SearchLites

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Introducing:

Our Regional Coordinator for Ukraine

Alexey V. Arkhipov was born in Kharkov (East Ukraine) in 1959. His education includes an M.S. in astronomy (Kharkov State University 1981) and a Ph.D. in astrophysics and radio astronomy (Main Astronomical Observatory of Nat. Acad. Sci. of Ukraine, Kyiv, 1998). His Dissertation was titled "New approaches to the problem of search for extra-terrestrial intelligence."

Alexy's professional experience includes the following SETI-related positions:

1980-84 Engineer, Scientific Researcher, Institute of Radiophysics and Electronics, Academy of Science, Ukrainian SSR.

1984- Scientific Researcher, Institute of Radio Astronomy, National Academy of Science, Ukraine.

In addition to SETI, his area of specialization includes studying the Decametric radio emissions of Jupiter. Alexey is a member of the Society for Planetary Research (SPSR), and of the SETI Center, Moscow, Russia. Here are abstracts of two of his current research activities:

Project SAAM (Search for Alien Artifacts on the Moon) was developed by the author in 1992. The justifications of Lunar SETI, the wording of specific principles of lunar archaeology and the search for promising areas on the Moon were the first stage of the project (1992-95). Already obtained results of lunar exploration show that the search for alien artifacts on the Moon is a promising SETI-strategy especially in context of the lunar colonization plans.

The purpose of the second SAAM stage is the search for promising objects on the Moon for archaeological reconnaissance in the future. Computer algorithms are proposed and realized for automatic search for unusual formations on Clementine's HIRES images. This survey is in progress.

Dr. Arkhipov has shown that finds of extraterrestrial artifacts are possible on the Earth, even if visits of extra-terrestrials to the Earth were not realized. Even without interstellar flights, the spontaneous leakage of interplanetary debris into the interstellar medium is inevitable (by e.g., gravitational interaction with the planets). That is why he is collecting information about promising finds in prehuman layers and among pseudo-meteorites.❖

A Word from our Founder

by SETI League President Richard Factor

In October of 1993, the U.S. Congress terminated all funding for two scientific endeavors: the $10 billion Superconducting Supercollider, and the $12.5 million per year NASA SETI program. Initially I was upset, as were many other individuals. Then I decided to do something. I realized that no single individual possessed the resources to save the Supercollider, but that, perhaps, many of us, working together, were in a position to help resurrect SETI.

That's how The SETI League came into existence. In just five years we have grown into a membership-supported, nonprofit venture involving more than 1,000 SETIzens of 53 countries and 49 of the 50 US states, and I'm proud to see those members doing highly credible amateur science.

Membership dues, though vital to meeting the day-to-day needs of The SETI League, are insufficient to cover all of our expenses. Long-term science demands long-term funding, and privatized science requires that such funding come from private sources. Won't you join me in supporting The SETI League's Endowment Fund, and other fund-raising efforts, to help us continue the research which Congress wouldn't let NASA finish? Thank you in advance for your generous support. ❖

Guest Editorial:

Communication by Entangled Particles

by Leon T. Darcy, Extra Terrestrial Research Centre

As we search for ETIs we ask ourselves, "Since any alien intelligence detected will be thousands, if not millions of years beyond us technologically, why do we assume they would use the electromagnetic spectrum for their communications?" This question being on my mind I decided to investigate alternative modes of interstellar communications.

The first question is, do all ETIs use the same senses as we do to "feel" their environment? The answer to that is an obvious no. The human life-form is highly unlikely to be repeated anywhere else in the universe. Other intelligent beings could have some of the same senses as we do. But the sun that they orbit dictates, for example, their visual frequency range. Thus, ET might well see only in the infra red or ultra violet frequencies. Sensing sound could also be in either higher or lower frequencies, depending on the atmospheric pressure of their planet. The sense of smell again is dictated by the planetary environment. Gravity will determine the stature of the beings; the more massive a planet the more "squat" the stature of its inhabitants. A habitable planet with the mass of Jupiter would produce life-forms, intelligent or otherwise, low to the ground and muscular. Imagine living on a planet with the atmospheric pressure of Venus. Light would be bent and to those looking over a landscape on that planet, the horizon would seem to "fold" in on itself, giving that planet's inhabitants a rather skewed view of the universe.

Mass shapes space and time, so light is bent by stars and other masses. Radio waves will also be bent. A space-faring intelligence would know this only too well and understand that to communicate over great distances with each other, or with other intelligent beings, a more instant and reliable method than radio is desirable. We here on Earth may soon have to do the same. How might we achieve real time, two-way communication where even light years of distance wouldn't bother us? We assume if ET is much more advanced than we are, then they must have that problem solved. Until we discover that technology, we may well remain in total ignorance of their presence.

