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SETI MADE SIMPLE

What can ***we*** *do?*

There are many things that excite me about the times in which we live. One is that I have been privileged to witness a perceptual revolution. Just 50 years ago, every credible authority maintained that mankind is alone among the stars—the sole sentient species in the vast cosmos. Today, the overwhelming preponderance of scientific thinking holds that we are not. How quickly we have completed the Copernican revolution!

In these pages, we'll explore the pertinent cosmological evidence that leads most knowledgeable scientists to envision a universe teeming with life. We'll see why many astrophysicists believe that the best evidence of extrasolar civilizations is to be found in the microwave spectrum. If these lines of thinking are correct, it is you, the radio amateurs and microwave experimenters of planet Earth, who have the best chance of detecting such evidence. I'll lay out a strategy for amateur SETI—a Search for Extra-Terrestrial Intelligence involving several thousand hobbyists that can rival any government search ever proposed and denied funding. Finally, I'll list the equipment requirements for you to join the team: the microwave, computer, and digital signal processing (DSP) hardware and software that would make a planet like our own visible from across the galaxy, and which is today within your grasp.

Each of these topics is worthy of an article, so my comments will, of necessity, be cursory. For those interested in pursuing this subject further, abundant literature exists, much of which is available through The SETI League.

So, who is SETI?

Not too many years ago, when I wrote about a previous amateur breakthrough, people would ask: "Who is OSCAR?" The present acronym represents the *Search for Extra-Terrestrial Intelligence*. It was coined in the 1960s to describe the use of radiotelescopes to seek out electromagnetic signals of possible intelligent origin, emanating from beyond our planet. Dozens of such searches have been conducted over the past 35 years, with some interesting results, none yet conclusive. On the other hand, not only have we not yet scratched the surface, we haven't even found the itch. We *have* surveyed several thousand stars, for brief periods of time, at limited frequencies. But with an estimated two hundred billion stars in our galaxy, and perhaps a hundred billion other galaxies, we have a long way to go before we can start drawing any conclusions.

In fact, logic and probability theory suggest that we should *not* have yet succeeded in receiving intelligent signals. SETI pioneer Dr. Frank Drake, who conducted the first search in 1960, now estimates that there are perhaps 10,000 advanced civilizations in the Milky Way Galaxy.[1] That makes each star we survey a 20 million-to-one long-shot. To have found the elusive needle in the cosmic haystack by now, would be equivalent to walking into the Library of Congress blindfolded, selecting one book at random, and getting home to find that we had checked out *Macbeth*. If we try, and fail, does that mean that Macbeth does not exist? The data is incomplete.

Then again, our elected leaders are hardly averse to drawing conclusions from incomplete data, and acting upon them precipitously. NASA once had a modestly funded SETI effort, which consumed about a tenth of a percent of the agency's budget. Both a targeted search of likely candidate stars and an overall sky survey were initiated in October 1992 (significantly, the 500th anniversary of Columbus' first voyage of discovery). Absent immediate results, NASA's funding was suspended by Congress just one year later, and both searches were curtailed. The SETI League, SETI Institute, Planetary Society, and other organizations are now trying to privatize those efforts.

The SETI League was founded in 1994 as a membership supported, non-profit [501(c)(3)] scientific and educational corporation. Our charter involves organizing and conducting an electromagnetic search of the skies, to spot signals of possible intelligent origin. This search will involve thousands of radio amateurs, microwave hobbyists, and DSP experimenters around the world, working in concert to accomplish the seemingly impossible. In other words, we seek to do what hams have always done!

Cosmic evolution

Current thinking, as first theorized by George Gamow, holds that the universe began as a single, extremely dense point in space-time, which exploded perhaps 9 to 18 billion years ago, and has been expanding and cooling ever since. Gamow's evidence in support of this theory was the consistent red-shift (decreasing frequency Doppler shift) that Edwin Hubble had measured in distant galaxies. Fred Hoyle derisively dubbed that universal birth the Big Bang, and the name stuck. Gamow's theory further predicted that the Big Bang should have left a residue of microwave radiation, which was indeed first measured by Arno Penzias and Robert Wilson in 1965. The so-called Three Kelvin (3K) Background Radiation has been reaffirmed countless times, and stands as the best evidence to date of an expanding universe.

