Radio JOVE

RJ1.2 Antenna Kit
Assembly Manual
December 2004

Antenna Kit and Manual
Developed for NASA Radio JOVE Project
by
The Radio JOVE Project Team

Contents

Jove Antenna Manual

RJ1.2

December 2004

1. Introduction

This manual describes an improved version of the original Jove antenna. The original antenna, called the RJ1.1, was introduced in 1999. It was mounted 10 feet above ground and designed to observe when Jupiter was passing high in the sky, close to overhead. Between 2005 and 2010, Jupiter will be at southern declinations, appearing lower in the southern sky for observers in the northern hemisphere. The new Jove antenna (RJ1.2) can be setup to "look" toward southern skies. Using many of the parts of the original Jove antenna, the new RJ1.2 design uses height above ground and a phasing cable to steer the antenna beam toward Jupiter.

1.1 Basic Antenna Theory

A radio antenna is like an optical telescope in that it intercepts energy from an electromagnetic wave. It converts that energy into an electrical signal at the antenna terminals. This weak radio frequency signal is fed from the antenna thru a transmission line to the radio receiver.

If you took a cheerleader's megaphone and held the small end to your ear you would find that it magnifies sounds from certain directions. Antennas have these same properties – the antenna has *gain* (it amplifies signals) and it has a <u>beaming pattern</u> (it amplifies signals best coming from certain directions). For a given frequency, the larger the area of the antenna the more energy it collects, and the more gain it has. The higher the gain of an antenna, the narrower the beam will be.

1.2 Frequency and Wavelength

A radio wave is an electromagnetic wave traveling through the vacuum of space at the speed of light. Two important characteristics of the wave are its *frequency* and its *wavelength*. The frequency of the wave is the number of cycles that occur each second, and the wavelength is the distance that the wave travels during one cycle. The frequency (f), wavelength (λ – Greek symbol lambda), and speed of light (c) are related by a simple equation:

$$\lambda=c/f \qquad [1]$$

If the speed of light is given in meters per second ($3x10^8$), and the frequency in hertz (Hz), then the unit for wavelength is meters. Our Radio Jove antenna operates at a frequency of 20.1 megahertz (MHz). The free-space wavelength is therefore:

$$\lambda = 3x10^8/20.1x10^6 = 14.925 \text{ meters}$$

Some folks still visualize dimensions better in feet than meters. Since there are 3.28 feet per meter the wavelength at the Jove operating frequency is 48.955 feet.

The formula relating free-space wavelength in feet (meters) to frequency (in MHz), and the speed of light is:

$$\lambda_{ft} = 984/f_{MHz} \qquad (\lambda_m = 300/f_{MHz}) \qquad [2]$$

1.3 The Dipole Antenna

One of the simplest antennas is called a dipole. It can be made from two pieces of wire and three insulators (figure 1). The length of a dipole antenna using infinitely thin wires is exactly half a wavelength ($\lambda/2$). Much like an organ pipe is cut to a specific length to make it resonant for a particular frequency of sound, our dipole antenna is cut to a length of half a wavelength to make it resonant at the frequency of 20.1 MHz. Since we are using real wire that is not infinitely thin we have to take into account some real world effects that shorten the actual antenna (these are called capacitive end effects).

The formula for the length of a **real world half-wavelength dipole** antenna in feet (meters) is:

$$\lambda/2_{ft} = 468/\ f_{MHz} \qquad (\lambda/2_m = 142.65/f_{MHz}) \qquad [3]$$

A dipole cut for 20.1 MHz has a length of 23.28 ft (23' 3" or 7.09 m) as measured from tip to tip of the wire.

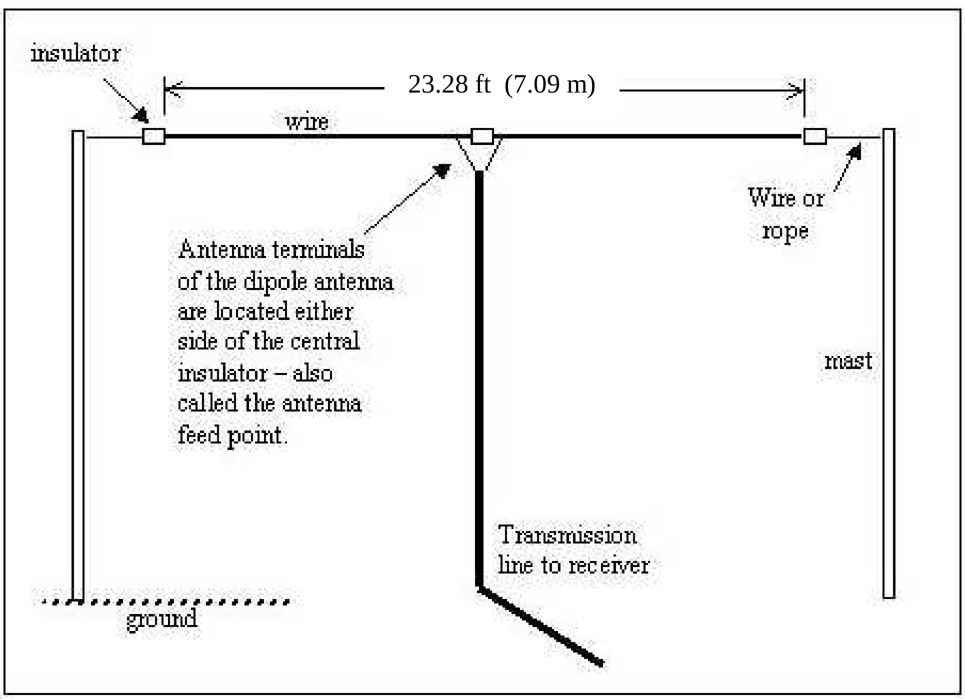


Fig.1.1. The dipole antenna cut to be resonant at the Jove frequency of 20.1 MHz.

1.3.1 Dipole Antenna Terminals

Antenna terminals (also called the antenna feed point) are where you connect a transmission line to deliver signals from the antenna to the receiver. In the case of a dipole, the feed point is located at either side of the central insulator – its where the two wires making up the transmission line connect to the two dipole wires.

1.3.2 Transmission Line

The transmission line used in the Radio Jove project is called coaxial cable (figure 1.2). It's the same type of cable that you probably have connected to your TV set – about as big around as a pencil with a central wire surrounded by a white insulating material (dielectric) inside of a braid covered with another layer of insulation.

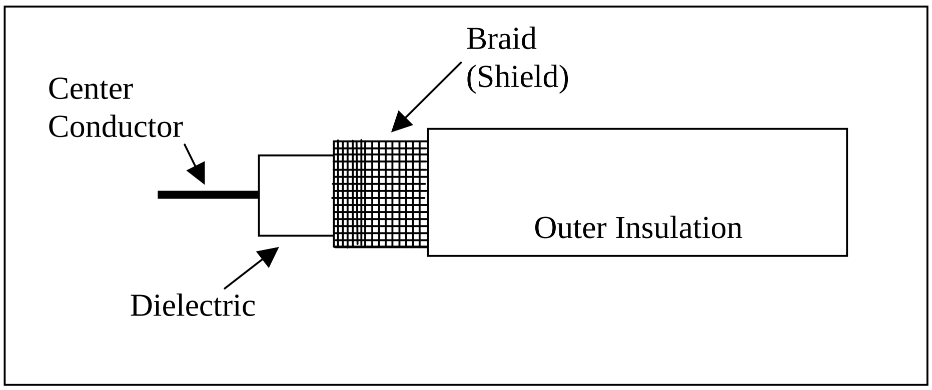


Fig.1.2. Coaxial transmission line (coax), showing the layers of wire and insulation.

The coax cable has two wires – the center conductor and the shield, which is either braided copper wire or a thin metallic sheath. Signals are conducted along the center conductor and on the inside of the braid. Several characteristics are important in describing coaxial cable. These include:

Impedance – measured in ohms and determined by the internal dimensions and geometry of the cable. The coax used in the Jove antenna has an impedance of 75 ohms.

Attenuation – a measure of how much signal is lost due to wire resistance and dielectric losses in the transmission line. Less loss is better. Attenuation varies with frequency and is typically measured in decibels (dB) per hundred feet of cable. A loss of 3 dB means half the power that enters the cable is lost before reaching the other end. This is about the maximum loss that can be tolerated between the Jove antenna and receiver. The coax cable provided with the Jove kit is manufactured by Belden Company (their type 8241) and is designated as RG-59/U. At 20.1 MHz it has a loss of 1.5 dB per 100 ft, which means that when using this cable the maximum recommended separation between the antenna and the receiver is about 200 feet.

Velocity Factor (Vf)– a measure of the speed of an electrical signal moving through the cable. The velocity factor is given as a percent of the speed of light in vacuum. RG-59/U has a velocity factor of 0.66, meaning that signal velocity is 66% of the speed of light. Several cables in the Jove antenna system are described in terms of wavelength, so we need to know the wavelength of a 20.1 MHz signal traveling through RG-59/U. The wavelength of a 20.1 MHz wave in free-space is 48.955 feet. The wavelength in RG-59/U equals the free-space wavelength times the velocity factor (48.955 x 0.66) = 32.31 feet. [The equation reads: $\lambda_{cable} = Vf \times \lambda_{freespace}$]

1.4 Antenna Patterns

Every antenna has a directional pattern – that means that it responds better to signals coming from certain directions. It is easy to imagine a conical shaped beam extending outward from a megaphone or a flashlight. Receiving antennas have similar beams that must be aimed toward the source of the signals that you are trying to receive. Fortunately, in the case of the Jove antenna the beam is tens of degrees wide so precise aiming is not required.

1.5 JOVE RJ1.2 Dual Dipole Array

The Jove antenna array uses two dipole antennas (figure 1.3). This configuration achieves twice the gain (signal amplification) of a single dipole and also allows us to steer the antenna beam to a desired region of the sky.

