Frequency Allocation for Radio Astronomy in the L-Band: Implications for Spectrum Management and Spectra Analysis in Malaysia

Ahmad Hariz Bely
East Coast Environmental Research Institute, Universiti Sultan Zainal Abidin

Sharifah Nurul Aisyah Syed Zafar
East Coast Environmental Research Institute, Universiti Sultan Zainal Abidin

Roslan Umar
East Coast Environmental Research Institute, Universiti Sultan Zainal Abidin

Nor Hazmin Sabri
Advanced Nano Materials Research Group, Faculty of Science and Marine Environment, Universiti Malaysi

他

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Frequency Allocation for Radio Astronomy in the L-Band: Implications for Spectrum Management and Spectra Analysis in Malaysia

Ahmad Hariz Bely[1], Sharifah Nurul Aisyah Syed Zafar[1], Roslan Umar[1*], Nor Hazmin Sabri[2], Zamri Zainal Abidin[3], Nur Zulaikha Mohd Afandi[1], Liheng Yang[4], Jazeel H. Azeez[5], Basree Maseng[6]

[1]East Coast Environmental Research Institute, Universiti Sultan Zainal Abidin, 21300, Terengganu, Malaysia.
[2]Advanced Nano Materials Research Group, Faculty of Science and Marine Environment, Universiti Malaysia Terengganu, 21030 Kuala Nerus, Terengganu, Malaysia.
[3]Department of Physics, Universiti Malaya, Kuala Lumpur, 50603, Malaysia.
[4]Fuxian Observatory, Yunnan Astronomical Observatory, Chinese Academy of Sciences, Kunming, 650216, China.
[5]Department of Physics, College of Sciences, Al-Nahrain University, Al-Jadriya, Baghdad,10072, Iraq.
[6]Department of Physics & Materials Science, Faculty of Science, Chiang Mai University, Chiang Mai 50200, Thailand.

roslan@unisza.edu.my

Abstract: *The L-band (1300–1500 MHz) is crucial for radio astronomy, particularly for detecting the neutral hydrogen line (H I) at 1420.4057 MHz, which is essential for studying galaxy evolution and large-scale cosmic structures. However, increasing anthropogenic Radio Frequency Interference (RFI) from telecommunications, aviation navigation and radar systems threatens the usability of this band. This study compares L-band RFI contamination across various locations in Malaysia with a proposed site at Pusat Astronomi Borneo (PAB), Sarawak, to assess their suitability for radio astronomy. RFI measurements were conducted using a spectrum analyzer and dicone antenna at urban sites (al-Biruni Observatory, Negeri Sembilan Observatory), a suburban site (Langkawi Nationional Observatory) and remote locations (KUSZA Observatory and Borneo Astronomy Center). This study highlights the need for targeted spectrum protection policies to preserve Sarawak's potential as a regional hub for radio astronomy. The findings benefit stakeholders, including Jabatan Mufti Sarawak and Malaysia Space Agency, by providing a data-driven framework for sustainable observatory site selection.*

Keywords: Astronomy Observation, Site-Testing, Radio Astronomy, Radio Frequency Interference, Spectrum Analyzer.

1. INTRODUCTION

Engaging with reality enables us to study the universe by detecting naturally emitted radio waves from sources in the universe. Its origin dates to 1932, when Karl G. Jansky discovered radio emissions whilst exploring static noise for the Bell Telephone Laboratories [1]. His accidental finds and the pioneering sky surveys of Reber [2] gave rise to a whole new field of astronomy capable of revealing new phenomena previously imperceptible to telescopic inspection. One of the most critical frequency ranges for radio astronomy is the L-band (1300 - 1500 MHz), especially the 21-cm neutral hydrogen (H I) line at 1420.4057 MHz, which is vital to map the structure of the galaxy, trace star formation, and study the distribution of dark matter [3]. The rising need for telecommunications, aeronautical navigation, mobile networks and satellite communication has created challenges for passive services like radio astronomy. Radio Frequency Interference (RFI) increasingly impacts L-band observations in many areas and RFI has the potential to distort or mask weak cosmic signals. Although the International Telecommunication Union (ITU) reserved 1400-1427 MHz as a protected passive band under ITU RA.769, the protection enforcement is left to the national spectrum managers. In Malaysia, this role is assumed by the Malaysian Communications and Multimedia Commission (MCMC), which carries out the National Spectrum Plan in collaboration with global and regional stakeholders, including the Asia-Pacific Telecommunity (APT) [4]. The lack of formally designated Radio Quiet Zones (RQZ's) or a national framework to provide passive band protection limits Malaysia's capabilities, despite having several observatory locations within and around East and Peninsular Malaysia. Earlier work, for example, Abidin et al. (2013) [5], has made the case for more protection on the L-band with subdivision of four sub-windows (A: 1400–1427 MHz, B: 1380–1400 MHz, C: 1350–1380 MHz, D: 1300–1350 MHz). However, there is still a lack of regional site comparisons and long-term suitability assessments using modern RFI analysis methods.

