アルマーの冒険 ALMAr

ALMAr's Adventure 11
Observing Jovian Radio Waves with Software Defined Radio (Part 2)

Main Characters


Nao Senri


ALMAr


Izayoi

*Please refer to back issues for the Main Characters' profiles.

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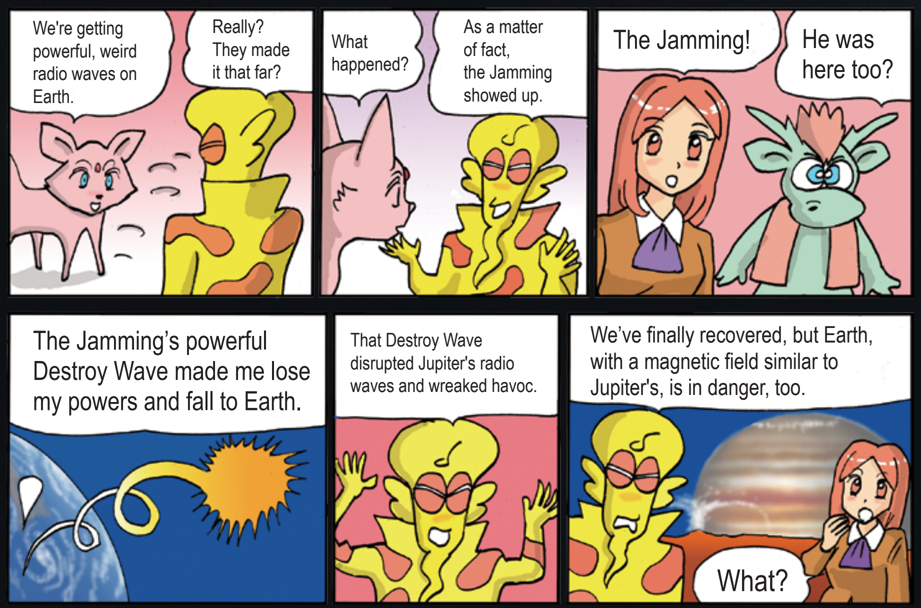
★ Summary up through Issue 11 (Part 1)
Observing Jovian Radio Waves with Software Defined Radio

During meteor observations by the Soten "Deep Blue Sky" High School astronomy club, both Nao and ALMAr sensed suspicious radio waves. Both of them opened from their radio wave eyes. They pointed to Jupiter as the source of the signal. Izayoi took Nao and ALMAr and flew to Jupiter in her hidden dome-shaped spaceship. On the moon Io, Iou, an old acquaintance of Izayoi's, informed her that the Jamming had disrupted Jupiter's radio waves and that Earth, which has a magnetic field like Jupiter's, was also in danger.
(Below: the last scene from Issue 11 Part 1.)

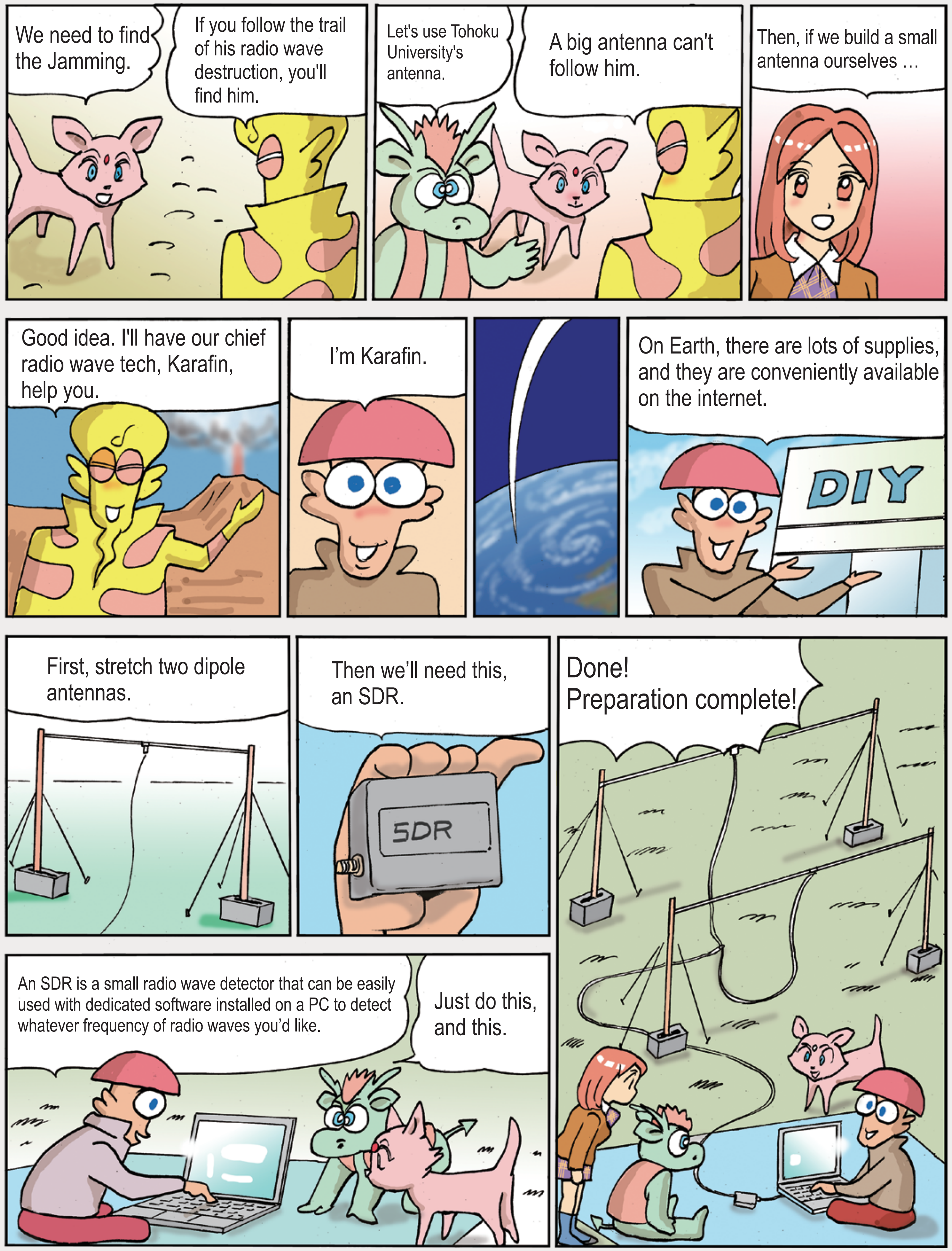


At last, we actually started Jovian decameter wave observations. The observations use an antenna to catch the radio waves, an SDR as a receiver, and a PC to acquire data. The antenna could have been made from a commercially available kit, but since those kits are expensive and the mechanism itself is very simple, we decided to make our own from scratch. Based on the information provided by the American Radio JOVE, we constructed it from parts available in Japan. The SDR is, of course, commercially available. The PC is a desktop PC with Windows 10 installed, since the analysis software runs on Windows. Did we succeed in receiving radio waves from Jupiter?

