MANUAL OF DMAS

RADIO TELESCOPE

CONSTRUCTIONS AND SPECIFICATIONS

September 2019

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The 1.42 GHz 8-Foot Dish Radio Telescope

A. THE DISH ANTENNA – DESCRIPTION, DIMENSIONS, AND SPECIFICATIONS

The Dish antenna is a parabolic, solid surface dish with an inside-the-flanged-edges diameter of 91 inches (7 feet, 11 inches). The depth of the dish, measured from the center point on the concave surface to the point perpendicular to the surface center and intersecting a diameter line from edge to edge across the dish, is 15 inches.

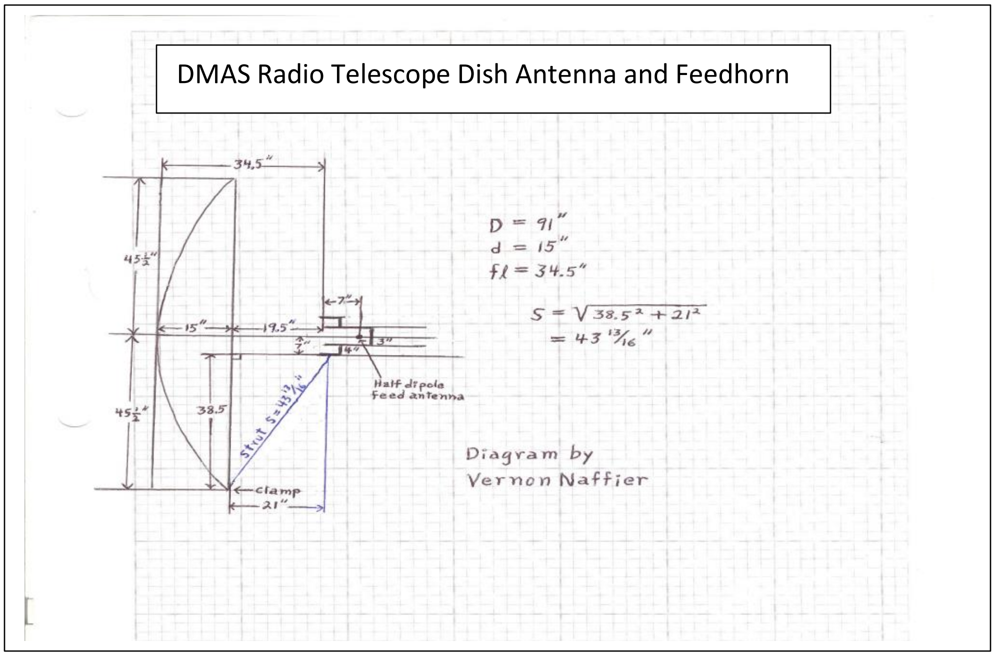
The focal length of the dish antenna is calculated by the formula: $\mathbf{F = D^2/16d}$ where D is the diameter of the dish and d is the depth of the dish. In the case of the DMAS 91 inch diameter dish, the focal length is 34.5 inches. The Focal Length to Dish Diameter ratio is 34.5/91 = 0.38.

An 8-foot dish is regarded as a relatively small dish antenna suitable for amateur backyard performance. The diameter of a dish antenna should be at least ten times the wavelength of the EM radiation received. That limits an 8-foot dish antenna to the lower microwave range of frequencies (1 GHz up to 40 GHz, or wavelengths of from about 1 to 30 centimeters, at which upper frequency the earth's atmosphere begins to become opaque to microwave radiation). The 1.42 GHz frequency to which the DMAS radio telescope is tuned lies in the L band of the microwave spectrum (1 to 2 GHz, 15 cm to 30 cm).