What if other intelligent life forms evolved from insects? Experience with insects on our own planet indicates that they would probably communicate by chemical means. Would we recognize their intelligence when we see it? Perhaps not.

With this problem in mind I considered the thought experiment where a particle here on Earth, which has a left-hand spin, and its twin two million light years away, which has a right-hand spin, still interact instantaneously with each other. If we change the spin in the particle here on Earth, then instantly the other particle two million light years away reverses its spin. This quantum particle entanglement has now been proved by experiment, though admittedly in the laboratory, at more modest distances than two million light years!

With that experiment in mind, I envisioned a theoretical particle spin modulator, with transmit and receive capability. First, we need a candidate particle that is common throughout the universe, then we build a vacuum chamber with a high electromagnetic field. We then inject the selected particles into the chamber. By switching the magnetic fields North to South, we change the spin of the particles in the chamber, and by switching this field we could modulate a "signal" where all twin particles in the universe should instantly change their polarization opposite to the chambered particles.

If ETIs are using this "instant" communication technology, then we should be able to detect the rapid spin changes in the particles in our own Galaxy. Polarized light is detected as a matter of course by optical Astronomers, and the same is true in the radio spectrum. If we were to find an area in the sky with rapid polarization changes, then this could well be an indication of artificial manipulation of those particles by an alien civilization.

In a cloud of gas and dust, particles spin left and right randomly. But, if ETI is using the polarization modulation method of communication, then we should be able to detect a "hot" spot of spin change in a cloud of gas, where it seems that all the particles polarize at the same time. I assert that we probably couldn't make any sense out of the changes, but leaving aside the influence of nearby Pulsars and like exotic objects, we must at least contemplate that an intelligent communicating civilization may be involved.

Editor's Note: *Like all editorial submissions to The SETI League, the above opinions are those of the author. For a different perspective on the question of FTL communication, see the* Ask Dr. SETI *column on page seven of this issue.* ❖

Event Horizon

SETI League members are invited to check the website at <http://www.setileague.org/general/confrnce.htm>, or email to <info@setileague.org>, for further details about these events.

*** - SETI League participation confirmed**

September 2 - 6, 1999: *Aussiecon Three* / 1999 Worldcon, Melbourne Australia.
*** September 8, 1999:** *SETI Colloquium* at University of Kentucky, Lexington KY.
October 2, 1999: *Mid-Atlantic VHF Conf.*, Willow Grove PA.
*** October 8 - 10, 1999:** *AMSAT Symposium*, San Diego CA.
*** October 21 - 23, 1999:** *Microwave Update*, Plano TX.
*** November 12 - 14, 1999:** *Philcon '99*, Philadelphia PA.
November 14, 1999: *Martlesham Microwave Roundtable*, Ipswich England.
March 26, 2000: *SETI League Annual Meeting*, Little Ferry NJ.
*** April 21, 2000:** Second annual *SETI League Ham Radio QSO Party*, 14.204 MHz.
*** April 21 - 23, 2000:** *Balticon 34*, Baltimore MD.
May 12 - 14, 2000: *ARRL National Convention* and *Dayton Hamvention*, Dayton OH.
June 2 - 4, 2000: *ARRL Atlantic Division Convention* and *Rochester Hamfest*, Rochester NY.
July 20 - 23, 2000: *Central States VHF Conference*, Winnipeg Manitoba.
August 7 - 19, 2000: *XXIVth International Astronomical Union General Assembly*, Manchester University, UK.
August 31 - September 4, 2000: *Chicon 2000* World Science Fiction Convention, Chicago IL.
September 3 - 4, 2000: *Weinheim VHF Convention*, Mannheim Germany.
*** September 9 - 10, 2000:** *Second Convention of the European Radio Astronomy Club*, Heppenheim Germany. ❖

Editorial Response and Counter-Responses:
Microprobes Won't Survive Interstellar Travel

by Mario Zadnik (rzadnikm@curtin.edu.au)

The Spring 1999 issue of *SearchLites* carried a guest editorial by Prof. Paul Davies, in which he wrote (based on a suggestion by Allen Tough) "that they could send a small smart space probe to eavesdrop on our activities...It might be no more than the size of a pea..." I would argue that cosmic ray fluxes and energies mitigate against this suggestion.