*Back issues of the ALMAr's Adventure radio astronomy Manga can be viewed at:
https://www.nao.ac.jp/en/about-naoj/reports/naoj-news/almar/

Near infrared image of Jupiter taken by JWST. The glow at both poles are auroras created by Jupiter's magnetic field.
Credit: NASA, ESA, CSA, Jupiter ERS Team; image processing by Ricardo Hueso (UPV/EHU) and Judy Schmidt.

Chapter 11-4: Meet Chief Radio Wave Tech Karafin Looking for the Jamming with a Homemade Antenna



1 DIY antenna construction

First, we built a dipole antenna to catch Jovian radio waves.

To observe Jovian decameter waves, you will need an antenna, an SDR, and a PC (see the bottom right panel on the opposite page). The SDR and PC are commercially available, but you must make your own antenna. The antenna is made in the style recommended by Radio JOVE. The antenna has a center frequency of 20.1 MHz.

The structure of the antenna itself is the same as the dipole antenna we used for meteor radio wave observation, but it is a dual dipole antenna configuration, using two dipole antennas in combination. This is to increase the sensitivity and to give the antenna more directivity.

A center frequency of 20.1 MHz corresponds to a wavelength of about 14.92 meters. A dipole antenna consists of two straight elements (conductors) stretched symmetrically from the feed point of the coaxial cable that leads radio waves to the receiver. Calculating that each element should be 1/4 of the wavelength, we get a length of 3.75 m. But as described in the Radio JOVE's antenna manual, in reality, the length is 3.51 m, taking into account the shortening rate as the speed of the radio waves slows down in the conductor.

Incidentally, since the two dipole antennas are placed side by side with some distance between them, the installation site must have an area of at least 10 m to a side.

In addition, the dipole antenna element is longer and heavier than the previously fabricated elements for meteor observations. Therefore, it is necessary to make a structure that will not be damaged even if force is applied by stretching a rope from the feed point to both antenna masts. In this case, we decided to use PVC pipe left over from making the antenna masts as described below and cut it to 10 cm lengths, and used it as an insulator (a device that provides electrical insulation and supports the wires) and reinforcement.

Furthermore, radio waves captured by the two dipole antennas are combined by a component called a combiner. Provided the dipole antennas are offset from each other in the north-south direction, when observing radio waves from Jupiter at its meridian transit (due south, also the highest elevation angle it will reach in the sky), the radio waves will reach the northern dipole antenna slightly later than the southern antenna. Therefore, when combining the signals with the combiner, the coaxial cable from the south dipole antenna is made longer to be in phase with the radio waves received by the north dipole antenna. During the summer and fall of 2022, when the observations were made, Jupiter's elevation angle at meridian transit was approximately 55 degrees. According to the Radio JOVE manual, adding a 90 degree phase delay to the length of the south coaxial cable points the antenna beam at 60 degrees elevation angle, which will enable higher sensitivity for receiving radio waves from Jupiter at meridian transit.

The lengths of the coaxial cables are 11.94 m for the north side, corresponding to one wavelength, and 14.92 m for the south side with an additional 90° phase delay. We made the length from the combiner to the SDR 11.94 m, i.e. one wavelength. All of these values were obtained by calculation, taking into account the shortening ratio (0.8 was adopted from the wire catalog). The length from the combiner to the SDR is arbitrary, but we chose 11.94 m, which is equivalent to one wavelength, because we wanted to keep the PC away from the antenna to prevent noise, but a longer distance would cause radio wave attenuation problems.

Tips

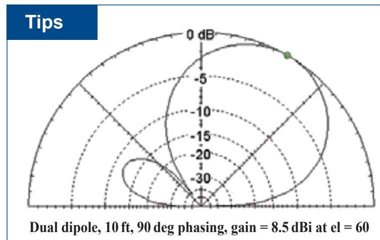
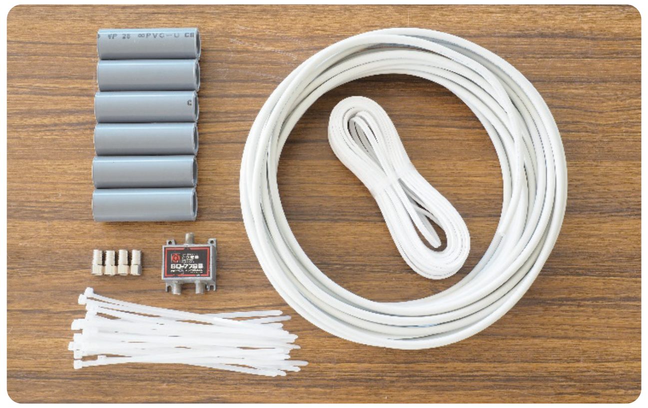


Figure from Radio JOVE's antenna manual showing the beam pattern of an antenna mounted 10 feet (about 3 m) above the ground with the phase of the antenna on the south side shifted by 90 degrees. You can see that the antenna beam is pointed to have the highest sensitivity at approximately 60 degrees elevation angle in the southern sky.



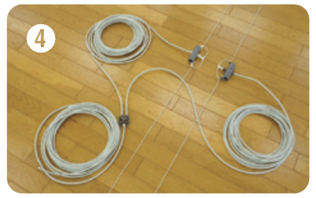
◆Antenna (Elements) Material List (total cost: approx. 16,000 JPY)

Copper wire (2 mm^2)	20 m
Coaxial cable (5C-FB)	50 m
F type connector (for 5C-FB)	4 pcs.
Toroidal core (GTR-28-16-20)	2 pcs.
PVC pipe (VP25, 10 cm)	6 pcs.
Zip ties (at least 10 cm long)	22 pcs.
Combiner (2 dividers for TV antenna)	1 unit.
F-SMA adapter (for SDR connection)	1 unit
Solder	A little
Vinyl tape	A little

❶ The copper wire and coaxial cable will need to be cut to size. However, the wavelength of the radio waves to be received is long enough and the frequency band is broad enough that there is no need to worry about a slight difference in length.

❷ Prepare a total of six PVC pipes. Cut them to 10 cm in length and drill holes at both ends to pass the elements through. For two of the pipes, drill additional holes in the center of the PVC pipes to pass the coaxial cables through.

