Chapter 8

JOVIAN non-Io RADIO BURSTS OBSERVED WITHIN 18 – 25MHz

8.1 Introduction

Radio signals from outer space have always fascinated both scientists and layman. In this Universe a large number of physical processes and phenomena are occurring very uniquely at lower frequencies – in decameter (DAM) and hectometer (HOM) wavelength bands. Karl Jansky (1933) first came across oddly regular extraterrestrial radio noise at a frequency of around 20MHz by using a short wave or “ham” radio in 1928 in the Bell Laboratory. Eventually he realized that the signals he was picking up could not be dismissed simply as noise and that they were coming from the center of the Milky way (Garcia, 1960). Burke and Franklin (1955) discovered the Jovian decametric (DAM) emission at the 22.2 MHz frequency. Krauss (1958) reported the distinctive short staccato bursts in the year 1956. Since that time, Jupiter has proven to have a wealth of complex radio – emission mechanisms from decimetric to kilometnc range (Fig 8.1) which have been verified from terrestrial and extraterrestrial (e.g. Pioneer10 / 11, Voyager 1 / 2, Ulysses, Galileo and Cassini spacecrafts) radio telescopes and all have noticed that as the terrestrial observations, there are different sources emitting radio emissions from the magnetosphere of Jupiter in the DAM range. The occurrence probabilities of detecting the emission depend strongly on the ranges of the Jovian central meridian longitude (CML) III, phase of Jupiter’s satellite Io and related with same CML, but, independent of Io – phase (non-Io DAM).
Fig 8.1 Average flux density vs Frequency/Wavelength
Radio emission (Kilometric to Decimetric) from Jovian Magnetosphere (adopted from A J DESSLER)
According to the classification of Carr et al. (1983) and spacecraft observations the sources of emission of Jupiter DAM with the characteristic features are given in Table 8.1

Table 8.1 Jovian sources with characteristic features

<table>
<thead>
<tr>
<th>Source designation</th>
<th>CML Range</th>
<th>Io Phase</th>
<th>$f_{\text{max}}$ MHz</th>
<th>Polar</th>
<th>ARC</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Io-A</td>
<td>(200-270°)°</td>
<td>205-260°</td>
<td>38</td>
<td>RH</td>
<td>Late</td>
<td>N</td>
</tr>
<tr>
<td>Non-Io-A</td>
<td>(230-280°)°</td>
<td>0°-360°</td>
<td>38</td>
<td>RH</td>
<td>Late</td>
<td>N</td>
</tr>
<tr>
<td>Io-B</td>
<td>(105-185°)°</td>
<td>80°-110°</td>
<td>39.5</td>
<td>RH</td>
<td>Early</td>
<td>N</td>
</tr>
<tr>
<td>Non-Io-B</td>
<td>80-200°</td>
<td>0°-360°</td>
<td>38</td>
<td>RH</td>
<td>Early</td>
<td>N</td>
</tr>
<tr>
<td>Io-C</td>
<td>(300-20°)°</td>
<td>225-260°</td>
<td>36</td>
<td>RH &amp; LH</td>
<td>Late</td>
<td>N/S</td>
</tr>
<tr>
<td>Non-Io-C</td>
<td>300-360°</td>
<td>0°-360°</td>
<td>32</td>
<td>RH &amp; LH</td>
<td>Late</td>
<td>N/S</td>
</tr>
<tr>
<td>Io-D</td>
<td>0-200°</td>
<td>95-130°</td>
<td>18</td>
<td>LH</td>
<td>Early</td>
<td>S</td>
</tr>
</tbody>
</table>

