Technical Analysis of Frequency, Receiver Sensitivity and Site Suitability for Amateur Radio VHF Repeater Deployment

Syamsul Bahri Mohamad[1*], Shahidzwan A. Rahim[1], Azmi Ali[2], and Mohd Nor Zamani Abdul Afri[3]

[1]Department of Electrical Engineering, Politeknik Merlimau Melaka, KM 2.5, Jalan Merlimau-Jasin, 77300 Merlimau, Melaka, Malaysia.

[2]Muar District Amateur Radio Association, 84000 Muar, Johor, Malaysia.

[3]CTS Energy Resources (M) Sdn Bhd, No. 122-1, Jalan TU 2, Taman Tasik Utama, 75450 Ayer Keroh, Melaka, Malaysia.

[*]Corresponding Author's Email: syamsulbahri@pmm.edu.my

Article History: Received 12 April 2026; Revised 23 June 2026; Accepted 24 June 2026; Published 30 June 2026

Abstract

This study presents a technical analysis of frequency suitability, downlink receiver sensitivity, and site suitability for a proposed local VHF amateur radio repeater deployment in Bandar Maharani, Muar, Johor, Malaysia. The proposed repeater operates at 146.900 MHz downlink and 146.300 MHz uplink with a −0.6 MHz offset and 203.5 Hz CTCSS tone. The repeater is planned for installation at Wisma Daim, where the Muar District Amateur Radio Association has office access and permission to install the antenna system on the rooftop. The study evaluates frequency compatibility through nearby VHF channel separation, local coverage prediction using FSPL baseline and adjusted ITU-R P.1546 analysis, and downlink receiver sensitivity margin using the Baofeng UV-5RE as a worst-case handheld receiver reference. The findings indicate that the proposed 146.900 MHz output channel provides acceptable preliminary spectral clearance. At the same time, the Wisma Daim rooftop site is technically reasonable for local communication coverage within Bandar Maharani, the Muar town area, and nearby mukim. The downlink sensitivity assessment also shows that the predicted signal level remains above the minimum receiver sensitivity threshold under planning assumptions. Overall, this study provides structured technical evidence to support repeater planning and application, while recommending post-installation spectrum monitoring, drive testing, and receiver verification before full operational use.

Keywords: Amateur Radio Repeater, Frequency Suitability, Local Coverage, Receiver Sensitivity, VHF Communication

1.0 Introduction

Amateur radio communication continues to serve as an important alternative communication platform for community coordination, public service activities, and emergency response support. During disaster or contingency situations, amateur radio can provide independent communication links when conventional telecommunication infrastructure becomes disrupted, congested, or unavailable. The role of amateur and amateur-satellite services in disaster mitigation and relief has been recognised by ITU-R, particularly in supporting communication needs during emergency conditions [1]. In

Malaysia, previous studies have similarly highlighted the relevance of amateur radio as a contingency communication technology during emergencies [2].

In the local context of Bandar Maharani, Muar, VHF amateur radio communication is relevant for supporting community-based operations such as flood response coordination, cycling events, fun runs, volunteer communication, and public service activities. The proposed repeater deployment at Wisma Daim, Muar is not intended for long-range or regional-scale coverage, but to support reliable local communication within Bandar Maharani, the Muar town area, and nearby mukim. Compared with simplex operation, a local repeater can improve communication reliability by retransmitting user signals from a higher rooftop location.

The proposed system operates within the Malaysian Amateur Radio Service VHF band of 144–148 MHz, which is governed by the Standard Radio System Plan for Amateur Radio Service issued by the Malaysian Communications and Multimedia Commission [3]. Therefore, frequency suitability must be evaluated to ensure that the proposed repeater channel does not create harmful interference, adjacent-channel overlap, or QRM with nearby amateur radio operations. In addition, propagation suitability must be assessed because VHF communication is affected by antenna height, terrain, clutter, and line-of-sight conditions. Recommendation ITU-R P.1546 is relevant for this purpose because it provides a point-to-area prediction method for terrestrial radio services in the frequency range from 30 MHz to 4000 MHz [4].

