Evolution in Electrical and Electronic Engineering Vol. 2 No. 2 (2021) 369-377

EEEE

Homepage: http://publisher.uthm.edu.my/periodicals/index.php/eeee
e-ISSN : 2756-8458

Electromagnetic Compatibility (EMC) Ambient Measurement Effect from Rail Environments Towards Cardiac Pacemaker Immunity

Mohamad Nor Izzuddin Yaman[1], Syarfa Zahirah Sapuan[1*]

[1] Department of Electronic Engineering, Faculty of Electrical and Electronic Engineering,
Universiti Tun Hussein Onn Malaysia, Batu Pahat, 86400, MALAYSIA

*Corresponding Author Designation

DOI: https://doi.org/10.30880/eeee.2021.02.02.044
Received 04 July 2021; Accepted 23 July 2021; Available online 30 October 2021

Abstract: The purpose of this research is to investigate the impact of electromagnetic compatibility (EMC) ambient measurement on cardiac pacemaker immunity in train settings. When a railway station employs more electronics, the system's complexity increases as a result of interference and attenuation. External factors, such as train environments or the surrounding surroundings, may cause interference with an implanted device like as a pacemaker. To avoid this unintentional electromagnetic interference (EMI) effect, it is necessary to be aware of the possibility and take specific measures. Real measurements will be taken at the train station under various circumstances using loop and tri-log antennas, each of which must be linked to a spectrum analyzer. For analysis, the measurement data was compared to the pacemaker immunity level. This study shows that just one measurement failed out of 44, particularly at the Kepong Baru station in the V-N direction at the frequency 393.975 MHz. The test yielded a value of 111.86 dBµV/m, which is 2.39 dBµV/m over the pacemaker's allowed limit.

Keywords: Electromagnetic Compatibility, Pacemaker, Rail Environments

1. Introduction

Radiation is defined as energy or an element of a source that moves across space or other media and penetrates a variety of materials. Light, radio, and microwaves are all examples of non-ionizing radiation. The environment is inherently densely populated with radiation due to the many buildings that surround it.

Since the 1990s, Malaysia's railway system has grown steadily in terms of transportation. Since then, transport users have grown in number and spread throughout the country, especially in urban areas such as Kuala Lumpur and its surroundings. In recent years, the government has focused progressively on rail infrastructure improvement through the implementation of Mass Rapid Transit (MRT) projects

**Corresponding author: syarfa@uthm.edu.my*

in Kuala Lumpur and Selangor, with the goal of preserving the environment and reducing pollution on roads, thereby simplifying transportation and saving time locally.

The overall trend toward increasing traffic flow, faster speeds, more trains per hour, longer trains, and heavier axle loads necessitates the use of more powerful engines and stronger supply line currents [1]. When more electronics are deployed in a railway station, the complexity of the railway system rises [2]-[4]. Magnetic and electric fields are generated on railway tracks by trains, railway power supply systems, adjacent electric transmission lines, and other sources [5]-[6]. As a result, electromagnetic emissions from railway systems are increasing with time [7]-[8]. The combination of more sensitive electrical circuits [9] and increased electromagnetic noise with higher frequencies may increase the overall sensitivity of the railway system [10]. The final objectives of this proposed research area to define the method to be used for ambient electromagnetic measurement in rail environment. The aim of this study is also to measure radiation levels and power transmission in the train environment. Finally, the electromagnetic radiation level will be compared to the pacemaker's minimum immunity as defined by British Standards BS EN 50527-2-2:2018.

2. Materials and Methods

This research will compare the pacemaker's immunity level to electromagnetic ambient data to determine the impact of the train environment and power transmission line on the pacemaker's sensitivity. The latest British Standard for Pacemaker is used which is EN 50527-2-2:2018. Based on the standard which shows the limit for radio-frequency field range from 5 MHz to 450 MHz for unipolar pacemaker. The electric field limit of frequency 5 MHz is 121.44 dBµV/m. The value of the limit shows downward trend from 5 MHz to 200 MHz with the limit value is 91.87 dBµV/m, but the limit value goes up again from 250 MHz to 450 MHz, which at 97.64 dBµV/m and 109.89 dBµV/m, respectively. At the frequency of 400 MHz until 450 MHz, the value of the limit not change. This standard shows the immunity limit of the pacemaker that will be compared with the measured value. This research will need the adoption of many methods in order to assess the pacemaker's effect.