Our uncertainty as the exact age of the universe stems from our inability (thus far) to precisely measure the Hubble Constant, which relates to the rate of expansion of the universe. Since measurements from (appropriately) the Hubble Space Telescope bring us a new estimate every few weeks, I've taken to calling this number the Hubble Variable! We do know that our planet is on the order of four and a half billion years old. Thus, the Earth appears to be only half to one fourth the age of the universe. This is significant, because it suggests that our planet (and the star around which it revolves) are youngsters—relatively new arrivals on the cosmic scene.

Our rather ordinary star is but one of perhaps two hundred billion in its galaxy (which we call the Milky Way), and perhaps a tenth of those stars appear to be of similar size, heat, and composition to our Sun. Although we can not detect planetary systems optically,[2] they evidence themselves in several other ways, and everywhere we have looked for planets, we have detected what we believe to be indications of their presence. It is theorized that the formation of planets is an essential process by which a rotating star dissipates some of its angular momentum. So planetary formation appears commonplace, and we can assume that each of the sun-like stars in our galaxy has its own retinue of planets. Because the stuff from which our planet is made is hardly unique to Earth, but common throughout the cosmos, we can expect at least some of those hundreds of billions to have a rocky crust, liquid oceans, puffy clouds, and nitrogen skies. What *Star Trek* calls "M-class planets."

Finally, our galaxy is one of perhaps a hundred billion such star groups in the universe. Now there's no reason to expect the laws of physics, or chemistry, to be different in those other galaxies, from the ones we observe on Earth. Which leads us to image the existence of countless billions of Earth-like planets circling Sun-like stars. And remember, most of these planets are older than our homeland, and have had more time to spawn their particular versions of life.

The emergence of life

Perhaps the most amazing aspect of our existence is that *life evolved from non-living things*! Not just any non-living things, mind you, but a specific group of complex organic molecules called amino acids. Of course, we have no way of knowing that life on other planets is necessarily "organic" as we use the term, but let's assume for just a moment that it is. (If we're wrong, this suggests the existence of more, not less, life than I am supposing.)

One of the most important contributions of radio astronomy is its ability to discern the composition of its target objects. Not just stars (which we know to burn primarily hydrogen into helium); radio telescopes can measure the composition of interstellar gasses and molecular dust clouds as well.

The presence of abundant interstellar hydrogen was first detected by Harvard University graduate student Harold Ewen and his advisor Edward Purcell, in 1952, by measuring its 21-cm microwave emissions.[3] In 1963, a group at MIT's Lincoln Laboratory first detected the characteristic 18-cm emission of interstellar hydroxyl ions. We shall learn shortly about the significance to SETI of these two spectral emission lines. Less well known, but even more important for discussions involving the origin of life, is that dozens of complex molecules, many organic, have also been detected in the interstellar medium. A partial list includes: cyanogen, ammonia, water, formaldehyde, carbon monoxide, hydrogen cyanide, cyanoacetylene, methyl alcohol, formic acid, carbon monosulfide, silicon oxide, carbonyl sulfide, acetonitrile, isocyanic acid, methylacetylene, hydrogen isocyanide, acetaldehyde, methyleneimine, deuterium cyanide—the interstellar medium is anything but an empty void. It's a veritable chemistry set.

But can it spawn life? Nobel chemist and SETI pioneer Melvin Calvin believed so. At Berkeley in 1951, he sparked a mixture of carbon dioxide, hydrogen, and water with an energy burst from a cyclotron, and produced organic chemicals—some of which are known to be precursors of life. In 1955, another graduate student, Stanley Miller, working with his advisor Harold Urey at the University of Chicago, restructured the Calvin experiment with an even more startling result. Using several of the precursors form the above list, they produced a wide variety of amino acids!

If solar systems indeed condense out of the interstellar medium, then the chemicals of life may be found on countless planets. Necessary energy sources (lightning, volcanism, whatever) are readily available. Building amino acids appears relatively easy. In fact, "alien" amino acids have already been found in meteorite fragments,[4] so we know they are commonplace in the cosmos, by no means unique to Earth. The clincher is that, using an electron microscope, Hans Dieter Pflug has detected what appear to be micro-organisms within meteorites! They're only fossilized bacteria, but they certainly present us with our most promising evidence of the existence of alien life.