Beyond frequency and propagation analysis, receiver sensitivity is also important in determining whether the repeater signal can be received by common handheld transceivers used by amateur radio operators. In analogue FM systems, receiver sensitivity is commonly evaluated using a 12 dB SINAD criterion, which represents the minimum usable signal level for intelligible voice reception [5]. Therefore, this study evaluates the technical suitability of the proposed local VHF amateur radio repeater in Bandar Maharani, Muar by considering frequency suitability, downlink receiver sensitivity and link margin, propagation prediction, and rooftop site suitability. The outcome of this study is intended to provide structured technical evidence to support local repeater planning and future application to the Malaysian Communications and Multimedia Commission.

The deployment of a local VHF amateur radio repeater requires compliance with national spectrum planning requirements to minimise service disruption and radio frequency interference. In Malaysia, the 144 MHz to 148 MHz band is specified for Amateur Radio Service, including direct communication between amateur stations, radio links to repeater stations, links between repeaters, beacon stations, gateways, and APRS applications [3]. Therefore, the proposed 146.900 MHz downlink and 146.300 MHz uplink must be evaluated not only as an operating frequency pair but also as a frequency assignment that remains compatible with nearby amateur radio operations in the Muar area.

VHF repeater coverage is strongly influenced by antenna height, terrain profile, clutter condition, and local obstruction. ITU-R P.1546 is relevant for this study because it provides a recognised point-to-area prediction method for terrestrial radio services within 30 MHz to 4000 MHz, including field-strength prediction based on frequency, distance, antenna height, time percentage, terrain clearance, and clutter correction [4]. Previous analytical work on VHF/UHF line-of-sight communication also shows that antenna height affects expected radio-link distance, while surrounding terrain and environmental conditions influence practical coverage [6]. Similarly, amateur radio antenna planning guidance emphasises that antenna height has a direct relationship with communication effectiveness [7]. These references support the evaluation of Wisma Daim as a rooftop site for local communication coverage within Bandar Maharani and the surrounding Muar area.

Receiver sensitivity is another important parameter in repeater planning because the transmitted repeater signal must be strong enough to be received by handheld users within the intended local coverage area. In analogue FM radio systems, receiver sensitivity is commonly expressed using the 12 dB SINAD criterion, which indicates the minimum RF input level required to produce intelligible demodulated audio with acceptable signal-to-noise-and-distortion performance [5], [8]. Technical measurement guidance for FM receiver sensitivity also describes the use of modulated test signals and SINAD measurement as a practical reference for assessing receiver performance [9]. In this study, the Baofeng UV-5RE is used as a worst-case handheld receiver reference to determine whether the predicted repeater signal remains above the minimum usable receiver threshold.

The practical suitability of a repeater site also depends on installation feasibility, antenna arrangement, power availability, maintenance access, and post-installation validation. Although the proposed system uses separate transmitting and receiving antennas to reduce self-interference, its actual performance still requires verification, as insufficient antenna separation or nearby RF sources may degrade receiver performance [10]. In addition, ITU-R Report M.2085-1 highlights the importance of amateur radio services in supporting disaster mitigation and relief communication [1]. Based on these considerations, this study evaluates the proposed Wisma Daim repeater using an integrated technical framework consisting of frequency compatibility, ITU-R P.1546 local coverage prediction, downlink receiver sensitivity margin, antenna configuration practicality, and rooftop installation suitability.

2.0 Methodology

2.1 Study Area and Proposed Repeater Configuration

This study evaluates the technical suitability of a proposed local VHF amateur radio repeater deployment at Wisma Daim, Bandar Maharani, Muar, Johor, Malaysia. The site was selected because the Muar District Amateur Radio Association, which manages the proposed repeater initiative, operates its office on the fourth floor of the building. In addition, permission has been obtained from the building owner to install the repeater antenna system on

the flat rooftop above the fourth floor. This makes Wisma Daim a practical site for installation, monitoring, maintenance, and future technical adjustment.

The rooftop location provides better antenna elevation than a ground-level installation while still allowing convenient access for the repeater management team. This arrangement is suitable for local operational communication, community coordination, public service activities, and emergency support within the Muar area. The repeater is proposed to operate at 146.900 MHz for the downlink and 146.300 MHz for the uplink, using a standard −0.6 MHz duplex offset and 203.5 Hz CTCSS tone. The system will use a Motorola GM338 VHF mobile radio and a Gazten VHF antenna, with separate transmitting and receiving antenna arrangements planned to reduce self-interference between the transmitter and receiver paths. The proposed technical parameters are summarised in Table 1.