2.1 Measurement equipment

In EMC ambient measurement there are numerous standard protocols that are need to be followed. The following measurement equipment are used to measurement the EMC ambient at railway station:

- **Spectrum analyzer** are connected to the antenna to generate and save the value or graph of signal at the surroundings.
- **Loop antenna** with the frequency range of 1 kHz to 30 MHz are used to receive the signal with low frequency between 9 kHz to 30 MHz and send to the connected spectrum analyzer.
- **Tri-log antenna** with the frequency range of 30 MHz to 1 GHz and linear polarization are used to received the signal then send to the spectrum analyzer to generate the value or graph of the signal.

2.2 Measurement method

Measurement will be performed at chosen locations between 9 kHz and 450 MHz. It is solely referenced to two (2) aspects: antenna height (Section 7.3.4.2.4 of the standard) and four measurements in orthogonal directions (Section 10 of the standard). Radio frequency ambient measurements would be conducted utilizing a variety of antennas attached to the spectrum analyzer. The measurement of the frequency from 9 kHz to 30 MHz, loop antenna will be used. The tri-log antenna will measurement the signal from 30 MHz to 450 MHz. The measurement set-ups are seen in Figure 1 to Figure 4.

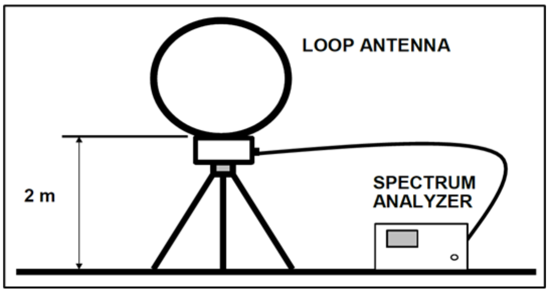

Figure 1: Test set-up for the loop antenna (9 kHz to 30 MHz)

Figure 2: Real test set-up for the loop antenna at KVMRT 2 station

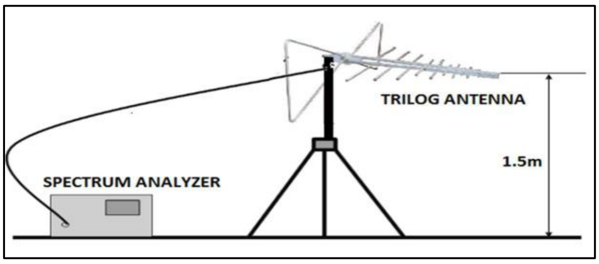

Figure 3: Test set-up for the tri-log antenna (30 MHz to 1 GHz)

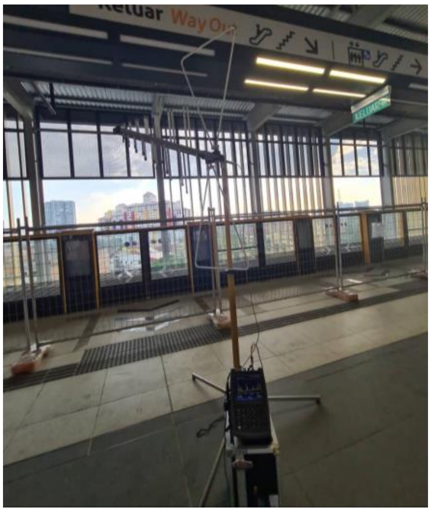

Figure 4: Real test set-up for the tri-log antenna at KVMRT 2 station

Peak Detector and Max-Hold spectrum analyzer functions are used to detect the maximum field strengths. For at least one minute, the Max-Hold function will be kept. Either the magnetic field H(dBμA/m) or electric field E (dBμV/m) are the measurement quantities to be derived from the measurement. These quantities can be derived on the basis of the voltage detected by the spectrum analyzer V_{SA} (dBμV), electrical antenna factor AF_E (dB), and cable failure L (dB). Therefore, the relationship is given as in Eq. 1 and Eq.2 :