Now it's a long way from bacteria to thinking beings capable of harnessing electromagnetic communications (and hence detection by our radiotelescopes). On the other hand though, the number of potential life sites in the universe is truly mind-boggling. If we take the Milky Way to be typical, there are on the order of a million billion billion "good" suns among the galaxies. Should intelligent life not have evolved on planets orbiting a good many of those suns? If an infinite number of monkeys sits down at an infinite number of typewriters, one of them is bound to write out the whole *Encyclopedia Galactica*.

How to search

We don't know for certain that all species eventually develop electromagnetic communications, but it's a safe bet some do. Photons are, after all, the fastest space ships we can imagine. Radio communication is cheap, and quick, and easy to learn. If we can figure it out, the assumption of mediocrity suggests, then so can more advanced civilizations, who may have been around millions, perhaps billions, of years longer than ourselves. Okay, so maybe a given technologically advanced civilization adopted, and then abandoned radio communications a billion years ago. No matter. If they are a billion light years distant, their photons are just now reaching us, and are in fact falling silently on our heads even as we speak.

The greatest obstacle to interstellar communication is naturally occurring noise. Galactic, cosmic, quantum, and synchrotron noise sources span the spectrum, but they aren't uniform. The quietest part of the sky, the 1 to 10 GHz microwave window, is a logical starting point, and by no means geocentric. But we're taking an incredible bandwidth here. Can we narrow the search spectrum?

Most SETI scientists think we can. Toward the bottom of the microwave window are two rather strong spectral radiation lines, emanating from hydrogen and hydroxyl, among the most abundant substances in interstellar space. It has long been suggested that between these two markers falls a natural, universal communications band.

Significantly, hydrogen and hydroxyl are the disassociation products of water. Although we needn't limit our search to water-based life, it's interesting to speculate that others might recognize an additional significance to these two frequencies. Dr. Bernard M. Oliver, retired vice president of engineering for Hewlett-Packard Company, headed NASA's SETI office until it was closed, and was senior technical advisor for the SETI League until his death last November. It was Oliver who, in a 1971 study,[5] first suggested scanning the cosmos between the hydrogen and hydroxyl lines. He coined the rather poetic term for this proposed communications band. "Where shall we seek out our kind?" Oliver asked. "At the water hole, where species have always gathered."

Other frequency bands than the water hole, and other technologies than microwave, are certainly worthy of SETI consideration. In fact, a good deal of attention is being paid to Optical SETI, by optical astronomers who, after all, do have a 400 year head start on their radio counterparts. But since radio waves are what the ham community knows best, it is here that I propose concentrating our amateur SETI efforts.

The water hole extends from roughly 1420 to 1660 MHz, a bandwidth of 240 MHz. Monitoring it at, let us say, 10-Hz resolution, we have 24 million channels to scan. Consequently, much SETI research has been devoted to developing mega-channel real time spectrum analyzers. This can be approached as a digital signal processing project, an area in which hams are emerging as the technological innovators. The AMSAT/TAPR DSP-93 project, for example, may not be capable of scanning the entire water hole in real time, but it can certainly cover audio bandwidths, at reasonable resolution, with astounding sensitivity. Given the appropriate accompanying software, there's no reason not to believe such DSPs capable of recognizing very weak coherent signals coming out of our microwave receivers.

The late NASA SETI study had two complementary components: a targeted search and an all-sky survey. The former, involving parking on likely candidate stars for long periods of time, is well suited to large, steerable dishes with their narrow beamwidths and high sensitivities. If we guess right as to which stars are likely candidates, the targeted search will provide us with the greatest likelihood of immediate success. But because we only know of a limited number of relatively nearby candidate stars, concentrating our search in their direction may cause us to miss an equally good star of which we happen to be unaware.

An all-sky survey, on the other hand, makes no *a priori* assumptions as to the most likely direction to explore. The sky survey attempts to sweep out the entire sky that can be seen from a given location. No antenna tracking is required, because it is sky, rather than individual stars, which we seek to survey. Therefore, we can use our antennas in drift scan mode, as Grote Reber did when he invented the radiotelescope,[6] by aiming in a north/south line, letting the Earth turn the antennas, and varying only their elevation.