Table 1: Proposed local repeater technical parameters

Parameter	Value
Proposed site	Wisma Daim, Muar, Johor
Repeater Mode	Local VHF Analogue FM voice repeater
Downlink / Uplink frequency	146.900 MHz / 146.300 MHz
Duplex offset / CTCSS tone	−0.6 MHz / 203.5 Hz
Target coverage	Bandar Maharani, Muar
Repeater radio	Motorola GM338 VHF
Antenna	Gazten VHF antenna
Installation concept	Rooftop with a separate TX/RX antenna

2.2 Frequency Compatibility and QRM Screening

Frequency compatibility analysis was conducted to evaluate whether the proposed repeater frequency pair is suitable for local VHF amateur radio operation in the Muar area. The assessment was carried out with reference to the Malaysian Amateur Radio Service allocation for the 144–148 MHz band, where repeater operation must comply with applicable technical requirements [3]. This confirms that the proposed frequency pair remains within the permitted amateur radio band and follows the standard repeater offset arrangement.

In amateur radio communication, QRM refers to man-made interference or unwanted signal disturbance from other radio transmissions operating on the same or nearby frequencies. In repeater planning, QRM may occur due to co-channel use, adjacent-channel overlap, insufficient channel spacing, or strong nearby transmitters that affect receiver performance [11], [12]. Therefore, the proposed frequencies were compared with nearby active VHF amateur radio channels to identify possible co-channel use, adjacent-channel overlap, and QRM risk.

In repeater coordination practice, channel spacing refers to the frequency

separation between adjacent frequency allocations, and this spacing is an important factor in reducing interference between repeaters operating within the same band [11], [12]. Therefore, the frequency difference between the proposed candidate frequency and each existing nearby VHF channel was calculated using the absolute separation method:

$$\Delta f = |f_c - f_e|$$

where Δf represents the frequency separation, f_c is the proposed repeater frequency, and f_e is the frequency of an existing nearby VHF channel. This calculation is used as an initial screening method to determine how close the proposed channel is to existing operating frequencies [13]. For this study, the calculated frequency separation was classified into three qualitative QRM risk levels, as shown in Table 2. The classification is used as a conservative screening guideline for local repeater planning and does not replace formal regulatory coordination or post-installation spectrum monitoring.

Table 2: Frequency separation and QRM risk classification

Δf	Risk Class	Interpretation
≤ 25 kHz	High	High adjacent-channel or QRM risk
>25 kHz to <75 kHz	Medium	Possible intermittent interference
≥ 75 kHz	Low	Acceptable spectral clearance

The screening result was then used to determine whether 146.900 MHz provides sufficient spectral clearance from nearby active VHF channels. Since the proposed frequency is intended for a local repeater rather than a long-range regional channel, the assessment focuses on minimising QRM within the intended service area. Any channel classified as “Medium” or “High” would require further review, additional monitoring, or selection of an alternative frequency before deployment.

2.3 Propagation Prediction and Local Coverage Estimation

Propagation analysis was conducted to estimate the expected local coverage of the proposed 146.900 MHz repeater output. Recommendation ITU-R P.1546 was selected as the main propagation reference because it provides a point-to-area prediction method for terrestrial radio services within the frequency range of 30 MHz to 4000 MHz [4]. This makes it suitable for VHF coverage estimation in the urban and semi-urban environment of Bandar Maharani and the surrounding Muar area.

The coverage analysis focuses on local service suitability rather than maximum communication range. The prediction considers the proposed rooftop antenna location at Wisma Daim, estimated antenna height, receiving antenna height of handheld or mobile users, and the surrounding urban/semi-urban environment. A free-space path loss (FSPL) baseline was also calculated for comparison to show the difference between ideal free-space

propagation and more realistic terrestrial propagation. The FSPL baseline was calculated using:

$$FSPL\ (dB) = 32.44 + 20\log_{10} f_c + 20\log_{10} d_c$$

where f_c is the operating frequency in MHz and d_c is the distance in km. The predicted coverage result is interpreted based on whether the repeater can provide a useful local communication service within Bandar Maharani, Muar. The result is not intended to confirm guaranteed coverage, but to provide an analytical indication of expected local coverage before post-installation field validation is conducted.

2.4 Downlink Receiver Sensitivity and Link Margin Analysis

Downlink receiver sensitivity analysis was conducted to determine whether the signal transmitted from the proposed repeater can be received by a common handheld transceiver used by amateur radio operators. This analysis focuses only on the downlink path, which represents the signal from the repeater transmitter to the user's handheld receiver. The purpose is to evaluate whether the proposed repeater can provide usable local reception.