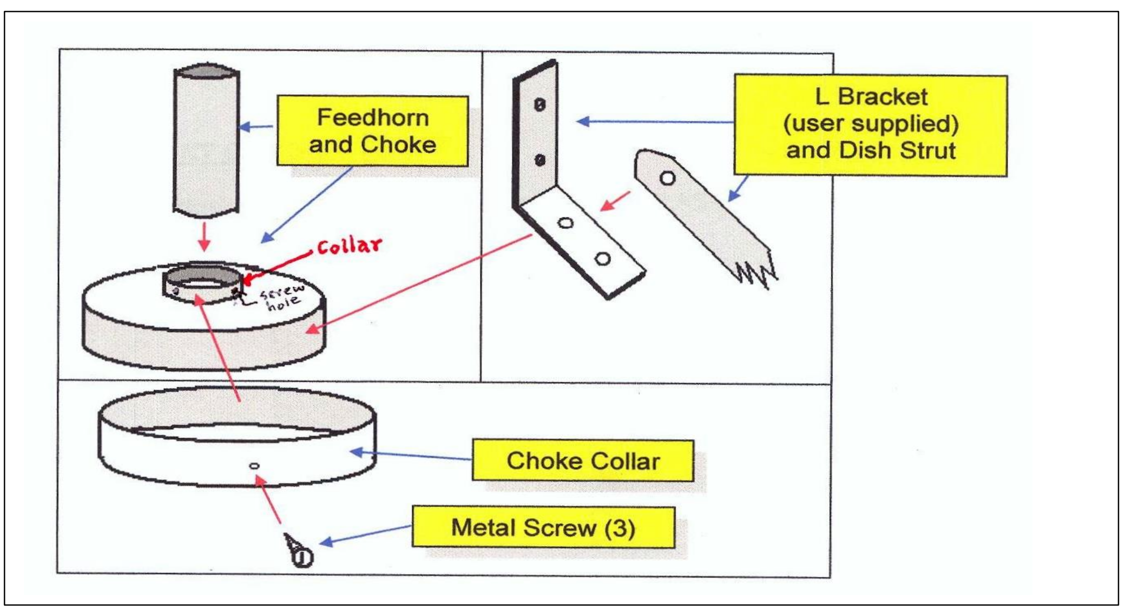
For very high antenna gain (>50 dB) the diameter of the dish should be on the order of 100 wavelengths of the ElectroMagnetic radiation received. At 21 cm wavelength the dish diameter should ideally be 21 meters or over 68 feet. At this wavelength the 8-foot dish, which has a diameter 15 times the 21 cm wavelength) has a fairly low gain of less than 7 dB but is still quite usable at the 1.42 GHz frequency. Interestingly, the 8-foot dish, which was designed originally for reception of 12 GHz (25 mm wavelength) TV satellite reception, has, at that frequency, maximum gain of 50 dB.

Center mounted on the dish antenna is a feed horn containing a feed antenna called a probe (half-dipole rod) ¼ wavelength-sized for 1.42 GHz. The feed horn consists of a metal cylinder 6 inches in diameter and 9 inches long. These are minimal dimensions at 1.42 GHz to prevent wave guide cutoff. The feedhorn contains the half dipole feed antenna and is fitted into a metal choke 14 inches in diameter. A choke collar or ring is located on the top side of the choke through which the feed horn can slide and be set in place by means of set screws.

The distance of the feed horn from the dish is set so that the focal point falls just inside the front rim of the feedhorn. (See diagram below). The feed antenna (half dipole) sits 7 inches behind the focal point. The positioning of the feed horn is fixed by three support struts clamped at the rim of the dish and extending to the choke. From the accompanying diagram it can be seen that, by Pythagoras, the length of each strut from the edge clamp to the choke is calculated to be 43-7/8 inches. An adjustment in strut length may need to be made to obtain proper focal length distance.



Placement of the feedhorn in the choke color is critical for maximum noise vs. gain (lowest antenna noise temperature). Below is a diagram of the feedhorn configuration showing the feedhorn in relation to the choke and choke collar (disregard the L Bracket)..



For the DMAS dish antenna with focal length of 34.5 inches, diameter of 91 inches, and F/D ratio of 0.38, the distance between the front of the feedhorn and the back of the choke collar or ring should be 4.27 inches (<4-5/8 inches). This will give an optimal illumination pattern and lowest noise temperature for SETI operation. If higher gain (with accompanying higher noise) is desired, then the distance should be increased to about 4.47 inches or nearly 4-1/2 inches.

Antennas have specific **beamwidths**, which are degrees of arc within which an antenna is sensitive down to the half-power point. The half-power point is that level of decibel power received which amounts to half the power of a target or direction in which the antenna is center aimed.

The formula for estimating the bandwidth of a dish antenna is:

Beamwidth = 57λ/d

where λ is the wavelength in meters of the EM radiation being received and d is the diameter of the dish in meters. For the DMAS dish the calculation works out as **Bw = (57 x .21)/2.5 = 4.8** degrees. Actual beamwidth will have to be tested by scanning operation.

Band width is a term, analogous to beam width, which is defined conventionally as the range of frequencies which an antenna system is capable of picking up without falling below half the power, measured in decibels, of the central frequency of the range. The formula for calculating what is called the fractional band width is :

$Bw = (f_2 - f_1)/f_0$

where f_2 is the upper frequency at which radiation power drops to one-half maximum power, f_1 is the lower frequency at which radiation power drops to one-half maximum power, and f_0 is the center frequency at which power is at a maximum. In this form of a ratio the bandwidth is referred to as Fractional Bandwidth (FBW). It is usually expressed in terms of percentage. Wide fractional bandwidths can range up to 20% while ultra-wideband antennas can have FBWs greater than 50%. Band widths are specified for electronic receiver equipment, which will be described further below.

There is a trade-off between antenna sensitivity and bandwidth. The wider the bandwidth is the more frequencies and information the antenna system is able to receive, but sensitivity (ability to pick up weak signals) diminishes. If sensitivity is of paramount importance an antenna system with a narrow bandwidth is preferred. The gain of a dish antenna like the 8-foot dish typically ranges from 20dB to 34 dB.

