September 2009
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ISSN 1748-8117

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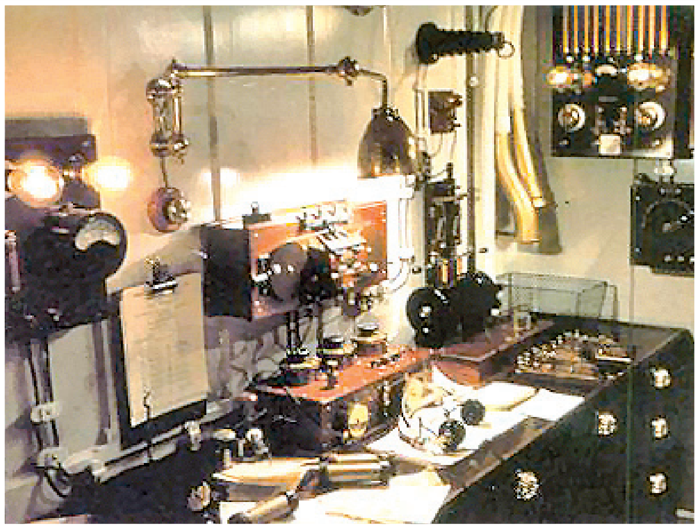
Listening to Jupiter's Radio Storms

Maritime Communications
A Brief History



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A basic radio astronomy project by Whitham D Reeve

Listening to Jupiter's Radio Storms Part 1

In response to feedback we've received from readers asking for a basic article on radio astronomy, Whitham D Reeve shows you how easy it is to pick up radio signals from Jupiter. The first part of this two-part article provides background information and describes the simple equipment you'll need.

Whitham D Reeve
Whitham Reeve was born in Anchorage, Alaska and has lived there his entire life. He became interested in electronics in 1959 and worked in the airline industry in the 1960s and 1970s as an avionics technician, engineer and manager responsible for the design, installation and maintenance of electronic equipment and systems in large airplanes. For the next 36 years he worked as an engineer in the telecommunications and electric utility industries with the last 31 years as owner and operator of Reeve Engineers, an Anchorage-based consulting engineering firm. He is a registered professional electrical engineer with BSEE and MEE degrees. He has written a number of books for practicing engineers and enjoys writing about technical subjects. Recently, he has been building a radio science observatory for studying electromagnetic phenomena associated with the Sun, the Earth and other planets.

Courtesy of NASA/JPL/USGS

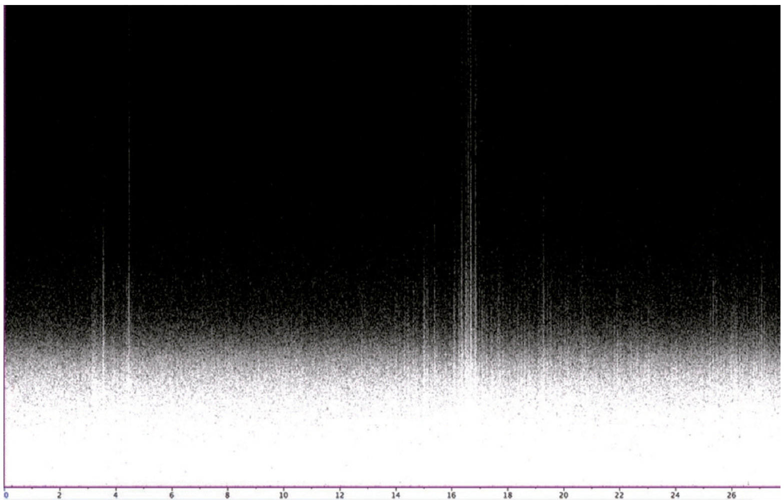
Moving at the speed of light, the signals take more than 30 minutes to travel about 590 million kilometres before they can be heard on Earth. They are so powerful that the regular HF receivers used by listening enthusiasts and amateur radio operators can detect them. They were first detected in 1950 but the observers at the time did not realise that they were unusual and it was not until 1955 that investigators determined their source. However, even though researchers have been studying them for almost 60 years, the methods by which they are generated are not yet fully understood. Such are the radio emissions, or radio storms, of Jupiter, the largest planet in the solar system and the fifth planet from the Sun.

In this article I will describe not only Jupiter and its emissions but also the radio setup that is required to monitor them, how to determine the best times to listen and how to recognise Jupiter's signals. I also provide some results and charts from my own observing sessions here in Anchorage, Alaska USA during spring 2009.

I wrote this article not as an expert (I am far from it) but as an observer who has had modest success. I have spent my entire 40-year professional career in communications trying to extract manmade signals from nature's interference. When I started observing Jupiter in early 2008, the challenge became extracting nature's signals from manmade interference. I think *RadioUser* readers would enjoy building a simple radio telescope and exploring another aspect of their hobby as much as I have.

Jovian Planet

Jupiter is the largest of the Jovian (also called gaseous or giant) planets that orbit the Sun beyond Mars. It has a diameter 11 times that of Earth (142,800km) but it spins on its axis much faster (9.9 hours for one revolution). Jupiter has 63 known satellites, or moons, and one thin ring but since is a gaseous planet, it does not have a solid surface like the Terrestrial planets (Mercury, Venus, Earth and Mars).



Thomas Ashcraft

Fig. 1: The spectrogram of Jupiter emissions recorded by Thomas Ashcraft in New Mexico on April 11th, 2009 at 1514 UTC over a span of 28 seconds.

Emissions

The frequencies of Jupiter's most intense radio emissions extend from around 50kHz up to 40MHz. However, the Earth's ionosphere reflects back into space frequencies below approximately 15MHz so we cannot detect them at the Earth's surface. That's why this article is concerned with emission frequencies in the range of 18 to 24MHz.

The signals have a broad bandwidth so you don't have to have a precisely tuned receiver to detect them. Many observers listen on **20.1MHz** because it is well above the ionospheric cut-off frequency and it is not where manmade transmission frequencies would interfere.

