JOVE

RJ1.1 Antenna Kit

Assembly Manual

Radio JOVE

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Antenna Kit and Manual
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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.

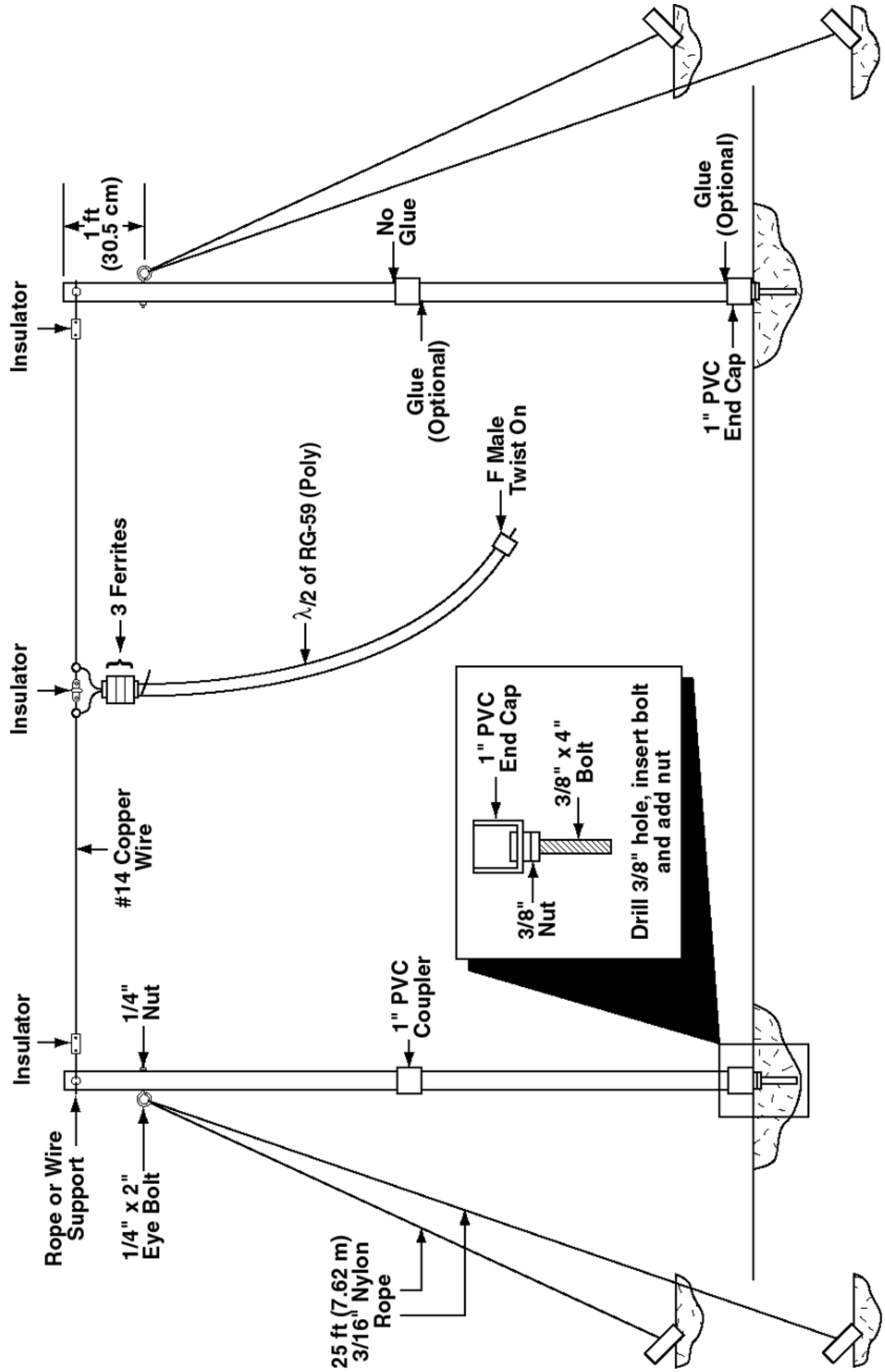
Site Requirements

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.