The best reference I have found on cosmic ray fluxes and energies is "Cosmic-Ray Record in Solar System Matter" by Reedy, Arnold and Lal, Science Vol 219, pages 127-135, 14 January 1983 . There are probably many more recent reviews, perhaps in the Annual Review of Astronomy and Astrophysics and on the Web. However, the Reedy et al. paper is an excellent introduction and has a very useful Table 1 in which the energies (MeV/nucleon), mean flux (particles/second/square centimetre) and effective depth in solid matter (centimetres) are presented for solar and galactic cosmic rays (CRs). The data in the Reedy et al. paper can be used to address the question of damage which CRs will do to interstellar probes.

Ignoring nearby stellar/solar cosmic rays (which will only exacerbate the damage), interstellar probes will be subject to galactic CR fluxes of about 3 particles/second/square centimetre with an effective penetration depth of between 0 to 100 cm. Taking microprobes of a few square cm area (say 10) and some mean travel time of say a few million years (10^14 seconds) to traverse a significant fraction of the galaxy at a few percent of the speed of light, the probe will encounter about 3 x 10^15 high energy (100 to 3000 MeV/nucleon) cosmic rays.

Although such microprobes will have about 10^24 atoms, which is a billion times larger than the number of incident CR particles, the CR particles when colliding with the nuclei of the microprobe in their path will create cascade showers of many thousands high energy fragments thereby causing further damage to the probe. An analogy would be a very high powered dumdum bullet hitting a watermelon and blasting a cone-shaped trail of destruction through it. So, my guess is that beside the problem of the large amount of energy required to get the probes up to some significant percentage of the speed of light and then slow them down, probes with less than a few metres shielding will not survive hostile CR environment for the time required for interstellar travel.

Regarding our satellites and probes (Voyager, Pioneer), some have survived for a couple of decades, but this is vastly shorter than the time scales required for interstellar travel and hence have experienced far less damage. Even the comparatively mild solar activity (particles with energies/nucleon of a million times smaller than galactic CRs) is enough to damage some communications satellites.

Peter Backus from the SETI Institute corresponded with me on this matter, and concluded that "whatever their technology, they can't avoid the physics. Small probes will require a thick shell to reduce damage from cosmic rays." ❖

Prof. Davies Replies:

Thank you for your message about cosmic ray damage to space probes. I believe you have identified a legitimate problem, although it may not be a fatal one. I agree with Allen that nanotechnology might enable repair operations to be carried out. After all, bacteria are nanomachines, and they have good repair mechanisms for radiation damage, perhaps good enough for them to survive for quite long in outer space. ❖

Cosmic Rays? No Problem!

by Allen Tough (AllenTough@aol.com)

Actually, we probably need not worry much about cosmic rays fatally damaging interstellar probes. Here are some reasons for NOT worrying:

1. No one else seems worried. In all the NASA material and web sites on interstellar travel that I have checked out, nothing is said about cosmic rays. Nor in the nanotechnology literature, as far as I can recall. Nor in the National Space Society position paper. Nor in any of the other 35 references in my "Small Smart Interstellar Probes" paper
(preprint at http://members.aol.com/WelcomeETI/8.html).

2. We have to remember that any civilization we are likely to detect is probably thousands of years ahead of our technology. Even now, our nanotechnology literature indicates that within a few decades we will be able to manufacture "active materials" atom-by-atom. These intelligent active materials will incorporate sensors, diagnosis, and repair capacities right in the material itself. So any cosmic ray damage could presumably be repaired. (Nanotechnology, like interstellar probes, has become widely accepted within mainstream science over the past 2 years.)

3. We need not worry about a probe surviving for "a few million years" as you mention. A few thousand years might be enough if the probe travels only a few hundred light years.

4. If our satellites and space station and interplanetary probes had been devastated by cosmic rays, I would worry more. You are right, they have been in existence only a fraction of the time needed for interstellar travel, but still they are the best practical test so far of likely damage from cosmic rays.

All in all, as we think about a civilization thousands of years ahead of our technology, it seems unlikely that cosmic rays will stop their interstellar exploration. ❖

Members In The News

SETI League member Dr. Clifford Pickover has recently completed three new books:

The Science of Aliens (Basic Books, ISBN 0-465-06314-X is lavishly illustrated and contains scientifically-based speculation regarding alien life. The illustrations and frequent references to popular culture should make it appeal to all ages. (For fans of the SETI League, this book even has two wonderful photos of Dr. H. Paul Shuch, the Executive Director of the SETI League.)

Time: A Traveler's Guide (Oxford University Press) probes mysteries that have baffled mystics, philosophers, and scientists throughout history -- What is the nature of time? Is time travel possible?