Other studies focus on RFI detection methods, for example, kurtosis, ANOVA, or even some forms of machine learning, citing Offringa et al. (2012) [6] and Sharifah et al. (2017) [7]. At the same time, Roslan Umar et al. (2015, 2022) [8, 9] propose the use of GIS for low-interference site screening using environmental data. These approaches shape the methodology of the current study and highlight the need for integration of the geographic, technical, and statistical aspects in planning observatories. Radio astronomy also essential observational frontier for the astrophysical events such as pulsars, fast radio bursts, active galactic nuclei and supernova remnants. The use of radio interferometry methods, especially in Very Long Baseline Interferometry (VLBI), drastically improved observational capability with the coherent combination of signals from telescopes that thousands of kilometers apart, achieving sub-milliarcsecond resolution. Radio astronomy remains equipment in validating theoretical and observation including imaging the event horizon of the supermassive black hole in M87 and detecting spiral structures in protostellar disks [10].

As the International Telecommunication Union (ITU) invents radio frequency bands as slices of the electromagnetic spectrum from low frequency (LF) to extremely high frequency (EHF) with certain reservations for scientific and communication activities, portions of the spectrum around 30 kHz to 300 MHz are vital for several radio astronomy studies. These studies are the monitoring of some solar phenomena like solar flares and coronal mass ejections (CMEs), redshifted neutral hydrogen (HI) surveys, pulsar-timing variation measurements, cosmic magnetism studies including large scale structure of the Universe investigations. Radio observatories are being built around these requirements.

One of the most advanced instruments is Very Large Array (VLA), which has capabilities at 74 MHz and 330 MHz In Europe, the Low-Frequency Array (LOFAR) has a range of 10–240 MHz and was crucial for Epoch of Reionization studies and cosmic ray detection [11]. Australia hosts the Murchison Widefield Array (MWA), operational between 70–300 MHz, which advances heliosphere physics, ionospheric dynamics and early cosmology of the universe [12]. Also contributing to these studies is India's Giant Microwave Radio Telescope (GMRT) range of 150–1450 MHz, which has significantly advanced pulsar and HI science research. These facilities are soon to be supplemented by Australia's Square Kilometer Array – Low (SKA-low), expected to operate in the 50–350 MHz region with unmatched sensitivity and survey speed [13]. In the Asia region, China is known for holding the world record for the most sensitive single-dish radio telescope known as FAST (Five-hundred-meter Aperture Spherical Telescope) which operates between 70 MHz and 3 GHz. The telescope is used in pulsar discovery, HI mapping and the search for fast radio bursts [14]. Japan has several facilities, including VERA (VLBI Exploration of Radio Astromy) that conducts maser parallax measurements and Galactic structure mapping at 22 and 43 GHz and the Nobeyama Radio Observatory (NRO) which studies interstellar molecular clouds and star formation at 20-116 GHz [15]. Thailand's TNRT (Thai National Radio Telescope) located at Chiang Mai covers from 300 MHz to 115 GHz, focusing on public outreach in addition to academic work, especially in solar research [16]. Indonesia wants to build first VGOS Radio Telescope which provides educational tools in the form of radio astronomy research at the Bosscha Observatory and Timaru Observatory which admission form Institute Technology Bandung [17].

