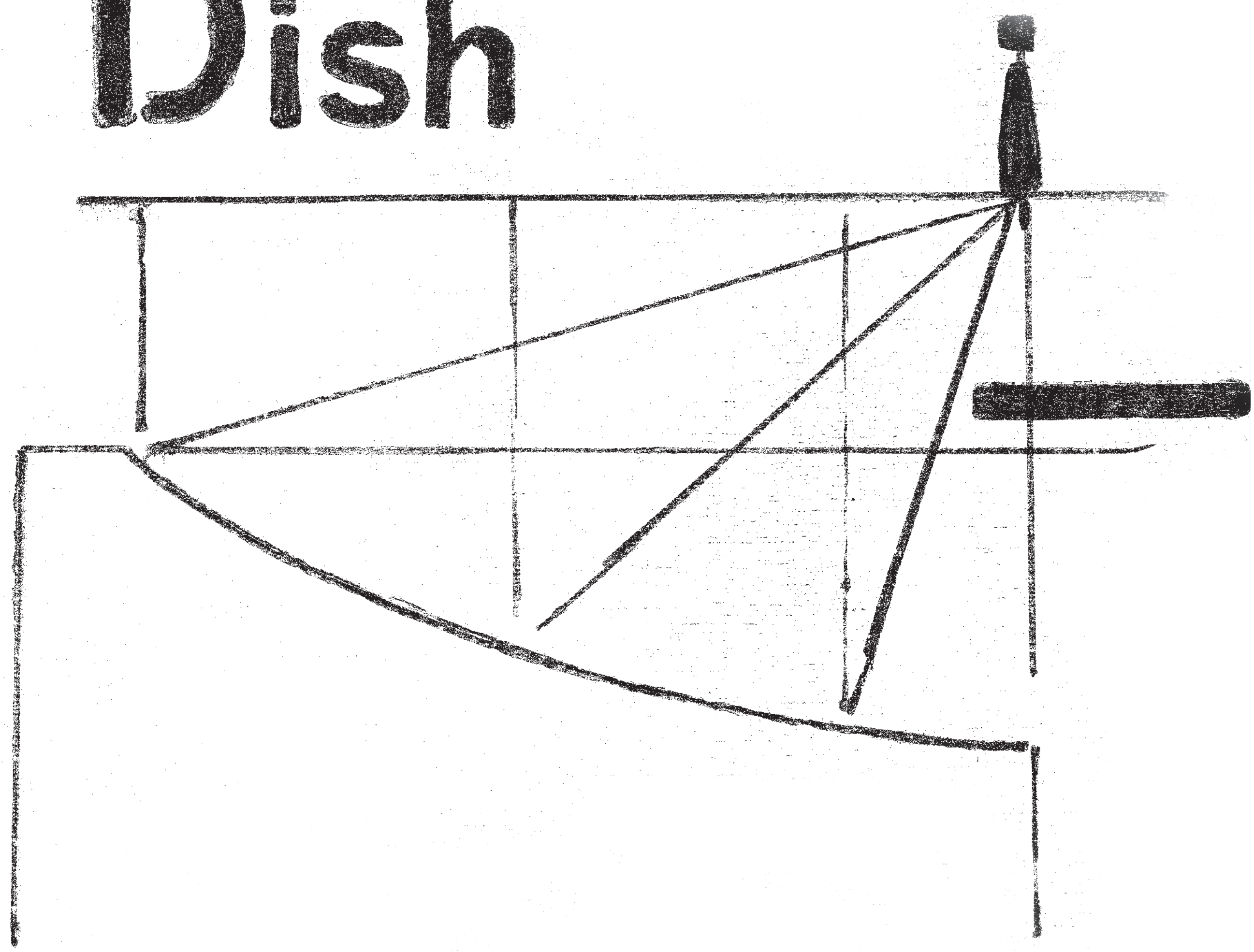
Big Art Dish



• A Report and Proposal

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April 2015

Big Art Dish

The Big Art Dish is proposed as an instrument for gathering astronomical radio frequency signals that will be made available as online streams of data for use by artists of all types. Located in the desert near Los Angeles, it will also be a latter-day earthwork: a parabolic dish carved into the ground facing the sky directly above. Its gaze will transit the heavens, carried by the planet of which it is a part.

Contents

1

Radio Telescopes

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What is radio?