The emissions have been found to be strongly dependent on Jupiter's longitude. There are three longitude ranges where Jupiter emissions are more likely to be detected and they are known as A, B and C. It has also been found that emissions are strongly enhanced when Jupiter's moon, Io, is in certain orbital positions. These enhanced emissions are called Io-A, Io-B and Io-C. These Io-enhanced emissions are the ones we will usually receive with an amateur radio telescope.

Listening Season

For several months Jupiter had been hiding behind the Sun and invisible to radio telescopes, but on April 11th, the 2009 Jupiter listening season unofficially kicked off when **Spaceweather.com** reported reception of Jupiter's emissions by Thomas Ashcraft in New Mexico USA. His recorded spectrogram of Jupiter emissions is shown in **Fig. 1**. The vertical scale of the spectrogram is the receiver's audio output frequency and the horizontal scale is time in seconds. Emissions can be seen as the white vertical traces above the background noise at about 4 and 16 seconds. The whiteness of the traces indicates the signal strength. These were Io-B emissions.

This listening season is expected to last through to November 2009, after which Jupiter will once again become invisible behind the Sun for several months. Therefore, the coming months will be a great time to turn your existing short wave receiver and antenna into a radio telescope and start listening. If you get really interested, you could buy a complete kit tailor-made for Jupiter listening (described later). Even if you miss this season, another one will be here before you know it. In the meantime, you could use your radio telescope to listen to and record the Sun's radio emissions, but that is another subject for another article.

When to Listen

Several factors affect your ability to detect Jupiter's emissions. One factor is the condition of the Earth's ionosphere. The best time to listen is nighttime between around midnight and 7.00am because the ionosphere is less dense then and it will not reflect as much manmade and lightning noise toward the receiving station. This timeframe allows enough time after sunset and before the next sunrise for the Earth's ionosphere to dissipate and 'quieten down'. The transparency of the ionosphere is also related to the sunspot cycle and the Sun has been relatively quiet since the last cycle ended in late 2008. In fact, the Sun has been so quiet that I have been able to receive Jupiter emissions during the daytime, which is considered quite unusual.

Another factor is the relative positions of Jupiter and Earth in their orbits around the Sun. The Sun is a huge source of radio frequency interference. If Jupiter is behind the Sun or roughly in line with it when viewed from Earth, the Sun's interference will normally be much stronger than Jupiter's emissions and it will effectively blot them out at a receiving station.

Jupiter's position in the sky as seen by your antenna is another factor. Jupiter must be above the horizon at your location so that the Earth itself does not stop the emissions reaching your antenna. This latter requirement makes it somewhat difficult for observers in the northern latitudes because Jupiter might be too low for much of the listening season.

As mentioned above, Jupiter's radio emissions are likely to occur when Jupiter's moon, Io, is in particular positions. This causes the emissions to be directional and if the Earth is not in the beam of the emissions, they will not be detected here. The process is like a flashlight that must be beamed toward Earth before our antennas can 'see' it. Since the orbits of Jupiter, Io and Earth are well known, as are the locations of the sources on Jupiter that cause the emissions, it is possible to predict when radio emissions are likely to occur. However, since the emission sources vary in intensity and are not completely predictable, it is still possible that nothing will be received.

There are several online sources for these predictions, including the US National Aeronautics and Space

Administration (NASA) and the University of Florida Radio Observatory (UFRO). These websites provide prediction times in Coordinated Universal Time (UTC), which is equivalent to Greenwich Mean Time (GMT), and they can be used anywhere by simply converting UTC to your local time zone.

http://radiojove.gsfc.nasa.gov/observing/predictions.htm

www.astro.ufl.edu/juptables.html

An astronomy magazine website (for example, Astronomy or Sky & Telescope) can be used to determine if Jupiter will be in the daytime or nighttime sky and above or below the horizon at the predicted times.

www.astronomy.com

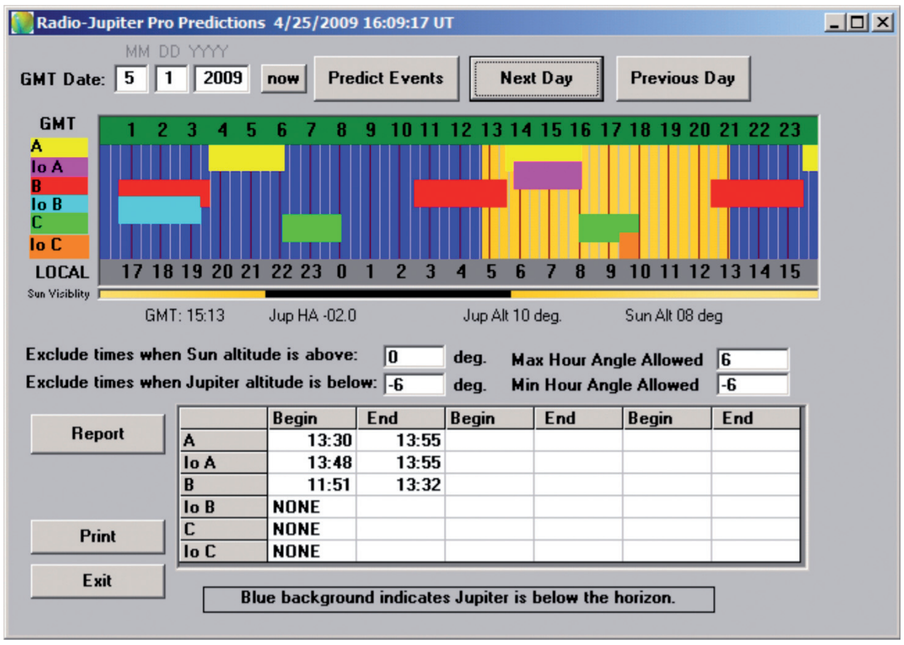
www.skyandtelescope.com

Other websites such Solar System Live allow you to visualise the orbital relationships of the planets.