B. ALTAZIMUTH AND ALTITUDE AXES

Currently the dish antenna has a motorized altazimuth axis powered by 36 Volts DC. The Altitude axis is very limited in movement and must be manually adjusted.

Ideally, the dish antenna should have motorized control on both axes, which would greatly expand the aiming capability of the scope.

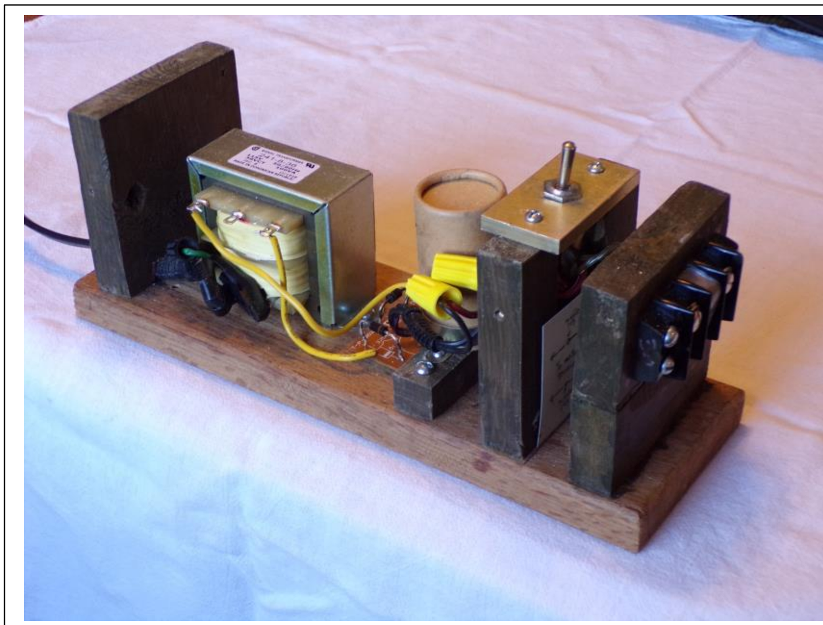
If only one axis is motorized and remotely controlled, the preferred axis would be the Altitude axis which would better facilitate drift scanning of the sky. This is the arrangement employed by a sister astronomy group – the Little Thompson Observatory in Berthoud, Colorado, which is operating its radio telescope with just a single motorized axis (the altitude). DMAS should look into the possibility of motorizing both axes or at least motorizing the Altitude axis.

C. POWER SUPPLIES

Four separate power supplies are utilized for the 1.42 GHz radio telescope:

A 36 Volt DC reversible polarity, 2 Amp power supply provides power to the altazimuth axis motor on the dish antenna.

The axis power supply (shown here) is polarity reversible by means of toggle switching. This allows the rotation of the axis motor to be reversed thus making back-and-forth east-west movement of the-dish possible.



Other power supplies required for operation of the radio telescope include a 12 Volt DC supply for the LNA on the feedhorn, a 4.7 Volt DC supply for the SDR, and a power supply (usually 17 or 18 volts) for the computer.

D. ELECTRONIC COMPONENTS – lNA, Band Pass Filter, SDR, Computer

Tucked into a PVC housing attached to the feedhorn assembly are two electronic components:

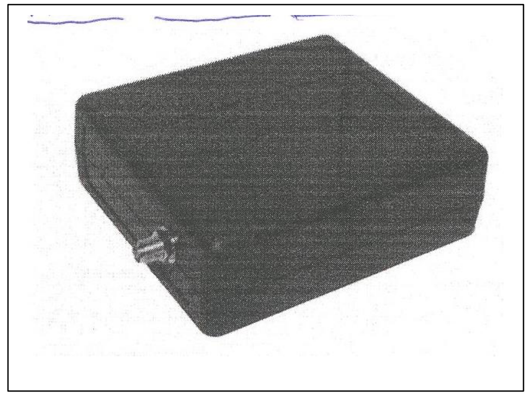
The LNA (Low Noise Amplifier) is directly connected to the feed antenna probe inside the feedhorn. The LNA, purchased from Radio Astronomy Supplies, is tuned to 1.42 GHz. It has a Gain of 37 dB and a very low Noise Figure (FN) of 0.29 dB. The lower the NF the better is the receiver. The LNA is powered by a 12 Volt DC power supply. Caution: The power must not be delivered by means of a T-bias (a circuit which transfers voltage and signal on the same conductor), which could seriously damage the LNA. Power is delivered via 50 ohm or 75 ohm coaxial cable with F connectors. The power conductor must be shielded to prevent stray RF (Radio Frequency) energy from being picked up and fed into the LNA.; hence the use of coaxial cable. The 1.42 GHz signal is fed through an output N connector into a following band pass filter.

