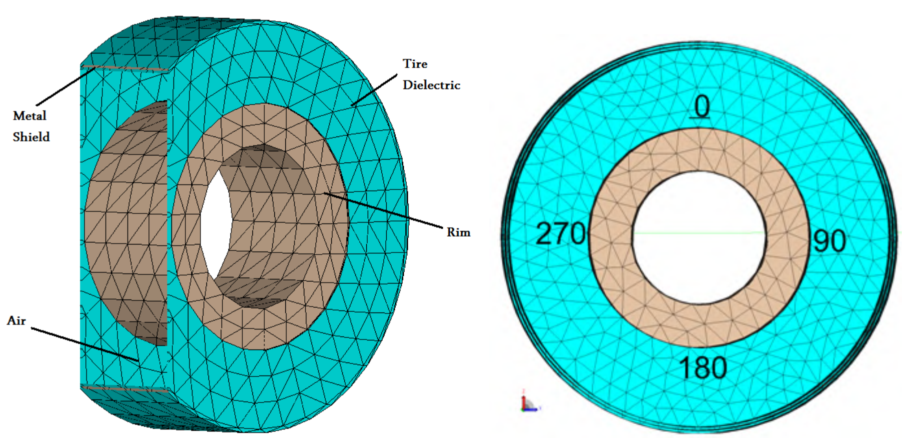
2. K. Tanoshita, K. Nakatani and Y. Yamada, "Electric Field Simulations around a Car of the Tire Pressure Monitoring System," IEICE Trans. Commun., vol.E90-B No.9, Sept. 2007.



a) b)

Figure 1. a) Tire model and b) sensor positions in tire for simulations

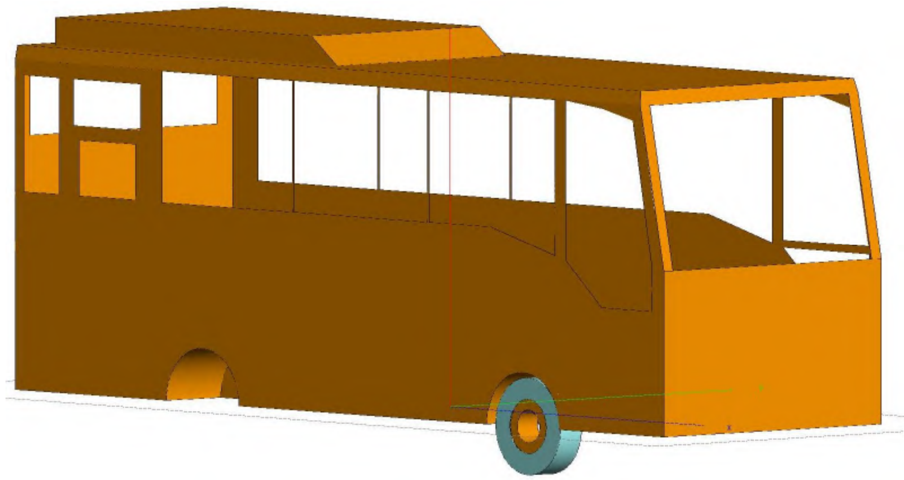


Figure 2. Isuzu midibus model for 3D simulator

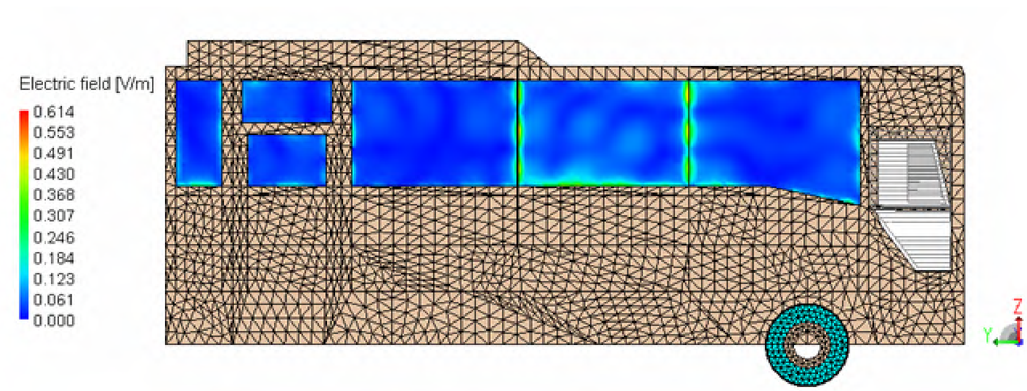


Figure 3. Electric field distribution when small loop antenna is on passenger side