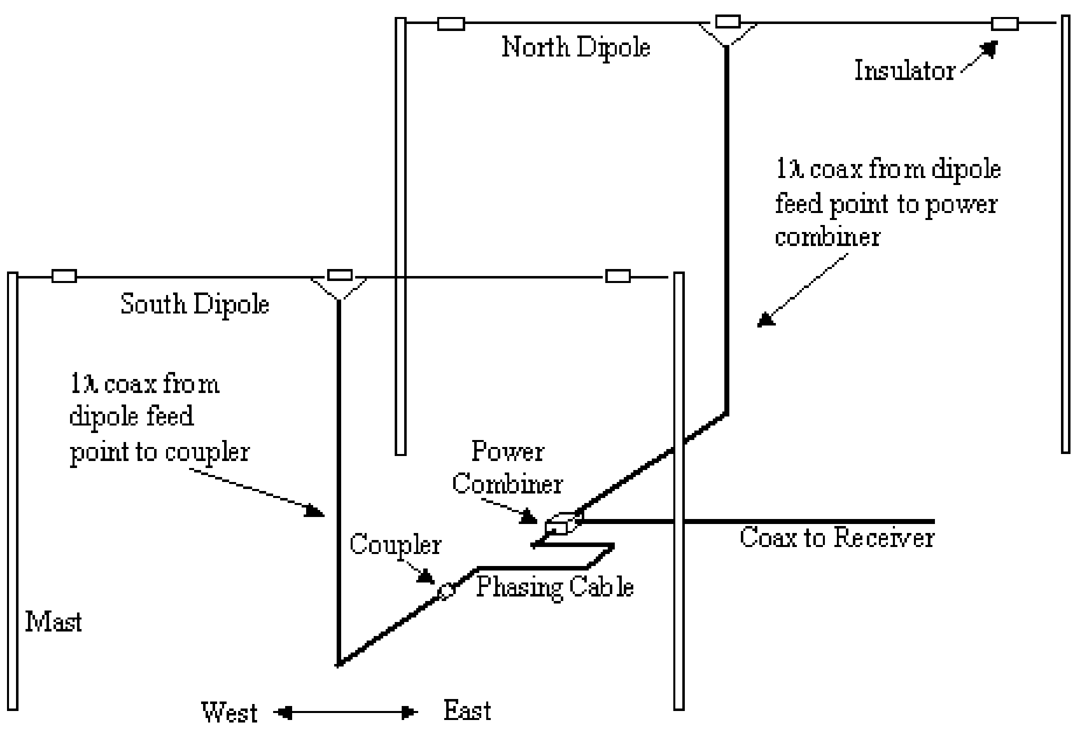


Fig. 1.3. The Jove dipole system setup with the dipole wires running East-West.

This two-dipole array is designed for use in the northern hemisphere. In the basic configuration with the dipole wires running East-West, the antenna beam will look toward southern skies. Coax transmission lines connect each dipole to a power combiner. The combiner adds the signals from the two dipoles together and feeds them to the receiver. Notice that there is an extra length of coax called a *phasing cable* between the south antenna and the power combiner. Not counting the phasing cable, the transmission lines from each antenna to the power combiner would be the same length (1 λ_{cable}).

The direction of the antenna beam is determined by the length of the phasing cable and the height of the dipole wires above ground. As Jupiter moves south over the next several years many northern hemisphere observers will find, that for optimum performance, they should change the height of the antenna. Fortunately these changes will only have to be made about once a year. The phasing cable length has been optimized to allow beam changes to be made by changing the antenna height. The only way to get the antenna beam down close to the southern horizon is to raise the antenna.

1.6 Jupiter's Position in the Sky

We are all familiar with seasonal changes in the Sun's track across the sky. In summer the Sun passes high overhead in the northern hemisphere while in winter it is lower in the southern sky. Using the equator as a reference, the north or south position of a celestial body is known as its *declination*. Jupiter's declination goes thru changes similar to the Sun, but it takes nearly 12 years for a complete cycle (figure 1.4).

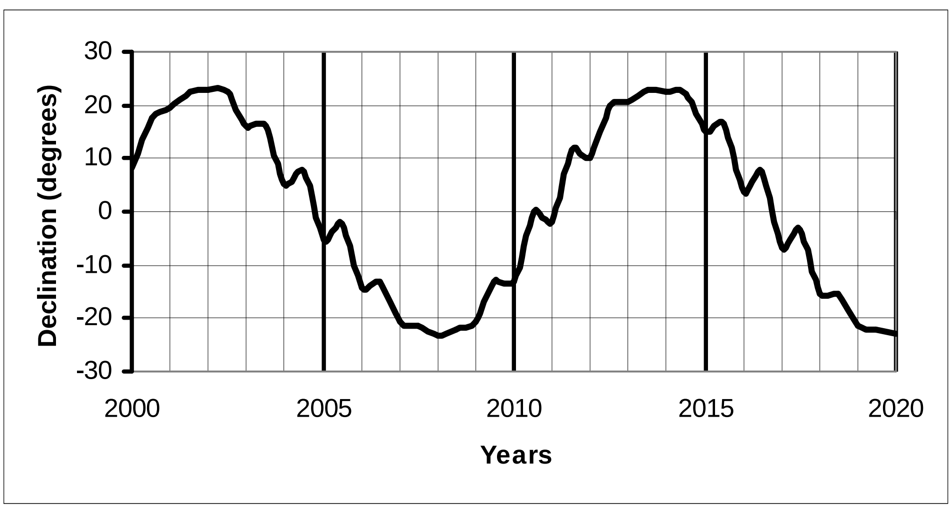


Fig. 1.4. Jupiter's declination changes each year. During 2002 it reached its maximum northern declination. In 2008 Jupiter will be at its maximum southern declination.

1.7 Maximum Elevation Angle vs. Year, and Observer's Latitude

Jupiter's declination directly effects how high it will appear in the sky. The highest point in Jupiter's daily track across the sky occurs at *transit.* Transit is when a celestial body is crossing the observer's meridian, when the object is on the observer's longitude. The maximum elevation angle (angle measured upward from the southern horizon) of Jupiter depends on the declination of Jupiter and the latitude of the observer. The further north an observer is located, the lower in the southern sky Jupiter will appear. Figure 1.5 shows Jupiter's elevation for observers at different northern latitudes for the next several years.

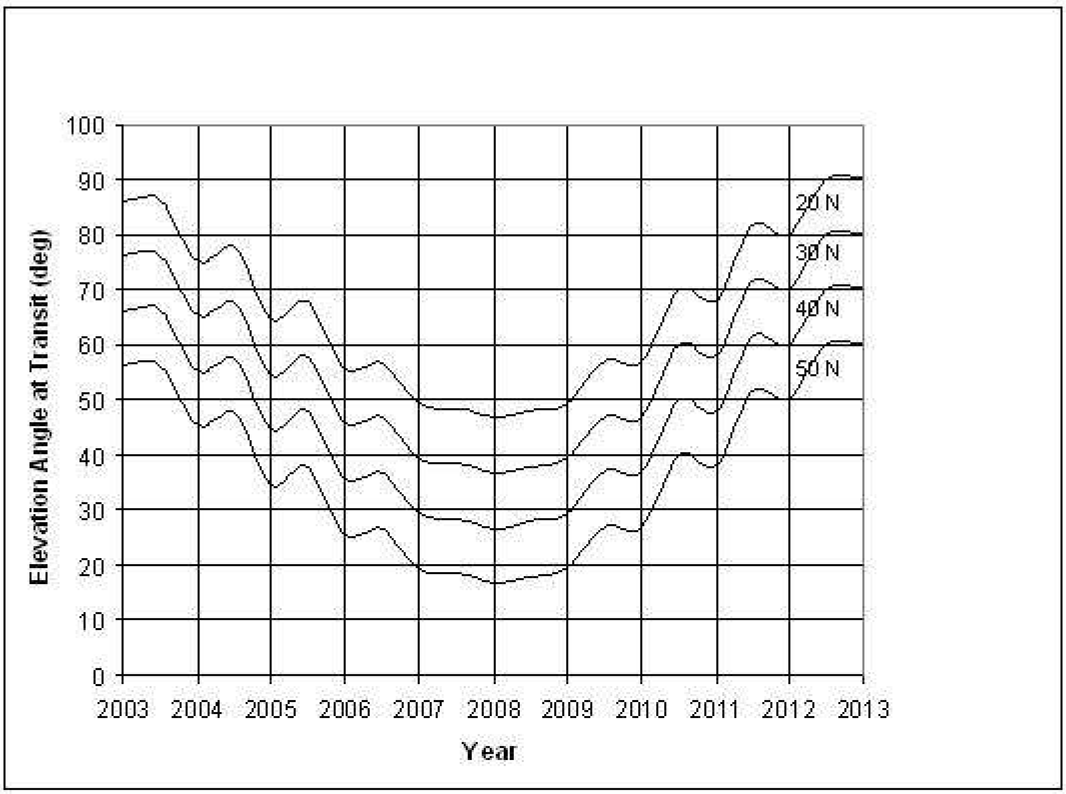


Fig. 1.5. Elevation angle of Jupiter at transit for observers at different northern latitudes from 2003 to 2013. The year label is beneath the gridline for Jan 1 of the indicated year.

Suppose you live at 40 degrees N latitude, say in Denver or Philadelphia or Madrid. At the beginning of 2005 Jupiter will reach 45 degrees above your southern horizon. In January of 2007 Jupiter's maximum elevation angle will only be 30 degrees. Understanding how to read this graph is important. You will use it to determine the best height of your Jove antenna.

1.8 It's As Easy as 1, 2, 3

Enter information from the following steps into Table 1.

STEP 1: Find your latitude (accurate to +/- a couple of degrees is good enough). The map in figure 6 may help North American observers.

STEP 2: Pick the year(s) you are interested in making observations.

STEP 3: Estimate the average elevation angle of Jupiter based on your latitude and the year using figure 1.5.

