HamSCI Grape1-DRF System

Startup Guide

Version 1.9; September 18, 2023

This document, and documents on Grape1-DRF internals, wave propagation, and other White Papers
may be found on the HamSCI website at:
https://hamsci.org/grape1-drf-docs

Forward

Dear Grape Participant,

Welcome to the HamSCI Great Radio Amateur Propagation Experiment (GRAPE) for studying ionospheric variability and the ionospheric impacts of solar eclipses! I am very grateful that you have volunteered to be a part of this project. As a volunteer, you will help collect data that will be used to better understand high frequency (HF) radio propagation, ionospheric physics, and the connection between the ionosphere, the neutral atmosphere, and space. You will also be continuing a more than one-hundred-year long tradition of radio amateurs who have used their time and expertise to help advance scientific knowledge.

If we look back over the past one hundred years, we can see how much we have already learned about the ionosphere and HF radio propagation. We know about diurnal (day/night), seasonal, and solar cycle variations. We have equations and computer programs that can predict how radio waves propagate through ionospheric models. We have extensive observations of the ionosphere from the ground, in situ, and from space. Even so, we cannot effectively predict exactly where our radio signals will go or what the ionosphere will do any better than a monthly median sense. This truly speaks to both the complexity and vastness of the ionosphere and the systems that impact it. Even though many professional ionospheric observation platforms exist, there still are not enough measurements to adequately sample the system.

The Grape experiment that you are hosting is an opportunity to contribute unique observations to ionospheric science while simultaneously seeing how space weather and ionospheric dynamics impact signals received at your individual station. The Grape receiver has been carefully designed to make precision frequency measurements that show ionospheric effects that are simply not apparent when using standard amateur radio equipment. An explanation of the Grape theory, as well examples of observed ionospheric effects, including seasonal and diurnal variations, solar flares, and traveling ionospheric disturbances, can be found in a recent publication led by HamSCI's first PhD graduate, Dr. Kristina Collins KD8OXT[1]. I should note that the data you will collect will look different than the data in that paper; we are now using a more advanced version of the data collection software to allow for the capture of the full spectrum around the carrier, rather than just a single peak frequency as a function of time.

I would like to extend my heartfelt gratitude to all the people, many of whom are volunteers, who have made this project possible. This especially includes the teams at Case Western Reserve University who led the development of the Grape, at the University of Alabama who are developing the Central Database, the New England Grape Group who led the production of the Grape 1 deployment for the eclipse, and the many other volunteers, students, and collaborators who have participated on the project.

[1] https://essd.copernicus.org/articles/15/1403/2023/

I truly hope that you find your participation in this project edifying. In addition to collecting data and making observations, I invite you to participate in development discussions and even work on your own data analysis. All the data collected is publicly available for analysis. HamSCI has many venues for sharing ideas and asking for help, including e-mail lists, regular telecons, and even an in-person annual HamSCI workshop. I look forward to meeting you through these channels and am excited to see how far this project can go!

VY 73,

Nathaniel A. Frissell, W2NAF, Ph.D.
HamSCI Principal Investigator
Assistant Professor of Physics and Engineering
The University of Scranton

Grant Acknowledgement: We are grateful to the United States National Science Foundation (NSF) Division of Atmospheric and Geospace Sciences for support of this work through grants AGS-1932972, AGS-1932997, AGS-2002278, AGS-2230345, and AGS-2230346.

