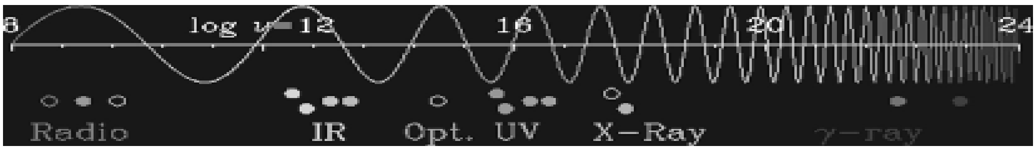
Whispers from the Cosmos



By Larry Van Horn

It's a warm summer evening and you have some spare time to do a little radio listening. You walk into your radio room and sit down in front of your modest rack of equipment. Slowly you turn the dial of your favorite VHF/UHF communications receiver looking for something new to monitor.

Suddenly you notice an increase in the noise level on your receiver's S-meter. You quickly run through your computer frequency database to see what local or satellite targets are in the vicinity of your received signal. Finding nothing, you now swing your dish antenna a few degrees off its original position and notice that the noise source fades away.

Where is this increased noise level coming from? What kind of signal has your dish antenna captured? The chances are good that you are hearing a signal from a distant galaxy or quasar — a whisper from the cosmos.

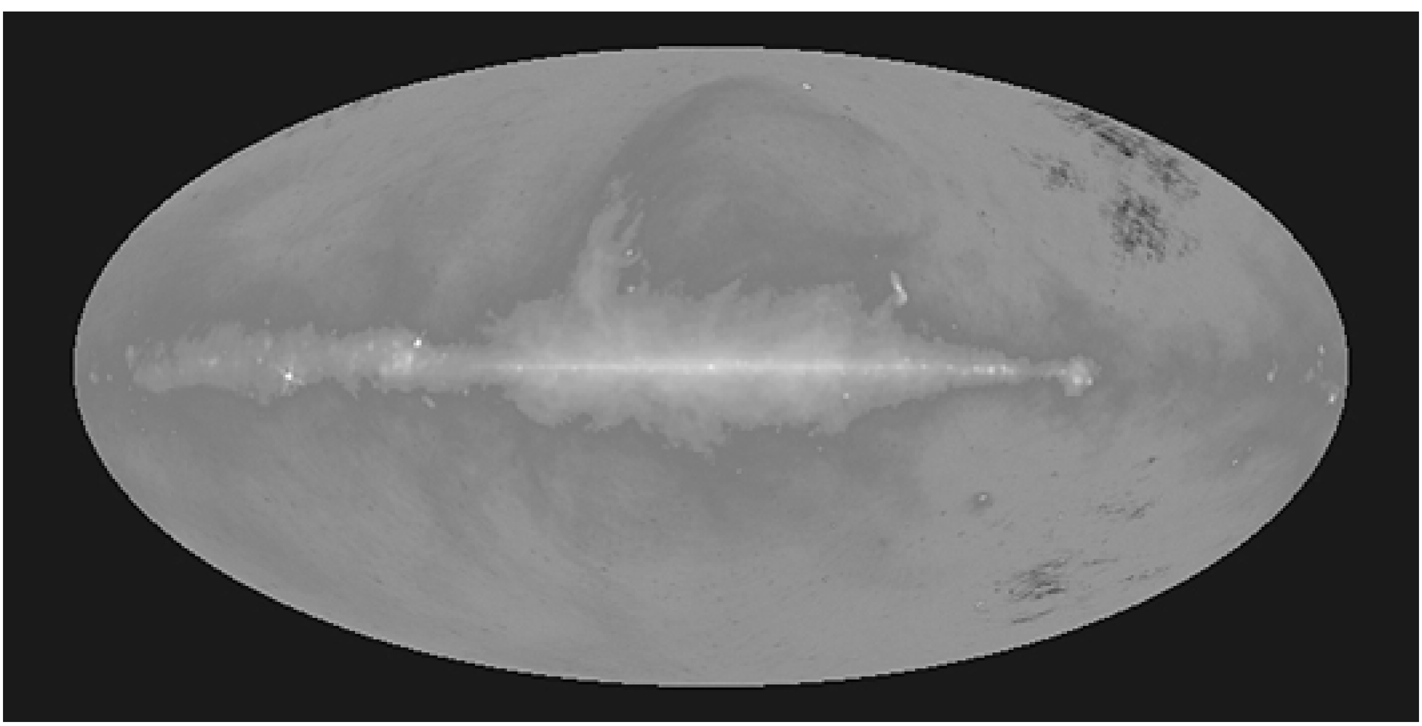
In the Beginning

Many of the great discoveries of science have been made by accident. It was just such a discovery which launched the science of radio astronomy.