A 1420 MHz (1.42 GHz) Bandpass Filter to block out frequencies other than 1.42 GHz is connected to the LNA output. The BPF, sold by Radio Astronomy Supplies, as a line insertion component, has a low Decibel loss of 3 dB. Its bandpass (See bandwidth above) is -20dB at +/-43 Mhz. It has a high Q (sharp selectivity) of >12 and a fractional band width of 8%. The BPF is thus designed to effectively reject unwanted frequencies while isolating the 1.42 GHz frequency for signal pass-through.

Above: 1.42 GHz Low Noise Amplifier

Below: 1.42 GHz Band Pass Filter

At the console end inside the Observatory the signal sent from the RT feedhorn is fed into an SDR-play RSP1 (Software Defined Receiver), which amplifies the signal before sending it to a computer and other optional equipment. The SDRplay is popularly used by amateur radio operators but comes in handy for radio astronomy as well. Equipped with an ON/OFF low noise preamplifier, this receiver covers a wide range of frequencies from 10 KHz to 2 GHz. It also has a wide band width of 10 MHz that is able to capture the H1 spectrum, which the radio telescope is observing. It incorporates eight built in front-end pre-selection filters and comes with SDRuno software. It is powered by a 4.7 VDC power supply. The receiver is compatible with any computer loaded with Radio SkyPipe software to produce time-functioned strip charts of H1 signal impulses.



E. CABLING

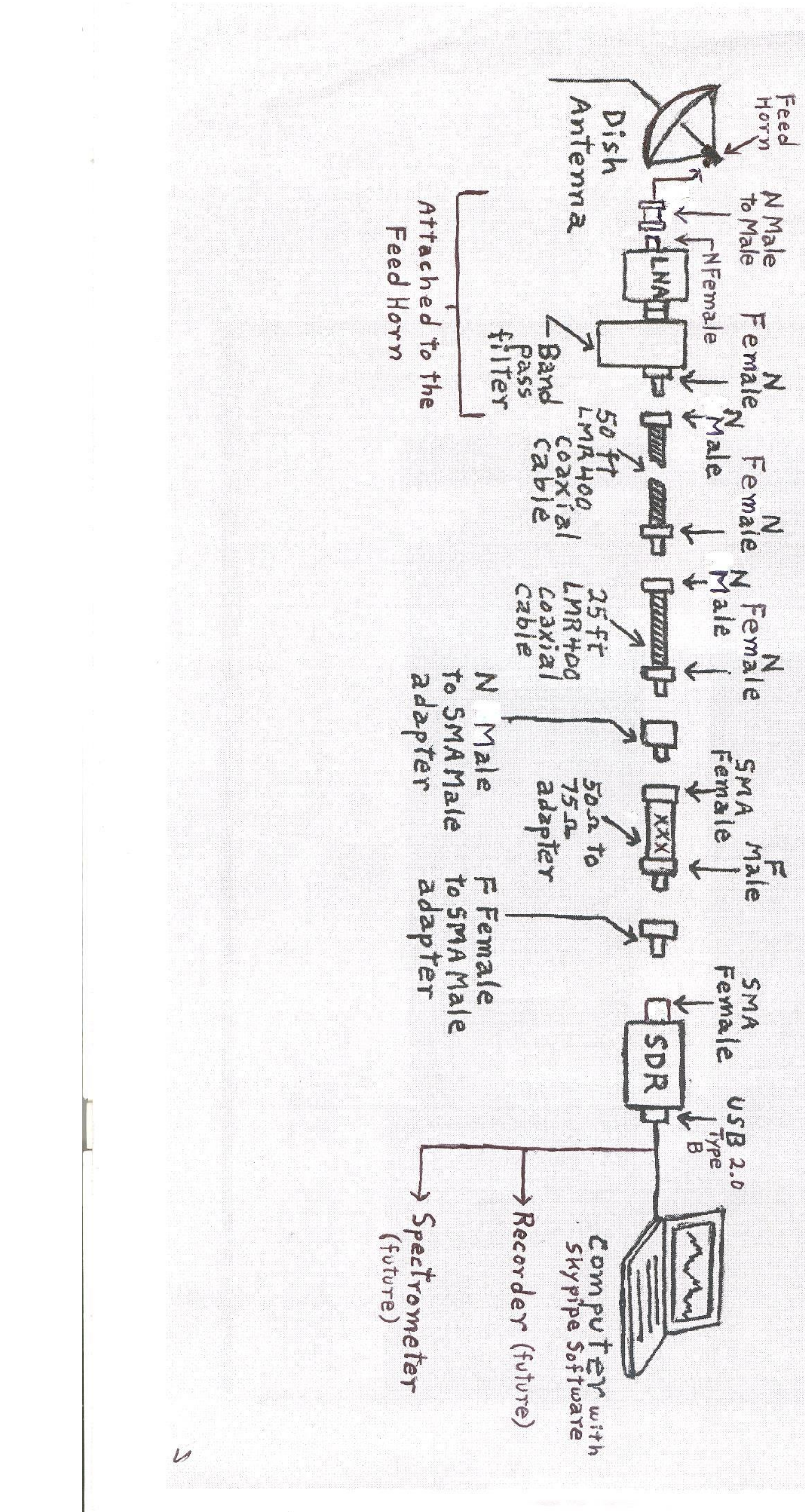
The signal from the radio telescope feedhorn is transported into the observatory via low loss LMR 400 coaxial cable with N connectors especially designed for weak signal radiotelescopy. Total length of signal coaxial cable from the feedhorn to the receiver in the observatory is 75 feet. The Decibel loss at the 1.42 GHz frequency for this length of LMR 400 coax is 4.43 dB.