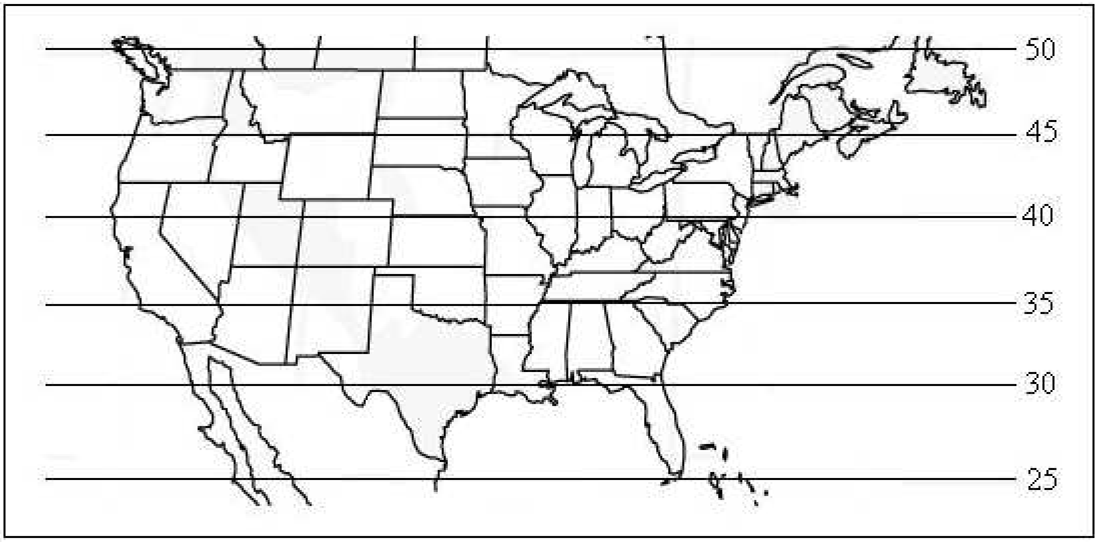


Fig.1.6. Partial map of North America showing north latitude gridlines.

Latitude ___________

Year	Jupiter Elevation

Table 1.1. Jupiter's average elevation angle for your latitude.

Now that you know how high Jupiter will be it is time to select the best antenna configuration using the information in Table 2. Just match-up the elevation angle you entered in Table 1 with the range of Jupiter elevation angles in Table 2 and read off the height of the Jove dipoles above ground

Jup Elev (deg)	Height above Ground
20-40	20 ft (6.10 m)
40-55	15 ft (4.57 m)
55-70	10 ft (3.05 m)

Table 1.2. RJ1.2 optimum antenna height vs. elevation of Jupiter at transit.

An Example

Suppose that you live in Philadelphia at 40 degrees N latitude and want to observe Jupiter late in the spring of 2005. From Figure 5 you determine that Jupiter's elevation angle will be about 48 degrees. Looking in Table 1.2 for an elevation angle of 48 degrees you see that you should use an antenna height of 15 feet. This is the best configuration for your antenna for this particular elevation.

To make observations during 2007 (when Jupiter will be at 28 degrees elevation) our Philadelphia station should raise the antenna to 20 feet for best performance.

Remember however that the beaming pattern of your antenna is quite broad. This means that the antenna will still work even if it isn't at exactly the optimum height – signals just won't be quite as strong. Actual antenna beaming patterns are presented in Appendix A for those of you that wish to see more details.

Now that you have decided upon the proper antenna configuration for your latitude, and the year of observations, use this information to fill out Table 3. Then it's time to go on to the next section and learn how to build the Jove RJ1.2 dual dipole array.

YEAR	Antenna Height

Table 1.3. RJ1.2 antenna height vs. year.

2. Pre-Assembly Antenna

The wire and coax parts of the Jove antenna system are the same, regardless of how high the antenna is located. Fabrication of the individual dipoles and coax cables will be treated first and then options will be presented for mounting the dipoles at different heights (see Section 4 and 5).

2.1 Site Requirements and Considerations

The area occupied by the antenna requires at a minimum a reasonably flat 30 ft N-S by 45 ft. E-W area that has soil suitable for putting stakes into the ground. Since the antenna is sensitive to electrical noise it is best not to set it up near power lines or close to buildings. **For safety reasons, keep the antenna away from power lines during construction and operation**. The best location may be a sports field or a rural setting. Since Jupiter 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.

The Jove antenna is supplied with a 0.5λ (16.16 ft) cable to run from the power combiner to the receiver. If you want to use a longer coax cable it should be a multiple half wavelength long. The maximum recommended cable length is 5 wavelengths. If you need additional cable then it must be purchased from Radio Shack or some other electronics distributor. 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 half wavelength piece - rather than coupling another length of cable onto the end. Type F connectors are not interchangeable between RG-59 and RG-6. For RG-6 cable use Radio Shack 278-0228 connectors (or 278-0236).

λ_{cable} in wavelengths	RG-59/U feet (m)	RG-6 or QS feet (m)
0.5	16.16 ft (4.93 m)	19.09 ft (5.82 m)
1	32.31 ft (9.85 m)	38.18 ft (11.64 m)
2	64.62 ft (19.70 m)	76.36 ft (23.28 m)
3	96.93 ft (29.55 m)	114.55 ft (34.82 m)
4	129.24 ft (39.40 m)	152.39 ft (46.46 m)
5	161.55 ft (49.25 m)	190.57 ft (58.10 m)

Table 2.1. Cable lengths for RG-59/U and RG-6 accounting for the velocity factor.

If you have no clear open space on the ground to erect the antenna then it may be worth trying it on a flat rooftop. However, we offer a fair warning that the antenna pattern may be seriously affected by the lack of a good ground plane, and nearby air conditioning units and other motors may generate undesirable electrical noise. A rooftop antenna may also be more susceptible to lightning and should always be disconnected when not in use.

Disconnect the Jove antenna when not in use - particularly during lightning season.

2.2 Construction Time Estimates

Wire and Coaxial Cable Construction	2 hours
Antenna Mast Fabrication	1 hour
Antenna site layout	1 hour
Field Setup and Testing (first time)	1.5 hours
Approximate Total Time	5.5 hrs.

Table 2.2. Construction Time Estimates

2.3 Antenna Components

The antenna is composed of copper wire, coaxial cable, connectors, insulators, toroid cores, a power combiner, rope, support masts, and hardware.

Figure 2.1a and 2.1b. Antenna Parts for the standard 10 ft. antenna.

Copper Wire is used for the dipole elements. You will build two identical half-wave dipole antennas. The tip-to-tip length (Figure 5.2) of the dipole wires is 23.28 ft.

Coaxial Cable (coax) is used to feed the signal from the dipoles to the receiver. The kit is supplied with RG-59/U coax with a velocity factor of 0.66. The lengths of cables used in the Jove antenna system are tabulated below (Table 2.3).

Antenna Part	Number of cables needed	Cable length in wavelengths	Cable length
Cable from dipole	2	1 λ	32.31 ft. (9.85 m)
Phasing cable	1	0.375 λ (135 deg)	12.12 ft. (3.69 m)
Cable to Receiver	1	0.5 λ	16.16 ft. (4.93 m)

Table 2.3. Coax cable lengths for RG-59/U cable (velocity factor 0.66).

F-Connectors are used to connect coax cables to the power combiner and to the antenna input of the JOVE receiver.

Insulators support the antenna wires while isolating the received signals from ground. Six insulators are used for the antenna, one at the feed point in the middle of each dipole, and one on each end. Insulators are usually plastic or ceramic cylinders with holes for the wire and rope supports.

Toroid cores slipped over the coax cable near the feedpoint restrict current flow on the outer surface of the coaxial shield and help to improve antenna performance.

A Power combiner adds the signals from each dipole antenna together. The combined signals are then fed to the receiver.

Support masts support the dipoles. Metal, wood or PVC may be used. PVC tubing is inexpensive and lightweight but requires more guying than metal tubing.

Rope is used as guy lines for each support mast.

Hardware in the form of bolts and nuts are used to connect and anchor various parts of the antenna. Bolts are used as foot pegs to help keep the masts in place and eyebolts are used to help attach the guy lines to the masts. For long outdoor exposure stainless steel hardware is desirable, although it is more expensive than plated steel (See Tables 4.1 and 4.2).

2.4 Tools

Soldering Iron (RS 64-2071 – 40Watt) 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
Lighter
Tape measure (at least 25 ft. is best)
Black Marker
Small flat screwdriver
Crescent Wrench
Pliers
Drill with 1/8 in., 1/4 in., and 3/8 in. drill bits

2.5 Radio JOVE Antenna Kit Parts List

#	Parts included in the Radio JOVE Antenna Kit Description	Parts Checklist
1	50 ft. (15.24 m) #14 Gauge Bare Copper Wire (7-stranded)	
1	95 ft. (29 m) RG59U Coaxial Cable (Belden 8241)	
4	PVC End Insulators (cylinders)	
2	Plastic Center (dogbone) insulators	
6	Twist-on F-connectors	
1	Coaxial cable coupler	
1	Power combiner / splitter (2-to-1)	
6	Ferrite toroid cores	

Table 2.4. Antenna Parts List

Additional parts are required to fabricate the Jove antenna – these support structure parts depend upon the height of the antenna and the type of mast to be assembled. Parts lists are included in manual sections (4.1-4.2) dealing with antenna masts. The estimated PVC antenna mast costs = $75; the estimated metal antenna mast costs = $100.

3. Wire and Coaxial Cable

Regardless of the height of your antenna the wire and coax portions are identical.

3.1 Cutting the Wire and Coax

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

Use the O markers to check off each step as you complete it.

1. O Cut 4 pieces of copper wire each to a length of 12 ft. 4 in. (3.76 m). This length includes 5 inches extra on each end for attaching to the insulators.

2. O Using dimensions from Table 2.3 cut 4 lengths of the coaxial cable.

3. O Cut two lengths of rope, each 2 ft. (0.61m). Melt the ends with a lighter to keep the end from fraying.

3.2 Wrapping the Insulators

1. O Attach an end insulator to each wire. Thread 5 in. (12.7 cm) of copper wire through the hole in the end insulator and wrap it back on itself as seen in Figure 3.1a.

2. O As seen in Figure 3.1, thread each rope through the end insulator. Tie one end of each rope to an end insulator (use 6 in. of rope for each knot).

3. O Attach the pairs of wires to the center (dogbone) insulator. Thread 5 in. (12.7 cm) of copper wire through the hole in the center insulator and wrap the wire back on itself as seen in Figure 3.1b.