While in daily use "radio" is generally associated with auditory experience, radio phenomena are much more akin to visual experience. Radio is a technological extension of vision. This is not a metaphor.[1] Radio waves are the same stuff as what we see as visible light, but traveling at frequencies below our eye's ability to detect them. We experience differences of visible light frequencies as variations of color. So we can imagine radio, and other frequencies, as colors that occur beyond visual perception.

To understand radio transmission in a way that comports more comfortably with sensory experience, consider the experiments of Alexander Graham Bell. On 3 June 1880, Bell transmitted his voice using light beamed from the roof of the Franklin School in Washington, D.C., to an assistant sitting in his office some 700 feet away. This was the photophone.

The principle was simple: sound waves were converted into light-wave patterns on one end of the transmission, and on the other they were converted back into sound waves. The clarity of this model rests in our ability to perceive both light and sound. Imagining modulations in sound and light as analogous seems simple—sounds get higher and lower, louder and softer, while lights change in color and brightness. Both can follow patterns, beats, and rhythms, or be just noise. When we remember that visible light is only a small part of the electromagnetic spectrum, it's easier to imagine the same sorts of modulations in parts of the nonvisible spectrum, like radio.

AM (amplitude modulation) transmissions can be thought of as signals getting louder and softer, or brighter and dimmer, while at staying the same pitch or color. FM (frequency modulation) transmissions can be thought of as changes in pitch or color relative to a central pitch or color (carrier frequency). There are unbelievably complicated ways of directing, changing, and encoding information within such systems, but the idea is surprisingly simple.

1 To some extent this could be said of touch, too, in as much as infrared radiation is experienced as heat.

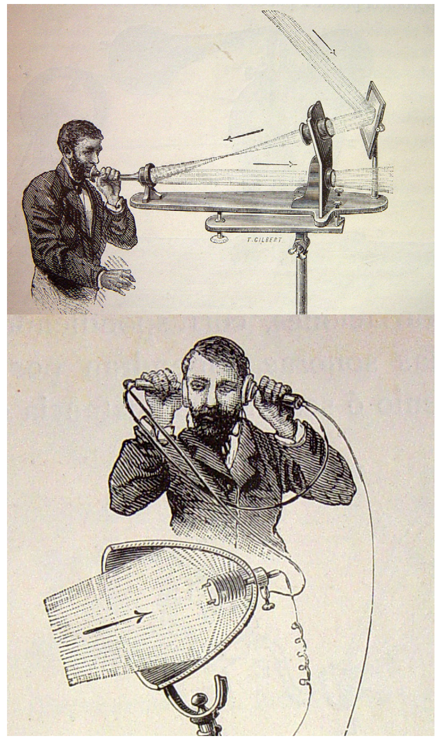

Figure 1.1.1-2

Photophone transmitter and receiver. Note the parabolic shape of the receiving mechanism.

This is also the principal behind the laser pulses traveling through the fiber-optic lines that form the backbone of contemporary communications.

Radio waves travel at much lower frequencies than visible light, i.e. each wave reaches a given point less often. Since the speed of light is constant, fewer radio waves cover the same distance in the same time, so each radio wave stretches further—is longer—than its visible counterpart. Another way to say this is that frequency (f) and wavelength (λ) are inversely proportional.[2] Radio waves are much, much longer than visible light waves; the distance between visible light waves is measured in nanometers (one billionth of a meter, or 1×10^{-9}m), whereas radio waves are defined as having wavelengths between one millimeter and one hundred kilometers.

2 Frequency (f) is measured in cycles per second (Hz) and wavelength (λ) in meters; therefore, frequency multiplied by wavelength equals speed in meters/second. For electromagnetic waves traveling at the speed of light (299,792,458 m/s or "c"), $f^*\lambda=c$ or $f=c/\lambda$ and $\lambda=c/f$. So if a wave has a wavelength of 1m, the frequency will be c/1 or 299,792,458/1 or 299,792,458 HZ or ~299 MHz, while a wave length of 2m will result in a frequency half that, or ~149.5 MHz.

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What is “seen” by radio telescopes?

A radio telescope, which BAD will be, is fundamentally the same as Newton’s optical reflecting telescope save for (1) the adjustment of the scale and precision of the reflector to accommodate radio frequencies and (2) the substitution of a radio detector for an eye.

The hugeness of radio waves compared to light waves has two main consequences for the design of the reflectors of such telescopes. First, the surface can be much less precise and much less dense. Chicken wire will work as a reflector of particularly long waves. (A high-performance optical telescope’s mirror requires grinding specially engineered glass with extreme precision.) Second, the surface used to gather larger wavelengths must be, in turn, significantly larger. The largest planned optical telescope, the so-called European Extremely Large Telescope (E-ELT) will have an aperture of forty meters, but the name of the largest single reflector radio telescope, currently under construction in Pingtang County, China, says it all: Five Hundred Meter Spherical Telescope (FAST).