www.fourmilab.ch/cgi-bin/Solar

If all the above makes you wonder if there is an easier way to determine the best observing times at a specific location, without converting time zones, looking through tabulated data and making corrections for latitude, there is. In fact, all that has been taken care of by Radio-Sky Publishing. Jim Sky has developed an amazingly easy-to-use and inexpensive software program called Radio-Jupiter Pro (**Figs. 2a & b**) that helps you determine the best listening times anywhere on Earth. It provides nice graphical views of the particular regions on Jupiter that have the highest likelihood of emission and the position of Jupiter in the sky at various times and it can be customised for your particular antenna installation and to predict the best listening times on any reasonable date in the past and future.

www.radiosky.com



	Begin	End	Begin	End	Begin	End
A	13:30	13:55				
Io A	13:48	13:55				
B	11:51	13:32				
Io B	NONE					
C	NONE					
Io C	NONE					

Fig. 2a: Radio Jupiter Pro prediction view. You enter the date and then use the Next Day and Previous Day buttons to step through a series of dates. The graphic shows when Jupiter's emission sources are oriented for reception on Earth. It also shows daylight and nighttime hours and when Jupiter is above and below the horizon according to the criteria you set immediately below the graph. The table at the bottom shows the best observing times.

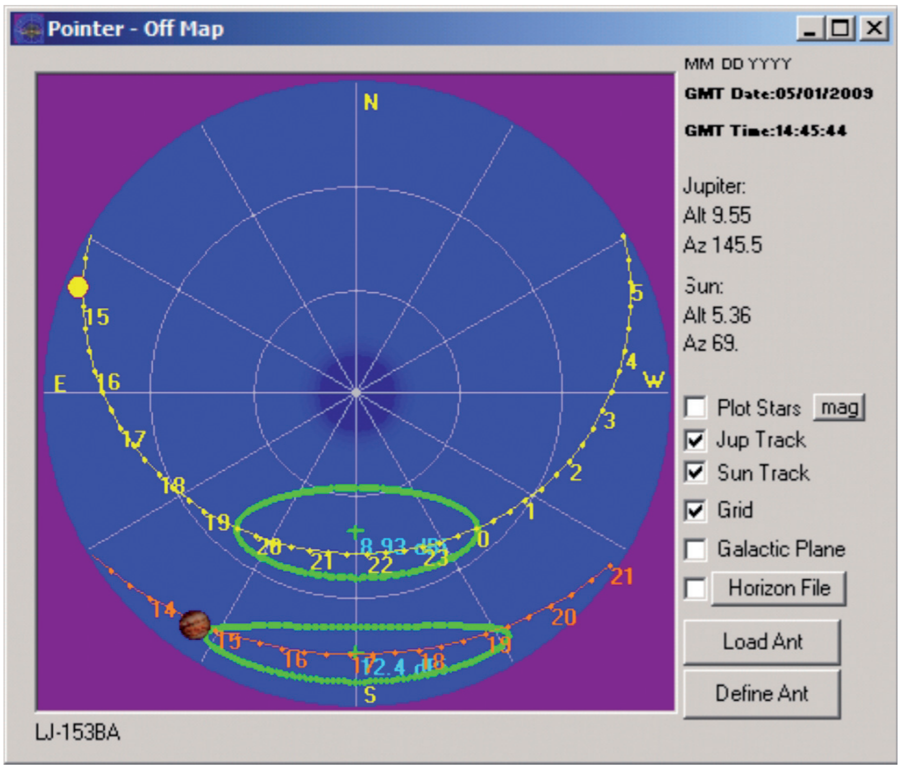


Fig. 2b: The pointer view shows the position of Jupiter in the sky as seen from your location (red line close to the bottom of the screenshot). It optionally can show the position of the Sun as well (yellow line). You can customise this view with the characteristics of your antenna. This screenshot show the two lobes of Whitham's 3-element Yagi antenna (green oblong lines in the lower-middle).

What to Listen For

One of the most common mistakes made by new Jupiter listeners is to assume that every pop, click, buzz and hiss heard on the receiver is from Jupiter (I speak from experience). Many signals do sound like Jupiter but it takes only a little practice to recognise the difference. Fortunately, many good recordings have been placed in NASA's Radio JOVE data archive and other websites (most are only a few seconds to a few minutes long). Once you know what Jupiter's emissions sound like, you will find it much easier to recognise them on your own receiver.

Sometimes Jupiter emissions are very weak so it is best to listen to your receiver in a very quiet room or with headphones. A technique that works well for me is to actively listen during the predicted times whilst also recording the audio. That way I can make a log entry of likely events in real time and then go back and listen to them again at my leisure. When predicted listening times are not convenient for me, I will set my software to record the audio and make a chart, which I can review when it is more convenient. A software program that I describe a little later allows you to make notations on its charting function or you can use any other type of log including a spreadsheet or old fashion paper (I use a combination of all of these).

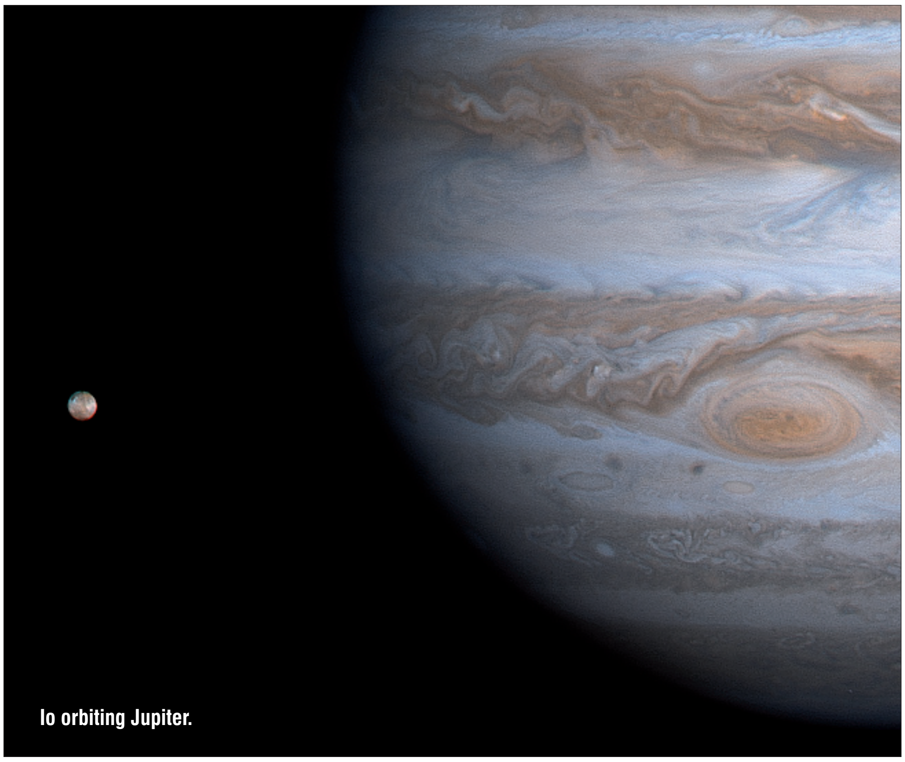
There are two types of signals and they have been categorised as L-bursts (long-bursts) and S-bursts (short-bursts), which indicate their relative time duration. L-bursts sound like ocean surf on a beach and can have a swishing sound whereas S-bursts sound like pebbles thrown on a tin roof, the snapping and popping of cooking popcorn or a kind of spitting sound. Each S-burst lasts for a few thousandths of a second and they can occur as often as several dozen times per second. Sometimes both types are heard together.