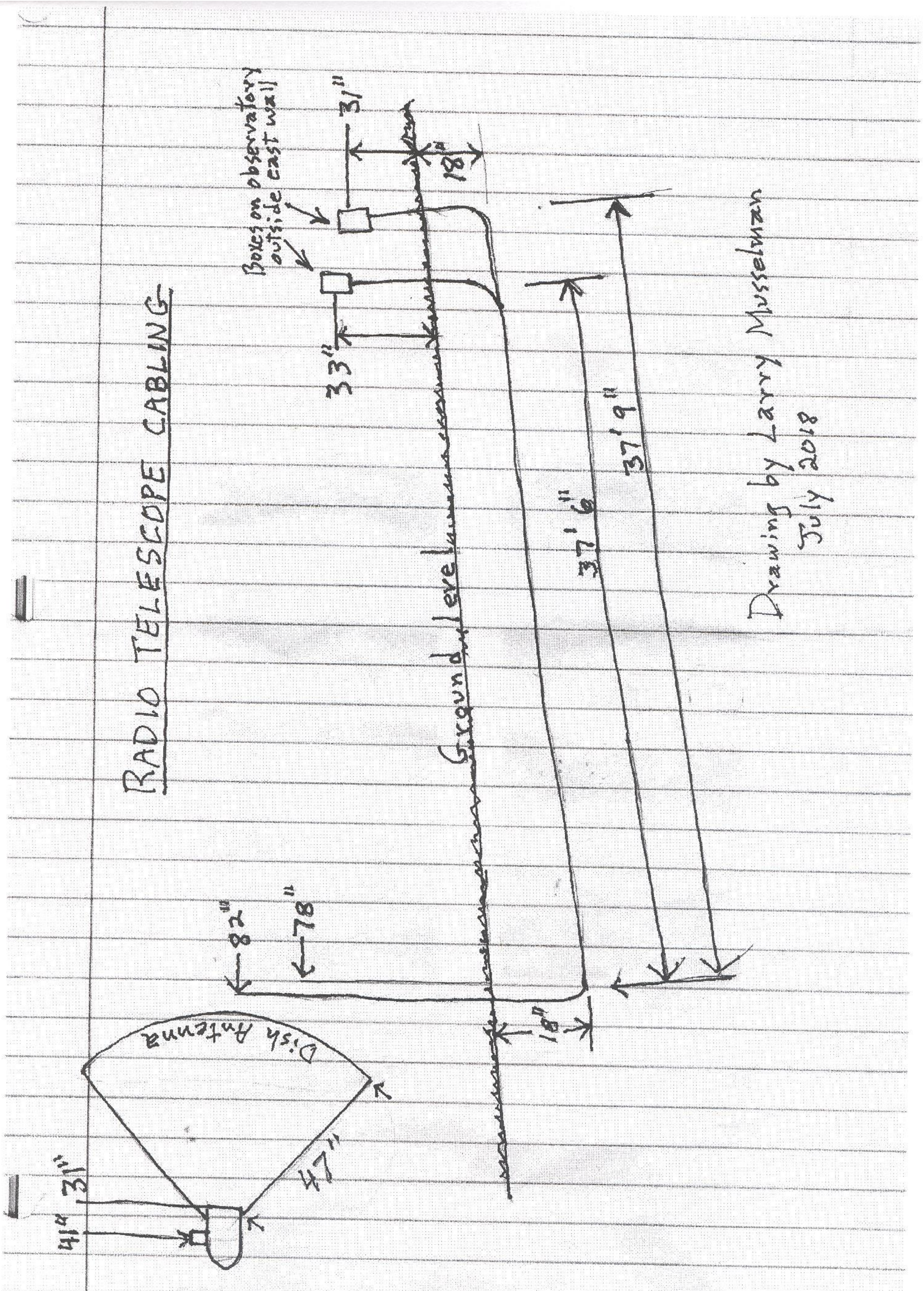
Because the signal coax and various electronic components have differently sized connectors (F, N , SMA, and USB), low loss adapters are inserted at various points in the feedline from the feedhorn to the receiver and computer. An impedance matching adapter (75 ohms to 50 ohms) is also inserted between the LMR 400 coaxial cable and the SDR.

In addition to the signal coaxial cable, 75 feet of a power coaxial cable is laid underground from the 12 Volt DC power supply at the coscole to the LNA on the feedhorn. A twin-conductor cable (unshielded) is also fed underground from the 36 Volt DC power supply at the RT console to the altazimuth axis motor on the dish antenna.