Strange Brains and Genius: The Secret Lives of Eccentric Scientists and Madmen (Plenum) takes readers on a wild ride through the bizarre lives of brilliant, but eccentric geniuses who made significant contributions to science and philosophy. Chapters on aliens and the UFO abduction experience should be of interest to SETI League members. ❖

Software Page

What's A Grid Square?

One of the things which makes The SETI League unique among grassroots science organizations is that we have hundreds of members around the world, dozens of amateur observatories in operation, hundreds more under construction, and a grand goal of perhaps 5,000 participating stations early in the next decade. Our size, scope and span demand a method for uniquely identifying each of our active stations, preferably by geographical location. After extensive discussion on our various email lists, our members have decided to adopt six-character grid square designations for this purpose.

Grid squares have recently become popular among radio amateurs to identify the location of their stations. First proposed at a conference in Maidenhead, England, in 1980 (and hence sometimes called Maidenhead Locators), grid squares allow low-precision (four-character) and high-precision (six-character) expression of a station's latitude and longitude. Each grid in the low-precision case consists of a region one degree of latitude high by two degrees of longitude wide. Such a region is expressed by a "grid" identified by two letters of the alphabet (generally shown in capitals), and a "square" consisting of two numeric characters. For example, SETI League headquarters is in location FN20.

For higher precision, each grid square may be further divided into subsquares, expressed as two lower-case alphabetical characters. Since each subsquare encompasses 2.5 minutes of latitude by 5 minutes of longitude, a station's location is thus identified to within better than 5.6 nautical miles anywhere on the surface of the Earth. Our headquarters building is at FN20xv in this nomenclature.

A more detailed explanation of grid squares, including downloadable software to enable you to compute yours, may be found on The SETI League's website, at this URL:

http://www.setileague.org/general/gridsq.htm.

When you register your Project Argus station, you will be asked to identify it by your grid square. If you don't know your grid square, please supply your latitude and longitude, as precisely as you are able to identify them, and we will compute your grid square for you, and assign it to you as your unique station identifier.

Because it has been his experience that not all grid square locator programs compute Southern Hemisphere locations correctly, Eastern Australia regional coordinator Noel Welstead recommends that you check your location with various different grid square programs (several are linked from the website) before deciding where you are. ❖

SETI@home Launched

The world's most ambitious application of distributed data processing was successfully launched in May by our colleagues at the University of California, Berkeley. SETI@home taps into the idle resources of perhaps a million personal computers, for the analysis of raw Arecibo SETI data. Although not a SETI League initiative, many of our members are participants, and in fact The SETI League has formed its own SETI@home Team. Signup details may be found on The SETI League, Inc. website, at <http://www.setileague.org/general/setihome.htm>. ❖

OS Grid Reference Method

Although the Maidenhead grid square system described above originated in England, many radio amateurs in the UK use a different system based upon Ordnance Survey maps. Adrian Kingsley-Hughes, The SETI League's volunteer regional coordinator for Wales, elaborates:

As mapped by the Ordnance Survey, Great Britain is covered by 100 x 100 km grid squares identified by two letters (91 in all - 7 across, 13 upwards). The origin of this grid is about 110 km west and 20 km south of Land's End. On the Ordnance Survey maps these squares are further divided by grid lines representing 10 km spacing, numbered 0 to 9 from the southwest corner in an easterly (left to right) and northerly (upwards) direction. Using this system you can identify a 10 km square grid. On the more detailed maps (Landranger) you can further divide up the grid into 1 km squares.

Using this method you get an Ordnance Survey grid reference. It takes the following format:

SH551725 (my station's location).

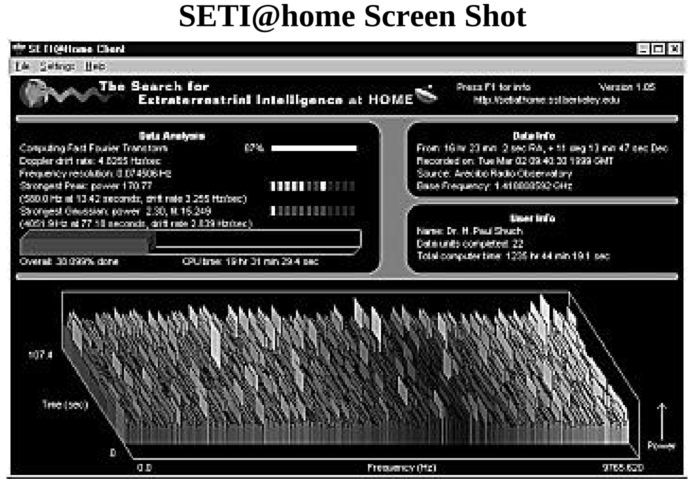
The first two letters are the sheet identifier. The next three digits give the eastings along the grid and the final three digits give the northings.

