JOVE

RJ1.1 Antenna Kit

Assembly Manual

Radio JOVE

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March 2002

Antenna Kit and Manual
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Contents

Theory of Operation - Antenna

The antenna intercepts weak electromagnetic waves that have traveled some 500 million miles from Jupiter to the Earth or 93 million miles (1 Astronomical Unit = 1 AU) from the Sun. When these electromagnetic waves strike the wire antenna, a tiny radio frequency (RF) voltage is developed at the antenna terminals. Signals from each single dipole antenna are brought together with a power combiner via two pieces of coaxial cable. The output of the power combiner is delivered to the receiver by another section of coaxial transmission line.

Site Requirements

The antenna system requires a fair-sized area for setup: minimum requirements are a 25 x 35 ft. flat area that has soil suitable for putting stakes into the ground. Since the antenna system is sensitive to noise it is best not to set it up near any high tension power lines or close to buildings. Also for safety reasons, please keep the antenna away from power lines during construction and operation. The best locations are in rural settings where the interference is minor. Since many of the observations occur at night it is wise to practice setting up the antenna during the day to make sure the site is safe and easily accessible.

Site Considerations

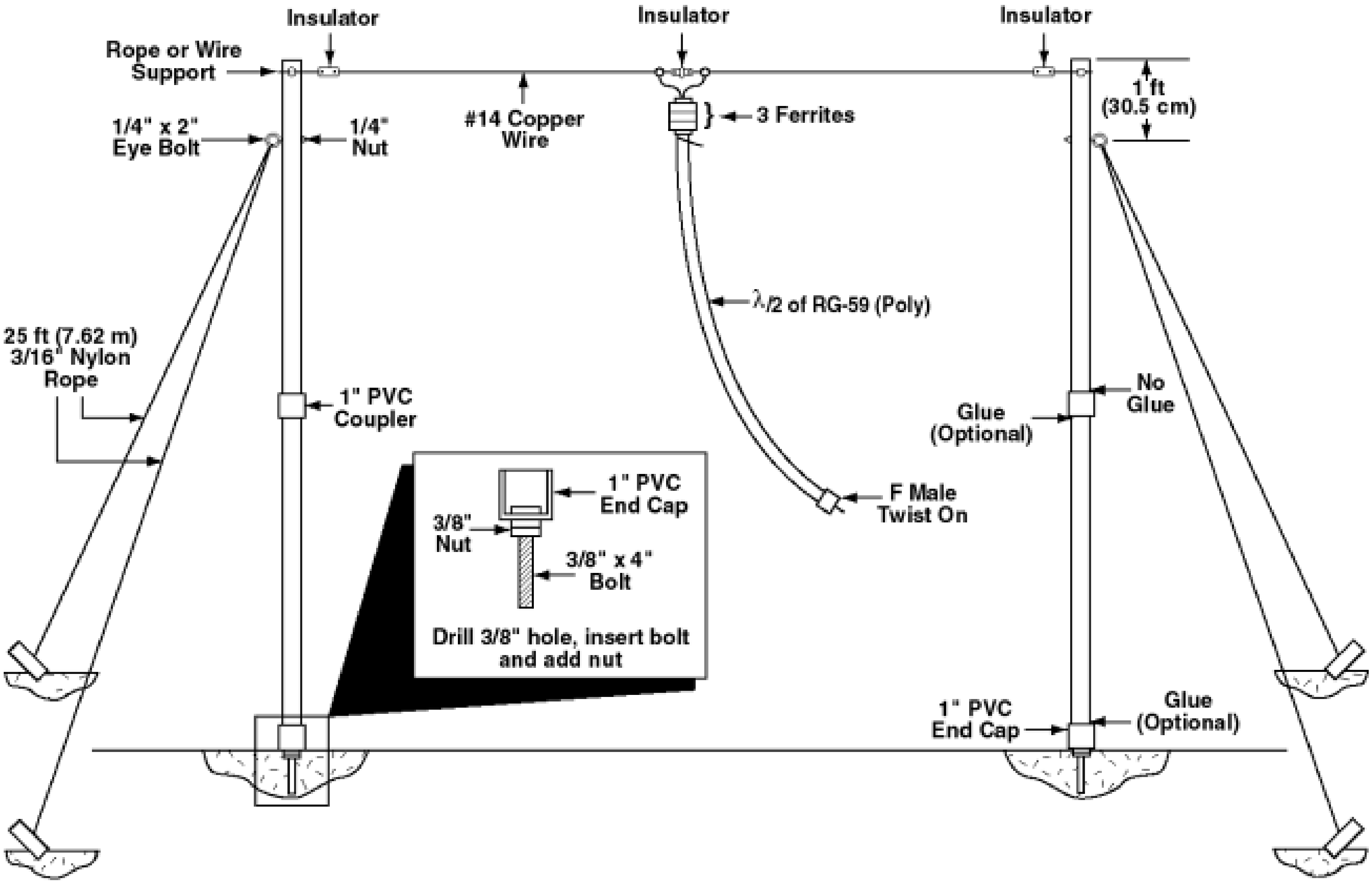
If you have no clear open space on the ground to erect the antenna then it may be worth trying it on a rooftop. The antenna pattern may be affected by metal in the roof structure and roof mounted air conditioning units may generate undesirable electrical noise. A rooftop antenna may also be more susceptible to lightning and should always be disconnected when not in use. (It is a good precaution to disconnect any antenna when not in use - particularly during lightning season.)