The design and technology that goes into radio receivers (the substitute eye) is beyond this summary, but basically such receivers intercept, filter, and amplify electromagnetic signals by converting them into electrical signals. An analogy may be drawn to the retina and optic nerves of our eyes, which allow light energy to be detected and analyzed by the brain as neuro-electrical impulses.

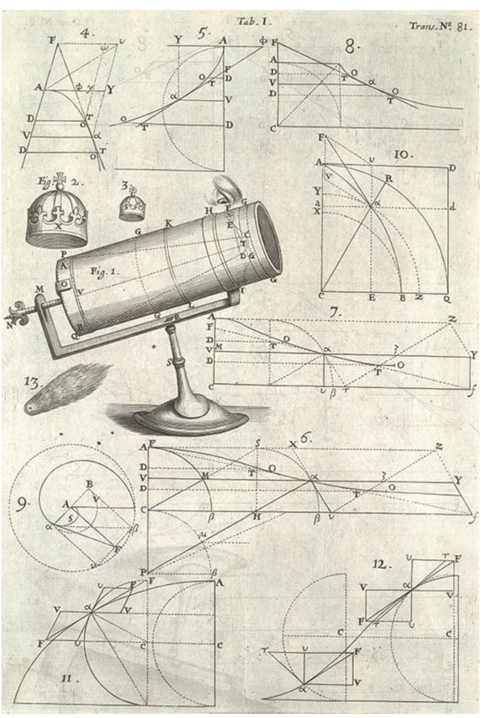

Figure 1.1.3

The Reflecting Telescope. From: An Account of a New Kind of Telescope, Invented by Mr. Isaac Newton, London, 1672.

If radio is an extension of vision at lower frequencies, then what radio telescopes “see” is an extension of what we observe when we see light emitted from distant or not so distant bodies. When we think about a light bulb or the sun or any luminous object, we typically imagine a hot material emitting a radiant glow. But “all objects emit electromagnetic radiation, and the amount of radiation emitted at each wavelength depends on the temperature of the object. Hot objects emit ... at short wavelengths, and cold objects emit ... at long wavelengths.”[3] So objects that are “too cold” to emit visible light ($\lambda \approx 390$–700nm), nonetheless emit electromagnetic radiation at longer infra-red (1mm–750nm) and radio (1mm –100km) wavelengths, and those that are “too hot” will radiate Gamma, X-ray, or other higher frequency (shorter wavelength) radiation.

Simply put, radio telescopes see what we don’t see. They see objects whose temperature is below that necessary for them to radiate in the visible spectrum. They sense the things that we would only bump into in the night. They are not concerned with visible light and such light doesn’t interfere with observations. For radio observations, there is no need for what we think of as darkness—no long tubes or late-night stargazing.

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Where do you look if you can’t see what’s out there?

Imagine looking through a telescope in the middle of the night without the ability to look at the sky as a whole. This is more or less the situation that a radio telescope finds itself in. The existence of astronomical radio sources was discovered serendipitously in 1931 by Karl Jansky. Working for Bell Labs, Jansky made a large steerable antenna array, “Jansky’s Merry-go-round”(fig. 1.3.1), to search for sources of radio interference disrupting long-distance communications.

Jansky’s idea was to direct the antenna toward terrestrial sources of interference like far-off thunderstorms. But there were also disruptive radio waves that had no relation to such sources. Jansky first assumed they were caused by solar radiation, but eventually realized that the interference

3 http://hubblesite.org/reference_desk/faq/answer.php.cat=light&id=74

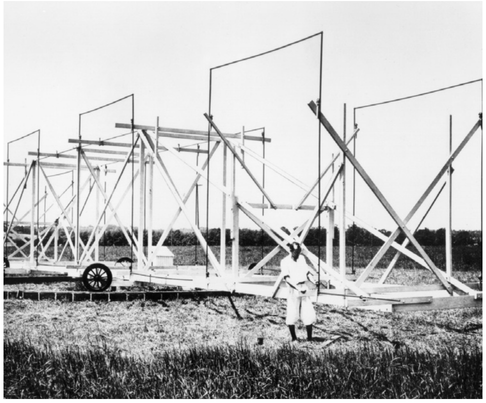

Fig. 1.3.1

Jansky with his “Merry-Go-Round” ca. 1931.

peaked in regular intervals every 23 hours and 56 minutes and 4 seconds or once every sidereal day (the time the earth takes to revolve once on its axis), not every 24-hour solar day. This suggested that these emissions were being detected every time Earth pointed in the same direction relative to outer space, not the sun. He located this extraterrestrial source along the Milky Way roughly in line with Sagittarius. Though he would only later be recognized for his accomplishment, Jansky had discovered the radio emissions emanating from the massive black hole at the center of our galaxy and ushered in an entirely new discipline, radio astronomy.