Contents

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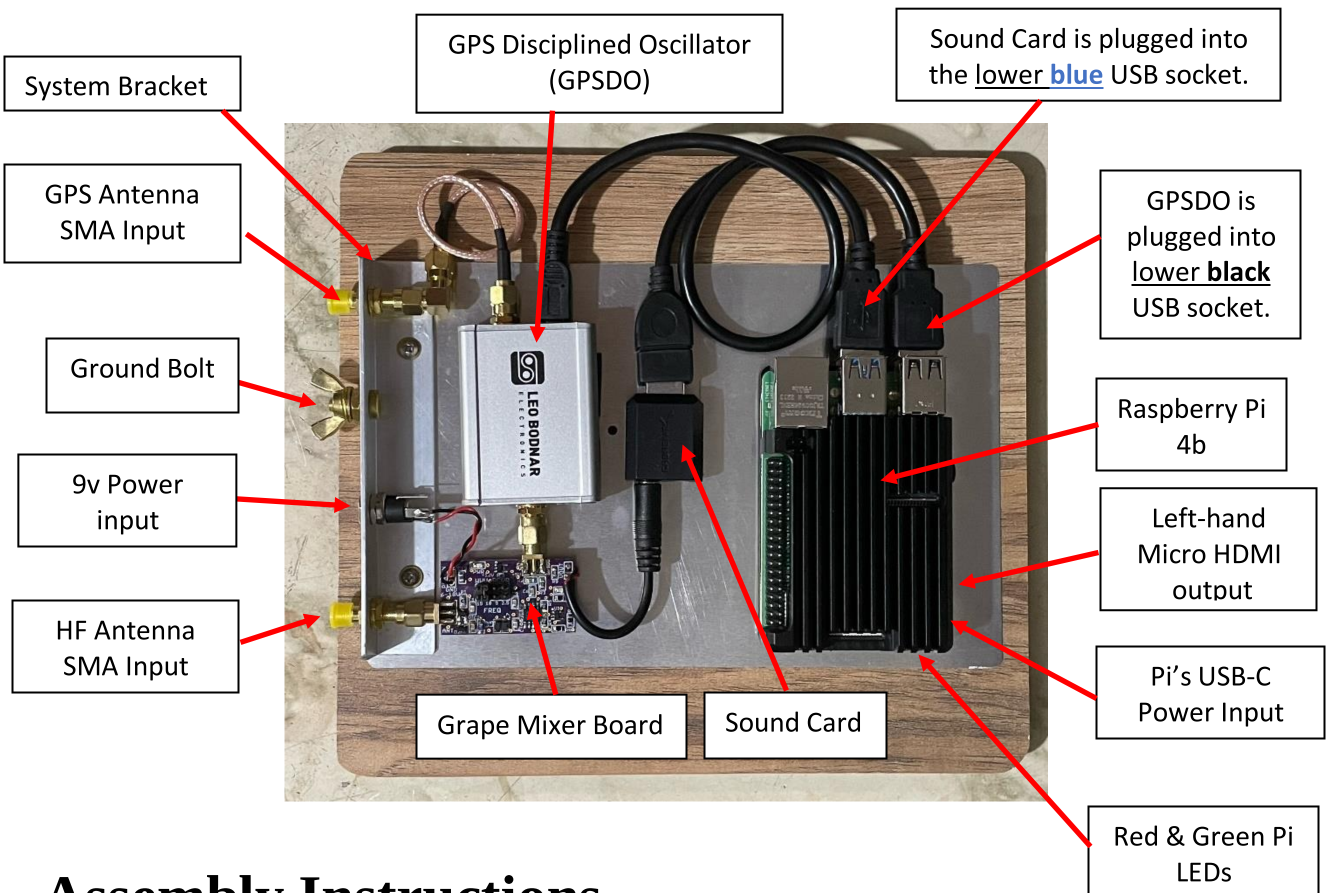
Packing List

This package contains the following:

- Box of parts containing:
  Pi power supply
  Bodnar GPS antenna
  USB-A to USB-mini cable
  SMA to SO239 adapter cable
- System Board containing:
  Raspberry Pi in a case with SD card installed, sound card, Grape mixer board, Bodnar GPSDO, and connecting cables.
- Triad 9v power supply to power the Grape mixer board.
- Western Digital disk drive.
- Sabrent disk drive case with power supply.
- Antenna kit if you requested one.



Assembly Instructions

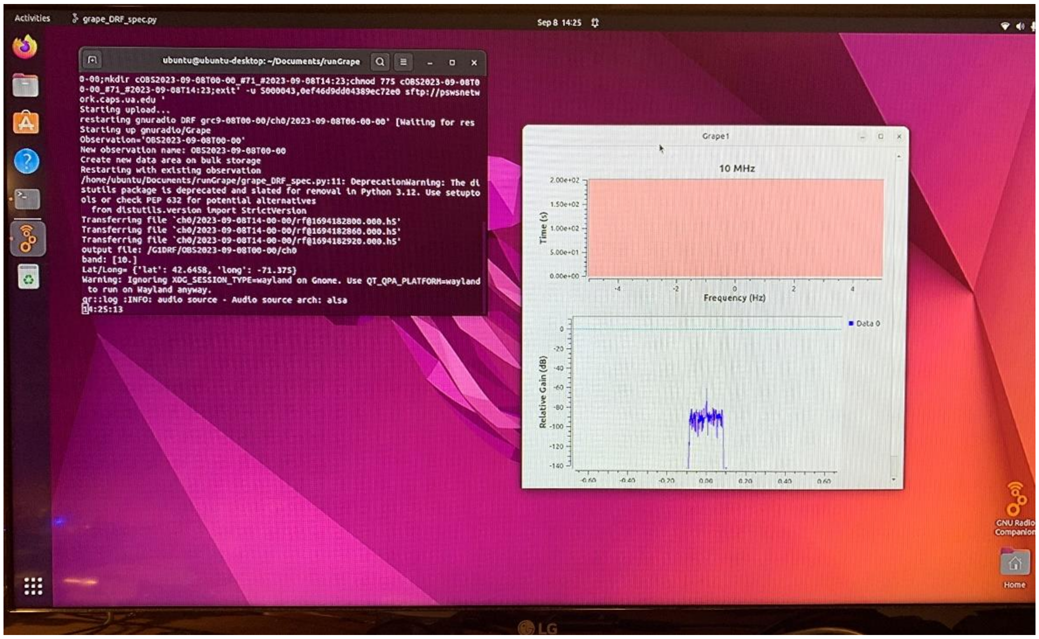
1. Unpack the system and check for completeness.
2. Choose a location where you have access to bring the GPS and Grape HF antenna to the system from the outside. You also need access to three AC sockets plus any display or additional items such as powered USB hubs.
3. Connect a suitable ground to the Ground Bolt on the system bracket.