For those finding it difficult to remember that eastings come before northings, then remember to go "along the hall and up the stairs."

The OS system is a very good system indeed. An advantage of it is that if you want to find the distance between two points then you can use the Pythagorean theorem.

The Pythagorean theorem states that in a right triangle, the square of the length of the hypotenuse equals the sum of the squares of the other two sides. As eastings lines are perpendicular to northings, it can be used to calculate the distance between the two points (ie, the hypotenuse) by just calculating the difference in eastings by subtracting the smaller figure from the larger, and then calculating the difference in northings by subtracting the smaller figure from the larger. Now square the two results and add together; now the square root of this result is the length of the hypotenuse. Using this method you can get a value in meters. ❖

SETI@home Screen Shot



Hardware Page

How Do You Know Where You're Pointing?

by Malcolm Mallette, WA9BVS (mallettem@tcon.net)

If you do not know where your SETI dish is pointed, any discovery has no meaning as it cannot be confirmed. Confirmation of reception of a signal is impossible unless the radiotelescope doing the confirmation can be pointed to the Right Ascension and Declination that the signal comes from.

Our radiotelescope at the University of Indianapolis is doing wide band Radio Astronomy. However, the pointing problem is the same as an Argus station. With a 15 ft dish at 3.8 GHz, we have a one degree half power beamwidth. Accurate pointing is a primary consideration.

We first tried using an angle finder for rough setting. Then we moved the dish in what we hoped were fractions of a degree until the drift scan observation showed that a natural source was centered. We often moved the dish up and down while an object was in transit while watching the receiver output on a computer monitor and on a analog meter to set the dish right on. The maximum signal position was right on the source. Of course, we were pointing south and setting the elevation.

We then tried a potentiometer driven by a belt with teeth that was in turn driven by the rotation of the dish up and down. That worked fine for accuracy up to 1.5 degrees but was not accurate enough for our operation.

We finally used a digital level. The digital level reads out in tenths of a degree. The dish was centered on Taurus A by moving the dish up and down while Taurus A was transiting. The digital level has a magnetic mount as an option. Using the magnetic mount, the digital level was fastened to a selected steel bar that supports the dish and moves with the dish. The place the magnet on the digital level's mount is placed on the bar is marked so the digital level can always be placed on the same spot.

The digital meter was read and its reading compared with the actual elevation, which we knew as we knew that the dish was centered on Taurus A. An offset was then determined. For example, if the actual elevation is 72.3 degrees and we read 72.5 degrees on the digital level, we know that we must subtract 0.2 degrees when we read the digital level.

Using the digital level, we can set the dish elevation, and therefore the declination at which it is pointed, to within about 0.2 degrees. To set the dish's azimuth heading to exactly south, merely observe transits of a natural object and move the dish slightly until the peak signal coincides with the time the object should transit the south meridian.

I am assuming that you will use the drift scan method of observation for a SETI search. By setting the dish on an exact elevation using a known natural source, you can determine the offset for a digital level and set the dish accurately for elevations at which there are no strong natural sources.

We will probably go to a more complex system that remotely reads the dish position for computer aiming and star tracking. However, for an individual's Argus station used in drift scan operation, the digital level is adequate, costs about $130 with magnetic mount, and is easy to use and calibrate. ❖

Cooling Radio Astronomy Preamplifiers

by Dr. Thomas A. Clark, W3IWI
(clark@tomcat.gsfc.nasa.gov)

In my professional life, I have been responsible for the global network of radio telescopes used in Very Long Baseline Interferometry (VLBI) for high accuracy (millimeters on a global scale) geodetic science (see our web site at http://lupus.gsfc.nasa.gov for some info). The geodetic VLBI network operates at S-band (2.2-2.4 GHz) and X-band (8.1-8.9 GHz) and all the stations use HEMTs (High Electron Mobility Transistors) operating at cryogenic temperatures (~20K). At S-band, the HEMT LNAs have amplifier noise temperatures < 5K, resulting in Tsys ~30-50K, and at Xband they contribute ~10K to the ~50K Tsys. Cooled HEMTs are used all the time in the radio astronomy world. As an example of the current state-of-the-art, take a look at the plot on cooled FET/HEMT performance on the NRAO web site at:

<http://www.cv.nrao.edu/~nbailey/hfet-prf.gif>.