If you want to locate your receiver indoors and your antenna is outside or on the rooftop, and your antenna lead will not reach, you must use a longer coax cable. DO NOT JUST USE ANY LENGTH OF COAX. The cable going from the power combiner to the receiver should be a multiple of half the wavelength. The cable supplied with the kit is one wavelength - that is 9.85 meters long (taking into account the 66% velocity factor of the RG-59/U cable). The maximum recommended cable length is 5 wavelengths. There are many different manufacturers and qualities of coaxial cable. The 75 ohm cable supplied with the kit is manufactured by Belden and has a solid center conductor and velocity factor of 66%. Radio Shack does not carry RG-59/U cable but they do have RG-6 and the higher grade RG-6QS (quad shield), which is also 75 ohm cable. Both of these cables have a velocity factor of 78%. One wavelength at 20.1 MHz in RG-6 cable is 11.64 meters. If you are going to put in a longer feedline we recommend that you completely replace the existing one wavelength piece - rather than splicing another length of cable onto the end.

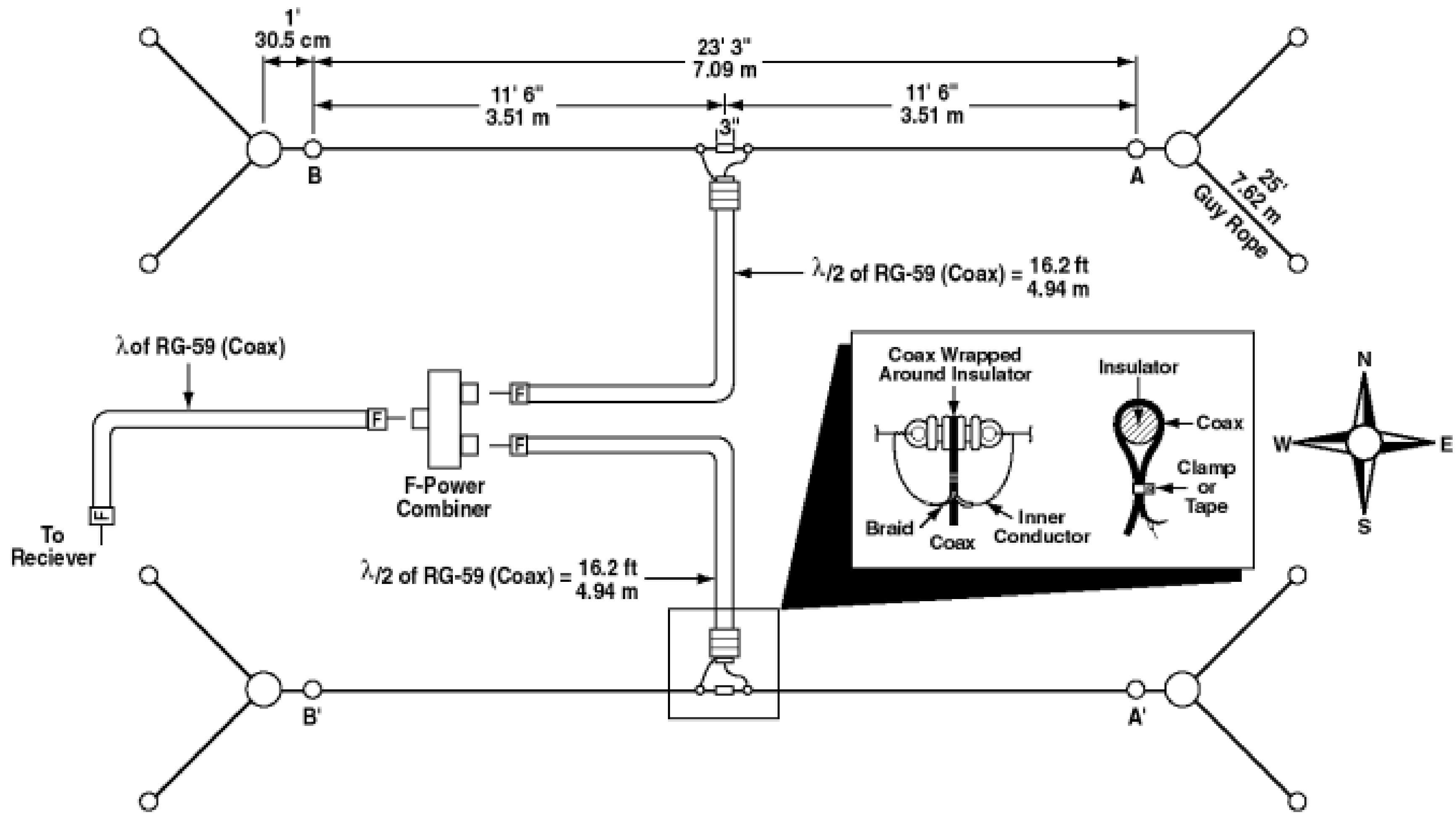
Construction Time Estimates

Measuring and Cutting Wire and Cable	30 min.
Wrapping Insulators	30 min.
Preparing and Soldering Coax	60 min.
Installing Toroids and Connectors	60 min.
Assembling the Mounting Hardware	60 min.
Field Setup (first time)	45 min.
Total Time	4.75 hrs.