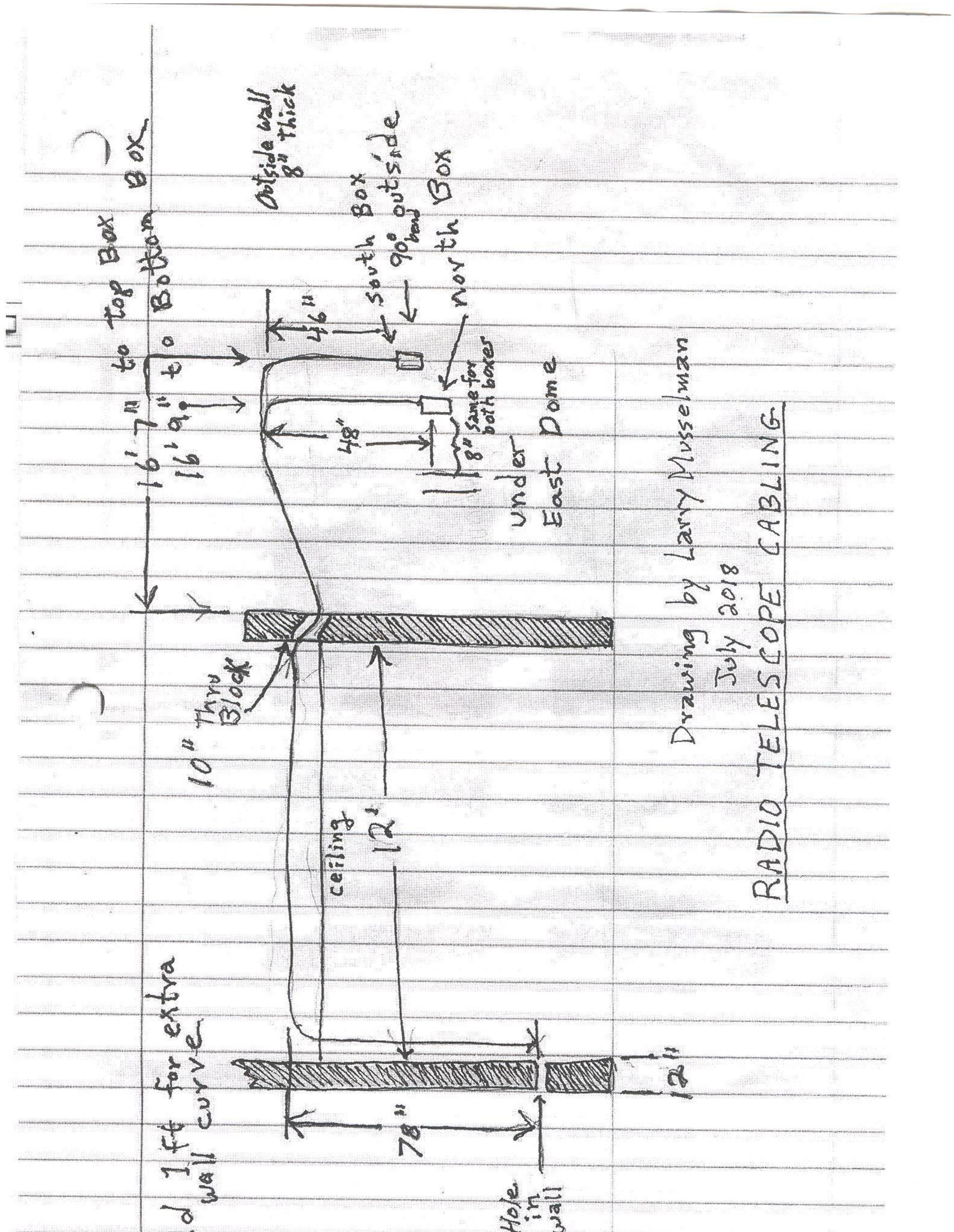
The next page shows a diagram of the feedline with all components.

