An RFI investigation for setting up a VLBI station below 2.8 GHz in Malaysia

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Abstract

In this paper, we investigated the radio frequency interference (RFI) that future Very Long Baseline Interferometer (VLBI) observations in Malaysia may encounter. Four frequency windows below 2.8 GHz were chosen for this study and their spectra were measured at four sites. The frequency windows are 322–328 MHz, 608–614 MHz, 1660–1660.5 MHz and 1660.5–1668.4 MHz. The measured averaged RFI floor noise levels in these windows are $99.992 \pm 0.570$ dBm, $99.907 \pm 0.639$ dBm, $100.220 \pm 0.494$ dBm and $100.359 \pm 0.110$ dBm, respectively. We found that only two bands below 2.8 GHz are permitted for the purpose of radio astronomy in Malaysia. They are 608–614 MHz and 1660–1660.5 MHz. The RFI levels in these permissible bands at the best site (Langkawi) were also measured and concluded to be relatively low. Main sources of RFI in these bands in Malaysia were identified. We also reviewed several current VLBI observations in these two bands.

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1. Introduction

Previous works by the main author have identified several prime candidate sites which are suitable for the purpose of setting up radio telescopes in Malaysia. The key goal of setting up a radio astronomy observatory in this country is to be part of the East Asia VLBI Network (EAVN), with a long term goal of joining the Global Very Long Baseline Interferometer (Global-VLBI) project. The addition of radio telescopes in Malaysia can be used to improve the UV-coverage of VLBI networks between Asia and Oceania.

VLBI is currently operating in a wide range of frequency bands. This paper investigated selected bands below 2.8 GHz. These bands are: 322–328 MHz, 608–614 MHz, 1660–1660.5 MHz and 1660–1668.4 MHz. The spectra of radio frequency interference (RFI) in these bands were carefully measured and monitored. The selected sites were Langkawi, the National Land and Survey Institute (INSTUN), Jelebu and the University of Malaya main campus (Table 1). The University of Malaya site was used as the reference site.

2. Methods and instruments

For the purpose of this investigation, the receiver system used comprises the following: copper discone antenna (designed for L-band), 1.4 GHz Low Noise Amplifier (LNA) and 2.8 GHz Spectrum Analyzer with 180 kHz resolution bandwidth.

A full spectrum was measured every 3 h in a 24 h period at the selected sites. See Table 1 for the main features of each selected site. The selected VLBI spectrum bands were identified on each of the measured spectra. Averaged value were calculated and compared against one another. The comparison of the best site (Langkawi) with the reference site (University Malaya) was also performed to show the difference in the noise floor level of the overall RFI.

We also compared the frequency allocations for our selected VLBI bands between the International Telecommunication Union (ITU) and the Malaysian Communication and Multimedia Commission (MCMC). This was done to study the spectrum allocation agreed by the two departments.

3. Results and analysis

The spectra observed in the selected sites are listed and analyzed in Figs. 1–5. The three VLBI bands below 3 GHz are drawn as double vertical lines in these figures. The reference site (Fig. 1) showed a very high floor noise level. This is mainly due to the location and altitude of the site. The INSTUN site (Fig. 2) has better floor noise level in comparison. However, the strong RFI peak signals are still visible from the spectrum. The Jelebu site (Fig. 3) has even fewer RFI peak signals, although the ground floor noise level is slightly higher. The best site with the lowest average floor noise RFI level is the Langkawi site (Fig. 4). Its floor noise level is
This value is approximately equivalent to $4.363 \times 10^6$ Jy. This is better by 5 dBm as compared to those in the INSTUN and Jelebu sites. This is also better by 16 dBm than the reference site (Fig. 5).

We then measured the averaged RFI floor noise levels in the four VLBI windows (322–328 MHz, 608–614 MHz, 1660–1660.5 MHz and 1660.5–1668.4 MHz) as $-99.992 \pm 0.570$ dBm, $-99.907 \pm 0.639$ dBm, $-100.220 \pm 0.494$ dBm and $-100.359 \pm 0.110$ dBm, respectively. They are approximately at the level between $4.383 \times 10^6$ Jy to $4.403 \times 10^6$ Jy. There were no strong man-made peak radio signals in these bands. This is an encouraging fact if a future VLBI station were to be built on this site.

Table 2 lists the averaged RFI signals in the selected VLBI bands. We combined the last two windows since they are of continuous bands. Table 2 also lists the spectrum allocation agreed by the ITU and MCMC for these bands. Finally, the detailed spectra for the VLBI bands of the best site (Langkawi) are listed in Fig. 6–8.

It was also found that the averaged RFI floor noise in these bands fluctuated only slightly (roughly between 1 dBm and 2 dBm) when monitored for 24 h at the Langkawi site.

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### Table 1

The four selected sites for RFI observations in Malaysia.