In the Southern Hemisphere, Australian SKA Pathfinder (ASKAP) and Parkes Radio Telescope continue to play major roles in transient radio astronomy and deep space tracking. ASKAP operates in the 700 MHz to 1.8 GHz range focusing on hydrogen line mapping and wide field surveys [18]. Parkes, in comparison, works from 700 MHz to 25 GHz and has been pivotal in pulsar surveys and FRB research [19]. Moreover, South Africa's SKA-mid precursor Meerkat telescope which covers 580 MHz – 14.5 GHz also contributes to the studies on magnetism, galaxy evolution, and compact object astrophysics [20]. These observatories not only illustrate a global endeavor towards a unified systematic framework in radio astronomy infrastructure but also highlight the need for geopolitical spectrum management in sustaining frequency protection against the artificial RFI, satellite constellations and terrestrial use of the band. The output from these collaborations serves critical scientific discoveries and simultaneously supports the development of multi-national policies and governance frameworks for spectrum management compliant with ITU-R recommendations. For Radio Astronomy in Malaysia, Radio Frequency Interference (RFI) is an intensifying problem, particularly within the L-band (1–2 GHz) allocated for neutral hydrogen (HI) observations. Maintaining clean spectrum access is crucial due to unregulated terrestrial signals, urbanization, and increasing emissions from Low Earth Orbit (LEO) satellites like Starlink. Currently, Malaysia has no designated Radio Quiet Zones (RQZs), and numerous observatories function in poorly shielding environments. The primary objective of this research is to analyze and assess RFI at KUSZA Observatory (BCK), Langkawi National Observatory (LNO), Negeri Sembilan Observatory (BCTK), al-Biruni Observatory (BCB), and Pusat Astronomi Borneo (PAB) using spatial analysis, statistical profiling, and spectrum analysis. Special focus is given to PAB, Sarawak which demonstrates RFI levels consistently lower than –80 dBm, making it a prime candidate for potential RQZ designation.

This study advances empirical data aligned with ITU criteria, thus aiding national and regional policymaking by the MYSA and RAFCAM. It also advances collaborations planned within the Radio Astronomy Frequency Committee of Asia-Pacific (RAFCAP), reinforcing Malaysia's position in sustainable spectrum governance global initiatives for radio astronomy [21].

2. METHODOLOGY

A comprehensive observational and analytical approach was adopted to determine the boundaries of RFI in the L-band in the context of Malaysian observatory sites. This methodology combines field spectrum measurements, frequency analysis and statistical grading relative to the designated 1420.4057 MHz hydrogen line to determine the suitability of each site for radio astronomy. Every step undertaken is geared towards international standards for radio spectrum monitoring and site classification, in this case, aimed at finding a candidate for RQZ in Malaysia.

2.1 Site Selection

Five observatory sites were chosen to illustrate the various geographical features within Malaysia. KUSZA Observatory (BCK) in Terengganu was selected for the East Coast, Langkawi National Observatory (LNO) in Kedah represented the northwestern peninsular, Negeri Sembilan Observatory (BCTK), formerly Teluk Kemang Observatory, represented the southern region, al-Biruni Observatory (BCB) in Sabah was selected for Sabah representative and Pusat Astronomi Borneo (PAB) in Sarawak was chosen for its remoteness, forested in the interior highlands which represents Sarawak itself. The sites enable inter-regional assessments of the RFI profile in urban, suburban and rural settings in Peninsular and Borneo Malaysia [22, 23].

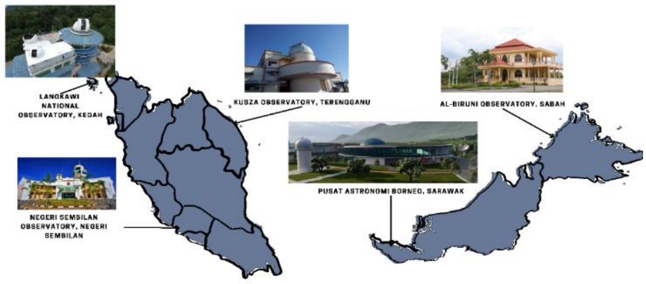

Fig. 1. Selected Observatory Sites Across Malaysia for L-Band RFI Assessment.