4. O As seen in Figure 5.2, the total length of the dipole wires (from one end insulator to the other end insulator) should be 23 ft. 3 in. (7.09 m). Ropes should extend about 1.5 ft (45 cm) from each end insulator.

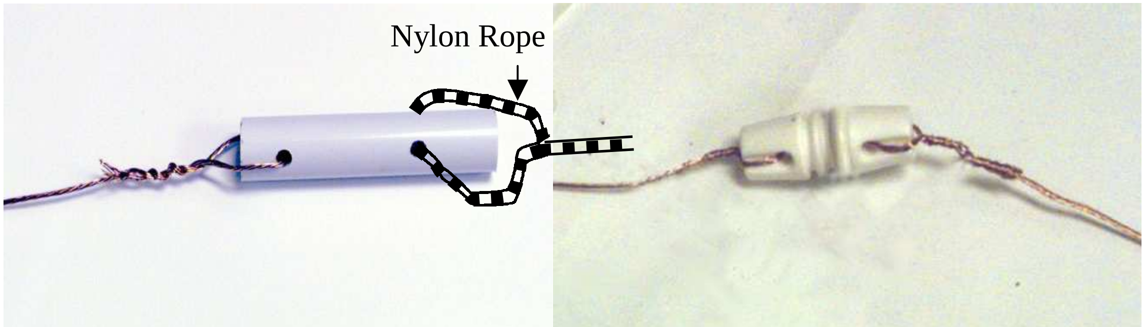


Figure 3.1a and 3.1b. Wrap the center and end insulators with the antenna wire.

3.3 Preparing and Soldering the 1 λ Coax lines

1. O Strip back (remove) the outer covering about 4 - 5 inches (10 - 12 cm) from ***one end only*** of each of the 1λ cables. [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 3.2a and 3.2b). A few broken strands of braid are normal.

Figure 3.2a and 3.2b. Unbraid the copper shielding.

3. O Twist all the individual wires together to form one continuous wire (Figure 3.2c).

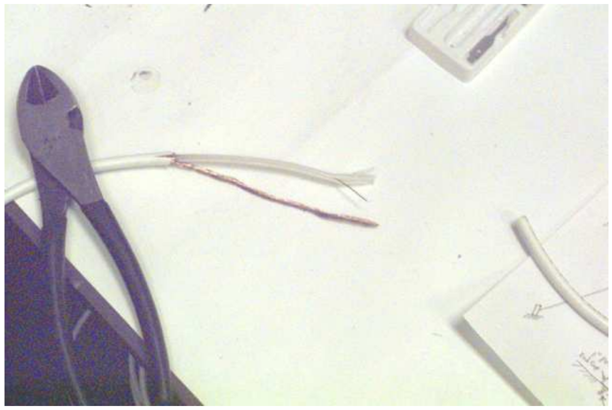


Figure 3.2c. Twist the copper shielding and expose the center conductor.

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 sharp knife with caution. **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.

5. O Loop the coaxial cable over the center insulator and tie wrap or tape it (Figure 3.3) 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 (see Figures 3.3 and 3.4).

7. O If necessary, clean the ends of the wire with sand paper. Solder the coax center conductor and shield to the copper wires (we recommend using a soldering gun). Use plenty of solder and heat the wires until you see the solder seep into the wires. Check all around the wire to make sure the connection is good (Figure 3.4).

8. O Repeat for the other dipole.

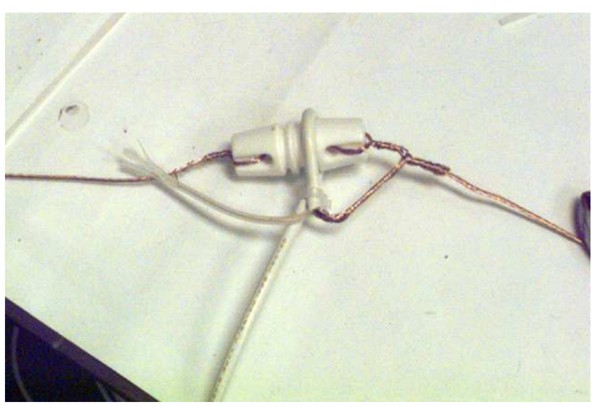


Figure 3.3. Tie wrap the coax over the center insulator. Wrap the center conductor around one side of the dipole and the twisted shielding around the other.

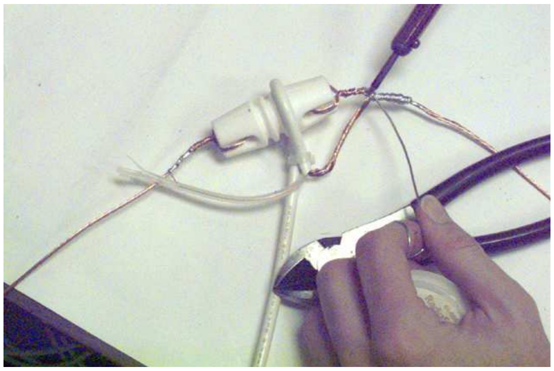



Figure 3.4. Solder the shielding and center conductor to the copper wires.
Figure 3.5. Install the ferrite toroid cores.

3.4 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 3.5).

2. O Install the F-connector on the coax feed line to each dipole. To install, remove about 1 inch (2.5 cm) of the outer coax casing (Figure 3.6a).

3. O Carefully unbraid about half of the exposed shielding about 1/2 inch (1.25 cm) and fold it back over the other half of the copper shielding and over the outer casing (Figure 3.6b).

4. O Remove the insulation around the center conductor leaving about 1/2 inch (1.3 cm) of bare center conductor (Figure 3.6c, 3.6d).

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 3.6e).

6. O Repeat this connector installation procedure for each end of the phasing cable and for the 0.5λ cable, which will run to the receiver.

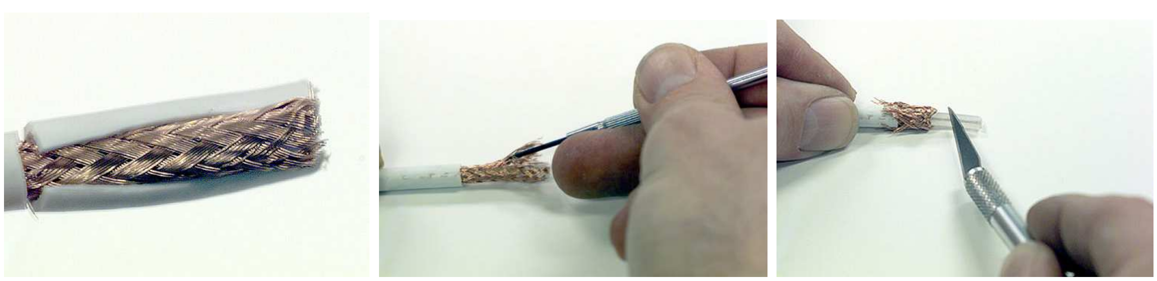


Figure 3.6a – 3.6c. Prepare the coax and install the F-connector.

Figure 3.6d – 3.6e. Prepare the coax and install the F-connector.

4. Antenna Mast Assembly

Section 1 of this manual described how to select the antenna height based on your latitude and Jupiter's elevation. The wire and coax portion of the antenna is the same for each height. There are 3 choices of antenna height: 10, 15, and 20 ft. The next sections of the manual describe two different antenna mast options.

4.1 PVC Masts – more guy ropes, less rigid (approximate cost for all parts $75)

4.2 Metal Masts – fewer guy ropes, more rigid (approximate cost for all parts $100)

4.1 PVC Masts

Parts needed for Antenna Mast Assembly		Parts Checklist
#	Description	
1	300 ft. (30.48 m) x 3/16 in. Nylon Rope	
4	10 ft. (3.048 m) x 1 in. PVC Sch40 pipes (White)	
4	10 ft. (3.048 m) x 1¼ in. Non-metallic Conduit pipes (Gray)	
4	1¼ in. Non-metallic Conduit End Caps	
12	4 in. x ¼ in. Eye Bolts	
4	4 in. x ¼ in. regular Bolts (Stop Bolts)	
16	¼ in. Nuts/Lock washers	
4	4 in. x 3/8 in. Bolts (for end caps)	
4	3/8 in. Nuts, Flat Washers, and Lock Washers (for end caps)	
10	Ground Spikes (or tent stakes)	
6	6 in. black Tie wraps (optional)	

Table 4.1. PVC Antenna Parts List.

PVC Mast Assembly (Refer to Figures 4.1, 4.2 and 4.3)

1. ❑ The dipole mast assembly consists of a 10 ft bottom section (1.25 inch gray electrical conduit, schedule 40, PVC) and a 10ft top section (1 inch white schedule 40 PVC). The 10, 15, and 20 ft antenna heights are achieved by telescoping the top mast up or down inside the bottom mast. Overall antenna heights may vary a few inches (or cm); this is perfectly acceptable.

2. ❑ **Drill all holes through the masts at ¼ inch diameter.** The hole through the end-cap for the spike is 3/8-inch diameter. All holes in the masts should be in the same plane (i.e. not rotated around the mast pipe). A hammer and punch (or nail) can be used to make a starting point for drilling. A pilot hole using a 1/8 in drill bit is recommended. Eyebolts and regular bolts should be secured using a flat washer, lock washer and a nut.

3. ❑ Draw a guide line the length of the top mast to insure that all holes line up. (You can draw this line by laying the mast on the floor and moving the side of the pen along the floor). Using the guideline, drill holes (A and B) through the top mast.

Figures 4.1a and 4.1b. Drill the PVC piping (¼ in. drill bit) and end cap (3/8 in. bit).

4. ❑ Draw a guide line from the top to the midpoint of the bottom mast. Using the guideline for orientation, drill holes (E and F) through the mast. Secure the stop bolt in hole (F).

5. ❑ With the guide lines on the two mast sections aligned, insert the top mast 6 inches into the bottom mast section. Using hole (E) as a guide, match-drill a hole though the top mast section – this becomes hole (D). The best way to match-drill the holes is to drill the mast from each side – using hole E as a guide. Then without moving the two masts relative to each other, run the drill all the way through both masts.

