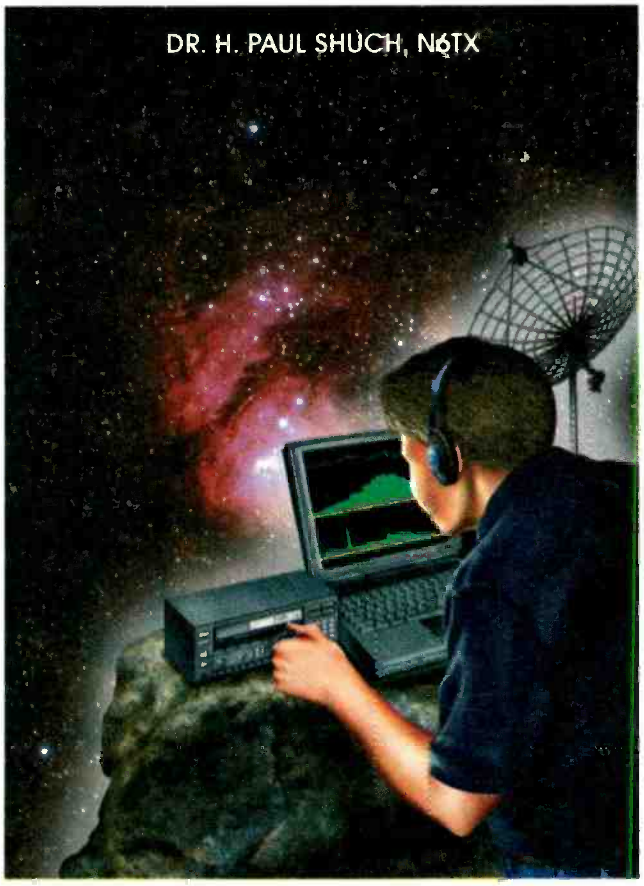
Join The Search For

Extra-Terrestrial Intelligence

DR. H. PAUL SHUCH, N6TX



Remember SETI, the electromagnetic search for extra-terrestrial intelligence? For more than three decades, beginning in 1960, this quasi-government research project sought clear, unambiguous evidence of other technologically advanced civilizations in the cosmos. SETI existed under the auspices of the *National Radio Astronomy Observatory* (NRAO), *National Atmospheric and Ionospheric Center* (NAIC), *National Science Foundation* (NSF), *National Aeronautics and Space Administration* (NASA), other various alphabet-soup organizations, and several universities. Three dozen different SETI programs once scanned the skies with the world's greatest radio telescopes, sifting through "buckets of bits" with massive computers, trying to separate the "cosmic wheat" from the "galactic chaff." When each search came up dry, tax dollars funded the next with still more sensitive receivers, yet more massive antennas, even grander computers. SETI, so the conventional wisdom held, required the kinds of facilities that only governments could afford.

Then in 1993, Congress pulled the plug, pushing SETI away from the public trough. SETI science was just too expensive. SETI, it began to appear, required the kinds of facilities that *not even* governments could afford. By terminating government-funded SETI, Congress reduced the federal deficit by . . . 0.0006 percent!

But SETI is a science that refuses to die. Driven by humankind's insatiable curiosity, it seeks to answer the fundamental question that has haunted humankind since first we realized that the points of light in the night sky are other suns: "Are we alone?" Today the search continues, privatized by laymen from all walks of life who cannot let that question go unanswered. Around the world, dozens of amateur SETI observatories are springing up, built by radio hams, microwave experimenters, and computer hobbyists who hope to make up in strength of numbers what they lack in government funding. Today's "*SETIzens*" embrace a new wisdom: that as technology advances, SETI begins to require the kinds of facilities that *ordinary citizens* can afford.

Ham radio operators call SETI the ultimate DX. In this article, we'll explore the privatization of SETI, what it takes in nuts and bolts and ones and zeroes to seek out our cosmic companions, and how you can join the search.

Where Do We Look? Today's amateur SETI efforts scan the skies in the range of radio frequencies known as the *microwave window*, where photons (the fastest spaceship known to man) can travel relatively unimpeded through the interstellar medium. Most searches concentrate on the 1.3- to 1.7-GHz band, exactly where the pros started out. That's a spectral region for which much inexpensive equipment

Is Earth the only planet in the universe that's capable of sustaining intelligent life? You can help to answer that question for yourself by joining the legion of dedicated enthusiasts who are already scanning the heavens for signs of intelligent life—it can be an exciting as well as fulfilling pastime.