Like Jansky’s accidental telescope, many contemporary radio telescopes use the rotation of the earth combined with very precisely directed antennae, often in groups or arrays, to scan the depths of the universe. Using Earth’s motion to direct a stationary telescope (radio, optical, or other) is known as drift scanning (fig. 1.3.3). This is what BAD will do from its location in the desert.

The apparent motion of stars around the north pole of the Earth’s axis seen in a time-lapse image (fig 1.3.2) of the Karl G. Jansky Very Large Array (VLA) shows the motion of the telescopes’ drift scanning. In an array, multiple telescopes synchronize data, acting like a single much larger telescope. In some cases data is used from telescopes thousands of miles apart, thus increasing the virtual aperture of the instrument to planetary proportions. Telescopes like the VLA are also capable of tracking objects as they appear to move across the sky,. Because BAD will be dug directly into the earth, it will be restricted to drift scanning the sky directly above.

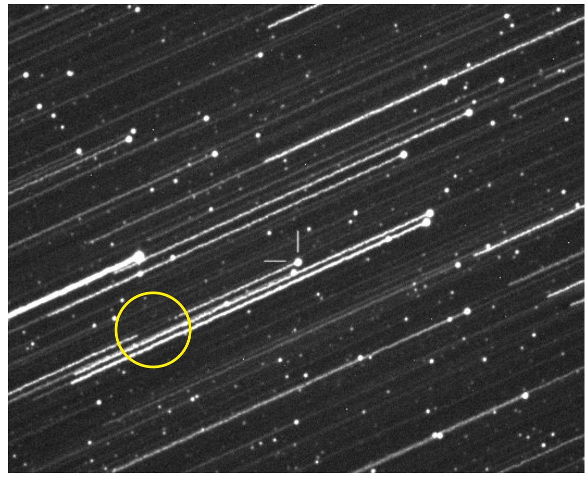

Fig 1.3.3

Image from Tinyblue Observatory: A Private Observatory on Whidbey Island (Washington State): “Around midnight on October 26, 2008, a 51km asteroid known as (270) Anahita occulted [blocked] a 10.5 magnitude star in the constellation Gemini for observers along a path across western Canada and Northwest USA, blocking starlight for a little over 10 seconds. This image, taken using a “drift scan” technique shows a gap [yellow circle added by the author] in the star trail of the target star (indicated by tick marks). The star’s identification is TYC 1880-01064-1.”

Figure 1.3.2

The Karl G. Jansky Very Large Array (VLA), fifty miles west of Socorro, NM

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BAD: AN ASTRONOMICAL HOLE IN THE GROUND

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Big Art Dish (BAD)

There are numerous data streams available from radio observatories, but none designed to fulfill a cultural rather than scientific purpose. BAD asks different questions than those posed by astronomers and cosmologists. It asks us to consider our own relationship to the cosmos and to one another through cultural knowledge production. Its formal construction and placement in the desert also prompts us to examine the technological, scientific, social, and governmental use of the environment in which it is located. It will: look out at the universe; provide information freely; be visible from above; be visited on land.

The BAD project has three main components (fig. 2.1.1):

(1) a parabolic dish dug into the desert floor
(2) a receiving mechanism
(3) a means of making data available online

The development of this project requires:

(1) establishing the technical requirements for designing and engineering the shape, structure, and surface of the dish
(2) site selection and procurement
(3) testing of materials and techniques
(4) excavation and construction of the dish and technical equipment
(5) distribution and display of information and collaborative contributions
(6) maintenance and further development of the site and project.

Plans are developing and tests have begun to understand the physical, technological, and formal/spatial characteristics of building and using such an instrument. The following pages outline ongoing progress.