CML Range: central meridian longitude system III. Io phase. The position of Io relative to Superior Geocentric Conjunction, the point at which Io is directly opposite from Earth with respect to Jupiter, concerned with respective emission $f_{\text{max}}$. Maximum observed frequency. Polar: dominant polarization of the emitted DAM radio emission. RH - right hand polarization from Jovian Northern (N) Hemisphere. LH - left hand polarization from Jovian southern (S) Hemisphere. ARC: spectral arc curvature as observed in the dynamic spectra of Jovian DAM. 'Late-' and 'Early- ' refer to arrival time of the vertex of the emission spectra. Ranges in parentheses based on widths of the half maxima for the major sources as observed from terrestrial stations at 20 MHz. Other ranges based on extraterrestrial observation from Voyager Spacecrafts 1/2.
The source locations in the co-ordinate space of CML-/o-phase ($\Phi_o$) have been confirmed by Lecacheux et al (1998), Quemnec and Zarka (1998) and Aubier et al. (2000). Of the two types, /o and non-/o emission, the later emission has been found to be very much correlated with the solar parameters (Teraswa, 1979; Pokorney, 1982; Barrow, 1981, Bose and Bhattacharya, 2000, 2001, 2002, 2003). We have tried to highlight the degree of dependence of non-/o DAM on the different solar parameters by analyzing the terrestrial radio telescope data from 1957-1978 (Thieman, 1979) prepared by Godard Space Flight Centre. We with other two electronics Engineers, S Joardar and S Chakraborty had taken a preliminary step to arrest the Jovian signal on the occasion of ‘Mini School on Introductory Astronomy and Astrophysics’ organized by the Kalyani Govt. Engg College in collaboration with Inter-University Centre for Astronomy and Astrophysics, Pune from 4-7Feb, 2004.

Radio astronomy at DAM radio spectrum (~10-50MHz) suffers a very high pollution by man-made interference. A lot of natural and artificial interferences produce signals of intensity many times higher than those of radio emissions from space. The wave propagation from extraterrestrial sources in their propagation path from the source interacts with various media (plasma condition near the source, interstellar medium /interplanetary medium and at last in its journey with ionosphere medium) leading to absorption, refraction/ diffraction and scattering of radio waves. Decameter range brightness temperature of the galactic background is quite high and this fact determines the noise temperature of the receiving systems.

Two main difficulties (interferences and ionosphere effects) are now removed by receiving the signal through satellite/spacecraft (mentioned earlier) borne radio telescope, which are obviously set outside of the Earth ionosphere and sometimes near the magnetosphere of the source. Under
such scenario of space borne very low frequency radio astronomy, a
question may be raised about the so-called ground based DAM radio
astronomy. The several points may be solicited in this support, e.g.
economic, reliability with long term data etc., which are not feasible with
space project.

Thus, the approach of giant, ground based, and low frequency radio
telescope has received support (Zarka et al., 1997; Konovalenko et al.,
1999) in the world of radio astronomy community. It is realized that new
astrophysical results obtained with ground-based instruments will allow to
optimize and to strengthen the future programmes on space borne projects.
All this thinking boost us to take a small step in performing such an
experiment considering all the restrictions and also keeping in mind the
information of the installation of giant radio telescope UTR-2 with Acousto-
Optical Spectrographic facility to search for exoplanets and stars closer
than ~25 parsecs at DAM wavelengths.

8 2. Techniques and Instruments

The measurements were conducted at Kalyani Govt. College, Kalyani
(22.95° N and 268 33° E), India on 7 Feb 2004. The radio spectrum in the
decametric range suffers a very high pollution by man made interference
below 18MHz from SW1 and SW2 radio stations. Also due to the Jovian
magnetospheric cutoff it is not possible to receive signal above 39.5MHz
from Jupiter. Under such restrictions we have made a radio telescope tuned
at 20MHz (Fig 8.2) following Krauss (1956). To avoid unnecessary signal
attenuation we have taken care of proper impedance matching between the
antenna, cable and the receiver. The radio telescope comprises of the
following three components –