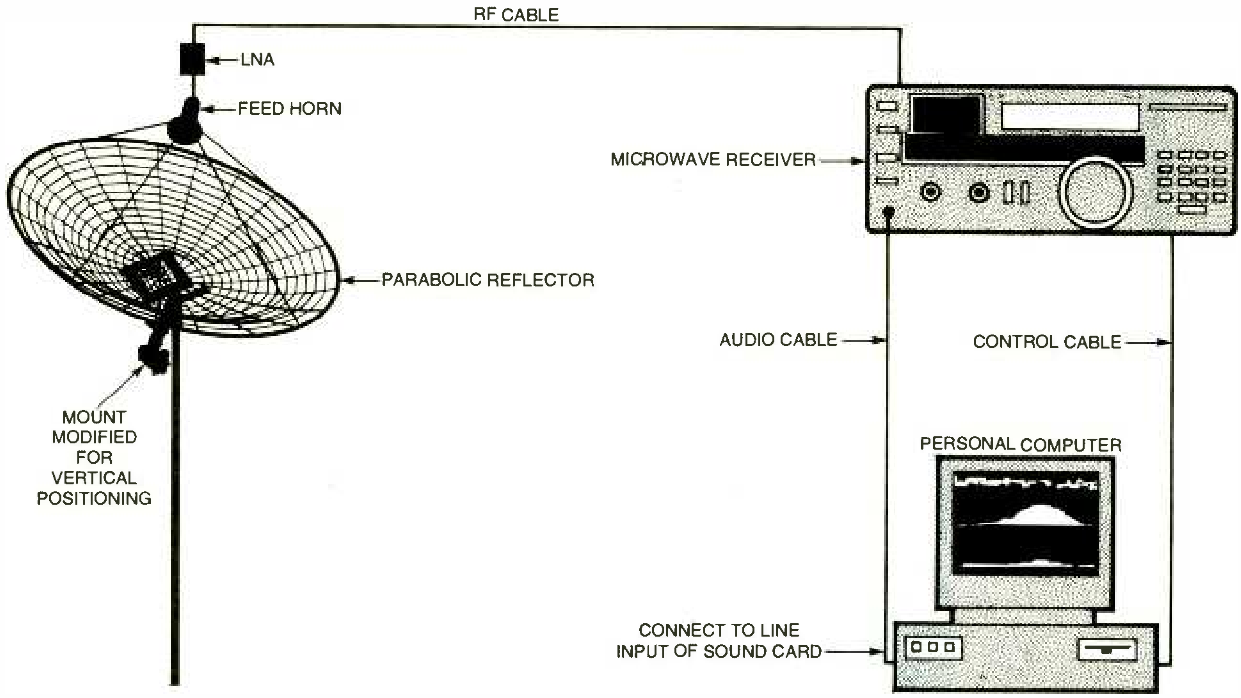


Fig. 1. While no two amateur SETI stations are ever exactly alike, they all have much in common—all contain some sort of antenna, an amplifier, a receiver (downconverter), and a computer.

already exists and much amateur-radio activity takes place on planet Earth. Though other interesting frequency bands show considerable promise, they generally require equipment that is either too costly or too complex for today's amateurs.

But that is changing even as we speak. The rule is that, since we don't know exactly from where ET might be transmitting, there are no *wrong* frequencies for SETI. So we build the best equipment today's technology allows and search where we can. If we get incredibly lucky, we'll find the definitive proof we seek. If not, we'll continue searching, knowing that tomorrow's technology will tune wider, hear farther, dig deeper, and greatly improve the odds. Amateurs are not discouraged by the primitive nature of their stations, because today's private SETI observatory is fully as sensitive as the best NASA had to offer just twenty years ago. And with NASA out of the game, the gap is narrowing!

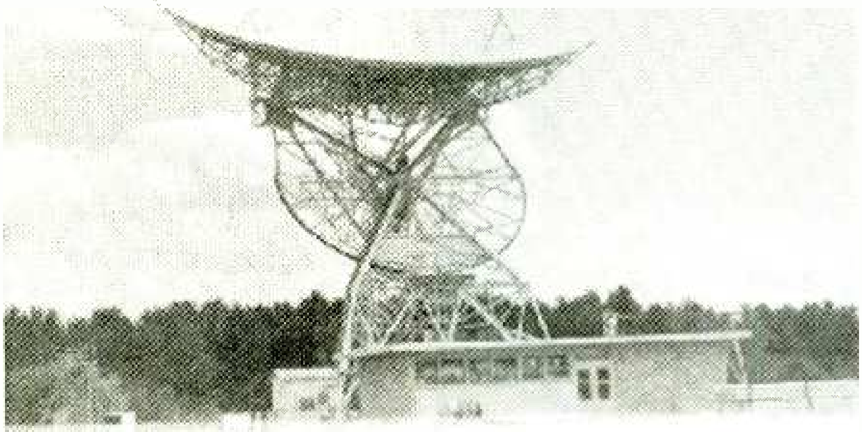
Strength in Numbers. The giant radio telescopes from the era of NASA SETI were incredibly sensitive. They dug deep into the noise by zeroing in on an incredibly small portion of the sky and surveying it for hours on end. But the immensity of the antennas, while making the telescope tremendously powerful, also imparted an important limitation. The typical research-grade radio telescope only sees about one millionth of the sky at a time. Even if it were tuned to exactly the right frequency, at exactly the instant when *the call* came in, there would still be a 99.9999% chance it would be pointed the wrong way, and miss the signal completely.

One solution to that dilemma is to build a million such research-grade instruments and point them in all possible directions. But at a cost of about $100 million apiece, we've just exceeded the *gross* planetary product. Isn't there a cheaper way?