BASIC DIPOLE



Dual Dipole Antenna (Top View)



IMPORTANT PHASING NOTE! - Be sure that coax center conductor is connected to A and A'
(or make sure that the A and A' side of the antenna is always facing the same direction, i.e., facing east).

Components

The antenna is composed of several types of components (Figure 1) including wire, coaxial cable, connectors, insulators, rope, supports, and hardware.

Figure 1a and 1b. Antenna Parts.

Wire – the copper wire is used for the antenna elements. We are constructing two identical half-wave dipole antennas and phasing them together with feed line. The entire length of the dipole is, therefore, equal to 1/2 of the wavelength (λ) of radiation to be detected. Thus each side of the dipole antenna is 1/4 wavelength long (See Schematic on previous pages). Since the Radio JOVE receiver is tuned to the frequency of 20.1 MHz (M=mega=10^6), the wavelength is 48.968 feet (14.925 meters). A useful formula for calculating the half-wavelength for an "ideal" dipole in free space for a specific frequency is:

$$\lambda/2 \text{ (in feet)} = 492 / \text{frequency (in MHz)}$$

or $$\lambda/2 \text{ (in meters)} = 150 / \text{frequency (in MHz)}.$$

For practical antennas, however, the measured values are smaller than the "ideal" values. This is a result of resistance in the wire and *end effects* of the dipole. These two properties effectively shorten the length at which the wire will resonate or most effectively receive radiation at a frequency of 20.1 MHz. To calculate the "practical" half-wavelength of antenna use the formula:

$$\lambda/2 \text{ (in feet)} = 468 / \text{frequency (in MHz)}$$

or $$\lambda/2 \text{ (in meters)} = 142.5 / \text{frequency (in MHz)}.$$

For the antenna to be an effective receptor of signals, the wire dipoles must be mounted horizontally above the ground by about $\lambda/4$ feet (8-12 feet [2.44 - 3.66 m] is acceptable). This is accomplished by attaching the wire to poles held up by support rope (see below).

Coaxial Cable (coax) – the coaxial transmission cable is used to feed the signal intercepted (or collected) by the antenna to the receiver. Therefore the coaxial cable must be attached to the antenna wire by solder joints. The coaxial cable has a center conductor surrounded by a dielectric insulator (polyethylene) and a copper braided shielding. These help conduct the signal from the antenna to the receiver with a minimum of loss of signal. Because the cable is not a perfect conductor, the speed at which the signal propagates along the wire depends on the type of dielectric insulation used in the cable. For the coax included in your kit, the velocity factor (V_f) is 66%. Therefore the proper lengths for cutting the coax must take this factor into account.

Connectors – the connectors used for the Radio JOVE are called F-type connectors and can be manually twisted onto the ends of the coax line. These connectors are used to connect the cables to the power combiner and to the antenna input on the JOVE receiver.

Insulators – insulators are needed to keep the antenna from shorting the received signals to ground. Six insulators are needed for the antenna, one in the middle of each dipole, and one on each end. Insulators are usually plastic or ceramic cylinders with holes cut in each end for the wire and rope supports.

Support poles – PVC piping is suggested for the antenna support poles. It is a cheap and lightweight support structure that is portable and effective.

Rope – rope is used to support the antenna poles as guy lines for each support pole.

Hardware – hardware in the form of bolts and nuts are used to make it easy to support the antenna. Bolts are used as foot pegs to help keep the poles in place and eyebolts are used to help attach the guy lines to the poles.

Toroids – the magnetic toroids are needed for the antenna assembly to restrict current flow along the outer surface of the coaxial cable shielding. This allows for optimal reception by creating a better antenna pattern.

Tools

Soldering Iron (SP40 – 40Watt or CXG-32 – 48Watt) or Soldering Gun (RS 64-2193 – 100Watt)
Solder, 60/40, 0.050 in diameter rosin core (RS 64-006)
Wire Cutters (RS 64-1833) and Wire Strippers (RS 64-2129)
X-acto® Knife (or equivalent)
Scissors
Tape measure (at least 12 ft. is best)
Small screwdriver
Crescent Wrench
Pliers
Drill with > 1/4 in. and > 3/8 in. drill bit

Radio JOVE Antenna Parts List

Parts included with the Radio JOVE Antenna Kit	Parts Checklist	
1 50 ft. (15.24 m) #14 Gauge Bare Copper Wire (7-stranded)		
1 70 ft. (21.336 m)RG59U Coaxial Cable (Beldon 8241)		
4 PVC End Insulators (cylinders)		
2 Plastic Center (dogbone) insulators		
4 Twist-on F-connectors		
1 Power combiner / splitter (2-to-1)		
6 Ferrite toroids		
Parts necessary but NOT included with the Radio JOVE Antenna Kit		
1 100 ft. (30.48 m) x 3/16 in. Nylon Rope		
4 10 ft. (3.048 m) x 1 in. PVC pipes (Sch 40)		
4 1 in. PVC End Caps		
4 1 in. PVC Couplers		
4 3-4 in. x 3/8 in. Bolts		
4 3/8 in. Nuts		
4 3/8 in. Flat Washers and Lock Washers (optional)		
4 3 in. x 1/4 in. Eye Bolts		
4 1/4 in. Nuts		
1 Small can of PVC Cement (optional)		
6 Tie wraps (optional)		
8 Tent stakes		

Assembling the Antenna

Measuring and Cutting Wire and Rope

Measure and cut the proper lengths of the bare copper wire, the coaxial cable, and the rope. A good long hallway is excellent for this job. Use tape on the floor to mark the lengths for each of the different cuts.