The proposed repeater will use a Motorola GM338 VHF mobile radio with a Gazten VHF antenna. The Motorola GM338 supports conventional FM operation and programmable channel spacing of 12.5/20/25 kHz, making it suitable for VHF repeater configuration [15]. The worst-case receiving device considered in this study is the Baofeng UV-5RE handheld transceiver, as it is a common low-cost handheld radio used by amateur radio operators. The Baofeng UV-5RE receiver sensitivity is specified as approximately 0.2 μV at 12 dB SINAD, which is equivalent to about −121 dBm in a 50-ohm system [14]. The received power at the handheld user receiver is estimated using the downlink link-budget equation:

$$P_{rx,user} = P_{tx,c} + G_{tx,c} + G_{rx,user} - L_{path} - L_{cable} - L_{misc}$$

where $P_{rx,user}$ is the received power at the Baofeng UV-5RE, $P_{tx,c}$ is the transmitter output power of the Motorola GM338, $G_{tx,c}$ is the gain of the Gazten VHF antenna, $G_{rx,user}$ is the effective antenna gain of the handheld receiver, L_{path} is the propagation path loss, L_{cable} represents feeder and connector losses, and L_{misc} includes practical losses such as body shielding, handheld antenna inefficiency, indoor penetration, vehicle loss, and local obstruction. The downlink margin is then calculated by comparing the estimated received power with the receiver sensitivity threshold:

$$D_M = P_{rx,user} - P_{sen,user}$$

where $P_{sen,user}$ is the receiver sensitivity of the Baofeng UV-5RE. A positive margin indicates that the received signal is above the minimum receiver sensitivity level, while a negative margin indicates that the signal may not be

usable. The margin is interpreted using the criteria in Table 3.

Table 3: Downlink receiver sensitivity and link margin interpretation

Downlink Margin, D_M	Interpretation
≥ 20 dB	Strong reception margin
10–19 dB	Acceptable reception margin
0–9 dB	Marginal reception margin
< 0 dB	Below the receiver sensitivity threshold

For practical interpretation, this study does not rely only on the theoretical receiver sensitivity limit. Additional losses may occur because handheld radios are commonly used with compact rubber-duck antennas, near the human body, inside vehicles, or around buildings. Therefore, a downlink margin of at least 10 dB is considered acceptable for basic local communication, while a margin of 20 dB or higher is considered more suitable for reliable local FM voice operation.

2.5 Site Suitability Scoring Matrix

A site suitability scoring matrix was developed to provide a structured technical assessment of the proposed local VHF amateur radio repeater deployment at Wisma Daim, Bandar Maharani, Muar. The scoring matrix combines five main evaluation criteria: frequency compatibility, local propagation coverage, downlink receiver sensitivity margin, antenna configuration practicality, and rooftop installation practicality. The results are shown in Table 4. Each criterion is scored using a three-level scale, where 0 indicates not acceptable, 1 indicates mitigation needed, and 2 indicates acceptable.

Table 4: Site suitability evaluation criteria

Evaluation Criterion	Score Range, T_s
Frequency compatibility based on channel separation and QRM risk	0 – 2
Local propagation coverage capability	0 – 2
Downlink receiver sensitivity margin for Baofeng UV-5RE reception	0 – 2
TX/RX antenna arrangement practicality	0 – 2
Rooftop access and installation feasibility	0 – 2

The final suitability decision, S_I is interpreted based on Table 5. The total score is converted into a percentage using the following equation:

$$S_I = \frac{T_s}{10} \times 100\%$$

Table 5: Site suitability decision criteria

Suitability Index, S_I	Decision
≥ 80%	Suitable
60–79%	Conditionally suitable
< 60%	Not recommended

This scoring method allows the proposed repeater deployment to be evaluated in a balanced manner before installation. Frequency compatibility verifies whether the selected channel provides acceptable spectral clearance, while local propagation coverage estimates whether the site can support the intended local service area. The downlink receiver sensitivity margin provides a practical indication of whether common handheld receivers can receive the repeater signal, whereas antenna configuration and rooftop practicality assess whether the proposed installation can be implemented and maintained effectively. Actual suitability results based on this scoring method are presented in the following section.

