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Feasibility Study on Application of Radio Frequency Identification (RFID) in Railway Wheel Monitoring System

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Abstract: In practise, most of the railway wheel monitoring activity in Malaysia is being done manually such as using underfloor wheel lathe(UWFL) and dial gauge. The process of manual monitoring is time consuming, requires more manpower and with higher tendency of error during the transportation of data. Therefore, to improve the process, this project proposes RFID based system for the wheel monitoring, as it could increase the effeciency of the process as the data can be delivered directly to the Operation Control Centre (OCC). Matlab Simulink was used to guarantee that the design of the simulation is feasible. The final result for this simulation is based on the data of the output spectrum analyzer. By using Kurtosis method, it is possible to detect the condition of the railway wheel whether in healthy or damaged. Overall, application of RFID in railway wheel monitoring system enhanced the effectiveness of railway wheel maintenance operation.

Keywords: Wheel Monitoring System, RFID, Manual Monitoring

1. Introduction

The majority of the nations in the developing countries are now undergoing significant population and urban expansion. Significant growth in population and economic increase the demand for the usage of public transportation especially railway transportation. According to Malaysia's National Transport Policy 2019 - 2030, it is estimated that public transportation usage will achieve 40% by the end of 2030 [1]. During the last decades, the usage of railway transportation in Malaysia has increased dramatically. Figure 1 shows the overall usage of railway transportation such as train services, commuter and electric train services by Malaysian citizens from 2011 to 2020. From the figure, it can be concluded that number of passengers using railway transportation has been increasing rapidly for the past few years especially in the electric train service [1].

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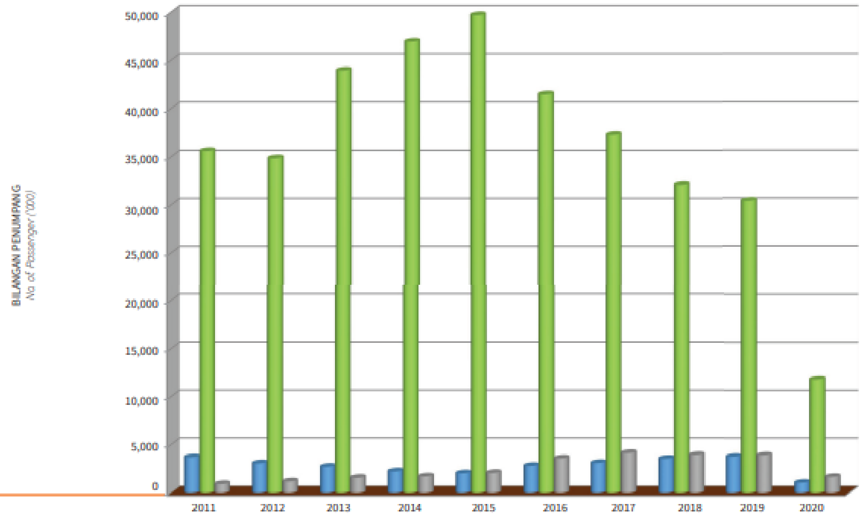

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Perkhidmatan Keretapi *Train Service*	3,685	3,056	2,703	2,223	2,015	2,791	3,092	3,527	3,746	1,041
Komuter *Commuter*	35,599	34,847	43,942	46,957	49,690	41,469	37,274	32,078	30,404	11,796
Electric Train Service (ETS)	912	1,180	1,563	1,692	2,060	3,565	4,148	3,933	3,902	1,647

Figure 1: Overall usage of railway transportation by Malaysian citizens from the year 2011 to 2020 [1]

The anticipated increase in traffic requires effective and efficient train maintenance to assure passenger comfort as well as safe and timely train movement. Railway transit relies heavily on rolling stock maintenance. Its purpose is to maintain the safety of operations along with the safety and comfort of passengers. Consequently, it is a significant cost for railway transportation operations. Thus, greater competitiveness in the transportation market necessitates maintenance improvement, with the goal of reducing maintenance expenses while maintaining operational safety [2]. Figure 2 illustrates the life cycle cost of a high speed train maintenance. The chart illustrates that the highest cost was used for both maintenance and energy [3]. According to Oliver Wyman, the life cycle cost for other type of train is similar to the high speed train but only differ in energy as lower speed require in train service [3]. From that, it can be concluded that maintenance is the highest in cost for train operation.