Table 1. The list of selected observatories in Malaysia for radio frequency interference study.

	Site Points	Moon Sighting observatory (Yes / No)	Latitude	Longtitude	Category (Pristine or Rural)
1.	KUSZA Observatory, Terengganu	Yes	5.54	102.95	Pristine
2.	Langkawi National Observatory, Kedah	No	6.31	99.78	Pristine
3.	Al-Biruni Observatory, Sabah	Yes	5.90	116.04	Rural
4.	Pusat Astronomi Borneo, Sarawak	No	1.75	110.31	Pristine
5.	Negeri Sembilan Observatory, Negeri Sembilan	Yes	2.45	101.85	Rural

2.2 Measurement System Configurations

Measurements were taken with a patch antenna of roughly 5 dBi gain oriented toward the Protek 3290N portable spectrum analyzer. The spectrum analyzer was sweep to the range of 1300–1500 MHz with a frequency resolution of 1 MHz.

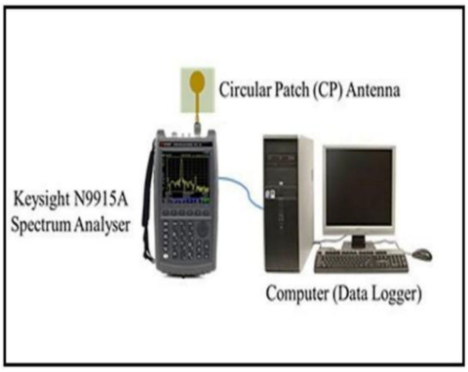

Fig. 1. Measurement Setup using Circular Patch

Antenna, Spectrum Analyzer, and Data Logging System Levels of power were asserted in decibel-milliwatts signifying dBm while signal detection was referenced to calibrated threshold of –80 dBm. This value was chosen based on system sensitivity, validation in the field, and endorsed by ITU-R RA.769 [4] which sets forth the minimum protection limits to enable uncontested radio astronomy operation zones. Conclusions regarding patch antenna systems in the absence of noise corroborated system value of idea the threshold on [5].

2.3 Statistical Methods and Equations

For each site, the mean value of RFI power was computed and the descriptive analysis conducted at the site was synonymous with the power defined in the RFI region of interest. The average spectral intensity was determined by the following equation:

$$\mu = \frac{1}{n}\sum_{i=1}^{n} xi$$

where μ is the average dBm power level and n is the frequency point spacing. The dispersion of RFI values was calculated using the standard deviation (σ):

$$\sigma = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(xi-\mu)^2}$$

These steps are commonplace in the statistical treatment of environmental signal data, signal processing and engineering texts [6]. To eliminate the mean RFI level dependency in site comparison as well of unintentional bias originating from differing site means, the coefficient of variation (CV) was computed:

$$CV = \left(\frac{\sigma}{\mu}\right) \times 100$$

The CV is a portrayal of signal variance, with lower values indicating the more consistent and reliably radio-quiet lower-values conditions [6]. To determine the degree of power distribution asymmetry, the Skewness (γ) was used. Observations skew positive when strong intermittent RFI peaks, dry radio quiet conditions give stronger but consistent and quiet undefined radio-measurements consistently pull lower the mean measurement.

To assess the peaks and tail density of the distribution, the kurtosis (κ) for each dataset was calculated as follows:

$$\gamma = \frac{1}{n}\sum_{i=1}^{n}\left(\frac{xi-\mu}{\sigma}\right)^4$$

As noted previously, higher values of kurtosis are an indication of extreme RFI events which, as mentioned, are particularly harmful to radio astronomy [24].