Since large antennas are quite narrow, the sky survey is better performed with dishes of moderate size. Of course, smaller antennas have less gain, so to achieve reasonable sensitivities, they need to scan for extremely long periods of time. The sky survey approach, it would seem, is ideally suited to the community of radio amateurs and microwave experimenters. This is the area in which I feel hams can make their most significant SETI contributions.

Why to search

Any endeavor that commits significant resources must promise substantial benefits, if it is to be justified. In this section, more philosophical than technological, I'd like to quote the rationale given by some of the SETI pioneers. Their comments are gleaned from the references that appear at the end of this article.

> "We believe such a coordinated search program is well justified on its scientific merits. It will also have important subsidiary benefits for radio astronomy in general. It is a scientific activity that seems likely to garner substantial public support.
>
> "You find out who you are. It's a basic question. Are there beings in some sense like you, elsewhere in the universe, or are we the only ones around? It touches deeply into myth, folklore, religion, mythology; and every human culture in some way or another has wondered about that kind of question. It's one of the most basic questions there is."
>
> **—Dr. Carl Sagan, Duncan Professor of Astronomy, Cornell University**
>
> "...a vast body of knowledge will have accumulated over the aeons, and this knowledge is accessible to any race whose technological prowess qualifies it.
>
> "I have termed this body of knowledge our galactic heritage, and I believe that access to it would truly be the most important event in the recorded history of man. The galactic heritage could include a large body of science that we have yet to discover—answers to questions that we haven't even thought of...
>
> "But more important, I think, would be the societal benefits. We will be in touch with races that have achieved longevity. The galactic community would have already distilled out of its member cultures the political systems, the social forms, and the morality most conducive to survival, not for just a few generations, but for billions of years. We might learn how other races solved their pollution problems, their ecological problems, and how they have shouldered the responsibility for genetic evolution in a compassionate society."
>
> **—Dr. Bernard M. Oliver, former Vice President of Engineering, Hewlett-Packard Company; Senior Technical Advisor, SETI Institute**
>
> "There are few questions that more excite the curiosity, the imagination and the exploratory bent of modern man than the one posed in this study: Are we humans alone in this vast universe? The question is usually expressed in terms of other possible intelligent beings, on other planets. The philosopher in me would want to believe that if there are other intelligent beings, they are also free, and will use that freedom

to try to find us. The basic problem to which this study is addressed is similar: Will we use our freedom to find them? What priority should this search have for modern man, everywhere?

"I must now mention God—otherwise quite properly unmentioned in these scientific studies—and must go a step further and pose the question: Can a religious person, or even more, a theologian, possibly be legitimately involved in, even be excited by these discussions of the possibility of other intelligent and free creatures out there?

"As a theologian, I would say that this proposed search for extraterrestrial intelligence (SETI) is also a search of knowing and understanding God through His works—especially those works that most reflect Him. Finding others than ourselves would mean knowing Him better."

—Father Theodore M. Hesburgh, C.S.C., President Emeritus, University of Notre Dame

"...the lesson we have learned from all our previous searching is that the greatest discovery is not a simple one to make. If there were once cockeyed optimists in the SETI endeavor, there aren't any now. In a way, I am glad. The priceless benefits of knowledge and experience that will accrue from interstellar contact should not come too easily. To appreciate them, we should expect to devote a substantial portion of our resources, our assets, our intellectually vigor, and our patience. We should be willing to sweat and crawl and wait.

"The goal is not beyond us. It is within our grasp."

—Dr. Frank Drake, Professor of Astronomy and Astrophysics, University of California, Santa Cruz; President, SETI Institute

"I think the SETI enterprise can best be understood as a kind of exercise in the archeology of the future. We are well aware of the archeology of the past. We find a site, a tumulus, or a ruin, and we take a spade and dig into the ground—and if we are lucky, we discover Ur of the Chaldees or something marvelous.

"Now we never thought that we could examine the same thing in reverse time. But in fact, in a way, we can. We know that it is possible that some other civilization, who wants to, can bring us in. Of course it will be their past, but our future, which we are investigating to some degree. Even though they are made of different chemistry, even though they have never seen our star, even though they have nothing biological in common with us, if they have radio astronomy and the kind of technology we are imagining, they have very much in common with us: the development of culture which is unmatched in all the 10 billion species or more that have come to the face of the Earth.