6. ❑ With the guide lines on the two mast sections aligned, push the top mast section into the bottom mast section until it hits the stop bolt at (F). Using hole (E) as a guide, match drill a hole though the top mast section – this becomes hole (C).

7. ❑ Secure an eyebolt in hole (B).

8. ❑ Assemble and attach the bottom cap and spike. (Glue optional)

9. ❑ Repeat assembly steps above for the remaining masts.

10a. ❑ For the 20 foot antenna assembly, insert the top mast 6 inches into the bottom mast and secure with a 4 inch eyebolt thru holes E/D.

10b. ❑ For the 15 foot assembly insert the top mast until it hits the stop bolt and secure with an eyebolt through holes E/C

10c. ❑ For the 10-foot assembly remove the stop bolt. Insert the top mast until eyebolt (B) hits the top of the bottom support mast. The inner guy rope is not used. The total antenna height will be closer to 11 feet; this is perfectly acceptable.

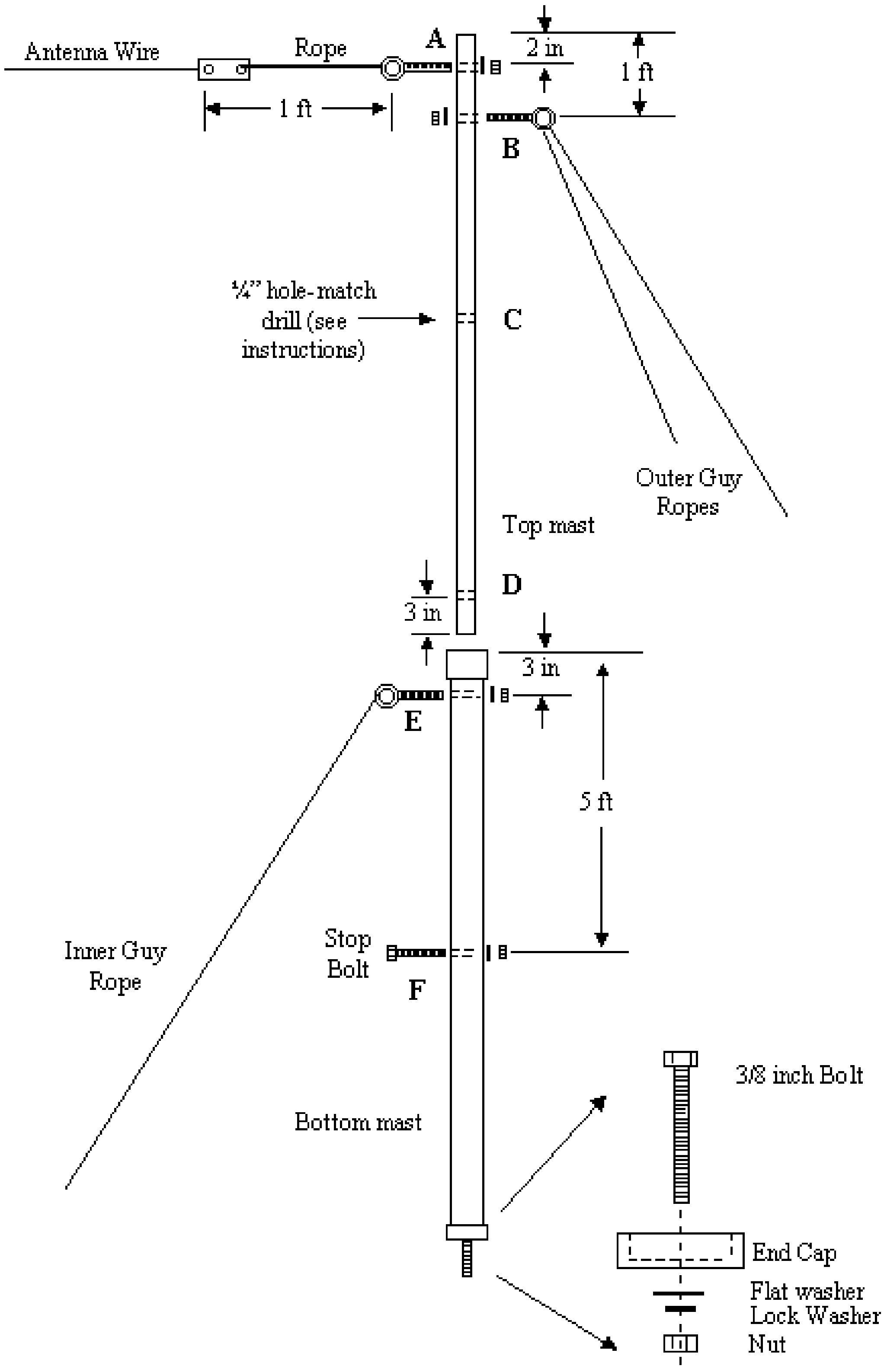


Figure 4.2. PVC Mast Assembly.

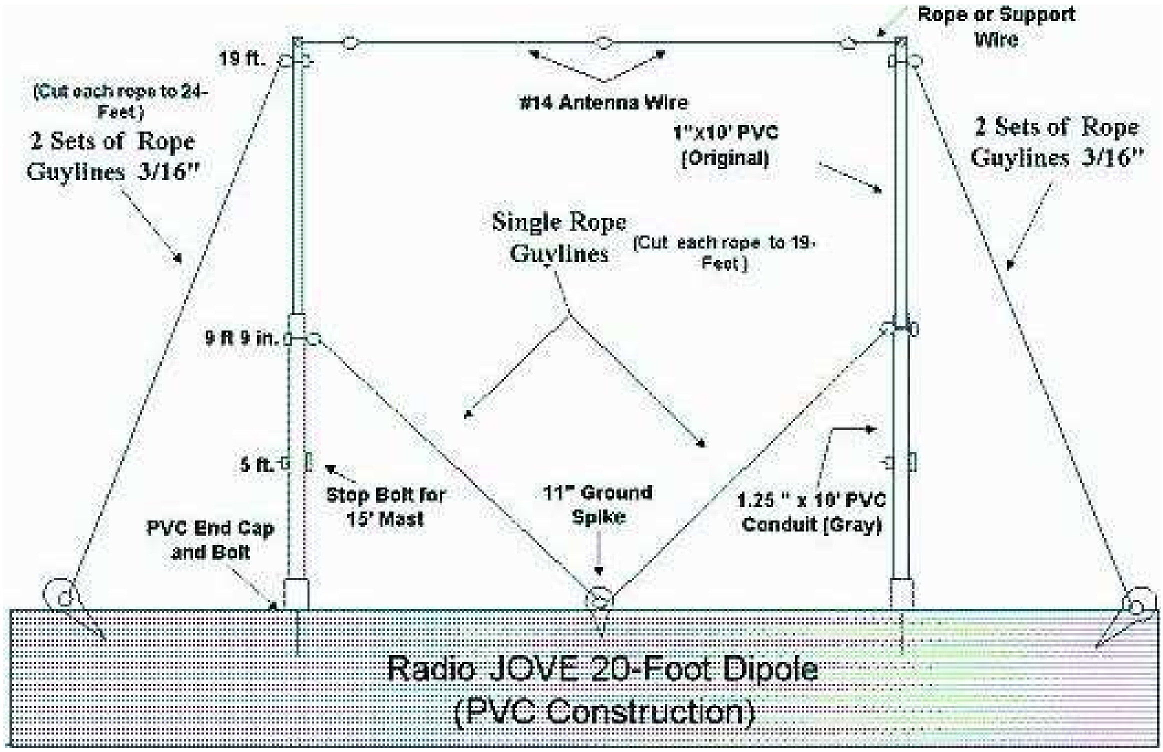


Figure 4.3. Side-view schematic of PVC dipole.

END PVC antenna mast assembly instructions

4.2 Metal Masts

Parts needed for Antenna Metal Mast Assembly		Parts Checklist
#	Description	
1	200 ft. (30.48 m) x 3/16 in. Nylon Rope	
8	10 ft. 6 in. (3.2 m) x 1-3/8 in. Metal Fence Top Rail (approx. $8 at Home Depot)	
8	4 in. x ¼ in. Eye Bolts	
12	¼ in. Nuts/Lock washers	
4	2 in. x ¼ in. Bolts	
8	Ground Spikes (or tent stakes)	

Table 4.2. Metal Antenna Parts List.

Metal Mast Assembly (Refer to Figures 4.4 and 4.5)

1. ❑ Each dipole mast assembly consists of two metal pipes (commonly sold as the top rail in a chain-link fence). Each pipe is 10'6" long with a 6" necked down section at one end. Two of the pipes are connected to form a mast that can be used to support the Jove dual dipoles at either 15 or 20 ft. (a single mast could be used for a 10 ft installation). Overall antenna heights may vary a few inches (or cm); this is perfectly acceptable.

2. ❑ **Refer to Figure 4.4. All holes through the masts are ¼ inch diameter.** A hammer and punch (or nail) can be used to make a starting point for drilling. A pilot hole using a 1/8 in drill bit is recommended. Eyebolts and bolts should be secured using a flat washer, lock washer and a nut. All holes in the top mast should be in the same plane.

3. ❑ Draw a guideline the length of the top mast to insure that all holes line up. (You can draw this line by laying the mast on the floor and moving the pen along the floor). Using the guideline, drill holes (A, B and C) thru the top mast.

4. ❑ Drill hole (E) thru the bottom mast.

5. ❑ Insert the top mast section 6 inches into the bottom mast section. Using hole (E) as a guide, match-drill a hole though the top mast section – this becomes hole (D). The best way to match-drill the holes is to drill the inner mast from each side – using hole E as a guide. Then without moving the two masts relative to each other, run the drill all the way thru both masts

6. ❑ Secure eyebolt in hole (B).

7. ❑ Repeat assembly steps above for the remaining masts.

8. ❑ Insert top mast into bottom mast and secure with a 2-inch bolt thru holes E/D.

9a. ❑ For a 20-foot high antenna attach the antenna eyebolt at hole (A).