1. o Cut 4 sections of the copper wire to 12 ft. 4 in. (3.76 m).
   Use the formula for practical antennas and calculate $\lambda/2$ length for the wire.
   $\lambda/2$ (practical) = 23.28 ft. or 23 ft. 3 in.
   Divide by 2 to calculate $\lambda/4$
   $\lambda/4$ (practical) = 11.64 ft. or 11 ft. 7.7 in.
   Subtract 1.5 in. to account for the 3 in. center insulator
   $\lambda/4$ (corrected) = 11.52 ft. or 11 ft. 6 in.
   Add 5 in. to each end of the wire for wrapping the insulators
   Proper Wire Length = 12.35 ft. or 12 ft. 4 in.
2. o Cut 2 sections of the coaxial cable to $\lambda/2$ = 16.2 ft. (4.94 m)
   Use the formula above for the ideal antenna wavelength and calculate $\lambda/2$ for the coaxial cable.
   $\lambda/2$ (coax) = 24.48 ft. or 24 ft. 5 in.
   Multiply by the velocity factor (V_f = 66%) to calculate the proper coax length
   $\lambda/2$ (corrected) = 16.15 ft. or 16 ft. 2 in.
3. o Cut 1 section of coax to λ = 32.3 ft. or 32 ft. 4 in. (9.85 m).

Wrapping the Insulators

1. o Using the copper wire, thread the extra 5 in. (12.7 cm) through the hole in the insulators and wrap it back on itself. If necessary use pliers to wrap the wire tight.
2. o Wrap the ends of two copper wires around one insulator (center insulator) and then the other ends around two separate insulators (end insulators). The result should look like the examples in Figure 2.
3. o Repeat this procedure for the second dipole. A measurement of the total length of the antenna (from one end insulator to the other end insulator) should be 23 ft. 3 in. (7.09 m).

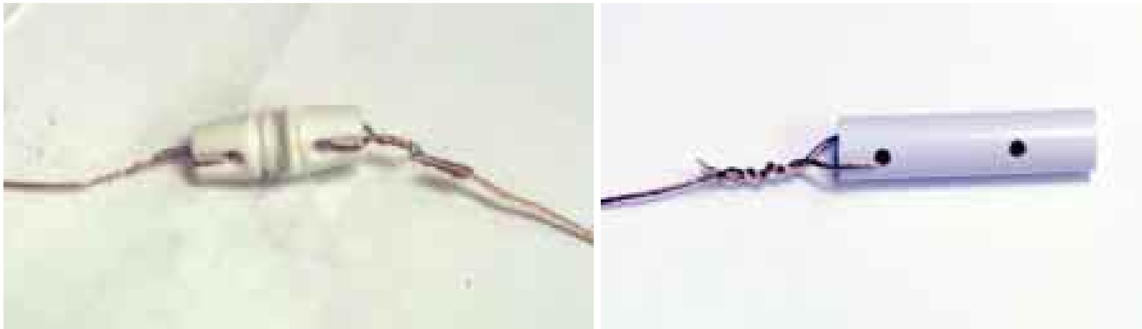


Figure 2a and 2b. Wrap the center and end insulators with the antenna wire.

Preparing and Soldering the Coax

1. O Using the end of one of the $\lambda/2$ pieces of coax, strip back (remove) the outer covering about 4 - 5 inches (10 - 12 cm). [Note: Be careful not to cut the braided copper shielding wires underneath the outer cover].
2. O Unweave the braided copper shielding using a small screwdriver or the tip of a pen or pencil. Start at the end of the wire and carefully unbraid all of the exposed copper shielding (Figure 3a and 3b). Be careful not to cut or break too many of the wires, but breaking a few is okay.

Figure 3a and 3b. Unbraid the copper shielding.

3. O Twist all the individual wires together to form one continuous wire (Figure 3c).

Figure 3c. Twist the copper shielding and expose the center conductor.

4. O Strip off the insulation around the center conductor approximately 2 inches (5 cm). This is polyethylene and is fairly tough, so use a good knife.
   WARNING: Be careful not to nick the center conductor when cutting and stripping off the insulation around it. Nicking the center conductor will weaken it and most likely cause it to break after swinging in the wind for a long time.
5. O Loop the coaxial cable over the center insulator and tie wrap or tape it (Figure 4) just below the section of stripped coax. This will provide strain relief so the solder joints will not break.
6. O Wrap the bare center conductor around the end of one of the copper wires attached to the center insulator. Wrap the twisted shielding around the other copper wire attached to the center conductor (Figure 4).
7. O Solder the coax center conductor and shield to the copper wires (we recommend using a soldering gun). Use a lot of solder and hold the heat on the wires a long time until you see the solder seep into the wires. Check all around the wire to make sure the connection is good (Figure 5).
8. O Repeat for the other dipole.

Figure 4. Tie wrap the coax over the center insulator. Wrap the center conductor around one side of the dipole and the twisted shielding around the other.