Antenna, Radio Receiver, Spectrum Analyzer
8.2.1 Antenna

We have designed and constructed a half wave (λ/2) dipole antenna (Fig. 8.2) of length 7.125 m. At 20 MHz, the effective wave length is 14.25 m (= 0.95C / 20 MHz, C = 3 x 10^8 m/s; 0.95 - the velocity factor). We have used 8SWG aluminium wire for the said antenna. The bandwidth of the antenna is 4 MHz (= 2 x 10% of 20 MHz) in the range from 18 MHz to 22 MHz. The ends of the antenna are fixed with two wooden stands and is aligned along North and South direction. The antenna is connected to the receiver with a flat twine lead, 300ohm cable, which is generally used in TV antenna. 1.1 balun (balanced to unbalanced matching circuit) necessary to connect the antenna with the cable.

Fig 8.2 Half wave dipole antenna for a radio telescope

8.2.2 Radio Receiver

A short wave superhet radio receiver (band width = 20 kHz) is used for arresting the Jupiter noise. Use of superheterodyne eliminates the need for complex adjustment of the filter. The superhet uses a fixed filter. The radio signal is picked up by the antenna and selected by a relatively broadband RF filter. This signal is amplified before entering the mixer. The mixer then
combines the incoming RF signal and the local oscillator signal to shift the input signal to a lower frequency (IF 450kHz). The purpose of mixing the two is to extract the difference frequency at the IF amplifier. The envelope of IF signal is the same as the original signal. The signal is then passed through a multiple stage filter tuned at 450kHz. The IF signal is then amplified and passed through an envelope detector before the AF power amplification.

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**8.2.3 Spectrum Analyzer Features**

**Model MS2651B,**

- Range -9 kHz - 3GHz
- RF Input - 50Ω, +30dBm, ± 50 V DC Max
- AT – RF Attenuation ; ST – Sweep Time, VB – Video Bandwidth;
- RB – Resolution Bandwidth

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**8.3 Setting of Radio Telescope for Spectrum Analysis**

The schematic circuit of the radio telescope is shown in the Fig.8.4. The radio receiver of ~ 20kHz bandwidth can receive signal in a very narrow frequency region around 20MHz. As we had an antenna of 4MHz...
bandwidth connected with 9kHz to 3GHz spectrum analyzer, so we set the starting frequency at 18MHz and stop frequency at 25MHz to the Spectrum Analyzer to analyze the received signal.

8.4 Observation

From the Indian Ephemeris we came to know that in the sky of India Jupiter would be visible during the time (4-8 Feb, 2004) of the said school and we observed the planet with four Galilean satellite from our observatory situated on the roof-top of the college through our 10 inch Newtonian type reflecting telescope on and from Feb4, 2004 and we planned to set our Radio Telescope to arrest the Radio noise from Jupiter on 7th Feb, 2004.

At daytime when there was only Sun in the sky we started observing from 10:40 IST (IST- Indian Standard Time, our time zone is +5.5h of GMT) to 11.10 IST. Throughout the half an hour observing time we found that the average noise level was at -85dBm (dBm = (log 10 (mW))x10) and a fixed
man made communication channel signal at 21.584MHz with average noise level-73.32 dBm. The captured signal is presented in the Fig.8.5

Almost over the whole daytime we did not observe any other feature than the spectrum as shown above. So we decided to start our second phase when Jupiter would be visible in the evening sky. Accordingly we started our evening programme to see the Jupiter in two ways – one through our optical telescope to see Jupiter by the reflected Sun light and its magnetospheric characteristic feature in the decametric wavelength range through our tested radio telescope.
In this phase we switched on the total system around 20 IST and around 22:00 IST suddenly we saw some noisy bursts run away past the spectrum analyzer screen entering from lower frequency side and quickly shifted towards higher frequency side and all of us got puzzled for a while to capture it in the memory space of the spectrum analyzer. At that time Jupiter was visible in the clear sky at 49.38° altitude through our optical telescope with its nearby four Galilean satellites. As there were no other celestial objects but Jupiter in our view we all agreed that the signals are coming from Jupiter. We started to record the signals in the succeeding times as shown in the Figs 8.6 – 8.13.