"So that is the story. Maybe the spade will turn up a good site one day. We hope it will. It's just a question of being patient. When you've got the spade, and you know the future is there, it seems very wrong not to dig."

—Dr. Philip Morrison, Professor Emeritus of Physics, Massachusetts Institute of Technology

What can *we* do?

The beauty of SETI is that there's something for everyone—enough work to spread around. And if we succeed, it will not be the individual, but all of humankind, to whom the glory will accrue. What I intend to show you here is that, should we succeed, it will be due not to any individual effort, but to the cooperative efforts of thousands of dedicated amateurs.

Consider that the average ham moonbounce or TVRO dish has a beamwidth on the order of three degrees. Let's put that dish on a transit mount, and let the Earth be our antenna rotor. Now the dish will be rotating at 15 degrees per hour, which means a given star will be within its beamwidth for at least twelve minutes. Given existing amateur DSP technology, and employing a few tricks, twelve minutes is enough time to roughly scan about 14.4 kHz of spectrum, at 10-Hz resolution (which I consider consistent with the frequency stability of amateur microwave local oscillators). But the water hole is 240 MHz wide, which means to cover our assigned swath of sky at all water hole frequencies, we need to be listening for 16,667 days. That's a little over 46 years.

Well, perhaps a dedicated experimenter will be willing to devote 46 years of his life to studying the sky. Tycho Brahe did. But a 46-year search at a single antenna elevation will only survey a three degree wide swath of sky. To cover the range of declinations from southern to northern horizon, we need to conduct 60 such surveys, which brings the time dimension of the effort up to about 2760 years. And that only covers the one hemisphere of sky we can see from our QTH; a complete sky survey may demand we spend as long searching from Earth's other hemisphere as well. So a dedicated amateur can complete one full sweep of the water hole in just under six millennia!

On the other hand, 5220 experimenters can do that same sky survey in just one year. Which is why it becomes important to make SETI a broad-based effort. And where but in the amateur radio service are we as likely to find several thousand dish-equipped experimenters, scattered around the globe, with the means to communicate, hence coordinate their efforts? I submit that the problem might have been tailor-made for us.

What do you need to join the search? Here's the list:

1) a three-to-five meter parabolic reflector with surface smoothness adequate for TVRO, or 23 cm moonbounce;[7]
2) a low-noise preamp that covers the 1.4 to 1.7-GHz range;
3) a downconverter (in the manner of the popular Rick Campbell/Jim Davey No Tune Transverter Boards) to shift the water hole down to a suitable IF;
4) IF amplifiers, filters, and a square law detector that will derive audio from that IF;
5) a digital signal processor, such as a computer sound card;
6) spectrum analysis software, and a home computer on which to run it.

That which you don't build can be purchased at a cost on a par with a typical OSCAR station. Several hundred stations are already so equipped. By the turn of the century, it's possible several thousand will be, and then—well, who knows?

I expect some kind of coordination to be required, and that's where The SETI League comes in. We are a tax-exempt, nonprofit scientific and educational organization devoted to keeping the search alive. Our mission involves research, economics, and more than a little politics. We will encourage restoration of NASA's SETI funding if possible, help to privatize the effort if necessary, coordinate the efforts of a wide range of SETI amateurs and professionals, and educate the public as to the possible benefits of the search. We also stand prepared to assign particular amateurs specific search declinations to assure full sky coverage, and will act as a clearinghouse for information and results. I'm sure once one suspicious signal is detected, everybody will want to know where to point his or her dish to help confirm it! The information superhighway will certainly help, and we're already a presence there. If you happen to have World Wide Web access, I invite you to browse our home page. It's hypertext linked to numerous other related Web sites. The Uniform Resource Locator (a Web address) is http://seti1.setileague.org/homepg.html.

A broad membership base will make it possible to put amateur SETI on track. It will also enable us to keep our membership on track with SETI-related information through a quarterly newsletter, and journal articles such as this one. We hope to promote the best hardware and software schemes to come out of the ham community, and will design, prototype, and evaluate various detection and signal analysis technologies. For further information on joining the SETI League, call 1(800) TAU-SETI, or e-mail to info@setileague.org. In the immortal words of Rick Blaine, "If that call comes, and you don't answer, you'll regret it. Maybe not today, maybe not tomorrow. But soon, and for the rest of your life."