4. Connect the Bodnar GPS antenna to the GPS Antenna SMA input socket on the system bracket. The GPS antenna may work inside a window if placed on a horizontal metal surface. The best performance is generally found outside.
5. Connect the Grape HF antenna to the SMA HF Antenna SMA input socket on the system bracket. If necessary, use the SMA to SO-239 adapter.
6. Connect the 9v Triad power supply barrel connector to the power jack on the system bracket.
7. If you have a wireless keyboard/mouse with a single USB receiver connect it to the open upper black USB port. If you intend to use a wired keyboard and mouse you will need a USB hub as there is only one USB port open after the rest of the equipment is connected.
8. Firmly insert the Hard Disk into the Sabrent case and connect the USB cable to the Raspberry Pi's upper blue USB jack.
   Connect the Sabrent 12v power supply wallwart cable to the Sabrent enclosure.
9. Connect your monitor to the Raspberry Pi video port using the micro-HDMI port to the right of the Pi's power connector.
10. Plug in your CAT-5 cable if you are using wired internet.
11. Plug in the disk's power supply to AC power and push the button on the case. The blue light should illuminate. For the Pi to boot successfully, the drive must be powered up <u>before</u> you power up the Pi. Allow 30 seconds before continuing to give the disk time to spin up.
12. Connect the Pi power supply to the PI's USB-C power input jack.
13. Power up the Pi by using the power button on the Pi's power adapter cord.
14. If you intend to use a WiFi connection to the internet, be sure to configure Ubuntu to connect wirelessly.

15. **Before <u>removing</u> power to the system, first do a graceful shutdown of the Raspberry Pi:**
    1. Left click on the terminal window and do a CTRL-C to stop the gnuradio process.
    2. Select the Power icon in the upper right corner of the screen. In the dropdown menu that appears, choose "Power Off/Logout", then "Power off". In the popup that then appears, select "Power Off" again.
    3. Wait until the Pi's green LED stops blinking, then remove power from the Pi.
    4. The disk will continue to run if it is powered. To shut it down, first do a graceful shutdown of the Pi, as defined above, and then power off the disk with it's power button.

<u>Improper shutdown can, and will, corrupt the SD card</u>.

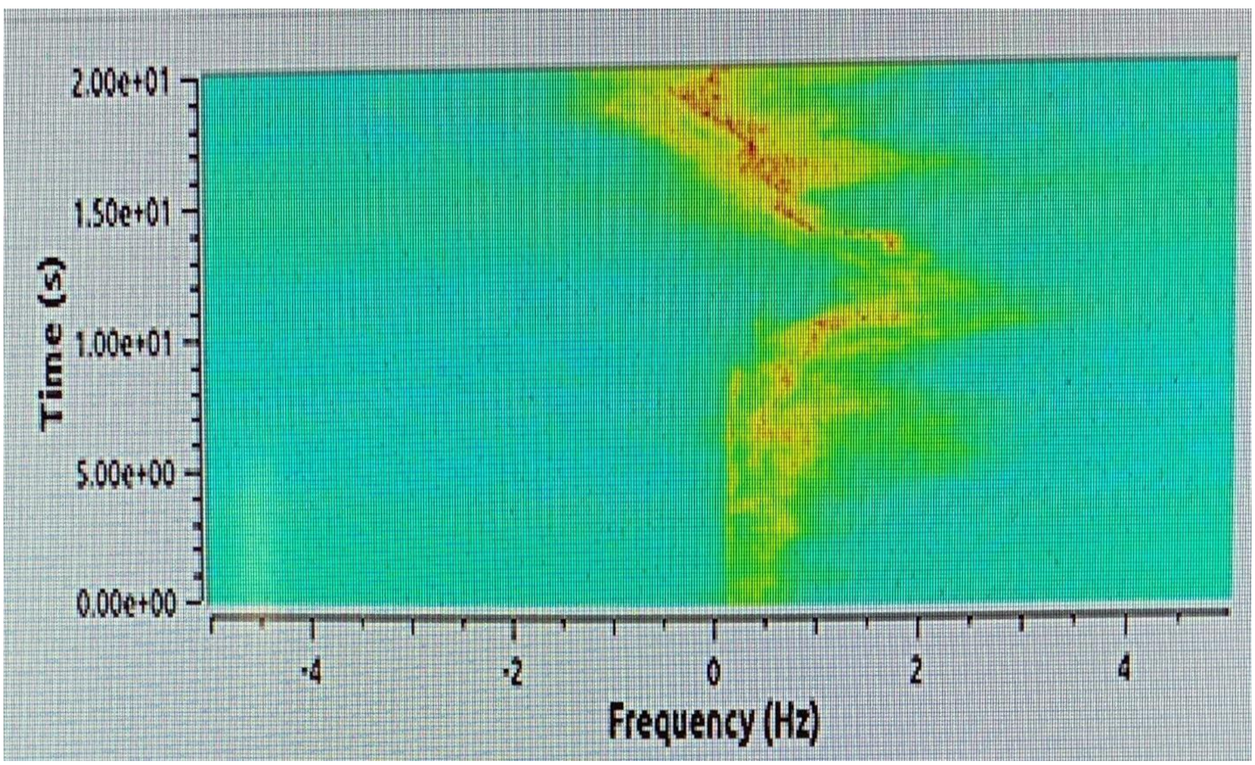
When all is setup correctly, you should see something like this on your monitor:



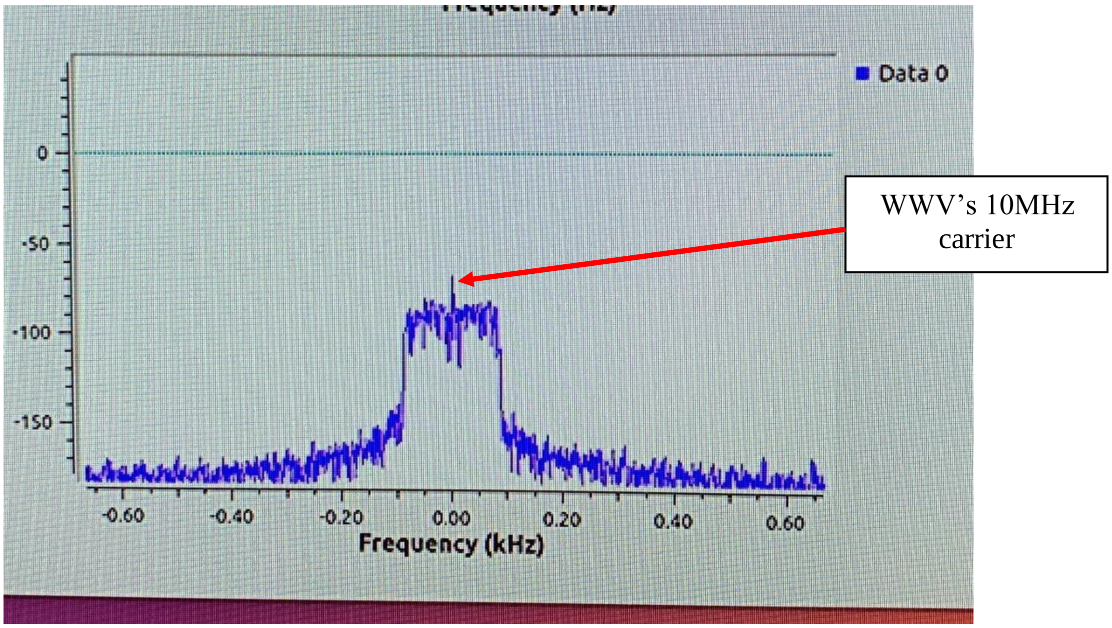
The upper left terminal window will show the progress of a startup script.

The second window will show two plots:

1. On top, a waterfall. “falling” up. Over time it will depict the Doppler shift of the WWV 10 MHz carrier (yellow streaks), and the relative signal strength (orange/red spots). The plot updates a line at a time, once every several minutes.



2. The second plot shows a frequency spectrum centered on WWV10's MHz carrier, which updates once every several seconds. If you left click on the frequency spectrum plot, you can zoom in and out using the mouse wheel. Here it is zoomed out enough to show the noise floor.



Note that these plots are not from calibrated lab equipment and are presented only for comparison and determination of correct operation.

Antenna Configurations

de Bob Reif, W1XP

Note:
I am sure that there are many in the HamSCI group who don't need this elementary treatment of antennas and my crude hand drawn sketches. But I have included these for the Beginners, young or old, who ask for help with the antenna part of this experiment. It is to you I offer any help I can provide. Email me if you are having trouble.

Bob, W1XP
cw4ever4@gmail.com

This section is primarily for those that have requested an antenna furnished with the Grape1-DRF system and are unsure of how best to deploy it. However, these comments may be of interest to all.

First, when working with antennas, **Safety First** is the number one consideration. So, work safely in all phases of the antenna installation.

If your installation requires working above ground, be sure to do it safely or get help from someone that can do the job correctly and safely Also avoid any Power wires that may be in the area of the proposed antenna installation.

The often heard suggestion that the antenna should be as high as possible is not a hard requirement: I have seen many cases where an antenna close to the ground is giving very adequate results. So, it probably is not necessary for that extra effort to receive adequate signals from WWV.

With regards to Antenna Safety and Grounding, a review of the antenna safety section of the ARRL Handbook or ARRL Antenna Book is recommended. Keep in mind that safety goes beyond installation. Remember: the antenna should be high enough that people will not trip over it or get caught on it. The wire is small enough to be not noticeable to people walking or working around the antenna.

The antenna furnished by HamSCI is a simple kit of three insulators, several lengths of antenna wire, and a roll of coax cable. Additionally, user supplied, support line is required.

If there is anything that DOES NOT come under the "One Size Fits All" category it is Antennas!

Every location has its own requirements and restrictions. The task of the antenna installer is to choose the antenna to fit the available space and the requirement for the antenna, while meeting the local requirements, rules, regulations, and preferences.

With the material supplied in the HamSCI antenna kit I think most of us should be able to come up with an antenna that will provide suitable performance to copy WWV at the location if propagation to that location is possible on 10 MHz. There are certainly locations in the US where WWV and/or WWVH may not be receivable 24/7. If the propagation is not there, a better antenna may not do any better at receiving WWV.