The SETI League believes there is. Small radio telescopes of the type that amateurs have been building for years are perhaps 200 times less sensitive than NASA's finest. That means they'll be somewhat deaf, detecting only the very strongest extra-terrestrial signals. It also dictates that each unit cut across a swath of sky that's about 200 times wider than what its professional counterpart can handle. So, it would only take about 5000 small SETI telescopes, properly aimed and coordinated, to accomplish something NASA never even contemplated—to see in all directions at once, so that no direction in the sky could evade our gaze.

Better still, the cost of the typical amateur SETI station is today on the order of $2000 US dollars. That means the entire global network described above can be built for a total cost of about a tenth of that of a *single* research-grade radio telescope. And that's individual hobbyists' money, not tax dollars, at work. SETI's detractors call it a waste of time and money. And I agree. This is, after all, a hobby for most of us, and isn't "wasting time and money" the very definition of a hobby?

The dream of real-time all-sky monitoring is still a long way off, but it is the vision of The SETI League to be implemented by its *Project Argus* search. Argus was the mythical Greek guard-beast who had a



Three dozen different SETI programs once scanned the skies with the world's greatest radio telescopes, sifting through "buckets of bits" with massive computers, trying to separate the "cosmic wheat" from the "galactic chaff."

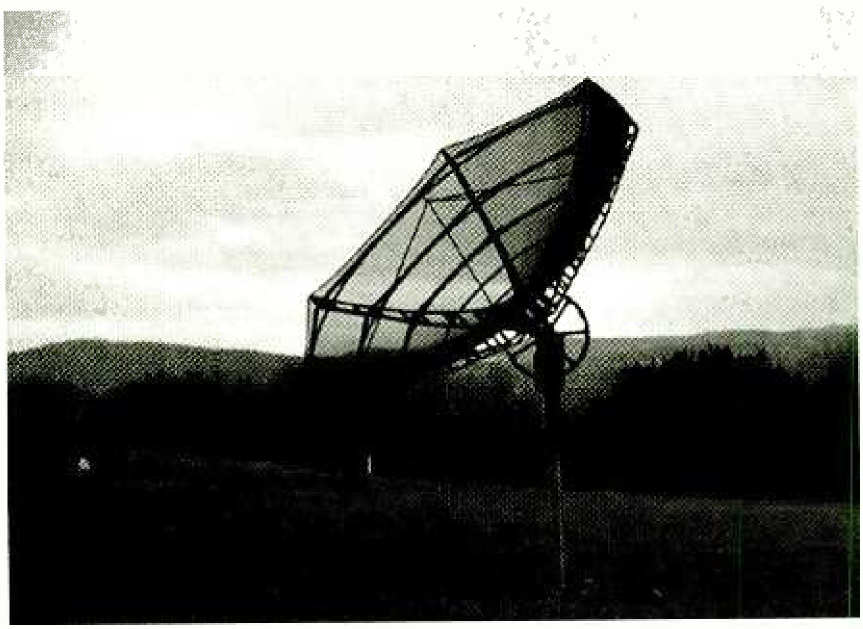
hundred eyes and could see in all directions at once. Mythology tells us that when Argus died, the gods put his eyes on the tail of the peacock. Though that's a lovely story, we of The SETI League know better. When Argus died, the gods put his eyes in the backyards of 5000 amateur-radio astronomers, all over the world. With their help, we'll someday see in all directions at once.

The Typical Station. While no two amateur SETI stations are ever exactly alike, they all have much in common. For example, all use some kind of antenna to scoop up weak photons from space, an amplifier to boost weak signals, a receiver to shift them down (downconvert) to audio signals, and a computer to sift through the audio noise in search of patterns that could not have been naturally occurring phenomena. Figure 1 shows a typical block diagram of just such a station.

The sections below provide a general overview of the main elements of a typical amateur SETI station. Further details are available in the appropriate chapter in *The SETI League Technical Manual* online at *www.setileague.org* or in hard-copy from The SETI League, Inc., PO Box 555, Little Ferry, NJ 07643 USA. While it's unlikely that the average experimenter can build a successful station from either this article or the tech manual alone, The SETI League's worldwide network of volunteer regional coordinators stands ready to assist any member in getting his or her station on the air.

The Antenna. Though many other antenna types have been used successfully, by far the favored antenna for amateur SETI use is the parabolic reflector (or dish). The chief advantage of the parabolic reflector is that it operates over an extremely wide range of frequencies, limited at the low end by its diameter (which must be a respectable multiple of the longest wavelength being received to provide reasonable gain), and at the high end by its surface accuracy (which must not deviate from the parabolic shape by more than a small fraction of the shortest wavelength being received to maintain reasonable efficiency). Typical satellite TV dishes generally provide reasonable performance over the 1- to 10-GHz portion of the microwave window.

For reception in the 1.3- to 1.7-GHz L-band region, which is highly favored for amateur SETI activity, optimum dish size is about three to five meters in diameter. In countries such as the US and Canada, where C-band satellite television distribution has been widely used for two decades, suitable dishes are abundantly available at low to no cost. In other parts of the world, they're



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harder to come by. Enterprising SETI League members have acquired surplus commercial telecommunications dishes or even built their own from scratch.

