9. Signals from Space: Radio Astronomy for Beginners

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9.1 Introduction

The radio-wave region of the electromagnetic spectrum offers amateur astronomers interesting opportunities for observing. Regardless of weather, time of day, or time of year, they can detect astronomical objects like the Sun and Moon, the planets, supernova remnants, and distant galaxies. Radio astronomy is astronomy 24/7.

If our eyes were able to see in the radio-wave region, we would experience the heavens in a completely different way than is revealed to us in the optical region: Radio filaments of the Milky Way, the eggshell-like structures of close-by supernova remnants, and tremendous regions of star formation would dazzle us (Fig. 1). Furthermore, the radio sky would be strewn with countless point sources that appear to us like stars. Yet we would look in vain for the familiar constellations since, unlike the stars that form figures like the great bear of Ursa Major, very few "radio stars" are located within our Milky Way. These "stars" are usually the nuclei of distant radio galaxies and quasars, some being located at the very edge of the observable universe.

After a journey often lasting billions of years through the expanding universe, the radiation from these distant galaxies one day happens to reach the antenna of a radio telescope on Earth, where it generates a tiny electrical current. This must be amplified millions of times by the stages of sensitive electronic equipment in order to then move the indicator of an X–Y plotter or to appear as a curve on a computer screen. It is only due to the unimaginably huge radiative power ranging up to 10^{39} watts that the distant radio galaxies are able to be detected by Earth-based telescopes.

By "stars" of the radio sky we mean the active cores of very distant galaxies.

9.2 What is Radio-Frequency Radiation?

Physically speaking, radio-frequency radiation is similar to optical radiation—in both cases these entail electromagnetic waves. The only difference is that radio waves are of a significantly greater wavelength than visible light. The wavelengths for the spectrum usable for telecommunication extends roughly from one centimeter to ten kilometers. In contrast, optically visible light possesses wavelengths of less than a thousandth of a millimeter. Aside from the optical and radio regions, there are countless other wavelength regions (Fig. 2) that can also be observed.

The radiation from various regions is differentiated either by indicating its wavelength λ, or its frequency ν. Often, both pieces of information are used together. The two parameters are interrelated by the speed of light $c = 3 \times 10^8$ m/s: λ [m] = c/ν [Hz], or ν [Hz] = c/λ [m]. Frequencies are usually stated in Hertz, while wavelengths are given

Fig. 1. Seen here is the radio sky over the telescopes of the National Radio Astronomy Observatory in Green Bank, VA. Note the shell-like supernova remnants and irregularly shaped star formation regions. The point-like objects are not stars but mostly distant radio galaxies. Image courtesy of National Radio Astronomy Observatory/AUI/NSF

in meters. The wavelength region in which Earth-based radio astronomy can be pursued comprises wavelengths ranging between 15 m and 1 mm. This corresponds to frequencies of between 20 million Hertz (20 MHz) and 300 billion Hertz (300 GHz).

Radio-frequency radiation is a form of light. The radio region comprises wavelengths from 1 mm to 20 m.

The atmosphere of our planet places natural limits on the radio spectrum of celestial objects detectable from the Earth. The Earth is surrounded by a shell of electrically charged particles. This shell is composed of multiple layers and is called the ionosphere. Radio signals from space at frequencies of less than 15 to 20 MHz normally do not penetrate our atmosphere. They are either absorbed or reflected back into space. As a result, an Earth-based radio telescope must operate at higher frequencies. At very high frequencies, however, the Earth's atmosphere places a limit on radio observations. Radio signals at frequencies above 300 GHz do not reach the ground since they are absorbed by water molecules of the Earth's atmosphere. The wavelength range extending from 20 m to 1 mm is called the "radio window" of the electromagnetic spectrum.

Countless radio sources can be detected within the natural limits of 15 MHz to 300 GHz. The spectra of the radio-frequency radiation shown in Fig. 3 show a curve that depends on the mechanism for generating the radiation. A differentiation is made

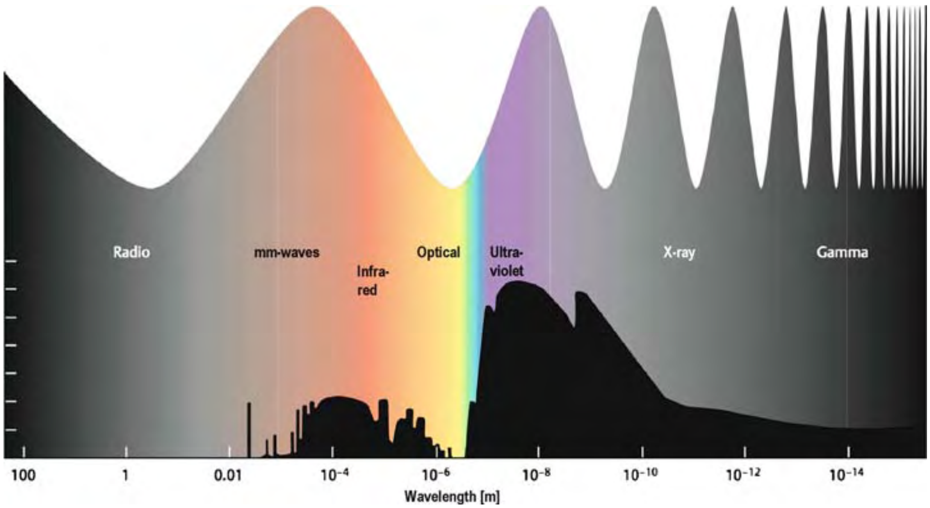

Fig. 2. The radio region observable from Earth occupies a wide range within the electromagnetic spectrum. Radio waves cover an area that is considerably larger than the optical spectrum of light visible to the eye. Image courtesy of *Sterne und Weltraum*