Here in New England, we have good WWV10 signals most of the time, but the path will fail at times. Remember that in terms of the experiment, no signal is still information.

The Antenna Kit is configurable into three general configurations. These are:

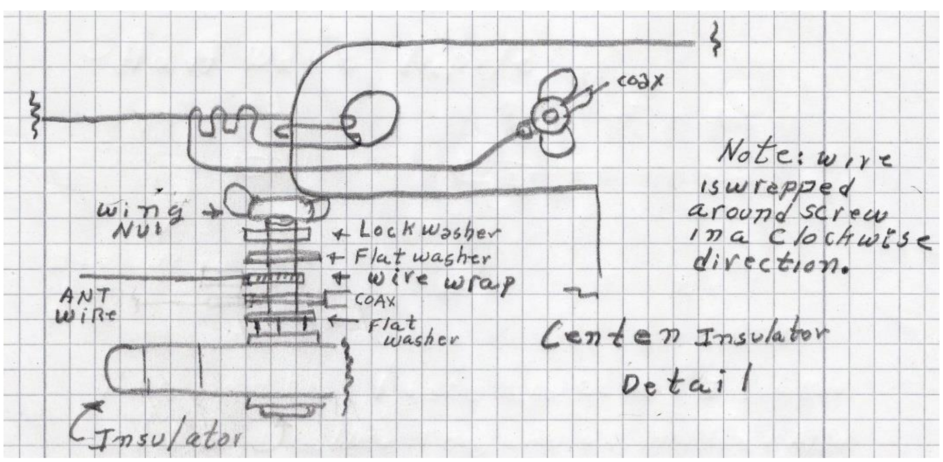
- a halfwave, center fed dipole,
- an off center fed dipole, and
- a vertical end fed wire against ground.

The Antenna Kit has a 50-foot length of RG-58 coax with an SMA connector on one end to match the connector on the Grape receiver. The other end of the coax has pigtail leads that connect to the center insulator. If this length of coax is not sufficient to meet your requirements, additional coax can be added as required. Most of the big box stores have coax for cable television, which will do fine for this application. Also, try online from the ham radio outlets, or Amazon. Amazon has coax with SMA connectors. Some lengths of cable are available with male and female connectors, so that you don't need a barrel, female to female, adapter.

Any extra coax may just be coiled up at either end of the cable. The center insulator may or may not be attached when you receive the kit.   The two lengths of wire are each nominally a quarter wavelength long. The two end insulators are for connecting additional support lines (user supplied) to the ends of the antenna as required for connection to supports.

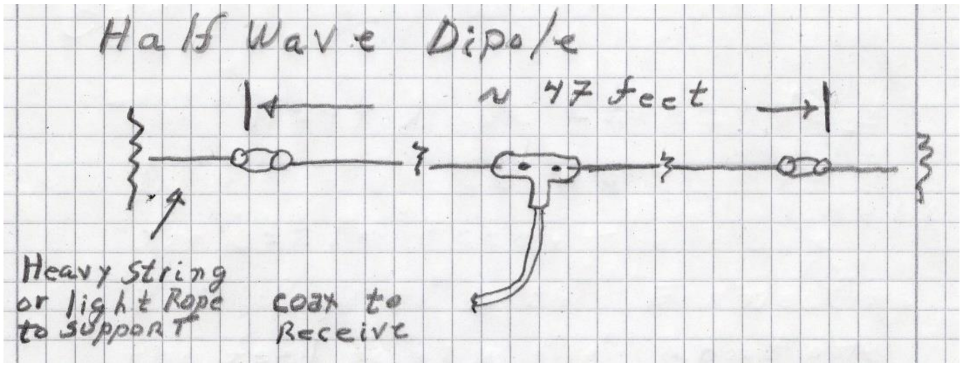
To assemble the antenna:

1. Locate the center insulator and attached coax cable assembly.
2. Unroll several feet of a roll of antenna wire from the end without an insulator.
3. Measure 6 inches from the end of the wire and bend it 90°.
4. Insert the wire, from the back of the center insulator, into one of the end holes in the insulator.
5. Bend the wire over at the 90° bend and wrap the end of the wire tightly about the insulator, through the hole several times.
6. Wrap the end of the wire tightly about the outgoing wire several times. You should have enough length remaining to reach the coax terminal.
7. Carefully remove the wingnut, lock washer & flat washer.
8. Wrap the wire on the screw, replace the flat washer, lock washer, and wingnut. Be sure the wingnut is firmly tightened.