The size of the dish and the operating wavelength together determine antenna gain. As a first order approximation, the voltage gain (as a ratio) is equal to the circumference of the reflector, measured in wavelengths. Consider, for example, a three-meter dish that has a circumference of 3 × π (*i.e.*, 3 × 3.1416) or about 9.4 meters. At the 21-cm resonant wavelength of neutral hydrogen atoms (which corresponds to the popular SETI frequency of 1420 MHz), the voltage gain of the dish would approach (940/21) = 45.

Since the power ratio equals the voltage ratio squared, the power gain of such an antenna would be about 2000; *i.e.*, a gain of +33 dBi. However, since the efficiency of amateur SETI antennas is generally about 50%, the actual gain realized is more like +30 dBi.

Dish size also determines beamwidth, thereby dictating the degree of aiming precision required when targeting specific stars. As an approximation, half-power beamwidth in radians equals wavelength divided by antenna diameter. Thus, for our example of a three-meter dish operated at 21 cm, the beamwidth is approximately (21/300) = 0.07 radians or 70 milli-radians, which is about four degrees.

If you choose to use a surplus antenna, dish condition is an important factor. The main consideration for the dish is surface accuracy. In order to perform up to expectations, the dish surface cannot deviate from the parabolic by more than a tenth of a wavelength. At 1420 MHz, that's about 2 cm of allowable surface error. If the dish surface is dimpled, dented, or distorted beyond 2 cm, avoid that dish! Look for something that approximates a smooth parabolic curve. If panels are missing or bent, performance is sure to suffer.

Next, look at the mounting hardware. If it's rusted, expect trouble in getting the dish apart and even more trouble reassembling it. Weight is sometimes a consideration, as is wind loading. If weight or wind concerns you, a more realistic approach might be to use a mesh dish instead of a solid one.

Many of the accessories that come along with a satellite TV dish are of limited use for SETI; therefore, you should not pay extra for them. C-band or Ku-band feedhorns and preamps are only useful if you're going to search in C-band or Ku-band (some of our members do; most prefer to scan the popular L-band region). TVRO systems are great sources of microwave components, but unless ET uses exactly the same TV transmission standards as we *Earthlings*, they're not particularly useful as SETI receivers. And a motorized mount that tracks the Clarke geosynchronous orbital belt is not particularly useful for drift-scan, meridian transit-mount radio telescopes, except if modified per the instructions in the following "Antenna Mount" section of this article.

The most common feedhorn for amateur SETI use is a metal pipe, closed off at the end farthest from the dish, forming a shorted cylindrical waveguide. The chief drawback of the cylindrical waveguide feedhorn is its large physical size, which actually blocks a part of the dish surface from the "view" of incoming signals, thereby reducing the effective gain of the parabolic antenna.

In the final analysis, your financial situation is likely to be your chief limitation, so go with what you can afford. Any old dish receives better than no dish at all!

(Additional information on various SETI antenna options, along with vendor recommendations, may be found in the "Antennas and Feedhorns" chapter of *The SETI League Technical Manual.)*

The Antenna Mount. The beauty of mounting a parabolic antenna for SETI use is that you just can't go wrong. Since we are interested in monitoring the sky for artificial signals from beyond, the antenna merely need be pointed up—there are stars (with potentially habitable planets) to be found in all directions. So mounting an antenna for SETI use is considerably simpler than, for example, using the same antenna for satellite TV, where it must be precisely aimed at the satellite's location.

Because there are no wrong directions for SETI, many SETI antennas are simply set on the ground, "bird-bath" style, looking straight up. But a disciplined sky survey, such as The SETI League's *Project Argus* effort, requires coordinated sky coverage, and that, in turn, necessitates a limited steering ability for at least some of the antennas in the network.

Where steering of the antennas is desired, we need to consider two degrees of freedom: azimuth (the compass heading to which the antenna points) and elevation (the angle that the antenna's beam makes with respect to the horizon). In terms of celestial coordinates, the azimuth of a radio telescope (along with a station's latitude and longitude, and the date and time) determines the *right ascension* (RA) of its target, while elevation (again, along with latitude/longitude, time, and date) determines *declination* (Dec). Conversion between terrestrial and celestial coordinates is handled by a spreadsheet found on The SETI League's Web site.

Since we live on a rotating sphere, the earth itself makes a most cost-effective RA rotor, as long as you are patient enough to let the proper portion of the sky eventually rotate into view. But since (thankfully!) the earth doesn't rotate north-to-south, the only way to achieve Dec control is to physically rotate the antenna along a north-south line.

That can be accomplished by aligning a satellite-TV antenna's position rotor as a vertical (elevation) rotor, as described in an article on The SETI League's Web site.

(Additional information on mounting SETI antennas can be found in the "Antennas and Feedhorns" chapter of *The SETI League Technical Manual.*)

High-end microwave scanning receivers (typified by the Icom models R-7000, R-7100, and R-8500, as well as the AOR 3000, 5000, and 7000) are multi-mode receivers capable of receiving AM, FM, CW, SSB, and sometimes video and digital modes.