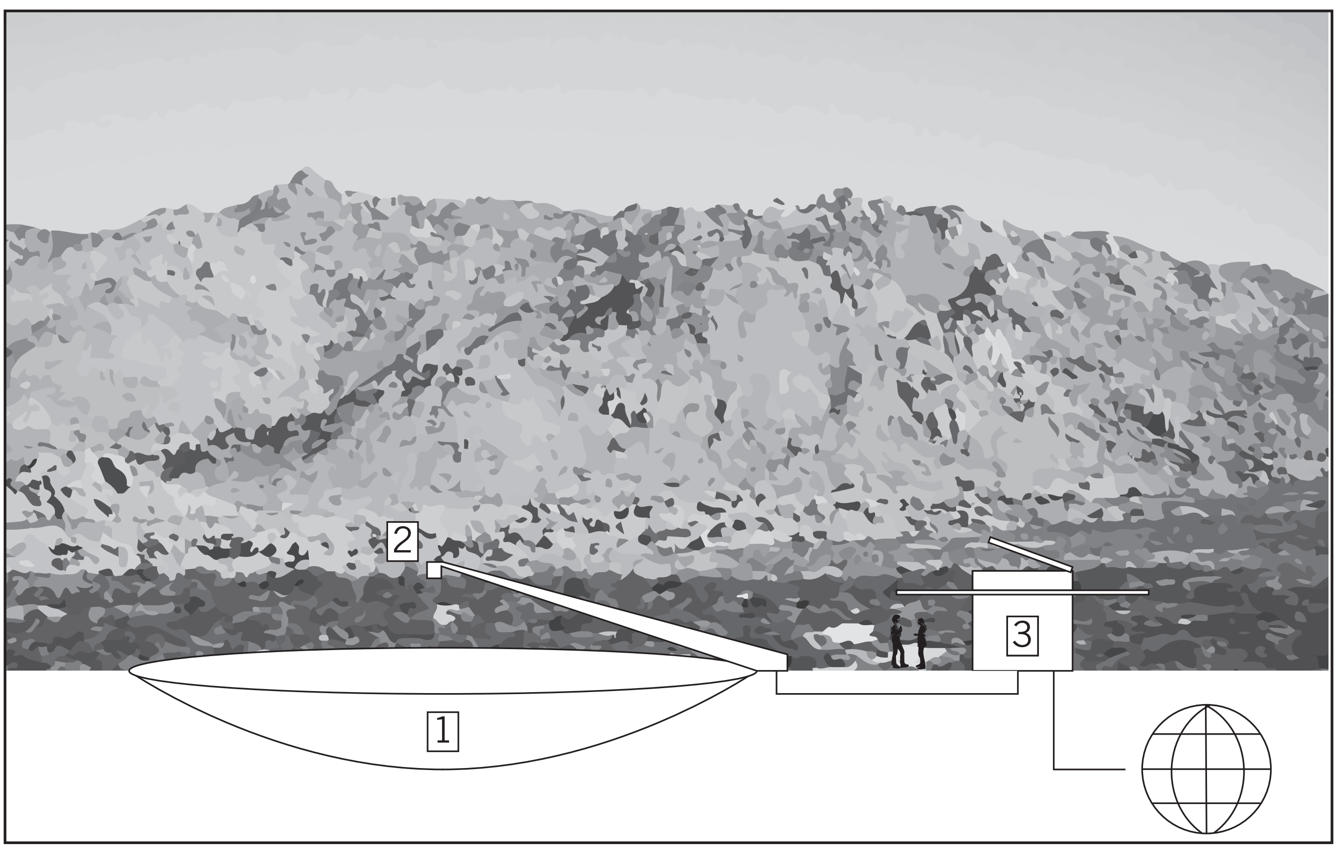

Figure 2.1.1

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Number One Test, Big Art Dish (NOTBAD)
Completed December 2014

NOTBAD is a 1:5 scale model of a parabolic dish described by Marcus Leech in *A 21cm Radio Telescope for the Cost-Conscious* (Science Radio Laboratories, Inc. 2011). It was conceived to aid in the practical understanding of the mathematical and formal properties of parabolic surface construction.

The twenty-one centimeter dimension mentioned in Leech's title does not refer directly to the scale of the antenna, but rather to the wavelength that his design investigates. The 21cm line (1420MHz) is a popular frequency for astronomical research as it corresponds to the emissions generated by neutral hydrogen atoms changing from one energy state to another. Because neutral hydrogen is the most abundant atom in the known universe, this frequency (also called the hydrogen line) is used to observe broad swathes of space and time. It is also popular among SETI enthusiasts (figure 2.2.1) who assume extra-terrestrial intelligence shares our affection for a common but very specific molecular behavior.[1]