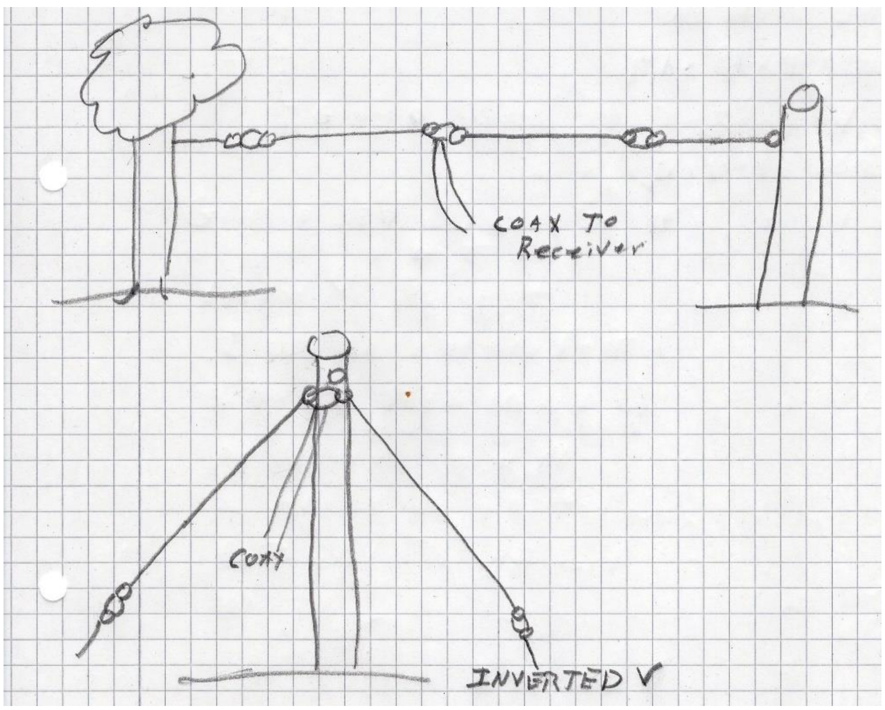


Halfwave, Center Fed Dipole

Of the three antenna configurations the center fed dipole is probably the best if the horizontal space is available. This is just under 47 feet.   The best direction is with the antenna broadside to the path from your location to WWV in Boulder, CO. But the elevation angle of arrival of the signal is generally high so other orientations are acceptable since the azimuth plot’s nulls off the ends of the antenna are generally not a problem.



It is not necessary that the antenna be in a straight line. Supporting the center of the antenna and running the two wires off in different directions will probably work fine. An inverted V should work also.



I have used the dipole as low as two feet above the ground here in Notrtheast Massachusetts and had adequate signals. If the antenna is not a safety issue of tripping, this is a possible solution, but only if you have adequate signal strength.

In general, I would try for 8 feet minimum or more above ground if only so people don't bump into it. Fifteen to twenty feet seems to work fine in my experience here. Not that higher won't work better.

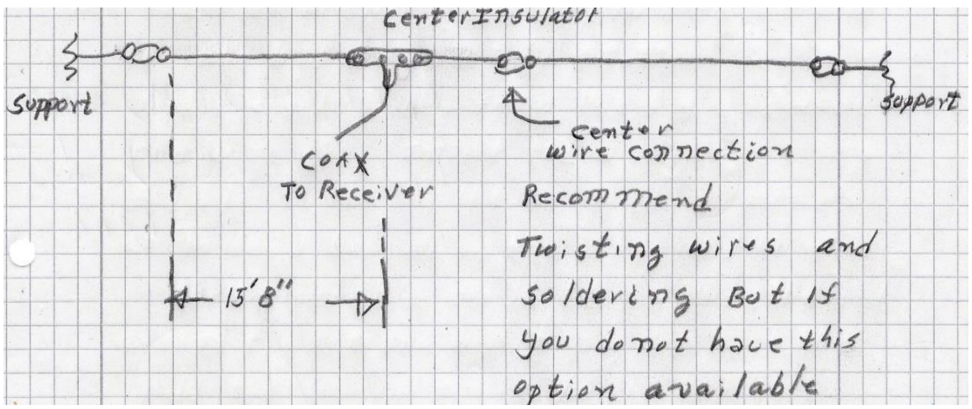
Some may feel that since WWV is transmitting a vertical polarized signal the antenna should match the transmitting polarization. This would only apply if the propagation was via ground wave from WWV. In such a case a vertical antenna would be necessary.

The interaction of the linearly polarized wave being emitted by the antenna can be changed significantly by the interaction with the ionosphere. The resulting propagating wavefront can be random and time varying resulting in an unpredictable polarization of the propagated wave. For this reason, either a vertical or horizontal polarized antenna will function to receive the signal from sky wave propagation.[2]

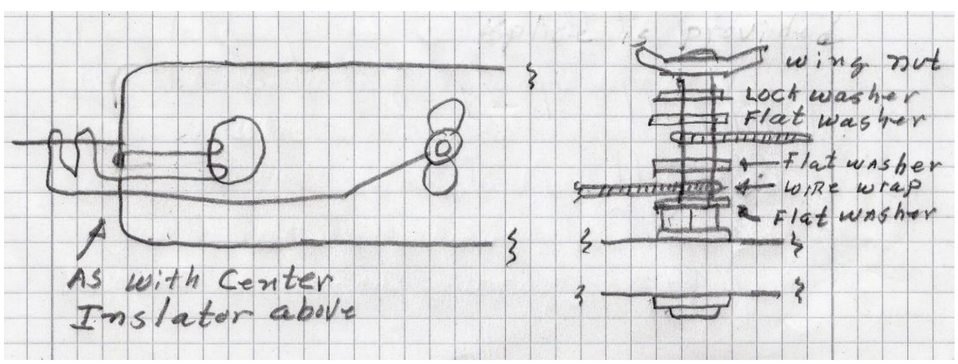
It is not necessary that the antenna be horizontal or vertical. A sloping antenna will work if that fits your location.