$$E(dB\mu V/m) = V_{SA}(dB\mu V) + AF_E(dB) + L\ (dB) \quad \text{Eq.1}$$

$$H(dB\mu A/m) = V_{SA}(dB\mu V) + AF_M(dB) + L\ (dB) \quad \text{Eq.2}$$

The measurement would be carried out from the ground to the center of the antenna at 2 m ± 0.2 m with both Vertical (V) and Horizontal (H) antenna polarizations. The spectrum analyzer was connected to the antennas spanning frequency ranges using coaxial cables. Measurements will be performed in four directions (North (N), South (S), East (E) and West (W).

2.3 Total uncertainty

The measurement result approximates the value of the measurand and is only complete if it includes a statement of the uncertainty. Total uncertainty specifies each source of uncertainty and its intensity in decibels (dB). For each contribution, the probability distribution and its divisor value were determined using previous measurement data. The combined uncertainty, u_c (y), is then calculated for each contribution of m by taking the square root of the total of the squares of the individual uncertainties, as shown in equation below:

$$u_c(y) = \sqrt{\sum_{i=1}^{m} u_i^2(y)} \quad \text{Eq.3}$$

where;
$u_c(y)$ = Combined uncertainty
m = m uncertainty contributions
$u_i^2(y)$ = Standard uncertainty

Expended uncertainty was determined by multiplying the combined uncertainty by the coverage factor, k. This is the overall uncertainty for the measurement. For a 95 % confidence level, the coverage factor, k, was set to 2.

3. Results and Discussion

The purpose of this study is to provide the findings and conclusions from the research that has been performed. Apart from recognizing the impact on the pacemaker while it is at the train station, the trend of the electromagnetic ambient value will be compared to the pacemaker's maximal immunity level. The spectrum analyzer will instantly record the ambient measurement data as voltage versus frequency. The computer will use the recorded measurement data to convert the voltage to the electric field (E) against frequency. The final findings will then be displayed graphically for assessment of the electromagnetic environment's severity at that specific site. Figure 5 indicates the measurement result of EMI ambient measurement at KVMRT 2 Kampung Batu station from z-polarization. The maximum peak values are then extracted into Table 1. The red line shows the limit of the pacemaker based on the British standard.

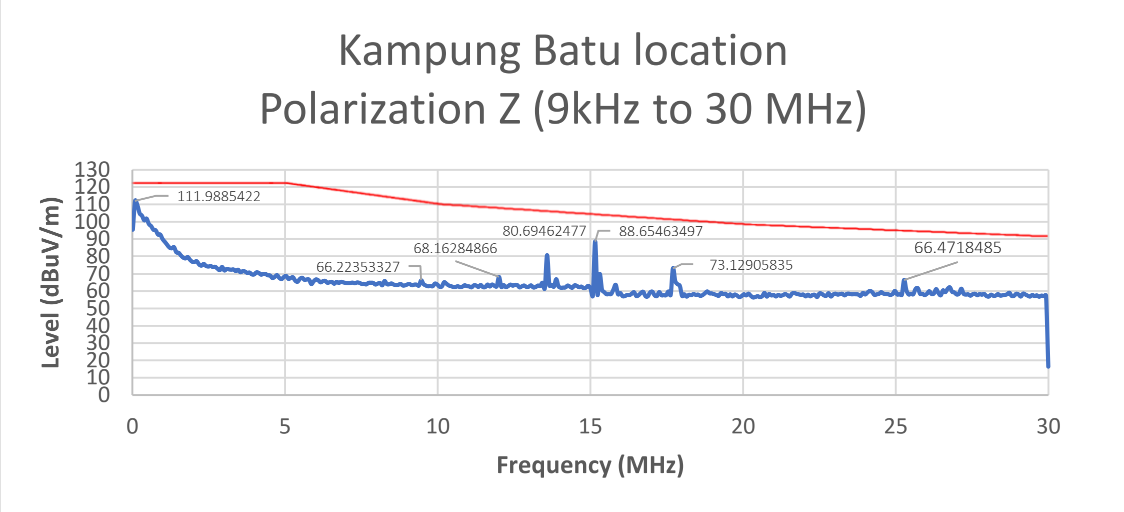

Figure 5: Measurement result for polarisation Z (9 kHz to 30 MHz)