To get the cryogenic temperatures, we use commercial 2- or 3-stage closed- cycle Joule-Thompson refrigerators. These refrigerators are rather similar to conventional air conditioners, except that Helium is used as the "working fluid" -- Freon would freeze hard as a rock! The 1st "warm" stage cools the ~300K ambient temperature down by a factor ~4-5 to ~60-70K. The 2nd "cold" stage cools the ~60-70K by another factor of 4-5 to ~15-20K. Some receivers use a 3rd stage to get down to the ~4K level.

Note that I used absolute temperatures in this description. A large portion of the cooling improvement comes from the reduction of the kTB noise contribution, where T is the absolute temperature. Thus, cooling from ~300K ambient by ~30C (which is also 30K) results in only a 10% drop in the thermal noise contribution -- hardly worth the effort! Basically, the solid-state thermionic refrigerators just can't "pump" enough heat to make a significant improvement.

A much better approach has been used by optical astronomers for years to cool photomultiplier tubes (see, for example <http://www.photocool.com/dricrf.htm>). Dry ice can be obtained at your local Ice Cream store -- it's even advertised at local "Seven-Eleven" neighborhood stores (for an example in the Tampa, FL area, see <http://www.dels24hours.com/>).

I'll tell an anecdote from ~15 years ago to illustrate how well dry ice works. It was at a Central States meeting with Barry Malawanchuk (VE4MA) and I competing to win the 1296 MHz Noise Figure contest. Barry brought his newest FET amplifier built with copper water pipe. I brought a 1420 MHz LNA we were using for radio astronomy. I put my 21cm LNA into a foam plastic box with only the coax & bias cables visible and filled the box with dry ice, and let it cool for a few minutes.

Barry was so proud of his LNA and was certain he would win. He was showing ~0.5 dB NF and ~20 dB of gain. My "black box" had more that a tenth dB better NF and about 40 dB of gain. It was also broad as a barn, with little difference anywhere in the 1200-1500 MHz range. My only "tweaker" was a gate-voltage bias pot.

Then Barry realized what I had done and decided to cool his LNA. Unfortunately, copper water pipe presents a huge thermal mass. And since his FET biases were optimized for ambient temperatures, his amplifier was a bitch to tune when it finally got cold. After a couple of hours of tweaking, Barry matched my LNA and we declared a tie.

So my advice, if you want to get a significant performance improvement, try putting your LNA into a foam plastic box; the kind that holds a 6-pack of beer is about the right size. To minimize moisture condensation problems, first dry the amplifier well, then put it in your kitchen freezer. While still cold, seal the amplifier from moist air by putting it into a condom. Depending on how you bias the amplifier, you might want to bring the bias out separately so you can tweak it cold. ❖

Ask Dr. SETI®

Dear Dr. SETI:

I understand that light is a form of electromagnetic radiation. So are radio waves. Now if a telescope can magnify light 400x, couldn't it also do the same with radio waves? You could focus your telescope on a star, put your reciver at the eye piece,and get a signal 400x more powerful! If this would work,it would cost less than a dish, and take up less space. So, would it work?

CC, Scotland

The Doctor Responds:

You have just described exactly how both (Newtonian) optical telescopes and (parabolic dish) radio telescopes work. The reason the optical telescope mangifies light hundreds or thousands of times is that its mirror is large relative to the wavelength of light being gathered. A radio telescope similarly "magnifies" its "light" hundreds or thousands of times, because its mirror (the parabolic dish -- which focuses light to its eyepiece, the feedhorn) is large relative to the wavelength it is focusing. The only problem is, the radio telescope is dealing with electromagnetic radiation about half a million times longer than visible light wavelengths, so for equivalent performance, its "mirror" needs to be about half a million times larger than the equivalent optical telescope's.

Now that we agree on the basics, let's run the numbers. A reflecting telescope (optical or radio, it doesn't matter) has a "magnification" which can be described in terms of power gain. At 100 percent efficiency (which we can never achieve, because the real world isn't perfect), we can calculate that power gain. It's actually easier to calculate voltage gain, and then square it, since power ratio varies with the square of voltage ratio. The relationship is:

Voltage gain ~ (Reflector circumference) / (wavelength)

where both are measured in the same units. Of course, circumference equals diameter times pi (for a round mirror), and diameter is twice radius, which is why all the textbook formulae contain a (2 pi * r) factor.

Next, power gain = (voltage gain)^2. Think of this as your "magnification" of light.