between thermal and non-thermal radiation. Thermal radiation, from the Moon or the Orion Nebula, for example, is produced purely by the temperature of these sources. In other words, these involve heat radiation in the radio region. Here the spectrum rises with increasing frequency or is flat. The situation is completely different for sources involving non-thermal radiation, such as, for example, the quasar 3C 273 and the supernova remnant Cassiopeia A. The radiation from these sources is created by the synchrotron mechanism. Here charged particles moving almost at the speed of light are deflected in magnetic fields and thereby transmit radio waves. A characteristic feature of synchrotron radiation is a decrease in intensity with increasing frequency (Fig. 3).

9.3 The Radio Sun

Anyone wanting to explore the radio universe from his or her own backyard should first try to detect the radiation coming from the Sun. Due to its proximity and high level of activity, the Sun appears to us to be the strongest radio source in the sky. Its radio-frequency radiation originates only to a small extent from the hot gas of the Sun's atmosphere. Much more intensive signals are generated by the interaction of electrically charged particles with magnetic fields, e.g., within the sunspot groups. These are non-thermal radio signals.

Particularly at times of high solar activity, the Sun is an especially interesting radio source for the amateur that he or she can easily observe with easily obtainable equipment. Many amateur radio devotees will have already heard these signals—perhaps without realizing that they are of cosmic origin. The Moon is an entirely different matter. Its temperature-induced radio-frequency radiation is so weak that detecting it is a real challenge for beginners, analogous to observing radio galaxies.

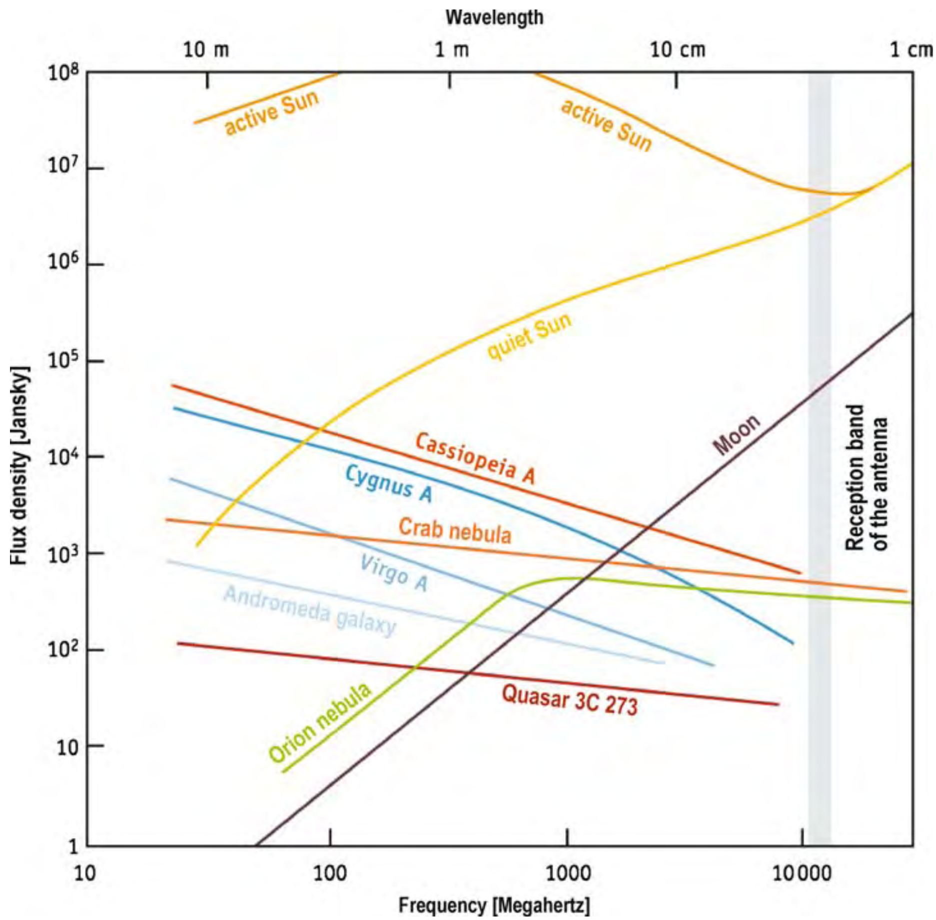

Fig. 3. The diagram illustrates the intensity of the strongest cosmic radio sources as a function of frequency and wavelength. The vertical bar marks the frequency range in which the TV satellite antenna described in this chapter is sensitive. Image courtesy of *Sterne und Weltraum*

The Sun continually emits noise sounding like a hiss from the speaker of a sensitive radio receiver and heard between FM and TV stations. Furthermore, during strong solar activity powerful solar eruptions (flares) can occur that emit intensive pulses of radio noise (radio bursts) that can be received in almost all radio-frequency bands. The radio bursts are in turn grouped together as radio storms that can last minutes or even days. Sometimes they are so strong that they impair radio communication as long as the Sun is located over the horizon for the receiving antenna during the outbreak.