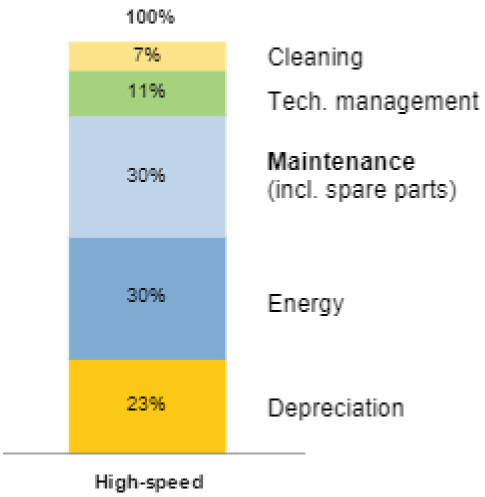

Figure 2: Overall life cycle cost for a high speed train [3]

1.1 Problem Statement

The wheel-rail system is a method that has a substantial influence on the railway system's operation. As a result, maintaining the wheel-rail system requires a substantial amount of effort. The wheels of the rolling stock have a significant impact on the operation of the wheel-rail system. According to Ekberg, the yearly wheel probability of failure is about one in 1000 wheels, with an overall amount of wheels in track of roughly 50 million, resulting at about 25000 to 50000 wheel failures each year [4]. In practise, most of the wheel monitoring activity in Malaysia is being done manually. The process of manual monitoring is time consuming, requires more manpower and with higher tendency of error during the transportation of data. Therefore, to improve the process, this project proposes RFID based system for the wheel monitoring, as it could increase the effeciency of the process as the data can be delivered directly to the Operation Control Centre (OCC).

1.2 Objectives

The purpose of this research is to look at the use of radio frequency identification technology in railway wheel monitoring systems and use the findings to improve the performance of the systems. The following are the objective of this paper's research:

1. To determine the characteristics and parameters of RFID system that is suitable with the operation.
2. To simulate RFID system that can be used to deliver the wheel problem to the OCC.
3. To suggest the best RFID system, based on objective 2 findings, in terms of delivering the information of the wheel problem failure.

1.3 Project Scope

The scope for this research has been set to achieve all the objectives. The scope will be focus on:

1. The application of the RFID system will be focusing on wheel monitoring only at MRT 2 Line.
2. The selected wheel failure are wheel profile measurement.
3. The maximum runout diameter for the wheel is 0.8mm.
4. MATLAB Simulink will be used to carry out the simulation.

2. Materials and Methods

Figure 3 depicts the project's progress from beginning to finish.

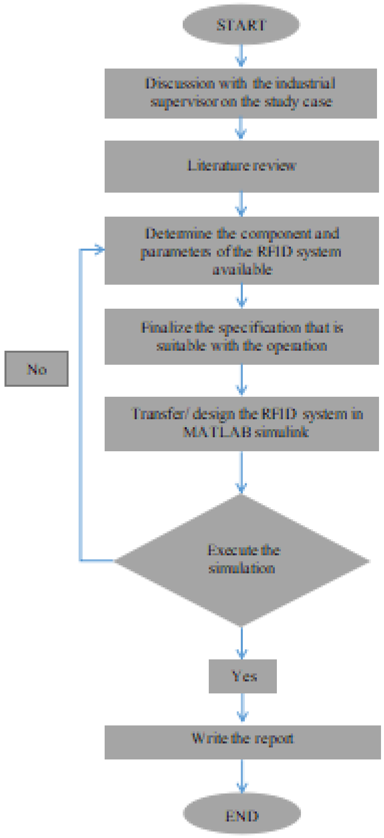

Figure 3: Flowchart for the analysis on application of radio frequency identification in railway wheel monitoring system

2.1 Complete set up of the simulation

Figure 4 depicts the block diagram for the development of the simulation. The baseband signal generator is connected to free space path loss to reduce the amplitude of the input signal with the parameter set to 115dB loss. This component is later connected to power meter to determine the value of the power for the transmitter. Then, the power meter is connected to display to display the RF power from power meter. Power meter is connected to RF blockset. The RF blockset was create using the RF Budget Analyzer app. The RF Budget Analyzer app uses Friis equations to determine the noise gain and nonlinearity budget of an RF chain. It also taking into account impedance mismatches. The RF blockset was connected to spectrum analyzer to analyze the graph of the input from transmitter. Later, ADC is connected to RF blockset then to DC blocker to block DC component to input signal. The DC blocker is connected to receiver subsytem. The receiver is finally connected to display to display the output value and spectrum analyzer to analyze the graph of the output value. Additionally there is also include a display component to display the symbol error rate to altered the number of symbol error of a data stream in communication channel such as noise and interference.