Fig.8.6 The Radio Bursts Received at 22:08 IST
Fig.8.7 Radio Bursts from Jupiter at 22.30 IST.

Fig.8.8 The Radio Bursts Received at 22:36 IST.
Fig. 8.9 The Radio Bursts Received at 22:39 IST.

Fig. 8.10 Spectrum Received at 22:52 IST
Fig. 8.11 Spectrum Received at 22:53 IST.

Fig. 8.12 Spectrum Received at 22:54 IST
Fig. 8.13 The Radio Bursts Received at 22:58 IST.

Fig. 8.14 The Radio Bursts Received at 23:14 IST.
### 8.5 Results and Discussion

The observed signals are analyzed. The noise power maximum in each spectrum with the corresponding frequency and the signal to noise ratio are shown in Table 8.2

**Table 8.2 Noise power Maximum and the corresponding Frequency**

<table>
<thead>
<tr>
<th>Signal</th>
<th>Max power in dBm</th>
<th>$\frac{\text{signalpower}}{\text{noisepower}}$</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fig 8.5</td>
<td>-73.32</td>
<td>21,584</td>
<td>Man made noise</td>
</tr>
<tr>
<td>Fig.8.6</td>
<td>-66.71</td>
<td>21,024</td>
<td></td>
</tr>
<tr>
<td>Fig.8.7</td>
<td>-69.29</td>
<td>18,98</td>
<td></td>
</tr>
<tr>
<td>Fig 8.8</td>
<td>-66.47</td>
<td>18,476</td>
<td></td>
</tr>
<tr>
<td>Fig 8.9</td>
<td>-68.86</td>
<td>19,750</td>
<td></td>
</tr>
<tr>
<td>Fig.8.10</td>
<td>-72.10</td>
<td>21,898</td>
<td>**</td>
</tr>
<tr>
<td>Fig.8.11</td>
<td>-67.83</td>
<td>21,598</td>
<td>**</td>
</tr>
<tr>
<td>Fig.8.12</td>
<td>-66.65</td>
<td>20,94</td>
<td></td>
</tr>
<tr>
<td>Fig 8, 13</td>
<td>-67.59</td>
<td>21,36</td>
<td></td>
</tr>
<tr>
<td>Fig.8.14</td>
<td>-69.74</td>
<td>20,114</td>
<td></td>
</tr>
</tbody>
</table>
In the Figs 8.8 and 8.14 fading is observed at 22:36 IST and 23:14 IST. It might be due to the interference between noise burst and the man made radio signal where as no such phenomena have been observed with the other cases.

**At 22:52 IST and 22:53 IST a sharp spike at the frequency 22.5MHz was observed in the Figs 8.10 and 8.11. This spike might be coming from a communication channel of -75.02dBm power.**

After observing 2/3 bursts we were very much aware of the prior indication of receiving the bursts and we would alert to capture it in the spectrum analyzer. The prior indication was gradual increase of the disturbances in the noise level in the form of spikes and after this phenomenon successively bursts of signals were running one after another for couple of minutes and after a little gap again that phenomenon recurred. The above recordings are only a few captured among all the bursts. As we were not experienced too much, so some bursts fled before capturing. We recorded the phenomenon up to 23:15 IST.

Later we started to compare our observation with the Rjpro3 prediction software. Following the instruction of the software we set our sky at the location of longitude 268.33° E and 22.95° N and we saw in the real time sky map the position of Jupiter, stars, sun and the Galactic plane relative to the N-S extended dipole antenna as we set. We also found the Jovicentric Declination (\( \Delta E = -1.7^\circ \)) of the Earth on 7th FEB 2004, Jupiter's altitude, azimuth, magnetic latitude of the planet and also the Central meridian longitude \( \lambda \) and also the phase of \( I_0 \) in the whole duration our observing time. At that day in the time specified the observed altitude of Jupiter was very much the same as predicted by the said software and we were confident that the signal, as we received in our location, were coming from Jupiter in the decametric range of wavelength. Then we searched the
Jupiter / solar Ephemeris on that day in that location, the predicted position of Jupiter in the CML - Io co-ordinate space has been shown in the Table 8.3 and also we have taken a print (Fig. 8.15) regarding the position of Jupiter in the said CML - Io phase plane in the GMT real time corresponding to our observing time.

