Annales Geophysicae (2002) 20: 599–607 © European Geophysical Society 2002

Jovicentric latitude effect on the HOM radio emission observed by Ulysses/URAP at 5 AU from Jupiter

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Received: 2 July 2001 – Revised: 14 January 2002 – Accepted: 23 January 2002

Abstract. During 1994 and into 1996, Ulysses was at distances of 5 AU or more from Jupiter and travelling from south to north of the ecliptic plane between jovicentric latitudes −36° to 20°. Observations by the Unified Radio and Plasma Experiment (URAP) on board the Ulysses spacecraft during this period have been searched for jovian hectometric (HOM) radio events. At these distances, the HOM was only received occasionally. The signals were generally weak and much care was needed to find and to identify the events.

All of the HOM events were observed when Ulysses was at jovicentric latitudes between $-12.2^\circ \leq D_{Uly} \leq 14.7^\circ$, relatively close to the plane of the jovicentric equator. Both senses of polarization were observed with left-hand (LH) predominant. The events occurred when the *jovimagnetic* latitude D_ϕ was between −8.5° and 14.2° and suggest that the HOM was only detectable within a beam some 23° wide, centred on about 3° jovimagnetic latitude. This is roughly consistent with previous work by Alexander et al. (1979) and by Ladreiter and Leblanc (1989, 1991), based upon observations made by Voyager and other spacecraft when these were relatively close to Jupiter. The results are consistent with an emission process due to the Cyclotron-Maser instability, as suggested by a number of scientists in the past.

Key words. Magnetospheric physics (planetary magnetospheres) – Radio science (radio astronomy)

1 Introduction

Observations by the Radio Astronomy Explorer (RAE-1) and the Interplanetary Monitoring Platform 6 (IMP 6) gave the first indications of jovian radio emission at frequencies close to 1 MHz (Brown, 1974; Desch and Carr, 1974; Kaiser, 1977). The Voyager Planetary Radio Astronomy (PRA) experiment established the existence of four main components in the low-frequency radio spectrum of Jupiter; three components were distinguished at frequencies below the critical frequency of the Earth's ionosphere, in addition to the decametre-wave radiation (DAM), already well-known from almost thirty years of systematic ground-based observations. The low-frequency components were classified as a hectometre-wave component (HOM) and two kilometre-wave components, a narrow-band emission (nKOM) and a broad-band emission (bKOM). The characteristics of each of these components have been reviewed by Alexander et al. (1981), Boischot et al. (1981), Carr et al. (1983), Kaiser and Desch (1984), Leblanc and Daigne (1985), Boischot (1988) and Leblanc (1988).

The present paper is concerned with observations of the HOM made by the Ulysses Unified Radio and Plasma (URAP) experiment (Stone et al., 1992a), during 1994 and into 1996, when Ulysses was at distances of 5 AU or more from Jupiter and travelling from south to north of the ecliptic plane between jovicentric latitudes −36° to 20°. In a previous paper (Barrow et al., 2001; hitherto called "Paper 1"), it was found that the polarization of the bKOM, observed during the same period, depends upon the jovicentric latitude D_{Uly} of the observer at the time of the observation, although the actual emission could be observed from any latitude. For the HOM, the polarization and also the visibility are found to depend upon D_{Uly}, but in a completely different manner from the bKOM.

2 Ulysses antennas and receivers

The receivers cover two bands, from 1.25 to 48.5 kHz (lo-band) and from 52 to 940 kHz (hi-band). In this paper, we are only concerned with hi-band which operates in 12 channels, approximately logarithmically spaced, each frequency being determined by one of twelve crystal local oscillators. The intermediate frequency (IF) amplifier frequency is 10.7 MHz, the dynamic range is about 70 dB and the bandwidth is 3 kHz. URAP uses a complex frequency sweep in the high band that is optimized for type III bursts. The frequencies sampled

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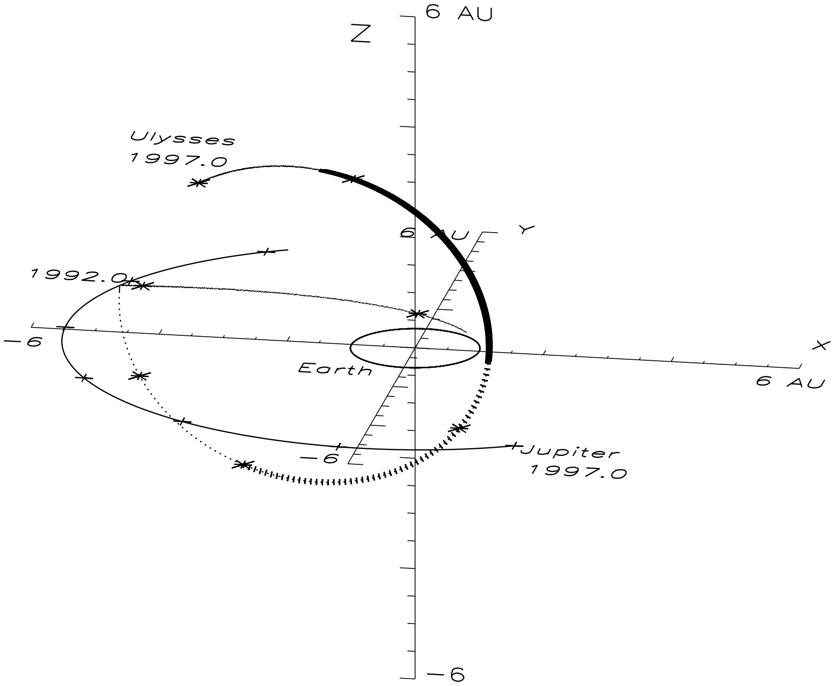

Fig. 1. Trajectories of Ulysses and Jupiter. The heavy line represents the trajectory of Ulysses during the period of the observations.

most often are 940 and 740 kHz, which are sampled, on average, 8 times per spin at 0.25 s per sample when in high bit rate (1024 bps). The spin period is approximately 12 s. This yields an "integration" time of 24 s for these data averaged over 144 s intervals. The receivers are connected to a 72 m wire antenna perpendicular to the spacecraft spin axis and to a 7.5 m monopole antenna along the spin axis. The spacecraft and the antenna system spin with a 12 s period. The inputs from the antennas can be combined to synthesize an equivalent dipole tilted with respect to the spin axis. By combining the inputs with suitable phase differences, the polarization of the incoming waves can be determined (Manning and Fainberg, 1980; Stone et al., 1992b). Polarization can only be calculated when the receiver inputs are combined in summation mode (SUM) and when the spacecraft data telemetry rate is high (1024 bps). The sensitivity, when used in separation mode (Stone et al., 1992a), is about $S_{\min} \simeq 5 \text{ x } 10^4$ Jy at 100 kHz. In the summation mode, for polarization measurements, the sensitivity is down by about 10 dB. Polarization measurements of the radiation have been used to improve existing knowledge of the source location and the beaming characteristics of the HOM.