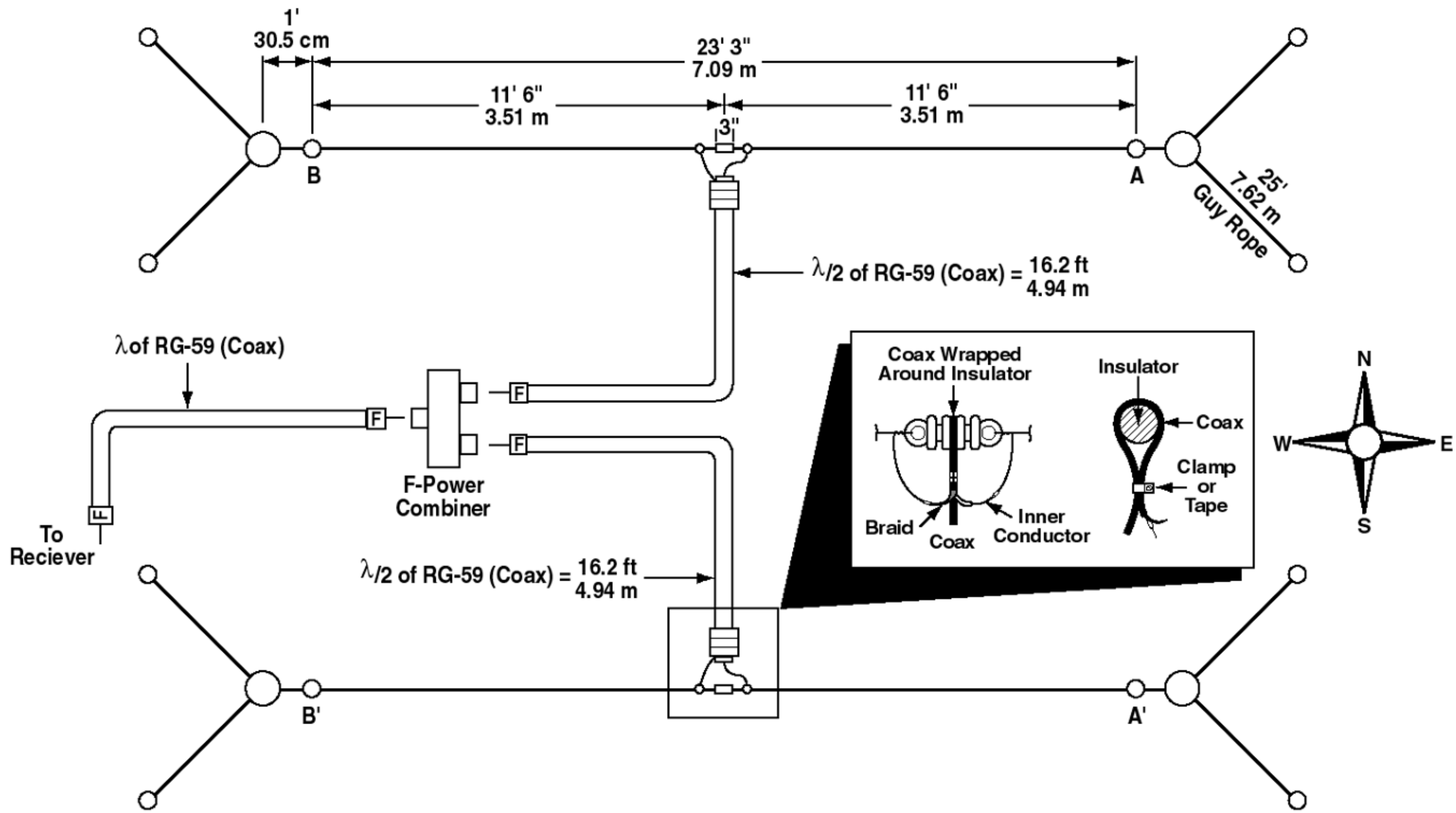
Construction Time Estimates

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 the length of 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 (RS 64-2070C)
Solder, 60/40, 0.050 in diameter rosin core (RS 64-006), or finer
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).