The Sun is the strongest radio source in our sky. Its signals can be detected over the entire radio band.

The Sun emits noise even outside of the active phases—the noise of the "quiet Sun." This can be observed primarily in the centimeter to decimeter region, and therefore in the frequency band of television satellites. The weak radio-frequency radiation from the Moon, which emits thermal radio waves due to its temperature, is located in the same region.

Certain celestial radio sources can also be observed by amateur radio telescopes. Initial forays through the radio universe can be performed in the gigahertz region using a satellite antenna and a satellite finder. In the following section, we will take a closer look at how a simple radio telescope can be constructed using this approach. Then we will tackle a project at the lower end of the radio spectrum: observing the planet Jupiter using a home-made dipole antenna and a sensitive short-wave receiver.

9.4 A Compact Radio Telescope for the Gigahertz Band

Even commercially available parabolic antennas 60 or 90 cm in diameter provide the basis for a sensitive radio telescope that detects radio-frequency radiation from the Sun and the Moon in a frequency range between 10 and 12 GHz. They are inexpensive and also easy to obtain, as is true for the other components of the compact radio telescope described below.

The signal received by the satellite antenna is usually amplified by a so-called low-noise converter (LNC) then converted to a lower frequency, the so-called intermediate frequency, to enable it to then be transmitted through a coaxial cable. The LNC is always supplied along with the parabolic antenna (Fig. 4).

For little money, a simple radio telescope able to detect radio-frequency radiation from the Sun can be built using a TV dish antenna and a satellite finder.

A tiny change in voltage corresponds to the signal leaving the LNC. To detect this, what is needed is a detector that converts it into direct current, as well as an amplifier. Both functions are performed by a "satellite finder" (Fig. 5), which normally functions to align a parabolic antenna with a desired TV satellite. The antenna is moved here until the indicator of the device displays the maximum signal amplitude. The same process is also possible with radio signals from the Sun and from a natural Earth satellite: our Moon.

The Satellite Finder, Model 3735 from Conrad Electronic contains both a broadband detector and an operational amplifier, which boosts the signal voltages from a few millivolts up to 1 V. The gain is manually adjustable by a controller. The satellite finder detects signals in the 950 MHz to 2050 MHz frequency range and operates at normal voltages of 13 V and 18 V.

A small modification lets you easily route the signal voltage from the satellite finder externally to be measured in volts and recorded as a function of time. This is implemented either by an X–Y plotter or a computer connected through the appropriate interface to the voltmeter. Digital multimeters with a computer interface, such as, e.g., the Voltcraft M3610 model, are also available from Conrad Electronic.

The rear panel of the satellite finder is first removed. On the left side of the housing is a connector jack F-Norm (Fig. 6). This is the output for the device. During normal TV operation, this is where the satellite tuner is attached (using an F-connector plug). On the right side is another F jack (F2) that is connected to the LNC of the parabolic antenna to receive a signal. Below this is an operational amplifier chip (OP-Amp) with eight connectors. For our modification, only the connector (pin 1) located on the lower left of the OP-Amp is important: pin 1 supplies the positive potential for the DC voltage sought. A strand of insulated wire is soldered on here.