Table 1: Extracted value from measurement for polarization Z with uncertainty

No	Frequency (MHz)	Level (dBµV/m)	Limit (dBµV/m)	Uncertainty (dBµV/m)
1	0.084	111.99	121.44	113.87
2	9.456	66.22	111.24	68.10
3	12.005	68.16	107.70	70.04
4	13.580	80.69	105.90	82.57
5	15.154	88.65	104.10	90.53
6	17.704	73.13	101.18	75.01
7	25.276	66.47	95.03	68.35

From the graph of the measurement for polarization Z, the maximum electric field value obtained is 111.99 dBµV/m at the lowest frequency which is 84 kHz with its uncertainty value is 113.87 dBµV/m. Next, the measured electric field is compared to the British Standard limit, where the value is 121.44 dBµV/m. This indicates that the status is pass. As well as other measured measurements indicate that the electric field is lower than the limit of the pacemaker. The EMI found in railroad environments in Z- polarization will not affect the functionality of the pacemaker.

Figure 6 indicates the measurement result of EMI ambient measurement at KVMRT 2 Damansara Damai Medical Centre station from X-polarization. The maximum peak values are then extracted into Table 2. According to the graph of the polarization X measurement, the highest electric field measured is 112.39 dBµV/m at the lowest frequency of 84 kHz with an uncertainty of 114.27 dBµV/m. The electric field is then compared to the British Standard limit of 121.44 dBµV/m. This means that the status is successfully passed. Additionally, other measured parameters show that the electric field is less than the pacemaker's limit. The EMI observed in train settings with X-polarization has no effect on the pacemaker's functioning.

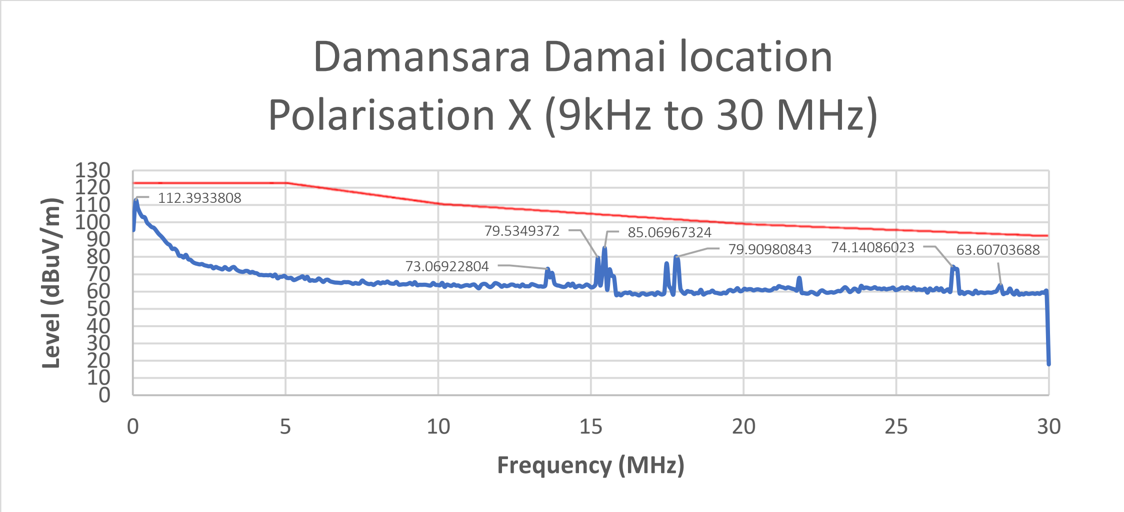

Figure 6: Measurement result for polarisation X (9 kHz to 30 MHz)