Getting Started

There are two basic ways to observe Jupiter emissions. The more obvious is to use your own receiver and antenna with a method of charting, recording and logging the results. The other method is to observe remotely on your own PC using a free software program that is specially designed for Jupiter listening. The former method allows you to have the most control over what you see and hear but requires the most equipment (receiver, antenna, PC and software). The latter only requires a PC, software and an Internet connection.

A disadvantage of remote monitoring and observing is the lack of receiver audio. Being able to listen and watch at the same time provides the highest chances of successful observations. However, it also is possible to listen with your own receiver while remotely monitoring someone else's chart at the same time. This is a good way of confirming your observations are really Jupiter emissions. Currently, I am working on streaming my receiver audio to the Internet to allow remote observers to watch and listen at the same time.

If you want to assemble your own system, the equipment requirements are modest. You will need a receiver capable of tuning around 20MHz – almost any general coverage receiver designed for short wave listening will usually cover this frequency. One thing the receiver should have is the ability to disable the Automatic Gain Control (AGC) function. AGC, which is also called Automatic Volume Control (AVC) on some receivers, is needed to smooth the audio volume for manmade communications when the radio signals vary due to propagation effects. However, the AGC is not desirable when listening for Jupiter emissions because you want to be able to hear the variations. Generally, higher quality general coverage receivers have a hardware or software switch to turn off or disable the AGC.


Io orbiting Jupiter.

Courtesy of NASA/JPL/University of Arizona

Radio JOVE

To help new as well as experienced listeners, NASA sponsors an educational project called Radio JOVE, originally started in 1998. The Radio JOVE website provides a wealth of information not only for students and teachers but for anyone interested in hearing Jupiter's emissions or learning about them.

http://radiojove.gsfc.nasa.gov/index.html

One of the great benefits of this program is collaborative observing. NASA regularly prearranges a toll-free (in the US) telephone number to a conference bridge so observers can discuss their observations and ask questions. Some calls are set up for general discussions and some calls are set up when observing conditions are predicted to be good. I have found both types of call sessions to be very helpful. To become a Radio JOVE Observer, go to the Joining In page on the website. Once signed up (it is free), you automatically receive notifications of the call sessions.

http://radiojove.gsfc.nasa.gov/joinin.htm

There also is a Yahoo Group that is dedicated to the Radio JOVE project. You can apply to join at this site.

http://tech.groups.yahoo.com/group/Radio_JOVE/

If you don't already have a suitable receiver, you can purchase a complete listening kit from NASA. It includes a receiver kit specially designed for the project (the Radio JOVE receiver designed by Richard Flagg), parts to assemble a dual-half-wave dipole antenna and a CD with software and educational materials. The antenna parts do not include the pipe supports but they can be obtained from almost any