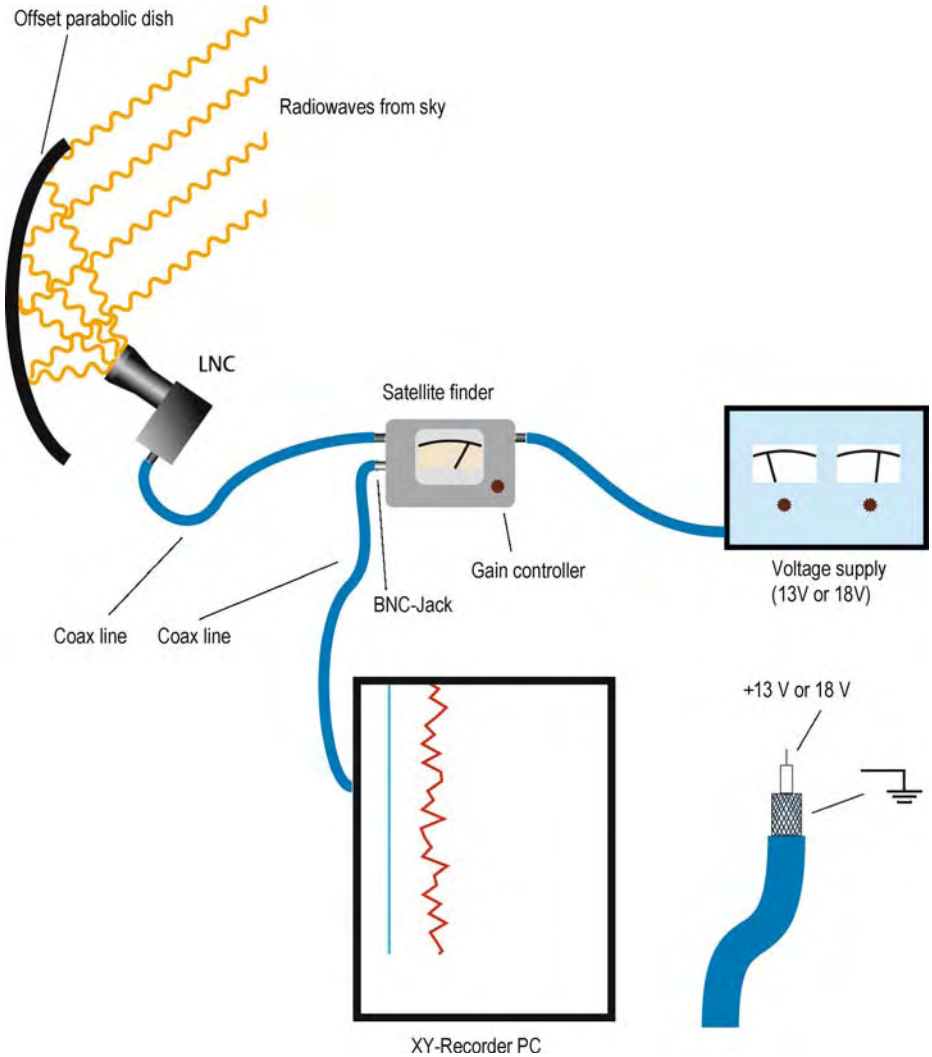

Fig. 4. Diagram illustrating a simple radio telescope. Located at the focus of the offset parabolic antenna is a small horn antenna that sends the radio signal through a short waveguide to the low-noise converter (LNC). From here it goes through a 75-Ω coaxial cable to the terminal F1 of the satellite finder. Terminal F2 is connected to a power supply unit or batteries. Image courtesy of *Sterne und Weltraum*

A minor modification of the satellite finder enables the observer to record the signals received from the radio telescope.

An additional BNC connector jack must be attached (Fig. 6) to the housing to later enable the signal voltage to be easily measured and recorded. Such a BNC connector jack is available from any electronics mail-order supplier. Its purpose, as is true of the F-jacks, is to connect the coaxial cables; in other words, it has a central wire and an outer conductor that symmetrically surrounds the central wire. The free end of the wire connected to pin 1 is soldered to the central wire of the BNC jack to be installed in the housing panel wall. To enable a voltage to be measured between the central wire and outer conductor of the BNC jack, its outer conductor must be connected to the outer conductor of

Fig. 5. A satellite finder, such as the Model 3735 from Conrad Electronic shown here, can be easily modified to receive radio-frequency radiation from space. Image courtesy of Peter Wright

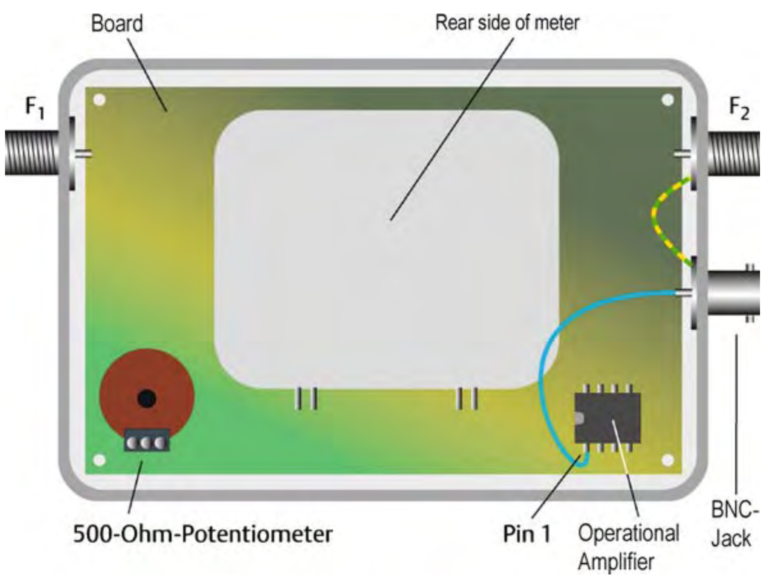

Fig. 6. The diagram shows *the back* of the modified Model 3735 satellite finder. Only components relevant for modification are indicated. At *right* is an operational amplifier (OP) with the connection pin 1, which is connected to the central wire of the BNC connector jack. Image courtesy of *Sterne und Weltraum*

jack F2, since this contains the ground potential. Modification of the satellite finder is then complete.

Now the satellite finder is provided with a power source. For this purpose, terminal F1 is connected to a coaxial cable using an F-plug connector. The cable leads to a stabilized power supply unit that generates voltages of either 14 or 18 V. The outer conductor of the coaxial cable carries the minus while the central wire carries the positive potential of the supply voltage. The power supply unit can be replaced with two 9-V batteries.

9.5 Initial Tests

A good system test consists in connecting the modified satellite finder to a parabolic antenna that has already been aligned with a TV satellite. The satellite receiver is disconnected from the antenna, the incoming antenna line is connected to jack F2, and the power supply is finally connected to F1. Now the needle of the satellite finder should deflect. Adjust the gain control of the satellite finder using the control element "gain control" so as to make the needle deflect all the way over. As soon as the antenna is moved away from the direction of the satellite, the needle should indicate a lower value on the scale. If an X–Y plotter is connected to the BNC jack at the same time, a curve is generated on the plotting paper.