3.0 RESULT AND DISCUSSION

This section describes the analysis conducted on the Radio Frequency Interference (RFI) characteristics using

3.2 RFI Spectral Analysis Across Sites.

Data obtained from the patch antenna for the entire 0–4 GHz spectrum showed sharp RFI interference in the commercial bands, most prominently in urban impacted locations. All five sites are shown in Figure 2 which illustrates the full range RFI spectrum. Enhanced RFI peaks were identified outside of the protected bands, relative to established mobile and satellite emissions [21]. The five observatories exhibit noteworthy differences in RFI levels as shown in figure 3. LNO (Langkawi) bears the highest RFI peak at approximately 1.44 – 1.45 GHz, reaching close to -76 dBm of interference level. This indicates high interference, likely from maritime or aeronautical transmitters. BCB (Al-Biruni Observatory,

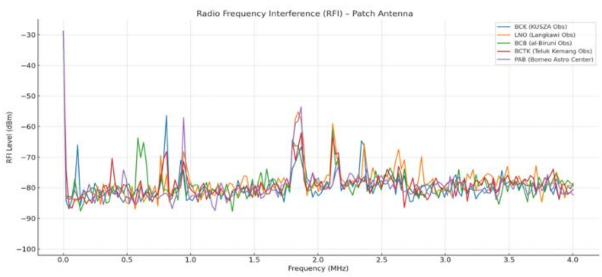

Fig. 2. RFI Power Spectrum Across Malaysian Observatory Sites (0–4 GHz).

patch antenna techniques at the five observatory sites in Malaysia. The analysis addresses the frequencies within the L-band (1.2 GHz to 1.6 GHz). The data is processed and interpreted through various methods which include statistical descriptors, spatial relevance matrices, hotspot evaluation, and comparative spectrum profiles for determining the suitability of the sites for radio astronomy purposes. Besides these, this section also compiles policy considerations, implications of moon sighting practices, and juxtaposition of other works from previous literature.

3.1 Applications of the L-Band in Radio Astronomy

For observing neutral hydrogen (HI) which is an important tracer for galactic rotation, formation of cosmic large structures, and emission studies is done in the L-band (1300–1500 MHz) and especially in 1420.4057 MHz [5]. Dark matter distribution, the evolution of galaxies, and the processes associated with the realization of the universe are in some way dependent on the observations made in this band. The L-band is also used for the study of pulsars, for the continuum emission of synchrotron radiation, and for the study of maser emissions which need very good spectral sensitivity and a very low radio frequency interference (RFI) background. Due to the sensitivity to RFI, places like PAB (Pusat Astronomi Borneo) which are less RFI contaminated are preferred.

Sabah) also registers sharp anomalies near 1.33 and 1.46 GHz, suggesting proximity to ground based urban RFI sources.

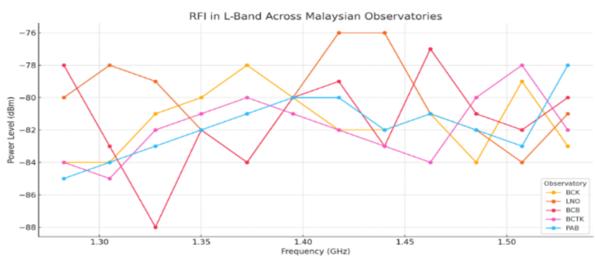

Fig. 3. RFI Levels in L-Band (1.2825–1.53 GHz) Across Observatories

Table 1. RFI in L-band at five Malaysian observatories.

Frequency (GHz)	BCK	LNO	BCB	BCTK	PAB
1.28	-78.0	-79.0	-83.0	-80.0	-85.0
1.293	-80.0	-78.0	-84.0	-82.0	-84.0
1.305	-79.0	-80.0	-88.0	-81.0	-83.0
1.318	-82.0	-79.0	-82.0	-80.0	-83.0
1.331	-84.0	-78.0	-80.0	-79.0	-82.0
1.343	-81.0	-77.0	-83.0	-80.0	-82.0
1.356	-80.0	-76.0	-81.0	-78.0	-81.0
1.368	-79.0	-78.0	-80.0	-76.0	-81.0
1.381	-78.0	-77.0	-82.0	-77.0	-82.0
1.394	-81.0	-80.0	-83.0	-76.0	-82.0
1.406	-83.0	-82.0	-85.0	-78.0	-83.0
1.419	-82.0	-81.0	-83.0	-79.0	-84.0
1.432	-80.0	-80.0	-82.0	-80.0	-83.0
1.444	-82.0	-79.0	-85.0	-81.0	-84.0
1.457	-81.0	-81.0	-83.0	-83.0	-83.0
1.469	-80.0	-83.0	-84.0	-84.0	-82.0
1.482	-79.0	-82.0	-81.0	-83.0	-83.0
1.495	-80.0	-80.0	-82.0	-81.0	-84.0
1.507	-81.0	-79.0	-83.0	-80.0	-83.0
1.52	-80.0	-82.0	-80.0	-82.0	-82.0