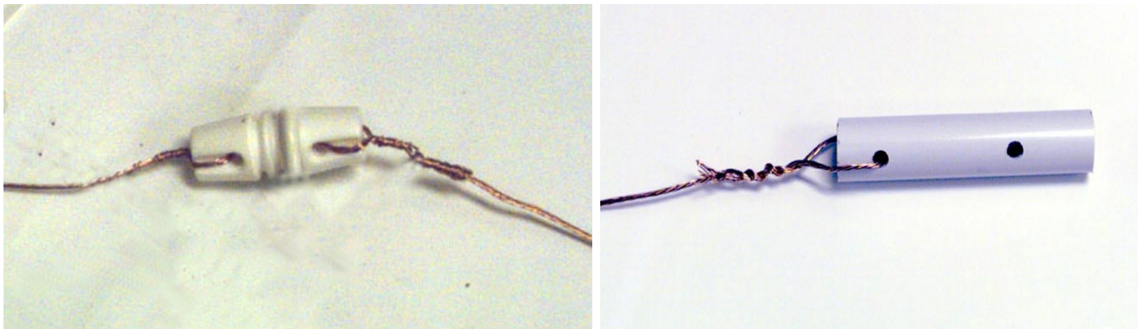


Figure 2a and 2b. Wrap the center and end insulators with the antenna wire.

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).

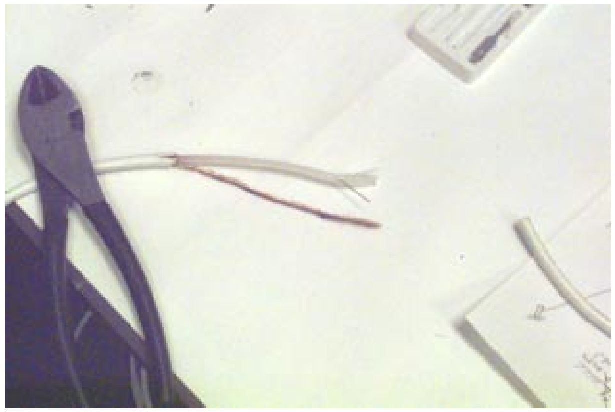


Figure 3c. Twist the copper shielding and expose the center conductor.

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. The center conductor is pretty strong so there is little worry that you will cut it.
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. 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.

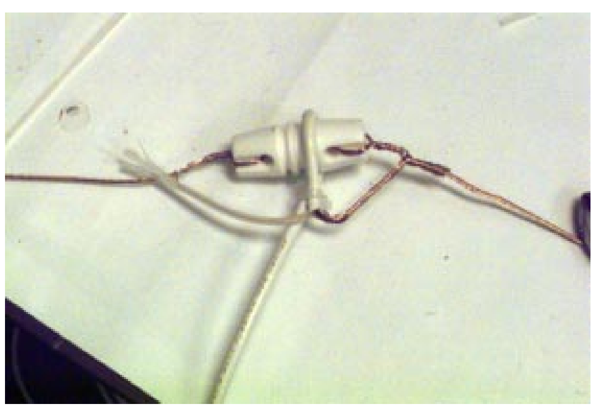


Figure 4. Tie wrap the coax over the center insulator. Wrap the center conductor around one side of the dipole and the twisted shielding around the other.

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.