Finally, in radio we usually convert power gain to dBi, a logarithmic shorthand. dBi means deciBels compared to an isotrope. An isotropic radiator is a theoretical (can't actually build one, buy one, or find one in nature) ideal omnidirectional antenna. Omnidirectional means it radiates equally poorly in all directions. Anyway, the conversion is:

dBi = 10 * log (power ratio),

where we use a base 10 logarithm.

So, let's put all this together and run some examples.

First: my optical telescope (a Celestron model C-8) has a 100 mm radius reflector. That mirror has a circumference of (2 * pi * 100 mm) ~ just over a half meter. I use it to magnify visible light which has a 500 nanometer wavelength.

The voltage gain is (1/2 m)/(500 nm) = 1,000,000!

Theoretical power gain is (1,000,000)^2 = 1,000,000,000,000!

Converting to dBi, that's 10 log (10^12) = +120 dBi

(only I won't really get anywhere near that performance, because my eyepiece and mirror are quite imperfect).

Next: let us consider the world's largest radio telescope, Arecibo radio observatory, at the hydrogen line. The mirror at Arecibo has a 152 meter radius. Its circumference is (2 * pi * 152 meters) ~ just under 1 kilometer. I use it to receive "light" at a wavelength of 21 cm. So:

Voltage gain is (1 km)/(21 cm) ~ 5,000.

Theoretical power gain is (5,000)^2 = 25,000,000.

Converting to dBi, that's 10 log (2.5 * 10^7) ~ +74 dBi

(only Arecibo won't really get anywhere near that performance, because its eyepiece {the feedhorn} and mirror {the reflector} are quite imperfect).

Well, actually I've misled you a little here, because I'm comparing apples to kumquats. If we level the playing field by restricting each instrument to its intended application, we see that my Celestron telescope and my 12 foot radio telescope are just about equivalent in performance (see the Appendix below). But this doesn't invalidate our...

Conclusion:

In terms of power gain, my Celestron telescope is tens of thousands of times more sensitive than Arecibo. Which explains why optical SETI is so appealing.

Appendix: Optical Magnification and the Eye

You may be wondering why the typical amateur optical telescope has a magnification of about 400, while we have just computed its power gain at 1,000,000,000,000. The apparent discrepancy is because antenna gain is calculated relative to that elusive isotrope, while optical magnification is generally specified relative to the naked eye. So, if we know the optical telescope's gain, and want to know its magnification, we need also to compute the "gain" (relative to isotropic) of the human eye. Fortunately (although optical physics has its own formulas), straight antenna theory can apply here as well.

Let's consider the human eye to be an antenna whose aperture to electromagnetic radiation is the pupil. Say the radius of the dilated pupil (it is dark when we use a telescope, after all) is on the order of 2 mm. We can use the same equations we use for a parabolic antenna:

Voltage gain ~ (pupil circumference) / (wavelength)

Voltage gain ~ (2 pi * 2 mm) / (500 nm) = 25,000

Power gain = (voltage gain)^2 ~ 600,000,000 = +88 dBi

which makes the naked human eye an optical Arecibo!

Now, as to the question of the magnification of my Celestron, let's assume I have an eyepiece which perfectly couples to my pupil (I don't, which means its efficiency is less than 100 percent, but this is the ideal case). Theoretical magnification would be the ratio of the antenna's power gain to that of the naked eye. That comes to (1,000,000,000,000) / (600,000,000) = 1667. The optics people have simpler formulas for calculating magnification, to be sure (ratio of mirror to eyepiece dimensions being the favored one). We would expect the results to correlate well with antenna theory.

Next, let's calculate the power gain of that Celestron telescope, not in dBi (deciBels compared to isotropic), but rather in a new unit which I'm going to call dBe (deciBels compared to the human eye). The relationship should be (and in fact is):

Telescope Gain (dBe) = Telescope Gain (dBi) - Human Eye Gain (dBi)

Telescope Gain (dBe) = (+120 dBi) - (+88 dBi) = +32 dBe

[notice that the i's in the dBi units above cancel].

It has been previously shown in the article *SETI Sensitivity: Calibrating on a Wow! Signal* (available on The SETI League website) that the "standard" 12-foot dish used in Project Argus stations achieves a gain of +31.8 dBi. Comparison to an isotrope is as appropriate for radio telescopes as comparison to an eyeball is for optical telescopes. Thus, it appears that, as far as their intended applications are concerned, the average amateur radio telescope (typified by the Argus station) and the typical optical telescope (exemplified by the Celestron C-8) are roughly equivalent in performance.