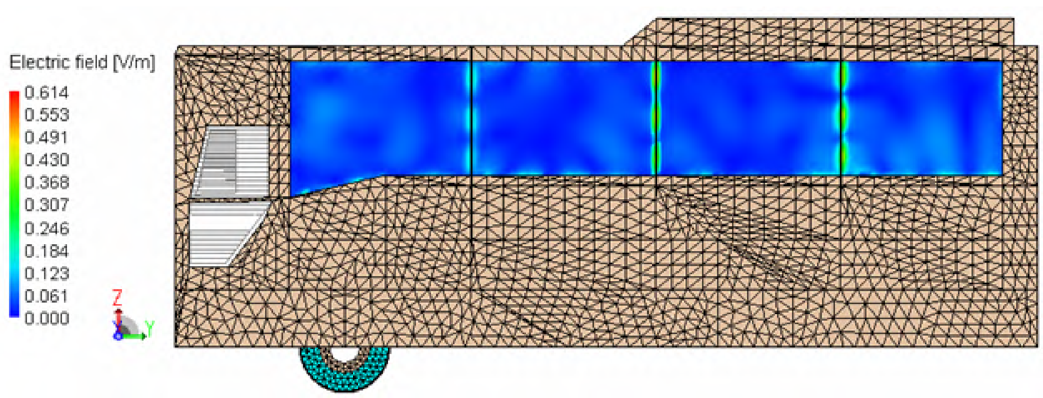


Figure 4**.** Electric field distribution when small loop antenna is on driver side

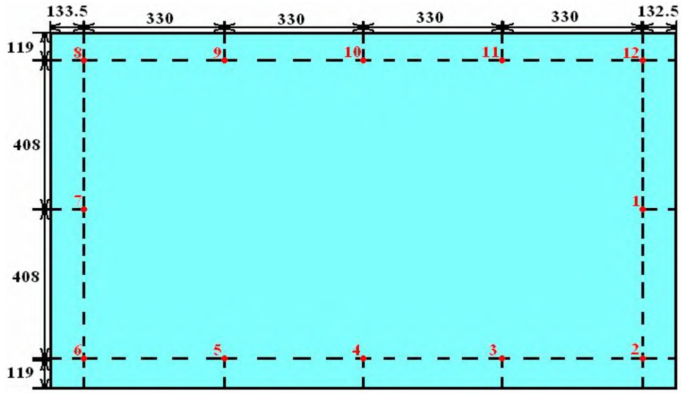


Figure 5. Receiver antenna placement in side window (dimensions in mm)

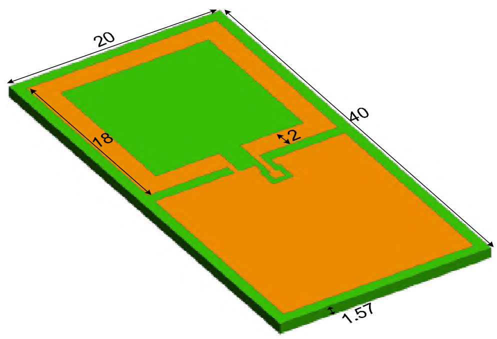
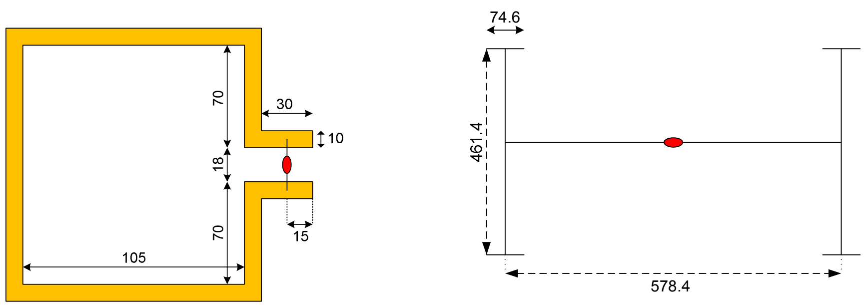


Figure 6. Small loop antenna (dimensions in mm)



a) b)

Figure 7. Receiver antenna configurations (dimensions in mm) a) loop b) H-shaped antenna

Table 1. Comparison of S-parameters of loop and H-shaped antenna

S21 (dB)					Average
	0^o	90^o	180^o	270^o	(dB)
Loop	-93,45	-90,33	-99,5	-93,11	-93,52
H-shaped ant	-89,8	-92,92	-98,98	-90,8	-92,50