F. LAYOUT DIAGRAMS





Layout of cabling from the dish antenna to the observatory



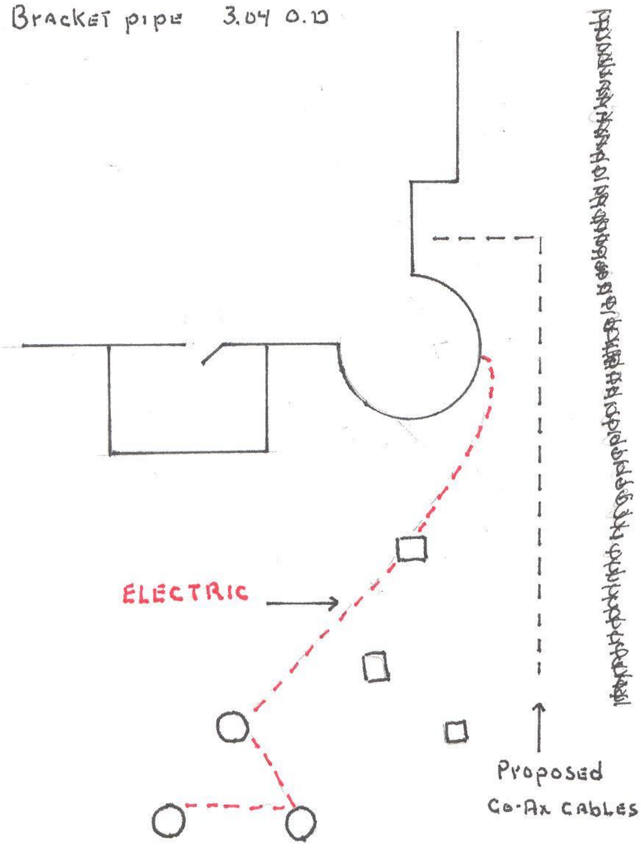
Layout of cabling at the observatory

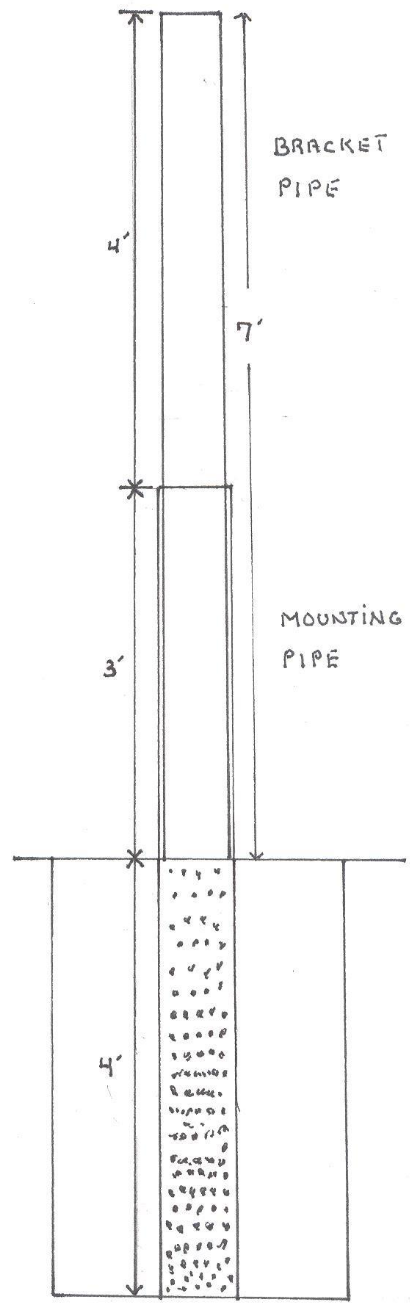
3" Outside Diameter Steel Pipe 7' Long (Optional)
1 1/2" PVC Pipe 10' Long (10 each)
1 1/2 PVC Pipe Couplings (10 each)
1 1/2" PVC 45 Degree Elbows (10 each)
PVC Glue (1 each)
Outside Junction Box (2 each)
Co-Ax Wire (250 feet)
Strong bodies-weak mind (4 each)

Dish post and pedestal
and cable routes
Drawing by Dave Lynch

MOUNTING Pipe 3.07" I.D

BRACKET pipe 3.04 O.D





Construction Notes by Dave Lynch

I purchased a steel post seven (7) feet long and drilled three (3) 9/16" holes in it and welded nuts (1/2") to it. I put it in the barn at Jerry's place Saturday night. This pipe is what I will call the "Mounting Post." It is 3.52" outside diameter and 3.07 inside diameter.

The bracket that the 10' dish mounts on is 3.04. With some small persuasion and some grease a three (3) inch post will fit inside the mounting post and firmly attach to the mounting bracket for the dish.

If you will be at Ashton Saturday night, October 11th, I will have a scale drawing of how I think we can attach all the pieces together. Sometime soon, like yet this month, we can get Jerry to auger a hole at least four (4) feet deep and bury the mounting post. This would leave three (3) feet above ground.

Next spring it will take 3-4 of us to hand dig a trench 4" wide and 6" deep from the mounting post to the east side of the south room. We will need to bury a PVC conduit 1 1/4" to 1 1/2" containing the wires from the mounting post to the building. We could rent a small ditch witch to dig the trench but we would have no way to transport it and the cost would be prohibitive.

Right now I estimate we will need the following materials:

Pea Gravel (2 bags)

Dry Quick Crete (Cement) 2 bags

10 foot PVC pipe 1 1/4" to 1 1/2" in diameter (8 pieces)

PVC Pipe Couplings (10 pieces)

PVC Pipe Glue (1 can)

PVC Elbows (4 pieces)

Outside Junction Box (2)

250" of Wire (I estimate this wire is between 1/4" to 3/8" in diameter)

I can come up with a drill to put a hole in the wall of the south room to bring the wires into the room. Same with the bit to drill through the block wall. We can seal it later with Silicone. I'm guessing with the weather coming on that this won't be done until next spring.