Off-center Fed (OCF) Dipole

The off center or end fed antenna may be used if there is an advantage to this style of configurations, that is, if the coax is not long enough to reach a dipole at your site. However, these are less desirable antenna configurations than the simple dipole.



Overview



Center Wire connector (detail)

The off center fed antenna is, by the nature of the off-center feed system, an unbalanced antenna. This can lead to common mode currents flowing on the outside of the coax shield. The downside of this, in a receiving antenna, is that the coax can pick up noise on the

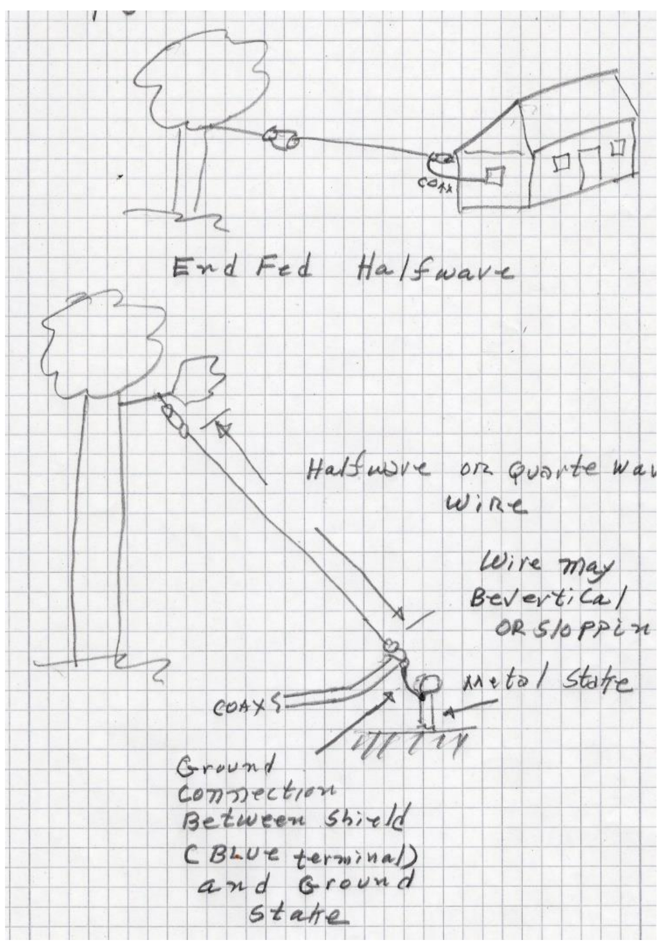
[2] ARRL publication: Here to There: Radio Wave Propagation pp 24-25
NASA publication: Propagation Effects on Satellite Systems

outside of the coax shield, itself acting as an antenna. This extra noise is then coupled into the signals at the antenna and degrades the signal to noise ratio. A balun at the antenna would help reduce this effect. This may not be a major issue, but it is pointed out as a potential problem.

Cutting one of the wires and placing the center insulator at that location may be a useful configuration for you if the center fed dipole won't work in your location. There is a small insulator with a screw to splice the center of the antenna together. A suggested point is 15 feet 8 inches from the end. This is an unbalanced feed system, and a 4 to 1 balun would improve performance, if necessary, to get adequate signals.

Placing the feed point at the end of the antenna is the least desirable way to use the antenna. Picking up noise is certain. And there is a large mismatch. A 7 to 1 turns ratio auto transformer (49 to 1 impedance ratio) would help but this is not in the keeping of the KISS (Keep It Simple, Stupid) philosophy of the antenna. But this configuration may be best for your location, and I would give it a try if it seems to be the only thing for your location. Contact me if you have questions on Antennas or Grounding:

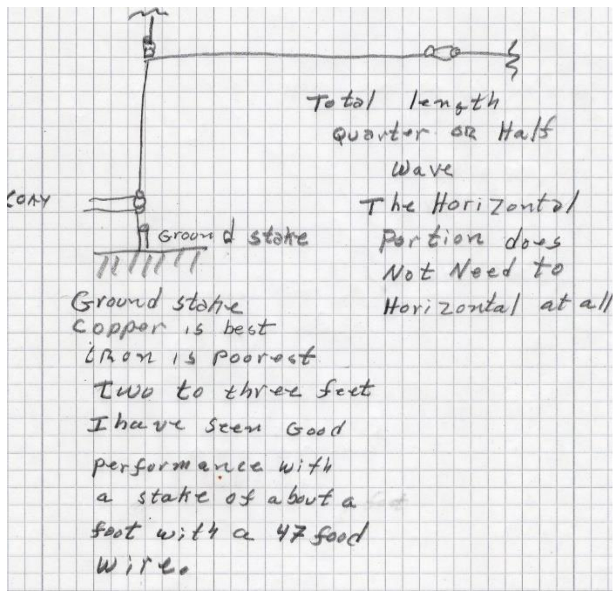
End Fed Vertical Wire



The last configuration of the antenna is a vertical wire. I know of a very successful installation of a vertical wire, 47 feet long, pulled up in a tree by a line over a limb. The lower end is connected to an insulator connected to a line to earth, as well as to the center of the coax. The shield terminal is connected to a short stake driven in the ground. There are no radials at all. Just a short stake driven in shallow soil on top of rock.