9.6 First Light for Your Radio Telescope

Before you aim your antenna for the first time at the Sun, attach a piece of white paper in front of the waveguide of the LNC. Now slew the antenna until a very bright spot appears on the paper. This is the sunlight reflected toward the LNC by the parabolic antenna. The satellite finder now displays the relative signal strength of the radio-frequency radiation from the Sun.

The LNC should generally never be exposed to the Sun without any protection since otherwise there is a risk it could heat up to the point that its plastic case would quickly melt. The best remedy here is to attach a piece of Styrofoam or, better yet, Styrodur in front of the input of the LNC. The material shields the LNC from heat while at the same time allowing radio-frequency radiation to pass unimpeded.

In our next experiment, the heat-protected antenna is again aimed at the Sun. This should be done around 3:00 p.m. since at this time no artificial satellites are situated in the line of sight whose signals could interfere with reception of the Sun. As soon as the antenna is aimed precisely at the Sun, adjust the gain control of the satellite such that the equipment needle deflects all the way over. By maintaining this setting, along with the alignment of the antenna, you will be able the following day to observe the passage of the Sun through the field of view of the fixed antenna between 2:00 and 4:00 p.m.

It is important to protect the LNC of the antenna when aimed at the Sun by a piece of Styrofoam so that it does not overheat!

If a plotter or a computer, through the interface of a digital multimeter, is also connected, you will obtain a bell-shaped curve of the solar radio-frequency radiation. Observe what happens when the antenna remains aligned in this position over several days: How does the recorded signal change and why?

Are you also able to use the above-described method to aim the antenna at the Full Moon? Can you detect temperature-dependent radio signals? How do they change as the phases of the Moon change?

9.7 Possible Upgrades

Technical enhancements for your radio telescope are possible both in terms of the mechanical system and the electronics. Finding objects is easier if the antenna is mounted equatorially, for example, in parallel with a small refractor (Fig. 7). This allows objects to be observed over many hours. You can, e.g., discover bursts of solar radio-frequency radiation and at the same time observe the Sun optically using the projection method.

Mount your antenna in parallel with an optical scope and observe the Sun simultaneously in the optical and radio regions.

You will soon find that the gain control for the satellite finder is too imprecise: It is difficult to reproduce previously set gain factors. It is therefore recommended that you replace the continuous gain control by a rotary switch that selects between multiple trimmer potentiometers with fixed settings, thereby providing reproducible gain factors. The trimmer potentiometers can have values between, for example, 100 and 500 Ω in 100-Ω steps.

We hope your radio telescope will give you much enjoyment and provide you with an interesting introduction to radio astronomy. If you have questions about amateur radio

Fig. 7. A satellite antenna mounted in parallel with a telescope enables you to easily track the rotation of the sky. This arrangement also allows for simultaneous observation of an object in the optical and the radio region. Image courtesy of Peter Wright

astronomy, the members of the European Radio Astronomy Club are ready and willing to help you (see Sect. 9.14).

9.8 The Giant Planet Jupiter

Even a small telescope shows Jupiter as a flattened sphere of gas with cloud bands running parallel to the equator. And, even binoculars will reveal the four Galilean moons Io, Europa, Ganymede, and Callisto as points of light. Jupiter's moon Io is the most volcanically active body in the Solar System. Its volcanos eject sulfur oxide and dioxide gas as fountains reaching 100 to 300 km in height. The gas leaves the surface of Io and is ionized by colliding with fast charged particles.

The ionized gas, known as the plasma torus, surrounds Jupiter as a thin toroidal cloud at a distance of 5.9 Jupiter radii. Its diameter is about one Jupiter radius. The orbital plane of the plasma torus is not identical with Io's orbital plane but is instead oriented by the effect of Jupiter's magnetic field in the plane of the magnetic equator tilted 10° relative to the equator of Jupiter.

Jupiter's magnetosphere surrounds the sphere of the planet and covers a volume of space hundreds of times greater than the volume of the Earth's magnetosphere. Jupiter's magnetosphere is deformed by the solar wind. The magnetospheric tail generated by Jupiter reaches beyond the orbit of Saturn. The magnetic axis (the connecting line between the magnetic north and south poles) is tilted 10° from Jupiter's rotational axis. In addition, the magnetic field rotates in fixed fashion along with the planet in 9 h 55 m 29.37 s. As a result, during one rotational period we see first the magnetic north pole and then the south pole.

9.9 Jupiter as a Radio Source

The fact that Jupiter is more than a cold gas ball was first revealed in early 1955 when two American radio astronomers came upon its radio-frequency radiation by accident. Franklin and Burke were observing the heavens at 22 MHz using a cross-shaped antenna configuration, the "Mills Cross" near Washington, DC. Mills Cross consists of a total of 64 dipole antennas arranged as a giant cross, each arm of the cross being more than 600 m long.

Jupiter is one of the strongest radio sources in the sky. Radio-interference storms are generated in its magnetosphere and can be detected by a sensitive short-wave receiver.

To test the telescope, the astronomers observed the radio emission of the Crab Nebula. Their measurements were at times disturbed by sporadic signals of unknown origin that appeared each day four minutes earlier. As a result, the signals could not have been terrestrial interference but had to emanate from an astronomical object. It was found that this interference occurred especially often when Jupiter was located within the lobe of the antenna. Subsequent investigation based on older observational data revealed that Jupiter's radio signals had already been recorded in the early 1950s in Australia and were even recorded in the early 1930s by radio astronomy pioneer Karl Jansky.