Dave
October 5, 2014

G. GOALS

To what use can this radio telescope be put? What shall users be able to observe by means of this instrument?

A 1.42 GHZ radio telescope is purposed to observe radiation of that frequency, which emanates from various regions of the Milky Way Galaxy. The radiation is most prominently observed streaming from the center of the galaxy but is detected also in other parts of the sky as well. 1.42 GHz is a very distinctive frequency serving as a marker of the quantum mechanical behavior of cold hydrogen, designated as H1 (Hydrogen 1), in space.

H1 is not to be confused with Hydrogen-alpha (Hα) which results when a hydrogen electron falls from its third to second lowest energy level in the atom and emits a photon; The emitted radiation of Hα has a wavelength of 656.28 nm and is observable in the visible part of the EM spectrum.

H1 is hydrogen in its lowest state of energy; that is, it is an atom of hydrogen whose electron is in its lowest energy state. In terms of the Bohr model of the atom, the hydrogen electron circles the nucleus in an orbit of lowest possible radius. In that lowest orbit the hydrogen electron may have one of two so-called spin directions. When the electron's spin direction is the same direction as that of the nucleus (proton), the energy level of the atom is at a maximum value for that orbit of the electron. But over very long periods of time amounting to millions of years the spin direction of the electron can abruptly change to opposite that of the proton. When that occurs the atom loses a tiny amount of energy. The lost energy is conserved in the emission of a photon which oscillates at a frequency of 1.42 GHz (the precise frequency is 1.420,405,751 GHz).

Seventy-five percent of the Milky Way and of the Universe is comprised of hydrogen. Cold hydrogen (H1) constitutes only a small fraction of all of the hydrogen in the Universe, but there is a sufficient amount of it to produce noticeable H1 radiation.

With the 8-foot radio telescope we should be able to locate the sources of H1 radiation in space. This radio telescope, moreover, is able to penetrate into the center of the Milky Way by virtue of its ability to capture radiation from the heart of the Galaxy. That is a feat which optical telescopes cannot achieve, since nebulae and interstellar dust block the light coming from the Galaxy's center. Microwave frequency energy, such as H1 radiation, on the other hand, is impervious to interstellar particulate obstruction.

Large dish radio telescopes and arrays are able to produce high resolution images of celestial objects which emit microwave energy. A small dish is not capable of delivering images other than a limited pixel image of the various layers of the Sun. Caution: a dish of 8 feet diameter should not be pointed to the Sun lest the electronic components of the feedhorn by fried. What a small radio telescope (SRT) can do is graphically register microwave radiation in time functioned strip charts on a computer monitor. Meter and audio reading are also possible with SRTs.

While detecting H1 signals from outer space and being able to locate their sources is interesting in itself, the real fun starts when going beyond these capabilities. By adding a data loader and a spectrometer as plug-ins to the SDR receiver much more can be observed than just the mere presence of H1 radiation.

A data loader can record and save information over time to compare variations in the strength of radiation from various points in space. Radio Sky Pipe software can also do this to an extent. Attachment of a spectrometer allows observation of Doppler shifts in received H1 microwave radiation. The spectrometer incorporates a local oscillator to simulate the stand-still H1 frequency, which is then compared to the received H1 frequency. The spectral analysis reveals line-of-sight recessional (Red Shift) and processional (Blue shift) movements of celestial objects which emit H1 radiation. By this means the movements of galactic emission nebulae can be tracked and their velocities, calculated.

By spectroscopic observation the position and layout of the outer arm, for example, of the Milky Way can be mapped. This is accomplished by noting the different velocities (spectral shifts) of various points of the galactic arm.

Via a fairly complex procedure a rotational curve for the Milky Way Galaxy using the 21 cm (1.42 GHz) spectral line can be produced. The velocities of various points in the galactic arm are recorded and then related to the radii associated with the various points. From this information an exponential curve, $\mathbf{v \propto \sqrt{r}}$, can be drawn, where v is velocity and r is radius. [Cf. *Listen Up!,* Laura A. Whitlock and Kiley Pulliam. Universe Pres, Inc., New York, 2008, pp. 43-48]

WIth or without spectroscopy the radio telescope can be set to do drift scans by setting the Altitude axis to some desired point in the sky and setting the Azimuth axis to some fixed number of degrees. The rotation of the Earth provides a sweeping motion to the radio telescope allowing the RT to pick up chance H1 hotspots along the path. These can be recorded and then compared to optical observations to identify radio emission sources or regions with corresponding visual objects or areas.

Other experiments may also be conducted with the 8-foot dish radio telescope.

While a small radio telescope is not likely to make new discoveries or first-time ever observations, the SRT serves as an excellent educational means for learning the basic principles of radiotelescopy. One of the major goals for use of this telescope is education in radiotelescopy.