The Feedhorn. When radio waves strike a dish antenna, the parabolic shape of its reflector directs all the energy to a single point—called its focus or focal point—out in front of the dish. The purpose of the feedhorn, which is mounted at the focus facing the reflector, is to scoop up all that energy and route it to the low-noise amplifier (LNA) and receiver for processing.

The most common feedhorn for amateur SETI use is a metal pipe, closed off at the end farthest from the dish, forming a shorted cylindrical waveguide. The horn contains a small metallic probe (connected to the center pin of a coaxial connector) that is used to collect the energy and channel it to the LNA. The horn might be surrounded by a metal ring, which serves to improve the efficiency of energy collection from the dish surface or to block interference from entering the feed from beyond the periphery of the dish (as described in yet another SETI League Web site article).

The chief drawback of the cylindrical waveguide feedhorn is that its large physical size actually blocks a part of the dish surface from the "view" of incoming signals, thereby reducing the effective size (hence, the gain) of the parabolic antenna. That signal loss due to blockage is most severe for small dishes, but is almost negligible at the popular 1.3- to 1.7-GHz SETI frequencies when the dish diameter exceeds about four meters.

An alternative to the cylindrical waveguide feedhorn is the helical feed, which consists of about three turns of heavy-gauge wire wound into a corkscrew shape with a circumference of one wavelength at the operating frequency, and a spacing between turns of a quarter wavelength. A helix feed doesn't block the aperture of the dish to the extent that the waveguide horn does, but it is more prone to interference from signals off to the side of the antenna. Both helix and waveguide feedhorn designs have been used successfully by SETI League members.

(Additional information on various SETI antenna feeds, along with vendor links, can be found in the "Antennas and Feedhorns" chapter of *The SETI League Technical Manual.*)

The Low-Noise Amplifier. The LNA, which is also sometimes called a preamplifier or preamp, is used to turn an impossibly weak signal into a merely ridiculously weak one. The critical parameters to consider in selecting an LNA are its frequency response, gain, and noise temperature.

Frequency response determines that portion of the electromagnetic spectrum over which a particular LNA will boost the received signal with minimum distortion or added noise. The LNA should be selected to have a frequency range consistent with your particular SETI station requirements. For example, C-band satellite-TV LNAs cover the portion of the spectrum ranging from 3.7 to 4.2 GHz; *ergo*, they are not suitable for use in SETI stations designed to monitor the 1.4-GHz hydrogen line.

Incorporated into some LNAs are filtering circuits that reduce the overall range of frequencies amplified; the filtering circuits can also help to reduce out-of-band interference.

Gain, which is measured in decibels (dB), indicates how much the LNA boosts the incoming signal. Although in many things "if a little is good, a lot is better," that's not the case for preamplifier gain. In fact, excessive LNA gain can actually reduce the sensitivity of a SETI receiver. The rule of thumb is that the gain of the LNA should equal the sum of the microwave receiver's noise figure (in dB) plus the RF cable insertion loss (also in dB), plus an additional ten dB. For the average SETI station with a short coaxial cable between the LNA and the receiver, 20 dB of preamp gain is usually about right. If a very long or unusually lossy RF cable is used, a 30-dB gain LNA might be more appropriate.

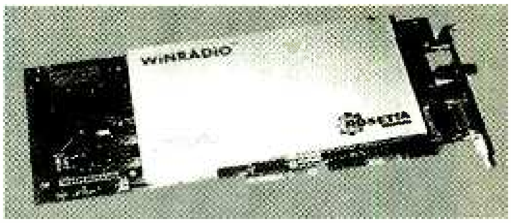
Noise temperature is a measure of how much additional noise the LNA adds to your SETI system. Since any actual signal has to compete with a variety of natural and artificial noise sources, the lower the noise temperature, the better. The LNAs commonly used for amateur SETI typically have between 35 Kelvin and 100 Kelvin of internal noise. Noise is sometimes expressed not in Kelvins, but as *noise figure* (in dB) or *noise factor* (a unitless power ratio). (The SETI League provides a Microsoft Excel spreadsheet for conversion between these various noise units.) The noise temperature of an LNA can sometimes be reduced by thermally cooling it. (An additional spreadsheet allows you to calculate the improvement achieved by lowering an LNA's ambient temperature.)

Many commercial LNAs are provided with a choice of coaxial input and output connectors. Most SETI League members prefer to standardize on the coax connector known as Type N, since that's the connector used on most feedhorns and microwave receivers. To minimize losses, the LNA should be mounted directly on the output connector of the antenna feedhorn, with the appropriate coaxial adapter (probably an N-type male-to-male barrel adapter).