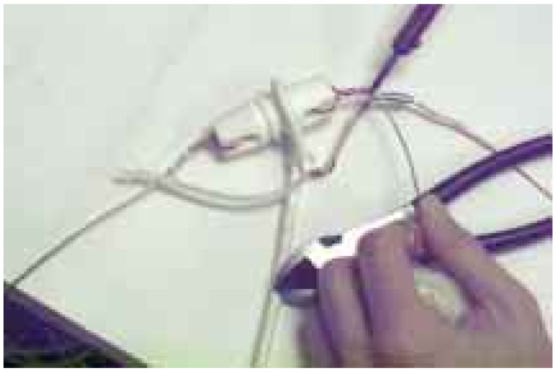
 

Figure 5. Solder the shielding and center conductor to the copper wires.
Figure 6. Install the ferrite toroid cores.

Installing the Toroids and Connectors

1. O For each dipole, slide 3 ferrite toroids cores up the cable to the very top of the coax near the dipole. Secure them all in a row with tape and a tie wrap. Be sure this is secure because they may slide down the coax after the antenna is up (Figure 6).
2. O Install the F-connector on the coax feed line to each dipole. To install, remove about 3/4 inches (2 cm) of the outer coax casing (Figure 7a).
3. O Carefully unbraid about half of the exposed shielding (about 3/8 inch (1 cm) and fold it back over the other half of the copper shielding and over the outer casing (Figure 7b).
4. O Remove the insulation around the center conductor leaving about 1/2 inch (1.3 cm) of bare center conductor (Figure 7c, 7d).
5. O Push the F-connector over the end of the coax and twist on as tightly as possible. The teeth of the F-connector will bite into the shielding that has been folded back and this will provide good contact for ground. About 1/8 - 1/4 inch (0.3- 0.6 cm) of center conductor should stick out of the end of the F-connector (Figure 7e).
6. O Repeat this connector installation for each end of the long piece of coaxial cable (the 1λ coax cable).

Figure 7a - 7c. Prepare the coax and install the F-connector.

Figure 7d - 7e. Prepare the coax and install the F-connector.

Assembling the Mounting Structure

1) O Cut all 4 of the 10 ft. (3.05 m) PVC pipes in half (two 5 ft. (1.52 m) sections each). This cut allows for ease of transport and storage of the antenna, but it is not necessary to make this cut if you can transport and store the 10 ft. (3.05 m) poles. If the PVC is cut then four poles will be the top masts and four poles will be the bottoms.
2) O Drill holes for the bolts and wires.

    i) Drill > 1/4 in. hole 2 inches (5.1 cm) from the top of all 4 top sections. Drill completely through both sides of the pipe. This is where the dipole will attach with rope or wire (Figure 8a).
    ii) Drill > 1/4 in. hole 1 foot (30.5 cm) from the top of all 4 top sections. Drill completely through both sides. This is for the 1/4-in. eyebolts.
    iii) Drill > 3/8 in. hole through the end of each PVC endcap. These are for the 3/8-in. bolts for the feet (Figure 8b).

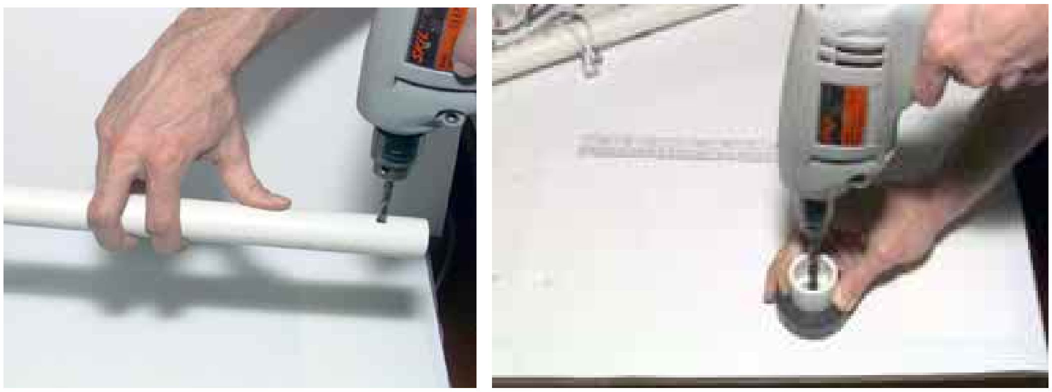


Figure 8a and 8b. Drill the PVC piping and end cap.

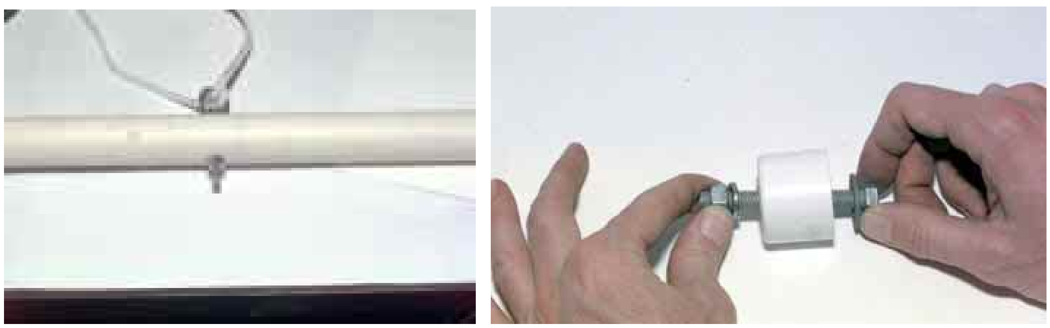


Figure 8c and 8d. Install the eyebolt and the 3/8 in. bolt into the end cap.

Figure 8e. Install the end cap foot onto the bottom section of the PVC pole.