Conclusions

It's my belief that radio amateurs and microwave experimenters, with our limited equipment but high level of dedication, have every bit as much likelihood of success as do operators of the world's great radiotelescopes, in detecting extraterrestrial signals of possible intelligent origin. It is, after all, amateur optical astronomers who have first detected the majority of comets, and radio amateurs who have pioneered most all of modern telecommunications technology. And that which the scientific establishment has in the past regarded as impossible, dedicated radio amateurs will doubtless accept as just another challenge to be met.

I like to view the SETI problem as an equation with four degrees of freedom: sensitivity, frequency coverage, sky coverage, and time. The amateur quest that I propose will of necessity be weak in the first variable, moderate in the second, but extremely strong in the third and fourth. Using readily available technology, a few thousand dedicated amateurs around the world can, in twenty year's time, repeatedly scan all 4π steradians of sky, over the entire water hole, to 10-Hz resolution, at sensitivities that rival NASA's late JPL All Sky Survey.

The Targeted Search aspect of the High Resolution Microwave Survey is another matter. Abandoned by NASA due to lack of funding, it has resurfaced as Project Phoenix, under

SETI Institute sponsorship. Phoenix started observations from a 64-meter dish at Australia's Parkes Observatory on February 2, 1995, and has already surveyed about 200 sun-like stars within 150 light years of Earth, at astounding sensitivities, from 1.2 to 3 GHz. The two efforts are, of course, complementary; just as the Targeted Search was resurrected as Project Phoenix, so we hope will amateur SETI give life to the All Sky Survey.

If we do the search, and do it right, a generation from now we'll either know for certain that we are not alone in the universe, or perhaps be forced to reluctantly conclude that we are. Either possibility boggles the imagination. So join us is seeking the ultimate DX. Maybe it's only SWL, but it's the rarest grid square of them all! ■

ARTICLE NOTES

1. Drake bases this estimate on his personal solution for the Drake Equation, an elegant tool for quantifying our ignorance, which he developed in 1961 as the agenda for the world's first SETI conference. Today the *Drake Equation* is a classic, to be found in nearly every astronomy textbook that addresses the question of alien life.

2. Trying to optically view a planet orbiting a star is a little like trying to spot a firefly perched on the rim of a searchlight.

3. The following year Purcell was awarded the Nobel Prize for this and other accomplishments. Ewen had the distinction of writing what is probably history's briefest doctoral dissertation—a scant dozen pages.

4. Could these samples have originated on Earth, resulting perhaps from contamination in the laboratory? A fair question. Amino acids come in two varieties: clockwise ("right-handed") and counterclockwise ("left-handed"). All life on Earth is composed exclusively of left-handed amino acids. But, meteor fragments have been found that contain right-handed amino acids, so we assume they are of extraterrestrial origin.

5. That study, part of a summer faculty fellowship program at Stanford University, brought together some of the leading minds in radio astronomy to puzzle the problem of interstellar communications. The group's most tangible result, the Project Cyclops report, remains one of the most important SETI publications to date. The SETI League and SETI Institute will be jointly reprinting "The Cyclops Report" in the summer of 1996.

6. Reber, an electrical engineer and radio amateur (W9GFZ), built the first true radiotelescope in his backyard in Wheaton, Illinois in 1937. Although lacking in formal astronomical training, he is today recognized as the patriarch of a new discipline. His 10-meter diameter dish (somewhat larger than the size that I propose for amateur SETI), on a transit mount, generated the *first* radio map of the Milky Way. Reber measured radiation levels millions of times in excess of what then favored theories predicted. His controversial measurements have subsequently been borne out repeatedly. Reber ultimately retired to Tasmania, apparently preferring to be, rather than merely work, DX.

7. If you don't want to dedicate your dish full time to the SETI effort, no problem. A water hole feed certainly doesn't preclude installing other feeds at the focal point as well. You can practice what's come to be known as Parasitic SETI, letting your water hole receiver scan while your dish goes about its daily business of EME, or TV, or whatever.

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PRODUCT INFORMATION

New Low-Loss RG-8U-Type Coax from Belden

Belden Wire & Cable Company has introduced their Part Number 9913F, a low-loss RG-8U-type coaxial cable. This new cable is a high-flex version of Belden's 9913 coax.

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