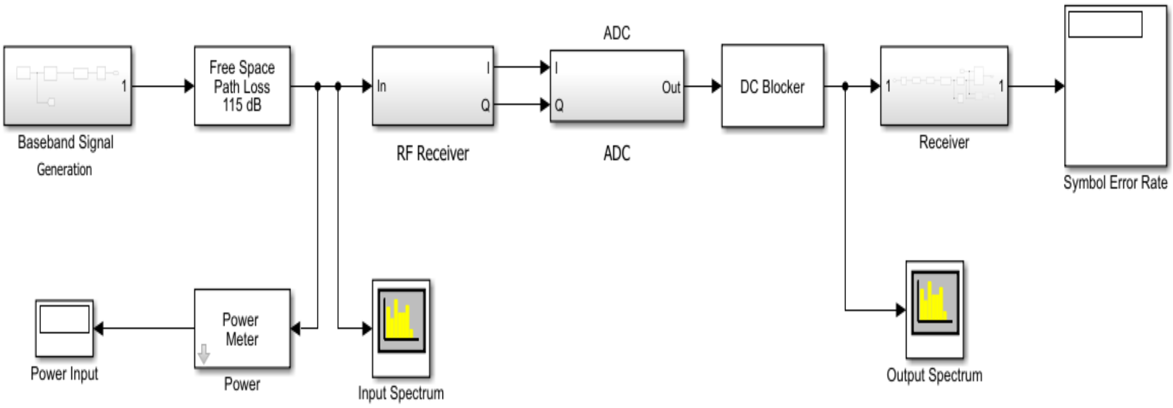

Figure 4: Complete set up of the simulation

3. Result and discussion

The result produced for three different set size of random integer generator will be shown and proved. The set size of the random integer generator is set to 1^M. The simulation time set to 1e-3 seconds as the spectrum analyzer needs 1024 samples to update the display. Morever, the graph in this duration is more smoother than any other duration.

3.1 Data analysis of the output spectrum with the set size of random integer generator 1^M

From the output spectrum graph in figure 5, we can see that the signal of the graph is containing less impulsive feature which indicate that there is less amount of spikes in the signal. The spectrum is almost constant at 46d Bm from -4 MHz until -1 Mhz. The graph reach its highest peak to 78.96 dBm at 0MHz. Then, the graph began decrease to 45 dBm until 4 MHz. The channel power for this graph is 80.48 dBm.

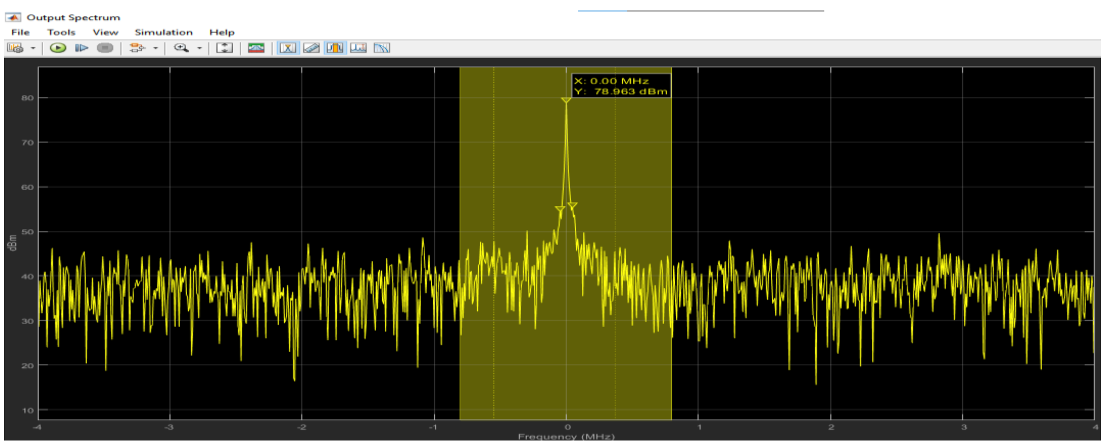

Figure 5: The graph of output spectrum for set size 1^M

3.2 Data analysis of the output spectrum with the set size of random integer generator 2^M

Figure 6 depicts the output spectrum graph for set size of 2^M. The signal of the graph is containing high impulsive forces between -1MHz to 1MHz which indicate there is high amount of spikes in signal.