3) O Attach 4 eyebolts and nuts to the PVC pipes at the hole drilled 1 foot (30.5 cm) below the top of the pole (Figure 8c).
4) O Install 4 3/8 in. bolts, washers, and nuts to the PVC endcaps to make the feet of the poles (Figure 8d).
5) O Firmly push on the PVC endcaps to one end of each bottom section of the poles (Figure 8e). [Note: Using glue to put on the endcaps is optional. The resistance alone is probably enough to hold them in place].
6) O Attach each 5-foot (1.52 m) section (top and bottom pole) together with the PVC coupler. Firmly press both poles into the coupler. [Note: Glue is again optional as the friction will hold the poles together. If you choose to glue the coupler in place ONLY GLUE ONE SIDE. The two sections of each pole must be able to be taken apart].
7) O Attach each end of one dipole antenna (the end insulator) to the top of one PVC pole through the hole drilled near the top. Attach using extra wire or rope and leave about 1 foot between the insulator and the top of the pole.

Field Setup

Antenna Configurations

The Radio Jove antenna can be installed in four different standard configurations – each configuration will produce a different antenna beam pattern in the sky. It is important that the antenna beam be aimed to the region of the sky where Jupiter or the Sun will be passing during the observation period.
The four standard configurations are:

1. In-phase East-West
2. Anti-phase East-West
3. In-phase North-South
4. Anti-phase North-South

The East-West or North-South terminology refers to the direction that the dipole antenna wires are running. For example in an East-West setup the wires of each dipole run from East to West.

In order to visualize the four different antenna patterns you should use Radio Jupiter Pro-Jove Edition software. This program is available on the Jove CD and also from the Jove website. The Radio Jupiter Pro (RJP) software includes a Sky Map view that shows both the track of Jupiter and the Sun across the sky and also a projection of the antenna beam pattern on the sky.

An RJP Sky Map display for each of the four antenna configurations is shown below. These examples, which show the path of Jupiter across the sky on January 1, 2002, were generated for a monitoring station located in Washington DC. The major tick marks along the track of Jupiter correspond to the location of Jupiter at hourly intervals. The best reception sensitivity occurs when Jupiter is inside of the oval(s) representing the antenna beam(s). The oval represents the half-power antenna beam contour – this means that the antenna is half as sensitive to signals at the edge of the oval as it is at the center. The antenna sensitivity (gain) decreases outside of the oval. Therefore, antenna performance is best at the center of the oval area with sensitivity decreasing rapidly outside the oval contour.

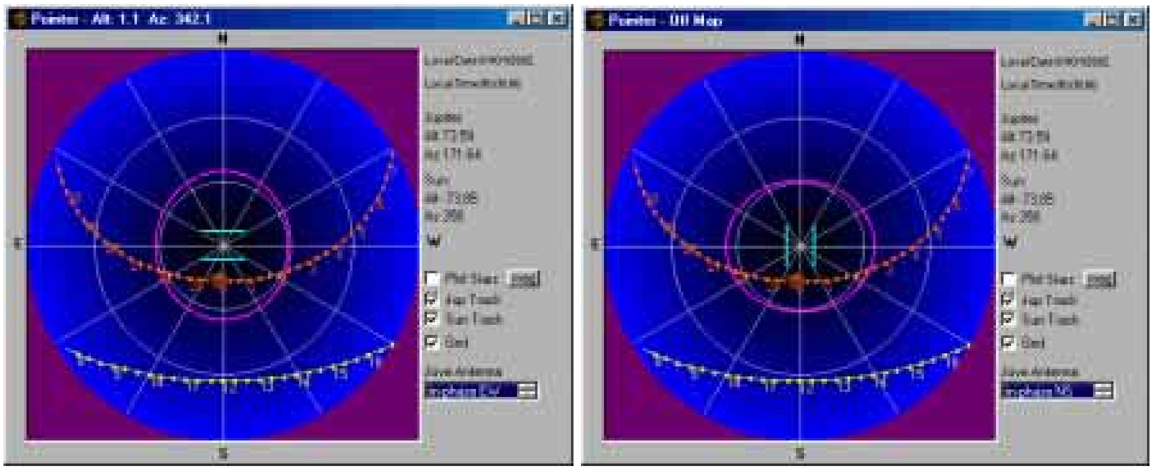


Figure 9a and 9b at midnight on January 1, 2002. 9a is setup in-phase EW and 9b is setup in-phase NS. Note that East and West are flipped because these views are looking up into the sky.