Figure 8 illustrates Jupiter's radio spectrum. Charged particles move within its magnetic field. They are deflected by the magnetic field lines and in the process emit synchrotron radiation in the decimeter wavelength. This is non-thermal radiation. Thermal

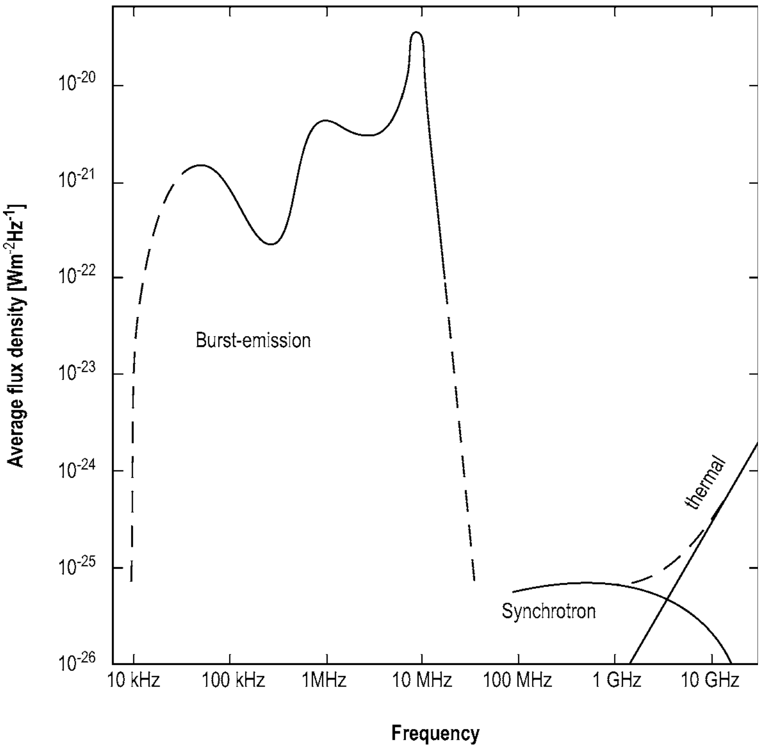

Fig. 8. The spectrum of a medium-strength Jupiter burst produces the curve shown to the left. However, bursts may be ten to hundreds of times stronger. Jupiter bursts can be detected primarily at frequencies around 20 MHz. At higher frequencies, the planet does not emit bursts but synchrotron radiation from its magnetosphere, as well as thermal radiation from its atmosphere. Image based on Carr et al. [1]

radiation can be detected at shorter wavelengths, in the range of a few centimeters, originating directly in the planetary sphere. Observation of this radiation yielded a temperature for the upper cloud boundary measuring 145 K (degrees Kelvin). In addition to the spectral components diagramed in Fig. 8, the Voyager probes detected sporadically occurring radiation at wavelengths of several kilometers.

The strongest component of the radio emission is created by radio-interference storms in the 5 to 39-MHz (decameter) range. They last from a few minutes to several hours and consist of a series of individual noise pulses or bursts. The radio storms occur only sporadically and are of varying intensity. For this reason, Fig. 8 shows only an averaged spectrum.

Earth-based observation of bursts below about 5 MHz is prevented by the ionosphere. Above 10 MHz, their intensity drops sharply. The cutoff frequency of the spectrum at a maximum of 39 MHz is interpreted as being due to the maximum energy of the charged particles being emitted: particles that radiate at this frequency lose their entire kinetic energy through radio emission. Based on this assumption, the site found for the radiation is a magnetic induction of 14 Gauss—a value that is attained in the vicinity of Jupiter's poles.

Two types of bursts can be detected in the short-wave region: L-bursts (long bursts), each of which lasts about 1 to 5 s, and S-bursts (short bursts), which last about 0.1 to 10 ms each. In the speaker of a receiver, L-bursts sound like ocean surf, while S-bursts resemble the crackling noise caused in the radio spectrum by distant thunderstorms. The homepages of the University of Florida Radio Observatory and the Radio Jove project provide sound samples of L-bursts and S-bursts (see Sect. 9.14).

9.10 Cause of Decameter Radiation

For a long period after their discovery, the cause of the radio storms remained mysterious. In 1964, K.S. Bigg noted a connection with the position of Jupiter's moon Io: Whenever the radio storms were most frequent and intensive, Io was located to the right or left of the planet as seen from Earth. These radio storms are called Io-A and Io-B. Furthermore, Bigg found two more types of radio storms independent of Io's position, the so-called A- and B-storms. Io-B- and B-storms consist primarily of S-bursts, while Io-A- and A-storms additionally contain L-bursts.

The radio bursts dependent on Io are created within a magnetic flux tube, a bundle of magnetic field lines that connects Jupiter to Io. Electrically charged particles can move along the flux tube in spiral orbits from Io to Jupiter and back again while emitting radio waves. The flux tube thus acts like a giant transmitting antenna. Since Io orbits Jupiter, the orientation of this "antenna" relative to the Earth is changing constantly. This is why we can receive the radio waves emitted by it only intermittently. In addition, the spiral motion of the emitting particles results in a cone-shaped radiation pattern of the flux tube (Fig. 9).