FEB7, 2004

Location- Kalyani Govt Engg College, Kalyani, India (26° 33' E, 22° 95' N)

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**Table 8.3  Jupiter / Solar Ephemeris**

<table>
<thead>
<tr>
<th>GMT Time</th>
<th>JUP P Alt</th>
<th>JUP Az</th>
<th>CML III</th>
<th>Mag Lat</th>
<th>Io Phase</th>
<th>SUN Alt</th>
<th>SUN Az</th>
<th>Local Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>17:00</td>
<td>43.9</td>
<td>103.9</td>
<td>237 69</td>
<td>07.91</td>
<td>154.25</td>
<td>-74.1</td>
<td>293.6</td>
<td>22:00</td>
</tr>
<tr>
<td>17:30</td>
<td>50.5</td>
<td>108.9</td>
<td>255.83</td>
<td>05.6</td>
<td>158.51</td>
<td>-79.9</td>
<td>313.1</td>
<td>22:30</td>
</tr>
<tr>
<td>18:00</td>
<td>56.9</td>
<td>115.4</td>
<td>273.97</td>
<td>02.8</td>
<td>162.77</td>
<td>-82.9</td>
<td>358.9</td>
<td>23:00</td>
</tr>
<tr>
<td>18:30</td>
<td>62.9</td>
<td>124.3</td>
<td>292.11</td>
<td>-00.4</td>
<td>167.04</td>
<td>-80.1</td>
<td>45.7</td>
<td>23:30</td>
</tr>
<tr>
<td>19:00</td>
<td>68.2</td>
<td>137.2</td>
<td>310.25</td>
<td>-03.5</td>
<td>171.31</td>
<td>-74.3</td>
<td>65.8</td>
<td>24:00</td>
</tr>
</tbody>
</table>

JUP-Jupiter, RA- Right ascension, DEC- Jupiter's Declination, $D_e$ - Jovian Declination relative to Earth, Dist - Distance of Jupiter from Earth, GMT - Greenwich Mean Time, ALT- Altitude, Az- Azimuth, CML- Central Meridian Longitude; Io- Jupiter's Satellite
From the Jupiter / solar ephemens (Table-8.3) it is observed that during our observation the burst was coming from CML range ~ 237-310° and range of Io-phase was 154-171°, Fig. - 8.15 and comparing the prediction with the source location as shown in the Table 8.4 below

Table 8.4 Part of Table-8.1 for comparison with Table8.3

<table>
<thead>
<tr>
<th>Source designation</th>
<th>CML Range</th>
<th>Io-Phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Io-A</td>
<td>(200-270)°</td>
<td>205-260°</td>
</tr>
<tr>
<td>Non-Io-A</td>
<td>(230-280)°</td>
<td>0°-360°</td>
</tr>
</tbody>
</table>

- significance of parenthesis in the CML range has been described in the foot note of Table-8.1

we arrived at the conclusion that the signals which we received on that day were originated from Jovian non- Io - A source. For further verification we searched the University of Florida Astronomy website From their website it has been seen that at their location which in the same northern hemisphere, but 6° above our location and longitude 185° ahead of us, They predicted that at that time on that day non-Io-A source would emit radio signal in the DAM range from Jupiter at 18 MHZ and 26 MHz, with absolute occurrence probability ~ 0.1.

All the above evidences led us to conclude that the signal received by us at that day was coming from Jovian-non-Io-A source within 18-25MHz.
Fig 8.15 Print showing the predicted position of the Jovian DAM source in the CML – Io phase coordinate (Rj Pro 3 Software)