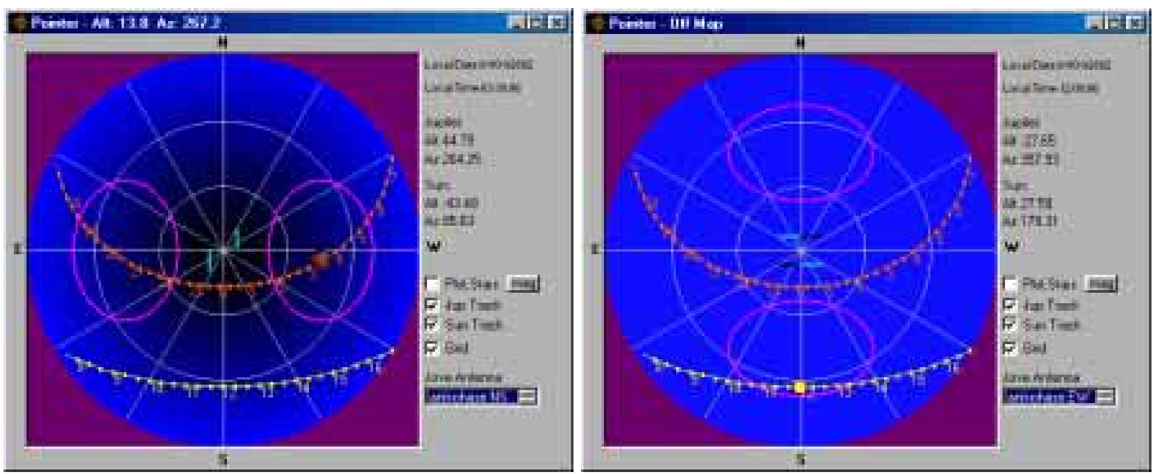


Figure 9c and 9d. Figure 9c is setup anti-phase NS at 03:30 on January 1, 2002. Figure 9d is setup anti-phase EW at noon on January 1, 2002. Note that Figure 9d is brighter than 9c because 9d is during the day, and 9c is at night.

The in-phase configurations produce nearly identical beams aimed directly overhead (Figure 9a, 9b). In both cases the beam is about 60 degrees wide – allowing for up to 4 hours of coverage if Jupiter or the Sun passes directly overhead thru the center of the beam.

The anti-phase configurations each produce two antenna beams up about 45 degrees from the horizon (Figure 9c, 9d). The East-West anti-phase beams are 45 degrees up from the North and South points (Figure 9d) while the North-South anti-phase beams are 45 degrees up from the East and West points (Figure 9c). The anti-phase configurations do not provide much sensitivity overhead.

Let’s assume that we want to listen to Jupiter at midnight local time on January 1, 2002 from our Washington DC station. Referring to Figures 9a and 9b we see that Jupiter is high in the sky and that either in-phase configuration will work. If we wanted to listen at 03:30 local time when Jupiter is in the western sky then the anti-phase NS configuration should be used (Figure 9c). High latitude observers (where Jupiter never passes directly overhead) may find that the anti-phase EW configuration is best with a beam up 45 degrees from the southern horizon. Solar observers can take advantage of the anti-phase EW configuration in the winter months to listen near local noon when the Sun is fairly low in the southern sky (Figure 9d).

Now that you understand how to select the best antenna configuration using Radio Jupiter Pro the next question is how to actually set up the antenna in each of these configurations. The key to this is understanding the feedpoint wiring. The feedpoint of each dipole is the center insulator where the coaxial cable is soldered. Recall that the coaxial shield is soldered to the dipole wire on one side of the insulator and the coax center conductor is soldered to the other wire. Think of the dipole wire connected to the center conductor as “hot” and the dipole wire connected to the shield as “cold”. It might even help to put a piece of colored tape on the “hot” wire of each dipole. Now consider the EW in-phase configuration. The hot side of each dipole must be on the same side of the insulators – it doesn’t matter if it’s the east side or the west side – but they must be on the <u>same</u> side. For the anti-phase EW connection one dipole will have the “hot” wire on the east end of the insulator and the other dipole will have the “hot” wire on the west end of the insulator. If you have the two dipoles set up in-phase and then flip one dipole end for end you will have the anti-phase connection. RJP shows the “hot” and “cold” antenna wires at the center of the Sky Map diagram with a light and dark color for the anti-phase setup but only a light color for the in-phase configuration.

Setting Up the Antenna

Find a clear location at least 30 feet on a side to erect the antenna. Moderately soft soil will make it easier to insert the antenna mast tips. Three or four people can make quick work of putting up the antenna. Be sure to avoid any location where there are low power lines that might come into contact with the Jove antenna.

If you plan on setting up your antenna on a rooftop or plan on using a longer than usual antenna feedline, please refer to the Site Considerations section on page 5.

Standard In-Phase Antenna Setup

1) O Lay out each dipole antenna flat on the ground with the ends of each dipole running in the EAST-WEST direction (Figure 10a). Separate each dipole by about 20 feet (6.3 m). When the antenna is completely setup, the dipole wires are parallel to the ground and the ends are running in an EAST-WEST direction. **IMPORTANT**: for correct phasing of the antenna, make sure that the feedpoint of each antenna is oriented in the same direction. That is, the side of the dipole that has the center conductor soldered to it MUST be pointed toward the same direction (EAST, for example).
2) O Using one 25 ft. (7.6 m) section of rope, loop it TWICE through an eyebolt (Figure 8c). Tie loops into each end of the rope.
3) O One person holds up the pole straight while one or two others attach the rope loops to the tent stakes and push them into the ground (Figure 10b). Push them in at an angle where the top of the stake faces away from the pole. Once the pole is in position, push the foot of the pole (protruding bolt) into the ground and then tighten the ropes.
4) O Repeat steps 2 and 3 for the other pole making sure the poles stay vertical. The PVC poles will flex and show some bending, but that is okay. Make sure that the guy ropes are secure enough that the wire antenna is roughly horizontal (not too much sagging). Do not tighten the guy wires too tight because this will cause undue stress on the dipole antenna.
5) O At a North-South distance of 20 ft. (7.6 m) from the first dipole, repeat steps 2-4 and set up the other half of the antenna. Make sure both antennas are parallel and are roughly facing in the EAST-WEST direction (See Figure 10). **NOTE**: setting up the antenna in a NORTH-SOUTH direction (in-phase) gives a similar beam sensitivity pattern (Figure 9a and 9b).