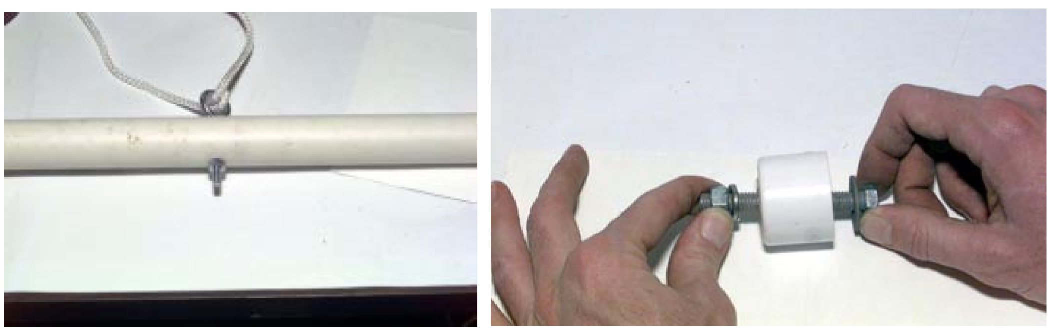


Figure 8c and 8d. Install the eyebolt and the 3/8 in. bolt into the end cap.

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

Setting up the Antenna

1) O Lay out each dipole antenna flat on the ground with the ends of each dipole facing in the EAST-WEST direction (Figure 9a). Separate each dipole by about 20 feet (6.3 m). When the antenna is completely setup, the dipole wires are HORIZONTAL to the ground and the ends are pointing in an EAST-WEST direction. **IMPORTANT**: for correct phasing of the antenna, make sure that each antenna is oriented 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 9b). Push them in at an angle where the top of the stake faces away from the pole. Once the pole is fairly secure, push the foot of the pole (protruding bolt) into the ground if possible. This will add stability.

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 9).

Figure 9a and 9b. Lay out each dipole on the ground. Set up one pole at a time.

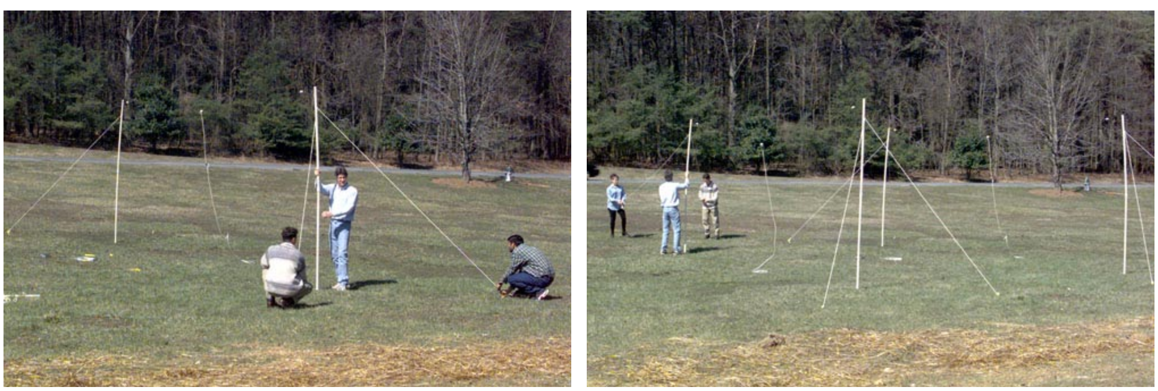


Figure 9c and 9d. Set up the remainder of poles.

Figure 9e and 9f. Lori and Kia help set up the antenna.

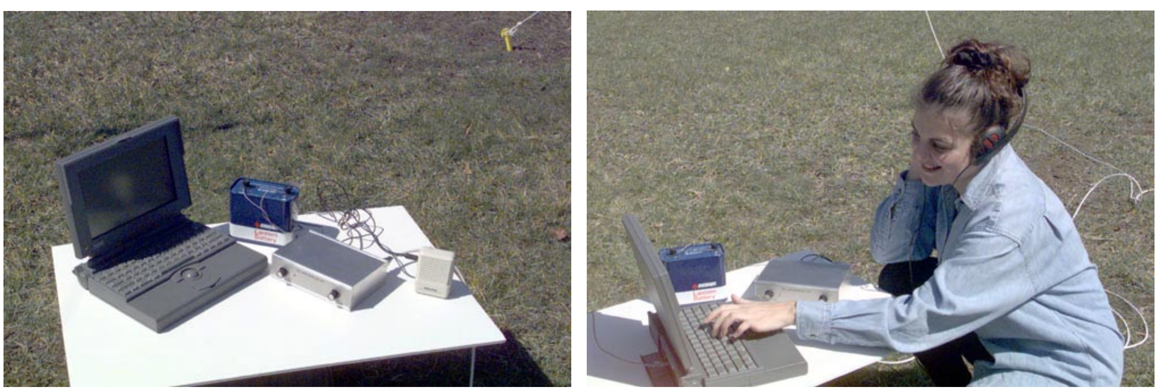


Figure 9g and 9h. JOVE receiver setup with computer.