On the other hand, PAB (Pusat Astronomi Borneo, Sarawak) exhibits the most stable and suppressed RFI level across the spectrum hovering between -85 and -80 dBm regarding the HI protected line 1420.4057 MHz, especially near the protected HI line. BCK and BCTK demonstrate intermediate behavior with occasional spikes above -80 dBm suggesting intermittent or directional RFI. Primary sources of RFI are GSM towers, maritime radars, mobile repeaters and telemetry infrastructure in high altitude uncovered highland or coastal regions. These outcomes reinforce the choice of PAB as the best candidate for HI line pulsar mapping detection sensitive L-band radio-astronomy observation due to being the quietest and spectrally cleanest for radio-quiet observations.

3.2 Descriptive Statistical Analysis of L-Band Data.

Table 2 summarizes the measures of central tendency and dispersion for the RFI values. The overall mean power levels across all sites are under the –80 dBm level, with PAB showing the lowest variability which indicates the site may be suitable for delicate radio measurements. BCB exhibited the highest standard deviation of 2.855 dBm which suggests that the RFI environment is more dynamic at this site due to more local transient and mobile RFI sources.

Table 2. Statistical RFI Power Levels Across L-Band Frequencies at Malaysian Observatories.

Descriptive Statistics	BCK	LNO	BCTK	PAB	BCB
Mean	-81.198	-79.856	-81.242	-81.366	-81.403
Std. Deviation	1.751	2.195	1.788	1.766	2.855
Skewness	0.530	0.534	-0.506	-0.331	-0.637
Kurtosis	0.308	-0.618	-1.299	0.455	0.896
Kurtosis Indicator	Leptokurtic	Platykurtic	Platykurtic	Leptokurtic	Leptokurtic
Minimum	-83.772	-82.732	-84.158	-84.994	-87.687
Maximum	-77.600	-76.121	-79.108	-78.581	-77.208

Figure 4 shows that skewness and kurtosis for BCB and BCTK data sets exhibit negative skewness values (-0.637 and -0.506, respectively), highlighting the high-activity RFI environments' typical left-side skew. In PAB, on the other hand, participants exhibit close to normal background interference levels. This further supports the idea that background, non-attenuated interference, is consistent and minimal. The analysis of RFIs (radio frequency interferences) within the L-band (1-2 GHz) range has shown that Regions of Interest power distributions of kurtosis reveal each observatory sites power distribution's shape in the statistical domain.

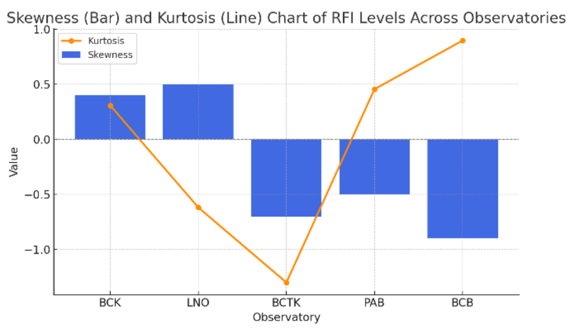

Fig. 4. Skewness and Kurtosis Line Chart of RFI Levels Across Observatories.

In this regard, platykurtic or negative kurtosis distributions signal that the RFI patterns are more homogeneous and have less potent spikes which are more desirable for radio telescopes observation. BCTK (–1.299) and LNO (–0.618) demonstrate such distributions which suggest these sites have stable interference conditions and, thus, are very favorable for L-band HI observations. As shown in PAB (0.455) and BCK (0.308), leptokurtic or positively skewed distributions suggest that the sites have low baseline noise, but they show some strong RFI bursts which render the sites moderately useful, thus requiring mitigation. BCB (0.896) demonstrates a strongly peaked curve for the RFI power distribution and represents the strongest positioned site which makes its the less usable. This assigned class geometry enables these put forward RAFCAM prioritize site suitability and RFI mitigation decisions during preconstruction in Malaysia [21].