This antenna has been providing excellent signals at 10 MHz for over a year.

If the full length of the antenna can't be vertical it can be used in the inverted L configuration with the upper end of the wire bent over in the horizontal direction.



Shortening the wire to a quarter wavelength will work well also in either the vertical or inverted L configuration.

<u>The half wave center dipole or the half wave vertical are my recommended configurations.</u> But I have a remote site that has just a 23-foot-long piece of wire under the eaves of a single-story house. The end of the wire drops down about six feet to a window and connects to the center of a piece of coax. The shield of the coax goes to a ground stake below the window. Despite picking up a lot of noise from the house, it provides good signals from WWV on 5, 10, and 15 MHz. So simple wire antennas can work. At least give them a try if it is necessary in your location.

I think the vertical is a very good antenna to try if you can. Any length that is possible may work just fine. Give it a try.

Another thing about receive-only antennas. The location of the antenna is probably the most important thing. In general, SWR is not an issue like it is for a transmitting antenna. We don't need to worry about the high SWR (i.e., 2 to 1) shutting down the power amp. In general, the Signal to Noise ratio is what is important, and it should be established at the antenna.

The Grape has more than adequate sensitivity, so at 10 MHz. Choosing an antenna site that is quiet may be more important than a site that provides more signal and noise.

Grounding

Grounding of the receiver is recommended, and a ground connection is provided on the receiver board. This connection should be connected to the station ground for both safety and noise reduction. Again, the ARRL handbook or Antenna book are good references on this subject.

If you have any questions or problems with antennas for the Grape1-DRF, please contact me by E mail. I'll be glad to work with you to get you on the air for this HamSCI event.

Again, please contact me if you have questions on Antennas or Grounding at:

cw4ever4@gmail.com.

73 Bob W1XP

System Support & Troubleshooting

If you need system support or encounter problems in getting the Grape1-DRF system to work, please post questions to the HamSCI Google Group, https://groups.google.com/g/hamsci-grape which our Grape1-DRF consulting team will monitor. They will respond to your queries.

Known Issues

Issue 1:

The system has been seen to "lock up", with no response from keyboard or mouse, and the clock in the lower left corner of the terminal window not updating. Upon rebooting, before the Ubuntu logo splash screen, error messages are presented concerning USB port assignments. This is being actively addressed by the development team.

Workaround:

1. Power down the Pi and the hard drive.
2. Unplug all USB devices except keyboard & mouse. Remember what was plugged in where.
3. Power up the system. The system will boot into EMERGENCY mode, since it expects the hard drive to be connected, but it is not.
4. Hit "enter" to get a command prompt.
5. Type "nano /etc/fstab".
6. Comment out the line that begins LABEL=G1DRF, by adding a "#" character to the start of the line.
7. Save the fstab with ctrl-o, hit Enter, and ctrl-x to save & get out of nano.
8. When returned to the command prompt, type "exit".
9. Wait (sometimes quite a while). The system will reboot into Ubuntu's Graphic User Interface (GUI), and gnuradio will start up.
10. Power down **using the GUI exiting rules (see below).**
11. Plug in all USB devices into their remembered USB sockets.

12. Power up the system: power up the disk drive first and wait at least 30 seconds for the disk to spin up before powering up the Raspberry Pi. An Ubuntu GUI will appear.
13. Open a terminal window and type “sudo nano /etc/fstab”. Enter password “HamSCI2023!”. Don’t enter the quotes.
14. Remove the # that commented out the LABEL=G1DRF line in /etc/fstab. Do a ctrl-o, Enter, ctrl-x, to save the file & get out of nano.
15. Power down using GUI exiting rules.
16. Power up, again powering the disk first and waiting 30 seconds before powering up the Pi. All should be seen to be working properly.

GUI exiting rules

1. Left click on the startup terminal window and do a CTRL-C to stop the gnuradio process.
2. Select the Power icon in the upper right corner of the screen. In the dropdown menu that appears, choose “Power Off/Logout”, then “Power off”. In the popup that then appears, select “Power Off” again.
3. Wait until the Pi’s green LED stops blinking, then remove power from the Pi.
4. The disk will continue to run if it is powered. To shut it down, first do a graceful shutdown of the Pi, as defined in steps 1-3 above, and then remove the disk’s 12v power (if using the Sabrent disk enclosure, push the enclosure’s power button and observe the blue LED turn off).

Issue 2:

If, upon powering up the system, the Bodnar GPSDO’s LED continues to blink for a very long time, try unplugging the Bodnar’s USB cable (which powers it), wait a bit, and then reconnect it. This sometimes helps the GPSDO reach a “locked onto GPS” state.

Tips:

If you see Ubuntu offer you software updates, please ignore these offers until after the eclipse.

Further Reading

Documents on Grape1-DRF internals, propagation, and White Papers may be found at https://hamsci.org/grape1-drf-docs.