An additional consideration is how to get the appropriate operating potential to the LNA. Most LNAs operate from a DC power supply, typically in the +12-volt DC range. Some designs require that the operating voltage be applied via the center-conductor of the RF cable, and some LNA vendors give you a choice between internal and separate DC feed. DC feed via the transmission line requires that the microwave receiver be designed to provide the voltage or that an accessory called a *DC Inserter* or *Bias Tee* be connected in the signal path ahead of the receiver and tied in to an appropriate power source. Although that's the scheme commonly used to power antenna-mounted circuitry in commercial satellite-TV receivers, most SETI experimenters see direct DC feed through the coax as more of a problem than a cure. It's generally preferred that a separate DC cable be run outside to the LNA; the DC potential is then applied to the LNA from inside the SETI station. (**Caution:** It is extremely important that the polarity of voltage applied to the cable be double-checked, as reversing the positive and negative power-supply leads can damage the LNA.)

Although most commercial (and many home-built) LNAs are housed in metal enclosures to provide shielding against radio-frequency interference (RFI), few reside in weather-proof enclosures. To prevent damage from exposure to the elements, I like to put my LNAs in plastic Tupperware sandwich boxes. It is necessary to drill or punch holes in the plastic for the input coax adapter, output cable, and power wiring. Be sure to seal the openings with room-temperature vulcanizing (RTV) silicon rubber (which can be purchased from most any hardware store).

(Information on various commercial LNAs available in kit form or fully assembled, along with vendor links, can be found in the "Preamplifiers and Filters" chapter of *The SETI League Technical Manual*. For the experienced microwave experimenter, schematics, component-selection criteria, and do-it-yourself information are also provided.)



The first generation of computer-controlled receivers, which were prone to RFI generated by the computer itself, were built on ISA cards, and plugged directly into one of the vacant slots on the motherboard of a personal computer.

The RF Cable. The most common SETI station configuration places the microwave receiver, signal-analysis computer, and related accessories inside the house, with the antenna and LNA mounted outside some distance away. An RF cable—usually coaxial (*i.e.*, "coax" cable), preferably those with low loss at radio (specifically microwave) frequencies is—used to link the two halves of a SETI station.

The stuff used for cable TV is cheap (pennies per meter), but pretty lossy in the 1.4- to 1.7-GHz region of the spectrum typically used for amateur SETI. The kind used for, say, CB radio antennas is a little better, but a bit more costly. If you have a local RadioShack or similar store, you can probably find what they call low-loss coax. Low-loss coax is larger (perhaps 1 cm diameter) than the CB or TV type, costs maybe a dollar or more per meter, and may go under such part numbers as Belden 9913, RG-8 Polyfoam, *etc.* It may take special connectors—called Type N—which require some experience to properly install.

For any type of coax, the longer the run, the lossier. So try to keep your antennas near the radio room. If that's not practical, there are several things that can be done: Use more gain in the preamp (to boost the weak signal before it suffers cable loss), mount the whole receiver or just the downconverter outside on the dish (pumping a lower frequency through the cable is more efficient), or use specialized cables such as hardline or Andrew Heliax (which can cost upwards of tens of dollars per meter).

The Microwave Receiver. The microwave receiver takes a small, selected portion of the radio spectrum and converts it to audio for signal analysis. Selection of the appropriate receiver leaves more to the discretion of the experimenter than any other portion of the amateur SETI system. Four distinct options present themselves. In descending order of cost, they are:

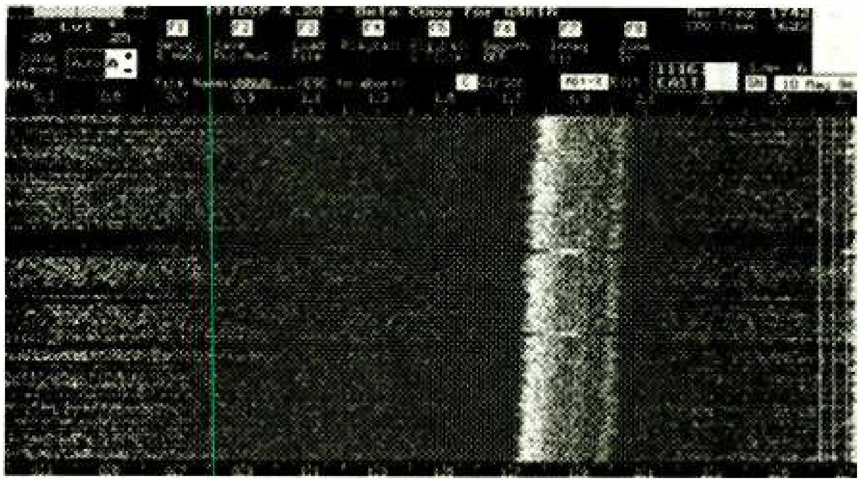
1. High-end microwave scanning receivers—typified by the Icom models R-7000, R-7100, and R-8500, as well as the AOR 3000, 5000, and 7000—are multimode receivers capable of receiving AM, FM, CW, SSB, and sometimes video and digital modes. Various IF bandwidths are usually available, and these receivers are normally programmable to scan a selected range of frequencies. They typically tune from a few hundred kHz all the way up to about 2 GHz, which actually exceeds our SETI needs. Prices are likely to start around $2000 US, making the receivers as expensive as all other portions of an amateur SETI station combined.