Jupiter's radio bursts can be observed mainly whenever its moon Io is situated to the left or right of the planet as seen from the Earth.

The engine for Jupiter's radio bursts is the volcanism of the moon Io. Its volcanoes constantly spew out sulfurous gas to altitudes of more than 300 km, where it is ionized by ultraviolet light from the Sun. This is why Io is surrounded by a cloud of electrically conductive gas. In terms of its electric properties, Io thus acts like a conductive sphere.

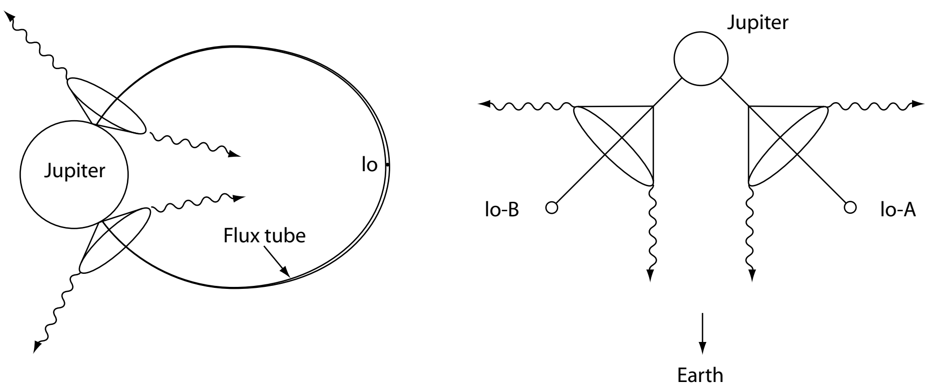

Fig. 9. Jupiter's short-wave radiation is emitted within the surface shell of a cone (*left*). Only when the envelope of the cone passes the line-of-sight to Earth (*right*) can the radio storms be received. When Io is located to the left of the planetary sphere, the right edge of the cone faces Earth and we receive Io-B bursts. When it is situated to the right of the planet, we receive Io-A bursts

Io takes about 42 h to revolve around Jupiter once, whereas Jupiter's magnetic field rotates in about 10 h. As a result, Io is continually overtaken by Jupiter's magnetic field lines. The magnetic field induces a voltage of around 400,000 volts in the electrically conductive moon. This voltage source forces a current of three million amperes along the magnetic flux tube that connects Io to Jupiter. The total power output radiated in the radio-frequency region is about a trillion watts (10^{12} watts).

Not all the radio bursts detected from Jupiter depend on the position of Io. The existence of radio storms not dependent on Io indicates that charged particles are also present away from the flux tube that actively contribute to the radio emission. The active regions are apparently located in the polar regions of Jupiter's magnetic field. Here, where the field lines funnel together, is where Jupiter's magnetic field is the strongest. In fact, the radio storms are observed most frequently when the flux tube has the correct orientation vis-à-vis Earth and at the same time the north or south pole of Jupiters magnetic field is tilted in the direction of the flux tube.

9.11 A Simple Radio Telescope for Jupiter

A receiver system for observing Jupiter consists of a short-wave antenna, a preselector, the short-wave receiver, and a cassette recorder or other tape recorder to record the signals (Fig. 10). In the following segment, we take a closer look at these components.

The key components of a radio telescope for Jupiter are a $\lambda/2$ dipole antenna and a sensitive short-wave receiver operating in the 18 to 24-MHz range.

The antenna. In principle, any antenna that resonates in the 18 to 24-MHz frequency range is suitable for observing Jupiter. Below 18 MHz, the Earth's ionosphere blocks reception of radio waves from space, while above 24 MHz the radio-frequency radiation from Jupiter is too weak. An appropriate unit is, e.g., a $\lambda/2$ dipole for the 15-m amateur radio band (21.0 to 21.45 MHz) suspended at a height of $0.35 \times \lambda$ above the ground and oriented in an east–west direction. Its antenna pattern favors radio-frequency radiation coming from the south and at an altitude of about 40° above the horizon. (This corre-

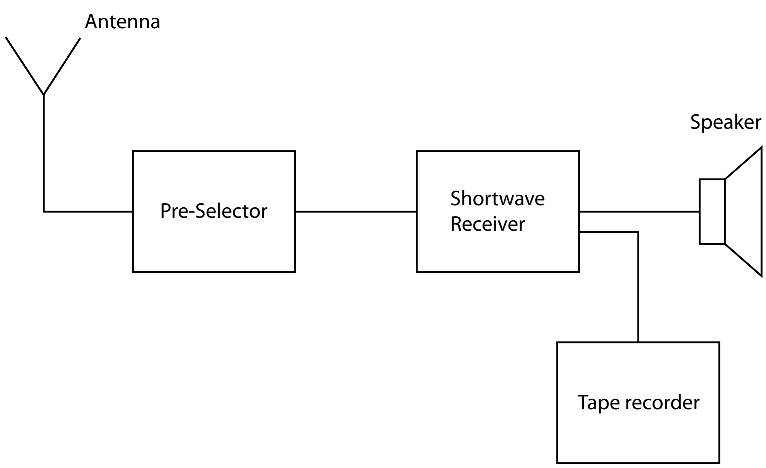

Fig. 10. Components of a simple amateur radio telescope

sponds to the altitude of the celestial equator for a geographic latitude of 50°.) Jupiter remains within field of view of the antenna for about 2.5 h before and after culmination.