It all began more than half century ago when Bell Telephone assigned a noise-finding task to one of their engineers and physicist, Karl Jansky. The noise was a periodic disruption to the company's transatlantic radio links in the high frequency spectrum around 20.6 MHz.

Jansky constructed an elaborate rotatable directional antenna array (called the Bruce Curtain) and immediately discovered that all the noise originated from two sources: thunderstorms (local and distant) and an area of the sky near the center of the Milky Way Galaxy in the Sagittarius constellation.

These sources of terrestrial and cosmic noises were noted, and subsequent experiments by individuals occasionally took place. In 1937 another engineer, Grote Reber, built a parabolic reflector (dish antenna) in his back yard in Wheaton, Illinois, and began mapping the sky for radio emissions at 160



This survey is a mosaic of data taken at Jodrell Bank, Effelsberg and Parkes telescopes. The data was distributed in the "NRAO Images from the Radio Sky" CDROM. This image was generated by SkyView. Energy= 1.69x10^-6 eV Frequency= 408x10^6 Hz (408MHz) Wavelength= 73.5 cm. (Credit: Max Planck Institute for Radio Astronomy, generated by Glyn Haslam)

MHz. He later determined that our own sun was a major source of radio emissions.

Over the next several decades, radio emanations (noise) from the Crab Nebula, Cygnus A, interstellar hydrogen, quasars (quasi-stellar radio sources), stars in the Milky Way and other galaxies, and even our own solar system (the planet Jupiter) have been pinpointed by radio astronomers.

But it is still noise, and who wants to listen to that?!

Radio astronomers do, and in recent years, amateur radio astronomers have also joined in the hunt. Receiving equipment costs have come way down, making it much more affordable for the amateur to join in on the fun. In fact, for the first time ever, a company called Radio Astronomy Supplies* has turnkey radio astronomy systems for sale to the general public.

The single largest contributing factor in the increased number of amateurs entering into the radio astronomy field is the power of home personal computers. The personal computers of today have the power and speed that are needed in order to do meaningful radio astronomy work.

Where Do You Listen

The single most common question I get asked is, "Where do you listen for cosmic signals and what are you listening for?" In the many references I have read over the years, they really never answer that question. Looking at official International Telecommunications Union (ITU) and Federal Communications Commission (FCC) tables of allocations, you will find radio astronomy bands scattered throughout the radio spectrum. But what are the radio astronomers listening to on these frequencies?

Table one (see page 16) gives you a complete breakdown of those radio astronomy bands and what is being heard on them. With this resource, the amateur will find quite a few interesting targets to observe and explore in the invisible universe of radio astronomy world.

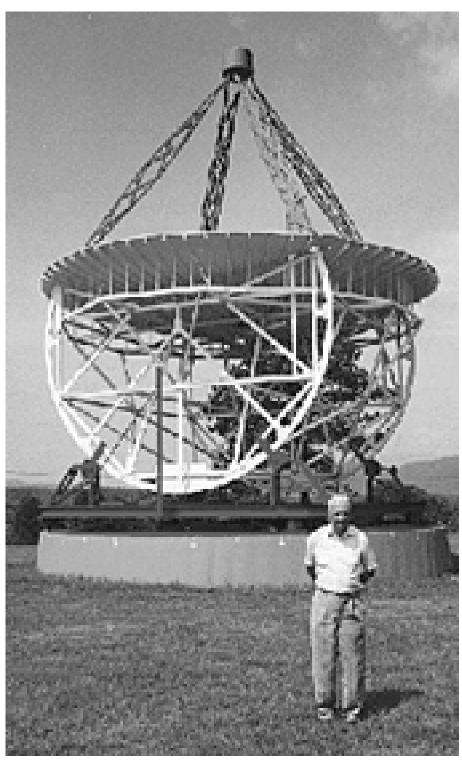
What Can the Amateur Contribute?

You may be surprised to learn the opportunities for significant discovery are practically infinite. But how can this be so?