3 Observations

In Paper 1, URAP observations were examined for the period 1 January 1994 to 29 February 1996 (940101 to 960229, a total of 790 days). During this period, Ulysses was at distances of about 4.7 to 7.2 AU from Jupiter and travelling from south to north of the ecliptic plane, as shown in Fig. 1, the jovicentric latitude of the spacecraft changing from about $-36°$ to $20°$. During this same period and, generally consistent with previous work (Alexander, et al., 1979; Ladreiter and Leblanc, 1989; Barrow and Lecacheux, 1995), it was found that the HOM could not be seen from jovicentric latitudes much farther from the jovicentric equatorial plane, than about $-12.2°$ and $14.7°$, corresponding to a range of *jovimagnetic* latitudes between about $-8.5°$ and $14.2°$. These and other parameters in the paper have been taken from the NASA SEDR file (a sort of "Mission Ephemeris"). The hourly values of jovimagnetic latitude used here have been extrapolated from the 3-hourly values in the SEDR file. The HOM was only received occasionally and the number of events suitable for study was further limited by the considerations outlined in the following two paragraphs.

At distances greater than 5 AU, the problem of finding and identifying the HOM requires much care. In general, the procedure was similar to that described in more detail in Paper 1 for the bKOM, with the exception that the HOM is more easily distinguished from auroral kilometric radiation (AKR) than the bKOM because the characteristic frequency range of the HOM is about 350 kHz to over 1 MHz, as compared to about 50 to 700 kHz for the AKR (Hilgers and de Feraudy, 1992).

We recall that, immediately after the Jupiter encounter in 1992 when Ulysses was at an extreme southerly jovicentric latitude ($D_{Uly} \simeq -38°$), Barrow and Lecacheux (1995) found that, out as far as $2000 R_J$, no emission of any kind was present at frequencies above about 400 kHz. As the characteristic frequency range of the HOM is from about 400 kHz up to a few MHz, the events reported here, when they eventually appeared as Ulysses moved into more northerly jovicentric declinations, were identified from the characteristics shown by the three highest frequency channels of the URAP

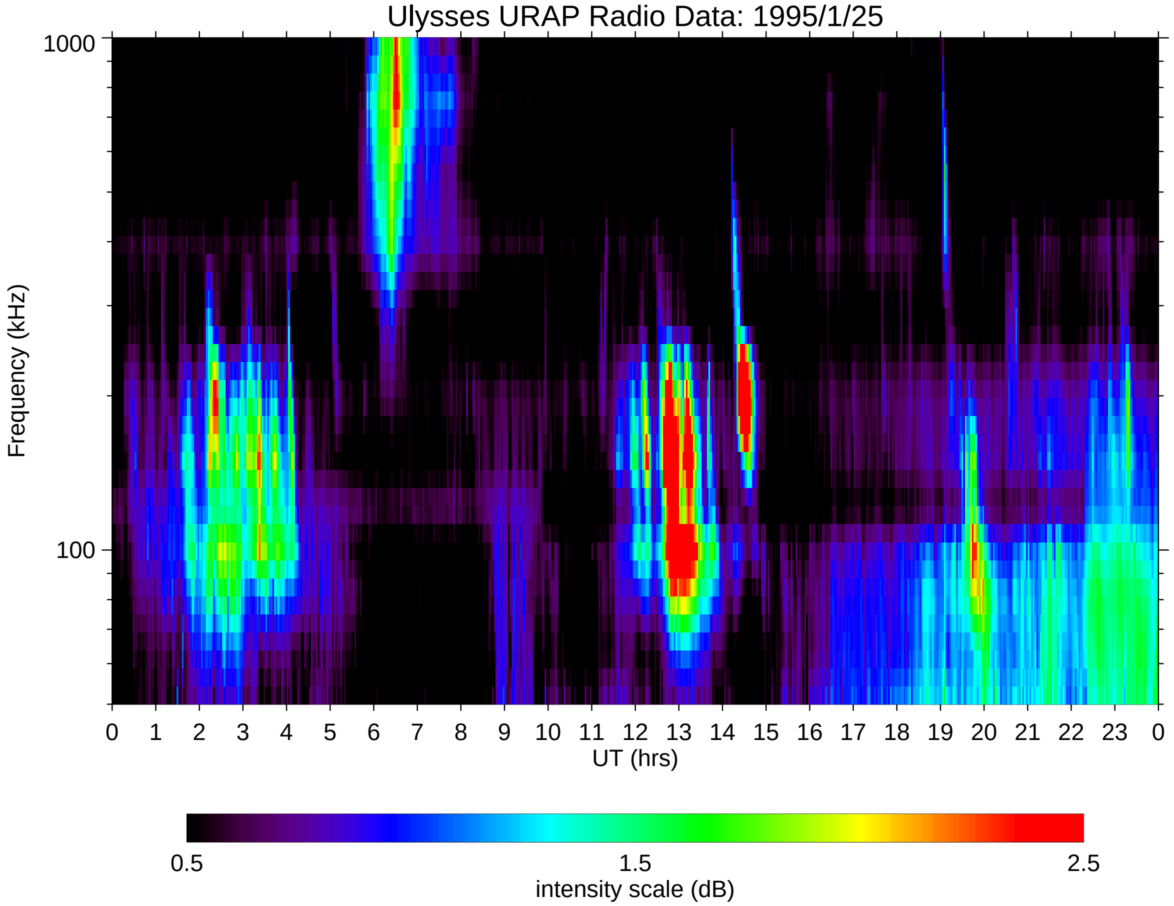

Fig. 2. Ulysses/URAP hi-band spectrum for 950125 (DOY 94390).

hi-band receiver, 540, 740 and 940 kHz. It is possible, however, that some very weak HOM events may have occurred at the lowest frequencies and passed unnoticed. We have only considered HOM events for which polarization data are available and which could be identified with a good degree of certainty. 58 HOM events, recorded over 37 days, eventually met these criteria.