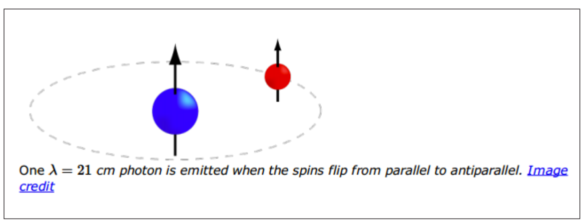

Figure 2.2.1

Hydrogen is the most abundant element in the interstellar medium (ISM), but the symmetric H_2 molecule has no permanent dipole moment and hence does not emit a detectable spectral line at radio frequencies. Neutral hydrogen (HI) atoms are abundant and ubiquitous in low-density regions of the ISM. They are detectable in the λ≈21cm (ν10=1420.405757... MHz) hyperfine line. Two energy levels result from the magnetic interaction between the quantized electron and proton spins. When the relative spins change from parallel to antiparallel, a photon is emitted.

Figure 2.2.2-4

NOTBAD—Plaster cast segments of a 1:5 scale model showing the curvature of a f/D .4 dish with a 52cm focal length.

1 *"... [T]he modern SETI [Search for Extra-Terrestrial Intelligence] era can be defined as beginning in 1959. In that year, Cornell physicists Giuseppi Cocconi and Philip Morrison published an article in Nature in which they pointed out the potential for using microwave radio to communicate between the stars." (http://www.seti.org/node/662 accessed 3/29/15)*

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Big Art Dish Model of Little Dish (BADMoLD)
January–February 2015

The BADMoLD was a full-scale, 130cm (f/D=.4) diameter dish cast in concrete. It was meant to further understand material qualities of dish construction, and to serve as a test platform for building and using radio technologies. It was hoped that it would develop early signals for distribution to collaborators.

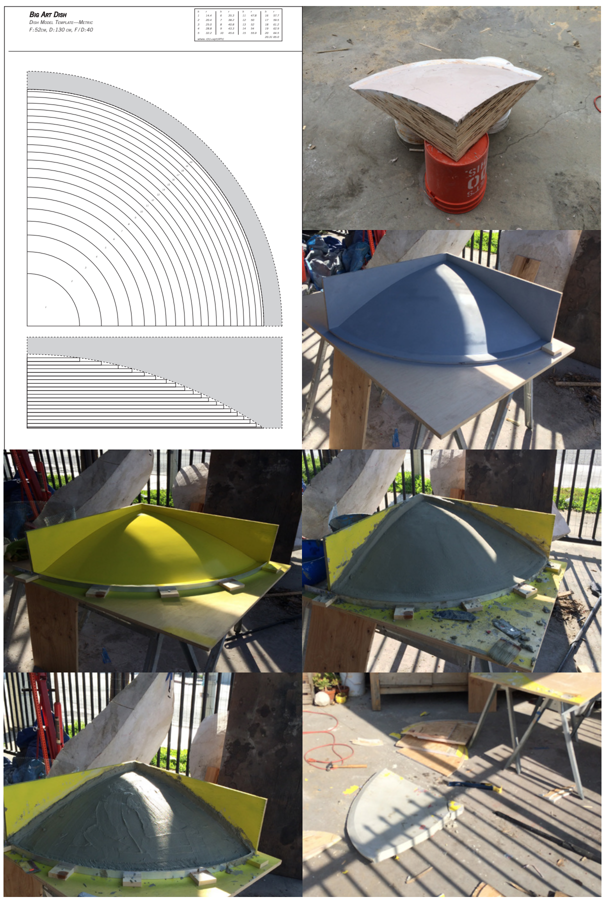

Figure 2.3.1

Unfortunately, the mold and first cast were irreparably damaged, but BADMoLD did lead to a better understanding of the unique characteristics of paraboloid surfaces:

> A parabola (plural "parabolas"; Gray 1997, p. 45) is the set of all points in the plane equidistant from a given line L (the conic section directrix) and a given point F not on the line (the focus). ... The surface of revolution obtained by rotating a parabola about its axis of symmetry is called a paraboloid. (http://mathworld.wolfram.com/Parabola.html)

Parabolic dish antennae are paraboloid surfaces. As defined above, a parabola (blue in fig 2.3.1) is all the points that are the same distance from the focus (red point) and the directrix (red line) following a line parallel to the axis of symmetry. So measuring from the focus to the parabola and from that point to the directrix gives two segments of equal length (green).