- Large observatories, to justify their huge cost, usually look at very remote sources with very narrow beams for very short periods of time. They cannot — by virtue of their design — monitor large sky areas like amateur radio astronomers can.
- The amateur has something else going for him that the professionals lack — unlimited time that he can devote to a single observing program.
- Modern state-of-the-art equipment and inexpensive computers enable amateurs to do useful and viable work, when it is pursued with intelligence and attention to detailed data.
- Just as the patient visual amateur astronomer is likely to discover a new comet or asteroid, likewise the amateur radio astronomer is most likely to discover a new radio source or one whose flux output has changed radically.

Some Opportunities for the Amateur

Our own solar system offers all sorts of interesting exploration. Emissions from Jupiter are quite easy to monitor and this work has by no means been "mined out" by the professionals. Equipment as simple as a shortwave receiver, a quiet spot in the 20 MHz band, and a dipole antenna are all that is required to hear the Jovian planet.



Grote Reber poses with his original dish antenna at the National Radio Astronomy Observatory in Green Bank, West Virginia. (Photo courtesy of the NRAO)

Our own sun, as close as it is to us and as vital as it is to our existence, isn't fully understood in all of its mechanisms. Every single bit of information we have gathered about the sun has been derived from events occurring on its surface. Aside from the idea that the power source involves a nuclear furnace in its interior which converts hydrogen to helium, we haven't the foggiest notion of what's really going on. Valuable radio observations of the sun may be done with minimal and inexpensive radio receivers and antennas.

On average, a supernova can occur in our own galaxy every 10 to 30 years. If such an event occurred right now, would we see it? Probably not. If the nova occurred along the galactic equator, it would not be visually seen due to interstellar dust. However, the nova would stand out as a new radio source, radiating powerfully in the radio spectrum. It would be easily detected with a simple interferometer radio telescope.

Even strong signals from the center of our galaxy are quite easily detected with minimal radio equipment. These signals remain a mystery. There could quite possibly be from a black hole at the heart of our galaxy. These strong pulses have been recorded by amateur radio astronomers.

So turn on that radio and aim that antenna toward the sky. A whole new universe awaits you — the invisible universe of radio astronomy. You could be part of an ever larger group of amateurs looking for "Whispers from the Cosmos" if you are willing to take up the challenge.

This feature originally appeared in the May 1998 Satellite Times. The author is deeply indebted to the Committee on Radio Astronomy Frequencies and Jeffrey Lichtman for their assistance in preparing this feature article.

* Radio Astronomy Supplies, 190 Jade Cove Drive, Roswell, GA 30075. 770-992-4959; www.nitehawk.com/rasmit/ras.html

TABLE 1: Radio Astronomy Bands

Unless otherwise indicated all frequencies are in MHz.