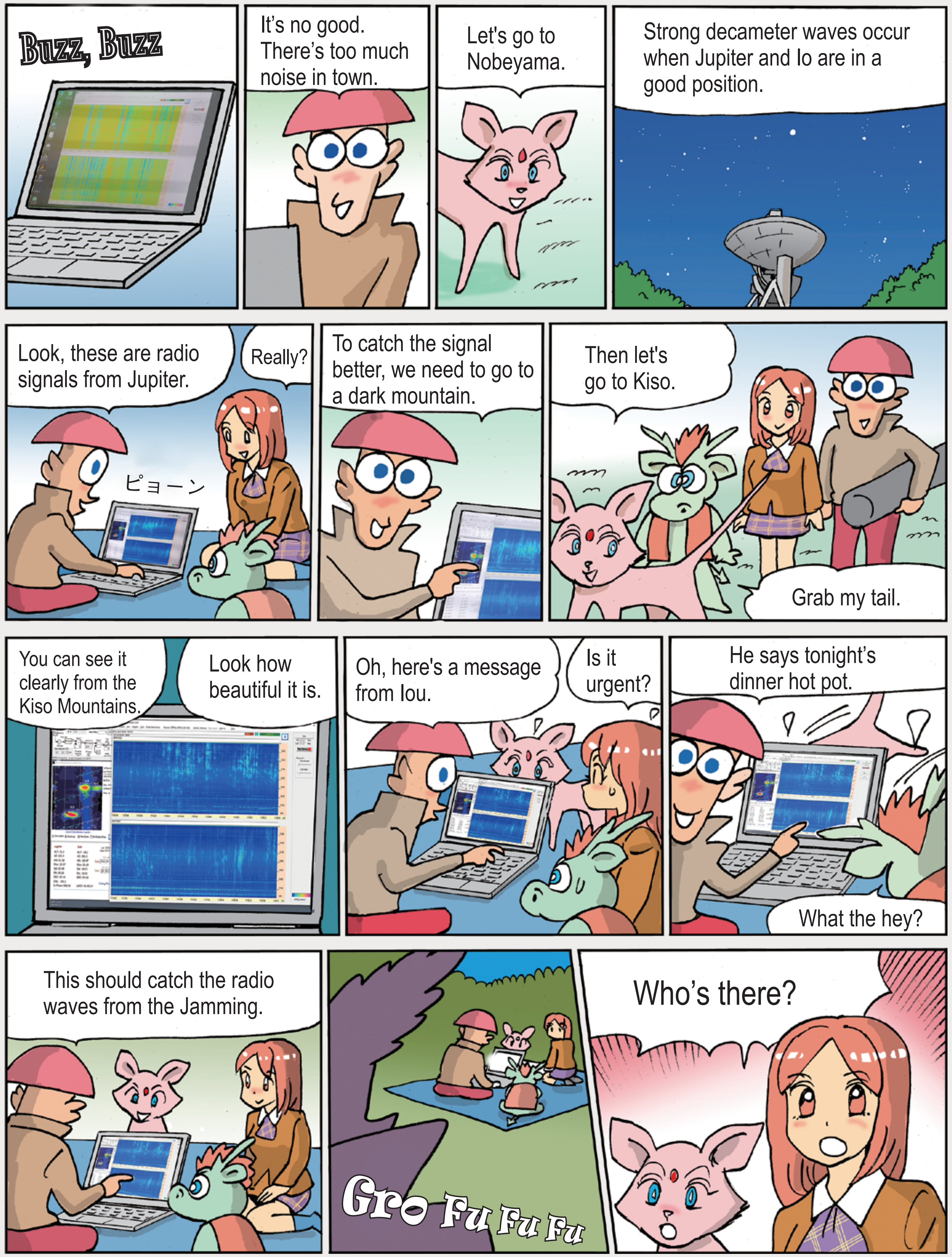
❸ Soldering the part that serves as the feed point for the antenna. Pass the coaxial cable through the through-hole in the PVC pipe. Pass each element through the hole at one end of the pipe, double the elements back on themselves, and secure them each with a zip tie, then solder the elements to the coaxial cable. In addition, a toroidal core was not installed at the beginning of the test observation, but before full-scale operation, we modified the assembly to pass the coaxial cable through the toroidal core. Attach zip ties to the coaxial cable running through the PVC pipe, to prevent vertical motion and keep it from falling out. An F-type connector is attached to the opposite end of the coaxial cable from the feed point (for details, see Issue 10, p. 7). Finally, vinyl tape is wrapped around the cable for insulation and waterproofing.



❹ The element and coaxial cable portion of the dual dipole antenna are complete. The one on the right is for the south dipole antenna with a longer coaxial cable. The radio wave signals are combined at the combiner and transmitted to the SDR using a single coaxial cable.

Chapter 11-5: Heading into the Mountains to Get Away from Noise

A mysterious figure looms over Nao and her friends as they continue to capture radio waves.



2 Erecting the Antennas

Making dipole antennas with homemade 3 m high antenna masts

The antenna elements need to be strung at a certain height. In the Radio JOVE antenna manual, which we used as a model, there were comparisons of antenna sensitivity when the elements are stretched at 10 feet (about 3 m), 15 feet (about 4.5 m), and 20 feet (about 6 m), but there did not seem to be any big differences. So we decided to put the elements at a height of about 3 m above the ground.

The Radio JOVE antenna manual uses PVC or metal pipes for antenna masts (poles) as examples. We decided to use PVC plumbing pipes, based on their availability in Japan and the ease of use. We purchased PVC pipes with an outside diameter of 32 mm, called PV25. Initially, we trimmed 4 m long pipes to 3 m lengths to be used as the masts, but they were too long and inconvenient to carry (there is no place to permanently install the antennas), so we cut them in half into 1.5 m lengths and the two halves were connected during operation using a joint for PVC pipes.

An antenna mast must be freestanding, so the lower part of the mast is inserted into a concrete block. We set up the elements and masts using guy ropes for a camping tent with tensioners and pegs. The top of the mast is also anchored by a guy rope using a combination of pipe hangers and eyebolts.

Of course, the antenna we have fabricated this time is for experimental observations; if you are aiming for full-scale, continuous observation, you will need to ensure durability. For long-term, fixed-location observation, you should consider installing an antenna using metal poles or stands for amateur radio operators.

The antenna installation site needs to be as flat and open as possible. Naturally, you cannot observe where buildings or other obstructions block your view of Jupiter. Observation also requires a PC. For short observations, you can probably rely on a laptop battery, but if you have access to a commercial 100 VAC power supply, you do not need to worry about the power supply for a long observation.