Event occurrence times were measured from the spectra and from single frequency intensity-time plots. The maximum estimated uncertainty was about ±5 min or ±3° of CML. System III Central Meridian Longitudes (CML) for Ulysses are taken from the NASA SEDR file and corrected for the light-travel time from Jupiter to the spacecraft.

Typical spectra, taken on 950125 (DOY 94390) when $D_{Uly} = -11.7°$, are shown in Figs. 2 and 3 where an HOM event can be seen to start close to 06:00 UT. The URAP hi-band spectrum is shown in Fig. 2 where the time resolution is 144 s. The background and the sensitivity of these spectra could be adjusted easily, and the time scale for the spectra and the single frequency cuts from them could be expanded; this proved to be essential for finding and identifying the HOM events. In hi-band, the data at each frequency are collected for 12 s, approximately equal to the spacecraft spin period; these are averaged together and so spin-modulation should not be present in these data. Some of the typical structure of the HOM may have been smoothed out by the effects of temporal broadening due to scattering over the distance travelled by the radiation through the interplanetary medium (Barrow et al., 1999).

The polarization is represented as a spectrum of the degree of circular polarization m_c, shown in the second panel of Fig. 3. The total intensity $I_L + I_R$ measured by URAP is presented in the top panel. Then, m_c is given by

$$m_c = \frac{I_L - I_R}{I_L + I_R}, \tag{1}$$

where I_L and I_R are, respectively, the LH and RH polarized intensities.

In the third panel, the azimuth, with respect to the direction of the Sun, gave an additional identification criterion and, in particular, distinguished jovian emission from possible saturnian (SKR) emission (Lecacheux and Aubier, 1997). The position of each planet is indicated by the letters “J” or “S” adjacent to the colour scale. The modulation index, shown in the fourth panel, is essentially an indication of the certainty of identification. The numbers above the top panel represent the rotation number of Jupiter, taken as zero on 1 January 1982, and the CML, corrected for light-travel time from Jupiter to Ulysses.

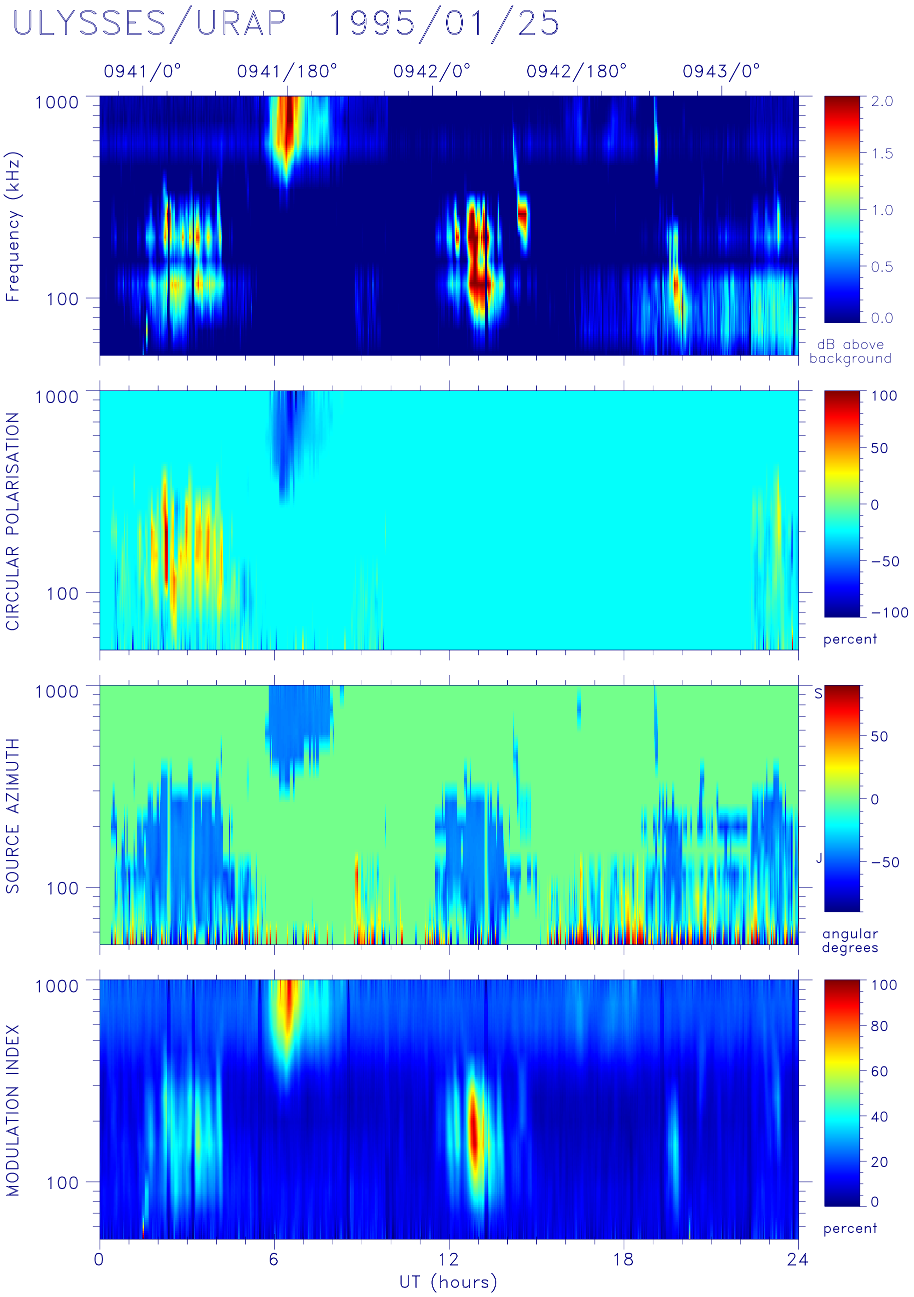

Fig. 3. Ulysses/URAP hi-band spectra for 950125 (DOY 94390). The four panels, from top to bottom, show spectra of total intensity, degree of polarization, azimuth of the direction of origin of the emission with respect to the direction of the Sun and modulation index. The numbers along the top of the first spectrum give the jovian rotation number (zero on 820101) and CML values, corrected for the light-travel time from Jupiter to the spacecraft. The HOM event beginning close to 06:00 UT is RH, while a bKOM event beginning at about 01:00 UT is LH.