13.36-13.41	This band is very important for observations of decametric radiation from the planet Jupiter and from the Sun.
25.55-25.67	This band is very important for observations of decametric radiation from the planet Jupiter and from the Sun.
37.00-38.25	This band is very important for research of radiation from Jupiter. Long after all the decametric frequency bands have been allocated and widely used by active services Jovian decametric radiation was discovered. The allocations to the radio astronomy service are extremely narrow since the interesting Jovian phenomena can cover the entire spectrum from 3-40 MHz.
73.00-74.60	ITU Region 2: Observations of emissions from the Sun (solar wind), Jupiter, stars, galaxies and interstellar clouds.
79.25-80.25	This band is used for monitoring the interplanetary "weather" structure in the solar wind by an international network of instruments.
150.05-153.00	ITU Region 1: This band is widely used in the United Kingdom and is a major band for the Giant Meter wave Radio Telescope (GMRT) in India. Also used for pulsar observations and solar observations.
322.0-328.6	Observations of pulsars (not allocation as passive only band): This band has the desired octave-spacing relation with the 150.05-153 MHz and 608-614 MHz bands, which is needed for continuum observations and in addition it contains an important atomic spectral line–the hyperfine- structure spectral line of deuterium at 327.384 MHz.
406.1-410.0	Observations of pulsars (not allocation as passive only band)
420.0-450.0	Arecibo Observatory, Puerto Rico radar and astronomy observations (not allocation as passive only band)
430.0000	National Astronomy and Ionospheric Center and Cornell University planetary research radar (part of Arecibo Radio Astronomy Observatory in Puerto Rico).
608.0-614.0	Very Long Baseline Interferometry (VLBI) for observing sources such as pulsars. (US TV channel 38 receive only scientific band)
1330-1400	Observations of Doppler-shifted radiation from hydrogen in galaxies
1420-1427	This band is the most important band for studies of the hydrogen line at 1420.4060 MHz and for continuum observations. 1420-1660 MHz also used for SETI survey programs.
1610.6-1613.8	This band is an important band for Hydroxyl radical (OH) line observations and is used in conjunction with the main OH bands in the next higher OH-band (1660-1668.4 MHz).
1660.0-1668.4	Observations of the Hydroxyl radical (OH) spectral line which is important for understanding interstellar medium and star formation in galaxies. In addition this band is used for continuum observations and also for VLBI.
1718.8-1722.2	Secondary allocation internationally for observation of hydroxyl radical spectral line.
2290.0-2300.0	Very Long Baseline Interferometry and NASA Deep Space Network
2320.0000	NASA's Solar System Radar in Goldstone, California
2655.0-2700.0	This band is primarily of interest for the study of continuum emission of radio sources. The spectral region 2655.0 to 2700.0 MHz is a good band for continuum measurements partly because the galactic background radiation is low, and also because radio astronomy receivers are of excellent quality and have very low noise at such frequencies.
2690.0-2700.0	Observations of galactic and extragalactic radio sources. Solar observations by the Air Force Solar Telescope Network.
2800.0000	Daily solar flux index is measured from Ottawa, Ontario, Canada on this frequency.
3260-3267	Three molecular lines of the CH molecule have been detected at 3263, 3335 and 3349 MHz. The study of interstellar CH is considered to be extremely important in understanding the chemistry of the interstellar material. The presence of CH suggests the existence of the molecule CH4 (methane) which is considered one of the basic molecules for the initial stages of the formation of life.
3332-3339	Three molecular lines of the Methyladyne molecule (CH) have been detected at 3263.794, 3335.481 and 3349.193 MHz.
4800-5000	The spectral region around 5 GHz has been one of the widely used frequency ranges in radio astronomy during the last decade. One of the most important uses of the band around 5 GHz is the study of the formaldehyde (H_2CO) interstellar clouds at 4829.66 MHz. The H_2CO line at this frequency is considered to be one of the most important radio lines in the entire spectrum, primarily because it can be detected in absorption in almost any direction where there is a continuum radio source.
4990-5000	Used to observe the distributions of brightness of objects in our galaxy and others, radio maps of interstellar clouds and supernova remnants. This area of the spectrum has a low level of galactic background continuum radiation. This band is also used for Very Long Baseline Interferometry (VLBI).
6650-6675.2	This band is important for observations of Methanol (CH_2OH) which is an important tracer of star formation activity.
8510.000	NASA's Solar System Radar in Goldstone, California (I Megawatt of power)

All frequencies below this point are measured in GHz.