Antenna installation diagram

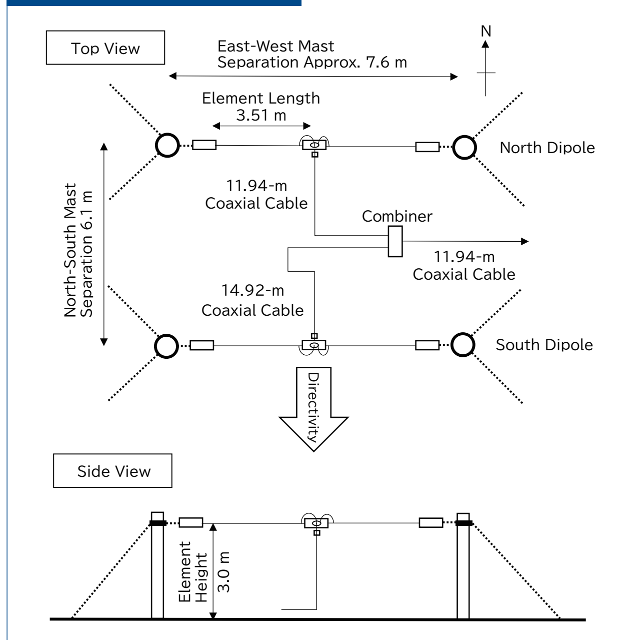


Diagram of antenna placement, adapted from the Radio JOVE manual. In the original, lengths are expressed in feet and inches, but here they are expressed in meters. The length of the coaxial cable from the combiner is arbitrary, but we used a little less than 12 m, corresponding to one wavelength.

◆Antenna Mast Components List (total cost approx. 10,000 yen)

PVC pipe (VP25, 4 m)	4 pcs.
TS socket (for VP25)	4 pcs.
TS cap (for VP25)	4 pcs.
Pipe hangers (for VP25)	4 pcs
Eyebolts (M6)	4 pcs.
Colored polyethylene rope (4 mm thick)	30 m
Aluminum tensioners	12 pcs.
Round steel pegs 265 mm	8 pcs.
Hollow concrete blocks (10 cm, basic)	4 pcs.
Wood chips (for shoring up the PVC pipes in the blocks)	as needed
PVC pipe adhesive	as needed

❶ In a dual dipole antenna, two antennas are placed parallel to each other, separated north to south. Although it is not necessary to set up the antennas this precisely, I used the shadow of a vertically hanging line when the Sun transited the meridian as reference, since a compass does not point to true north.

❷ The antenna mast bases were made of inexpensive hollow concrete blocks. The structure is simple: the pipe that forms the antenna mast, is inserted into the hole, and thin wooden shims are used to fill the gaps.

❸ The tip of the antenna element is fixed to a short PVC pipe with a hole drilled in it and secured using two cable ties. In addition, a guy rope with a tensioner is passed through the pipe hanger attached to the top of the antenna mast, and the element is stretched so that it is as parallel to the ground as possible. The mast guy rope is simply a loop made by tying the guy rope to itself and hooking it to the tip of the mast.

❹ The completed antenna. The extent of the antenna masts is about 6.1 m from north to south and about 8 m from east to west. So including the pegs for fixing the tension ropes, a flat open space of about 10 m to a side is required for installation. Of course, it is pointless to set it up someplace where Jupiter won't be visible.

Chapter 11-6: Friend or Foe, Dr. BS Finally Revealed And the secret of Nao's birth revealed.

3 SDR Setup and Observation Software

Installation of free software designed for Jovian radio wave observations

Radio JOVE recommends the RSP1A by SDRplay, a British manufacturer, for the SDR. Software specialized for the RSP1A is also available, so there is no other choice if you want to observe in the style advocated by Radio JOVE.

The RSP1A has higher performance than the one used in our radio wave observations of meteors (see Issue 10), especially the AD converter used to digitize analog signals is improved. The AD converter in the SRD we used for our radio wave observations of meteors had 8-bit resolution, but the RSP1A has improved to 14 bits, giving it 64 times better resolution. The noise reduction and signal detection capability are also improved. The RSP1A connects to a PC via USB2.0.

Actual observation requires a PC running Windows 7 or later for the OS. If the PC is a model sold in recent years and has an Intel "Core i" series or AMD "Ryzen" series as the CPU, it can be considered usable.

If you follow the Radio JOVE's Setup and Operation Manual, the first step is to install "SDRuno" to check the functionality of the RSP1A as a radio. SDRuno is software from SDRplay, the manufacturer of the RSP1A, and is available for free download and includes the RSP1A driver.

After installing SDRuno, be sure to check the operation of the RSP1A. If you are indoors, you can experimentally connect a TV antenna and listen to FM broadcasts in the neighborhood.

To receive Jovian decameter waves and observe their frequency and intensity, you can use "Radio-Sky Spectrograph" (hereinafter abbreviated as RSS). The software is provided free of charge by Radio-Sky Publishing, a company that supports Radio JOVE, and can display and record time-varying spectra of frequencies and radio wave intensities in real time.

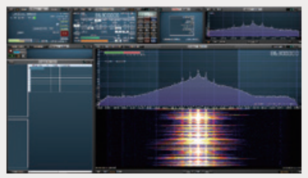
RSS alone cannot read data from the RSP1A, but RSS also includes SDRPlay2RSS, an intermediate software that bridges to the RSP1A, so once RSS is installed, it can be operated with minimal setup.

RSP1A

The RSP1A is an SDR receiver manufactured by SDRplay in the UK. Despite its compact size, it has a wide receiving range from 1 kHz to 2 GHz and employs a 14-bit AD converter. It connects to a PC via USB2.0 and is operated by the dedicated SDRuno software. In Japan, ICAS Enterprises handles the product, which was priced at 17,300 yen (tax included) at the time of purchase in 2022.
icas.to/sdrplay/lineup-1a.htm

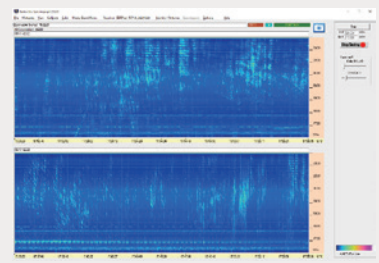
SDRuno

SDRuno is the free SDR operation software from SDRplay. It is not used for Jovian decameter wave observations, but can be used to test the operation of the RSP1A, such as by receiving radio station broadcasts. It also includes a PC driver for the RSP1A, so installation of SDRuno is mandatory. However, as of the summer of 2022, the latest version of the driver does not support the software for the observations described later, so it is necessary to download and install an older version. The manual of Radio JOVE specifies SDRuno version 1.41.1. Download the software from the following URL, specifying the model and OS, but note that the older version will not be displayed unless you click on the words "Legacy software Click here to show".
www.sdrplay.com/softwarehome/



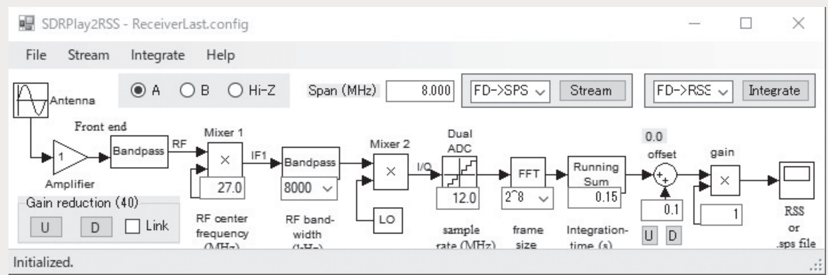
Radio-Sky Spectrograph (RSS)

The observation software that displays data from SDRs is Radio-Sky Spectrograph (abbreviated as RSS). When configured for the RSP1A, it acquires spectra over a wide frequency range from 18 MHz to 24 MHz. It plots changes in radio wave intensity over time for you, with time on the horizontal axis and frequency on the vertical axis. By default, the upper window shows 2 minutes and the lower window shows 10 minutes of data. Of course, it is also possible to save the observation data and redisplay the data from a specified time.
www.radiosky.com/specdownload.html



SDRPlay2RSS

"SDRPlay2RSS" is software that feeds RSP1A data into RSS. It is included in the RSS installer, so that when the RSP1A is configured to be used with RSS. SDRPlay2RSS is started at the same time that RSS observation begins.