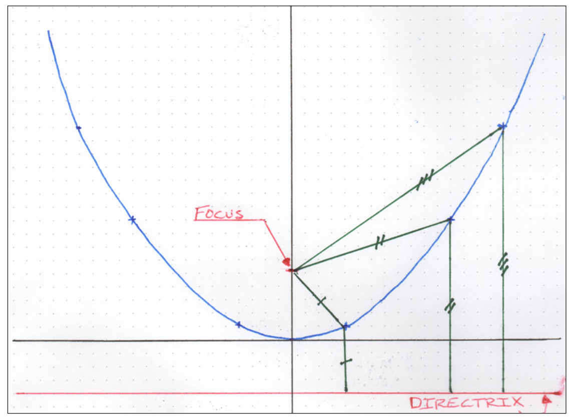

Figure 2.3.1

If you imagine a parallel wave front (orange in fig, 2.3.2) entering the parabola perpendicular to the axis (i.e. parallel to the directrix), the distance traveled by a wave reflected off the surface to the focus is equal to that of traveling through the surface to directrix, meaning that waves meet at the focus precisely when they would hit the directrix but all at one point. So, the simultaneous force of the wave hitting the focus is greatly increased by concentrating the force of an entire wave front at a single point. This is the magic of parabolic reflectors!

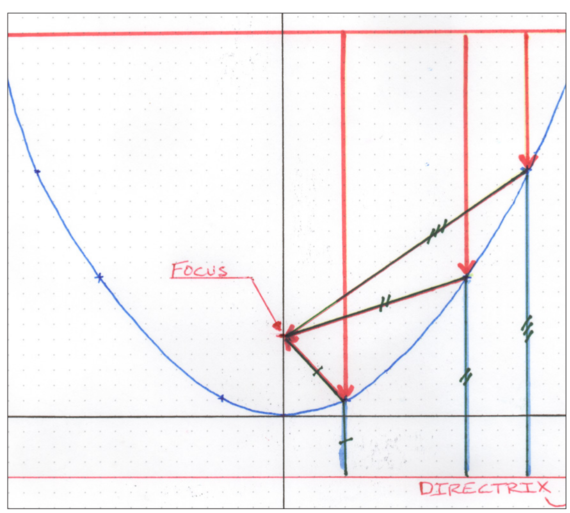

Figure 2.3.1

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First Operational Antenna Model (FOAM)
Spring 2015

Following the failure of the BADMoLD a new lightweight design for a dish of the same dimensions has been made using foam-core, chipboard, and steel window screening (fig. 2.3.1). The Leech model includes the construction of a wave guide feedhorn receiver made using a coffee can and coaxial cable (a "cantenna" see fig. 2.3.3) along with a high-gain low-noise amplifier (LNA) and Software Directed Radio (SDR). Changes in design are being considered based on other publicly available resources published online by amateur radio astronomers as well as educational and research institutions. A feedhorn (cantenna) and receiver (fig. 2.3.2) are being made to test the apparatus with the hope of recording the first signals to be distributed to select collaborators including electronic musicians, video, film, performance, and visual artists.

Figure 2.3.1

Figure 2.3.2

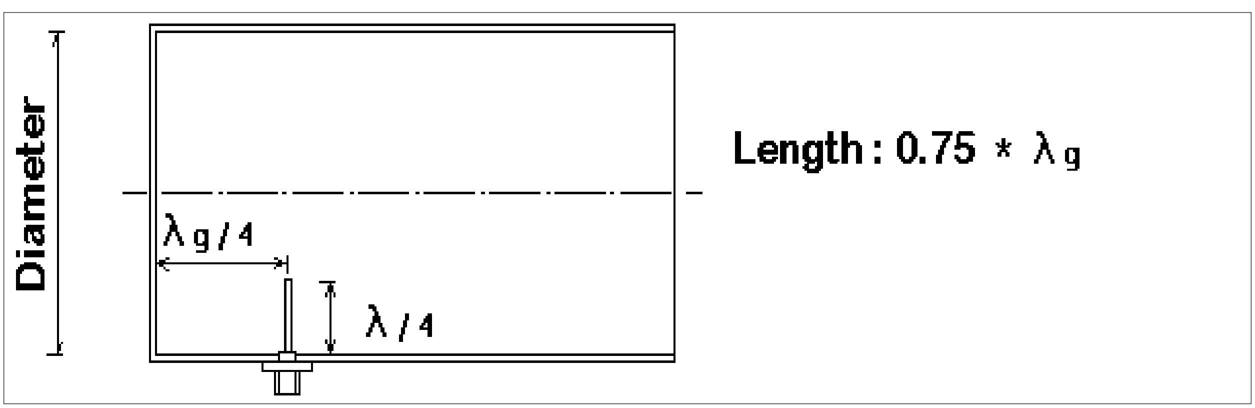

Figure 2.3.3 (http://www.changpuak.ch/electronics/cantenna.php)