2. Modified radio-telescope receivers. One of the very few vendors of commercial radio-astronomy receivers for the amateur market is Radio Astronomy Supplies of Roswell, GA, USA. Their microwave receivers, which are designed specifically for continuum radio astronomy (that is, searching for natural astrophysical phenomena) can sometimes be modified for SETI use. Such modifications generally require considerable electronics expertise, but offer the ultimate in performance. As this is being written, Radio Astronomy Supplies reports being hard at work developing a dedicated SETI receiver, named *Seeker 2000*, which is slated to sell in the $1200 (US) range.

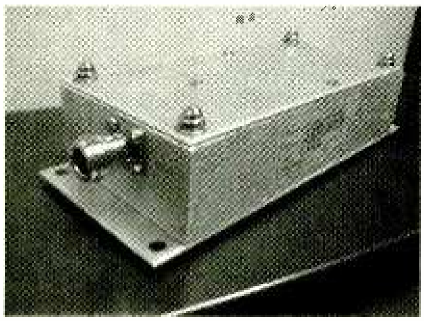
3. Computer-controlled receivers. The first generation were built on ISA cards and plugged directly into one of the vacant slots on the motherboard of a personal computer. The units were prone to RFI generated by the computer itself. Later units, like the Icom PRC1000 and WinRadio 1500e, are separate boxes that plug into a computer via a serial, parallel, or USB port. They have many of the features offered by high-end microwave scanning receivers, but

since they rely on a companion computer for digital control, they typically cost half as much.

4. Downconverter/receiver combinations are available to down-shift selected portions of the microwave spectrum for reception via a shortwave or VHF ham-radio receiver. Popular units are available from Down East Microwave in the US, and VHF Communications in Europe. Downconverters are appealing for those who already own a high-performance communications receiver, which unfortunately doesn't tune to the SETI frequency of interest. Downconverters cost about half as much as the computer-controlled receivers, but require the user to couple them to an existing receiver.



To accomplish their objective—to reach farther and farther out into space in the hopes of contacting intelligent life forms—SETI stations use digital signal processing. Shown here is an example of the first candidate signal received by The SETI League in May of 1996, which turned out to be interference from a classified military satellite.



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Whichever receiver scheme is selected, present practice suggests operating it in single sideband mode (either upper sideband or lower sideband) and leaving it fixed-tuned, rather than scanning it across the spectrum. The reason for avoiding frequency scanning is that the Earth is turning the antenna continually, so that the spatial dimension of the observation is always changing. Only by holding frequency constant for at least one rotational period of the Earth (*i.e.*, one day) can we avoid the problem of "too many variables."

The bandwidth of the receiver's audio stages will typically be the limiting factor, as far as instantaneous frequency span is concerned. Many SSB receivers cover as little as 3 kHz of spectrum at a time, which is an inefficient way to search for ETI. Advanced SETI experimenters sometimes modify their receivers for up to 22 kHz of instantaneous IF and audio bandwidth, while custom-built receivers can cover from several hundred kHz to a few MHz of the spectrum at a time.

(Information on various commercial and kit receivers, recommended modifications, and vendor contact information can be found in the "Receivers and Converters" chapter of *The SETI League Technical Manual*.)

The Computer. Even the simplest of today's personal computers is thousands of times more powerful than the ones NASA used to put men on the moon. Of course, the objective of SETI is not to reach the moon, but rather to reach much farther out into space for intelligently generated signals. To do so, a technique known as digital signal processing (DSP) is used.

The first step in the DSP process is to feed the receiver's audio output into the computer in a form (*i.e.*, binary data) that the computer can recognize. An analog-to-digital converter (ADC) is required to accomplish that task; the ADC of choice for amateur SETI is the PC sound card. Just about any *SoundBlaster*-compatible audio card will work with The SETI League's signal analysis software. The cards sample an audio waveform 44,000 times per second. One of the rules of information theory is that to digitize a signal, it must be sampled no less than twice for every cycle at its highest frequency. With 44-ksps (kilo-samples per second) sound cards, it's possible to digitize and analyze audio components out of our receiver up to 22 kHz in frequency—a rather narrow bandwidth that even a 486 computer can analyze in real time with excellent resolution. The typical DSP program chops the received audio band into 2048 individual channels, each about 10 Hz wide, analyzing and displaying all those channels simultaneously, in real time. Thus, the computer turns the SETI station into a 2048-channel receiver.

The required software, developed by SETI League members, typically runs under the Microsoft DOS or Windows operating systems. It is shareware, offered at low or no cost to all participating SETI League members via the software pages of The SETI League Web site. Its job is to identify signals that exhibit the hallmarks of artificiality—characteristics that distinguish intelligently generated signals from natural phenomena—and then to help determine whether those characteristics might have come from some terrestrial source. Our civilization pollutes its own radio environment, so we need to sift through any detected signals rather thoroughly in order to rule out man-made interference from our own transmitters, aircraft, spacecraft,

(Continued on page 79)

JOIN THE SEARCH

(continued from page 36)

and orbiting relay stations.