9b. ❑ For a 15-foot high antenna attach the antenna eyebolt at hole (C).

9c. ❑ For a 10-foot assembly simply use the top mast section.

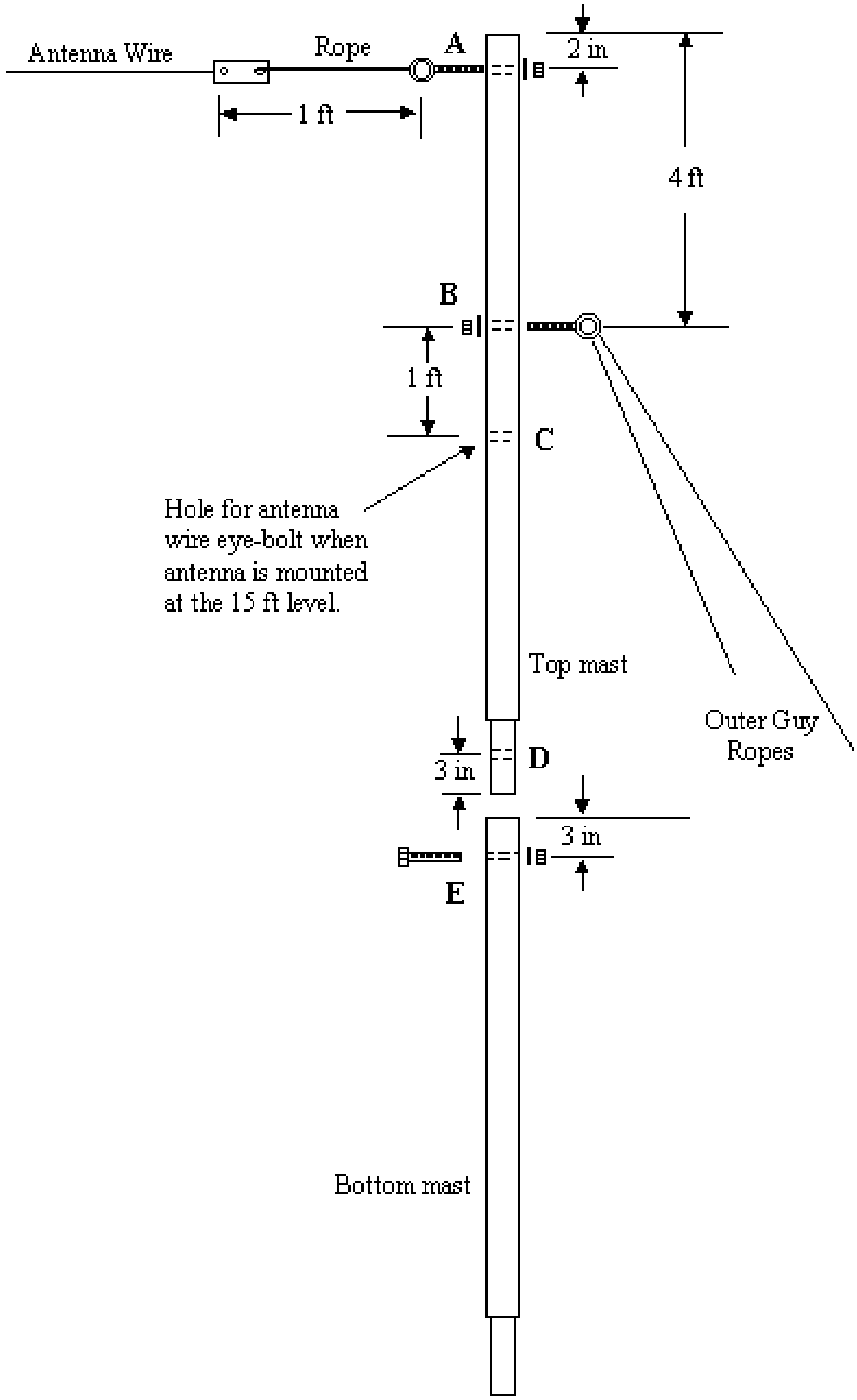


Figure 4.4. Metal Mast Assembly.

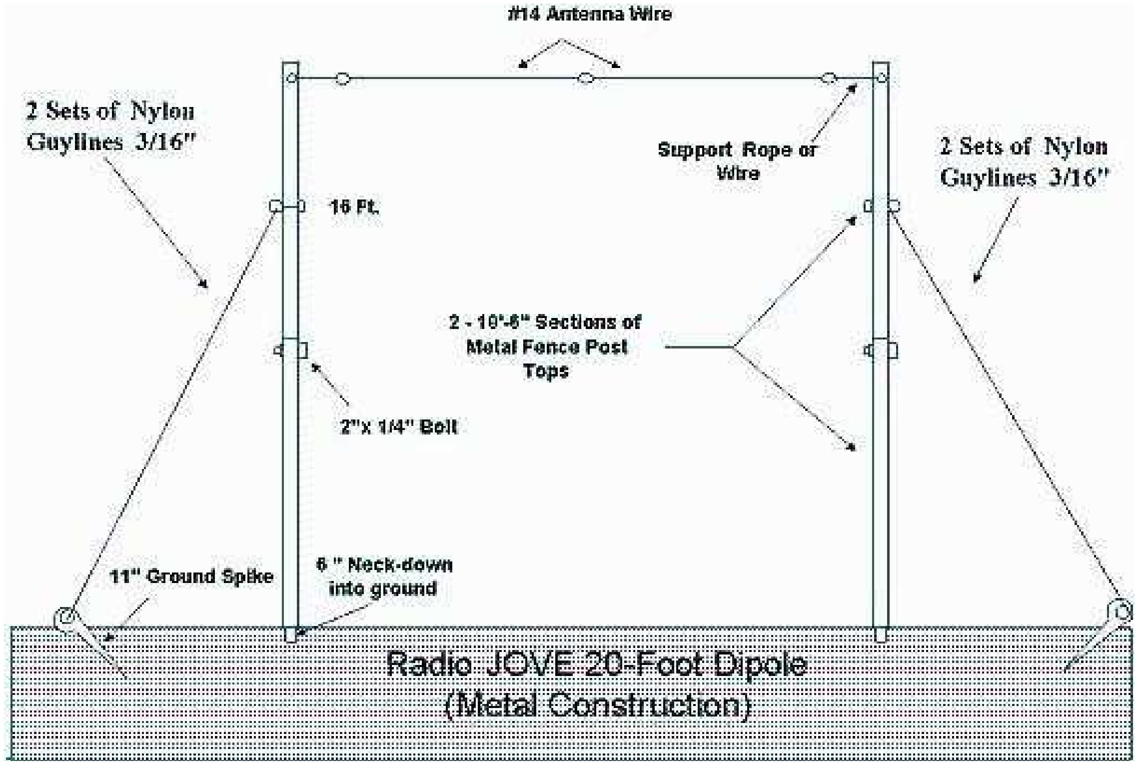


Figure 4.5. Side-view schematic of Metal dipole.

END Metal antenna mast assembly instructions

5. Field Setup, Safety and Testing

5.1 Field Setup

5.1.1 Grounds Preparation

Before the antenna masts can be assembled and raised, you must layout the antenna field. Study Figure 5.1 and note that the antenna wires run in an East-West direction. Also note the mast locations and the guy spike locations. Proceed as follows.

1. Find a clear area about 30 ft N-S by 45 ft E-W. The further from power lines, metal fences, tall buildings and other obstacles the better. An unobstructed view down to within about 20 degrees of the southern horizon is desirable.

2. The basic tools you will need to layout the antenna array are: a magnetic compass, 25 to 50-foot measuring tape, guy rope, stakes, hammer, and at least two helpers. It may be useful to use a can of spray paint to mark the ground where the stakes are to be pounded in.
3. Establish the mast and guy stake locations on the antenna field using the compass and tape measure. Take one of the guy stakes and pound it into the ground to create a hole at each mast mounting point. Then remove the stake – these holes are where you will insert the bottom end of the metal masts or the spikes on the bottom of the PVC masts. Hammer in the guy stakes (with the top of each stake tilted outward from its mast at about a 45 degree angle).

The antenna field is now ready for installation of the masts and dipoles.

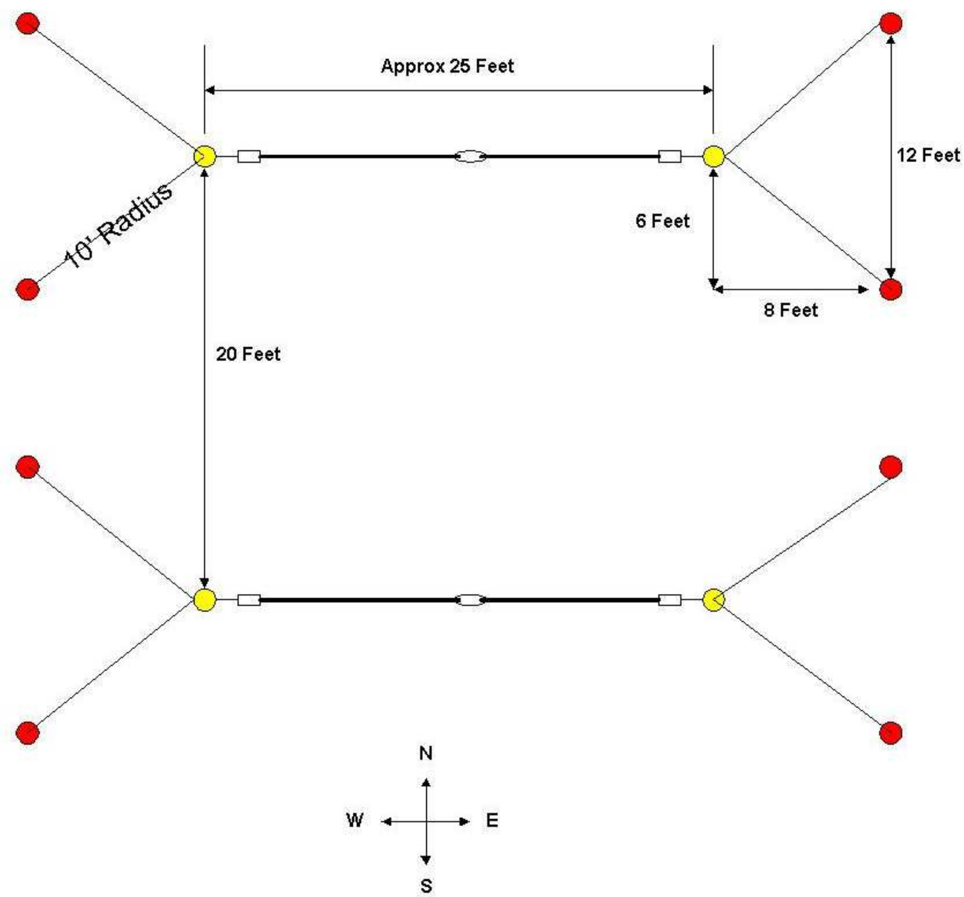


Figure 5.1. Antenna field layout for masts and guy stakes.