The graph is constant at 46 dBm from -4 MHz until -1 MHz. Then the graph began to increase rapidly until 75.87 dBm at 0MHz. Later the graph the began to drop until 46 dBm from 1 MHz until 4 MHz.

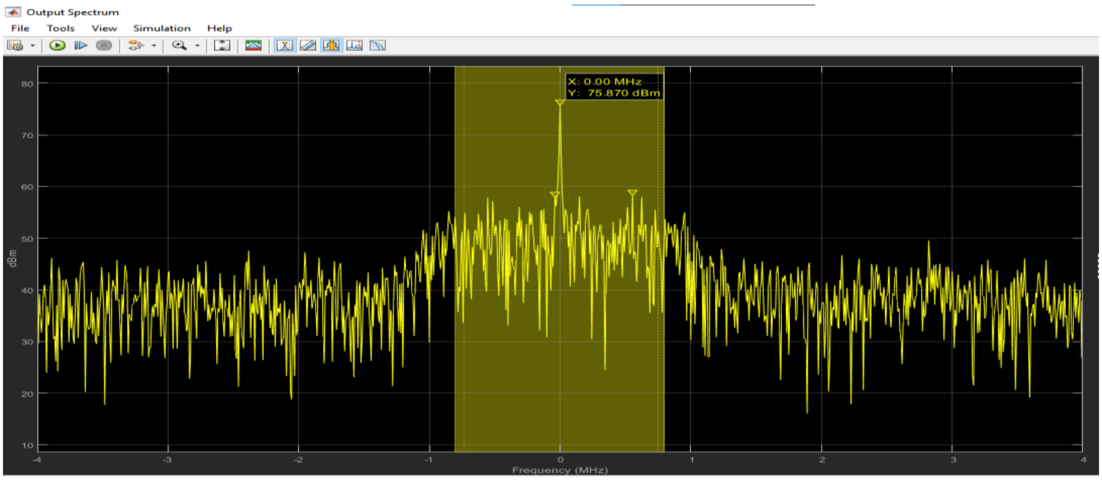

Figure 6: The graph of output spectrum for set size 2^M

3.3 Data analysis of the output spectrum with the set size of random integer generator 3^M

From the output spectrum graph in Figure 7, we can see that the signal of the graph is containing high amount of impulsive feature between -2MHz to 2 MHz. High amount of impulsive feature indicates that there is high amount of spikes in the signal. The graph is constant at 46 dBm from -4 MHz until -1 MHz. Then, the graph began to increase to the highest peak at 71.75 dBm. Later, the graph began to decrease to 46 dBm from 1 MHz until 4MHz.