3.4 Frequency Hotspot Detection and Thresholding

In radio astronomy, data is significantly threatened with a signal strength exceeding -80 dBm, as per ITU-R RA.769-2. A scan was done to assess the number of frequencies that surpassed this limit in the entire 1.2–1.6 GHz band. This limit serves as a baseline for analyzing other locations in international studies [4]. Figure 5 shows the frequency count above the -80 dBm limit for all sites. LNO had the highest hotspot frequency count with 5, followed by BCB with 4, while PAB showed only

2 hotspots reinforcing the classification as the quietest site. This corroborates earlier L-band studies which reported significant interference experienced at the efficiency of observational tasks. Locations that have frequent exceedances would need extreme RFI flagging based on observational execution synchronization. The lesser the hotspots, the greater the data segments available for long duration observations, particularly in spectral line studies [6]. Supporting evidence is available in the approach provided in Hafez et al. [25], which asserts that radio quiet conditions requiring stringent maintenance above -80 dBm are necessary for crucial data operations such as lunar occultation or HI line detection.

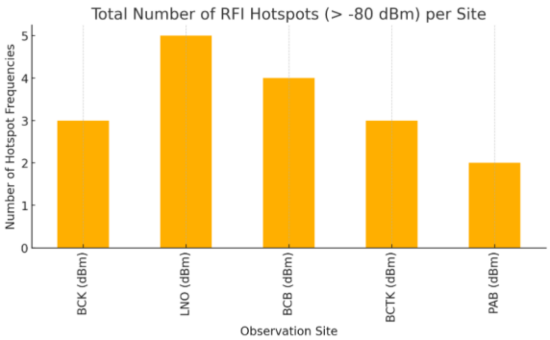

Fig.5. Number of RFI Hotspots (-80 dBm) per Site.

In the study, extreme threshold breaches were modeled and classified using temporal and spectral domain parameters which reinforces the importance of sub-band 1.2-1.6 GHz range analysis. The additionally pointed out that these hotspots without mitigation can directly cause degradation in the signal to noise ratio in HI detection and inhibit Doppler frequency lock during track frequency lock on fast moving celestial objects. These distributions of hotspots affect applications such as moon sighting (rukyah hilal) which portable radio receivers and CCD sensors could be impacted by local RFI interference because of saturation or detection distortion [26, 27]. Spectral cleanliness is important not only for astronomy, but also for religious observances and precise timekeeping. The Implementation of tailored RFI flagging methods for remote monitoring informed by local spectra databases is recommended for long-term monitoring [28-30].

3.5 Qualitative Matrix Analysis for Environment RFI

Exposure to radio frequency interference (RFI) is affected greatly by the environmental factors surrounding each observatory. To assess each site as a case study, a qualitative matrix with seven environmental components was created: (1) natural terrain shielding, (2) vegetative absorption, (3) low electromagnetic line-of-sight (EM-LoS), (4) partial exposure to RFI, (5) high elevation RFI exposure, (6) proximity to residential or urban sources, and (7) lack of natural or human-made barriers. Such parameters, following the ITU-R SM.1133-2 recommendations, enable a coherent analysis of the passive protective features of each observatory site.

Langkawi and Sabah sites from radar communications [8, 9]. The distribution of hotspots has a direct impact on the

Of the five observatories analyzed, Pusat Astronomi Borneo (PAB) presented the most optimal surrounding factors [31]. PAB is positioned within a valley and is surrounded by dense forest, resulting in high terrain masking coupled with vegetative absorption alongside low EM LoS. On the other hand, BCB (Al-Biruni Observatory) and BCTK (Negeri Sembilan Observatory) are in more open urban areas lacking significant terrain or vegetative buffering, making these sites permanently RFI dominant. Alongside Langkawi National Observatory (LNO), KUSZA Observatory (BCK) demonstrate mid-range shielding, incorporating higher surrounding urban land alongside some elevated terrain.