What's known as a balun is placed at the center of the antenna. Additional information on constructing dipole antennas can be found in reference books for amateur radio operators and the homepages of NASA's Radio Jove Project, as well as from Radio-Sky Publishing (see Sect. 9.14).

Preselector. Commercially available short-wave receivers are often affected by signals from strong short-wave stations transmitting outside the intended reception band. Short-wave transmitters operating in the lower frequency bands, e.g., in the 49-m band, can cause interference in the upper frequency bands, e.g., in the 15-m band. These undesirable signals are most noticeable at night when the signal level of the short-wave transmitters is increased. The best solution to this problem consists in not allowing the interfering signals to ever reach the receiver. This function is performed by a tunable filter, known as a preselector, that is connected between the antenna and receiver input and allows only those signals that are in the frequency band of interest to pass. Preselectors are commercially available or can be home-built.

Receiver. The receiver should be a sensitive short-wave receiver (manufacturer's specifications: 1 μV for 10 dB (S+N)/N or better) for the 18 to 24-MHz band that has good selectivity and a coaxial antenna jack. This selectivity is needed in order to avoid interfering transmitters. In addition, it must be possible to switch off the automatic gain control, AGC, that functions during the reception of short-wave transmitters to compensate for signal fluctuations (fading), since otherwise Jupiter's radio signal of highly variable intensity could not be detected. Radio signals from space are always amplitude-modulated; therefore, only reception in AM mode is useful.

Suitable receivers do not have to be expensive. They are often sold used at ham-radio flee markets. Radio sets for the short-wave bands used for amateur radio are also suitable for observing Jupiter. NASA offers a complete radio telescope in the form of a kit for observing Jupiter as part of its Radio Jove Project. A free downloadable manual describes all the technical details of the radio telescope in depth.

Reception test:
When the antenna is connected to the receiver, the noise audible in the speaker must rise significantly.

Recording the signals. The signals received can be recorded on cassette tape, standard audio tape, or a computer. Most cassette recorders are equipped with an automatic volume control (AVC) that causes differences in intensity to become almost inaudible. Therefore it must be possible to switch off the AVC of the cassette recorder. Many recorders allow the recorded tape to be played back at higher speed, thereby enabling suspected signals to be found quickly.

9.12 Reception in Practice

The following test will show if a receiving system for observing Jupiter is sufficiently sensitive. Set the receiver to a frequency free of interference. When the antenna is connected to the receiver's coaxial jack, the background noise should rise by an audibly significant amount. This additional noise originates mainly in our Milky Way and shows that your receiving system is detecting noise from space. The system's sensitivity is therefore not limited by the internal noise of the receiver but by galactic noise. Jupiter must drown out this natural background noise to be heard from the speaker. In the event the noise does not rise with the antenna connected, the signal must undergo preamplification. The preamplifier must be installed as close to the antenna as possible. To avoid interference from strong short-wave transmitters, you should operate the amplifier together with a preselector.

Reception tests only make sense when Jupiter is in the sky. Information to this effect is provided by various planetarium programs, such as, e.g., Calsky or Easy Sky. The optimum observing period is the second half of the night when the attenuating effect of Earth's ionosphere diminishes. During daytime observations, not only the ionosphere but also the Sun make their presence known: especially during the period of maximum solar activity, the Sun emits intensive radio bursts that resemble the L-bursts from Jupiter.

Before each observing session, the receiver is set to "AM" and the AGC is switched off. Now search for an interference-free frequency and retain this position. Then turn on the receiver; note the starting time or record this verbally on the tape. As soon as you believe you are hearing Jupiter, the receiver is slightly detuned; this is because the presumed L-burst could also be a signal fading in and out from a distant radio station.

To completely exclude the possibility there was interference, you should continually listen to the noise during the observation, then later compare what you've recorded with what Jupiter fans at remote sites have recorded concurrently.

9.13 Future Opportunities

We have attempted in this chapter to describe some initial steps into the invisible universe. Due to their high intensity, radio waves from the Sun and Jupiter are among the strongest signals that an amateur radio astronomer can receive using simple equipment. As we indicated at the beginning, a large number of other projects are also possible beyond these two. An interesting one, for example, is the search for signals from intelligent extraterrestrial civilizations (SETI, Search for Extraterrestrial Intelligence). The US-based SETI League provides guidance for amateur astronomers on how to build your own radio telescope and participate in the search. Additional projects involve observing the Milky Way in light at the 21-cm line of hydrogen and the detection of pulsars. It is our hope that the information of this chapter along with the following references to interest groups, literature, and electronic components for building equipment will assist you in making a successful launch into the realm of radio astronomy.

9.14 Additional Information

9.14.1 Contact Addresses

European Radio Astronomy Club, c/o Peter Wright, Ziethenstr. 97, D-68259 Mannheim, Germany, Tel.: +49-(0)-621-794597, E-Mail: erachq@aol.com: http://www.eracnet.org/

Society of Amateur Radio Astronomers, USA: http://www.radio-astronomy.org/

SETI League, 433 Liberty Street, PO Box 555, Little Ferry, NJ 07643:
http://www.setileague.org/

University of Florida Radio Observatory (UFRO), with predictions of Jupiter's radio bursts: http://ufro1.astro.ufl.edu/