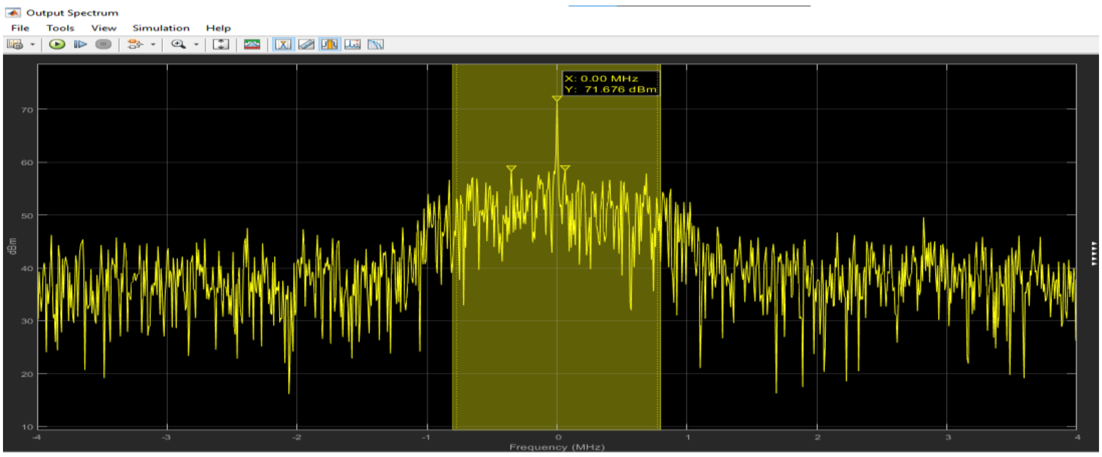

Figure 7: The graph of output spectrum for set size 3^M

3.4 Data comparison of different set size of random integer generator

Output spectral plots of three different batch sizes are recorded and an analysis is performed to illustrate the plots. Kurtosis method was used to determine if the wheel was normal or damaged. Kurtosis is known as the degree of sharpness of a signal spike. Therefore, it is used as a method of measuring the relative peak or flatness of a signal. On a healthy rotating machine, the kurtosis value is close to Mesokurtic. A value greater than or less than Mesokurtic indicates the presence of defects that can cause the monitored system to fail. Figure 8 illustrates the general forms of the Kurtosis. The analysis of the wheel condition was done using 2 method. The first method is comparing the shape of the output spectrum with the general forms of the Kurtosis [5]. From the comparison, we can see that the output spectrum graph in Figure 5 is similar to the Leptokurtic while the output spectrum graph in Figure 6 and Figure 7 is similar to the Platykurtic. From this we can conclude that the conditions of the wheel for the set size of 1^M, 2^M and 3^M is not in healthy condition.

The second method is analyze the occuration of impulsive features in the signal of the output spectrum. When the wheel is defects, the implusive features will be occur in the signal which will causes spikes in the signal. The higher the occuration of impulsive features, the higher the spikes in the signal. In Figure 6, the signal of the graph containing less implusive feature which prove that there is less amount of spikes in signal. The signal of the graph in Figure 7 and 8 containing high amount of implusive features, thus the higher the amount of spikes in the signal. This indicates that the wheel condition in Figure 7 and 8 is already in defect condition.

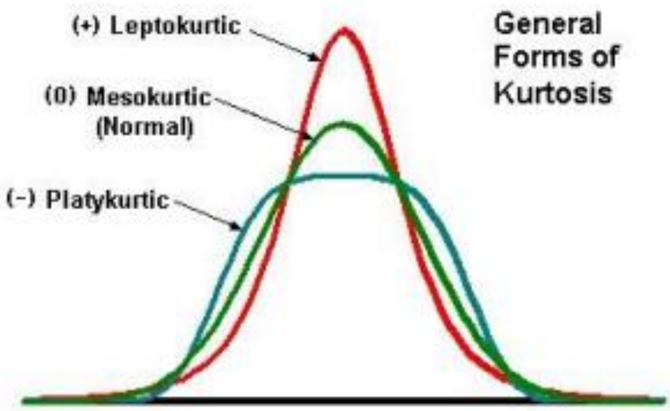

Figure 8: General form of kurtosis [5]

The analysis was further made by comparing the highest peak of the output spectrum graph with the data of the Tamtron Train Information System in Swedish Rail Transportation. Table 1 illustrates the data of the Tamtron Train Information System. [6]

Table 1: The data of the Tamtron Train Information System [6]

Alarm	Level	Limit(dB)	Actions
Wheel profile measurement	P5	>70	To be removed from the train ASAP, speed limit of 50km/h until removal
	P4	>72.5	Speed limit of 50km/h after alarm, wheelset shall be fixed before the next operation
	P3	>75	No speed limit, wheelset shall be fixed before next operation
	P2	>77.5	Wheelset shall be fixed during the next service
	P1	>80	ECM schedules the corrective actions

This data is use by Swedish Rail Transportation to monitoring the railway wheel. This data was used in the project to analzye the graph of the output spectrum. The highest peak of the graph in Figure 4.2.2 is 78.96 dBm which is in level P2 >77.5 dB. From here we can conclude that the wheel is defective but can further continue operation until the next maintenance services. The highest peak of the graph is 75.87 dBm. The wheel condition is in level P3. The wheel is in defect condition with moderate range and need to fixed the wheelset before the next operation. Finally the highest peak of the output spectrum graph is 71.68 dBm which is in level P5 >70 dB. The wheel condition is highly defective and need to be removed form the train immediately and change with a new wheelset.

4. Conclusion

The three objectives of this project are being achieved by used the technology of radio frequency identification in railway wheel monitoring system to improve the performance of the system. The characteristics and parameters of RFID systems have been determined which is suitable with the operations. Next, based on the determined characteristics and parameters of RFID systems, a simulation model was developed based on RFID system to deliver the wheel problems to OCC. Finally, the potential of RFID system have been analyzed in terms of delivering the information of the wheel problem failure with the development of the simulation. From the results, a conclusion can be made that the higher the occuration of impulsive features, the higher the amount of spikes in signal thus the condition of the railway wheel will be more defective. During the simulation stage, the performance and effeciency of the components are also determined by making the right value of the parameters to be used for the components. By completing this simulation, it will provide a new idea of using the technology of radio frequency identification in railway wheel monitoring system which will be beneficial for both rolling stock maintenance and safety of railway passengers.

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