3.0 Results and Discussion

This section presents the analytical results for the proposed 146.900/ 146.300 MHz local VHF amateur radio repeater at Wisma Daim, Bandar Maharani, Muar. The results are discussed based on frequency compatibility, predicted local coverage, downlink receiver sensitivity margin, and overall site suitability. Since this study is conducted at the planning stage, the findings are interpreted as preliminary technical indicators and should be validated through post-installation field testing.

The frequency compatibility result in Table 6 shows that the proposed 146.900 MHz output channel has acceptable preliminary separation from the nearest identified VHF amateur channels. The closest identified channel is 146.975 MHz, with a separation of 75 kHz, which falls within the low-risk category based on the screening criteria used in this study. Compared with the earlier 146.925 MHz option, the proposed 146.900 MHz channel provides improved spacing from the nearest adjacent channel. Therefore, no direct co-channel conflict is identified at this stage. However, this result should still be verified through actual spectrum monitoring before commissioning.

Table 6: Frequency compatibility result

Nearby Site	f_e (MHz)	Δf	Risk Class	Remarks
9M4RSG Segamat	146.975	75 kHz	Low	Acceptable preliminary clearance
9M4RBP Batu Pahat	146.800	100 kHz	Low	Acceptable
9M4RGL Gunung Ledang	147.100	200 kHz	Low	Acceptable
9M4RML Bukit Beruang	147.025	125 kHz	Low	Acceptable
9M4RMN Bukit Nyalas	146.775	125 kHz	Low	Acceptable

Note: Existing VHF amateur repeater information was compiled from the Malaysian Amateur Radio Service 144–148 MHz regulatory reference, the MARTS repeater directory, and the RepeaterBook Malaysia amateur repeater database [3], [16], [17].

Figure 1 shows the comparison between FSPL baseline and ITU-R P.1546 local coverage prediction at 146.900 MHz. The propagation analysis indicates that the Wisma Daim rooftop location is technically reasonable for supporting local VHF communication around Bandar Maharani, Muar.

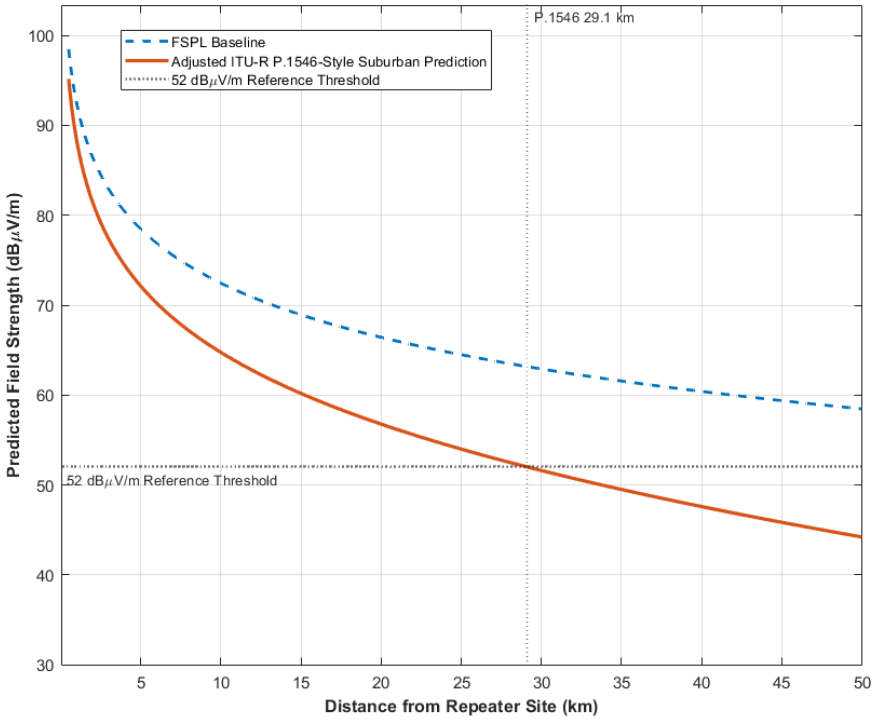

Figure 1: Comparison between FSPL baseline and ITU-R P.1546 local coverage prediction at 146.900 MHz

The adjusted ITU-R P.1546-style prediction provides a more practical local coverage estimate compared with the FSPL baseline because it includes additional suburban loss factors such as clutter, obstruction, and distance-

related excess attenuation. Based on the prediction curve, the 52 dBμV/m reference threshold is reached at approximately 29 km, while the FSPL baseline remains above the same threshold across the plotted local distance range. This difference shows that ideal free-space assumptions may overestimate coverage and that local clutter effects should be considered in repeater planning.