Convolusion [Convoluted Conclusion]:

Whereas, the human eye is the optical equivalent of an Arecibo, the standard Project Argus station is the microwave equivalent of a Celestron! And since significant optical astronomical discoveries have been made with Celestron-class telescopes, we have every reason to expect significant microwave astronomical discoveries to be within the grasp of our Project Argus-class amateur radio telescopes.

Dear Dr. SETI:

When a Native American sends a smoke signal today, who hears or sees what is being said? I think the reason we are not having any luck in finding transmissions from other worlds, near or far, is that we are using technology that is current only for us. But what if the inhabitants of some other world are traveling between stars, having developed a system that allows them to travel faster than the speed of light?

If you can travel at warp speed, why would you communicate using a system that propagates at the speed of light? They would need some sort of system that transmits a signal beyond the speed of light.

Oh! People have said we cannot surpass the speed of light, just as it was once felt we could not surpass the speed of sound. I think the speed of light is no different than the speed of sound, just a tad faster. I feel that is where research needs to be done, looking for a method of communication that can surpass the speed of light. Dr. A. Einstein gave us a leg-up on some of this type of knowledge; now we need to find someone that can take this information and run with it, to the most distant star.

Don, San Antonio TX

The Doctor Responds:

Actually, the speed of light is about Mach 1,000,000, or a million times the speed of sound. If that's "just a tad" faster, I'd like to have a SETI League budget which is "just a tad more" than $1! But that's a different discussion altogether.

During one of his last lectures, which I had the pleasure to attend, Dr. Isaac Asimov (who was eulogized by SETI League advisor Arthur C. Clarke as "the world's second greatest Science Fiction writer") fielded a question about faster-than-light (FTL) travel. Specifically, he was asked if his refusal to write scenarios incorporating FTL travel stemmed from his closed-mindedness about the possibilities of future technology. His reply included an elegant analogy, which I will paraphrase:

> Back in 1491, when the world was still flat, people imagined that if they walked far enough, they would fall off the edge of the Earth. Today we know that couldn't happen, because our Earth is a sphere. If you walk far enough you might drown, but you won't fall off.
>
> We all agree that writing a story about someone walking off the edge of the world isn't realistic. It violates a basic law of nature, as we understand it. Accepting that the world is round does not represent closed-mindedness, as no degree of imagination can change that fact. FTL travel is like that. Unless we are wrong about the laws of the Universe (and we could be, but that's just speculation -- we've never seen any evidence to suggest so), it's just not a credible story line.

Not all science fiction authors are so constrained by the laws of nature. Dr. Robert Forward, for example, subscribes to what has become known as "Forward's Law": never let the facts get in the way of a good story. While this philosophy is fine for fiction, it doesn't sit well with SETI. In fact, we embrace what I like to call "Dr. SETI's Corollary to Forward's Law": never let a good story get in the way of the facts.

Now, what about your analogy of FTL to the supposed "sound barrier"? Actually, they are not equivalent at all. There was never any scientific law to which anyone was ever able to point which led to claims that we'd never exceed the speed of sound. On the contrary, we had direct physical evidence (primarily from meteorites entering the atmosphere) that the "sound barrier" was not an impenetrable barrier at all! What the general public (and some scientists) did believe is that we would never have the technology for faster-than-sound travel. But that's a very different thing from the light barrier, which is based on physical laws (as we understand them), not limits imposed by our own technological immaturity.

We see here another example of the public confusing technology with science. No advance in technology will ever let us step off the edge of the flat earth, or violate other basic physical laws. Nature is very unforgiving that way. And I hasten to point out that, unlike meteors, which routinely go faster than sound, we have not one shred of verifiable evidence that anything has ever gone faster than light, in nature or otherwise.

So much for FTL travel. But what of FTL communications? Similar arguments apply, but the bottom line is, even if I'm wrong about this, microwave and optical SETI still make good sense. Imagine that there is a continuum of technological development somewhere on which each of the multitudes of probable civilizations will fall. They are not all at the same level of development, because they are neither all the same age nor evolutionarily homogeneous.

I'm willing to stipulate that *some* civilizations may have developed technology undetectable, or unrecognizable, to us, or in Clarke's words, indistinguishable from magic. (Maybe some even have FTL travel. Maybe even FTL communications. Though I doubt it. Paramount Studios holds all the patents on Warp Drive, and they're not sharing them.) Are you willing to stipulate that at least *some* civilizations may still be using, or may have recently (in terms of their light-distance) used, radio?

The reason we "aren't having any luck," as you so pessimistically put it, has more to do with the fact that in all of human history, we've been looking for less than an eye-blink. SETI requires patience and a multi-generational perspective. It offers little to he or she who demands instant gratification. Even if we bend the laws of nature. ❖

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