It can be seen that an HOM event was observed by Ulysses to begin close to 06:00 UT (CML $\simeq$ 156°). This event was RH polarized (i.e. $m_c < 0$; the emission originated in the northern hemisphere of Jupiter). Other periods of jovian activity can be seen at lower frequencies, the first of which is LH polarized. There is no polarization data available subsequent to about 07:00 UT. The azimuth spectrum indicates that all of this activity originated from the direction of Jupiter.

Scattering effects in the interplanetary medium (Barrow et al., 1999) will cause Faraday rotation in the jovian emission. This will tend to depolarize linearly polarized radiation, but will only cause phase differences in circularly polarized radiation. Thus, the actual sense of polarization of the HOM will not be changed by scattering (Woan, 1997, 1999).

All of the 37 days when the 58 HOM events were observed by Ulysses are shown in Fig. 4a, where it can be seen that, during the period studied (940101 to 960229), the HOM events were only observed when the spacecraft was in jovicentric latitudes between $-12.2° \le D_{Uly} \le 14.7°$, relatively close to the plane of the jovicentric equator. Both senses of polarization were observed with left-hand (LH) predominant. Oppositely polarized events occurring at different times on the same day can, of course, be shown separately in jovimagnetic latitude, but not in jovcentric latitude, which does not change appreciably during a day. In Fig. 4b, the same events are plotted against the jovimagnetic latitude of Ulysses at the

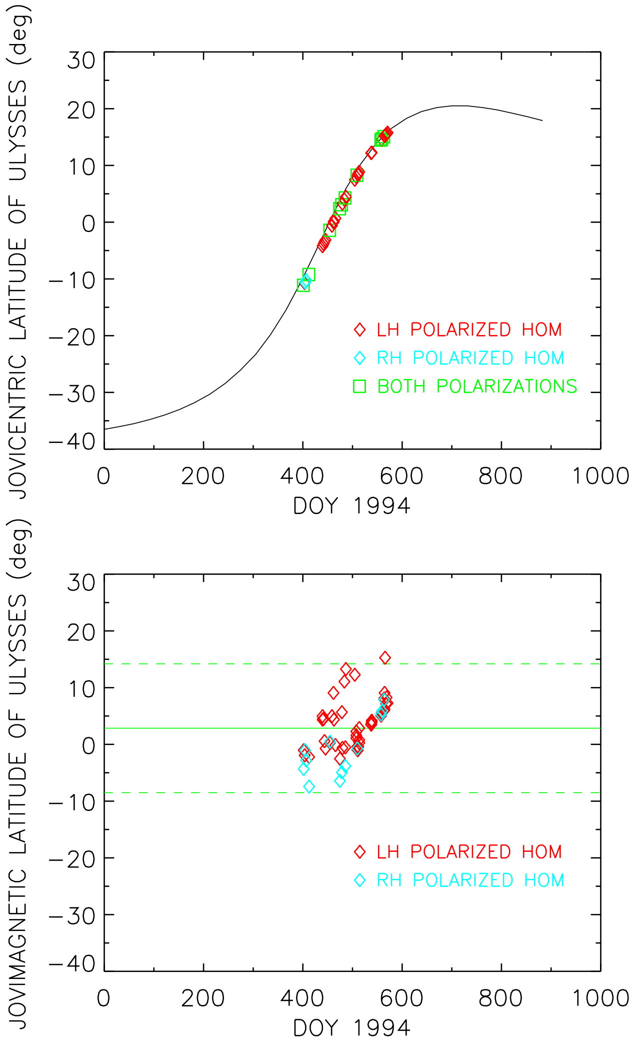

Fig. 4. Days on which HOM events were observed by Ulysses, during the period 940101 to 960229 (DOY 94001 to 94790), against **(a)** jovicentric latitude and **(b)** jovimagnetic latitude of the spacecraft.

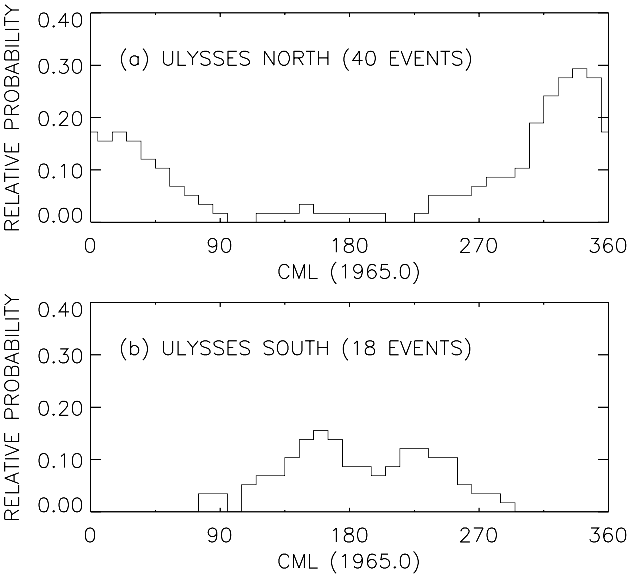

Fig. 5. Relative occurrence probability of the HOM observed when the Ulysses was **(a)** north of the jovicentric equatorial plane and **(b)** south of the jovicentric equatorial plane.

nearest hour to the event time; these show a narrower spread in jovimagnetic latitude than in jovicentric latitude due to beaming. Of the 12 RH periods of activity only two occurred without associated LH emission, either immediately before or after the RH emission. It can be seen that all of the events were observed when the spacecraft was within a band of jovimagnetic latitude between −8.5° and 14.2°, centred on about 3°. This is the same centre jovimagnetic latitude as that found by Alexander et al. (1979) and by Ladreiter and Leblanc (1989, 1991), although the emission beam is wider.