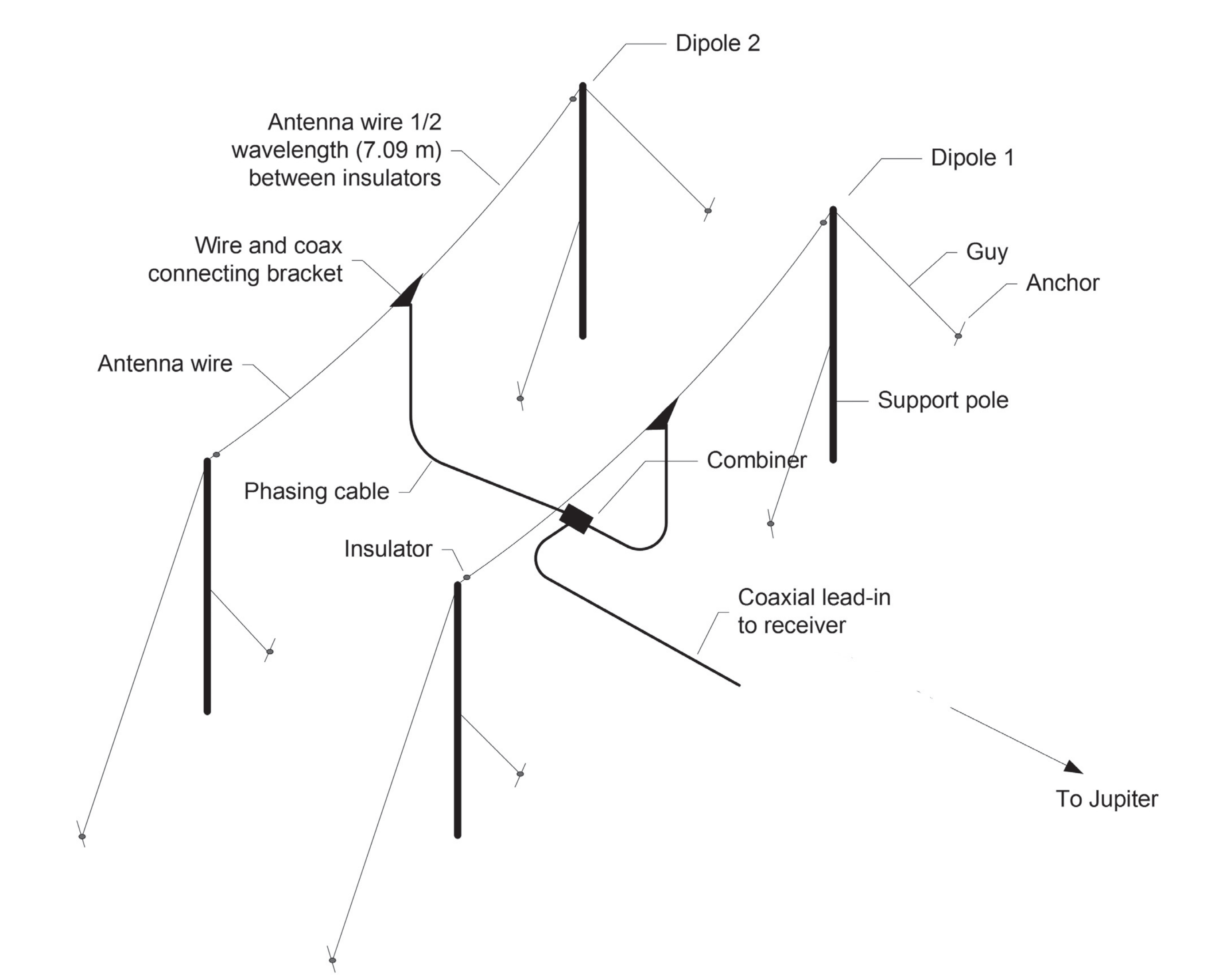


Fig. 3: The dual-dipole recommended for Jupiter listening. This antenna is easy to build from locally available parts or it can be ordered in kit form from NASA's Radio JOVE project.

hardware store. The complete kit costs US$190 plus shipping. You also can buy just the receiver kit alone. Built versions of the receiver or just the antenna parts and CD also are available.

If you already have a suitable high-frequency receiver and like do-it-yourself projects, you can simply download the free software and information. Included are detailed instructions on building an antenna using locally purchased materials. Even if you do not want to purchase a receiver or other components, you still can be a Radio JOVE observer by downloading the software and using it as a client to Radio JOVE servers around the world (including mine in Anchorage, Alaska).

Suitable Antennas

The most important component in any radio project is the antenna and the best antennas for detecting Jupiter emissions have some gain and directional characteristics.

Gain means that the antenna will receive more signal than a reference antenna with no gain. A gain of 4 to 10 times (6 to 10dB) above a half-wave dipole is fine.

Directional means that the antenna will receive more signal in certain directions than in others. A typical directional antenna receives more signals from the front than the back or the sides and this helps to reduce interference.

Some observers have had good results with random-length (untuned) long-wire antennas and a single half-wave dipole has worked fine for many others. However, for better results, the current recommended configuration is a dual-half-wave dipole with each dipole separated by about one-half wavelength (**Fig. 3**).

Many other types such as Yagi, log-periodic and Moxon antennas designed for the desired frequency range should also work well. A horizontal or vertical loop that is a full wavelength long (15m) will probably receive the more powerful emissions. Active antennas, with or without vertical whips, and active or passive small loop antennas are not recommended.

One important thing to remember is that directional antennas should be pointed in the direction of Jupiter as it transits the sky. For observers in the northern hemisphere and depending on the part of the listening season, this could be anywhere from east through south to west.

next month

In the concluding part of this article, Whitham Reeve describes how you can improve your chances of hearing Jupiter and how to record your observations, shows you his setup and what his results look like and then he recommends some additional reading.

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A basic radio astronomy project by Whitham D Reeve

Listening to Jupiter's Radio Storms Part 2

Last month, I showed you how easy it is to pick up radio signals from Jupiter, gave you some background information and described the simple equipment you'll need. This time I'll conclude by showing you my setup and offering some tips and suggesting some software and books that will help if you decide to try this fascinating aspect of radio monitoring.

Recording Your Observations

Dedicated listeners and even casual listeners like to keep logs, notes and recordings of the signals they receive. For Jupiter observing, logs are very important. A free program, developed by Jim Sky, called Radio-SkyPipe is the benchmark software used almost universally for logging and charting Jupiter's emissions. Radio-SkyPipe is included in the NASA kit or it can be downloaded from the Radio-Sky website. **http://radiosky.com/skypipeishere.html**

The program's main feature is charting (examples are provided later). The chart is driven by the PC's soundcard, which is connected to the receiver's audio output. However, the chart is not recording the audio itself. Instead, the chart periodically takes a sample of the audio and plots the sample amplitude on the vertical scale and time on the horizontal scale. The sample rate usually is one or two per second but it can be adjusted above or below this value. Sampling at too fast a rate generally does not improve the observations but it could overtax your PC. It is important to remember that charting alone is usually not sufficient for recognising Jupiter emissions. Many signals look the same on the chart and listening to the receiver audio is the only way you can differentiate.

Another very helpful feature of Radio-SkyPipe is a chat window that allows you to communicate in real time with other online observers, saving the cost of a possibly expensive telephone call. There are many more features available in Radio-SkyPipe but there is not enough space to describe them all here – you can find more details on their website.