5.1.2 Mast and Antenna Installation

<u>Read all installation instructions before starting.</u> Do not attempt installation of antenna masts with fewer than 3 people.

DO NOT INSTALL NEAR POWER LINES

ITEMS NECESSARY ON HAND:
4 mast pairs, dipole assemblies (which includes the soldered one-wavelength coax and ferrites), all coax cable with F-connectors attached, eyebolts, bolts, washers, nuts, rope, sharp knife, lighter (After cutting the rope, melt the end with the lighter to keep the end from unraveling).

Step 1. (Refer to Figures 4.2 – 5.3)
Lay out the 4 masts, with the base of each mast near its hole. Stretch out the dipoles. Attach one end of the dipole to its mast using its eyebolt using the rope. Do not connect the other end of the dipole to its mast yet. **Be sure that the dipoles are oriented in phase – that is, be sure that the side (or arm) of the dipole soldered to the center conductor is on the same side on both dipoles.**

A. *For the PVC mast installation refer to Figures 4.2 and 4.3.* Cut 8 ropes to 24-feet. Attach 2 ropes to each of the eyebolts at the 19 ft level (hole B). Cut 4 ropes to 19-feet and attach each to an eyebolt at the 9-foot 9-inch level (holes D/E).
B. *For the metal mast installation refer to Figures 4.4 and 4.5.* Cut 8 ropes to 21 feet. Attach 2 ropes to each of the eyebolts at the 16 ft level (hole B).

Step 2.
Insert the mast with the dipole wire attached into its hole in the ground and erect it to the vertical position. Tie guy ropes to their stakes so that the mast is approximately vertical.

Step 3.
Attach the dangling end of the dipole to its mast using the attached eyebolt. Stick the second mast into its hole, and secure the guy ropes so that the mast is approximately vertical. The antenna should be fairly taut with both masts near vertical. If it is not, move one mast as needed along the E-W line, reinsert in ground, and retie the guy ropes.

<u>USE CAUTION ERECTING MASTS – BE SURE THAT GUY ROPES ARE SECURE.</u>

Step 4.
You may have to adjust all guy ropes to make the antenna masts vertical. It is normal for the PVC top section of the masts to pull inward due to the force from the guy ropes. It

may take a few adjustments to get the best fit. Do not expect perfectly straight PVC masts, as the PVC pipes will flex one direction or another.

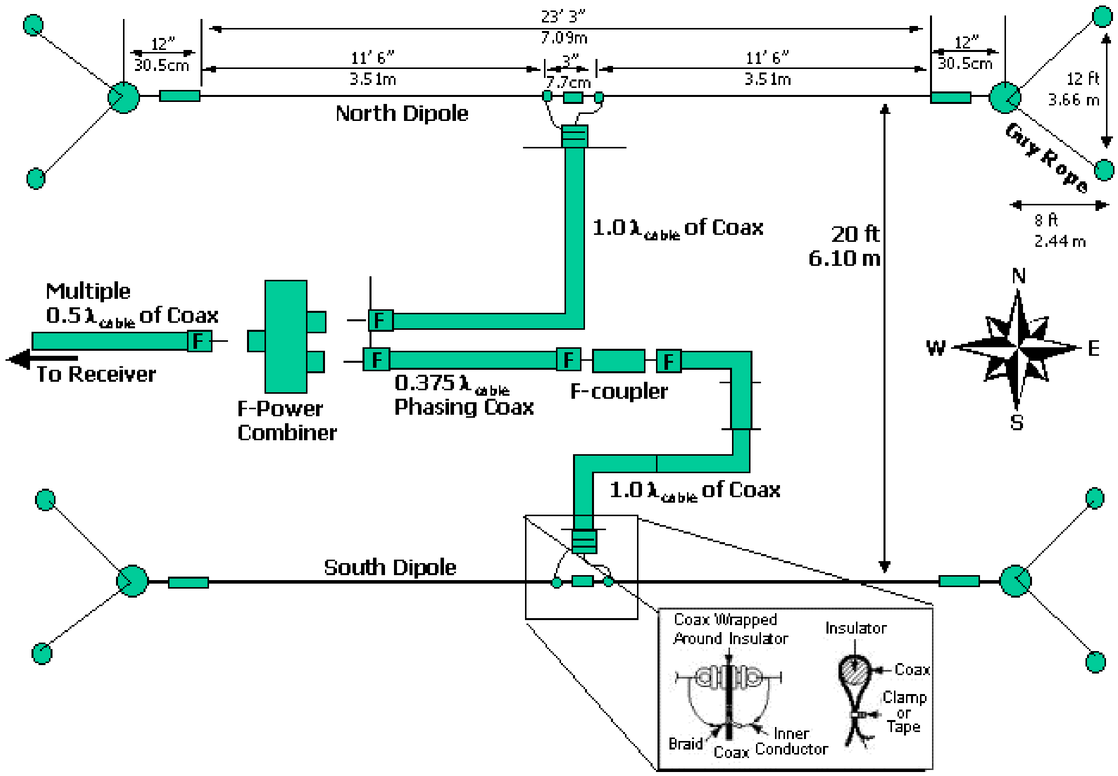


Figure 5.2. Top-view schematic of Radio JOVE dual dipole with phasing cable.

Figure 5.3a and 5.3b. Sample pictures for 10-foot mast setup. Lay out each dipole on the ground and set up one pole at a time.

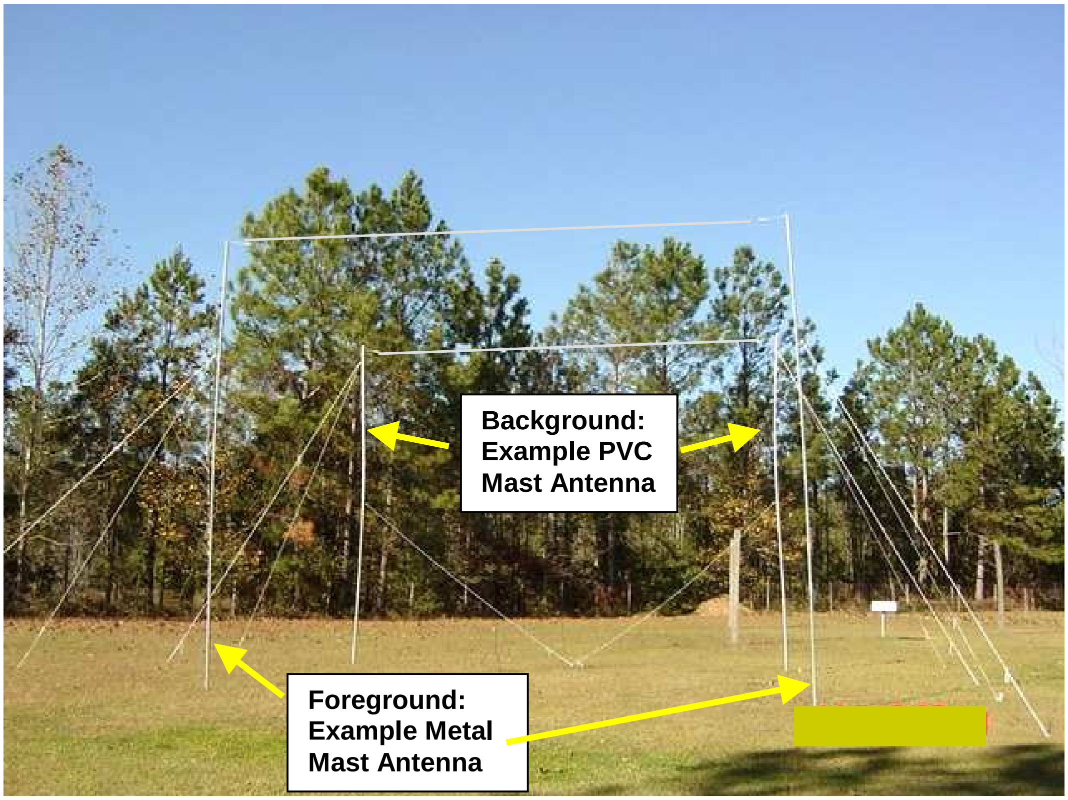


Figure 5.3c. Sample picture of the 20-foot mast.

Connecting the Cables to the Radio JOVE Antenna and Receiver

1. Connect all coax cables as shown in Figure 5.2. Make sure that all F-connectors are snug.
2. Connect all cables to the receiver as shown in Figure 5.4.

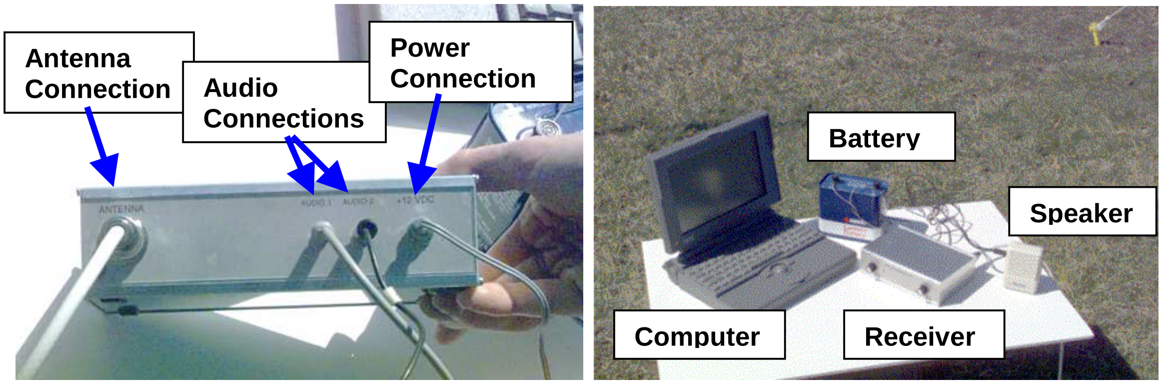


Figure 5.4a and 5.4b. JOVE receiver connections and setup with computer.