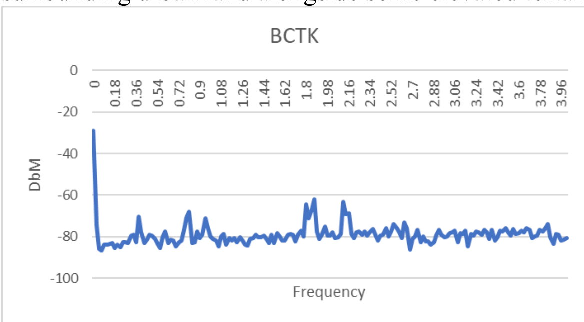

Fig.6. High RFI at BCTK, indicating low suitability for radio astronomy from 0-4 GHz.

As shown in Table 3, PAB holds the highest rank in suitability for RFI protection, followed by LNO and BCK. BCB and BCTK are placed in the least suitable category due to their high exposure and poor shielding features. These findings align with RFI measurements such as mean dBm values, standard deviation, and the total RFI hotspot count.

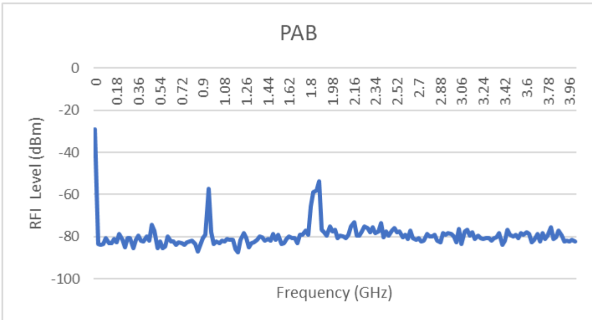

Fig.6. RFI at PAB, indicating good suitability for radio astronomy from 0-4 GHz.

From the point of view of the public policy, this assessment of the environment strengthens the case to extend formal designation of RQZ PAB for RQZ under the national spectrum plan by MCMC. More localized regulatory frameworks, as well as ASEAN-level cooperative action through APT, could better protect scientifically important band 1400–1427 MHz Furthermore, Malaysia could be strategically planned to host future observatories in the less radio-bright regions, which would help sustain the radio astronomy infrastructure over time.

Table 3. Decision Table for Site Ranking – Based on Relevance to RFI

Site	Environmental Factors	Suitability Recommendation
PAB	Optimal environment with full terrain shielding, forestry absorption, valley placement and only partial exposure. Most suitable for sensitive observations.	Suitable
LNO	Some shielding from terrain and forestry, moderately elevated, still partially exposed.	Moderately Suitable
BCK	Hilly area with residential exposure, elevated location increases long-distance RFI vulnerability.	Moderately Suitable
BCTK	Like BCB, flat, open land near human activity, making it highly susceptible to RFI.	Less Suitable
BCB	Open terrain near residential zone; lacks shielding, high risk of consistent anthropogenic RFI.	Less Suitable

Conclusion

This study evaluated the RFI environment from five observatories in Malaysia focusing on the L-band (1.2–1.6 GHz) because of its relevance to neutral hydrogen (HI) studies in the universe. Based on patch antenna data, terrain features and statistical processes, Pusat Astronomi Borneo (PAB) in Sarawak was found to have the cleanest and the most stable spectrum with lesser RFI hotspots as well as potent natural shielding. PAB's condition is having been the most approximal site for radio astronomy in Malaysia, thus validating earlier observations that PAB was the best location. Other places, particularly those situated in more urban or exposed zones, had considerably less RFI protection and greater interference. The findings also stress the need for proactive policies on management of the protected astronomy frequencies. We propose that PAB be proclaimed a Radio Quiet Zone (RQZ). This will curtail future interference and support use of the region as a national observatory [16][17]. Ongoing RFI monitoring at PAB and other locations, coupled with improvements in RFI flagging systems and the application of machine learning based advanced noise filtering and signal classification will enhance long-term research prospects.

Acknowledgements

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