PC

The PC used for this observation had an Intel Corei7 3770K as the CPU, and was running Windows 10. We conducted observations with several different PCs. Some models picked up noise that may have been introduced from the power supply line, so it would be advisable to have a PC with a power supply of the highest possible quality. If the duration of observation allows, it may be possible to use a laptop PC on battery power. There were also some PCs that could not operate RSS properly, although the cause was unknown. It is always advisable to check the operation of the PC in advance.

4 Predicting Jupiter Radio Bursts

The forecasting software identifies the date and time when the decameter wave radiation is particularly strong.

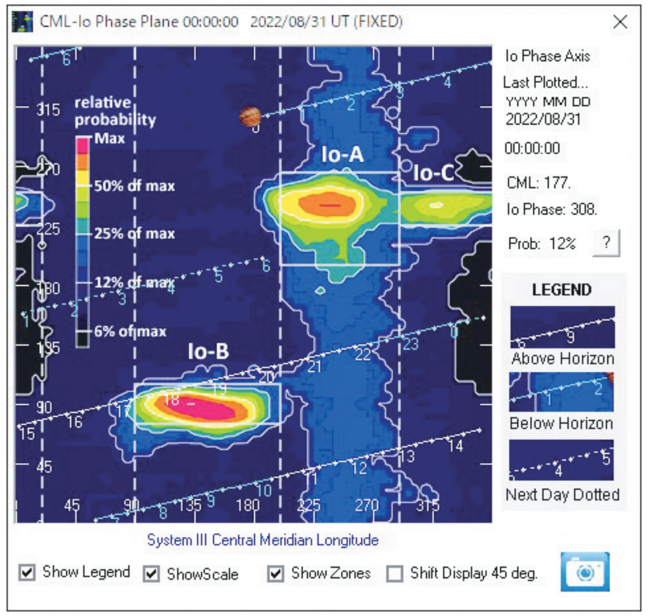
As explained in the previous issue, there are times when Jupiter's decameter waves are more powerful than normal, depending on Jupiter's central meridian longitude and Io's phase. These can last a few hours at most, and are also called a "Jupiter radio bursts" or "Jupiter radio storms." As their names suggest, these phenomena show extreme changes with time. If you want to observe Jupiter's radio waves, you should first try to observe some of Jupiter's strong radio bursts. Unfortunately, simple handmade dipole antennas and SDRs are not sensitive enough to continuously capture Jovian radio waves at times other than bursts.

Fortunately, we can accurately predict the motions of the planets and moons in the Solar System. Thus, the positions of Earth, Jupiter, and Io at a particular time, as well as the central meridian longitude of Jupiter, can be calculated. There is special simulation software available to make such predictions. "Radio-Jupiter Pro 3," is provided free of charge by Radio-Sky Publishing, the company that released the above-mentioned RSS. This software assists in the observation of Jovian decameter waves.

The interface is somewhat old-fashioned, but by entering information such as the latitude, longitude, and time zone (time difference) of the observation location in advance, it can display a planisphere-like display showing Jupiter's position in the sky at that observation location, as well as a color-coded graph showing the probability of Jupiter radio bursts. In addition, it can display the antenna's sensitivity beam pattern, which is very useful for planning an observation. Of course, it is also possible to display changes in status during an observation in real time.

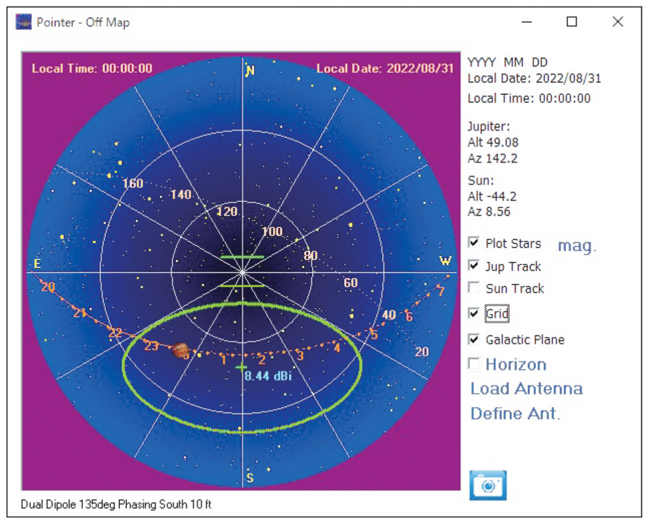
Although decameter waves are always bombarding Earth from Jupiter, there are three particularly strong radio wave bursts, named Io-A, Io-B, and Io-C, that can be received depending on the combination of Jupiter's central meridian longitude and Io's phase. Other decameter waves based only on Jupiter's central meridian longitude are called non-Io-A (somewhat strong), non-Io-B (weak and difficult to observe), and so on.

Jupiter's radio bursts are characterized by two types of bursts: L bursts (L stands for long), which show frequency fluctuations over relatively long periods of time, ranging from tens of minutes to several hours, and S bursts (S stands for short), which show large frequency fluctuations within a few seconds. For this observation, we aimed for L bursts, which do not require much time resolution.

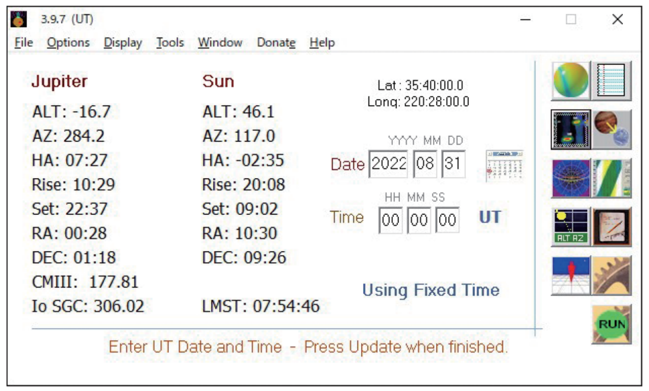


A probability figure for Jupiter radio storms based on past observational data. The vertical axis shows Io's phase and the horizontal axis shows Jupiter's central meridian longitude. The red indicates the area where there is a possibility to observe extremely strong Jovian decameter waves. Once you have set up your antenna and constructed your system, you should try to aim as much as possible for times when Jupiter is passing through this red area.