5.1.3 Weatherproofing Your Antenna

It is important to weatherproof the coaxial cable connections at the antenna feedpoint, the power combiner, and the cable coupler, particularly if the antenna will be subject to moisture. Simply wrapping them in electrical tape will help, but a better solution is to use Radio Shack Coax Sealing tape. The rubberized plastic compound sold at hardware stores to insulate tool handles makes a great outer coating on top of the tape and will help ensure complete protection from moisture penetration.

5.2 Safety Precautions

1. Avoid Lightning (always disconnect the antenna when not in use, and always disconnect the antenna before a lightning storm is present, and preferably well before the storm arrives.)
2. Never assemble the antenna under overhead power lines. The antenna should be located as far from overhead power lines as is practical – several hundred feet if possible.
3. Mark your guy ropes with reflective high visibility tape

5.3 Testing Your Antenna

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 (Figure 5.4). If you do not hear this noise increase, then there is something wrong with either the antenna or the receiver.

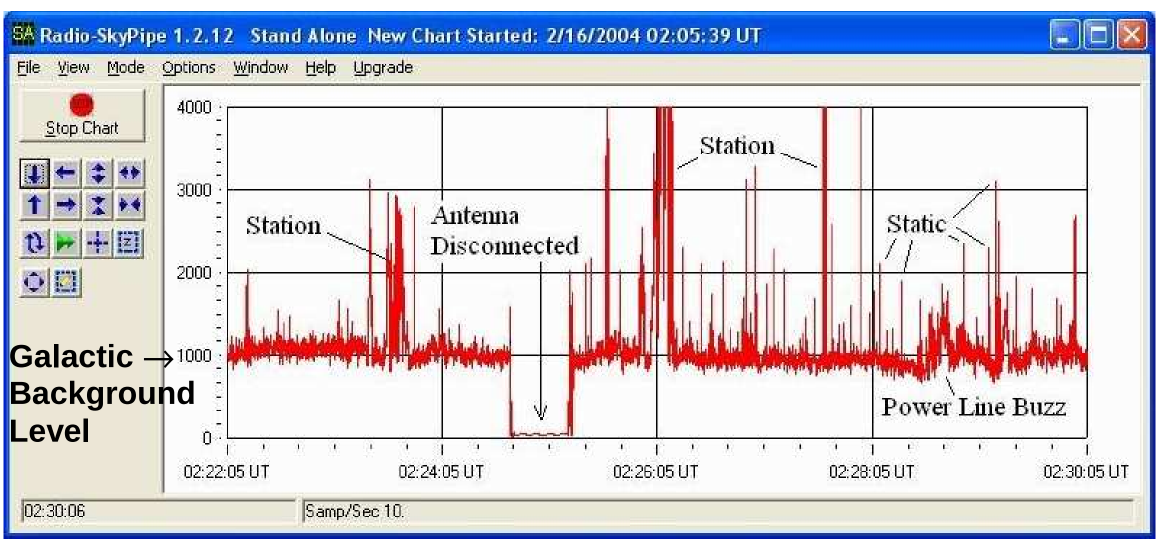


Figure 5.4. Sample RJ output showing a typical SkyPipe record. The effect of connecting and disconnecting the antenna is clearly seen.

CONGRATULATIONS! YOU HAVE JUST BUILT A RADIO TELESCOPE!

6. Solar Observations with the RJ1.2 Antenna

The RJ1.2 antenna can be used for solar observations as well as for Jupiter. The principle is the same – use antenna height and phasing to steer the beam.

The Sun's declination varies between 23.5 degrees N and 23.5 degrees south during the course of a year.

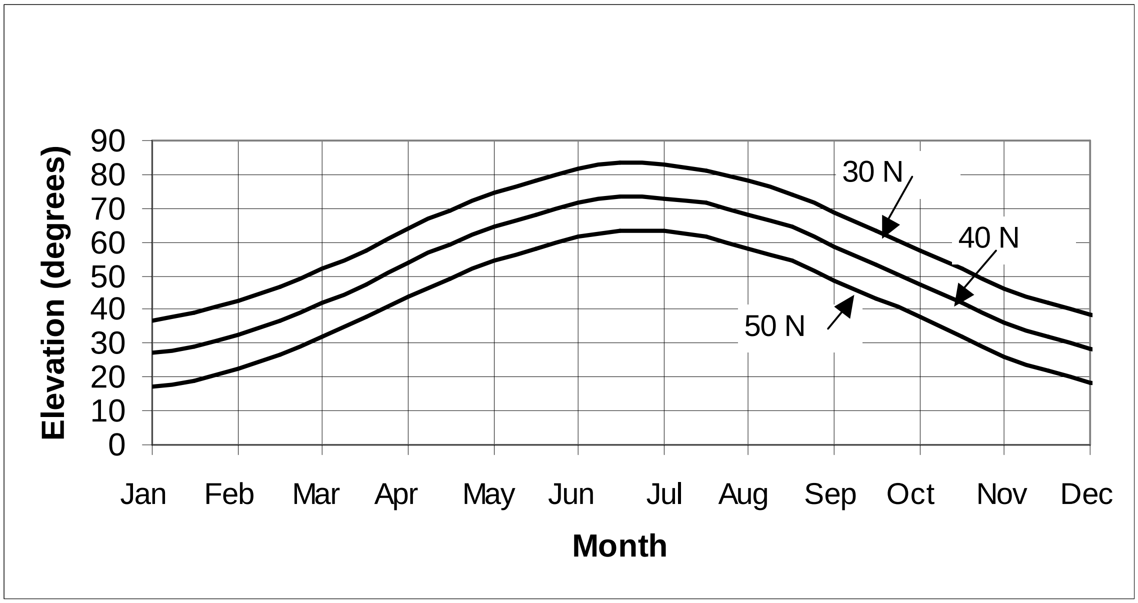


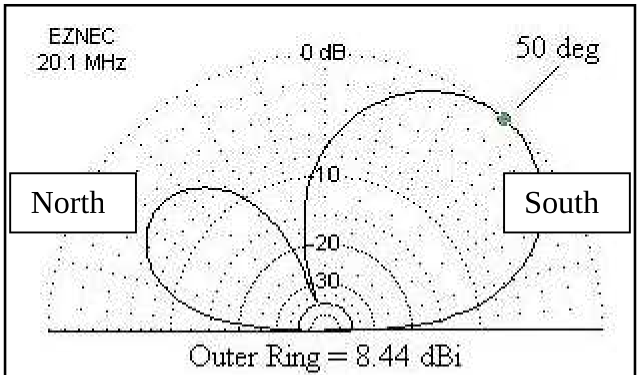
Figure 6.1. The elevation of the Sun for different north latitude observers. Three different latitudes are shown.

Using figure 6.1 and the beaming information in Appendix A, you can adjust the height of the RJ1.2 antenna to aim the beam at the Sun in order to receive the strongest possible signals. The only difficulty is that with the phasing cable inserted, the Jove antenna will not "look" overhead. For solar observations in the summertime (if the Sun is higher than 60 degrees at your location) it is best to remove the phasing cable and set the antenna height to 10 or 15 ft.

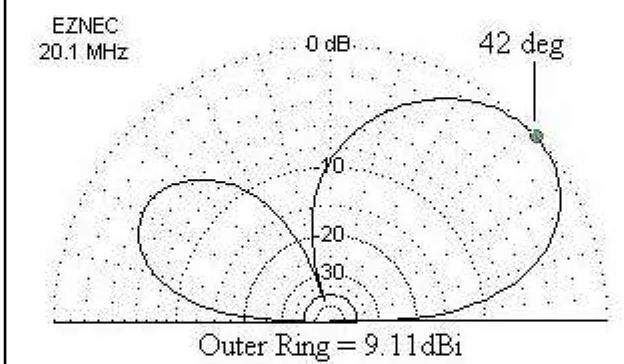
Since solar radio bursts can be very strong it is not necessary to aim the antenna beam at the Sun as carefully as with Jupiter. In fact, you could simply use a single E-W dipole for solar observations. During winter months the dipole could be up at 20 feet and down at 10 feet during the summer. Or you could compromise and just leave it at 15 feet all year round.

7. Appendix A - Jove RJ1.2 Antenna Patterns

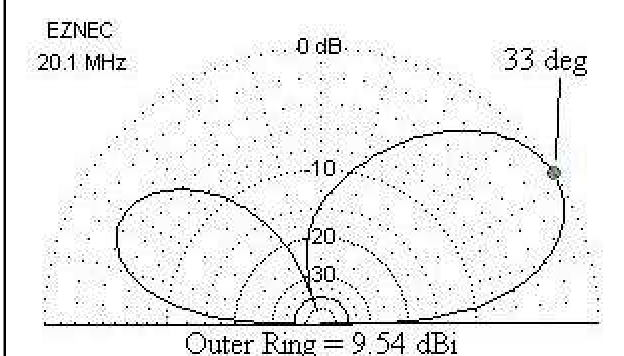
RJ1.2 antenna patterns are shown below for antenna heights of 10, 15, and 20 feet. These patterns are in a plane perpendicular to the dipole wires. Assuming the antenna wires run East-West, these patterns show the main beam tilted down toward the South. By raising the antenna, the main beam drops closer to the horizon and gain increases. The back lobe of the antenna pattern (the North pointing lobe) has reduced sensitivity by about 5 dB.



Antenna height 10 ft



Antenna height 15 ft



Antenna height 20 ft