Table 2: Extracted value from measurement for polarization X with uncertainty

No	Frequency (MHz)	Level (dBµV/m)	Limit (dBµV/m)	Uncertainty (dBµV/m)
1	0.084	112.39	121.44	114.27
2	13.580	73.07	105.90	74.95
3	15.229	79.53	104.01	81.41
4	15.454	85.07	103.76	86.95
5	17.778	79.91	101.10	81.79
6	26.851	74.14	93.98	76.02
7	28.425	63.60	92.92	65.48

Figure 7 shows the EMI ambient measurement result at the KVMRT 2 Kepong Baru station using from vertical polarization and north direction. The graph's highest peak values are then retrieved and stored in Table 3.

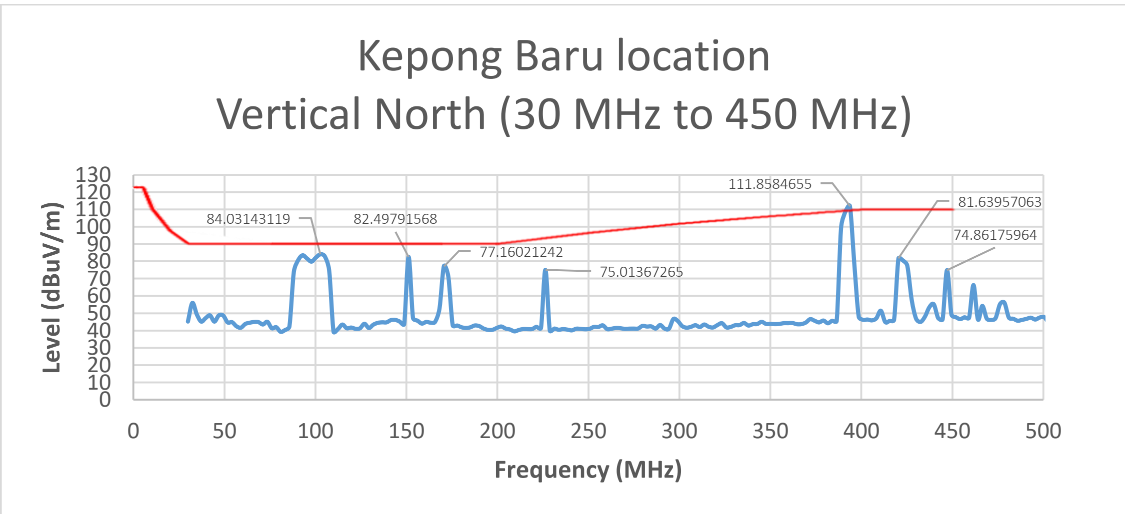

Figure 7: Measurement result for V-N (30 MHz to 450 MHz)

Table 3: Extracted value from measurement for V-N direction with uncertainty

No	Frequency (MHz)	Level (dBμV/m)	Limit (dBμV/m)	Uncertainty (dBμV/m)
1	102.750	84.03	91.87	86.14
2	151.250	82.50	91.87	84.61
3	170.650	77.16	91.87	79.27
4	226.425	75.01	94.92	77.12
5	393.750	111.86	109.45	113.97
6	420.425	81.64	109.89	83.75
7	447.100	74.86	109.89	76.97

The electric field value derived the maximum peak from the V-N direction measurement graph is 111.86 dBμV/m at the frequency of 393.750 MHz and an uncertainty value of 113.97 dBμV/m. This obtained value seems higher than the limit from the standard, which is 109.45 dBμV/m. The obtained value from the measurement is 111.86 dBμV/m which is 2.39 dBμV/m higher than permissible limit of the pacemaker. This can be concluded that the status of all the generated value from this direction is fail and may affected the pacemaker function.

Figure 8 illustrates the EMI ambient measurement result from Y-polarization at the KVMRT 2 Metro Prima station. The greatest peak values on the graph are then extracted and placed in Table 4.