The predicted local coverage should not be interpreted as guaranteed full-district communication. Instead, the result supports the suitability of the Wisma Daim site for local operational coverage, especially for routine amateur radio activities, public service coordination, and emergency communication support within the intended Muar town area. Weaker or inconsistent reception may still occur in obstructed locations, indoor areas, vehicles, or areas affected by building shadowing and handheld antenna limitations. Table 7 shows the downlink receiver sensitivity margin assessment.

Table 7: Downlink receiver sensitivity margin assessment

Assessment Item	Value / Assumption
Repeater setup	Motorola GM338 with Gazten antenna
User receiver reference	Baofeng UV-5RE handheld transceiver
Operating frequency	146.900 MHz
Receiver sensitivity	Approximately −121 dBm at 12 dB SINAD
Reference received signal	52 dBμV/m ≈ −68.5 dBm at 0 dBi
Theoretical downlink margin	Approximately 52.5 dB

The downlink receiver sensitivity analysis shows that, at the reference field strength level of 52 dBμV/m, the equivalent received power at a 0 dBi handheld receiver antenna is approximately −68.5 dBm. When compared with the Baofeng UV-5RE receiver sensitivity of approximately −121 dBm at 12 dB SINAD [14], the theoretical downlink margin is about 52.5 dB. This indicates that the signal level at the reference threshold is well above the minimum receiver sensitivity. However, this margin is only an analytical planning indicator. Actual reception may be reduced by handheld antenna inefficiency, body shielding, indoor penetration, vehicle attenuation, and local obstruction.

Table 8: Site suitability score for the proposed local repeater deployment

Evaluation Criterion	Score, T_s
Frequency compatibility and QRM risk	2
Local coverage capability	2
Baofeng UV-5RE downlink reception margin	1
TX/RX antenna practicality	1
Rooftop installation feasibility	2
Suitability Index, S_I	80%

The overall suitability score of 80% indicates that the proposed repeater deployment is technically suitable at the planning stage. The strongest factors are the improved preliminary frequency separation of the 146.900 MHz output channel and the practicality of the Wisma Daim rooftop site, where installation permission and maintenance access are available through the local amateur radio association. The downlink receiver sensitivity and antenna configuration components are scored conservatively because actual performance depends on post-installation validation, including received signal checks, antenna placement verification, and on-air communication trials.

4.0 Conclusions

This study presents a technical analysis of frequency suitability, downlink receiver sensitivity, and site suitability for the proposed 146.900 / 146.300 MHz local VHF amateur radio repeater deployment at Wisma Daim, Bandar Maharani, Muar, Johor. The findings indicate that the proposed frequency pair provides acceptable preliminary spectral clearance from nearby identified VHF amateur channels, while the Wisma Daim rooftop site offers practical advantages in terms of accessibility, installation permission, maintenance convenience, and elevated antenna placement. The downlink receiver sensitivity analysis using the Baofeng UV-5RE as a worst-case handheld receiver reference also supports the technical feasibility of the repeater for local operational communication, provided that actual field signals remain above the required receiver sensitivity margin. Overall, the proposed repeater is considered technically suitable at the planning stage for supporting local communication within Bandar Maharani, the Muar town area, and the nearby mukim. However, the results should not be interpreted as final operational proof because the study is based on analytical evaluation, frequency screening, propagation prediction, and receiver sensitivity estimation. Therefore, post-installation validation is strongly recommended through spectrum monitoring, drive-test measurements, received signal reports, SINAD-based receiver verification, antenna placement verification, and on-air communication trials using common handheld transceivers such as the Baofeng UV-5RE. This study provides structured technical evidence that can support the Muar District Amateur Radio Association in preparing a stronger repeater application to the Malaysian Communications and Multimedia Commission (MCMC/SKMM). At the same time, the proposed analysis framework may assist MCMC/SKMM and amateur radio practitioners in reviewing local repeater proposals based on frequency compatibility, downlink receiver sensitivity, propagation suitability, and site practicality. Hence, this study can serve as a practical reference for amateur radio operators and hobbyists who intend to conduct responsible, evidence-based, and interference-conscious repeater planning in Malaysia.

Acknowledgements

The authors acknowledge the institutional, logistical, and technical support provided by Politeknik Merlimau Melaka, the Muar District Amateur Radio Association, and CTS Energy Resources (M) Sdn. Bhd. throughout this study.