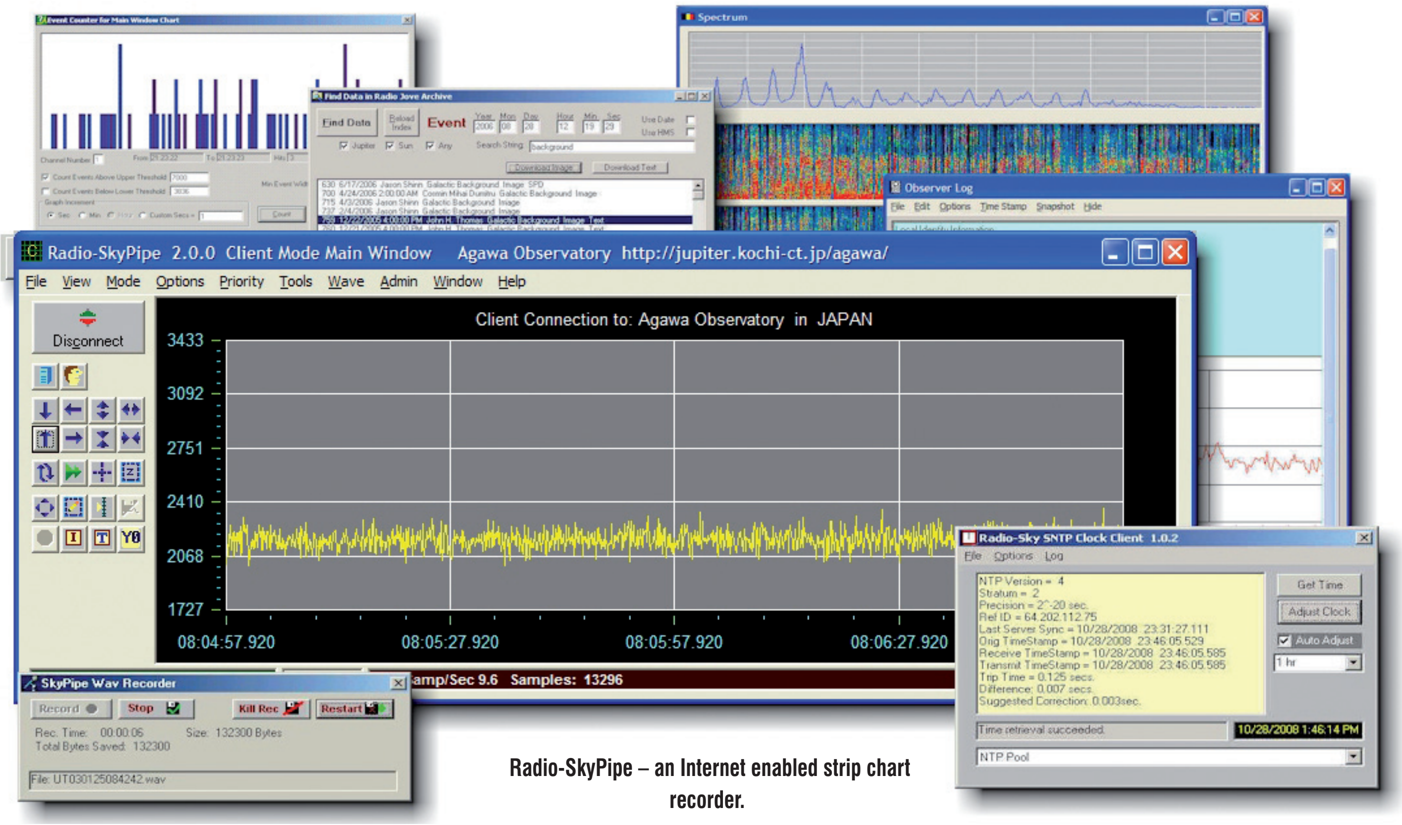
Jim Sky also has a modestly priced Radio-SkyPipe Pro version that has additional capabilities. The Pro version allows audio recording and can act as a server so that anyone with the free version can access the SkyPipe charts from any location. Of course, both the server and client locations must have Internet access and all versions of the program require a soundcard or an analogue-to-digital converter (data logger) to convert the receiver audio output to a format that can be charted and recorded.

I have found that written notes are indispensable for keeping track of real time observations and helping me organise and decipher my observations later. I have learned to not trust my

Courtesy of NASA/JPL/USGS

Radio-Sky Publishing

Resources for Amateur Radio Astronomers, Teachers, and Students



Radio-SkyPipe – an Internet enabled strip chart recorder.

memory. You should keep a log or notes of your observations, including date, times, type or description of the bursts, equipment setup, equipment problems (if any) and interference. When events are unfolding, you will want to concentrate on listening and you might end up with short cryptic notes. Immediately after the observing session is over, be sure to go back and expand your notes so they can be understood days, weeks or months later.

An important technique for confirming your observations is to correlate them with observations by others. To improve your ability to confirm results, you should try to make certain your computer keeps accurate time to within at least a couple tenths of a second. Radio-SkyPipe has built-in synchronisation capability or you can use a small PC clock synchronisation program running in the background. You also can synchronise your PC by using online services such as the US National Institute of Standards and Technology (NIST).

http://tf.nist.gov/service/its.htm

Be aware that most PC clocks can drift quite rapidly so synchronisation might be required at 15-minute intervals (more or less). Even with crude timing accuracy, comparing your results with others can be very useful and is an important reason why Radio Jove maintains a data archive, an e-mail distribution list and encourages coordinated observing sessions.

How to Improve Your Chances of Hearing Jupiter

Here are some tips that I gathered from NASA, UFRO and Radio-Sky Publishing. If you heed the advice of these expert organisations, your chances of hearing and recognising Jupiter emissions will be significantly improved. As for me, I probably never would have had any success without it.

- Observe during the predicted Io-enhanced storms – Io-A, Io-B and Io-C
- Observe when Jupiter is above the horizon at your location
- If you use a directional antenna, point it toward Jupiter during your observing sessions
- Start out with a receiver frequency of **20.1MHz** but tune to either side depending on local interference
- Keep the tuning at a clear spot on the band; if you hear a buzz, music, voice or periodic signals, tune away from them
- If you hear what you think is Jupiter, tune to one side of the centre frequency. You should continue to hear the burst if it lasts long enough or you might have to wait for additional bursts; if you hear the same thing, they probably are Jupiter emissions
- In relation to the previous point, do not waste your time searching up and down the frequency band for Jupiter emissions (most emissions are wide enough to receive over a considerable bandwidth)

My Setup

I use an Icom R-75 general coverage high-frequency receiver and a Hy-Gain LJ-153BA 3-element Yagi antenna in my installation (**Fig. 4**). The R-75 is a fairly expensive but very capable, high-quality receiver. I have had this receiver for several years and use it for Jupiter observing because I had it to hand and the AGC can be turned off. I want to stress that, based on discussions with other participants in NASA's Radio