Anti-Phase Antenna Setup

1) O Let’s say the antenna is set up in the standard in-phase configuration (EAST-WEST)
2) O Take one of the two dipoles (it does not matter which one) and switch the support poles so that what was the EAST end of the wire is now the WEST end and vice-versa. In other word’s, rotate one of the dipoles setup position 180 degrees. Your antenna is now setup anti-phase EAST-WEST.
   IMPORTANT: The antenna sensitivity pattern now breaks into two oval areas centered 45 degrees down from the zenith and the line through the center of the ovals is perpendicular to the dipole wires (Figure 9c). **NOTE**: Setting up the antenna anti-phase NORTH-SOUTH is similar to anti-phase EAST-WEST and is achieved by repeating step 2 with the antenna setup NORTH-SOUTH instead of EAST-WEST (Figure 9d).

Figure 10a and 10b. Lay out each dipole on the ground. Set up one pole at a time.

Figure 10c and 10d. Set up the remainder of poles.

Figure 10e and 10f. Lori and Kia help set up the antenna.

Figure 10g and 10h. JOVE receiver setup with computer.

Figure 10i and 10j. JOVE receiver connections and setup with tape recorder.

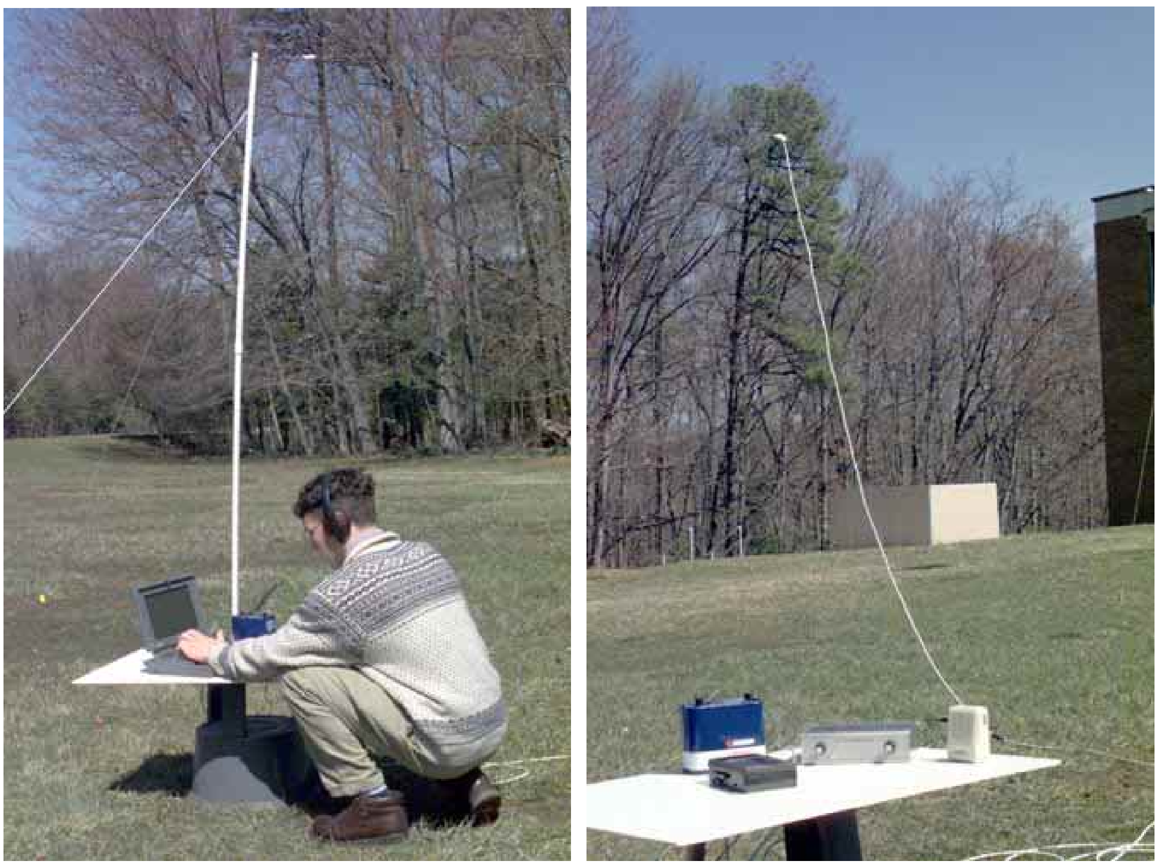


Figure 10k and 10l. Kia checks the equipment at NASA's Goddard Space Flight Center.

Figure 10m. Completed JOVE receiver and antenna setup.

Connect Cables to JOVE Receiver

1) O Connect the two coaxial feed lines to the power combiner on the twin-side by screwing on each F-connector to the threads of the combiner (Figure 9f).
2) O Connect the 1 λ coaxial cable (long coax) to the single-side of the power combiner.
3) O Connect the other end of the 1λ coax to the antenna input on the JOVE RJ1.1 Receiver.

NOTE: You should hear a significant increase in noise level when the antenna is connected to the receiver as compared to listening to the receiver with no antenna. If you do not hear this noise increase, then there is something wrong with either the antenna or the receiver.

CONGRATULATIONS! YOU HAVE JUST BUILT A RADIO TELESCOPE!