Author Contributions

Syamsul Bahri Mohamad: Conceptualisation, Methodology, Investigation, Formal Analysis, Data Curation, Visualisation, Writing – Original Draft, Project Administration; **Shahidzwan A. Rahim**: Methodology, Investigation, Validation, Resources and Writing – Review & Editing; **Azmi Ali**: Investigation, Resources, Field Data Collection and Technical Validation; **Mohd Nor Zamani Abdul Afri**: Technical Validation, Resources, Formal Analysis and Writing.

Conflicts of Interest

The manuscript has not been published elsewhere and is not under consideration by any other journal. All authors have reviewed and approved the manuscript, consent to its submission, and declare that there are no conflicts of interest.

References

[1] International Telecommunication Union, *Role of the Amateur and Amateur-Satellite Services in Support of Disaster Mitigation and Relief*, Rep. ITU-R M.2085-1, Geneva, Switzerland: ITU, 2011.

[2] A. Johar, W. R. S. Osman, and A. A. Aziz, "Amateur radio communication technology contingency communication in emergency situation," *SHS Web of Conferences*, vol. 33, Art. no. 00023, 2017, doi: 10.1051/shsconf/20173300023.

[3] Malaysian Communications and Multimedia Commission, *Standard Radio System Plan: Requirements for Amateur Radio Service Operating in the Frequency Band of 144 MHz to 148 MHz*, MCMC SRSP ARS 144, Cyberjaya, Malaysia, Nov. 2022.

[4] International Telecommunication Union, *Method for Point-to-Area Predictions for Terrestrial Services in the Frequency Range 30 MHz to 4 000 MHz*, Recommendation ITU-R P.1546-6, Geneva: ITU, Aug. 2019.

[5] National Institute of Justice, *Fixed and Base Station FM Receivers*, NIJ Standard-0206.01, Washington, DC, USA: U.S. Department of Justice, Jul. 1988.

[6] F. A. E. Abdul Kareem and R. H. Abbas, "An analytic study for the effect of antenna height on line-of-sight VHF/UHF communications coverage distance applied to Baghdad city," *Periodicals of Engineering and Natural Sciences*, vol. 7, no. 4, pp. 1965–1976, Dec. 2019, doi: 10.21533/pen.v7.i4.1799.

[7] R. D. Straw and G. L. Hall, *Antenna Height and Communications Effectiveness: A Guide for City Planners and Amateur Radio Operators*, 2nd ed. Newington, CT, USA: American Radio Relay League, 1999.

[8] D. Layne, "Receiver sensitivity and equivalent noise bandwidth," *High Frequency Electronics*, Jun. 2014. [Online]. Available: https://highfrequencyelectronics.com. [Accessed: Jun. 20, 2026].

[9] J. DePolo, "Measuring FM receiver sensitivity," *Repeater Builder Technical Information Page*, Apr. 2, 2001. [Online]. Available: https://www.repeater-builder.com. [Accessed: Jun. 20, 2026].

[10] Morris, "Isolation between the repeater receiver and RF sources," *Repeater Builder Technical Information Page*. [Online]. Available: https://www.repeater-builder.com. [Accessed: Jun. 20, 2026].

[11] Radio Amateurs of Canada, "VHF, UHF and repeater definitions." [Online]. Available: https://www.rac.ca. [Accessed: Jun. 20, 2026].

[12] Upstate New York Repeater Council, "Repeater coordination terminology." [Online]. Available: https://www.unyrepco.org. [Accessed: Jun. 21, 2026].

[13] International Telecommunication Union, *Radio-Frequency Channel Arrangements for Fixed Service Systems*, Recommendation ITU-R F.746-5, Geneva, Switzerland: ITU, May 2001.

[14] Baofeng, "UV-5RE dual band 5W two-way radio." [Online]. Available: https://www.baofengradio.com. [Accessed: Jun. 21, 2026].

[15] Motorola, *GM338/GM398 Conventional MDC Mobile Radio*, product brochure, 2009.

[16] Malaysian Amateur Radio Transmitters' Society, "List of repeaters." [Online]. Available: https://marts.org.my. [Accessed: Jun. 21, 2026].

[17] RepeaterBook, "Malaysia amateur radio repeaters." [Online]. Available: https://www.repeaterbook.com. [Accessed: Jun. 21, 2026].