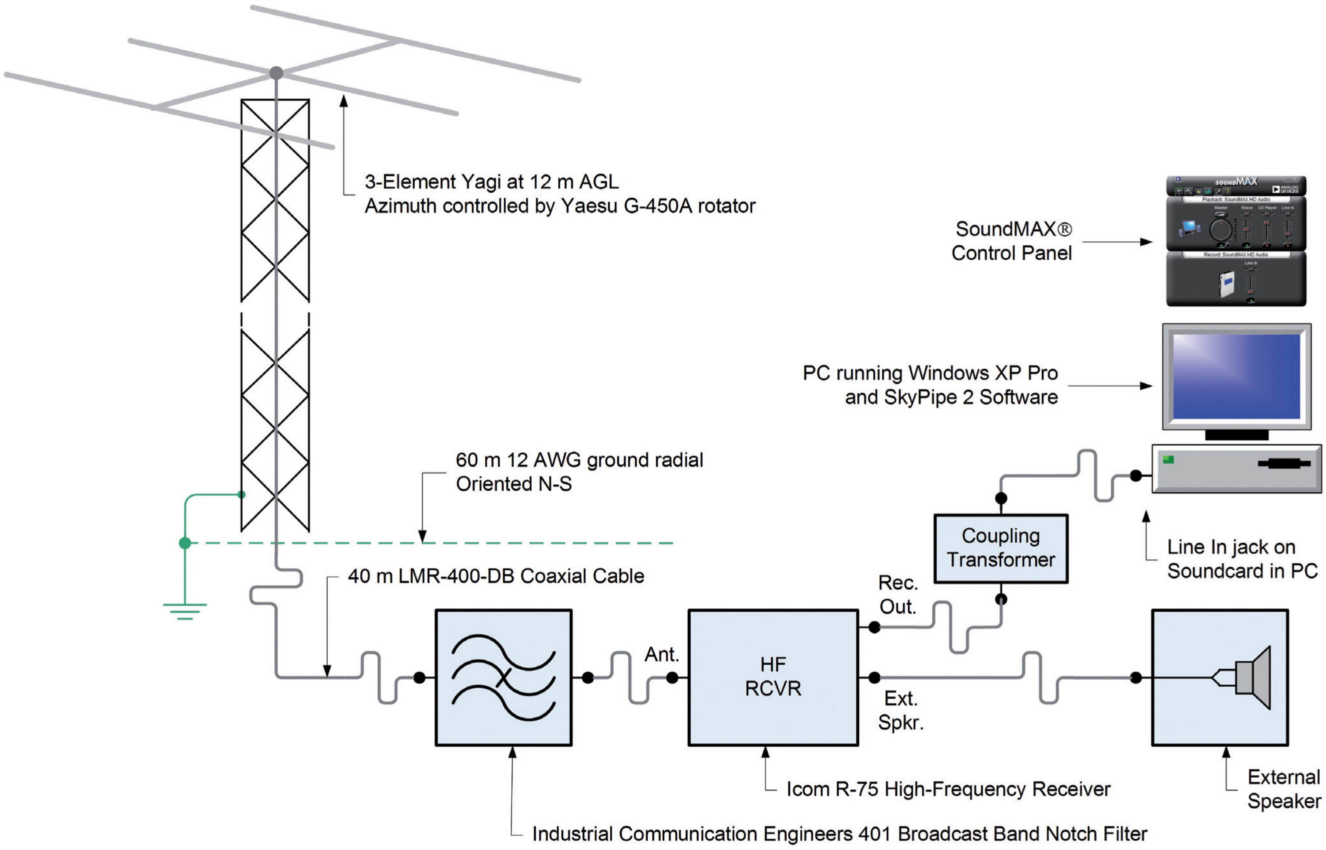


Fig. 4: My monitoring station in Anchorage, Alaska USA.

JOVE project, this type of receiver is not necessary for successful Jupiter observations. I also have the Radio JOVE receiver kit and plan to put it into service this summer.

Because of nearby AM broadcast stations that were overloading my receiver, I connected a broadcast band (BCB) filter between the antenna coaxial lead-in and the receiver. I also run the receiver from an electrically quiet power supply and use a coupling transformer between the receiver audio output and the soundcard input to eliminate hum problems. I had to take these extra steps because of my location and the inevitable electrical noise in the city. Not everyone will have to do this.

What the Results Look Like

The 2009 listening season started out in a very interesting way. Because interference from the Sun has been so low since the last sunspot cycle ended in late 2008, I have been able to capture Jupiter emissions during the daytime, which is most unusual.

The first SkyPipe chart (**Fig. 5a**) was taken on April 17th when Io-C was predicted to be active. There is nothing in the chart itself that indicates the emissions were L-bursts but there definitely was some activity during the interval shown. In this case, I reviewed the chart after the end of the observing session and listened to the recorded audio corresponding to the time shown on the chart. It was then that I was able to identify the L-bursts.

The second chart (**Fig. 5b**) was taken on April 18th when Io-B was predicted to be active. Against the background, there was some obvious activity. I again listened to the audio recording to identify S-bursts. My logs show several notations during this session and I reviewed the chart and associated audio recording for each of them. Not all were Io-B, some were local interference. For example, my wife's coffee grinder is a huge source of interference but, luckily, she ran it for less than five or six seconds during my observations.