In addition to analyzing signals, some SETI League computers also control the station. Remember the computer-controlled microwave receivers discussed above? They can often be tuned by software, driven from the PC's serial, parallel, or universal-serial-bus (USB) port. Antennas can similarly be computer-aimed, if they're equipped with software-driven azimuth and elevation rotors. Some SETI computers make lights flash and bells ring whenever they detect something interesting. And the most advanced of the computers used by SETI League members also dial into the Internet when an interesting candidate signal is received, automatically alerting other participants that their assistance in signal verification is required.

(More SETI computer information may be found in the "Software" chapter of *The SETI League Technical Manual.*)

Putting It All Together. When I built my first amateur dish more than twenty years ago, I was going it alone. That was frustrating, because I had to learn from my own mistakes. Today there's assistance. The non-profit, membership-supported SETI League exists to help you become one of the 5000 active *Argus* observers. Though only 1000-members strong at present, The SETI League is still a young organization, just three years into its search. The group's volunteer regional coordinators in over 50 countries on six continents have already helped more than five dozen members to put stations on the air. The SETI League's extensive Web site and various books and articles are already attracting hundreds of like-minded enthusiasts into the SETI community. To come on line with The SETI League, e-mail them your postal address (join@setieague.org), call their membership hotline (800-TAU-SETI), or write for a free brochure. Together, amateur SETI volunteers may well end humanity's isolation in the universe. ■

SOUND PARTNER

(continued from page 44)

time to test the project. **Note:** No calibration adjustments are needed. Simply plug PL1 into the headphone output of the personal sound system and connect two 16-

Adjust the audio level for headphone 1 (J1) using the volume control of the personal-sound system. After that, adjust volume of headphone 2 by adjusting R1. **Caution:** Never use the Sound Partner without a headphone connected to J1. Doing so could damage your

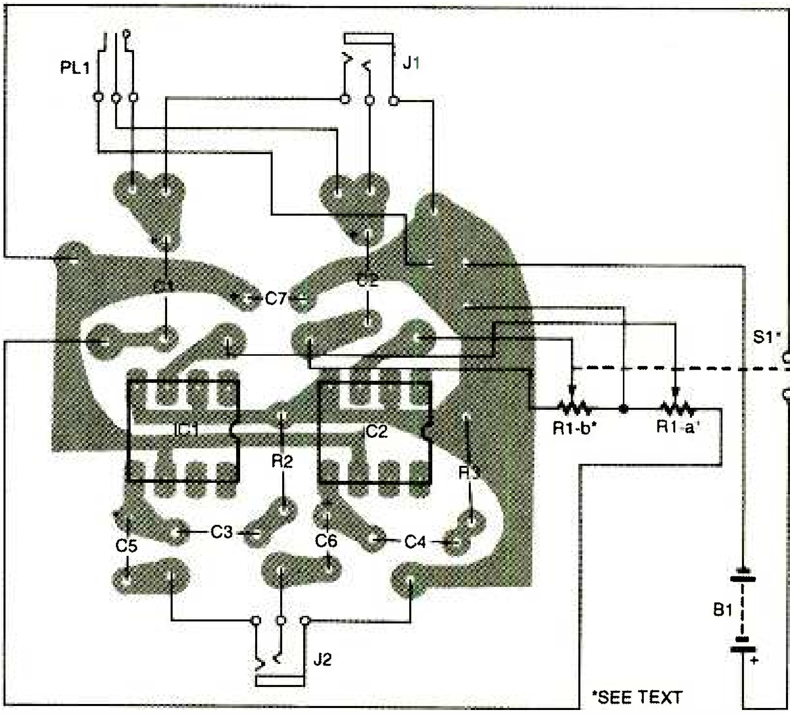

Fig. 5. Assemble the Sound Partner's printed-circuit board guided by this parts-placement diagram. Note that with the exception of the input and output jacks, the battery with its holder, and the VOLUME *control (R1), all of the components mount to the printed-circuit board.*

to 100-ohm stereo headphones to the Sound Partner outputs (J1 and J2). Set power switch S1 (ganged to R1) to the off position, install the batteries in their holder, and the Sound Partner is ready for use.

personal sound system.

When all is working properly, there is nothing left to do but seal the project into its enclosure, plug it into your personal sound system, and share that must-hear tune. ■

PARTS LIST FOR THE SOUND PARTNER

RESISTORS

(All fixed resistors are ¼-watt, 10% units.)
R1—10,000-ohm dual-gang audio taper potentiometer with SPST switch (see text)
R2, R3—10-ohm

CAPACITORS

C1, C2—4.7-µF, 16-WVDC, miniature electrolytic
C3, C4—0.01-µF, ceramic-disc or metal-film
C5, C6—220-µF, 16-WVDC, miniature electrolytic
C7—100-µF, 16-WVDC, miniature electrolytic

ADDITIONAL PARTS AND MATERIALS

IC1, IC2—LM386 low-power audio-amplifier, integrated circuit
B1—6-volt battery, see text
J1, J2—⅛-inch stereo phone jack (see text)
PL1—⅛-inch stereo phone plug (see text)
S1—SPST (ganged to R1)
Printed-circuit materials, 8- to 100-ohm headphones, plastic knob, enclosure, battery holder, IC sockets, wires, solder, hardware, *etc.*