<table>
<thead>
<tr>
<th>Site</th>
<th>Altitude (m)</th>
<th>Longitude</th>
<th>Latitude</th>
<th>Important RFI-related features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Langkawi</td>
<td>87</td>
<td>099°46.738'E</td>
<td>06°18.206'N</td>
<td>Located in a forest reserve area. Very low population density</td>
</tr>
<tr>
<td>INSTUN</td>
<td>65</td>
<td>101°31.035'E</td>
<td>03°45.916'N</td>
<td>Shielded by mountains from all sides about 200 m away. Low population density</td>
</tr>
<tr>
<td>Jelebu</td>
<td>144</td>
<td>102°03.912'E</td>
<td>03°03.108'N</td>
<td>Least total annual rainfall area in Malaysia. Low population density</td>
</tr>
<tr>
<td>University of Malaya</td>
<td>109</td>
<td>101°39.445'E</td>
<td>03°07.443'N</td>
<td>On top of a hill overseeing part of the city. Very high population density</td>
</tr>
</tbody>
</table>

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4. Conclusion and discussion

According to the MCMC, the government of Malaysia holds exclusive rights to the frequency bands of 315–328.6 MHz and
1660.5–1690 MHz. This implies that future VLBI observations in the abovementioned bands may require official permission from the Government. However, in a private communication between the main author with the chairman of the Committee on Radio Frequency Frequencies (CRAF), Axel Jessner in October 2010, the latter suggested that this ‘restriction’ might also be established to protect radio astronomy itself. This statement will require further confirmation. The other two bands are not within any ‘restriction’ limit.

The first band (608–614 MHz) is used by VLBI to study continental drift, rotation of the Earth, earthquakes, and space navigation. From our results, we concluded that this band could be used for radio astronomy but it contains high risks of man-made interferences. They may arise from the usage of fixed and mobile, radio navigation and broadcasting services. Additionally, man-made signals in this band may also originate from the Wireless Medical Telemetry Service (WMTS). Other bands for WMTS are 1395–1400 MHz and 1427–1429.5 MHz. However, the WMTS equipment usage is only permitted and restricted to health care facilities.

The second band (1660–1668.4 MHz) is potentially the best option to be used for future VLBI observations in Malaysia, although the usage of GPS and other navigation satellites signals within the band will need to be constantly monitored and filtered. Signals from and to aircrafts may also contribute to RFI in this band. They are transmitting at 1626.5–1660.5 MHz and 1530–1559 MHz.

**Table 2**

<table>
<thead>
<tr>
<th>VLBI bands (MHz)</th>
<th>Averaged signals level (dBm)</th>
<th>Ratio to overall noise floor level</th>
<th>ITU allocation</th>
<th>MCMC allocation</th>
<th>Radio astronomy purposes</th>
</tr>
</thead>
<tbody>
<tr>
<td>322–328</td>
<td>99.992 (±0.570)</td>
<td>1.009</td>
<td>Fixed and mobile, radio astronomy</td>
<td>Fixed and mobile (Government of Malaysia) radio astronomy</td>
<td>Deuterium observations, continuum observations and VLBI</td>
</tr>
<tr>
<td>608–614</td>
<td>99.907 (±0.639)</td>
<td>1.008</td>
<td>Radio astronomy and mobile-satellite except aeronautical mobile-satellite (Region 2), fixed and mobile, radionavigation and broadcasting (Region 3)</td>
<td>Fixed and mobile, radionavigation and broadcasting</td>
<td>Continuum observations and VLBI</td>
</tr>
<tr>
<td>1660–1668.4</td>
<td>100.359 (±0.110)</td>
<td>1.013</td>
<td>Radio Astronomy, space research (passive), mobile satellite (Earth-to-space), fixed and mobile except aeronautical mobile</td>
<td>Radio astronomy, space research (passive), mobile satellite (Earth-to-space), fixed and mobile (Government of Malaysia) except aeronautical mobile</td>
<td>L-band, continuum observations, line observations and VLBI</td>
</tr>
</tbody>
</table>

**Fig. 4.** RFI floor noise level at the Langkawi site. The averaged floor noise level is 99.454 (±3.462) dBm.

**Fig. 5.** A comparison of the RFI floor noise level between the best site (Langkawi; green solid line) and the reference site (University of Malaya; blue solid line). (For interpretation of the references in color in this figure legend, the reader is referred to the web version of this article.)
respectively. Table 3 summarizes the possible main RFI sources in these two bands in Malaysia.

The selected published work using VLBI in these two bands include the study of Supernova SN1979C with the Very Long Baseline Array, Green Bank, Effelsberg, Robledo, Westerbork and Arecibo telescopes (Marcaide, 2009), observations of galaxies NGC4051, NGC4388, NGC 4501, NGC5194 and NGC5273 with the European VLBI Network (EVN) (Marcello and Francesca, 2009), observations of high redshift quasars 3C446 at 1.6 GHz with the Japanese HALCA, China's Shangai, Usada, Australia's ATCA and South Africa's Hartebeesthoek telescopes (Paragi, 2000) (all at 1.6 GHz) and the VLA’s observations of the giant radio sources 3C35 and 3C223 (at 74, 327, 608 and 1400 MHz) (Orru’, 2006).

We will also consider venturing into setting up radio telescopes and VLBI-related facilities above 2.8 GHz in the future. In the immediate future, we hope to be able to use a spectrum analyzer with a bandwidth of 6.6 MHz and spectral line bandwidth of 10 kHz to measure these RFI levels in order to compare them with the thresholds set by the ITU Recommendation ITU-R RA 769-2 within these two bands.

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