I have posted these charts and audio files in NASA's Radio JOVE data archive and also on my website. The charts make much more sense when you can listen to the corresponding audio.
www.reeve.com/radiojove.htm

Conclusions

Now is the time to set up your radio telescope. Using an ordinary high-frequency receiver will probably yield good results if you use the recommended Radio JOVE antenna, or you can observe remotely. If you have problems or need additional information, there are forums and people you can contact through NASA's Radio JOVE project for help. I owe special thanks to **Leonard Garcia**, **Victor Herrero**,

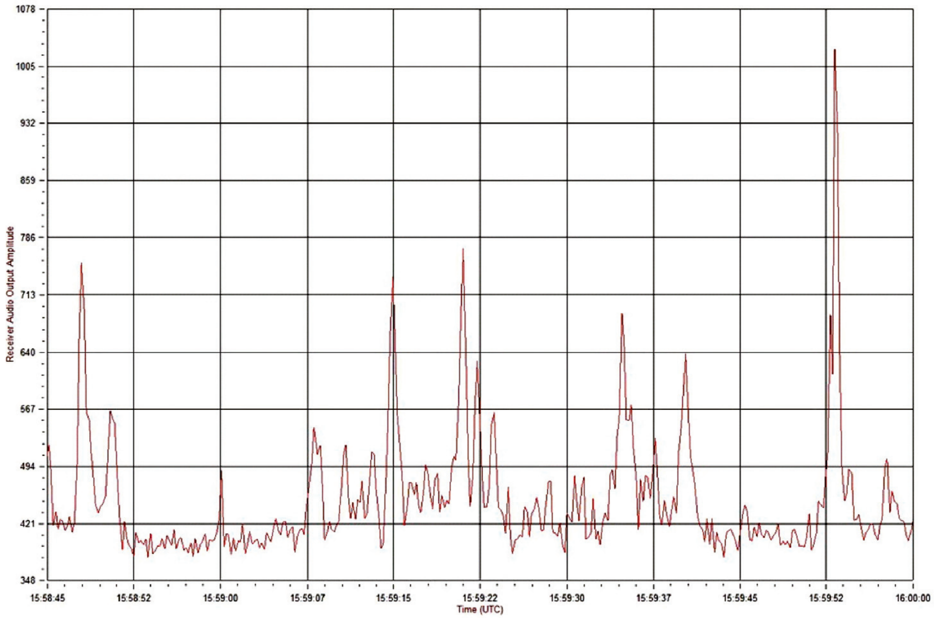


Fig. 5b : A Radio-SkyPipe chart showing S-bursts from Io-B on April 18th 2009. The time scale lasts 85 seconds. The bursting took place mostly at the beginning and end of the chart, but I also heard some S-bursts in between.

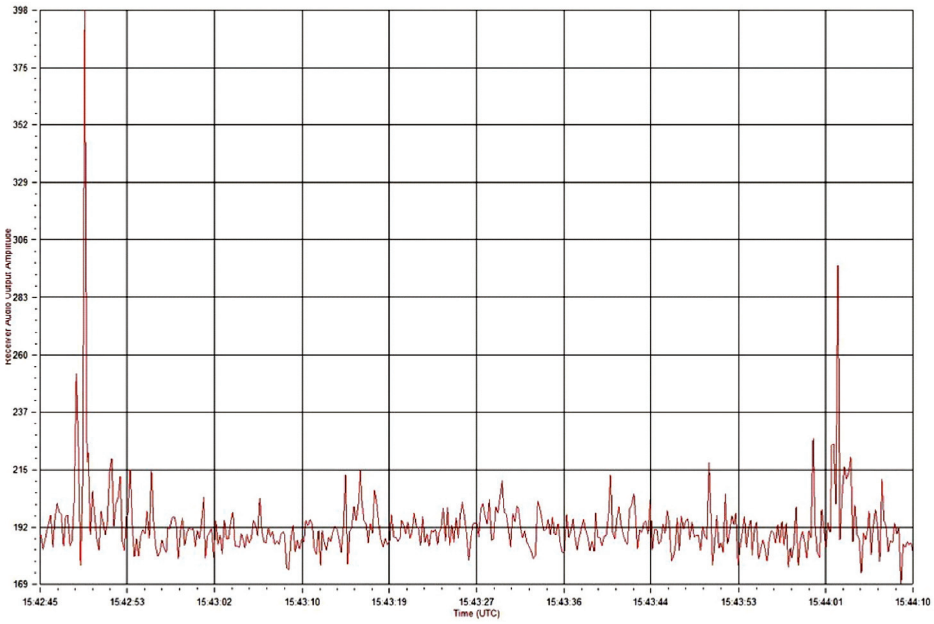


Fig. 5a: A Radio SkyPipe chart showing L-bursts from Io-C on April 17th 2009. The time scale covers a span of 75 seconds. The chart shows activity (amplitude spikes or excursions) that I identified as L-bursts. A particularly strong burst is evident just before the end of the chart.

and **Jim Thieman** for their help and constructive comments; they all are dedicated Jupiter observers. I also have NASA, University of Florida, **Thomas Ashcraft** and many online sources to thank for information I used in preparing this article. Good luck and good listening! ●

Additional Reading

Listening to Jupiter, Richard Flagg (available from www.radiosky.com/booksra.html)
Frequently Asked Questions: radiojove.gsfc.nasa.gov/help/faq1.htm
The Jovian Decametric Radio Emission: radiojove.gsfc.nasa.gov/library/sci_briefs/decametric.htm
The Discovery of Jupiter's Radio Emission: radiojove.gsfc.nasa.gov/library/sci_briefs/discovery.htm

Software

Radio-Jupiter Pro
Radio-SkyPipe II

Websites

radiojove.gsfc.nasa.gov/index.html
radiojove.gsfc.nasa.gov/library/
tech.groups.yahoo.com/group/Radio_JOVE/
www.astronomy.com/
www.obs-nancay.fr/a_index.htm
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www.skyandtelescope.com

Whitham D Reeve

Whitham Reeve was born in Anchorage, Alaska and has lived there his entire life. He became interested in electronics in 1959 and worked in the airline industry in the 1960s and 1970s as an avionics technician, engineer and manager responsible for the design, installation and maintenance of electronic equipment and systems in large airplanes. For the next 36 years he worked as an engineer in the telecommunications and electric utility industries with the last 31 years as owner and operator of Reeve Engineers, an Anchorage-based consulting engineering firm. He is a registered professional electrical engineer with BSEE and MEE degrees. He has written a number of books for practicing engineers and enjoys writing about technical subjects. Recently, he has been building a radio science observatory for studying electromagnetic phenomena associated with the Sun, the Earth and other planets.