There is also a useful table for planning observations of Jupiter's radio storms. It shows the type of storm and its time, as well as a color-coded graph.



There is also a window that displays the entire sky, like a planisphere. It is also possible to display the position of Jupiter and the beam pattern of the antenna sensitivity. (In this example, the phase of the south antenna is delayed by 135 degrees.)



The startup screen of Radio-Jupiter Pro 3. The locations of Jupiter and the Sun are shown, as well as icons for opening windows with various functions. Once the observation location is set (latitude and longitude; for some reason, the west longitude is displayed even if the east longitude is entered), the time system can be switched between Universal Mean Time (UT) and local time (Japan Standard Time if the observation location is Japan). You can also set the time to simulate phenomena, or use the PC's built-in clock for real-time operation.

5 Elusive Jovian Decameter Waves Captured

As hoped, Jupiter radio bursts were successfully observed at the predicted date and time!

Radio JOVE states that low-frequency radio waves such as Jupiter's decameter waves around 20 MHz suffer from lots of terrestrial artificial noise, and that the best observation sites are open spaces such as secluded sports fields. In addition, Dr. Atsushi Kumamoto, Associate Professor in the Department of Geophysics, Faculty of Science at Tohoku University, warned us, "In fact, it will be quite difficult to observe Jovian decameter waves in urban areas in Japan due to the high level of artificial noise. Even in the mountains relatively far from urban areas, the noise tends not to decrease until late at night, when human activities are calmer." Dr. Kumamoto also provided us with a forecast of Jupiter's radio bursts that he had calculated himself, which we used in conjunction with the Radio-Jupiter pro 3 simulation to plan our observation of Jupiter's radio bursts.

ALMAr's Adventure Production Unit preparing for observations.

As luck would have it, Jupiter was in the vicinity of Pisces, the autumn constellation, during the summer and fall of 2022, with perfect conditions for its meridian transit from midnight to dawn. Therefore, we looked for a time when we could observe Jupiter when there was expected to be less man-made noise. First, we conducted a trial observation from the night of July 21 to the early morning of July 22, 2022, because Jupiter was expected to transit the meridian around midnight, and Io-A radio bursts were predicted to occur.

The observation site needed to be a secluded place away from big cities, so we rented staff quarters at a campground located halfway up Mt. Ontake in Kiso, Nagano Prefecture, and set up the antenna in front of the building.

Even though there were no large cities nearby, there was still lots of artificial noise in the evening, but as night fell, the noise subsided dramatically. Then, as we gazed intently at the PC screen, a fuzzy, stain-like spectrum suddenly began to appear. This was exactly when the Io-A Jupiter radio burst was predicted. Thus, we succeeded in capturing radio waves from Jupiter using our homemade antenna with SDR.

We also improved some parts of the antennas and relocated to a borrowed campground parking lot which was larger and had a better view. Here, there was even less artificial noise, and on three consecutive nights starting on August 30 we were able to capture Jupiter radio bursts: Io-A, Io-B, and Non-Io-A,.

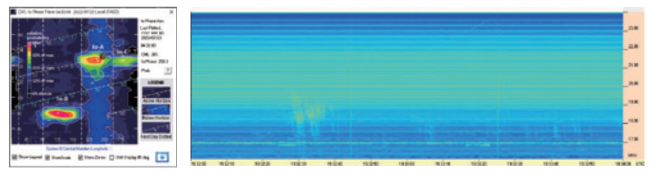
Jovian decameter waves as observed by ALMAr's Adventure Production Unit

The following are the results of actual observations of Jupiter's decameter waves using the homemade dual dipole antenna described so far, the RSP1A SDR, and a Windows PC with RSS installed. All of these observations were aimed at Jupiter radio bursts predicted by Radio-Jupiter Pro 3. The spectra shown here are two-minute spectra of the acquired RSS data, in which the radio waves are particularly strong. Unlike the streaky artificial noise that is continuously received at the same frequency, this spectrum is characterized by its blurred, lumpy appearance. We continued our observations for several hours before and after the burst was predicted to appear, but these lumpy spectra almost never appeared outside of the predicted time period, suggesting that the radio waves were in fact coming from Jupiter.

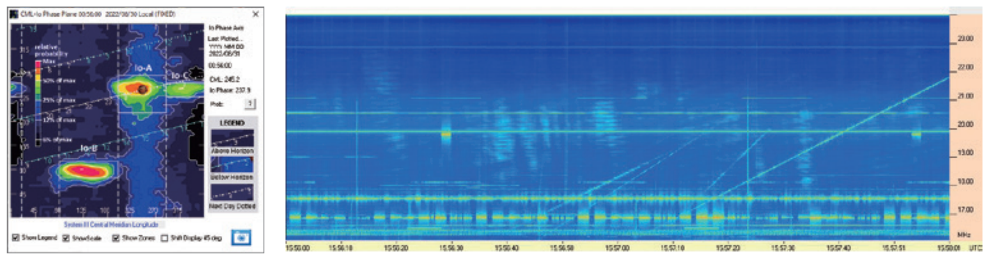
Weak ← Radio wave intensity → Strong

In RSS, radio wave intensity is indicated by color. In the observed data, the background is blue and the environment is relatively noise-free. You can see that the spectrum of Jovian radio waves is only slightly stronger than the background. The actual radio wave intensity is not known because the observation was not "calibrated" to know the quantitative radio wave intensity.

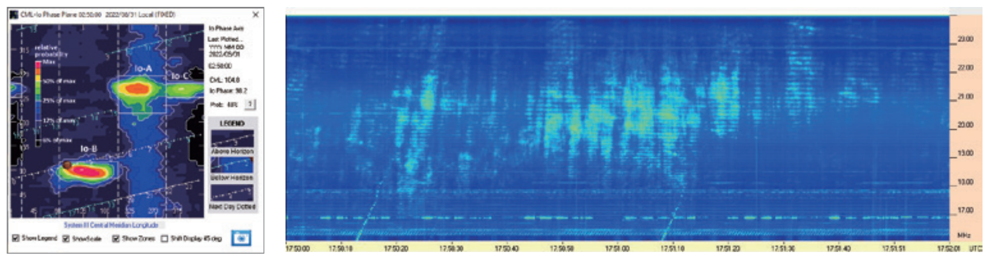
◆ July 23, 2022 4:32-34 Io-A
Otaki Village, Kiso-gun, Nagano Prefecture (In front of Ontake Galaxy Village Campground/Staff quarters)