A cantenna (a portmanteau blending the words can and antenna) is a homemade directional waveguide antenna, made out of an open-ended metal can. … The cylinder portion of the can may consist of metal-coated paperboard. Although some designs are based on a Pringles potato chips can, this tube is too narrow to increase the signal by a useful amount. However, a cantenna can be made from various cans or tubes of an appropriate diameter. Some designs include a pole mount to elevate the cantenna. (http://en.wikipedia.org/wiki/Cantenna)

3.

Further Questions

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Parameters: What wavelength(s) should be looked for? The famed 21cm line? Which frequency produces the most data/varied signals? Which are the “important” frequencies—scientifically, historically, culturally?

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Material: Can a hole be a reflector? What is required to make a radio reflective surface? How do we avoid making a solar cooker?

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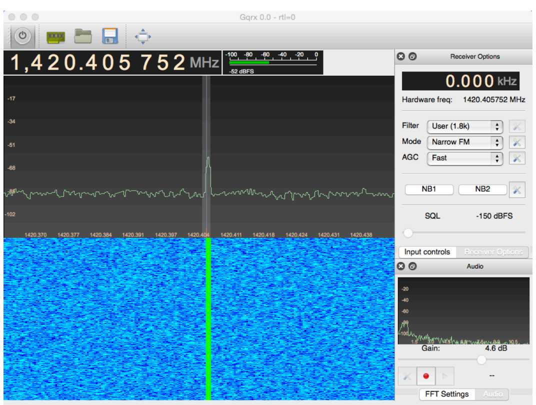
Temperature: How hot is too hot? Will the desert make either the reflector or the receiver too hot? How will swings in desert temperature affect the mechanism?



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Technology: What is required to detect, encode and disseminate signals from BAD? Software Directed Radio (SDR)?

■
Site Selection: Weather? Radio Interference? Permitting? Cost? Infrastructure?

■ ●
Collaborators: How, and who to ask?

4.

Resources

—
Dick Comly (N3AOG), PARABOLIC ANTENNAS AND THEIR FEEDS

—
Peter W. East, Low Cost Hydrogen Line Radio Telescope using the RTL SDR–Phase 2

—
John Fielding, *Amateur Radio Astronomy*, Radio Society of Great Britain; 7th edition (May 1, 2006)

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Marcus Leech, *A 21cm Radio Telescope for the Cost-Conscious*, Science Radio Laboratories, Inc.

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David Morgan, *Construction of a 3 metre Amateur Radio Astronomy Dish Antenna for 1420MHz*, 2011

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Kevin Murphy (ZL1UJG), Tom Bevan (ZL1THG), Robin Holdsworth (ZL1IC) 1420 MHz Radio Astronomy Receiver Notes (2006) Preliminary, Hamilton Astronomical Society,

—
Bill Petrachenko, NRCan Radio Antennas, Feed Horns, and Front-End Receivers, NRCan, EGU and IVS Training School on VLBI for Geodesy and Astrometry, March 2-5, 2013, Aalto University, Espoo, Finland

—
Rein A. Smit, Radio Astronomy Supplies—United States West Coast Representative, Alta Loma, CA 91701

—
Cantenna Calculator, http://www.changpuak.ch/electronics/cantenna.php

5.

Personal Addendum

A few years back, 2 May 2011 to be exact, I came across Dürer's *St. Jerome in the Wilderness* in the National Gallery in London. On the front is the rather ordinary image of the early church father whose pursuit of knowledge and some sort of truth drove him into the desert. On the reverse is a depiction of an astronomical event. Explanations vary as to what it is—perhaps a comet or a meteorite—but as a painting it has an almost Turner-esque atmospheric brushiness. Coming from the upper right, there is a blaze of yellow and red crashing through a tumultuous field of what can only be imagined as cosmic clouds.

Rarely, at least for me, does an image—or to be more precise, an object (it measures 23 cm by 17 cm and is about 2 or 3 cm thick)—hold the kind of sway this little five-hundred-year-old piece of wood does. It is as if sandwiched between the two surfaces, in that 3cm margin, is a 300 year span of intellectual, aesthetic, and scientific change. In its anachronism, it foresees a nineteenth-century sublimity, one that comes with going into the desert. But it sees, in the technology of its time, a condition that stands outside time.