Figure 9i and 9j. JOVE receiver connections and setup with tap recorder.

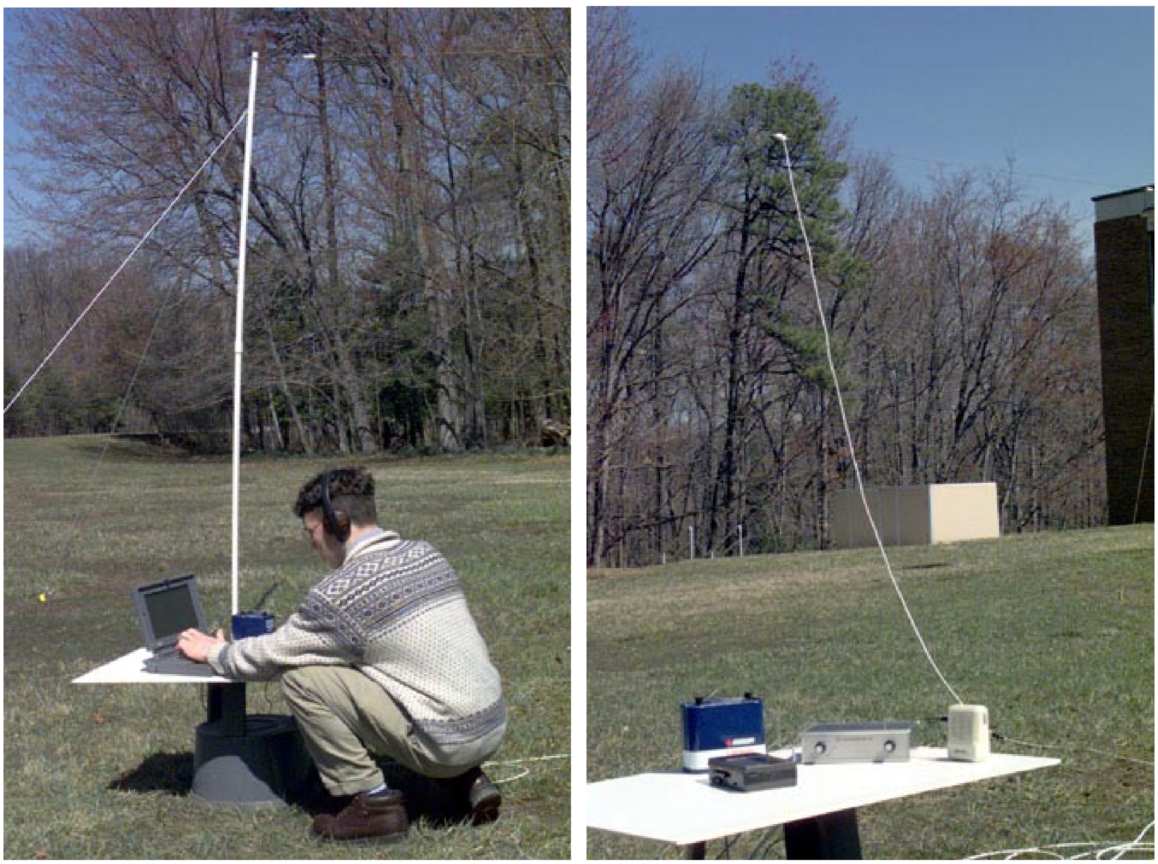


Figure 9k and 9l. Kia checks the equipment at NASA's Goddard Space Flight Center.

Figure 9m. 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.

CONGRATULATIONS! YOU HAVE JUST BUILT A RADIO TELESCOPE!