Relative occurrence probabilities for observations made when Ulysses was north and south of the jovicentric equatorial plane are shown in Figs. 5a and 5b, respectively. The histograms are for 10° intervals of CML (rotation), corresponding to about 16.5 minutes of time. Most events last longer than this, however, and can, therefore, appear in more than one time bin. Although the occurrence probabilities are lower due to the greater distance of Ulysses from Jupiter, the distributions show some similarity to those found previously by Alexander et al. (1979), shown in Fig. 6, for observations made from jovicentric latitudes $-3.2^\circ \leq D_{s/c} \leq 6.5^\circ$. In their observations made from northerly (positive) jovicentric latitudes, there is a null centred on about 180°, while for observations made from southerly (negative) jovicentric latitudes there is a single peak centred on about 160°. The occurrence probability profiles shown in Figs. 5a and 5b seem to follow this trend *in jovicentric latitude* and suggest that it continues out to the jovicentric latitudes of Ulysses in the present observations. The pre- and post-encounter Voyager observations studied by Ladreiter and Leblanc (1989) did not include observations made from south of the jovicentric equatorial plane and so they could not show this effect.

Occurrence probabilities for RH and LH polarized emission are shown in Figs. 7a and 7b, respectively. The occurrence probabilities for the HOM, shown in Figs. 5 and 7, appear to be differently distributed, while for the bKOM (Paper 1) the distributions were the same, with LH/RH polarization being seen when Ulysses was south/north of the jovicentric equator.

4 Discussion

A number of workers have suggested that the HOM emission process is due to the Cyclotron-Maser instability (CMI) with dominant emission in the R-X mode (see, for example, Ladreiter et al. (1994) and the references therein). The emission is beamed into a radiation pattern in the form of a wide-angled, thin-walled hollow cone with apex at the source and axis tangent to the magnetic field direction. Propagation is in the R-X mode at frequencies equal to or just above the local

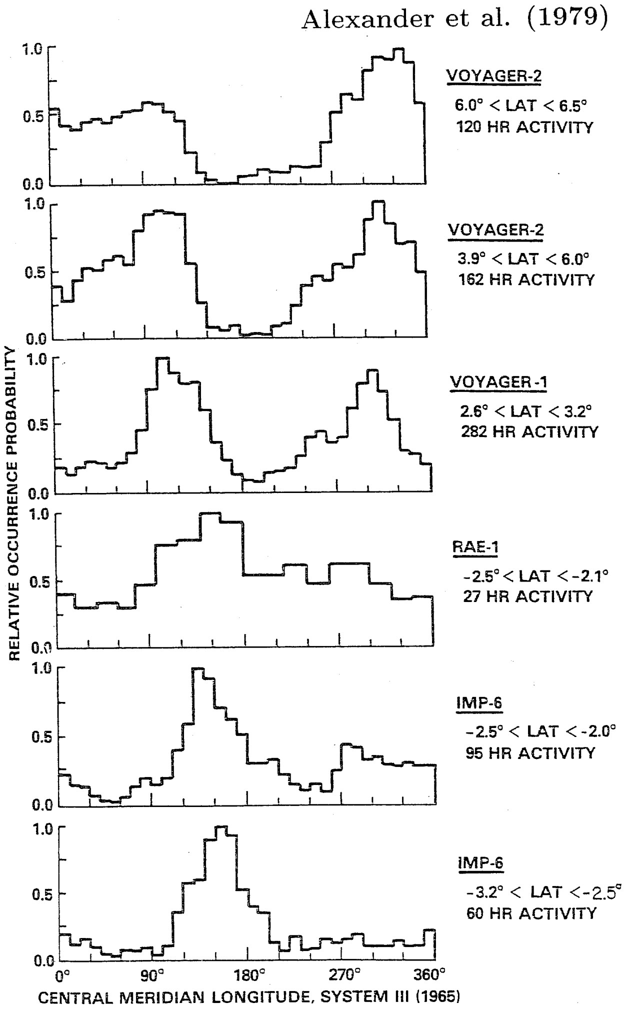

Fig. 6. Relative occurrence probability of the HOM for the range of jovicentric latitudes −3.2° to 6.5° (from Alexander et al., 1979).

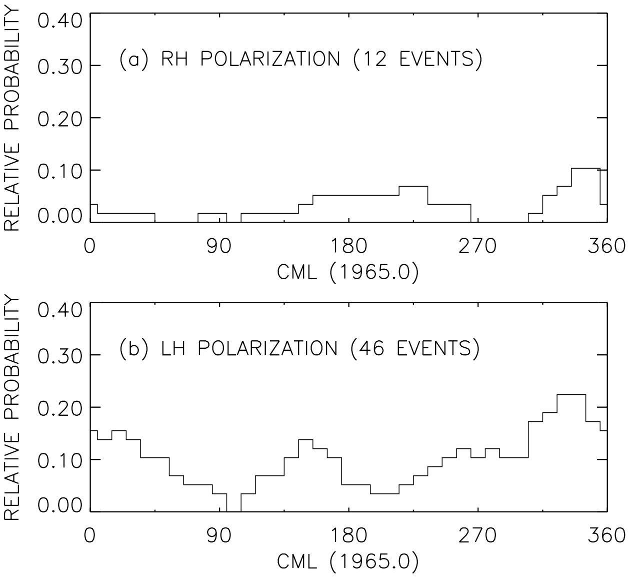

Fig. 7. Relative occurrence probability of the HOM observed by Ulysses for **(a)** RH polarization and **(b)** LH polarization.

gyrofrequency f_c. An event is seen as a continuous emission due to radiation from the edges of a succession of CMI cones, distributed over a range of CMLs and rotating with the planet.

The HOM source has been found to lie on some L-shell between 7 and 11, by Ladreiter et al. (1994), and between 8 and 10 by Zarka et al. (2001). Reiner et al. (1993a, b), however, using direction finding and URAP data for four events taken during the Jupiter encounter, have found the HOM source to lie on L-shells 4 to 6. According to Ladreiter et al. (1994), the difference between their results and those of Reiner et al. (1993a) is due to the inclusion by Reiner et al. of the URAP Z-antenna response in the direction finding. This can lead to ambiguities as the Z-signal modulation pattern due to spacecraft spin is not that of a simple monopole. Also, Reiner et al. (1993a, b) did not consider systematic errors due to uncertainties in the antenna calibration parameters. In the discussion that follows, we will assume that the HOM is generated from tilted dipole field lines close to L=9.