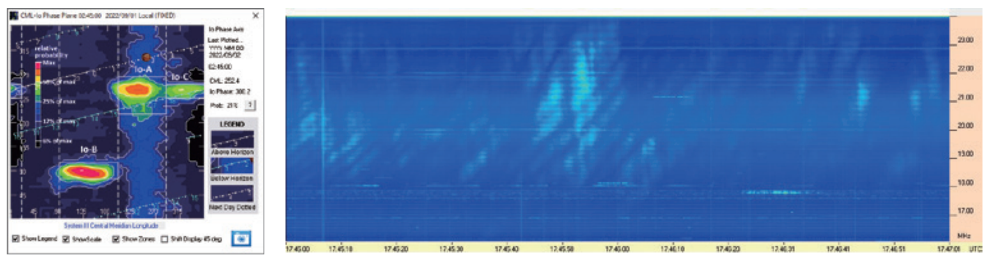
◆ August 31, 2022 0:56-58:00 Io-A
Otaki Village, Kiso-gun, Nagano Prefecture (Ontake Galaxy Village Campground/Parking Lot)



◆ September 1, 2022, 2:50-52 minutes Io-B
Otaki Village, Kiso-gun, Nagano Prefecture (Ontake Galaxy Village Campground/Parking Lot)



◆ September 2, 2022, 2:45-47 minutes Non-Io-A
Otaki Village, Kiso-gun, Nagano Prefecture (Ontake Galaxy Village Campground/Parking Lot)



6 Comparison of Artificial Noise at Different Observation Sites

The biggest obstacle to Jovian decameter wave observations is the noise associated with human activity.

When observing celestial bodies by light, it is desirable to observe as far away from large cities as possible. In large cities, lights for civic purposes light up the starry sky, and this has a detrimental effect on celestial body observation known as "light pollution."

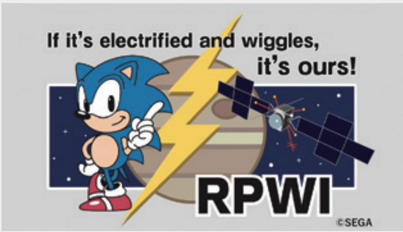
The same is true of radio waves, which are used for everyday life, but spill over into other places as well. However, because radio waves cannot be seen with the naked eye the way city lights can, without actually erecting an antenna, it is difficult to know whether the site is suitable for observing Jovian decameter waves or not. Therefore, we checked the decameter wave noise level at four locations: the Ontake Galaxy Village Campground in Ohtaki Village, Nagano Prefecture; NAOJ Mitaka Campus in Mitaka City, Tokyo; the NAOJ Nobeyama Radio Observatory in Nobeyama, Nagano Prefecture; and the University of Tokyo Kiso Observatory in Agematsu Town, Nagano Prefecture, which were planned from the beginning as observation sites.

We also observed from Nobeyama. Dr. Ishiguro also participated and was very interested in the RSS spectrum display.

Significance of Observing Jupiter's Radio Waves

Even in the environment surrounding far away Jupiter, the state of the magnetic fields is very difficult to observe directly. We have to rely on indirect methods such as decameter waves and auroras in Jupiter's atmosphere. The generation principle of decameter waves is briefly explained in the previous issue, but the radio wave intensity varies greatly depending on the positional relationship between Jupiter and its satellites (especially Io), as well as on changes in solar activity and the intensity of Jupiter's magnetic field itself. Therefore, continuous observation and data accumulation will provide clues to the physical states of Jupiter and the Sun.

Of course, direct exploration is also important. Currently, JUICE (JUpiter ICy moons Explorer), a probe launched by ESA (European Space Agency) on April 14, 2023, is on its way to Jupiter. JUICE primarily targets the icy satellites of Jupiter, such as Ganymede and Callisto, but it also carries instruments to observe Io's plasma and the interactions between the magnetic fields of Ganymede and Jupiter.



The team logo for the RPWI (Radio and Plasma Wave Investigation) instrument onboard JUCIE depicts "Sonic the Hedgehog," a video game character from Sega Corporation. Professor Yasumasa Kasaba (Director of the Planetary Plasma and Atmospheric Research Center) of the Tohoku University Faculty of Science, is the Japanese representative. At the team's request, Sega fully cooperated and provided the logo free of charge.

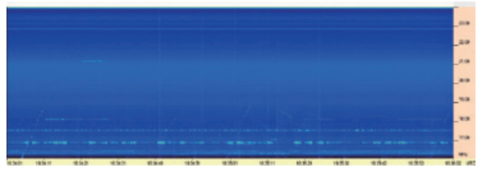
At NAOJ Mitaka Campus, an antenna was installed on the roof of a building, but the noise level did not drop even in the middle of the night, making it impossible to detect Jovian decameter waves. At Nobeyama Radio Observatory, the Nobeyama 45-m Radio Telescope continues to observe in millimeter waves. However, we found that in the decameter wave environment, a certain amount of artificial noise remains even after midnight. Nevertheless, we were able to capture Jovian radio wave bursts.

The University of Tokyo's Kiso Observatory was surprising. An antenna was installed on the roof of a single-story enclosure called the Night Sky Observation Room (1100 m above sea level), but the noise level did not drop until midnight, despite the fact that it was located only 10 km away from the Ontake Galaxy Village campground (1410 m above sea level), where the Jovian radio wave bursts were reliably captured. At first, we suspected noise from the facility itself, but then we realized that there was a big difference in topography between Kiso Observatory and the Ontake Galaxy Campground. The Ontake Galaxy Village Campground is surrounded on three sides (all sides but south) by mountains and small hills, while Kiso Observatory is located near a mountain ridge, and the noise coming from far away seems to be quite different.

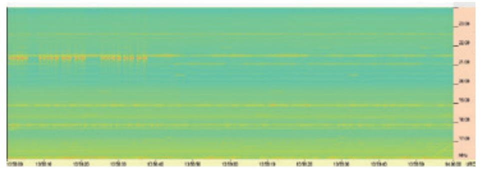
We later used a simple single dipole antenna to check the noise level, and found that it is clearly harder to pick up artificial noise in a valley with a poor vantage point than in an open plateau-like area. We also confirmed that raising the antenna's ground altitude too high would increase the noise level, perhaps because of the better vantage point.

Jovian decameter wave observations are a battle against noise from artificial radio waves. If you want to install an antenna, you might want to find a location in a valley where Jupiter will definitely be visible.