10.60-10.70	The frequency band 10 to 15 GHz provides some of the best angular resolutions (~2 arc minutes) using many large and accurate radio telescopes.This high-frequency range is also important for monitoring the intensity variability of the enigmatic quasars. The energy emitted during any one burst from a quasar is equivalent to completely destroying a few hundred million stars in a period of a few weeks or months.
14.47-14.50	At 14.4885 GHz, an important formaldehyde (H_2CO) line exists, which has been observed in the direction of many galactic sources.
15.1365-15.35	Radio astronomy band (shared)
15.35-15.40	Observations of quasars (passive receive only band): The small sizes of the quasars are revealed from the VLBI observations mentioned earlier (10.6-10.7 GHz). Such observations are also being made in the frequency band 15.35-15.40 GHz. The higher frequencies provide us with better angular resolution and enable us to determine more accurately the sizes and structure of quasars.
22.21-22.50	Used by radio astronomers to measure distances to far galaxies and Very Long Baseline Interferometry (VLBI). The band 22.01-22.21 GHz is of importance in conjunction with the adjacent band (22.21-22.5 GHz) for observations of redshifted H_2O.
22.81-22.86	This band is of importance for studies of a non-metastable ammonia line and two lines of methylformate.
23.07-23.12	This band is of special importance for studies of ammonia lines. There is a highly interesting methanol maser line immediately above the protected band at 23.121 GHz.
23.60-24.00	The band is used for observations of the main ammonia band in the interstellar medium and also important for continuum observations and for observations of a number of other spectral lines.
30.00-106.00	The new Millimeter Array (MMA) will help scientists understand the age of the universe; image distant galaxies/pre-planetary structures; measure the properties of subsurface layers of asteriods; and probe the outflows from thousands of stars, among other possibilities. The US-Mexican Large Millimeter Wave Telescope (LMT) will also use this frequency range.
31.10-31.80	This band is a continuum band.
36.43-36.50	This band is of importance for the search for HC_3N and OH lines.
42.50-43.50	The frequency region between 42.5 and 49 GHz contains important spectral lines of some diatomic and other molecules. The lines of SiO indicate maser emission. Other molecules detected in this frequency range include H2CO, CH3OH and OCS.
47.20-50.20	(See 42.50-43.50 GHz above)
48.94-49.04	Observations of molecular material in galaxies
51.40-54.25	This is an important radio astronomy band in the series of continuum bands.
58.20-59.00	(See 51.40-54.25 GHz above)
64.00-65.00	(See 51.40-54.25 GHz above)
86.00-92.00	This is an important radio astronomy band for continuum measurements and contains several natural lines, two of which are considered of special importance (see Table 2 for a complete list)
92.0-95.0	The band is important for many spectral lines including diazenylium (HNN+) (rest-frequency = 93.174 GHz).
95.0-100.0	This frequency range is important for its "forest" of molecular spectral lines: The primary allocation for the band 97.88-98.08 Ghz has the carbon monosulphide (CS) spectral line (rest-frequency = 97.981 GHz).
100-102	Radio astronomy band
101-120	SETI survey programs
105-116	This is one of the most important bands in the radio frequency spectrum, at least equal in importance to the hydrogen line band 1400-1427 MHz. The band contains many spectral lines, in particular the lines of carbon monoxide and its isotopes (CO) at 109.782, 110.201, 112.359 and 115.271 GHz which are not only the most powerful tool in the study of isoptope ratios, but are also essential in the study of cool clouds, regions of star formation and structure of our Galaxy and other galaxies.
116-126	Observations of ozone, carbon monoxide and nitrous oxide
140.69-140.98	This band is 300 MHz wide centered on 140.839 GHz, which is the rest-frequency of Formaldehyde (H_2CO).
144.68-144.98	This band is 300 MHz wide centered on 144.827 GHz, which is the rest-frequency of Deuterated Hydrogen cyanide (DCN).
145.45-145.75	This band is 300 MHz wide centered on 145.603 GHz, which is the rest-frequency of Formaldehyde (H2CO).
146.82-147.12	This band is 300 MHz wide centered on 146.969 GHz, which is the rest-frequency of Carbon monosulphide (CS).
150.0-151.0	This band is 300 MHz wide centered on 150.498 GHz, which is the rest-frequency of Formaldehyde (H_2CO).
160.0000	Cosmic background radiation from the Big Bang peaks around this frequency
164.0-168.0	This band is used for continuum observations.
174.42-175.02	Frequencies in the 174.0-182.0 GHz range contain useful lines for radio astronomy at 174.6, 174.85, 177.26, 178.4 and 181.2 GHz.
177.0-177.4	(See 174.42-175.02 GHz above)
178.2-178.6	(See 174.42-175.02 GHz above)
181.0-181.46	(See 174.42-175.02 GHz above)
182.0-185.0	This band contains important lines of water vapour at 183.31 GHz and ozone at 184.75 GHz.
186.2-186.6	In the band 185-200 GHz, the subband 186.2-186.6 GHz is used for observations of a spectral line of diazenylium.
197.0-220.0	SETI survey programs
217.0-231.0	The most important millimeter wave radio astronomy band. Observations of carbon monoxide, nitrous oxide and other complex molecules in gas within galaxies. Also used for observations of broadband noise from cosmic background radiation associated with the Big Bang (peaks around 160 GHz). The relevance of the band 217-231 GHz is that lines of carbon monoxide (CO) at 219.560, 220.399 and 230.542 GHz need to be observed in conjunction with CO lines in the band 105-116 GHz.
265.0-275.0	This band contains a very important series of spectral lines of the molecules C2H (262.5 GHz), HCN hydrogen cyanide (265.9 GHz), HCO+, formalyl (272.0 GHz).
300 and above	Not yet allocated but supposedly widely used for radio astronomy work.
500.000	NASA's Submillimeter Wave Astronomy satellite will observe astrochemical phenonmena near this frequency.