Beaming can be represented by the two-dimensional geometry of the electron cyclotron frequency surface superimposed upon a dipolar jovian magnetic field, as sketched in Fig. 8, where the shaded area represents the range of jovimagnetic latitudes (−8.5° to 14.2°) over which the HOM was observed. The point S represents an HOM source (i.e. the apex of an emission cone) in the southern magnetic hemisphere and the northern edge of the cone is directed towards the spacecraft when it is in a northerly magnetic latitude.

A two-dimensional model has been used by a number of other workers in the past (Ladreiter and Leblanc, 1990; Reiner et al., 1993a; Barrow and Lecacheux, 1995). This is also suitable for our purposes here as the HOM event durations measured for this paper were generally shorter than those measured closer to Jupiter and imply that the observed emission originated from close to the top or the bottom of the emission cone; this would require the source to be oriented close to the Jupiter-Ulysses meridian. A three-dimensional model would be ideal, but we do not know where the source would be in CML and the problem is further complicated by the time variability of the emission.

It is shown in Paper 1 that, if S lies on some specific L-shell, then for a given gyrofrequency f_c at S,

$$\beta = \phi - \alpha \pm \delta, \qquad (2)$$

where δ is the magnetic latitude of the spacecraft, β is the emission cone half-angle, ϕ is the magnitude of the jovimagnetic latitude of the source S and α is the angle between the field line and OS at the point S. The geometry is the same for both hemispheres but, in Eq. (2), the positive/negative sign of δ refers to the spacecraft on the opposite/same side of the magnetic equator as the source.

It follows from Eq. (2) that, in the two-dimensional model, the detection of HOM at a given frequency f_c by a spacecraft at a given location specified by δ, determines a unique value

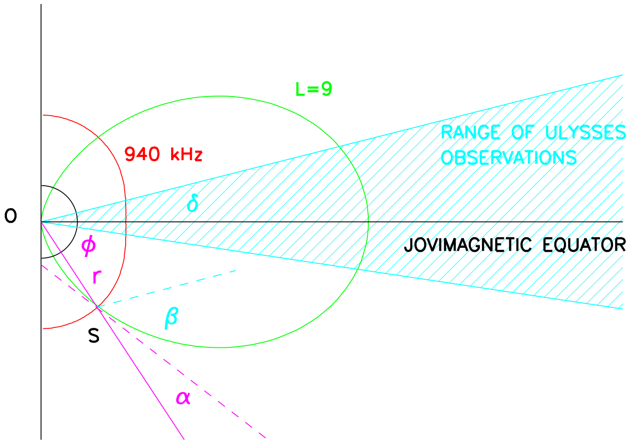

Fig. 8. Two-dimensional beaming geometry for HOM emission in a dipole magnetic field from a source on L-shell $\simeq$ 9 close to the f_c = 940 kHz surface. The shaded area represents the emission beam of the HOM within the jovimagnetic latitudes −8.5° and 14.2° where the HOM was observed.

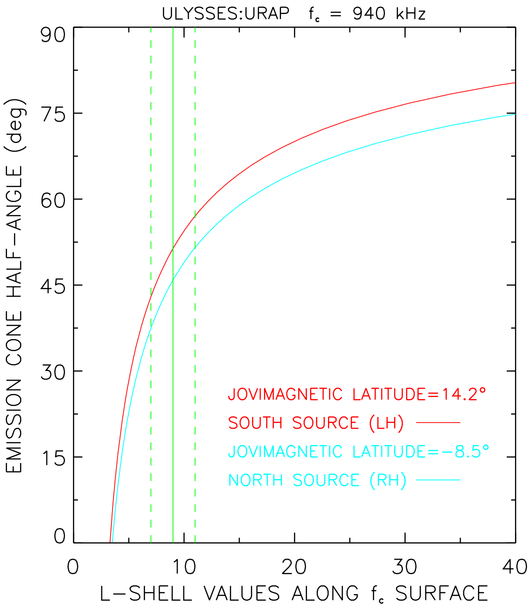

Fig. 9. Calculated values of emission cone half-angle β against L-shell for an assumed dipole magnetic field and an emission frequency of 940 kHz. The jovimagnetic latitudes −8.5° and 14.2° are the limiting values within which the HOM was observed. The solid green line represents L = 9. Dashed lines represent L = 7 and L = 11.

of β for an assumed value of L and a given field model. This is not true for the three-dimensional model.

The durations of many of the HOM events considered here and shown in Fig. 4 were relatively short, often less than an hour, considerably less than typical durations observed closer to the planet (see, for example, Barrow and Lecacheux, 1995; their Fig. 3). On the other hand, an occasional event, like that shown in Figs. 2 and 3, lasted somewhat longer.

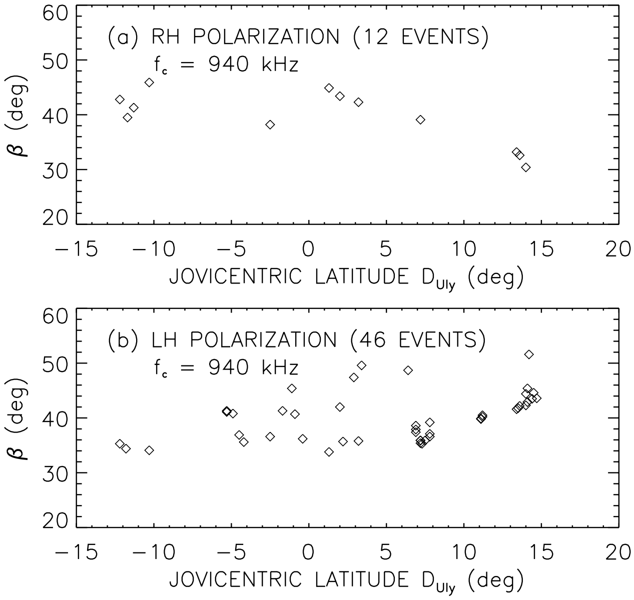

Fig. 10. Calculated values of emission cone half-angle β, for the events represented in Fig. 4, against jovicentric latitude for **(a)** the northern jovimagnetic hemisphere source (RH), and **(b)** the southern jovimagnetic hemisphere source (LH). A dipole magnetic field is assumed and an emission frequency of 940 kHz from a source on L-shell $\simeq$ 9.