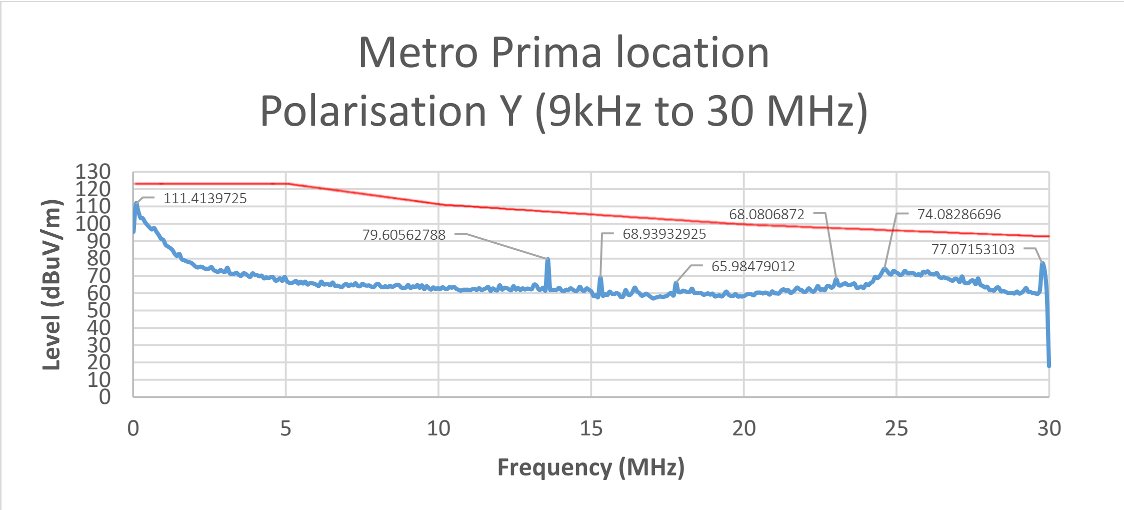

Figure 8: Measurement result for polarization Y (9 kHz to 30 MHz)

Table 4: Extracted value from measurement for polarization Y with uncertainty

No	Frequency (MHz)	Level (dBμV/m)	Limit (dBμV/m)	Uncertainty (dBμV/m)
1	0.084	111.41	121.44	113.29
2	13.580	79.61	105.60	81.49
3	15.304	68.94	103.93	70.82
4	17.778	65.98	101.10	67.86
5	23.027	68.08	96.53	69.96
6	24.601	74.08	95.48	75.96
7	29.780	77.07	92.01	78.95

The measurement for polarization Y has a graph, which reveals that the highest electric field value at the lowest frequency of 84 kHz is 111.41 dBµV/m with a 113.29 dBµV/m uncertainty. The next step is to calculate the electric field, which is compared to the British Standard limit, where the value is 121.44 dBµV/m. The presence of this means the condition is currently good. As more evidence is required, the electric field was measured and shown to be lower than the pacemaker's maximum permitted level. Railroad settings have low levels of electromagnetic interference, and the pacemaker is not affected by this.

The findings show that radio and television, as well as mobile phones and Wi-Fi, are mostly accountable for the background electromagnetic noise present at all sites. The highest signal strength shown in Table 5 is for each site. According to the findings, the electromagnetic ambient measurement is within the pacemaker minimum radiated immunity allowed limit.

Table 5: Maximum signal strength for each location

Location No.	Location Name	Frequency (MHz)	Maximum Electric Field (dBµV/m)	Polarization	Direction	Permissible Limit (dBµV/m)	Status (PASS/ FAIL)
1	Damansara Damai Station	0.084	112.39	X-polarization	North-South	121.44	PASS
2	Kampung Batu Station	0.084	111.99	Z-Polarization	-	121.44	PASS
3	Kepong Baru	393.750	111.86	Vertical	North	109.47	FAIL
4	Metro Prima	0.084	111.41	Y-polarization	East-West	121.44	PASS