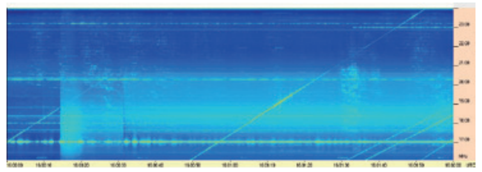
◆September 1, 2022
Predawn
Otaki Village, Kiso-gun, Nagano Prefecture
(Ontake Galaxy Village Campground)
Ideal quite environment



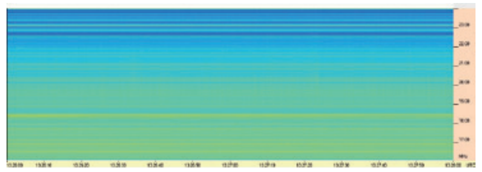
◆October 8, 2022
Late at night
Mitaka City, Tokyo
(National Astronomical Observatory of Japan, Mitaka Campus)
Observations not possible



◆October 17, 2022
Predawn
Minamimaki Village, Minamisaku-gun, Nagano Prefecture
(NAOJ Nobeyama Radio Observatory)
Io-B observations in progress



◆November 17, 2022
Before midnight
Kiso Town, Kiso-gun, Nagano Prefecture, Japan
(Night Sky Observation Room, Kiso Observatory, University of Tokyo)
Observations not possible

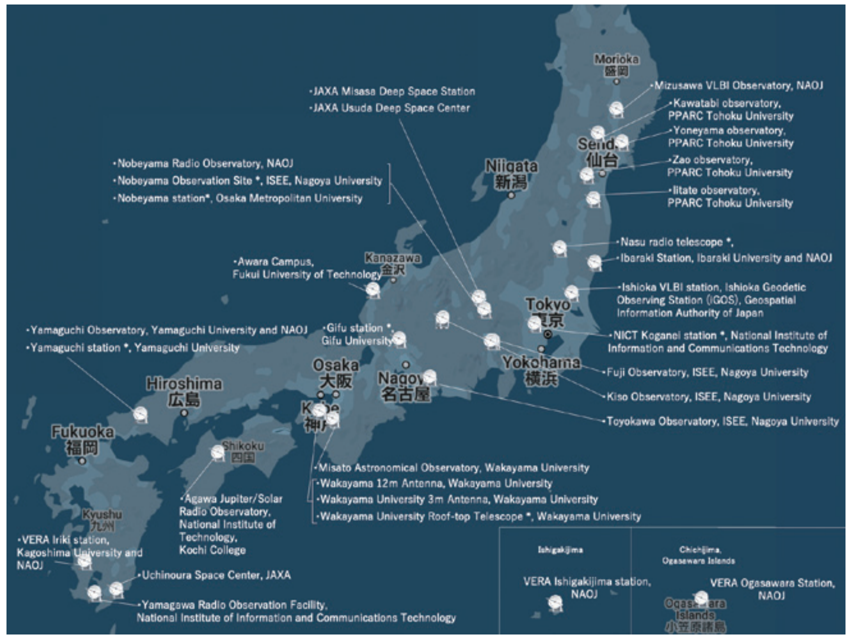


7 Radio Astronomy Observations and Frequency Resource Protection

For coexistence with a convenient and safe society.

The ALMAr's Adventure Production Unit encountered noise caused by artificial radio waves. The frequency observed was 20.1 MHz, which is in the frequency band called "short wave." Since shortwave can reach very far, it is widely used in ship and aircraft radio and broadcasting applications. The fact that the noise decreases as night falls is evidence that it is closely related to human activities.

Radio waves from celestial bodies are very weak. For example, if you placed your cellphone on the Moon, turned it on, and then observed it from Earth, you would find that it is one of the strongest radio wave sources in the entire sky. That is what one cell phone 380,000 km away can do. The radio waves from all the cell phones on Earth is correspondingly much stronger. With Wi-Fi, TV, radar, and many other radio waves flying around us, it is very difficult to detect extremely weak radio waves from celestial bodies.



Radio astronomy observatories in Japan. There are about 30 observation facilities ranging from low frequency to high frequency. (Map data ©2022 Google)

If machines for various purposes could emit radio waves anyway they please, they might not be able to communicate properly or may interfere with other uses. For this reason, there is a system to organize radio wave traffic. Radio wave frequencies are separated and their uses are prescribed, this is called "frequency assignment." In Japan, the Ministry of Internal Affairs and Communications (MIC) announces in its "Frequency Assignment Plan" the uses assigned to each frequency. Internationally, the International Telecommunication Union, a specialized agency of the United Nations, has established the "Radio Regulations," which determine international frequency allocations. Basically, frequency allocation in each country is done within this international framework.

Radio astronomy is also one of the activities that deals with radio waves, and therefore, we have received assignments mainly in the frequency bands that are particularly important for astronomy; for example, radio waves emitted by hydrogen atoms, which are abundant in the Universe (wavelength 21 cm, frequency 1.4 GHz), ammonia molecules (wavelength 1.3 cm, frequency 23 GHz), and carbon monoxide molecules (wavelength 2.6 mm, frequency 115 GHz). Radio astronomy has priority in the allocated frequency bands, so if there is radio wave interference (harmful interference) from other uses, we can request that the interference be eliminated.

However, compared to the wide frequency range of radio waves as a whole, only a few frequency bands are allocated to radio astronomy. The 20 MHz band where we observed Jupiter's radio waves this time is not one of the ones allocated to radio astronomy. In other words, we have no right to say, "I can't see Jupiter's radio waves in the 20 MHz band, so you need to use weaker radio waves for communication!" Radio wave frequencies are finite and must be shared by everyone, so it is unavoidable that priorities are assigned. If you want to observe in a frequency band that is not protected, you have no choice but to conduct your observations in a low-noise location away from urban areas, as our production unit did.

Frequency allocation is not something that will remain the same forever. When new services such as "5G" and "Wi-Fi 7" are introduced, new frequencies must be allocated. Since there are few frequency bands that are completely unused, it becomes necessary to distribute the radio wave intensity and emission methods between the operations already using the frequency band and those newly allocated, to make sure that they do not interfere with each other. Recent examples of such adjustments in frequency bands allocated to radio astronomy include the extension of wireless LAN to the 6 GHz band, the allocation of the 40 GHz band to 5G cell phones, and the deregulation of 76 GHz-band vehicle-mounted radar. Based on the technical specifications of radio wave emitting devices, we can calculate whether there will be harmful interference to radio wave observatories in Japan, and if interference is a concern, we need to negotiate with the other users to avoid the frequency bands allocated for radio astronomy or to limit the areas where radio waves can be emitted. Established in 2019, the Spectrum Management Office of the National Astronomical Observatory of Japan's Public Relations Center is responsible for these tasks.

However, the Spectrum Management Office does not believe that radio astronomy is the highest priority. We can enjoy the convenience, fun, and safety of modern society through various services using radio waves. The main mission of the Spectrum Management Office is to create a balance between modern society and an environment suitable for radio astronomy observations. (Head of the Spectrum Management Office: Masaaki Hiramatsu)

Background: The International Telecommunication Union conference was held in Geneva in March 2023, with approximately 1,900 participants, including online participants. There were many topics on the agenda, and each topic was discussed in knowledgeable subcommittees, but it was quite an eventful conference, with situations where the interests of different countries clashed.

Next Issue

The ALMAr's Adventures production staff is finally leaving the Solar System. The next theme is Galactic radio waves. We will try to catch radio waves coming down to Earth from the Milky Way. Furthermore, we will detect the different Doppler shifts in each spiral arm to analyze the structure of the Milky Way Galaxy. Don't miss it.