As Jupiter rotates, an observer sees the event as an emission from a succession of CMI cones distributed over a range of CMLs. As the cone half-angles have, in general, been found by various workers to be large, estimates ranging from 30° to 90° (Ladreiter et al., 1994) and, as Jupiter rotates at a rate of about 36°/h, an event might be expected to last for some two or three hours, as seen in observations close to Jupiter. The shorter duration events seen here may be simply an effect of reduced flux density due to the large distance of the spacecraft from Jupiter, but it is also possible that they may be due to emission from sectors of the extreme northern or southern edges of the CMI cones when the source is approximately on the Jupiter-Ulysses meridian or from just a few cone edges if the source is turned away from Ulysses.

In Fig. 8, we have shown the two-dimensional geometry (i.e. when the emission cone is facing Ulysses) of the beaming, taking the source to be on L = 9 where this field line cuts the f_c = 940 kHz surface, the highest URAP frequency which has always been active during the HOM events. This source would be at a jovimagnetic latitude of about 56° south and at a distance of some 2.8R_J from the planet. Some of the HOM would have to pass through the torus to reach Ulysses but, as the maximum electron density in the torus corresponds to a plasma frequency of about 500 kHz, refraction effects in the torus should be small.

In Fig. 9, we show the variation of β for the north and south limits of observation of the HOM shown in Fig. 8, with L=9 and f_c = 940 kHz. In Fig. 10, we plot the values of β calculated for the events shown in Fig. 4, again assuming values of f_c = 940 kHz and L = 9 in a two-dimensional model, (a) for RH events and (b) for LH events. These values of β lie between about 30° and 46° for the RH events and between about 34° and 52° for the LH events as compared, respectively, to $\beta \sim 46°$ and $\beta \sim 51°$ for L = 9 (represented by the solid green line) in Fig. 9. Figures 9 and 10 demonstrate the implication of Eq. (2), that there can be no unique value for β that does not involve assumed values of L and f_c.

We have seen in Fig. 4 that the HOM emission is confined to specific ranges of jovicentric and jovimagnetic latitude, $-12.2° \leq D_{Uly} \leq 14.7°$ and $-8.5° \leq D_\phi \leq 14.2°$, respectively. The jovimagnetic latitude range is centred on 3°, in good agreement with the findings of Alexander et al. (1979) for Voyager PRA and other data. The results are also consistent with the conclusion of Ladreiter and Leblanc (1991) that the overall emission beam appears to be wider in jovimagnetic latitude if weaker HOM events are considered. The values of the emission cone angle β, calculated assuming a two-dimensional model and shown in Fig. 10, are within the range of likely values given by Ladreiter et al. (1994) and compatible with previous work. Unlike the bKOM (Paper 1), although LH polarization predominates, there is no jovicentric or jovimagnetic latitude within the range of latitudes where the HOM is detected that is particularly favourable to one sense of polarization or the other.

The two-dimensional geometry shown in Fig. 8 and all of the foregoing discussion assumes that the HOM source is radiating from the face of Jupiter directed towards Ulysses. This may not be the case because the locii of the intersections of L and f_c are circles around the planet, one to the north and one to the south of the jovimagnetic equator. In the direction finding analysis presented by Ladreiter et al. (1994), it is implicit that large-angle emission cones must point away from Ulysses, i.e. be close to the limb of the planet with respect to Ulysses, if their edges are to radiate in the direction of the spacecraft.

If the cone angles are fairly large, there should be configurations where HOM originating in one hemisphere of Jupiter could have been received by Ulysses when the spacecraft was in the opposite hemisphere; this appears to have taken place as can be seen in Fig. 4 and in contrast to the bKOM (Paper 1).

Thus, it seems that the present observations do not contradict previous work on the HOM and may be taken as further support for the CMI theory of emission.

5 Conclusion

We have studied the HOM radio emission from Jupiter observed by the URAP experiment on board Ulysses during the period 940 101 to 960 229, when the spacecraft was passing from south to north of the jovian equatorial plane at distances ranging from 4.7 to 7.2 AU. It is found that the HOM events were only observed when Ulysses was within the jovicentric latitude range $-12.2° \leq D_{Uly} \leq 14.7°$. The corresponding jovimagnetic latitude range was $-8.5° \leq D_\phi \leq 14.2°$, indicating an emission beam about 23° wide centred on jovimagnetic latitude 3°, consistent with earlier work, notably that of Alexander et al. (1979) using observations made by the PRA experiment on board Voyager compared with observations by RAE-1 and IMP-6.

Occurrence probabilities were lower than those found by Alexander at al. (1979), although the distributions seem to continue the trend that they found, as shown in Fig. 6. Unlike the bKOM (Paper 1), the LH and RH polarized HOM occurrence probabilities shown in Fig. 7 were differently distributed to those in Fig. 5, perhaps because the HOM polarization does not appear to be latitude dependent.

We have shown that, in the two-dimensional model, the detection of HOM, at a given frequency f_c by a spacecraft at a given location specified by δ, determines a unique value of β for an assumed value of L and a given field model. This is not true for a three-dimensional model.

If the emission cones are assumed to be directed towards Ulysses, calculated values of β for all of the events reported here, assuming values of L = 9 and f_c = 940 kHz, are found to be within the range of about 30° to 52° and compatible with previous work by Ladreiter et al. (1994).

Observations at distances of 5 AU or more reveal important differences between the HOM reported here and the bKOM reported previously (Paper 1). These differences were presented briefly at the recent Planetary Radio Emissions IV Meeting (Barrow et al., 2001) and will be compared in more detail in the conference proceedings.