The measurement of ambient has been done at the railway station. The measurement's result is shown in graphs along with a table containing the extracted value from the graph. After that, the measured electric field value is compared to the limit specified in British Standard BS EN 50527-2-2:2018. Only one of the 44 measurement findings failed all comparisons, and that was at the Kepong Baru station in the V-N direction at a frequency of 393.975 MHz. The measured value is 111.86 dBµV/m, which is 2.39 dBµV/m over the pacemaker's allowed limit. This is believed as a result of the on-board train's radio system and the portable radio carried by the railway worker at the train platform. If response is enabled, detection of EMI may result in pacing at the sensor-induced higher rate limit. This results in the pacemaker user being unable to stay at the station, since the electrical field value surpasses the limit, rendering the pacemaker ineffective and having a disastrous impact on the user. As a result, numerous further studies are required to evaluate the pacemaker's possible impact on the train environment and to ensure that the pacemaker is safe to use at all KVMRT 2 stations.

4. Conclusion

This research was done to find out how much electromagnetic radiation comes from the railway and to find out whether pacemakers might be dangerous because of that radiation. The first objective was to provide a technique for measuring ambient electromagnetic fields in a train environment. From this research, new results about the ambient measuring technique, utilizing loop antenna, trilog antenna, and spectrum analyzer, have been found. Measurement of the electric field (dBµV/m) at the train environment was the second objective. There was four KVMRT 2 station have been selected to obtain the actual electromagnetic field measurement data. The measurement method and process are based on the standard. The result of the measurement stored in spectrum analyzer then be graphically displayed for assessment of the electromagnetic environment's severity. The result of the measurement also emphasizes uncertainty. The third aim was to create a comparison with the standard minimum immunity of the pacemaker between the level of electromagnetic radiation. The measurement result from each direction and polarization shows a positive impact from three KVMRT 2 stations and got one of the measurement results from one station getting a failed status when the peak maximum value of the graph shows a value higher than the limit standard. The mitigation for future work must be proposed to guarantee that the pacemaker functions correctly when the consumer is at this station.

Acknowledgement

The authors would like to thank the Faculty of Electrical and Electronic Engineering, Universiti Tun Hussein Onn Malaysia for its support.

References

[1] Niska S., Measurements and analysis of electromagnetic interferences in the Swedish railway systems, Doctoral Thesis, Luleå Tekninska Universitet, 2008

[2] Cella, R. et al., Measurement of AT electric railway system currents at power-supply frequency and validation of a multiconductor transmission-line model, IEEE Transactions on Power Delivery, Vol. 21, Issue 3, pp. 1721- 1726, July 2006

[3] Bourne, A. et al., Managing electromagnetic compatibility on the London underground system, EMC assurance in a railway environment, IEE, Vol. 8, pp. 1 – 11, 9 Sept. 2003

[4] Midya, S. and Thottappillil, R., An overview of electromagnetic compatibility challenges in European rail traffic management system, Transportation Research Part C: Emerging Technologies, Vol. 16, Issue 5, pp. 515-534, Oct. 2008

[5] Al Dhalaan, S.M. and Elirbawy, M.A., 'A quantitative study of the electromagnetic field coupling between the electric power transmission line and railway'. Proc. Canadian Conf. on Electrical and Computer Engineering, May 2003

[6] Hill, R.J., Electric railway traction. Part 6 Electromagnetic compatibility -disturbance sources and equipment susceptibility, Power Engineering Journal, Vol. 11, Issue 1, 1997

[7] Ruddle, A.R., 'Computation of electromagnetic fields in the vicinity of a railway catenary'. Proc. IEE Coll. on EMC in Electric Traction and Signalling, 1995

[8] Solbiati, G.L., 'Managing the EMC between an AC railway line and the external world'. Proc. Electrotechnical Conf., May 1996

[9] Holmes, R., 'Electromagnetic compatibility of electrified railways'. Proc. Int. Conf. on Electric Railways in a United Europe, March 1995

[10] Muttaqi, K., & Haque, M. (2008, January). Electromagnetic Interference Generated from Fast Switching Power Electronic Devices. Retrieved October 28, 2020, fromhttps://www.researchgate.net/publication/228812621_Electromagnetic_Interference_Generated_from_Fast_Switching_Power_Electronic_Devices/citations