Acknowledgements. We thank G. Woan and P. Zarka for valuable discussions. URAP is the collaborative effort of the four institutions, NASA Goddard Space Flight Center, Observatoire de Paris-Meudon, Centre de Recherches en Physique de l'Environnement Terrestre et Planétaire and the University of Minnesota. C.H.B. is pleased to acknowledge support from Copernicus Gesellschaft e.V. during a one-month visit to the Observatoire de Paris-Meudon.

The Editor in Chief thanks G. Woan for his help in evaluating this paper.

References

Alexander, J. K., Desch, M. D., Kaiser, M. L., Thieman, J. R.: Latitudinal beaming of Jupiter's low-frequency radio emissions, J. Geophys. Res., 84, 5167–5174, 1979.

Alexander, J. K., Carr, T. D., Thieman, J. R., Schauble, J. J., and Riddle, A. C.: Synoptic observations of Jupiter's radio emissions: average statistical properties observed by Voyager, J. Geophys. Res., 86, 8529–8545, 1981.

Barrow, C. H. and Lecacheux, A.: Problems concerning the radio emission from Jupiter observed by Ulysses after encounter, Astron. Astrophys., 301, 903–913, 1995.

Barrow, C. H., Woan, G., and MacDowall, R. J.: Interplanetary scattering effects in the jovian bKOM radio emission observed by Ulysses, Astron. Astrophys., 344, 1001–1013, 1999.

Barrow, C. H., Lecacheux, A., and MacDowall, R. J.: Jovicentric latitude effect on the bKOM radio emission observed by Ulysses/URAP, Astron. Astrophys., 366, 343-350, 2001.

Barrow, C. H., Lecacheux, A., and MacDowall, R. J.: Polarization and beaming of the jovian bKOM and HOM observed at 5 AU from Jupiter by Ulysses/URAP, Radio Emissions from Planetary Magnetospheres IV, an international workshop held at Graz, Austria, April, 2001.

Boischot, A., Lecacheux, L., Kaiser, M. L., Desch, M. D., and Alexander, J. K.: Radio Jupiter after Voyager: an overview of planetary radio astronomy, J. Geophys. Res., 86, 8213–8226, 1981.

Boischot, A.: Radio Emissions from Planetary Magnetospheres II, Proceedings of an international workshop held at Graz, Austria, (Eds) Rucker, H. O., Bauer, S. J., and Pedersen, B. M., Verlag der Österreichischen Akademie der Wissenschaften, 15–39, 1988.

Brown, L. W.: Spectral behaviour of Jupiter near 1 MHz, Astrophys. J., 194, L, 159–162, 1974.

Carr, T. D., Desch, M. D., and Alexander, J. K.: Physics of the Jovian Magnetosphere, (Ed) Dessler, A. J., Cambridge University Press, Cambridge, 226–284, 1983.

Desch, M. D. and Carr, T. D.: Decametric and hectometric observation of Jupiter from the RAE-1 satellite, Astrophys. J., 194, L57–L59, 1974.

Hilgers, A., and de Feraudy, H.: Radio Emissions from Planetary Magnetospheres III, Proceedings of an international workshop held at Graz, Austria, (Eds) Rucker, H. O., Bauer, S. J., and Kaiser, M. L., Verlag der Österreichischen Akademie der Wissenschaften, 199–216, 1992.

Kaiser, M. L.: A low frequency radio survey of the planets with RAE-2, J. Geophys. Res., 82, 1256–1260, 1977.

Kaiser, M. L. and Desch, M. D.: Radio emissions from the planets Earth, Jupiter, and Saturn, Rev. Geophys., 22, 373–384, 1984.

Ladreiter, H. P. and Leblanc, Y.: Jovian hectometric radiation; beaming, source extension, and solar wind control, Astron. Astrophys., 226, 297–310, 1989.

Ladreiter, H. P. and Leblanc, Y.: Source location of the Jovian hectometric radiation via ray tracing technique. J. Geophys. Res., 95, 6423–6435, 1990.

Ladreiter, H. P. and Leblanc, Y.: The jovian hectometric radiation: an overview after the Voyager mission, Ann. Geophysicae, 9, 784–796, 1991.

Ladreiter, H. P., Zarka, P., and Lecacheux, A.: Direction finding study of jovian hectometric and broadband kilometric radio emissions: evidence for their auroral origin, Planet Space Sci., 42, 913–931, 1994.

Leblanc Y. and Daigne, G.: Broadband jovian kilometric radiation: New results on polarization and beaming, J. Geophys. Res., 90, 12 073–12 080, 1985.

Leblanc, Y.: Radio Emissions from Planetary Magnetospheres II, Proceedings of an international workshop held at Graz, Austria, (Eds) Rucker, H. O., Bauer, S. J., and Pedersen, B. M., Verlag der Österreichischen Akademie der Wissenschaften, 149–171, 1988.

Lecacheux, A. and Aubier, M. G.: Radio Emissions from Planetary Magnetospheres IV, Proceedings of an international workshop held at Graz, Austria, (Eds) Rucker, H. O., Bauer, S. J., and Lecacheux, A., Verlag der Österreichischen Akademie der Wissenschaften, 313–325, 1997.

Manning, R. and Fainberg, J.: A new method of measuring radio source parameters of a partially polarized distributed source from spacecraft observations, Space Sci. Instr., 5, 161, 1980.

Reiner, M. J., Fainberg, J., and Stone, R. G.: Source characteristics of jovian hectometric emissions from the northern jovian hemisphere. Geophys. Res. Lett., 20, 321–324, 1993a.

Reiner, M. J., Fainberg, J., and Stone, R. G.: Source characteristics of jovian hectometric emissions. J. Geophys. Res., 98, 18 767–18 777, 1993b.

Stone, R. G. et al. (31 co-authors): The unified radio and plasma wave investigation, Astron. Astrophys. Supp. Ser. 92, 291–316, 1992a.

Stone, R. G. et al. (25 co-authors): Ulysses radio and plasma wave observations in Jupiter environment, Sci. 257, 1524, 1992b.

Woan, G.: Very low frequency array on the lunar far side. ESA Report SCI(97)2, 25–26, 1997.

Woan, G.: Private communication, 1999.

Zarka, P., Queinnec, J., and Crary, F. J.: Low-frequency limit of jovian radio emissions and implications on source locations and Io plasma wake, Planet Space Sci., 49, 10/11, 1137–1149, 2001.